LILCO
LONG ISLAND LIGHTING COMPANY
SHOREHAM NUCLEAR POWER STATION
P.O. BOX 618, NORTH COUNTRY ROAD • WADING RIVER, N.Y. 11792

September 9, 1982 SNRC-767

Mr. Harold R. Denton, Director
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Environmental Qualification
Shoreham Nuclear Power Station - Unit 1
Docket No. 50-322

Dear Mr. Denton:

Enclosed are 15 copies of information relative to the environmental qualification of safety related equipment (mechanical and electrical). This information is organized as noted in the attached "Index of Submittal".

Exhibit 1 describes the analyses done on the B.O.P. (SH-1 series) specifications. It contains four mechanical equipment data packages and a supporting reference library. The approach which was used, the methodology, data format, and the conclusions reached are detailed.

A similar approach and methodology was used for the analyses done on the NSSS (3000 M series) specifications in Exhibit 2. Details of approach are included in the four data packages. A supporting reference library on materials aging has been included with this submission.

Exhibit 3 responds to two verbal questions on mechanical equipment environmental qualification and maintenance which were posed by the Staff.

The additional information on the Electrical Equipment Environmental Qualification Audit, basically consisting of clarifying information on the GE 100 Series and 200 Series Electric Penetrations, is being submitted as Exhibit 4 in response to a July 22, 1982 letter from Mr. A. Schwencer concerning this NRC audit.

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Finally, LILCO is providing written responses to nine verbal requests for information on the Environmental Qualification Report submittal dated May 1982 which were received during a conference call with Mr. J. Kennedy of the NRC on August 17, 1982.

This submittal is responsive to all outstanding requests by the Staff relative to environmental qualification of safety related equipment, and it should provide sufficient information to allow closure of Safety Evaluation Report Issue No. 9, Environmental Qualification.

If you have any questions regarding this matter, please contact this office.

Very truly yours,

J. L. Smith

J. L. Smith
Manager, Special Projects
Shoreham Nuclear Power Station

RSH:mp

Enclosures

cc: J. Higgins
All parties

LILCO
LONG ISLAND LIGHTING

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Index of Submittal

Mechanical Equipment Environmental Conformance:
Selected SH 1 Packages

Shoreham Nuclear Power Station - Unit 1

Long Island Lighting Company

September 9, 1982

EVALUATION

Methodology

This review consisted of a five-step process as follows:

- Identification of Active (Passive performed under Phase 2 of program) Safety-Related Mechanical Equipment
- Identification of Nonmetallic Components
- Identification of Design Environmental Conditions
- Identification of Nonmetallic Material Capabilities
- Evaluation of Environmental Effects

Identification of Safety-Related Mechanical Equipment

Safety-related Balance of Plant mechanical equipment is procured for the Shoreham Nuclear Power Station - Unit 1 using equipment procurement specifications. The Specification Index, dated 6/1/82, was reviewed and relevant specifications were selected. Each of the specifications was reviewed and those which met the following criteria were selected for detailed review and evaluation:

a) QA Category I

b) Active/Passive Nuclear Safety-Related Equipment

c) Equipment Located in a Potentially Harsh Environment

d) Equipment which includes Nonmetallic Sub-Components

Identification of Nonmetallic Sub-Components

The latest revision of the manufacturers' bills of material for the equipment to be evaluated were reviewed and a nonmetallic subcomponents list was prepared for each group or piece of equipment. Where necessary additional information was obtained from the equipment vendor to explain trade names or for identification of specific trade name materials, or incomplete/unsatisfactory material identification.

Identification of Maximum Postulated Environmental Conditions

The environmental conditions used for the review of mechanical equipment were those presented in the report prepared by Stone & Webster Engineering Corporation (SWEC) entitled

"Environmental Qualification Report for Class 1E Equipment for Shoreham Nuclear Power Station - Unit 1" Rev. 2, May 1982 (the Equipment Environmental Qualification Report, submitted to the NRC by Long Island Lighting Company (LILCO) letter SNRC-704, dated 5/17/82).

Of the environmental conditions (temperature, pressure, humidity and radiation) only radiation and temperature were considered in the review. Pressure and humidity were not considered relevant since the design of nonmetallic portions of mechanical equipment for these parameters is governed by system process conditions which already have been addressed in the specification.

The values used for preliminary screening based on equipment location were as follows:

radiation - total plant lifetime exposure plus postulated accident exposure.

temperature - maximum calculated accident environment temperature.

The radiation levels and temperatures that were used for each of the zones are shown in Table 1 entitled "Post-TMI Values for Harsh Environment".

Where equipment would potentially be exposed to suppression pool water on the wetted side of the component following a LOCA, radiation levels were developed to take these exposure levels into consideration.

Valves which have no unique identification numbers (such as check valves) were procured and evaluated as a group based on the valve type and design. Identical valves in a group were evaluated to the most severe environmental zone that any single member would be exposed. Spare valves were evaluated as a minimum to the most severe environmental zone applicable to the purchase specification to which they were procured, so that they may be used to replace any of the original components.

Identification of Nonmetallic Material Capabilities

Each material identified as explained above was examined to determine the effect of the environmental conditions on the material properties. For initial screening, it was conservatively chosen to use the threshold radiation level and maximum service temperature. Materials handbooks, textbooks, and industry and government reports were researched to obtain material data. In some cases vendor data were utilized to supplement the above sources.

Threshold Radiation - the lowest radiation exposure at which a property change in the material is documented.

Maximum Service Temperature - the maximum steady state temperature a material can be subjected to without loss of function.

Evaluation of Environmental Effects

A conservative initial screening of the nonmetallic components was made by the comparison of the material capabilities (threshold radiation level and maximum service temperature) with the maximum postulated environmental conditions. Those items which were not shown to be acceptable based on the comparison were evaluated in further detail considering:

a. degree of material degradation

b. material properties affected

c. equipment/component function

d. degree of functional degradation

Any component which could not be adequately justified based on this evaluation has been identified as "Outstanding" for further evaluation.

Verification of Completeness of Mechanical Equipment Included in Review

In order to verify that all of the Category I safety-related mechanical equipment located in a harsh environment has been reviewed, a comparison of the listing developed as described above has been made with "List of Active Safety-Related Equipment at Qualification Level (SQRT List)" dated June 1982. This document is an up-to-date compilation of all of the active safety-related equipment in the Shoreham Plant. It was developed for use in the Seismic Qualification Review Team (SQRT) program. Since safety-related equipment is purchased using specifications and with the reassurance that a cross check with the SQRT listing has been performed, it has been concluded that the active mechanical equipment contained in the safety-related systems identified in the "Environmental Qualification Report for Class 1E Equipment for Shoreham Nuclear Power Station - Unit 1", Rev. 2, May 1982 has been included in this review.

Acceptance Criteria

In order to be considered acceptable, nonmetallic portions of mechanical equipment must either:

a) be shown to be acceptable for the plant environment by exhibiting threshold radiation values and maximum service temperatures above the maximum postulated environmental conditions, or

b) be shown to be acceptable for the plant environment by analysis that demonstrates that the safety function of the component is not compromised and they are noted as "Justified".

Documentation Description

Data Packages

The documentation of the review is contained in the data packages of Appendix A. A data package provides the complete documentation of the review of one specification and is numbered with the specification number and represents an individual type of component purchased under a specific purchase order. Each data package contains the following documents:

a) Cover Sheet

This sheet serves as a table of contents for the package identifying all contained sections.

b) Mechanical Equipment Environmental Conformance Review Sheets (ECR).

These sheets provide a summary of the environmental review status for the packages. Each sheet contains the equipment mark number (unique equipment identification number); the component name and manufacturer; the QA Category; the equipment location by building code (defined below) and zone locations obtained from Environmental Qualification Report; the applicable Environmental Conformance Data Sheet (ECD); (providing the detailed review parameters) and the results of the review.

Building Codes: RBP-Reactor Building Primary
RBS-Reactor Building Secondary
RBD-Reactor Building Drywell

Status Codes:

A - Acceptable - The maximum service temperature and threshold radiation levels are greater than the maximum postulated exposure.

J - Justified - Either the maximum service temperature or the threshold radiation level is lower than the maximum postulated exposure; however, it is shown that the equipment can perform its required safety function.

Outstanding Item - insufficient data is currently available to demonstrate environmental acceptability and further investigation is required.

c) Mechanical Equipment Environmental Conformance Data Sheet (ECD)

These sheets provide the identification of nonmetallic subcomponents, materials, environmental conditions and conservative values for material acceptability.

d) Equipment Justification Sheets (J)

These sheets provide a more detailed review of equipment which is not judged to be acceptable on the conservative use of the threshold radiation levels and maximum service temperature alone.

e) Material Resistance Data Sheets (NM)

Summarize the material property sensitivity to radiation and temperature. These sheets include threshold radiation values, maximum service temperature, other significant material data and documentation referenced for the above.

f) Documentation

Additional documentation unique to data package is included where applicable.

Reference Library

The reference library contained in Appendix B provides the results of the material data search made as part of this review. It includes sufficient information to allow this report to be reviewed and utilized without the need for rechecking the reference material.

Conclusion

The results of this review demonstrate that the environmental effects due to normal operation and postulated accidents will not result in the degradation of nonmetallic components of active safety function except those identified in the following data packages.

SH1-172 - Air Operated Butterfly Valves, Manufactured by Fisher Controls.

This component will be further investigated.

BUNA-N Sub Components:

The review of the various materials used in sub components has identified the use of BUNA-N typically as oil seals in pumps, O-rings on pumps and valves, and as diaphragm in air actuators/valves. IE Bulletin No. 78-14 discusses the limitations of BUNA-N. BUNA-N deteriorates through natural aging in 10 years therefore the NRC suggests replacement every seven years. Radiation is not the cause of the problem and so the threshold of 1×10^6 Rads is unaffected. It is recommended that the preventive maintenance program include inspection and replacement of all BUNA-N components at intervals not to exceed those of the IE Bulletin No. 78-14.

TABLE 1

POST-TMI VALUES FOR HARSH ENVIRONMENT

	Radiation (rads-gamma)			
Zone	40 Yr. Dose	6-Month Accident Dose	Total Dose	
A	8.8×10^6	1×10^8	1.1×10^8	Primary Containment Locations: Zone A thru F
B	7.0×10^7	1×10^8	1.8×10^8	
C	2.5×10^6	1×10^8	1.0×10^8	
D	1.8×10^7	1×10^8	1.2×10^8	
E	3.5×10^4	1×10^8	1.0×10^8	
F	3.5×10^4	1×10^8	1.0×10^8	
G	1.8×10^3	5.75×10^6	5.8×10^6	Secondary Containment Locations: Zone G thru T
H	1.8×10^3	5.08×10^4	5.3×10^4	
J	1.8×10^3	2.45×10^5	2.5×10^5	
K	1.8×10^3	1.27×10^8	1.3×10^8	
L	1.8×10^3	3.06×10^6	3.1×10^6	
M	1.8×10^3	2.06×10^5	2.1×10^5	
N	1.8×10^3	3.06×10^5	3.1×10^5	
P	1.1×10^5	5.08×10^4	1.6×10^5	
Q	1.3×10^8	5.08×10^4	1.3×10^8	
R	2.1×10^5	5.08×10^4	2.6×10^5	
S	1.8×10^6	5.08×10^4	1.9×10^6	
T	4.9×10^5	3.06×10^6	3.6×10^6	
ST	4.9×10^5	3.06×10^6	3.6×10^6	Steam Tunnel

Maximum Temperature ($^{\circ}F$)

Primary Containment

Zone	Temp.	Duration
22	340	0-3 hrs.
	320	3-6 hrs.
	250	6-24 hrs.
	200	1-4 days
23	225	0-12 hrs.
	212	12-24 hrs.

Steam Tunnel

Use process fluid temperature = $575^{\circ}F$

Secondary Containment

Zone	Temp.	Zone	Temp.
1	150	11	190
2	152	12	194
3	148	13	217
4	155	14	217
5	173	15	158
6	183	16	178
7	168	17	215
8	215	18	138
9	184	19	148
10	177	20	118
		21	Non-harsh (MCC cubical)

NOTES:

1. Values for harsh environment taken from Appendix D of the Environmental Qualification Report (Rev. 2) for Class 1E Equipment.
2. Effects of Neutron Fluence are negligible.
3. Some equipment in system E11,E21,E41, and E51 will have a minimum radiation value of 7×10^5 due to suppression pool water carried in them during LOCA.
4. Effects of humidity and pressure are negligible for types of components evaluated.
5. Temperature values indicated above are the highest values in a LOCA, HELB, or MELB.
6. Total dose may not always equal the 40 year dose plus accident dose due to rounding off.

APPENDIX A

DATA PACKAGE SH1-88V

TYPE OF EQUIPMENT: MOTOR OPERATED CARBON STEEL VALVES 2½" AND LARGER

MANUFACTURER: VELAN ENGINEERING CORPORATION

STONE & WEBSTER SPECIFICATION NUMBER: SH1-88V

Package contents:

Prepared by Louis S. Fine

Reviewed by K.M. Evans

Issue Date: August 16, 1982

JOB NO.: 11600.02

MECHANICAL EQUIPMENT ENVIRONMENTAL
CONFORMANCE REVIEW SHEET

JOB NAME: SHOREHAM - UNIT 1

DATE: 8/02/82

JOB CLIENT: LILCO

SORTED BY SPEC.

COMPILED BY: L.S. Fiore

SYSTEM TITLE: NUCLEAR BOILER (B21)

SHT. NO. ECR-88V-1 REV. 0

Mark No.	Vendor/Description	Spec.	Q.A. Cat.	Bldg./Elev.	Zone	E.C.Data Sht.	Status	Comments
	VELAN/							
1B21*MOV031	Drain to Cond. North Drywell	SH1-88V	I	RBD/79	D-22	88V-1	A	
1B21*MOV032	Drain to Cond.	SH1-88V	I	RBS/79	T-08	88V-1	A	
1B21*MOV034	Drain to Cond.	SH1-88V	I	RBS/78	H-08	88V-1	A	

A = Acceptable

JOB NO.: 11600.02

MECHANICAL EQUIPMENT ENVIRONMENTAL
CONFORMANCE REVIEW SHEET

JOB NAME: SHOREHAM - UNIT 1

DATE: 8/02/82

JOB CLIENT: LILCO

SORTED BY SPEC.

COMPILED BY: L.S. Fiore

SHT. NO. ECR-88V-2 REV. 0

SYSTEM TITLE: RESIDUAL HEAT REMOVAL (E11)

Mark No.	Vendor/Description	Spec.	Q.A. Cat.	Bldg./Elev.	Zone	E.C.Data Sht.	Status	Comments
	VELAN/							
1E11*MOV033A	RHR Hx Shell Inlet Nr Col. C-10	SH1-88V	I	RBS/22	G-01	88V-1	A	
1E11*MOV033B	RHR Hx Shell Inlet Nr Col. C-6	SH1-88V	I	RBS/22	G-01	88V-1	A	
1E11*MOV035A	RHR Hx Shell Outlet Nr Col. C-11	SH1-88V	I	RBS/30	G-01	88V-2	A	
1E11*MOV035B	RHR Hx Shell Outlet Nr Col. C-5	SH1-88V	I	RBS/30	G-01	88V-2	A	
1E11*MOV039A	Cont. Spray HDR RHR Nr Col. C-11	SH1-88V	I	RBS/103	G-10	88V-2	A	
1E11*MOV039B	Cont. Spray HDR RHR Nr Col. C-5	SH1-88V	I	RBS/103	G-10	88V-2	A	
1E11*MOV040A	RHR Flow to Supp. Pool Nr C-11	SH1-88V	I	RBS/72	G-03	88V-2	A	
1E11*MOV040B	RHR Flow to Supp. Pool Nr C-5	SH1-88V	I	RBS/72	G-07	88V-2	A	

A = Acceptable

JOB NO.: 11600.02

MECHANICAL EQUIPMENT ENVIRONMENTAL
CONFORMANCE REVIEW SHEET

JOB NAME: SHOREHAM - UNIT 1

DATED: 8/02/82

JOB CLIENT: LILCO

SORTED BY SPEC.

COMPILED BY: L.S. Fiore

SYSTEM TITLE: RESIDUAL HEAT REMOVAL (E11)

SHT. NO. ECR-88V-3 REV. 0

Mark No.	Vendor/Description	Spec.	Q.A. Cat.	Bldg./Elev.	Zone	E.C.Data Sht.	Status	Comments
	VELAN/							
1E11*MOV041A	RHR Supp. Pool Spray HDR Nr C-10	SH1-88V	I	RBS/51	G-02	88V-3	A	
1E11*MOV041B	RHR Supp. Pool Spray HDR Nr C-6	SH1-88V	I	RBS/40	G-02	88V-3	A	
1E11*MOV043A	RHR Hx to Recirc. Pump Suct. Nr C-11	SH1-88V	I	RBS/17	G-01	88V-3	A	
1E11*MOV043B	RHR Hx to Recirc. Pump Suct. Nr C-5	SH1-88V	I	RBS/17	G-01	88V-3	A	
1E11*MOV044A	RHR Hx Drain to Supp. Pool C-11	SH1-88V	I	RBS/17	G-01	88V-3	A	
1E11*MOV044B	RHR Hx Drain to Supp. Pool C-5	SH1-88V	I	RBS/17	G-01	88V-3	A	
1E11*MOV045A	RHR Pump Min. Flow Bypass Nr C-11	SH1-88V	I	RBS/17	G-01	88V-4	A	
1E11*MOV045B	RHR Pump Min. Flow Bypass Nr C-5	SH1-88V	I	RBS/17	G-01	88V-4	A	

A = Acceptable

JOB NO.: 11600.02

MECHANICAL EQUIPMENT ENVIRONMENTAL
CONFORMANCE REVIEW SHEET

DATE: 8/02/82

JOB NAME: SHOREHAM - UNIT 1

COMPILED BY: L.S. Fiore

JOB CLIENT: LILCO

SORTED BY SPEC.

SHT. NO. ECR-88V-4 REV. 0

SYSTEM TITLE: RESIDUAL HEAT REMOVAL (E11)

Mark No.	Vendor/Description	Spec.	Q.A. Cat.	Bldg./Elev.	Zone	E.C.Data Sht.	Status	Comments
	VELAN/							
1E11*MOV049	FM-HPCI Turbine Inlet Line C-8	SH1-88V	I	RBS/66	G-03	88V-4	A	
1E11*MOV050	RHR Main Flow Crossover C-5	SH1-88V	I	RBS/72	G-07	88V-4	A	
1E11*MOV051	RHR to Radwaste Surge Tank	SH1-88V	I	RBS/63	G-07	88V-4	A	
1E11*MOV052	To Radwaste Surge Tank C-4	SH1-88V	I	RBS/73	G-07	88V-4	A	
1E11*MOV053	RHR Head Spray Nr Col. C-5	SH1-88V	I	RBS/103	G-12	88V-4	A	
1E11*MOV054	RHR Head Spray Nr Col. C-5	SH1-88V	I	RBD/104	B-22	88V-5	A	

A = Acceptable

JOB NO.: 11600.02

JOB NAME: SHOREHAM - UNIT 1

JOB CLIENT: LILCO

SYSTEM TITLE: CORE SPRAY (E21)

MECHANICAL EQUIPMENT ENVIRONMENTAL
CONFORMANCE REVEIW SHEET

SORTED BY SPEC.

DATE: 8/02/82

COMPILED BY: L.S. Fiore

SHT. NO. ECR-88V-5 REV. 0

Mark No.	Vendor/Description	Spec.	Q.A. Cat.	Bldg./Elev.	Zone	E.C.Data Sht.	Status	Comments
	VELAN/							
1E21*MOV033A	Core Spray Pump Disc. Nr Col. C-10	SH1-88V	I	RBS/104	G-09	88V-5	A	
1E21*MOV033B	Core Spray Pump Disc. Nr Col. C-11	SH1-88V	I	RBS/104	G-12	88V-5	A	
1E21*MOV034A	Core Spray Pump Min. Flow Nr Col. C-11	SH1-88V	I	RBS/15	G-01	88V-5	A	
1E21*MOV034B	Core Spray Pump Min. Flow Nr Col. C-5	SH1-88V	I	RBS/15	G-01	88V-5	A	

A = Acceptable

JOB NO.: 11600.02

MECHANICAL EQUIPMENT ENVIRONMENTAL
CONFORMANCE REVIEW SHEET

DATE: 8/02/82

JOB NAME: SHOREHAM - UNIT 1

COMPILED BY: L.S. Fiore

SORTED BY SPEC.

JOB CLIENT: LILCO

SHT. NO. ECR-88V-6 REV. 0

SYSTEM TITLE: HIGH PRESSURE COOLANT INJECTION (E41)

Mark No.	Vendor/Description	Spec.	Q.A. Cat.	Bldg./Elev.	Zone	E.C.Data Sht.	Status	Comments
	VELAN/							
1E41*MOV031	HPCI PP. Suct. Cond. Stg Nr C-6	SH1-88V	I	RBS/20	G-01	88V-5	A	
1E41*MOV032	HPCI PP. Suct. Pool Nr C-7	SH1-88V	I	RBS/24	G-01	88V-6	A	
1E41*MOV034	HPCI Pump Disc. Nr C-9	SH1-88V	I	RBS/63	G-05	88V-6	A	
1E41*MOV036	HPCI PP. Min. Flow Bypass Nr C-7	SH1-88V	I	RBS/20	G-01	88V-6	A	
1E41*MOV037	HPCI PP. Disch. to Cond. Stg. C-7	SH1-88V	I	RBS/18	G-01	88V-6	A	
1E41*MOV038	HPCI PP. Disch. to Cond. Stg. C-7	SH1-88V	I	RBS/18	G-01	88V-6	A	
1E41*MOV041	HPCI Stm to Turb. N. Drywell	SH1-88V	I	RBD/66	D-22	88V-6	A	
1E41*MOV042	HPCI Stm to Turb. Nr Col. C-8	SH1-88V	I	RBS/63	G-05	88V-6	A	
1E41*MOV043	HPCI Stm to Turb. Near Col. C-8	SH1-88V	I	RBS/19	G-01	88V-7	A	
1E41*MOV044	Turbine Exh. to Supp. Pool C-8	SH1-88V	I	RBS/30	G-01	88V-7	A	

A = Acceptable

JOB NO.: 11600.02

MECHANICAL EQUIPMENT ENVIRONMENTAL
CONFORMANCE REVIEW SHEET

DATE: 8/02/82

JOB NAME: SHOREHAM - UNIT 1

COMPILED BY: L.S. Fiore

JOB CLIENT: LILCO

SORTED BY SPEC.

SHT. NO. ECR-88V-7 REV. 0

SYSTEM TITLE: REACTOR CORE ISOLATION COOLING (E51)

Mark No.	Vendor/Description	Spec.	Q.A. Cat.	Bldg./Elev.	Zone	E.C.Data Sht.	Status	Comments
	VELAN/							
1E51*MOV031	RCIC PP. Suct. Cond. Stg.	SH1-88V	I	RBS/24	G-01	88V-7	A	
1E51*MOV032	RCIC PP. Suct. Supp. Pool	SH1-88V	I	RBS/24	G-01	88V-7	A	
1E51*MOV034	RCIC Pump Disch.	SH1-88V	I	RBS/19	G-01	88V-7	A	
1E51*MOV035	RCIC Pump Disch.	SH1-88V	I	RBS/80	H-12	88V-7	A	
1E51*MOV037	RCIC PP. Disch. To Cons. Stg.	SH1-88V	I	RBS/20	G-01	88V-7	A	
1E51*MOV041	RCIC Stm. to Turb. North Drywell	SH1-88V	I	RBD/88	D-22	88V-8	A	
1E51*MOV042	RCIC Stm. to Turb.	SH1-88V	I	RBS/88	T-08	88V-8	A	
1E51*MOV043	HPCI Stm to Turbine	SH1-88V	I	RBS/12	G-01	88V-8	A	
1E51*MOV045	RCIC Exhaust To Supp. Pool	SH1-88V	I	RBS/31	G-01	88V-8	A	

A = Acceptable

JOB NO.: 11600.02

MECHANICAL EQUIPMENT ENVIRONMENTAL
CONFORMANCE REVIEW SHEET

JOB NAME: SHOREHAM - UNIT 1

DATE: 8/02/82

JOB CLIENT: LILCO

SORTED BY SPEC.

COMPILED BY: L.S. Fiore

SYSTEM TITLE: RADWASTE (G11)
REACTOR WATER CLEANUP (G33)

SHT. NO. ECR-88V-8 REV. 0

Mark No.	Vendor/Description	Spec.	Q.A. Cat.	Bldg./Elev.	Zone	E.C.Data Sht.	Status	Comments
	VELAN/							
1G11*MOV246	Drywell Floor Drains	SH1-88V	I	RBS/40	G-02	88V-8	A	
1G11*MOV247	Drywell Floor Drains	SH1-88V	I	RBS/40	G-02	88V-8	A	
1G11*MOV248	Drywell Equip Drains	SH1-88V	I	RBS/40	L-02	88V-8	A	
1G11*MOV249	Drywell Equip Drains	SH1-88V	I	RBS/40	L-02	88V-8	A	
1G11*MOV639C	Supply Pool Pump	SH1-88V	I	RBS/20	G-01	88V-9	A	
1G33*MOV030A	Reactor Recirc. Suct. East Drywell	SH1-88V	I	RBD/98	B-22	88V-9	A	
1G33*MOV030B	Reactor Recirc. Suct. East Drywell	SH1-88V	I	RBD/99	B-22	88V-9	A	
1G33*MOV031	Reactor Recirc. Suct. East Drywell	SH1-88V	I	RBD/99	B-22	88V-9	A	
1G33*MOV032	Reactor Vessel Drain	SH1-88V	I	RBD/99	B-22	88V-9	A	

A = Acceptable

JOB NO.: 11600.02

MECHANICAL EQUIPMENT ENVIRONMENTAL
CONFORMANCE REVIEW SHEET

JOB NAME: SHOR[illegible] - [illegible]IT 1

DATE: 8/02/82

JOB CLIENT: LILCO

SORTED BY SPEC.

COMPILED BY: L.S. Fiore

SYSTEM TITLE: REACTOR WATER CLEANUP (G33)

SHT. NO. ECR-88V-9 REV. 0

Mark No.	Vendor/Description	Spec.	Q.A. Cat.	Bldg./Elev.	Zone	E.C.Data Sht.	Status	Comments
	VELAN/							
1G33*MOV033	Reactor Vessel Disch. East Drywell	SH1-88V	I	RBS/121	P-14	88V-9	A	
1G33*MOV034	Reactor Vessel	SH1-88V	I	RBS/121	P-14	88V-9	A	
1G33*MOV041	RWCU System Reactor Return	SH1-88V	I	RBS/78	T-08	88V-9	A	

A = Acceptable

Note: The following valves have not been reviewed and are not safety related:
1G33-MOV035, 1G33-MOV036, 1G33-MOV037, 1G33-MOV038, 1G33-MOV039, 1G33-MOV040

JOB NO.: 11600.02

MECHANICAL EQUIPMENT ENVIRONMENTAL
CONFORMANCE REVIEW SHEET

DATE: 8/02/82

JOB NAME: SHOREHAM - UNIT 1

COMPILED BY: L.S. Fiore

SORTED BY SPEC.

JOB CLIENT: LILCO

SHT. NO. ECR-88V-10 REV. 0

SYSTEM TITLE: FUEL POOL COOLING AND CLEANUP (G41)

Mark No.	Vendor/Description	Spec.	Q.A. Cat.	Bldg./Elev.	Zone	E.C.Data Sht.	Status	Comments
	VELAN/							
1G41*MOV033A	Suppression Pool Inlet	SH1-88V	I	RBS/46	G-02	88V-10	A	
1G41*MOV033B	Suppression Pool Inlet	SH1-88V	I	RBS/44	G-02	88V-10	A	
1G41*MOV034A	P-211 Suction	SH1-88V	I	RBS/30	G-01	88V-10	A	
1G41*MOV034B	P-211 Suction	SH1-88V	I	RBS/30	G-01	88V-10	A	

A = Acceptable

JOB NO.: 11600.02

MECHANICAL EQUIPMENT ENVIRONMENTAL
CONFORMANCE REVIEW SHEET

DATE: 8/02/82

JOB NAME: SHOREHAM - UNIT 1

COMPILED BY: L.S. Fiore

SORTED BY SPEC.

JOB CLIENT: LILCO

SHT. NO. ECR-88V-11 REV. 0

SYSTEM TITLE: REACTOR BUILDING CLOSED LOOP COOLING WATER (P42)

Mark No.	Vendor/Description	Spec.	Q.A. Cat.	Bldg./Elev.	Zone	E.C.Data Sht.	Status	Comments
	VELAN/							
1P42*MOV031A	RBCLCW Hx Disc. X Over	SH1-88V	I	RBS/59	L-02	88V-10	A	
1P42*MOV031B	RBCLCW Hx Disc. X Over	SH1-88V	I	RBS/59	L-02	88V-10	A	
1P42*MOV032A	RBCLCW Hx Disc. X Over VV	SH1-88V	I	RBS/150	H-18	88V-10	A	
1P42*MOV032B	RBCLCW Hx Disc. X Over VV	SH1-88V	I	RBS/150	H-18	88V-10	A	
1P42*MOV033A	RBCLCW Isol Valve VV	SH1-88V	I	RBS/150	H-18	88V-11	A	
1P42*MOV033B	RBCLCW Isol Valve VV	SH1-88V	I	RBS/150	H-18	88V-11	A	
1P42*MOV034A	RBCLCW Isol Valve VV	SH1-88V	I	RBS/126	P-14	88V-11	A	
1P42*MOV034B	RBCLCW Isol Valve VV	SH1-88V	I	RBS/126	P-14	88V-11	A	

A = Acceptable

JOB NO.: 11600.02

MECHANICAL EQUIPMENT ENVIRONMENTAL
CONFORMANCE REVIEW SHEET

DATE: 8/02/82

JOB NAME: SHOREHAM - UNIT 1

COMPILED BY: L.S. Fiore

SORTED BY SPEC.

JOB CLIENT: LILCO

SHT. NO. ECR-88V-12 REV. 0

SYSTEM TITLE: REACTOR BUILDING CLOSED LOOP COOLING WATER (P42)

Mark No.	Vendor/Description	Spec.	Q.A. Cat.	Bldg./Elev.	Zone	E.C.Data Sht.	Status	Comments
	VELAN/							
1P42*MOV035	RBCLCW Inlet To P-1A Coolers	SH1-88V	I	RBS/67	G-03	88V-11	A	
1P42*MOV036	RBCLCW Outlet From P-1A	SH1-88V	I	RBS/67	G-03	88V-11	A	
1P42*MOV041A	RBCLCW Hx Crossover Inlet VV	SH1-88V	I	RBS/28	G-01	88V-12	A	
1P42*MOV041B	RCLCW Hx Crossover Inlet VV	SH1-88V	I	RBS/28	G-01	88V-12	A	
1P42*MOV042A	Inlet to H.E.E. - 11A	SH1-88V	I	RBS/30	G-01	88V-12	A	
1P42*MOV042B	Inlet to H.E.E. - 11B	SH1-88V	I	RBS/30	G-01	88V-12	A	
1P42*MOV043A	MG Set Flow Cplg Inlet VV	SH1-88V	I	RBS/56	L-02	88V-12	A	

A = Acceptable

JOB NO.: 11600.02

MECHANICAL EQUIPMENT ENVIRONMENTAL
CONFORMANCE REVIEW SHEET

DATE: 8/02/82

JOB NAME: SHOREHAM - UNIT 1

COMPILED BY: L.S. Fiore

SORTED BY SPEC.

JOB CLIENT: LILCO

SHT. NO. ECR-88V-13 REV. 0

SYSTEM TITLE: REACTOR BUILDING CLOSED LOOP COOLING WATER (P42)

Mark No.	Vendor/Description	Spec.	Q.A. Cat.	Bldg./Elev.	Zone	E.C.Data Sht.	Status	Comments
	VELAN/							
1P42*MOV043B	MG Set Flow Cplg Inlet VV	SH1-88V	I	RBS/54	L-02	88V-12	A	
1P42*MOV044A	MG Set Flow Cplg Inlet VV	SH1-88V	I	RBS/56	L-02	88V-13	A	
1P42*MOV044B	MG Set Flow Cplg Inlet VV	SH1-88V	I	RBS/54	L-02	88V-13	A	
1P42*MOV047	RBCLCW Inlet To P-1B Coolers	SH1-88V	I	RBS/68	G-03	88V-13	A	
1P42*MOV048	RBCLCW From Outlet P-18	SH1-88V	I	RBS/68	G-03	88V-14	A	
1P42*MOV147	Drywell Cooler Outlet VV	SH1-88V	I	RBD/74	D-22	88V-14	A	
1P42*MOV148	RBCLCW Drywell Outlet VV	SH1-88V	I	RBD/74	D-22	88V-14	A	
1P42*MOV231	RBCLCW Drywell Out VV to Drywell Cooler 17B	SH1-88V	I	RBS/66	G-07	88V-15	A	

A = Acceptable

JOB NO.: 11600.02

MECHANICAL EQUIPMENT ENVIRONMENTAL
CONFORMANCE REVIEW SHEET

DATE: 8/02/82

JOB NAME: SHOREHAM - UNIT 1

COMPILED BY: L.S. Fiore

SORTED BY SPEC.

JOB CLIENT: LILCO

SHT. NO. ECR-88V-14 REV. 0

SYSTEM TITLE: REACTOR BUILDING CLOSED LOOP COOLING WATER (P42)

Mark No.	Vendor/Description	Spec.	Q.A. Cat.	Bldg./Elev.	Zone	E.C.Data Sht.	Status	Comments
	VELAN/							
1P42*MOV232	RBCLCW In VV To Drywell Cooler 17A	SH1-88V	I	RBS/67	G-03	88V-15	A	
1P42*MOV233	RBCLCW In VV To Drywell Cooler 17A	SH1-88V	I	RBS/68	G-03	88V-15	A	
1P42*MOV234	RBCLCW In VV To Drywell Cooler 17A	SH1-88V	I	RBS/69	G-03	88V-15	A	
1P42*MOV235	RBCLCW In VV To Drywell Cooler 17A	SH1-88V	I	RBS/70	G-03	88V-15	A	
1P42*MOV236	RBCLCW Out VV To Drywell Cooler 17B	SH1-88V	I	RBS/66	G-03	88V-15	A	
1P42*MOV237	RBCLCW In VV To Drywell Cooler 17B	SH1-88V	I	RBS/67	G-03	88V-15	A	

A = Acceptable

JOB NO.: 11600.02

MECHANICAL EQUIPMENT ENVIRONMENTAL
CONFORMANCE REVIEW SHEET

DATE: 8/02/82

JOB NAME: SHOREHAM - UNIT 1

COMPILED BY: L.S. Fiore

SORTED BY SPEC.

JOB CLIENT: LILCO

SHT. NO. ECR-88V-15 REV. 0

SYSTEM TITLE: REACTOR BUILDING CLOSED LOOP COOLING WATER (P42)

Mark No.	Vendor/Description	Spec.	Q.A. Cat.	Bldg./Elev.	Zone	E.C.Data Sht.	Status	Comments
	VELAN/							
1P42*MOV238	RBCLCW In VV To Drywell Cooler 17B	SH1-88V	I	RBS/68	G-03	88V-16	A	
1P42*MOV239	RBCLCW In VV To Drywell Cooler 17B	SH1-88V	I	RBS/69	G-03	88V-16	A	
1P42*MOV240	RBCLCW In VV To Drywell Cooler 17B	SH1-88V	I	RBS/70	G-03	88V-16	A	

A = Acceptable

JOB NO.: 11600.02

MECHANICAL EQUIPMENT ENVIRONMENTAL
CONFORMANCE REVIEW SHEET

DATE: 8/02/82

JOB NAME: SHOREHAM - UNIT 1

COMPILED BY: L.S. Fiore

SORTED BY SPEC.

JOB CLIENT: LILCO

SHT. NO. ECR-88V-16 REV. 0

SYSTEM TITLE: PRIMARY CONTAINMENT ATMOSPHERIC CONTROL (T48)

Mark No.	Vendor/Description	Spec.	Q.A. Cat.	Bldg./Elev.	Zone	E.C.Data Sht.	Status	Comments
	VELAN/							
1T48*MOV031A	Atmos. Inbd. Cont. Iso NW Drywell	SH1-88V	I	RBD/67	D-22	88V-17	A	
1T48*MOV031B	Atmos. Inbd. Cont. Iso SE Drywell	SH1-88V	I	RBD/73	D-22	88V-17	A	
1T48*MOV032A	Atmos. Inbd. Cont. Iso SE Drywell	SH1-88V	I	RBD/71	D-22	88V-17	A	
1T48*MOV032B	Atmos. Inbd. Cont. Iso SW Drywell	SH1-88V	I	RBD/71	D-22	88V-17	A	
1T48*MOV033A	Atmos. Inbd. Cont. Iso N Supp Chm	SH1-88V	I	RBS/51	L-02	88V-17	A	
1T48*MOV033B	Atmos. Inbd. Cont. Iso NE Supp Chm	SH1-88V	I	RBS/51	L-02	88V-17	A	
1T48*MOV034A	Atmos Inbd. Cont. Iso SW Supp Chm	SH1-88V	I	RBS/51	L-02	88V-17	A	
1T48*MOV034B	Atmos Inbd. Cont. Iso S Supp Chm	SH1-88V	I	RBS/51	L-02	88V-17	A	
1T48*MOV035A	Atmos. Otbd. Cont. Iso	SH1-88V	I	RBS/68	G-03	88V-18	A	

A = Acceptable

JOB NO.: 11600.02

MECHANICAL EQUIPMENT ENVIRONMENTAL
CONFORMANCE REVIEW SHEET

DATE: 8/02/82

JOB NAME: SHOREHAM - UNIT 1

COMPILED BY: L.S. Fiore

SORTED BY SPEC.

JOB CLIENT: LILCO

SHT. NO. ECR-88V-17 REV. 0

SYSTEM TITLE: PRIMARY CONTAINMENT ATMOSPHERIC CONTROL (T48)

Mark No.	Vendor/Description	Spec.	Q.A. Cat.	Bldg./Elev.	Zone	E.C.Data Sht.	Status	Comments
	VELAN/							
1T48*MOV035B	Atmos. Otbd. Cont. Iso	SH1-88V	I	RBS/73	G-03	88V-18	A	
1T48*MOV037A	Atmos. Otbd. Cont. Iso	SH1-88V	I	RBS/73	G-03	88V-18	A	
1T48*MOV037B	Atmos. Otbd. Cont. Iso	SH1-88V	I	RBS/72	G-03	88V-18	A	
1T48*MOV038A	Atmos. Otbd. Cont. Iso	SH1-88V	I	RBS/51	L-02	88V-18	A	
1T48*MOV038B	Atmos. Otbd. Cont. Iso	SH1-88V	I	RBS/51	L-02	88V-18	A	
1T48*MOV040A	Atmos. Otbd. Cont. Iso	SH1-88V	I	RBS/51	L-02	88V-19	A	
1T48*MOV040B	Atmos. Otbd. Cont. Iso	SH1-88V	I	RBS/51	L-02	88V-19	A	
1T48*MOV041	Release to Atmos.	SH1-88V	I	RBS/112	J-15	88V-19	A	
1T48*MOV042	Release to Atmos.	SH1-88V	I	RBS/112	K-15	88V-19	A	
1T48*MOV043A	Atmos. Otbd. Cont. Iso	SH1-88V	I	RBS/68	G-03	88V-19	A	

A = Acceptable

JOB NO.: 11600.02

MECHANICAL EQUIPMENT ENVIRONMENTAL
CONFORMANCE REVIEW SHEET

DATE: 8/02/82

JOB NAME: SHOREHAM - UNIT 1

COMPILED BY: L.S. Fiore

SORTED BY SPEC.

JOB CLIENT: LILCO

SHT. NO. ECR-88V-18 REV. 0

SYSTEM TITLE: PRIMARY CONTAINMENT ATMOSPHERIC CONTROL (T48)

Mark No.	Vendor/Description	Spec.	Q.A. Cat.	Bldg./Elev.	Zone	E.C.Data Sht.	Status	Comments
	VELAN/							
1T48*MOV043B	Atmos. Otbd. Cont. Iso	SH1-88V	I	RBS/73	G-03	88V-19	A	
1T48*MOV044A	Atmos. Otbd. Cont. Iso	SH1-88V	I	RBS/51	L-02	88V-20	A	
1T48*MOV044B	Atmos. Otbd. Cont. Iso	SH1-88V	I	RBS/51	L-02	88V-20	A	

A = Acceptable

JOB NO.: 11600.02

MECHANICAL EQUIPMENT ENVIRONMENTAL
CONFORMANCE REVIEW SHEET

DATE: 8/02/82

JOB NAME: SHOREHAM - UNIT 1

COMPILED BY: L.S. Fiore

SORTED BY SPEC.

JOB CLIENT: LILCO

SHT. NO. ECR-88V-19 REV. 0

SYSTEM TITLE: SPARES

Mark No.	Vendor/Description	Spec.	Q.A. Cat.	Bldg./Elev.	Zone	E.C.Data Sht.	Status	Comments
	VELAN/							
1Z91*MOV001	Leakage Ret. Pump To Supp. Pool	SH1-88V	I	N/A	N/A	88V-20	A	
1Z91*MOV002	Leakage Ret. Pump	SH1-88V	I	N/A	N/A	88V-20	A	
1Z91*MOV067	MSIV Drain Header	SH1-88V	I	N/A	N/A	88V-20	A	
1Z91*MOV460	MSIV Leakage Control	SH1-88V	I	N/A	N/A	88V-20	A	
1Z91*MOV461	MSIV Leakage Control	SH1-88V	I	N/A	N/A	88V-21	A	
1Z91*MOV462	MSIV Leakage Control	SH1-88V	I	N/A	N/A	88V-21	A	
1Z91*MOV653	CRD System Return	SH1-88V	I	N/A	N/A	88V-21	A	
1Z91*MOV925A	RCIC Pump Disch.	SH1-88V	I	N/A	N/A	88V-21	A	
1Z91*MOV925B	Reactor System React. Ret.	SH1-88V	I	N/A	N/A	88V-21	A	
1Z91*MOV975	Spare Operator	SH1-88V	I	N/A	N/A	88V-21	A	

A = Acceptable
N/A = Not Applicable

JOB NO.: 11600.02

JOB NAME: SHOREHAM - UNIT 1

JOB CLIENT: LILCO

COMPILED BY: Louis S. Fiore

DATE: 8/2/82

SHT. NO. FCD-88V-1 REV. 0

MECHANICAL EQUIPMENT ENVIRONMENTAL CONFORMANCE DATA SHEET

Specification No./Vendor: SH1-88V/Velan Engineering Co.

Mark No.	Sub-Component Identification			Environmental Qualification Report Environment			Documented Material Data		Status	Reference Comments
	Vendor Dwg. No Shoreham File No. (SFN)	Non-Metallic Sub-Components	Material	Zone	Total* Radiation (Rads)	Temp. (°F)	Threshold Radiation (Rads)	Service Temperature (°F)		
1B21*MOV031	P2-328 7-N-1 SFN6.37-194G	Packing Ring	Braided Asbestos	D-22	1.2×10^8	340	1×10^{10}	1200	A	NM-88V-1
		Spiral Wound Gasket	SS/Asbestos	D-22	1.2×10^8	340	1×10^{10}	1200	A	NM-88V-2
1B21*MOV032	P2-3287-N-2 SFN6.37	Same as 1B21*MOV031	Same as 1B21*MOV031	T-08	3.6×10^6	215	1×10^{10}	1200	A	Same as 1B21*MOV031
1B21*MOV034	P2-3287-N-15 SFN6.37-206	Same as 1B21*MOV031	Same as 1B21*MOV031	N-08	5.3×10^4	215	1×10^{10}	1200	A	Same as 1B21*MOV031
1E11*MOV033A	P2-3287-N11 SFN6.37-203M	Same as 1B21*MOV031	Same as 1B21*MOV031	G-01	7×10^6	150	1×10^{10}	1200	A	Same as 1B21*MOV031
B	P2-3287-N11 SFN6.37-203M	Same as 1B21*MOV031	Same as 1B21*MOV031	G-01	7×10^6	150	1×10^{10}	1200	A	Same as 1B21*MOV031

* Some equipment in Systems E11, E21, E41 and E51 will have a minimum radiation value of 7×10^6 due to suppression pool water carried in them during a LOCA.

JOB NO.: 11600.02

JOB NAME: SHOREHAM - UNIT 1

JOB CLIENT: LILCO

COMPILED BY: Louis S. Fiore

DATE: 8/2/82

SHT. NO. ECD-88V-2 REV. 0

MECHANICAL EQUIPMENT ENVIRONMENTAL CONFORMANCE DATA SHEET

Specification No./Vendor: SH1-88V/Velan Engineering Co.

Mark No.	Sub-Component Identification			Environmental Qualification Report Environment			Documented Material Data		Status	Reference	Comments
	Vendor Dwg. No Shoreham File No. (SFN)	Non-Metallic Sub-Components	Material	Zone	Total* Radiation (Rads)	Temp. (°F)	Threshold Radiation (Rads)	Service Temperature (°F)			
1E11*MOV035A	P2-3287-N11 SFN6.37-203M	Same as 1B21*MOV031	Same as 1B21*MOV031	G-01	7×10^6	150	1×10^{10}	1200	A	Same as 1B21*MOV031	
B	P2-3287-N11 SFN6.37-203M	Same as 1B21*MOV031	Same as 1B21*MOV031	G-01	7×10^6	150	1×10^{10}	1200	A	Same as 1B21*MOV031	
1E11*MOV039A	P2-3287-N-8 SFN6.37-94J	Same as 1B21*MOV031	Same as 1B21*MOV031	G-10	7×10^6	177	1×10^{10}	1200	A	Same as 1B21*MOV031	
B	P2-3287-N-8 SFN6.37-94J	Same as 1B21*MOV031	Same as 1B21*MOV031	G-10	7×10^6	177	1×10^{10}	1200	A	Same as 1B21*MOV031	
1E11*MOV040A	P2-3287-N11 SFN6.37-203M	Same as 1B21*MOV031	Same as 1B21*MOV031	G-03	7×10^6	148	1×10^{10}	1200	A	Same as 1B21*MOV031	
B	P2-3287-N11 SFN6.37-203M	Same as 1B21*MOV031	Same as 1B21*MOV031	G-07	7×10^6	168	1×10^{10}	1200	A	Same as 1B21*MOV031	

* Some equipment in Systems E11, E21, E41 and E51 will have a minimum radiation value of 7×10^6 due to suppression pool water carried in them during a LOCA.

JOB NO.: 11600.02

JOB NAME: SHOREHAM - UNIT 1

JOB CLIENT: LILCO

COMPILED BY: Louis S. Fiore

DATE: 8/2/82

SHT. NO. ECD-88V-1 REV. 0

MECHANICAL EQUIPMENT ENVIRONMENTAL CONFORMANCE DATA SHEET

Specification No./Vendor: SH1-88V/Velan Engineering Co.

Mark No.	Sub-Component Identification: Vendor Dwg. No Shoreham File No. (SFN)	Sub-Component Identification: Non-Metallic Sub-Components	Sub-Component Identification: Material	Environmental Qualification Report Environment: Zone	Environmental Qualification Report Environment: Total* Radiation (Rads)	Environmental Qualification Report Environment: Temp. (°F)	Documented Material Data: Threshold Radiation (Rads)	Documented Material Data: Service Temperature (°F)	Status	Reference	Comments
1E11*MOV041A	P2-3287-N-14 SFN6.37-105F	Same as 1B21*MOV031	Same as 1B21*MOV031	G-02	7×10^6	152	1×10^{10}	1200	A	Same as 1B21*MOV031	
B	P2-3287-N-14 SFN6.37-105F	Same as 1B21*MOV031	Same as 1B21*MOV031	G-02	7×10^6	152	1×10^{10}	1200	A	Same as 1B21*MOV031	
1E11*MOV043A	P2-3287-N-6 SFN6.37-92E	Same as 1B21*MOV031	Same as. 1B21*MOV031	G-01	7×10^6	150	1×10^{10}	1200	A	Same as 1B21*MOV031	
B	P2-3287-N-6 SFN6.37-92E	Same as 1B21*MOV031	Same as 1B21*MOV031	G-01	7×10^6	150	1×10^{10}	1200	A	Same as 1B21*MOV031	
1E11*MOV044A	P2-3287-N-6 SFN6.37-92E	Same as 1B21*MOV031	Same as 1B21*MOV031	G-01	7×10^6	150	1×10^{10}	1200	A	Same as 1B21*MOV031	
B	P2-3287-N-6 SFN6.37-92E	Same as 1B21*MOV031	Same as 1B21*MOV031	G-01	7×10^6	150	1×10^{10}	1200	A	Same as 1B21*MOV031	

* Some equipment in Systems E11, E21, E41 and E51 will have a minimum radiation value of 7×10^6 due to suppression pool water carried in them during a LOCA.

COMPILED BY: Louis S. Fiore

DATE: 8/2/82

SHT. NO. ECD-88V-4 REV. 0

JOB NO.: 11600.02

JOB NAME: SHOREHAM - UNIT 1

JOB CLIENT: LILCO

MECHANICAL EQUIPMENT ENVIRONMENTAL CONFORMANCE DATA SHEET

Specification No./Vendor: SH1-88V/Velan Engineering Co.

Mark No.	Sub-Component Identification			Environmental Qualification Report Environment			Documented Material Data		Status	Reference	Comments
	Vendor Dwg. No. Shoreham File No. (SFN)	Non-Metallic Sub-Components	Material	Zone	Total* Radiation (Rads)	Temp. (°F)	Threshold Radiation (Rads)	Service Temperature (°F)			
1E11*MOV045A	P2-3287-N-5 SFN6.37-143J	Same as 1B21*MOV031	Same as 1B21*MOV031	G-01	7×10^6	150	1×10^{10}	1200	A	Same as 1B21*MOV031	
B	P2-3287-N-5 SFN6.37-143J	Same as 1B21*MOV031	Same as 1B21*MOV031	G-01	7×10^6	150	1×10^{10}	1200	A	Same as 1B21*MOV031	
1E11*MOV049	P2-3287-N-3 SFN6.37-178E	Same as 1B21*MOV031	Same as 1B21*MOV031	G-03	7×10^6	148	1×10^{10}	1200	A	Same as 1B21*MOV031	
1E11*MOV050	P2-3287-N-18 SFN6.37-139G	Same as 1B21*MOV031	Same as 1B21*MOV031	G-07	7×10^6	168	1×10^{10}	1200	A	Same as 1B21*MOV031	
1E11*MOV051	P2-3287-N-6 SFN6.37-92E	Same as 1B21*MOV031	Same as 1B21*MOV031	G-07	5.8×10^6	168	1×10^{10}	1200	A	Same as 1B21*MOV031	
1E11*MOV052	P2-3287-N-13 SFN6.37-98C	Same as 1B21*MOV031	Same as 1B21*MOV031	G-07	5.8×10^6	168	1×10^{10}	1200	A	Same as 1B21*MOV031	
1E11*MOV053	P2-3287-N-15 SFN6.37-206	Same as 1B21*MOV031	Same as 1B21*MOV031	G-12	5.8×10^6	194	1×10^{10}	1200	A	Same as 1B21*MOV031	

* Some equipment in Systems E11, E21, E41 and E51 will have a minimum radiation value of 7×10^6 due to suppression pool water carried in them during a LOCA.

JOB NO.: 11600.02

JOB NAME: SHOREHAM - UNIT 1

JOB CLIENT: LILCO

COMPILED BY: Louis S. Fiore

DATE: 8/2/82

SHT. NO. ECD-88V-5 REV 0

MECHANICAL EQUIPMENT ENVIRONMENTAL CONFORMANCE DATA SHEET

Specification No./Vendor: SH1-88V/Velan Engineering Co.

Mark No.	Sub-Component Identification			Environmental Qualification Report Environment			Documented Material Data		Status	Reference	Comments
	Vendor Dwg. No Shoreham File No. (SFN)	Non-Metallic Sub-Components	Material	Zone	Total* Radiation (Rads)	Temp. (°F)	Threshold Radiation (Rads)	Service Temperature (°F)			
1E11*MOV054	P2-3287-N-1 SFN6.37-194G	Same as 1B21*MOV031	Same as 1B21*MOV031	B-22	1.8×10^8	340	1×10^{10}	1200	A	Same as 1B21*MOV031	
1E21*MOV033A	P2-3287-N-17 SFN6.37-151H	Same as 1B21*MOV031	Same as 1B21*MOV031	G-09	7×10^6	184	1×10^{10}	1200	A	Same as 1B21*MOV031	
B	P2-3287-N-17 SFN6.37-151H	Same as 1B21*MOV031	Same as 1B21*MOV031	G-12	7×10^6	194	1×10^{10}	1200	A	Same as 1B21*MOV031	
1E21*MOV034A	P2-3287-N-5 SFN6.37-143J	Same as 1B21*MOV031	Same as 1B21*MOV031	G-01	7×10^6	150	1×10^{10}	1200	A	Same as 1B21*MOV031	
B	P2-3287-N-5 SFN6.37-143J	Same as 1B21*MOV031	Same as 1B21*MOV031	G-01	7×10^6	150	1×10^{10}	1200	A	Same as 1B21*MOV031	
1E41*MOV031	P2-3287-N11 SFN6.37-203M	Same as 1B21*MOV031	Same as 1B21*MOV031	G-01	7×10^6	150	1×10^{10}	1200	A	Same as 1B21*MOV031	

* Some equipment in Systems 1E11, 1E21, 1E41 and 1E51 will have a minimum radiation value of 7×10^6 due to suppression pool water carried in them during a LOCA.

JOB NO.: 11600.02

JOB NAME: SHOREHAM - UNIT 1

JOB CLIENT: LILCO

COMPILED BY: Louis S. Fiore

DATE: 8/2/82

SHT. NO. ECD-88V-6 REV. 0

MECHANICAL EQUIPMENT ENVIRONMENTAL CONFORMANCE DATA SHEET

Specification No./Vendor: SH1-88V/Velan Engineering Co.

Mark No.	Sub-Component Identification			Environmental Qualification Report Environment			Documented Material Data		Status	Reference	Comments
	Vendor Dwg. No Shoreham File No. (SFN)	Non-Metallic Sub-Components	Material	Zone	Total* Radiation (Rads)	Temp. (°F)	Threshold Radiation (Rads)	Service Temperature (°F)			
1E41*MOV032	P2-3287-N11 SFN6.37-203M	Same as 1B21*MOV031	Same as 1B21*MOV031	G-01	7×10^6	150	1×10^{10}	1200	A	Same as 1B21*MOV031	
1E41*MOV034	P2-3287-N-4 SFN6.37-106M	Same as 1B21*MOV031	Same as 1B21*MOV031	G-05	7×10^6	173	1×10^{10}	1200	A	Same as 1B21*MOV031	
1E41*MOV036	P2-3287-N-15 SFN6.37-206	Same as 1B21*MOV031	Same as 1B21*MOV031	G-01	7×10^6	150	1×10^{10}	1200	A	Same as 1B21*MOV031	
1E41*MOV037	P2-3287-N-21 SFN6.37-167G	Same as 1B21*MOV031	Same as 1B21*MOV031	G-01	7×10^6	150	1×10^{10}	1200	A	Same as 1B21*MOV031	
1E41*MOV038	P2-3287-N-3 SFN6.37-178E	Same as 1B21*MOV031	Same as 1B21*MOV031	G-01	5.8×10^6	150	1×10^{10}	1200	A	Same as 1B21*MOV031	
1E41*MOV041	P2-3287-N-17 SFN6.37-151N	Same as 1B21*MOV031	Same as 1B21*MOV031	D-22	1.2×10^8	340	1×10^{10}	1200	A	Same as 1B21*MOV031	
1E41*MOV042	P2-3287-N-17 SFN6.37-151N	Same as 1B21*MOV031	Same as 1B21*MOV031	G-05	5.8×10^6	173	1×10^{10}	1200	A	Same as 1B21*MOV031	

* Some equipment in Systems 1E11, 1E21, 1E41 and 1E51 will have a minimum radiation value of 7×10^6 due to suppression pool water carried in them during a LOCA.

COMPILED BY: Louis S. Fiore

DATE: 8/2/82

SHT. NO. ECD-88V-7 REV 0

JOB NO.: 11600.02

JOB NAME: SHOREHAM - UNIT 1

JOB CLIENT: LILCO

MECHANICAL EQUIPMENT ENVIRONMENTAL CONFORMANCE DATA SHEET

Specification No./Vendor: SH1-88V/Velan Engineering Co.

Mark No.	Sub-Component Identification			Environmental Qualification Report Environment			Documented Material Data		Status	Reference	Comments
	Vendor Dwg. No Shoreham File No. (SFN)	Non-Metallic Sub-Components	Material	Zone	Total* Radiation (Rads)	Temp. (°F)	Threshold Radiation (Rads)	Service Temperature (°F)			
1E41*MOV043	P2-3287-N-3 SFN6.37-178E	Same as 1B21*MOV031	Same as 1B21*MOV031	G-01	5.8×10^6	150	1×10^{10}	1200	A	Same as 1B21*MOV031	
1E41*MOV044	P2-3287-N-18 SFN6.37-139G	Same as 1B21*MOV031	Same as 1B21*MOV031	G-01	5.8×10^6	150	1×10^{10}	1200	A	Same as 1B21*MOV031	
1E51*MOV031	P2-3287-N-7 SFN6.37-95J	Same as 1B21*MOV031	Same as 1B21*MOV031	G-01	7×10^6	150	1×10^{10}	1200	A	Same as 1B21*MOV031	
1E51*MOV032	P2-3287-N-7 SFN6.37-95J	Same as 1B21*MOV031	Same as 1B21*MOV031	G-01	7×10^6	150	1×10^{10}	1200	A	Same as 1B21*MOV031	
1E51*MOV034	P2-3287-N-1 SFN6.37-194G	Same as 1B21*MOV031	Same as 1B21*MOV031	G-01	7×10^6	150	1×10^{10}	1200	A	Same as 1B21*MOV031	
1E51*MOV035	P2-3287-NB24 SFN6.37-236C	Same as 1B21*MOV031	Same as 1B21*MOV031	H-12	7×10^6	194	1×10^{10}	1200	A	Same as 1B21*MOV031	
1E51*MOV037	P2-3287-N-15 SFN6.37-206	Same as 1B21*MOV031	Same as 1B21*MOV031	G-01	7×10^6	150	1×10^{10}	1200	A	Same as 1B21*MOV031	

* Some equipment in Systems E11, E21, E41 and E51 will have a minimum radiation value of 7×10^6 due to suppression pool water carried in them during a LOCA.

JOB NO.: 11600.02

JOB NAME: SHOREHAM - UNIT 1

JOB CLIENT: LILCO

COMPILED BY: Louis S. Fiore

DATE: 8/2/82

SHT. NO. ECD-88V-9 REV. 0

MECHANICAL EQUIPMENT ENVIRONMENTAL CONFORMANCE DATA SHEET

Specification No./Vendor: SH1-88V/Velan Engineering Co.

Mark No.	Sub-Component Identification: Vendor Dwg. No Shoreham File No. (SFN)	Sub-Component Identification: Non-Metallic Sub-Components	Sub-Component Identification: Material	Environmental Qualification Report Environment: Zone	Environmental Qualification Report Environment: Total Radiation (Rads)	Environmental Qualification Report Environment: Temp. (°F)	Documented Material Data: Threshold Radiation (Rads)	Documented Material Data: Service Temperature (°F)	Status	Reference	Comments
1G11*MOV639C	P2-3287-H23 SFN6.37-237F	Same as 1B21*MOV031	Same as 1B21*MOV031	G-01	5.8×10^6	150	1×10^{10}	1200	A	Same as 1B21*MOV031	
1G33*MOV030A	P2-3287-H-1 SFN6.37-194G	Same as 1B21*MOV031	Same as 1B21*MOV031	B-22	1.8×10^8	340	1×10^{10}	1200	A	Same as 1B21*MOV031	
B	P2-3287-H-1 SFN6.37-194G	Same as 1B21*MOV031	Same as 1B21*MOV031	B-22	1.8×10^8	340	1×10^{10}	1200	A	Same as 1B21*MOV031	
1G33*MOV031	P2-3287-H-1 SFN6.37-194G	Same as 1B21*MOV031	Same as 1B21*MOV031	B-22	1.8×10^8	340	1×10^{10}	1200	A	Same as 1B21*MOV031	
1G33*MOV032	P2-3287-H-1 SFN6.37-194G	Same as 1B21*MOV031	Same as 1B21*MOV031	B-22	1.8×10^8	340	1×10^{10}	1200	A	Same as 1B21*MOV031	
1G33*MOV033	P2-3287-H-1 SFN6.37-194G	Same as 1B21*MOV031	Same as 1B21*MOV031	P-14	1.6×10^5	217	1×10^{10}	1200	A	Same as 1B21*MOV031	
1G33*MOV034	P2-3287-H-1 SFN6.37-194G	Same as 1B21*MOV031	Same as 1B21*MOV031	P-14	1.6×10^5	217	1×10^{10}	1200	A	Same as 1B21*MOV031	
1G33*MOV041	P2-3287-HB24 SFN6.37-236J	Same as 1B21*MOV031	Same as 1B21*MOV031	T-08	3.6×10^6	215	1×10^{10}	1200	A	Same as 1B21*MOV031	

JOB NO.: 11600.02

JOB NAME: SHOREHAM - UNIT 1

JOB CLIENT: LILCO

COMPILED BY: Louis S. Fiore

DATE: 8/2/82

SHT. NO. ECD-RRV-10 REV. 0

MECHANICAL EQUIPMENT ENVIRONMENTAL CONFORMANCE DATA SHEET

Specification No./Vendor: SH1-88V/Velan Engineering Co.

Mark No.	Sub-Component Identification: Vendor Dwg. No. Shoreham File No. (SFN)	Sub-Component Identification: Non-Metallic Sub-Components	Sub-Component Identification: Material	Environmental Qualification Report Environment: Zone	Environmental Qualification Report Environment: Total Radiation (Rads)	Environmental Qualification Report Environment: Temp. (°F)	Documented Material Data: Threshold Radiation (Rads)	Documented Material Data: Service Temperature (°F)	Status	Reference	Comments
1G41*MOV033A	P2-3287-N-7 SFN6037-95J	Same as 1B21*MOV031	Same as 1B21*MOV031	G-02	5.8×10^6	152	1×10^{10}	1200	A	Same as 1B21*MOV031	
B	P2-3287-N-7 SFN6037-95J	Same as 1B21*MOV031	Same as 1B21*MOV031	G-02	5.8×10^6	152	1×10^{10}	1200	A	Same as 1B21*MOV031	
1G41*MOV034A	P2-3287-N-8 SFN6.37-94J	Same as 1B21*MOV031	Same as 1B21*MOV031	G-01	5.8×10^6	150	1×10^{10}	1200	A	Same as 1B21*MOV031	
B	P2-3287-N-8 SFN6.37-94J	Same as 1B21*MOV031	Same as 1B21*MOV031	G-01	5.8×10^6	150	1×10^{10}	1200	A	Same as 1B21*MOV031	
1P42*MOV031A	P2-3287-N-10 SFN6.37-213F	Packing Ring	Braided Asbestos	L-02	3.1×10^6	152	1×10^{10}	1200	A	NM-RRV-1	
B	P2-3287-N-10 SFN6.37-213F	Same as 1P42*MOV031A	Same as 1P42*MOV031A	L-02	3.1×10^6	152	1×10^{10}	1200	A	Same as 1P42*MOV031A	
1P42*MOV032A	P2-3287-N-10 SFN6.37-213F	Same as 1P42*MOV031A	Same as 1P42*MOV031A	H-18	5.3×10^4	138	1×10^{10}	1200	A	Same as 1P42*MOV031A	
B	P2-3287-N-10 SFN6.37-213F	Same as 1P42*MOV031A	Same as 1P42*MOV031A	H-18	5.3×10^4	138	1×10^{10}	1200	A	Same as 1P42*MOV031A	

JOB NO.: 11600.02

JOB NAME: SHOREHAM - UNIT 1

JOB CLIENT: LILCO

COMPILED BY: Louis S. Fiore

DATE: 8/2/82

SHT. NO. ECD-BBV-11 REV. 0

MECHANICAL EQUIPMENT ENVIRONMENTAL CONFORMANCE DATA SHEET

Specification No./Vendor: SH1-BBV/Velan Engineering Co.

Mark No.	Sub-Component Identification			Environmental Qualification Report Environment			Documented Material Data		Status	Reference	Comments
	Vendor Dwg. No Shoreham File No. (SFN)	Non-Metallic Sub-Components	Material	Zone	Total Radiation (Rads)	Temp. (°F)	Threshold Radiation (Rads)	Service Temperature (°F)			
1P42*MOV033A	P2-3287-N-10 SFN6.37-213F	Same as 1P42*MOV031A	Same as 1P42*MOV031A	N-18	5.3×10^4	138	1×10^{10}	1200	A	Same as 1P42*MOV031A	
B	P2-3287-N-10 SFN6.37-213F	Same as 1P42*MOV031A	Same as 1P42*MOV031A	N-18	5.3×10^4	138	1×10^{10}	1200	A	Same as 1P42*MOV031A	
1P42*MOV034A	P2-3287-N10 SFN6.37-213F	Same as 1P42*MOV031A	Same as 1P42*MOV031A	P-14	1.6×10^5	217	1×10^{10}	1200	A	Same as 1P42*MOV031A	
B	P2-3287-N-10 SFN6.37-213F	Same as 1P42*MOV031A	Same as 1P42*MOV031A	P-14	1.6×10^5	217	1×10^{10}	1200	A	Same as 1P42*MOV031A	
1P42*MOV035	P2-3287-N-22 SFN6.37-225D	Packing Ring	Braided Asbestos	G-03	5.8×10^6	148	1×10^{10}	1200	A	NM-BBV-1	
		Spiral Wound Gasket	SS/Asbestos	G-03	5.8×10^6	148	1×10^{10}	1200	A	NM-BBV-2	
1P42*MOV036	P2-3287-N-22 SFN6.37-225D	Same as 1P42*MOV035	Same as 1P42*MOV035	G-03	5.8×10^6	148	1×10^{10}	1200	A	Same as 1P42*MOV035	

COMPILED BY: L. S. Fiore

DATE: 8/2/82

SHT. NO. ECD-88V-12 REV. 0

JOB NO.: 11600.02

JOB NAME: SHOREHAM - UNIT 1

JOB CLIENT: LILCO

MECHANICAL EQUIPMENT ENVIRONMENTAL CONFORMANCE DATA SHEET

Specification No./Vendor: SH1-88V/Velan Engineering

Mark No.	Sub-Component Identification: Vendor Dwg. No Shoreham File No. (SFN)	Sub-Component Identification: Non-Metallic Sub-Components	Sub-Component Identification: Material	Environmental Qualification Report Environment: Zone	Environmental Qualification Report Environment: Total Radiation (Rads)	Environmental Qualification Report Environment: Temp. (°F)	Documented Material Data: Threshold Radiation (Rads)	Documented Material Data: Service Temperature (°F)	Status	Reference	Comments
1P42*MOV041A	P2-3287-H-12 SFN6.37-152E	Packing Ring	Braided Asbestos	G-01	5.8×10^6	150	1×10^{10}	1200	A	NM-88V-1	
B	P2-3287-H-12 SFN6.37-152E	Same as 1P42*MOV041A	Same as 1P42*MOV041A	G-01	5.8×10^6	150	1×10^{10}	1200	A	Same as 1P42*MOV041A	
1P42*MOV042A	P2-3287-H-12 SFN6.37-152E	Same as 1P42*MOV041A	Same as 1P42*MOV041A	G-01	5.8×10^6	150	1×10^{10}	1200	A	Same as 1P42*MOV041A	
B	P2-3287-H-12 SFN6.37-152E	Same as 1P42*MOV041A	Same as 1P42*MOV041A	G-01	5.8×10^6	150	1×10^{10}	1200	A	Same as 1P42*MOV041A	
1P42*MOV043A	P2-3287-H-10 SFN6.37-213F	Same as 1P42*MOV041A	Same as 1P42*MOV041A	L-02	3.1×10^6	152	1×10^{10}	1200	A	Same as 1P42*MOV041A	
B	P2-3287-H-10 SFN6.37-213F	Same as 1P42*MOV041A	Same as 1P42*MOV041A	L-02	3.1×10^6	152	1×10^{10}	1200	A	Same as 1P42*MOV041A	

COMPILED BY: Louis S. Fiore

DATE: 8/2/82

SHT. NO. ECD-88V-11 REV. 0

JOB NO.: 11600.02

JOB NAME: SHOREHAM - UNIT 1

JOB CLIENT: LILCO

MECHANICAL EQUIPMENT ENVIRONMENTAL CONFORMANCE DATA SHEET

Specification No./Vendor: SH1-88V/Velan Engineering Co.

Mark No.	Sub-Component Identification			Environmental Qualification Report Environment			Documented Material Data		Status	Reference	Comments
	Vendor Dwg. No Shoreham File No. (SFN)	Non-Metallic Sub-Components	Material	Zone	Total Radiation (Rads)	Temp. (°F)	Threshold Radiation (Rads)	Service Temperature (°F)			
1P42*MOV044A	P2-3287-B-10 SFN6.37-213F	Same as 1P42*MOV041A	Same as 1P42*MOV041A	L-02	3.1×10^6	152	1×10^{10}	1200	A	Same as 1P42*MOV041A	
B	P2-3287-F-10 SFN6.37-213F	Same as 1P42*MOV041A	Same as 1P42*MOV041A	L-02	3.1×10^6	152	1×10^{10}	1200	A	Same as 1P42*MOV041A	
1P42*MOV047	P2-3287-B-22	Packing Ring	Braided Asbestos	G-03	5.8×10^6	148	1×10^{10}	1200	A	NM-88V-1	
	SFN6.37-225D	Spiral Wound Gasket	SS/Asbestos	G-03	5.8×10^6	148	1×10^{10}	1200	A	NM-88V-2	

JOB NO.: 11600.02

JOB NAME: SHOREHAM - UNIT I

JOB CLIENT: LILCO

COMPILED BY: Louis S. Fiore

DATE: 8/2/82

SHT. NO. ECD-88V-14 REV. 0

MECHANICAL EQUIPMENT ENVIRONMENTAL CONFORMANCE DATA SHEET

Specification No./Vendor: SH1-88V/Velan Engineering Co.

Mark No.	Sub-Component Identification			Environmental Qualification Report Environment			Documented Material Data		Status	Reference	Comments
	Vendor Dwg. No Shoreham File No. (SFN)	Non-Metallic Sub-Components	Material	Zone	Total Radiation (Rads)	Temp. (°F)	Threshold Radiation (Rads)	Service Temperature (°F)			
1P42*MOV048	P2-328-7-H22 SFN6.37-225D	Packing Ring	Braided Asbestos	G-03	5.8×10^6	148	1×10^{10}	1200	A	NM-88V-1	
		Spiral Wound Gasket	SS/Asbestos	G-03	5.8×10^6	148	1×10^{10}	1200	A	NM-88V-2	
1P42*MOV147	P2-3287-H-22 SFN637-225D	Same as 1P42*MOV048	Same as 1P42*MOV048	D-22	1.2×10^8	340	1×10^{10}	1200	A	Same as 1P42*MOV048	
1P42*MOV148	P2-3287-H-22 SFN6.37-225D	Same as 1P42*MOV048	Same as 1P42*MOV048	D-22	1.2×10^8	340	1×10^{10}	1200	A	Same as 1P42*MOV048	

JOB NO.: 11600.02

JOB NAME: SHOREHAM - UNIT 1

JOB CLIENT: LILCO

COMPILED BY: Louis S. Fiore

DATE: 8/2/82

SHT. NO. ECD-88V-15 REV. 0

MECHANICAL EQUIPMENT ENVIRONMENTAL CONFORMANCE DATA SHEET

Specification No./Vendor: SH1-88V/Velan Engineering Co.

Mark No.	Sub-Component Identification			Environmental Qualification Report Environment			Documented Material Data		Status	Reference	Comments
	Vendor Dwg. No Shoreham File No. (SFN)	Non-Metallic Sub-Components	Material	Zone	Total Radiation (Rads)	Temp. (°F)	Threshold Radiation (Rads)	Service Temperature (°F)			
1P42*MOV231	P2-3287-N-5 SFN6.37-143J	Packing Ring	Braided Asbestos	G-07	5.8×10^6	168	1×10^{10}	1200	A	NM-88V-1	
		Spiral Wound Gasket	SS/Asbestos	G-07	5.8×10^6	168	1×10^{10}	1200	A	NM-88V-2	
1P42*MOV232	P2-3287-N-5 SFN6.37-143J	Same as 1P42*MOV231	Same as 1P42*MOV231	G-03	5.8×10^6	148	1×10^{10}	1200	A	Same as 1P42*MOV231	
1P42*MOV233	P2-3287-N-5 SFN-6.37-143J	Same as 1P42*MOV231	Same as 1P42*MOV231	G-03	5.8×10^6	148	1×10^{10}	1200	A	Same as 1P42*MOV231	
1P42*MOV234	P2-3287-N-5 SFN6.37-143J	Same as 1P42*MOV231	Same as 1P42*MOV231	G-03	5.8×10^6	148	1×10^{10}	1200	A	Same as 1P42*MOV231	
1P42*MOV235	P2-3287-N-5 SFN6.37-143J	Same as 1P42*MOV231	Same as 1P42*MOV231	G-03	5.8×10^6	148	1×10^{10}	1200	A	Same as 1P42*MOV231	
1P42*MOV236	P2-3287-N-5 SFN6.37-143J	Same as 1P42*MOV231	Same as 1P42*MOV231	G-03	5.8×10^6	148	1×10^{10}	1200	A	Same as 1P42*MOV231	
1P42*MOV237	P2-3287-N-5 SFN6.37-143J	Same as 1P42*MOV231	Same as 1P42*MOV231	G-03	5.8×10^6	148	1×10^{10}	1200	A	Same as 1P42*MOV231	

JOB NO.: 11600.02

JOB NAME: SHOREHAM - UNIT 1

JOB CLIENT: LILCO

COMPILED BY: Louis S. Fiore

DATE: 8/2/82

SHT. NO. ECD-88V-16 REV. 0

MECHANICAL EQUIPMENT ENVIRONMENTAL CONFORMANCE DATA SHEET

Specification No./Vendor: SH1-88V/Velan Engineering Co.

Mark No.	Sub-Component Identification: Vendor Dwg. No Shoreham File No. (SFN)	Non-Metallic Sub-Components	Material	Environmental Qualification Report Environment: Zone	Total Radiation (Rads)	Temp. (°F)	Documented Material Data: Threshold Radiation (Rads)	Service Temperature (°F)	Status	Reference	Comments
1P42*MOV238	P2-3287-W-5 SFN6.37-143J	Same as 1P42*MOV231	Same as 1P42*MOV231	G-03	5.8×10^6	148	1×10^{10}	1200	A	Same as 1P42*MOV231	
1P42*MOV239	P2-3287-W-5 SFN6.37-143J	Same as 1P42*MOV231	Same as 1P42*MOV231	G-03	5.8×10^6	148	1×10^{10}	1200	A	Same as 1P42*MOV231	
1P42*MOV240	P2-3287-W-5 SFN6.37-143J	Same as 1P42*MOV231	Same as 1P42*MOV231	G-03	5.8×10^6	148	1×10^{10}	1200	A	Same as 1P42*MOV231	

JOB NO.: 11600.02

JOB NAME: SHOREHAM - UNIT 1

JOB CLIENT: LILCO

COMPILED BY: Louis S. Fiore

DATE: 8/2/82

SHT. NO. ECD-88V-17 REV. 0

MECHANICAL EQUIPMENT ENVIRONMENTAL CONFORMANCE DATA SHEET

Specification No./Vendor: SH1-88V/Velan Engineering Co.

	Sub-Component Identification			Environmental Qualification Report Environment			Documented Material Data				
Mark No.	Vendor Dwg. No Shoreham File No. (SFN)	Non-Metallic Sub-Components	Material	Zone	Total Radiation (Rads)	Temp. (°F)	Threshold Radiation (Rads)	Service Temperature (°F)	Status	Reference	Comments
1T48*MOV031A	P2-3287-N-7 SFN6.37-95J	Packing Ring	Braided Asbestos	D-22	1.2×10^8	340	1×10^{10}	1200	A	NM 88V-1	
		Spiral Wound Gasket	SS/Asbestos	D-22	1.2×10^8	340	1×10^{10}	1200	A	NM 88V-2	
B	P2-3287-N-7 SFN6.37-95J	Same as 1T48*MOV031A	Same as 1T48*MOV031A	D-22	1.2×10^8	340	1×10^{10}	1200	A	Same as 1T48*MOV031A	
1T48*MOV032A	P2-3287-N-19 SFN6.37-146E	Same as 1T48*MOV031A	Same as 1T48*MOV031A	D-22	1.2×10^8	340	1×10^{10}	1200	A	Same as 1T48*MOV031A	
B	P2-3287-N-19 SFN6.37-146E	Same as 1T48*MOV031A	Same as 1T48*MOV031A	D-22	1.2×10^8	340	1×10^{10}	1200	A	Same as 1T48*MOV031A	
1T48*MOV033A	P2-3287-N-7 SFN6.37-95J	Same as 1T48*MOV031A	Same as 1T48*MOV031A	L-02	3.1×10^6	152	1×10^{10}	1200	A	Same as 1T48*MOV031A	
B	P2-3287-N-7 SFN6.37-95J	Same as 1T48*MOV031A	Same as 1T48*MOV031A	L-02	3.1×10^6	152	1×10^{10}	1200	A	Same as 1T48*MOV031A	
1T48*MOV034A	P2-3287-N-19 SFN6.37-146E	Same as 1T48*MOV031A	Same as 1T48*MOV031A	L-02	3.1×10^6	152	1×10^{10}	1200	A	Same as 1T48*MOV031A	
B	P2-3287-N-19 SFN6.37-146E	Same as 1T48*MOV031A	Same as 1T48*MOV031A	L-02	3.1×10^6	152	1×10^{10}	1200	A	Same as 1T48*MOV031A	

COMPILED BY: Louis S. Fiore

DATE: 8/2/82

SHT. NO. ECD-88V-18 REV. 0

JOB NO.: 11600.02

JOB NAME: SHOREHAM - UNIT 1

JOB CLIENT: LILCO

MECHANICAL EQUIPMENT ENVIRONMENTAL CONFORMANCE DATA SHEET

Specification No./Vendor: SH1-88V/Velan Engineering Co.

	Sub-Component Identification			Environmental Qualification Report Environment			Documented Material Data				
Mark No.	Vendor Dwg. No Shoreham File No. (SFN)	Non-Metallic Sub-Components	Material	Zone	Total Radiation (Rads)	Temp. (°F)	Threshold Radiation (Rads)	Service Temperature (°F)	Status	Reference	Comments
1T48*MOV035A	P2-3287-H-5 SFN6.37-143J	Same as 1T48B*MOV031A	Same as 1T48*MOV031A	G-03	5.8×10^6	148	1×10^{10}	1200	A	Same as 1T48*MOV031A	
B	P2-3287-H-5 SFN6.37-143J	Same as 1T48*MOV031A	Same as 1T48*MOV031A	G-03	5.8×10^6	148	1×10^{10}	1200	A	Same as 1T48*MOV031A	
1T48*MOV037A	P2-3287-H-19 SFN6.37-146K	Same as 1T48*MOV031A	Same as 1T48*MOV031A	G-03	5.8×10^6	148	1×10^{10}	1200	A	NM-88V-1	
B	P2-3287-H-19 SFN6.37-146K	Same as 1T48*MOV31A	Same as 1T48*MOV031A	G-03	5.8×10^6	148	1×10^{10}	1200	A	Same as 1T48*MOV031A	
1T48*MOV038A	P2-3287-H-5 SFN6.37-143J	Same as 1T48*MOV31A	Same as 1T48*MOV031A	L-02	3.1×10^6	152	1×10^{10}	1200	A	Same as 1T48*MOV031A	
B	P2-3287-H-5 SFN6.37-143J	Same as 1T48*MOV31A	Same as 1T48*MOV031A	L-02	3.1×10^6	152	1×10^{10}	1200	A	Same as 1T48*MOV031A	

JOB NO.: 11600.02

JOB NAME: SHOREHAM - UNIT 1

JOB CLIENT: LILCO

COMPILED BY: Louis S. Fiore

DATE: 8/2/82

SHT. NO. ECD-88V-12 REV. 0

MECHANICAL EQUIPMENT ENVIRONMENTAL CONFORMANCE DATA SHEET

Specification No./Vendor: SH1-88V/Velan Engineering Co.

Mark No.	Sub-Component Identification: Vendor Dwg. No Shoreham File No. (SFN)	Non-Metallic Sub-Components	Material	Environmental Qualification Report Environment: Zone	Total Radiation (Rads)	Temp. (°F)	Documented Material Data: Threshold Radiation (Rads)	Service Temperature (°F)	Status	Reference Comments
1T48*MOV040A	P2-3287-N-19 SFN6.37-146K	Same as 1T48*MOV031A	Same as 1T48*MOV031A	L-02	3.1×10^6	152	1×10^{10}	1200	A	Same as 1T48*MOV031A
B	P2-3287-N-19 SFN6.37-146K	Same as 1T48*MOV031A	Same as 1T48*MOV031A	L-02	3.1×10^6	152	1×10^{10}	1200	A	Same as 1T48*MOV031A
1T48*MOV041	P2-3287-N-5 SFN6.37-143J	Same as 1T48*MOV031A	Same as 1T48*MOV031A	J-15	2.5×10^5	158	1×10^{10}	1200	A	Same as 1T48*MOV031A
1T48*MOV042	P2-3287-N-5 SFN6.37-143J	Same as 1T48*MOV031A	Same as 1T48*MOV031A	K-15	1.3×10^8	158	1×10^{10}	1200	A	Same as 1T48*MOV031A
1T48*MOV043A	P2-3287-N-5 SFN6.37-143J	Same as 1T48*MOV031A	Same as 1T48*MOV031A	G-03	5.8×10^6	148	1×10^{10}	1200	A	Same as 1T48*MOV031A
B	P2-3287-N-5 SFN6.37-143J	Same as 1T48*MOV031A	Same as 1T48*MOV031A	G-03	5.8×10^6	148	1×10^{10}	1200	A	Same as 1T48*MOV031A

COMPILED BY: Louis S. Fiore

DATE: 8/2/82

SHT. NO. ECD-88V-20 REV. 0

JOB NO.: 11600.02

JOB NAME: SHOREHAM - UNIT 1

JOB CLIENT: LILCO

MECHANICAL EQUIPMENT ENVIRONMENTAL CONFORMANCE DATA SHEET

Specification No./Vendor: SH1-88V/Velan Engineering Co.

Mark No.	Sub-Component Identification			Environmental Qualification Report Environment			Documented Material Data		Status	Reference	Comments
	Vendor Dwg. No Shoreham File No. (SFN)	Non-Metallic Sub-Components	Material	Zone	Total Radiation (Rads)	Temp. (°F)	Threshold Radiation (Rads)	Service Temperature (°F)			
1T48*MOV044A	P2-3287-N-5 SFN6.37-143J	Same as 1T48*MOV031A	Same as 1T48*MOV031A	L-02	3.1×10^6	152	1×10^{10}	1200	A	Same as 1T48*MOV031A	
B	P2-3287-N-5 SFN6.37-143J	Same as 1T48*MOV031A	Same as 1T48*MOV031A	L-02	3.1×10^6	152	1×10^{10}	1200	A	Same as 1T48*MOV031A	
1Z91*MOV001	P2-3287-NB23 SFN6.37-237F	Same as 1T48*MOV031A	Same as 1T48*MOV031A	*	1.8×10^8	340	1×10^{10}	1200	A	Same as 1T48*MOV031A	
1Z91*MOV002	Same as 1T48*MOV031A	Same as 1T48*MOV031A	Same as 1T48*MOV031A	*	1.8×10^8	340	1×10^{10}	1200	A	Same as 1T48*MOV031A	
1Z91*MOV067	P2-3287-N20 SFN6.37-214E	Same as 1T48*MOV031A	Same as 1T48*MOV031A	*	1.8×10^8	340	1×10^{10}	1200	A	Same as 1T48*MOV031A	
1Z91*MOV460	P2-3287-N15 SFN6.37-206	Same as 1T48*MOV031A	Same as 1T48*MOV031A	*	1.8×18^8	340	1×10^{10}	1200	A	Same as 1T48*MOV031A	

*All valves in System 1Z91 (spares) are qualified to the harshest environment (B-22).

COMPILED BY: Louis S. Fiore

JOB NO.: 11600.02

DATE: 8/2/82

JOB NAME: SHOREHAM - UNIT 1

SHT. NO. ECD-88V-21 REV. 0

JOB CLIENT: LILCO

MECHANICAL EQUIPMENT ENVIRONMENTAL CONFORMANCE DATA SHEET

Specification No./Vendor: SH1-88V/Velan Engineering Co.

Mark No.	Sub-Component Identification			Environmental Qualification Report Environment			Documented Material Data		Status	Reference	Comments
	Vendor Dwg. No Shoreham File No. (SFN)	Non-Metallic Sub-Components	Material	Zone	Total Radiation (Rads)	Temp. (°F)	Threshold Radiation (Rads)	Service Temperature (°F)			
1Z91*MOV461	Same as 1Z91*MOV460	Same as 1T48*MOV031A	Same as 1T48*MOV031A	*	1.8×10^8	340	1×10^{10}	1200	A	Same as 1T48*MOV031A	
1Z91*MOV462	Same as 1Z91*MOV460	Same as 1T48*MOV031A	Same as 1T48*MOV031A	*	1.8×10^8	340	1×10^{10}	1200	A	Same as 1T48*MOV031A	
1Z91*MOV653	P-2387-N-9 SFN6.37-96D	Same as 1T48*MOV031A	Same as 1T48*MOV031A	*	1.8×10^8	340	1×10^{10}	1200	A	Same as 1T48*MOV031A	
1Z91*MOV925A	P-2387-N-1 SFN6.37-194G	Same as 1T48*MOV031A	Same as 1T48*MOV031A	*	1.8×10^8	340	1×10^{10}	1200	A	Same as 1T48*MOV031A	
1Z91*MOV925B	P2-2387-NB-24 SFN6.37-236C	Same as 1T48*MOV031A	Same as 1T48*MOV031A	*	1.8×10^8	340	1×10^{10}	1200	A	Same as 1T48*MOV031A	
1Z91*MOV975	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	

* All valves in System 1Z91 (spares) are qualified to the harshest environment (B-22).
1Z91*MOV975 is a motor operator only and is not reviewed in this effort.

SHT. NO. NM-88V-1
COMPILED BY: B. Roe

JOB NO. 11600.02

JOB NAME: SHOREHAM-UNIT 1

JOB CLIENT: LILCO

MATERIAL RESISTANCE TO ENVIRONMENT

TRADE NAME: Asbestos (Blue/African, Crane Packings 187I, 187J)*

CHEMICAL NAME: Asbestos

		Ref. No.
THRESHOLD (RADS)	1×10^{10}	11
MAX. SERVICE TEMPERATURE (°F)	1200	2

REFERENCES:

2. Materials Handbook, George S. Brady and Henry R. Clauser, 11th Edition, McGraw Hill Inc., 1977 (Pages 64-65).

11. "Shaft Seals for Power Generating Stations," Crane Bulletin No. S-2005-1 (Chart E).

19. Telex - from Flexitallic Gasket Company, Inc. to Lou Fiore (SWEC), dated 7/16/82.

24. Telex - from C. Dunkerley (SWEC) to G. McKillop (Crane Packing Co.), dated 7/19/82.

* When asbestos is used in gaskets and packings, a binder is added which will burn off at temperatures near 700°F, as indicated by various manufacturers. The manufacturers also claim that the binder is not important to the sealing function. Therefore, the binder's destruction by temperature or radiation is not of significance (References 19 and 24). The pure asbestos value is used.

JOB NO. 11600.02

SHT. NO. NM-88V-2
COMPILED BY: B. Roe

JOB NAME: SHOREHAM-UNIT 1

JOB CLIENT: LILCO

MATERIAL RESISTANCE TO ENVIRONMENT

. TRADE NAME: Asbestos-Inconel-Graphite, SS/w Asbestos, Flexitallic Items With Metals*

. CHEMICAL NAME: Asbestos

		Ref. No.
. THRESHOLD (RADS)	1×10^{10}	11
. MAX. SERVICE TEMPERATURE (°F)	1200	2

REFERENCES:

2. Materials Handbook, George S. Brady and Henry R. Clauser, 11th Edition, McGraw Hill Inc., 1977 (Pages 64-65).

11. "Shaft Seals for Power Generating Stations," Crane Bulletin No. S-2005-1 (Chart E).

19. Telex - from Flexitallic Gasket Company, Inc. to Lou Fiore (SWEC), dated 7/16/82.

24. Telex - from C. Dunkerley (SWEC) to G. McKillop (Crane Packing Co.), dated 7/19/82.

★ **For compositions such as Asbestos-Inconel-Graphite or S.S. with Asbestos, the data for asbestos is used.**

When asbestos is used in gaskets and packings, a binder is added which will burn off at temperatures near 700°F, as indicated by various manufacturers. The manufacturers also claim that the binder is not important to the sealing function. Therefore, the binder's destruction by temperature or radiation is not significant (References 19 and 24).

DATA PACKAGE SH1-102

TYPE OF EQUIPMENT: FANS

MANUFACTURER: BUFFALO FORGE COMPANY

STONE & WEBSTER SPECIFICATION NUMBER: SH1-102

Prepared by C. Dunkerley

Reviewed by KMEnos

Issue Date: August 16, 1982

JOB NO.: 11600.02

JOB NAME: SHOREHAM - UNIT 1

JOB CLIENT: LILCO

SYSTEM TITLE: REACTOR BLDG. STANDBY VENT SYSTEM (1T46)

MECHANICAL EQUIPMENT ENVIRONMENTAL CONFORMANCE REVIEW SHEET

SORTED BY SPEC.

DATE: 7/30/82

COMPILED BY: C. Dunkerley

SHT. NO. ECR-102-1 REV. 0

Mark No.	Vendor Description	Spec.	Q.A. Cat.	Bldg./Elev.	Zone	E.C.Data Sht.	Status	Comments
	BUFFALO FORCE FAN							
1T46*FN79A	Reactor Bldg. Exhauster Booster Fan	SH1-102	I	RBS/112	K-15	102-1	A	
1T46*FN79B	Reactor Bldg. Exhauster Booster Fan	SH1-102	I	RBS/112	K-15	102-1	A	

A = Acceptable

JOB NO.: 11600.02

JOB NAME: SHOREHAM - UNIT 1

CLIENT: LILCO

COMPILED BY: C. Dunkerley

DATE: 7/30/82

SHT. NO. ECD 102-1 REV. 0

MECHANICAL EQUIPMENT ENVIRONMENTAL CONFORMANCE DATA SHEET

Specification No./Vendor: SH1-102/Buffalo Forge Fan

Mark No.	Sub-Component Identification			Environmental Qualification Report Environment			Documented Material Data				
	Vendor Dwg. No Shoreham File No. (SFN)	Non-Metallic Sub-Components	Material	Zone	Total Radiation (Rads)	Temp. (°F)	Threshold Radiation (Rads)	Service Temperature (°F)	Status	Reference	Comments
1T46*FN79A	4W-70096 SFN 10.51-2B 7W-94490 SFN 10.51-3B	Paint	Mobil 13-R-53 No-Rust Primer	K-15	1.3×10^8	158	1×10^9	250	A	NM-102-1	
1T46*FN79B	Same as 1T46*FN79A	Paint	Mobil 13-R-53 No-Rust Primer	K-15	1.3×10^8	1°8	1×10^9	250	A	NM-102-1	

Note: No other non-metallic sub-components.

JOB NO. 11600.02

SHT. NO. NM-102-1
COMPILED BY: B. ROE

JOB NAME: SHOREHAM-UNIT 1

JOB CLIENT: LILCO

MATERIAL RESISTANCE TO ENVIRONMENT

- TRADE NAME: Mobil 13-R-53 No-Rust Primer
- CHEMICAL NAME: Oil-Alkyd Base Paint Containing Zinc Chromate and Red Iron Oxide

		Ref. No.
THRESHOLD (RADS)		
MAX. SERVICE TEMPERATURE (°F)	250	29
RADIATION RESISTANCE (RADS)	1×10^9	40

REFERENCES:

29. Mobil 13-R-53 No-Rust Primer Publication, dated 11/1/76.

40. Environmental Effects on Polymeric Materials, D.V. Rosato and Schwartz, John Wiley & Sons, Inc., New York, 1968

DATA PACKAGE SH1-172

TYPE OF EQUIPMENT: BUTTERFLY VALVES

MANUFACTURER: FISHER CONTROLS

STONE & WEBSTER SPECIFICATION NUMBER: SH1-172

Package contents:

Prepared by W. Barton Roe

Reviewed by KMcEnay

Issue Date: August 16, 1982

JOB No.: 11600.02

JOB NAME: SHOREHAM - UNIT 1

JOB-CLIENT: LILCO

SYSTEM TITLE: REACTOR BUILDING STANDBY VENTILATION

MECHANICAL EQUIPMENT ENVIRONMENTAL
CONFORMANCE REVIEW SHEET

SORTED BY SPEC.

DATE: 8/12/82

COMPILED BY: B. Roe

SHT. NO. ECR-172-1 REV. 0

Mark No.	Vendor/Description	Spec.	Q.A. Cat.	Bldg./Elev.	Zone	E.C.Data Sht.	Status	Remarks
	FISHER CONTROL VALVE W/BETTIS ACTUATOR							
1T46*AOV038A	RB Air to Drywell	SH1-172	I	RBP/78	D-22	172-1,2,3	Out-standing	Pending Further Evaluation
B	RB Air to Drywell	SH1-172	I	RBS/78	H-10	172-4,5,6	A	
C	RB Air to Suppres. Pool	SH1-172	I	RBS/40	L-02	172-7	A	
D	RB Air to Suppres. Pool	SH1-172	I	RBS/40	L-02	172-7	A	
1T46*AOV039A	RB Air From Drywell	SH1-172	I	RBP/112	B-22	172-7	Out-standing	Pending Further Evaluation
B	RB Air From Drywell	SH1-172	I	RBS/112	K-15	172-7	Out-standing	Pending Further Evaluation

A = Acceptable
N/A = Not Applicable

JOB No.: 11600.02

MECHANICAL EQUIPMENT ENVIRONMENTAL
CONFORMANCE REVIEW SHEET

DATE: 8/12/82

JOB NAME: SHOREHAM - UNIT 1

COMPILED BY: B. Roe

SORTED BY SPEC.

JOB-CLIENT: LILCO

SHT. NO. ECR-172-2 REV. 0

SYSTEM TITLE: REACTOR BUILDING STANDBY VENTILATION

Mark No.	Vendor/Description	Spec.	Q.A. Cat.	Bldg./Elev.	Zone	E.C.Data Sht.	Status	Remarks
1T46*AOV039C	RB Air From Suppres. Pool	SH1-172	I	RBS/40	G-02	172-7	A	
D	RB Air From Suppres. Pool	SH1-172	I	RBS/40	G-02	172-7	A	

A = Acceptable

JOB NO.: 11600.02

JOB NAME: SHOREHAM - UNIT 1

CLIENT: LILCO

COMPILED BY: B. Koe

DATE: 8/12/82

SHT. NO. ECD-172-1 REV. 0

MECHANICAL EQUIPMENT ENVIRONMENTAL CONFORMANCE DATA SHEET

Specification No./Vendor: SH1-172/Fisher Control Valves & Bettis Actuator

Mark No.	Sub-Component Identification			Environmental Qualification Report Environment			Documented Material		Status	Reference	Comments
	Vendor Dwg. No Shoreham File No. (SFN)	Non-Metallic Sub-Components	Material	Zone	Total Radiation (Rads)	Temp. (°F)	Threshold Radiation (Rads)	Service Temperature (°F)			
1T46*AOV038A	F42451-F SFN-10.90-8K	Valve:									
		T-Ring	EPT	D-22	1.2×10^8	340	8.77×10^6	300	Out-standing	J-172-1 NM-172-1	
		Packing Ring	Asbestos-Inconel Graphite	D-22	1.2×10^8	340	1×10^{10}	1200	A	NM-172-2	
		Gasket	SS#304 w/Asbestos	D-22	1.2×10^8	340	1×10^{10}	1200	A	NM-172-2	
		Bushing	AISI 1018 W/Teflon	D-22	1.2×10^8	340	1.5×10^4	400	J	J-172-1 NM-172-4	External to Valve
		Bushing	Bronze w/Graphite	D-22	1.2×10^8	340	9.1×10^8	500	A	NM-172-3	
		Actuator:									
		Piston Retainer Nut	Steel & Nylon	D-22	1.2×10^8	340	N/A	N/A	J	J-172-2	External to Valve

JOB NO.: 11600.02

JOB NAME: SHOREHAM - UNIT 1

CLIENT: LILCO

COMPILED BY: B. Roe

DATE: 8/12/82

SHT. NO. ECD-172-2 REV. 0

MECHANICAL EQUIPMENT ENVIRONMENTAL CONFORMANCE DATA SHEET

Specification No./Vendor: SH1-172/Fisher Control Valves & Bettis Actuator

Mark No.	Sub-Component Identification: Vendor Dwg. No Shoreham File No. (SFN)	Non-Metallic Sub-Components	Material	Environmental Qualification Report Environment: Zone	Total Radiation (Rads)	Temp. (°F)	Documented Material: Threshold Radiation (Rads)	Service Temperature (°F)	Status	Reference	Comments
1T46*AOV038A	F42451-F SFN-10.90-8K	Piston Seal	Duro 70A Nitrile	D-22	1.2×10^8	340	N/A	N/A	J	J-172-2	
		Yoke Seal	Duro 90A Molythane	D-22	1.2×10^8	340	N/A	N/A	J	J-172-2	
		Piston Rod Seal	Duro 65A Nitrile	D-22	1.2×10^8	340	N/A	N/A	J	J-172-2	
		Cylinder Seal	Duro 70A Nitrile	D-22	1.2×10^8	340	N/A	N/A	J	J-172-2	
		Housing Cover Gasket	Asbestos/ASTM D1170	D-22	1.2×10^8	340	N/A	N/A	J	J-172-2	
		Cylinder Adapter Gasket	Asbestos/ASTM D1170	D-22	1.2×10^8	340	N/A	N/A	J	J-172-2	
		Piston Head Seal	Duro 70A Nitrile	D-22	1.2×10^8	340	N/A	N/A	J	J-172-2	
		Adjusting Screw Seal	Nylon	D-22	1.2×10^8	340	N/A	N/A	J	J-172-2	

COMPILED BY: B. Roe

DATE: 8/12/82

SHT. NO. ECD-172-3 REV. 0

JOB NO.: 11600.02

JOB NAME: SHOREHAM - UNIT 1

CLIENT: LILCO

MECHANICAL EQUIPMENT ENVIRONMENTAL CONFORMANCE DATA SHEET

Specification No./Vendor: SH1-172/Fisher Control Valves & Bettis Actuator

Mark No.	Sub-Component Identification			Environmental Qualification Report Environment			Documented Material		Status	Reference	Comments
	Vendor Dwg. No Shoreham File No. (SFN)	Non-Metallic Sub-Components	Material	Zone	Total Radiation (Rads)	Temp. (°F)	Threshold Radiation (Rads)	Service Temperature (°F)			
1T46*AOV038A	F42451-F SFN-10.90-8K	Piston Rod Anti-Extrusion Seal	Duro 90A Molythane	D-22	1.2×10^8	340	N/A	N/A	J	J-172-2	
		Breather Cap	Aluminum & Buna-N	D-22	1.2×10^8	340	N/A	N/A	J	J-172-2	
		Air Set	N/A	D-22	1.2×10^8	340	N/A	N/A	J	J-172-2	External to Valve

JOB NO.: 11600.02

JOB NAME: SHOREHAM - UNIT 1

CLIENT: LILCO

COMPILED BY: B. Moe

DATE: 8/12/82

SHT. NO. ECD 172-4 REV. 0

MECHANICAL EQUIPMENT ENVIRONMENTAL CONFORMANCE DATA SHEET

Specification No./Vendor: SH1-172/Fisher Control Valves & Bettis Actuator

Mark No.	Sub-Component Identification			Environmental Qualification Report Environment			Documented Material		Status	Reference	Comments
	Vendor Dwg. No Shoreham File No. (SFN)	Non-Metallic Sub-Components	Material	Zone	Total Radiation (Rads)	Temp. (°F)	Threshold Radiation (Rads)	Service Temperature (°F)			
1T46*AOV038B	F42450-E SFN-10.90-6E	Valve:									
		T-Ring	EPT	H-10	5.3×10^4	177	8.77×10^6	300	A	NM-172-1	
		Packing Ring	Asbestos-Inconel Graphite	H-10	5.3×10^4	177	1×10^{10}	1200	A	NM-172-2	
		Gasket	SS#304 w/Asbestos	H-10	5.3×10^4	177	1×10^{10}	1200	A	NM-172-2	
		Bushing	AISI 1018 W/Teflon	H-10	5.3×10^4	177	1.5×10^4	400	J	J-172-1 NM-172-4	External to Valve
		Bushing	Bronze w/Graphite	H-10	5.3×10^4	177	9.1×10^8	500	A	NM-172-3	
		Actuator: Piston Retainer Nut	Steel & Nylon	H-10	5.3×10^4	177	N/A	N/A	J	J-172-2	External to Valve

JOB NO.: 11600.02

JOB NAME: SHOREHAM - UNIT 1

CLIENT: LILCO

COMPILED BY: B. Roe

DATE: 8/12/82

SHT. NO. ECD-172-5 REV. 0

MECHANICAL EQUIPMENT ENVIRONMENTAL CONFORMANCE DATA SHEET

Specification No./Vendor: SH1-172/Fisher Control Valves & Bettis Actuator

Mark No.	Sub-Component Identification			Environmental Qualification Report Environment			Documented Material		Status	Reference	Comments
	Vendor Dwg. No Shoreham File No. (SFN)	Non-Metallic Sub-Components	Material	Zone	Total Radiation (Rads)	Temp. (°F)	Threshold Radiation (Rads)	Service Temperature (°F)			
1T46*AOV038B	F42450-E SFN-10.90-6K	Piston Seal	Duro 70A Nitrile	N-10	5.3×10^4	177	N/A	N/A	J	J-172-2	
		Yoke Seal	Duro 90A Holythane	N-10	5.3×10^4	177	N/A	N/A	J	J-172-2	
		Piston Rod Seal	Duro 65A Nitrile	N-10	5.3×10^4	177	N/A	N/A	J	J-172-2	
		Cylinder Seal	Duro 70A Nitrile	N-10	5.3×10^4	177	N/A	N/A	J	J-172-2	
		Housing Cover Gasket	Asbestos/ASTM D1170	N-10	5.3×10^4	177	N/A	N/A	J	J-172-2	
		Cylinder Adapter Gasket	Asbestos/ASTM D1170	N-10	5.3×10^4	177	N/A	N/A	J	J-172-2	
		Piston Head Seal	Duro 70A Nitrile	N-10	5.3×10^4	177	N/A	N/A	J	J-172-2	
		Adjusting Screw Seal	Nylon	N-10	5.3×10^4	177	N/A	N/A	J	J-172-2	

COMPILED BY: B. Roe

DATE: 8/12/82

SHT. NO. ECD-172-6 REV. 0

JOB NO.: 11600.02

JOB NAME: SHOREHAM - UNIT 1

CLIENT: LILCO

MECHANICAL EQUIPMENT ENVIRONMENTAL CONFORMANCE DATA SHEET

Specification No./Vendor: SH1-172/Fisher Control Valves & Bettis Actuator

Mark No.	Sub-Component Identification			Environmental Qualification Report Environment			Documented Material		Status	Reference	Comments
	Vendor Dwg. No Shoreham File No. (SFN)	Non-Metallic Sub-Components	Material	Zone	Total Radiation (Rads)	Temp. (°F)	Threshold Radiation (Rads)	Service Temperature (°F)			
1T46*AOV038B	F42450-E SFN-10.90-6R	Piston Rod Anti-Extrusion Seal	Duro 90A Molythane	N-10	5.3×10^4	177	N/A	N/A	J	J-172-2	
		Breather Cap	Aluminum & Buna-N	N-10	5.3×10^4	177	N/A	N/A	J	J-172-2	
		Airset	N/A	N-10	5.3×10^4	177	N/A	N/A	J	J-172-2	External to Valve

JOB NO.: 11600.02

JOB NAME: SHOREHAM - UNIT 1

CLIENT: LILCO

COMPILED BY: B. Roe

DATE: 8/12/82

SHT. NO. ECD 172-7 REV. 0

MECHANICAL EQUIPMENT ENVIRONMENTAL CONFORMANCE DATA SHEET

Specification No./Vendor: SH1-172/Fisher Control Valves & Bettis Actuator

Mark No.	Sub-Component Identification			Environmental Qualification Report Environment			Documented Material		Status	Reference Comments
	Vendor Dwg. No Shoreham File No. (SFN)	Non-Metallic Sub-Components	Material	Zone	Total Radiation (Rads)	Temp. (°F)	Threshold Radiation (Rads)	Service Temperature (°F)		
1T46*AOV038C C	F42453-E SFN-10.90-9E	Same as 1T46*AOV038B	Same as 1T46*AOV038B	L-02	3.1×10^6	152	Same as 1T46*AOV-038B	Same as 1T46*AOV-038B	J	Same as 1T46*AOV038B
D	F42452-F SFN-10.90-7E	Same as 1T46*AOV038B	Same as 1T46*AOV038B	L-02	3.1×10^6	152	Same as 1T46*AOV-038B	Same as 1T46*AOV-038B	J	Same as 1T46*AOV038B
1T46*AOV039 A	F42454-E SFN-10.90-10E	Same as 1T46*AOV038B	Same as 1T46*AOV038B	B-22	1.8×10^8	340	Same as 1T46*AOV-038A	Same as 1T46*AOV 038A	Out-standing	Same as 1T46*AOV038A
B	F42455-G SFN-10.90-12E	Same as 1T46*AOV038B	Same as 1T46*AOV038B	K-15	1.3×10^8	158	Same as 1T46*AOV-038A	Same as 1T46*AOV-038A	Out-standing	Same as 1T46*AOV038A
C	F42456-E SFN-10.90-11E	Same as 1T46*AOV038B	Same as 1T46*AOV038B	G-02	5.8×10^6	152	Same as 1T46*AOV-038B	Same as 1T46*AOV-038B	J	Same as 1T46*AOV038B
D	F42457-E SFN-10.90-13F	Same as 1T46*AOV038B	Same as 1T46*AOV038B	G-02	5.8×10^6	152	Same as 1T46*AOV-038B	Same as 1T46*AOV-038B	J	Same as 1T46*AOV038B

EQUIPMENT JUSTIFICATION

MARK NO. 1T46*AOV038A, B, C, D
NO. 1T46*AOV039A, B, C, D

SYSTEM NAME: REACTOR BUILDING STANDBY VENTILATION SYSTEM (RBSVS)

PREPARED BY: B. ROE

EQUIPMENT NAME: AIR OPERATOR BUTTERFLY VALVE

MANUFACTURER: FISHER CONTROL

MODEL NO: 9220

ECD SHT: 172-1, 2, 3, and 4

1. Function

The RBSVS is initiated during an accident or abnormal condition. When the RBSVS is initiated, the Reactor Building Secondary Containment is automatically isolated from the Primary Containment by the closing of the Primary Containment purge isolation valves *AOV038A, B, C, D and *AOV039A, B, C and D. These valves are closed under normal operating conditions, except during purge. During RBSVS operation, they receive signals to close.

2. Non-Metallic Sub-Components Requiring Justification

T-Ring (EPT-Ethylene/Propylene Terpolymer, Sulphur Cured)

The adjustable T-Ring seat is contained in the valve disc. The adjusting set screws and compression ring force the T-Ring against the body bore to provide an interference fit between the T-Ring and body bore seating surface. This provides a bubble tight shut-off feature to the valve.

The known radiation threshold for this type of EPT is 8.77×10^6 rads (Ref. NM172-1); however the manufacturer has observed leakage at high differential pressure across the disc at temperatures over 381°F and at a radiation dose of 1×10^8 rad (see NM172-1 Ref. 13). In the light of this, the T-Ring requires further evaluation for use in radiation in environment above 10^7 rads.

Bushing (AISI 1018 W/Teflon)

This bushing is external to the valve body and provides a bearing surface for the shaft. Degradation of the "Teflon" (Ref. NM-172-4) in the bushing may result in a loss of the bearing surface lining. However, a loss of this lining will not prevent the valve from performing its intended safety function (closing).

EQUIPMENT JUSTIFICATION

Actuator

Although several of the non-metallic components used in the actuator assembly may have radiation thresholds less than the maximum postulated exposure, the sub-component's function is not relied upon for maintaining the valves in a closed position. The actuator is air-operated and relies on air pressure to open, and a spring to close. The valves are normally closed, and the metal spring will maintain the disc in a closed position regardless of the functional capabilities of the non-metallic sub-components used here.

In summary, the non-metallic sub-components have no relevance in maintaining these valves in their fail-safe, closed position, and are therefore acceptable for service.

Airset

Although some of the non-metallic components used in the airset may have radiation thresolds less than the maximum postulated exposure, the airset is not required to maintain the valve in a closed position. Failure of the airset components will allow leakage through the regulator or out of the regulator body. These failures will not cause the valve to move from its fail-safe, closed position.

JOB NO. 11600.02

SHEET NO. NM-172-1
COMPILED BY: B. Roe

JOB NAME: SHOREHAM-UNIT 1

JOB CLIENT: LILCO

MATERIAL RESISTANCE TO ENVIRONMENT

. TRADE NAME: EPT

. CHEMICAL NAME: Ethylene Propylene Terpolymer

		Ref. No.
. THRESHOLD (RADS)	8.77×10^6	*
. MAX. SERVICE TEMPERATURE (°F)	300	11

REFERENCES:

1. "Radiation Effects on Organic Materials in Nuclear Plants," EPRI Report No. NP 2129, November 1981 (Page 3-24).

11. "Shaft Seals for Power Generating Stations," Crane Bulletin No. S-2005-1 (Chart E).

12. "Evaluation of ITT Grinnell Diaphragm Valve Diaphragms After Being Subjected to Gamma Radiation," ITT Grinnell Corporation Report No. 998B, January 12, 1971 (Table 1).

13. Letter - from J.S. McLagan (Fisher Controls, Inc.) to K. Menon (SWEC), dated 7/12/82.

* **Although several references indicate an EPT threshold radiation value of 1×10^6 Rads based on the property of Compression Set (Ref. 1), research has substantiated that this material is not subject to any degree of degradation which would prevent its general use below an exposure of 8.77×10^6 Rads (Refs. 11 and 12). Further confirmation (Ref. 13) of the 8.77×10^6 Rads value is provided in a Fisher test. The test also indicates EPT becomes sensitive to temperature and radiation near the postulated value in zone D-22.**

JOB NO. 11600.02

SHEET NO. NM-172-2
COMPILED BY: B. Roe

JOB NAME: SHOREHAM-UNIT 1

JOB CLIENT: LILCO

MATERIAL RESISTANCE TO ENVIRONMENT

TRADE NAME: Asbestos - Inconel - Graphite, SS/W Asbestos, Flexitallic Items With Metals*

CHEMICAL NAME:

		Ref. No.
THRESHOLD (RADS)	1×10^{10}	11
MAX. SERVICE TEMPERATURE (°F)	1200	2

REFERENCES:

2. Materials Handbook, George S. Brady and Henry R. Clauser, 11th Edition, McGraw Hill Inc., 1977 (Pages 64-65).

11. "Shaft Seals For Power Generating Stations," Crane Bulletin No. S-2005-1 (Chart E).

19. Telex - from Flexitallic Gasket Company, Inc. to Lou Fiore (SWEC), dated 7/16/82.

24. Telex - from C. Dunkerley (SWEC) to G. McKillop (Crane Packing Co.), dated 7/19/82.

* For compositions such as Asbestos-Inconel-Graphite or S.S. with Asbestos, the data for asbestos is used.

When asbestos is used in gaskets and packings, a binder is added which will burn off at temperatures near 700°F, as indicated by various manufacturers. The manufacturers also claim that the binder is not important to the sealing function. Therefore, the binder's destruction by temperature or radiation is not significant (References 19 and 24).

JOB NO. 11600.02

SHT. NO. NM-172-3
COMPILED BY: B. Roe

JOB NAME: SHOREHAM-UNIT 1

JOB CLIENT: LILCO

MATERIAL RESISTANCE TO ENVIRONMENT

. TRADE NAME: Graphite

. CHEMICAL NAME: Carbon

		Ref. No.
. THRESHOLD (RADS)	9.1×10^8	8
. MAX. SERVICE TEMPERATURE (°F)	500	2

REFERENCES:

2. Materials Handbook, George S. Brady and Henry R. Clauser, 11th Edition, McGraw Hill Inc., 1977 (Pages 356-359).

8. Letter - from G. McKillop (Crane Packing Co.) to Steve Poller (SWEC), dated 6/21/82.

JOB NO. 11600.02

SHEET NO. NM-172-4
COMPILED BY: B. Roe

JOB NAME: SHOREHAM-UNIT 1

JOB CLIENT: LILCO

MATERIAL RESISTANCE TO ENVIRONMENT

TRADE NAME: Teflon

CHEMICAL NAME: Polytetrafluoroethylene

		Ref. No.
THRESHOLD (RADS)	1.5×10^4	1
MAX. SERVICE TEMPERATURE (°F)	400	7

REFERENCES:

1. "Radiation Effects on Organic Materials in Nuclear Plants," EPRI Report No. NP 2129, November 1981 (Page 3-13).

7. Reactor Handbook, Volume 1, Tipton, 2nd Edition, Interscience Publishers, Inc., 1960 (Page 1088).

DATA PACKAGE SH1-276

TYPE OF EQUIPMENT: FANS

MANUFACTURER: BUFFALO FORGE

STONE & WEBSTER SPECIFICATION NUMBER SH1-276

Package contents:

Prepared by C. Dunkerley

Reviewed by KM Enos

Issue Date: August 16, 1982

JOB NO.: 11600.02

MECHANICAL EQUIPMENT ENVIRONMENTAL
CONFORMANCE REVIEW SHEET

JOB NAME: SHOREHAM - UNIT 1

DATE: 8/11/92

JOB CLIENT: LILCO

SORTED BY SPEC.

COMPILED BY: C. Dunkerley

SYSTEM TITLE: Reactor Bldg. Standby Vent System (1T46)

SHT. NO. ECR-276-1 REV. 0

Mark No.	Vendor/Description	Spec.	Q.A. Cat.	Bldg./Elev.	Zone	E.C.Data Sht.	Status	Comments
1T46*FN833A	Buffalo Forge/ 1T46*UC 002A Fan	SH1-276	I	RBS/8	G-01	276-1	A	
1T46*FN833B	1T46*UC 002B Fan	SH1-276	I	RBS/40	O-02	276-1	A	
1T46*FN834A	1T46*UC 003A Fan	SH1-276	I	RBS/8	G-01	276-1	A	
1T46*FN834B	1T46*UC 003B Fan	SH1-276	I	RBS/40	O-02	276-1	A	
1T46*FN835A	1T46*UC 004A Fan	SH1-276	I	RBS/219	H-20	276-1	A	
1T46*FN835B	1T46*UC 004B Fan	SH1-276	I	RBS/219	H-20	276-1	A	
1T46*FN836A	1T46*UC 005A Fan	SH1-276	I	RBS/219	H-20	276-1	A	
1T46*FN836B	1T46*UC 005B Fan	SH1-276	I	RBS/219	H-20	276-2	A	
1T46*FN837A	1T46*UC 020A Fan	SH1-276	I	RBS/112	J-16	276-2	A	
1T46*FN837B	1T46*UC 020B Fan	SH1-276	I	RBS/112	K-15	276-2	A	
1T46*FN838A	1T46*UC 021A Fan	SH1-276	I	RBS/150	H-19	276-2	A	
1T46*FN838B	1T46*UC 021B Fan	SH1-276	I	RBS/150	H-19	276-2	A	
1T46*FN839A	1T46*UC 022A Fan	SH1-276	I	RBS/161	H-19	276-2	A	
1T46*FN839B	1T46*UC 022B Fan	SH1-276	I	RBS/161	H-19	276-3	A	
1T46*FN023	1T46*UC 023 Fan	SH1-276	I	RBS/40	L-02	276-3	A	

A = Acceptable

JOB NO.: 11600.02

JOB NAME: SHOREHAM - UNIT 1

CLIENT: LILCO

COMPILED BY: S. Lebreault

DATE: 8/11/82

SHT. NO. ECD 276-1 REV. 0

MECHANICAL EQUIPMENT ENVIRONMENTAL CONFORMANCE DATA SHEET

Specification No./Vendor: SH1-276/BUFFALO FORGE FAN

Mark No.	Sub-Component Identification			Environmental Qualification Report Environment			Documented Material Data		Status	Reference	Comments
	Vendor Dwg. No Shoreham File No. (SFN)	Non-Metallic Sub-Components	Material	Zone	Total Radiation (Rads)	Temp. (°F)	Threshold Radiation (Rads)	Service Temperature (°F)			
1T46*FN833A	7C-68344 SFN-10.64-14E	Paint	Mobil 13-R-53 no-rust primer	G-01	5.8×10^6	150	1×10^9	250	A	NM-276-1	
1T46*FN833B	7C-68345 SFN-10.64-33E 7W-93030 SFN-10.64-27A	Paint	Mobil 13-R-53 no-rust primer	G-02	5.8×10^6	152	1×10^9	250	A	NM-276-1	
1T46*FN834A	7C-68344 SFN-10.64-14E	Paint	Mobil 13-R-53 no-rust primer	G-01	5.8×10^6	150	1×10^9	250	A	NM-276-1	
1T46*FN834B	7C-68345 SFN-10.64-33E 7W-93030 SFN-10.64-27A	Paint	Mobil 13-R-53 no-rust primer	G-02	5.8×10^6	152	1×10^9	250	A	NM-276-1	
1T46*FN835A	7C-68346 SFN-10.64-38C	Paint	Mobil 13-R-53 no-rust primer	H-20	5.3×10^4	118	1×10^9	250	A	NM-276-1	
1T46*FN835B	7C-68346 SFN-10.64-38C	Paint	Mobil 13-R-53 no-rust primer	H-20	5.3×10^4	118	1×10^9	250	A	NM-276-1	
1T46*FN836A	7C-68345 SFN-10.64-38C	Paint	Mobil 13-R-53 no-rust primer	H-20	5.3×10^4	118	1×10^9	250	A	NM-276-1	

JOB NO.: 11600.02

JOB NAME: SHOREHAM - UNIT 1

CLIENT: LILCO

COMPILED BY: S. Lebreault

DATE: 8/11/82

SHT. NO. ECD 276-2 REV. 0

MECHANICAL EQUIPMENT ENVIRONMENTAL CONFORMANCE DATA SHEET

Specification No./Vendor: SH1-276/BUFFALO FORGE FAN

Mark No.	Sub-Component Identification			Environmental Qualification Report Environment			Documented Material Data				
	Vendor Dwg. No Shoreham File No. (SFN)	Non-Metallic Sub-Components	Material	Zone	Total Radiation (Rads)	Temp. (°F)	Threshold Radiation (Rads)	Service Temperature (°F)	Status	Reference	Comments
1T46*FN836B	7C-68346 SFN-10.64-38C	Paint	Mobil 13-R-53 no-rust primer	H-20	5.3×10^4	118	1×10^9	250	A	NM-276-1	
1T46*FN837A	D1-1571 SFN-10.64-43A D4-1641 SFN-10.64-34F	Paint	Mobil 13-R-53 no-rust primer	J-16	2.5×10^5	178	1×10^9	250	A	NM-276-1	
1T46*FN837B	D1-1571 SFN-10.64-43A D4-1641 SFN-10.64-34F	Paint	Mobil 13-R-53 no-rust primer	K-15	1.3×10^8	158	1×10^9	250	A	NM-276-1	
1T46*FN838A	D4-3377 SFN-10.64-39D	Paint	Mobil 13-R-53 no-rust primer	H-19	5.3×10^4	148	1×10^9	250	A	NM-276-1	
1T46*FN838B	D4-3854 SFN-10.64-42E	Paint	Mobil 13-R-53 no-rust primer	H-19	5.3×10^4	148	1×10^9	250	A	NM-276-1	
1T46*FN839A	D4-3377 SFN-10.64-39D	Paint	Mobil 13-R-53 no-rust primer	H-19	5.3×10^4	148	1×10^9	250	A	NM-276-1	

JOB NO.: 11600.02

JOB NAME: SHOREHAM - UNIT 1

CLIENT: LILCO

COMPILED BY: S. Lebreault

DATE: 8/11/82

SHT. NO. ECD 276-3 REV. 0

MECHANICAL EQUIPMENT ENVIRONMENTAL CONFORMANCE DATA SHEET

Specification No./Vendor: SH1-276/BUFFALO FORGE FAN

Mark No.	Sub-Component Identification			Environmental Qualification Report Environment			Documented Material Data				
	Vendor Dwg. No Shoreham File No. (SFN)	Non-Metallic Sub-Components	Material	Zone	Total Radiation (Rads)	Temp. (°F)	Threshold Radiation (Rads)	Service Temperature (°F)	Status	Reference	Comments
1T46*FN839B	D4-3854 SFN-10.64-42E	Paint	Mobil 13-R-53 no-rust primer	H-19	5.3×10^4	148	1×10^9	250	A	MM-276-1	
1T46*FN023	D4-4946 SFN-10.64-44B	Paint	Mobil 13-R-53 no-rust primer	L-02	3.1×10^6	152	1×10^9	250	A	MM-276-1	

Note: No other non-metallic sub-components.

JOB NO. 11600.02

SHT. NO. NM-276-1
COMPILED BY: B. Roe

JOB NAME: SHOREHAM-UNIT 1

JOB CLIENT: LILCO

MATERIAL RESISTANCE TO ENVIRONMENT

. TRADE NAME: Mobil 13-R-53 No-Rust Primer

. CHEMICAL NAME: Oil-Alkyd Base Paint Containing Zinc Chromate and Red Iron Oxide

		Ref. No.
. THRESHOLD (RADS)		
. MAX. SERVICE TEMPERATURE (°F)	250°	29
. RADIATION RESISTANCE (RADS)	1×10^9	40

REFERENCES:

29. Mobil 13-R-53 No-Rust Primer Publication, dated 11/1/76.

40. Environmental Effects on Polymeric Materials, D.V. Rosato and Schwartz, John Wiley & Sons, Inc., New York, 1968.

APPENDIX B

REFERENCE LIBRARY
for
SPECIFICATION DATA SHEETS

The References listed are those used in the NM sheets and do not represent all the references used in the evaluation.

Ref. No. Title

1. "Radiation Effects on Organic Materials in Nuclear Plants", EPRI Report No. NP 2129, November 1981.

Vellumoid	Page No. 3-8,9
Cellulose	3-8,9
Teflon	3-13
Polyethylene	3-16,17
Ethylene-Propylene	3-24
Ethylene-Propylene Terpolymer	3-24
Viton	3-25,26
Rubber (Neoprene)	3-27,28
Buna-N (Nitrile)	3-28,29
Asbestos (Crane Packing 5810)	3-37,38
American Mineral Oil	3-37,38
Exxon Teresstic 68	3-37,38

2. Materials Handbook, George S. Brady and Henry R. Clauser, 11th Edition, McGraw-Hill, Inc., 1977.

Asbestos	Page No. 64,65
Glass	341-347
Graphite	356-359

7. Reactor Handbook, Volume 1, Tipton, 2nd Edition, Interscience Publishers, Inc., 1960 (Page 1088).

8. Letter - from G. McKillop (Crane Packing Co.) to Steve Poller (SWEC), dated 6/21/82.

11. • "Shaft Seals for Power Generating Stations", Crane Bulletin No. S-2005-1 (Chart E).

• Letter - from Crane Packing Company (S. Lemberger) to Stone & Webster Engineering Corp. (J. Dunkerley), dated June 15, 1982.

12. "Evaluation of ITT Grinnell Diaphragm Valve Diaphragms After Being Subjected to Gamma Radiation", ITT Grinnell Corporation Report No. 998B, January 12, 1971.

Ethylene Propylene Terpolymer	Table 1
Natural Gum Rubber	Table 1
Buna-N (Nitrile)	Table 1
Teflon	Table 1 and Page 7
Neoprene	Table 1, Pages 5 and 6, and fig. 8b

Ref. No.	Title
13.	Letter - from J.S. McLagan (Fisher Controls Inc.) to K. Menon (SWEC), dated 7/21/82.
19.	Telex - from Flexitallic Gasket Co., Inc., to L. Fiore (SWEC), dated 7/16/82.
24.	Telex - from C. Dunkerley (SWEC) to G. McKillop (Crane Packing Co.), dated 7/19/82.
29.	Mobil 13-R-53 No-Rust Primer Publication, dated 11/1/76.
40.	<u>Environmental Effects on Polymeric Materials</u>, D.V. Rosato and Schwartz, John Wiley & Sons, Inc., New York 1968 (Pages 36 & 37, 725 and 726)

degradation but unchanged insulation resistance and a 7% decrease in dielectric constant. Dissipation factor increased one decade.[33]

Polytetrafluoroethylene/threshold - 1.5 x 10^4 rads/elongation. Reference 47 reports a threshold change of elongation at 1.5 x 10^4 rads for Teflon (TFE) in air, of tensile strength at 2.1 x 10^4 rads, of shear and impact strength and elastic modulus at 1.8 x 10^5 rads. A 25% decrease was noted at 3.4 x 10^4 rads for elongation, 1.2 x 10^5 rads for tensile strength, and 4 x 10^5 rads for shear strength. Impact strength increased 25% at 3.6 x 10^5 rads. Oxidation effects are quite large. Radiation resistance is approximately ten times greater in vacuum or fluid. Teflon hoses tested under simulated operating conditions failed, by leakage, at 1 x 10^5 rads when exposed to intermittent fluid pressure of 1,000 psig and at approximately 1 x 10^6 rads when subjected to 1,200 psig static pressure. The radiation exposure-damage relation was relatively insensitive to temperature in the range of 100 to 350°F in that test. Teflon back-up rings (in fluid) have been found serviceable in some applications to approximately 4 x 10^7 rads, although physical degradation occurs.[36]. Sharp decreases in melting temperature were noted for irradiations above 330°C.

Teflon-FEP (copolymer of fluoroethylene and perfluoropropylene) is more resistant that Teflon-TFE. Teflon-FEP shows ten times greater radiation resistance in vacuum and sixteen times greater resistance in air for 10-mil films.[46] Temperature effects have been noted. Damage at cryotemperatures was negligible for a dose that produced 40% loss of tensile strength at 73°F and 60% damage at 350°F.

Electrical properties are affected differently for irradiation in air and vacuum. TFE volume resistivity has been observed to drop by a factor of 10^2-10^3 in vacuum radiation and to drop an additional factor of 10-10^2 after irradiation (gradual recovery may occur). One Teflon-insulated wire is reported to show slightly reduced flexibility at 10^3 rads in a 5 psia O_2 atmosphere at 90°C. A similar Teflon wire lacking a polyimide coating present on the first wire did not show reduced flexibility under the same conditions.[33] This indicates that the materials were incompatible, not that the radiation level was significant.

Tetran, Fluorlon, and Hostaflon FT are a few of the other commercial names for polytetrafluoroethylene. Main chain scission is dominant and there is little evidence of any crosslinking during irradiation.

REFERENCE 1

"Radiation Effects on Organic Materials in Nuclear Plants", EPRI Report No. NP 2129, November 1981.

Ethylene-Propylene/threshold - 1×10^6 rads/compression set

Although some experimental formulations showed poor radiation resistance, a number of commercial materials appear to be comparable to crosslinked polyethylene. As with other polyolefins, radiation resistance will depend on the effectiveness of antioxidant systems (especially at elevated temperatures). Reference 28 reports dose rate effects with greater degradation at low dose rates when the total dose exceeded about 2×10^7 rads for one ethylene-propylene cable insulation. Reference 8 details effects of radiation on cable insulation and jacket materials, including EPDM-based and EPM-based insulations (both mineral filled). No changes in oxidation resistance were found following total dose up to 10^8 rads (dose rate was 5×10^5 rads/hour). Elongation of the EPDM insulation was not significantly changed after 5×10^6 rads, but was reduced to 48% of the initial value after 5×10^7 rads and 37% after 1×10^8 rads. The EPM insulation retained 81% of its unirradiated value after 5×10^6 rads, 41% after 5×10^7 rads, and 26% following 1×10^8 rads. Reference 39 also reports very good radiation resistance of EP rubber (EPDM base) and that cables using special chloroprene jackets and EP insulation passed IEEE-383 tests.

EPDM retained 79% and EPM retained 90% of the original tensile strength after 10^8 rads. Changes in permanent electrical properties were relatively unimportant. Reference 35 reports similar results for ethylene propylene cable insulations, but reports that a fire-retardant additive appeared to cause instability of electrical properties in an EPDM-based material at exposures above 10^7 rads. Reference 55 reports minor reductions in mechanical properties of EP-F234 after 5×10^4 rads, but less than 25% decrease in those properties at 10^6 rads. A 50% decrease in elongation was noted after 2×10^7 rads and in tensile strength after 2×10^8 rads. The 5×10^4 rad value is not cited above, since it is not generally applicable and does not represent significant change to the material.

Barbarin[6] recommended an EP compound (Parker-Hannifin E740-75) as exhibiting the best known combination of radiation, fluid, and temperature tolerance. He warned that variations in compounding can cause wide difference in properties. One EP compound showed 28.6% increase in compression set after 10^7 rads and would be acceptable as a dynamic seal, while one (Parker-Hannifin E515-80) exhibited 46.6% increase in that property under the same test conditions. He recommended that no dynamic seals be used after radiation doses greater than 10^7 rads due to excessive compression set. Reference 61 indicates a 10^7 rad "allowable" dose for EP as for polyethylenes.

ASBESTOS. A general name for several varieties of fibrous minerals, the fibers of which are valued for their heat-resistant and chemical-resistant properties, and are made into fabrics, paper, insulating boards, and insulating cements. The long fibers are used for weaving into fireproof garments, curtains, shields, and brake linings. The short fibers are compressed with binders into various forms of insulating boards, shingles, pipe coverings, paper, and molded products. The original source of asbestos was the mineral actinolite, but the variety of **serpentine** known as chrysotile now furnishes most of the commercial asbestos. **Actinolite** and **tremolite**, which furnish some of the asbestos, belong to a great group of widely distributed minerals known as **amphiboles** which are chiefly metasilicates of calcium and magnesium, with iron sometimes replacing part of the magnesium. They occur granular, in crystals, compact such as nephrite which is the jade of the Orient, or in silky fibers as in the iron amphibole asbestos mined in the United States. This latter type is more resistant to heat than chrysotile. Its color varies from white to green and black.

Jade occurs as a solid rock and is highly valued for making ornamental objects. Jade quarries have been worked in Khotan and Upper Burma for many centuries, and large pebbles are also obtained by divers in the Khotan River. The most highly prized in China was white speckled with red and green and veined with gold. The most valued of the **Burma jade** is a grass-green variety called **Ayah kyauk**. Most jade is emerald green, but some is white and others are yellow, vermilion, and deep blue. This form of the mineral is not fibrous.

Asbestos is a hydrated metal silicate with the metal and hydroxyl groups serving as lateral connectors of the molecular chain to form long crystals which are the fibers. The formula for **chrysotile** is given as $Mg_6Si_4O_{11}(OH)_6 \cdot H_2O$. Each silicon atom in the Si_4O_{11} chain is enclosed by a tetrahedron of four oxygen atoms so that two oxygen atoms are shared by adjacent tetrahedra to form an endless chain. When the crystal orientation is perfect, the fibers are long and silky and of uniform diameter with high strength. When the orientation is imperfect, the Si_4O_{11} chain is not parallel to the fiber axis and the fibers are uneven and harsh. In chrysotile the metal connector is magnesium with or without iron, but there are at least 30 other different types of asbestos.

Chrysotile is highly fibrous, and is the type most used for textiles. The fiber is long and silky, and the tensile strength is from 80,000 to 200,000 psi. The color is white, amber, gray, or greenish. The melting point is 2770°F, and specific gravity is 2.4 to 2.6. Chrysotile is mined chiefly in Vermont, California, Quebec, Arizona, Turkey, and Rhodesia. Only about 8% of the total mined is long spinning fiber, the remainder being too short for fabrics or rope. The Turkish fiber is up to ¾ in. in length. Asbestos produced in Quebec is chrysotile occurring in serpentized rock

REFERENCE 2

MATERIALS HANDBOOK, GEORGE S. BRADY & H.R. CLAUSER, 11th EDITION 1977 in veins ¼ to ½ in. wide, though veins as wide as 5 in. occur. The fibers run crosswise of the vein, and the width of vein determines the length of fiber. **Calidria asbestos,** of Union Carbide Corp., is short-fiber chrysotile from California marketed as fibrils or pellets for use as a reinforcing agent in plastic laminates, thickening agent, and opacifier in coatings and adhesives. Chrysotile fiber has about 14% water of crystallization. At temperatures near 1800°F, it loses its water, and the dehydration has a cooling effect. Thus **chrysotile felt** is used as a heat sink in missile and space construction laminates.

Blue asbestos, from South Africa, is the mineral **crocidolite,** $NaFe(SiO_3)_2 \cdot FeSiO_2$. The fiber has high tensile strength, averaging 600,000 psi, is heat-resistant to 1200°F, and is resistant to most chemicals. The fibers are ⅛ to 3 in. long with diameters from 0.06 to 0.1 in. It is compatible with polyester, phenolic, and epoxy resins, and is available in all standard forms for reinforcement of plastics and insulating uses. A molding powder is made by mixing the fibers with epoxy and, after partial curing, grinding the mixture to a free-flowing powder. **Form Pack 2,** of Devcon Corp., is this fiber impregnated with Teflon for packing valves and pistons for use at temperatures to 500°F.

The classes of **cape asbestos** from South Africa are chrysotile, **amosite,** and **Transvaal blue.** Amosite has a coarse, long, resilient fiber, and is used chiefly in insulation, being difficult to spin. It comes in white and dark grades, and the fibers are graded also by length from ⅛ to 6 in. It has a chemical resistance slightly less than crocidolite and tensile strength of 200,000 psi. The name amosite was originally a trade name for South African asbestos, but now refers to this type of mineral. Transvaal blue is a whitish, iron-rich, **anthophyllite** $(MgFe)SiO_3$, noted for the length of its fiber. The best grades are about 1½ in. long. The fibers are resistant to heat and to acids, and the stronger fibers are used for making acid filter cloth and fireproof garments. This type of asbestos is also found in the Appalachian range from Vermont to Alabama. Canadian, Vermont, and Arizona asbestos is chrysotile; that from Georgia and the Carolinas is anthophyllite.

Canadian asbestos is graded as crude, mill fibers, and shorts. Crudes are spinning fibers ⅜ in. or longer, hand-cobbed. Mill fibers are obtained by crushing and screening. Shorts are the lowest grades of mill fibers. **Rhodesian asbestos** is graded in five C & GS grades separated by screen boxes. Kenya asbestos is anthophyllite, and that from Tanzania is largely amphibole. **Nonspinning asbestos** is graded as shingle stock, ¼ to ⅜ in.; paper stock, ⅛ to ¼ in.; and shorts, 1/16 to ⅛ in. The shorts are washed and ground for use as resistant filler in molded plastics. In England this material is known as **micro asbestos.**

Asbestos fabrics are often woven mixed with some cotton. For brake linings and clutch facings the asbestos is woven with fine metallic wire.

oxide, 0.12 titanium oxide, 0.20 manganese oxide, and 0.36 lime. The granite known as **pegmatite,** of which there are vast quantities, contains beryllium in the form of **beryl** as a minor constituent.

GRAPHITE. A form of carbon. Also called **plumbago.** It was formerly known as **black lead,** and when first used for pencils was called **Flanders' stone.** A natural variety of elemental carbon having a grayish-black color and a metallic tinge.

Natural graphite comes chiefly from Mexico, India, Ceylon, and Mala-gasy. In the United States it is found in Alabama. It occurs in veins in rocks, and always contains some impurities. The high-grade lump graph-ite of Ceylon, often preferred for crucibles, is found in closely foliated masses in underground veins in gneiss interbedded with limestone. It occurs in two forms: foliated and amorphous. **Foliated graphite** is used principally for crucibles and lubricants, and amorphous for lead pencils, foundry facings, electric brush carbons, molded parts, and paint pig-ments. It is infusible, subliming at 6700°F, but oxidizing above 600°C. It is a good conductor of heat and electricity, is resistant to acids and alkalies, and is readily molded. **Molded graphite** is usually made by mixing calcined petroleum coke with a binder of coal-tar pitch, pressing, baking in an inert atmosphere, and then heating to above 3500°F to promote crystal growth. Molded parts increase in strength with increasing tempera-ture up to about 4500°F. The specific gravity of graphite is 2 to 2.5. The hardness is 1 to 2, sometimes less than 1, and it has a decidedly greasy feel. It is a good lubricant, especially when mixed with grease, but the natural graphite contains silica and other abrasive materials so that the artificial graphite is preferred for lubricants.

Graphite is marketed in grades by purity and fineness. No. 1 flake should contain at least 90% graphitic carbon. Mexican **amorphous graph-ite** contains 80%. The best Malagasy graphite contains 95% carbon, while the powders may be as low as 75%. **Crystalline graphite** and **flake graphite** are synonymous terms for material of high graphite content as distinguished from amorphous. Some natural graphite, useful for paints, contains as little as 35% graphitic carbon, but high-grade graphite, suita-ble for crucibles and nuclear reactors, is made from low-grade ores containing 20% carbon by flotation, purification at high heat, and press-ing into blocks. Ultrapure graphite, for nuclear reactors, is graphitized at temperatures to 5400°F to free it of silicon, calcium, aluminum, and manganese, and treated with a Freon gas to eliminate boron and vana-dium. In general, **artificial graphite** made at high temperatures in the electric furnace is now preferred for most uses because of its purity.

Recrystallized graphite is produced by a proprietary hot-working process which yields recrystallized or "densified" graphite with specific gravities in the 1.85 to 2.15 range, as compared with 1.4 to 1.7 for

conventional graphites. The material's major attributes are a high degree of quality reproducibility, improved resistance to creep, a grain orienta-tion that can be controlled from highly anisotropic to relatively isotropic, lower permeability than usual, absence of structural macroflaw, and ability to take a fine surface finish.

Graphite fibers are produced from organic fibers such as rayon. The fiber or textile form (for example, fabric, yarn, or felt) is graphitized at temperatures up to 5400°F. The resulting fibers are high-purity (99.9%) graphite, with extremely high individual fiber strengths. They run about one-third of a mil in diameter, and have a specific gravity of from 1.7 to 2.0. When used in composites, they are generally made into yarn contain-ing some 10,000 fibers. Depending on the precursor fiber, their tensile strength ranges from 200,000 to nearly 500,000 psi; and their modulus of elasticity is from 28 million to 75 million psi. **Graphite fiber-epoxy composites** provide exceptionally high strength and stiffness, and because of their light weight are finding increasing use for golf club shafts and tennis racquet frames. **PT graphites** are graphite fibers impregnated or bonded with an organic resin (such as furfural) and then carbonized. The result is a graphite-reinforced carbonaceous material with a high degree of thermal stability. The composite has a low density (0.93 to 1.2 specific gravity), and what is reported to be the highest strength-to-weight ratio of any known material at temperatures in the 4000 to 5000°F range.

Extremely fine particles of pure artificial graphite, or **colloidal graph-ite,** will remain in suspension indefinitely, and are marketed in distilled water, oils, or solvents, under trade names. **Mexacote,** of the U.S. Graph-ite Co., is colloidal graphite powder to be mixed with water for spraying on sand molds. When a solution of colloidal graphite in alcohol is sprayed on machine bearings, the alcohol evaporates to leave a thin coating of graphite as a lubricant. **Prodag,** of Acheson Industries, Inc., is a solution in water for foundry facings. **Dag dispersion 154,** of the same company, is colloidal graphite in ethyl silicate used to produce black coatings on glass. **Dag 440** is **graphite powder** in a silicone resin for use as a resistance coating for continuous temperatures up to 500°F. A 0.002-in. coating has a volume resistivity of 100 ohms per sq in. **Grafita** and **Grafene,** of the U.S. Graphite Co., are grease and oil solutions of colloidal graphite for producing lubricating films. **Acheson 1127,** of Acheson Colloids, is a **release agent** for spraying on molds in aluminum die-casting machines. It is a water solution of graphite powder. It prevents adherence of the metal to the die and also gives better flow of metal because of reduced friction.

For making lead pencils, amorphous graphite is mixed with clay and fired, the amount of clay determining the hardness of the pencil. **Flexico-lor pencils,** of Koh-I-Noor, Inc., have a plastic binder to give pliable strength to the pencil. **Poco Graphite,** of the Pure Oil Co., is a graphite powder with maximum particle size of 0.001 in. used for molded parts.

The parts have a smooth surface and a tensile strength to 6,000 psi. **Graphite carbon raiser** is a term given to graphite powder used for adding to molten steel to raise the carbon content. Molded graphite **brushes** for motors and generators may have metal powders mixed with the graphite to regulate the conductivity or may be molded from carbon-graphite powder especially heat-treated. **Graphited metals**, used for graphite bearings and bushings, are made by molding metal powders with graphite and sintering, and may contain up to about 45% graphite evenly dispersed in the metal matrix to act as a lubricant. Or powdered oxides of the metals may be used, and these oxides are reduced in the sintering to give greater porosity for oil retention. The **Genelite**, of the General Electric Co., is a porous **graphited bronze** made with oxides of copper, tin, and lead, with graphite powder. It will absorb about 20% by volume of oil. It has a compressive strength of 50,000 psi, and a tensile strength of 8,000 psi. **Durex bronze**, of the General Motors Corp., made by reducing the oxides with graphite under pressure, will take up 29% by volume of oil. Graphited metals, with the matrix of bronze or of babbitt, are marketed in the forms of rods and bushings under a variety of trade names such as **Gramix**, of the U.S. Graphite Co., **Graphex**, of the Wakefield Bearing Corp., and **Ledaloyl**, of the Johnson Bronze Co. **Iron-bonded graphite**, developed by the Ford Motor Co. for oilless bearings, is made by powder metallurgy with a content of 40 to 90% graphite and the balance iron powder and a calcium-silicon powder. The calcium-silicon overcomes the normal low compatibility of the iron and graphite, resulting in a strong, nonbrittle material.

The **supergraphite**, of the National Carbon Co., used for rocket casings and other heat-resistant parts, is recrystallized molded graphite. It will withstand temperatures to 5500°F. **Pyrolytic graphite**, developed by the General Electric Co., is an oriented graphite. It has high density, with a specific gravity of 2.22, has exceptionally high heat conductivity along the surface, making it very flame-resistant, is impermeable to gases, and will withstand temperatures to 6700°F. It is made by deposition of carbon from a stream of methane on heated graphite, and the growing crystals form with thin planes parallel to the existing surface. The structure consists of close-packed columns of graphite crystals joined to each other by strong bonds along the flat planes, but with weak bonds between layers. This weak and strong electron bonding is characteristic of a semimetal, giving the laminal structure. The material conducts heat and electricity many times faster along the surface than through the material. The flexural strength is 25,000 psi, compared with less than 8,000 for the best conventional graphite. At 5000°F the tensile strength is 40,000 psi. Sheets as thin as 0.001 in. are impervious to liquids or gases. It is used for nozzle inserts and reentry parts for spacecraft. **Boron Pyralloy**, of High Temperature Materials, Inc., for atomic shielding, is this material with an addition of boron.

GRAVEL. A natural material composed of small, usually smooth, rounded stones or **pebbles**. It is distinguished from sand by the size of the grain, which is usually above ¼ in., but gravel may contain large stones up to 3 in. in diameter, and some sand. It will also contain pieces of shale, sandstone, and other rock materials. Gravel is used in making concrete for construction, and as a loose paving material. Commercial gravel is washed to remove the clay and organic matter, and screened. **Pea gravel** is screened gravel between ¼ and ½ in. in diameter. It is used for surfacing with asphalt, or for roofing. Gravel is sold by the cubic yard or by the ton, and is shipped by weight. **Bank-run gravel**, with both large and small material, weighs about 3,000 lb per cu yd.

GRAY CAST IRON. The most common, least costly, and most widely used of the cast irons. It also holds the honor of being the cheapest of all engineering metals. The distinguishing microstructural characteristic is the presence of graphite flakes in a matrix of, usually, ferrite, pearlite, and austenite. The graphite flakes occupy about 10% of the total volume of the metal so that gray irons have a lower density than steels. Alloying produces a broader range of properties than is possible in unalloyed types. Common elements added are chromium, copper, nickel, molybdenum, and vanadium. Standard gray irons are classified according to tensile strengths into nine main classes from 20,000 to 65,000 psi, in increments of 5,000 psi. A complicating factor is that the tensile strength varies with casting section thickness. Thus strengths of class 20 (20,000 psi), for example, can range from 13,000 to 40,000 psi, depending on the thickness of the test bar. This strength increase occurs as section thickness decreases because of the faster cooling rates in thinner sections.

Gray cast irons possess the highest fluidity of the ferrous casting metals and are thus well suited to the production of relatively intricate and thin-walled castings. In addition, solidification shrinkage is low, ranging from 0 to about 2%, compared to about 5% for steel and malleable iron. Also, the machinability is superior to virtually all grades of steel. Gray irons are notably low in tensile strength but high in compressive strength—about three to four times the equivalent values of tensile strength. Their compressive strengths are higher than those of most nonferrous materials and are about equal with those of non-heat-treated low-alloy steels. They retain their strength properties down to below −300°F and up to about 800°F. Unlike that of most ferrous metals, the modulus of elasticity of gray irons is not constant (12×10^6 to 20×10^6 psi); it decreases with increasing strain and varies with the specific grade of iron. Because their

TABLE 51.103. Classification and Heat Resistance of Plastics*

Trade name	Thermal type: Thermoplast[a]	Thermal type: Thermoset[b]	Chemical type	Max continuous service temp., °F
Acryloid	X		Acrylate	155-185
Alathon	X		Polyethylene	210
Bakelite		X	Phenol formaldehyde	300-350
Beckacite		X	Phenol formaldehyde	300-350
Beckosol		X	Polyester	
Beetle		X	Urea formaldehyde	170
Butacite	X		Polyvinyl butyral	100-140
Butvar	X		Polyvinyl butyral	100-140
Catalin		X	Phenol formaldehyde	300-350
Celcon	X		Ethylcellulose	140-220
Celluloid	X		Cellulose nitrate	120-140
Cerex	X		Polystyrene	150-185
Duraplex		X	Polyester	
Durez		X	Phenol formaldehyde	300-350
Durite		X	Phenol furfural or phenol formaldehyde	300-350
Elvacet	X		Polyvinyl acetate	105-120*
Elvanol	X		Polyvinyl alcohol	
Ethocel	X		Ethylcellulose	140-220
Fibestos	X		Cellulose acetate	140-220
Formvar	X		Polyvinyl formal	
Gelva	X		Polyvinyl acetate	105-120
Geon	X		Polyvinyl chloride	150-175
Glyptal		X	Polyester	
Kel-F	X		Polytrifluorochloroethylene	370
Koroseal	X		Polyvinyl chloride	150-175
Lucite	X		Acrylate	155-185
Lumarith	X		Cellulose acetate	140-220
Lumarith EC	X		Ethylcellulose	140-220
Lustrex	X		Polystyrene	150-185
Makalot		X	Phenol formaldehyde	300-350
Marblette		X	Phenol formaldehyde	300-350
Melmac		X	Melamine formaldehyde	210-250
Nitron	X		Cellulose nitrate	120-140
Nixon CA	X		Cellulose acetate	140-220
Nixon CN	X		Cellulose nitrate	120-140
Nixon EC	X		Ethylcellulose	140-220
Nylon	X		Polyamide	300
Plaskon		X	Urea formaldehyde	170
Plastacele	X		Cellulose acetate	140-220
Plexiglas	X		Acrylate	155-185
Plioform	X		Isomerized rubber	165-220
Polythene	X		Polyethylene	210
Pyralin	X		Cellulose nitrate	120-140
Resimene		X	Melamine formaldehyde	210-250
Resinox		X	Phenol formaldehyde	300-350
Resistoflex	X		Polyvinyl alcohol	
Rezyl		X	Polyester	
Saflex	X		Polyvinyl butyral	100-140
Saran	X		Polyvinylidene chloride	160-200
Styramic	X		Polystyrene	150-185
Styron	X		Polystyrene	150-185
Teflon	X		Polytetrafluoroethylene	400
Teglac		X	Polyester	
Tenite I	X		Cellulose acetate	140-220
Tenite II	X		Cellulose acetate-butyrate	140-220
Textolite	X		Phenol formaldehyde	
Tygon	X		Polyvinyl chloride	150-175
Uformite		X	Urea formaldehyde	170
			Melamine formaldehyde	210-250
Vinylite A	X		Polyvinyl acetate	105-120*
Vinylite Q	X		Polyvinyl chloride	150-175
Vinylite V	X		Vinyl chloride acetate copolymers	
Vinylite X	X		Polyvinyl butyral	100-140

* Compiled by author from data of Refs. 28 and 35.

a A thermoplast is a plastic material which never loses its ability to flow under heat and pressure after initial forming.

b A thermoset is a material which loses its ability to flow under heat and pressure after initial formation; thermoset materials require mechanical fabrication such as machining, chilling, etc.

c This plastic never attains great hardness, usually used as coatings for paper, etc.

REFERENCE 7

Reactor Handbook, Volume #1, Tipton, 2nd Edition.

Interscience Publishers, Inc., 1960.

CC: JOB 8002 11600 0285N M IV E

CRANE PACKING COMPANY

6400 OAKTON STREET, MORTON GROVE, ILLINOIS 60053

Phone 312/967-2400
Cable Address "CRANPAC
TWX 910 223 3623
TELEX 724 420

June 21, 1982

Stone & Webster Engineering
P.O. Box 2703
New York, New York 10116

Attention: Mr. Steve Pollar

NOTED JUL 2 1982 S.G.POLLER

Subject: John Crane Packing/Radiation

Gentlemen:

You recently talked to our people in Morton Grove regarding the radiation resistance of both, 187I and Grafoil material.

The 187I, when we make it for nuclear applications is changed to Style N187I, as the materials used in the manufacture of this product are separated and tested for low chloride content. While we have not any specific tests regarding the radiation resistance of an 187I, information that we have obtained through various writings and communications with NRC, show this material to have a radiation resistance of 1×10^6.

In regards to Grafoil, we have a number designation, Style N240 designating that the Grafoil will be used in a nuclear application and again, tested to meet a low chloride content.

Further, I'm attaching a letter from Union Carbide along with certain statistical information that they had in regards to the radiation resistance of Grafoil.

I hope that this information will be helpful to you, but if you have further questions please don't hesitate in contacting us.

For your convenience we also have a branch located in Fairfield, New Jersey whose location and phone are as follows:

Crane Packing Company
24 Madison Road
Fairfield, New Jersey 07006
201-227-8818

We appreciate your interest in our products, and look forward to hearing from you again.

Very truly yours,

G. R. McKillop

G. R. McKillop
Sales Manager
Packing Division

cc: Frank Crosetti - Fairfield

REFERENCE 8

UNION CARBIDE

UNION CARBIDE CORPORATION
11709 MADISON AVENUE, CLEVELAND, OHIO 44107 TELEPHONE: 216-226-2824
Carbon Products Division
ADDRESS REPLY TO: P. O. BOX 6087, CLEVELAND, OHIO 44101

January 6, 1981

Mr. Mike Noble
Wylie Laboratories
7800 Governor's Drive, West
Huntsville, Alabama 35807

Dear Mr. Noble:

Enclosed per your discussion with Mr. Goldman is a table describing the irradiation resistance of GRAFOIL flexible graphite. Note that the 1972 Oak Ridge National Laboratory data has the most documentation. GRAFOIL was in the form of discs 1 cm. in diameter x 0.15 to 0.40 mm. thick. Neutron fluence was 9×10^{25} n/m^2 and the temperature range 900-1350°C. Hundreds of discs were irradiated. They remained flat and showed no visible degradation, thereby demonstrating GRAFOIL's outstanding irradiation resistance.

I trust this information assists with application of GRAFOIL, from our distributor Crane Packing Company, in the machine for a nuclear environment.

If I can be of further technical assistance, please advise.

Very truly yours,

P.S. Petrunich

P.S. Petrunich

/sw
Enclosure
cc: Mr. G.R. McKillop
Crane Packing Company
6400 Oakton Street
Morton Grove, IL

K.A. Mason

NUCLEAR RADIAT... RESISTANCE
of GRAFOIL

(1970 Data)

Neutron Dosage	1.7×10^{17} to 4.5×10^{17} NVT	-No apparent effect
Gamma Radiation	9.1×10^{10} to 1.5×10^{11} ergs/gram	-No apparent effect
	1 Rad - 100 ergs/gm	

(1972 Data)

Oak Ridge National Laboratory (Source)	9.0×10^{21} NVT (about 900°C) (E greater than 0.18 Mev)	-No apparent effe
Gulf General Atomic (Source)	4.0×10^{21} NVT (about 950°C)	-No apparent effect
	5.5×10^{21} NVT (about 1000°C)	-No apparent effect
	4.5×10^{21} NVT (about 1000°C)	-No apparent effect
	2.5×10^{21} NVT (about 650°C)	-No apparent effect
	4.0×10^{21} NVT (about 650°C)	-No apparent effect

SHAFT SEAL RECOMMENDATIONS
FOR POWER GENERATING STATIONS

GENERAL (Non-nuclear) SERVICE

On all fossil fuel generating stations and where the seal is not a part of the nuclear power or containment system, the various seal recommendations in Charts B and C should be used to avoid premiums and delays.

It is important to realize all pumps and seals in a nuclear power plant are not necessarily a part of the nuclear power system or its containment system. Where this is true, Nuclear Code of the ASME code does not apply and conventional seal selection and design procedures may be used, as is the case with fossil fuel power generating stations.

CHART A: CLEAR WATER

Clear water is defined as water containing up to 150 PPM maximum total dissolved solids. Up to 250 PPM additional sodium chromate can be tolerated.

CHART B: UNCOOLED CLEAR AND CHROMATE TREATED WATER

Chart B gives recommendations for chromate treated water above 250 PPM and temperatures up to 300°F.

CHARTS C AND D: BORIC ACID (H_3BO_3) MATERIAL SELECTION GUIDE

NUCLEAR SERVICE

For seals that are a part of the nuclear power system or containment system, the first consideration is radiation. Where the radiation level is within the limits of conventional elastomers (~10^6 rads total dosage) conventional seals may be used with the exception of TFE seals which may only be used to 5×10^4 rads. Beyond 10^6 rads, ethylene propylene rubber may be used to 2×10^7 rads.

CHART E gives the radiation limits of various materials which may be used in combination with the temperature limits to eliminate unsatisfactory materials.

Full particulars on the rules governing the design of components for a nuclear power system or its containment system can be found in Section III of the ASME boiler and pressure vessel code.

It covers the requirements for the construction of nuclear power plant components and appurtenances such as vessels, storage tanks, piping, pumps, valves and core support structures for use in, or containment of portions of, the nuclear power system of any power plant.

Mechanical seals are specifically excluded from the requirements of the code. However the gland plate, an item associated with the seal is covered.

In order to provide the proper seal for a nuclear application, the full specifications as they affect the seal must be known.

Whenever a gland plate is to be supplied, the ASME code requires the purchaser to supply the following information to provide the basis for stress calculations.

1. Division of code applicable
2. Class of service
3. Design requirements
4. Environmental conditions, including radiation

Design requirements include:

1. Pressure
2. Temperature
3. Mechanical loads
4. Maximum leakage allowed

It is required that a complete description of the operating conditions be given with respect to the time variation of each of the loadings and of the following quantities.

1. Coolant pressure
2. Coolant temperature
3. Flow rate

REFERENCE 11
.CRANE BULLETIN NO. S-2005-1, "SHAFT SEALS FOR POWER GENERATING STATION."

CHART E
RADIATION AND TEMPERATURE LIMITS OF MATERIALS

[illegible]	Grade Code	[illegible] Threshold Limits, Rads, At Room Temperature	Temperature Limits, F, Boric Acid Solution
TFE (Polytetrafluoroethylene)	O	5×10^4	500
Ethylene Propylene† terpolymer *	O_{28}	2×10^7	300
Fluoroelastomers (Viton*)	X	1×10^6	350
Nitrile Rubber	B	1×10^6	225
Neoprene	N	4×10^7	90
Chlorosulfonated Rubber (Hypalon)	O_{44}	4×10^7	80
Silicone Rubber	J	1×10^8	225
Urethane Rubber	—	9×10^5	175
Asbestos	O_{13}	1×10^{10}	—
Ceramic	C	1×10^{11}	—
Glass	—	1×10^8	—
Graphite	F	1×10^{10}	—
Mica	—	1×10^7	—
Perfluoroelastomer (Kalrez*)	X_5	1×10^6	—

* DuPont T.M.'s

†John Crane's Ethylene Propylene Compound O_{40} which is specially compounded and has been tested for radiation service has been shown to be functional to 1.1×10^8 rads. gamma radiation.

* C. Dunkerley

MECHANICAL SEALS AND PACKINGS ■ OIL SEALS ■ TFE PRODUCTS ■ LAPMASTER LAPPING MACHINES ■ THREAD SEALERS

CRANE PACKING COMPANY

6400 OAKTON STREET, MORTON GROVE, ILLINOIS 60053

July 15, 1982

Stone & Webster
1 Penn Plaza
40th Street
New York, N.Y. 10016

Attention: Mr. Charles Dunkerley

Subject: Elastomers For Nuclear Service

Dear Mr. Dunkerley:

This letter is in reference to our telephone conversation of June 30, 1982 in which you requested information on radiation resistance and temperature limits of our Cranelast material.

I would like to inform you that the radiation limit of our 040 (Cranelast) material is 1.1×10^8 rads gamma radiation and the temperature limit (in boric acid solution) is 300°F.

The above information can be found on page 7 of our bulletin S-2005-1 which I am enclosing.

If you have any further questions, please call me at (312)967-3739.

Sincerely,

CRANE PACKING

S. Lemberger
Mechanical Engineer

SL:mt
enclosures

RESEARCH, DEVELOPMENT AND ENGINEERING DIVISION
ITT GRINNELL CORPORATION
PROVIDENCE, RHODE ISLAND

EVALUATION OF
ITT GRINNELL DIAPHRAGM VALVE DIAPHRAGMS
AFTER BEING SUBJECTED
TO GAMMA RADIATION

January 12, 1971

Report No. 998B

REFERENCE 12

TABLE I

Radiation Dosage	8.77×10^4 Rads Duro	8.77×10^4 Rads Flex	8.77×10^5 Rads Duro	8.77×10^5 Rads Flex	8.77×10^6 Rads Duro	8.77×10^6 Rads Flex	8.77×10^7 Rads Duro	8.77×10^7 Rads Flex	2.98×10^8 Rads Duro	2.98×10^8 Rads Flex
Natural Rubber Black	51	50,000	53	50,000	60	50,000	65	14,160	74	0
Natural Rubber White	64	50,000	66	50,000	69	50,000	78	50,000	90	0
Falstaff Gum Natural Rubber	45	50,000	45	50,000	55	39,812	80	27,760	76	0
Styrene-Butadiene Rubber	67	50,000	68	50,000	70	50,000	77	15,712	92	0
Nitrile Rubber	70	50,000	68	50,000	72	50,000	85	15,712	96	0
Carboxylated Nitrile Rubber	74	50,000	74	50,000	74	50,000	75	16,199	90	15
Ethylene-Propylane Terpolymer Sulfur-Cured	70	50,000	70	50,000	70	50,000	73	16,579	84	95
Peroxide Cured	65	50,000	65	50,000	69	50,000	70	40,700	75	400
Neoprene	65	50,000	65	50,000	65	50,000	80	12,508	96	0
Hypalon	71	50,000	71	50,000	73	50,000	80	16,340	93	0
Urethane	72	50,000	73	50,000	69	50,000	55	14,053	54	11,660
Viton	74	50,000	74	50,000	74	50,000	84	300	96	0
Plasticized PVC	70	50,000	70	50,000	70	50,000	76	767	72	0
TFE Teflon	-	5,640	-	100	-	0	-	0	-	0
FEP Teflon	-	27,160	-	12,116	-	100	-	0	-	0
Polyallomer	-	50,000	-	50,000	-	0	-	0	-	100

Fisher Controls International, Inc
205 South Center Street
Marshalltown, Iowa 50158
Phone 515/754-301"

F'SHEF

Fisher Controls

July 12, 1982

Mr. Chris Menon
Stone & Webster Engineering Corporation
One Penn Plaza
250 West 34th Street
New York, New York 10001

Subject: Environmental Capabilities of
Type 9200 Butterfly Valve

Gentlemen:

In response to our recent telephone conversation, the following summarizes the test sequence and maximum levels that the type 9200 Butterfly valve has been tested. These test were performed on a 20" 9200 with a pneumatic piston operator.

1) Accelerated heat and cycle aged to 5 year life at 120°F.

2) $1 X 10^7$ rads - No leakage.

3) DBE Pressure Temperature profile - No leakage.

4) 381°F (15 minutes) - No leakage below 30 psid
- Small leakage at 75 psid.

5) 400°F (15 minutes) - No leakage at 2.5 psid.

6) $1 X 10^8$ rads - Small leakage at 2.5 psid.
- Larger leakage at 60 psid.

I hope that this information is adequate to meet your needs. Unfortunately, any further documentation could require an appreciable amount of engineering time and would have to carry an appropriate charge. We would request any inquiries requiring more documentation be made in writing to my attention.

If there are comments or questions on tne contents herein, please do not hesitate to contact me.

Sincerely,

Scott McLagan

J. S. McLagan
Applications Engineering Manager
Power Industry

JSM/ds

REFERENCE 13

7/14/82

STOWEBENS NYK

VTIA TLXI NYK

20200

SAVE24789A

999"

FLEX CO BLMR SAV24789A

TLK

123291

ATTN: LOU FIORE EXT. 5234

FLEXITALLIC HAS NOT SUBJECTED SPIRAL WOUND GASKETS TO RADIATION EXPOSE
TESTING INFORMATION MAY BE AVAILABLE FROM OAK RIDGE NAT'L LAB,
OAK RIDGE TENN, OR BROOKHAVEN NATL LAB, UPTON N.Y.
OUR STANDARD CANADIAN ASBESTOS FILLER CONTAINS APPROX. 7% RUBBER LATEX
BINDER. WHILE THE BINDER DOES CONTRIBUTE SOMEWHAT TO SEALING, ITS MAI
FUNCTION IS TO FACILITATE HANDLING AND MANUFACTURING OF THE ASBESTOS
INTO A SPIRAL WOUND GASKET. THE BINDER WILL NORMALLY BE BURNED OUT AT
APPROX. 700 DEGREES F BUT THE GASKETS ARE SUITABLE TO 1200-1400 DEGRE
(DEPENDING ON WINDING METAL AND FLUID BEING SEALED) SOME CUSTOMERS SE
REQUEST THAT GASKETS BE BAKED TO REMOVE BINDER.

REGARDS

ED CROWLEY

FLEX CO BLMR

REFERENCE 19

TELEX, TO L. FIORE FROM E. CROWLEY OF FLEXITALLIC, 7/16/82

MMMM+

STOWEBENS NYK

T

CRANE PAK MSVE #24

C. Dunkerly
40ff

STOWEBENG NYK

1:19

JULY 19 82 MSG NO. 1733

ATTN: MR G MCKILLOP MGR- PACKING DIVISION

CRANE PACKING CO MORTON GROVE ILLINOIS

TLX NO. 289434

MSG NO. 1733

CC: VERN NELSON

REF : TELEPHONE CONVERSATION BETWEEN C. DUNKERLEY OF STONE AND WEBSTER ENGINEERING CORPORATION AND MR. V. NELSON DATED 7/15/82 AND RELATED TO NON-METALLIC MATERIALS [illegible]ED IN A NUCLEAR PLANT ENVIRONMENT

FIRST, LET ME THAK YOUR PERSONNEL AND PARTICULARLY MR.V. NELSON PROFOUNDLY FOR THE INFORMATION AND BASIC UNDERSTANDING OF YOUR PACKINGS, RELATED TO ME IN THE ABOVE PHONE CONVERSATION. I WAS SADLY LACKING IN SUCH INFORMATION AND IF I HAVE CORRECTLY UNDERSTOOD YOUR EXPLANATION, THAT INFORMATION WILL BE EXTERMELY HELPFUL WITHIN MY COMPANY TO FACILITATE THE TASK ASSIGNED, NAMELY QUALIFYING/JUSTIFYING NON-METALLICS IN THE LILCO SHOREHAM NUCLEAR PLANT.

I WOULD LIKE TO TRANSMIT BACK TO YOU THE GIST OF WHAT I WAS TOLD, TO BE SURE I HAVE NO MISUNDERSTANDING OF THAT INFORMATION.

REFERENCE 24
TELEX, TO G. McKILLOP OF CRANE PACKING FROM C. DUNKERLY, 7/19/82

WE ARE PRESENTLY USING PACKINGS SUCH AS CRANE STYLES 1371,137J, AND 5313 WHICH ARE GENERALLY A BASIC ASBESTOS FIBRE WITH GRAPHITE AND OTHER MATERIAL ADDITIONS SUCH AS ALLOY WIRE AND ELASTOMER BINDERS (IE, BUNA-S, ETC.). IN ADDITION, A WIDE variety of sheet packings are used, primarily as gaskets, which ARE BASICALLY LONG FIBER ASBESTOS SHEETS WITH ADDED ELASTOMER BINDERS SUCH AS BUNA-N, BUNA-S, EPDM, ETC.

SPECIFICALLY WITH THE 1371/J STYLE TYPICALLY USED AS VALVE PACKING, WE UNDERSTAND THE 2-3PCT (MAX 12 PCT) BUNA-S BINDER ADDED IS A FABRICATION AND/OR INSTALLATION AID AND PERFORMS NO FUNCTION IN THE SEALING CHARACTERISTIC OF THE MATERIAL. HEATED TO NEAR THE TEMPERATURE RA[illegible] (1200 DEGREE F), IT IS ANTICIPATED THE BINDER WILL VAPORIZE OR BURNOFF WITH NO DELETERIOUS AFFECTS ON THE SEALING CAPABILITY OF THE MATERIAL.

ALTHOUGH NOT SPECIFICALLY DISCUSSED, WE ASSUME THAT LOWER TEMPERATURE EXPOSURE (TYPICAL IN OUR CASES), RESULTING IN DETERIORATION OF BINDER PROPERTIES WITH PERHAPS PARTIAL OXIDATION, WILL NOT RESULT IN BASIC MATERIAL SEALING CAPABILITY DETERIORATION.

IN A SIMILAR VEIN, THE RADIATION LEVEL IN MOST OF OUR CASES IS ONLY SUFFICIENT TO DEGRADE THE PROPERTIES OF THE BINDER BUT NOT HIGH ENOUGH TO CAUSE DISINTERGRATION.

WITH THE LOW PERCENTAGE OF BINDER IN THE PACKING MATERIAL AND ITS LOCATION IN THE CORE OF THE PACKING, THE DETERIORATION EXPECTED SHOULD HAVE NO APPRECIABLE EFFECT ON THE SEALING PROPERTIES OF THE packing.

IN THE CASE OF SHEET PACKING USED AS A GASKET THE BINDER CONTENT IS SOMEWHAT HIGHER (11-15PCT) AND THE PACKINGS ARE KNOWN BY SUCH NAMES AS:

AFRICAN ASBESTOS

BLUE ASBESTOS

ASBESTOS WITH EPDM BINDER.

ASBESTOS WITH BUNA-N BINDER

ASBESTOS WITH BUNA-S BINDER.

WITH THE SHEET PACKING MATERIAL TIGHTLY COMPRESSED BETWEEN FLANGES, THE BINDER DOES NOT CONTRIBUTE APPRECIABLY TO THE SEALING PROPERTIES OF THE GASKET. THE DETERIORATION OF THE BINDER UNDER EXCESS TEMPERATURE OR RADIATION LEVELS SHOULD NOT THEN AFFECT GASKET SEALING CHARACTERISTICS SIGNIFICANTLY.

THE TYPICAL MEXIMUM TEMPERATURE FOR THE ASBESTOS/BUNA-S TYPE SHEET PACKING IS 700 DEGREE F. THE VARIOUS BINDERS (EPDM, BUNA-S, BUNA-N) WILL SHOW TEMPERATURE DETERIORATION IN THE 130-255 DEGREE F RANGE. IF THE SERVICE TEMPERATURE LEVEL WAS SUFFICIENT TO BURN OFF THE BINDER, IT MIGHT BE DESIRABLE TO TIGHTEN THE FLANGE BOLTS TO COMPENSATE FOR THE MISSING BINDER VOLUME. THE TEMPERATURES REACHED IN ANY OF OUR APPLICATIONS IS BELOW BURNOUT TEMPERATURE.

THESE PACKINGS ARE USED IN A VARIETY OF EQUPMENT INCLUDING:

GOULDS PUMPS

FISHER VALVES

ANCHOR-DARLING VALAVES

VELAN VALVES

CONTROMATIC VALVES

IF THERE IS NO SUBSTANTIAL ERROR IN THE ABOVE, PLESE CONFIRM.
SHOULD ANY INDIVIDUAL STATEMENT BE IN ERROR OR REQUIRE CLARIFICATION,
PLEASE ADVISE.

REGARDS,
CHARLES DUNKERLEY
STOWEBENG NYK /128291
 ZK
•
CRANE PAK MOVE

STOWEBENG NYK

Mobil Chemical Product Data

NOVEMBER 1, 1976 / Printed in U.S.A.
This supersedes all previous publications.
Always consult your Mobil representative for latest information and recommendations for Mobil Products.

NO-RUST® PRIMER

13-R-53

CONFORMS WITH AIR POLLUTION RULES AND REGULATIONS

COLOR	Red
FINISH	Low Luster
VEHICLE TYPE	Alkyd Resin and Linseed Oil
PIGMENT TYPE	Zinc Chromate, Red Iron Oxide and inerts.
SOLVENT TYPE	Aliphatic hydrocarbons
FLASH POINT, MINIMUM	80°F. *(27°C.)* PMC
% SOLIDS BY VOLUME	63%
RECOMMENDED DRY FILM (per coat)	2.0 mils *(50 μm)*
COVERAGE (THEORETICAL)	1010 square feet per gallon *(24.7 m^2/ltr)* per dry mil *(25 μm)*. The actual coverage will be less, depending on application technique, job conditions and type of surface to be coated.
VISCOSITY AT 75°F. *(24°C.)*	70-75 Krebs Units
AVERAGE DRY TIME AT 75°F. *(24°C.)*	To touch 6-8 hours. Recoat 24-48 hours.
RECOMMENDED THINNER	Brush or Roller – Thinner 7-T-38 For Spray – Thinner 7-T-39 up to 1 pint per gallon
RESISTANCE TO	Dry Heat – To 250°F. *(121°C.)*
RECOMMENDED PRIMER	None- apply to clean, bare steel
APPLICATION	Brush, Roller or Spray CONVENTIONAL SPRAY (Suggested Equipment) DeVilbiss MBC-510 Spray Gun, "E" Fluid Tip #704, #765 or #78 Air Cap Binks #18 Spray gun, 66 Tip, 66 PE or 63 PB Nozzle AIRLESS SPRAY Use of spray tips with .015 to .021", orifice is suggested, depending on available pressure and job conditions.

REFERENCE 29

NO-RUST® PRIMER 13-R-53

No-Rust Primer 13-R-53 is suitable for use as a priming coat on steel which has been prepared by hand-tool or power-tool cleaning. All loose rust, loose milliscale, oil, dirt, and improperly adhering old paint should be removed before painting. Surfaces should be dry. 13-R-53 is intended to penetrate and bond to surfaces which have only tightly adherent rust.

Due to the oil content of this product, at lower temperatures increased drying intervals to handle and overcoat must be expected.

NOTICE: This product is for industrial use only and is not intended or suitable for use in or around a household or dwelling.

WARNING: FLAMMABLE. VAPOR HARMFUL. CAUSES IRRITATION. CONTAINS – ORGANIC SOLVENTS AND LEAD. Keep away from heat, sparks, and open flame. Avoid breathing vapor. Avoid contact with eyes, skin, and clothing. Wash thoroughly after handling. Use with adequate ventilation. Wear an air supplied mask to avoid breathing concentrated vapors in enclosed areas. Do not apply on toys, cribs, or other surfaces which may be accessible to children. Keep container closed. FIRST AID: If inhaled, remove to fresh air. If not breathing give artificial respiration, preferably mouth-to-mouth. Call a physician. In case of contact, immediately flush eyes with plenty of water for at least 15 minutes. Call a physician.

Mobil Chemical Company / MAINTENANCE & MARINE COATINGS DEPARTMENT

Edison, New Jersey 08817
P.O. Box 250 / Tel: (201) 287-2626

Beaumont, Texas 77704
P.O. Box 3431 / Tel: (713) 835-5324

Kankakee, Illinois 60901
901 North Greenwood Avenue / Tel: (815) 933-5561

Los Angeles Area / Azusa, California 91702
1004 West Tenth Street / Tel: (213) 334-8251

Louisville, Kentucky 40210 (Railroad Coatings)
1630 West Hill Street / Tel: (502) 774-4411

These products also available from: Delft, Holland/Toronto, Canada Bogota, Colombia/Sao Paulo, Brazil/Mexico City, Mexico

REFERENCE 4C

TNOLOGY

manufacture, applications.

MERIC MATERIALS

REINFORCED PLASTIC

F MAN-MADE FIBERS

OF POLYMER FILMS

TION

Environmental Effects on Polymeric Materials

Edited by DOMINICK V. ROSATO
Technical Editor, *Plastics World*
and Engineering Consultant

and ROBERT T. SCHWARTZ
Chief, Nonmetallic Materials Division,
Air Force Materials Laboratory, Dayton, Ohio

VOLUME I: Environments

Interscience Publishers
a division of John Wiley & Sons   New York • London • Sydney

POLYETHYLENE, PAGES 36 & 37
MOBIL 13-R-53 NO RUST PRIMER, PAGES 725 & [illegible]
ALKYD BASE ENAMELS

Library of Congress Catalog Card Number: [illegible]-13[illegible]

Printed in the United States of America

TABLE 1-58. Contemporary Thermoplastic Materials—Properties

Resin material	Compressive modulus, psi × 10³	Heat distortion temperature, °F, 264 psi	Heat resistance, continuous °F	Coefficient thermal expansion, in./in.-°C × 10⁻⁵	Thermal conductivity, cal/cm²-sec-°C-cm × 10⁻⁴	Volume resistivity, ohm-cm
1. Acetal	410	255	185	8.1-8.5	1.6-5.5	1-10[illegible]
2. ABS	200-450	185-230	180-225	5.7-10	5-8	10[illegible]-10[illegible]
3. Acrylic	390-430	167-198	120-200	5-6.5	4.4	>10[illegible]
4. Acrylic high impact	230-380	180-190	140-185	6.5-10.5	4.0	10[illegible]-10[illegible]
5. Cellulose acetate	—	111-185	140-175	8-18	4-8	10[illegible]-10[illegible]
6. Cellulose acetate butyrate	—	113-202	140-175	11-17	4-8	10[illegible]-10[illegible]
7. Cellulose propionate	—	121-228	140-175	11-16	4-8	10[illegible]-10[illegible]
8. Chlorinated polyether	130	185-210	250-275	8	3.13	1.5×10[illegible]
9. Chlorotrifluoroethylene	180	160-170	390	4-7	4-6	10[illegible]
10. Ethyl cellulose	—	130-200	140-180	10-20	3.8-7	—
11. Ethyl vinyl acetate	—	—	130-170	16-20	8	—
12. FEP	70	124	400	8.3-10.5	5.9	>10[illegible]
13. Nylon 6	247	150-175	250	8.3	5.9	4.5[illegible]-4.5[illegible]
14. Nylon 6/6	400	300	250	10	5.8	10[illegible]-10[illegible]
15. Nylon 6/10	—	145	220	10	5.5	4.5×10[illegible]
16. Polyallomer	—	115-140	250	8-11	3-4	>10[illegible]
17. Polycarbonate	345	270	250-270	7	4.6	2.1×10[illegible]
18. Polyethylene low density	—	—	140-175	10-30	8	10[illegible]-10[illegible]
19. Polyethylene medium density	—	—	150-180	10-20	8	10[illegible]-10[illegible]
20. Polyethylene high density	80-110	110-125	180-250	10-20	8	6×10[illegible]-10[illegible]
21. Polyethylene high molecular weight	110	130	250	13	8	>10[illegible]
22. Polypropylene	—	140-200	270	6-8.5	2.8-4	6.5×10[illegible]
23. Polystyrene	380-500	165-205	150-180	6-8	1.8-3.3	10[illegible]-10[illegible]
24. Polystyrene high impact	—	180-200	130-170	6.5-8.5	1-3	10[illegible]-10[illegible]
25. Polyurethane	—	—	150-180	10-20	6	2-10[illegible]
26. Poly(vinyl chloride) (flexible)	—	—	—	7-25	3-4	10[illegible]-10[illegible]
27. Poly(vinyl chloride) (rigid)	300-400	140-175	150-165	5-10	3-5	10[illegible]-10[illegible]
28. Poly(vinyl dichloride) (rigid)	—	202-230	165-210	7-8	3-4	10[illegible]
29. Styrene acrylonitrile (SAN)	530	200-208	—	7	3	10[illegible]
30. TFE fluorocarbon	70-80	122	550	5.5(25-80°C)	6	>10[illegible]
31. Ionomer	—	—	140	12-13	5.5	>10[illegible]
32. Phenoxy	325	175-180	—	2.2-3.8	—	2.75-6×10[illegible]
33. Polyphenylene oxide	—	375	—	—	—	10[illegible]
34. Polysulfone	336	345	300	3.1-10⁻⁵ in./in. °F	1.8 BTU/hr-sq ft-ft °F	8×10[illegible]

REFERENCE 40

Environmental Effects on Polymeric Materials,
D. V. Rosato and Schwartz, John Wiley & Sons, Inc.,
New York, 1968. (Page 36 & 37).

... e elastomers are valuable because
... inge of temperatures. They are
... 0°C and are degraded or oxidized
... e. They are, however, very diffi-
... re nature of the methyl groups.
... re usually employed, but a truly
... tain with chemical curing agents.
... r at higher temperatures because
... The action of ionizing radiation
... ich attention, and may be one of
... se radiations to polymers, since
... out more rapidly and effectively
... The vulcanizates do not crosslink
... and exhibit much less relaxation
... (84). Polydimethylsiloxane is
...). Patents applied for by the
... val tion of polydimethyl-
... ts . and 50 parts of carbon
... maximum tensile strength (65.6
... dose the elongation was 207%.
... at higher doses, the elongation
... ave optimum properties; tensile
... on. Gum polydimethylsiloxane
... ewhat in tensile after 1.3×10^{7}
... large increase in hardness, and
... y of gamma radiation on cured
... 10^{8} reps of cobalt-60 radiation
... m 1300 to 450 psi and in elonga-
... nd Hale (88) irradiated Silastic
... reps and reported vulcanization
... of 860 psi, elongation of 130%,
... ff (89) found that gum poly-
... from traces of acidic and basic
... tion catalyst, and then vulcan-
... howed little or no stress relaxa-
... slinked with benzoyl peroxide
... believed that this was due to
... peroxide, which caused chain
... relaxation. Polydimethylsilox-
... V electrons showed somewhat
... peroxide vulcanizates (90).

Compression set is caused by a tendency of the compressed sample to be remolded in its compressed shape, an effect due both to linking, which tends to "freeze on" the new chain configurations. The improvement observed probably resulted from the absence of any further vulcanization of the radiation-cured sample during the test.

3. Comparative Radiation Effects

a. Elastomers. Natural rubber is substantially unaffected by radiation up to a dose of about 2×10^{7} ergs/g and approximately 25% damage in various properties is observed at a dose of 5.5×10^{8} ergs/g. There is a spread therefore of slightly over one order of magnitude between no damage and 25% damage. On the other hand, polyurethane rubber shows no effects up to about 8.5×10^{8} ergs/g and shows approximately 25% damage at 4.3×10^{9} ergs/g. In this case, the spread from no damage to 25% damage is less than one order of magnitude. However, if a comparison were to be made between natural rubber and polyurethane rubber for a particular use, additional factors such as the much greater temperature capabilities of the polyurethane must be considered. GR-S elastomer or butadiene styrene rubber is more susceptible to radiation damage than natural rubber and deteriorates by crosslinking and hardens.

b. Plastics. In general, plastics are more radiation resistant than elastomeric materials. Among the class of thermosetting resins, phenolic materials may be regarded as good. Epoxy plastics have higher radiation resistance and polyester material have relatively poor radiation stability. However, polyester materials which are either oriented films or fibers show substantially improved radiation resistance. In the general class of thermoplastic resins, polystyrene and related plastics have the best radiation resistance. Polyethylene is also quite resistant and shows the interesting property of becoming improved with respect to melting and softening points when subjected to irradiation. Advantage of this property has been taken to commercially produce a grade of polyethylene not affected by boiling water. A given plastic material will vary in radiation resistance, depending upon, for example, filler materials. A phenol formaldehyde plastic with no filler will show 25% damage at 10^{7} rads. With a graphite filler the 25% damage level would be about 8×10^{7} rads and with asbestos filler it can be greater than 10^{9} rads.

c. Organic Coatings. When organic coatings are exposed to nuclear radiation they display behavior which is characteristic of the polymers upon which they are based. In a series of tests at the Naval Air Engineering Center phenolic resin base coatings are radiation resistant to greater than 4×10^{8} rads. Alkyd (phthalic anhydride) base enamels are good to approximately 10^{8} rads, while nitrocellulose base lacquers are useful only to 5×10^{6} rads.

Because organic coatings are normally used for some purpose of protective treatment, it is vitally important to consider other environmental conditions accompanying nuclear radiation. For example, if a small nuclear power unit is located in a satellite, and there is a thermal control coating in the vicinity of the power unit, then a realistic laboratory test of the potential coatings must be carried out under high vacuum conditions. If a nuclear power unit is located in a deep sea unmanned vehicle, and protective paint is applied to the outside of the vehicle, then it would be desirable to have laboratory irradiation tests conducted in the presence of sea water. The sea water should preferably be flowing slowly past the paint specimen being irradiated, to eliminate spurious results from the action of degradation products of a small amount of seawater which has been continuously irradiated.

E. Improving the Radiation Resistance of Polymeric Materials

Certain organic substances when added to polymeric materials have the property of improving the radiation resistance of the polymer. It has already been pointed out that nuclear radiation causes the generation of free radicals within the polymer and these free radicals are responsible for the progress of side reactions which lead to the breakdown of the polymer. Therefore, any additive material which would absorb or otherwise eliminate or reduce the free radicals should be beneficial to the polymer. The relative ratings of radiation can be developed so as to provide an indication of the types of structures useful as "antirads." For example, quinhydrone, pyrogallol, *N,N'*-cyclohexylphenyl-*p*-phenylenediamine, and *N*-*p*-tolyl-*N'*-*p*-toluenesulfonyl-*p*-phenylene-diamine have shown outstanding characteristics as additives to reduce radiation damage to natural rubber. α-Naphthylamine is an excellent antirad for nitrile rubber and styrene-butadiene rubber. Because progress is continually being made in this field, it is wise to consult industrial organizations working in this area in order to obtain the best recommendations for particular problems.

Mechanical Equipment Environmental
Conformance Data: Selected 3000M Packages

Shoreham Nuclear Power Station - Unit 1

Long Island Lighting Company

September 7, 1982

ENVIRONMENTAL QUALIFICATION SUMMARY

Environmental Qualification Summary No: 3004M

Title: ITT/Hammel Dahl Control Valve

Client: LILCO   Project: NSSS Equipment Qualification

Job No: 0630-001-671

Design Input/References:

The references included with this package are listed as appendices in the Table of Contents on page 2.

Assumptions:

N/A

Method:

N/A

Remarks:

This device has been qualified for all postulated accident conditions.

REV. NO.	REVISION	PERFORMED BY	CHECKED	APPROVED	DATE
0	Original	Kenneth Pratt	Ira Zbrak	N K Woodward	7/23/82
1	Pgs. 2,4,6,7.8,9	Kenneth Pratt	Ira Zbrak	N K Woodward	8/23/82

TABLE OF CONTENTS

APPENDICES

APPENDIX	TITLE
A	Documentation:

1. G.E. Purchase Specification No. 21A9239, Rev. 0, Nuclear Boiler System Valves, General (LILCO/SR-2 Document No. 2861-0400).

2. ITT Hammel Dahl Conoflow Drawing No. 79/2861-0400 Rev. 4, LILCO MPL C11-F010 General Drawing 3736-500 (LILCO/SR-2 Document No. 21A9239).

3. Form NPV-1 N Certificate Holders Data Report for Nuclear Pumps or Valves for Valve Serial Nos. 79/28671/003, 004, and 007, dated 5/21/82.

4. G.E. Product Quality Certification for Valve Serial Nos. 79/28671/003, 004, 007, and 008, dated 6/17/82. 1

B Analyses:

1. EDS Calculation No. 0630-001-039, Revision 0.

1.0 EQUIPMENT LIST

Equipment I.D. (Mark No.)	MPL No.	Description	Make/Model
1C11*AOV081	C11-F010	Control Valve	ITT/Hammel Dahl Conoflow, 1", 2500 lb. Class Control Valve
1C11*AOV082	C11-F181	Control Valve	ITT/Hammel Dahl Conoflow, 1", 2500 lb. Class Control Valve
1C11*AOV051	C11-F011	Control Valve	2", 2500 lb. Class Control Valve
1C11*AOV050	C11-F180	Control Valve	2", 2500 lb. Class Control Valve

2.0 EQUIPMENT SUMMARY EVALUATIONS

2.1 Description

The equipment under evaluation are ITT Hammel Dahl Conoflow diaphragm control valves (1", 2500 lb. class, and 2", 2500 lb. class). These valves are the scram discharge volume vent and drain valves.

2.2 Conclusions

This equipment is qualified for the postulated accident temperature, pressure, humidity, and radiation conditions.

Materials analysis (EDS Calculation No. 0630-001-039, Rev. 0) indicates that the non-metallic components contained within these devices will not be adversely affected by the postulated accident radiation and temperature environments.

2.3 Limitations

None.

2.4 Discussion

1. These devices are required to withstand a postulated accident radiation dose of 5.75×10^6 rads (Environmental Qualification Report [EQR], SNRC-704, May 17, 1982). Additionally, the Purchase Specification for Nuclear Boiler System Valves (Documentation Reference 1) required that they be constructed of materials which are resistent to radiation damage considering a total dose of 1×10^7 rads. Materials analysis (EDS Calculation No. 0630-001-039, Rev. 0) indicates that the limiting material contained within these devices is the BUNA-N/Nylon diaphragm having a radiation tolerance of 6×10^6 rads. Therefore, this device is expected to perform its safety function as required.

2. These valves are designed for an internal temperature and pressure of 450°F and 1250 psi, respectively (Documentation Reference 3). The thermal expansion stresses from the postulated EQR peak accident ambient temperature of 190°F are therefore considered insignificant as compared to the above stated temperature and pressure.

   Therefore, the postulated accident ambient temperature and pressure are negligible in light of the mechanical properties, materials of construction, and design of these vent and drain valves.

SECTION 3.0

ENVIRONMENTAL QUALIFICATION WORKSHEETS

Long Island Lighting Company
Shoreham Nuclear Power Station, Unit No. 1

Environmental Qualification Summary No. 3004M
Revision No. 1

MECHANICAL EQUIPMENT ENVIRONMENTAL QUALIFICATION WORKSHEET

Prepared by: [signature] Date: 8-23-82

Checked by: [signature] Date: 8-23-82

EQUIPMENT DESCRIPTION	ENVIRONMENTAL PARAMETER	POSTULATED ENVIRONMENT		DOCUMENTED ENVIRONMENT		OUTSTANDING ITEMS
		FSAR *	ENVIRONMENTAL QUAL. REPORT **	VALUE	REFERENCE	
EQUIP. I.D. (MARK NO.): 1C11*AOV051, 050	Maximum Temperature (degrees F)	212	152	Note 1	Note 1	None See Section 2.4
VENDOR I.D.: C11-F011, F180	Maximum Pressure (psig)	1	1	Note 1	Note 1	None See Section 2.4
EQUIPMENT TYPE: Scram Discharge Drain Valve	Maximum Relative Humidity (%)	100	100	Note 1	Note 1	None See Section 2.4
SERVICE: CRD Scram	Containment Spray	N/A	N/A	N/A	N/A	N/A
MANUFACTURER: ITT/Hammel	40-Year Normal Radiation Dose (Rads)	1.8×10^3	1.8×10^3	1×10^7	1	None
MODEL NO.: 2" 2500 Class	6-Month Accident Radiation Dose (Rads)	1×10^5	3.06×10^6	6×10^6	2	
LOCATION: RBS, El. 40' ZONE: L-02	Submergence	N/A	N/A	N/A	N/A	N/A

1

ATTACHMENT TO MECHANICAL EQUIPMENT ENVIRONMENTAL QUALIFICATION WORKSHEET

REFERENCES:

1. G.E. Purchase Specification 21A9239, Rev. 0, Nuclear Boiler System Valves, General.

2. EDS Calculation No. 0630-001-039, Rev. 0, Materials Analysis of ITT Hammel Diaphragm Valve.

NOTES:

1. Documented environment values for maximum temperature, pressure, and humidity could not be located.

* FSAR values for maximum temperature, pressure, and humidity are from Table 3C.3-9 and radiation doses are from Table 3.11.2-1.

** EQR values for maximum temperature, pressure, and radiation (normal and accident) are from Figures D-22, D-41 and D-2, respectively. EQR value for humidity is from Section 3.1.b of the EQR. 1

Long Island Lighting Company
Shoreham Nuclear Power Station, Unit No. 1

Environmental Qualification Summary No. 3004M
Revision No. 1

MECHANICAL EQUIPMENT ENVIRONMENTAL QUALIFICATION WORKSHEET

Prepared by: Kenneth Pratt Date: 8-23-82

Checked by: Ada Zebeak Date: 8-23-82

EQUIPMENT DESCRIPTION	ENVIRONMENTAL PARAMETER	POSTULATED ENVIRONMENT		DOCUMENTED ENVIRONMENT		OUTSTANDING ITEMS
		FSAR *	ENVIRONMENTAL QUAL. REPORT **	VALUE	REFERENCE	
EQUIP. I.D. (MARK NO.): 1C11*AOV081, 082	Maximum Temperature (degrees F)	212	190	Note 1	Note 1	None See Section 2.4
VENDOR I.D.: C11-F010, F181	Maximum Pressure (psig)	1	1	Note 1	Note 1	None See Section 2.4
EQUIPMENT TYPE: Scram Discharge Vent Valve	Maximum Relative Humidity (%)	100	100	Note 1	Note 1	None See Section 2.4
SERVICE: CRD Scram	Containment Spray	N/A	N/A	N/A	N/A	N/A
MANUFACTURER: ITT/Hammel	40-Year Normal Radiation Dose (Rads)	1.8×10^3	1.8×10^3	1×10^7	1	None
MODEL NO.: 1" 2500 Class	6-Month Accident Radiation Dose (Rads)	1×10^5	5.75×10^6	6×10^6	2	
LOCATION: RBS, El. 78' ZONE: G-11	Submergence	N/A	N/A	N/A	N/A	N/A

1

ATTACHMENT TO MECHANICAL EQUIPMENT ENVIRONMENTAL QUALIFICATION WORKSHEET

REFERENCES:

1. G.E. Purchase Specification 21A9239, Rev. 0, Nuclear Boiler System Valves, General.

2. EDS Calculation No. 0630-001-039, Rev. 0, Materials Analysis of ITT Hammel Diaphragm Valve.

NOTES:

1. Documented environment values for maximum temperature, pressure, and humidity could not be located.

* FSAR values for maximum temperature, pressure, and humidity are from Table 3C.3-9 and radiation doses are from Table 3.11.2-1.

** EQR values for maximum temperature, pressure, and radiation (normal and accident) are from Figures D-31, D-41 and D-2, respectively. EQR value for humidity is from Section 3.1.b of the EQR. 1

APPENDIX A

DOCUMENTATION

GENERAL ELECTRIC
NUCLEAR ENERGY DIVISION
ATOMIC POWER EQUIPMENT DEPARTMENT
San Jose, California

DOCUMENT NO. 21A9239 REV. 0

APPLICATION

☒ SPECIFICATION ☐ DRAWING

TYPE PURCHASE SPECIFICATION

DOCUMENT TITLE NUCLEAR BOILER SYSTEMS VALVES, GENERAL

REVISIONS			

P GREGORY 7.3.69	G YEAZELL [signature] 7-9-69	CONT ON SHEET 2	SH NO 1
JUL 9 1969			

REVISION STATUS SHEET

GENERAL ELECTRIC
NUCLEAR ENERGY DIVISION

Document No. 21A9239 Rev. 0

General Electric Class ________

TRANSMITTAL

PROJECT(S) COOPER

TITLE OF DOCUMENT NUCLEAR BOILER SYSTEM VALVES

TYPE OF DOCUMENT:
[X] PURCHASE SPECIFICATION
[ ] SYSTEM DESIGN SPECIFICATION
[ ] INSTALLATION SPECIFICATION
[ ] ________

REPLACES DOCUMENT NO. ________

PIPING OR COOLING SYSTEM INVOLVED ________

RESPONSIBLE ENGINEER G YEAZELL ISSUED BY P GREGORY DATE JUL 9 1969

REFERENCES
MASTER PARTS LIST (MPL) NOS. GENERAL REQUIREMENTS DOCUMENT
SPECIFICATIONS ________
DRAWINGS ________
OTHER QUALITY CONTROL PLAN NO. 353, Rev. 0

REVISION RECORD
REVISED PER (ECA, ECN, ETC.) ________
SHEETS AFFECTED ________ REVISION IDENTIFIED WITH __.

COMMENTS: ________

DISTRIBUTION

NAME	MAIL CODE	COPIES	NAME	MAIL CODE	COPIES
G YEAZELL	743	1			
A DeLOACH	621	1			
GRU	742	1			
ALEXANDER	366	2+1R			
LORENTZ	376	1			
DEVOSS	382	1			
	595	1			
	624	1			
	722	1			
	723	1			
	751	2			
	753	1			
	760	1			

SECTION I

GENERAL

1. SCOPE

1.1. This specification defines the requirements for valves used in high pressure steam, water, and air service in a Boiling Water Reactor Nuclear Power Plant.

1.2. The work done by the Seller in accordance with this specification shall include all necessary design, development, analysis, drawings, procedures, fabrication, shop testing, inspection and preparation for shipment, and shall meet the requirements specified herein.

1.3. The Seller shall accept full responsibility for his work and for compliance with this specification. Review or approval of drawings, data, procedures, or specifications by the Buyer with regard to general design and controlling dimension does not constitute acceptance of any designs, materials, or equipment which will not fulfill the functional or performance requirements established by the purchase contract.

2. APPLICABLE DOCUMENTS, CODES, AND STANDARDS

2.1. The following documents form a part of this specification to the extent specified herein.

2.2. General Electric Documents

2.2.1. A Data Sheet shall be used with this Base Specification to provide the complete Specification for the type of valve being purchased. This Base Specification provides the general functional and fabrication and testing requirements. The Data Sheets provide specific and individual performance and design requirements for the equipment being purchased. When there is a conflict between this Base Specification and the Data Sheets, the Data Sheets shall govern.

2.2.2. This base document contains four sections: (1) I, General; (2) A, GE-APED Classes A and B; (3) C, GE-APED Class C; (4) M, GE-APED Class M. Section I contains the requirements that are applicable to all classes of valves; A, B, C, and M. Section A contains the additional requirements for Classes A and B valves. Section C contains the additional requirements for Class C valves. Section M contains the additional requirements for Class M valves.

2.3. Codes and Standards

2.3.1. All equipment furnished in accordance with this specification shall be manufactured and tested in accordance with the following Codes and Standards of the issue in effect on the date of award of contract to the extent specified herein:

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2.3.1. (Continued)

Manufacturers Standardization Society of the Valve and Fittings Industry (MSS), Standard Practice SP-61, Hydrostatic Testing of Steel Valves
United States of America Standards (USAS)
B16.5 Steel Pipe Flanges and Flanged Fittings
B31.1.0 Code for Pressure Piping, Power Piping
American Society for Testing Materials (ASTM)
Book of ASTM Standards
American Society of Mechanical Engineers (ASME)
Boiler and Pressure Vessel Code - Section I, III, VIII and IX
National Electrical Manufacturers Association (NEMA)
Standards Publication No. 1C1, Industrial Control
National Electric Code (NEC)

3. DESCRIPTION

3.1. Supplied by Seller

3.1.1. The equipment to be furnished in accordance with this specification are various types of valves, complete with required actuators and accessory equipment as required by the Data Sheets. These valves are classified by General Electric, Atomic Power Equipment Department as A, B, C, and M.

3.2. Supplied by Others

3.2.1. Installation and external service connections will be furnished by others, unless specified otherwise.

4. REQUIREMENTS

4.1. Design

4.1.1. The valves shall function as required by this specification under service conditions and the environment specified in the applicable Data Sheets.

4.1.2. The valves shall be designed for a service life of 40 years, accounting for corrosion and material life.

4.1.3. Unless specified otherwise, all stem valves shall be provided with a back seat to prevent leakage into the gland chamber when the valve is in the fully open position.

4.1.4. All valves 12 inches nominal pipe size and larger shall be provided with drain connections in the valve bonnet and in the bottom of the valve body unless specified otherwise.

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4.1.5. The direction of rotation of manual handwheel actuators shall be indicated on the handwheel.

4.1.6. All stem valves over 2 inches nominal pipe size shall have a stem seal stuffing box with two complete sets of packing with a lantern ring between the two packings. Each set of packing shall be capable of withstanding the full design pressure without visible leakage. A leakoff connection with either a female pipe thread and a pipe plug or a socket welded nipple shall be provided as specified between the two sets of packing opposite the lantern ring.

4.2. Operators

4.2.1. General Operator and Control

4.2.1.1. Electrical equipment enclosures, conduit, and conduit connections shall be of water tight construction (NEMA Class 4 or better) suitable for the operating conditions and ambient environment specified.

4.2.1.2. Electrical insulation and enclosure seals, pneumatic and hydraulic seals, and similar nonmetallic components shall be furnished. They shall be made of materials which are resistant to radiation damage considering a total dose of 1×10^7 R gamma radiation. Radiation damage shall be construed to mean a detrimental change in the functional properties of the material.

4.3. Materials

4.3.1. Austenitic Stainless Steel Pressure Containing Parts

4.3.1.1. Materials of analysis equivalent to AISI 304, 304L, 316, or 316L in the following ASTM specifications shall be used except where furnace sensitization of the materials is unavoidable in which case, material with analysis equivalent to AISI 304L or 316L shall be used. Austenitic stainless steel will be considered to be furnace sensitized if it has been heated by means other than welding, within the range of 800 to 1800°F regardless of subsequent cooling rate. When heated to temperatures above 1800°F, the austenitic stainless steel shall be cooled through the range 1800°F to below 800°F within 5 minutes to minimize sensitization.

4.3.1.2. Tubular products

a. ASTM - A312 (Seamless or welded without filler metal)
b. ASTM - A376 (Seamless)
c. ASTM - A213 (Seamless)
d. ASTM - A249 (Welded without filler material)
e. ASTM - A358 (Welded with filler material)
f. ASTM - A451 (Centrifugally Cast Pipe) Note: require 5 percent minimum ferrite

4.3.1.3. Forged or wrought fittings, flanges or pressure retaining parts

a. ASTM - A182
b. ASTM - A336
c. ASTM - A403

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4.3.1.4. Cast fittings, flanges, or pressure retaining parts. Cast fittings, flanges or pressure retaining parts shall be made from ASTM - A351, Grade CF8 or CF8M and the following additional requirements. Austenitic stainless steel castings that have a minimum ferrite content of 5 percent. Ferrite determination by Schaeffler calculations or by use of a calibrated magnetic gage is satisfactory.

4.3.1.5. Plate

a. ASTM - A240

4.3.1.6. Bolting materials for joining stainless to stainless or carbon steel

a. ASTM - A193, Grades B8, B8M, or B6 (Rc 32 maximum)
b. ASTM - A194, Grades 8 or 8M
c. ASTM - A453, All Grades (if allowable stress at temperature are available)
d. ASTM - A276, Type 304, 304L, 316, 316L, or 410 (Rc 32 maximum)
e. ASTM - A564, Type 630 (17-4 PH) precipitation hardened at 1075°F or greater (Rc 32 maximum)
f. ASTM - A461, Grade 688

4.3.1.7. Welding materials

4.3.1.7.1. Filler metals including consumable inserts used for austenitic stainless steel welds shall be selected and controlled to produce welds that have a minimum ferrite content of 5 percent based upon one of the following:

a. Chemical analysis of weld metal compared to the Schaeffler Diagram for stainless steel weld metal. For coated electrodes or for submerged arc wire flux combinations, a chemical analysis as-deposited weld material is required.
b. Aminco - Brenner Magne-Gage Measurement
c. Severn-Gage Measurement on test weld deposit

4.3.1.7.2. Electrodes and welding rods. Acceptable electrode material for similar metal welds: A298 or A371 Type 308, 308L, 316, or 316L except where furnace sensitization will occur in which case Type 308L or 316L are mandatory. Acceptable electrode material for dissimilar metal welds: A298 or A371 - Type 309.

4.3.1.7.3. Consumable inserts. Consumable inserts shall be of the same nominal chemical composition as the filler metal.

4.3.1.8. Lubricants for the assembly of stainless steel parts

4.3.1.8.1. "Dag Dispersion Number 156" as manufactured by Acheson Colloid Corporation, Port Huron, Michigan, containing no more than 100 ppm chlorides, 20 ppm fluorides and 100 ppm sulfur, or Buyer approved equivalent shall be the only lubricant used on systems operating above 200°F for the assembly of stainless steel parts.

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4.3.1.8.2. "Silver Goop" as manufactured by the Crawford Fitting Company, Cleveland, Ohio, containing no more than 200 ppm chlorides, 200 ppm fluorides, and 25 ppm sulfur may be used on systems operating at temperatures below 200°F.

4.3.2. <u>Trim</u>

4.3.2.1. Acceptable hard-facing materials are ASTM-A399, Class CoCr-A; CoCr-B, CoCr-C, NiCr-A, NiCr-B, NiCr-C, or Stellite 21.

4.3.2.2. Martensitic or precipitation hardening stainless steels, if used, shall have a maximum hardness of Rockwell C32.

4.3.2.3. Where cast martensitic stainless steels are used for operations at temperatures below 150°F, maximum silicon content of 0.5 percent is required to reduce the probability of brittle fracture.

4.3.2.4. If a 17-4 PH stainless steel is used, it shall be in accordance with ASTM A564, Type 630, precipitation hardened at 1075°F minimum.

4.3.2.5. Valve stems shall be made of materials to ASTM Specifications.

4.3.3. <u>Alternate Materials</u>

4.3.3.1. The Seller shall be free to suggest alternate materials during preparation of detail drawings and shall bring such alternates to the attention of the Buyer but shall not make substitutions without approval of the Buyer. The proposed alternate materials shall be presented with the scope of application and a copy of codes or specifications equivalent to ASME or ASTM or detailed information equivalent to that furnished in the ASTM or ASME Codes and Specifications.

5. INSPECTION AND TEST

5.1. <u>Nondestructive Tests</u>

5.1.1. Inspection and testing, as required per applicable GE-APED equipment class, shall employ the following methods and techniques and shall meet the acceptance standards specified below.

5.1.2. <u>Radiography</u>

5.1.2.1. <u>Welds</u>. The radiography of welds, including acceptance standards, shall be in accordance with ASME Boiler and Pressure Vessel Code, Section III, Paragraph N624.

5.1.2.2. <u>Casting</u>. The radiography of castings shall employ methods and techniques in accordance with ASTM E94, Tentative Recommended Practices for Radiographic Testing, to the quality level in accordance with ASTM 142, Sandard Method for Controlling Quality of Radiographic Testing.

5.1.2.3. Acceptance criteria shall be Severity Level 2 per ASTM E71, E186 and E280 as appropriate for casting thickness, except that defect types D through G in E71 and defect types D and E in E186 and E280 are not permitted.

5.1.2.4. The H-D (Hurter-Driffield) density through acceptable metal shall be 2.0 minimum for single viewing, and 2.6 minimum for composite viewing of double film exposures. Each film of a composite set shall have a minimum density of 1.3.

5.1.3. Ultrasonic Testing. Ultrasonic examination of forgings shall be in accordance with ASTM A388-67, Ultrasonic Testing and Inspection of Heavy Steel Forgings, and shall meet the following acceptance standards.

5.1.3.1. Normal Beam Testing - Acceptance Sandards. The forging shall be considered unacceptable, unless repaired, based on the following test indications:

a. Indications of discontinuities in the material that produce a complete loss of back reflection not associated with the geometic configuration of the piece. A reduction in back reflection to 5 percent or less of screen height shall be considered a complete loss of back reflection.
b. Traveling indications of discontinuities 10 percent or more of the back reflection. A traveling indication is defined as an indication which displays sweep movement of the oscilloscope pattern at a relatively constant amplitude as the search unit is moved along the part being examined.

5.1.3.2. Angle Beam Testing - Acceptance Sandards. Forgings shall be unacceptable where indications exceed those produced by the reference standard. The reference standard notch shall be the smaller of a depth equal to 5 percent of the forging thickness or 3/8 inch.

5.1.4. Liquid Penetrant Testing. Method, techniques and acceptance standards for liquid penetrant testing shall be in accordance with Paragraph N627, Section III of the ASME Boiler and Pressure Vessel Code.

5.1.5. Magnetic Particle. Methods, techniques and acceptance standards for magnetic particle testing shall be in accordance with Paragraph N626, Section III of the ASME Boiler and Pressure Vessel Code.

5.1.6. Qualification of Nondestructive Examination Personnel. Personnel engaged in nondestructive testing of pressure-containing components shall be qualified in accordance with the requirements of Paragraph IX-325 of Section III of the ASME Boiler and Pressure Vessel Code.

5.2. Certification. The manufacturer of the materials or components shall certify that the requirements for which he is responsible, as well as those of the specific materials specification, have been fully satisfied. Certification shall include a certified report of results of all required tests, examinations, and repairs performed on the materials and identification of materials. Certified reports shall be submitted to the Buyer for concurrence and record.

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5.3. Hydrostatic Test. Hydrostatic shell and seat leakage tests shall be performed in accordance with MSS-SP-61 as applicable to valves furnished in accordance with a USAS primary service rating. Duration of shell test shall be greater than 10 minutes. All valves shall have a maximum seat leakage of 2cc/hr per inch of diameter across the valve seat when fully closed and at the specified hydrostatic seat test pressure.

5.4. Proof Testing. Valves not normally furnished in accordance with a USAS primary service rating (or equivalent) shall be shell and seat leakage tested in accordance with Sellers recommended procedure subject to Buyers approval.

5.5. Hydrotest, proof test, and flow testing shall be conducted with controlled water in accordance with Paragraph 6.1.2.

6. CLEANING AND PREPARATION FOR SHIPMENT

6.1. Cleaning (Austenitic Stainless Steel only)

6.1.1. Prior to hydrotesting austenitic stainless steel surfaces shall be in the mechanically cleaned, sand blast cleaned, or pickled (for unsensitized material only) condition and shall be free of scale and organic contaminants such as grease and oil. Sand-blast cleaned surfaces shall be free of residual quantities of the cleaning media and such as grit, aluminum oxide, and silica. Only nonhalogen or nonsulfur bearing solvents shall be allowed to contact stainless steel or nickel alloys.

6.1.2. The hydrotest fluid shall be either demineralized or filtered fresh water. The following water quality requirements shall be met:

		Filtered Fresh Water	Demin. Water
Conductivity	umhos/cm		3
Total Solids	ppm	500	
Chlorides (as Cl)	ppm	100*	≤1
Sulfides (as $S^{=}$ from hydrogen sulfide)	ppm	1	≤1
Fluoride (as F)	ppm	10	
Turbidity	ppm	20	
pH		6-13	6.5-8

*Maximum for final solutions after chemicals added

6.1.2. (Continued)

The initial water (whether demineralized or filtered fresh) used for flushing and/or hydrotesting requires the addition of trisodium phosphate to obtain a minimum concentration of 500 ppm PO_4. No flushing or rinsing is required after hydro test. Simply drain the valve making sure that no pockets are left undrained. Subsequent flushing water, if required for some reason, may be demineralized or fresh water, however either type water requires the addition of 500 ppm PO_4 and must meet the quality requirements given above.

6.2. Preparation for Shipment

6.2.1. Cleaning

6.2.1.1. Austenitic stainless steel. If additional work is to be performed on the valve subsequent to hydrotesting and prior to shipment the cleaning requirements of Paragraph 6.1.1 and the flushing requirements of Paragraph 6.1.2 shall apply to the as shipped valve. If no additional work is to be performed on the valve subsequent to hydrotesting, it is to be immediately sealed for shipment, the degree of cleanliness after draining following hydrotest is satisfactory.

6.2.1.2. Carbon-low Alloy Steel. Carbon-low alloy steel surfaces shall be in the mechanically cleaned or blast cleaned condition and shall be free of scale and organic contaminants such as grease and oil. Blast cleaned surfaces shall be free of residual quantities of the cleaning media such as grit, aluminum oxide, and silica. After cleaning, inside surfaces shall be coated with a readily water-soluble corrosion inhibitor such as a water solution of 1/2 of 1 percent sodium nitrite, 1/4 of 1 percent monosodium phosphate and 1/4 of 1 percent di-sodium phosphate. Outside unmachined surfaces shall be suitably protected by painting to prevent excessive corrosion during shipment or storage. Outside machined surfaces shall be coated with a rust preventative such as Tectyl 846 as manufactured by the Valvoline Oil Company. Other products will be considered on a case by case basis.

6.2.2. All equipment and parts shall be adequately packed to prevent damage or loss during shipment and while in storage. All carbon steel equipment and parts 12 inches and smaller shall be sealed in clear polyethylene bags with a desiccant; stainless steel parts shall not have desiccant. Weld ends of valves larger than 12 inches shall be fitted with a tight-fitting metal cap, tackwelded to the ends or securely attached to the valve by means of metal strapping bands affixed in a manner such that they will not slide off. Equipment shall be adequately protected from damage during handling, shipment and storage. Handling equipment, blocking, strapping, or hold-down devices shall be applied so the components are not marred in any way. During shipment the components shall be further separated by dunnage as is necessary to prevent damage. Packaging for shipment shall be applied in a manner to maintain cleanliness of the equipment. Outside storage of the equipment is anticipated to be approximately 12 months.

6.2.3. All boxes, crates, and shipments shall be identified with the parts list number and purchase order number. Desiccant packages shall be positively attached to the packaging material to ensure removal; the number of desiccant packages shall be noted on the outside of the package.

6.2.4. Marking. Each valve shall be clearly identified by legible marking on the valve. Marking shall include that required by applicable codes and standards and shall include additional marking as necessary to identify the component. Marking shall be done by any permanent method that does not result in any harmful contamination or sharp discontinuities and which will identify the valve when installed.

7. SUBMITTALS TO BUYER

7.1. The following shall be submitted by the Seller for Buyer's approval and/or as a certified copy as noted.

7.2. Drawings

7.2.1. Outline Drawings. A drawing depicting the outline of the valve indicating overall dimensions, location and size of connections, and operating weight. Motor horsepower, ampere rating (running and locked rotor), operating time, electrical connections, and wiring diagram shall also appear on these drawings.

7.2.2. Assembly Drawings. A section drawing or drawings depicting the arrangement of the functional parts, parts list, and material designations.

7.2.3. Drawings to be Certified. Outline and Assembly drawings and wiring diagrams shall, upon completion of the design, be certified to be correct with no further changes required. No alterations will be made to the design after certification without approval of the Buyer.

7.3. Instruction Manuals

7.3.1. Instruction manuals shall present the following basic categories of information in a practical, complete, and comprehensive manner; prepared for use by operating and/or maintenance personnel:

a. Valve description
b. Instructions for installation
c. Maintenance, repair, and periodic tests
d. Operation

7.3.2. The information shall be organized in a logical and orderly sequence. A general description of the equipment, including significant technical characteristics, shall be included to familiarize operating and maintenance personnel with the equipment.

7.3.3. Necessary drawings and/or other illustrations shall be included or copies of appropriate certified drawings may be bound into the manual. Test, adjustment, and calibration information, as appropriate, shall be specified and identified to the specific equipment. Safety and other warning notices and installation, maintenance, and operating cautions shall be emphasized.

7.3.4. A parts list shall be included showing part nomenclature, manufacturer's part number, and/or other information necessary for accurate identification and ordering of replacement parts. Common hardware items or other parts to be locally procured shall be adequately identified by technical description.

7.3.5. Instructions and parts list shall be clearly legible and prepared on good quality paper; carbon copies and tissue copies or other flimsy material are not acceptable. Multiple page instructions shall be securely bound.

7.3.6. If a standard manual is furnished covering more than the specific equipment purchased, the applicable model (or other identification), parts, and other information for the specific equipment purchased shall be clearly identified.

7.4. Special test procedures for equipment not furnished per USAS primary service rating.

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SECTION A

GE-APED CLASSES A AND B

A1. SCOPE

A.1. This Section defines GE-APED Class A and B Valve requirements that must be satisfied in addition to those requirements of Section I of this Specification.

A2. DESIGN

A2.1. Seismic Coefficient. The valves, including operator and accessories, shall withstand static seismic forces, as noted on the Data Sheet, applied at the mass center assuming that the operator is cantilevered from the valve body, and the valve is installed as described in Data Sheet.

A2.1.1. The stresses due to horizontal and vertical seismic forces shall be considered to act simultaneously and shall be added directly.

A2.1.2. The stresses in the valve components due to seismic loads shall be combined with stresses due to other live and dead loads and operating loads. The allowable stress level for this combination of loads shall be as listed in the applicable codes. The one-third increase in allowable stress usually allowed for earthquake loading shall not be used.

A2.2. Pressure containment. The valves shall be capable of operating at a continuous pressure and temperature as specified in Data Sheet.

A2.2.1. The minimum wall thickness of the pressure-containing components of the valve shall be determined in accordance with the requirements of USAS B16.5 except as noted herein.

A2.2.2. The applicable equation shall be:

$$t = \left[1.5\left(\frac{Pd}{2S-1.2P}\right)\right] + C$$

where: t = calculated thickness, inches,

P = Primary service pressure rating

d = Inside diameter of the valve corresponding with the location for which wall thickness is being calculated.

S = Stress equals 7000 psi

C = Corrosion allowance as specified in the Data Sheet

Note: The additional requirements of Paragraph 6.1 of USAS B16.5 shall apply.

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A2.2.3. Pressure containing flanges and bolting shall be furnished in accordance with the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII.

A2.2.4. The valve disc, and similar pressure containing components shall withstand full differential pressure equal to the pressure rating of the valve at 100°F and 575°F. An appropriate analysis of the above affected components utilizing allowable stress levels as listed in ASME Boiler and Pressure Vessel Code, Section VIII, shall be conducted.

A3. MATERIALS

A3.1. Carbon Steel Pressure Containing Parts

A3.1.1. Carbon steel materials of the following ASTM Specifications shall be used when required.

A3.1.2. Tubular Products

a. ASTM A155 Class 1, Grade KCF70, Firebox (welded with filler metals). Base materials shall be ASTM A516, Grade -70.
b. ASTM A106, Grade B (seamless)
c. ASTM A333 (Seamless or welded without filler metal) Grade 1
d. ASTM A524, Grade I or II (seamless)

A3.1.3. Forged or Wrought Fittings, Flanges or Pressure Retaining Parts

a. ASTM A105, Grade II
b. ASTM A234, Grade WPB
c. ASTM A350, Grade LF1
d. ASTM A508, Class 1

A3.1.4. Cast Fittings, Flanges or Pressure Retaining Parts

a. ASTM A216, Grade WCB
b. ASTM A352, Grade LCB

A3.1.5. Plate

a. ASTM A285
b. ASTM A516

A3.1.6. Bolting Materials

a. ASTM A193, Grade B7
b. ASTM A194, Grade 7
c. ASTM A540, Grades B22, B23, and/or B24.

Note: Plating of bolts is not allowed unless specific written Buyer approval is obtained.

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A3.1.7. Welding Materials

A3.1.7.1. Electrodes, welding rods, and fluxes

a. Mild steel covered arc-welding electrodes per ASTM A233
b. Low alloy steel covered arc-welding electrodes per ASTM A316
c. Electrodes and fluxes for submerged arc welding per ASTM A558
d. Mild steel electrodes (solid only) for gas metal arc welding per ASTM A559

A3.1.7.2. Consumable inserts. Consumable inserts shall be of the same nominal chemical composition as the filler metal.

A3.1.7.3. For Shielded Metal Arc Welding. Low hydrogen electrodes shall be used for shielded metal arc welding of all welds where the pressure boundary material is greater than one-half inch in thickness and for all butt joints regardless of thickness. E7010 or 7010 A-1 electrodes may be used for root passes where the back side is ground or machined to a sound weld metal and subsequent examination is performed such as liquid penetrant or magnetic particle (when required) and visual examination.

A4. FABRICATION

A4.1. Welding

A4.1.1. Qualification. All welding including fillet, seal, repair, and attachment welds shall be performed in accordance with written welding procedures. Procedure qualification and weldor performance qualification shall be in accordance with USAS B31.1.0, Code for Power Piping.

A4.1.2. Attachment Welds. Attachment of non-pressure containing parts (such as supports and hangers) to pressure containing components shall be complete penetration groove welds and shall be subject to all the requirements and limitations imposed for fabrication of the valves to which they are attached.

A4.1.3. Joint design and welding procedures for longitudinal and girth butt joints larger than 2 inches in nominal pipe size shall be for complete penetration groove welds.

A4.2. Heat Treatment - Austenitic Stainless Steel

A4.2.1. Unsensitized austenitic stainless steel material shall be degreased and stripped in accordance with ASTM A 380-57, "Descaling and Cleaning Stainless Steel Surfaces," Paragraph 2, prior to heat treatment.

A4.2.2. Material shall be heat treated by heating to a temperature between 1900° and 2050°F and then held for one hour per inch of thickness but not less than ...

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A4.2.2. (Continued)

1/2 hour followed by rapid cooling to below 700°F. (Rapid cooling required for optimum retention of carbon in solution is best obtained by quenching in water. To ensure rapid uniform cooling, either agitation or water circulation should be employed). Cooling through the range 1800°F to 800°F shall be accomplished within 5 minutes. Final heat treatment shall follow all fabrication and major repair welding.

A4.2.3. Temperature indicating crayons shall not be used on austenitic stainless steels. Marks from marking crayons shall be cleaned off prior to heat treating and shipping.

A4.2.4. Only nonhalogen and/or nonsulfur bearing solvents shall be allowed to contact stainless steel.

A4.3. <u>Heat Treatment for Carbon and Low-Alloy Steel</u>. Carbon and low-alloy steel pressure containing parts shall be heat treated in accordance with the requirements of the applicable ASTM materials specifications except final heat treatment shall follow all fabrication weldings and major repair welding.

A4.4. <u>Defect Repair</u>. Repair of base metal or weld metal defects shall be in accordance with the following requirements.

A4.4.1. Surface defects such as laps, scabs, slivers, seams or tears, which do not encroach on minimum wall thickness, shall be removed by machining or grinding and shall be blended into the adjacent metal surfaces.

A4.4.2. When defects or defect removal encroaches on minimum wall thickness, repairs may be made by welding. Magnetic particle or liquid penetrant examination of excavations shall be conducted to ensure complete defect removal prior to repair welding.

A4.4.3. Major Repairs - Major repairs, as defined herein, shall require the concurrence of the General Electric Company. The General Electric Company shall be notified of all major repairs. Records shall indicate the nature of the defect removed, the location of the defect, subsequent heat treatment or other pertinent data and they shall be made available to the General Electric Company upon request. Preparation for repairing all defects may proceed without notifying Buyer's Quality Control Representative. As soon as it is apparent that the defect will terminate as a major defect as defined by the specification, and before repair welding can proceed, Buyer's Quality Control Representative is to be notified. If the defect terminates as a minor defect, weld repair can proceed without notifying Buyer's Quality Control Representative.

A4.4.4. Major repairs in base materials such as plates, forgings, extruded pipes or castings are defined as (a) a repair which requires excavation of material to a depth greater than 20 percent of the wall thickness or when the extent of the cavity is greater than 10 square inches, (b) the repair of any crack and (c) the repair of defects which are indicative of fundamental materials problems.

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A4.4.5. Major repairs in welds are defined as (a) the repair of any crack other than crater cracks or (b) the repair of defects which are indicative of either a fundamental materials problem or of a process out of control.

A4.4.6. Inspection of Repair Welds - Repair welds of a depth greater than 10 percent of the wall thickness shall meet the inspection requirements for the base material. Other inspection methods shall not be employed without the concurrence of the General Electric Company.

A4.4.7. Heat Treatment After Repair by Welding - Base material repair welds shall be heat treated as required by the applicable materials specifications except that final heat treatment shall follow all fabrication welding and major repair welding.

A4.4.8. Weld repairs shall be heat treated as required by USAS B31.1.0, Code for Power Piping.

A5. INSPECTION AND TEST

A5.1. The Seller shall be responsible for conducting the following inspections and tests and shall furnish all materials and equipment required. Buyer's authorized representative(s) shall have access to all fabrication and testing procedures described in this specification, including those of any of Seller's suppliers or subcontractors regardless of tier. Seller shall provide notice at least 48 hours in advance of examination and tests so described.

A5.2. Charpy V-Notch Impact Testing

A5.2.1. All ferritic materials including weld metal used in pressure containing components which require brittle fracture control shall be subjected to Charpy V-Notch impact testing, with minimum impact energy requirements in accordance with Table N-421, Section III, ASME Boiler and Pressure Vessel Code. Paragraphs N-331, N-332, and N-511 of Section III, ASME Boiler Code shall be followed regarding test procedures and acceptance standards. Test coupons shall be per N-313. Impact testing shall be performed at a temperature of Lowest Operating Temperature minus 60°F for material 1 inch in thickness and greater. For materials with a thickness of less than 1 inch, the test temperature shall be determined from the following formula:

$$T = (K) - 100t$$

where: T = Test Temperature °F

t = Thickness of material, inches

(K value is equal to the Lowest Operating Temperature specified in Data Sheet in °F plus 40)

The welding procedures used must be qualified by impact testing of weld metal and heat affected zone to the same requirements as the base metal of Item 1 in accordance with N-541, Section III.

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A5.3. Nondestructive Testing. Nondestructive examinations required for materials shall be performed after any heat treatments required by the materials specification. Examinations of the base materials may be made prior to postweld heat treatments of welded fabrication or fabrication repair welding unless otherwise stated in the code or the materials specification. Nondestructive examinations required of fabrication welds and fabrication weld repairs shall be made after postweld heat treatment.

A5.3.1. Qualification of Nondestructive Examination Personnel. Personnel engaged in nondestructive testing of pressure-containing components shall be qualified in accordance with the requirements of Paragraph IX-325 of Section III of the ASME Boiler and Pressure Vessel Code.

A5.3.2. Welds

A5.3.2.1. Girth and longitudinal pressure containing complete penetration groove welds shall be 100 percent examined by radiography and accessible surfaces of the weld and adjacent base material shall be examined by either liquid penetrant or magnetic particle method.

A5.3.2.2. Fillet welds, socket welds, and nonpressure containing attachment welds such as supports, lugs, anchors, and guides shall be examined on all accessible surfaces by either liquid penetrant or magnetic particle method. Radiography is not required.

A5.3.3. Castings. All castings for pressure containing components, and for valves over 4 inches in inlet pipe size shall be:

a. One hundred percent examined by radiography after all heat treatment, major repair welding and postweld heat treatment
b. all accessible surfaces including machined surfaces shall be examined by either the magnetic particle or liquid penetrant method in the finished condition. Final inspection shall be performed on surfaces after all grinding, machining, or other surface conditioning and after the final heat treatment.

A5.3.4. Forgings

A5.3.4.1. All forgings for pressure containing components, and forged valves over 4 inches in nominal pipe size shall be examined by ultrasonic method in either the furnished or finished condition, but after the final heat treatment or postweld heat treatment.

A5.3.4.2. All forgings for pressure containing components, and forged valves over 4 inches in nominal pipe size shall be examined in the finished condition on all accessible surfaces, including machined surfaces, by either the magnetic particle or liquid penetrant method.

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A5.3.5. Bolting

A5.3.5.1. Bolts, studs, nuts, or bolting material greater than 1 inch nominal bolt size for pressure containing components shall be examined by either liquid penetrant or wet magnetic particle testing. The examination shall be performed on either the finished part after threading or on the material stock of approximately the finished diameter before threading but after any heading.

A5.3.5.2. All bolting greater than 2 inches nominal bolt size shall be ultrasonically examined prior to threading.

A5.4. Quality Control

A5.4.1. Pressure containing components shall be manufactured to meet the requirements of a quality assurance control program which conforms to the requirements of Appendix IX, Paragraphs IX-200 of Section III of the ASME Boiler and Pressure Vessel Code.

A6. SUBMITTALS TO BUYER

A6.1. The following procedures shall be submitted by the Seller for Buyer's approval in addition to those requirements listed in Paragraph 7 of Section I.

A6.2. Procedures

A6.2.1. Cleaning procedures, including chemical composition of agents.

A6.2.2. Quality Control Plan

A6.2.3. Welding procedure and procedure qualification

A6.2.4. Repair procedure

A6.2.5. Heat treatment procedure

A6.2.6. Packaging procedure

A6.2.7. Test procedures

a. Radiography
b. Liquid Penetrant
c. Magnetic Particle
d. Ultrasonic
e. Hydrostatic Shell
f. Seat Leakage
g. Performance

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A6.2.8. The Seller shall furnish reports of all test and inspections.

A6.2.9. Certified fabrication records shall be furnished to include the following:

a. Heat treatment
b. Major repairs
c. Materials records
d. Performance

A6.2.10. Calculations relating to the design of pressure containing components including seismic analysis.

A7. MARKING

A7.1. Each pressure-containing component shall be clearly identified by legible marking on the parts.

A7.2. The marking shall consist of the applicable specification and grade of material, heat number of the material, and any additional marking required to facilitate traceability of the results of all tests and examinations performed on the part; in those cases where size or shape prohibits, a marking code shall be used that identifies the material with the certification reports.

A7.3. Marking shall be transferred to all pieces when a part is cut to make more than one component.

A7.4. The materials shall be marked by any method that will not result in any harmful contamination or sharp discontinuities and will identify the material until the system is completely installed. Material 1/4 inch and greater in thickness may be marked by steel indentation stamping. When steel indentation stamping is used, it shall be done with a round nose or interrupted-dot die having a minimum radius of 1/32 inch. The maximum depth of indentation shall not infringe upon minimum wall thickness.

A8. RECORDS

A8.1. Seller shall organize, maintain, and safely store all design, fabrication, construction, and quality control records, material certifications, and all other test and inspection records pertinent to the work hereunder, as required by the terms of this order or the provisions of any applicable standard, code, criteria, law, rule, regulation, or order. Upon payment by Buyer of the actual costs of reproduction, Seller shall promptly deliver to Buyer the originals of any or all such records. Seller shall retain all such records (except those records, the originals of which have been furnished to Buyer pursuant to this provision) in its possession for a period of five years after completion of the work hereunder. In no event shall Seller at any time destroy or discard any such records without prior written notice to Buyer.

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SECTION C

GE-APED CLASS C

C1. SCOPE

C1.1. This Section defines GE-APED Class C Valve requirements that must be satisfied in addition to those requirements of Section I of this Specification.

C2. MATERIALS

C2.1. <u>Carbon Steel Pressure Containing Parts</u>

C2.1.1. Carbon steel materials of the following ASTM Specifications shall be used when required.

C2.1.2. <u>Tubular Products</u>

a. ASTM A155 Class 1, Grade KCF70, Firebox (welded with filler metals). Base materials shall be ASTM A516, Grade -70
b. ASTM A106, Grade B (seamless)
c. ASTM A333 (Seamless or welded without filler metal) Grade 1
d. ASTM A526, Grade I or II (seamless)

C2.1.3. <u>Forged or Wrought Fittings, Flanges or Pressure Retaining Parts</u>

a. ASTM A105, Grade II
b. ASTM A234, Grade WPB
c. ASTM A350, Grade LF1
d. ASTM A508, Class 1

C2.1.4. <u>Cast Fittings, Flanges or Pressure Retaining Parts</u>

a. ASTM A216, Grade WCB
b. ASTM A352, Grade LCB

C2.1.5. <u>Plate</u>

a. ASTM A285
b. ASTM A516

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C2.1.6. Bolting Materials for Joining Carbon/Low-Alloy Steel Parts

a. ASTM A193, Grade B7
b. ASTM A194, Grade 7
c. ASTM A540, Grades B22, B23, or B24

Note: Plating of bolts is not allowed without specific written Buyer approval.

C2.1.7. Welding Materials

C2.1.7.1. Electrodes, welding rods, and fluxes

a. Mild steel covered arc-welding electrodes per ASTM A233
b. Low alloy steel covered arc-welding electrodes per ASTM A316
c. Electrodes and fluxes for submerged arc welding per ASTM A558
d. Mild steel electrodes (solid only) for gas metal arc welding per ASTM A559

C2.1.7.2. Consumable inserts. Consumable inserts shall be of the same nominal chemical composition as the filler metal.

C2.1.7.3. For Shielded Metal Arc Welding. Low hydrogen electrodes shall be used for shielded metal arc welding of all welds where the pressure boundary material is greater than one-half inch in thickness and for all butt joints regardless of thickness. E7010 or 7010 A-1 electrodes may be used for root passes where the back side is ground or machined to a sound weld metal and subsequent examination is performed such as liquid penetrant or magnetic particle (when required) and visual examination.

C3. FABRICATION

C3.1. Welding

C3.1.1. Qualification. All welding including fillet, seal, repair, and attachment welds shall be performed in accordance with written welding procedures. Procedure qualification and weldor performance qualification shall be in accordance with USAS B31.1.0, Code for Power Piping.

C3.1.2. Attachment Welds. Attachment of non-pressure containing parts (such as supports and hangers) to pressure containing components shall be complete penetration groove welds and shall be subject to all the requirements and limitations imposed for fabrication of the valves to which they are attached.

C3.1.3. Joint design and welding procedures for longitudinal and girth butt joints larger than 2 inches in nominal pipe size shall be for complete penetration groove welds.

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C3.2. Heat Treatment - Austenitic Stainless Steel

C3.2.1. Unsensitized austenitic stainless steel material shall be degreased and stripped in accordance with ASTM A 380-57, "Descaling and Cleaning Stainless Steel Surfaces," Paragraph 2, prior to heat treatment. Only nonhalogen and/or nonsulfur bearing solvents are allowed to contact stainless steel or nickel alloys.

C3.2.2. Material shall be heat treated by heating to a temperature between 1900° and 2050°F and then held for one hour per inch of thickness but not less than 1/2 hour followed by rapid cooling to below 700°F. (Rapid cooling required for optimum retention of carbon in solution is best obtained by quenching in water. To ensure rapid uniform cooling, either agitation or water circulation should be employed). Cooling through the range 1600°F to 800°F shall be accomplished with 5 minutes.

C3.2.3. Temperature indicating crayons shall not be used on austenitic stainless steels. Marks from marking crayons shall be cleaned off prior to heat treating and shipping. Halogen or sulfur bearing solvents shall not be allowed to contact stainless steel or nickel alloys.

C3.3. Heat Treatment for Carbon and Low Alloy Steel. Carbon and low alloy steel pressure containing parts shall be heat treated in accordance with the requirements of the applicable ASTM materials specifications except final heat treatment shall follow all fabrication welding and major repair welding.

C3.4. Defect Repair. Repair of base metal or weld metal defects shall be in accordance with the following requirements.

C3.4.1. Surface defects such as laps, scabs, slivers, seams, or tears, which do not encroach on minimum wall thickness, shall be removed by machining or grinding and shall be blended into the adjacent metal surfaces.

C3.4.2. When defects or defect removal encroaches on minimum wall thickness, repairs may be made by welding. Magnetic particle or liquid penetrant examination of excavations shall be conducted to ensure complete defect removal prior to repair welding.

C3.4.3. Major Repairs - Major repairs, as defined herein, shall require the concurrence of the General Electric Company. The General Electric Company shall be notified of all major repairs. Records shall indicate the nature of the defect removed, the location of the defect, subsequent heat treatment or other pertinent data and they shall be made available to the General Electric Company upon request. Preparation for repairing all defects may proceed without notifying Buyer's Quality Control Representative. As soon as is is apparent that the defect will terminate as a major defect as defined by the specification and before repair welding can proceed, Buyer's Quality Control Representative is to be notified. If the defect terminates as a minor defect, weld repair can proceed without notifying Buyer's Quality Control Representative.

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C3.4.4. Major repairs in base materials such as plates, forgings, extruded pipes or castings are defined as (a) a repair which requires excavation of material to a depth greater than 20 percent of the wall thickness or when the extent of the cavity is greater than 10 square inches, (b) the repair of any crack and (c) the repair of defects which are indicative of fundamental materials problems.

C3.4.5. Major repairs in welds are defined as (a) the repair of any crack other than crater cracks or (b) the repair of defects which are indicative of either a fundamental materials problem or of a process out of control.

C3.4.6. Inspection of Repair Welds - Repair welds of a depth greater than 10 percent of the wall thickness shall meet the inspection requirements for the base material. Other inspection methods shall not be employed without the concurrence of the General Electric Company.

C3.4.7. Heat Treatment After Repair by Welding - Base material repair welds shall be heat treated as required by the applicable materials specifications except that final heat treatment shall follow all fabrication welding and major repair welding.

C3.4.8. Weld repairs shall be heat treated as required by USAS B31.1.0, Code for Power Piping.

C4. INSPECTION AND TEST

C4.1. The Seller shall be responsible for conducting the following inspection and tests and shall furnish all materials and equipment required. Buyer's authorized representative(s) shall have access to all fabrication and testing procedures described in this specification, including those of any of Seller's suppliers or subcontractors regardless of tier. Seller shall provide notice at least 48 hours in advance of examination and tests so decribed.

C4.2. <u>Welds</u>

C4.2.1. Girth and longitudinal pressure containing complete penetration groove welds shall be 100 percent examined by radiography.

C4.2.2. Fillet welds, socket welds, and nonpressure containing attachment welds such as supports, lugs, anchors, and guides shall be examined on all accessible surfaces by either liquid penetrant or magnetic particle method. Radiography is not required.

C4.3. <u>Castings</u>

C4.3.1. All castings for pressure containing components, and valves over 4 inches in inlet pipe size shall be:

a. One hundred percent examined by radiography

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C4.3.1. (Continued)

b. all accessible surfaces including machine surfaces shall be examined by either the magnetic particle or liquid penetrant method in either the furnished or finished condition.

C4.4. Qualification of Nondestructive Examination Personnel

C4.4.1. Personnel engaged in nondestructive testing of pressure-containing components shall be qualified in accordance with the requirements of Paragraph IX-325 of Section III of the ASME Boiler and Pressure Vessel Code.

C4.5. Quality Control

C4.5.1. Pressure-containing components shall be manufactured to meet the requirements of a quality assurance control program which conforms to the requirements of Appendix IX, Paragraph IX-200 of Section III of the ASME Boiler and Pressure Vessel Code.

C5. SUBMITTALS TO BUYER

C5.1. The following procedures shall be submitted by the Seller for Buyer's approval in addition to these requirements listed in Paragraph 7 of Section I.

C5.2. Procedures

C5.2.1. Cleaning procedures, including chemical composition of agents.

C5.2.2. Quality Control Plan

C5.2.3. Welding procedure and procedure qualification

C5.2.4. Repair procedure

C5.2.5. Heat treatment procedure

C5.2.6. Packaging procedure

C5.2.7. Test procedures

a. Radiography
b. Liquid Penetrant
c. Magnetic Particle
d. Ultrasonic
e. Hydrostatic Shell
f. Seat Leakage
g. Performance

C5.2.8. The supplier shall furnish reports of all test and inspections.

C5.2.9. Certified fabrication records shall be furnished to include the following:

a. Heat treatment
b. Major repairs
c. Materials records
d. Performance

C6. MARKING

C6.1. Each pressure-containing component shall be clearly identified by legible marking on the parts.

C6.2. The marking shall consist of the applicable specification and grade of material, heat number of the material, and any additional marking required to facilitate traceability of the results of all tests and examinations performed on the part; in those cases where size or shape prohibits, a marking code shall be used that identifies the material with the certification reports.

C6.3. Marking shall be transferred to all pieces when a part is cut to make more than one component.

C6.4. The materials shall be marked by any method that will not result in any harmful contamination or sharp discontinuities and will identify the material until the system is completely installed. Material 1/4 inch and greater in thickness may be marked by steel indentation stamping. When steel indentation stamping is used, it shall be done with a round nose or interrupted-dot die having a minimum radius of 1/32 inch. The maximum depth of indentation shall not infringe upon minimum wall thickness.

C7. RECORDS

C7.1. Seller shall organize, maintain, and safely store all design, fabrication, construction, and quality control records, material certifications, and all other test and inspection records pertinent to the work hereunder, as required by the terms of this order or the provisions of any applicable standard, code, criteria, law, rule, regulation, or order. Upon payment by Buyer of the actual costs of reproduction, Seller shall promptly deliver to Buyer the originals of any or all such records. Seller shall retain all such records (except those records, the originals of which have been furnished to Buyer pursuant to this provision) in its possession for a period of five years after completion of the work hereunder. In no event shall Seller at any time destroy or discard any such records without prior written notice to Buyer.

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SECTION M

GE-APED CLASS M

M1. SCOPE

M1.1. This Section defines GE-APED Class M Valve requirements that must be satisfied in addition to those requirements of Section I of this Specification.

M2. MATERIALS

M2.1. Carbon Steel Pressure Containing Parts

M2.1.1. Carbon steel materials of the following ASTM Specifications shall be used when required.

M2.1.2. Tubular Products

a. ASTM A155, Class 1 or 2, Grade KCF70, Firebox
b. ASTM A106, Grade A or B
c. ASTM A53, Grade A or B
d. ASTM A333 (Seamless or welded without filler metal) Grade 1
e. ASTM A524, Grade I or II (seamless)

M2.1.3. Forged or Wrought Fittings, Flanges or Pressure Retaining Parts

a. ASTM A105, Grade I or II
b. ASTM A234, Grade WPA or WPB
c. ASTM A181, Grade I or II
d. ASTM A350, Grade LF1
e. ASTM A508, Class 1

M2.1.4. Cast Fittings, Flanges or Pressure Retaining Parts

a. ASTM A216, Grade WCA or WCB
b. ASTM A352, Grade LCB

M3. FABRICATION

M3.1. Valve fabrication shall be in accordance with the requirements of USAS B31.1.0, Paragraph 107.

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M4. INSPECTION AND TESTS

M4.1. Valves shall be inspected and tested in accordance with the requirements of USAS B31.1.0, Paragraph 107.

M4.2. The weld ends of valves prepared for butt welding shall be radiographed; each end full circumference, and 2-inch minimum length. Methods, techniques, and acceptance criteria shall be as noted in Section I, General.

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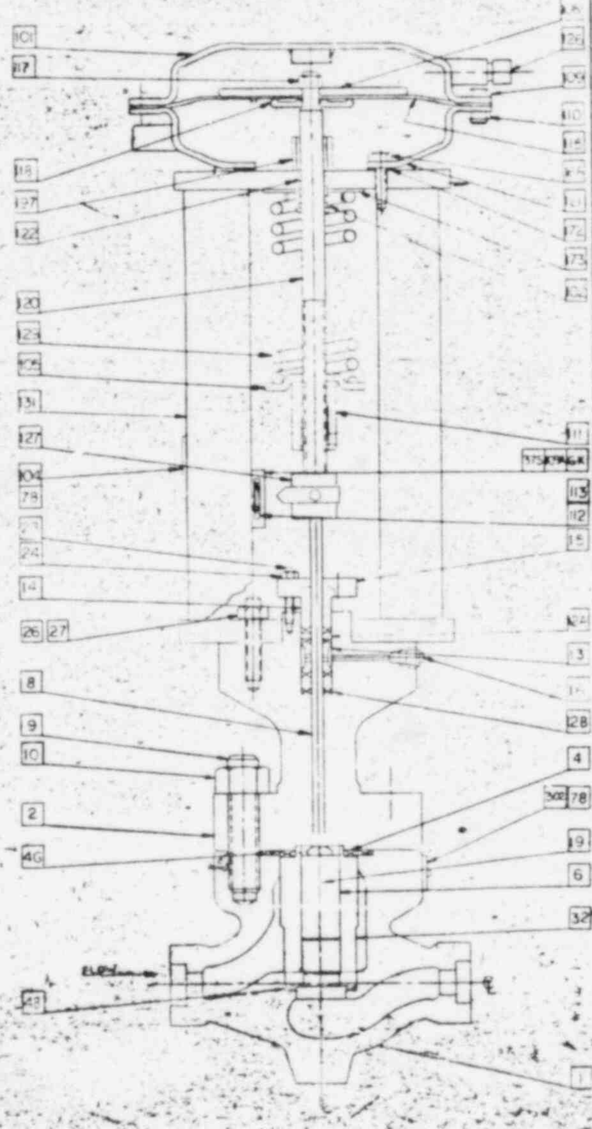
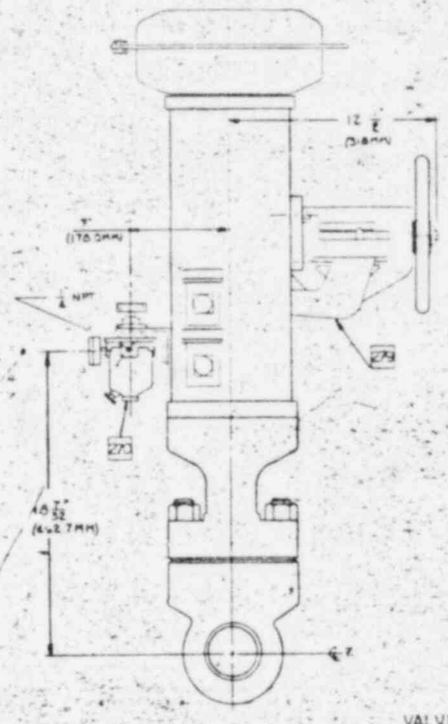
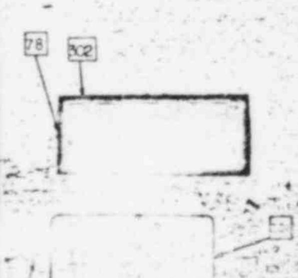
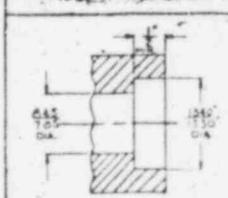
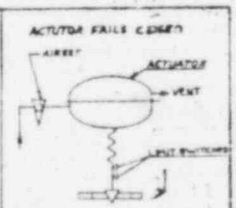




①
General Notes :
1. Also G.E. Specification B50YP158
2. Also G.E. Specification B50YP157
3. Also G.E. Specification B50YP178
4. Also G.E. Specification B50YP 64
5. Also G.E. Specification B50YP 5







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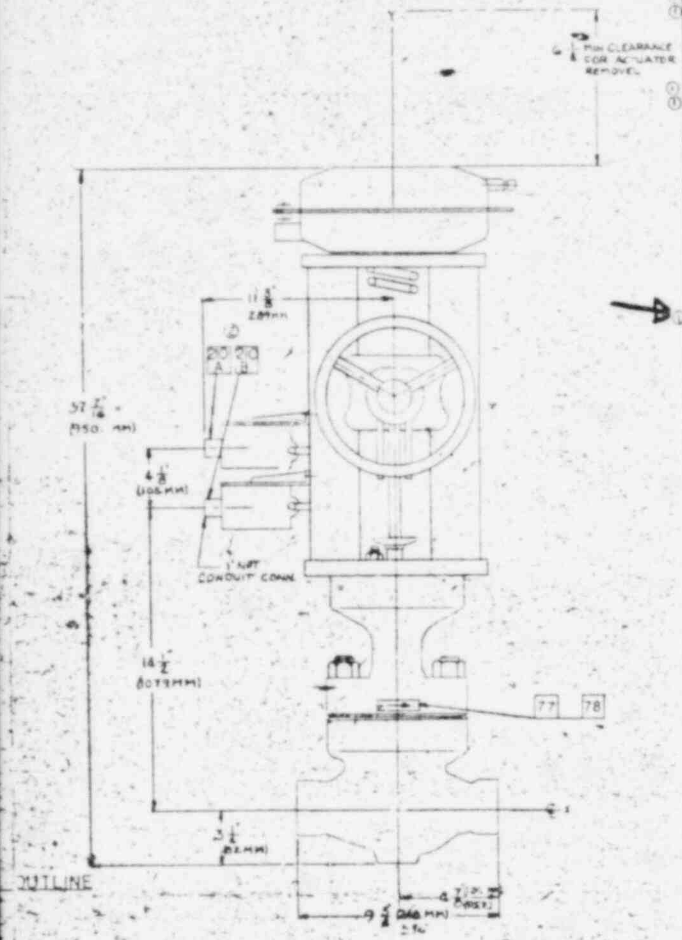
2500# · 3/4-24 · 3/4"-16

SUMMER 1977



Item	Description	Qty	Material	Spec	
	[illegible]	1	STEEL	SA 352 LC8	1
	[illegible]	1	STEEL	SA 350 LF2	2
	[illegible]	1	316 ASB		
	[illegible]	1	316 SS		
45	BONNET BU GSKT		316 ASB		
6	VALVE PLUG	1	SS BAR	SA 479-410	3
8	PLUG STEM	1	SS BAR	A 479-316A	4
9	BODY STUD	6	STEEL	SA 193 B7	
10	BODY STUD NUT	6	STEEL	SA 194 2H	
12A	PACKING RING	3	GRAFOIL		
12B	PACKING RING	4	J.CRANE	[illegible]	
13	LANTERN RING	2	SS BAR	A 276-316	COND A
14	PACKING FOLL	1	SS BAR	A 276-316	COND A
15	PACKING FLANGE	1	SS BAR	A 276-316	COND A
16	BONNET PLUG	1	S.S.	SA 479-316	COND A
19	PLUG STEM PIN	1	SS BAR	A 276-316	COND A
23	PACKING STUD	4	SS BAR	A 193 B8M	[illegible]
24	PACKING NUT	4	SS BAR	A 194 GR 8M	[illegible]
26	[illegible] STUD	6	STEEL	A 193 B7	
27	[illegible] STUD NUT	6	STEEL	A 194 GR 7	
32	CAGE	1	17-4PH	A 564-630	H1100.5
77	FLOW ARROW	1	ALUM		
78	TAPPING SCREW	6	[illegible]		
[illegible]	DIAPH CASE ASSY	1	STEEL		
[illegible]	PACKING BOX	1	BRASS		
[illegible]	NAME PLATE	1	18-8		
[illegible]	SPRING SEAT	1	STEEL [illegible]		
[illegible]	DIAPH PLATE	1	[illegible]		
[illegible]	CAP SCREW	10	[illegible]		
[illegible]	[illegible]	10	[illegible]		
[illegible]	[illegible]	1	[illegible]		
[illegible]	SCALE TRAV [illegible]	1	18-8		
[illegible]	[illegible]	2	[illegible]		
[illegible]	DIAPHRAGM		[illegible]		
[illegible]	ACT STEM NUT	1	[illegible]		
[illegible]	DIAPH WASHER	1	STEEL		
[illegible]	ACT STEM	1	[illegible]		
[illegible]	[illegible]	1	STEEL		
[illegible]	[illegible]	2	BUNA-N		
[illegible]	AIR VENT ASSY	1	MISC		
[illegible]	STEM CONN	1	416 SCP		
[illegible]	SPRING	1	STEEL		
31	YOKE	1	STEEL		
		1			
		1			
[illegible]	[illegible]	6	STEEL [illegible]		
[illegible]	GASKET	1			
[illegible]	SPRING [illegible]	1	STEEL		
[illegible]	TRAVEL [illegible]				
30	PACKING TAG	1	SS		
30A	PKG TAG WIRE	1	316 SS		
30[illegible]	NUCLEAR NP	1	304 SS		
[illegible]	[illegible]	1	ST		
[illegible]	CAP SCREW	2	SCP		
[illegible]	LOCKWASHER	2	SCP		

Item No.	Accessory	Part No.	Qty	Vendor's Part No.	Accessory S/N	Remarks
210A	LIMIT SWITCHES	6395255	1	EA180-11302	P-2315	
210	AIRSET	FH-60XT-KXG1F	1	N/C	P-2315	
27	[illegible]	1493458	1	N/C	P-2234	
2109	LIMIT SWITCH	6395263	1	EA180-12302	P-2315	

CONTROLLED MANUFACTURING CERT LIST

3736-500-2

SHOREHAM
APL ITEM NO. C11-F010
PART OR GROUP NO.

GENERAL ELECTRIC
3736-500-2
DF105PC

OUTLINE AND SECTIONAL DRAWING PRACTICES

GENERAL TOLERANCE NOTE
EXCEPT WHERE STATED OTHERWISE TOLERANCES
FRACTIONAL ± 1/16
DECIMAL ± .030

NAME: 1" 2500 CLASS CENTRAL VALVE SOCKET WELD

ITT HAMMEL DAHL CONOFLOW
175 POST ROAD, WARWICK, RHODE ISLAND 02888

SIZE E 522F/A41AD/

AOV
C11-F010
F011

RECEIVED 6/11/82

APPENDIX B

ANALYSES

CALCULATION/PROBLEM COVER SHEET

Calculation/Problem No: 0630-001-039

Title: Materials Analysis of ITT Hammel Dahl Control Valves

Client: LILCO Project: NSSS Equipment Qualification

Job No: 0630-001-671

Design Input/References:

Refer to Table of Contents on page 2 of 11

Assumptions:

Refer to Table of Contents on page 2 of 11

Method:

Refer to Table of Contents on page 2 of 11

Remarks:

The purpose of this calculation is to determine the temperature and radiation tolerance of the materials of construction of ITT Hammel Dahl Control Valves.

REV. NO.	REVISION	PERFORMED BY	CHECKED	APPROVED	DATE
0	Original	Ken Tr[illegible]	[illegible] Zilch	N K Woodward	7/23/82
1	Pages 1-11	Ken [illegible]	Ira Zilch	N K Woodward	8/20/82

EDS 1004 3/7

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LIST OF TABLES

APPENDICES

1

1.0 PURPOSE

1. To determine the temperature tolerance of the ITT/Hammel scram discharge drain valves (1", 2500 lb. class) and the scram discharge vent valves (2", 2500 lb. class) by examination of the materials of construction..

2. To determine the radiation tolerance of these devices by examination of the materials of construction.

2.0 SCOPE

This calculation applies to the ITT/Hammel scram discharge drain and vent valves exposed to environmental conditions at SNPS-1.

3.0 REFERENCES

1. ITT Hammel Dahl Conoflow Drawing No. 79/2861-0400, Revision 4. LILCO MPL C11-F010 General Drawing 3736-500.

2. ROC, Ken Trotta (EDS) to Mike Frost (ITT Hammel), dated 6/25/82.

3. Handbook of Plastics and Elastomers, Charles A. Harper, McGraw-Hill Book Co., Copyright 1978.

4. Desk Top Data Bank, Plastics Edition 5, Book A.

5. Parkinson & Sisman, "The Use of Plastics and Elastomers in Nuclear Radiation," Oak Ridge National Laboratory, 10/19/70

6. ROC, Ken Trotta (EDS) to Rich Soeder (J. Crane Co.), dated 6/25/82.

7. ROC, Ken Trotta (EDS) to Linda Williams (J. Crane Co.), dated 6/25/82.

4.0 METHOD OF ANALYSIS

The temperature and radiation tolerance of all materials contained within these devices was determined by a document search of published information and EDS calculations. The sensitivity of the "weak link" component is then assumed to be the temperature or radiation tolerance of the entire device.

5.0 BASIC DATA AND ASSUMPTIONS

5.1 The materials of construction for the ITT Hammel valves are identical (Reference 2).

5.2 Only non-metallic materials have been evaluated since they will be the most sensitive to potential radiation damages.

6.0 SUMMARY RESULTS

The limiting material in this device, with respect to radiation, is nylon, with an acceptable dose of 6×10^6 rads. The limiting material with respect to temperature is BUNA-N with a maximum operating temperature of 250°F.

7.0 BODY OF CALCULATION

See Table 1.

Calculation No. 0630-001-039
Revision No. 1

Prepared by: [illegible] Date: 8-20-82
Checked by: [illegible] Date: 8-20-82

TABLE 1

COMPONENT MATERIALS EVALUATION WORKSHEET

Manufacturer: ITT/Hammel

Model No. 1", 2", 2500 lb. Class, Control Valves

Component	Material	Reference	TEMPERATURE Maximum Operating	TEMPERATURE Reference	RADIATION Acceptable Dose	RADIATION Reference
Part No. 115 Diaphragm	BUNA-N/ Nylon	1, 2	250°F 491°F	3 4	1×10^7 rads 6×10^6 rads	5 5
Part No. 122 Packing Box O-Ring	BUNA-N	1, 2	250°F	3	1×10^7 rads	5
Part No. 12A Packing Ring	Graphite	1, 2, 7	Not Sensitive		Not Sensitive	
Part No. 12B Packing Ring	Asbestos	1, 2, 6	Not Sensitive		Not Sensitive	

| 1
| 1

APPENDIX A

eds nuclear MATERIALS ANALYSIS, CALC. No. 0630-001-029

RECORD OF CONVERSATION

FILE: 1290-001-671

COPY: N. Woodward
I. Zebrak
K. Trotta

[X] Telephone [ ] Meeting [ ] Other ____

TO: Mike Frost FROM: Ken Trotta KT DATE 6/25/82

COMPANY: ITT Hammel Dahl Conoflow PHONE NO.: 401-781-6200

SUBJECT: Comparison of 1" and 2" Diaphragm Valves

Summary of Conversation:

Mike informed me that the materials of construction for the CRD vent and drain valves supplied to GE are identical. The one inch and two inch valves differ only in physical size, not materials of construction.

KT/jh

SHEET 6 OF 11

eds nuclear

EDS Nuclear Inc.
445 Broad Hollow Road
Melville, New York 11747
(516) 454-0200

cc: N. Woodward
rf/jft/jfc

August 17, 1982
0630-001-NY-105

ITT Hammal Dahl
175 Post Road
Warwick, Rhode Island 02888

ATTENTION: Mr. Mike Frost

SUBJECT: Verification of Record of Conversation

Gentlemen:

Thank you for the information which you supplied to EDS with respect to the materials of construction of 1" and 2" Diaphragm Valves. EDS Quality Assurance Procedures require that you receive the enclosed record of our conversation of June 25, 1982.

If this is an accurate account of our conversation, no action is requested of you. Should there be any errors or misunderstandings in this record, please contact me at (516) 454-0579.

Very truly yours,

Kenneth Trotta - Engineer
Systems Engineering Division

KT/jm

Enclosures

1

Sheet 7 of 11

APPENDIX H
MATERIALS ANALYSIS, CALC. No. 0630-001-039

eds nuclear

FILE: 0630-001-671

RECORD OF CONVERSATION

COPY: N. Woodward
I. Zebrak
K. Trotta

[X] Telephone ☐ Meeting ☐ Other ____________

TO: Rich Soeder FROM: Ken Trotta KT DATE 6/25/82

COMPANY: J. Crane Company PHONE NO.: 914-345-2420

SUBJECT: J. Crane 187-I Material Analysis

Summary of Conversation:

Rich informed me that 187-I valve stem packing is manufactured of braided asbestos.

KT/jh

eds nuclear

EDS Nuclear Inc.
445 Broad Hollow Road
Melville, New York 11747
(516) 454-0200

cc: N. Woodward
rf/jft/jfc

August 17, 1982
0630-001-NY-104

Crane Company
500 Executive Building
Elmsford, New York 10523

ATTENTION: Mr. Rich Soeder

SUBJECT: Verification of Record of Conversation

Gentlemen:

Thank you for the information which you supplied to EDS with respect to 187-I valve stem packing. EDS Quality Assurance Procedures require that you receive the enclosed record of our conversation of June 25, 1982.

If this is an accurate account of our conversation, no action is requested of you. Should there be any errors or misunderstandings in this record, please contact me at (516) 454-0579.

Very truly yours,

Kenneth Trotta

Kenneth Trotta - Engineer
Systems Engineering Division

KT/jm

Enclosures

1

APPENDIX A
MATERIALS ANALYSIS, CALC. No.
0630-001-039

eds nuclear

FILE: 0630-001-671

RECORD OF CONVERSATION

COPY: N. Woodward
I. Zebrak
K. Trotta

[X] Telephone ☐ Meeting ☐ Other

TO: Linda Williams FROM: Ken Trotta KT DATE 6/25/82

COMPANY: J. Crane Company PHONE NO.: 201-227-8818

SUBJECT: GRAFOIL Material Analysis

Summary of Conversation:

Linda informed me that GRAFOIL is a J. Crane commercial name for standard graphite valve stem packing.

KT/jh

eds nuclear

EDS Nuclear Inc.
445 Broad Hollow Road
Melville, New York 11747
(516) 454-0200

cc: N. Woodward
rf/jft/jfc

August 17, 1982
0630-001-NY-103

John Crane Houdaillae
P.O. Box 866
Fairfield, New Jersey 07006

ATTENTION: Ms. Linda Williams

SUBJECT: Verification of Record of Conversation

1

Gentlemen:

Thank you for the information which you supplied to EDS with respect to Grafoil valve stem packing. EDS Quality Assurance Procedures require that you receive the enclosed record of our conversation of June 25, 1982.

If this is an accurate account of our conversation, no action is requested of you. Should there be any errors or misunderstandings in this record, please contact me at (516) 454-0579.

Very truly yours,

Kenneth Trotta - Engineer
Systems Engineering Division

KT/jm

Enclosures

ENVIRONMENTAL QUALIFICATION SUMMARY

Environmental Qualification Summary No: 3005M

Title: Byron Jackson (Borg-Warner) Core Spray Pumps

Client: LILCO Project: NSSS Equipment Qualification

Job No: 0630-001-671

Design Input/References:

The references included with this package are listed as appendices in the Table of Contents on page 2.

Assumptions:

N/A

Method:

N/A

Remarks:

This device has been qualified for all postulated accident conditions.

REV. NO.	REVISION	PERFORMED BY	CHECKED	APPROVED	DATE
0	Original	Ara Zebrak	Ken Trotts	NK Woodward	7/23/82
1	pp 3,4,7,8 added pg. 9 calc no. 0630-001-038 added pg. 6	Ara Zebrak	Ken Trotts	NK Woodward	8/18/82

Sheet 1 of 9

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APPENDICES

APPENDIX	TITLE
A	Documentation:

1. Technical Manual, Core Spray Pump, Byron Jackson Pump Division, Serial Numbers 691-S-1111/1112, Manual No. 8020-1E-3525 (LILCO/SR-2 Document No. 2777-033[01]).

2. G.E. Purchase Specification No. 21A9221, Revision 4, Core Spray and RHR Pumps (LILCO/SR-2 Document No. 21A9221).

3. G.E. Purchased Part Drawing, Core Spray Pump. Revision 4 (LILCO/SR-2 Document No. 117C2857).

4. G.E. Purchase Order No. 205-AA728 Core Spray Pumps (LILCO/SR-2 Document No. AA728).

5. Certificates of Compliance with Purchase Order for Core Spray Pumps 691-S1111 and S1112, 10/19/72 (LILCO/SR-2 DocumentNo. AA728-G017).

6. Certificates of Code Compliance Pumps 691-S1111 and S1112, 10/19/72 (LILCO/SR-2 Document No. AA718-G017).

APPENDIX	TITLE
B	Analyses:

1. EDS Calculation No. 0630-001-038, Revision 0.

Long Island Lighting Company
Shoreham Nuclear Power Station
Unit No. 1

Equipment Qualification
Summary No. 3005M
Revision No. 0

1.0 EQUIPMENT LIST

Equipment I.D. (Mark No.)	MPL No.	Description	Make/Model	
1E21*P013A	E21-C001A	Core Spray Pump	Byron Jackson 691-S-1111	1
1E21*P013B	E21-C001B	Core Spray Pump	Byron Jackson 691-S-1112	1

2.0 EQUIPMENT SUMMARY EVALUATION

2.1 Description

The equipment under evaluation is Byron Jackson Pump Division, Borg-Warner Corp., Core Spray (CS) Pumps, serial numbers 691-S-1111/1112.

2.2 Conclusions

The Core Spray pumps are qualified for the postulated accident temperature, pressure, humidity, and radiation conditions. Materials analysis (EDS Calculation No.0630-001-038, Rev. 0) indicates that the non-metallic components contained in this device will not be affected by the postulated radiation and temperature accident environments.

2.3 Limitations

None.

2.4 Discussion

1. This device is required to withstand a postulated total integrated radiation dose (40 year normal plus 6 month accident) of 7×10^6 rads. (See Attachment 2 to Mechanical Equipment Environmental Qualification Worksheet.) Materials analysis (EDS Calculation No. 0630-001-038, Rev. 0) indicates that the only non-metallic material contained within this device is ethylene propylene, with a radiation tolerance of 1×10^7 rads. Therefore, this device is expected to perform its safety function as required. 1

2. Since the maximum design process fluid temperature of 212°F (Documentation Reference 3) for the CS pumps is much greater than the postulated EQR peak accident temperature of 150°F, the thermal expansion stresses from exposure to this temperature are considered insignificant as compared to the thermal stresses that will be created from the process fluid temperature. Although the documented maximum ambient temperature of 148°F (Documentation Reference 3) is less than the EQR specified environment of 150°F, this 2°F difference should have an insignificant impact in view of the thermal stresses discussed above.

   Similarly, the environmentally specified maximum pressure of 1 psig is also considered insignificant as compared to the CS pump design pressure of 500 psig (Documentation Reference 3).

Therefore, the accident ambient temperature and pressure are negligible in light of the mechanical properties, materials of construction and design of the core spray pumps.

SECTION 3.0

ENVIRONMENTAL QUALIFICATION WORKSHEETS

Long Island Lighting Company
Shoreham Nuclear Power Station, Unit No. 1

Environmental Qualification Summary No. 3005M
Revision No. 0

MECHANICAL EQUIPMENT ENVIRONMENTAL QUALIFICATION WORKSHEET

Prepared by: ________________ Date: __________

Checked by: ________________ Date: __________

EQUIPMENT DESCRIPTION	ENVIRONMENTAL PARAMETER	POSTULATED ENVIRONMENT: FSAR *	POSTULATED ENVIRONMENT: ENVIRONMENTAL QUAL. REPORT **	DOCUMENTED ENVIRONMENT: VALUE	DOCUMENTED ENVIRONMENT: REFERENCE	OUTSTANDING ITEMS
EQUIP. I.D. (MARK NO.): 1E21*P013A,B	Maximum Temperature (degrees F)	212	150	148	2	None See Section 2.4
VENDOR I.D.: E21-C001A,B	Maximum Pressure (psig)	1	< 1	Note 1	Note 1	None See Section 2.4
EQUIPMENT TYPE: Pump	Maximum Relative Humidity (%)	100	100	100	2	None
SERVICE: Core Spray	Containment Spray	N/A	N/A	N/A	N/A	N/A
MANUFACTURER: Byron Jackson Borg-Warner	40-Year Normal Radiation Dose (Rads)	1.8×10^3	See Note ***.	1×10^7	1	None
MODEL NO.: Serial No. 691-S-1111 and 1112	6-Month Accident Radiation Dose (Rads)	1×10^5	7×10^6 See Note ***.			
LOCATION: RBS El. 8'; ZONE: G-01	Submergence	N/A	N/A	N/A	N/A	N/A

ATTACHMENT 1 TO MECHANICAL EQUIPMENT ENVIRONMENTAL QUALIFICATION WORKSHEET

REFERENCES:

1. EDS Calculation No. 0630-001-038, Rev. 0, Materials Analysis of Byron Jackson RHR/CS Pump.

2. G.E. Purchase Part Drawing 117C2857, Rev. 4.

NOTES:

1. Documented value for maximum pressure could not be found.

* FSAR values for maximum temperature, pressure, and humidity are from Table 3C.3-9 and radiation doses are from Table 3.11.2-1.

** EQR values for maximum temperature and pressure are from Figures D-21 and D-41, respectively. EQR value for humidity is from Section 3.1.b of the EQR. 1

*** The normal and accident radiation doses would usually be derived from Figure D-2 of the EQR (i.e., 1.8×10^3 and 5.75×10^6 rads). However, a total integrated dose of 7×10^6 rads (40 year plus 6 month accident dose) should be used instead. (See attached letter from P. J. Holden [S&W] to N. Woodward [EDS], dated August 5, 1982, re Mechanical Equipment Environmental Qualification.) 1

STONE & WEBSTER ENGINEERING CORPORATION

COPY

Copy to:
Dr. JFEtzweiler (LILCO)
JSherman
Proj Engr-7
TFGerecke (LILCO-Hicksville)
WJMuseler-5 (LILCO-WR)
NWoodward
EDS Nuclear Inc.

RECEIVED AUG 0 6 1982 NW

Attachment 2 to Mechanical Equipment Environmental Qualification Worksheet 3005M-Core Spray Pumps

August 5, 1982

J.O.No. 11600.02
File No. 221.21

Mr. N. Woodward
Project Engineer
EDS Nuclear Inc.
200 Broad Hollow Road
Melville, NY 11747

Dear Mr. Woodward:

MECHANICAL EQUIPMENT ENVIRONMENTAL QUALIFICATION
SHOREHAM NUCLEAR POWER STATION - UNIT 1
LONG ISLAND LIGHTING COMPANY

As requested by Mr. J. Sherman of LILCO, the following information is provided for your use in the Shoreham Mechanical Equipment Qualification effort.

The calculated six-month integrated gamma dose to the inside surface of pipe containing suppression pool water following a postulated LOCA is 7×10^6 rads based on Stone & Webster calculation No. SNPS-1-UR-21-G. Where mechanical components are exposed directly to suppression pool water the above value has been utilized in this effort as a minimum exposure. This would apply generally to the following systems which are included in our scope for this effort: 1

E-11	Residual Heat Removal
E-21	Core Spray
E-41	High Pressure Coolant Injection
E-51	Reactor Core Isolation Cooling

Very truly yours,

P.J. Holden

P.J. Holden

SLT:lmm

APPENDIX A

DOCUMENTATION

E21-2

[illegible] E21-2

[illegible]

BJ

INSTRUCTION MANUAL

NUCLEAR SERVICE PUMPS

BORG WARNER

BJ Byron Jackson Pump Division — BORG-WARNER CORPORATION	MANUAL NO. 8020 1E-3525

[illegible] 8 2L21.2

[illegible] 1111/1112

TECHNICAL MANUAL

CORE SPRAY PUMP

BYRON JACKSON PUMP DIV.

Borg-Warner Corp.

SERIAL NUMBER: 691-S-1111 1112

SIZE: 12 x 14 x 27

TYPE: VERTICAL DVDS

FOR GEARED

PURCHASE ORDER NUMBER 205AA7254A

LILCO

TITLE PAGE

FOREWORD

This manual describes the BYRON JACKSON Type DVDS pump which is available in various sizes for application in core spray or residual heat removal service. The Title Page and Data Page, at the front of the manual, are prepared especially for each pump order. These pages supply the specific information relative to customer's plant location, such as the pump size and application, the driver specifications, the auxiliary equipment supplied, the unit weights, the torque values and any special reference materials required. The main text of the manual describes the details applicable to all pumps of this type applied as core spray or residual heat removal pumps.

Included in the first section of the manual are general details pertaining to the equipment supplied, the applicable drawings, shipping arrangements, recommended lubricants and special precautions for assembly, installation, operation and disassembly. The second and third sections describe the pump and shaft seal, respectively. The fourth, fifth and sixth sections relate to installation, operation and maintenance, in that order. The seventh section includes directions for ordering spare parts and the eighth section contains the applicable drawings.

Some of the assembly procedures provided may not apply to initial installation, but will be required for maintenance work. Personnel performing initial assembly and installation should disregard any portion of the procedures which relate to assembly of any part that is shipped as part of another sub-assembly.

Successful mechanical operation is dependent on careful study of the manual and a well planned maintenance program. It is also essential, especially during initial start up in a new plant, that foreign material be prevented from entering the pumps, and that all liquid supply lines be flushed and thoroughly cleaned.

MANUAL NO. 8020 1E-3525	BJ Byron Jackson Pump Division BORG-WARNER CORPORATION

TABLE OF CONTENTS

NOTE: The reference materials are those listed in Paragraph 1.2, and are arranged in the sequence listed.

MANUAL NO. 8020 1E-3525	BJ Byron Jackson Pump Division BORG WARNER CORPORATION

SPECIAL DATA FOR

CORE SPRAY PUMP

SERIAL NUMBER: 691-S-1111 1112

LOCATION: LILCO

1. DRIVER: General Electric Vertical Solid Shaft Motor
   Drawing No. 992C302CX
   3/60/4000; 1250 HP; 1800 RPM

2. AUXILIARY EQUIPMENT: Borg-Warner Cyclone Separator, Model No. 10043.

3. UNIT WEIGHT (LBS.):
   (a) Pump - - - - - - - - - 6,200
   (b) Motor- - - - - - - - - 6,300
   (c) Total - - - - - - - - -13,000

4. SPECIAL REFERENCE MATERIALS: The materials listed below are supplementary to those listed in Paragraph 1.2.
   (a) Pump Outline Drawing (BJ) 2E-2119
   (b) Pump Piping Drawing (BJ) 2C-4966
   (c) Cyclone Separator Instructions (B-W) 1860-25

5. TABLE I, RUNNING CLEARANCES (DIAMETRAL):

LOCATION		RUNNING CLEARANCES (DIA.)	
From	To	From	To
Impeller (3-1)	Case Wear Ring (1-6)	[illegible]	.03?"
Impeller (3-1)	Hydrostatic Bearing Cover Wear Ring (2-7)	.020	.024"
Pump Shaft (4-1)	Pump Cover (2-1)	.125	.155"
Pump Shaft (4-1)	Seal Flange (5-1)	.125	.138"

6. TABLE II, TABLE OF TORQUE VALUE:

6. TABLE II, TABLE OF TORQUE VALUES:

REFERENCE NUMBER	DESCRIPTION	*RECOMMENDED TORQUE (IN FOOT POUNDS) ± 5 %
2-6	Nut, Cover-to-Case Stud	380
2-9	Cap Screw, Motor Hold Down	150
2-12	Cap Screw, Seal Flange-to-Cover	65
3-2	Nut, Impeller	400 or 1/10 nut turn ± 10%
3-3	Cap Screw, Impeller Nut	65
6-2	Lock Nut, Pump Half Coupling	400 or 1/8 nut turn ± 10%
6-6	Nut, Coupling Cap Screw	30

*NOTE: The listed values are based on well lubricated threads.

SECTION ONE - TECHNICAL DATA AND CHARACTERISTICS

1.1 LEADING PARTICULARS:

1.1.1 Pump Type: Vertical DVDS, with Borg-Warner Model U-4500 Mechanical seal.

1.1.2 Pump Size and Service: Refer to Data Page (Following the Title Page).

1.1.3 Driver and Auxiliary Equipment: Refer to Data Page (Following the Title Page).

1.1.4 Rotation (as viewed looking down on top of driver): COUNTER-CLOCKWISE.

1.1.5 Driver-to-Pump Coupling: BYRON JACKSON adjustable coupling with spacer.

1.2 APPLICABLE DRAWINGS (Included in SECTION EIGHT, "REFERENCE MATERIALS"):

*Pump Sectional Drawing	(BJ) 1E-3525
*Materials of Construction (3 sheets)	(BJ) 1T-3855
**Pump Outline Drawing	Refer to Data Page
**Pump Piping Drawing	Refer to Data Page
***Addition Mechanical Seal Details	(B-W) Manual 1810
**Auxiliary Equipment Instruction Sheets	Refer to Data Page
Cleaning, Packaging and Storing Specifications	(BJ) 1T-3752

NOTES:
*Parenthesized numbers used in the text of the Manual reflect the pump and seal part Reference Numbers as shown in the Sectional Drawing and Materials of Construction Drawing.

For example: The pump case is referred to as "Pump Case (1-1)", and the mechanical seal rotating face is referred to as "Rotating Face (S-S-14)".

**The Data Page follows the Title Page of this manual.

***The seal shown in Manual 1810 is essentially the same seal supplied for these pumps as reflected in the Sectional Drawing (1E-3525) and Materials of Construction Drawing (1T-3855). The only exceptions are that the rotating sub-assembly requires no shaft sleeve (S-1) or sleeve gasket (S-14), the seal flange (S-17) and gasket (S-18) are supplied as pump parts (S-1 and 2-11), and the seal flange (S-7) requires no bushing (S-24).

1.3 SHIPPING ARRANGEMENTS: All parts making up one pump assembly are first assembled at the factory for accurate fit and alignment. The pump is then tested, disassembled, cleaned and reassembled for shipment to the job site. The cleaning, packaging and shipping specifications are shown in Drawing IT-3752.

The motor will ship separately from the pump, but field alignment of motor-to-pump is not required, because all pump parts are adjusted for fit at the factory and the motor has a rabbet fit with the top plate (2-3) of the motor barrel (2-2). The approximate shipping weights of pump and motor are listed in the Data Page, following the Title Page of this manual.

NOTE: Due to the fact that the suction and discharge nozzles must be welded to the system piping, the pump can not be installed in the as-shipped condition. For proper installation, the foundation plate (1-4) must be secured to the customer's foundation and the pump cover-rotating element assembly separated from the pump case (1-1) prior to welding of the nozzles. When welding operations are completed, the pump cover-rotating element assembly can be reassembled on the pump case. | (1)

1.4 RUNNING CLEARANCES (DIAMETRAL): Refer to Data Page, following the Title Page of this manual.

1.5 TORQUE VALUES: Refer to Data Page, following the Title Page of this manual.

1.6 ASSEMBLY LUBRICANTS:

CAUTION: USE NO LUBRICANT ON THE SEAL FACES (5-5-14 and 5-5-15).

Prior to assembly, lightly coat the pump components with lubricant as directed below.

1.6.1 U-Cup and O-Ring Gaskets: For the U-Cup (5-5-4) and the O-Ring gaskets (2-4, 2-10, 2-11 and 5-5-13), use only Dow Corning Silicone Grease No. 55M.

1.6.2 Fasteners, internal: For the wear ring set screws (1-3 and 2-8), impeller nut (3-2) and cap screw (3-3), use Neolube (Huron Industries) or Dag Dispersion No. 156 (Acheson Colloid Corp.).

1.6.3 Fasteners, External: For the cover-to-case studs (2-5) and nuts (2-6); seal flange cap screws (2-12); motor hold down cap screws (2-9); and coupling cap screws (6-5) and nuts (6-6); use Molykote "G" (Dow Corning Corp.), or Hi-Temp CS-A Anti-Seize (Fel-Pro, Inc.).

1.7 PRECAUTIONS FOR ASSEMBLY, INSTALLATION AND MAINTENANCE:

1.7.1 CAUTIONS:

1. WHEN ARRANGING COMPONENTS FOR ASSEMBLY, AND WHEN ASSEMBLING COMPONENTS, REFER TO SECTIONAL DRAWING 1E-3525 AND MATERIALS OF CONSTRUCTION DRAWING 1T-3855 TO BE CERTAIN THAT ALL COMPONENTS WILL BE CORRECTLY ASSEMBLED.

2. PRIOR TO ASSEMBLY OF THE RESPECTIVE COMPONENTS, LIGHTLY LUBRICATE THE U-CUP, THE O-RING GASKETS, AND THE MAIN FASTENERS AS DIRECTED IN PARAGRAPH 1.6.

3. WHEN THE MAIN FASTENERS ARE ASSEMBLED, TORQUE THE MAIN FASTENERS AS DIRECTED IN PARAGRAPH 1.5.

4. PUMP THRUST IS TAKEN BY THE MOTOR THRUST BEARING. WHEN HYDRO-TESTING THE ASSEMBLED PUMP, THE COUPLING SPACER MUST BE IN PLACE AND CONNECTED (OR BLOCK-OFF ARRANGEMENTS MUST BE PROVIDED) IN ORDER TO PREVENT SERIOUS DAMAGE TO THE MECHANICAL SEAL.

1.7.2 NOTES:

1. Refer to the Outline Drawing for orientation of the motor, and to the motor instruction book for details regarding motor lubrication.

2. When installing the instruments and connecting the auxiliary piping and wiring, refer to the Outline and Piping Drawing and the applicable sections of the motor instruction book.

3. Other than monitoring of flow, pressures and temperatures, the pump should require no attention during operation.

4. If any conditions (flow, pressure or temperature) are not as specified in the system procedures manual, seek to determine the cause.

5. If disassembly of any components is required, be certain to match-mark, tag or otherwise identify all parts not previously identified, and provide separate marked containers for all small parts. When removing seal faces, protective wrap the seal faces pending inspection, and replace the protective wrapping after inspection of the seal faces.

6. Prior to any disassembly work, proceed as follows:

(a) Deenergize and tag electrical power and control circuits to the pump and motor.

(b) Disconnect all electrical connections and piping connections to the pump and motor.

(c) If the entire pumping unit is to be disassembled, drain the pump completely.

WARNING: ALTHOUGH CIRCUIT BREAKER IS OPENED LOCALLY, IT MAY STILL BE CLOSED BY ANY OF THE REMOTE SWITCHES. WHEN WORKING ON PUMP, DO NOT RELY ON OPEN CIRCUIT BREAKER FOR PROTECTION AGAINST MOTOR STARTING.

7. If the motor is removed to storage, observe the requirements of the motor manual with respect to idle periods.

8. These pumps are designed for service with radioactive fluids, are installed in radiation areas, and are subject to radioactive contamination. The pump impellers especially can be sources of radiation. Observe all radiological controls when performing maintenance on these pumps.

9. Make every effort to perform each maintenance procedure efficiently to minimize exposure to radiation. Review the procedures carefully. Ensure that all necessary tools and spare parts are available at the work area.

10. Take special care to avoid dropping any tools, bolts, or debris into the opening when the cover is removed from the pump case. Use lanyards for tools or other items which must be used near the open pump case.

1.3 OPERATING DATA:

1.3.1 General: The pumps are located near the bottom of the pressure suppression pool from which they draw their suction. The purpose of the core spray pumps is to prevent overheating of the core during an accident when the emergency core cooling system is in operation. The RHR (Residual Heat Removal) pumps will be used for three different modes of operation. The Low Pressure Coolant Injection (LPCI) mode is used to restore and maintain reactor water level after a loss of coolant accident, the Containment Cooling mode is used to cool the suppression pool during an accident and during hot standby, and the Shutdown Cooling mode is used to cool the reactor during shutdown.

1.3.2 Standby Condition: After installation, initial system test and preparation for standby condition, the pumps will remain on standby in the flooded condition, ready to be started by remote control switches actuated by an alarm system.

1.3.3 Cooling Water Data (RHR Pumps Only): Whether on standby or operating, supply cooling water to the heat exchanger of the RHR pumps. The heat exchanger requires 20 g.p.m. of water at 80°F inlet temperature. The pressure drop equals 10 psi.

SECTION TWO - DESCRIPTION OF PUMP COMPONENTS

SECTION TWO - DESCRIPTION OF PUMP COMPONENTS (REFER TO DRAWINGS 1E-3525 AND 1T-3855): The
2.1 GENERAL DESCRIPTION (REFER TO DRAWINGS 1E-352' AND 1T-3855): The rotating
pump is composed of the pump case assembly, the pump cover assembly, the rotating
element assembly (which includes the coupling components) and the shaft seal assembly.
The shaft seal assembly is described in SECTION THREE.

The installed and connected pump case and pump cover components enclose and align
the internal rotating components. The pump cover also provides a mounting surface
for the motor.

2.2 PUMP CASE AND PUMP COVER ASSEMBLIES: The pump case assembly consists
of the pump case (1-1), the cover-to-case locating pin (not shown), the case wear
ring (1-2), the foundation plate (1-4) and the sixteen cover-to-case studs (2-5) with
nuts (2-6). The case wear ring (1-2) is press fitted and located by three set screws
(1-3). The foundation plate (1-4) is fabricated integral with the bottom flange of the
pump case (1-1).

The pump cover assembly consists of the pump cover (2-1), the barrel (2-2), the top
plate (2-3), the cover-to-case gasket (2-4), the hydrostatic bearing chamber gasket
(2-10), the seal flange-to-cover gasket (2-11), the four seal flange-to-cover cap
screws (2-12), the four motor hold down cap screws (2-9) and the combination hydro-
static bearing-cover wear ring (2-7). The barrel (2-2) and top plate (2-3) are fabri-
cated integral with the pump cover (2-1). The combination hydrostatic bearing-cover
wear ring (2-7) is press fitted and located by the three set screws (2-8).

2.3 ROTATING ELEMENT ASSEMBLY: The rotating element assembly consists of the
pump shaft (4-1), the impeller (3-2) and the driver-to-pump coupling components.
The impeller (3-1) is driven by the key (4-2) and retained by the impeller nut (3-2,
L.H. Thread) with cap screw (3-3, R.H. Thread). The impeller nut cap screw (3-3)
is locked by the plug welded pin (3-4).

The driver-to-pump coupling components are the pump half coupling (6-1) with pump
shaft key (6-11), lock washer (6-3) and lock nut (6-2); the coupling spacer (6-4) with
sixteen each cap screws (6-5), lock washers (6-7) and nuts (6-6); the thrust disc (6-10);
and the driver half coupling (6-8) with driver shaft key (6-12) and split ring (6-9).
The assembled and connected coupling components transmit up and down thrust from
the pump shaft (4-1) to the motor thrust bearing.

The pump half coupling lock washer (6-3) has one internal tab and several external
tabs. When the pump half coupling (6-1), lock nut (6-2) and lock washer (6-3) are
installed, the internal tab is bent to fit a slot in the pump shaft (4-1) and one of the
external tabs will line up with and engage one of the slots in the lock nut (6-2).

The split ring (6-9) locates the driver half coupling (6-8) on the driver shaft. The thrust disc (6-10) is installed between the top inner face of the spacer (6-4) and the bottom face of the driver shaft. The spacer-to-half coupling cap screws (6-5), lock washers (6-7) and nuts (6-6) are interchangeable, eight each of these pieces being used to connect each flange of the spacer (6-4) to its respective half coupling (6-1 or 6-8). After all the coupling components are installed and connected, the thrust disc (6-10) locates the rotating element and the rotating components of the shaft seal assembly. For original installation, the thrust disc (6-10) is furnished correctly sized. However, should subsequent installations involve a replacement spacer (6-4) or replacement driver, it is required that the thrust disc (6-10) also be replaced and correctly sized as described in SECTION FOUR, Paragraph 4.1, Step 18.

CAUTION: PUMP THRUST IS TAKEN BY THE MOTOR THRUST BEARING. WHEN HYDROTESTING THE ASSEMBLED PUMP, THE COUPLING SPACER MUST BE IN PLACE AND CONNECTED (OR BLOCK-OFF ARRANGEMENTS MUST BE PROVIDED) IN ORDER TO PREVENT SERIOUS DAMAGE TO THE MECHANICAL SEAL.

SECTION THREE - SHAFT SEAL

3.1 GENERAL DESCRIPTION: The shaft seal is a mechanical seal consisting of the stationary sub-assembly, the U-Cup (5-S-4), the rotating face (5-S-15) and the spring holder sub-assembly. The seal flange (5-1) is by BYRON JACKSON and the remaining stationary and rotating parts are components of the Borg-Warner Model U-4500 Mechanical Seal. The stationary sub-assembly includes the seal flange (5-1) which retains the seat gasket (5-S-13) and the stationary face (5-S-14). The spring holder sub-assembly consists of the spring holder (5-S-17), the coil spring (5-S-16), the seal drive (5-S-2) and the two drive keys (5-S-3).

The spring holder sub-assembly is installed on the pump shaft (4-1), the drive keys (5-S-3) engaging milled slots in the pump shaft (4-1) while the seal drive (5-S-2) locates over and against a shoulder of the pump shaft (4-1). The U-Cup (5-S-4) is installed over the inner lip of the spring holder (5-S-17). The rotating face (5-S-15) is installed over the U-Cup (5-S-4) to engage its lugs with the slots in the outer diameter of the spring holder (5-S-17). The stationary sub-assembly is retained to the pump cover (2-1) by the cap screws (2-12), the joint of flange-to-cover being sealed by the gasket (2-11).

3.2 MAINTENANCE: Removal of the driver is not required for disassembly and reassembly of the mechanical seal. Only the coupling spacer (6-4) and pump half coupling components need be removed to permit maintenance access. Procedures for disassembly, inspection, cleaning and reassembly of the mechanical seal components are described in SECTION SIX, "MAINTENANCE".

SECTION FOUR - INSTALLATION

CAUTION: BEFORE BEGINNING THE INSTALLATION PROCEDURES, REVIEW THE REQUIREMENTS OF PARAGRAPH 1.7.

4.1 INSTALL UNIT:

1. Establish a clean area around the uncrating site, between the uncrating site and the foundation site, and around the foundation site.

2. Arrange the lifting equipment for convenience, and uncrate the unit.

3. Attach eye bolts in two of the motor cap screw taps in the top plate (2-3), and attach lifting slings to the eye bolts.

4. Transfer the pump to the foundation site.

5. Line up the mounting stud holes in the foundation plate (1-4) with the studs of the foundation, carefully install the pump to rest the foundation plate (1-4) over its studs and install the foundation stud nuts. Do not yet apply final torque to the foundation studs and nuts (See Step 9, below).

6. Remove the stud nuts (2-6) from the case studs (2-5), and, if required, use back-off screws in the taps provided to break the gasket joint of cover (2-7) to case (1-7).

7. Lift up on the slings to remove the pump cover-rotating element assembly from the pump case (1-7).

8. Remove the cover-to-case gasket (2-4), place a temporary cover (of plywood or other material) over the pump case (1-7), transfer the pump cover-rotating element out of the work area to rest on wood block supports placed under the flange of the pump cover (2-7), and remove the lifting slings from the eye bolts in the top plate (2-3).

9. Before applying final torque to the foundation studs, be certain that the top face of the pump case (1-7) is level to within 1/4" slope. (E)

10. Weld the suction and discharge nozzles into the system piping.

11. Attach the lifting slings to the eye bolts in the top plate (2-3).

12. Transfer the pump cover-rotating element assembly to the foundation site.

13. Remove the temporary cover from the pump case (1-1), inspect and clean the gasket seat, then install the cover-to-case gasket (2-4).

14. Determine that the hydrostatic bearing chamber gasket (2-10) is installed in its groove in the pump cover (2-1). Line up the pump cover stud holes and locating pin hole with the pump case studs (2-5) and locating pin, then lower the pump cover-rotating element assembly to engage the studs and locating pin. Install the cover stud nuts (2-6), and remove the lifting lines and eye bolts.

15. Support the driver in operating position and install the coupling key (6-17) and driver half coupling (6-8) to install the driver half coupling (6-8). Push up on the driver half coupling (6-8) firmly on the split ring (6-9), then pull down to seat the driver half coupling (6-8) firmly on the split ring (6-9).

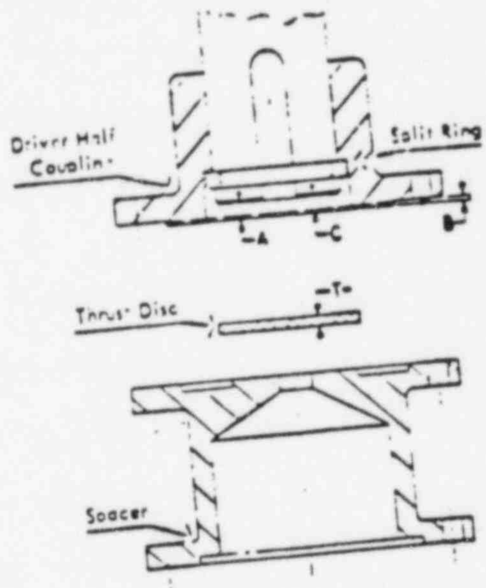
16. Attach lifting lines to the driver lifting lugs, lift the driver to position on the pump cover top plate (2-3) and install the driver hold down cap screws (2-9). Remove the lifting lines from the driver lifting lugs.

17. Determine that the driver half coupling (6-8) is seated firmly on the split ring (6-9). Determine that the mounting faces of the pump half coupling (6-1), spacer (6-4), thrust disc (6-10) and driver half coupling (6-8) are free of dirt, burrs or raised surfaces caused by nicks. If this installation involves only the originally supplied driver and coupling components, disregard Step 18 and proceed to Step 19. If this installation involves a replacement driver or a replacement spacer (6-4), provide also a replacement thrust disc (6-10), check the thrust disc (6-10) for proper thickness as described in Step 18, then proceed to Step 19.

(Continued on Page 4-3)

18. Determine the proper thickness of the thrust disc (6-10) according to the procedures shown in Figure 1, below. If the thrust disc (6-10) is oversize, machine the thrust disc (6-10) to achieve the proper dimensions. When the thrust disc is properly sized, proceed to Step 19.

CAUTION: SURFACES OF THRUST DISC (6-10) MUST BE HELD PARALLEL WITHIN .001".



PROCEDURE FOR SIZING THE THRUST DISC:

1. Measure and record the thickness of the thrust disc (6-10) as supplied.

2. Find the required thickness (Dimension "T") from the formula:

C = A-B; T = C-.002" to .004".

FIGURE 1 - SIZING THE THRUST DISC

19. Install the spacer (6-3), push up on driver half coupling (6-8) to install the thrust disc (6-4), pull down to seat the driver half coupling (6-8) firmly on the split ring (6-9), then install and connect all of the coupling-to-spacer cap screws (6-5), washers (6-7) and nuts (6-6).

20. Refer to the Outline and Piping Drawings for details regarding orientation and installation of the auxiliary equipment.

4.2 PREPARE FOR STANDBY CONDITION:

1. Install and connect any required auxiliary piping and wiring.

2. Check for security of all bolting piping and wiring.

3. Refer to the reactor systems manual for instructions regarding filling the pump.

4. Refer to the motor instruction book to determine that the motor bearings are sufficiently lubricated.

5. Refer to the reactor systems manual for instructions regarding starting of the motor. Energize the pump motor only enough to check motor shaft rotation, which should be COUNTER-CLOCKWISE as viewed looking down on the top end of the motor. If motor shaft rotates incorrectly, interchange any two motor leads to establish correct rotation.

6. Recheck all equipment for proper lubrication, recheck security of all bolting, piping and wiring, and refer to the reactor systems manual for directions regarding securing the unit in standby condition.

SECTION FIVE - OPERATION

5.1 EMERGENCY OPERATION: As discussed in Paragraph 1.8.1, the pump remains in flooded condition, ready to be started at any time by the remote control switches. Refer to the reactor systems manual for directions regarding starting and stopping of the pump.

5.2 IDLE PERIODS AND WET LAY-UP: Unless the pump is stopped for inspection and repair, maintain the pump in standby condition as directed in Paragraph 4.2 and as governed by the reactor systems manual.

5.3 DRY LAY-UP: If the pump is to be removed from the installation site, proceed as follows:

1. Disassemble the unit as directed in Paragraph 6.1.
2. Place a temporary cover (of plywood or other material) over the pump case (1-1).
3. Inspect, clean and store the pump components as directed in Paragraph 6.2.
4. Inspect, clean and store the motor as directed in the motor instruction book.

SECTION SIX - MAINTENANCE

CAUTION: BEFORE BEGINNING THE MAINTENANCE PROCEDURES, REVIEW THE REQUIREMENTS OF PARAGRAPH 1.7.

6.1 DISASSEMBLY:

6.1.1 Remove Shaft Seal Only:

1. Determine that the motor leads are disconnected from the power source, and that the unit can not be started by the remote control switches.

2. Drain the pump as far as possible.

3. Disconnect all auxiliary piping and wiring, and remove all instruments that could interfere with the disassembly work.

4. Disconnect and remove the spacer-to-driver half coupling nuts (6-6), washers (6-7) and cap screws (6-5) and lower the rotating element assembly to rest the pump half coupling (6-1) against the seal flange (5-1).

5. Push up on the driver half coupling (6-8) to permit removal of the thrust disc (6-10), disconnect and remove the remaining coupling nuts (6-6), washers (6-7) and cap screws (6-5), then remove the coupling spacer (6-4).

6. Bend down the tab of the lock washer (6-3), then remove the lock nut (6-2), R.H. Thread), lock washer (6-3), pump half coupling (6-1) and key (6-11).

7. Remove the seal flange (5-1) from the pump cover (2-1), then remove as a unit the seal flange (5-1) and stationary face (5-S-14).

8. Remove the stationary face (5-S-14) from the seal flange (5-1). Remove the rotating face (5-S-15) and U-Cup (5-S-4) from the pump shaft (4-1). Protective wrap and store the seal faces (5-S-14 and 5-S-15) pending inspection.

9. Take hold of the spring holder (5-S-17) to remove as a unit the spring holder sub-assembly. Push the drive keys (5-S-3) out of the spring holder (5-S-17) and seal drive (5-S-2), then remove the seal drive (5-S-2) and coil spring (5-S-16) from the spring holder (5-S-17).

10. Inspect and clean the shaft seal components as directed in Paragraph 6.2. Re-assemble the shaft seal sub-assemblies as directed in Paragraph 6.3.1.

6.1.2 Disassemble Pumping Unit:

1. Remove the shaft seal as directed in Paragraph 6.1.1.

2. Attach lifting slings to the motor lifting lugs.

3. Remove the stud nuts (2-6) from the case studs (2-5), and, if required, use back-off screws in the taps provided to break the gasket joint of cover (2-1) to case (1-1).

4. Lift up on the slings to remove the motor-pump cover-rotating element assembly to a clean work area. Support this assembly on wood blocks placed under the flange of the pump cover (2-1), allowing space beneath for access to and removal of the impeller (3-1). Remove the hydrostatic bearing chamber gasket (2-10). Do not yet remove the motor lifting slings.

5. Remove the cover-to-case gasket (2-4), and place a temporary cover (of plywood or other material) over the pump case (1-1).

6. Disconnect and remove the motor hold down cap screws (2-9), lift up and remove the driver to another set of support blocks, and detach the lifting slings. If the motor bearings are to be inspected, push up on driver half coupling (6-8) to remove the split ring (6-9), then remove the driver half coupling (6-8) and key (6-12).

7. A[illegible] an eye bolt in the tapped hole at the top face of the pump shaft (4-1) and attach a lifting line to the eye bolt. Place wood block supports at the outer diameter of the impeller (3-1). Drill out the lock pin (3-4), remove the cap screw (3-3, R.H. Thread), remove the impeller nut (3-2, L.H. Thread), then lift and draw the pump shaft (4-1) out of the impeller (3-1) and pump cover (2-1) and remove the impeller key (4-2). Place the pump shaft (4-1) horizontally on suitable supports and remove the lifting line and eye bolt. Carefully lower the impeller (3-1) clear of the pump cover (2-1), and place the impeller (3-1) safely on a work bench.

8. Refer to diametral running clearances, shown in the Data Page (following the Title Page) and examine the case wear ring (1-2) and the combination hydrostatic bearing-cover wear ring (2-7) for evidence of damage or increase in clearances. If examination reveals ovality, heavy marks or approximately 10% increase in the referenced clearances of the piece, replacement is indicated. To remove these pieces first drill out the set screws (1-3 and 2-8), then use puller tools in the taps provided to free and remove the pieces.

CAUTION: WHEN REMOVING THE CASE WEAR RING SET SCREWS (1-3), BLOCK OFF THE CASE NOZZLE OPENINGS TO PREVENT ENTRY OF DRILL CHIPS INTO SYSTEM PIPING.

Note: Removal of the combination hydrostatic bearing-cover wear ring set screws (2-8) does not affect the case nozzle openings, as the pump cover (2-1) has been removed from the pump case (1-1) to a clean area.

6.2 INSPECTION AND CLEANING:

1. Inspect cover-to-case gasket (2-2), hydrostatic bearing chamber gasket (2-10), seal flange gasket (2-11), U-Cup (5-S-4) and seat gasket (5-S-13) for out of roundness and loss of resiliency. Discard and provide replacement parts for any of these parts showing out-of-roundness or loss of resiliency.

2. Determine that the pump shaft (4-1) is free of dirt and burrs. Mount the pump shaft (4-1) in a lathe and use a dial indicator to check the shaft for straightness. Total indicator reading at any point should not exceed .001".

3. Discard, and provide replacement parts for, any pump parts not meeting the diametral running clearance specifications (see Data Page following the Title Page).

4. Wash, rinse and dry all pump and mechanical seal metal parts as directed in the Cleaning, Packaging and Storing Specifications, IT-3752.

5. Check all parts for wear or damage. Discard, and provide replacement parts for, all parts worn or damaged sufficiently to affect pump operation.

6. Inspect the mechanical seal faces (5-S-14 and 5-S-15) as follows:

A. Stationary Face (5-S-14): If circular lines are visible on the lapped surface, return the face to the factory for relapping. If edges on the I.D. or O.D. are chipped 1/32" or less, chamfer the edges to remove the nicks. If the edges are chipped or nicked more than 1/32", or fractured all the way through, replace the stationary face (5-S-14).

B. Rotating Face (5-S-15): If the lapped surface is heat checked and penetrations are 1/32" or less, return the face to the factory for relapping. If penetrations are more than 1/32", or fractured all the way through, replace the rotating face (5-S-15).

7. Repeat the cleaning procedures of Step 4 for all metal parts to be reassembled. Use clean, filtered compressed air to blow out all parts and orifices.

NOTE: If the pump parts are to be stored for some time before reassembly, protective wrap the parts as directed in the Cleaning, Packaging and Storing Specification, IT-3752.

6.3 REASSEMBLY:

6.3.1 Reassemble Shaft Seal Sub-Assemblies:

1. Sort out on a work bench all parts for the mechanical seal. Determine that all seal parts are clean and in working condition.

2. Identify and place in separate protective sacks the seal flange-to-[illegible] (2-11), the four seal flange-to-cover cap screws (2-12) and the [illegible]. Identify and protective wrap the rotating face (5-S-15).

3. Identify the seal flange (5-1), seat gasket (5-S-13) and stationary face (5-S-14). Place the seal flange (5-1) on the work bench with its inner face upward. Lightly lubricate the seat gasket (5-S-13), install the seat gasket (5-S-13) on the stationary face (5-S-14) and install the stationary face (5-S-14) in the seal flange (5-1), being certain that the stationary face is held firmly by fit of the seat gasket (5-S-13) with the seal flange (5-1). Identify these components as "Stationary Sub-Assembly", and protective wrap the sub-assembly.

4. Identify the spring holder (5-S-17), coil spring (5-S-16), seal drive (5-S-2) and the two drive keys (5-S-3). Place the spring holder (5-S-17), large I.D. upward, on blocks or in a holding fixture. Install the coil spring (5-S-16) in the spring holder (5-S-17) and rest the seal drive (5-S-2), large I.D. upward, on the coil spring (5-S-16). Press down on the seal drive (5-S-2), line up the drive key holes in the seal drive (5-S-2) with the slots in the spring holder (5-S-17), and install the drive keys (5-S-3) through the bore of the seal drive (5-S-2) to engage the slots in the spring holder (5-S-17). Identify these assembled components as "Spring Holder Sub-Assembly" and protective wrap the sub-assembly.

5. Pending installation of the shaft seal components, provide a protective box or carton for storing the stationary sub-assembly, the spring holder sub-assembly, and the components identified and wrapped in Step 2.

6.3.2 Reassemble Pumping Unit:

1. Install a new case wear ring (1-2) and/or combination hydrostatic bearing-cover wear ring (2-7) if either of these pieces has been removed.

2. Place the pump cover (2-1) on wood block supports at sufficient height to permit access for installation of the impeller (3-1). Lightly lubricate the hydrostatic bearing chamber gasket (2-10), and install the gasket (2-10) in its groove in the pump cover (2-1).

3. Support the impeller (3-1) beneath the pump cover (2-1) in a manner that will not interfere with the clearance required for attachment of the impeller fasteners.

4. Attach a lifting eye bolt and line at the top face of the pump shaft (4-1), lift and center the pump shaft (4-1) in the bore of the pump cover (2-1), place the impeller key (4-2) in the impeller (3-1), then lower the pump shaft (4-1) through the pump cover (2-1) and into the impeller (3-1) to engage the key (4-2).

5. Lightly lubricate the impeller nut (3-2) and cap screw (3-3). Install the impeller nut (3-2, L.H. Thread), cap screw (3-3, R.H. Thread) and lock pin (3-4), then plug weld the lock pin (3-4) as shown in the Sectional Drawing, 1E-3525. Remove the line and eye bolt from the pump shaft (4-1).

6. Refer to Paragraph 6.2.1, Step 5. Place the shaft seal components convenient to the pump assembly area.

7. Install the spring holder sub-assembly on the pump shaft (4-1), engaging the drive keys (5-5-3) with the shaft slots and mating the inner shoulder of the seal drive with the shaft shoulder. Check for engagement of the drive keys (5-5-3) by attempting to rotate the spring holder sub-assembly.

8. Lightly lubricate the U-Cup (5-5-4) on all its surfaces. Install the U-Cup (5-5-4) on the lip of the spring holder (5-5-17), being certain that the U-Cup (5-5-4) does not curl up against the pump shaft (4-1).

9. Install the rotating face (5-5-15) over the U-Cup (5-5-4) to engage the rotating face lugs with the slots in the spring holder (5-5-17).

10. Lightly lubricate the seal flange gasket (2-11) and cap screws (2-12). Position the gasket (2-11) on the seal flange (5-1), install the seal stationary sub-assembly on the pump cover (2-1), then install and tighten the seal flange-to-cover cap screw (2-12).

11. Install the coupling key (6-11) and the pump half coupling (6-1). Install and tighten the pump half coupling lock nut (6-2), line up one external tab of the lock washer (6-3) with the corresponding lock nut slot, and bend the tab into the slot of the lock nut (6-2).

12. Attach eye bolts in two of the motor cap screw taps in the top plate (2-3), and attach lifting slings to the eye bolts. Complete the reassembly of the pumping unit as directed in Paragraph 4.1, Steps 12 through 20. Return the pump to standby condition as directed in Paragraph 4.2.

SECTION SEVEN - SPARE PARTS

7.1 RECOMMENDED SPARE PAPTS: It is recommended that customer stock for these pumps the spare parts listed below. The parts are shown in Sectional Drawing 1E-3525 and Materials of Construction Drawing 1T-3855.

Part No.		Quantity Per Pump
1-2	Case Wear Ring	3
1-3	Hex. Soc. Hd. Set Screw, Wear Ring	1
2-4	Gasket, Cover-to-Case	1
2-7	Hydrostatic Bearing and Wear Ring	3
2-8	Hex. Soc. Hd. Set Screw, Wear Ring	1
-10	Gasket, Hydrostatic Bearing Chamber	1
2-11	Gasket, Seal Flange-to-Cover	1
3-3	Hex. Soc. Hd. Cap Screw, Impeller Nut	1
3-4	Lock Pin, Impeller Nut Cap Screw	1
5-5-4	U-Cup	1
5-5-13	Seat Gasket	1
5-5-14	Stationary Face	1
5-5-15	Rotating Face	1
6-2	Lock Nut, Pump Half Coupling	1
6-3	Lock Washer, Pump Half Coupling Lock Nut	

7.2 ORDERING SPARE PARTS:

1. Standard Parts: When ordering standard replacement parts, be certain to state:

(a) Parts for BYRON JACKSON Pump of type, service and serial number shown on pump nameplate.
(b) Correct part numbers and nomenclature, without abbreviations, as shown in the Sectional Drawing, 1E-3525, and Materials of Construction Drawing, 1T-3855.

(Continued on Page 7-2)

2. Parts for pumps on which operating conditions have been changed: If operating conditions have been changed since pump was purchased, add full particulars of new operating conditions. This is especially important in selection of new impellers.

NOTE: Should a change in operating conditions be considered, consult nearest BYRON JACKSON representative or factory to determine whether such a change is feasible.

3. Oversized or Undersized Parts: If oversized or undersized parts are required add:

(a) Dimensions (with sketch of part, if possible).
(b) "BYRON JACKSON TO FINISH", or "LEAVE ROUGH - CUSTOMER TO FINISH".

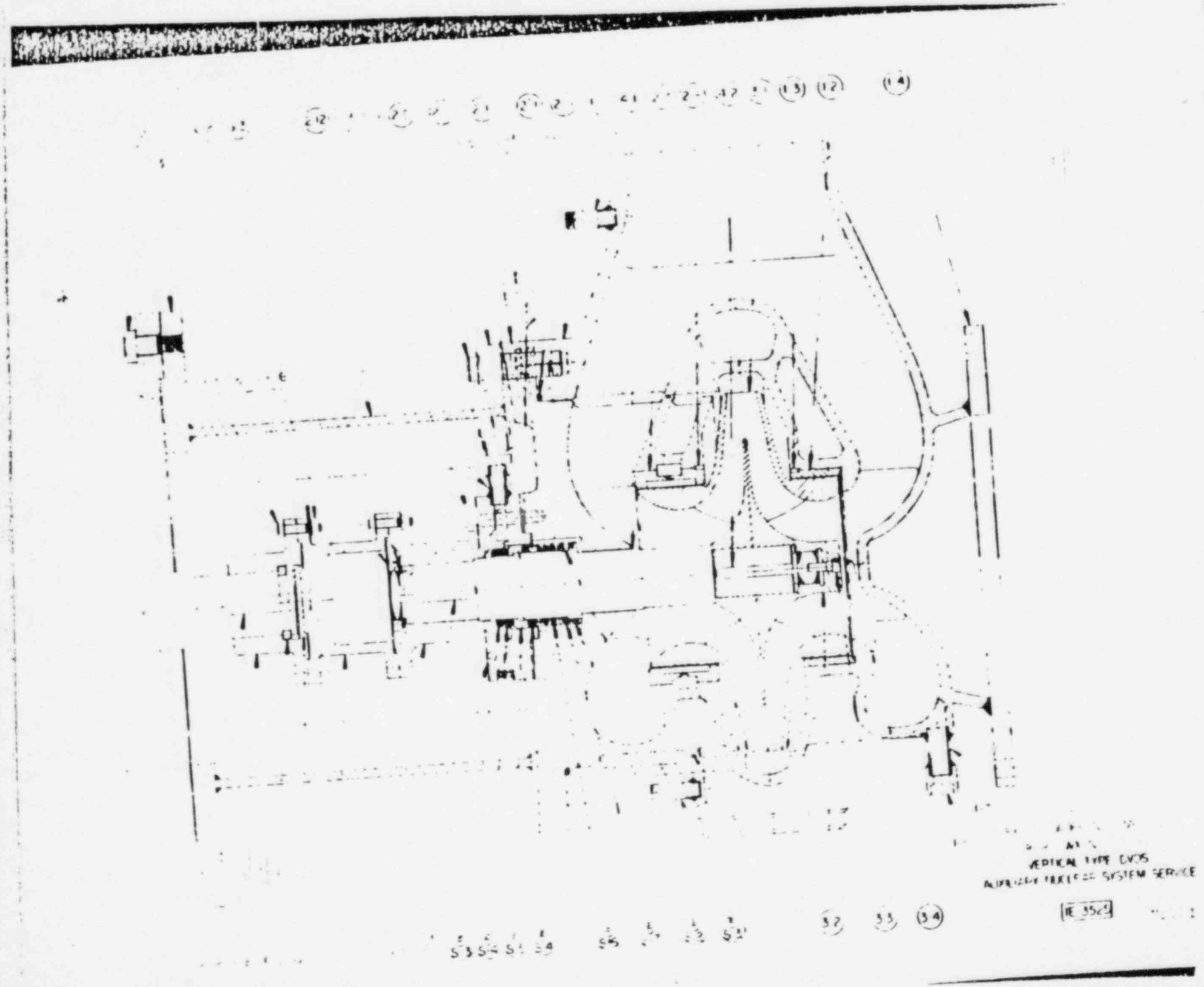
NOTE: Customer finishes parts at customer's own risk.

4. Field Alterations: BYRON JACKSON accepts no responsibility for incorrect replacement of original parts which have been altered in the field.

SECTION EIGHT

REFERENCE MATERIALS

(See List in Paragraph 1.2)



13
12
14
34
SYSTEM SERVICE

Byron Jackson Pump Division
BORG-WARNER CORPORATION
LOS ANGELES DIVISION

MATERIALS OF CONSTRUCTION

L.I.L.CO. CORE SPRAY PUMPS

CUSTOMER: General Electric Company - APED G.E. ORDER NO. 205 AA 728

REF: Byron Jackson Drawing No. 1E-3525 B.J. ORDER NO. 691 S-1111 12

PART NO.	NAME	MATERIAL SPECIFICATION
1	Pump Case Assembly	
1-1	Pump Case	ASTM A-216 GR. WCB
1-2	Case Wear Ring	ASTM A-564 Type 630 Cond. H1075
1-3	Hex Soc. Hd. Set Screws - Wear Ring	ASTM A-193 GR. B8
1-4	Foundation Plate	ASTM A-516 GR. 55
1-5	Pipe	ASTM A-106 GR. B
1-6	Pipe	ASTM A-106 GR. B
1-7	Pipe	ASTM A-106 GR. B
1-8	Coupling	ASTM A-234 GR. WPB
2	Pump Cover Assembly	
2-1	Pump Cover	ASTM A-216 GR. WCB
2-2	Barrel	ASTM A-516 GR. 55
2-3	Top Plate	ASTM A-516 GR. 55
2-4	Gasket - Cover to Case	ASTM D-2000 CL. 2 BA810 C_{12} F_{17}
2-5	Stud - Cover to Case	ASTM A-193 GR. B7 Phosphate Coated
2-6	Nut - Cover to Case Stud	ASTM A-194 GR. 7
2-7	Hydrostatic Bearing and Wear Ring	ASTM A-564 Type 630 Cond. H1075
2-8	Hex. Soc. Hd. Set Screws	ASTM A-1[illegible] GR. [illegible]
2-9	Hex. Hd. Cap Screw - Motor Hold Down	ASTM A-325
2-10	Gasket - Hydrostatic Bearing Chamber	ASTM A-2000 CL. 2 4A 810 C_{12} F_{17}
2-11	Gasket - Seal Flange to Cover	ASTM A-2000 CL. 2 BA 8.0 C_{12} F_{17}
2-12	Hex. Hd. Cap Screw - Seal Flange	ASTM A-193 GR. 7 Phosphate Coated
2-13	Union	ASTM A-2[illegible] GR. [illegible]
2-14	Pipe	ASTM A-[illegible]

9-1E-3055
691-S-1111
Page 1 of 3
25 Feb. 19[illegible]

Byron Jackson Pump Division
BORG-WARNER CORPORATION

PART NO.	NAME	MATERIAL SPECIFICATION
3	Impeller Assembly	
3-1	Impeller	ASTM A-351 GR. CA15 B/C 28-32
3-2	Impeller Nut	ASTM A-276 Tp. 410 B/C 28-32
3-3	Hex. Soc. Hd. Cap Screw - Impeller Nut	ASTM A 193 GR. B6 B/C 28-32
3-4	Lock Pin - Impeller Nut Cap Screw	ASTM A-276 Tp. 304
4	Shaft Assembly	
4-1	Pump Shaft	ASTM A-479 Tp. 316
4-2	Key - Impeller Drive	ASTM A-276 Tp. 316
5	Seal Assembly	
5-1	Seal Flange	ASTM A-182, F 304
5-3	Pipe	ASTM A 106 GR. B
5-4	Union	ASTM A-234 GR. WPB
5-5	Pipe	ASTM A-106 GR. B
5-6	Union	ASTM A-234 GR. WPB
5-8-2	Seal Drive	ASTM A-276 Tp. 304
5-8-3	Drive Key	ASTM A-276 Tp. 304
5-8-4	U-Cup	ASTM D-2000 Cl. 2 B/810 C_{12} F_{17}
5-8-13	Seat Gasket	ASTM D-2000 Cl. 2 B/810 C_{12} F_{17}
5-8-14	Stationary Face	Carbon A
5-8-15	Rotating Face	ASTM A-276 Tp. 304L/Stellite Overlay
5-8-16	Coil Spring	ASTM A-276 Tp. 304
5-8-17	Spring Holder	ASTM A-276 Tp. 304
6	Coupling Assembly	
6-1	Pump Half Coupling	ASTM A-362 GR. CA15 B/C 28-32
6-2	Locknut - Pump Half Coupling	ASTM A-108 GR. C1020
6-3	Lockwasher	Cad Plated AISI C-1020 Commercial
6-4	Spacer	ASTM A-[illegible]
6-5	Hex. Hd. Cap Screws	ASTM A-325
6-6	Nuts	ASTM A-325
6-7	Lockwashers	AISI C1020 Commercial
6-8	Motor Half Coupling	ASTM A-362 GR. CA15 B/C 28-32
6-9	Split Ring - Motor Coupling	ASTM A-276 Tp. 410 B/C 28-32
6-10	Thrust Disc	ASTM A-276 Tp. 410 B/C 28-32
6-11	Key - Pump Half Coupling	ASTM A-276 Tp. 416 B/C 32 max.
6-12	Key - Motor Half Coupling	ASTM A-276 Tp. 416 B/C 32 max.

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Page 2 of ...
... Feb. 1971

Byron Jackson Pump Division
BORG-WARNER CORPORATION

PART NO.	NAME	MATERIAL SPECIFICATION
**	Cyclone Separator Assembly	ASTM A-351, GR. CF8M
	Housing	ASTM A-108, GR. C1020
	Tube Fittings - Swagelok or Equal	ASTM A-193, GR. B7
	Hex. Hd. Cap Screws	ASTM A-194, CL. 2H
	Nuts	ASTM D-2000, CL. 2 BA810 C_{12} F_{17}
	Gasket	ASTM A-276, Tp. 304
	Orifice	ASTM A-179
	Tubing	

** Not shown

[illegible]	DESCRIPTION	REMARKS	MATERIAL
1	[illegible] SEPARATOR	[illegible]	STAINLESS STEEL
2	ORIFICE	[illegible]	STEEL
3	[illegible] CONNECTOR	[illegible] (OR EQUAL)	STEEL
4	MALE CONNECTOR	[illegible] (OR EQUAL)	STEEL
5	FEMALE CONNECTOR	[illegible] (OR EQUAL)	[illegible]
6	TUBING	[illegible]	[illegible]

[illegible]

[illegible]	DESCRIPTION	REMARKS	MATERIAL
1	[illegible] SEPARATOR	[illegible]	STEEL
2	ORIFICE	[illegible]	STEEL
3	[illegible] CONNECTOR	UNIVERSAL TUBE FS [illegible] (OR EQUAL)	STEEL
4	MALE CONNECTOR	UNIVERSAL TUBE FS [illegible] (OR EQUAL)	STEEL
5	FEMALE CONNECTOR	UNIVERSAL TUBE FS [illegible]	[illegible] STEEL
6	TUBING	[illegible] W/ [illegible] WALL	

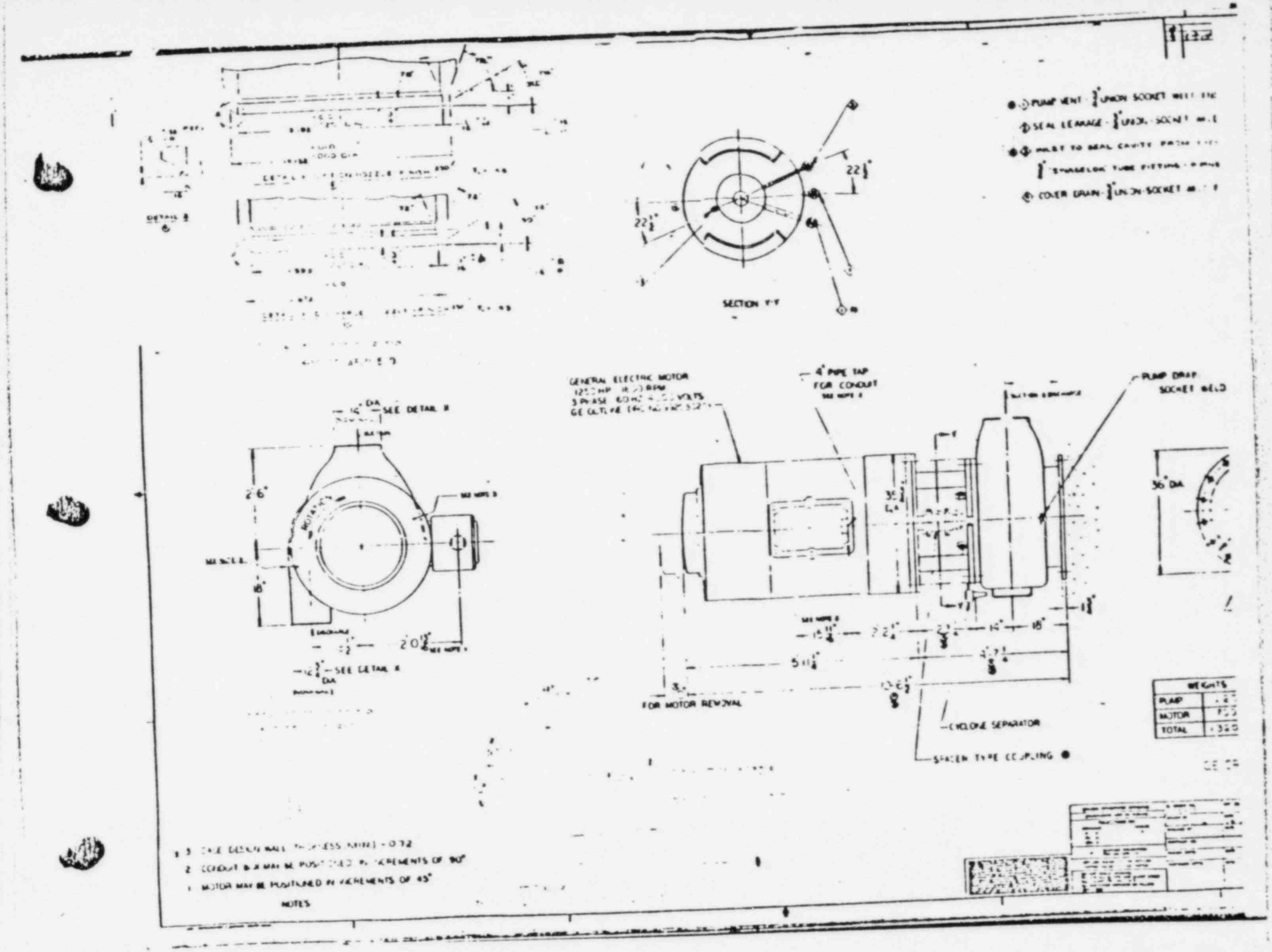
B&W

[illegible] RING

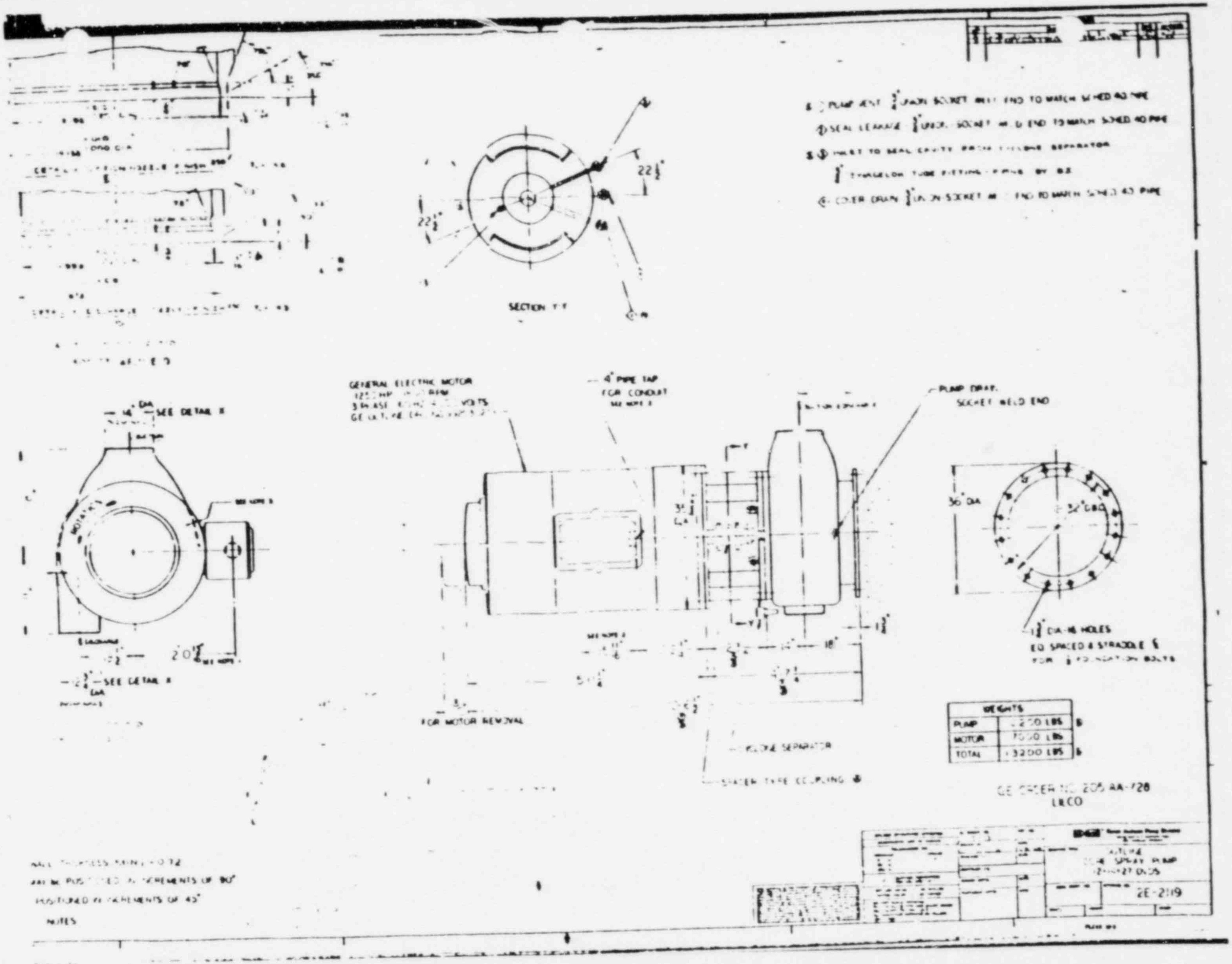
CORE SPRAY [illegible]

[illegible] VERTICAL

EC-4966



PUMP VENT · 3/4" UNION SOCKET WELD
SEAL LEAKAGE · 3/4" UNION SOCKET WELD
INLET TO SEAL CAVITY
3/4" SWAGELOK TUBE FITTING
COVER DRAIN · 3/4" UNION SOCKET WELD
SECTION Y-Y
22 1/2°
DETAIL B
GENERAL ELECTRIC MOTOR
4" PIPE TAP FOR CONDUIT
PUMP DRAIN SOCKET WELD
36" DIA
SEE DETAIL B
SEE DETAIL A
2'-6"
18"
FOR MOTOR REMOVAL
CYCLONE SEPARATOR
SPACER TYPE COUPLING
WEIGHTS
PUMP
MOTOR
TOTAL
3 CASE DESIGN WALL THICKNESS (MIN) = 0.72
2 CONDUIT BOX MAY BE POSITIONED IN INCREMENTS OF 90°
1 MOTOR MAY BE POSITIONED IN INCREMENTS OF 45°
NOTES


PUMP VENT ¾ UNION SOCKET WELD END TO MATCH SCHED 40 PIPE
SEAL LEAKAGE ¾ UNION SOCKET WELD END TO MATCH SCHED 40 PIPE
INLET TO SEAL CAVITY FROM CYCLONE SEPARATOR
COVER DRAIN ¾ UNION SOCKET WELD END TO MATCH SCHED 40 PIPE
22½°
SECTION Y-Y
GENERAL ELECTRIC MOTOR
4" PIPE TAP FOR CONDUIT
PUMP DRAIN SOCKET WELD END
SEE DETAIL X
36" DIA
32" DIA
DIA 16 HOLES
EQ SPACED & STRADDLE ℄
FOR MOTOR REMOVAL
CYCLONE SEPARATOR
SPACER TYPE COUPLING
WEIGHTS
PUMP
MOTOR
7050 LBS
TOTAL
13200 LBS
GE ORDER NO 205 AA-728
LECO
CORE SPRAY PUMP
2E-2119
NOTES

BYRON JACKSON PUMP DIVISION
BORG WARNER CORPORATION
LOS ANGELES, CALIFORNIA

SPECIFICATION FOR CLEANING, PAINTING, AND PACKAGING OF AUXILIARY PUMPS FOR NUCLEAR SYSTEM SERVICE

1. <u>SCOPE</u>:

   1.1 This specification covers the procedures for cleaning, painting, and packaging of auxiliary pumps for nuclear system service, unless otherwise specified on Engineering Bills of Material.

2. <u>CLEANING</u>:

   2.1 After testing the pump shall be detergent washed and steam rinsed to remove all dirt, grease, oil, and other foreign material.

3. <u>PAINTING</u>:

   3.1 All external, non-machined surfaces shall be painted one coat of zinc chromate primer with a minimum dry thickness of 2 mils, and one coat of standard Byron Jackson enamel. The total dry thickness shall be a minimum of 3 mils.

   3.2 Precautions must be taken to ensure that no primer or paint is deposited on internal pump surfaces.

   3.3 Austenitic stainless steel shall not be painted.

4. <u>PACKAGING FOR SHIPMENT</u>:

   4.1 All internal surfaces shall be coated with a solution of 1/2 percent sodium nitrite, 1/4 percent monosodium phosphate and 1/4 percent disodium phosphate prior to closure of openings.

   4.2 All accessible exposed machined surfaces shall be coated with Valvoline Tectyl 846.

   4.3 All openings shall be closed with tight fitting covers which are firmly secured in place and covered with polyethylene so that no dirt or moisture can enter the pump during transit or storage. Connections, nozzle welding end preparations, and other areas subject to damage, shall be suitable protected against mechanical abuse.

   4.4 Small items may be shipped in sealed polyethylene or similar plastic containers. When containers are used provisions shall be made to ensure that containers are protected from punctures.

   4.5 The pump shall be suitable crated to prevent mechanical damage to the openings during transit and storage.

INSTALLATION AND MAINTENANCE

I. PUMP PREPARATION

[illegible]

II. SEAL ASSEMBLY

[illegible]

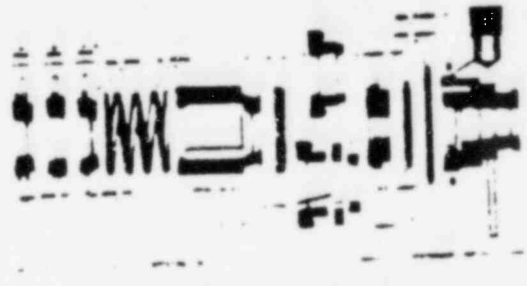


Figure 2 – Rotating Unit – Stationary Unit

III. ASSEMBLE SEAL AS FOLLOWS:

Figure 3 – Place spring (S-16) in spring holder (S-17). [illegible]

Figure 4 – Compress spring (S-16) into spring holder (S-17) with seal drive (S-2) [illegible]

Figure 5 – [illegible]

Figure 6 – [illegible]

Figure 7 – Be sure rotating face (S-15) is clean and free of scratches before installing [illegible]

Figure 8 – [illegible]

Figure 9 – [illegible]

Figure 10 – [illegible]

Figure 11 – [illegible]

IV. COMPLETING ASSEMBLY

[illegible]

V. PIPING INSTRUCTIONS

Mechanical seal [illegible] will be [illegible] Piping should be [illegible] from the seal flange [illegible] than existing in the stuffingbox. A throttle [illegible] to seal flow to the minimum [illegible] cooling. A very [illegible] When [illegible] seal so that stuffingbox pressure [illegible] to prevent flashing [illegible]

Figure A – Single stage overhung process pump with [illegible] Stuffingbox under suction pressure. Pipe from discharge to seal flange. Control flow with orifice in line or throttle bushing in bottom of the stuffingbox.

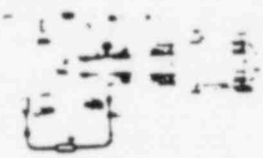


Figure B – Single stage overhung pump with enclosed impeller. Stuffingbox normally under discharge pressure [illegible]. Pipe from seal flange to [illegible] suction. Control flow with orifice in line.

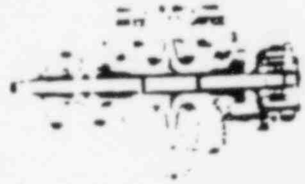


Figure C – Single stage double suction [illegible] pump. Stuffingboxes under [illegible]. Pipe from discharge to [illegible] with orifice [illegible] with throttle bushing in [illegible] stuffingbox.

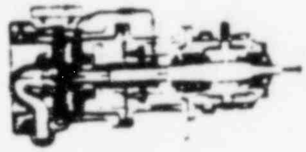


Figure D – Two stage overhung process pump. Stuffingbox under first stage suction pressure. Pipe from discharge of first or second stage. Control flow with orifice in line or by throttle bushing in bottom of stuffingbox.

Figure E – Two stage opposed impeller two bearing pump. One stuffingbox under suction and the other under first stage pressure. Pipe from seal flange to seal flange. Control flow with orifice in line.

Figure F – Four stage opposed impeller two bearing pump. One stuffingbox under suction [illegible] other under second stage pressure. Pipe from seal flange to seal flange. Control flow with orifice in line.

Figure G – Vertical [illegible] turbine type pump. Stuffingbox under discharge pressure. Pipe from seal flange back to suction [illegible]. Control flow with orifice in line.

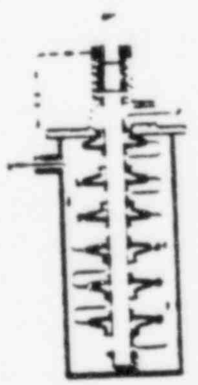


Figure H – Vertical multi-stage pump. Stuffingbox under suction pressure. Pipe from discharge to seal flange. Control flow with orifice in line.

VI. OPERATING INSTRUCTIONS

Before starting [illegible] mechanical seal [illegible] pump is full of liquid [illegible] NEVER be allowed to run dry at any time.

Occasionally mechanical [illegible] slight leakage when first started. [illegible] have not quite seated. [illegible] However after a short time leakage [illegible] mechanical seal still [illegible] and seal checked for alignment [illegible] checked for scoring and wear.

VII. MAINTENANCE SUGGESTIONS

Relapping Seal Faces

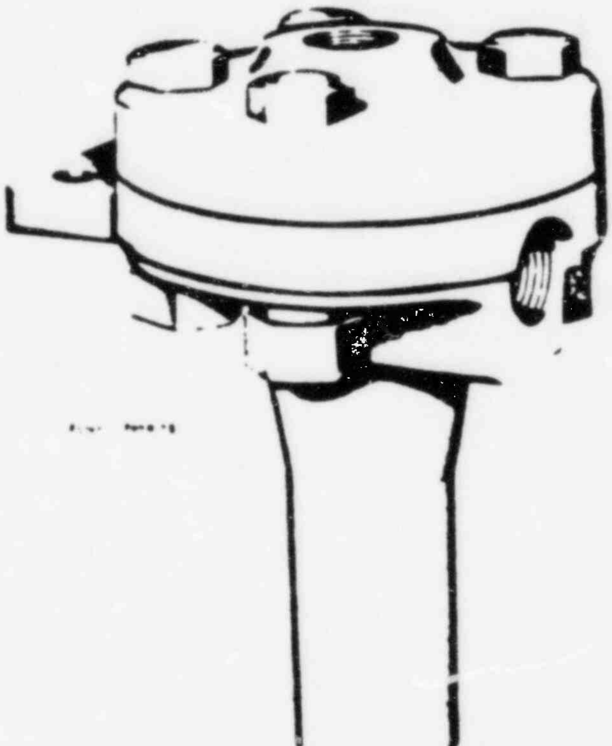
Seal faces can be [illegible] excellent [illegible] provided proper equipment [illegible] are careful [illegible] These [illegible]

DIAMOND LAPPING PLATES

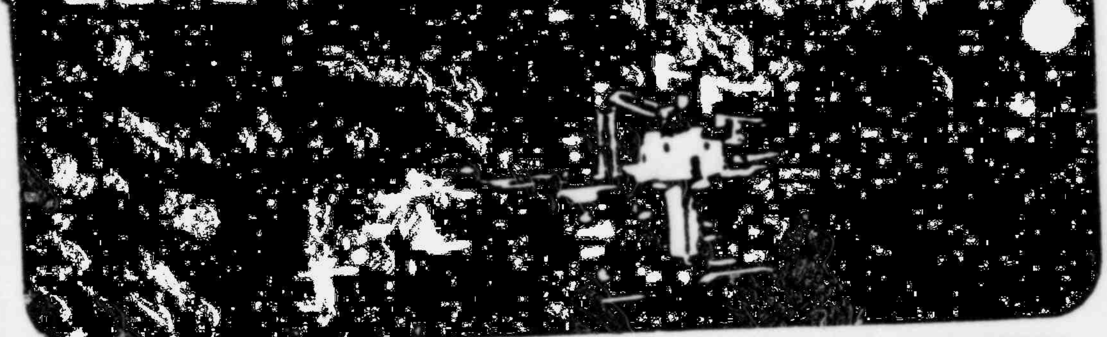
[illegible]

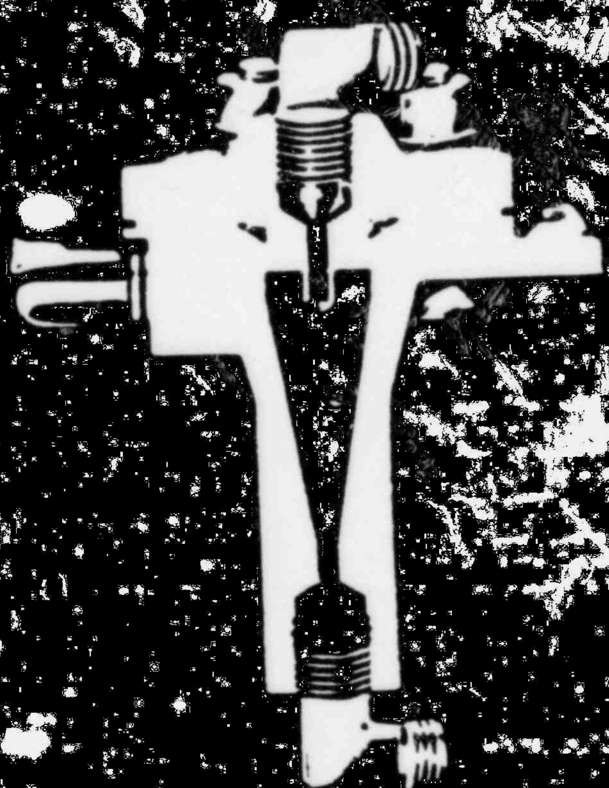
The lap plates [illegible] with diamond [illegible]

BORG-WARNER
SEPARATORS
CYCLONE and MAGNETIC



BORG-WARNER SEPARATORS





T.043

Borg-Warner Cyclone Separators Successfully Eliminate Seal Problems

by efficiently removing sand, pipe scale and other abrasive [illegible] flow to mechanical seals

Model 10062 Zirite Separator

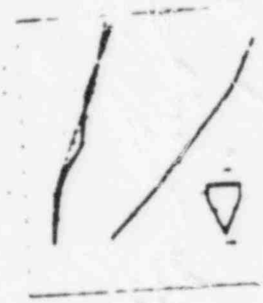
Constructed [illegible] resistant Zirite [illegible]

Can be used for water [illegible] hydrocarbons [illegible]

Acting pressure [illegible] [illegible] P.S.

[illegible] [illegible]

Acting pressure [illegible] [illegible] 350 P.S.



Models 10043 and 10045

Model 10043 is constructed of Type 316 Stainless Steel. Model 10045 is of Type 410 Chrome Steel hardened to about 40 Rockwell C.

Working pressure 2000 P.S.I.

Temperature limit [illegible] standard [illegible] 450° F

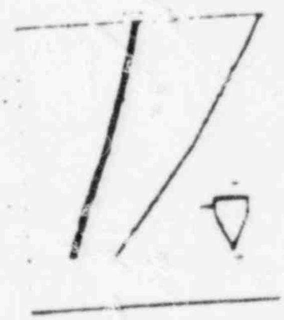
Temperature limit [illegible] special [illegible] 650° F

These models were developed for corrosive and non-corrosive fluids found in petroleum refining, petroleum [illegible] water systems and other high pressure service.

Models 10056 and 10057

Both of these models have the same pressure and temperature limits as Model 10043 and 10045 and were designed for the same service but at higher capacity.

Model 10056 is constructed of Type 316 Stainless Steel. Model 10057 is of Type 410 Chrome Steel hardened to about 40 Rockwell C.



As an example of separation efficiency, these Cyclone Separators remove [illegible] [illegible] P.S. [illegible] pressure

	SAND
[illegible] micron size	[illegible]
[illegible] micron size	[illegible]
[illegible] micron size	[illegible]

Pressure differential [illegible] should not be lower than 20 P.S.I. nor higher than 125 P.S.

Borg-Warner Magnetic Separators
Model 6670

The Borg-Warner Magnetic Separator removes Iron Oxide particles from boiler water and other liquids.

Although the Magnetic Separator was designed for Mechanical Seal injection flow, it can be installed in control lines and other locations to prevent Iron Oxide particles from causing operational problems.

Liquid enters the separator through one of the leads. Direction of flow is not important. Impinges against a baffle, flows through the magnetic field at low velocity, then flows over a second baffle and leaves the separator through the outlet lead.

As water flows through the magnetic field, Iron Oxide particles are attracted and held by the magnets.

Sales and Service Offices

CALIFORNIA
LOS ANGELES 90058
[illegible]
Phone 213 587 7151

SAN FRANCISCO [illegible]
[illegible]
Phone 415 781 6091

GEORGIA
ATLANTA 30301
[illegible] Box 383
Phone 404 237 [illegible]

ILLINOIS
CHICAGO [illegible]
[illegible]
Phone 312 427 2923

LOUISIANA
BATON ROUGE [illegible]
[illegible]
Phone [illegible]

NEW JERSEY
[illegible]
Phone 201 226 1434

OHIO
CLEVELAND [illegible]
[illegible] Box 422
Phone 216 331 2321

OKLAHOMA
TULSA 74145
[illegible]
Phone 918 627 5605

PENNSYLVANIA
PHILADELPHIA [illegible]
[illegible]
Phone 215 563 7932

TEXAS
[illegible]

WASHINGTON
[illegible]

AUSTRALIA
[illegible]

CANADA
[illegible]

JAPAN
[illegible]

MEXICO
[illegible]

NETHERLANDS
[illegible]

Borg-Warner Mechanical Seals [illegible]

BORG WARNER

[illegible] U.S.A.

INSTALLATION OPERATION AND MAINTENANCE INSTRUCTIONS

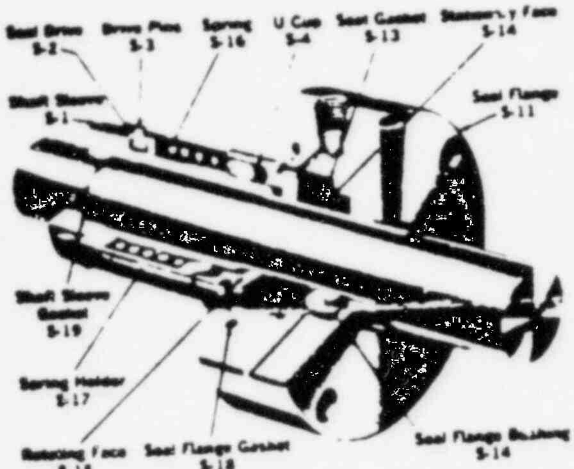
TYPE "U" MECHANICAL SEALS

BORG WARNER

TYPE "U" MECHANICAL SEALS

A BALANCED SEAL FOR HIGH PRESSURES AND TEMPERATURES

- Maximum Pressure to 1000 p.s.i.
- Pumping Temperature: water plus 32° F to plus 150° F; other liquids minus 100° F to plus 600° F
- Liquids: corrosive and non-corrosive
- Shaft Sizes: [illegible] through [illegible]



FEATURES

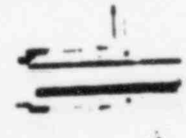
- U CUP AND SEAT GASKET FULLY CONFINED
  [illegible]
- POSITIVE DRIVE
  [illegible]
- SINGLE COIL SPRING
  [illegible]
- UNIFORM SPRING PRESSURE
  [illegible]
- FLEXIBILITY OF FACES
  [illegible]
- EASE OF DISMANTLING
  The entire rotating unit can be removed for inspection or repair without removing the shaft sleeve.
- PROTECTION AGAINST DAMAGE
  [illegible]

CHOICE OF 4 SHAFT SLEEVE & 4 FLANGE STYLES TO FIT YOUR INDIVIDUAL APPLICATION

Shaft Sleeve Arrangement Style No. 1
Synthetic rubber O ring shaft sleeve gasket. Maximum pressure to 1000 p.s.i. Temperature range minus 40° F to plus 450° F.

Shaft Sleeve Arrangement Style No. 2
Synthetic rubber O ring shaft sleeve gasket and [illegible]. Maximum pressure to [illegible]. Temperature range minus [illegible] F to plus 450° F.

Shaft Sleeve Arrangement Style No. 3
Teflon or metal shaft sleeve gasket. Maximum pressure to [illegible] p.s.i. Temperature range minus [illegible] F to plus [illegible] F.



Shaft Sleeve Arrangement Style No. 4
[illegible] Maximum pressure to [illegible] p.s.i. Temperature range minus [illegible] F to plus [illegible] F.
*Provided high temperature stationary face and gasket are used with proper seal design.

Flange Style "A"
No pipe taps. No flange bushing. Flush through stuffing box tap. Use for petroleum products under 175° F and [illegible]. Can also be used for water and other chemical service.

Flange Style "B"
Quench and drain taps only. Flush through stuffing box tap. Uses standard flange bushing. [illegible]

Flange Style "C"
Flush, quench, and drain taps. Uses standard flange bushing, auxiliary [illegible]. [illegible]

Flange Style "D" (not shown)
Similar to Style C except that it has flush tap only. No quench or drain taps. No flange bushing.

GENERAL ELECTRIC
NUCLEAR ENERGY DIVISION
ATOMIC POWER EQUIPMENT DEPARTMENT
San Jose, California

DOCUMENT NO. 21A9221 REV. [illegible]

APPLICATION

☒ SPECIFICATION ☐ DRAWING

TYPE PURCHASE

RECEIVED [illegible]

DOCUMENT TITLE CORE SPRAY AND RHR PUMPS

REVISIONS			
2	Revision per ECA #90701-2 - General Changes indicated by (♠)		
[illegible]	per ECN NE20843 - General Revision. Changes indicated by ([illegible]).		
[illegible]	per ECN's #NE215[illegible] and NE21594. Multiple changes. Changes indicated by (◆).		

RECEIVED [illegible] 2 1982

[illegible]	[illegible]	[illegible]	4-4-70	[illegible]

REVISION STATUS SHEET

TITLE CORE SPRAY AND RHR PUMPS

1. SCOPE

1.1. This specification defines the engineering requirements for Core Spray and RHR Pumps.

1.2. The work done by the Seller in accordance with this specification shall include all necessary design, development, analysis, drawings, fabrication, shop testing, inspection, and preparation for shipment.

1.3. The Seller shall accept full responsibility for his work and for compliance with this specification. Review or approval of drawings, data or specifications by the Buyer with regard to general design and controlling dimensions does not constitute acceptance of any designs, materials or equipment which will not fulfill the functional or performance requirements established by the purchase contract.

2. APPLICABLE DOCUMENTS

2.1. General

2.1.1. When a purchase part drawing and data sheet are used in conjunction with this specification, they form a part of this specification and shall be the controlling documents.

2.2. Codes

2.2.1. The following codes and standards of the issue in effect on the date of award of contract form a part of this specification to the extent specified herein.

2.2.1.1. Section III of the ASME Boiler and Pressure Vessel Code for Class C vessels shall be used as a guide in calculating the thickness of pressure-retaining parts and in sizing the cover bolting. Code stamps are not required.

2.2.1.2. USA Standard Code for Pressure Piping, Power Piping USAS B31.1.0.

2.2.1.3. Pumps shall be tested in accordance with the Standards of the Hydraulic Institute.

2.2.1.4. Materials selected for pump components shall be in accordance with the American Society for Testing and Materials (ASTM) as specified herein.

2.2.1.5. ASME Code for Nuclear Pumps and Valves as specified herein.

3. DESCRIPTION

3.1. General

3.1.1. The pumps are located near the bottom of the pressure suppression pool from which they draw their suction. The purpose of the core spray pumps is to prevent overheating of the core during an accident when the emergency core cooling system is in operation.

3.1.2. The RHR (Residual Heat Removal) pumps will be used for three different modes of operation. The Low Pressure Coolant Injection (LPCI) mode is used to restore and maintain reactor water level after a loss of coolant accident, the Containment Cooling mode is used to cool the suppression pool during an accident and during hot standby, and the Shutdown Cooling mode is used to cool the reactor during shutdown.

3.2. Supplied by Seller

3.2.1. The equipment to be furnished in accordance with this specification shall be a centrifugal pump complete with mechanical seals with cyclone dirt separator and seal-cooling heat exchanger (when required), with base plate, and all necessary accessories (such as tubing, piping, valves, fittings, etc.) which form an integral part of the pump sealing, venting, draining, and/or lubricating system.

3.2.2. All special tools required for the erection, dismantling, or replacement of any part of the pump assembly.

3.3. Supplied by Others

3.3.1. A suitable minimum-flow bypass line on discharge piping.

3.3.2. Motor

3.3.3. Installation Labor

3.3.4. External Piping, Valves, and Instrumentation

3.3.5. Motor Starter and Controls

3.3.6. Foundation, Anchor Bolts, and Leveling Plates

4. DESIGN REQUIREMENTS

4.1. Operating Conditions

4.1.1. Seal Cooling

4.1.1.1. Seal cooling water shall be provided by taking coolant from the pump discharge.

4.1.1.2. The maximum temperature of the water being pumped shall be as specified in applicable data sheets or purchase part drawing.

4.2. Hydraulic Requirements

4.2.1. Refer to applicable Data Sheet for hydraulic requirements.

4.3. Fabrication

4.3.1. General

4.3.1.1. The pump impeller, volute, wear rings, shaft, and seals shall be designed for as long a life as is practical. The design objective shall be to provide a unit which will not require removal from the system for rework or overhaul at intervals of less than 5 years (with the exception of mechanical seals). The casings shall be designed for a useful life of 40 years, accounting for corrosion, erosion, and material fatigue. Mechanical seals shall be made to be easily replaced.

4.3.2. Seals

4.3.2.1. Mechanical shaft seals shall be used. Leakage through or over the seals under any normal operating or malfunction condition shall be carefully controlled by the design of the seal. Provision shall be made to drain away separately any seal leakage, including leakage from serious failure of the seal. This drain shall be connectable to drain piping by 3/4 in. socket welds connections.

4.3.3. Drainage

4.3.3.1. All passages of the pump shall be designed to permit complete drainage with the pump in the normal operating position. A low point drain shall be provided which can be connected to drain piping by 3/4 in. socket welds connections.

4.3.4. Lifting Lugs

4.3.4.1. The lifting lugs shall be made so that a lifting attachment may be used during installation or removal of the motor-pump assembly from the pump casing.

4.3.5. Bolts, Nuts and Studs

4.3.5.1. Bolts, nuts and studs shall conform to [illegible] standards and shall be positively locked in such a manner that no possibility of loosening in service will exist. Bolt heads in high-fluid-velocity regions shall be retained in case they break off.

4.3.6. Vents

4.3.6.1. The pump shall be designed to permit venting while being filled with water. The design shall permit connection of piping by 3/4 in. socket welds connections for routing to disposal system.

4.3.7. Connections

4.3.7.1. Pump suction and discharge nozzles shall be prepared for welding in accordance with applicable data sheet.

4.3.7.2. Screwed connections shall be prepared to conform to [illegible] standards.

4.3.8. Impellers

4.3.8.1. Impellers shall be keyed to pump shafts. Unless otherwise specified, all impellers and shafts, as sub assemblies, shall be dynamically balanced before incorporation into the pump. Pump rotors shall be designed with critical speeds at least 25 percent above normal rated speed.

4.3.9. Maintenance

4.3.9.1. If possible, maintenance of the unit shall require no special skills. All parts which are susceptible to wear shall be capable of removal without cutting heavy structural members or main strength welds.

4.3.10. Design Pressure. Design pressure and maximum operating temperature shall be specified in the applicable data sheet or purchased part drawing.

5. DESIGN ANALYSIS

5.1. Pressure Containing Components, Supports, and Anchor Bolts

5.1.1. The Seller shall make all calculations for the design of the pressure containing components, supports, and anchor bolts.

5.1.2. The equipment and supports shall be designed to withstand the [illegible] acceleration applied at the mass center assuming the pump to be [illegible] horizontal and vertical seismic forces shall be considered to act [illegible] and shall be added directly. The stress in the supports and the anchor [illegible] shall be combined with stress due to other live, dead, and [illegible] [illegible] represents maximum [illegible] [illegible] which shall be imposed on the equipment. The allowable stress [illegible] allowable tensile stress and [illegible] [illegible] bolting material.

[illegible] shall provide all pump geometry coefficients to [illegible] outline drawing.

5.2.5. All equipment shall be anchored or fastened without reliance upon friction.

6. MATERIALS

6.1. Materials for Pressure Containing Parts

6.1.1. Materials according to the following ASTM specifications shall be used: A 155 KCF 70, A 106B, A 524, A 105 Gr. II, A 234 WPB, A216 WCB, A 516, A 2[illegible], A 251, A 588, A 599.

6.1.2. Low hydrogen electrodes shall be used for shielded metal arc welding.

6.2. Materials according to the following ASTM Specification shall be used for bolting which is exposed to water: A 193-B8, A 194-8, A 453 or A 461 Gr. 688.

6.3. Materials according to the following ASTM Specification shall be used for bolting which is not exposed to water: A 193-B7, B8, B14, B16, A 194-7, [illegible] 540-B[illegible] A 461 Gr. 688.

6.4. Additional requirements for all materials:

6.4.1. Hardfacing materials shall be one of the following:

a. Colmonoy 4, 5 or 6

b. Stellite 1, 3 or 6 or Haynes, Stellite Alloy 21.

6.4.2. Martensitic stainless steels, if used, shall have a maximum hardness of Rockwell C32.

6.4.3. Where cast martensitic stainless steels are used for operation at temperature below 250°F, silicon contents of 0.50 percent maximum are recommended to reduce the probability of brittle fracture.

6.4.4. 17-4 PH stainless steel, if used, shall be in accordance with ASTM A-564, Type 630, precipitation hardened at 1085 ±15°F.

6.4.5. Pump shafts and impellers shall be made of materials to ASTM specification

6.4.6. The pump volute, stuffing box, shaft and impeller shall be serialized for permanent identification. Bolts and nuts over 1 inch shall be marked per ASTM Material Standards. The control and identification of materials shall be in accordance with ASME Boiler and Pressure Vessel Code, 1968, Section III, Appendix IX, Paragraph 126.

6.5. Alternate Materials

6.5.1. Materials other than those specified shall not be used without the concurrence of the Buyer. For consideration of alternate materials, the requester shall demonstrate that they comply with applicable codes and that they are compatible with the conditions of use.

7. FABRICATION OF PRESSURE CONTAINING PARTS

7.1. Welding. Piping and equipment pressure parts assembled or erected by welding shall be in accordance with the applicable codes, specifications and requirements specified herein.

7.1.1. Qualification. All welding including fillet, seal, repair, and attachment welds shall be performed in accordance with written welding procedures. Procedure qualification and welder performance qualification shall be in accordance with ASME Section IX.

7.1.2. Qualification Records. Qualification records shall be in accordance with ASME Section IX.

7.1.3. Butt Joints

7.1.3.1. Joint design and welding procedures for longitudinal and girth butt joints larger than 2 inches in nominal pipe size shall be for complete penetration groove welds.

7.1.3.2. Backing rings. Backing rings which are left in place shall not be used on longitudinal welds. They may only be used on girth welds provided the suitability for cyclic operation is analyzed by the methods of Paragraph N-415, Section III of the ASME Boiler and Pressure Vessel Code using a fatigue-strength reduction factor of not less than 2. Backing rings which are left in place must be continuous, and any splices shall be butt welded. Backing rings which are removed after welding shall have the root area inspected as required for the applicable piping classification.

7.1.3.3. Weld end preparation.

7.1.3.3.1. The preparation of weld ends for matching ends of pipe for correction of out-of-roundness shall not result in a wall thickness less than the specified minimum thickness.

7.1.4. Branch Connections. Branch connections shall be in accordance with the requirements of USAS B31.1.0, Code for Power Piping, except that branch connections over 4 inches must be inspected by radiography.

7.1.5. Socket Welds

7.1.5.1. Socket welds may be employed for nominal pipe sizes 2 inches and smaller.

7.1.5.2. Socket welds shall have a gap of approximately 1/16 inch between the bottom of the socket and the end of the pipe prior to welding. The minimum engagement within the socket after welding shall be as follows:

Pipe Size	Minimum Engagement
1/2 inch and less	1/4 inch
1/2 to 1-1/2 inch	3/8 inch
1-1/2 inch or larger	1/2 inch

A marking technique shall be employed to verify minimum engagement after welding.

7.1.5.3. Socket welds shall have a minimum of two weld layers for nominal pipe wall thickness of 3/16 inch and larger.

7.1.6. Attachment Welds. Non-pressure parts which are welded to and become an integral part of pump pressure parts shall conform to the requirements of Paragraph 512.3.7 of the ASME Nuclear Pump and Valve Code.

7.1.7. Welding Procedures and Processes

7.1.7.1. Welding procedures and processes shall be utilized to produce welds of complete penetration and complete fusion, and be completely free of unacceptable defects. The finished surfaces of the weld (both root and crown) shall merge smoothly into the adjacent component surfaces. Weld layers shall be built up uniformly around the circumference and across the width of the joint. Weld starts and stops shall be staggered. Block welding or peening of welds is not allowed without the concurrence of the Buyer. The maximum inter-pass temperature for all austenitic stainless steel and dissimilar metal welds shall be 350°F.

7.1.7.2. Pressure-containing and attachment welds, as specified herein, shall employ the following processes within the limitations of this specification. The use of other processes or procedures is not allowed without the concurrence of the Buyer.

a. Gas Tungsten Arc Welding (GTAW)

b. Gas Metal Arc Welding (GMAW)

   Gas metal arc welding (GMAW) utilizing the short circuiting or globular mode of transfer shall not be used for austenitic stainless steel welds.

c. Shielded Metal Arc Welding (SMAW)

d. Submerged Arc Welding (SAW)

7.1.7.3. Groove Butt Welds. Austenitic stainless steel groove butt welds shall be made by one of the following methods within the limitations of this specification.

a. Double welded (welded from both sides) by any acceptable processes. Double welded joints shall be inspected on the back of the first side welded, prior to welding the second side.

b. Single welded (welded from one side) employing the GTAW process with filler metal added shall be used for the root pass. Completion of the weld may be by other acceptable welding processes. A protective gas back purge must be held until a minimum of 3/16 inch of weld thickness is completed.

7.1.7.3.1. Socket welds. Austenitic stainless steel socket welds shall employ the GTAW process with filler metal added for at least the root layer. Protective gas back purging is not required.

7.1.7.4. Carbon Steel Welds. Carbon steel groove welds shall be made by one of the following methods within the limitations of this specification.

a. Double welded (welded from both sides) by any acceptable processes. Double welded joints shall be inspected on the back of the first side welded, prior to welding the second side.

b. Single welded (welded from one side) employing the GTAW process with filler metal added for the root pass. Completion of the weld may be by other acceptable processes.

7.1.7.5. Dissimilar Metal Welds. Welded connections between austenitic stainless steel and carbon/low alloy steel are considered to be dissimilar metal welds.

7.1.7.5.1. Groove Welds. Dissimilar metal groove welds shall be in accordance with the following requirements.

a. When the carbon/low alloy steel component is over 3/4 inch thick it shall be "buttered" with Type-309 filler metal and heat treated in accordance with the requirements of USAS B31.1.0, Code for Power Piping. Completion of the weld joint can then be accomplished with either Type-308 or -309 filler metal. The completed weld joint shall not be heat treated.

b. When the carbon/low alloy steel component is 3/4 inch or less in thickness one of the following apply: (1) It shall be welded utilizing the SMAW process with Type-309 filler metal. (2) It shall be "buttered" with Type-309 filler metal when utilizing GTAW, GMAW, or SAW for additional welding of the joint. Type-308 or -309 filler metal may be used for completion of the weld.

The completed weld joint shall not be heat treated.

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7.1.7.5.1. (continued)

c. The minimum thickness of the "buttered" area after end preparation shall be 3/16 inch.

7.1.7.5.2. Socket Welds. Dissimilar metal socket welds shall be in accordance with the following requirements:

a. The socket fitting shall be carbon/low alloy steel.

b. Dissimilar metal socket welds shall employ the GTAW process with filler metal added for at least the root layer. Filler metal shall be Type-309. Protective gas back purging is not required.

7.2. Bending and Forming. Bending and forming shall be in accordance with USAS B31.1.0, Code for Power Piping and the supplementing requirements specified herein.

7.2.1. Austenitic stainless steel piping may be hot or cold bent within the following limitations:

a. Cold bent to any radius within the limitations of USAS B31.1.0-1967 provided the maximum operating temperature does not exceed 200°F for more than one percent of the design life and the base material, prior to bending, is in the fully annealed condition.

b. Cold bent to a minimum radius equal to 20 nominal pipe diameters regardless of service temperature. Cold bending to less than 20 nominal pipe diameters is acceptable for piping which has a normal operating temperature above 200°F provided the bending operation is followed by solution heat treatment.

c. Hot bent to a minimum radius equal to 5 nominal pipe dimensions regardless of service temperature. Hot bending shall be followed by solution heat treatment.

d. Bending of austenitic stainless steel piping at temperatures below 300°F shall be considered cold bending.

7.3. Heat Treatment

7.3.1. Austenitic Stainless Steel. Austenitic stainless steel piping components and equipment pressure parts shall be solution heat treated at least once.

7.3.1.1. Austenitic stainless steel material shall be degreased and stripped in accordance with ASTM A380, Descaling and Cleaning Stainless Steel Surfaces, Paragraph 2, prior to heat treatment.

7.3.1.2. Casting or forging material shall be heat treated by heating to a temperature between 1900 and 2050°F and then held for one hour per inch of thickness but not less than 1/2 hour followed by rapid cooling to below 700°F. (Rapid cooling required for optimum retention of carbon in solution is best obtained by quenching in water. To assure rapid uniform cooling, either agitation or water circulation should be employed.)

7.3.1.3. Temperature-indicating crayons shall not be used on austenitic stainless steels. Marking crayon shall be cleaned off before heat treatment.

7.3.2. Carbon and Low Alloy Steel. Carbon and low alloy steel piping components and equipment pressure parts shall be heat treated in accordance with the requirements of the applicable ASTM materials specification.

7.3.3. Welds. Heat treatment of welds shall be in accordance with the requirements and recommendations of ANSI B31.1.0, Code for Power Piping.

7.4. Descaling and Cleaning After Heat Treatment

7.4.1. Austenitic Stainless Steel. Austenitic stainless steel material shall be descaled and cleaned by one, or a combination, of the following methods:

a. Machining

b. Brushing with austenitic stainless steel brushes which have not been used on carbon or low alloy steels.

c. Blast cleaning with clean sand or grit not previously used on carbon or low alloy steels. Steel grit shall not be used.

d. Pickling in accordance with ASTM A380, Paragraph 4-b) (5) with the following restrictions: (1) Pickling at room temperature shall be limited to a maximum of ten minutes for each submersion. The total number of submersions shall be limited to six. (2) Pickling at temperatures greater than 100°F shall be limited to a maximum of 3 minutes for each submersion and the total number of submersions shall be limited to six. (3) Stainless steel material shall be pickled only when in the solution heat treated condition. Weldments, weld joints, or weld repairs shall be pickled only when the weldment and component have been solution heat treated subsequent to the welding.

7.4.2. Carbon and Low Alloy Steels. Carbon and low alloy steels shall be descaled and cleaned by one, or a combination, of the following methods - [illegible] shall not be used:

a. Machining or grinding

b. Blasting in accordance with the Steel Structures Painting Council Standard SP-5 except anchor patterns need not apply. When used, sandblasting shall be followed by vacuum or air-blast cleaning.

c. Pickling in accordance with the Steel Structures Painting Council Standard SP-8.

7.5. Major Repairs

7.5.1. Major repairs, as defined herein, shall require the concurrence of the Buyer. The Buyer shall receive prior notification of all major repairs. Records shall indicate the nature of the defect removed, the location of the defect, subsequent heat treatment, or other pertinent data and they shall be made available to the Buyer upon request.

7.5.2. Major repairs in base materials such as plates, forgings, extruded pipes, or castings are defined as (a) a repair which requires excavation of material to a depth greater than 20 percent of the wall thickness or when the extent of the cavity is greater than 10 square inches, (b) the repair of any crack in wrought material, and (c) the repair of defects which are indicative of fundamental materials problems.

7.5.3. Major repairs in welds are defined as (a) the repair of any crack other than crater cracks or (b) the repair of defects which are indicative of either a fundamental materials problem or a process out of control.

7.6. Heat Treatment After Repair by Welding

7.6.1. Base material repair welds shall be heat treated as required by the applicable materials specifications. It shall be the manufacturer's responsibility to determine whether heat treatment shall be performed after repair welding.

7.6.2. Weld repairs shall be heat treated as required by USAS B31.1.0, Code for Power Piping.

7.7. Surface Finish. The surface finish of either materials, welds, piping, or equipment pressure parts shall be suitable for the inspection and testing required by the applicable test schedule. Surface discontinuities which are markedly different from the overall finish shall be removed or blended into the adjacent surfaces.

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8. INSPECTION, TEST, AND QUALITY CONTROL

8.1. Performance Testing

8.1.1. The pump shall be tested in the Seller's shop to demonstrate that it fulfills the requirements of this specifications. These tests shall be conducted in accordance with Hydraulic Institute Standards. At least 5 points shall be tested, including full capacity, shut-off, and 125 percent of capacity.

8.2. Hydrostatic Testing

8.2.1. The pump casing shall be hydrostatically leak-tested in accordance with Section III C of ASME Pressure Vessel Code.

8.2.1.1. through 8.2.1.5. Deleted

8.2.2. Following the application of the hydrostatic test pressure (for a minimum of 10 minutes), the pressure may be reduced to design pressure at which time the pressure-retaining components shall be examined for leaks. The pressure-retaining components are unacceptable if any leaks are present.

8.3. Nondestructive Examination

8.3.1. Methods, techniques, and acceptance standards for non-destructive examination shall be in accordance with the ASME Nuclear Pump and Valve Code or ASTM Specifications as described and limited below.

8.3.2. Castings

8.3.2.1. Pump casings shall be nondestructively examined and the defects eliminated or repaired in accordance with the requirements of Paragraph 314.5 of the ASME Nuclear Pump and Valve Code with the following exceptions. Accessible internal surfaces for MPI or LPI are defined as those which can be repaired without cutting windows. If a surface is accessible at any time during manufacturing cycle and will become inaccessible, the nondestructive examination on such surface shall be performed prior to that surface becoming inaccessible.

8.3.2.1.1. Radiographic examination shall be confined to the area of nozzle preparations from the end of the preparation backward for a distance of at least 2 inches, and any girth or longitudinal pressure-containing welds.

8.3.2.1.2. Post-weld magnetic particle or liquid penetrant acceptance criteria shall be as required by Paragraph 512.3.2(f) 2 and 3 of the ASME Nuclear Pump and Valve Code.

8.3.2.1.3. All non-destructive testing shall be performed after any process-associated heat treatment.

8.3.2.1.4. A visual inspection per Paragraph 515 of Nuclear Pump and Valve Code shall be performed prior to any nondestructive examination.

8.3.3. Forgings. All pressure containing forgings shall be examined in the finished condition on all surfaces accessible for repair by liquid penetrant methods per ASME, Nuclear Pump & Valve Code Paragraph 314.4.3 or by magnetic particle methods per ASME, Paragraph 314.4.2.

8.3.4. Welds

8.3.4.1. The following shall be 100 percent examined by radiography per N 624. ASME Section III.

a. Girth and longitudinal pressure-containing, full-penetration groove welds.

b. Welds attaching branch connections 4 inches and larger in pipe size.

8.3.4.2. The following shall be examined on all accessible surfaces by either magnetic particle methods per Paragraph N 626 of ASME Section III or liquid penetrant methods per Paragraph N 627.

a. Fillet welds, socket welds and non-pressure-containing attachment welds such as supports, lugs, anchors and guides.

b. The back of the first side welded of double-welded joints prior to welding the second side.

c. The back side of joints utilizing backing rings which are subsequently removed, after the ring has been removed.

8.4. Buyer's representative shall have access to all testing during their performance. A final inspection will be made by the Buyer's representative before pump is shipped.

8.5. Quality Control

8.5.1. The Seller shall be responsible for the quality of the equipment fabricated to this specification regardless of whether such fabrication is in his own shop or that of a subvendor. The Seller shall provide the procedures and records required regardless of where the work is performed. The Seller shall originate and maintain record system in a central file in accordance with ASME Pressure Vessel Code, Appendix IX, Paragraph 225.

8.5.1.1. The Seller shall obtain material certification, and chemical and physical test reports for pressure boundary material, pump shaft, and impellers. These records shall be identified by part name, part number, drawing number, and serial number.

8.5.1.2. A report shall be written showing the results of each non-destructive test performed. Each report shall reference an accepted examination procedure, part name, part serial number.

8.5.1.3. Each major defect repair shall require the records called out in 314.1.6 of the ASME Nuclear Pump and Valve Code.

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8.5.1.4. The Seller shall prepare and maintain a quality control summary sheet or equivalent for pressure boundary material which provides for but is not limited to the following:

8.5.1.4.1. Heat treat or post weld heat treating procedure number and date accomplished.

8.5.1.4.2. Fabrication and repair weld procedures and dates accomplished for the particular operation called out.

8.5.1.4.3. Radiographic inspection report number and date accomplished.

8.5.1.4.4. Magnetic particle or liquid penetrant inspection report number and date accomplished.

8.5.1.4.5. Hydrostatic report number and date accomplished.

8.5.1.4.6. Seller's quality control personnel shall initial or stamp each dated entry. Space shall be provided for the General Electric Quality Control Representative to do likewise.

8.5.1.5. Measuring instruments and the accuracy thereof shall be assured by the Seller to be within the tolerance specified for the measurement to be made.

8.5.1.6. In addition, the Seller shall prepare in quantities defined in the Purchase Order consolidated binders of the documents listed below for each item of equipment prior to shipment. Each binder will be submitted to the Buyer. It shall be index tabbed for each major section that it contains for easy reference. The binder itself shall be a standard hard cover type for 8-1/2 x 11 paper and labeled on the front with the equipment description, General Electric Purchase Order Number, Project Name and Item Mark Number.

8.5.1.6.1. Material certifications.

8.5.1.6.2. Certificate of compliance

8.5.1.6.3. Nondestructive test reports.

8.5.1.6.4. Major repair charts.

8.5.1.6.5. Heat treat charts.

8.5.1.6.6. Hydrostatic test report.

8.5.1.6.7. Performance test report.

9. CLEANING, COATING, AND PREPARATION FOR SHIPMENT

9.1. Component parts shall be cleaned during final assembly to provide an assembled unit free of chips, lubricants, and other foreign material. Adequate precautions shall be taken by the Seller while performing tests to prevent the introduction of foreign material.

9.2. After completion of testing, the pump shall be cleaned and packaged for shipment in a manner which will prevent the introduction of foreign material into the unit. After cleaning, inside surfaces shall be coated with a readily-water-soluble corrosion inhibitor, such as a solution of 1/2 percent sodium nitrite, 1/4 percent monosodium phosphate and 1/4 percent disodium phosphate. A tight-fitting metal cap shall be fitted over all weld ends. The temporary seals used on the nozzles shall not affect the weld preparation of flange faces of the nozzles.

9.3. Exterior Surfaces (Not Machined)

9.3.1. Exterior carbon steel surfaces shall be cleaned of oil and grease, after which mill scale, rust scale, rust, paint and other foreign matter shall be thoroughly removed by such means as sandblasting. After the surfaces are prepared for painting, they shall be painted with the Seller's standard metal primer.

9.4. Exterior Surfaces (Machined)

9.4.1. All accessible exposed machined surfaces, except those of stainless steel material, shall be coated with an antirust compound readily removable by solvent wiping.

9.5. All equipment and parts shall be bagged, boxed, crated or otherwise protected against damage, loss, moisture, and other contaminants during shipment and while in storage. (NOTE: Equipment may be in storage up to 12 months.)

9.6. All boxes, crates, and shipments shall be identified with the equipment piece number.

9.7. Maintenance tools shall be shipped in a separate container.

10. SUBMITTALS TO BUYER

10.1. Drawings

10.1.1. Outline Drawing. A drawing depicting the outline of the pump assembly, indicating over-all dimensions, location of supports, shipping and operating weights, weld-end preparations and all motor and pump interface dimensions.

10.1.2. Assembly Drawings. A section drawing depicting the arrangement of the functional parts, part list, and material designations.

10.1.3. Drawings to be Certified. Outline drawings and wiring diagrams, upon completion of the design, shall be certified to be correct with no further changes required. No alterations may be made to the design after Certification without the approval of the Buyer.

10.2. Design Items

10.2.1. Design Calculations

10.2.1.1. Seismic

10.2.1.2. Code calculations for pressure containing parts.

10.2.2. Design Procedures

10.2.2.1. Submittals shall be related to the fields listed below. They shall state in detail the steps taken in making the stated design, the difference between this design and standard designs already in service, if any, and the field-proven success the Seller has had with this or similar designs.

a. Vibration, bearing span, and critical speed determination.

b. Deleted

c. Deleted

d. Bearing load determination

10.3. Procedures (For Approval)

a. Heat treating

b. Repair welding

c. Radiographic

d. Fabrication welding

e. Liquid penetrant

f. Magnetic particle

g. Packaging and marking

10.3.1. Cleaning, Preserving and Painting

10.3.2. Hydrostatic Test

10.3.3. Performance Test

10.3.4. If welding is employed for fabrication or repair, the Seller shall prepare welding procedures and submit them to the Buyer for approval.

10.4. Instruction Manuals

10.4.1. Instruction manuals shall present the following basic categories of information in a practical, complete, and comprehensive manner, prepared for use by operating and/or maintenance personnel:

a. Storage maintanence

b. Instructions for initial installation

10.4.1. (continued)

c. Instructions for operations, maintenance, and repair

d. Recommended inspection points and period for inspection

e. Ordering instructions for all replaceable parts, gaskets, etc.

10.4.2. The information shall be organized in a logical and orderly sequence. A general description of the equipment, including significant technical characteristics, shall be included to familiarize operating and maintenance personnel with the equipment.

10.4.3. Necessary drawings and/or other illustrations shall be included or copies of appropriate certified drawings may be bound into the manual. Test, adjustment, and calibration information, as appropriate, shall be specified and identified to the specific equipment. Safety and other warning notices and installation, maintenance and operating cautions shall be emphasized.

10.4.4. A parts list shall be included showing part nomenclature, manufacturer's part number and/or other information necessary for accurate identification and ordering of replacement parts. Common hardware items, or other parts to be locally procured, shall be adequately identified by technical descriptions.

10.4.5. Instructions and parts list shall be clearly legible and prepared on good-quality paper; carbon copies, tissue copies, or other flimsy material are not acceptable. Multiple-page instructions shall be securely bound.

10.4.6. If a standard manual is furnished covering more than the specific equipment purchased, the applicable model (or other identification), parts, and other information for the specific equipment purchased shall be clearly identified.

10.4.7. Information shall be furnished on seals, including recommended frequency of inspection, criteria for replacement, frequency of pump shaft rotation, and other criteria of importance in connection with seals used in standby equipment.

10.5. Test Reports

10.5.1. Hydrostatic

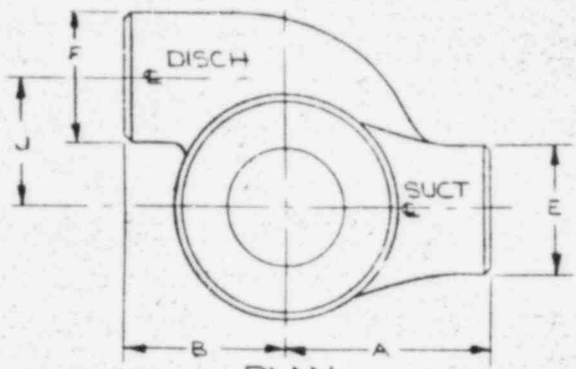
10.5.2. Performance

10.6. Certificate of Compliance

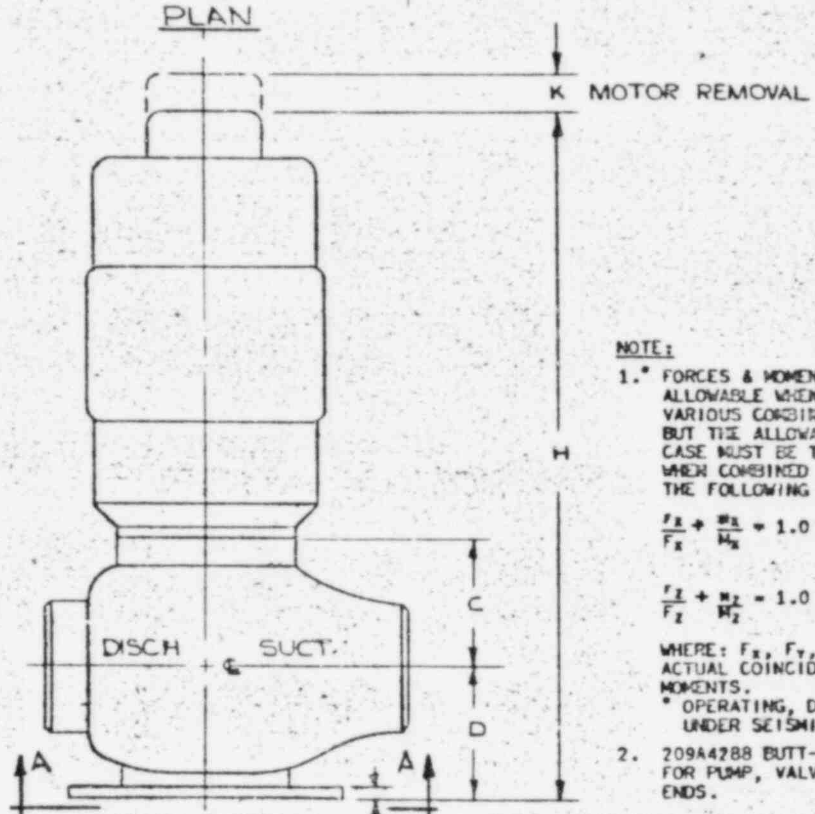
10.6.1. The Seller shall furnish certification of compliance with all applicable electrical and mechanical construction codes, with copies of pertinent test data. The Seller shall supply the drawings, calculations, and material samples required for submittal to the appropriate code and/or license bodies for approval.

APR 1 1970

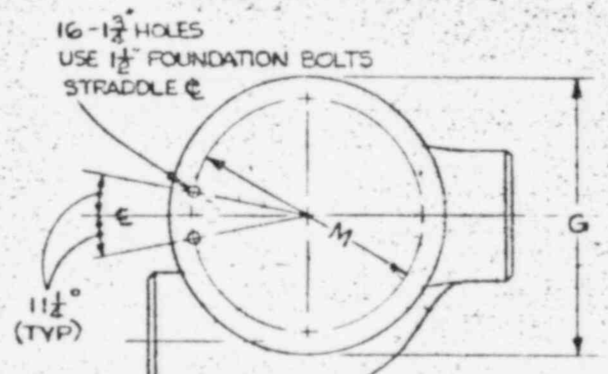
GE. PART IDENT NO	VPF NO



PLAN



ELEVATION



VIEW A-A

NOTE:

1.* FORCES & MOMENTS GIVEN ARE THOSE ALLOWABLE WHEN ACTING ALONE. VARIOUS COMBINATIONS ARE POSSIBLE, BUT THE ALLOWABLE FORCES IN EACH CASE MUST BE TREATED SEPARATELY. WHEN COMBINED IN THE SAME PLANES, THE FOLLOWING CONDITIONS WILL APPLY:

$$\frac{f_X}{F_X} + \frac{m_X}{M_X} = 1.0 \quad \frac{f_Y}{F_Y} + \frac{m_Y}{M_Y} = 1.0$$

$$\frac{f_Z}{F_Z} + \frac{m_Z}{M_Z} = 1.0$$

WHERE: F_X, F_Y, F_Z, M_X, M_Y, M_Z ARE ACTUAL COINCIDENT * FORCES AND MOMENTS.

* OPERATING, DEAD AND LIVE LOADS UNDER SEISMIC CONDITIONS.

2. 209A4288 BUTT-WELD PREPARATION FOR PUMP, VALVE & COMPONENT NOZZLE ENDS.

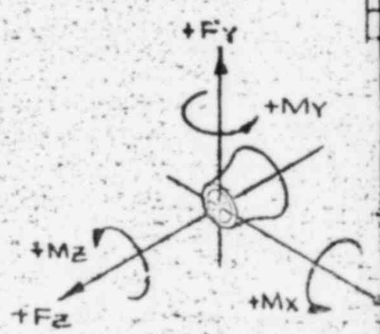


FIGURE ONE

GENERAL ELECTRIC

117C2857 CONT ON SHEET F SH NO 1

UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING — APPLIED PRACTICES | SURFACES ✓ | TOLERANCES ON MACHINED DIMENSIONS: FRACTIONS ± | DECIMALS ± | ANGLES ±

TITLE: PUMP

FIRST MADE FOR: CORE SPRAY SYS

PURCHASED PART

FCF: E21-C001
14-1

5	4	3	2	1	PART NUMBER
		24"	28"		A
		17"	20"		B
		10"	10 1/4"		C
		10"	10"		D
		12 3/4"	14"		E
		10 3/4"	12 3/4"		F
		36"	36"		G (CIRCLE DIAMETER)
		108"	108"		H
		12"	14"		J
		17"	17"		K
		—	—		L
		32"	32"		M (BOLT CIRCLE DIA.)
		212	212		MAX. PROCESS TEMP °F
		148	148		AMBIENT MAX TEMP °F
		90 TO 100	90 TO 100		MAX RELATIVE HUMIDITY %
		31	120		WET WR^2 (LBS. FT^2)
		25	100		DRY WR^2 (LBS. FT^2)
		320	470		MIN. REQ COOLING WATER FLOW G.P.M.
		NA	NA		COOLING WTR. MAX. PRESS DROP, FT. (AT MIN FLOW)
		500	500		DESIGN PRESSURE, PSIG
		1.5	1.5		HORIZ, G SEISMIC COEFF
		0.14	0.14		VERT, G SEISMIC COEFF
		40	40		PIPE SCHEDULE SUCTION NOZZLE
		12	14		NOMINAL SIZE, IN. SUCTION NOZZLE
		40	40		PIPE SCHEDULE DISCHARGE NOZZLE
		10	12		NOMINAL SIZE, IN. DISCHARGE NOZZLE
		2110	3510		PUMP WEIGHT, WET, LBS.
		40,000	52,000		*Fx MAX. ALLOW (SUCTION)
		40,000	52,000		*Fy NOZZLE FORCE, LB
		40,000	50,000		*Fz (SEE FIGURE ONE)
		40,000	52,000		*Mx MAX. ALLOW. (SUCTION)
		40,000	52,000		*My NOZZLE MOMENTS, LB-FT
		46,000	60,000		*Mz (SEE FIGURE ONE)
		26,000	40,000		*Fx MAX. ALLOW (DISCHARGE)
		26,000	40,000		*Fy NOZZLE FORCE, LB
		30,000	40,000		*Fz (SEE FIGURE ONE)
		26,000	40,000		*Mx MAX. ALLOW. (DISCHARGE)
		26,000	40,000		*My NOZZLE MOMENTS, LB-FT
		30,000	46,000		*Mz (SEE FIGURE ONE)

117C2857 CONT ON SHEET F SH NO 1 — REV NO. 4

E21

RECEIVED 6/11/92

LILCO
MPL # E21-C001

+Fx

REVISIONS | PRINTS TO

3 — INCREASE REVISION STATUS TO REVISION 3 PER ECA 50724-4

4 — RETRACED WITH CHANGES COMPLETE REVIEW REQ'D PER ECA 50701-2

MADE BY G. BARTOS 10/14/63 | CHECKED J RYAN NOV 12.63 | APPROVALS H. EHSAN | APED SAN JOSE, CAL | 117C2857 CONT ON SHEET F SH NO 1

R DPL

GENERAL ELECTRIC COMPANY
NUCLEAR ENERGY DIVISION
175 CURTNER AVENUE
SAN JOSE, CALIFORNIA 95125

PURCHASE ORDER NO. 205- AA728

THIS PURCHASE ORDER SHALL BE CONSTRUED, INTERPRETED AND APPLIED IN ACCORDANCE WITH THE LAWS OF THE STATE OF CALIFORNIA AND IS SUBJECT TO THE TERMS AND CONDITIONS ON THE FACE AND REVERSE SIDE HEREOF AND ANY SUPPLEMENTS, SPECIFICATIONS OR OTHER DOCUMENTS EXPRESSLY INCORPORATED HEREIN BY REFERENCE.

SELLER'S CODE	BUYER'S CODE	CONFIRMING	REVISION NO.	DATE OF ORDER OR REVISION	SHEET OF SHEETS
008510299	38	X		9/18/69	1 3

SHIP TO
STONE AND WEBSTER ENGINEERING CORPORATI
AGENT
LONG ISLAND LIGHTING COMPANY
SHOREHAM NUCLEAR POWER STATION
ACCESS ROAD ON ROUTE 25A
EAST OF WILLIAM FLOYD PARKWAY
SHOREHAM, NEW YORK (HEREIN CALLED "SITE")

BYRON JACKSON PUMP DIVISION
BORG-WARNER CORP.
2 PINE STREET
SAN FRANCISCO, CALIFORNIA

ATTENTION: MR. G.C. GODWIN (HEREIN CALLED "SELLER")

SHIP VIA: TRUCK

CODE	PAYMENT TERMS	F.O.B.	
T-0	NET 30 DAYS	DESTINATION	

FABRICATION POINT	ACCOUNT NO.	M.R. OR QUOTE	SHIPPING DATE	SITE DELIVERY DATE
BYRON JACKSON PUMP DIV., VERNON, CA.	632-03137-L62	AA728 REV. 0-1		2/20/72

CODE	PROJECT NAME			UNIT PRICE	TOTAL
H	LILCO				

DESCRIPTION OF GOODS OR SERVICES

''THE TERMS AND CONDITIONS APPLICABLE TO THIS PURCHASE ORDER SHALL BE THOSE SET FORTH IN THE AGREEMENT, EFFECTIVE JULY 17, 1969, BETWEEN GENERAL ELECTRIC COMPANY, ACTING THROUGH ITS NUCLEAR ENERGY DIVISION AND BORG-WARNER CORPORATION, ACTING THROUGH ITS BYRON JACKSON PUMP DIVISION.''

ARTICLE I - SCOPE OF SUPPLY

BYRON JACKSON PUMP DIV., BORG-WARNER CORP., HEREINAFTER CALLED 'SELLER' SHALL PROVIDE ALL MATERIALS AND SERVICES TO DESIGN, FABRICATE, TEST AND DELIVER THE FOLLOWING.

1 2 EA. CORE SPRAY PUMPS - IN ACCORDANCE WITH THE FOLLOWING DOCUMENTS:

DOCUMENT NO.	REV.	DATE	TITLE
21A9221BC	0	8/27/69	DATA SHEET
21A9221	3	9/15/69	PURCHASE SPEC. CORE SPRAY AND RHR PUMPS
21A9825	2	3/13/69	STANDARD SPARE PTS. REQUIREMENTS

/CONTINUED ON PAGE 2/

CARRIER'S NAME

AMOUNT

V14

GENERAL ELECTRIC COMPANY
NUCLEAR ENERGY DIVISION

PURCHASE ORDER NO. 205- AA728

CONTINUATION SHEET

THIS CONTINUATION SHEET IS SUBJECT TO THE TERMS AND CONDITIONS ON THE FACE AND REVERSE SIDE OF THE FIRST SHEET AND ALL OTHER CONTINUATION SHEETS OF THIS ORDER AND ANY SUPPLEMENTS, SPECIFICATIONS OR OTHER DOCUMENTS EXPRESSLY INCORPORATED HEREIN BY REFERENCE.

ITEM	QUANTITY	DESCRIPTION OF GOODS OR SERVICES	UNIT PRICE	TOTAL PRICE

DOCUMENT NO.	REV.	DATE	TITLE
209A4283	1	3/12/68	WELD END PREPARATION
117C1110P2	3		PURCHASE PART DWG.
ATTACHMENT A1	1		TO SPEC. 21A9221
	2	9/19/69	
Q.C. PLAN	1	6/18/69	QUALITY CONTROL PLAN
I	0	8/ 1/69	Q.C. NOTIFICATION POINTS TO Q.C. PLAN 1
21A1150	2	2/18/69	GEN. REQUIREMENTS FOR VENDOR DWGS.
QSI 7.2.19	3	12/ 5/68	DEVIATION DISPOSITION REQUEST PROCEDURE
	1	7/21/69	TERMS AND CONDITIONS SUPPLEMENT

1A 1 LOT DATA AND DOCUMENTATION SUBMITTALS IN ACCORDANCE WITH ATTACHMENT A. THESE, UPON APPROVAL BY THE BUYER, BECOME PART OF THE REQUIREMENTS OF THE PURCHASE ORDER. SELLER'S WORK SHALL CONFORM TO THE DRAWINGS AND PROCEDURES SO APPROVED. — INCLUDED IN BASIC PRICE

MARK NO. E21C001 /INCLUDE THIS MARKING WITH ITEMS CONTAINED IN ARTICLE 7/C/ OF TERMS AND CONDITIONS/

ARTICLE II - PRIOR TO POURING OF CASTINGS NOTIFICATION REQUIRED

SELLER TO ADVISE BUYER SIXTY /60/ DAYS PRIOR TO POURING OF CASTINGS, TO ALLOW BUYER TO CONTACT CUSTOMER IN THE EVENT 100 PERCENT RADIOGRAPHABLE CASTINGS BECOME A REQUIREMENT. BUYER MUST RESPOND WITHIN THIRTY /30/ DAYS, ADVISING QUALITY OF CASTINGS DESIRED.

ARTICLE III - MOTOR BUY AGREEMENT

1. ALL MOTORS TO BE SUPPLIED BY GE-APED. SELLER TO MOUNT MOTORS ON PUMP AND TO ADVISE BUYER WHEN ALL MOTORS ARE REQUIRED TO BE MOUNTED AND TESTED.

/CONTINUED ON PAGE 3/

GENERAL ELECTRIC COMPANY
NUCLEAR ENERGY DIVISION

PURCHASE ORDER NO. 205-AA728

CONTINUATION SHEET

SHEET 2 OF SHEETS 2

THIS CONTINUATION SHEET IS SUBJECT TO THE TERMS AND CONDITIONS ON THE FACE AND REVERSE SIDE OF THE FIRST SHEET AND ALL OTHER CONTINUATION SHEETS OF THIS ORDER AND ANY SUPPLEMENTS, SPECIFICATIONS OR OTHER DOCUMENTS EXPRESSLY INCORPORATED HEREIN BY REFERENCE.

ITEM	QUANTITY	DESCRIPTION OF GOODS OR SERVICES	UNIT PRICE	TOTAL PRICE
		2. THE BUYER'S RESPONSIBILITY SHALL BE TO FURNISH A MOTOR WHICH COMPLIES WITH THE MOTOR DATA FURNISHED BY THE SELLER. THE SELLER'S RESPONSIBILITY WITH REGARD TO THE MOTOR SHALL BE THE CORRECTNESS AND COMPLETENESS OF THE MOTOR DATA.		
		3. SELLER SHALL NOTIFY BUYER WITHIN ONE /1/ WEEK AFTER SELLER'S RECEIPT OF THE MOTOR AS TO ITS ACCEPTABILITY BASED ON VISUAL EXAMINATION ONLY FOR MEETING MOTOR SPECIFICATIONS.		
		4. SELLER SHALL BE RESPONSIBLE FOR ASSEMBLING THE PUMP AND MOTOR IN A WORKMANSHIP-LIKE MANNER FOR TESTING THE PUMP AND MOTOR ASSEMBLY AS AN INTEGRAL UNIT, FOR MEETING WARRANTED PUMP CONDITIONS, SUCH AS HEAD, FLOW AND BRAKE HORSEPOWER, AND FOR SHIPPING THE PUMP AND MOTOR AS AN INTEGRAL UNIT.		
		PURCHASE ORDER TOTAL		

0/10/09 KL

CERTIFICATE OF COMPLIANCE

Pump serial number 691-S1111 was designed, fabricated and tested in accordance with the requirements of General Electric Company purchase order 205 AA 718.

All welding procedures and welders used in repair or fabrication of this pump were qualified in accordance with A.S.M.E. Section IX.

All Non-destructive testing was performed by personnel qualified in accordance with SNT-TC-1A or other applicable specifications as required by the pruchase order.

[signature] Signature

Manager - Quality Control Title

BYRON JACKSON DIVISION
Borg-Warner (Canada) Limited Vendor Name

October 19th 1972 Date

OCT. 2 ' 1972

CERTIFICATE OF COMPLIANCE

Pump serial number 691-S1112 was designed, fabricated and tested in accordance with the requirements of General Electric Company purchase order 205 AA 718.

All welding procedures and welders used in repair or fabrication of this pump were qualified in accordance with A.S.M.E. Section IX.

All Non-destructive testing was performed by personnel qualified in accordance with SNT-TC-1A or other applicable specifications as required by the pruchase order.

[signature] Signature

Manager - Quality Control Title

BYRON JACKSON DIVISION
Borg-Warner (Canada) Limited Vendor Name

October 19th 1972 Date

APED QC TC

OCT. 2 1972

Byron Jackson Division

BORG WARNER (CANADA) LIMITED
P.O. BOX 180, STATION H, TORONTO 13, ONTARIO, CANADA

Date: October 19th 1972

THIS IS TO CERTIFY THAT THE EQUIPMENT DESCRIBED BELOW COMPLIES WITH THE REQUIREMENTS WHERE APPLICABLE TO THE FOLLOWING REFERENCED (21 A 9221 Rev.4) CODES -

Section III ASME for Class "C" Vessels.
USA Standard Code for Pressure Piping;
Power Piping USAS B.31.1.0;
Standards of the Hydraulic Institute;
ASTM where specified; ASME Code for
Nuclear Pump and Valves.

1 - LILCO CORE SPRAY PUMP - BJ SERIAL NO. 691-S1111 ←
1 - LILCO CORE SPRAY PUMP - BJ SERIAL NO. 691-S1112

A. A. MacPhail
Manager, Quality Control.

OCT 2 1972

Byron Jackson Division

BORG WARNER (CANADA) LIMITED
P.O. BOX 188, STATION H, TORONTO 13 ONTARIO, CANADA

Date: October 19th 1972

THIS IS TO CERTIFY THAT THE EQUIPMENT DESCRIBED BELOW COMPLIES WITH THE REQUIREMENTS WHERE APPLICABLE TO THE FOLLOWING REFERENCED (21 A 9221 Rev.4) CODES -

Section III ASME for Class "C" Vessels.
USA Standard Code for Pressure Piping;
Power Piping USAS B.31.1.0;
Standards of the Hydraulic Institute;
ASTM where specified; ASME Code for
Nuclear Pump and Valves.

1 - LILCO CORE SPRAY PUMP - BJ Serial No. 691-S1111

1 - LILCO CORE SPRAY PUMP - BJ SERIAL NO. 691-S1112 ←

A. A. MacPhail
Manager, Quality Control.

OCT 2 1972

APPENDIX B

ANALYSES

CALCULATION/PROBLEM COVER SHEET

Calculation/Problem No: 0630-001-038

Title: Materials Analysis of Byron Jackson (Borg-Warner) RHR and CS Pumps

Client: LILCO

Project: NSSS Equipment Qualification

Job No: 0630-001-671

Design Input/References:

Refer to Table of Contents on page 2 of 6

Assumptions:

Refer to Table of Contents on page 2 of 6

Method:

Refer to Table of Contents on page 2 of 6

Remarks:

The purpose of this calculation is to determine the temperature and radiation tolerance of the materials of construction of Byron Jackson (Borg-Warner) RHR and Core Spray Pumps.

REV. NO.	REVISION	PERFORMED BY	CHECKED	APPROVED	DATE
0	Original	Kenneth Pitts	Ira Zebrak	NK Woodward	7/23/82
1	Added Page 6	Kenneth Pitts	Ira Zebrak	NK Woodward	8/18/82

EDS 1004 972

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LIST OF TABLES

APPENDICES

1.0 PURPOSE

1. To determine the radiation tolerance of this device by examination of the materials of construction.

2. To determine the temperature tolerance of this device by examination of the materials of construction.

2.0 SCOPE

This calculation applies to the Byron Jackson Residual Heat Removal and Core Spray pumps exposed to environmental conditions at SNPS-1.

3.0 REFERENCES

1. Technical Manual, RHR Pump, Byron Jackson Pump Division, Manual No. 8020, 1E-3525, Section 1.2, Materials of Construction 1T-3855.

2. Technical Manual, CS Pump, Byron Jackson Pump Division, Manual No. 8020, 1E-3525, Section 1.2, Materials of Construction 1T-3855.

3. ROC, K. Trotta (EDS) to Shirly Migdon (ASTM), 6/21/82.

4. Handbook of Plastics and Elastomers, Charles A. Harper, McGraw-Hill Book Co., Copyright 1978.

5. Radiation Effects on Organic Materials in Nuclear Plants, EPRI NP-2129, November, 1981.

4.0 METHOD OF ANALYSIS

The temperature and radiation tolerance of all materials contained within this device was determined by a document search of published materials and other EDS calculations. The sensitivity of the "weak link" component is then assumed to be the temperature tolerance or radiation tolerance of the entire device.

5.0 BASIC DATA AND ASSUMPTIONS

5.1 Only non-metallic materials have been evaluated since they will be the most sensitive to potential heat or radiation damage.

6.0 SUMMARY RESULTS

The limiting material in this device, with respect to temperature and radiation, is Ethylene Propylene, with a radiation tolerance of 1×10^7 rads and a maximum operating temperature of 300°F.

7.0 BODY OF CALCULATION

See Table 1.

Calculation No. 0630-001-038
Revision No. 0

Prepared by: Kenneth [signature] Date: 7-23-82
Checked by: [signature] Date: 7/23/82

TABLE 1

COMPONENT MATERIALS EVALUATION WORKSHEET

Manufacturer: Byron Jackson

Serial No. 691-S-1111 - 1116

Component	Material	Reference	TEMPERATURE Maximum Operating	TEMPERATURE Reference	RADIATION Acceptable Dose	RADIATION Reference
Gasket-Cover to Case	ASTM D-2000 CL. 2BA810 C12F17 (Ethylene Propylene)	1, 2, 3	300°F	4	1×10^7 rads	5
Gasket-Hydro-static Chamber	ASTM D-2000 CL. 2BA810 C12F17 (Ethylene Propylene)	1, 2, 3	300°F	4	1×10^7 rads	5
Gasket-seal Flange to Cover	ASTM D-2000 CL. 2BA810 C12F17 (Ethylene Propylene)	1, 2, 3	300°F	4	1×10^7 rads	5
U-cup	ASTM D-2000 CL. 2BA810 C12F17 (Ethylene Propylene)	1, 2, 3	300°F	4	1×10^7 rads	5
Seat Gasket	ASTM D-2000 CL. 2BA810 C12F17 (Ethylene Propylene)	1, 2, 3	300°F	4	1×10^7 rads	5
Cyclone Separator Assembly Gasket	ASTM D-2000 CL. 2BA810 C12F17 (Ethylene Propylene)	1, 2, 3	300°F	4	1×10^7 rads	5

APPENDIX A
MATERIALS ANALYSIS, CALC. No. 0630-001-038

eds nuclear

RECORD OF CONVERSATION

FILE: 0630-001-671

COPY: N. Woodward
I. Zebrak
K. Trotta

[X] Telephone [ ] Meeting [ ] Other ________

TO: Shirly Migdon FROM: Ken Trotta KT DATE 6/21/82

COMPANY: ASTM - Rubber Standards PHONE NO.: 215-299-5432

SUBJECT: Code Explanation

Summary of Conversation:

Shirly explained the significance of the following ASTM material code:

D-2000CL.2 BA810C12F17.

D-2000 refers to the rubber standards group; BA refers to standard Ethylene Propylene; C12 refers to O_3 resistance; F17 refers to low temperature brittelness; 810 refers to the tensile strength (in PSI).

KT/jh

edis nuclear

EDS Nuclear Inc.
445 Broad Hollow Road
Melville, New York 11747
(516) 454-0200

August 17, 1982
0630-001-098

ASTM
1916 Race Street
Philadelphia, PA 19103

ATTENTION: Ms. Shirley Migdon

SUBJECT: Verification of Record of Conversation

Gentlemen:

Thank you for the information which you supplied to EDS with respect to ASTM standards. EDS Quality Assurance Procedures require that you receive the enclosed record of our conversation of 6/21/82. 1

If this is an accurate account of our conversation, no action is requested of you. Should there be any errors or misunderstandings in this record of our conversation, please contact me at (516) 454-0579.

Very truly yours,

Kenneth P. Trotta

Kenneth P. Trotta
Systems Engineering Division

/sa

Enclosure

ENVIRONMENTAL QUALIFICATION SUMMARY

Environmental Qualification Summary No: 3006M

Title: Rockwell International MSIV's

Client: LILCO

Project: NSSS Equipment Qualification

Job No: 0630-001-671

Design Input/References:

The references included with this package are listed as appendices in the Table of Contents on page 2.

Assumptions:

N/A

Method:

N/A

Remarks:

For qualification conclusions, see Section 2.2.

REV. NO.	REVISION	PERFORMED BY	CHECKED	APPROVED	DATE
0	Original	[signature]	[signature]	[signature]	8/24/82

TABLE OF CONTENTS

APPENDICES

APPENDIX	TITLE
A	Documentation:

1. Certificate of Compliance, Rockwell International, 3/26/75, for MSIV MPL B21-F022 and F028 (LILCO/SR-2 Document No. AB317-G039).

2. G.E. Product Quality Certification MSIV MPL B21-F022 (LILCO/SR-2 Document No. AB317-G039).

3. Purchase Part Drawing for Main Steam Isolation Valves, Drawing 731E615, Rev. 4 (LILCO/SR-2 Document No. 731E615).

4. G.E. Purchase Order 205-AB317, Rev. 0, Rev. 16, Rev. 17 (LILCO/SR-2 Document No. AB317).

5. G.E. Purchase Specification 21A9230, Rev. 2, MSIV's (LILCO/SR-2 Document No. 21A9230).

6. Rockwell International Instruction Manual for MSIV's, 4/4/80, 2793-65-5 (LILCO/SR-2 Document No. 2793-65-5).

7. Rockwell Drawing P-419504, Rev. G, Sheets 2 and 3, List of Materials and Parts Drawing 2793-22-6, 2793-23-6 (LILCO/SR-2 Document No. 2793-22, 23-6). See Appendix A to Calculation No. 0630-001-043.

APPENDICES

APPENDIX	TITLE
A	Documentation (cont.):
	8. Drawing P-419504, Rev. L, Sheet 3 (Parts List) (LILCO/SR-2 Document No. 2793-23).
B	Analyses:
	1. EDS Calculation No. 0630-001-043, Revision 0.

1.0 EQUIPMENT LIST

Equipment I.D. (Mark No.)	MPL No.	Description	Make/Model
1B21*AOV081A	B21-F022A	Main Steam Isolation Valve	Rockwell International/1612
1B21*AOV081B	B21-F022B	Main Steam Isolation Valve	Rockwell International/1612
1B21*AOV081C	B21-F022C	Main Steam Isolation Valve	Rockwell International/1612
1B21*AOV081D	B21-F022D	Main Steam Isolation Valve	Rockwell International/1612
1B21*AOV082A	B21-F028A	Main Steam Isolation Valve	Rockwell International/1612
1B21*AOV082B	B21-F028B	Main Steam Isolation Valve	Rockwell International/1612
1B21*AOV082C	B21-F028C	Main Steam Isolation Valve	Rockwell International/1612
1B21*AOV082D	B21-F028D	Main Steam Isolation Valve	Rockwell International/1612

2.0 EQUIPMENT SUMMARY EVALUATIONS

2.1 Description

The equipment under evaluation are Rockwell International Main Steam Isolation Valves, Model 1612.

2.2 Conclusions

2.2.1 MSIV's Outside Containment

The MSIV's outside containment are fully qualified over the 40-year plant life for the postulated accident temperature, pressure, humidity, and radiation conditions. Materials analysis (EDS Calculation No. 0630-001-043, Rev. 0) indicates that the non-metallic components contained within these valves will not be adversely affected by the postulated accident radiation and temperature environments.

2.2.2 MSIV's Inside Containment

The MSIV's inside containment are fully qualified for the first 2 years after plant startup for the postulated accident temperature, pressure, humidity, and radiation. Materials analysis (EDS Calculation No. 0630-001-043, Rev. 0) indicates that the non-metallic components contained within these valves will not be adversely affected by the postulated accident radiation and temperature environments up to the first 2 years of plant operation.

2.3 Limitations

Although no limitations exist for the outboard MSIV's, the non-metallic components contained within the inboard valves should be examined within 2 years of plant startup in order that their radiation tolerance will not be exceeded (see Section 2.4.2 below).

2.4 Discussion

2.4.1 MSIV's Outside Containment

Since the documented maximum temperature, pressure, humidity, and radiation for these valves is greater than or equal to the EQR specified environment for the same respective parameters, it is expected that these valves will be capable of performing their safety function as required when subjected to this environmental loading.

Although the outboard MSIV's are only required to operate for 70 minutes subsequent to the accident, they can withstand the 6-month radiation dose of 3.06×10^6 rads. Materials analysis (EDS Calculation No. 0630-001-043, Rev. 0) indicates that the limiting material contained in this device is comprised of Viton with a radiation tolerance of 1×10^7 rads. Hence, these valves are fully qualified and are expected to perform their safety function whenever required during the 40-year life of the plant.

2.4.2 MSIV's Inside Containment

Since the documented maximum temperature, pressure, and humidity for these valves located inside containment is greater than or equal to the EQR specified environment for the same respective parameters, it is expected that these valves will be capable of performing their safety function as required when subjected to the EQR specified environments.

In addition, the inboard MSIV valves are required to withstand a 40-year-plus accident integration radiation dose of 2.7×10^7. This accident dose is based on a required operating time plus margin of 70 minutes. The 2-year normal radiation plus 70 minute accident integrated radiation dose is 9.8×10^6 rads. Materials analysis (EDS Calculation No. 0630-001-043, Rev. 0) indicates that the limiting material contained in this device is Viton, with a radiation tolerance of 1×10^7 rads. Therefore, these valves are expected to perform their safety function as required.

SECTION 3.0

ENVIRONMENTAL QUALIFICATION WORKSHEETS

Long Island Lighting Company
Shoreham Nuclear Power Station, Unit No. 1

Environmental Qualification Summary No. 3006M
Revision No. 0

MECHANICAL EQUIPMENT ENVIRONMENTAL QUALIFICATION WORKSHEET

Prepared by: [signature] Date: 8-24-82

Checked by: [signature] Date: 8-24-82

EQUIPMENT DESCRIPTION	ENVIRONMENTAL PARAMETER	POSTULATED ENVIRONMENT		DOCUMENTED ENVIRONMENT		OUTSTANDING ITEMS
		FSAR *	ENVIRONMENTAL QUAL. REPORT **	VALUE	REFERENCE	
EQUIP. I.D. (MARK NO.): B21*AOV081A,B,C,D	Maximum Temperature (degrees F)	340	340	340	1	None
VENDOR I.D.: B21-F022A,B,C,D	Maximum Pressure (psig)	48	48	65	1	None
EQUIPMENT TYPE: Air-Operated Valve	Maximum Relative Humidity (%)	100	100	100	1	None
SERVICE: MSIV - Inside Containment	Containment Spray	H_2O	H_2O	None	None	See Note 2.
MANUFACTURER: Rockwell	40-Year Normal Radiation Dose (Rads)	1.8×10^7	8×10^5 See Note 1.	1×10^7	1	None See Sect. 2.4.
MODEL NO.: 1612	6-Month Accident Radiation Dose (Rads)	1×10^8	9×10^6 See Note 1.			
LOCATION: RBP El. 82' ZONE: D-22	Submergence	N/A	N/A	N/A	N/A	N/A

ATTACHMENT TO MECHANICAL EQUIPMENT ENVIRONMENTAL QUALIFICATION WORKSHEET

REFERENCES:

1. G.E. Purchase Specification 21A9230, Rev. 2, Main Steam Isolation Valves.

NOTES:

1. The EQR 40-year normal and 70-minute (required operating time) accident radiation doses for these valves are 1.8×10^7 and 9×10^6 rads, respectively. Furthermore, the expected 2-year normal radiation dose for these valves is 8×10^5 rads.

2. These valves, as part of the pressure boundary, have a design pressure of 1250 psia and are hydrostatically tested to 2380 psig (Documentation References 5 and 6, respectively). In addition, these valves do not contain any electrical components that have not already been qualified for impingement from containment spray. It is therefore considered inconceivable that demineralized water spray will impair the ability of these valves from performing their safety function.

* FSAR values for maximum temperature, pressure, and humidity are from Table 3.11.1-1. Normal radiation dose is derived from EQR Figure C-1 in conjunction with FSAR Table 3.11.2-1. Accident dose is derived from Table 3.11.2-1.

** EQR values are from Table D-1; however, see Note 1 above.

Long Island Lighting Company
Shoreham Nuclear Power Station, Unit No. 1

Environmental Qualification Summary No. 3006M
Revision No. 0

MECHANICAL EQUIPMENT ENVIRONMENTAL QUALIFICATION WORKSHEET

Prepared by: [signature] Date: 8-24-82

Checked by: [signature] Date: 8-24-82

EQUIPMENT DESCRIPTION	ENVIRONMENTAL PARAMETER	POSTULATED ENVIRONMENT FSAR *	POSTULATED ENVIRONMENT ENVIRONMENTAL QUAL. REPORT **	DOCUMENTED ENVIRONMENT VALUE	DOCUMENTED ENVIRONMENT REFERENCE	OUTSTANDING ITEMS
EQUIP. I.D. (MARK NO.): 1B21*AOV082A,B,C,D	Maximum Temperature (degrees F)	300	215	340	1	None
VENDOR I.D.: B21-F028A,B,C,D	Maximum Pressure (psig)	1	1	65	1	None *
EQUIPMENT TYPE: Air-Operated Valve	Maximum Relative Humidity (%)	100	100	100	1	None
SERVICE: MSIV - Outside Containment	Containment Spray	N/A	N/A	N/A	N/A	N/A
MANUFACTURER: Rockwell	40-Year Normal Radiation Dose (Rads)	4.9×10^5	4.9×10^5	1×10^7	1	None See Sect. 2.4.
MODEL NO.: 1612	6-Month Accident Radiation Dose (Rads)	1×10^5	3.06×10^6			
LOCATION: Main Steam Tunnel El. 82' ZONE: T-08	Submergence	N/A	N/A	N/A	N/A	N/A

ATTACHMENT TO MECHANICAL EQUIPMENT ENVIRONMENTAL QUALIFICATION WORKSHEET

REFERENCES:

1. G.E. Purchase Specification 21A9230, Rev. 2, Main Steam Isolation Valves.

NOTES:

* FSAR Section 3C.3.2.2.1 excludes breaks for those portions of piping passing through primary containment penetrations and extending to the first restraint beyond the outermost outboard isolation valve (see FSAR Figures 3C.4-1, -2, -3, and -4). The limiting temperature, pressure, and humidity profiles are derived from Table 3C.3-9. Radiation doses are derived from Table 3.11.2-1.

** EQR values for maximum temperature, pressure, and radiation (normal and accident) are from Figures D-28, D-41, and D-2, respectively.

APPENDIX A

DOCUMENTATION

Flow Control Division
Rockwell International

CERTIFICATE OF COMPLIANCE

This is to certify that the Main Steam Isolation Valves, Tag Number MPL B21-F028 and B21-F022 meet the requirements as set forth in General Electric Purchase Order 205-AH-317, General Electric Drawing 761F615 Rev. A, General Electric Specification 21A9230 Rev. 2 and Rockwell International Corporation Drawing 419504 Rev. K, Sheet 1.

E.L. Green
Quality Assurance Documentation Technician

Date: 3-26-75

BWRPD QC
R.S

RECEIVED 6/17/82

3.300

GENERAL ELECTRIC

RECEIVED AUG 1 1 1982

NUCLEAR ENERGY DIVISION

PRODUCT QUALITY CERTIFICATION

CUSTOMER PROJECT		PRODUCT NAME	
LILCO		MAIN STEAM ISOLATION VALVE	B21-F0[illegible]
PART/DRAWING NO.	REV	QUALITY REQUIREMENTS DOCUMENT / REV.	[illegible]
731E615	4	21A9230 / 2	2*

VENDOR'S CERTIFICATION

THIS IS TO CERTIFY THAT THE PRODUCTS IDENTIFIED HEREIN HAVE BEEN MANUFACTURED UNDER A CONTROLLED QUALITY ASSURANCE PROGRAM AND ARE IN CONFORMANCE WITH THE PROCUREMENT QUALITY REQUIREMENTS INCLUDING APPLICABLE CODES, STANDARDS AND SPECIFICATIONS IDENTIFIED IN THE ABOVE-REFERENCED DOCUMENTS AND AS SPECIFIED IN GENERAL ELECTRIC PURCHASE ORDER NO. 205-AB317 REVISION 17 FOR P.O. ITEM NO. [illegible] UNLESS NOTED BELOW. ANY SUPPORTING DOCUMENTATION WILL BE FORWARDED OR RETAINED IN ACCORDANCE WITH PURCHASE ORDER REQUIREMENTS.

SIGNED: [signature] DATE: January 10, 1975

TITLE: Manager, Quality Assurance ORGANIZATION: Rockwell International

GE QUALITY ASSURANCE CERTIFICATION

THIS IS TO CERTIFY THAT EVIDENCE SUPPORTING THE ABOVE VENDOR'S CERTIFICATION STATEMENT HAS BEEN REVIEWED AND NO DEVIATIONS FROM PURCHASE ORDER REQUIREMENTS HAVE BEEN FOUND UNLESS NOTED BELOW.

SIGNED: [signature] DATE: January 10, 1975

TITLE: GE QA REPRESENTATIVE ORGANIZATION: BWRPD

NONCONFORMANCES FROM PROCUREMENT QUALITY REQUIREMENTS

DDR 1675 Rev. 1, 3053 & 3054, Rev. 1

REMARKS/EQUIPMENT SERIAL NUMBERS

S/N 178 & 179

* This PQC corrects a clerical error. Equipment was released on January 3, 1975

RECEIVED DISTRIBUTED

3.300

GENERAL ELECTRIC

NUCLEAR ENERGY DIVISION

RECEIVED AUG 11 1982

PRODUCT QUALITY CERTIFICATION

CUSTOMER/PROJECT		[Product]	MPL NO.
LILCO		MAIN STEAM ISOLATION VALVE	B21-F0[illegible]
PART/DRAWING NO.	REV	[Quality Requirements Document] 21A9230 [Rev] 2	[Quantity] 2
731E615	1		

VENDOR'S CERTIFICATION

THIS IS TO CERTIFY THAT THE PRODUCTS IDENTIFIED HEREIN HAVE BEEN MANUFACTURED UNDER A CONTROLLED QUALITY ASSURANCE PROGRAM AND ARE IN CONFORMANCE WITH THE PROCUREMENT QUALITY REQUIREMENTS INCLUDING APPLICABLE CODES, STANDARDS AND SPECIFICATIONS AS IDENTIFIED IN THE ABOVE-REFERENCED DOCUMENTS AND AS SPECIFIED IN GENERAL ELECTRIC PURCHASE ORDER NO. 205-A3317 REVISION 17 FOR P.O. ITEM NO. 1 UNLESS NOTED BELOW. ANY SUPPORTING DOCUMENTATION WILL BE FORWARDED OR RETAINED IN ACCORDANCE WITH PURCHASE ORDER REQUIREMENTS.

SIGNED: [signature] DATE: January 10, 1975

TITLE: Manager, Quality Assurance ORGANIZATION: Rockwell International

GE QUALITY ASSURANCE CERTIFICATION

THIS IS TO CERTIFY THAT EVIDENCE SUPPORTING THE ABOVE VENDOR'S CERTIFICATION STATEMENT HAS BEEN REVIEWED AND NO DEVIATIONS FROM PURCHASE ORDER REQUIREMENTS HAVE BEEN FOUND UNLESS NOTED BELOW.

SIGNED: Robert Bragg DATE: January 10, 1975

TITLE: GE QA REPRESENTATIVE ORGANIZATION: SWRPD

NONCONFORMANCES FROM PROCUREMENT QUALITY REQUIREMENTS

DDR 1675, Rev. 1, 3053 & 3054, Rev. 1

REMARKS/EQUIPMENT SERIAL NUMBERS

S/N 180 & 183

See Reverse for Instructions

NED-0098 (8/73)

33-9

GENERAL ELECTRIC

NUCLEAR ENERGY DIVISION

PRODUCT QUALITY CERTIFICATION

CUSTOMER/PROJECT		PRODUCT NAME		
LILCO	REV	MAIN STEAM ISOLATION VALVE	REV	QUANTITY
PART/DRAWING NO.	4	QUALITY REQUIREMENTS DOCUMENT 21A9230	2	2
731E615				

VENDOR'S CERTIFICATION

THIS IS TO CERTIFY THAT THE PRODUCTS IDENTIFIED HEREIN HAVE BEEN MANUFACTURED UNDER A CONTROLLED QUALITY ASSURANCE PROGRAM AND ARE IN CONFORMANCE WITH THE PROCUREMENT QUALITY REQUIREMENTS INCLUDING APPLICABLE CODES, STANDARDS AND SPECIFICATIONS AS IDENTIFIED IN THE ABOVE REFERENCED DOCUMENTS AND AS SPECIFIED IN GENERAL ELECTRIC PURCHASE ORDER NO. 205-AB317 REVISION 17 FOR P.O. ITEM NO. 1 UNLESS NOTED BELOW. ANY SUPPORTING DOCUMENTATION WILL BE FORWARDED OR RETAINED IN ACCORDANCE WITH PURCHASE ORDER REQUIREMENTS.

SIGNED: [signature] DATE: January 10, 1975

TITLE: Manager, Quality Assurance ORGANIZATION: Rockwell International

GE QUALITY ASSURANCE CERTIFICATION

THIS IS TO CERTIFY THAT EVIDENCE SUPPORTING THE ABOVE VENDOR'S CERTIFICATION STATEMENT HAS BEEN REVIEWED AND NO DEVIATIONS FROM PURCHASE ORDER REQUIREMENTS HAVE BEEN FOUND UNLESS NOTED BELOW.

SIGNED: [signature] DATE: January 10, 1975

TITLE: GE QA REPRESENTATIVE ORGANIZATION: BWRPD

NONCONFORMANCES FROM PROCUREMENT QUALITY REQUIREMENTS

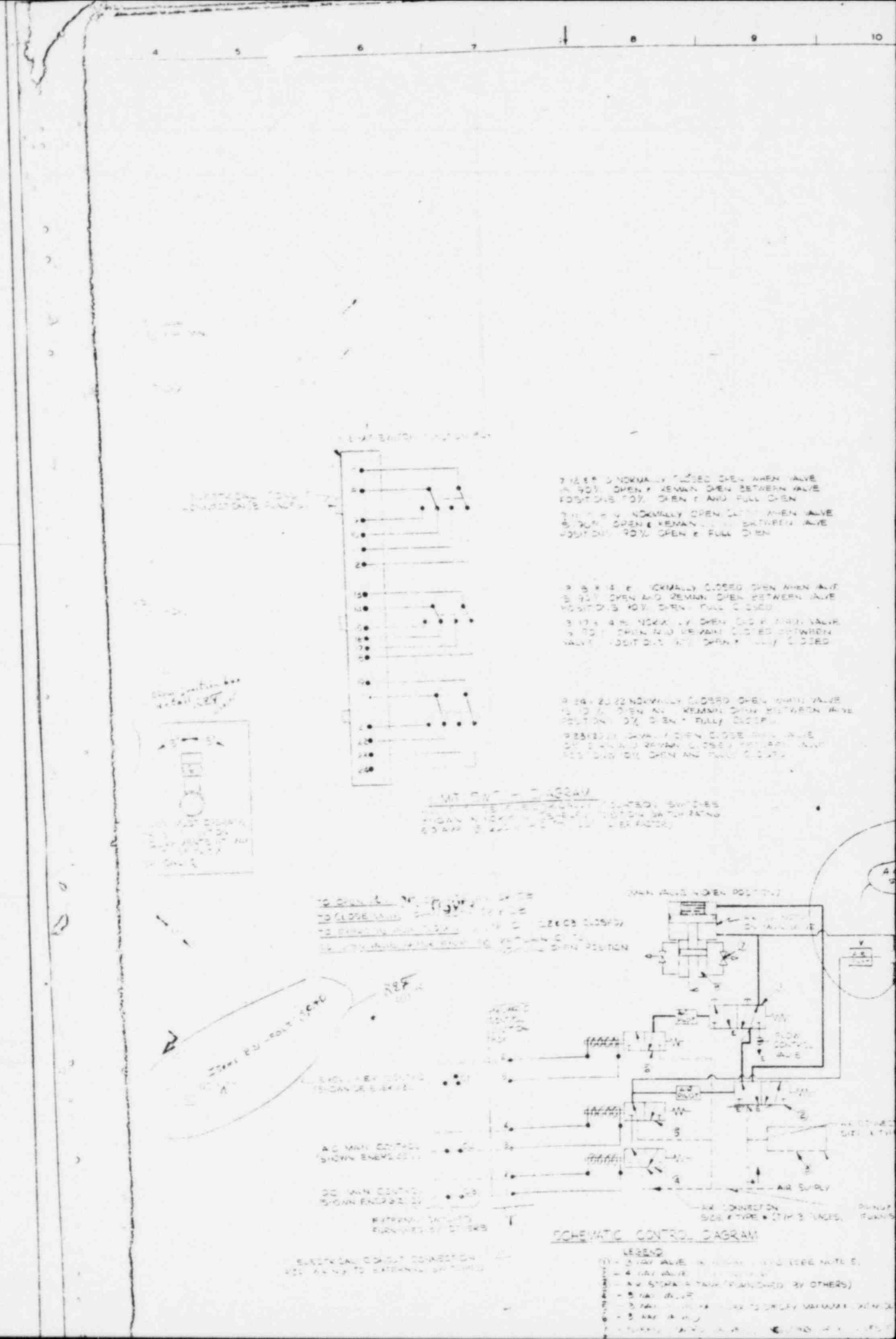
DDR 1675, Rev. 1, 3053 & 3054, Rev. 1

REMARKS/EQUIPMENT SERIAL NUMBERS

S/N 180 & 183

RECEIVED 6/17/82

See Reverse for Instructions



LIMIT SWITCH DIAGRAM
FLOW CONTROL VALVE
AIR SUPPLY
SCHEMATIC CONTROL DIAGRAM
LEGEND

GENERAL ELECTRIC 781E 615 [illegible]

PURCHASE PART
ISOLATION VALVE
PRIMARY STEAM PIPING

B21-F022 2.50
B21-F028 2.56

FOR LILCO

8	7	6	5	[illegible]	[illegible]	2	[illegible]	
26				25	[illegible]	28	83	PLANT SIZE
24				24	[illegible]	24	[illegible]	VALVE SIZE (NOMINAL)
20				26	[illegible]	20	[illegible]	A DIA
38				40	[illegible]	38	34	B VALVE DIA
6				7	[illegible]	6	[illegible]	[illegible]
1255				360	[illegible]	155	[illegible]	[illegible]
21.827				23.47	[illegible]	[illegible]	[illegible]	[illegible]
21				23	[illegible]	21	7	MAX
[illegible]				[illegible]	[illegible]	32	[illegible]	MAX
134				142	[illegible]	34	[illegible]	MAX
14				[illegible]	14	14	2	[illegible]
35°				35°	[illegible]	35°	35°	[illegible]
2.5 in O				[illegible]	[illegible]	[illegible]	[illegible]	STROKE TIME
20AC				20AC	[illegible]	20AC	20AC	VOLTS
50				60	[illegible]	60	[illegible]	CYCLES CONTROL
25DC				25DC	[illegible]	24DC	[illegible]	VOLTS DC POWER
[illegible]				5	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]				[illegible]	[illegible]	[illegible]	[illegible]	WEIGHT LBS
								FLOODED
								VALVE [illegible]

FOR LILCO

PILOT SHOWN ...

...OUP SHOWN DOTTED
...BY 511249

LILCO
MPL # B21-F022, F028

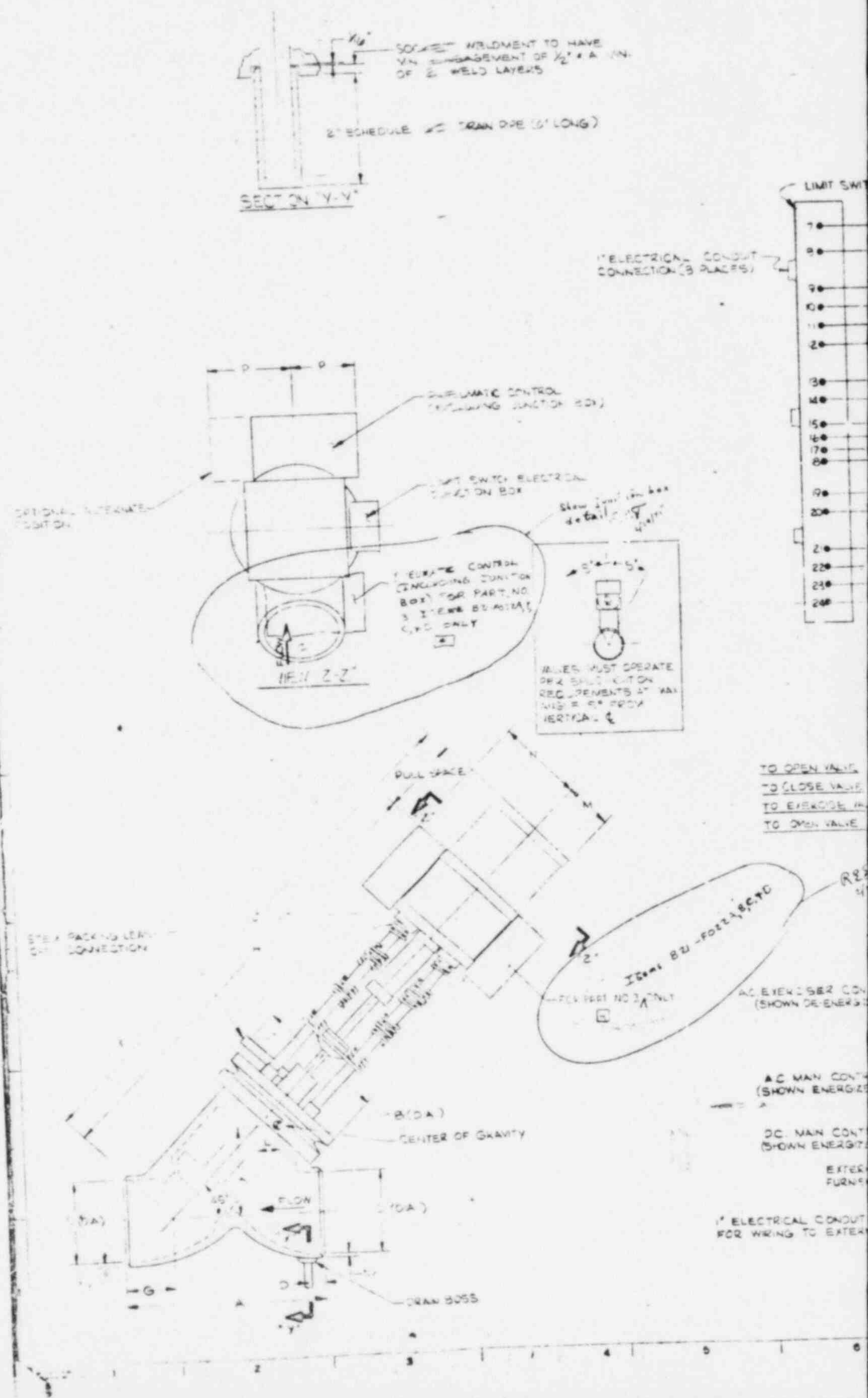
RECEIVED AUG 1 1 1982

11600.02— —

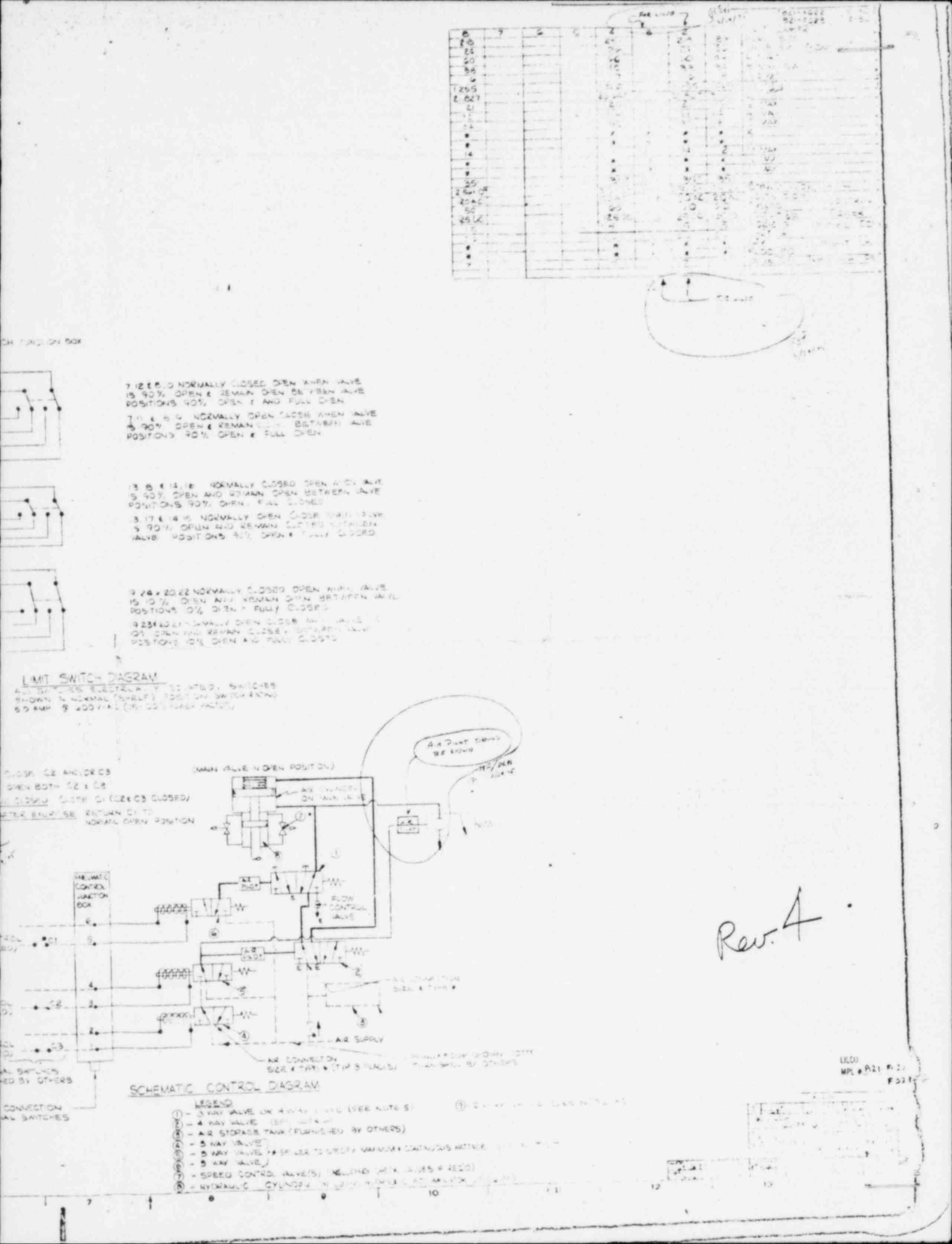
LONG ISLAND LIGHTING COMPANY
File No. 11600.02
Title Isolation Valve ...
Vendor GE
P.O. ...
System Name ...
BUILDING ...
Supersedes 11600.02
Superseded by 11600.02

EXTRA PRINTS REQUESTS

APPROVED AS REFINED IN SPECIFICATION
APPROVED AS REVISED AS DEFINED IN SPECIFICATION
FOR INFORMATION ONLY
RELEASED FOR MATERIAL PURCHASE
RELEASED FOR FABRICATION



SOCKET WELDMENT TO HAVE
OF 2 WELD LAYERS
SECTION "Y-Y"
LIMIT SWIT
1" ELECTRICAL CONDUIT CONNECTION (3 PLACES)
PNEUMATIC CONTROL
LIMIT SWITCH ELECTRICAL JUNCTION BOX
OPTIONAL ALTERNATE POSITION
VIEW Z-Z
VALVES MUST OPERATE PER SPECIFICATION REQUIREMENTS AT MAX ANGLE 5° FROM VERTICAL ℄
TO OPEN VALVE
TO CLOSE VALVE
TO OPEN VALVE
PULL SPACE
STEM PACKING LEAK OFF CONNECTION
A.C. EXERCISER CON
(SHOWN DE-ENERGIZ
A.C. MAIN CONT
(SHOWN ENERGIZE
D.C. MAIN CONT
(SHOWN ENERGIZE
1" ELECTRICAL CONDUIT
FOR WIRING TO EXTER
B (DIA.)
CENTER OF GRAVITY
FLOW
DRAIN BOSS



7.12 & 8.10 NORMALLY CLOSED OPEN WHEN VALVE IS 90% OPEN & REMAIN OPEN BETWEEN VALVE POSITIONS 90% OPEN & AND FULL OPEN
13.18 & 14.16 NORMALLY CLOSED OPEN WHEN VALVE IS 90% OPEN AND REMAIN OPEN BETWEEN VALVE POSITIONS 90% OPEN, FULL CLOSED
19.24 & 20.22 NORMALLY CLOSED OPEN WHEN VALVE IS 10% OPEN AND REMAIN OPEN BETWEEN VALVE POSITIONS 10% OPEN & FULLY CLOSED
LIMIT SWITCH DIAGRAM
(MAIN VALVE IN OPEN POSITION)
AIR CYLINDER ON MAIN VALVE
FLOW CONTROL VALVE
PNEUMATIC CONTROL JUNCTION BOX
AIR SUPPLY
AIR CONNECTION SIZE & TYPE
AIR PILOT
SCHEMATIC CONTROL DIAGRAM
LEGEND
① – 3 WAY VALVE OR 4 WAY VALVE (SEE NOTE 5)
② – 4 WAY VALVE
③ – AIR STORAGE TANK (FURNISHED BY OTHERS)
④ – 3 WAY VALVE
⑤ – 3 WAY VALVE
⑥ – 3 WAY VALVE
⑦ – SPEED CONTROL VALVE(S)
⑧ – HYDRAULIC CYLINDER
Rev. 4

GENERAL ELECTRIC

GENERAL ELECTRIC COMPANY
NUCLEAR ENERGY DIVISION
175 CURTNER AVENUE
SAN JOSE, CALIFORNIA 95125

PURCHASE ORDER NO. 205-AB317

THIS PURCHASE ORDER SHALL BE CONSTRUED, INTERPRETED AND APPLIED IN ACCORDANCE WITH THE LAWS OF THE STATE OF CALIFORNIA AND IS SUBJECT TO THE TERMS AND CONDITIONS ON THE FACE AND REVERSE SIDE HEREOF AND ANY SUPPLEMENTS, SPECIFICATIONS OR OTHER DOCUMENTS EXPRESSLY INCORPORATED HEREIN BY REFERENCE.

SELLER'S DUNS CODE	BUYER'S RESP. CODE	CONFIRMING	REVISION NO.	DATE OF ORDER OR REVISION	SHEET	OF SHEETS
	66		17	1/3/75	1	1

RECEIVED AUG 1 1 1982

SHIP TO:

NO CHANGE

OCKWELL MFG. CO.
.O. BOX 689
ORTE MADERA, CA. 94925

ENTION: H. BIERMAN

(HEREIN CALLED "SELLER") (HEREIN CALLED "BUYER")

CODE	PAYMENT TERMS	F.O.B.	SHIP VIA
	NO CHANGE	NO CHANGE	NO CHANGE

FABRICATION POINT IF DIFFERENT FROM SHIP

BUYER	NO CHANGE AND UNIT NO.	ACCOUNT NO.	M.R. OR QUOTE NO.	SHIPPING DATE	
	LILCO	NO CHANGE		NO CHANGE	

	QUANTITY	DESCRIPTION OF GOODS OR SERVICES

THIS REVISION IS ISSUED TO CORRECT A TYPOGRAPHICAL ERROR.

P.O. REVISION NO. 18, DATED 11/19/74 SHOULD BE REVISION NO. 16.

PURCHASE ORDER TOTAL REMAINS:

ALL 0

ALL OTHER TERMS OF THE ORIGINAL ORDER AND ORDER REVISIONS NO. 1 THROUGH 16 NOT MODIFIED HEREIN, REMAIN UNCHANGED AND APPLY HERETO.

1/7/75 gs

JAN 1 5 1975

SHIP NO.	DATE REC'D	QTY. REC'D BY ITEM 1	2	3	4	5	6	7	8	9	10	CONTAINERS NO.	KIND	C	RECEIVED BY
1															
2															
3															
4															

SHIP NO.	VIA	CARRIERS NAME	FREIGHT BILL NO.	FRT. BILL DATE	P-PPD. C-COLL.	AMOUNT	REMARKS
1							
2							
3							
4							

RECEIVING REPORT

GENERAL ELECTRIC

GENERAL ELECTRIC COMPANY
NUCLEAR ENERGY DIVISION
175 CURTNER AVENUE
SAN JOSE, CALIFORNIA 95124

PURCHASE ORDER NO. 205- AB317

THIS PURCHASE ORDER SHALL BE CONSTRUED, INTERPRETED AND APPLIED IN ACCORDANCE WITH THE LAWS OF THE STATE OF CALIFORNIA AND IS SUBJECT TO THE TERMS AND CONDITIONS ON THE FACE AND REVERSE SIDE HEREOF AND ANY SUPPLEMENTS, SPECIFICATIONS OR OTHER DOCUMENTS EXPRESSLY INCORPORATED HEREIN BY REFERENCE.

RECEIVED AUG 1 1 1982

SELLER'S CODE	BUYER'S REF. CODE	CONFIRMING	REVISION NO.	DATE		
	56	X	18	11/19/74	1	1

ROCKWELL MFG. COMPANY
P. O. BOX 689
CORTE MADERA, CAL. 94925

SHIP TO:
NO CHANGE

ATTENTION: (HEREIN CALLED "SELLER") (HEREIN CALLED "BUYER")

	PAYMENT TERMS	F.O.B.	SHIP VIA
F-O	NO CHANGE	NO CHANGE	NO CHANGE

SHIPPING POINT: NO CHANGE | FABRICATION POINT (IF DIFFERENT FROM SHIPPING POINT):

SECTION	PROJECT NAME AND UNIT NO.	ACCOUNT NO.	M.R. OR QUOTE NO.	SHIPPING DATE
11	LILCO	NO CHANGE	AB317, REV. 18	NO CHANGE

ITEM	QUANTITY	DESCRIPTION OF GOODS OR SERVICES
1		THIS PURCHASE ORDER IS HEREBY REVISED TO INCORPORATE THE FOLLOWING CHANGES:

ARTICLE I - SCOPE OF SUPPLY

PURCHASE PART DRAWING 731E675, REV. 4 SUPERSEDES ALL PREVIOUS ISSUES.

ARTICLE XIII - PURCHASE ORDER AMOUNT

TOTAL PURCHASE ORDER PRICE REMAINS:

NOTE: PRICE TO INCORPORATE ABOVE CHANGE WAS INCLUDED IN P.O. REVISION 13, DATED 3/27/74.

ALL OTHER TERMS OF THE ORIGINAL ORDER AND ORDER REVISIONS NO. 1 THROUGH 17 NOT MODIFIED HEREIN, REMAIN UNCHANGED AND APPLY HERETO.

11/19/74 gs

NOV 22 1974

SHIP NO.	DATE REC'D	QTY. REC'D BY ITEM 1	2	3	4	5	6	7	8	9	10	CONTAINERS NO.	KIND
1													
2													
3													
4													

SHIP NO.	VIA	CARRIERS NAME	FREIGHT BILL NO.	FRT. BILL DATE	P-PD. C-COLL	AMOUNT
1						
2						
3						
4						

RECEIVING REPORT

GENERAL ELECTRIC COMPANY
NUCLEAR ENERGY DIVISION
175 CURTNER AVENUE
SAN JOSE, CALIFORNIA 95125

PURCHASE ORDER 205- AB317

THIS PURCHASE ORDER SHALL BE CONSTRUED, INTERPRETED AND APPLIED IN ACCORDANCE WITH THE LAWS OF THE STATE OF CALIFORNIA AND IS SUBJECT TO THE TERMS AND CONDITIONS ON THE FACE AND REVERSE HEREOF AND ANY SUPPLEMENTS, SPECIFICATIONS OR OTHER DOCUMENTS EXPRESSLY INCORPORATED BY REFERENCE.

SELLER'S CODE	BUYER'S CODE	CONTINUING	REVISION NO.	DATE OF ORDER OR REVISION
064-195025	GG			10/15/69

SHIP TO: SEE BELOW

RECEIVED AUG 0 9 1982

ROCKWELL MANUFACTURING CO.
435 LESSER STREET
OAKLAND, CALIFORNIA 94601
ATTENTION: HANK DIERMAN (HEREIN CALLED "SELLER")

HEREIN CALLED "BUYER"

PAYMENT TERMS	F.O.B.	SHIP VIA
NET 30 DAYS	SHIPPING POINT - FULL FREIGHT ALLOWED OVER 500 LB.	PREPAID/INVOICE

RALEIGH, NORTH CAROLINA

	REQUISITION NO.	M.R. OR QUOTE NO.	SHIPPING DATE	SITE DELIVERY DATE
SHOREHAM	632-D3131-L62	AB317 REV. 1	SEE BELOW	

QUANTITY	DESCRIPTION OF GOODS OR SERVICES	UNIT PRICE	TOTAL
	SHOREHAM PROJECT MAIN STEAM ISOLATION VALVES		

SHOREHAM PROJECT MAIN STEAM ISOLATION VALVES

ARTICLE I - SCOPE OF SUPPLY

ROCKWELL MANUFACTURING CO. - HEREINAFTER CALLED "SELLER" SHALL PROVIDE ALL THE MATERIALS AND SERVICES NECESSARY TO DESIGN, FABRICATE, TEST AND DELIVER THE FOLLOWING EQUIPMENT:

8 EA. 24-INCH SHOREHAM MAIN STEAM ISOLATION VALVES IN ACCORDANCE WITH DRAWING 731E615 PART NO. 2, REVISION NO. 1 AND:

DOCUMENT NO.	REV.	DOCUMENT TITLE
21A9230	0	GENERAL SPECIFICATION
21A1150	2	VENDOR PRINTS
21A9825	2	SPARE PARTS
209A4288	1	WELD END DETAIL
731E224	0	WELD END DETAIL
	2	QUALITY CONTROL PLAN 222
		QUALITY CONTROL STANDING INSTRUCTION 7.2.19

/CONTINUED ON PAGE 2/

DATE REC'D	QTY REC'D BY ITEMS 1	2	3	4	5	6	7	8	9	10	CONTAINERS NO.	KIND

VIA	CARRIER'S NAME	FREIGHT BILL NO.	FRT. BILL DATE	P-PPD. C-COLL.	AMOUNT	REMARKS

RECEIVING REPORT

THIS CONTINUATION SHEET IS SUBJECT TO THE TERMS AND CONDITIONS ON THE FACE AND REVERSE SIDE OF THE FIRST SHEET AND ALL OTHER CONTINUATION SHEETS OF THIS ORDER AND ANY SUPPLEMENTS SPECIFICATIONS OR OTHER DOCUMENTS EXPRESSLY INCORPORATED HEREIN BY REFERENCE.

ITEM	QUANTITY	DESCRIPTION OF GOODS OR SERVICES
1A	1 EA.	SPRING PRELOADING FIXTURE /ONE /1/ REQUIRED PER PLANT/
1B	1 LOT	DATA AND DOCUMENT SUBMITTALS IN ACCORDANCE WITH ATTACHMENT 'A', REVISION 0 TO SPECIFICATION 21A9230.
		NOTE: IF SUBMITTALS ARE NOT CURRENT WITH EQUIPMENT SHIPMENTS, 5 PERCENT OF THE ITEM PRICE WILL BE WITHHELD.
1C	1 LOT	INSTRUCTION MANUALS /30 REQUIRED/

TOTAL UNIT PRICE

TOTAL ITEM NO. 1 PRICE /8 VALVES/

ARTICLE II - SHIPPING

P.O. ITEM NO.	MARK	QUANTITY	PROJECT	GE ACCOUNT NO.
1	B21-F022	4	SHOREHAM	632-D3134-L62
1	B21-F028	4	SHOREHAM	632-D3134-L62

SHIPPING DESTINATION:

SHIP TO - SHOREHAM

TRUCK

STONE AND WEBSTER ENGINEERING CORPORATION, AGENT
LONG ISLAND LIGHTING COMPANY
SHOREHAM NUCLEAR POWER STATION
ACCESS ROAD ON ROUTE 25A
EAST OF WILLIAM FLOYD PARKWAY
SHOREHAM, NEW YORK

REQUIRED SHIP DATE:

ITEM 1 /8 VALVES/ 4/1/72
ITEM 1A /FIXTURE/ 4/1/72

/CONTINUED ON PAGE 3/

QUANTITY	DESCRIPTION OF GOODS OR SERVICES	UNIT PRICE	TO...

ARTICLE III - ORDER OF PRECEDENCE

ATTACHED GENERAL ELECTRIC CO. PURCHASE ORDER SUPPLEMENT 'E' /REV. 3-69/ APPLIES.

ARTICLE IV - SOURCE INSPECTION

GENERAL ELECTRIC COMPANY QUALITY CONTROL PURCHASED MATERIAL REPRESENTATIVE WILL CONDUCT SOURCE INSPECTION OF MATERIAL COVERED BY THIS INQUIRY/PURCHASE ORDER. SEVENTY-TWO /72/ HOURS ADVANCE NOTICE TO BE FURNISHED BY SUPPLIER FOR QCPM INSPECTION. MATERIAL ON THIS ORDER MUST NOT BE SHIPPED WITHOUT APED QCPM APPROVAL.

ARTICLE V - MONTHLY PROGRESS REPORTS

MONTHLY PROGRESS REPORTS SHALL BE SUBMITTED THE FIRST DAY OF EACH MONTH, STARTING WITH THE MONTH FOLLOWING AWARD OF THE PURCHASE ORDER. THE REPORT SHALL INCLUDE THE STATUS OF ENGINEERING, MATERIALS, PARTS, FABRICATION, ASSEMBLY, TEST AND ANY PROBLEM AREAS. ACTION BEING TAKEN IN EACH PROBLEM AREA TO RECOVER SCHEDULE DELAYS SHALL BE STATED.

ARTICLE VI - TRANSMITTALS

ALL DOCUMENT SUBMITTALS ARE TO BE MADE USING THE APED DOCUMENT TRANSMITTAL FORMS SUPPLIED BY THE BUYER IN ACCORDANCE WITH INSTRUCTION SHEET NED 785 AND SHALL BE SENT DIRECTLY TO:

GENERAL ELECTRIC CO.
ENGINEERING RELEASES
175 CURTNER AVENUE
SAN JOSE, CALIFORNIA 95125
ATTN: L.L. KLEINHESSELINK
M/C 630

ONE /1/ COPY OF EACH TRANSMITTAL FORM ONLY SHALL BE MAILED DIRECTLY TO THE BUYER. ALL TRANSMITTAL DOCUMENTS SHALL CONTAIN THE FOLLOWING INFORMATION:

1. DATE
2. GE PURCHASE ORDER NUMBER
3. PROJECT DESIGNATION
4. EQUIPMENT MARK NUMBER
5. MPL NUMBER
6. IDENTIFICATION OF DOCUMENTS SUBMITTED BY TYPE, NUMBER, REVISION NUMBER, TITLE AND DATE.
7. SELLER'S SIGNATURE AND TITLE

/CONTINUED ON PAGE 4/

ITEM	QUANTITY	DESCRIPTION OF GOODS OR SERVICES	UNIT PRICE	TOTAL

ARTICLE VII - SPARE PART SUBMITTALS

THE SELLER SHALL SUBMIT TO APED ENGINEERING RELEASES, THE SPARE PART RECOMMENDATIONS AS REQUIRED BY SPECIFICATION 21A9825 IN ACCORDANCE WITH ATTACHMENT A.

ARTICLE VIII - MARKING

SELLER SHALL MARK EACH COMPONENT, INVOICE, SHIPPING NOTICE, PACKING LIST, BOX, CRATE AND SHIPPING STRUCTURE WITH THE MARK NUMBER, PURCHASE ORDER NUMBER, QUANTITY, PROJECT AND GE ACCOUNT NUMBER SPECIFIED ABOVE.

ARTICLE IX - SHIPPING NOTICE

SELLER SHALL SUBMIT TO BUYER ON THE SAME DAY THAT SHIPMENT IS MADE, ONE /1/ COPY EACH OF A BILL OF LADING AND MEMO OF SHIPMENT INDICATING ITEMS, ROUTING, DATE SHIPPED AND CARRIER. A COPY OF THE PACKING LIST SHALL ALSO BE SUBMITTED. IF SHIPPING IS TO ANOTHER VENDOR, SELLER SHALL REQUEST THE ABOVE INFORMATION BE SUBMITTED TO HIM WITH SUBSEQUENT TRANSMITTAL TO THE BUYER.

ARTICLE X - WARRANTY

ATTACHED GENERAL ELECTRIC P.O. SUPPLEMENT 'E' /REV. 3-69/ APPLIES.

ARTICLE XI - CUSTOMER REPRESENTATIVE VISITS

CUSTOMER REPRESENTATIVES SHALL HAVE THE RIGHT TO OBSERVE MANUFACTURE, TEST AND INSPECTION IN THE SELLER'S FACILITIES ONLY IF ACCOMPANIED BY A GENERAL ELECTRIC REPRESENTATIVE, AND PRIOR NOTIFICATION HAS BEEN GIVEN THE SELLER. CUSTOMER REPRESENTATIVES ARE NOT PERMITTED TO DIRECT ANY CHANGES OR GIVE ANY INSTRUCTIONS TO SELLER THAT WOULD MODIFY OR CHANGE ANY CONTRACT REQUIREMENTS.

ARTICLE XII - PAYMENT

AFTER SUBMITTAL OF AN INVOICE, BUT BEFORE FINAL PAYMENT IS MADE, THE FOLLOWING IS REQUIRED:

1. THE BUYER MUST HAVE EITHER A DESTINATION RECEIVING INSPECTION REPORT OR SHIPPING POINT RECEIPT INSPECTION ON AN OVERSEAS SHIPMENT.

/CONTINUED ON PAGE 5/

THIS CONTINUATION SHEET IS SUBJECT TO THE TERMS AND CONDITIONS ON THE FACE AND REVERSE SIDE OF FIRST SHEET AND ALL OTHER CONTINUATION SHEETS OF THIS ORDER AND ANY SUPPLEMENTS, SPECIFICATION OTHER DOCUMENTS EXPRESSLY INCORPORATED HEREIN BY REFERENCE.

QUANTITY	DESCRIPTION OF GOODS OR SERVICES	UNIT PRICE	TOTAL PRICE

2. DETERMINATION BY THE BUYER THAT ALL REQUIREMENTS OF THE ORDER, INCLUDING DOCUMENTATION AND RECORDS HAVE BEEN MET.

IN THE EVENT THAT DOCUMENTATION SUBMITTALS HAVE NOT BEEN COMPLIED WITH AT THE TIME OF SHIPMENT AS DETERMINED BY THE BUYER, THEN 5 PERCENT OF THE TOTAL PURCHASE ORDER PRICE MAY BE WITHHELD BY BUYER UNTIL DOCUMENT SUBMITTALS ARE COMPLETE.

INVOICES, INCLUDING THOSE FOR PARTIAL PAYMENT, SHALL BE FORWARDED TO THE ADDRESS SHOWN ON THE FACE OF THE PURCHASE ORDER, ATTENTION M/C 116. BILL OF LADING AND SHIPPING MANIFESTS MUST BE ATTACHED TO INVOICES.

ARTICLE XIII - PURCHASE ORDER AMOUNT

THE TOTAL AMOUNT OF THIS PURCHASE ORDER IS

ARTICLE XIV - ENTIRE AGREEMENT

SELLER AGREES THAT THE PROVISIONS OF ARTICLES I THROUGH XIV OF THIS PURCHASE ORDER AND ALL OTHER DOCUMENTS INCLUDED THEREIN BY REFERENCE SHALL CONSTITUTE THE ENTIRE AGREEMENT BETWEEN THE PARTIES HERETO AND SUPERSEDES ALL PRIOR AGREEMENTS, VERBAL OR WRITTEN RELATING TO THE SUBJECT MATTER HEREOF AND CAN BE AMENDED ONLY IN WRITING.

GENERAL ELECTRIC
NUCLEAR ENERGY DIVISION
ATOMIC POWER EQUIPMENT DEPARTMENT
San Jose, California

DOCUMENT NO. 21A9230, REV. 2

APPLICATION

[x] SPECIFICATION [ ] DRAWING

TYPE PURCHASE

DOCUMENT TITLE MAIN STEAM ISOLATION VALVES

REVISIONS			
1	Revisions per ECN #NE20891. Sheets 1-3-6-7-8-9-12-15-17-18 are affected. Revisions indicated by (♠).		RECEIVED 6-11-82
2	Per ECN NE 27573. Sheets 1,2,3,4,5, and 16 are affected. Revisions identified with a spade (♠). T.N.G. 2/15/71		

MADE BY	JA MAST	BP BROOKS	SHEET 1	1a
ISSUED	FEB 10 1971			

REVISION STATUS SHEET

NEC 895 (2-69)

GENERAL ELECTRIC

ATOMIC POWER EQUIPMENT DEPARTMENT

PURCHASE SPECIFICATION

1p
tad

SPEC NO 21A9230	REV NO 2
SH NO 1	CONT ON SHEET 2

TITLE MAIN STEAM ISOLATION VALVES

1. SCOPE

1.1. This specification defines the requirements for quick-closing isolation valves for high pressure steam service.

1.2. The work done by the Seller in accordance with this specification shall include all necessary design, development, analysis, drawings, fabrication, shop testing, inspection and preparation for shipment and shall meet the requirements described herein.

1.3. The Seller shall accept full responsibility for his work and for compliance with this specification. Review or approval of drawings, data or specifications by the Buyer with regard to general design and controlling dimensions, does not constitute acceptance of any designs, materials or equipment which will not fulfill the functional or performance requirements established by the purchase contract.

2. APPLICABLE DOCUMENTS, CODES AND STANDARDS

2.1. General

2.1.1. Purchased Part Drawing, 731E613, a Data Sheet, or both documents may be used with this Base Specification to provide the complete specification. The Base Specification provides the general functional requirements, and the Purchase Part Drawing and Data Sheet provide specific and individual performance requirements for the equipment being purchased. Therefore, when a Purchase Part Drawing is used, it shall be controlling. When a Data Sheet or both Drawing and Data Sheet are used with this specification, the Data Sheet shall be the controlling document. When Data Sheets or Purchase Part Drawings are not used with this document, the equipment requirements shall be considered as completely specified in Base Specification and it shall be the governing document.

2.2. Codes and Standards

2.2.1. The following standards and codes of the issue in effect on the date of award of contract from a part of this specification to the extent specified herein.

Manufacturers Standardization Society (MSS)-SP-61 Hydrostatic Testing of Steel Valves

American National Standards Institute (ANSI)
ANSI B16.5, Steel Pipe Flanges and Flanged Fittings
ANSI B31.1.0, Code for Pressure Piping, Power Piping

American Society for Testing Materials (ASTM)

American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section I, III, VIII, and IX

National Electrical Manufacturers Association (NEMA)

National Electric Code (NEC)

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3. DESCRIPTION

3.1. Supplied by Seller

3.1.1. The equipment to be furnished in accordance with this specification is a wye pattern globe type valve complete with actuator and accessory equipment. The actuator shall be air-to-open, air-and/or-spring-to-close.

3.1.2. A set of any special tools which may be required for installation, maintenance, and adjustment shall be furnished as necessary.

3.2. Supplied by Others

3.2.1. Insulation and external service connections (e.g. thermocouples, piping, etc.) will be furnished by others, unless otherwise specified.

3.2.2. Seal welding of body to bonnet (if required) shall be performed by others.

4. REQUIREMENTS

4.1. Operating Conditions

4.1.1. The valves shall function as required by this specification, when installed in a horizontal steam line, two valves in series per steam line, one valve located within a pressure-containing enclosure (valve inaccessible during operation) and one outside the enclosure in a pipe tunnel. The design, materials, and configuration of the valves shall be identical regardless of location of installation. The maximum angle of inclination from vertical of the centerline of the valve shall be as listed in the Purchased Part Drawing.

4.1.2. Valve shall operate as specified at the following ambient conditions within the pressure-containing enclosure:

	Normal	Emergency (Total Duration is the Sum of the Separate Durations)				
		A	B	C	D	E
Temperature	150°F max.	340°F max.	340°F max.	320°F max.	250°F max.	200°F max.
Pressure	0 to 2 psig	65 psig max.	35 psig max.	35 psig max.	25 psig max.	20 psig max.
Rel. Hum.	100%	100%	100%	100%	100%	100%
Duration	continuous	<60 sec	3 hours	3 hours	18 hours	100 days

Incident Radiation (continuous for design life)

Gamma: 15 R/hr
Gamma and Neutron: 25 R/hr

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4.1.2.1. The valves shall be capable of operation within specified limits, except regarding variance in closing speed due to superimposed back pressure resulting from emergency ambient conditions during one hour (total) exposure to emergency ambient conditions A and B (per Table), and shall remain closed during the continance of emergency ambient conditions.

4.1.3. Steam Flow

4.1.3.1. During normal operation, valves shall operate with steam at 1005 psig and saturated conditions and at a flow rate as listed on the Purchased Part Drawing.

a. Moisture content of the steam will be less than or equal to 0.25 percent,
b. Oxygen content will be less than or equal to 30 ppm,
c. Hydrogen content will be less than or equal to 4 ppm.

4.1.3.2. Valve shall close during emergency steam flow conditions following rupture of the main steam line downstream of the valve. Steam flow rate will increase to 200 percent of rated flow and internal parts of the valve will be subject to impact by a mixture of water and steam at the following conditions:

a. Upstream pressure prior to impact: 1135 psig (or less) saturated steam.
b. Mass velocity of impacting fluid: 2400 lb/sec ft^2
c. Impacting fluid: A mixture consisting of 95 percent water and 5 percent steam by weight at nominally 925 psig and 540°F.
d. At impact, the internal pressure in the valve shall increase instantly to 1145 psig and will rapidly decay from this peak pressure to a steady state system pressure of approximately 955 psig. At subsequent valve closure pressure will increase to 985 psig.
e. Valve position at the time of impact is estimated to be between 10 percent and 45 percent open.

4.1.3.3. The maximum continuous system pressure and temperature will be 1250 psig and 575°F.

4.1.3.4. Valve shall operate at the minimum system pressure and temperature of 250 psig at 400°F.

4.1.4. Valve shall be capable of actuating 50 to 400 cycles per year (full open-to-full-closed-and-return). Actuating cycles are comprised essentially of exercising cycles.

4.2. Construction

4.2.1. Valve ends shall be prepared for butt welding in accordance with drawings and dimensions as listed on the Purchased Part Drawing.

4.2.2. The valve body-to-bonnet joint shall be of bolted construction. The joint shall incorporate a spiral wound stainless steel, asbestos-filled gasket. The gasket shall be totally enclosed at installation. Gasket compression shall be established by metal-to-metal assembly of the bonnet to the body with the gasket installed in a groove of predeterimined depth as required to obtain proper gasket "crush."

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4.2.3. The body-to-bonnet joint shall be prepared for seal welding. Seal welding may be performed by others at the installation site after extensive service.

4.2.4. The valve stem and valve bonnet shall be provided with a back seating configuration such that the valve can be repacked while full pressure is in the pipeline.

4.2.5. The stem seal stuffing box shall be provided with two complete sets of packing, each capable of withstanding design pressure without visible leakage. A lantern ring shall be provided between the two sets of packing with a leakoff connection opposite the lantern ring. The leakoff connection shall be provided with a 3/4 inch Schedule 80 pipe nipple, socket-welded in position and machined square on the outboard end preparatory for socket welding in the field. Length of the pipe nipple shall be such as to provide easy access for the subsequent field welding.

4.2.6. Surface finish of the valve stem shall be 4 to 8 micro-inch rms.

4.2.7. <u>Seismic Coefficient</u>. The valves, including operator and accessories, shall withstand static seismic forces, as noted on the Purchased Part Drawing, applied at the mass center assuming that the operator is cantilevered from the valve body, and the valve is installed as described in Paragraph 4.1.1.

4.2.7.1. The stresses due to horizontal and vertical seismic forces shall be considered to act simultaneously and shall be added directly.

4.2.7.2. The stresses in the valve components due to seismic loads shall be combined with stresses due to other live and dead loads and operating loads. The allowable stress level for this combination of loads shall be as listed in the applicable codes. The one-third increase in allowable stress usually allowed for earthquake loading shall not be used.

4.2.8. <u>Pressure containment</u>. The valves shall be capable of operating at a continuous pressure and temperature of 1250 psig at 575°F.

4.2.8.1. The minimum wall thickness of the pressure-containing components of the valve shall be determined in accordance with the requirements of ANSI B16.5 except as noted herein.

4.2.8.2. The applicable equation shall be:

$$t = 1.5 \frac{Pd}{2S-1.2P} + C$$

where: t = calculated thickness, inches,

P = Primary service pressure rating = 655 psi

d = Inside diameter of the valve corresponding with the location for which wall thickness is being calculated.

S = Stress equals 7000 psi

C = Corrosion allowance equals 0.120 inches

4.2.8.2. (Continued)

Note: The additional requirements of Paragraph 6.1 of ANSI B16.5 shall apply.

4.2.8.3. Pressure containing flanges and bolting shall be furnished in accordance with the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII.

4.2.8.4. The valve disc, and similar pressure containing components shall withstand full differential pressure equal to the pressure rating of the valve at 100°F and 575°F. Pressure shall be considered to be acting in a direction tending to close the valve. An appropriate analysis of the above affected components, utilizing allowable stress levels as listed in ASME Boiler and Pressure Vessel Code, Section VIII, shall be conducted.

4.2.9. Valve Operator. The valve operator and all related accessories described herein shall be mounted directly onto the valve yoke (or equivalent).

4.2.9.1. The valve operator shall be air-to-open and air and/or spring-to-close.

4.2.9.2. The pneumatic cylinder and related components will utilize oil-free, filtered air, dried to a dew point of -40°F at the pressure the air is supplied, as the actuating medium. Actuating air pressure will be 90 to 100 psig. The pneumatic cylinder and related components shall not require additional lubrication such as that provided by an oil-entraining device in the actuating air system.

4.2.9.3. The pneumatic cylinder shall be provided with a hydraulic snubber device suitable for controlling the speed of opening and closing of the valve (see applicable Purchased Part Drawing for arrangement). Provision shall be made to accommodate increase in fluid pressure due to the increase of ambient temperature from that existing during filling and sealing of the hydraulic system to that existing during emergency conditions.

4.2.9.4. Valve closure time shall be adjustable from 3 to 10 seconds for full valve stroke for any of the following conditions of line pressure and steam flow.

a. Zero psig line pressure and zero steam flow.

b. 1000 psig line pressure and zero steam flow.

c. 1000 psig upstream line pressure with steam flow varying from rated flow to zero; valve pressure drop increasing from nominally 5 psi to 40 psi respectively for full open and full closed positions.

d. 100 psig to 1000 psig upstream line pressure with steam flow varying from 200 percent of rated flow (following a pipe rupture) to zero; valve pressure drop increasing from nominally 5 psi to 1000 psi respectively for full open and full closed positions.

4.2.9.4.1. The speed control valve(s) shall accomplish the range of adjustment with at least two full revolutions of the adjustment spindle (or equivalent).

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4.2.9.4.1. (Continued)

The adjustment spindle shall be provided with a positive locking device. The speed control valve shall be provided with a minimum flow position stop (or equivalent) to prevent its full closure.

4.2.9.5. Valve shall open at a rate of one inch, plus or minus 1/2 inch, per second as measured at the valve stem.

4.2.9.6. The valve operator shall open the valve with a 200 psi differential pressure tending to hold the valve closed, utilizing 90 psig air pressure to the valve actuator.

4.2.9.7. The pneumatic cylinder and related components shall function safely at a working pressure of 125 psig.

4.2.9.8. The hydraulic snubber and related components shall function safely at a working pressure based on calculated pressure rise due to maximum acceleration of the valve disc during closing. Piston size shall limit pressure rise to 3000 psig or less.

4.2.9.9. The valve operator shall be provided with solenoid control valves, pneumatic control valves and limit switches as depicted on Purchased Part Drawing. All components shall be prewired and prepiped by the Seller. Wire terminations shall be made to a terminal board with identification as shown. All wiring shall be in accordance with requirements of the National Electric Code. The valve operator shall be provided with equipment as shown for exercising the valve from 100 percent open to full closed position in 45 to 60 seconds, and from 100 percent open to 90 percent open at the same speed.

4.2.9.10. Electrical equipment enclosures, conduit, and conduit connections shall be of water tight (NEMA Class 4 or better) construction suitable for the operating conditions and ambient environment specified in Paragraph 4.1.

4.2.9.11. Electrical insulation and enclosure seals, pneumatic and hydraulic seals, hydraulic fluids, and similar non-metallic components shall be constructed of materials which are resistant to radiation damage (see Paragraph 4.1.2.) considering a total dose of 1×10^7 R gamma radiation. Radiation damage shall be construed to mean a detrimental change in the functional properties of the material.

4.3. Fabrication

4.3.1. Welding

4.3.1.1. Qualification. All welding including fillet, seal, repair, and attachment welds shall be performed in accordance with written welding procedures. Procedure qualification and weldor performance qualification shall be in accordance with ASME Boiler and Pressure Vessel Code, Section IX.

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4.3.1.2. Attachment welds. Attachment of non-pressure containing parts (such as supports and hangers) to pressure containing components shall be by complete penetration groove welds and shall be subject to all the requirements and limitations imposed for fabrication of the valve component to which they are attached.

4.3.2 Heat Treatment

4.3.2.1. Carbon and low alloy steel. Carbon and low alloy steel piping components and equipment pressure parts shall be heat treated in accordance with the requirements of the applicable ASTM materials specifications.

4.3.2.2. Welds. Heat treatment of welds including [illegible] in accordance with the requirements and recommendations of [illegible] B31.1, Code for Power Piping.

4.3.2.3. Cleaning after heat treatment shall be by machining, grinding, or sandblasting. When used, sandblasting shall be followed by vacuum or air blast cleaning.

4.3.3. Defect Repair. Repair of base metal or weld metal defects shall be in accordance with the following requirements.

4.3.3.1. Surface defects such as laps, seams, slivers, scars, or tears -- which do not encroach on minimum wall thickness -- shall be removed by machining or grinding and shall be blended into the adjacent metal surfaces.

4.3.3.2. When defect removal encroaches upon minimum wall thickness, repairs may be made by welding.

4.3.3.3. Major repairs, as defined herein, shall require the concurrence of the Buyer. The Buyer shall receive prior notification of all major repairs. Records shall indicate the nature of the defect removed, the location of the defect, subsequent heat treatment, or other pertinent data and they shall be made available to the Buyer upon request.

4.3.3.4. Major repairs in base materials such as plates, forgings, extruded pipes, or castings are defined as: a) a repair which requires excavation of material to a depth greater than 20 percent of the wall thickness or to a depth of [illegible] inch, whichever is less, or when the extent of the cavity is greater than [illegible] square inches; b) the repair of any crack in wrought or forged material; and c) the repair of defects which are indicative of fundamental materials problems.

4.3.3.5. Major repairs in welds are defined as: a) the repair of any crack other than crater cracks or b) the repair of defects which are indicative of either a fundamental materials problem or of a process out of control.

4.3.4. Inspection of Repair Welds. Repair welds of a depth greater than 10 percent of the wall thickness shall meet the inspection requirements for the base material.

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4.3.5. Surface Finish. The surface finish of either materials, welds, or equipment pressure parts shall be suitable for the inspection and testing required by the applicable test. Surface discontinuities which are markedly different from the overall finish shall be removed or blended into the adjacent surfaces.

5. MATERIALS

5.1. Shell components (valve body, bonnet):

ASTM-A216 Gr. WCB

ASTM-A105 Gr. II

5.2. Trim Components.

5.2.1. Valve disc: ASTM A216 Gr. WCB

ASTM A105 Gr. II

Ferritic Alloy Steel, per ASTM A182 (Seller shall specify Grade) are acceptable in the "low" alloy range (F1,F11,F12)

5.2.2. Valve trim components shall be hardfaced with materials of chemistry per ASTM A 399 Class R C_oC_r- A on all seating and wear surfaces. Minimum thickness of deposition on seating surfaces shall be 3/32 inch after final machining and lapping. Valve body seat shall be integrally hardfaced.

5.3. Other valve components shall be as follows:

a. Valve stem: ASTM A276 Gr. 410 (Hardened-Rockwell 28-32)

b. Stem packing: John Crane Co. #187-I

c. Bolting: ASTM A193 Gr. B7 /or/ B16
ASTM A194 Gr. 7 /or/ 2H

d. Valve Actuator: Electrical insulation - Class H
Pneumatic and Hydraulic seals (Rubber materials) Viton as manufactured by DuPont Corp. or Buyer approved equal.

5.4. Welding materials

5.4.1. Coated arc welding electrodes shall be:

a. Mild Steel - ASTM A233
b. Low Alloy Steel - ASTM A316

5.4.2. Mild steel electrodes (solid only) used for gas metal arc welding, shall be ASTM A559

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5.5. Alternate Materials. The Seller shall be free to suggest alternate materials during preparation of detailed drawings and shall bring such alternates to the attention of the Buyer, but shall not make substitutions without approval of the Buyer. The proposed alternate materials shall be presented with the scope of application and a copy of codes or specifications equivalent to ASME or ASTM, or detailed information equivalent to that furnished in the ASME or ASTM codes and specifications.

6. INSPECTION AND TEST

6.1. General

6.1.1. The Seller shall be responsible for conducting the following inspection and tests and shall furnish all materials and equipment required. Buyer's authorized representative(s) shall have access to all fabrication and testing procedures described in this specification, including those of any of Seller's suppliers or subcontractors regradless of tier. Seller shall provide notice at least 48 hours in advance of examination and tests so described.

6.1.2. Quality Control. The manufacturer of the pressure-containing components of the valve (body, bonnet, stem, disc, nozzles and bonnet bolting, or equivalent) shall maintain a quality assurance control program that conforms with the requirements of Appendix IX, Para. IX-200 of Section III of the ASME Boiler and Pressure Vessel Code.

6.2. Non-Destructive Examination

6.2.1. Pressure-containing welds shall be 100 percent examined by radiography and accessible surfaces of welds and adjacent base metal shall be examined by either liquid penetrant or magnetic particle testing following heat treatment. Non-pressure containing attachment welds, except as limited by Para. 4.3.1.2. shall be examined on all accessible surfaces by either liquid penetrant or magnetic particle testing. Re-examination of repaired areas shall be in accordance with the original inspection requirements following heat treatment.

6.2.2. Forgings and stock (plate, bar, etc) for pressure-containing components, shall be examined by ultrasonic method in either the "as-furnished" or finished condition.

6.2.3. All forgings and stock (plate, bar, etc) for pressure-containing components shall be examined in the finished condition, on all accessible surfaces, including machined surfaces, by either liquid penetrant or magnetic particle testing.

6.2.4. Castings for pressure-containing parts shall be 100 percent examined by radiography and all accessible surfaces, including machined surfaces, shall be examined by either liquid penetrant or magnetic particle methods following heat treatment. Re-examination of repaired areas shall be by the above techniques following heat treatment.

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6.2.5. Bolts, studs and nuts, used on pressure-containing components shall be examined by either liquid penetrant or magnetic particle testing. The examination shall be performed on either the finished part after threading or on the material stock of approximately the finished diameter before threading but after heading.

6.2.6. Final machined and ground surfaces of all hardfaced surfaces, including at least 1/2 in. of the base metal adjacent to the hardfacing shall be examined by liquid penetrant testing.

6.3. Methods, Techniques and Acceptance Standards

6.3.1. Inspection and testing shall employ the following methods and techniques and shall meet the acceptance standards specified below.

6.3.2. Radiography

6.3.2.1. Welds. The radiography of welds, including acceptance standards, shall be in accordance with ASME Boiler and Pressure Vessel Code, Section III, Paragraph N624.

6.3.2.2. Casting. The radiography of castings shall employ methods and techniques in accordance with ASTM E94, Tentative Recommended Practices for Radiographic Testing, to the quality level in accordance with ASTM 142, Standard Method for Controlling Quality of Radiographic Testing.

6.3.2.3. Acceptance criteria shall be Severity Level 2 per ASTM E71, E186 and E280 as appropriate for casting thickness, except that defect types D through G in E71 and defect types D and E in E186 and E280 are not permitted.

6.3.2.4. The H-D (Hurter-Driffield) density through acceptable metal shall be 2.0 minimum for single viewing, and 2.6 minimum for composite viewing of double film exposures. Each film of a composite set shall have a minimum density of 1.3.

6.3.3. Ultrasonic Testing. Ultrasonic examination of forgings shall be in accordance with ASTM A388-67, Ultrasonic Testing and Inspection of Heavy Steel Forgings, and shall meet the following acceptance standards.

6.3.3.1. Normal Beam Testing - Acceptance Standards. The forging shall be considered unacceptable, unless repaired, based on the following test indications:

a. Indications of discontinuities in the material that produce a complete loss of back reflection not associated with the geometric configuration of the piece. A reduction in back reflection to 5 percent or less of screen height shall be considered a complete loss of back reflection.

b. Traveling indications of discontinuities 10 percent or more of the back reflection. A traveling indication is defined as an indication which displays sweep movement of the oscilloscope pattern at a relatively constant amplitude as the search unit is moved along the part being examined.

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6.3.3.2. Angle Beam Testing - Acceptance Standards. Forgings shall be unacceptable where indications exceed those produced by the reference standard. The reference standard notch shall be the smaller of a depth equal to 5 percent of the forging thickness or 3/8 inch.

6.3.4. Liquid Penetrant Testing. Method, techniques and acceptance standards for liquid penetrant testing shall be in accordance with Paragraph N627, Section III of the ASME Boiler and Pressure Vessel Code.

6.3.5. Magnetic Particle. Methods, techniques and acceptance standards for magnetic particle testing shall be in accordance with Paragraph N626, Section III of the ASME Boiler and Pressure Vessel Code.

6.3.6. Qualification of Non-Destructive Examination Personnel. Personnel engaged in non-destructive testing of pressure-containing components shall be qualified in accordance with the requirements of Paragraph IX-325 of Section III of the ASME Boiler and Pressure Vessel Code.

6.4. Final Tests

6.4.1. Final tests shall be performed on each completed valve and shall be witnessed by the Buyer's authorized representative. (Sequence of testing shall be as follows:)

6.4.1.1. Valve shell shall be hydrostatically tested with the valve in the full open and back-seated position. Stem packing shall be installed and compressed to normal condition. The valve ends shall be closed and the valve completely filled with clean potable water:

a. Temperature of the Water: 60 - 100°F

b. Test pressure: 2380 psig

c. Duration of test: 10 minutes minimum

d. Results: The valve shall show no leakage under test conditions noted.

6.4.2. Packing Test. Stem packing shall be hydrostatically tested at a test pressure of 1875 psig. Duration of test shall be 2 minutes minimum and shall show no leakage. The valve shall not be back seated during testing. The valve shall be actuated from full open to full closed and return a minimum of three times and the packing retested as noted above, without additional compression of the packing, and shall show no leakage.

6.4.3. Stem back seat shall be hydrostatically tested with the valve in the full open and back seated position. Stem packing shall be backed off sufficiently to permit detection of seat leakage. Test fluid and test conditions shall be equivalent to that defined in Para. 6.4.1.1 except as follows:

6.4.3.1. Test pressure: 1875 psig

6.4.3.2. Duration of test: 2 minutes minimum

6.4.3.3. Maximum permissible leakage rate: 1 cubic centimeters per hour per inch of stem diameter.

6.4.4. Main valve seat shall be hydrostatically tested with the valve in the fully closed position. The upstream end of the valve shall be closed and the valve cavity between the valve seat and the upstream end completely filled with clean tap water.

6.4.4.1. Temperature of the Water: 60 - 100°F

6.4.4.2. Test pressure: 1875 psig

6.4.4.3. Duration of test: 5 minutes

6.4.4.4. Maximum permissible leakage rate: 2 cubic centimeters per hour per inch of nominal valve size.

6.4.5. Main valve seats shall be tested pneumatically with the valve seats clean and dry and with the valve operator cylinder pressurized with 90 psig clean dry air (or nitrogen) to apply seat loading force to the main valve seats.

6.4.5.1. The inlet side of the valve shall be pressurized with 50 psig clean dry air (or nitrogen) and leakage across the seat collected and measured by fluid displacement. Duration of the test shall be 5 minutes (or more if required to obtain reliable results.)

6.4.5.2. Maximum permissible leakage rate shall be 1/10 of a standard cubic foot of air per hour per inch of diameter of nominal valve size.

6.4.6. The hydraulic snubber and related piping and accessories shall be hydrostatically tested using the hydraulic fluid as the test medium. Test pressure shall be applied simultaneously on both sides of the piston.

6.4.6.1. Test Pressure: 5000 psig

6.4.6.2 Duration of test: 1 minute, with no visible leakage.

6.4.7. The cylinder operator and related piping, valves and accessories shall be pneumatically tested, as a system, using clean dry air (or nitrogen) as the test medium.

6.4.7.1. Test pressure: 90 psig and shall be applied alternately to the "opening" circuit, the "closing" circuit, and the "exerciser" portions of the system. Test pressure shall be applied by energizing or de-energizing the appropriate solenoid valves.

6.4.7.2. System leakage shall be determined after valve has reached the full extreme of travel in the open and closed direction. The maximum permissible pneumatic system leakage rate shall not exceed 0.5 standard cubic feet of air

6.4.7.2. (Continued)

per hour in either the "open" or "closed" position of the main valve. Means shall be established to determine the actual leak rate. Leakage from all accessible static seals and joints of the system shall be determined by search with soap bubble type leak detection, duration of test shall be sufficient to search all potential leakage points. There shall be no indication of leakage.

6.4.8. The complete valve shall be tested to demonstrate that the closing time against line pressure of 1000 psig (non-flowing) is adjustable between three and ten seconds. Requirements of Paragraph 4.2.9.4.1 shall be verified.

6.4.8.1. The three second closing shall be demonstrated with springs only as the closing force.

6.4.8.2. Ten second closing shall be demonstrated with 90 psig air pressure to top of cylinder operator plus springs as the closing force. Adjustment of the speed control valve to accomplish closing time noted is permitted.

7. CLEANING, MARKING AND PREPARATION FOR SHIPMENT

7.1. Cleaning

7.1.1. After completion of all testing, interior surfaces of the valves shall be cleaned free of all foreign material and residues and shall be thoroughly dried. Chloride or fluoride bearing solvents shall not be used.

7.1.2. After cleaning, inside surfaces shall be lightly coated with a readily water soluble corrosion inhibitor mixture, such as a solution of 0.5 percent sodium nitrite, 0.25 percent monosodium phosphate, and 0.25 percent di-sodium phosphate.

7.1.3. Valve stem packing shall be removed and discarded and the stuffing box cleaned, dried, and treated with corrosion inhibitor (described herein). A replacement set of stem packing with installation instructions shall be packaged separately with the valve.

7.1.4. Exterior non-functional carbon steel surfaces shall be cleaned of oil and grease after which mill scale, rust, rust scale, paint and other foreign matter shall be thoroughly removed by such means as sandblasting. After the surfaces are prepared for painting, they shall be painted with the Seller's standard metal primer.

7.1.5. Sandblasting shall be per the Steel Structures Painting Council Standard SP-5, except anchor patterns need not apply. Surfaces shall be brushed, and vacuumed or air-blast cleaned to remove all traces of sand or grit and shall then be dried and coated with the Seller's standard metal primer. The temperature shall be at least 50°F when the item is painted.

7.1.5.1. Exterior, functional, machined carbon steel surfaces shall be coated with a corrosion inhibiting coating or tape.

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7.1.5.2. Crevices shall be protected with a tape such as 3M Company Nos.390 or 480, John Mansville 357 or "Trantex" E10 or E12, or Johnson and Johnson "Permaseal" Type P69. Paper backed tapes are not acceptable as they age quickly and are not waterproof. Alternates will be considered on a case basis.

7.1.5.3. Surfaces without crevices may be protected with tape or a rust preventative such as Valvoline Oil Company "Tectyl" 846. Alternates will be considered on a case basis.

7.2. Preparation for Shipment

7.2.1. After completion of cleaning the valve shall be packaged for shipment in a manner which will prevent the introduction of foreign material into the unit. All openings shall be covered. A tight-fitting metal cap shall be fitted over all weld ends. The temporary seals used on the nozzles shall not affect the weld preparation or flange faces of the nozzles.

7.2.2. Special precautions shall be taken by the manufacturer to prevent deterioration of sensitive surfaces and materials of the valve actuator.

7.2.3. Piping and equipment shall be adequately protected from damage during handling, shipment and storage. Handling equipment, blocking, strapping, or hold-down devices shall be applied so the components are not marred in any way. During shipment the components shall be further separated by dunnage as is necessary to prevent damage. Packaging for shipment shall be applied in a manner to maintain cleanliness of the equipment. Outside storage of the equipment is anticipated to be approximately 12 months.

7.3. Marking and Materials Identification

7.3.1. Each valve shall have a stainless steel plate securely affixed to the superstructure on which the following minimum information shall be permanently marked:

a. Seller's Name

b. Serial Number of the Valve*______________

c. Size of Valve: Inlet______________

Seat Bore______________

Outlet______________

d. Pressure and Temperature Rating (ANSI B16.5)______________

e. Body-Bonnet Material______________

f. Rated Steam Flow and Pressure Drop______________

* The Seller's serial number (or equivalent marking) shall serve to identify all certifications, tests, and examinations pertinent to the valve which shall be maintained by the Seller as specified by the Buyer.

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7.3.1. (continued)

g. Buyer's Spec. No.__________ Rev.__________

h. Buyer's Purchase Order No:______________

i. Buyer's Master Parts List Number________

7.3.2. Each pressure-containing component (body, bonnet, stem, disc, nozzles and bonnet bolting, or equivalent) shall be clearly identified by legible marking on the parts.

7.3.2.1. The marking shall consist of the applicable specification and grade of material, heat number of the material, and any additional marking required to facilitate traceability of the results of all tests and examinations performed on the part; in those cases where size or shape prohibits, a marking code shall be used that identifies the material with the certification reports.

7.3.2.2. Marking shall be transferred to all pieces when a part is cut to make more than one component.

7.3.2.3. The materials shall be marked by any method that will not result in any harmful contamination or sharp discontinuities and will identify the material until the system is completely installed. Material 1/4 inch and greater in thickness may be marked by steel indentation stamping. When steel indentation stamping is used, it shall be done with a round nose or interrupted-dot die having a minimum radius of 1/32 inch. The maximum depth of indentation shall not infringe upon minimum wall thickness.

8. SUBMITTALS TO BUYER

8.1. Drawings

8.1.1. Outline Drawings - A drawing depicting the outline of the valve and operator indicating over all dimensions, shipping and operating weights, and details of construction such as weld preparations, finished dimensions and accessory connections.

8.1.2. Assembly and Cross-Section Drawings - Section drawing of all components depicting the arrangement of the parts, parts list and material designations. This drawing shall indicate those components which are pressure containing and shall designate the nondestructive test procedures upon which acceptance or rejection of the component is established.

8.1.3. Drawings for Approval - Outline and assembly drawings, and wiring diagrams shall be submitted for approval. The outline drawings submitted for approval shall be for design details enumerated in Paragraph 8.1.1. These drawings are required for coordination with piping and structure and shall include design details which are at variance with the code or the requirements of this specification.

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8.1.4. Drawings to be Certified - Outline drawings, and wiring diagrams for design coordination shall, upon completion of the design, be certified to be correct with no further changed required. No alterations may be made to the design after certification without the approval of the Buyer.

8.2. Submittals for Information

8.2.1. Engineering Schedule

8.2.2. Fabrication Schedule

8.3. Submittals for Approval

8.3.1. Calculations shall be furnished to establish conformance with design requirements as applied to pressure containment, seismic coefficents, pressure drop at rated flow, stress level and force delivered by actuating springs, sizing of pneumatic actuator including inlet and outlet porting, sizing of hydraulic snubber including related orifices.

8.3.2. Complete valve operator calculations including curves of displacement, velocity, accelerations and cylinder (pneumatic and hydraulic) pressures versus time shall be provided for valve closure at each of the conditions listed in Paragraph 4.2.9.4.

8.4. Test Procedures - Submittals for Approval

8.4.1. Liquid Penetrant Examination

8.4.2. Radiographic Examination Including Exposure Sketches

8.4.3. Hydrostatic Test

8.4.4. Magnetic Particle Examination

8.4.5. Leak Check and Valve Performance Procedures

8.4.6. Ultrasonic Examination

8.5. Fabrication Procedures, Qualification Procedures and Processes - Submittals For Approvals

8.5.1. Heat treatment procedures, including pre-heat for welding, post-heat for welding, heating for forming and heating for stress relief.

8.5.2. Welding, hardfacing and weld repair procedures.

8.5.3. Cleaning and preserving procedures, with chemical composition of solutions or agents.

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8.5.4. Plating procedures (if performed) as applicable to springs.

8.5.5. Quality Assurance Control Program

8.6. Instruction Manuals - Submittal for Approval

8.6.1. Instruction manuals shall present the following basic categories of information in a practical, complete and comprehensive manner prepared for use by operating and maintenance personnel:

a) Initial installation

b) Initial testing and adjustment

c) Maintenance, repair and periodic tests

d) Operation

8.6.2. The information shall be organized in a logical and orderly sequence. A general description of the equipment, including significant technical characteristics, shall be included to familiarize operating and maintenance personnel with the equipment.

8.6.3. Necessary drawings and other illustrations shall be included, or copies of appropriate certified drawings may be bound into the manual. Test, adjustment and calibration information, as appropriate, shall be specified and identified to the specific equipment. Safety and other warning notices and installation, maintenance and operating cautions shall be emphasized.

8.6.4. A parts list shall be included showing part nomenclature, manufacturer's part number, and other information necessary for accurate identification and ordering of replacement parts. Common hardware items, or other parts to be locally procured shall be adequately identified by technical description.

8.6.5. Instructions and parts list shall be clearly legible and prepared on good quality paper; carbon copies and tissue copies or other flimsy material are not acceptable. Multiple page instructions shall be securely bound.

8.6.6. If a standard manual is furnished covering more than the specific equipment purchased, the applicable model (or other identification), parts, and other information for the specific equipment purchased shall be clearly identified.

8.6.7. Specific detailed instructions for replacement of the stem packing shall be included.

8.7. Certification of Compliance

8.7.1. The manufacturer of the materials or components shall certify that the requirements for which he is responsible, including those of this specification,

8.7.1. (continued)

21A9230 as well as those of the specific materials specification, have been fully satisfied. Certification shall include a certified report of results of all required tests, examinations, and repairs performed on the materials and identification of materials. Certified reports shall be submitted to the Buyer for concurrence and record.

8.8. Records

8.8.1. Seller shall organize, maintain and safely store all design, fabrication, construction and quality control records, material certifications and all other test and inspection records pertinent to the work hereunder, as required by the terms of this order or the provisions of any applicable standard, code, criteria, law, rule, regulation or order. Upon payment by Buyer of the actual costs of reproduction, Seller shall deliver to Buyer certified copies of any or all such records. Upon payment by Buyer of actual cost of transfer, Seller shall promptly deliver to Buyer the originals of any or all such records. Seller shall retain all such records (except those records, the originals of which have been furnished to Buyer pursuant to this provision) in its possession for a period of five years after completion of the work hereunder. In no event shall Seller at any time destroy or discard any such records without prior written notice to Buyer.

END

RAL-5045

INSTRUCTION MANUAL

24" x 20" x 24" - FIG. 1612
Steam Isolation Valves for G.E.
G.E. P.O. Nos. AB-311
AB-313
AB-317
RMC S.O. Nos. 36-07968 - Fukushima 2
36-70037 - Carolina 1 & 2
36-50934 - Carolina 1 & 2
36-50936 - Lilco

GENERAL ELECTRIC
NUCLEAR ENERGY BUSINESS GROUP

APPROVED: KWthue	DATE: 4/4/80
VPF NO. 2793-65-5	
TRANSMITTAL NO. D800167	
PRINTS TO	

Rockwell Manufacturing Company

Prepared By: J.P. Tucker

Date: 12-11-70

Revision Date: 11-5-71

VPF ORIGINAL

TABLE OF CONTENTS

Information on Purchased Component Parts

Operating ... (illegible)

6 of 1

A. Pressure and Temperature Ratings:
   1. Max. continuous design conditions: 1250 psia at 575°F
   2. Primary Service Rating: 655 psig
   3. Max. Allowable service conditions: 1575 psig at 100°F

B. Ambient Conditions
   1. Temperature: 135°F normal, 340°F maximum at emergency conditions
   2. Relative Humidity: 100 percent continuous
   3. Pressure: Atmospheric at normal conditions, increases to 65 psig maximum at emergency conditions.
   4. Incident Radiation: Continuous for Design Life

      Gamma: 15R/hr.
      Gamma & Neutron: 25R/hr

Valve Description & Features

Springs mounted on the yoke provide stored energy for closing the valve in the event of loss of service air pressure. A second source of stored energy is provided by a bottle of compressed air mounted by the owner near the steam valves.

On emergency, the valve can close in as little time as 3 seconds but provision is made to control the rate of stem speed in both opening and closing directions independently.

Flag pins are provided which can be inserted in holes in the yoke during maintenance to hold the operator in the open position. This permits uncoupling the valve stem and operator rod and removal of the entire valve operator in one piece. It is also possible to remove the operator, bonnet flange and disk as one assembly, if it is required, to get at the interior of the valve for any reason.

The packing chamber is deep enough to permit 1-1/2 sets of packing with a leak-off lantern ring between. The size of the leak-off connection is more than adequate to remove any leakage that could occur through the annulus between the stem and backseat, even if all the packing was removed below the lantern ring.

Clearances between parts of the spring guides, spring flange and stem coupling are such that even if a spring broke, the mechanism cannot be distorted by the remaining springs to such an extent that the stem is jammed and made inoperable. Even if the spring flange would hang up, there is enough clearance between it and the stem coupling that the latter is still free to move downward if required.

A drain connection can be added if required to remove any condensate formed upstream of the seat.

The operating cylinder piston rod is connected to one end of a double ended hydraulic cylinder piston rod, the other end of which is coupled to the valve stem. The hydraulic cylinder itself is firmly attached to the operating cylinder. For the valve to open or close; therefore, hydraulic fluid has to be displaced from one end of the cylinder to the other and does so through two pressure compensated variable flow control valves, each with an integral check valve feature. These are set up so that each check valve permits flow only in the direction opposite to the other. The rate of flow is controlled independently in each direction and is adjustable. In this way, the main valve can operate at different speeds in both opening and closing directions. The pressure compensating feature insures that the stem moves only at the preset speed regardless of the differential across the main valve seat. A temperature compensating reservoir prevents damaging overpressure caused by any increase of temperature of the hydraulic fluid.

All valves which will be called on to operate during an emergency condition must periodically be shown to be operable. At selected intervals the valve can be "exercised," i.e. operated at a slow speed to ensure that all parts are operable, for either a partial or a full stroke. A 3-way solenoid valve and a 3-way air pilot valve are provided to permit this exercising the main valve. They do this by interrupting the service air to the operating cylinder and allowing the valve to close by means of the springs only as the cylinder is vented.

The disk/piston assembly itself features full stroke guiding. Stellited guide ribs and the stellited guiding surfaces of piston assembly provide the sliding surfaces with a suitable difference of hardness to insure that galling does not occur. The balancing port is centered in the main disk and closed by the stem disk. All seating surfaces of the main valve and balancing port are conical in shape and are stellited. The balancing port is more than adequately sized to insure equalization of pressure between the bonnet and downstream pipe. The flexible disk, designed to yield elastically with design pressure over the disk, provides tight shut off throughout the range of pressure differential from zero to full design.

Installation:

Page 3

1. To remove the valve from the crate, cut straps holding the valve in place.

2. Place a sling capable of lifting 12,000 pounds around the bonnet bore section of the valve just below the bonnet flange. (NOTE: This location is near the c.g. of valve.) Rig a stabilizing sling to the top of the operator through eyebolts in the top of the operator. (NOTE: This sling should not support the main weight of the valve.)

3. Lift valve out of crate carefully and set on wooden blocks.

4. After the valve has been unpacked from its shipping container, inspect for any obvious damage which might have occurred during shipment.

5. Hoist the valve into position in the pipe line by wrapping a sling around the upper part of the valve body (below the flange). This sling is to bear the valve assembly weight. To steady the valve in the upright position, install two 5/8" dia. x 11NC eyebolts in the drilled and tapped holes in the top of the pneumatic cylinder assembly and install a sling through the eyebolts. NOTE: Do not load eyebolts to over 4000 lbs. total weight. Valve assembly weight is 10,000 lbs.

6. The valve is to be installed in the pipe line with flow over the top of the valve disk.

7. Peel off the tape which retains the protective shipping caps on the valve body ends and pull off the caps.

8. Blank.

9. Remove the small bags of dessicant from inside the valve body. These bags of dessicant have been placed inside the valve body to prevent rusting during shipment.

10. The valve body material is ASTM-A216-Grade WCB. The proper welding rod for use with this material is ASTM A233-E7018. Rod size will depend on the amount of weld material to be deposited. (1/8 to 1/4 rod). (NOTE: Welding shall be done per all applicable codes and requirements.)

11. Weld valve into pipe line with valve in seated position. Maximum allowable weld interpass temperature should not exceed 400°F.

12. Remove shipping cover from drain hole on lower side of valve body, (Pt. No. 1), weld drain valve assembly supplied by buyer to drain hole and stress relieve. Remove shipping cover from bonnet packing leak off pipe, (Pt. No. 41), weld to leak off system and stress relieve weld.

13. A supply of air of "instrument air quality" is required for the control and operator of the pneumatic operator on this valve. The air supply pressure can vary from a minimum of 90 PSI to a maximum of 100 PSI.

13. Continued

The pneumatic cylinder and related components will utilize oil-free, filtered air, dried to a dew point of $-40^{\circ}F$ at the pressure the air is supplied as the actuating medium. Actuating air pressure will be 90 to 100 psig. The pneumatic cylinder and related components shall not require additional lubrication such as that provided by an oil-entraining device in the actuating air system.

14. Connect instrument air supply to the inlet of the Norgren four way valve. (See Dwg A-428397 on page 28)

15. Connect the same instrument air supply to the opening between the two "Asco" valves.

16. Recharge hydraulic accumulator per instruction in the appendix. The accumulator leaves the factory charged but could lose some pressure if stored over a period of time.

17. Turn each monotrol valve in the clockwise direction until it is fully closed.

18. Wire the small junction box on top of the pneumatic actuator and the large junction box (Pt. No. 17, page 17) for the limit switches to the plant control panel in accordance with drawing D-449245 Sht. 4, page 21.

19. Cycle valve to the open position slowly.

20. Install packing per instructions on page 15.

Adjustment & Test

1. The valve is now ready to operate. The speed at which the valve opens and closes can be adjusted by revolving the small knobs on the hydraulic snubber. (See "Piece No. 20", page 17). The upper knob is revolved to adjust the opening speed and the lower knob is revolved to adjust the closing speed.

   NOTE: Turning valves in a clockwise direction reduces operating speed. Counter clockwise increases speed.

2. Cycle the valve open and close a few times to adjust to the desired operating speed and to gain assurance that the valve has been installed properly. After adjusting to desired speed, lock the adjusting knob by means of the knob set screw.

3. Adjust limit switches per instructions on pages 13 & 14.

   CAUTION: It should be kept in mind that these valves have been assembled with the absence of lubrication in accordance with the General Electric Equipment Specifications. For this reason the valves should not be cycled any more than is absolutely necessary until water or steam has been let into the piping and valve system.

Disassembly

NOTE: Refer to Drawing D-449245, Sheets 2 & 3 (pages 17, 18)

1. Actuate the valve to the open position.

2. Insert the four flagged pins in the upper holes in the spring guides (Piece No. 13) See Note No. 1 of Dwg. D-449245, Sht. 2 (page 17).

3. Actuate valve to the closed position.

4. Remove the set screws (Piece No. 27) from the coupling (Piece No. 11). There are two set screws and a brass plug in each of the two holes. Make certain all the set screws and brass plugs are removed.

5. Revolve the coupling (Piece No. 11) off the end of the stem (Piece No. 3).
Do not revolve the stem (Piece No. 3).
Do not revolve the pneumatic cylinder (Piece No. 16) shaft. Revolve the coupling (Piece No. 11) completely onto the threads on the end of the pneumatic cylinder shaft (Piece No. 16) and off the end of the stem (Piece No. 3). Be careful not to allow the disk, piston, and stem assembly to drop against the valve seat.

(NOTE: Disk piston and stem assembly weight = 1200 lbs.)

6. Actuate valve to the open position and remove the flagged pins from the upper holes in the spring guides. Then insert the flagged pins in the holes located 5-3/4" from the bottom of the spring guides (Piece No. 13), and actuate valve to the closed position.

7. Disconnect all air and electrical supplies.

8. Install two 5/8" diameter x 11NC eyebolts (Pt. No. 25) into the drilled and tapped holes in the top of the pneumatic cylinder assembly.

9. Install a sling through the eyebolts. Hook the sling to a hoist and support weight of valve upper structure with the hoist. Do not support over 4000 lbs.

10. Remove the bolts and lockwashers holding the limit switch support (Piece No. 21) to the bonnet (Piece No. 4).

11. Lay the limit switch support (Piece No. 21) aside.

12. Remove the bolts and lockwashers (Piece No. 7) holding the spring guides (Piece No. 13) to the bonnet (Piece No. 4).

13. Hoist the pneumatic cylinder/spring assembly off the bonnet (Piece No. 4) (wt = 2000 lbs.) and set upright on a level surface.

NOTE: Determine the problem area. If the problem or defective part is in the lower structure see instructions entitled "Disassembly of Lower Structure". If the problem area is in the upper structure, see instructions entitled "Disassembly of Upper Structure."

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Disassembly of Upper Structure (See Drawing D-449245, Sht. 2, Page 17)

1. Remove the nuts and lockwashers (Piece Nos. 19) holding the pneumatic cylinder (Piece No. 16) to the mounting flange (Piece No. 14).

2. Hoist the pneumatic cylinder assembly away and lay on its side on a wooden pallet or some rags, being careful not to damage pneumatic control valves.

3. Blank.

4. Unscrew the four nut & stud Assemblies (Piece 44,45 & 46) in even increments until all tension on the springs has been relieved.

5. Remove the mounting flange (Piece No. 14), the springs (Piece No. 12), and spring dividers (Piece No. 40). Be careful not to chip or scrape the special corrosion resistant paint off the springs.

Disassembly of Lower Structure (See Drawing D-449245 Sht. 2, Page 17)

1. Remove the gland nuts (Piece No. 10) and the gland (Piece No. 28). See Packing Instructions - Page No. 16.

2. If the leak off nipple (Piece No. 41) has been welded into the system, it will be necessary to cut this weld before the bonnet (Piece No. 4) can be lifted off the valve.

3. Screw the eyebolts (5/8-11UNC) (Part No. 25) into two of the drilled and tapped holes in the top surface of the bonnet (Piece No. 4). (NOTE: There are 20 tapped holes in the top of bonnet.)

4. Remove the bonnet hold down nuts (Piece No. 6).

5. Remove 4 bonnet studs (Piece No. 5) each 90° apart.

6. Screw four bonnet guide studs (Page 27) into top of body to replace those removed.

7. Using a hoist, a sling and the two eyebolts that have been screwed into the upper surface of the bonnet (Piece 4) lift the bonnet off the valve and lay aside on some clean rags. (NOTE: Use bonnet guide studs to guide bonnet when removing).

8. Remove bonnet studs (Piece No. 5), bonnet guide studs, and gasket (Piece No. 31).

9. Attach the piston guide assembly to the drilled and tapped holes with (5/8-11UNC Bolts) in the top of the piston assembly (Piece No. 2). This will act as protection for stem and can be used as a guide to prevent piston-disk assembly from binding. (See page 27)

10. After the bonnet and gasket have been removed, fashion a sleeve of corregated carboard and slip it over the stem. This will protect the stem finish.

11. With the use of a hoist and piston guide assembly which has been attached to the top of the piston, lift the stem (Piece No. 3) piston assembly (Piece No. 2) out of the valve. It will be necessary to attach a second lifting sling in the vertical position as the piston assembly is being removed from the bore of the bonnet. This will guide the assembly

a

11. Continued

and keep it from falling to the deck. Be certain that the piston assembly is pulled out of the valve body squarely with the body bore. Lay assembly on some soft rags being careful not to marr the guiding or sealing surfaces. (See Picture "E" page 25)

(NOTE: Do not use stem as a lever. It will damage stem disk seat.)

12. To disassemble the piston assembly further, lay the piston assembly on its side under a drill press and drill out the disk lock pin (Piece No. 35). Use a drill of 1/2 inch diameter. Be careful not to drill over 2.60 deep. (Ref. Picture "F", p. 26)

13. Unscrew the piston (Piece No. 2) from the disk (Piece No. 37).

14. To disassemble the stem (Piece No. 3) from the stem disk (Piece No. 38) drill out the stem disk pin (Piece No. 36) using a 5/16 inch diameter drill. Do not drill deeper than 0.14 . (Ref. Picture "F", p. 26)

15. Unscrew the stem disk (Piece No. 38) from the stem (Piece No. 3). The lower structure has now been disassembled part by part.

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REPAIR PROCEDURES

Body Bore Repairs

First make a visual inspection all around this area, noting, if possible where flaws may occur. Next wash the area with acetone, drying with clean rags and, if necessary, polishing with a fine grade of emery cloth to remove any undesirable scale or foreign matter which may have been deposited on the area suspected of having flaws. Use a dye penetrant test if cracks are suspected.

1. Prior to any cutting or welding operations being performed on the valve, it is necessary that adequate seat joint protection be provided and some means of insurance against getting chips, weld spatter or other foreign matter into the pipe line if the valve is permanently mounted. A thick bed of asbestos paper placed over the seat and cemented in place will furnish adequate protection.

2. Chip out the defective area in the body, being careful to remove the affected portion to its end, inside the casting, and to thoroughly clean it away.

3. With a small hand grinder, grind the chipped area smooth.

4. Preheat an area large enough around the imperfection so that during the entire welding operation heat will be retained at approximately 400 degrees Fahrenheit.

5. Use an ASTM -A233 E7018 welding rod. Proper rod diameter depends on the size of the cavity to be filled.

6. Lay the weld in thin, even layers, and being careful to maintain a temperature above 400 degrees Fahrenheit in the area being repaired. The last layer of weld must overlay onto the sound metal to insure a weld without an undercut at the edges. The overlapping should be done along this edge by using a welding rod of 1/8" maximum diameter. The last layer should bring the height of the welded area up to 1/16" above the original surface, as checked with a straight edge along the body bore.

   Thermal stress relieving is not recommended.

   NOTE: Major repairs should not be attempted without GE-APED approval.

   With a hand grinder, rough grind the welded surface to within about .010" of the finished surface. A simple template cut from thin sheet metal and having the same arc as the body bore diameter, and a straight edge laid along the body bore can be used as a guide. A final cut then can be made, using a boring fixture similar to the one shown in picture "B". (page 22)

After removing all dirt, chips, slag, spatter, and grinding dust from the body, the bore should be polished with fine emery cloth and then thoroughly cleaned before reassembly of the valve. NOTE: Repaired defect must be liquid penetrant examined after repair. For repairs with cavities deeper than 3/8" or 10% of wall thickness radiography must be performed.

Seat & Disk Repairs

A valve seat joint will require repairing in any instance where the seating surface permits a leak because it has been altered from the original state in which it was shipped from the factory; where corrosion has set in to cause pit marks on the seating surfaces of either the body or disk; where the seat has become distorted because of an abnormal heating condition; or, where a groove has been formed on the seat or disk by closing the valve against a foreign body.

The stellited seats in these valves are not easily scored, but where reconditioning is necessary, the following points should be observed:

Where an indention or pit marks on the valve seat joint are .020 in. or less a cast iron lap with suitable lapping compound will speed up repair. The included angle of the valve seat is 90 degrees and the cast iron lap should be closely guided in the body bore during the lapping. (See Picture "B") (page 22)

For initial lapping, use Clover compound "A". Norton 320 mixed with olive oil or sperm oil to a molasses consistency is also recommended for finish lapping. For rough lapping, Carborundum H120 coarse is also recommended.

In the lapping operation, lap against the seat with a small quantity of the lapping compound placed between the mating surfaces. It is important that not too much pressure be applied on the lap or disk against the seat. With the lapping compound in place between the mating surface, the lap should be reciprocally rotated as far as arm movements will permit while standing in one position; the strokes should be light, and the laps should be lifted frequently and turned to a new position circularly around the valve body so that lapping will be rotated over a new area.

When an indication in the valve seat is .020 in. or greater, seat grinding will be necessary. Seat grinding can be accomplished using a Van-Norman portable grinding machine such as shown in picture "B" on page 22 .

NOTE: For any seat repairs which requires a new stellite inlay or seat grinding the Rockwell International Co. in Raleigh, N.C. should be contacted for technical assistance.

The disk (Part No. 37, page 17) of the valves will also require refinishing. Hold the disk using a four jaw chuck so that the large O.D. and seating surface run true. (Be careful not to damage the surface of the disk.) Grind the seating surface using a tool post grinder. Just go deep enough to clean the surface. Polish the seating surface with fine emery cloth. When finishing the disk in this manner, it will not be necessary to lap it to the seat in the valve body. Lapping of disk should be done with lap tube (See Picture "D", Page 24).

Stem Disk and Disk Seat Repair

Where an indention of pit marks on the disk seat joint (Part No. 37, Page 17) is .020 or less, a cast iron lap with suitable lapping compound will speed up repair. The included angle of the stem disk seat (Part No. 37) is 90 degrees and the cast iron lap should be closely guided during the lapping. (See Picture "C" - Step 1), (page 23). (NOTE: Finish of seating surfaces should be from 2 rms - 12 rms).

The stem disk (Part. No. 38, page 17) will also require refinishing. Hold the stem disk using a four jaw chuck so that the O.D. and seating surface run true. (Be careful not to damage the surface of the stem disk.) Grind the seating surface using a tool post grinder. Just go deep enough to clean the surface. The included angle of the stem disk is 90°.

The stem disk (Part No. 38, page 17) will require lapping to the disk seat (Part No. 37, page 17) with the Norton 320 lapping compound mixed as described above. Lapping instructions are the same as described above. (See Picture "C" - Step 2). (page 23).

Disk-Piston Assembly Repair

It is possible that the bearing surfaces on the O.D. of the disk-piston assembly and I.D. of the body can become scored deeply enough to cause a binding or wedging of the piston assembly in a full, or partially, open or closed position. Such scores and resulting burrs may be caused by particles of weld spatter, flakes of hard line scale or other foreign matter which has inadvertently gotten into the line. Upon disassembly, any body and disk-piston assembly burrs must be removed with emery cloth, and the bearing surfaces otherwise made smooth and clean again. Where the burrs on the piston are very large, it may be more convenient to chuck the assembly in an engine lathe and file them off. Bonnet bore dimension is 18.503 in. maximum. Piston and disk turning dimension is 18.475 in. minimum.

Assembly of Valve Lower Structure (See Drawing D-449245, Sht.2) (page 17)

1. Apply a light coat of "Dag Dispersion 156" to all male threads and allow to dry before assembly.

2. Lap valve seat with portable lap. (See Picture "B", page 22)

3. Lap valve disk with lap tube. (See Picture "D", page 24)

   NOTE: Do not lap disk to valve seat body.

4. Lap inner disk seat in back of disk (37) with lap. Ref. Picture "C" page 23.

5. Lap stem disk (38) to disk seat (37). Ref. Picture "C" page 23.

NOTE: Steps 2-5 are not necessary if seat is not damaged.

6. Assemble stem (3) to stem disk (38). Grip the stem disk with a spanner wrench. Grip the stem by the stem flats with a soft jawed vise, torque to 100 ft. lbs.

7. Drill a 9/32" dia. hole in the stem disk 0.94" deep.
Ream the 9/32" hole to 5/16" $\frac{.3130}{.3125}$ using a drill press turning the ream at 750 rpm. (See Picture "F", page 26).

8. Drive stem disk pin into hole and plug weld. Use E8018 weld rod.

9. Working on a bench, assemble the stem disk (38), stem (3) assembly to the disk (37) and screw disk piston (2) all the way down into disk. Torque tight.

10. Drill a 15/32" dia. hole 2.0C" deep through the disk and into the piston.
Ream the 15/32" dia. hole to 1/2" $\frac{.5005}{.5000}$ using a drill press turning the reat at 650 rpm.

11. Drive disk lock pin into hole and lock weld. Use E8018 weld rod.

12. Blank.

13. Blank.

14. Using piston guide assembly (p. 25) work piston assembly into valve body being careful not to damage the piston, and body bore.

15. Install new bonnet gasket (31) on body. (NOTE: New bonnet gasket must be used each time valve is disassembled).

16. Install 16 bonnet studs (5) and 4 bonnet guide studs. (See Page 27). Lubricate the nuts with "Never-Seez".

17. Install bonnet (4) making sure the leak off is located on the valve, pointed towards the outlet end. Replace 4 bonnet guide studs with 4 bonnet studs (5). Torque bonnet hold down nuts in increments of 200 ft.lbs. using a star pattern until 1020 ft. lbs. has been reached.

18. Install junk ring (30) packing (29) and lantern gland (8). Use 7 new rings of packing below the lantern gland and 3 above. See page 15. Use a wooden dowel to tap junk ring into place.

19. Install gland (38), gland studs (9) and nuts (10). Torque to 100 ft. lbs.

20. Pour a small amount of loc-tite (Mfg. by Loc-Tite Corp.) into the four locating pin holes in the upper surface of the bonnet and install the four locating pins for the yoke/spring guides.

Assembly of Valve Upperstructure

NOTE: All non-pressure containing bolts are to be secured with lock washers.

1. Bolt four yoke/spring guides (13) to the bonnet. Torque to 45 ft. lbs.

2. Insert four flagged pins in holes 5-3/4" from the end of the spring guides.

3. Install spring flange (26) over the spring guides so that it rests on the four pins. Making sure the limit switch support (21) bolt holes in the bonnet are lined up with the limit switch actuator on the spring flange.

4. Install one spring divider (40) over each of the four yoke/spring guides (13).

5. Install another spring (12) over each of the four yoke/spring guides (13).

6. Install another spring (12) over each of the four yoke/spring guides (13).

7. Install mounting flange (14) over the springs. Make sure the centerline through the slot cut in mounting flange is rotated 90° counterclockwise from the limit switch actuators on the spring flange, (26).

8. Screw nut (44) on the end of stud (45) until the top of stud (45) is flush with the top of the nut (44). Drill hole .256/.250" dia. through the nut and stud and drive roll pin (46) into hole securely. Follow this step only if the nut and stud is not yet joined.

9. Insert nut and stud assembly through mounting flange (14) and thread into the end of the yoke/spring guide (13). Turn the four nut and stud assemblies until the mounting flange has compressed the springs (12) and the mounting flange is flush with the yoke/spring guide (13). Torque all four nut stud assemblies to 240 ft. lbs.

9a. Install limit switch support (21) on bonnet (4).

10. Install pneumatic cylinder (16) hydraulic cylinder (22) assembly on mounting flange (14) of upperstructure. Revolve cylinder assembly so the pneumatic valve assembly mounting holes are directly over the outlet flow centerline of the valve. Install universal plate (Part No. 39, page 17) over coupling. Turn coupling (11) into end of hydraulic cylinder shaft through the spring flange (26) as far as possible. Butt stem and cylinder rod together. Then thread coupling onto end of valve stem. Insert one brass plug into each hole. Lock coupling (11) in place with set screws (Part No. 27).

11. Install the pneumatic valve assembly (32) on the pneumatic cylinder (16) if assembly was removed from cylinder. Make sure the two "O" rings are in place on the mounting face of the pneumatic valve assembly.

12. Install limit switch assembly to the side of the bonnet with four bolts (18). See D-449245 Sht. 4 page 21, for wiring connection.

13. Make sure hydraulic control valves (20) are all the way closed. (To close, turn clockwise).

14. Connect air supply to the pneumatic valve and to the air connection to the solenoid valves. The pneumatic cylinder and related components will utilize oil-free, filtered air, dried to a dew point of -40°F at the pressure the air is supplied, as the actuating medium. Actuating air pressure will be 90 to 100 psig. The pneumatic cylinder and related components shall not require additional lubrication such as that provided by an oil-entraining device in the actuating air system. (See Dwg. A428397, page 28)

15. Connect electrical contacts to junction box on air valve assembly. (See D-449245 Sht. 4, page 21.)

16. Actuate both "open" toggle switches on the control panel and open the upper hydraulic control valve one turn (Valve should open slowly).

17. Remove flagged pins from the holes 5-3/4" from bonnet.

18. Actuate the exercise control toggle switch on the control panel and open the lower hydraulic control valve one turn (Valve should close slowly).

19. Adjust the hydraulic control valves (20) until the valve opens in 20 seconds and closes in 10 seconds.

20. Adjust limit switches on valve so that the upper limit switches trip when the valve is 1-1/2" from the fully open position. Adjust bottom switch so that it trips when the valve is 1-1/2" from fully closed position.

The following is a suggested method for adjusting the limit switches:

A. Lower Limit Switch (90% Closed)

1. Close valve.
2. Measure distance from bottom of spring flange (Part No. 26) to top of bonnet (Part No. 4). Add 1-1/2 in. to this figure.
3. Cut two lengths of 4 x 6 timber to the above calculated length.
4. Open valve.
5. Place the timbers 180° apart on bonnet so that when valve is actuated to a closed position (close slowly) the bottom of the spring flange will contact the timbers and block the valve open 1-1/2" from fully closed position.
6. Adjust lower limit switch to tripped position. Any rotary adjustment can be accomplished by loosening set screw on lever extension and retightening securely at desired position.

16

B. Upper Limit Switches

1. Open valve.

2. Measure distance from bottom of spring flange (Part No. 26) to the top of the bonnet (Part No. 4). Subtract 1-1/2 in. from this figure.

3. Cut two lengths of 4" x 6" timber to the above calculated length.

4. Place the timbers 180° apart on bonnet so that when valve is actuated to a closed position (close slowly) the bottom of the spring flange will contact the timbers and block the valve open 1-1/2" from fully open position.

5. Adjust upper limit switches to tripped position. In this position the valve is 90% open.

Adjustment of Hydraulic Cylinder Shaft Position

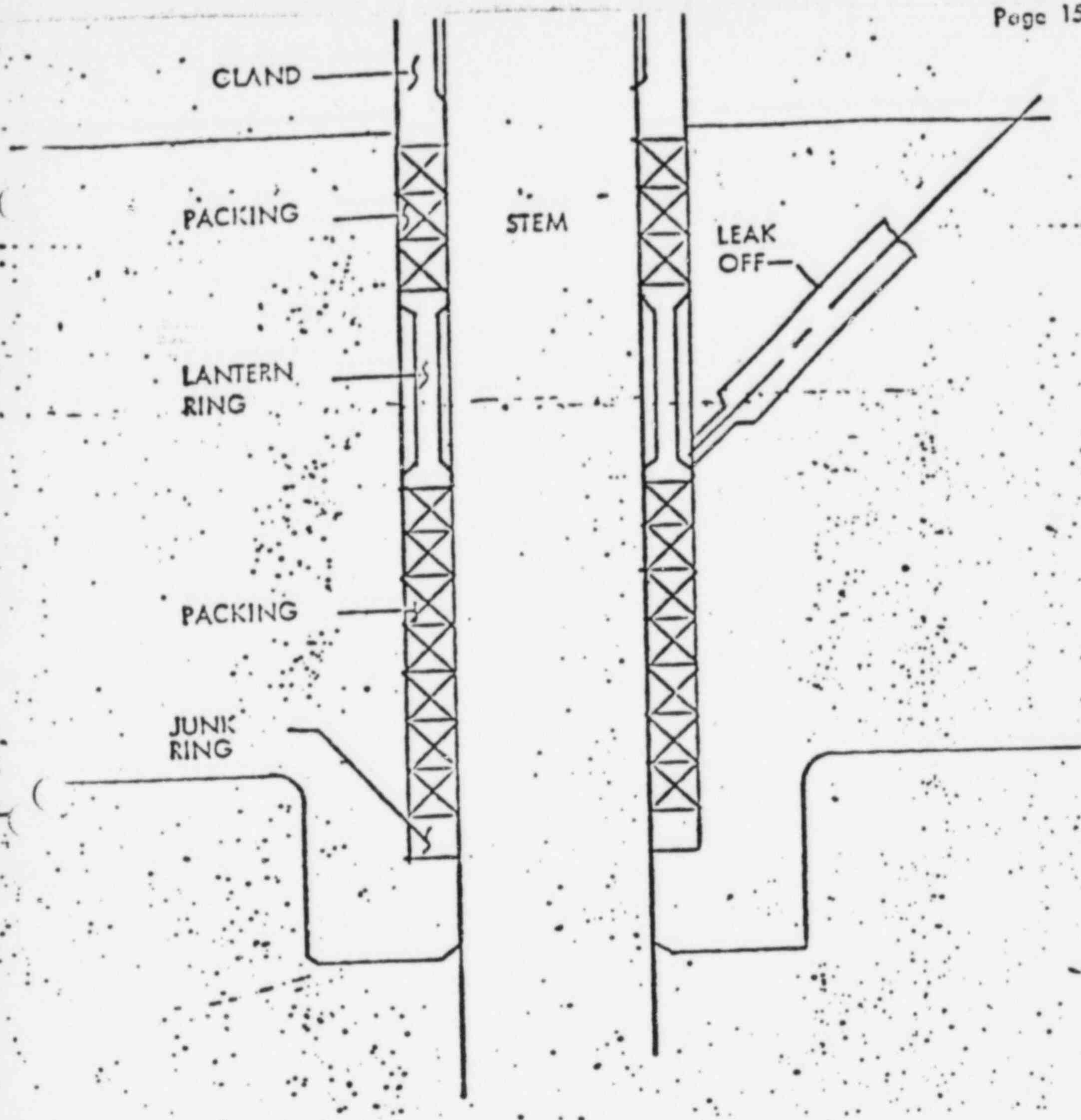
1. Remove the set screws (Piece No. 27) from the coupline (Piece No. 11). There are two set screws and a brass plug in each of the two holes. Make certain all the set screws and brass plugs are removed.

2. With valve in the closed position, adjust the coupling (11) to the hydraulic cylinder rod and valve stem such that the maximum extension of the hydraulic cylinder rod is 17-3/8.

3. Open valve. The minimmm extension of the hydraulic cylinder rod should be 11/16". If it is not 11/16", close valve and readjust coupling to cylinder rod and stem until the 11/16" and 17-3/8" dimensions are attained.

4. Insert one brass plug into each hole of the coupling (11). Lock coupling (11) in place with set screws (Part No. 27). There are two set screws per hole.

17



PACKING INSTALLATION INSTRUCTIONS
FOR 26" 1612 JMMNTY BALANCED DISK VALVE

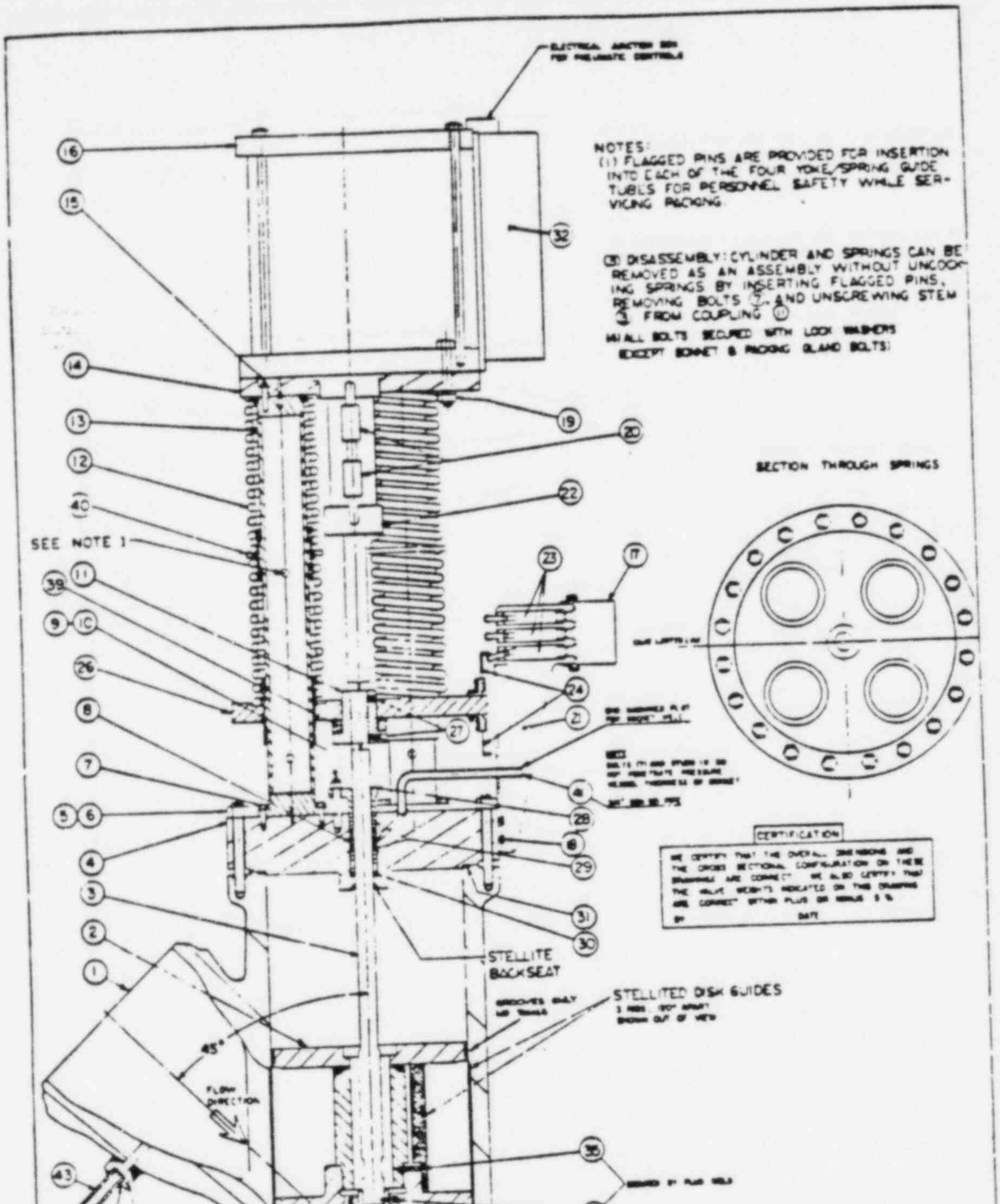
1. Actuate valve to open position (backseated).
2. Place junk ring in packing chamber, making sure it is not cocked.
3. Place 7 rings of packing in chamber over junk ring and press down with lantern gland.
4. Place three rings of packing over lantern ring and press into place with the gland.
5. Torque gland studs and nuts to 100 ft. lbs.

18

PACKING REMOVAL INSTRUCTIONS FOR BALANCED DISK VALVE

1. Remove packing gland.
2. Remove top three rings of packing one at a time using cork screw type packing tool.
3. Screw two threaded rods into the tapped holes in lantern gland and pull it out of the packing chamber. (Thread rods with a No. 5-40 die).
4. Remove lower seven rings of packing one at a time using the cork screw type packing tool.
5. To remove the junk-ring the bonnet must be removed. The junk ring can then be tapped out from the bottom side of the bonnet.

19



NOTES:
(1) FLAGGED PINS ARE PROVIDED FOR INSERTION INTO EACH OF THE FOUR YOKE/SPRING GUIDE TUBES FOR PERSONNEL SAFETY WHILE SERVICING PACKING.
(3) DISASSEMBLY: CYLINDER AND SPRINGS CAN BE REMOVED AS AN ASSEMBLY WITHOUT UNCOCKING SPRINGS BY INSERTING FLAGGED PINS, REMOVING BOLTS 7, AND UNSCREWING STEM 3 FROM COUPLING 11
(4) ALL BOLTS SECURED WITH LOCK WASHERS (EXCEPT BONNET & PACKING GLAND BOLTS)
SEE NOTE 1
SECTION THROUGH SPRINGS
CERTIFICATION
STELLITE BACKSEAT
STELLITED DISK GUIDES
45°
FLOW DIRECTION
DRAIN BOSS
THIS DRAWING FOR PART IDENTIFICATION
665-S
CAST CARBON STEEL WCB
1595 PSI AT 100°F
1250 PSI AT 575°F
665 PSI AT 850°F
Rockwell
MANUFACTURING COMPANY
ROCKWELL-EDWARD FLITE-FLOW STOP VALVE
FIG. 1612 JMMNY
FOR
GENERAL ELECTRIC
ATOMIC POWER EQUIPMENT DEPARTMENT
D-449245

20

LIST OF MATERIALS

QUANTITIES ARE FOR ONE VALVE

Rockwell MANUFACTURING COMPANY

WHERE A S T M SPECIFICATIONS ARE INDICATED THE LATEST REVISION APPLIES

PIECE NO	NAME	NO REQ'D	MATERIAL	SPECIFICATION	MS NO
1'	body (RT, MT)	1	cast carbon steel	ASTM A 216 Grade WCB	01023
2	piston assembly	1	forged carbon steel	ASTM A 105 Grade II	01111
3'	stem (PT, UT)	1	martensitic stainless steel	ASTM A 276 TYPE 410	02123
4'	bonnet (PT, UT)	1	mild carbon steel	ASME SA 105 Grade II	01112
5'	bonnet stud (PT)	20	cr.-ni-moly alloy steel	ASTM A-540 Grade B 23	02861
6'	nut (PT)	20	ALLOY STEEL NUTS	ASTM A 194 Grade 7	01291
7	bolt	20	alloy steel	ASTM A 354 Grade BD	02061
8	lantern ring	1	C. Dr. carbon st. evalized	AISI 1117	01230/606
9	gland stud	2	cr. moly alloy steel CD. PL	ASME SA 193 Grade B7	02080/604
10	nut	2	steel CD. PL.	ASTM A 194 Grade 2H	01270/604
11	coupling	1	alloy steel	AISI 4140	02360
12	spring	8	St./Deco-St. Vinyl St.St. moly coated	ASTM A 125	01760
13	yoke/spring guide	4	seamless carbon steel	ASTM A 106 Grade B AISI 1015-1025	01170/60
14	mounting flange	1	carbon steel	ASTM A 515 Grade 70	01150
16	pneumatic cylinder	1	steel	Sheffer	55555
17	electrical junction box	1	aluminum	Hoffman	55555
18	bolt	4	alloy steel	ASTM A 193 Grade BT6	02680
19	nut	4	steel	ASTM A 194 Grade 1	01240
20	hydraulic control valves	2	steel	Manitrol	55555
21	limit switch support	1	carbon steel sheet	ASTM A 515 Grade 70	01150
22	hydraulic cylinder	1	steel	Sheffer	55555
23	limit switches	3	steel	Namco No. SL 3DP DT	55555
24	limit switches actuators	3	carbon steel	ASTM A 515 Grade 70	01150
26	spring flange	1	carbon steel	ASTM A 515 Grade 70	01150
27	set screw	4	steel		55555
28	packing gland	1	heat treated forging grade carbon steel	ASTM A 105 Grade II	01350
29	packing rings	10	high temperature packing	John Crane 187-1	05060
30	junk ring	1	C. Dr. Carbon steel-stellited	AISI 1018	01200
31	bonnet gasket	1	stainless st. and asbestos	spiral wound	05180
32	Pneumatic Control System	1			55555
35	Disk lock pin	1	C. Dr. Carbon steel	AISI 1018	01200
36	stem disk pin	1	C. Dr. carbon steel	AISI 1018	01200
37'	disk (PT, UT)	1	forged alloy steel stellited	ASTM A 182 Grade F11	02271
38'	stem disk (PT, UT)	1	Low alloy steel stellited	ASME SA 182 Grade F11	02241
39	universal ring	1	alloy steel	AISI 4140	02360
40	spring divider	4	Carbon Steel	ASTM A 106 Grade B-1015-1025	01170
41	pipe nipple	1	seamless carbon steel	ASTM A 106 Grade B	01180
42'	drain boss (UT, PT)	1	mild carbon steel	ASME SA 105 Grade II	01112
43'	pipe nipple (PT, UT)	1	seamless carbon steel	ASTM A 106 Grade B	01180
44	nut	4	med. carbon steel cd. pl.	ASTM A 194 Grade 2H	01270/604
45	stud	4	chrome moly alloy steel	ASTM A 193 Grade B7	02080/604
46	pin, roll	4 *	stain. steel	AISI 420	65002

TESTING SYMBOLS
UT-ULTRASONIC
PT-LIQUID PENETRANT
MT-MAGNETIC PARTICLE
RT-RADIOGRAPHY

RECOMMENDED SPARE PARTS
Bonnet Studs
Bonnet Stud Nuts
Gland Studs
Gland Stud Nuts
Packing Rings
Bonnet Gasket

NOTE: * DENOTES SPARE PARTS

' NOTE: PRESSURE CONTAINING PARTS.

TYPED BY	DATE	CHK'D	APP'D	DATE	SPEC. IDENT.	SHT	REV.	DRG
WEM	3-13	[illegible]	[illegible]	[illegible]	1	3 OF 6	E	D-449245

ITEM NO	PART NO	DESCRIPTION	QTY
1A	[illegible]	HEAD	1
1B	[illegible]	HEAD	1
2A	[illegible]	CAP	1
2B	[illegible]	CAP	1
2C	[illegible]	CAP (ACCUMULATOR)	1
2D	[illegible]	CAP (ACCUMULATOR)	1
3A	[illegible]	PISTON ROD	1
3B	[illegible]	PISTON ROD	1
4A	[illegible]	TUBE	1
4B	[illegible]	TUBE	1
4C	[illegible]	TUBE (ACCUMULATOR)	1
5A	[illegible]	TIE RODS	4
5B	[illegible]	TIE RODS	4
5C	[illegible]	TIE RODS (ACCUMULATOR)	4
6	[illegible]	CARTRIDGE RETAINER	1
9A	[illegible]	PISTON	1
9B	[illegible]	PISTON	1
9C	[illegible]	PISTON (ACCUMULATOR)	1

ITEM NO	PART NO	DESCRIPTION	QTY
10	348-2364-0000	SCREWS - CARTRIDGE RETAINER	6
11A *	48-203-141	SEAL - PISTON I.D.	1
11B *	48-203-129	SEAL - PISTON I.D.	1
13A	440-06710	NUT - TIE ROD	4
13B	440-12182	NUT - TIE ROD	4
13C	440-06080	NUT - TIE ROD (ACCUMULATOR)	4
15	398-06520-[illegible]	SCREW - PISTON DOWEL	1
16A *	48-203-240	SEAL - TUBE	2
16B *	48-203-480	SEAL - TUBE	2
16C *	48-200-230	SEAL - TUBE (ACCUMULATOR)	2
18A *	580-0602-[illegible]	PACKING - PISTON	4
18B *	[illegible]	PACKING - PISTON	8
18C *	[illegible]	PACKING PISTON (ACCUMULATOR)	8
21 *	[illegible]	CARTRIDGE BUSHING	1
22 *	[illegible]	SEAL CARTRIDGE BUSHING	1
23 *	[illegible]	BACK UP WASH CART BUSH SEAL	1

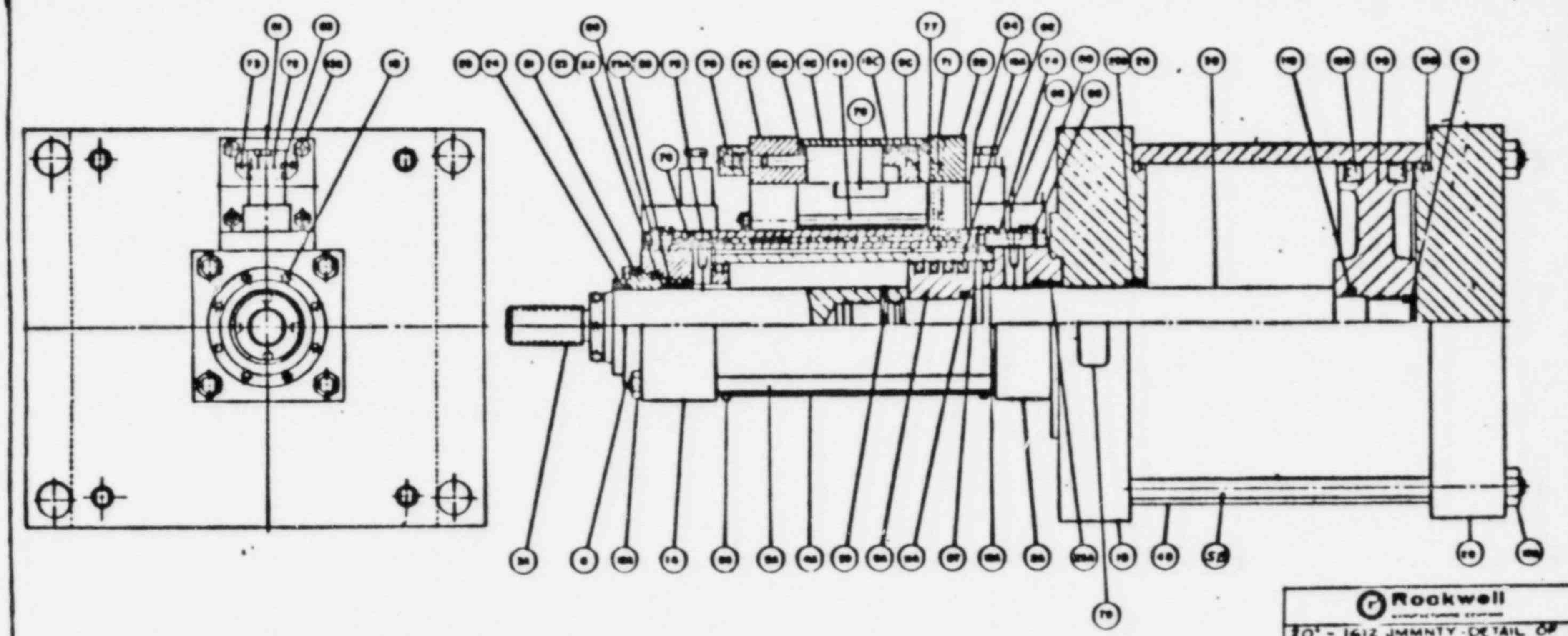
ITEM NO	PART NO	DESCRIPTION	QTY
24 *	200 22-0380-0500	ROD WIPER	3
25A *	200 22-0350-0500	ROD PACKING	5
25B *	200 22-0350-0500	ROD PACKING	5
26	300-0850	RETAINING RING ROD PACKING	3
28	455 856 208	PLUG - AIR BLEED	2
59	383-10-250-1000	ROLL PIN	1
70	049-30108	GAS VALVE	1
71	390-0375-0400	MOUNTING SCREW - ACCUMULATOR	4
72	049-54708	GAS VALVE COVER	1
73	348-0432-0080	GAS VALVE COVER SCREWS	8
74	049-20030	MANIFOLD ASSEMBLY	1
75	348-0606-[illegible]	SCREWS MANIFOLD PLATE	4
76 *	[illegible]	SEAL - MANIFOLD	2
77 *	[illegible]	SEAL - ACCUMULATOR	1
78	950-10002	DECAL	1
79	049-30075	NAME PLATE	1
80	049-40018-2	VALVE - CHARGING	1
81	049-30179	VALVE - FLOW CONTROL	1

* INDICATES RECOMMENDED SPARE PARTS, WHEN ORDERING PARTS BE SURE TO GIVE THE FOLLOWING INFORMATION, MODEL NO PART NO SERIAL NO AND QUANTITY DESIRED

ITEM 3A TORQUE 880 FT/LBS
ITEM 3B TORQUE 340 FT/LBS
ITEM 3C TORQUE 60 FT/LBS

\+ INDICATES PARTS SUPPLIED WITH VALVES.

ITEM NO	PART NO	DESCRIPTION	QTY
82	049-30179	VALVE - FLOW CONTROL	1
83 +	380-0440-0250	MOUNTING SCREWS - VALVE	4
84 +	380-06520-0175	MOUNTING SCREWS - VALVE	4
85 +	380-06520-0087	MOUNTING SCREWS - VALVE	4
86 +	[illegible]	SEAL - VALVE	2
87 +	[illegible]	SEAL - VALVE	2
88 +	[illegible]	SEAL - VALVE	2



Rockwell

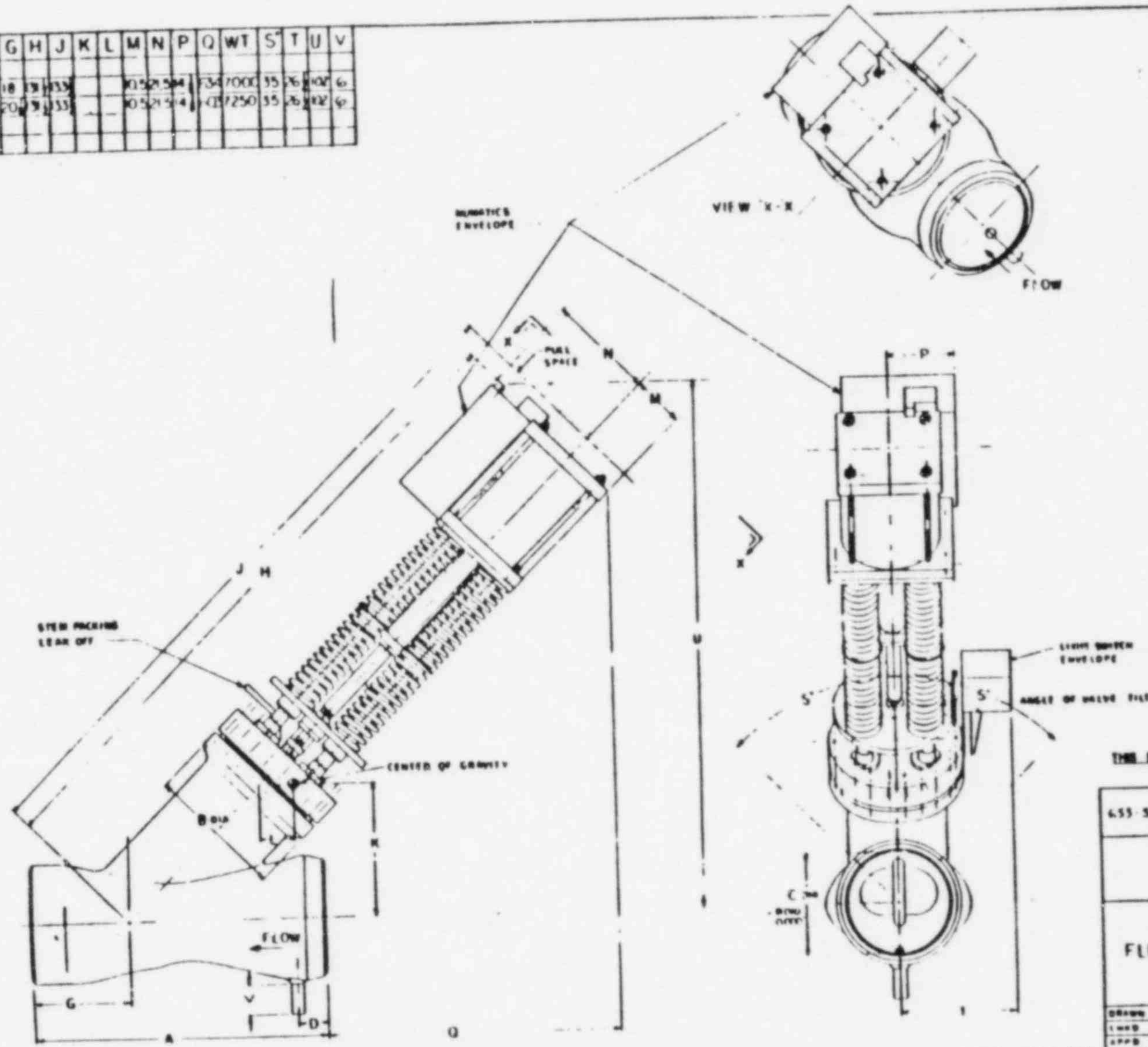
10" - 1612 JMMNTY - DETAIL OF 10/5 BORE 3" ROD TANDEM CYLINDER WITH ACCUMULATOR

DRWN	CHKD	APPD	REV H	SHT 6 OF
G			D-449245	

MATERIALS USED IN THIS ASSEMBLY COMPLY WITH REQUIREMENTS OF G.E. SPEC. 21A9257 REV. 3

22

SIZE	A	B	C	D	G	H	J	K	L	M	N	P	Q	WT	S°	T	U	V
20	[illegible]	27	[illegible]	4	18	[illegible]	33			10.5	21.5	[illegible]	[illegible]	7000	35	26	102	6
[illegible]	60	27	[illegible]	6	20	[illegible]	33		—	10.5	21.5	[illegible]	[illegible]	7250	35	26	102	6



THIS DRAWING FOR VALVE ORIENTATION

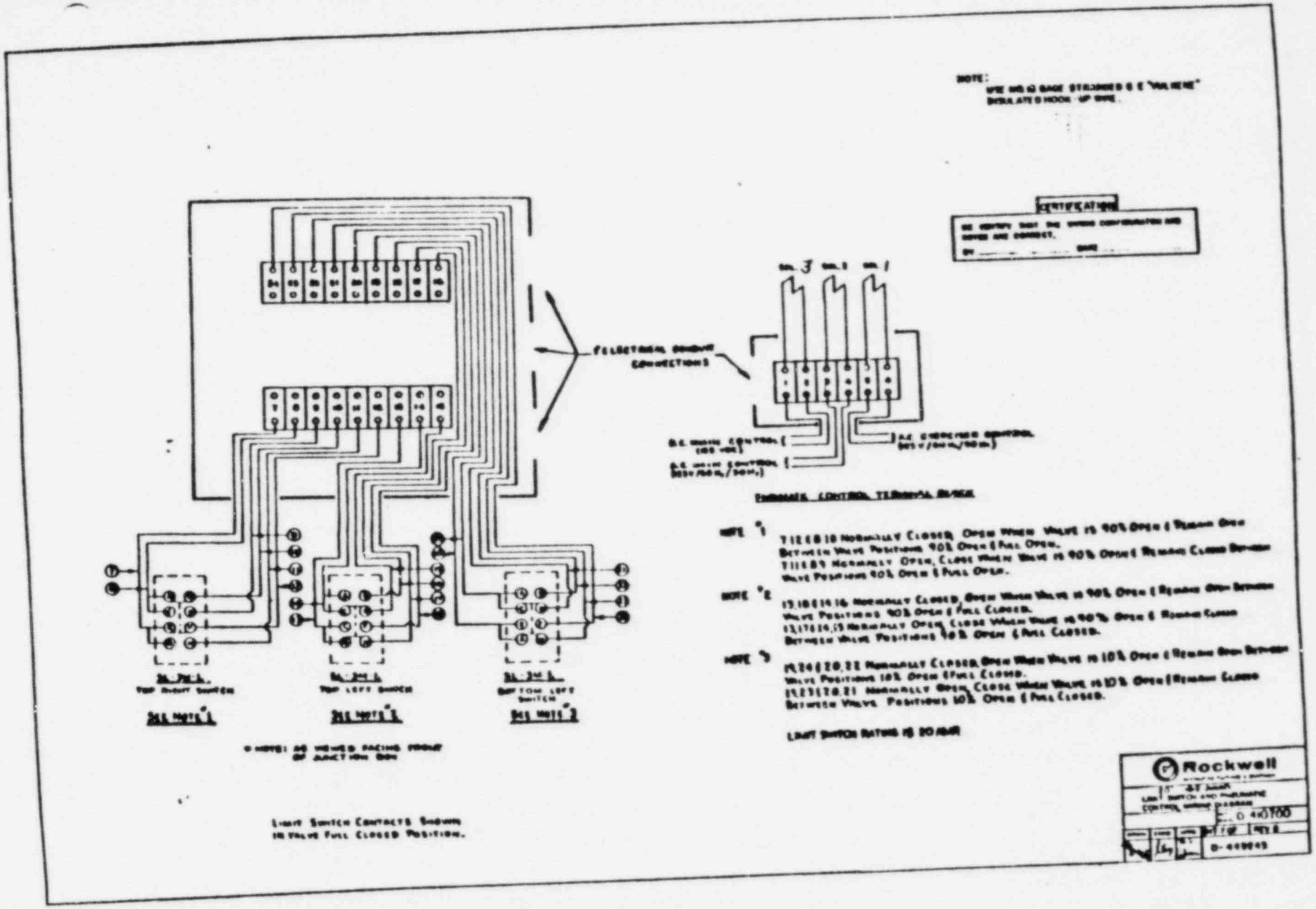
633-S	CAST CARBON STEEL WCB 1575 PSI AT 100°F, 1250 PSI AT 375°F, 665 PSI AT 850°F

Rockwell MANUFACTURING COMPANY

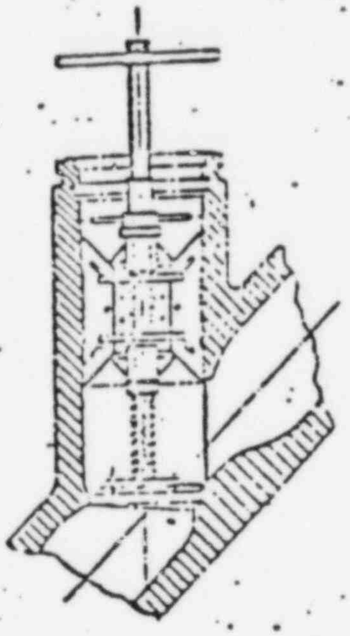
ROCKWELL-EDWARD
FLITE-FLOW, BALANCED STOP VALVE
FIG. 1612 JMMNY

D 44 7249

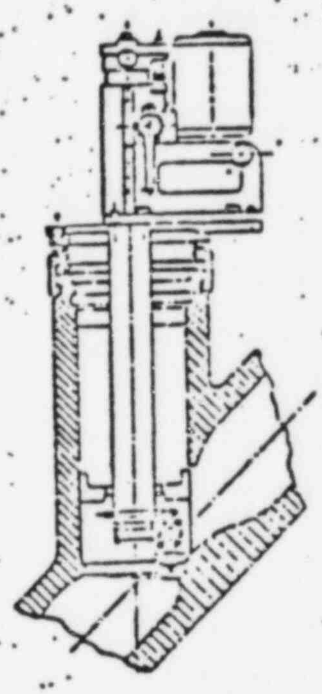
23


NOTE:
CERTIFICATION
ELECTRICAL CONDUIT CONNECTIONS
NOTE 1
NOTE 2
NOTE 3
LIMIT SWITCH RATING IS 20 AMP
TOP RIGHT SWITCH
TOP LEFT SWITCH
BOTTOM LEFT SWITCH
LIMIT SWITCH CONTACTS SHOWN IN VALVE FULL CLOSED POSITION.
Rockwell
D 410700

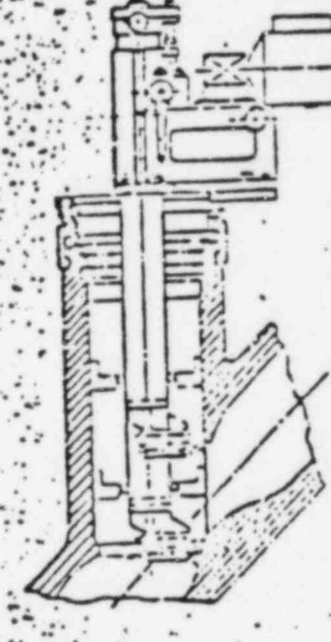
24



PORTABLE LAPPING TOOL
FOR LARGE VALVES



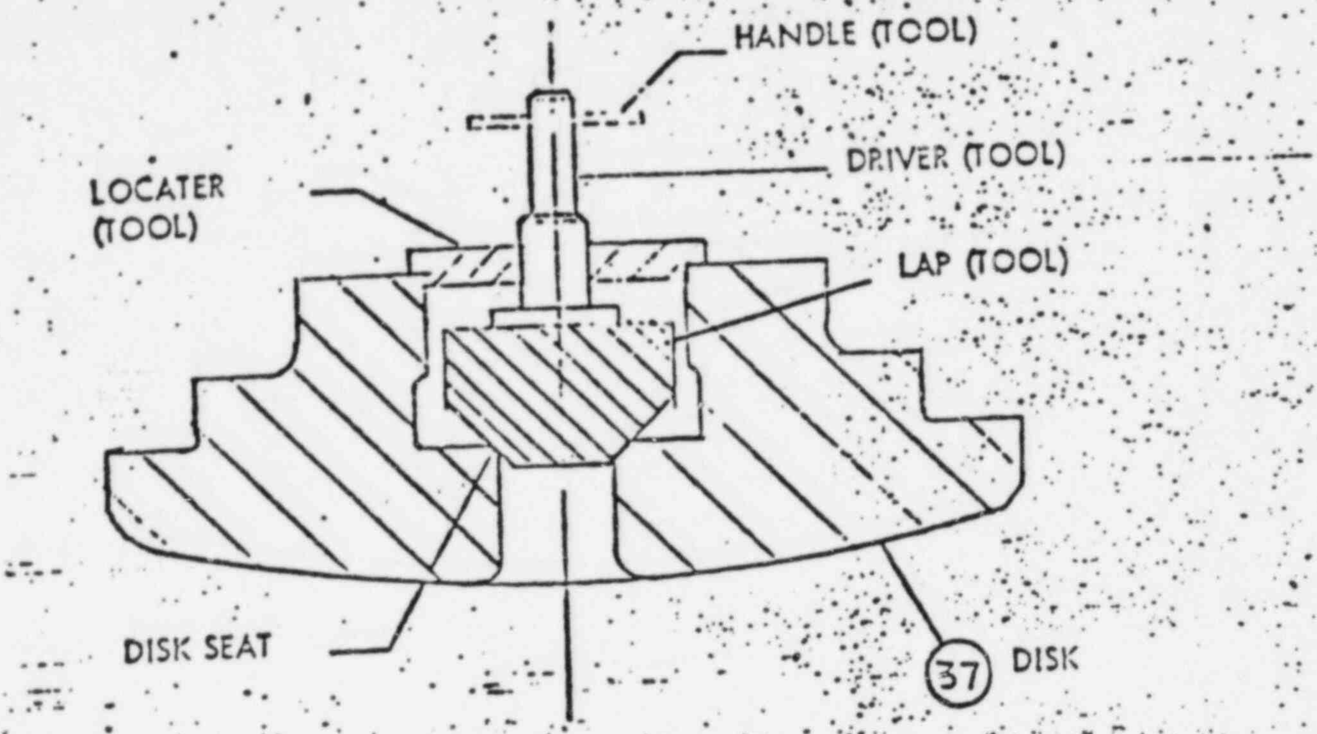
VAN NORMAN PORTABLE
GRINDING MACHINE



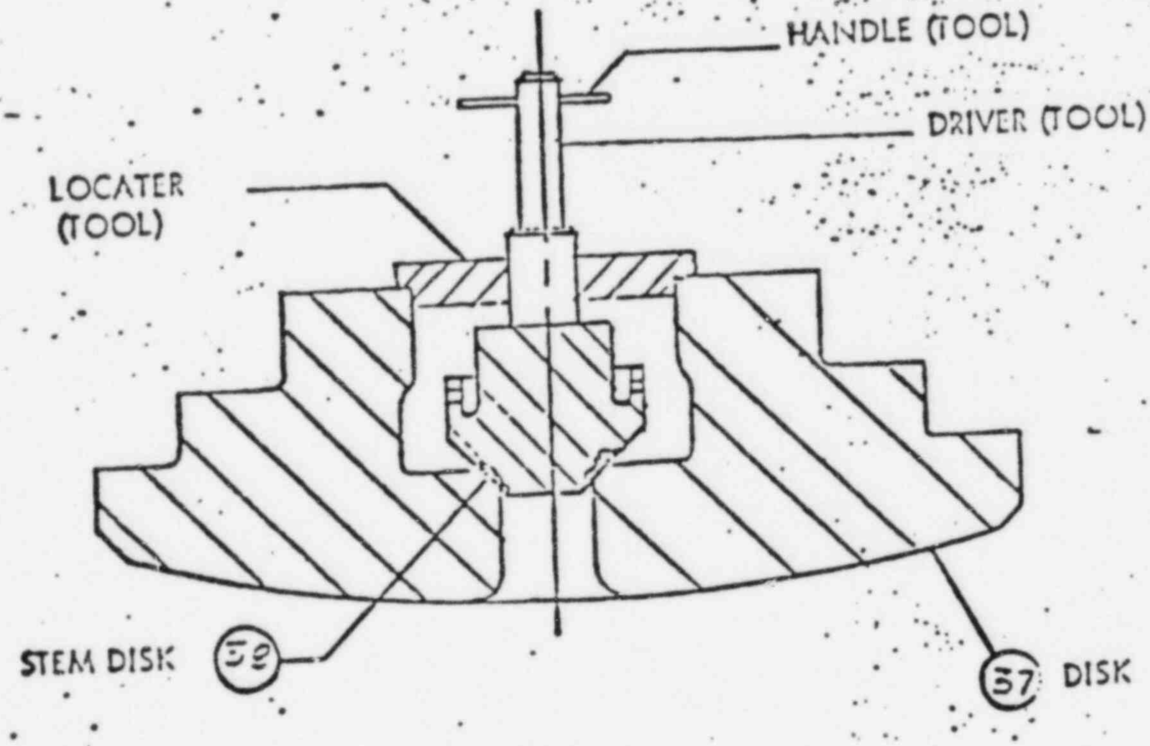
VAN NORMAN PORTABLE
BORING MACHINE

SUGGESTED REPAIR EQUIPMENT

PICTURE "B"

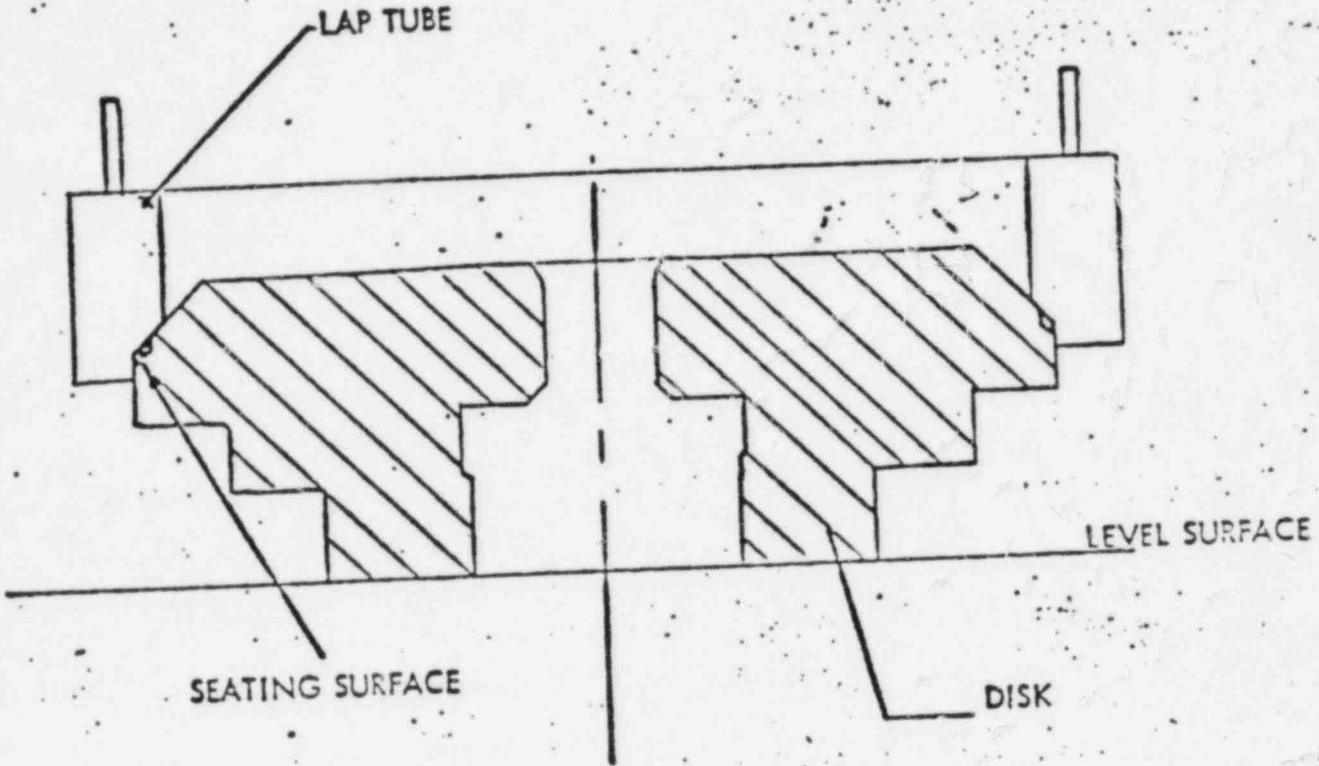


LAPPING DISK SEAT WITH LAP (TOOL)
STEP 1



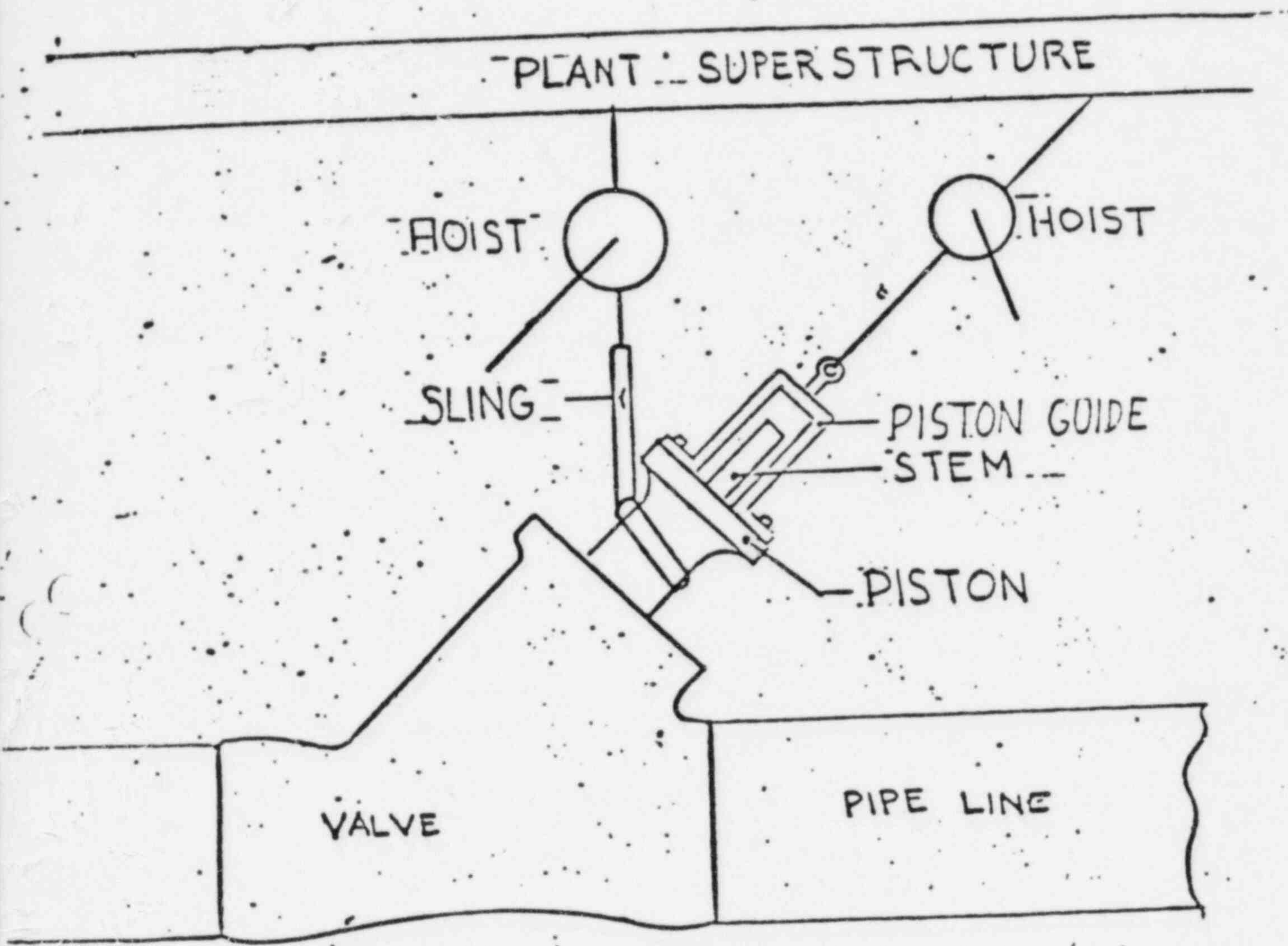
LAPPING STEM DISK TO DISK SEAT
STEP 2

PICTURE "C"



LAPPING DISK WITH LAP TUBE

FIGURE "D"



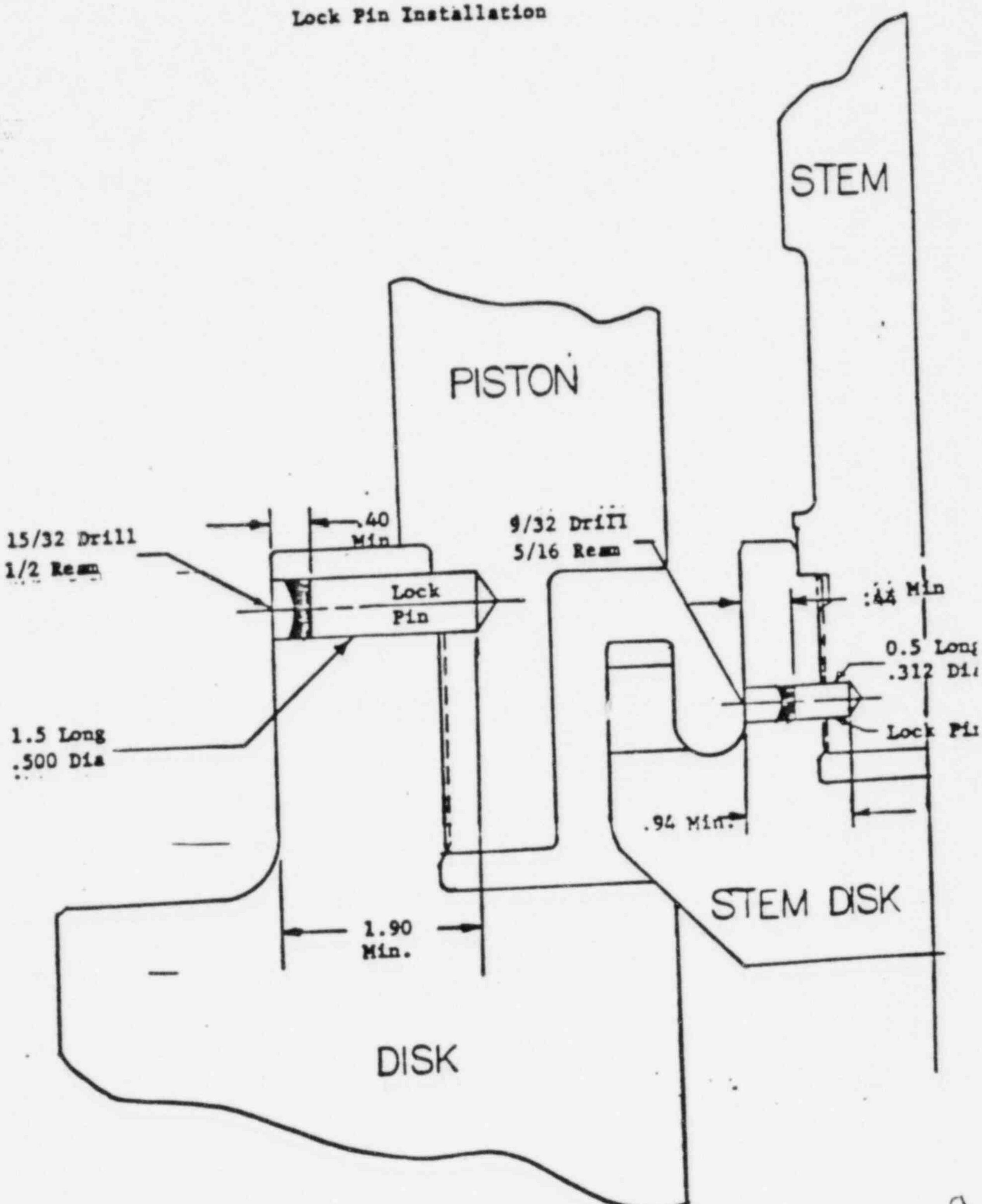
DISK PISTON REMOVAL

PICTURE "E"

28

Disk-Piston, Stem Disk-Stem Assembly

Lock Pin Installation



Picture "D"

ROCKWELL VALVE
SPARE PARTS LIST

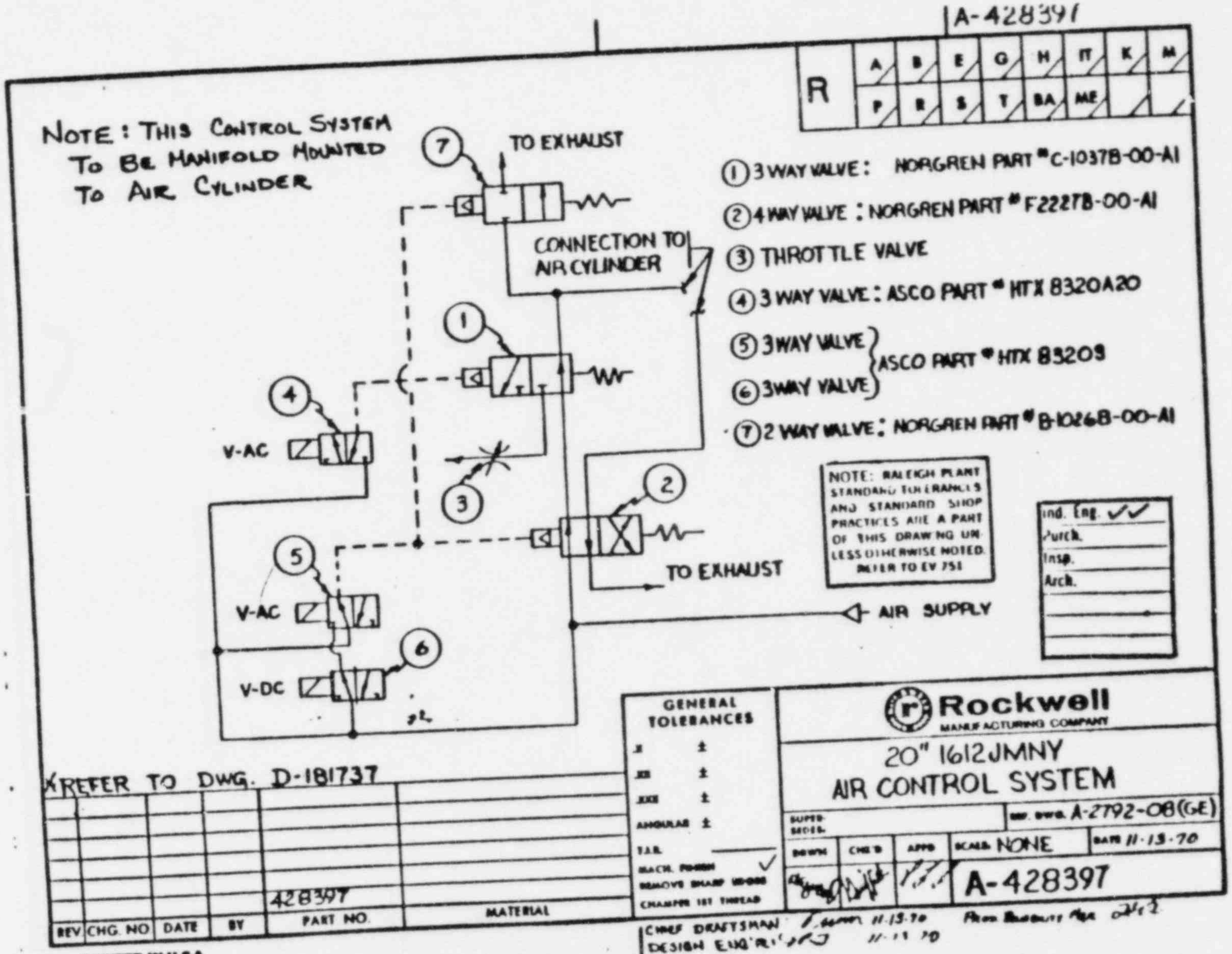
NAME	QTY.	PART NO. (See P. 17)
Packing	20	29
Bonnet Studs	20	5
Bonnet Nuts	20	6
Gasket	3	31
Gland Studs	2	9
Gland Nuts	2	10
Lock Pin	1	35
Lock Pin	1	36

(QUANTITY FOR ONE VALVE)

RECOMMENDED FIELD SERVICE EQUIPMENT

1. Portable lapping tool for seat in body. (1)
2. Inner disk seat lap. (1)
3. Blank
4. Packing removal tool. (1)
5. Lap tube. (1)
6. Bonnet Guide Studs (4)
7. Piston Guide Assembly (1)

(QUANTITY FOR ONE SITE)


A-428397
R
A B E G H IT K M
P R S T BA ME
NOTE: THIS CONTROL SYSTEM TO BE MANIFOLD MOUNTED TO AIR CYLINDER
TO EXHAUST
CONNECTION TO AIR CYLINDER
V-AC
V-AC
V-DC
TO EXHAUST
AIR SUPPLY
(1) 3 WAY VALVE: NORGREN PART # C-1037B-00-A1
(2) 4 WAY VALVE: NORGREN PART # F2227B-00-A1
(3) THROTTLE VALVE
(4) 3 WAY VALVE: ASCO PART # HTX 8320A20
(5) 3 WAY VALVE
(6) 3 WAY VALVE
ASCO PART # HTX 83209
(7) 2 WAY VALVE: NORGREN PART # B-1026B-00-A1
NOTE: RALEIGH PLANT STANDARD TOLERANCES AND STANDARD SHOP PRACTICES ARE A PART OF THIS DRAWING UNLESS OTHERWISE NOTED. REFER TO EV 751
Ind. Eng. ✓✓
Purch.
Insp.
Arch.
GENERAL TOLERANCES
ANGULAR ±
T.I.R.
MACH. FINISH
REMOVE SHARP EDGES
CHAMFER 1ST THREAD
Rockwell
MANUFACTURING COMPANY
20" 1612JMNY
AIR CONTROL SYSTEM
MFR. DWG. A-2792-08 (GE)
SCALE NONE
DATE 11-13-70
DRWN CHK'D APPD
A-428397
CHIEF DRAFTSMAN 11-13-70
DESIGN ENG'R 11-13-70
REFER TO DWG. D-181737
428397
REV CHG. NO DATE BY PART NO. MATERIAL
PRINTED IN U.S.A.

31

Charging Procedure for Hydraulic Cylinder

NOTE: Should it become necessary to drain and refill the hydraulic cylinder (Piece No. 22 on Drawing D-449245), (page 13) Shell Irus 902 hydraulic fluid or equivalent should be used. Do not use phosphate ester based fluids. They will destroy the seals in this equipment (See sketch on page 30)

1. Do not begin charging procedure until this unit is completely assembled and all parts are closed or sealed.
2. Attach the charging hose assembly to the pressure regulator (1) and gas charging valve (2) as shown.
3. Back off the adjusting screw (1A) on the pressure regulator (1).
4. Open the gas charging valve (2) by turning the nut (2A) on the valve counter-clockwise.
5. Open the shut-off valve (3) on the nitrogen bottle.
6. Slowly turn in (clockwise) the adjusting screw (1A) on the pressure regulator (1) until the gauge (4) reads 100 PSI.
7. Close the gas charging valve (2) by turning the nut (2A) on the valve clockwise.
8. Back off the pressure regulator adjusting screw (1A) until the gauge (4) reads 0 PSI.
9. Remove the long hose by breaking the connection at the fitting (5) and leave the gauge (4) connected to the gas charging valve (2).
10. Open the gas charging valve (2) by turning the nut (2A) counter-clockwise.
11. Bleed off nitrogen by pushing in the bleed-off valve (6) until the gauge (4) reads 90 PSI.
12. Remove the S.A.E. oil fill plug (7).
13. Connect a handpump to the oil fill port.
14. Fill the oil side with Shell Irus 902 hydraulic fluid until the gauge (4) reads 100-110 PSI.
15. Cycle the unit and bleed the air from 4" bore cylinder while cycling.
16. If necessary add oil to bring the pressure back up to 100-110 PSI on the gauge (4).

M

17. Remove the handpump, and install the oil fill plug (7).

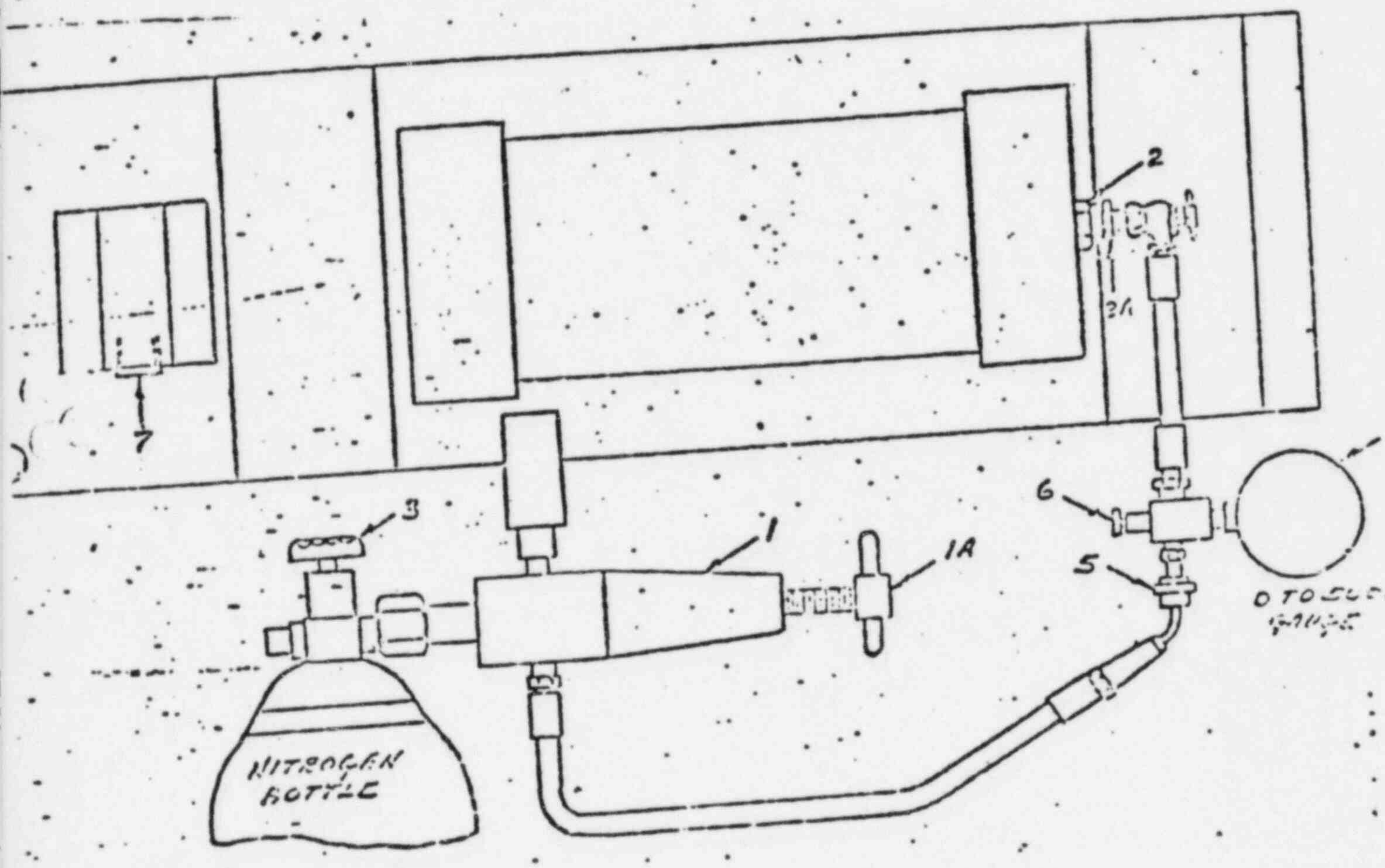
18. Close the gas charging valve (2) by turning the nut (2A) clockwise. Close off tightly.

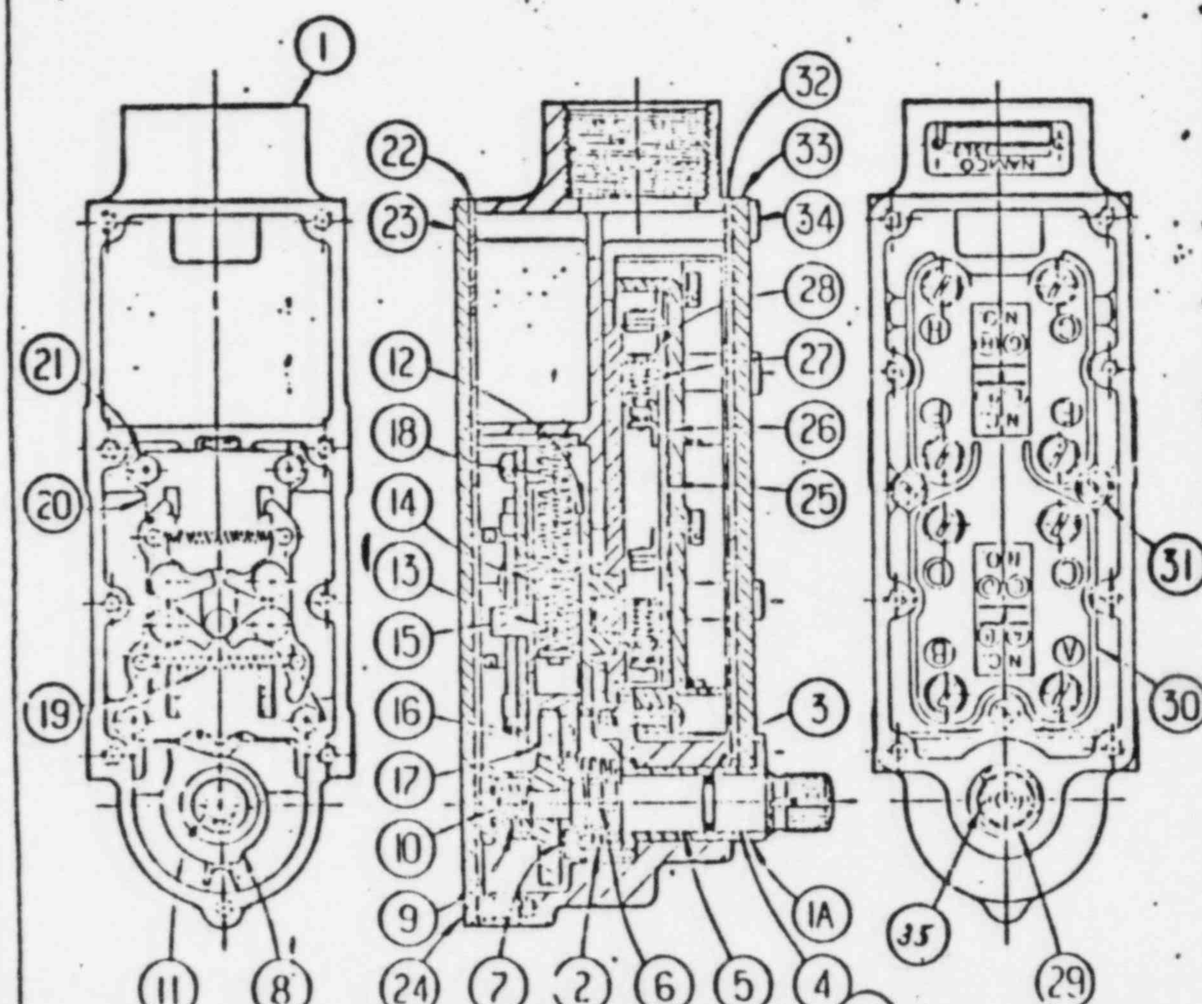
19. Remove the gauge (4) and hose assembly from the gas charging valve (2).

20. Place the seal cap on the gas charging valve (2).

21. Inspect for internal leakage.

22. CAUTION: Close the shut-off valve (3) on the nitrogen bottle before removing the pressure regulator (1).





REF. NO.	PART NUMBER	* DESCRIPTION	QTY.
1	SL102-B	HOUSING (INCLUDES NEXT ITEM)	1
1A	SL103	BUSHING	1
*2	SL136-B	TORSION SPRING (YELLOW)	1
3	30-7	"O" RING	1
4	SL140	LEVER ASSEMBLY - FOR SL3-M (INCLUDES ITEMS 5, 6 & 7)	1
4A	SL140-A	LEVER ASSEMBLY - FOR SL3C-M (INCLUDES ITEMS 5A, 6 & 7)	1
5	SL137	LEVER SHAFT - FOR SL3-M	1
5A	SL137-A	LEVER SHAFT - FOR SL3C-M	1
6	RRP 3-9	ROLL PIN	1
7	SL138	CAM CLUTCH	1
8	SL139-M	CAM	1
*9	SL142	CAM SPRING	1
10	SL141	RETAINING WASHER	1
11	SL167	RETAINING RING	1
12	SL145	SHUTTLE	1
*13	SL117-A	LATCH RELEASE SPRING (BLUE)	1
14	SL116	SPRING STOP	2
15	SL114	SLIDE	1
16	SL119	PIN	1
17	SL118	ROLLER	1
*18	SL163-A	RETURN SPRING (BLUE)	1
*19	SL111	LATCH RETURN SPRING	2
20	SL105	LATCH PLATE ASSEMBLY	1
21	SFCC6	SCREW	4
22	SL150-J	BOTTOM COVER GASKET	1
23	SL151-A	BOTTOM COVER (STANDARD MTG. ONLY)	1
	SL152-A	BOTTOM COVER (STYLE W MTG. ONLY)	1
	SL153-A	BOTTOM COVER (STYLE L MTG. ONLY)	1
24	SFCC7	SCREW	9
25	SL120-A	CONTACT CARRIER ASSEMBLY (INCLUDES NEXT 3 ITEMS)	1
26	SL121-A	CONTACT CARRIER	1
27	SL122-A	CONTACT SPRING	2
28	SL125	CONTACT	4
29	SL168	RETAINING RING	1
30	SL135-A	CONTACT BLOCK ASSEMBLY	1
31	SMCC3	SCREW	3
32	SL157-M	TOP COVER GASKET	1
33	SL164-B	TOP COVER	1
34	SHCC8	SCREW	8
35	RPPS-1	PIPE PLUG - FOR SL3C-M	1

* RECOMMENDED SPARE PARTS

THE NATIONAL ACME CO. CLEVELAND, OHIO

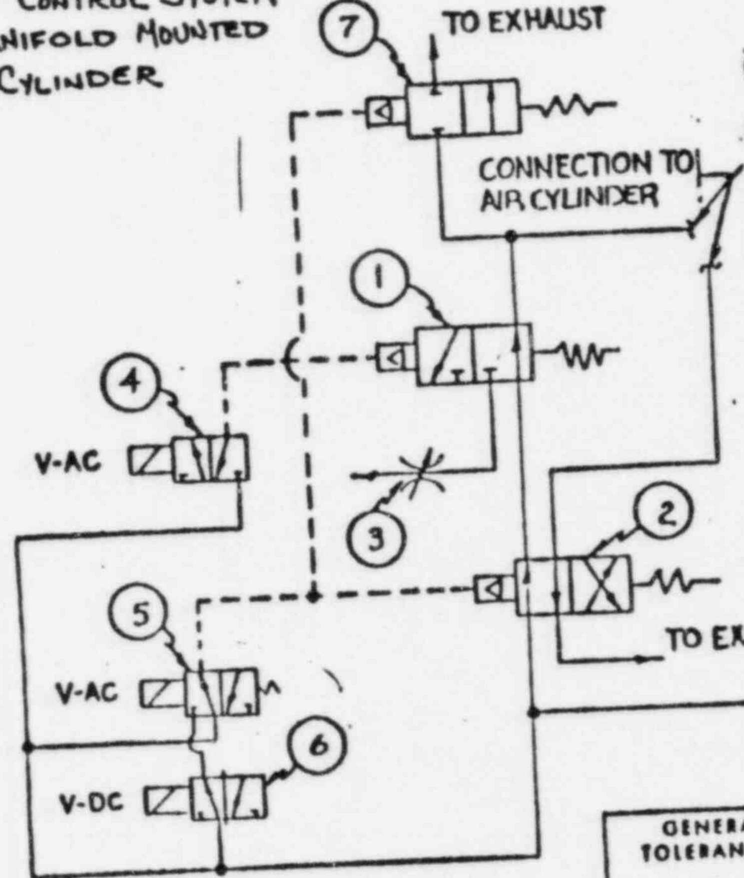
SNAP LOCK LIMIT SWITCH

[illegible]	[illegible]	SL3M, SL3CM	SHEET
SCALE FULL	[illegible]	CHART	2 OF 2

A-428397

R	A	B	E	G	H	IT	K	M
	P	R	S	T	BA	ME		

NOTE: THIS CONTROL SYSTEM TO BE MANIFOLD MOUNTED TO AIR CYLINDER



(1) 3 WAY VALVE: NORGREN PART # C-1037B-00-A1

(2) 4 WAY VALVE: NORGREN PART # F2227B-00-A1

(3) THROTTLE VALVE

(4) 3 WAY VALVE: ASCO PART # 11TX 8320A20

(5) 3 WAY VALVE } ASCO PART # HTX 8320S
(6) 3 WAY VALVE }

(7) 2 WAY VALVE: NORGREN PART # B-1026B-00-A1

NOTE: RALEIGH PLANT STANDARD TOLERANCES AND STANDARD SHOP PRACTICES ARE A PART OF THIS DRAWING UNLESS OTHERWISE NOTED. REFER TO EV 751

Ind. Eng. ✓✓	
Purch.	
Insp.	
Arch.	

REVISION NO	DATE	BY	PART NO.	MATERIAL
			428397	

GENERAL TOLERANCES
.X ±
.XX ±
.XXX ±
ANGULAR ±
T.I.R.
MACH. FINISH ✓
REMOVE SHARP EDGES
CHAMFER 1ST THREAD

Rockwell MANUFACTURING COMPANY

20" 1612JMNY AIR CONTROL SYSTEM

SUPERSEDES: | REF. DWG. A-2792-08 (GE)

DRWN	CHK'D	APPD	SCALE: NONE	DATE 11-13-70
[illegible]	[illegible]	[illegible]	A-428397	

CHIEF DRAFTSMAN [illegible] 11-13-70 Ileo Ruamm Fac. [illegible]

PRINTED IN U.S.A.

35

BULLETIN

8320

3-WAY Red-Hat® SOLENOID VALVES

MINIATURE SIZE

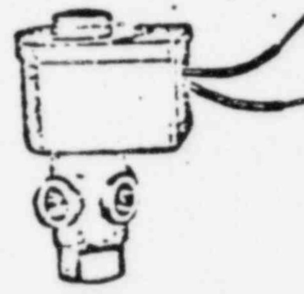
For Air, Gas, Water, Light Oil and Corrosive Media • ⅛" and ¼" N.P.T.

General Description

ASCO's radically new approach to 3 way valve design obsoletes all existing 3 way valves on the market. The compact new design eliminates the orifice connection in the solenoid — all connections are now in the valve body providing in-line piping.

This modern design concept with orifice and pipe connections in the body also permits coil replacement without opening pipe connections — now necessary on all other 3 way valves.

A wide selection of Bulletin 8320 Valves is offered in various pipe and orifice sizes and constructions for all applications.



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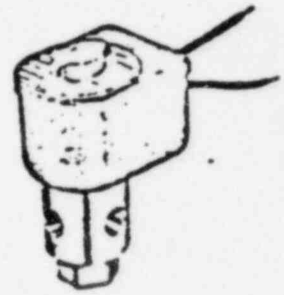

[illegible]

Applications

For automatic control of air, gas, water, oil, freon and all other gases and liquids . . . non-corrosive to brass and stainless steel. Valves are commonly used to apply pressure to and vent pressure from cylinders and diaphragms or for selection and diversion of pressure.

Some typical applications are:

- Automation
- Vending
- Air and Hydraulic Cylinders
- Pilot Operators
- Gas Sampling
- Copying and Reproduction Equipment
- Lubricating Devices
- Air Conditioning
- Instrumentation
- Air Dryers
- Laundry Equipment
- Compressors

Specifications

Operation: Three types available:

(a) Normally Closed — Applies pressure when solenoid is energized; exhausts pressure when solenoid is de-energized.

(b) Normally Open — Applies pressure when solenoid is de-energized; exhausts pressure when solenoid is energized.

(c) Universal — For normally closed or normally open operation. Selection or diversion of pressure can be applied at A, B or C without change of springs or making other adjustments.

Pipe Sizes: ⅛" and ¼" N.P.T.

Valve Body: Forged Brass and Stainless Steel.

Valve Seat: Buna "N" — tight shut-off.

Solenoid Construction: Internal parts in contact with fluid are made of Series 300 and 400 Stainless Steel.

Solenoid Enclosures: Two types available:

(a) General Purpose (NEMA 1).

(b) Explosion-Proof and Watertight (NEMA 4, 7 and 9).

Electrical: Standard Voltages:
24, 120, 240, 480 volts, A-C, 50 or 60 cycles.
6, 12, 24, 120 volts, D-C.
Other voltages available when required.

Coil: Continuous Duty Class A or Class B Molded Coils, as listed.

Temperature: For liquids and gases up to 200°F., as listed.

Installation: Mountable in any position without affecting operation.

Mounting: See dimension drawings.

Approvals: For full details of UL listings, CSA and FM approvals refer to Price Schedule, Form V5356.

Optional Features:

- Strain-Relief Connector
- Manual Operator
- ½" Threaded Conduit Hub or Adapter
- Class A or Molded Class B Coils with Spade Terminals or Leads
- Dual Voltage Class A or Molded Class B Coils
- Class H Hi-Temp. Coil
- Open Yoke Solenoid Frame for Cabinet Installation

ORDERING INFORMATION

IMPORTANT: [illegible] PIPE SIZE, CAT-[illegible], VOLTAGE [illegible] FREQUENCY, [illegible]

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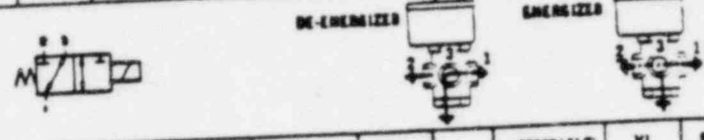
BULLETIN 8320 (continued)

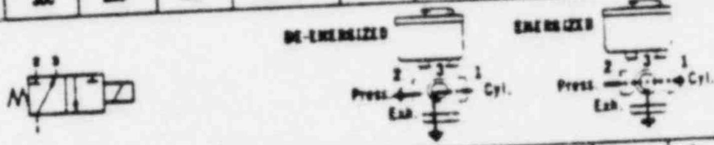
SPECIFICATIONS • BRASS BODY

Pipe Size (Ins.)	Orifice Size (Ins.)	Max. Operating Pressure Differential (P.S.I.) Air-Inert Gas A-C	Air-Inert Gas D-C	Water A-C	Water D-C	Light Hy-Drau. Oil ① A-C	Light Hy-Drau. Oil ① D-C	Safe Working Pressure (P.S.I.)	Max. ① A-C Fluid Temp. °F	Cv Flow Factor	General Purpose Solenoid Enclosure Catalog Number	Optional Feature Ref.	Constr. Ref.	Explosion-Proof — Watertight Solenoid Enclosure Catalog Number	Optional Feature Ref.	Watt Rating A-C	Watt Rating D-C	Class of Coil Insulation	Approx. Shipping Weight (Lbs.) GP	EP
Universal Operation (Pressure at any orifice)																				
1/8	3/64	175	125	175	125	175	125	300	140	.06	8320B130①	II	1	8320B131①	VI	9	9.7①	F	5/8	1 1/2
	1/16	100	65	100	65	100	65	300	180	.08	8320B81	II	1	8320B82	VI	9	9.7①	F	5/8	1 1/2
	3/32	50	50	50	50	50	50	300	180	.15	8320B83	I	1	8320B84	V	6	9.7	A	5/8	1 1/2
	1/8	30	20	30	20	30	20	300	180	.21	8320B83	II	1	8320B84	VI	9	9.7①	F	5/8	1 1/2
1/4	1/16	100	65	100	65	100	65	300	180	.08	8320A5	II	3	8320A6	VI	9	9.7①	F	1 1/8	2
	3/32	40	40	40	40	40	40	300	180	.15	8320A85	I	3	8320A86	V	6	9.7	A	1 1/8	2
	1/8	30	20	30	20	30	20	300	180	.31	8320A9	II	3	8320A10	VI	9	9.7①	F	1 1/8	2
1/4	1/32	395	280	410	305	410	305	1000	140	.02	8320A170①	[illegible]	4	8320A171①	VIII	16.7	11.2①	F	1 1/8	2 1/4
	1/16	125	75	130	75	130	75	300	200	.08	8320A172	III	4	8320A173	VII	10.5	11.2	A	1 1/8	2 1/4
	3/32	100	60	100	60	100	60	300	200	.15	8320B174	IV	4	8320B175	VII	16.7	11.2①	F	1 1/8	2 1/4
	1/8	50	25	50	25	50	25	300	200	.31	8320B176	IV	4	8320B177	VII	16.7	11.2①	F	1 1/8	2 1/4
	11/64	20	12	20	12	20	12	300	200	.38	8320A178	III	4	8320A179	VII	10.5	11.2	A	1 1/8	2 1/4
Normally Closed Operation (Pressure at 2)																				
1/8	3/64	200	200	200	200	200	200	300	180	.06	8320B132	I	1	8320B133	V	6	9.7	A	5/8	1 1/2
	3/64	300	250	300	250	300	250	300	140	.06	8320B134①	II	1	8320B135①	VI	9	9.7①	F	5/8	1 1/2
	1/16	125	125	125	125	125	125	300	180	.08	8320B13	I	1	8320B14	V	6	9.7	A	5/8	1 1/2
	3/32	100	100	100	100	100	100	300	180	.15	8320B15	I	1	8320B16	V	6	9.7	A	5/8	1 1/2
	1/8	40	40	40	40	40	40	300	180	.21	8320B17	I	1	8320B18	V	6	9.7	A	5/8	1 1/2
1/4	1/16	125	125	125	125	125	125	300	180	.08	8320A19	I	3	8320A20	V	6	9.7	A	1 1/8	2
	3/32	110	65	110	65	110	65	300	180	.15	8320A89	II	3	8320A90	VI	9	9.7①	F	1 1/8	2
	1/8	40	40	40	40	40	40	300	180	.31	8320A23	I	3	8320A24	V	6	9.7	A	1 1/8	2
	11/64	30	20	30	20	30	20	300	180	.38	8320A87	II	3	8320A88	VI	9	9.7①	F	1 1/8	2
1/4	1/32	750	520	750	560	750	570	1000	140	.02	8320A180①	IV	4	8320A181①	VIII	16.7	11.2①	F	1 1/8	2 1/4
	1/16	210	160	225	160	225	160	300	200	.09	8320A182	IV	4	8320A183	VIII	16.7	11.2①	F	1 1/8	2 1/4
	3/32	150	115	150	115	150	115	300	200	.15	8320A184	III	4	8320A185	VII	10.5	11.2	A	1 1/8	2 1/4
	1/8	85	60	85	60	85	60	300	200	.31	8320A186	III	4	8320A187	VII	10.5	11.2	A	1 1/8	2 1/4
	11/64	45	25	45	25	45	25	300	200	.38	8320A188	III	4	8320A189	VII	10.5	11.2	A	1 1/8	2 1/4
Normally Open Operation (Pressure at 3)																				
1/8	3/64	200	200	200	200	200	200	300	180	.06	8320B136	I	1	8320B137	V	6	9.7	A	5/8	1 1/2
	3/64	300	250	300	250	300	250	300	140	.06	8320B138①	II	1	8320B139①	VI	9	9.7①	F	5/8	1 1/2
	1/16	125	125	125	125	125	125	300	180	.08	8320B27	I	1	8320B28	V	6	9.7	A	5/8	1 1/2
	3/32	100	100	100	100	100	100	300	180	.15	8320B29	I	1	8320B30	V	6	9.7	A	5/8	1 1/2
	1/8	40	40	40	40	40	40	300	180	.21	8320B31	I	1	8320B32	V	6	9.7	A	5/8	1 1/2
1/4	1/16	125	125	125	125	125	125	300	180	.08	8320A33	I	3	8320A34	V	6	9.7	A	1 1/8	2
	3/32	110	65	110	65	110	65	300	180	.15	8320A91	II	3	8320A92	VI	9	9.7①	F	1 1/8	2
	1/8	40	40	40	40	40	40	300	180	.31	8320A37	I	3	8320A38	V	6	9.7	A	1 1/8	2
	11/64	30	20	30	20	30	20	300	180	.38	8320A99	II	3	8320A100	VI	9	9.7①	F	1 1/8	2
1/4	1/32	790	550	825	600	825	600	1000	140	.02	8320A190①	IV	4	8320A191①	VIII	16.7	11.2①	F	1 1/8	2 1/4
	1/16	235	160	250	160	250	180	300	200	.08	8320A192	IV	4	8320A193	VIII	16.7	11.2①	F	1 1/8	2 1/4
	3/32	140	100	140	100	140	100	300	200	.15	8320A194	III	4	8320A195	VII	10.5	11.2	A	1 1/8	2 1/4
	1/8	70	55	70	55	70	55	300	200	.31	8320A196	III	4	8320A197	VII	10.5	11.2	A	1 1/8	2 1/4
	11/64	40	30	40	30	40	30	300	200	.38	8320A198	III	4	8320A199	VII	10.5	11.2	A	1 1/8	2 1/4

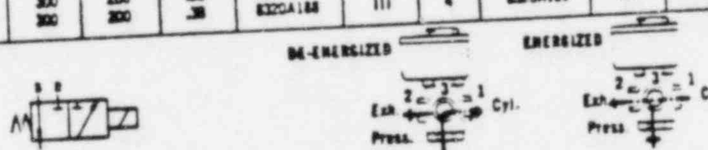
Universal Operation diagrams:



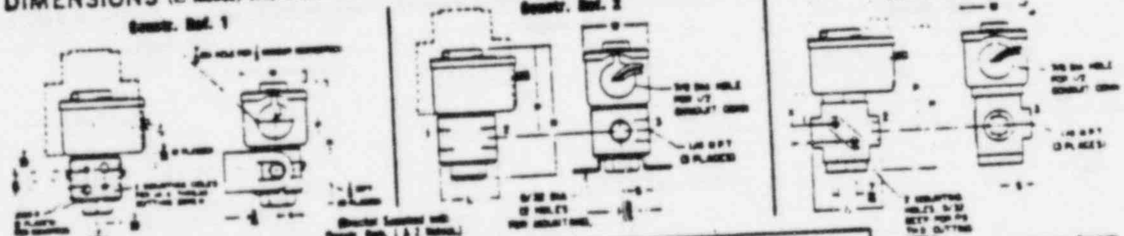
Normally Closed Operation diagrams:



Normally Open Operation diagrams:



DIMENSIONS (in inches) (Explosion-Proof — Watertight Solenoid Enclosure shown dotted-in, details available on request.)

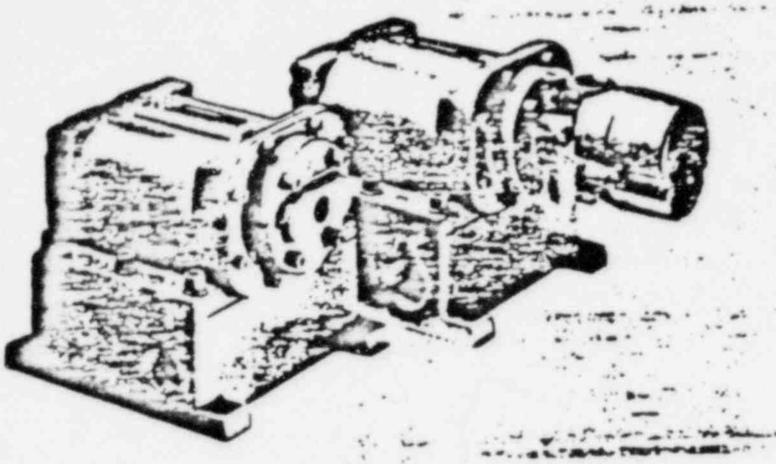


Constr. Ref.	1	2	3	4
Pipe Size	1/8	1/4	1/4	1/4
B	3 5/16	3 1/4	3 11/16	3 11/16
L	1 3/16	1 3/16	1 13/16	1 13/16
P	2 1/4	2 3/16	2 13/16	2 13/16
S	9/16	9/16	9/16	9/16
W	1 5/16	1 5/16	1 5/16	1 5/16
X	—	—	5/8	5/8

MANUAL OPERATORS (Push Type) (Screw Type)

4-WAY SUB BASE VALVES

NC-1831
(Replaces NC-950)
May, 1974



AIR OR SINGLE SOLENOID PILOT OPERATED

HOW TO ORDER

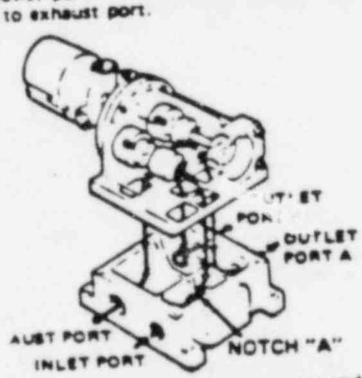
Operator	Basic Size	Port Size	Model Number 4-Port	Model Number 5-Port	C_v Flow Norm. Closed In-Cv 1	Norm. Closed Cv 1-Exh	Norm. Open In-Cv 2	Norm. Open Cv 2-Exh
	1/2"	1/4"	F22128-00-A1	F2232C-00-A1	1.8	3.4	3.0	3.2
		3/8"	F22138-00-A1	F2233C-00-A1	2.7	3.7	3.0	3.7
		1/2"	F22148-00-A1	F2234C-00-A1	3.2	4.7	3.8	4.7
		3/4"	F22158-00-A1	F2235C-00-A1	3.5	4.7	3.9	4.7
	1"	3/4"	F22258-00-A1	F2245C-00-A1	10.0	12.0	8.0	10.5
		1"	F22268-00-A1	F2246C-00-A1	11.9	12.7	10.3	11.1
		1-1/4"	F22278-00-A1	F2247C-00-A1	13.0	13.0	11.1	11.3
Solenoid Pilot	1/2"	1/4"	F22128-00-H1	F2232C-00-H1	1.8	3.4	2.0	3.2
		3/8"	F22138-00-H1	F2233C-00-H1	2.7	3.7	3.0	3.7
		1/2"	F22148-00-H1	F2234C-00-H1	3.2	4.7	3.8	4.7
		3/4"	F22158-00-H1	F2235C-00-H1	3.5	4.7	3.9	4.7
	1"	3/4"	F22258-00-H1	F2245C-00-H1	10.0	12.0	8.0	10.5
		1"	F22268-00-H1	F2246C-00-H1	11.9	12.7	10.3	11.1
		1-1/4"	F22278-00-H1	F2247C-00-H1	13.0	13.0	11.1	11.3

NOTE: Solenoid is furnished with non-locking manual override, 120V, 60HZ AC unless otherwise specified. For locking manual override substitute "H2" for the last two digits in the model number. The only difference between 4 Port and 5 Port configuration is notch A on 4 Port + Inlet Port A on 5 Port.

OPERATION

4-PORT SINGLE

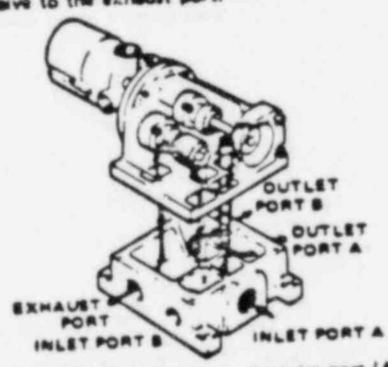
UNACTUATED – Air enters the inlet port and flows through the valve to outlet port (B). Exhaust air from the cylinder enters the outlet port (A) and flows through the valve to exhaust port.



ACTUATED – Air enters the inlet port and flows through the valve to outlet port (A). Exhaust air from the cylinder enters the outlet port (B) and flows through the valve to exhaust port.

5-PORT SINGLE

UNACTUATED – Air enters the inlet port (B) and flows through the valve to outlet port (B). Air entering the inlet port (A) is blocked. Exhaust air from the cylinder enters the outlet port (A) and flows through the valve to the exhaust port.



ACTUATED – Air enters the inlet port (A) and flows through the valve to outlet port (A). Air entering inlet port (B) is blocked. Exhaust air from the cylinder enters the outlet port (B) and flows through the valve to the exhaust port.

FUNCTION

4-PORT – Valves are used to operate double acting cylinders, etc. Side port is standard, bottom ported sub-base may be supplied if specified.

5-PORT – Valves are used to operate double acting cylinders, etc., with different supply pressures, the internal pilot supply is connected to the higher pressure inlet port by means of a check valve in each internal pilot supply.

SPECIFICATIONS

General

- 2-Position
- Pilot pressure must be equal to or greater than line pressure, 30 psig min.
- Available for vacuum service.
- Valves may be mounted in any position.
- 1/2" & 1" Basic valve sizes have equivalent full flow 1/2" & 1" pipe orifices. 1-1/4" orifice available in basic 1" valve.
- All aluminum construction – corrosion resistant treated.

Air Operated

- 5 to 200 psig air service.
- Ambient temperatures: 35°F. min., 175°F. max.

Solenoid Pilot Operated

- 120 volt, 60 HZ, Standard
- Optional voltages available see NC-1843.
- 30 to 180 PSIG Air Service
- Ambient temperatures: 35°F. min., 130°F. max.
- Power consumption: 7 watts AC, 12 watts DC
- .8 amps inrush at 120V, 60HZ, AC
- .23 amps holding at 120V, 60HZ, AC
- Epoxy, encapsulated, moisture resistant coils provided with all H1 operators.

HOW TO ORDER

Example: 4-Port F22128-00-A1
5-Port F2232C-00-A1

See Order Table

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LITTLETON, COLORADO

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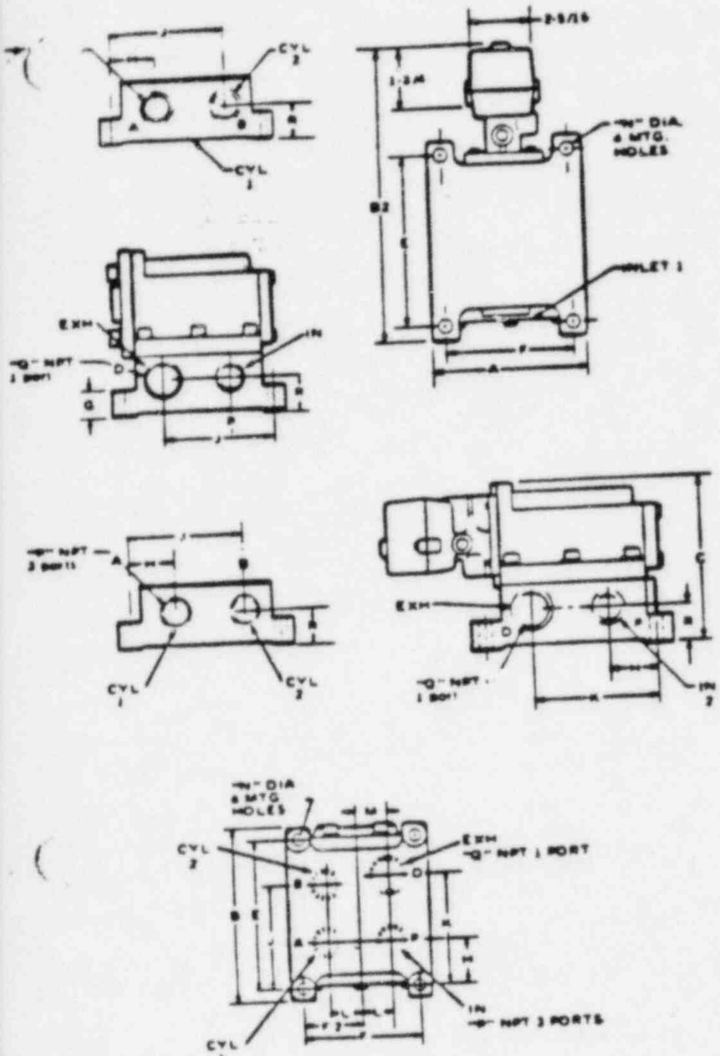
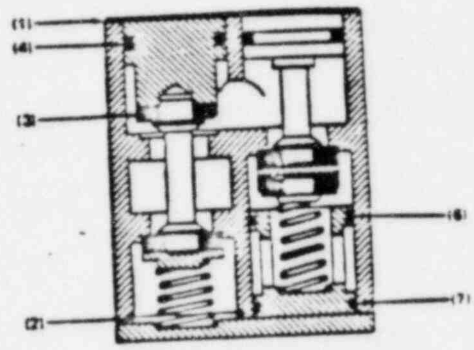


SERVICE KITS

4-Way Sub-base Mounted Valve Service Kit, 1/2" 53474-04

4-Way Sub-base Mounted Valve Service Kit, 1" 53475-04

Kits contain: (1) Gasket for adapter, (2) "O" ring (3) 4 Seals, (4) 2 "O" rings, (5) Sub-base gasket (not shown), (6) "O" ring, (7) "O" ring.



VITON KITS

SIZE	Field Conversion	Ordered "With" Or "In" Unit	For Models
1/2"	53474-11	53474-18	F2232/5 F2212/5
1"	53475-10	53475-16	F2225/7 F2245/7

CAUTION

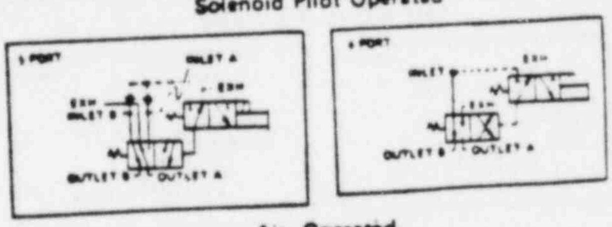
THESE PRODUCTS SHOULD NOT BE USED IN APPLICATIONS WHICH DO NOT FULLY COMPLY WITH RECOMMENDED OPERATING SPECIFICATIONS.

FOR USE WITH MEDIA OTHER THAN AIR OR INERT GAS, OR FOR LIFE SUPPORT SYSTEMS, CONSULT YOUR DISTRIBUTOR FOR FACTORY APPROVAL.

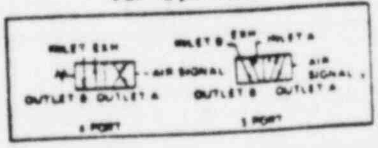
THE USER OF THESE PRODUCTS IS CAUTIONED TO CONFORM TO ALL APPLICABLE ELECTRICAL, MECHANICAL AND OTHER CODES.

CIRCUIT SYMBOLS

Solenoid Pilot Operated



Air Operated

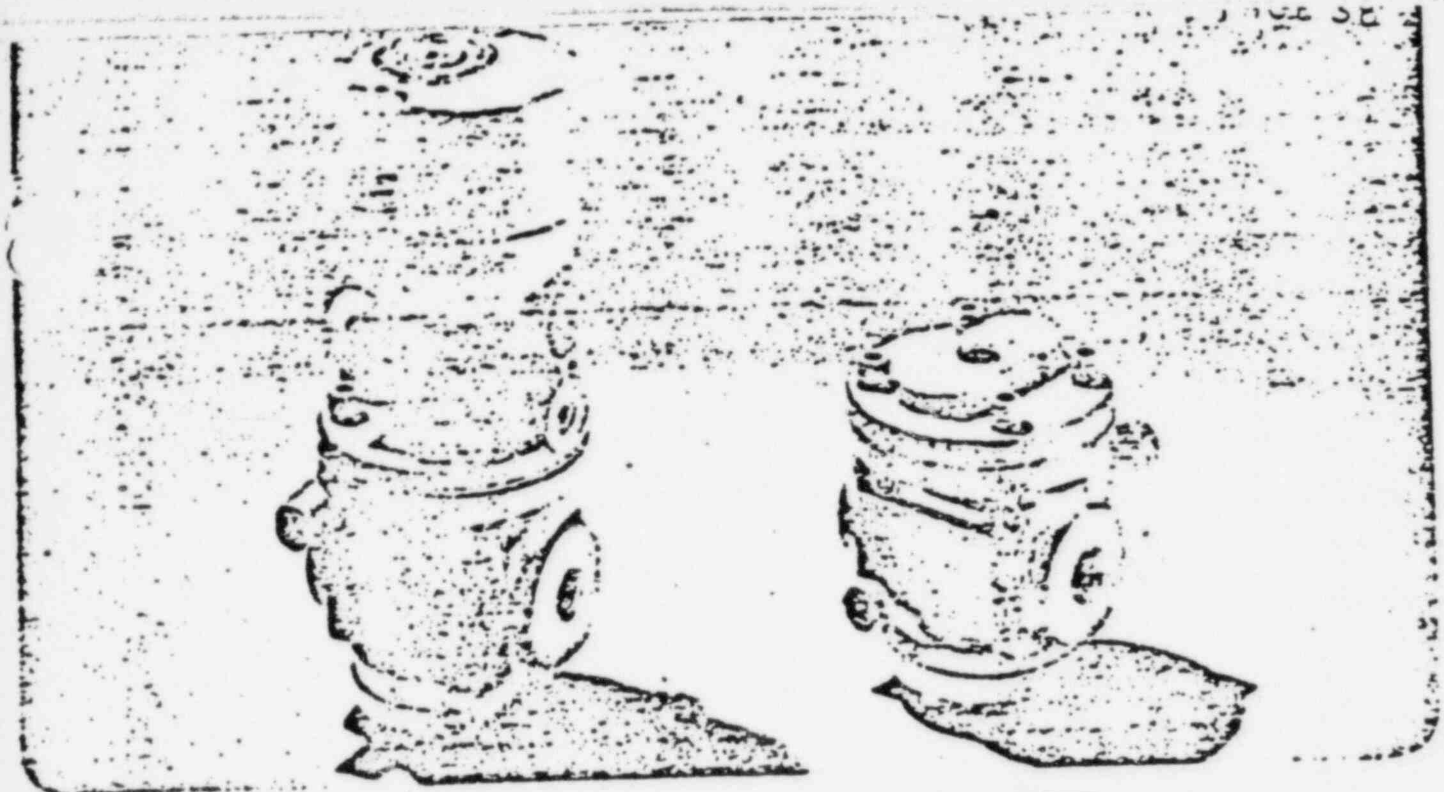


DIMENSIONS—Inches					
KEY	Basic Valve		KEY	Basic Valve	
	1/2"	1"		1/2"	1"
A	4-1/8	6-1/4	K	3 1/8	4-1/2
B1	4-15/16	6-3/4	L	15/16	3/4
B2	8	11	M	3/4	1-1/2
C	4-11/16	6	N	11/32	13/32
E	4-1/4	6	P	1/4, 3/8, 1/2, 3/4	3/4, 1, 1-1/4
F	3-3/8	5 1/4	Q*	3/8, 1/2, 3/4, 3/4	1, 1-1/4, 1-1/4
G	5/8	1/2	R	13/16	1-1/16
H	1-5/16	1-1/2	S	3-3/32	4-7/32
J	2-15/16	4-1/2			

LITTLETON, COLORADO 80120 / 303-794-2611

Printed in U.S.A.

NC-1831/5-74



3-WAY INLINE SELECTOR VALVES

IN THIS CATALOG SHEET: AIR or SINGLE SOLENOID PILOT OPERATED

Also Available: Time Delay Heads (NC-903)

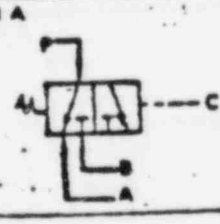
FUNCTION

Directs a single pressure source to either of 2 outlets (option "A") or connects either of 2 pressure sources to single outlet (option "B"). Basically a 3-way valve with special porting provisions.

USASI SYMBOLS

Air Operated

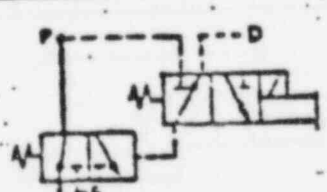
OPTION A



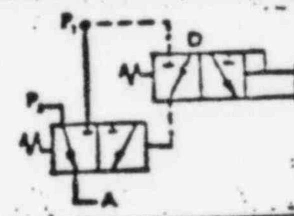
OPTION B

Solenoid Pilot Operated

OPTION A



OPTION B



ORDER TABLE

BASIC VALVE SIZE	PORT SIZE	ORDER MODEL NUMBER Air Operator	ORDER MODEL NUMBER Solenoid Pilot
Basic 1/2"	1/4"	C10126-00-A1	C10126-00-H1
	3/8"	C10132-00-A1	C10137-00-H1
	1/2"	C10145-00-A1	C10145-00-H1
	3/4"	C10258-00-A1	C10258-00-H1
Basic 1"	3/4"	C10358-00-A1	C10358-00-H1
	1"	C10368-00-A1	C10368-00-H1
	1 1/4"	C10376-00-A1	C10378-00-H1

NOTE: Solenoid is furnished with non-locking manual override, 120V 60C AC unless otherwise specified. For locking manual override substitute H2 for the last 2 digits in the model number.

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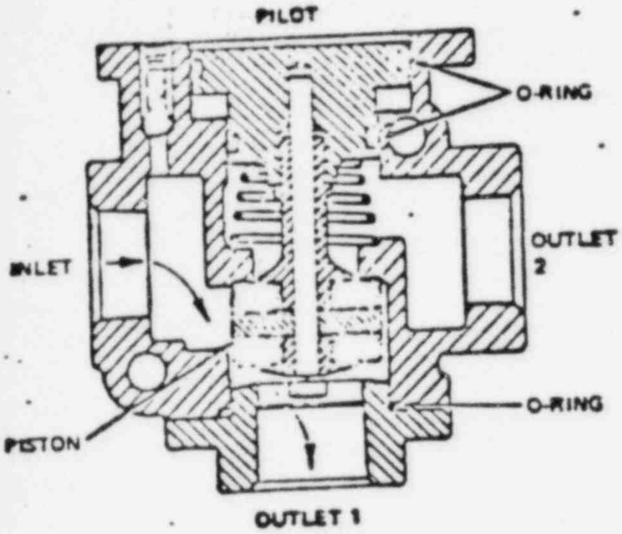
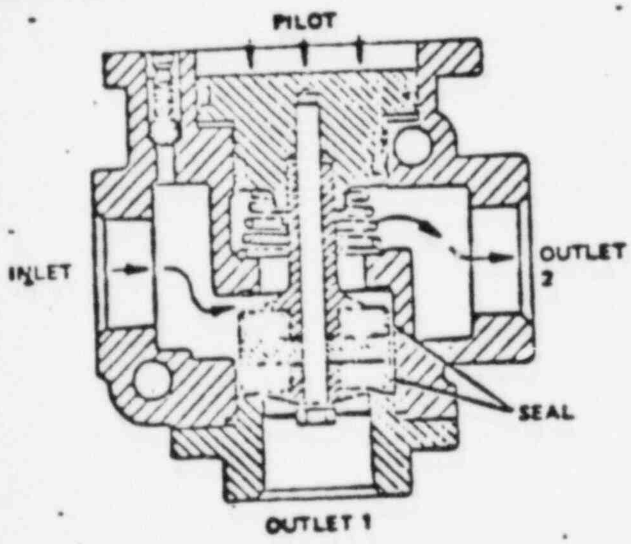
OPERATION

Option "A" (Two Outlets)

(..UATED – Air to pilot is exhausted (Air Operated) or ... 1 de-energized (Solenoid Pilot Operated). Upper poppet ... seated by spring pressure. Air entering the Inlet port is restricted from continuous flow to Outlet 2 but has continuous flow under the piston and through Outlet 1 port.

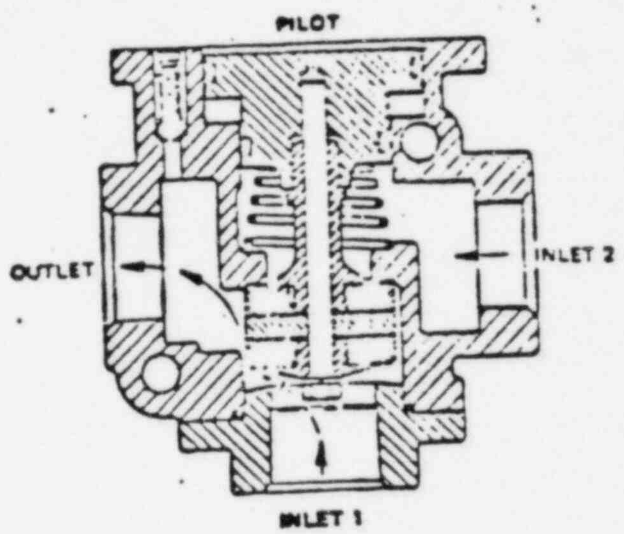


ACTUATED – Air to pilot is pressurized (Air Operated) or sole... energized (Solenoid Pilot Operated). Piston is forced ...ward, seating the lower poppet seal. Air entering the inlet ... restricted from continuous flow thru Outlet 1 port but is permitted to flow around the piston for continuous flow thru Outlet 2 port.

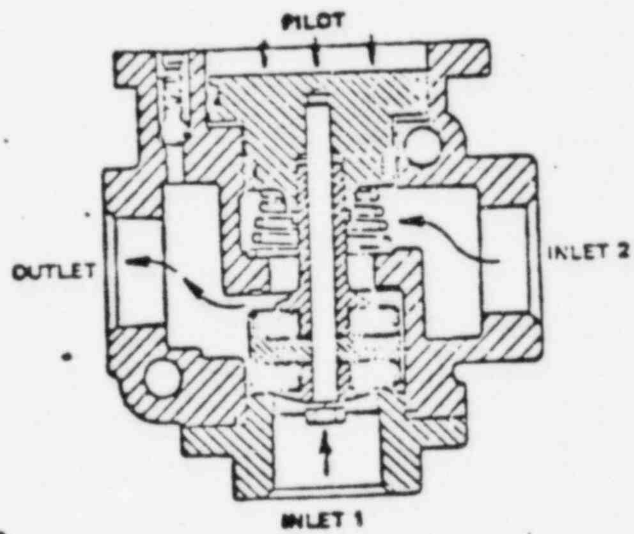


(... n "B" (Two Inlets)

UNACTUATED – Air to pilot is exhausted (Air Operated) or solenoid de-energized (Solenoid Pilot Operated). Upper poppet seal is seated by spring pressure. Air entering Inlet 1 port has continuous flow around the piston and through the Outlet port. Air from Inlet 2 is restricted from continuous flow.



ACTUATED – Air to pilot is pressurized (Air Operated) or solenoid is energized (Solenoid Pilot Operated). Piston is forced downward, seating the lower poppet seal. Air entering the Inlet 1 port is restricted from continuous flow. Air entering the Inlet 2 port is permitted continuous flow around the piston and through the Outlet port.



SPECIFICATIONS

General

- PORT SIZES 1/4", 3/8", 1/2", 3/4", 1", 1-1/4"
- 2 POSITION, SPRING RETURN
- PILOT PRESSURE MUST BE EQUAL TO OR GREATER THAN LINE PRESSURE WITH 30 PSIG AS MINIMUM
- AVAILABLE FOR VACUUM SERVICE (SEE NO. 1)
- FLUID TEMPERATURES 0° F. MIN., 175° F. MAX.
- FILTERED AND LUBRICATED AIR IS RECOMMENDED
- VALVES MAY BE MOUNTED IN ANY POSITION
- 1/2" AND 1" BASIC VALVE SIZES HAVE EQUIVALENT FULL FLOW 1/2" AND 1" PIPE ORIFICES. 1-1/4" ORIFICE AVAILABLE IN BASIC 1" VALVE
- ALL ALUMINUM CONSTRUCTION – CORROSION RESISTANT TREATED

Air Operated

- 5 TO 250 PSIG AIR SERVICE
- AMBIENT TEMPERATURES. 0° F. MIN., 175° F. MAX.

SPECIFICATIONS (Continued)

Solenoid Pilot Operated

- 30 TO 150 PSIG AIR SERVICE WITH INTERNAL OR EXTERNAL PILOT SUPPLY
- AMBIENT TEMPERATURES 0° F. MIN., 130° F. MAX.
- 120 VOLT, 60 HZ. SOLENOID STANDARD. ALSO AVAILABLE AT NO EXTRA COST ARE 240, 480V, 60 HZ SOLENOIDS, 120, 240 AND 480V, 50 HZ SOLENOIDS, AND 6, 12, 24, 115V D.C. SOLENOIDS, WHEN ORDERED IN UNIT
- 7 WATTS MAXIMUM POWER CONSUMPTION, A.C.
- .8 AMPS INRUSH AT 120V 60C AC
- .15 AMPS HOLDING AT 115V 60C AC
- EPOXY, ENCAPSULATED, MOISTURE RESISTANT COILS PROVIDED WITH ALL H1 OPERATORS

SERVICE KITS

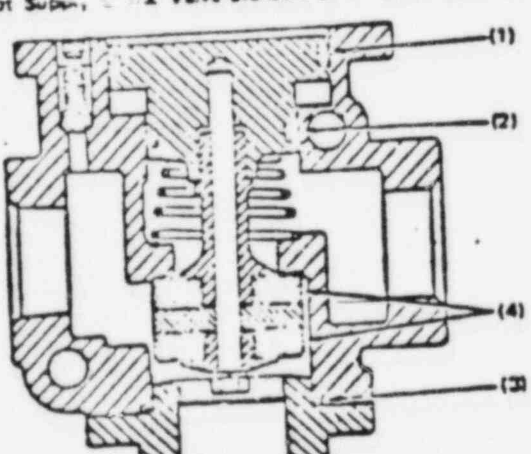
1/2" VALVE SERVICE KIT 53474-01
1" VALVE SERVICE KIT 53475-01

Contains:
(1) "O" Ring
(2) "O" Ring
(3) "O" Ring
(4) Seal (2)

SOLENOID PILOT SERVICE KIT 53542-01

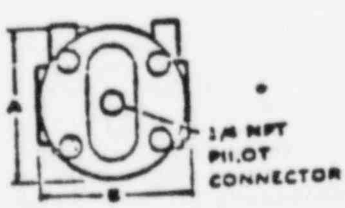
Contains:
Spacer
Block Vee Packing (2)
Seal
"O" Ring
...ol Assembly
...ring

...: Pilot Supp... ...k Valve available in 1" Basic Body size only.

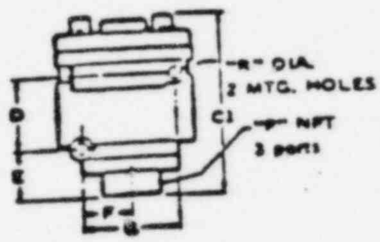


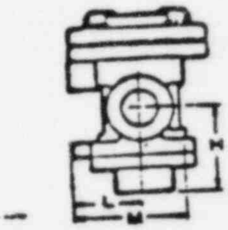
DIMENSIONS

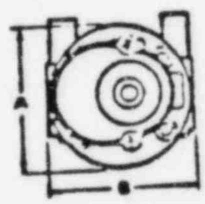
Air Operated

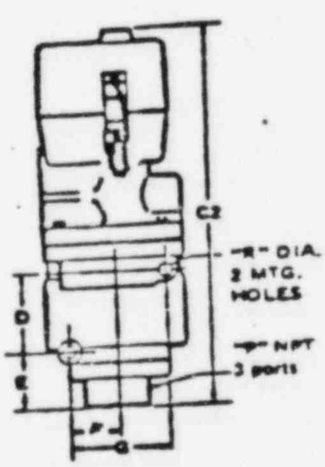


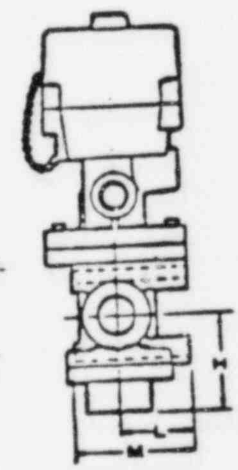
DIMENSIONS











DIMENSIONS					
KEY	1/2" VALVE	1" VALVE	KEY	1/2" VALVE	1" VALVE
A	3	4-1/16	G	2-1/8	2-7/8
B	3	4-5/8	H	1-3/4	2-1/2
C-1*	3-7/8, 4-1/8	6	L	1-9/16	1-9/16
C-2	7-11/16	9-7/8	M	2-1/2	3-5/16
D	1-21/32	2-3/8	P	1/4, 3/8, 1/2 3/4	3/4, 1, 1-1/4
E	15/16	1-5/16			
F	1"	1-13/16	R	9/32	13/32

* In the 3/4" pipe size this dimension is 4 1/8" because of an oversize bottom cap to accommodate this port size.

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NC-1810
(Replaces NC-920)
May, 1974

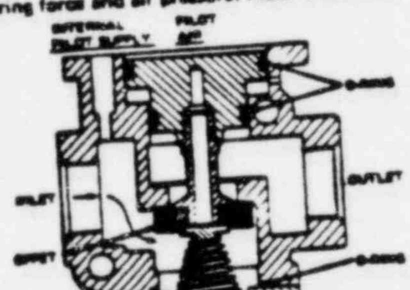
?-WAY INLINE VALVES

AIR OR SOLENOID PILOT OPERATED

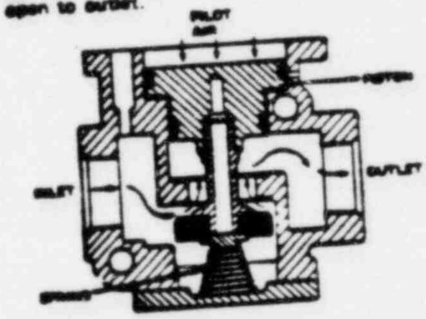
OPERATION

Normally Closed Valve

UNACTUATED – Air to pilot is exhausted (Air Operated) or solenoid de-energized (Solenoid Pilot Operated). Poppet assembly is seated by spring force and air pressure. Flow is blocked.

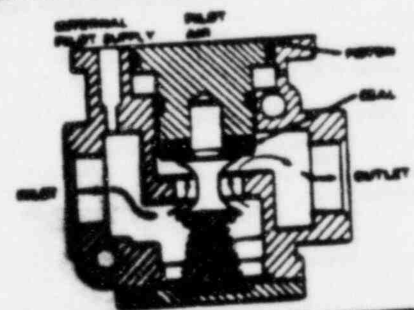


ACTUATED – Pilot is pressurized (Air Operated) or solenoid is energized (Solenoid Pilot Operated). Poppet assembly is forced downward by pilot air pressure opening the valve. Inlet is open to outlet.

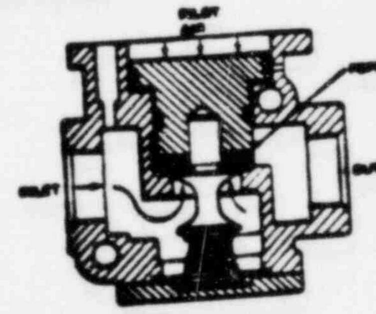


Normally Open Valve

UNACTUATED – Air to pilot is exhausted (Air Operated) or solenoid de-energized (Solenoid Pilot Operated). Poppet assembly is forced from its seat by spring force and air pressure. Valve is open from Inlet to Outlet.



ACTUATED – Pilot is pressurized (Air Operated) or solenoid is energized (Solenoid Pilot Operated). Poppet assembly is forced downward by pilot air pressure seating the poppet assembly. Flow is blocked.



C_v FACTORS

Basic Size	Model No.	Norm. Closed	Model No.	Norm. Open
1/2"	A1012	2.1	B1012	2.3
	A1013	3.4	B1013	3.5
	A1014	5.3	B1014	5.4
	A1015	6.3	B1015	6.3
1"	A1025	10.7	B1025	12.0
	A1026	13.5	B1026	15.4
	A1027	16.3	B1027	17.9
2"	A1028	28.6		
	A1029	33.6		

FUNCTION

Used for on-off control of air.

SPECIFICATIONS

General

- PORT SIZES 1/4", 3/8", 1/2", 3/4", 1", 1-1/4", 1-1/2", 2"
- NORMALLY CLOSED (NC) NORMALLY OPEN (NO)
- 2-POSITION, SPRING RETURN
- PILOT PRESSURE MUST BE EQUAL TO OR GREATER THAN LINE PRESSURE WITH 30 PSIG AS MINIMUM
- AVAILABLE FOR VACUUM SERVICE
- VALVES MAY BE MOUNTED IN ANY POSITION
- ALL ALUMINUM CONSTRUCTION-CORROSION RESISTANT TREATED

Air Operated

- 5 TO 250 PSIG AIR SERVICE
- AMBIENT TEMPERATURE: 35°F. MIN., 175°F. MAX.

Solenoid Pilot Operated

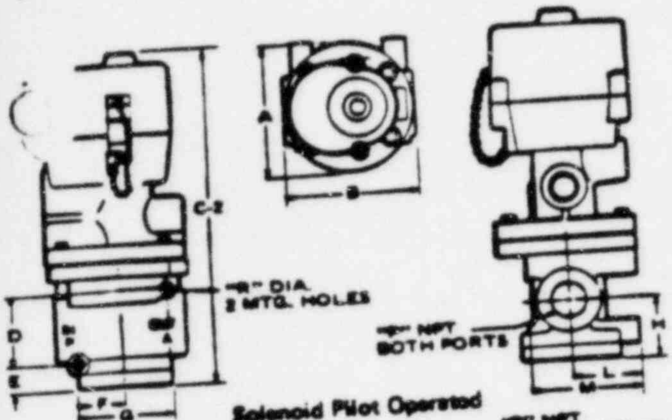
- 30 TO 150 PSIG AIR SERVICE WITH INTERNAL PILOT SUPPLY AC, 30 TO 120 PSIG DC
- 5 TO 150 PSIG AIR SERVICE MAIN VALVE WITH EXTERNAL PILOT SUPPLY
- AMBIENT TEMPERATURES: 35°F. TO 130°F.
- 120 VOLT, 60HZ STANDARD.
- OPTIONAL VOLTAGES AVAILABLE. SEE NC-1843.
- POWER CONSUMPTION 7 WATTS AC, 12 WATTS DC
- .3 AMPS INRUSH AT 120V, 60 HZ AC
- .23 AMPS HOLDING AT 120V, 60 HZ AC
- EPOXY, ENCAPSULATED, MOISTURE RESISTANT COILS PROVIDED WITH ALL H1 OPERATORS

HOW TO ORDER

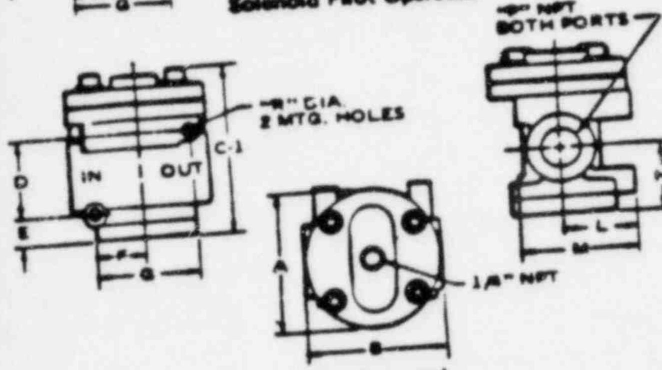
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	1/2"	[illegible]	[illegible]	[illegible]
	1"	[illegible]	[illegible]	[illegible]
	2"	[illegible]	[illegible]	--
[illegible]	1/2"	[illegible]	[illegible]	[illegible]
	1"	[illegible]	[illegible]	[illegible]
	2"	[illegible]	[illegible]	--

[illegible]

NORGREN
LITTLETON, COLORADO



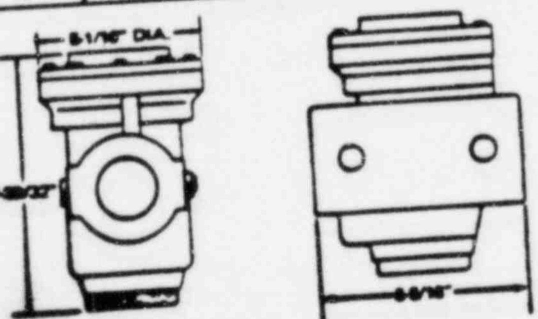
Solenoid Pilot Operated



Air Operated

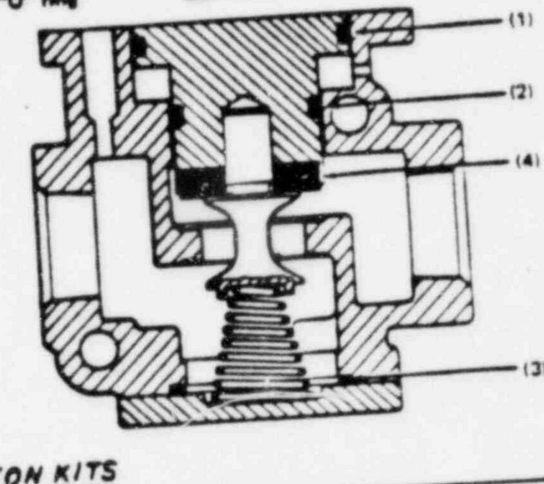
DIMENSIONS					
	BASIC VALVE		KEY	BASIC VALVE	
	1/2"	1"		1/2"	1"
A	3"	4"	G	2-1/8	2-7/8
B	3	4-5/8"	H	1-7/16	2-1/16
C-1	3-9/16"	5-11/16"	L	1-9/16	2-1/16
C-2	7-3/8	9-3/8	M	2-1/2	3-5/16
D	1-21/32	2-3/8	P	1/4, 3/8, 1/2, 3/4	3/4, 1, 1-1/4
E	5/8	13/16			
F	1	1-13/16"	R	9/32	13/32

Basic 2"



SERVICE KITS

SOLENOID PILOT KIT 53642-01
(See NC-1819)
1/2" VALVE KIT 53474-01
(1) "O" ring
(2) "O" ring
(3) "O" ring
(4) Seal
1" VALVE KIT 53475-01
(1) "O" ring
(2) "O" ring
(3) "O" ring
(4) Seal
2" VALVE KIT 53822-01
(2) "O" ring
(3) "O" ring
(4) "O" ring
Gasket, Seal

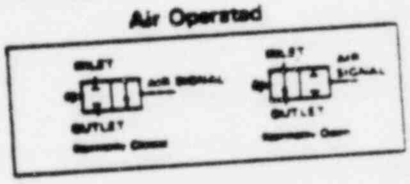


VITON KITS

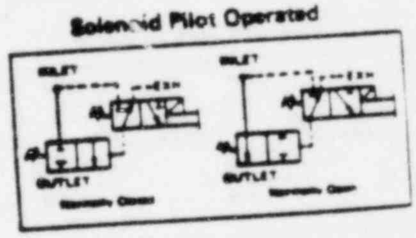
SIZE	Field Conversion	Ordered With	For Model Number
1/2" Basic	53474-08	53474-15	A1012B/15B B1012B/15B
1" Basic	53475-07	53475-13	A1025B/27B B1025B/27B
2" Basic	53909-01	53909-03	A1038/39

CIRCUIT SYMBOLS

Air Operated



Solenoid Pilot Operated



CAUTION

THESE PRODUCTS SHOULD NOT BE USED IN APPLICATIONS WHICH DO NOT FULLY COMPLY WITH RECOMMENDED OPERATING SPECIFICATIONS.

FOR USE WITH MEDIA OTHER THAN AIR OR INERT ... OR FOR LIFE SUPPORT SYSTEMS, CONSULT YOUR ...RIBUTOR FOR FACTORY APPROVAL.

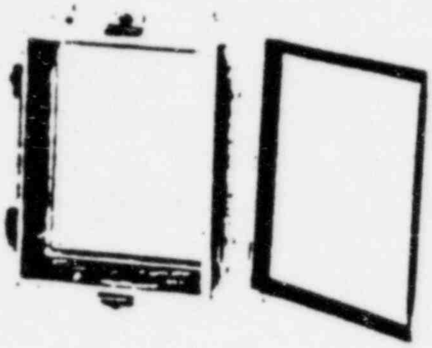
THE USER OF THESE PRODUCTS IS CAUTIONED TO CONFORM TO ALL APPLICABLE ELECTRICAL, MECHANICAL AND OTHER CODES.

NC-1818/8-74

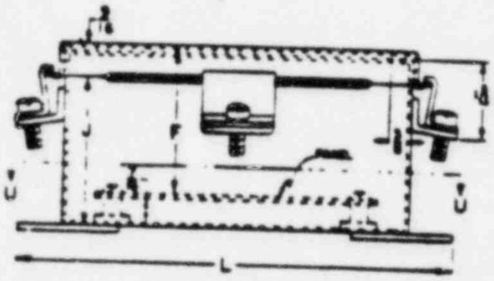
C. A. NORGREN CO.
LITTLETON, COLORADO 80120 / 303-794-2611

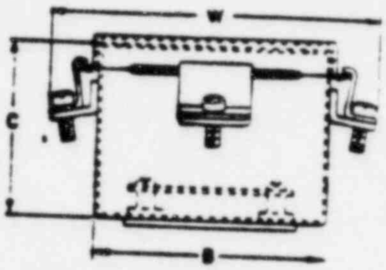
44

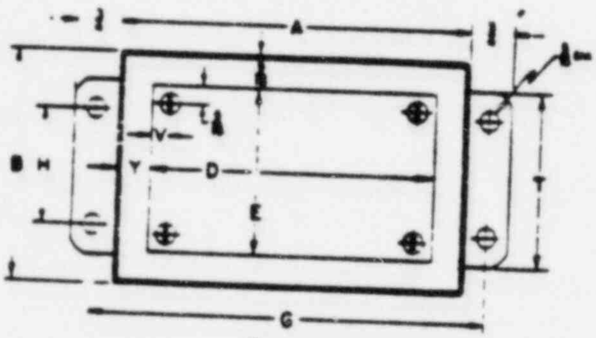
"NF" NEMA TYPE 4, CLAMP COVER BOXES



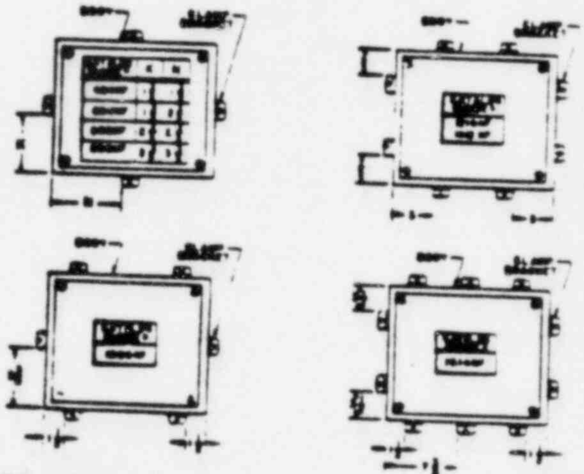
Hoffman NEMA Type 4 JIC Boxes are designed for use in areas which may be regularly hosed down or are otherwise very wet. They are suitable for use outdoors, or in dairies, breweries, and similar installations. These boxes are fabricated from 16 gauge or 14 gauge steel and have external screw clamps on all four sides of the cover. The screw clamps are quick and easy to operate and have no loose parts. The solid neoprene gasket is attached to the cover with oil-resistant adhesive. Cover clamps and clamp screws are stainless steel. All seams are continuously welded and there are no holes or knockouts. External feet are furnished for mounting. The standard finish is grey hammertone enamel inside and out over phosphatized surfaces. Additional finishing of the exterior is necessary if the box is located in a wet area. Weldnuts are provided in 6 x 4 and larger sizes for mounting the optional panels and terminal kits which must be ordered separately. These boxes conform to the NEMA standard for Type 4 (Watertight and Dusttight) enclosures. Most of these boxes are listed by Underwriters' Laboratories, Inc. as indicated in the table.







Section U-U



STANDARD SIZES

Box Catalog Number	Gauge	Box Size A x B x C	*Panel Catalog Number	Panel Size D x E	Mounting G x H	Overall L x W	F	J	T	V	Y
A-404CHNF	16	4 x 4 x 3	None	No Panel	4¾ x 2	5½ x 5¾	—	2⅝	3	—	—
A-604CHNF	16	6 x 4 x 3	A-6P4	4⅞ x 2⅞	6¾ x 2	7½ x 5¾	2½	2⅝	3	⅛	⅛
⊕A-606CHNF	16	6 x 6 x 4	A-6P6	4⅞ x 4⅞	6¾ x 4	7½ x 7¾	3½	3⅝	5	⅛	⅛
⊕A-806CHNF	14	8 x 6 x 3½	A-8P6	6⅞ x 4⅞	8¾ x 4	9½ x 7¾	3	3⅛	5	¼	¼
⊕A-1008CHNF	14	10 x 8 x 4	A-10P8	8⅞ x 6⅞	10¾ x 6	11½ x 9¾	3½	3⅝	7	¼	¼
⊕A-1210CHNF	14	12 x 10 x 5	A-12P10	10⅞ x 8⅞	12¾ x 8	13½ x 11¾	4½	4⅝	9	¼	¼
⊕A-1412CHNF	14	14 x 12 x 6	A-14P12	12⅞ x 10⅞	14¾ x 10	15½ x 13¾	5½	5⅝	11	¼	¼
⊕A-1614CHNF	14	16 x 14 x 6	A-16P14	14⅞ x 12⅞	16¾ x 12	17½ x 15¾	5½	5⅝	13	¼	¼

*Panels must be ordered separately.
⊕U.L. LISTED

LIST OF MATERIALS

QUANTITIES ARE FOR ONE VALVE S/M 712944

WHERE A.S.T.M. SPECIFICATIONS ARE INDICATED, THE LATEST REVISION APPLIES

PIECE NO	NAME	NO REQ'D	MATERIAL	SPECIFICATION	ROCKWELL RMC NO
1#	Body (RT, MT)	1	Cast Carbon Steel	ASTM A-216, GR. WCB	01023
2	Disk Piston (RT, MT)	1	Cast Carbon Steel	ASME SA-216 GR. WCB	01023
3#	Stem (PT, UT)	1	Martensitic Stainless Steel	ASME SA-564 TYPE 630 PH	01792
4#	Bonnet (PT, UT)	1	Mild Carbon Steel	ASTM A-105, GRII	01112
5#	Bonnet Stud (PT)	20	C.-NI.-Moly Alloy Steel	ASME SA-540 GR. B23 CL. 4	02861
6#	Nut (PT)	20	Chrom-Moly Steel	ASME SA-194, GR. 7	01291
7	Bolt	20	Chrom-Moly Steel	ASTM A-354, GR. BD	02061
8	Lantern Gland	1	Mild C. Sulf. Steel-Eval.	AISI 1117	01230/606
9	Gland Stud	2	Chrom-Moly Steel-Cad. Plt	ASTM A-193, GR. B7	02080/604
10	Nut	2	Medium Carbon Steel-Cd.Pl	ASTM A-194, GR. 2H	01270/604
11	Coupling	1	Hardened Alloy ST.	AISI 4140	02360
12	Spring	8	Alloy Steel Springs	ASTM A-125	01760
13	Yoke /Spring Guide	4	Seamless Carbon Steel	AISI 1015-1025	01170/608
14	Mounting Flange	1	Mild Carbon Steel	ASTM A-515, GR. 70	01150
15					
16	Pneumatic Cylinder	1	Steel	Sheffer	55555
17	Electrical Junction Box	1	Steel	Hoffman	55555
18	Bolt	4	Chrom-Moly Steel	ASTM A-354, GR. BD	02061
19	Soc. Hd. Cap Screw	24	Chrom.-Moly Steel/Cd.Pl.	ASTM A-354, GR., BD	02061/604
20	Hyd. Control Valves	2	Steel	Manitrol	55555
21	Limit Switch Support	1	Mild Carbon Steel	ASTM A-515, GR. 70	01150
22	Hydraulic Cylinder	1	Steel	Sheffer	55555
23	Limit Switch	1	Steel	Namco No. EA700-86010	55555
24	Limit Switch Act.	1	Steel	Commercial	55555
25	Lifting Bolt	3	Steel		55555
26	Spring Flange	1	Mild Carbon Steel	ASTM A-515, GR. 70	01150
27	Set Screw	4	Steel		55555
28	Packing Gland	1	Mild Carbon Steel	ASTM A-105	01350
29	Packing Rings	10	Hight Temperture Packing	John Crane 187-1	05080
30	Junk Ring	1	Mild Carbon Steel	AISI 1018	01200
31	Bonnet Gasket	1	Sprial Would	AISI 304	05180
32	Pneumatic Contr. System	1	Steel	Norgren	55555
33	[illegible]	[illegible]	[illegible]	[illegible]	
34	[illegible]			AISI 1018	01200
35	Disk Lock Pin	1	Mild Carbon Steel	AISI 1018	01200
36	Stem Disk Pin	1	Mild Carbon Steel	ASME SA-182, GR. F11	02271
37#	Disk (PT, UT)	1	Forged Alloy Steel Stellited	ASME SA-182, GR. F11	02271
38#	Stem Disk (PT, UT)	1	Low Alloy Steel		
39	Universal Ring	1	Hardened Alloy Steel	AISI 4140	02360
40	Spring Divider	4	Seamless Carbon Steel	AISI 1015-1025	01170

TESTING SYMBOLS

UT-ULTRASONIC
PT-LIQUID PENETRANT

MT-MAGNETIC PARTICLE
RT-RADIOGRAPHY
#NOTE: PRESSURE CONTAINING PARTS

VALVE DESCRIPTION	24x20x24" FIGURE 1612 JMMNY	DRAWING NO. P-419504	Rev. L
DRAWN BY: TAN	DATE: 6/1/82	CHK'D. BY: [illegible]	DATE: [illegible]

Sht. 3 of 7

LIST OF MATERIALS

QUANTITIES ARE FOR ONE VALVE

WHERE A S T M SPECIFICATIONS ARE INDICATED, THE LATEST REVISION APPLIES

PIECE NO.	NAME	NO REC'D	MATERIAL	SPECIFICATION	ROCKWELL RMC NO
41	Pipe Nipple (PT,UT)	1	Mild Carbon Steel	ASTM A-106, GR.B	01180
42✓	Drain Boss (UT,PT)	1	Mild Carbon Steel	ASTM A-105, GR. 2	01112
43✓	Pipe Nipple (PT,UT)	1	Mild Carbon Steel	ASTM A-106, GR.B	01180
44	Soc. Hd.Cap Screw	4	Hardened Alloy Steel Cad.Pl.	AISI 4140	02360/604
45	Spring Guide Collar	8	Seamless C. Steel Tube	AISI 1015-1025	01170
46	Spring Guide Sleeve	4	Seamless C. Steel Tube	AISI 1015-1025	01170
47	Nut	4	Mild Carbon Steel	ASTM A-194, Gr.1	01240
48	Hex bolt	4	Chrom. Molly Alloy Steel	ASTM A-193, Gr. B7	02080
49	Lockwasher	4	Steel	Commercial	55555
50	Limit Switch Lever	2	Steel		55555
51	Bolts	4	Steel	Commercial	55555
52	Lockwasher	4	Steel	Commercial	55555
53	Hex Nut	4	Steel	Commercial	55555
54	Bolt	4	Steel	Commercial	55555
55	Lockwasher	4	Steel	Commercial	55555
56	Hex Nut	4	Steel	Commercial	55555
23A	Limit Switch	1	Steel	NAMCO EA-740-3000	55555
23B	Limit Switch	1	Steel	NAMCO EA-740-2001	55555
24A	Limit Switch Act.	2	Steel	Commercial	55555
60	Plug	1	Carbon Steel	ASTM A-108-1013	01200
61	Belleville Washer	1	Inconel	Inconel X750	14003
62					
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80					

TESTING SYMBOLS

UT-ULTRASONIC

PT-LIQUID PENETRANT

MT-MAGNETIC PARTICLE

RT-RADIOGRAPHY

✓NOTE: PRESSURE CONTAINING PARTS

VALVE DESCRIPTION	24x20x24" FIGURE 1612 JMMNY			DRAWING NO. P-419504	Rev L
DRAWN BY TAW	DATE 6-1-82	CHK'D. BY [illegible]	DATE [illegible]	Sht 4 of 7	

APPENDIX B

ANALYSES

CALCULATION/PROBLEM COVER SHEET

Calculation/Problem No: 0630-001-043

Title: Materials Analysis of Rockwell International MSIV's

Client: LILCO **Project:** NSSS Equipment Qualification

Job No: 0630-001-671

Design Input/References:

Refer to Table of Contents on page 2.

Assumptions:

Refer to Table of Contents on page 2.

Method:

Refer to Table of Contents on page 2.

Remarks:

The purpose of this calculation is to determine the temperature and radiation tolerance of the materials of construction of the Rockwell International MSIV's.

REV. NO.	REVISION	PERFORMED BY	CHECKED	APPROVED	DATE
0	Original	[signature]	[signature]	[signature]	8/24/82

EDS 3004 8/78

TABLE OF CONTENTS

LIST OF TABLES

APPENDICES

1.0 PURPOSE

1. To determine the radiaton tolerance of this device by examination of the materials of construction.

2. To determine the temperature tolerance of this device by examination of the materials of construction.

2.0 SCOPE

This calculation applies to the Rockwell International Main Steam Isolation Valves exposed to environment conditions at Shoreham Nuclear Power Station, Unit 1.

3.0 REFERENCES

1. Rockwell Drawing P-419504, Rev. G, Sheets 2 and 3, List of Materials.

2. ROC, Ken Trotta (EDS) to Rich Soeder (J. Crane), dated 6/25/82.

3. ROC, Ken Trotta (EDS) to James Wright (Rockwell), dated 8/10/82.

4. ROC, Ken Trotta (EDS) to James Wright (Rockwell), dated 8/9/82.

5. The Engineering Properties of Viton Fluorelastomer, E.I. Dupont de Nemours & Co. Inc.

6. ROC, Ken Trotta (EDS) to Phil Ray (G.E. at Shoreham), 8/12/82.

7. ROC, Ira Zebrak (EDS) to James Frewin (G.E.), 8/12/82.

4.0 METHOD OF ANALYSIS

The temperature and radiation tolerance of all materials contained within this device was determined by a document search of published materials and other EDS calculations. The sensitivity of the "weak link" component is then assumed to be the temperature tolerance or radation tolerance of the entire device.

5.0 BASIC DATA AND ASSUMPTIONS

5.1 Only non-metallic materials will be evaluated since they will be the most sensiti~~ to potential heat or radiation damage.

6.0 SUMMARY RESULTS

The limiting material contained within this device with respect to temperature is the G.E. Silicone Hydraulic Fluid SF-1147 with a conservative maximum operating temperature of 350°F. The limiting material with respect to radiation is the viton seals with a radiation tolerance of 1 x 10^7 rads.

7.0 BODY OF CALCULATION

See Table 1.

Calculation No. 0630-001-043
Revision No. 0

Prepared by: Date:
Checked by: Date:

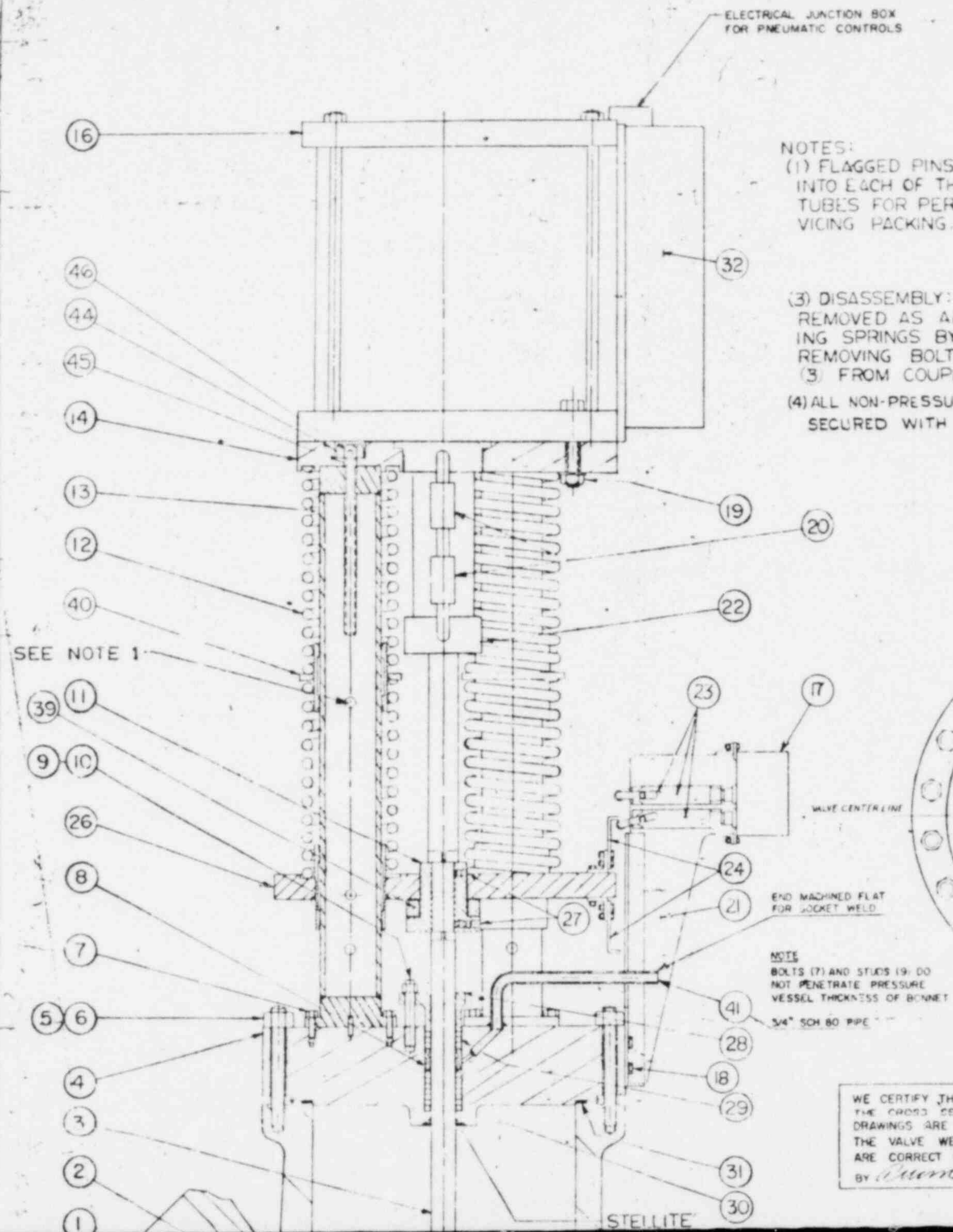
TABLE 1

COMPONENT MATERIALS EVALUATION WORKSHEET

Manufacturer: Rockwell International

Model No. MSIV 1612

Component	Material	Reference	TEMPERATURE Maximum Operating	TEMPERATURE Reference	RADIATION Acceptable Dose	RADIATION Reference
Part No. 29, Packing Rings	John Crane 187I (braided asbestos)	1, 2	Not Sensitive		Not Sensitive	
Part No. 31, Bonnet Gasket	Stainless steel and asbestos	1	Not Sensitive		Not Sensitive	
Part No. 32, Pneumatic Control System	Viton seals	1, 3, 4	450°F	5	1×10^7 rads	5
Part Nos. 20 and 22, Hydraulic Control Unit	Viton seals	1, 3, 4	450°F	5	1×10^7 rads	5
Hydraulic Fluid	G.E. Silicone Fluid SF-1147	6	350°F	7	4×10^7 rads	7



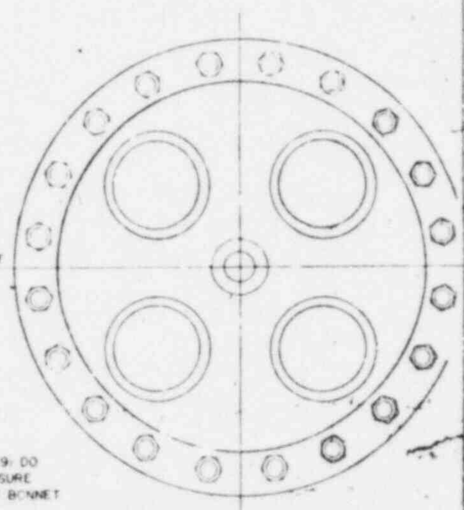
NOTES:

(1) FLAGGED PINS ARE PROVIDED FOR INSERTION INTO EACH OF THE FOUR YOKE/SPRING GUIDE TUBES FOR PERSONNEL SAFETY WHILE SERVICING PACKING.

(3) DISASSEMBLY: CYLINDER AND SPRINGS CAN BE REMOVED AS AN ASSEMBLY WITHOUT UNCOCKING SPRINGS BY INSERTING FLAGGED PINS, REMOVING BOLTS (7), AND UNSCREWING STEM (3) FROM COUPLING (11)

(4) ALL NON-PRESSURE RETAINING BOLTS TO BE SECURED WITH LOCK WASHERS.

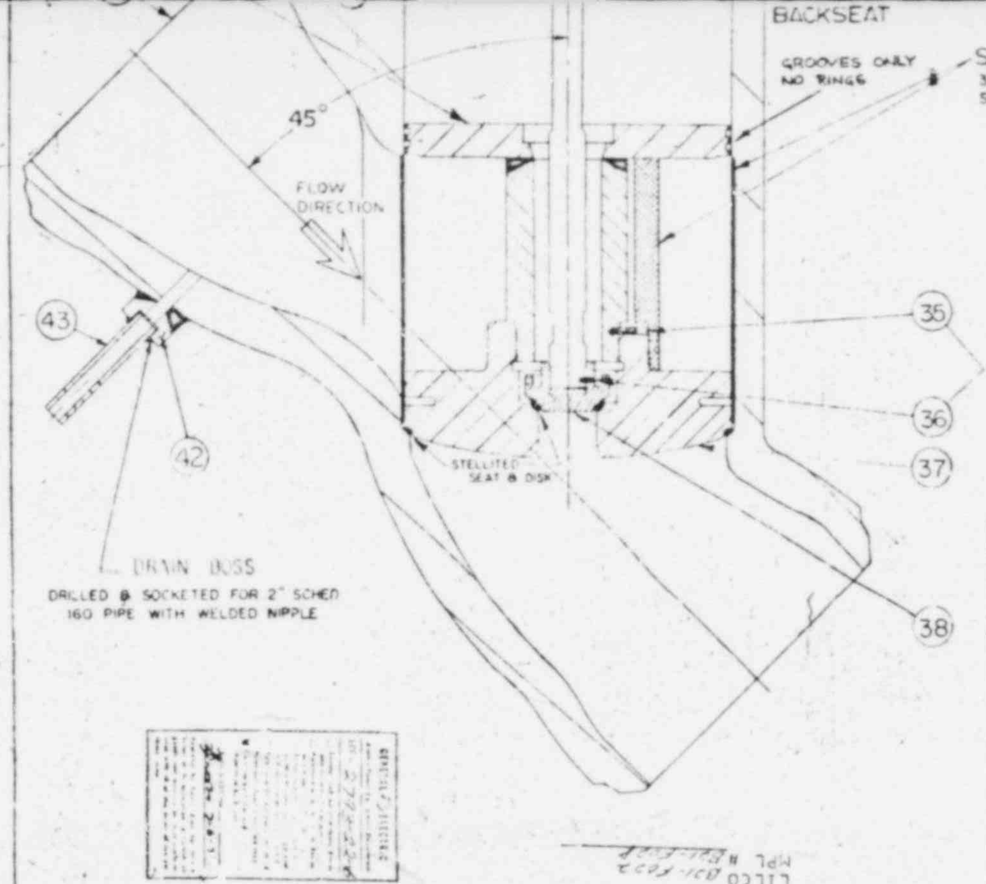
SECTION THROUGH SPRINGS



CERTIFICATION

WE CERTIFY THAT THE OVERALL DIMENSIONS AND THE CROSS SECTIONAL CONFIGURATION ON THESE DRAWINGS ARE CORRECT. WE ALSO CERTIFY THAT THE VALVE WEIGHTS INDICATED ON THIS DRAWING ARE CORRECT WITHIN PLUS OR MINUS 5%.

BY *[signature]* DATE 12-18-75



RECEIVED 6/11/82

THIS DRAWING FOR PART IDENTIFICATION

655-S	CAST CARBON STEEL WCB 1575 PSI AT 100°F 250 PSI AT 575°F 655 PSI AT 850°F

Rockwell
MANUFACTURING COMPANY

ROCKWELL-EDWARD FLITE-FLOW STOP VALVE
FIG. 1612 JMMNY
FOR
GENERAL ELECTRIC
ATOMIC POWER EQUIPMENT DEPARTMENT

DRAWN	DATE	DRAWING NO. P-49504	REV G
CHK'D	DATE		
APP'D	DATE 11-14-69		

LILCO MPL #

VPF# 2793-29-6

PROJECT Like

MPL# B21-F022
B21-F028

LIST OF MATERIALS
QUANTITIES ARE FOR ONE VALVE

Rockwell MANUFACTURING COMPANY

WHERE A.S.T.M. SPECIFICATIONS ARE INDICATED THE LATEST REVISION APPLIES

PIECE NO	NAME	NO REQ'D	MATERIAL	SPECIFICATION	MS NO
1*	body (RT, MT)	1	cast carbon steel	ASTM A 216 Grade WCB	01023
2	piston assembly	1	forged carbon steel	ASTM A 105 Grade II	01111
3*	stem(PT, UT)	1	martensitic stainless steel	ASTM A 276 TYPE 410	02123
4*	bonner (PT, UT)	1	mild carbon steel *	ASME SA 105 Grade II	01112
5*	bonnet stud (PT	20	cr ni moly alloy steel	ASTM A-540 Grade B23	02861
6*	nut(PT)	20	ALLOY STEEL NUTS	ASTM A 194 Grade 7	01291
7*	bolt	20	alloy steel	ASTM A 354 Grade BD	02061
8	lantern ring*	1	C. Dr. carbon st. evalized	AISI 1117	01230/606
9	gland stud	2	cr. moly alloy steel CD. PL	ASME SA 193 Grade B7	02080/604
10	nut	2	steel CD. PL.	ASTM A 194 Grade 2H	01270/604
11	coupling	1	alloy steel	AISI 4140	02360
12	spring	8	St. Deco-St. Vinyl St.St. * moly coated	ASTM A 125	01760
13	yoke/spring guide	4	seamless carbon steel	ASTM A 106 Grade B AISI 1015-1025	01170/60[illegible]
14	mounting flange	1	carbon steel	ASTM A 515 Grade 70	01150 55555

17	electrical junction box	1	steel	Hoffman	55555
18	bolt	4	alloy steel	ASTM A 193 Grade B16	02690
19	nut	4	steel	ASTM A 194 Grade 1	01240
20	hydraulic control valves	2	steel	Marrifrol	55555
21	limit switch support	1	carbon steel sheet	ASTM A 515 Grade 70	01150
22	hydraulic cylinder	1	steel	Sheffer	55555
23	limit switches	3	steel	Namco No. SL 3DP DT	55555
24	limit switches actuators	3	carbon steel	ASTM A 515 Grade 70	01150
26	[illegible] flange	1	carbon steel	ASTM A 515 Grade 70	01150
27	set screw	4	steel		55555
28	packing gland	1	heat treated forging grade carbon steel	ASTM A 105 Grade II	01350
29	packing rings	10	high temperature packing	John Crane 187-1	05080
30	junk ring	1	C. Dr. Carbon steel-stellited	AISI 1018	01200
31	bonnet gasket	1	stainless st. and asbestos	spiral wound	05180
32	Pneumatic Control System	1			55555
35	Disk lock pin	1	C. Dr. Carbon steel	AISI 1018	01200
36	stem disk pin	1	C. Dr. carbon steel	AISI 1018	01200
37 *	disk (PT, UT)	1	forged alloy steel stellited	ASTM A 182 Grade F11	02271
38 *	stem disk (PT, UT)	1	Low alloy steel stellited	ASME SA 182 Grade F11	02241
39	universal ring	1	alloy steel	AISI 4140	02360
40	spring divider	4	Carbon Steel	ASTM A 106 Grade B-XX5-XX5	01170
41	pipe nipple	1	seamless carbon steel	ASTM A 106 Grade B	01180
42 *	drain boss (UT, PT)	1	mild carbon steel	ASME SA 105 Grade II	01112
43 *	pipe nipple (PT, UT)	1	seamless carbon steel	ASTM A 106 Grade B	01180
44	nut	4	med. carbon steel cd. pl.	ASTM A 194 Grade 2H	01270 604
45	stud	4	chrome moly alloy steel	ASTM A 193 Grade B7	02080 604
46	pin, roll	4	stain. steel	AISI 420	65002
	TESTING SYMBOLS UT-ULTRASONIC PT-LIQUID PENETRANT MT-MAGNETIC PARTICLE RT-RADIOGRAPHY * NOTE: PRESSURE CONTAINING PARTS				

TYPED BY	DATE	CHK'D	APP'D	DATE	SPEC IDENT	SHT	REV	DWG
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		3 OF 6	G	P-419504

RECEIVED 6/11/82

FILE: 0630-001-671

eds nuclear

COPY: N. Woodward
I. Zebrak
K. Trotta

RECORD OF CONVERSATION

[X] Telephone [ ] Meeting [ ] Other

TO: Rich Soeder FROM: Ken Trotta KT DATE 6/25/82

COMPANY: J. Crane Company PHONE NO.: 914-345-2420

SUBJECT: J. Crane 187-I Material Analysis

Summary of Conversation:

Rich informed me that 187-I valve stem packing is manufactured of braided asbestos.

KT/jh

eds nuclear

EDS Nuclear Inc
445 Broad Hollow Road
Melville New York 11747
(516) 454-0200

August 17, 1982
0630-001-NY-104

Crane Company
500 Executive Building
Elmsford, New York 10523

ATTENTION: Mr. Rich Soeder

SUBJECT: Verification of Record of Conversation

Gentlemen:

Thank you for the information which you supplied to EDS with respect to 187-I valve stem packing. EDS Quality Assurance Procedures require that you receive the enclosed record of our conversation of June 25, 1982.

If this is an accurate account of our conversation, no action is requested of you. Should there be any errors or misunderstandings in this record, please contact me at (516) 454-0579.

Very truly yours,

Kenneth Trotta

Kenneth Trotta - Engineer
Systems Engineering Division

KT/jm

Enclosures

FILE: 0630-001-671

eds nuclear

COPY: N. Woodward
I. Zebrak
[redacted]

RECORD OF CONVERSATION

[X] Telephone ☐ Meeting ☐ Other ______

TO: James Wright FROM: Ken Trotta KT DATE August 10, 1982

COMPANY: Rockwell International PHONE NO.: (919)832-0525 x-234

SUBJECT: Non-Metallic Materials Contained within Control Unit.

Summary of Conversation:

James informed me that the pneumatic control unit of the MSIV is comprised of approximately 45 seals. The 3 way valves have 6 seals, 2 way valves have 5 seals, and the 4 way valves have 7 seals. all these seals are made of Viton pursuant to the GE purchase specification.

With respect to the hydraulic control unit it too is comprised of 15 seals all of which are made of Viton.

There are no lubricants used with this valve.

The hydraulic fluid (Shell Irus 902) will be changed due to seperation problems.

According to James further information can be obtained from Phil Ray of GE at (516)929-8300 ext-361 or 360.

LILCO has purchased a maintenance manual fro Hiller (who contracted from Sheffer) specifically dealing with the hydraulic and pneumatic control units. Phil Ray should be able to supply us a copy.

FILE: 0630-001-672

eds nuclear

COPY: N. Woodward
I. Zebrak
~~N. [illegible]~~

RECORD OF CONVERSATION

[X] Telephone [ ] Meeting [ ] Other ____

TO: James Wright FROM: Ken Trotta KT DATE August 9, 1982

COMPANY: Rockwell International PHONE NO.: (919) 832-0525 x-234

SUBJECT: Non-Metallic Materials Contained within Control Unit.

Summary of Conversation:

James explained that drawing A-428397, dated 11/13/70, titled 20" 1612 JMNY Air Control System, contains a schematic representation of what devices are housed within the Control Unit.

He also pointed out that drawing D-449245 Revision H, titled 20"-1612 JMNTY-Detail of 20/5 Bore 3" Rod Tandem Cylinder with Accumulator, (Hydraulic Control Unit) shows this device to have many small seals - all made of Viton.

The above referenced drawings are contained in Rockwell International Instruction Manual RAL-5045, dated 11/5/71.

eds nuclear

EDS Nuclear Inc
445 Broad Hollow Road
Melville, New York 11747
(516) 454-0200

cc: N. Woodward
~~I. Zebrak~~
K. Trotta
rf/jft/jfc

August 24, 1982
0630-001-NY-109

Rockwell International
1900 South Saunders Street
P.O. Box 1961
Raleigh, NC 27602

ATTENTION: Mr. James Wright

SUBJECT: Verification of Record of Conversation

Gentlemen:

Thank you for the information which you supplied to EDS with respect to the non-metallic materials contained within the MSIV control unit. EDS Quality Assurance Procedures require that you receive the enclosed record of our conversations of August 9 and 10, 1982.

If this is an accurate account of our conversation, no action is requested of you. Should there be any errors or misunderstandings in this record, please contact me at (516) 454-0579.

Very truly yours,

Kenneth Trotta - Engineer
Systems Engineering Division

KT/sa

Enclosures

APPENDIX A
Materials Analysis - Calc. No.0630-001-043
Rev. 0

eds nuclear

FILE: 0630-001-671

RECORD OF CONVERSATION

COPY: N. Woodward
I. Zebrak
K. Trotta

☐ Telephone ☒ Meeting ☐ Other

TO: Phil Ray FROM: Ken Trotta KT DATE 8/12/82

COMPANY: General Electric PHONE NO.: 929-8300 Ext. 361

SUBJECT: Main Steam Isolation Valve Hydraulic Fluid

Summary of Conversation:

Phil informed me that GE Silicone Fluid SF 1147 is now used as the hydraulic fluid in the MSIV control system. Shell Irus 902 hydraulic fluid is no longer in use.

KT/jh

edis nuclear

EDS Nuclear Inc
445 Broad Hollow Road
Melville, New York 11747
(516) 454-0200

August 23, 1982
0630-001-NY-112

Shoreham Nuclear Power Station
Long Island Lighting Company
O&S Building
P.O. Box 628
Wading River, NY 11792

ATTENTION: Mr. Phil Ray

SUBJECT: Verification of Record of Conversation

Gentlemen:

Thank you for the information which you supplied to EDS with respect to MSIV hydraulic fluid. EDS Quality Assurance Procedures require that you receive the enclosed record of our conversation of 8/12/82.

If this is an accurate account of our conversation, no action is requested of you. Should there be any errors or misunderstandings in this record, please contact me at (516) 454-0579.

Very truly yours,

Kenneth Trotta - Engineer
Systems Engineering Division

KT/sa

Enclosures

eds nuclear

FILE: 0630-001-671

RECORD OF CONVERSATION

COPY: N. Woodward
K. Trotta

[X] Telephone [ ] Meeting [ ] Other ____

TO: James Frewin **FROM:** Ira Zebrak **DATE** 8/12/82

COMPANY: General Electric Company **PHONE NO.:** 518-237-3330

SUBJECT: GE Silicone Fluid SF 1147

Summary of Conversation:

Mr. Frewin informed me that although a higher valve could be selected, a conservative maximum operating temperature of 350°F for the subject fluid should be used.

In addition, the subject fluid gells at approximately 5×10^8 rads, has a 100% change in viscosity at approximately 1.3×10^8 rads and has a 25% change in viscosity at approximately 4×10^7 rads.

ILZ/jh

eds nuclear

EDS Nuclear Inc
445 Broad Hollow Road
Melville, New York 11747
(516) 454-0200

August 24, 1982
0630-001-NY-113

General Electric Company
Silicone Products Division
Waterford, New York 12188

ATTENTION: Mr. James Frewin

SUBJECT: Verification of Record of Conversation

Gentlemen:

Thank you for the information which you supplied to EDS with respect to GE Silicone Fluid SF 1147. EDS Quality Assurance Procedures require that you receive the enclosed record of our conversation of 8/12/82.

If this is an accurate account of our conversation, no action is requested of you. Should there be any errors or misunderstandings in this record, please contact me at (516) 454-0595.

Very truly yours,

Ira Zebrak

Ira Zebrak - Lead Senior Engineer
Systems Engineering Division

IZ/jh

Enclosure

ENVIRONMENTAL QUALIFICATION SUMMARY

Environmental Qualification Summary No: 3007M

Title: Pacific Pumps, High Pressure Coolant Injection Pumps

Client: LILCO

Project: NSSS Equipment Qualification

Job No: 0630-001-671

Design Input/References:

The references included with this package are listed as appendices in the Table of Contents on Page 2.

Assumptions:

N/A

Method:

N/A

Remarks:

This device has been qualified for all postulated accident conditions.

REV. NO.	REVISION	PERFORMED BY	CHECKED	APPROVED	DATE
0	Original	Kenneth [signature]	[signature]	[signature]	8/24/84

Long Island Lighting Company
Shoreham Nuclear Power Station
Unit No. 1

Equipment Qualification
Summary No. 3007M
Revision No. 0

TABLE OF CONTENTS

APPENDICES

1. Instruction Manual, High Pressure Coolant Injection Pump Unit, Pacific Pumps, for Type DSK and RHCNDS, Serial Nos. 45768 and 45769, Revision 1, dated 5/25/72 (LILCO/SR-2 Document No. 2740-057-1).

2. G.E. Purchase Specification No. 21A9223, Revision 3, Standard Requirements for High Pressure Coolant Injection (HPCI) Pumps (LILCO/SR-2 Document No. 21A9223).

3. G.E. Purchase Specification Data Sheet No. 21A9223AM, Revision 1, High Pressure Coolant Injection (HPCI) Pump (LILCO/SR-2 Document No. 21A9223).

4. G.E. Purchased Part Drawing, Pump, HPCI Systems, Revision 1 (LILCO/SR-2 Document No. 117C3524).

5. G.E. Purchase Order No. 205-AA958 High Pressure Coolant Injection Pumps (LILCO/SR-2 Document No. AA958).

6. Pacific Pumps Certificate of Compliance with Purchase Order for High Pressure Coolant Injection Pumps 45768 and 45769, May 10, 1972 (LILCO/SR-2 Document No. AA958-G001).

B. Analyses:

1. EDS Calculation No. 0630-001-044, Revision 0, Materials Analysis of Pacific Pumps (HPCI Pump).

1.0 EQUIPMENT LIST

Equipment I.D. (Mark No.)	MPL No.	Description	Make/Model
1E41*P-016	E41-C001	High Pressure Coolant Injection Pump (Main)	Pacific Pumps, Model RHCH, Serial No. 45768.
1E41*P-016	E41-C001	High Pressure Coolant Injection Pump (Booster)	Pacific Pumps, Model DSK, Serial No. 45769.

2.0 EQUIPMENT SUMMARY EVALUATIONS

2.1 Description

The equipment under evaluation are Pacific Pump, High Pressure Coolant Injection (HPCI) Pumps, Serial Nos. 45768 and 45769.

2.2 Conclusions

The high pressure coolant injection pumps are qualified for the postulated accident temperature, pressure, humidity, and radiation conditions. Materials analysis (EDS Calculation No. 0630-001-044, Rev. 0) indicates that the non-metallic components contained in this device will not be affected by the postulated radiation and temperature environments.

2.3 Limitations

None.

2.4 Discussion

1. These devices are required to withstand a postulated accident radiation dose of 7×10^6 rads (Stone & Webster letter from P. J. Holden [S&W] to N. Woodward [EDS], dated August 5, 1982). Materials analysis (EDS Calculation No. 0630-001-044, Rev. 0) indicates that the limiting materials contained within these devices are BUNA-N and Neoprene. Both of the above materials have a radiation tolerance of 1×10^7 rads. Therefore, this device is expected to perform its safety function as required.

2. Since the maximum design process fluid temperature of 140°F (Documentation Reference 4) for the high pressure coolant injection pumps is very near to the postulated EQR peak accident environment temperature of 150°F, the thermal expansion stresses from exposure to this temperature are considered nearly equivalent as compared to the thermal stresses that will be created from the process fluid temperature. Additionally, Materials analysis (EDS Calculation 0630-001-044, Rev. 0) indicates that the most limiting non-metallic component contained within this device is Vapor Tech Light lubrication oil with a maximum operating temperature of 160°F. Although the documented maximum ambient temperature of 148°F (Documentation Reference No. 4) is less than the latest EQR specified environment of 150°F, this 2°F difference should have an insignificant impact in view of the discussions above.

Similarly, the environmentally (EQR) specified maximum pressure of 1 psig is considered insignificant as compared to the high pressure coolant injection pump internal design pressure of 450 psig for the booster pump and 1500 psig for the main pump.

Therefore, the accident ambient temperature and pressure are negligible in light of the mechanical properties, materials of construction, and design of the high pressure coolant injection pumps.

SECTION 3.0

ENVIRONMENTAL QUALIFICATION WORKSHEETS

Long Island Lighting Company
Shoreham Nuclear Power Station, Unit No. 1

Environmental Qualification Summary No. 3007M
Revision No. 0

MECHANICAL EQUIPMENT ENVIRONMENTAL QUALIFICATION WORKSHEET

Prepared by: [signature] Date: 8-12-82

Checked by: [signature] Date: 8-13-82

EQUIPMENT DESCRIPTION	ENVIRONMENTAL PARAMETER	POSTULATED ENVIRONMENT		DOCUMENTED ENVIRONMENT		OUTSTANDING ITEMS
		FSAR *	ENVIRONMENTAL QUAL. REPORT **	VALUE	REFERENCE	
EQUIP. I.D. (MARK NO.): 1E41*P-016	Maximum Temperature (degrees F)	212	150	148	1	None See Sect. 2.4.
VENDOR I.D.: E41-C001	Maximum Pressure (psig)	1	1	Note 1	Note 1	None See Sect. 2.4.
EQUIPMENT TYPE: Pump (Main)	Maximum Relative Humidity (%)	100	100	100	1	None
SERVICE: High Pressure Coolant Injection	Containment Spray	N/A	N/A	N/A	N/A	N/A
MANUFACTURER: Pacific Pumps	40-Year Normal Radiation Dose (Rads)	1.8×10^3	See Note ***.	1×10^7	2	None
MODEL NO.: RHCH	6-Month Accident Radiation Dose (Rads)	1×10^5	7×10^6 See Note ***.			
LOCATION: RBS ZONE: G-01	Submergence	N/A	N/A	N/A	N/A	N/A

ATTACHMENT TO MECHANICAL EQUIPMENT ENVIRONMENTAL QUALIFICATION WORKSHEET

REFERENCES:

1. G.E. Purchased Part Drawing 117C3524, Revision 1.

2. EDS Calculation No. 0630-001-044, Rev. 0, Materials Analysis of Pacific Pumps HPCI Pumps.

NOTES:

1. Documented value for maximum pressure could not be found.

* FSAR values for maximum temperature, pressure, and humidity are from Table 3C.3-9 and radiation are from Table 3.11.2-1.

** EQR values for maximum temperature and pressure are from Figures D-21 and D-41, respectively. EQR value for humidity is from Section 3.1.b of the EQR.

*** The normal and accident radiation doses would usually be derived from Figure D-2 of the EQR (i.e., 1.8×10^3 and 5.75×10^6 rads). However, a total integrated dose of 7×10^6 rads (40 year plus 6 month accident dose) should be used instead. (See attached letter from P. J. Holden [S&W] to N. Woodward [EDS], dated August 5, 1982, re Mechanical Equipment Environmental Qualification.)

Long Island Lighting Company
Shoreham Nuclear Power Station, Unit No. 1

Environmental Qualification Summary No. 3007M
Revision No. 0

MECHANICAL EQUIPMENT ENVIRONMENTAL QUALIFICATION WORKSHEET

Prepared by: Kenneth Potts Date: 8-12-82

Checked by: [signature] Date: 8-13-82

EQUIPMENT DESCRIPTION	ENVIRONMENTAL PARAMETER	POSTULATED ENVIRONMENT FSAR *	POSTULATED ENVIRONMENT ENVIRONMENTAL QUAL. REPORT **	DOCUMENTED ENVIRONMENT VALUE	DOCUMENTED ENVIRONMENT REFERENCE	OUTSTANDING ITEMS
EQUIP. I.D. (MARK NO.): 1E41*P-016	Maximum Temperature (degrees F)	212	150	148	1	None See Sect. 2.4.
VENDOR I.D.: E41-C001	Maximum Pressure (psig)	1	1	Note 1	Note 1	None See Sect. 2.4.
EQUIPMENT TYPE: Pump (Booster)	Maximum Relative Humidity (%)	100	100	100	1	None
SERVICE: High Pressure Coolant Injection	Containment Spray	N/A	N/A	N/A	N/A	N/A
MANUFACTURER: Pacific Pumps	40-Year Normal Radiation Dose (Rads)	1.8×10^3	See Note ***.	1×10^7	2	None
MODEL NO.: RSK	6-Month Accident Radiation Dose (Rads)	1×10^5	7×10^6 See Note ***.			
LOCATION: RBS, El. 8' ZONE: G-01	Submergence	N/A	N/A	N/A	N/A	N/A

ATTACHMENT TO MECHANICAL EQUIPMENT ENVIRONMENTAL QUALIFICATION WORKSHEET

REFERENCES:

1. G.E. Purchased Part Drawing 117C3524, Revision 1.
2. EDS Calculation No. 0630-001-044, Rev. 0, Materials Analysis of Pacific Pumps HPCI Pumps.

NOTES:

1. Documented value for maximum pressure could not be found.

* FSAR values for maximum temperature, pressure, and humidity are from Table 3C.3-9 and radiation are from Table 3.11.2-1.

** EQR values for maximum temperature and pressure are from Figures D-21 and D-41, respectively. EQR value for humidity is from Section 3.1.b of the EQR.

*** The normal and accident radiation doses would usually be derived from Figure D-2 of the EQR (i.e., 1.8×10^3 and 5.75×10^6 rads). However, a total integrated dose of 7×10^6 rads (40 year plus 6 month accident dose) should be used instead. (See attached letter from P. J. Holden [S&W] to N. Woodward [EDS], dated August 5, 1982, re Mechanical Equipment Environmental Qualification.)

STONE & WEBSTER ENGINEERING CORPORATION

COPY

Copy to:
Dr. JFEtzweiler (LILCO)
JSherman
Proj Engr-7
TFGerecke (LILCO-Hicksville)
WJMuseler-5 (LILCO-WR)
NWoodward ✓
EDS Nuclear Inc.

RECEIVED AUG 0 6 1982 NKW

Attachment 2 to Mechanical Equipment Environmental Qualification Worksheet
3007M HPCI PUMPS

August 5, 1982

J.O.No. 11600.02
File No. 221.21

Mr. N. Woodward
Project Engineer
EDS Nuclear Inc.
200 Broad Hollow Road
Melville, NY 11747

Dear Mr. Woodward:

MECHANICAL EQUIPMENT ENVIRONMENTAL QUALIFICATION
SHOREHAM NUCLEAR POWER STATION - UNIT 1
LONG ISLAND LIGHTING COMPANY

As requested by Mr. J. Sherman of LILCO, the following information is provided for your use in the Shoreham Mechanical Equipment Qualification effort.

The calculated six-month integrated gamma dose to the inside surface of pipe containing suppression pool water following a postulated LOCA is 7×10^6 rads based on Stone & Webster calculation No. SNPS-1-UR-21-G. Where mechanical components are exposed directly to suppression pool water the above value has been utilized in this effort as a minimum exposure. This would apply generally to the following systems which are included in our scope for this effort:

E-11	Residual Heat Removal
E-21	Core Spray
E-41	High Pressure Coolant Injection
E-51	Reactor Core Isolation Cooling

Very truly yours,

PJHolden

P.J. Holden

SLT:lmm

APPENDIX A

DOCUMENTATION

1E41-P-016 E41.110
INSTRUCTION MANUAL/E41-2
HPCI PUMP UNIT

PACIFIC PUMPS
MODEL 45768 & 45769
PO NO 310010

-N 16mm
5/9/23

213
533
2201

GENERAL ELECTRIC A.P.E.D.

PLANT: [illegible]
G. E. P. O.: [illegible] 958

SERVICE: H P C I PUMPS

PACIFIC ORDER NO. [illegible] AND [illegible]
PACIFIC SERIAL NO. 45768 AND 45769

PUMP SIZE & TYPE 12 x 17 [illegible] & 12 x 17 [illegible]

E41-SYS 016 E41*P-016 A X0102
GE/ ~~Pacific Pumps~~/E41-2 00005
7-10-72 6.120

RECEIVED JUL 22 1982

CERTIFIED
by VENDOR
VPF# 2740-103-1
APPROVED
By G.T. Buch
Date 7/10/72
FOR
GENERAL ELECTRIC
ATOMIC POWER EQUIP. DEPT
SAN JOSE, CALIFORNIA
DESIGN ENGINEERING
ENGINEERING [illegible]

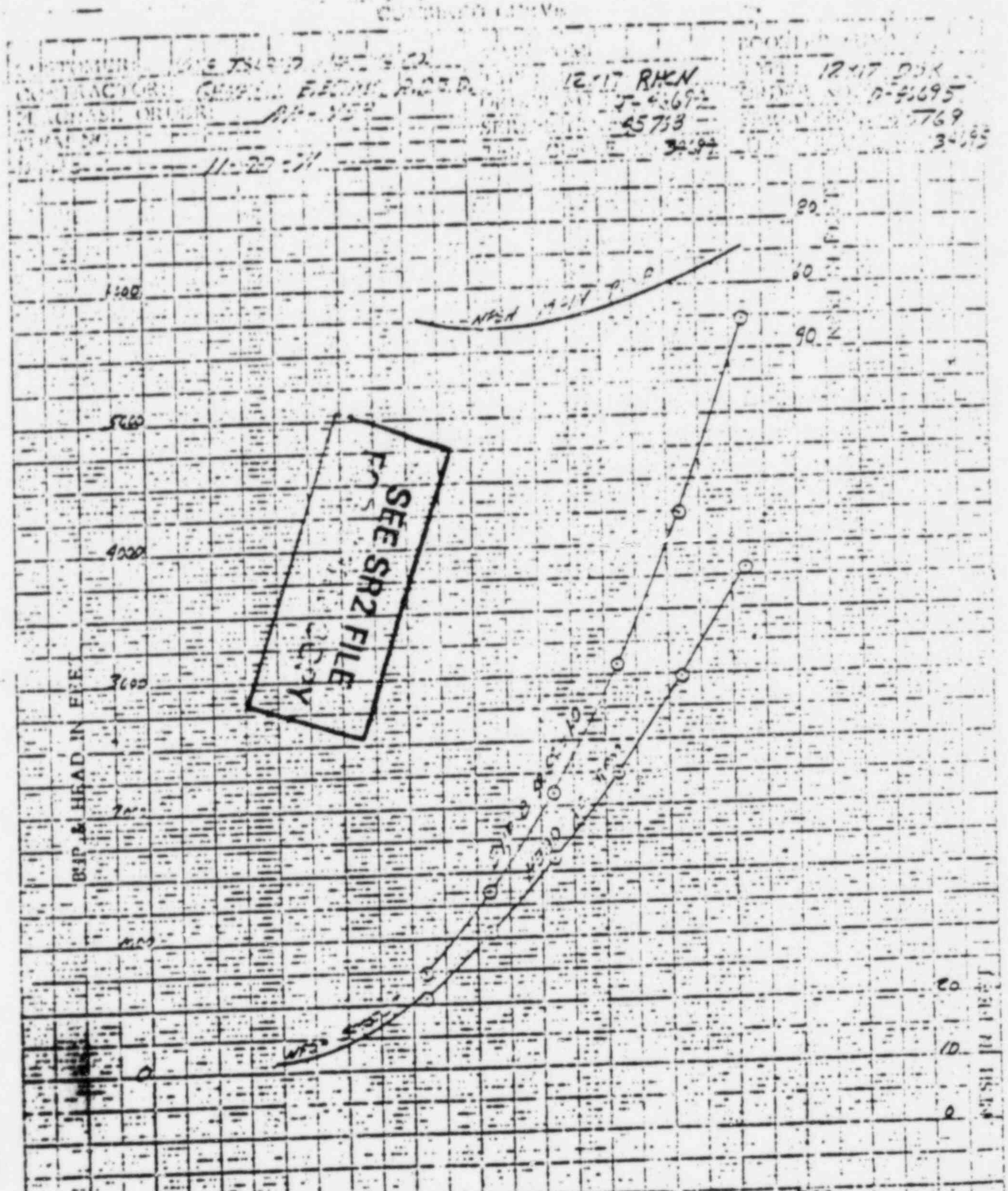

12-17 RHCN
12-17 DBX
SEE SR2 FILE
BHP & HEAD IN FEET
3000
4000
5000
SPEED IN RPM
CONSTANT CAPACITY

TABLE OF CONTENTS

SECTION 1 - BOOSER PUMP

SECTION 2 - MAIN PUMP

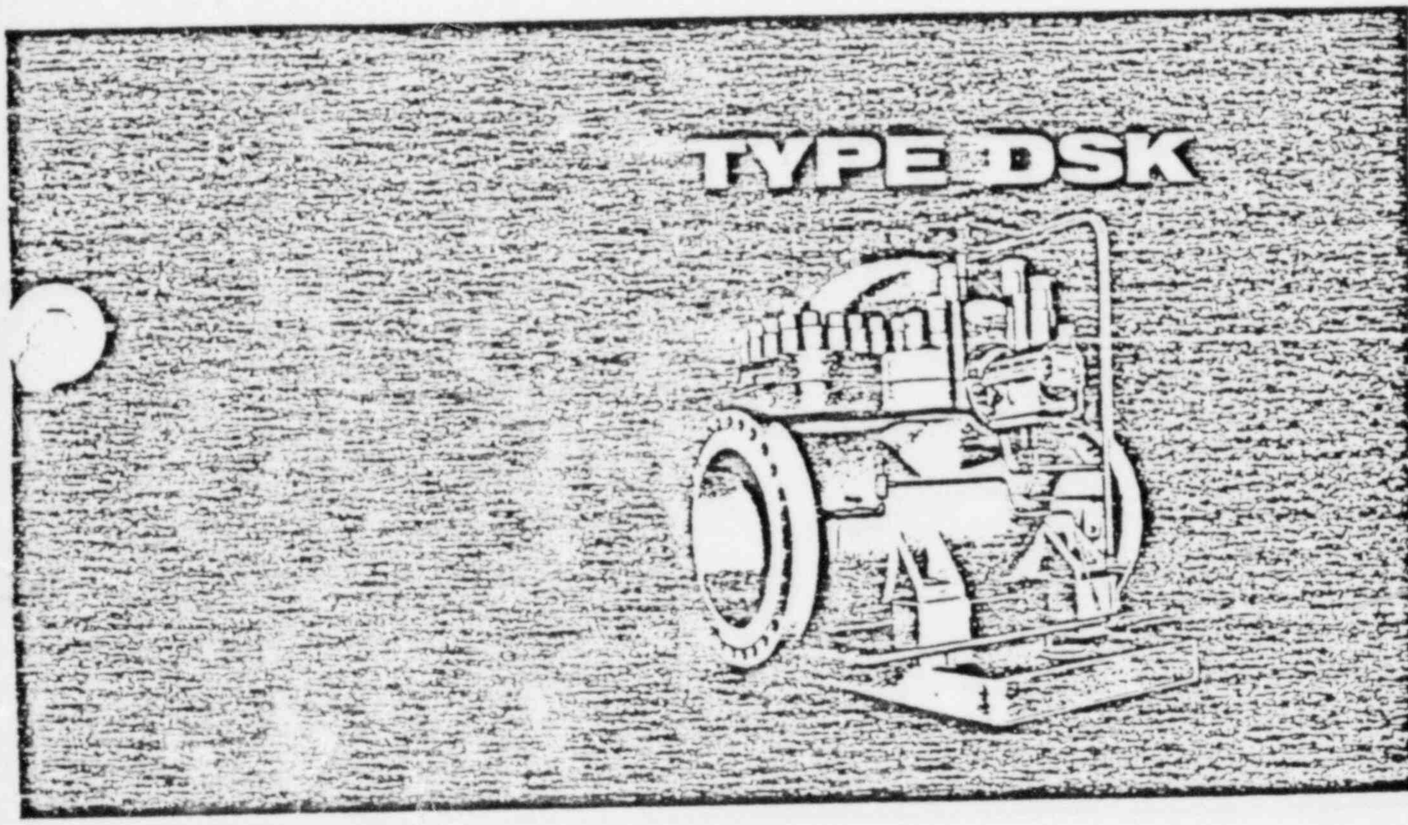
Rev. #1 added 5/25/72

Rev. #1 added 5/25/72

OPERATING/DESIGN CONDITIONS

Booster Pump

Flow	4350 GPM
Differential Head	300 Feet
Speed	1800 RPM
Temperature of Pumpage	40-140°F
BHP @ 1.0 Sp. Gr.	416 BHP
Max. Working Pressure, Casing	450 PSIG
Hydrotest Pressure w/o Mechanical Seals	675 PSIG


TYPE DSK

This instruction manual is intended to assist in the realization of maximum service and efficiency from your Pacific Centrifugal Pump. It is important that the instructions are carefully observed for installation operation, maintenance and testing.

Pacific Centrifugal Pumps are designed by experts to give you optimum performance for the service intended. Mechanical and hydraulic features have been incorporated in the design concept to assure you of dependability, economy, and long, trouble free operation.

Pacific's reputation for superior design and construction is backed by service centers throughout the world. Spare parts and engineering assistance are available to you should you need them.

In addition to the instruction manual several supplemental documents are included when applicable, depending on the particular design characteristics of your pump. These may include the following:

- Cross Sectional Drawing
- Seal Drawing (when applicable)
- Material List
- Piping Diagrams (when applicable)
- Alternate thrust bearing arrangement (when applicable)
- Kingsley thrust bearing arrangement (when applicable)
- Foundation Plan
- Orifice drawings (when applicable)

PACIFIC PUMPS

DIVISION OF DRESSER INDUSTRIES

HUNTINGTON PARK, CALIFORNIA

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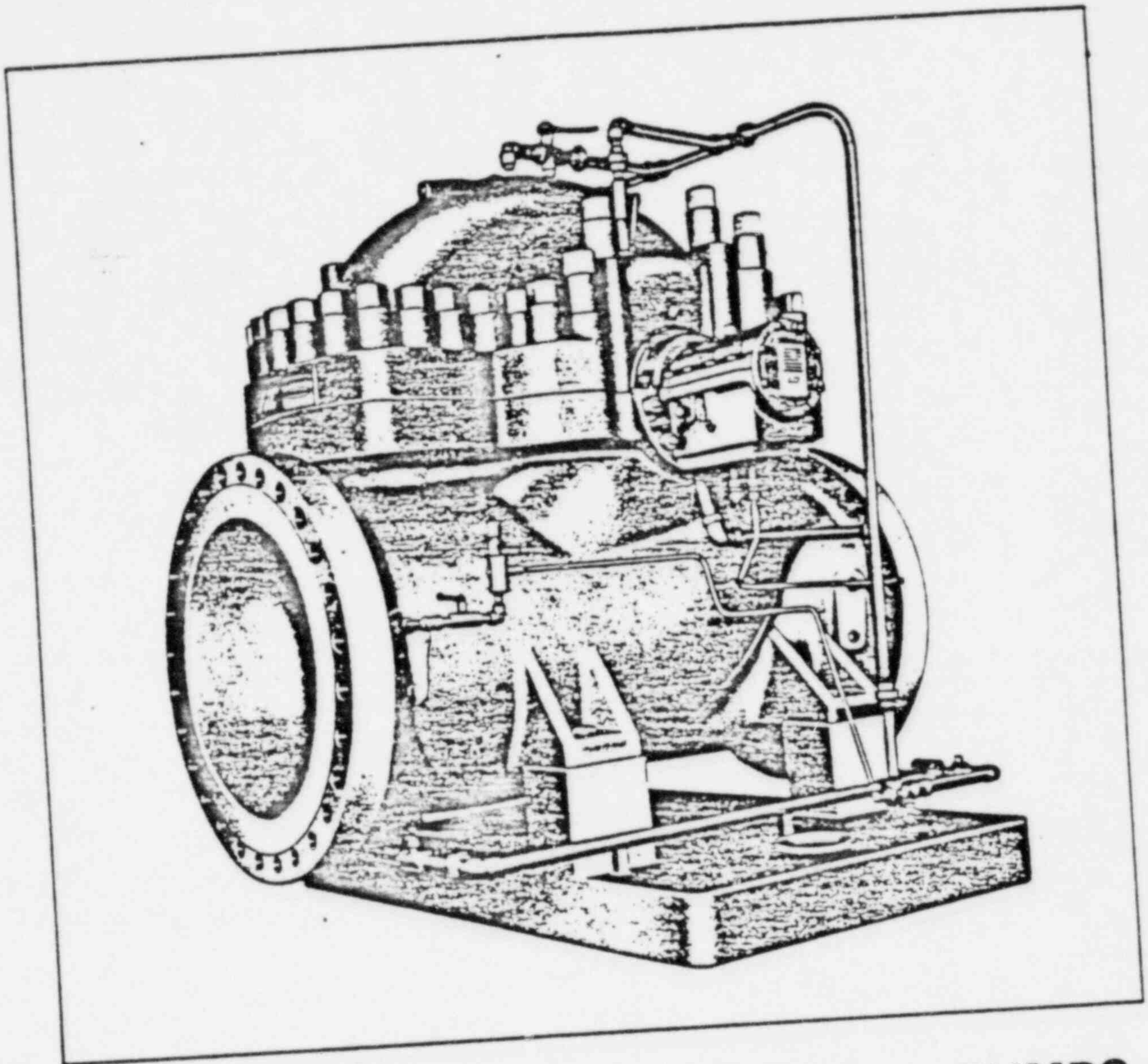
Page



PACIFIC TYPE DSK CENTRIFUGAL PUMPS

The Pacific Type DSK Pump is a single stage pump with double suction impeller and axially split case. Type DSK is available with either oil ring lubricated bearings or pressure lubricated sleeve and Kingsbury type thrust bearings. Shaft sealing is accomplished by standard packing or mechanical seals.

Section I
Installation

A. LOCATION OF PUMP

1. The pump should be located as near to the liquid source as possible.

2. Head room should be provided for the use of hoisting equipment.

3. The unit should be accessible for inspection during operation.

4. It is necessary for satisfactory operation that sufficient net positive suction head (NPSH) be available at the pump suction flange. (Net positive suction head is the total head in feet absolute, determined at the suction nozzle and referred to datum, less the vapor pressure of the liquid in feet absolute.)

B. FOUNDATION (See Fig. 1)

Concrete foundations built on solid ground are the most satisfactory. Foundation bolts of the specified size should be located as shown on the foundation drawing. It is recommended that each bolt be fitted with a pipe sleeve approximately three diameters larger than the bolt and with a washer to support the head of the bolt in the sleeve. After the concrete is poured, the pipe sleeves remain in place while the bolts may be shifted for alignment with the holes in the baseplate.

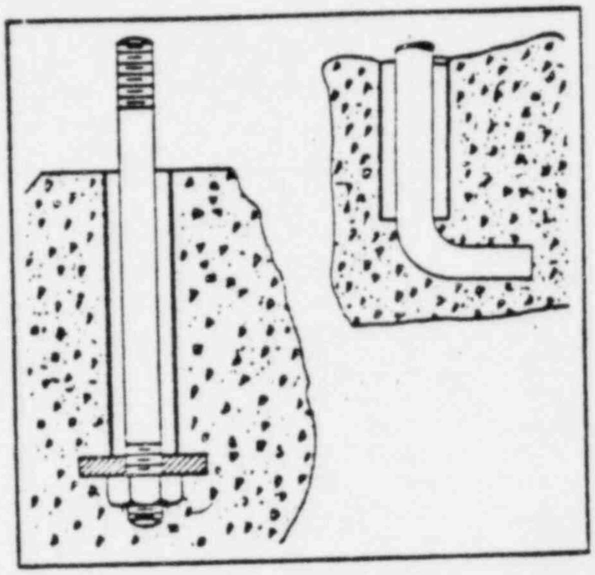


Fig. 1

C. LEVELING BASEPLATE (See Fig. 2)

1. Locate leveling plates and shims on both sides of each foundation bolt and in the center at the pump end of the baseplate. Allow a minimum of one inch between the baseplate and the foundation for grouting.

Fig. 2 Leveling Baseplate

2. Level baseplate across driver pads using shims at the foundation bolts on the driver end.

3. Level baseplate across pump pads using shims at the foundation bolts on the pump end.

4. Level baseplate lengthwise using shims at the center on the pump end.

5. Tighten nuts on the foundation bolts evenly but not too firmly.

D. GROUTING

1. Build forms to confine the grout. The forms must be securely anchored and shored.

2. Remove water and waste material from foundation bolt holes and clean off and dampen the foundation slab.

3. Pour grout through holes provided in the baseplate.

A recommended grout mixture is one part iron base aggregate, one part Portland cement and one part coarse, clean sand by weight. Approximately 1-3/4 to 2 gallons of clean water is required for each 100 pounds of mix., Use sufficient water to make the mix placeable.

4. Remove air pockets by working and rodding the grout through holes in the baseplate.

5. After grout is set, tighten nuts on the foundation bolts. Do not remove leveling plates and shims.

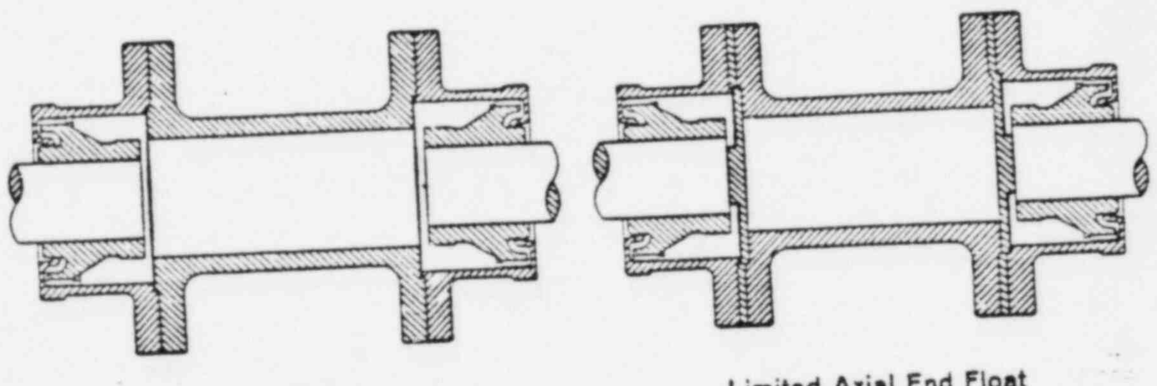


Fig. 3 Spacer Type Couplings

Fig. 4 Aligning Pump and Driver

F. ALIGNING PUMP AND DRIVER (See Fig. 4)

1. Clamp a dial indicator on the driver half coupling. The indicator bracket must be rigid to insure accuracy of the dial indicator reading.
2. Set the indicator button on the face of the hub and align the faces parallel at all points.
3. Set the indicator button on the outside diameter of the pump coupling hub and align the hubs to within .002 inch total indicator reading.

4. To check alignment, clamp the dial indicator to the pump half coupling and take readings on the outside diameter and the face of the driver coupling hub.

NOTE: If a steam turbine is used and is foot mounted, alignment should be made with the turbine hot. If alignment is made with the turbine cold, the turbine should be set low by the distance specified by the turbine manufacturer. A suggested turbine setting is .008 inch low, or .016 inch total indicator reading.

5. Scribe, drill and tap holes in the driver pads for the driver hold down bolts. Install the hold down bolts and draw up snugly, then re-check alignment.

G. PIPING

1. Both suction and discharge piping should be as short and direct as possible. There should be a minimum of bends and fittings and the bends should be made with a long radius, when possible.

2. Piping should be adequately supported near the pump to prevent strains being transmitted to the pump when tightening the flange bolts.

3. Pipes at the suction and discharge nozzles should be as large or larger than the openings in the pump.

H. SUCTION PIPING (See Figs. 5 through 8)

1. Suction lines must be free from pockets or high spots in which gas or vapors may be entrapped.

2. In horizontal lines leading to the pump, only eccentric reducers should be used.

3. The suction line must be free from air leaks and adequate provisions should be made for the

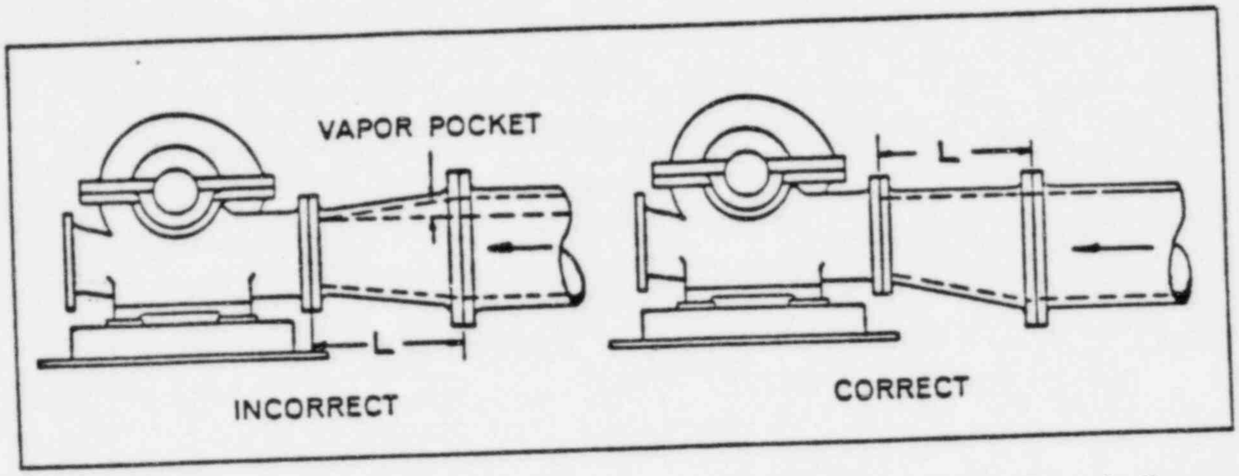


Fig. 5 Suction Line Configuration to Eliminate Pockets or High Spots (Example 1)

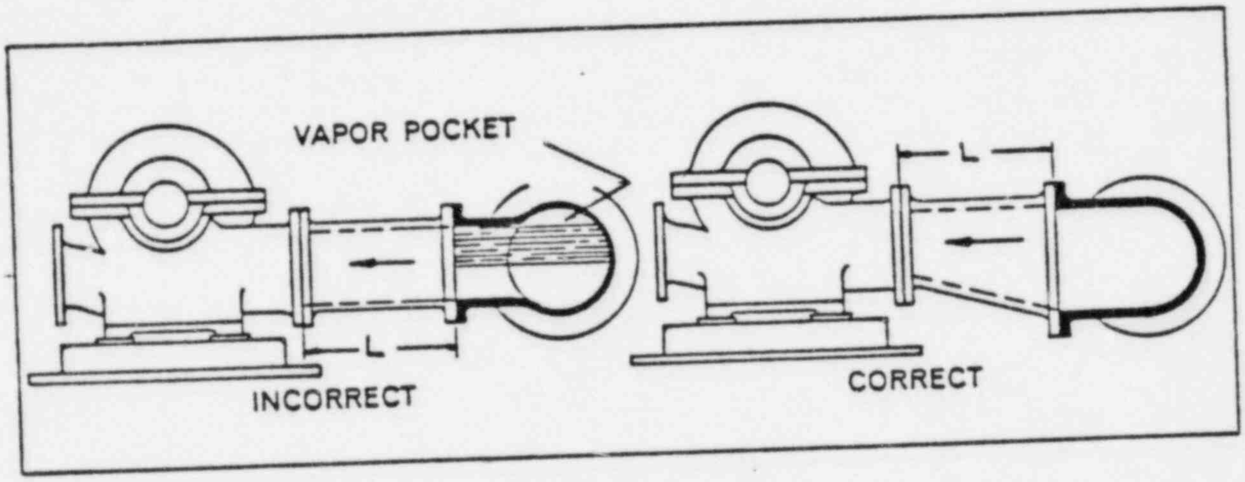


Fig. 6 (Example 2)

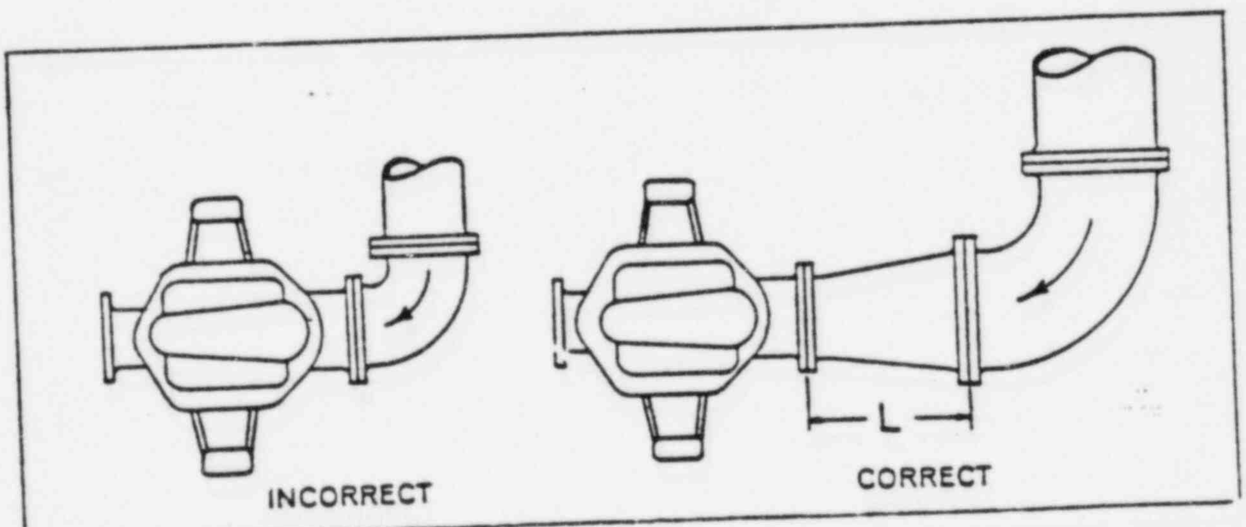


Fig. 7 (Example 3)

expansion of hot lines.

4. It is recommended that a temporary screen be installed in the line at or near the suction nozzle to catch scale or other foreign material. A pressure gauge installed on each side of the screen may be used for measuring pressure drop across the screen.

5. When a strainer or foot valve is used on the inlet end of the suction line, the free area through the strainer or valve should be three to four times the area of the suction pipe.

I. DISCHARGE PIPING

1. On some installations, a check valve and a gate valve may be required in the discharge line. The check valve is used to prevent liquid from running back through the pump in case of failure of the driver. The gate valve is used in priming, starting and when shutting down the pump.

2. When valves are required in the discharge line, they should be located as near as possible to the pump.

3. In all applications, provisions should be made for recirculating a portion of the liquid to prevent overheating of the pump while operating at reduced capacity.

J. AUXILIARY PIPING

When auxiliary piping is to be installed by the customer, the size and location of all pipe openings will be shown on the foundation drawing.

CAUTION

If unit is equipped with breakdown bushing assemblies and condensate is used for sealing, the condensate must be clean and free from scale, abrasive or other material that would either clog the clearance spaces or damage the bore of the breakdown bushings or the surface of the shaft sleeve. A filter or a fine mesh screen should be installed in the condensate feed line to the seals to insure clean condensate.

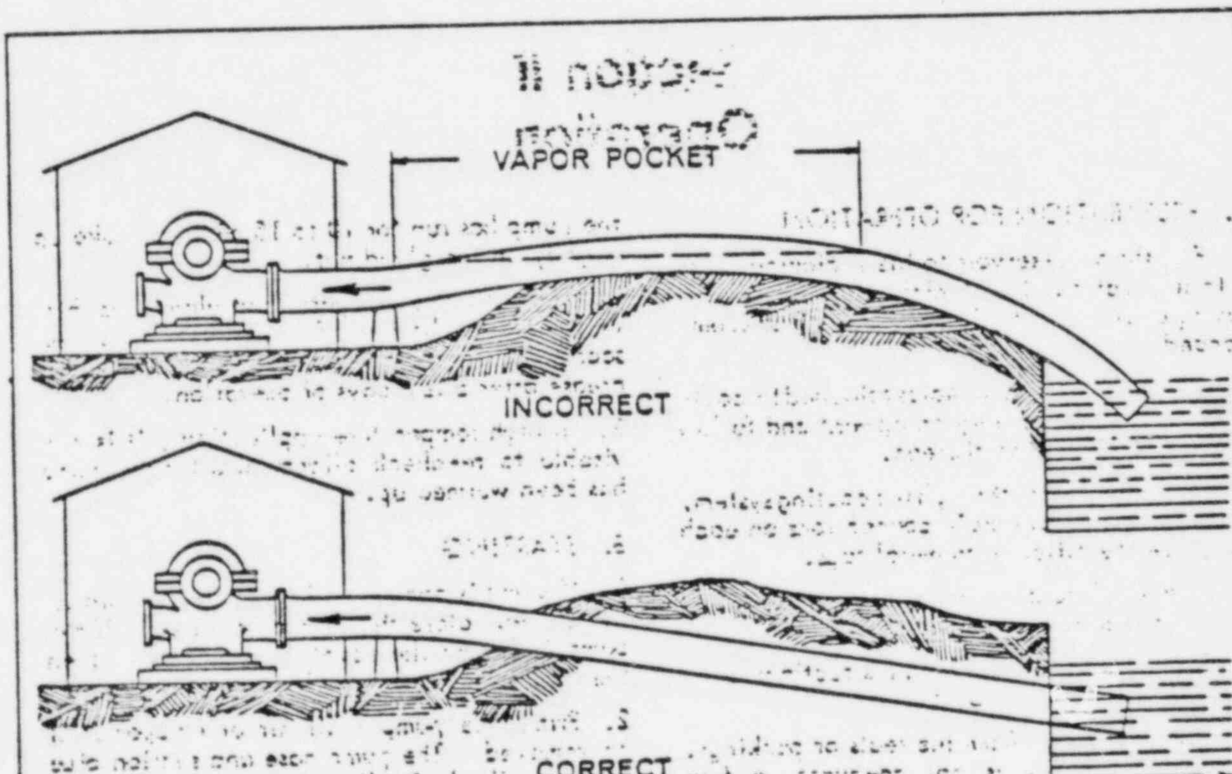


Fig. 8 (Example 4)

K. STUFFING BOXES

When installing packing, carefully read the instruction sheet included in the packing carton. The following procedures are generally recommended for packing installation:

1. Install the first packing ring and tamp it to the bottom of the box. If required, a suitable lubricant may be applied to each ring.

2. Insert a split sleeve or equivalent number of metal rings and compress the packing ring by tightening the stuffing box gland firmly.

3. Back off the gland and remove the sleeve or metal rings. Repeat steps 1 and 2 above for each ring, making sure to stagger the joints 90°. If a lantern ring is used, install the lantern ring as shown on the assembly sectional drawing.

4. After the box is packed, tighten the gland firmly and evenly and let the packing stand for 5 to 10 minutes. Then, loosen the gland nuts and re-tighten finger tight.

5. If possible, rotate the shaft a few times by hand. If a lantern ring is used, make sure it is installed so that adequate lubricating liquid will pass freely to the rings.

6. Refer to Section II - A. Preparation for Operation, for additional stuffing box requirements.

L. CONNECTING PUMP AND DRIVER

1. After piping is connected, check alignment of pump and driver as outlined in Paragraph F.

2. When pump is in alignment, tighten driver hold down bolts.

3. Check rotation of driver to be sure that it agrees with pump rotation.

4. Install spacer between pump and driver half couplings. For couplings which require lubrication, refer to the coupling manufacturer's manual for lubrication instructions.

Section II
Operation

A. PREPARATION FOR OPERATION

1. Fill the oil reservoir to the indicated level with lubricating oil. A high grade turbine oil having a viscosity of 150 SSU at 100°F is recommended.

2. Check metal tags or plates attached to coolers, filters and auxiliary equipment and follow instructions specified thereon.

3. Circulate water through the cooling system, if used. Inlet and drain connections on each pump are identified with metal tags.

4. Admit lubricating liquid to seals or packings that require lubrication.

5. Start the pump following instructions outlined in Paragraph B, below.

6. Check leakage from the seals or packings. If packing leakage is not adequate, a few light taps with a hammer on the gland will usually upset the packing sufficiently to increase the leakage to the required amount.

7. If leakage rate is more than required after the pump has run for 10 to 15 minutes, take up slightly on the gland nuts.

NOTE: Do not overtighten the gland, as this will increase the rate of wear and may cause scoring of the shaft. Leakage will usually decrease after a few days of operation.

8. In high temperature applications, it is advisable to re-check alignment after the pump has been warmed up.

B. STARTING

1. If pump is above the level of the liquid to be pumped, close the discharge valve. If the pump is below the level of the liquid, open the discharge valve 1-1/2 to 2 turns.

2. Prime the pump. All air and vapor must be removed. The pump case and suction pipe must be filled with liquid before the pump is started up.

NOTE: Pumps that are modified to function as hydraulic turbines must also be primed and filled with liquid before starting. If two turbines are used on a single installation, both turbines must be primed.

3. If the pump is fitted with a flushing line, open the line and admit flushing liquid to the seal chamber for 10 to 15 minutes.

4. Start the driver and bring the pump up to speed rapidly.

5. As soon as the pump is up to full speed, open the discharge valve slowly. Do not let the pump run with the discharge valve closed.

6. Check pressure gauges on each side of the temporary screen in the suction line. A pressure drop across the screen indicates it is becoming clogged with dirt or scale. In this case, the pump should be shut down and the screen cleaned or replaced. A clogged screen can cause damage to the pump.

7. The pump should be shut down if it fails to develop its rated discharge pressure at operating speed, or if bearings overheat or there is undue vibration or noise.

C. OPERATING AT REDUCED CAPACITY

If the pump is connected to a constant speed driver, capacity can be reduced by throttling the discharge. If the pump is connected to a variable speed driver, reduction of both the head and the capacity can be accomplished either by reducing the speed or by throttling the discharge.

When throttling the discharge, a by-pass connection may be used to by-pass sufficient liquid to prevent overheating and vaporization of the liquid in the pump.

D. OPERATING ROUTINE

1. Check bearing temperatures periodically. If there is overheating, check the oil level in the reservoir and the oil temperature. When ambient temperature is normal, the sump temperature should not exceed 165°F on pumps equipped with ball bearings. On pumps with Kingsbury or sleeve type bearings, the temperature at the cooler outlet should not exceed 140°F.

2. Check seals or packings for leakage.

3. Check circulation of the cooling system, if used. Cooling requirements will vary according to the ambient temperatures encountered.

4. Check suction and discharge pressure gauges If the differential pressure drops critically, shut down the pump at once.

E. STOPPING

The pump should be shut down rapidly to keep liquid in the pump and prevent parts from seizing. After stopping the driver, close the discharge valve and then the inlet valve, in that order. When Pumps are operating in parallel, it is sometimes necessary to close the discharge valve immediately after stopping the driver to prevent reverse rotation.

Section III
Trouble Shooting Information

Operating troubles and their probable causes are as follows:

A. NO DISCHARGE

1. Wrong direction of rotation
2. Pump not primed.
3. Suction line not full of liquid.
4. Air or vapor in suction line.
5. Suction pipe not submerged enough.
6. Available NPSH not sufficient.
7. Pump not up to rated speed.
8. Too much head.

B. INSUFFICIENT DISCHARGE

1. Wrong direction of rotation.
2. Suction line not full of liquid.
3. Air or vapor in suction line.
4. Air leaks in suction line.
5. Suction line not submerged enough.
6. Available NPSH not sufficient.
7. Pump not up to rated speed.
8. Too much head.

C. INSUFFICIENT PRESSURE

1. Air or vapor in liquid.
2. Pump not up to rated speed.
3. Wrong direction of rotation.
4. Mechanical defects:
   a. Wearing rings worn.
   b. Impeller damaged.
   c. Internal leakage.

D. CAVITATION AND NOISE

1. Air or gas in liquid.
2. Suction line not filled with liquid.
3. Suction line not submerged enough.
4. Available NPSH not sufficient.

E. PUMP LOSES SUCTION AFTER STARTING

1. Suction line not full of liquid.
2. Air leaks in suction line.
3. Air or vapor in liquid.
4. Air or vapor in suction line.
5. Suction line not submerged enough.
6. Available NPSH not sufficient.

F. EXCESSIVE POWER CONSUMPTION

1. Speed too high.
2. Insufficient system head.
3. Mechanical defects:
   a. Misalignment
   b. Shaft bent.
   c. Rotating element dragging.
   d. Wearing rings worn.
4. Specific gravity or viscosity of liquid pumped too high.

G. BEARINGS OVERHEAT

1. Oil pressure too low.
2. Improper or poor grade of oil.
3. Dirt in bearings.
4. Dirt or moisture in oil.
5. Failure in oiling system.
6. Bearings too tight.
7. Misalignment.

H. VIBRATION

1. Suction line not full of liquid.
2. Air or vapor in suction line.
3. Misalignment.
4. Worn or loose bearings.
5. Rotating element out of balance.
6. Shaft bent.
7. Foundation not rigid.
8. Vibration in the driver.
9. Wrong location of control valve.

SECTION IV

MAINTENANCE

A. DISASSEMBLY (See Sectional Drawings)

The correct sequence for complete unit disassembly is outlined below:

1. Disconnect auxiliary piping. It is not necessary to disconnect suction and discharge piping.

2. Remove driver coupling spacer and pump half coupling. (See coupling instructions)

3. Turn mechanical seal retainer plate (1065) into groove in shaft sleeve (443) and lock in position. Loosen or remove set screws and loosen shaft sleeve collar (976).

4. Loosen set screws holding deflector rings (7) and slide deflector back against shaft sleeve collar.

BEARING DISASSEMBLY

THRUST BEARING

5. Remove thrust bearing in following sequence:

   a. Remove cap screws holding bearing housing end covers (42) and (212) to bearing housing and remove outer bearing housing cover (212) and oiling ring (127). Remove bearing housing bracket nuts (not shown) and slide off thrust bearing housing (209).

   b. Fold back lock washer tab and remove bearing retaining lock nut and washer assembly (260). Slide off ball bearing thrust collar (136).

   NOTE: THE BALL BEARINGS (135), COMPLETE WITH INNER AND OUTER RACES, MUST BE REMOVED FROM THE SHAFT WITH THE AID OF A BEARING PULLER ASSEMBLY.

   c. Install puller assembly on the back side of bearing inner race and assemble puller so that the draw bolt or hydraulic cyclinder base of the puller rests against the end of the shaft. Note that if the bearing is to be re-used it cannot be pulled off by applying force to the outer race of the bearing; the puller assembly must rest only on the inner race. If a puller assembly that fits the back side of the inner race is not available the bearing may be removed by pulling the outer race. However, in this case the thrust bearing should be replaced.

   d. Remove spacer ring (259), bearing housing cover (42) with stationary oil baffle (48), and defector ring (7) from shaft.

RADIAL BEARING

6. It is assumed at this point that the shaft coupling has been removed. If it has not, refer to coupling instructions at the back of this manual. Dismantle bearing in following sequence:

   a. Remove all cap screws from inner and outer bearing housing covers (211) and remove outer cover with oil baffle (552) and oiling ring (127).

b. Remove bearing housing bracket-to-case stud nuts and slide radial bearing housing (209) off end of shaft.

c. Loosen set screw on ball bearing adapter (43).

d. Slide bearing adapter (43) from shaft.

NOTE: THE BALL BEARING ADAPTER (43) HAS A CLOSE SLIDING FIT TO SHAFT. THEREFORE, IT IS IMPORTANT, BEFORE SLIDING OFF, THAT ALL BURRS BE REMOVED FROM SHAFT SO THAT THE ADAPTER WILL NOT SEIZE.

Should seizure occur, a bearing puller assembly may be used to withdraw the adapter and bearing assembly. If it is intended to re-use the ball bearing, it is important not to let the puller assembly rest on the outer bearing race when applying the pulling force. Assemble bearing puller so that it applies force to the locknut assembly (137) when pulling.

e. Disassemble ball bearing and adapter in the following manner. Unfold lockwasher tab from slot on locknut (137) and remove locknut and washer assembly (137) from bearing adapter (43).

NOTE: THE BALL BEARINGS (41), COMPLETE WITH INNER AND OUTER RACES, MUST BE REMOVED FROM BEARING ADAPTER WITH THE AID OF A BEARING PULLER ASSEMBLY OR PRESS.

Install puller assembly (or press) on the back side of bearing (41) inner race (if bearing is to be re-used) and assemble other end of puller or press so that it rests against the end of the bearing adapter (43).

NOTE: IF THE BEARING OUTER RACE IS PULLED TO REMOVE BEARING THEN THE COMPLETE BEARING MUST BE REPLACED WITH A NEW PART.

f. Remove inner bearing housing cover (211) with oil baffle (48) and defector ring (7) from shaft.

7. Remove seal assembly complete as instructed in "Mechancial Seal Maintenance" section of back of manual.

8. Remove capnuts from pump case (37) parting flange and remove top half pump case (37).

9. Lift out rotating element and dismantle in following sequence.

   a. Slide off packing box bushings (227) and case wearing rings (226).

   b. Remove shaft sleeve keys (439).

   c. Loosen and spin off impeller locknuts (238 and 678).

   d. Slide off impeller (34) and remove impeller key (25).

B. INSPECTION AND REPAIR

1. Clean all parts and inspect for wear or damage. Particular attention should be given to the following:

   a. Check condition of wearing rings (200) and (226), packing box bushings (227) and impeller locknuts (238) and (678). Replace if worn. Remove worn impeller wearing rings by removing set screws and pulling or prying off. NOTE: STAKE ALL SET SCREWS UPON REPLACEMENT.

   b. Check bearings and bearing assembly parts for wear or damage. Replace if suspect.

   c. Check shaft (1) for straightness by mounting and rotating in soft lined "V" blocks or hardened rollers on a lathe steady rest assembly. In an emergency shaft centers may be used for mounting between lathe centers but are not as accurate as the preceding. Use a dial indicator to check shaft run out for the entire length of the shaft while rotating. Total indicator reading should be within 0.0015 inch.

C. REASSEMBLY (See Sectional Drawings)

1. Assemble rotating element parts on shaft in following sequence:

   a. Impeller (34) with impeller wearing rings (200) and impeller key (25).

      NOTE: THE DIRECTION OF CURVATURE OF IMPELLER VANES MUST BE AS SHOWN IN FIGURE NO. 9.

   b. Impeller locknuts (238) and (678). Install so that each locknut has equal thread engagement. It is suggested that a pencil mark be made approximately 2 inches outboard of the shaft thread on each end where the impeller locknut will engage. Reference to the pencil mark after engagement of the impeller locking nuts will allow judgement of locknut and impeller centering.

2. Check concentricity of rotating element by mounting in soft lined "V" blocks or hardened rollers of lathe steady rest. In an emergency the centers on the ends of the shaft may be used for mounting between lathe centers, but this method is not as accurate as the preceding. Turn shaft slowly by hand and take readings at impeller wearing rings (200) and impeller locknuts (238) and (678). Total indicator reading should be within 0.0015 inch at all points.

3. If indicator readings exceed 0.0015 inch, possible causes are:

   a. Shaft not straight.
   b. Abutting (end) faces of impeller hub and impeller locknuts not square with shaft centerline.
   c. Burrs or dirt particles on above faces.

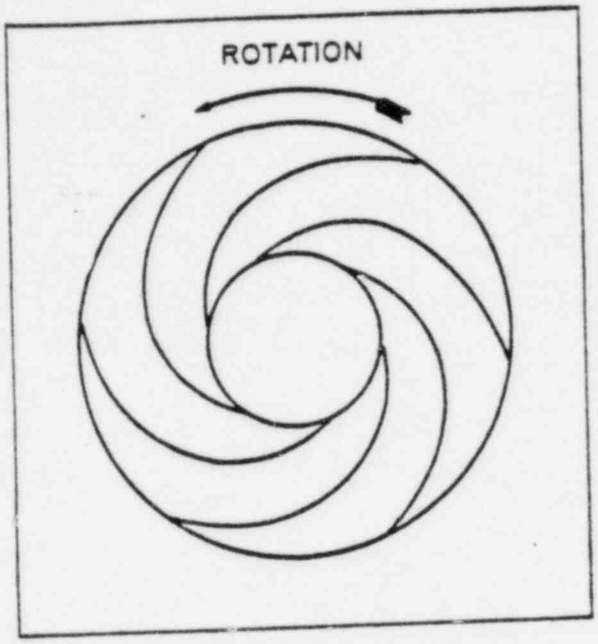


Fig. 9 Direction of Rotation in Relation to Curvature of Impeller Vanes

Fig. 10 Checking Concentricity of Rotating Element

4. When the rotating element checks straight and true:

   a. Install shaft sleeve key (439) and fasten in place with flat head screws.
   b. Slide case wearing rings (226) over impeller wearing rings (200).
   c. Slide packing box bushings (227) into position.
   d. Install rotating element in lowerhalf of case (37), making sure wearing rings (226) and dowel pins are in place.

5. The following operations are required to check axial alignment of the impeller and radial alignment of the shaft.

   a. Assemble thrust bearing and bearing housing as indicated under thrust bearing assembly section in following pages. Tighten bearing housing-to-case bolts lightly to allow alignment of housing by tapping with a mallet.

   b. Assemble radial bearing and bearing housing as indicated under radial bearing assembly section in following pages. Tighten bearing housing to casing bolts evenly but not too firmly.

   c. Check to see that impeller (34) is centered in case (37). If the impeller is not centered, adjust locknuts (238) and (678) to bring the impeller to center by loosening one and tightening the other.

d. Install top half of case (37).

NOTE: NEW GASKETS SHOULD ALWAYS BE USED AND SHOULD BE OF THE SAME MATERIAL (1/64" ASBESTOS WITH BUNA BINDER) AS THAT ORIGINALLY INSTALLED IN THE PUMP.

e. Verify that case parting flange studs are clean and install capnuts as indicated by bolting sequence drawing DBC-45769.

f. Rigidly clamp a dial indicator to the pump shaft for checking concentricity between the shaft and packing box bore at each end of the pump. Make adjustments by tapping the edge of the bearing housing flanges until total indicator reading is within 0.004 inch. When accurate alignment is established tighten the flange bolts firmly.

NOTE: WHEN DIMENSIONS OF THE PUMP DO NOT ALLOW FOR CONVENIENT USE OF A DIAL INDICATOR, A DOWEL PIN OF THE APPROPRIATE SIZE CAN BE USED AS A GAUGE BETWEEN THE SHAFT AND PACKING BOX BORE. ADJUST THE BEARING HOUSING, BY TAPPING UNTIL THE DOWEL PIN PASSES AROUND THE SHAFT WITH EVEN PRESSURE OR DRAG.

g. Check to see if the dowel holes in the bearing flanges are in line with the holes in the case flanges. If the holes are in line, install the dowels. If the holes are not in line, ream the holes to the next larger size and install new taper dowels.

h. Dismantle both bearing housings.

6. Assemble and install mechanical seal as instructed in Mechanical Seal Maintenance section at back of manual.

BEARING ASSEMBLY

THRUST BEARING

7. Assemble thrust bearing in following sequence:

NOTE: OIL ALL BEARING SURFACES WHEN ASSEMBLING.

a. Slide on shaft deflector ring (7), inner bearing housing cover (42) with oil baffle (48), 1/64" thick gasket, and ball bearing spacer ring (259).

b. Install ball bearing (135) by heating in an oil bath to 250° and sliding onto shaft and pressing firmly against spacer ring (259). Prior to sliding ball bearing onto shaft it is extremely important that the area of shaft over which bearing must slide, be inspected for burrs and dirt. The shaft must be absolutely free of burrs and dirt or the bearing will seize to the shaft when sliding in place. It is not possible to fit the thrust ball bearing to the shaft without heating as the bearing is mated to the shaft with and interference fit.

c. Slide on ball bearing thrust collar (136). Install and tighten locknuts and washer assembly (260). Fold lockwasher tab into slot on locknut.

d. Carefully position thrust bearing housing (209) over bearing and slide into position over bearing housing bracket studs. Install stud nuts finger tight and install taper alignment dowels in two places at bearing bracket mounting flange. Lightly tap the tapered dowel pins into place and tighten stud nuts holding bearing housing to mounting bracket.

e. Install oiling ring (127) and outer bearing housing cover (212) with 1/64" gasket in place. Install cap screws in both inner (42) and outer (212) bearing housing covers and tighten.

f. Locate deflector ring (7) and tighten set screw to shaft.

g. All thrust bearings require axial end play to allow for oil film and thermal expansion. Normal end play is established at the factory and should not require field adjustment. However, if damage or wear has occurred re-adjustment may be required. Always check thrust bearing end play after repairs and or assembly.

With the thrust bearing housing assembled, and after completion of the radial bearing housing assembly, bearing end play can be measured with a dial indicator placed against the shaft or a deflector ring (7) which has been set screwed to shaft. Push the shaft firmly one way against the thrust bearing and note the indicator reading. Push shaft the opposite direction and again note the indicator reading. The difference between the two readings should fall within 0.004 to 0.006 inch.

RADIAL BEARING

8. Assemble radial bearing in following sequence:

NOTE: OIL ALL BEARING SURFACES WHEN ASSEMBLING.

a. Slide deflector ring (7) and inner bearing housing cover (211) with 1/64" gasket and oil baffle (48) onto shaft.

b. Assemble ball bearing (41) to ball bearing adapter (43) by heating ball bearing in an oil bath to 250° or cool adapter with dry ice. Prior to sliding bearing onto adapter be sure that it is absolutely free of burrs and dirt. Press bearing onto adapter and install and tighten locknut and washer assembly (137). Fold tab on lockwasher into slot on locknut.

c. If a <u>new</u> shaft is installed, position bearing assembly on shaft as outlined in following paragraphs (d, e, f, and g). If the original shaft is used skip to paragraph (h).

d. Slide ball bearing assembly (43) onto shaft (1) and approximate final position. Do not tighten set screw in bearing adapter (43) to shaft.

e. Position bearing housing (209) over bearing and slide onto bearing housing-to-case mounting studs. Install and tighten one stud nut.

f. Place oiling ring (127) on bearing adapter. Slide adapter (43) along shaft to a position where oiling ring is centered on adapter and oil ring slot in bearing housing. Measure and record distance from end of shaft to one end of adapter (43). Remove oil ring (127) and bearing housing (209).

g. Carefully position bearing adapter (43) from end of shaft an amount equal to that measured in preceding step. Scribe the position of adapter set screw holes onto shaft. Slide adapter out of way and drill a small dimple into shaft just wide enough to accept end of set screw. Carefully remove any burrs left from drilling.

h. Slide bearing assembly to final position and tighten bearing adapter (43) set screw into drilled dimple on shaft. Stake set screw in place.

i. Position bearing housing (209) over ball bearing and slide into position over housing-to-case mounting studs. Install stud nuts finger tight. Slide the two taper dowel pins into position to align bearing housing and tap lightly in place. Tighten bearing bracket stud nuts.

j. Install oiling ring (127), outer bearing housing end cover (211) with 1/64" gasket and oil baffle (552). Install cap screws and tighten both inner and outer bearing housing covers.

9. Check axial thrust bearing play in accordance with note No. (7.g).

10. Postion deflector ring (7) on each end of pump shaft by pushing deflector ring in tight against stationary oil baffle (48), then pull deflector ring back 1/32 to 1/16 inch and tighten set screws to shaft.

11. Tighten all set screws in shaft sleeve collars (976) on both ends of pump. Turn retainer plate (1065) 180° out of shaft sleeve groove and lock in position so that it will not interfere with rotation of shaft during normal operation.

12. Press on pump half of flexible coupling as described in the shaft coupling instruction at end of this manual.

13. Fill radial and thrust end bearing housings with oil as indicated on oil level tags mounted on side of bearing housings. Re-fill automatic oiler glasses and install on bearing housings.

NOTE: USE ONLY A HIGH GRADE TURBINE TYPE MINERAL OIL HAVING A VISCOSITY OF 150 TO 250 SSU AT 100°F. OIL SHOULD BE CHANGED AT APPROXIMATELY 3 MONTH INTERVALS. INTERVALS SHOULD BE REDUCED IF CORROSION SPOTS APPEAR ON INTERNAL BEARING HOUSING PARTS.

14. Check shaft alignment, correct if necessary and install coupling spacer in accordance with shaft coupling insturctions at back of manual and assemble all auxiliary piping systems.

D. PARTS ORDERING

When ordering parts for spares or replacement the following information must be given:

1. Pump size, type and serial number as given on nameplate.
2. Quantity of parts.
3. Part name and number as shown on cross sectional drawing.
4. Complete shipping instructions.

MECHANICAL SEAL MAINTENANCE

1. Removal of Seal Assembly from Pump

In order to understand the following, reference must be made to the seal assembly drawing C-15962.

To remove mechanical seal for inspection, it is necessary to first remove the complete bearing assembly, including housing. If the seal to be inspected is on the coupling end of pump, the coupling (2) must be removed prior to dismantling the bearing.

Proceed as Follows:

NOTE: WHEN HANDLING SEAL PARTS AND ASSEMBLIES, EXTREME CARE IS REQUIRED TO AVOID DAMAGE.

a. Remove seal flushing piping to seal plate (375).

b. Turn retaining plate (1065) into groove in shaft sleeve (443) and lock in position by tightening cap screw.

c. Loosen set screws in shaft sleeve collar (976).

d. Remove cap screws holding seal plate (375) to casing (37).

e. Slide seal assembly off of shaft and remove to bench for inspection.

2. Disassembly of Seal Parts

a. Remove shaft sleeve collar (976) and "O" Ring (656).

b. Loosen cap screw and turn seal plate retainer (1065) out of shaft sleeve (443) groove and retighten cap screw to keep retainer out of the way.

c. Carefully slide shaft sleeve (443) out of seal plate (375). Lay seal plate on bench with stationary seal insert (2) up. Slide rotating seal ring (3) off of shaft sleeve and place on bench face up. NOTE: DO NOT ALLOW EITHER SEAL RUBBING FACE TO CONTACT ANY OBJECTS, AS THE SLIGHTEST NICK OR CHIP WILL RENDER THEM USELESS.

d. Slide remaining seal parts off of shaft sleeve in the following order after loosening set screws (S) in seal collar (5). Seal "O" ring (P), compression ring (4) and seal collar (5) with springs (C).

e. Carefully slide stationary seal insert (2) out of seal plate with fingers by pulling parallel to seal plate bore, and lay face up on bench. Remove insert "O" ring (6).

3. Inspection

a. Inspect insert (2) and seal ring (3) faces for chipped, nicked, scratched, grooved or heat checked surfaces. Surfaces not free of these defects and which are not perfectly flat should be replaced.

b. Inspect insert "O" ring (6), seal "O" ring (P) and shaft sleeve "O" ring for deterioration, scratches, gouges, etc., on all sides. If any of these defects are apparent, or either part is misshapen or crushed, they must be replaced. Best practice is to replace all three parts when seals are disassembled. NOTE: NEW PARTS MUST ALSO BE GIVEN THE SAME CAREFUL INSPECTION.

c. Clean and inspect shaft sleeve (443) for scratches, wear, etc., at the seal "O" ring contact point. If not free of damage or wear, it should be replaced.

d. Clean and inspect bore of seal plate (375) at the insert "O" ring (6) contact points. The surfaces must be free of pitting, gouges, scratches, etc.

e. Inspect parts C, S, 4, 5, 594, and 976 for general appearance. If any appear to be worn irregularly, misshapen, or fit poorly, they should be replaced.

4. Mechanical Seal Assembly

a. Smear a small amount of glycerin in seal plate bore and carefully push seal insert (2) with "O" ring (6) into seal plate (375) until "O" ring bottoms against seal plate. Carefully wipe clean, rubbing face of seal insert (2) with soft, lint free cloth. Using a depth micrometer measure the distance from seal inner plate face to rubbing face of seal insert face at four places around circumference of seat. Readings should all agree within plus or minus 0.0015 inches.

b. Install parts C, 4, 5, and tighten set screws (S) on shaft sleeve (443).

c. Smear a small amount of glycerin on shaft sleeve shoulder and slide "O" ring (P) and seal ring (3) onto shaft sleeve after carefully wiping all seal faces clean with a soft, lint free cloth.

d. Carefully, so as to avoid nicking or chipping, slide shaft sleeve assembly into seal plate (375). Compress complete assembly against seal springs and turn seal plate retainer (1065) into groove on shaft sleeve (443) and lock in place

e. Insert shaft sleeve "O" ring (656) into groove in bore of shaft sleeve (443).

5. Installation of Complete Seal Assembly to Pump

a. Verify that shaft sleeve key (439) is mounted in shaft with the flat head machine screw. Install new seal plate gasket (595) on seal plate and slide complete seal assembly onto shaft. Insert and tighten equally, the cap screws holding seal plate (375) to casing (37).

b. Install shaft sleeve collar (976) and set screw to four places on shaft sleeve.

DO NOT TIGHTEN LOCK COLLAR SET SCREWS TO SHAFT AT THIS TIME.

c. Install deflector ring (7) and bearing and housing complete as described in manual.

d. Tighten equally all six set screws in shaft sleeve collar (976) against shaft. Stake set screws in place. Turn retainer plates (1065) 180° out of shaft sleeve groove and lock in place with cap screw. NOTE: OPERATION 5.d MUST NOT BE PERFORMED UNTIL BEARING ASSEMBLY IS COMPLETED AT BOTH ENDS OF PUMP.

e. Replace seal piping.

SHAFT COUPLING INSTRUCTIONS

(Refer to Koppers Form #1900-2 attached for complete data)

1. Removal or installation of couplings requires application of heat as they are installed with an interference fit to shaft. An acetylene heating torch and puller assembly must be available at time of dismounting.

REMOVAL

(Read completely before starting)

2. Unbolt and remove coupling spacer. Slide coupling shroud as far back as possible toward bearing housing and remove all grease with solvent.

3. Set up puller assembly so that hook ends of puller may be quickly positioned on back of shroud between coupling and bearing housing after heating.

4. Using a large tip acetylene torch, evenly heat coupling (hub only) by playing torch continuously around circumference. Avoid coupling gear teeth and shaft. It is important to perform this operation quickly to avoid excess heating of shaft and thereby lose the advantage of expanding only the coupling. Heat to approximately 250° to 300° F.

5. Quickly install puller assembly and withdraw coupling hub and shroud from shaft. Do Not Hesitate. Keep the coupling hub sliding off shaft as rapidly as possible to avoid heating of shaft.

INSTALLATION

(Read completely before starting)

6. Thoroughly clean and inspect all coupling parts including keys, bolts and gaskets. Carefully remove any burrs on shaft bore, keyway and key. Do not work on bore except at burrs. Excessive work on bore will destroy the required interference fit.

7. Clean and inspect shaft. Carefully remove all burrs, including any found in keyway. Do not remove any metal except burrs.

8. Oil shaft and key with light oil and dust with a coat of Molybdenum Disulfide.

SHAFT COUPLING INSTRUCTIONS

9. Lay coupling shroud, open side up, so that itis immediately ready to receive heated coupling hub. Gloves and lifting devices for picking up heated assembly should be "at ready". NOTE: MAIN PUMP TO TURBINE COUPLING IS A DYNAMICALLY BALANCED ASSEMBLY. ALL SHROUDS, HUBS, AND SPACERS ARE "MATCH MARKED" AND MUST BE MATCHED AT RE-ASSEMBLY.

10. Heat hub with torch as in section #4 preceding.

11. Place heated hub into shroud (observing "matched marks") and immediately lift into position and tap onto shaft with lead mallet. Do Not Hesitate. Shaft will begin to absorb heat from coupling hub and loss of assembly clearance will cause hub to seize if delays occur while positioning.

    Position face of coupling hub flush with end of shaft.

12. After coupling has cooled, check alignment of equipment.

13. Pack coupling with grease per instruction sheet attached and install coupling spacer with gaskets and bolts.

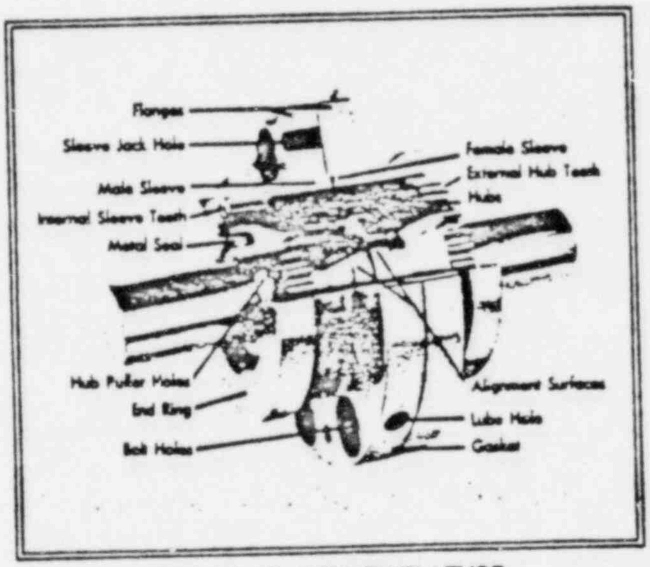
KOPPERS

INSTRUCTION DATA SHEET

FOR

FAST'S FORGED STEEL *Couplings*

(SIZES #1½ TO #6 INCLUSIVE)



COUPLING NOMENCLATURE

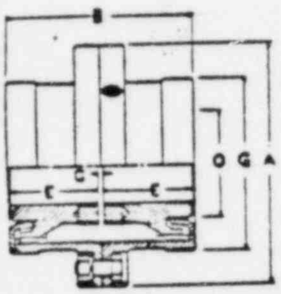
Refer to GENERAL INSTRUCTIONS (Form 1900)
for Installation and Lubrication Instructions

KOPPERS COMPANY, INC.
Fast's Coupling Department
Baltimore 3, Maryland

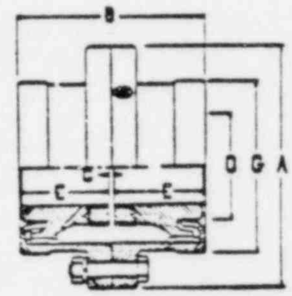
Form 1900-2
Rev. 2

FAST'S FORGED STEEL *Couplings*

(SIZES #1½ TO #6 INCLUSIVE)



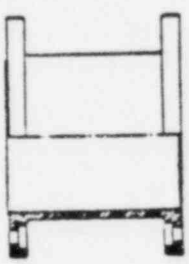
FORGED STEEL COUPLING WITH SHROUDED BOLTS (SIZE #1½ — #5)



FORGED STEEL COUPLING WITH EXPOSED BOLTS (SIZE #1½ — #6)

COL.	1	2	3	4	5	6	7	8	9	10	11	12
	DIMENSIONS—IN INCHES						APPROX. LUBRICANT REQUIRED—PINTS					
							OIL			GREASE		
Size Number	A	B	C	E	G	O	COUPLING ONLY	SPACER ONLY	COUPLING HALF WITH RIGID HALF	COUPLING ONLY	SPACER ONLY	COUPLING HALF WITH RIGID HALF
1½	6	4 5/16	1/8	1 15/16	3 11/16	2 5/16	1/8	.03	1/16	3/8	.15	3/16
2	7	5 9/16	1/8	2 7/16	4 11/16	2 7/8	1/6	.04	1/12	1/2	.20	1/4
2½	8 3/8	6 7/8	3/16	3 1/2	5 11/16	3 3/8	3/16	.06	1/12	1	.33	1/2
3	9 7/16	7 11/16	3/16	3 15/32	7	4 1/4	1/3	.09	1/6	1 1/2	.50	3/4
3½	11	8 1/2	1/4	4 3/16	8 1/16	5	3/4	.10	3/8	2 1/4	.60	1 1/8
4	12 1/2	10 1/8	1/4	4 3/4	9 1/2	5 3/4	1 1/4	.15	5/8	3 3/4	.80	1 7/8
4½	13 3/4	11 3/8	5/16	5 5/16	10 3/4	6 1/2	1 1/2	.18	3/4	4 1/2	1.0	2 1/4
5	15 5/16	12 5/8	5/16	6 1/8	12	7 5/16	2	.22	1	6	1.3	3
5½	16 3/4	13 1/2	5/16	6 29/32	12 1/8	8	3 1/8	.27	1 1/2	9 1/2	1.6	4 3/4
6	18	14 1/2	5/16	7 15/32	14	8 15/16	3 7/8	.43	2	12 1/2	2.5	6 1/4

Note: Use of excessive amounts of lubricant will not impair operation of the coupling. The excess lubricant will be thrown from the coupling during operation.



SPACER

When a spacer is used (to increase shaft separation), additional lubricant is necessary. To the amount required for the COUPLING ONLY (per column 7 or 10), add the amount required for SPACER ONLY (per column 8 or 11) multiplied by the length of spacer in inches.

example: #2 coupling with 5" spacer

Oil—1/6 plus .04 x 5 = 1/3 pt. (approx.)

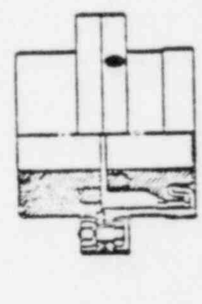
Grease—½ plus .20 x 5 = 1½ pt. (approx.)

When a rigid half is used with a coupling half (for angular misalignment only or floating shaft arrangements), less lubricant is required. Use the quantity specified in columns 9 or 12.

example: #4½ Coupling half with rigid half

Oil— ¾ pt. (approx.)

Grease—2¼ pt. (approx.)



COUPLING HALF WITH RIGID HALF

APPROVED LUBRICANTS

Oils

Use a mineral base oil having a viscosity no lighter than 150 SSU (Saybolt Seconds Universal) or heavier than 1000 SSU at 210°F.

DO NOT USE COMPOUNDED OILS

Use grease instead of oil if interval between lubrication exceeds 2 months.

Greases*

Atlantic Refining Company
American Oil Company
Brooks Oil Company
Cities Service Petroleum, Inc.
Continental Oil Company
Esso Standard Oil Company
Fiske Brothers Refining Company
Gulf Oil Corporation
Keystone Lubricating Company
Master Lubricants Company
Phillips Petroleum Company
Pure Oil Company

Atlantic Lubricant #17
Amobar S
Leadolene 375 Light
Trojan Grease A-1
Conoco Super Lube
Fibrax 370 or Nebula 1
Lubriplate #630 AA
Gulf Antifriction Grease #1
Keystone #15 EP XX Light
Lubriko Grease M-54
Philube #1 Stock 401
Poco Fibre Grease #1

Richfield Oil Corporation
Shell Oil Company
Sinclair Refining Company

Socony-Mobil Oil Co., Inc.
Standard Oil Co. of California
Standard Oil Co. of Indiana
Standard Oil Co. of Ohio
Sun Oil Company
Texas Company
Tidewater Associated Oil Co.
Union Oil Co. of California

Rocolube RR
Shell Alvania Grease #2
Sincolube #1, or Litholine Multi-Purpose Grease #2
Sovarex L-O or Kairex #1
Calol SA #1
Stanobar Grease "S"
Sohio #77
Sun Oil #901 Grease
Marfak #1
Tycol Alitho #10
Ball Roll #1 or Elnoba #1

*Greases listed are in response to requests for specific recommendations. This list is not complete and is not intended to restrict the use of equivalent lubricants manufactured by companies not listed.

DO NOT USE CUP GREASE

For applications with temperatures exceeding 250°F, contact Koppers Company, Inc., for specific recommendations.

Form 1900-2
Rev. 2

SUPPLEMENTARY INSTALLATION INSTRUCTIONS

(This section supplements pages (1) through (7) of the general manual and requires reference to those pages for effective use.)

1. When leveling the base plate prior to grouting, it is important to observe alignment of pump shafting to the drive turbine shaft.

   Main pump, booster and speed reducing gear, are furnished with 3/16" to 1/4" shims between mounting feet and base plate pedestals. Shims must be in place when leveling base plate and aligning to turbine shaft.

2. The following instructions assume that turbine is set in final position.

   Level and position base plate so that main pump shaft coupling hub is parallel and centered to turbine coupling hub. Use of a straight edge laid parallel to shaft on coupling hubs will be a sufficient preliminary check of centering. Couplings should be centered within 1/64" before grouting base plate.

   All pump and gear reducer shafts should be checked for level before completion of base plate leveling and prior to grouting.

   Check between all equipment shaft ends to assure that spacing is equal to that shown on drawing FC-45768.

3. When base plate is grouted and set, alignment with dial indicators should be made per the general instruction manual page seven. Begin at the main pump to turbine coupling and work back to the booster pump coupling last.

   Set main pump higher than turbine to accommodate turbine thermal growth. Set high by the amount recommended by turbine manufacturer.

   Set speed reducing gearbox lower than both pumps by 0.004" (0.008" total indicator reading) to allow for thermal growth.

4. A realignment with dial indicators must be performed once again after installation of all suction and discharge piping. At completion of this alignment, locating dowels should be installed at all pump mounting feet. A final check of alignment should be made with all equipment at normal operating temperature.

5. "Bedding In" of the bed plate and relaxation of certain piping stresses will affect alignment of all equipment. A realignment of equipment should be made after several months operation. At this time the locating dowels at pump mounting feet will require taper reaming to align both dowel holes. The speed reducing gearbox should be doweled at this time and not before.

LIFTING INSTRUCTIONS

1. Complete unit - Main, Booster and speed reducing Gear (total weight = 28,500 lbs.)

   Attach rigging to base plate at four (4) points labeled V-X1 on outline drawing FC-45768.

   Rigging should be positioned for a straight vertical lift only when all equipment is attached to base plate.

2. Booster pump - Type DSK (weight = 4,000 lbs.)

   Detach shaft couplings and common auxiliary piping before lifting pump separate from base plate.

   Booster pump may be lifted separate from other equipment by using two (2) wire rope slings. Position a sling beneath each bearing housing bracket on pump casing, or use lifing lugs VL-3 (two) as shown on drawing FC-45768.

3. Main pump - Type RHC (total weight = 10,680 lbs.)

   Detach shaft couplings and common auxiliary lube oil piping before lifting pump separate from base plate.

   Main pump may be lifted separate from other equipment by four (4) wire rope slings. Position each sling under one of four lifting lugs on pump casing. Lugs are labeled V-L2 on drawing FC-45768.

4. Speed reducing gear - (weight = 920 lbs.)

   Detach shaft couplings and common auxiliary piping before lifting separate from base plate.

   The speed reducing gear may be lifted separate from other equipment by attaching rigging to (2) 5/8" eyebolts located on the top of gear casing.

D46-695
D46-697
D46-699
D46-701

PACIFIC PUMPS, INC.

PARTS LIST

S/N 45-769
45-772
45-773
45-775

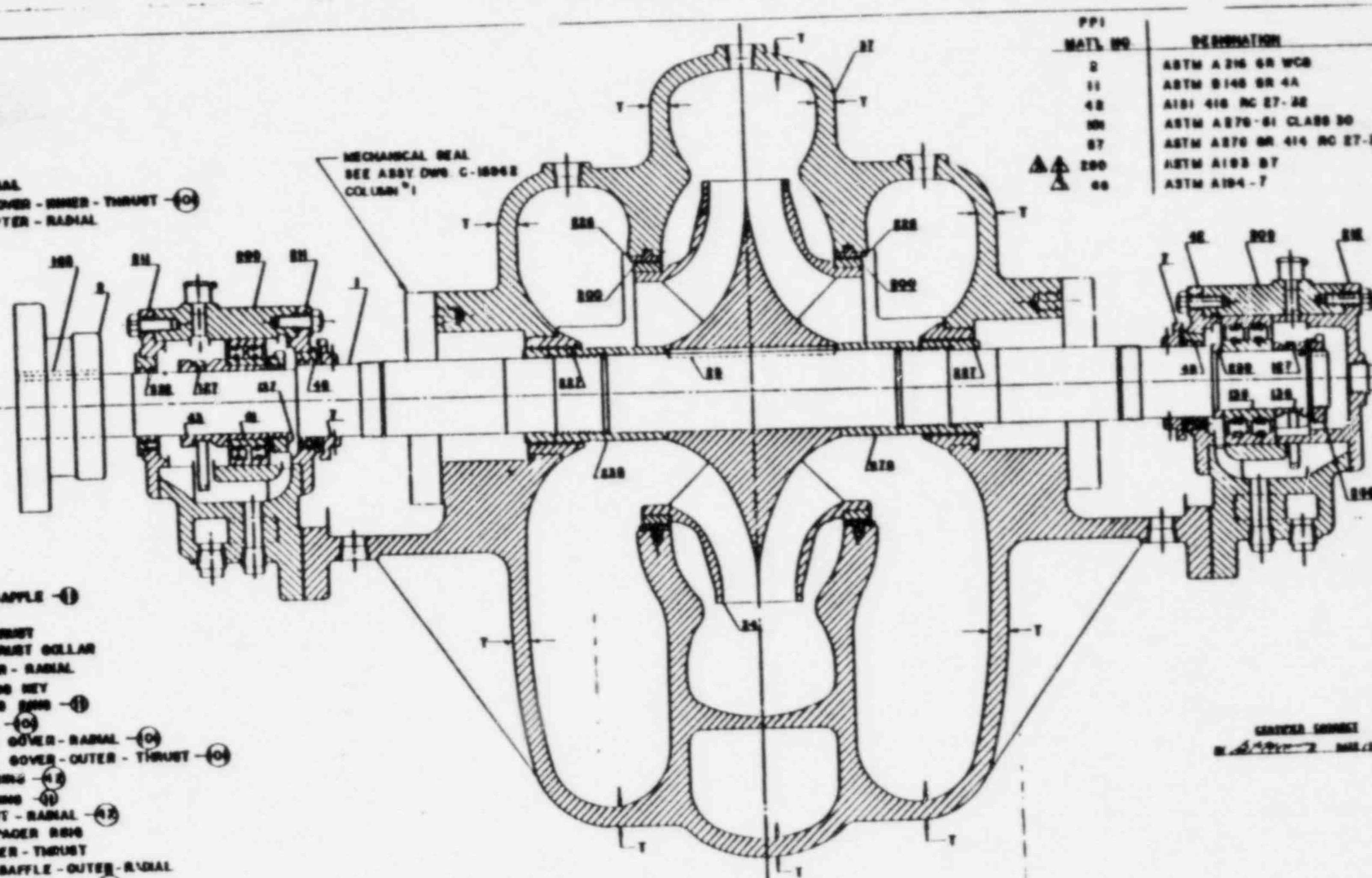
FOR:

OUR ORDER NO.

PCS. UNIT	TOTAL REQ'D	PART NO.	DESCRIPTION	PATTERN NO.	DRAWING NO.	LINE NO.	COLUMN NO.	MATERIAL NO.	HEAT TREAT.	FINISH
		1	MP3 SHFT DYNAMIC BAL OF CMPL ROT ASY		C15934		1	57	21	MP
		2	COUPLING 3 1/2 FAST STD DSK PUMP 4577		B05006	40		11		
1	1	7	RING DEFLCT 2.877 BORE		B05006	40		11		
1	1	7	RNG DFLCT 2.877 BORE	D2678	C09856	2	1	11		MP
1	1	34	MP 2 IMPELLER RPM 1800 VT AS CAST *	D3000	D13187		1	2		MP
1	1	37	MP 1 CASE ELEV UPR HLF * SEE PARTIAL	D3001	D13187		1	2		MP
1	1	37	MP 1 CASE ELEV LOWER HALF W/300 FLANG		J80110	52	15			
1	1	41	BRG BALL SKF 5215	D2555	B09646			101		
1	1	42	CVR HSG BRG INNER *		B05005	38		11		
1	1	48	BFLE OIL INNER		B05005	38		11		
1	1	48	BFLE OIL		B03803	20	2	11		
1	1	127	RING OILING 4 1/2X4 3/4X1/4		B03803	20	2	11		
1	1	127	RNG OILING 4 1/2X4 3/4X1/4		J80110	53	12			
1	1	135	BRG BALL SKF 5312		A17642			185		
1	1	136	COLLAR THRUST		A20216	14	1	14		
1	1	165	KEY FLEX CPLG		A23863			11		
2	2	200	WRG RING IMP CLR .020	D2556	C06716			101		
1	1	209	HSG BRG *	D2556	C06716			101		
1	1	209	HSG BRG *	D2555	B09647			101		
1	1	211	CVR HSG BRG INNER *	D2555	B09647			101		
1	1	211	CVR HSG BRG OUTER *	D2554	B09644			101		
1	1	212	CVR HSG BRG OUTER *		A30363	2		42	21	9
2	2	215	COLLAR SHFT SLV		A23862			42	21	
2	2	226	RING CASE WRG		A60545			11		
2	2	227	BUSHING PKG BOX		A60544			42	21	9
1	1	238	IMP LOCKNUT LH W/CARTR SEAL		A04961			185		
1	1	259	RING SPACER		LH0100		12			
1	1	260	LOCKNUT & WASHER SKF N W 12		A20210	13	2	23		
1	1	276	KEY IMP		C15935			23		MP
2	2	375	MP 4 PLATE SEAL		A22822	2		42	2[illegible]	
2	2	439	KEY SHFT SLV		A60546			42	2[illegible]	
2	2	443	SLEEVE SEAL SHAFT		B05005	64		11		
1	1	552	BFLE OIL OUTER		A24509	30		11		
2	2	594	BUSHING SEAL PLATE					39		
2	2	595	GASKET SEAL PLT 5 1/4X6X1/16		LU5680	2	34	211		
4	4	656	O RING SHFT SLV ARP 568 234		A60543			42	21	9
1	1	678	IMP LOCKNUT RH W/CARTR SEAL		A21550	4		42	21	
2	2	1065	PLATE RETAINER							

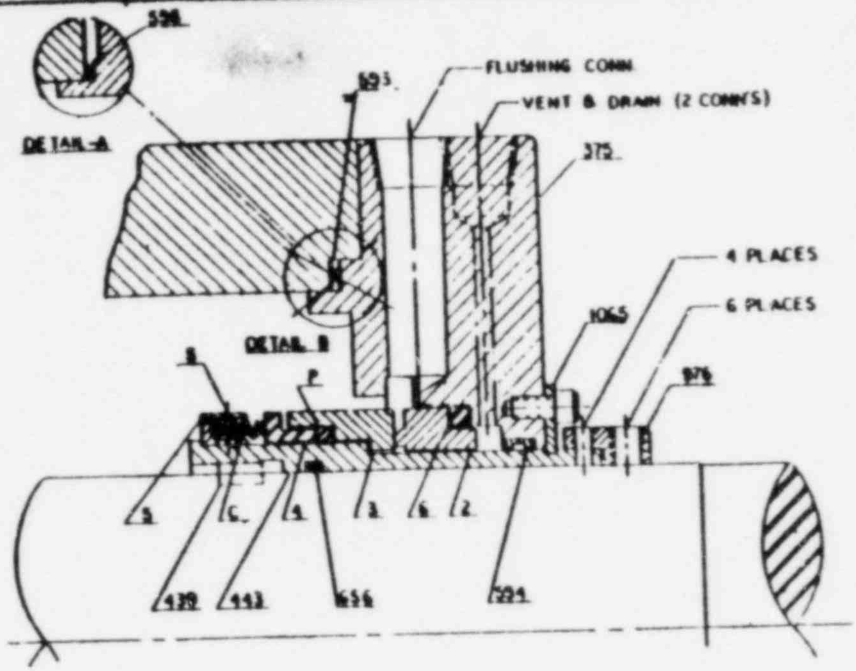
NO.	NAME OF PART
1	PUMP SHAFT
2	FLEXIBLE COUPLING
7	DEFLECTOR RING
20	IMPELLER KEY
24	IMPELLER
37	CASE
41	BALL BEARING - RADIAL
42	BEARING HOUSING COVER - INNER - THRUST - (104)
43	BALL BEARING ADAPTER - RADIAL
49	STATIONARY OIL BAFFLE
127	OILING RING
134	BALL BEARING - THRUST
136	BALL BEARING THRUST COLLAR
137	LOCKNUT & WASHER - RADIAL
140	FLEXIBLE COUPLING KEY
200	IMPELLER WEARING RING
209	BEARING HOUSING - (104)
211	BEARING HOUSING COVER - RADIAL - (104)
216	BEARING HOUSING COVER - OUTER - THRUST - (104)
226	CASE WEARING RING - (48)
227	PACKING BOX BUSHING
236	IMPELLER LOCKNUT - RADIAL - (48)
266	BALL BEARING SPACER RING
269	LOCKNUT & WASHER - THRUST
292	STATIONARY OIL BAFFLE - OUTER - RADIAL
370	IMPELLER LOCKNUT - THRUST - (48)
	CASE STUDS - (200)
	NUTS CAP (66)

PPI MAT'L NO	DESIGNATION
2	ASTM A 216 GR WCB
11	ASTM B148 GR 4A
48	AISI 416 RC 27-32
101	ASTM A278-61 CLASS 30
87	ASTM A276 GR 414 RC 27-32
200	ASTM A193 B7
66	ASTM A194-7



T = .5625 MIN. CASE THICKNESS

PACIFIC PUMPS
DIVISION OF DRESSER INDUSTRIES
ASSEMBLY
TYPE DSK
D13046



PACIFIC PUMPS SEAL PARTS

PART NO.	NO. REQ'D.*	NAME OF PART	MATERIAL
375	1	SEAL PLATE	ASTM A-479 TP304 ①
443	1	SHAFT SLEEVE	ASTM A-276 TP316-COND-B
596	1	SEAL PLATE BUSHING	ASTM B-145-4A
593	1	SEAL PLATE GASKET	ASBESTOS
656	1	SHAFT SLEEVE "O" RING	BY CAR
970	1	SHAFT SLEEVE COLLAR	ASTM A276 TP316 - ANNEAL
1065	1	RETAINER PLATE	ASTM A276 TP316 - ANNEAL
①415	1	SHAFT SLEEVE KEY	ASTM A276 TP410 - ANNEAL

NOTE: ① - LESS THAN 3000

DURAMET. PTO SEAL PARTS

PART NO.	NO. REQ'D.*	NAME OF PART	MATERIAL
5	1	INSERT	CARBON
3	1	SEAL RING	TUNG. CARB. "N"
4	1	COMPRESSION RING	AISI 316
2	1	COLLAR	AISI 316
①6	1	INSERT "O" RING	BUNA N
C	1 SET	SPRINGS	CARPENTER #20
①P	1	SEAL "O" RING	BUNA N
S	2	SET SCREWS	CARPENTER #20

*NOTE: QUANTITIES SHOWN ARE FOR EACH SEAL ASSEMBLY.

REV. NO.	DESCRIPTION
01	DETAIL A
02	DETAIL B

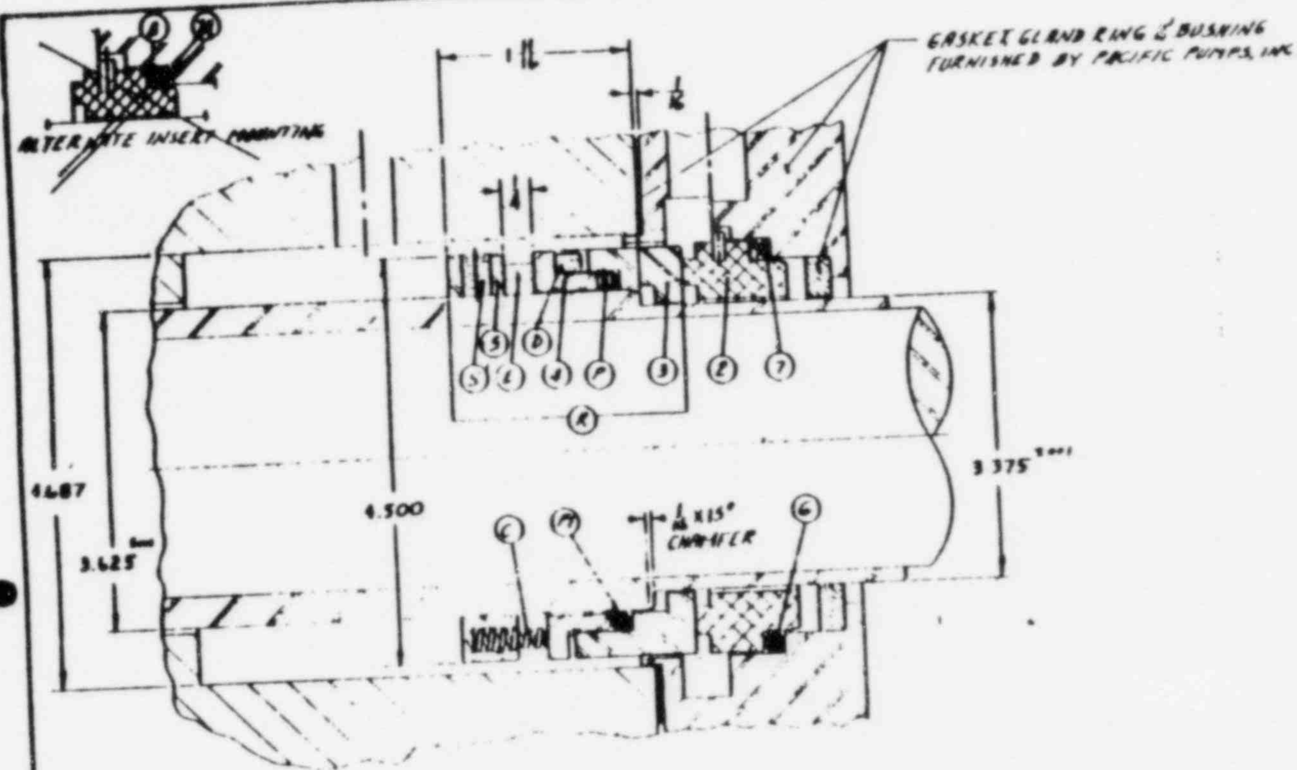
CERTIFIED CORRECT
BY S.T. Murray DATE 12-15-69

DURAMETALLIC PTO SIZE 3 625

PACIFIC PUMPS INC.
LOS ANGELES, CALIF.
SEAL ASSEMBLY
DSK
C15962

5746-689

D-46699



MARK.

PROJECT #

R	ROTARY UNIT CONSISTING OF		2	INSERT	5 CARBON
3	SEAL RING	316 SS/TUNG CARB	6	"O" RING	BUNA N
4	COMP RING	316 SS	7	"U" RING	
5	COLLAR	316 SS	P	SHELL PACK	
C	SPRINGS	20 SS	17	SAFETY PACK	BUNA N
D	DRIVE PINS	20 SS	10	V RING	
E	SPRING PINS	20 SS	8	WEDGE RING	
S	SET SCREWS	20 SS			

PARTS: 2, 3, 6 or 7, C, P or P1, 7, H, S TO BE KEPT IN STOCK AS SPARES

BUYER: PACIFIC PUMPS, INC., HUNTINGTON PARK, CALIF.

ORDER NO. 18081

USER: GENERAL ELECTRIC CO.

PUMP			REFERENCE DRAWING NO.	FLUID	PRESSURE		RPM	TEMP °F	SP. GR.
PACIFIC 18x17 DSA			3-1/2 ED 45632	WATER			1800	40 140	1.0

D.U.A. SEAL TYPE: INSIDE PTO

ORDER PARTS BY B/M NO. 31750

DURAMETALLIC CORPORATION
KALAMAZOO, MICH.

P.O. 34486
DATE 6-30-70
DRAWN DS
FORM 27-75090
SCALE NTS
DWG. NO. ED-96354

NOTE 1 ARRANGEMENT SHOWN IS SCHEMATIC ONLY [illegible] TO [illegible] AND [illegible] OF COMPONENTS.

NOTE 2 [illegible] SUPPORTS AT 5 FT MAX [illegible] SUPPORTS. [illegible] FOR VIBRATION AND ADD ADDITIONAL SUPPORTS IF NEEDED.

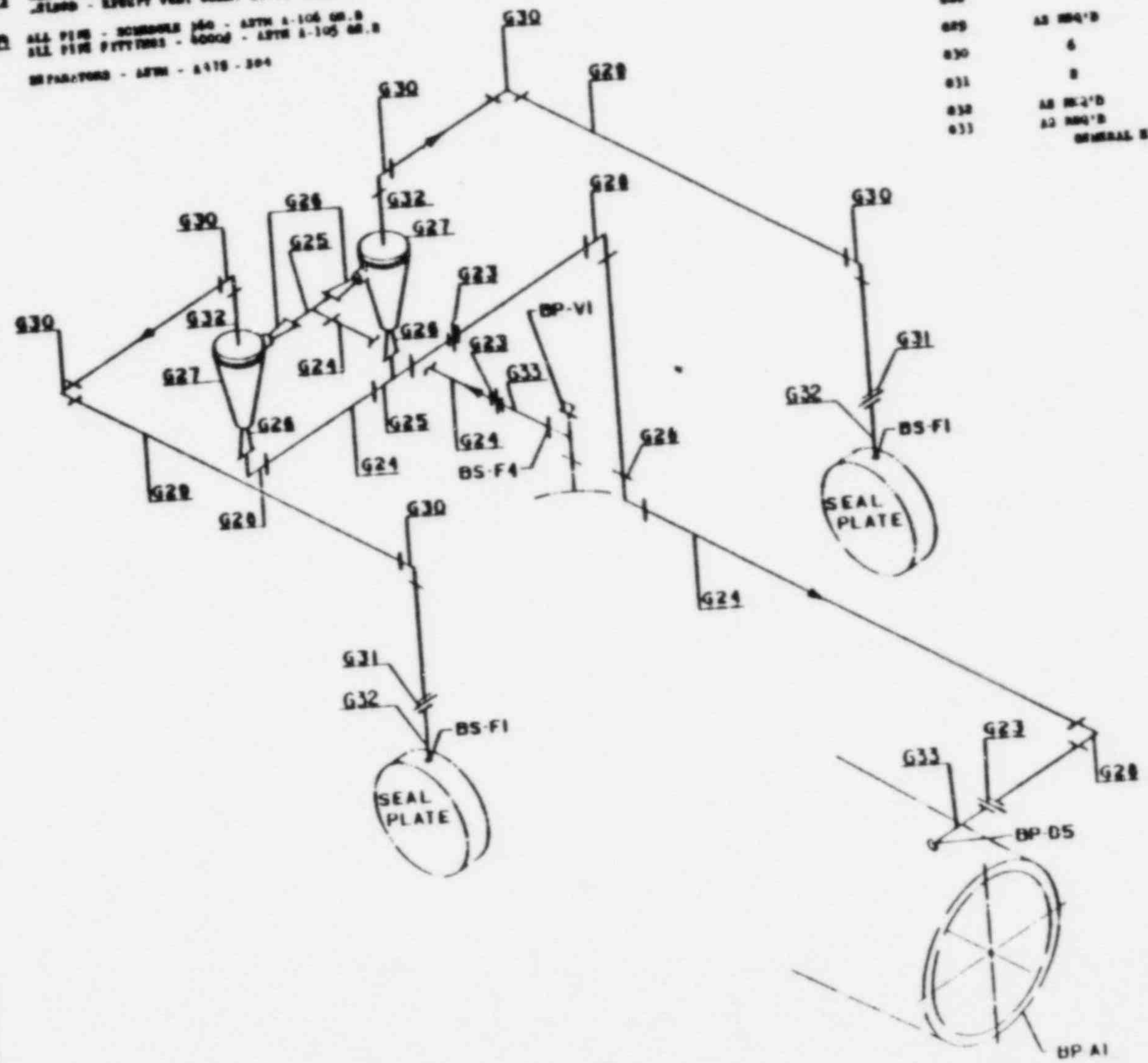
NOTE 3 ALL THREADED CONNECTIONS TO BE SEAL WELDED - EXCEPT VENT CONN. BP-V1-FLANGED

NOTE 4 ALL PIPE - SCHEDULE 160 - ASTM A-106 GR.B
ALL PIPE FITTINGS - 6000# - ASTM A-105 GR.B

SEPARATORS - ASTM - A479 - 304

ITEM NO.	NO. REQ'D	SIZE	DESCRIPTION
G23	3	3/4" S.W.	UNION
G24	AS REQ'D	3/4"	PIPE - S.T.S.
G25	8	3/4" S.W.	TEE
G26	4	3/4" x 1/2" T.O.E.	SWAGE NIPPLE
G27	2	1/2" NPT	PACIFIC "CENTRI-STRAIN" SEPARATORS
G28	4	3/4" S.W.	ELBOW X 90°
G29	AS REQ'D	1/2"	PIPE - S.T.S.
G30	6	1/2" S.W.	ELBOW X 90°
G31	2	1/2" S.W.	UNION
G32	AS REQ'D	1/2" T.O.E.	PIPE - S.T.S.
G33	AS REQ'D	3/4" T.O.E.	PIPE - S.T.S.

GENERAL ELECT. ATOMIC POWER EQUIP. DEPT.



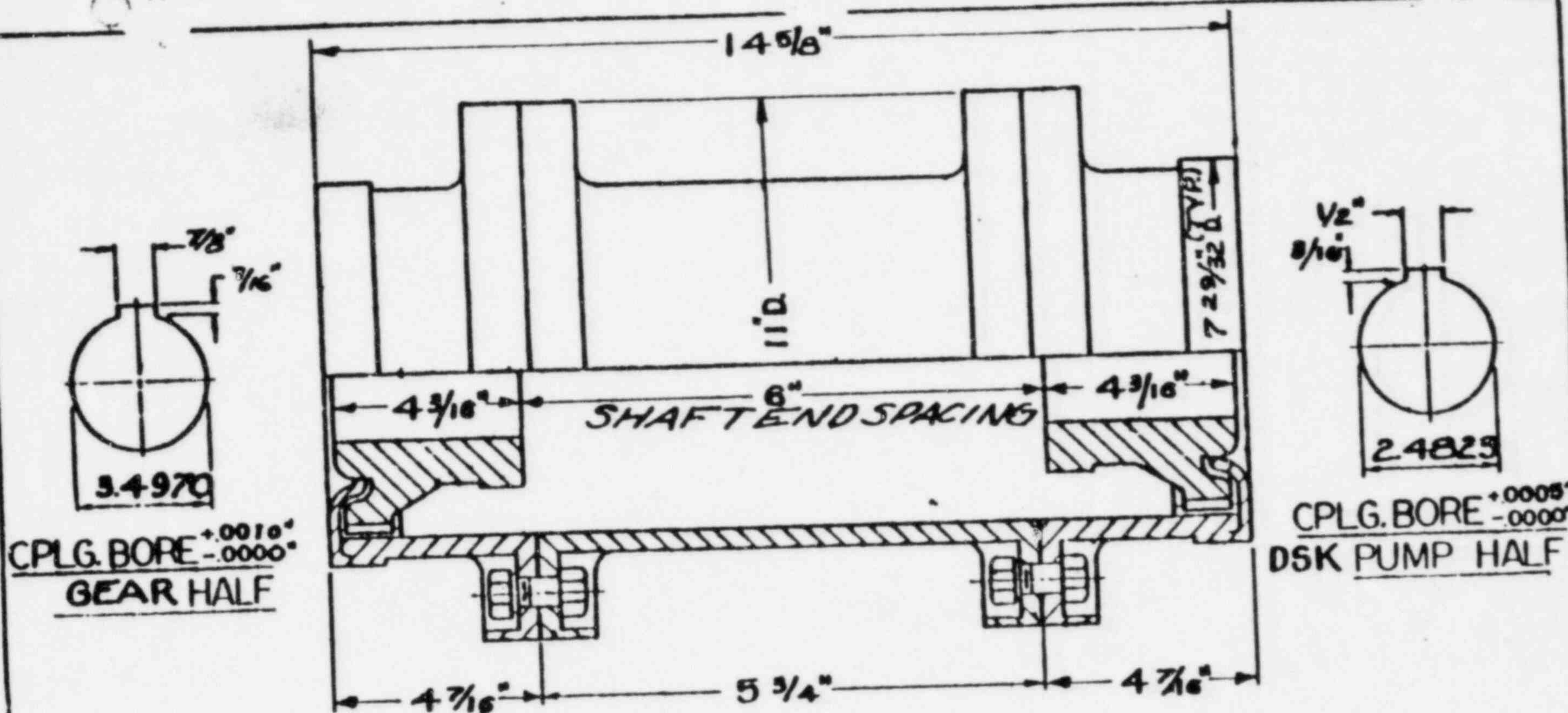
CERTIFIED CORRECT

BY [illegible] DATE [illegible]

PACIFIC PUMPS INC.
LOS ANGELES CALIF

SEAL FLUSH PIPING

CSF-457693



F40009

CPLG. TYPE - FAST STD.

CPLG. SIZE - #3 1/2"

416 H.P. 1800 R.P.M.

CERTIFIED CORRECT

BY [signature] DATE 1-14-70

REV. 1: 4-27-70
CPLG KW REVISED
TO MATCH NEW GEAR DWG
KW WAS 1" x 1/2"
& CPLG TOLL.
WERE +.0005
-.0000

PACIFIC PUMPS INC.			
COUPLING SHEET			
DWN. [initials]	CHK. COB	DATE: 1-12-70	ACB-45769

PACIFIC PUMPS TECHNICAL DATA	DATE EFFECTIVE Nov 3, 1969 DATE REVISED Feb 24, 1969	PAGE NO. 1 SECTION NO.

SUBJECT: CLEANING, PAINTING, AND PREPARATION FOR SHIPMENT

NUMBER: 102-2-0003-1

CUSTOMER APPROVAL CERTIFICATION

CUSTOMER-APPROVED G.E. DOCUMENT

APP. DATE 3-10-70

REF. NO. VPF 2740-39-2

CONTRACT AA9 52/53/58 46-694 thru

SHOP ORDER 46-701

PACIFIC PUMPS TECHNICAL DATA	DATE EFFECTIVE November 3, 1969	PAGE NO. 1 of 4
	DATE REVISED February 24, 1970	SECTION NO.

SUBJECT:

CLEANING, PAINTING, AND PREPARATION FOR SHIPMENT

NUMBER: 102-2-0003-1

1.0 PURPOSE:

1.1 To define cleaning, painting, and preparation for domestic or export shipment of pumps.

1.2 To establish acceptance criteria for Pacific Pumps Quality Control.

2.0 GENERAL:

2.1 Packaging is intended to provide protection for shipment of pumps and storage for a maximum period of twelve (12) months.

2.2 Packaging shall consist of polyethylene sheet covers, a canister of dessicant and a closed box lined with waterproof wrapping paper surrounding the complete assembly so as to reasonably avoid penetration of the polyethylene sheet covers by conventional lifting devices.

3.0 CLEANING, PAINTING AND PRESERVING:

3.1 Prior to assembly, the internal and external surfaces will be in the mechanically cleaned, blast cleaned, or pickled condition. The surfaces shall be free of dust, dirt, scale, body salts, machine cuttings and filings, grease, and oil. Blast cleaned surfaces shall be free of residual quantities of the cleaning media. All parts shall appear clean to the unaided eye.

3.2 All unpainted external surfaces will be amply coated with a petroleum based rust preventative which will maintain a protective coating for a minimum of 24 months, so long as the coating is not burned, dissolved, or mechanically rubbed off.

3.3 Internal surfaces shall be coated with a readily water-soluble corrosion inhibitor, such as a water solution mixture of one-half of one percent sodium nitrite, one-fourth of one percent mono-sodium phosphate, and one-fourth of one percent di-sodium phosphate. Using this corrosion inhibitor, customer accepts responsibility for any corrosion of pumps (30) days after shipment.

3.4 Painting -- External surfaces will be painted with Elixir 35-H-391, hammer finish (or equal). Paint is to be applied in a cross-spray pattern to obtain desired thickness.

3.5 Masking applied to glass gauges, etc., shall be left in place after painting.

3.6 External rotating shafting will be kept free of paint.

3.7 Closure of Machine Openings --

3.7.1 Immediately following the completion of shop cleaning and the application of corrosion inhibitors, all pipe ends and equipment openings shall be capped with metal or plywood caps to limit entry of foreign materials or moisture. Caps shall be securely anchored and taped in place.

4.0 PACKAGING MATERIALS:

4.1 Lumber -- All lumber used shall be sound and well seasoned to a moisture content of 12% to 18% based on the "Oven Dry" measurement method. Knots shall be sound and not in excess of one-third (1/3) the width of any board.

4.2 Cleats -- Use one inch by three inch (1" X 3") through one inch by six inch (1" x 6") nominal dimension commercial lumber. Cleats shall not be spaced more than 36" on center along the length of the box.

4.3 Skids and Runners -- Boxes with a gross weight of 100 lbs. or more shall be equipped with skids to allow four inch (4") minimum clearance for forklift tines. Where a box length is greater than ten (10) feet, four inch by four inch (4" x 4") rub strips or larger shall be used.

4.4 Nailing -- Nail sizes shall be such that there will be not less than 33% penetration of the secondary box member. Nail spacing shall not exceed two and a half inches (2-1/2") and shall be placed in a staggered pattern.

4.5 Splicing -- When splicing is necessary, splices shall be staggered -- with opposing splices located as close to the opposite ends of the box as practical. Splices may also be located at clear points with a reinforcing plate of plywood on the _ner surface of the box.

4.6 Strapping -- All boxes shall be banded with steel strapping around the container at not less than two (2) places. Straps shall be spaced approximately nine (9") inches from each end and along the length of the box so there will not be more than 24" between straps. Edge protectors shall be used.

5.0 PACKAGING PROCEDURE:

5.1 With the complete pump (and drivers when specified on purchase order) mounted on the bedplate, tape shut all bedplate grout and vent holes with fibre reinforced tape and 6 mil minimum thickness polyethylene sheeting.

5.2 Strap a 10 lb. canister of suitable dessicant to one of the pump pedestals. The canister shall be opened to allow entry of the package atmosphere after strapping in position and immediately prior to installation of the sealed polyethylene cover over the entire assembly. Premature opening of the canister will render it useless as it will become saturated with air laden moisture before the shipping and storage covers are installed. The canister must be installed in a position where it can be easily seen and replaced during storage at the job site.

5.3 Cover the entire assembly with 6 mil minimum thickness polyethylene sheet covers. With fibre reinforced tape, seal the covers (100% closed) to the inside edge of bed-plate drip rims and at all sheet joints. Reinforce the covers against wind damage by taping across the covers from each side of bedplate every three to four feet.

5.4 Export Box -- Fabricate and install a double box with export paper between, so constructed as to protect the contents from damage and from the elements (moisture, salt air, etc.). Sheathing may be composed of either lumber or plywood. If lumber is used, no board shall be less than four (4) actual inches in width. Plywood used for sheathing shall be a minimum of three-ply, not less than three-eights of an inch (3/8") thick. Consideration shall be given to stacking strength of the box as well as to support of the contents. Fiberboard and cardboard cartons are not acceptable for export shipment.

5.5 Domestic Box -- Fabricate a box so constructed as to protect the contents from damage and from the elements (moisture, salt air, etc.). Sheathing may be composed of either lumber or plywood. If lumber is used, no board shall be less than four (4) actual inches in width. Plywood used for sheathing shall be a minimum of three-ply, not less than three-eights of an inch (3/8") thick. Consideration shall be given to stacking strength of the box as well as to support of the contents.

6.0 PACKING LISTS:

6.1 Two (2) copies of the packing list, complete and accurate in all respects, shall be included with each container.

6.1.1 One (1) copy shall be placed inside the container, so located as to be visible when the container is opened.

6.1.2 One (1) copy shall be placed within a water-tight envelope and stapled to the outside of each container.

7.0 MARKING INSTRUCTIONS:

7.1 Each shipment shall be adequately identified with customer's name, and any special or additional markings specified in the purchase order.

7.2 Each crate or container which contains dessicant shall be marked as follows:

"This package contains moisture absorbing dessicant to prevent corrosion of pump components. Check once a month or as local conditions require for condition and replace with dry dessicant as necessary."

7.3 The pump and container shall also have a decal affixed, in a conspicuous place, to indicate as follows:

"Rotate pump shaft 180° every month. Reseal all entry points through plastic covers with tape immediately after inspection to prevent any possible contamination."

Units shall be shipped with coupling spacers <u>not</u> installed so as to facilitate rotation of shafts.

PREPARED BY: R. Via

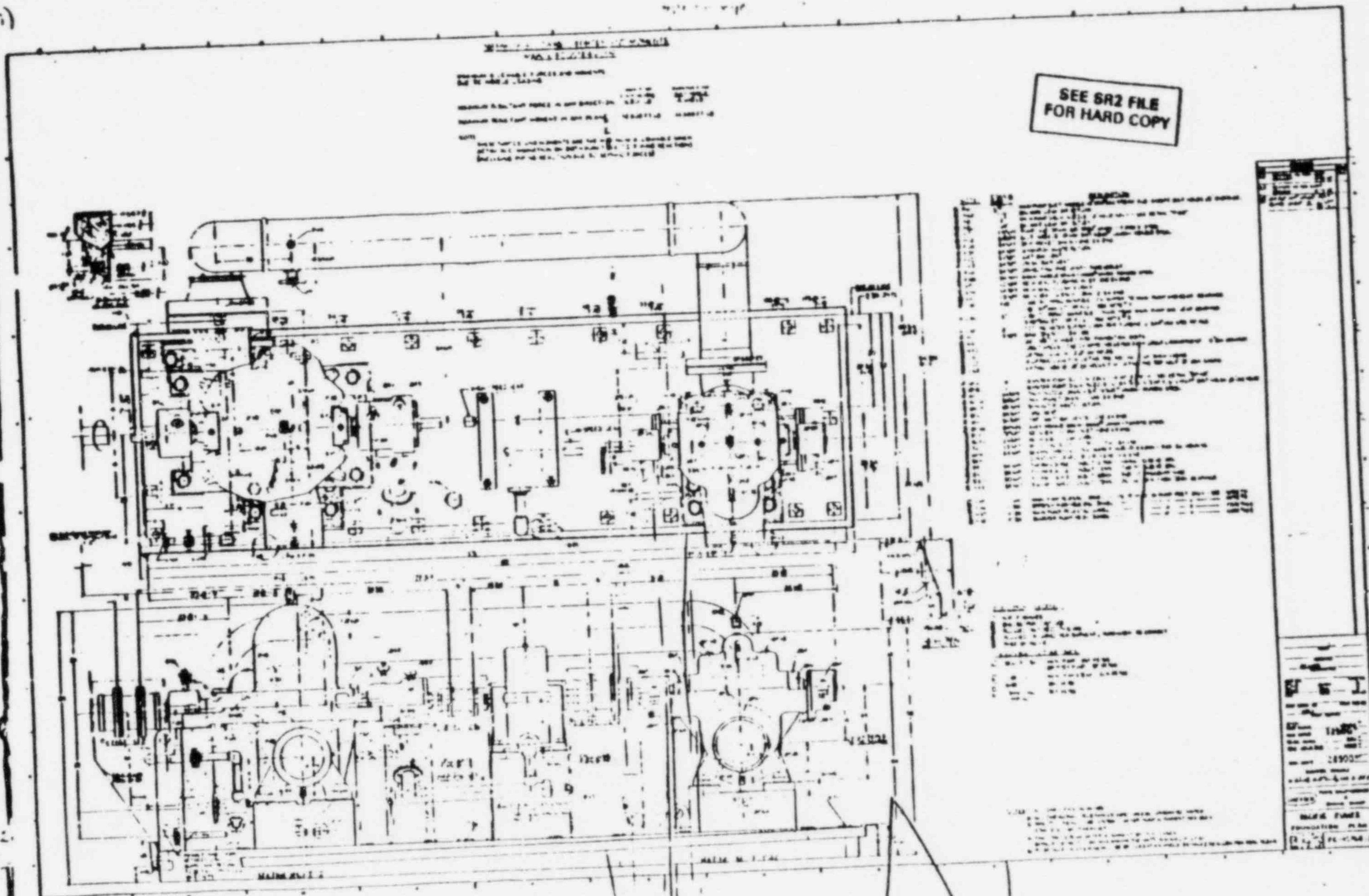
APPROVALS:

ENGINEERING D. B. Honey

QUALITY CONTROL John C. [illegible]

MANUFACTURING R. Via

PRODUCT ENG. [illegible]


SEE SR2 FILE
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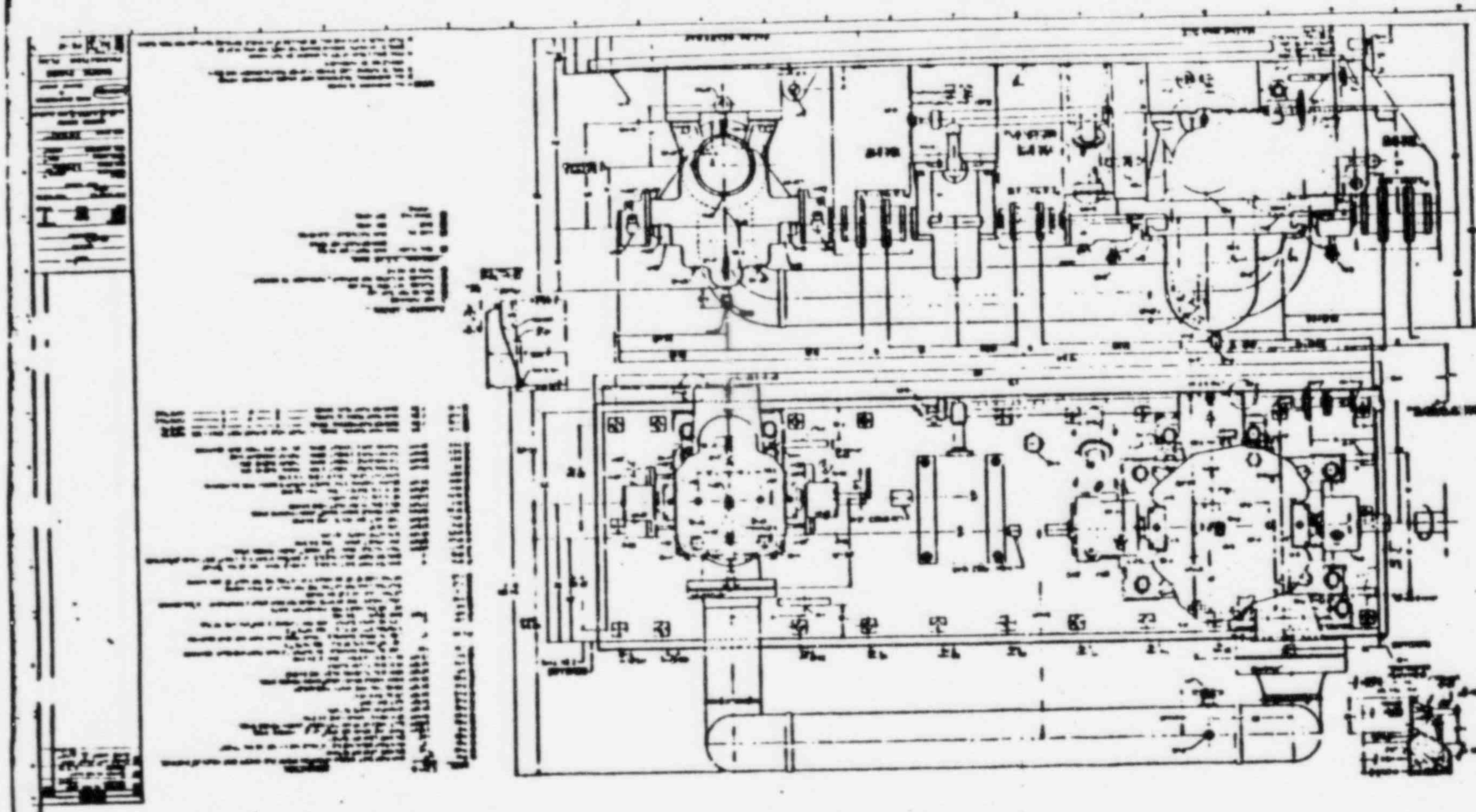

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DRESSER INDUSTRIES DRESSER PACIFIC pumps division

TECHNICAL DATA

DATE EFFECTIVE	PAGE NO.
1/12/72	1 OF 5
DATE REVISED	DOCUMENT NO.
4/25/72	LS 45768-2

SUBJECT:

LONG TERM STORAGE INSTRUCTIONS

1.0 PURPOSE:

1.1 - TO DEFINE STORAGE, MAINTENANCE, AND INSPECTION REQUIREMENTS FOR PIPING ASSEMBLY, PUMPS AND GEARS FOR LONG TERM STORAGE UP TO FIVE (5) YEARS MAXIMUM DURATION.

NOTE: INSTRUCTIONS OUTLINED IN THIS PROCEDURE SHALL BE ADHERED TO WITHIN FORTY-EIGHT (48) HOURS AFTER RECEIPT OF EQUIPMENT AT JOBSITE.

2.0 GENERAL:

2.1 - THIS EQUIPMENT IS PACKAGED IN TWO SEPARATE BOXES CONSISTING OF:

a - MAIN PUMP, GEAR, AND BOOSTER PUMP MOUNTED ON A COMMON BASE. NOTE: A SPACE HEATER IS PROVIDED FOR THIS BOX ONLY.

b - CROSS-OVER CONNECTING PIPE, COUPLING SPACERS WITH ATTACHING HARDWARE AND MISCELLANEOUS GASKETS, DOWELS, STUDS AND NUTS.

2.2 - EACH BOX OF EQUIPMENT IS PACKAGED (COMPLETELY ENCLOSED) IN ACCORDANCE WITH PACIFIC PUMPS "CLEANING, PAINTING, AND PREPARATION FOR SHIPMENT" PROCEDURE NO. 102-2-0003, PARA. 5.4, EXPORT TYPE BOXING, CONSISTING OF 1/2" THICK PLYWOOD (ALL SEAMS ARE STRIPPED), COMPLETELY LINED INSIDE WITH WEATHERPROOF EXPORT TYPE PAPER.

2.3 - THE POLYETHLENE SHEET COVER AND THE CANISTER OF DESICCANT AS REFERENCED IN PARAGRAPHS 2.2, 5.2 AND 5.3 OF PROCEDURE NO. 102-2-0003 HAVE BEEN DELETED AND AN ELECTRIC SPACE HEATER PROVIDED INSTEAD FOR THE PURPOSE OF PROVIDING AN ELEVATED TEMPERATURE INSIDE THE BOXING AND THEREBY PREVENTING CONDENSATION. NOTE: APPLICABLE TO EQUIPMENT BOX 2.1a ONLY.

3.0 SPACE HEATER (SEE GEJ-2791-CAT. NO. 2A755C230 (2 PAGES) ATTACHED)

3.1 - THE SPACE HEATER (SEE PARA 2.1a) IS MOUNTED (INSIDE OF THE BOX) ON THE PUMP BASE PLATE. THE HEATER IS AUTOMATICALLY CONTROLLED BY A THERMOSTAT. A CONTROL KNOB PROVIDES FOR TEMPERATURE SELECTION FROM (+) 50 TO (+) 95°F TEMPERATURE RANGE.

3.1.1 - JUNCTION BOX (240 VOLTS)

THE JUNCTION BOX IS EQUIPPED WITH A "RED LIGHT" TO INDICATE WHEN POWER IS AVAILABLE TO THE SPACE HEATER. THE JUNCTION BOX SHALL BE INSTALLED AS FOLLOWS: (SEE ATTACHED SKETCH #1)

SUBJECT

LONG TERM STORAGE INSTRUCTIONS

a - OPEN PUMP BOXING ACCESS HATCH DOOR (2) AND REMOVE JUNCTION BOX (3) LOCATED INSIDE LOWER LEFT SIDE OF HATCH. REMOVE WRAPPING.

b - INSTALL JUNCTION BOX (8) BY TURNING ONTO CONDUIT STUB (4) PROVIDED, AND LOCATED, ON OUTSIDE OF BOXING NEAR THE UPPER RIGHT HAND SIDE OF ACCESS HATCH.

c - CONNECT PURCHASER'S CONDUIT (10) TO JUNCTION BOX (8) AND CONNECT THE THREE LEADS (5). THE WHITE WIRE IS THE GROUND.

d - INSTALL HEATER CORD (6) 3 PRONG PLUG INTO OUTLET RECEPTACLE (LOCATED INSIDE ON UPPER RIGHT HAND SIDE OF ACCESS HATCH) AND SET HEATER CONTROL KNOB IN THE "OFF" POSITION.

e - TURN PURCHASER'S POWER SWITCH ON AND OBSERVE THAT THE CONDUIT JUNCTION BOX "RED LIGHT" (9) IS ON. IF LIGHT IS NOT ON THEN RECHECK AND CORRECT WIRING CONNECTIONS AND/OR REPLACE LIGHT BULB, AS NECESSARY.

f - ADJUST HEATER (7) CONTROL KNOB TO THE "HIGH" POSITION (+95°F) AND OBSERVE THAT THE HEATER IS OPERATING. IF NOT, THEN RECHECK ELECTRICAL CONNECTIONS AND 3 PRONG PLUG. HEATER SHOULD NOW BE OPERATING.

g - CLOSE AND SECURE ACCESS HATCH.

4.0 TARPAULIN

4.1 - ALL BOXING SHALL BE COMPLETELY COVERED (TOP & SIDES) DURING OUTDOOR STORAGE WITH A HEAVY WATERPROOF TARPAULIN WHICH IS TO BE PROVIDED AND MAINTAINED IN GOOD CONDITION BY THOSE RESPONSIBLE FOR STORING THE EQUIPMENT. THE BOXES MAY BE COVERED INDIVIDUALLY OR COLLECTIVELY AT RESPONSIBLE PARTY'S OPTION. THE TARPAULIN MUST BE PITCHED IN A MANNER TO PREVENT WATER FROM STANDING ON TOP OF THE BOXING.

4.1.1 - THE TARPAULIN COVERING FOR THE LARGER BOX (SEE PARA 2.1a) SHALL BE INSTALLED TO ALLOW THE "RED LIGHT" TO BE VISIBLE FROM OUTSIDE THE TARPAULIN.

NOTE: ENTIRE BOX(S) SHALL BE SUPPORTED, AT A MAXIMUM OF FOUR (4) FOOT INTERVALS, BY TIMBER, OR, OTHER SUITABLE DEVICES, AT A MINIMUM OF FOUR (4) INCHES ABOVE GROUND LEVEL. IT IS CRITICALLY IMPORTANT THIS FOUR (4) INCH MINIMUM BE MAINTAINED UNDER ALL CONDITIONS OF GROUND MOISTURE.

5.0 RECOMMENDED PERIODIC INSPECTIONS

5.1 PURCHASER SHALL BE RESPONSIBLE FOR ROUTINE SURVEILLANCE AND PERIODIC INSPECTION OF THE BOXING AND CONTENTS FOR ANY SIGNS OF DETERIORATION. BOXING SHALL BE MAINTAINED (REPAIRED OR REPLACED) AS NECESSARY TO PREVENT WATER DAMAGE TO THE EQUIPMENT. (SEE PARAGRAPH 2.2 OF THIS DOCUMENT FOR BOXING REQUIREMENTS). CONTENTS SHALL BE INSPECTED, CLEANED AND ADDITIONAL PRESERVATIVE ADDED AS DESCRIBED BELOW.

5.2 MONTHLY INSPECTION

5.2.1 PUMPS AND GEAR (SEE PARA 2.1a)

a VISUALLY INSPECT PUMPS AND GEAR FOR ANY SIGN OF PRESERVATIVE HAVING BEEN RUBBED OFF OF EXTERNAL UNPAINTED SURFACES SUCH AS THE SHAFT AND COUPLING HUBS AND FLANGES. WIRE BRUSH AND/OR SOLVENT CLEAN ANY AREAS SHOWING SIGNS OF CORROSION AND APPLY A NON-OXIDIZING TYPE PRESERVATIVE SUCH AS:

DEARBORN CHEMICAL CO.
A SPECIAL WW
NO OXIDE GREASE

b ROTATE EACH PUMP SHAFT 180° (1/2 TURN) EVERY MONTH. EXERCISE CARE NOT TO DAMAGE SHAFT OR COUPLINGS WHEN ROTATING

NOTE: DO NOT ROTATE GEAR SHAFT

5.3 QUARTERLY INSPECTION

5.3.1 PUMP NOZZLES

a REMOVE NOZZLE AND FLANGE COVERS AND VISUALLY INSPECT INSIDE OF PUMP NOZZLES FOR ANY SIGN OF CORROSION. A LIGHT FILM OF CORROSION SHOULD BE NO CAUSE FOR CONCERN. HOWEVER, SHOULD THE FILM OF CORROSION APPEAR TO BE FLAKING OFF, OR, SHOWS SIGNS OF LOCALIZED ERUPTIONS, THEN IT WILL BE NECESSARY TO COMPLETELY DISMANTLE, CLEAN, ADD CORROSION INHIBITOR (SEE PARAGRAPH 3.3 OF PROCEDURE 102-2-0003-1), AND REASSEMBLE PUMPS. TO MAINTAIN WARRANTY, A PACIFIC PUMPS SERVICE REPRESENTATIVE SHALL BE CONTRACTED TO SUPERVISE THIS EVENT.

b. IF CONDITION OF NOZZLES ARE SATISFACTORY THEN REINSTALL NOZZLE AND FLANGE COVERS.

5.4 SEMI-ANNUAL INSPECTION

5.4.1 GEAR CASE

a AT EACH SIX (6) MONTH INTERVAL REMOVE INSPECTION COVER (ITEM 3, PART NO. BM84858, GEAR DWG. N800C) AND SPRAY GEAR ASSEMBLY WITH STANDARD OIL OF CALIF. "CHEVRON RUST PREVENTATIVE" OR EQUAL.

NOTE: ROTATE GEAR SHAFT ONLY ENOUGH TO COMPLETELY COAT GEAR TEETH.

5.4.2 BEARINGS--MAIN PUMP

a REMOVE TOP HALF OF THRUST AND RADIAL BEARING HOUSINGS. SOLVENT CLEAN ANY AREAS SHOWING SIGNS OF CORROSION ON SHAFT, THRUST SHOES, JOURNAL BEARINGS ETC. THOROUGHLY COAT ALL PARTS WITH A MINIMUM OF 50 WEIGHT OIL AND REASSEMBLE BEARING HOUSINGS. SEE MAINTENANCE MANUAL FOR DISMANTLING AND ASSEMBLY INSTRUCTIONS.

5.4.3 BEARINGS--BOOSTER PUMP

a REMOVE BEARING HOUSING END COVERS (AND HOUSINGS IF NECESSARY) AND INSPECT FOR ANY SIGNS OF CORROSION ON SHAFT AND MISCELLANEOUS BEARING RETAINING ITEMS. SOLVENT CLEAN ANY AREAS SHOWING SIGNS OF CORROSION AND APPLY A NON-OXIDIZING TYPE PRESERVATIVE AS DEFINED IN PARAGRAPH 5.2.1 OF THIS DOCUMENT. SEE MAINTENANCE MANUAL FOR DISMANTLING AND ASSEMBLY INSTRUCTIONS.

5.4.4 LUBE OIL PIPING

a REMOVE LUBE OIL FLANGE COVERS AND INSERT SHELL OIL CO. V.P.I. 260 (OR EQUAL) CRYSTALS. THESE CRYSTALS VAPORIZE WITH TIME AND SHALL BE REPLACED AS REQUIRED.

5.4.5 CROSS-OVER CONNECTING PIPE (PARA 2.1b)

a OPEN BOXING AND REMOVE CONNECTING PIPE FLANGE COVERS AND VISUALLY INSPECT INSIDE OF PIPE. PROCEED AS INSTRUCTED IN PARAGRAPH 5.3.1 OF THIS DOCUMENT. ALSO, REPLACE DESICCANT WHICH IS ATTACHED TO FLANGE COVERS AS NECESSARY. REPLACE WITH DESICCANT SUCH AS:

W. R. GRACE CO.
80 UNIT DESICCANT
PROTEX - SORB 88
MIL D-3464D TYPE 1

LONG TERM STORAGE INSTRUCTIONS

6.0 OPERATION:

6.1 PRIOR TO ACTUAL OPERATION BOTH THE PUMPS AND GEAR SHALL BE DISASSEMBLED, VISUALLY INSPECTED, REBUILT (IF NECESSARY DUE TO CORROSION AND/OR HANDLING DAMAGE) AND REASSEMBLED AT THE DIRECTION OF THE PACIFIC PUMPS' SERVICE REPRESENTATIVE.

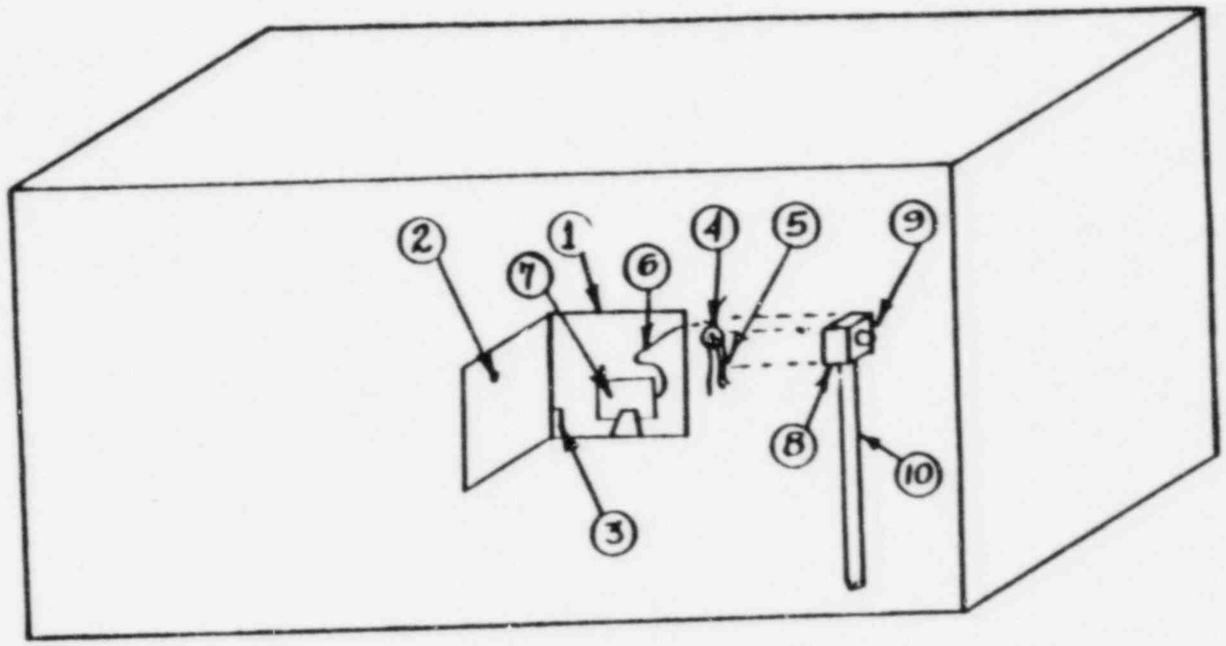
PREPARED BY: B. M. McClaskey

APPROVALS:

ENGINEERING D. B. Hong

PRODUCT ENGINEER [signature]

SERVICE MANAGER J W McCormick



(1) - ACCESS HATCH ENTRY

(2) - ACCESS HATCH DOOR

(3) - JUNCTION BOX (TEMPORARY SHIPPING LOCATION)

(4) - CONDUIT STUB

(5) - ELECTRICAL LEADS

(6) - HEATER CORD

(7) - HEATER

(8) - JUNCTION BOX

(9) - RED LIGHT

(10) - INCOMING CONDUIT (BY PURCHASER)

S-K-E-T-C-H #1

INSTRUCTIONS

AIR HEATERS

for forced-convection air heating

PORTABLE STYLE

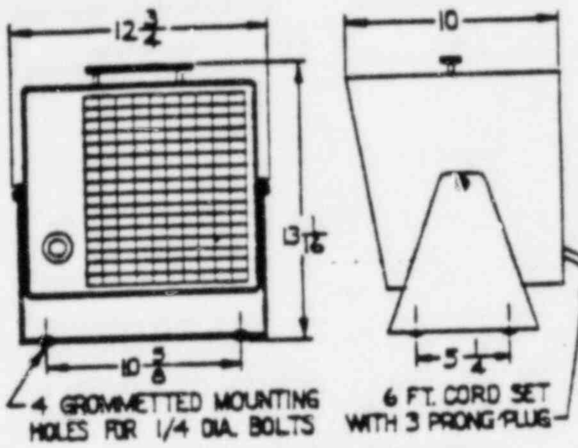


Fig. 1. Outline Dimensions

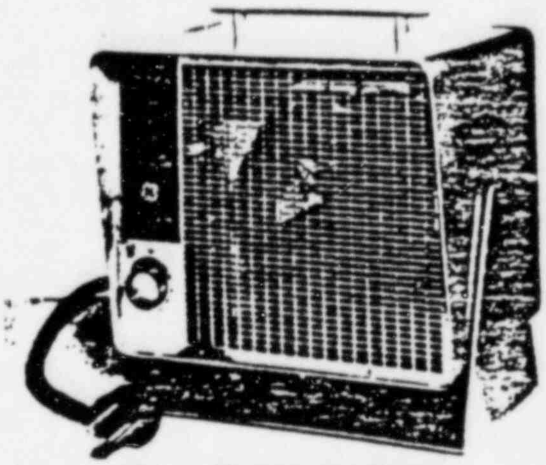


Fig. 2. Portable Air Heater

CATALOG NUMBER	ELECTRICAL RATING	HEATER CONTROL	WIRING DIAGRAM (NEXT PAGE)	SUGGESTED OUTLET RECEPTACLE
2A755A116	1650W, 120V, 50/60 cycles	External	1	GE4064-1
2A755B320	2000W, 208V, 50/60 cycles	Manual	2	GE4069-1
2A755B220	2000W, 240V, 50/60 cycles	Manual	2	
2A755B330	3000W, 208V, 50/60 cycles	Manual	2	
2A755C330	3000W, 208V, 50/60 cycles	Automatic	3	
2A755B230	3000W, 240V, 50/60 cycles	Manual	2	
2A755C230	3000W, 240V, 50/60 cycles	Automatic	3	
2A755A340	4000W, 208V, 50/60 cycles	External	1	GE4124-1
2A755C340	4000W, 208V, 50/60 cycles	Automatic	3	
2A755A240	4000W, 240V, 50/60 cycles	External	1	
2A755C240	4000W, 240V, 50/60 cycles	Automatic	3	
2A755A248	4800W, 240V, 50/60 cycles	External	1	GE4132-3
2A755C248	4800W, 240V, 50/60 cycles	Automatic	3	

DESCRIPTION

The General Electric Heater units above are the same in physical appearance and are contained in the same size housing. See the nameplate for data pertinent to the unit.

The complete device consists of a G-E Calrod tubular heating unit; a pressure-type fan; a G-E totally-enclosed impedance-protected motor; and a thermal cutout for protection against overheating.

The component parts are mounted within a heavy-gauge steel housing supported by a formed steel base. Housing and base are finished with baked enamel. Each unit is equipped with Type HS insulated cordset and standard UL-listed 3-prong plug.

As indicated in the table above, some units have no integral temperature controls and should be connected to EXTERNAL control devices; some are equipped with 3-position switch for MANUAL control; and some contain a thermostat for AUTOMATIC control.

CONTRACTOR Genl Al Electric A.P.E.D.

CUSTOMER Long Island Lighting Co.

ITEM NO. ______ P.O. AI-958

IMPELLER PATTERN D-2673 —

MAXIMUM DIAMETER 17 —

RATED DIAMETER 17 —

MINIMUM DIAMETER 14 —

TEST PERFORMANCE CURVE NO. 34695

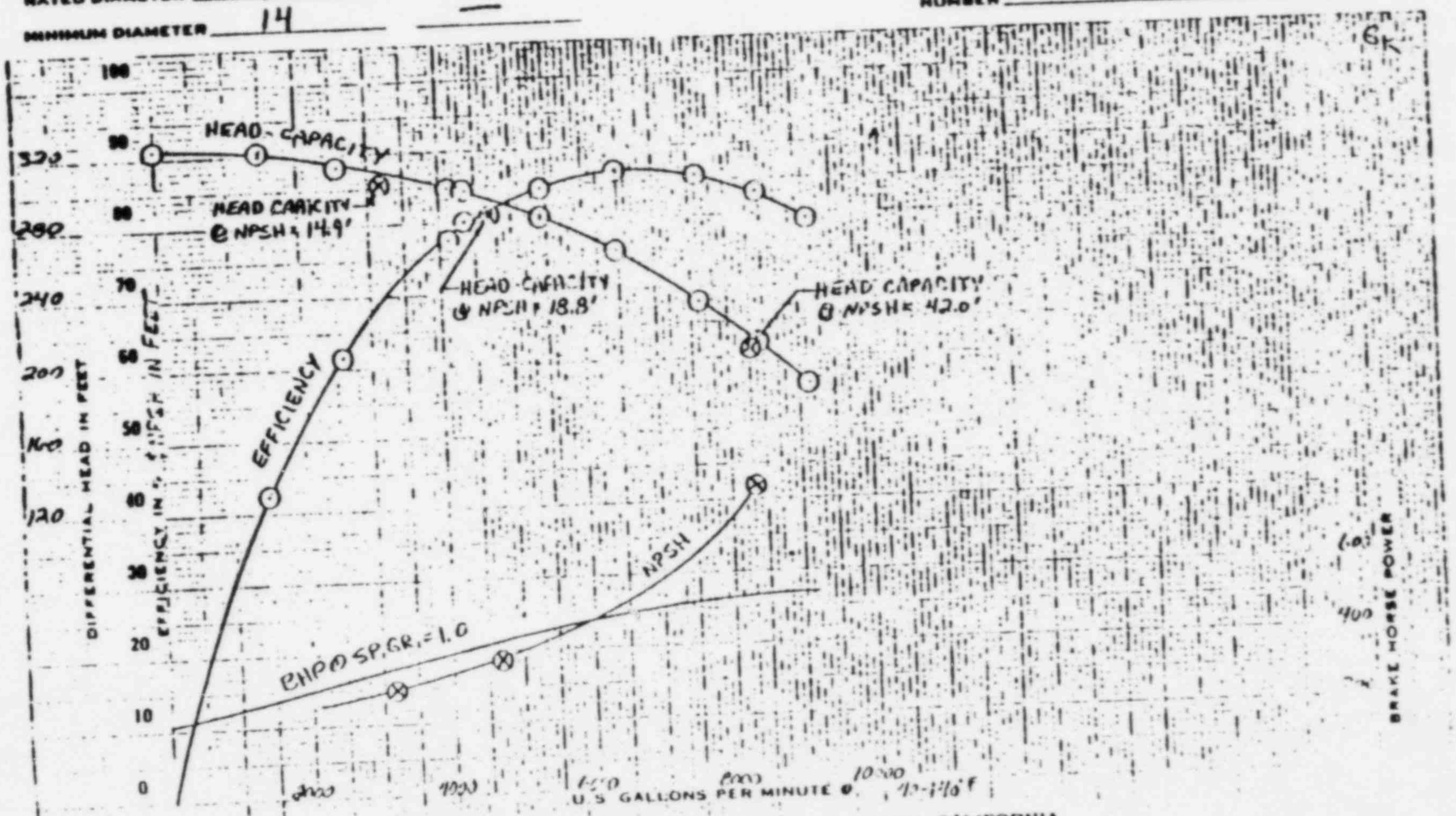
SIZE 12X17 TYPE DSK STAGES 1

R.P.M. 1800 DATE 2 NOV 1971

PUMP NUMBER 45769

PERFORMANCE ALSO APPLIES TO PUMP

NUMBER —



PACIFIC PUMPS. HUNTINGTON PARK, CALIFORNIA

PACIFIC PUMPS, HUNTINGTON PARK — PUMP TEST DATA — TEST CURVE NO.

Size 12x17	Type DSK	Stages 1	
P.P.I. Order No. P4-2195	Serial No. 4572		

	GPM	T.D. Head	EFF	NPSH	SP. GR.	RPM
Field Speed	4250	300	79	21	1.0	1800
Test Speed	4200	294	—	—	—	1780

	[illegible]	Radial Impeller
No.	D-2679	—
Test Dia.	17	—
Final Dia.	17	—

Clearances: Wear Ring .020; Spacer Slv. —; Gland Seal —

Case Mat'l: Carbon Steel

Impeller Mat'l: Bronze

Barometer: 30.00 in. Hg.

Suppression Test: Closed @ in. Hg.

Contractor: [illegible]

Customer: [illegible]

Customer's Order No. [illegible]

Item No. — Job/Req. No.

Tested By: BK For P.P.I.

Witnessed By: [illegible]

Driven: HP. - Pole 3ϕ - 60 Cy. - No.

Item No.	No. of Reading	1	2	3	4	5	6	7	8	9	10	11	12
1	Time												
2	R.P.M.	[illegible]											
3	Wattmeter	.394	.520	.517	.504	.476	.440	[illegible]	.321	.269	.210		
4	K. W. Input	315.2	416.0	413.6	403.2	380.8	352.0	308.8	256.8	214.?	168.0		
5	B.H.P. Output												
6	Wattmeter												
7	K. W. Input												
8	B.H.P. Output												
9	Total B.H.P. Output	395	522	513	505	475	442	387	320	266	206		
10	Discharge Gage	147	85	97	110	126	136	147	[illegible]	159	160		
11	Dis. Press. - P.S.I.												
12	Suction Gage	21.5	30.0	10.0	12.5	16.0	17.0	21.0	23.5	[illegible]	[illegible]		
13	Suction Press. P.S.I.												
14	Diff. Press. P.S.I.	125.5	77.0	87.0	97.5	110.0	111.0	126.0	132.5	135.7	136.5		
15	Test Water Temp. °F.	67	63	63	64	69	70	70	71	71	72		
16	Sp. Gr. of Water	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	.999		
17	Diff. Head - Ft.	290	178	201	225	254	275	291	306	314	316		
18	Diff. Vel. Hd. - Ft.	.8	3.4	2.9	2.3	1.7	1.2	.7	.3	.1	0		
19	Diff. Gage Elev. - Ft.	0	0	0	0	0	0	0	0	0	0		
20	Total Head - Ft.	291	181	204	227	256	276	292	306	314	316		
21	Flow Indication	4.15	18.3	15.6	12.7	9.2	6.4	3.7	[illegible]	.15	0		
22	Range Multiplier												
23	G.P.M.	4310	9050	8350	7540	6410	5350	4070	2550	1420	0		
24	Efficiency - %	80.1	79.3	83.1	85.6	86.7	84.3	77.6	61.6	42.3	0		

Characteristic Curve Conditions @ 1800 R.P.M. @ 1.0 Sp. Gr.

Item No.		1	2	3	4	5	6	7	8	9	10	11	12
25	G.P.M.	4360	9150	8450	7620	6490	5410	4120	2580	1430	0		
26	Total Head - Ft.	298	185	207	232	262	282	299	313	322	324		
27	B.H.P.	407	541	536	523	495	457	401	[illegible]	[illegible]	313		

Test Equipment & Calib. Nos.

Date of Test [illegible]

Hasler Tachometer [illegible]

Weston No. [illegible]

Wattmeter Ratio [illegible] To 1

Calib. Curve No.

Weston No.

Wattmeter Ratio To 1

Calib. Curve No.

Test Gage No. [illegible]

Calib. Curve No.

Test Gage No. C-1

Calib. Curve No.

M.H.B. Thermocouple / L. & N. Microjax

Curve No. 153 Rev.

Curve No. 12x14 4950

Pressure Test 0 Ft. Suppression Test 0 Ft.

Venturi Meter Size: [illegible]

GPM = 115 √ΔP

Remarks:

PACIFIC PUMPS, HUNTINGTON PARK, CA — PUMP TEST DATA — TEST CURVE NO. [illegible]

Size: 12x17 Type DSK Stages 1

P.P.I. Order No. D46695 Serial No. 45761

		Radial Impeller
No.	D-2678	—
Test Dia.	17	—
Final Dia.	17	—

	Guarant. GPM	GPM	T.D. Head	Eff	NPSH	Sp. Gr.
Field Speed	1800	4700	301	77	21	1.0
Test Speed	1780	4800	294	—	—	—

Clearances: Wear Ring .020; Spacer Sly. —; Drum Seal —

Case Mat'l: Carbon Steel

Impeller Mat'l: Bronze

Barometer: 30.03 in. Hg.

Suppression Test: Closed @ 11.4 in. Hg.

Contractor: [illegible]

Customer: [illegible]

Customer's Order No. [illegible]

Item No. — Job/Req. No.

Tested by: GK — For P.P.I.

Witnessed by: [illegible] 11-[illegible]

Driven: 300 HP; Pole 3Ø - 60 Cy. - No.

Item No.	No. of Reading	1	2	3	4	5	6	7	8	9	10	11	12
1	Time												
2	R.P.M.	1780											
3	Wattmeter	NPSH	35.4							16.6			
4	K. W. Input	Hv	5.7							1.0			
5	B.H.P. Output	NPSHR	41.1							18.4			
6	Wattmeter	NPSHR	42.0	@1800 RPM						18.3			
7	K. W. Input												
8	B.H.P. Output												
9	Total B.H.P. Output		*										
10	Discharge Gage	89	86	77	73		121	119	115	112	110		
11	Dis. Press. - P.S.I.												
12	Suction Gage	3.0	1.0	1.0"	2.0"		6.0"	10.0"	13.7"	14.5"	15.3"		
13	Suction Press. P.S.I.			-.5	-1.0		-2.5	-4.9	-6.7	-7.1	-7.4		
14	Diff. Press. P.S.I.	86.0	85.0	77.5	74.0		123.5	122.9	121.7	119.1	117.4		
15	Test Water Temp. °F.	73	73	73	73		74	74	75	75	76		
16	Sp. Gr. of Water	.999	.999	.999	.999		.999	.999	.999	.999	.999		
17	Diff. Head - Ft.	199	197	179	171		286	284	282	276	272		
18	Diff. Vel. Hd. - Ft.	2.9	2.8	2.7	2.5		1.0	.9	.9	.9	.9		
19	Diff. Gage Elev. - Ft.	0	0	0	0		0	0	0	0	0		
20	Total Head - Ft.	203	200	182	174		287	285	283	277	273		
21	Flow Indication	15.5	15.2	14.4	13.8		5.2	5.0	4.9	4.8	4.7		
22	Range Multiplier												
23	G.P.M.	8340	8250	8020	7850		4820	4730	4680	4640	4590		
24	Efficiency - %												

Characteristic Curve Conditions @ 1800 R.P.M. @ 1.0 Sp. Gr.

Item No.		1	2	3	4	5	6	7	8	9	10	11	12
25	G.P.M.	8430	8340	8110	7940		4870	4790	4739	4690	4640		
26	Total Head - Ft.	207	205	186	178		294	292	290	284	279		
27	B.H.P.												

Test Equipment & Calib. Nos.

Date of Test 2 Nov '[illegible]

Hasbler Tachometer 7334

Weston No. 3148

Wattmeter Ratio 800 To 1

Calib. Curve No.

Weston No.

Wattmeter Ratio To 1

Calib. Curve No.

Test Gage No. [illegible]-1

Calib. Curve No.

Test Gage No. C-1

Calib. Curve No.

M.H.B. Thermocouple L. & N. Micromax

Curve No. 153 Rev.

14" (Suction Nozzle) 3440

Curve No. 12x14 4930

Pressure Test — Ft. Suppression Test — Ft.

Venturi-Meter

Size: 12x9

GPM = 2115 √ΔP

Remarks:

PAC 363

FORM E-3

PACIFIC PUMPS, HUNTINGTON PARK, CAL. — PUMP TEST DATA — TEST CURVE NO. [illegible]

SIZE 12x17 TYPE PSK STAGES 1

P.P.I. ORDER NO. D-16675 SERIAL NO. 45729

	RPM	GPM	T.D. HEAD	EFF	NPSH	SP. GR.
GUARANTEED PUMPING CONDITIONS — FIELD SPEED	1800	[illegible]	300	7?	21	1.0
TEST SPEED	1790	[illegible]	294			

	SUCTION IMPELLER	RADIAL IMPELLER
No.	D-2679	—
TEST DIA.	17	—
FINAL DIA.	17	—

CLEARANCES: WEAR RING .020; SPACER SLV. —; DRUM SEAL —

CASE MAT'L: [illegible]

IMPELLER MAT'L: BRONZE

BAROMETER: 30.0? IN HG

SUPPRESSION TEST: CLOSED @ 11.? IN HG

CONTRACTOR: [illegible]

CUSTOMER: [illegible]

CUSTOMER'S ORDER NO.: [illegible]

ITEM NO. JOB/REQ. NO.

TESTED BY: [illegible] FOR P.P.I.

WITNESSED BY: [illegible]

DRIVER: [illegible] HP. POLE 3φ - 60 CY. - NO.

ITEM NO.	NO. OF READING	1	2	3	4	5	6	7	8	9	10	11	12
1	TIME												
2	R.P.M.	1790											
3	WATTMETER	NPSH		13.7									
4	K. W. INPUT	H1		.8									
5	B.H.P. OUTPUT	NPSHR		14.5									
6	WATTMETER	NPSHR		14.8	@ 1800 RPM								
7	K. W. INPUT												
8	B.H.P. OUTPUT												
9	TOTAL B.H.P. OUTPUT												
10	DISCHARGE GAGE	124	120	119	116	112							
11	DIS. PRESS. - P.S.I.												
12	SUCTION GAGE	13.2"	12.0"	11.0"	10.0	[illegible]							
13	SUCTION PRESS. P.S.I.	-4.5	-7.9	-8.3	-8.8	-9.1							
14	DIFF. PRESS. P.S.I.	130.5	127.9	127.3	124.8	121.1							
15	TEST WATER TEMP. °F.	76	76	76	76	77							
16	SP. GR. OF WATER	.999	.999	.999	.999	.999							
17	DIFF. HEAD - FT.	302	296	295	289	280							
18	DIFF. VEL. HD. - FT.	.4	.4	.4	.4	.4							
19	DIFF. GAGE ELEV. - FT.	0	0	0	0	0							
20	TOTAL HEAD - FT.	302	296	295	289	280							
21	FLOW INDICATION	2.25	2.20	2.20	2.20	2.15							
22	RANGE MULTIPLIER												
23	G.P.M.	3170	3140	3140	3110	3100							
24	EFFICIENCY - %												

CHARACTERISTIC CURVE CONDITIONS @ 1800 R.P.M. & 1.0 SP. GR.

ITEM NO.		1	2	3	4	5	6	7	8	9	10	11	12
25	G.P.M.	3205	3175	3175	3125	3135							
26	TOTAL HEAD - FT.	309	303	302	296	286							
27	D.H.P.												

TEST EQUIPMENT & CALIB. NOS.

DATE OF TEST [illegible]

HASSLER TACHOMETER [illegible]

WESTON NO. 3148

WATTMETER RATIO [illegible] TO 1

CALIB. CURVE NO.

WESTON NO.

WATTMETER RATIO TO 1

CALIB. CURVE NO.

TEST GAGE NO. [illegible]

CALIB. CURVE NO.

TEST GAGE NO. C-4

CALIB. CURVE NO.

M.H.B. THERMOCOUPLE L. & N. MICROMAX

CURVE NO. 153 REV.

14" (SUCTION NOZZLE) 3480

CURVE NO. 13.14 4830

PRESSURE TEST = FT. SUPPRESSION TEST 12 FT.

SIZE: 12 x 8 VENTURI METER

GPM = 2115 √Δh

REMARKS:

Rev.1

COMBINED CURVE PREPARATION DATA

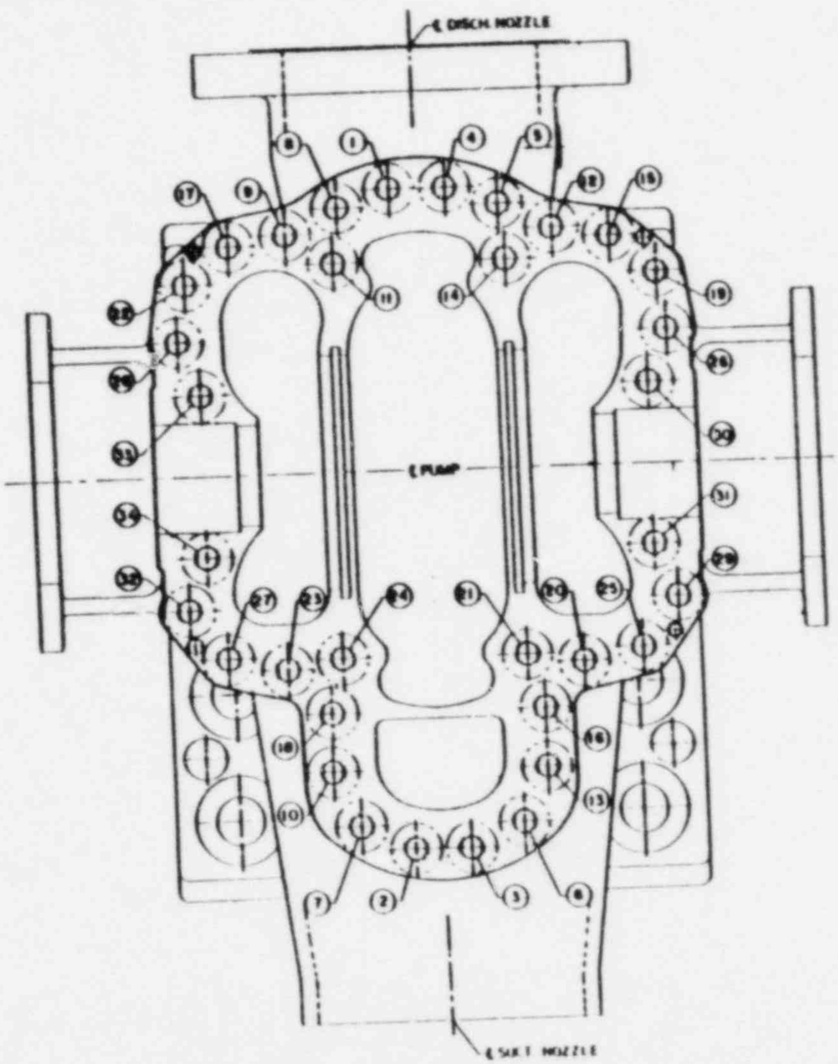
CUSTOMER: LONG ISLAND LIGHTING CO
CONTRACTOR: GENERAL ELECTRIC A.P.E.D
PURCHASER ORDER: 9H-958
DTAL NO.:
DATE: 11-22-71

MAIN PUMP
TYPE: 12x17 RHCN
ORDER NO.: J-46694
SERIAL NO.: 45769
TEST CURVE NO.: 39694

BOOSTER PUMP
TYPE: [illegible]
ORDER NO.: [illegible]
SERIAL NO.: [illegible]
TEST CURVE NO.: [illegible]

SEE SR2 FILE FOR HARD COPY

		1	2	3	4	5	6
1	VARIABLE RPM	[illegible]	2600	[illegible]	[illegible]	[illegible]	[illegible]
2	CONSTANT GPM @ 4250	[illegible]	4250	[illegible]	[illegible]	1150	[illegible]
3	EQUIV. GPM @ TEST RPM	[illegible]	1500	[illegible]	[illegible]	2505	[illegible]
4	HEAD @ EQUIV. GPM	[illegible]	2200	2585	[illegible]	[illegible]	3110
5	HEAD @ VARIABLE RPM	[illegible]	750	[illegible]	[illegible]	[illegible]	[illegible]
6	BHP @ EQUIV. GPM	[illegible]	4250	[illegible]	[illegible]	[illegible]	[illegible]
7	BHP @ VARIABLE RPM	[illegible]	1217	[illegible]	[illegible]	[illegible]	[illegible]
8	NPSH @ EQUIV. GPM	184	111	83	68	59	54
9	NPSH @ VARIABLE RPM	50.8	46.9	44.9	220	110	[illegible]
10	CONSTANT GPM @ 4350	4350	4350	4350	4350	[illegible]	4350
11	EQUIV. GPM @ TEST RPM [illegible]	[illegible]	6100	5210	[illegible]	[illegible]	3780
12	HEAD @ EQUIV. GPM	[illegible]	253	[illegible]	271	278	304
13	HEAD @ VARIABLE RPM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	385
14	BHP @ EQUIV. GPM	550	200	[illegible]	155	[illegible]	5650
15	BHP @ VARIABLE RPM	[illegible]	1372	[illegible]	[illegible]	420	92.5
16	BOOSTER GEAR EFF.	92.5	92.5	[illegible]	[illegible]	[illegible]	[illegible]
17	GEAR INPUT BHP @ VAR. RPM	[illegible]	[illegible]	222.0	[illegible]	[illegible]	16.3
18	NPSH @ EQUIV. GPM	41.5	21.5	[illegible]	19.5	11.1	21.5
19	NPSH @ VARIABLE RPM	[illegible]	11.6	[illegible]	15.0	28.6	[illegible]
20	OVERALL GPM	4250	4250	4250	4250	4250	4250
21	TOTAL HEAD	[illegible]	[illegible]	1591	2248	[illegible]	3512
22	TOTAL BHP	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]



NOTE: 1. TORQUE LOAD FOR 1 1/8"-12N CAPNUT IS 400 FT. LBS.

2. NUMBERS SHOWN (FROM 1 TO 34) INDICATE THE TIGHTENING SEQUENCE OF CASE PARTING FLANGE BOLTING.

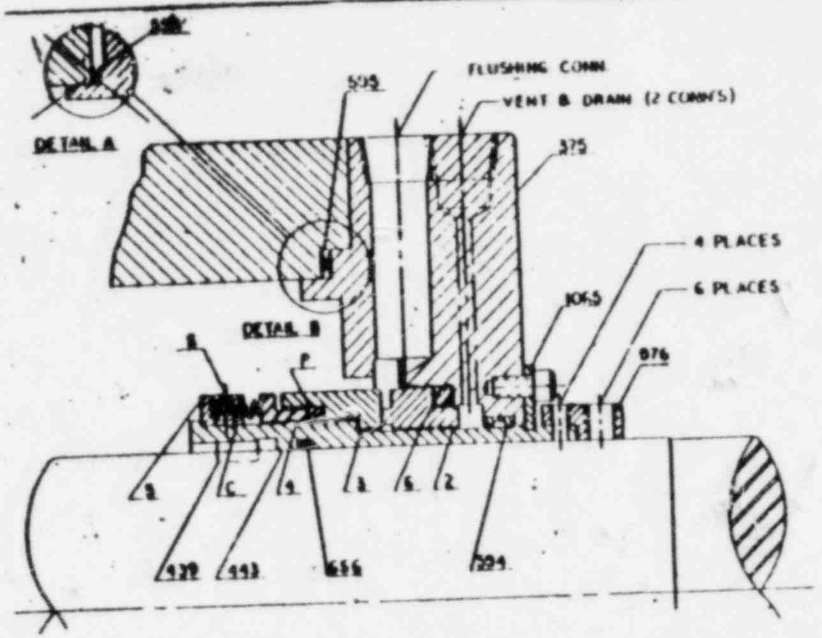
3. INDIVIDUAL NUTS AND BOLTS TO BE TIGHTENED IN A SERIES OF 2 PROGRESSIVE STEPS OF 75% AND 100% OF FINAL TORQUE LOAD.

4. NUT AND BOLT THREAD LUBRICANT SHALL BE "NEOLUBE" WHICH IS MANUFACTURED BY:
HURON INDUSTRIES
P.O. BOX 104
PORT HURON, MICH
THOROUGHLY LUBRICATE ALL STUD THREADS AND FACES OF ALL CAPNUTS

CERTIFIED CORRECT

PACIFIC PUMPS

BOLTING SEQUENCE



[illegible] PUMP SEAL PARTS

PART #	[illegible]	NAME OF PART	MATERIALS
375		SEAL PLATE	ASTM A [illegible]
[illegible]		SHAFT SLEEVE	ASTM A-276 [illegible]
[illegible]		SEAL PLATE BUSHING	ASTM B-145-4A
[illegible]		SEAL PLATE GASKET	BY CAP
[illegible]		SHAFT SLEEVE "O" RING	BY CAP
[illegible]		SHAFT SLEEVE COLLAR	ASTM A276 TP416 - NOTE A
1065		RETAINER PLATE	ASTM A276 TP416 - NOTE A
①450		SHAFT SLEEVE KEY	ASTM A276 TP410 - NOTE A

NOTE: A - LESS THAN 30 RC

[illegible] SEAL PARTS

PART NO.	[illegible]	NAME OF PART	MATERIALS
[illegible]		INSERT	CARBON
[illegible]		SEAL RING	TUNG. CARB. "N"
[illegible]		COMPRESSION RING	AISI 316
[illegible]		COLLAR	AISI 316
① [illegible]		INSERT "O" RING	BUNA N
C	[illegible]	SPRINGS	CARPENTER #20
① P	[illegible]	SEAL "O" RING	BUNA N
S	[illegible]	SET SCREWS	CARPENTER #20

NOTE: QUANTITIES SHOWN ARE FOR EACH SEAL ASSEMBLY.

REV NO	DESCRIPTION
01	DETAIL A
02	DETAIL B

CERTIFIED CORRECT
BY [signature] DATE 12-12-69

Main
DURAMETALLIC RO - SIZE 4.500

PACIFIC PUMPS INC.
SEAL ASSEMBLY
C15962

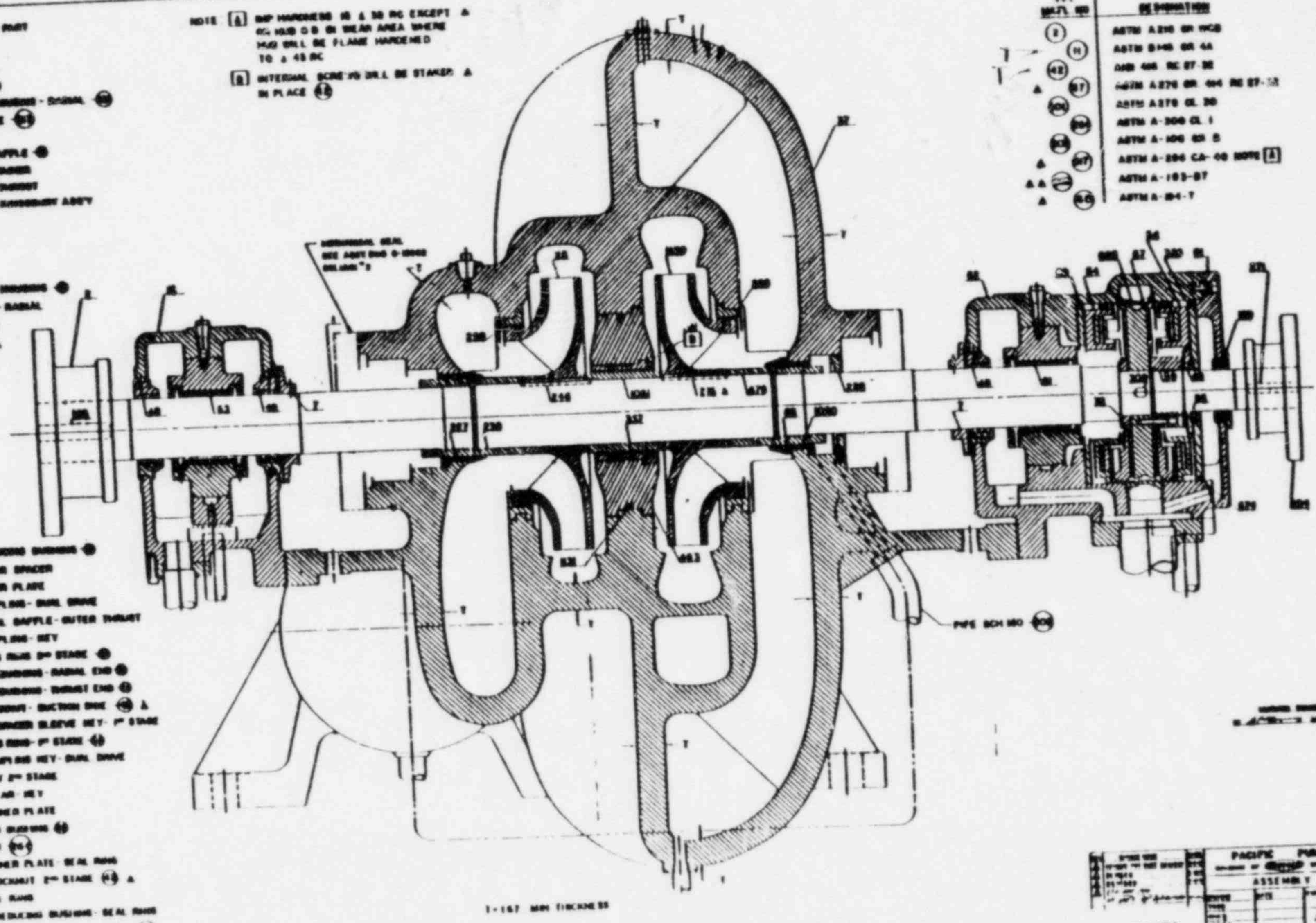
5346-698

NO	NAME OF PART
1	PUMP SHAFT
2	FLEXIBLE COUPLING
7	DEFLECTOR RING
13	SLEEVE BEARING HOUSING - RADIAL
20	IMPELLER - 1ST STAGE
37	CASE
48	STATIONARY OIL BAFFLE
49	OIL SEAL RING RETAINER
50	BEARING SLEEVE - THRUST
54	THRUST BEARING - KINGSBURY ASS'Y
56	OIL SEAL RING
57	THRUST COLLAR
59	THRUST NUT
61	END COVER
62	THRUST BEARING HOUSING
63	BEARING SLEEVE - RADIAL
	CASE STUDS
	STUD CAP
66	PRESSURE REDUCING BUSHING
76	THRUST COLLAR SPACER
90	INNER RETAINER PLATE
104	FLEXIBLE COUPLING - DUAL DRIVE
129	STATIONARY OIL BAFFLE - OUTER THRUST
166	FLEXIBLE COUPLING - KEY
210	CASE WEARING RING 2ND STAGE
217	PACKING BOX BUSHING - RADIAL END
220	PACKING BOX BUSHING - THRUST END
236	IMPELLER LOCKNUT - SUCTION SIDE
246	IMPELLER & SPACER SLEEVE KEY - 1ST STAGE
250	CASE WEARING RING - 1ST STAGE
271	FLEXIBLE COUPLING KEY - DUAL DRIVE
296	IMPELLER KEY 2ND STAGE
309	THRUST COLLAR - KEY
326	OUTER RETAINER PLATE
337	CASE SPACER BUSHING
463	CASE SPACER
674	OUTER RETAINER PLATE - SEAL RING
679	IMPELLER LOCKNUT 2ND STAGE
883	OIL CONTROL RING
1060	PRESSURE REDUCING BUSHING - SEAL RING
1061	IMPELLER SPACER SLEEVE - CENTER
1131	CASE SPACER 'O' RING
1150	IMPELLER 2ND STAGE

NOTE: [A] IMP HARDNESS 18 & 30 RC EXCEPT & OG HUB O.D. IN WEAR AREA WHERE HUB WILL BE FLAME HARDENED TO & 45 RC

[B] INTERNAL SCREWS WILL BE STAKED IN PLACE

PPI MAT'L NO	DESIGNATION
2	ASTM A216 GR WCB
11	ASTM B148 GR 4A
42	AISI 416 RC 27-32
87	ASTM A276 GR 404 RC 27-32
100	ASTM A276 CL 30
204	ASTM A-300 CL 1
212	ASTM A-106 GR B
217	ASTM A-296 CA-40 NOTE [A]
	ASTM A-193-B7
	ASTM A-194-7



PACIFIC PUMPS

ASSEMBLY

J 285

PACIFIC PUMPS, INC.

PARTS LIST

FOR General Electric Atomic Power Equipment

OUR ORDER NO. J46694

REQ. UNIT	TOTAL REQ'D	PART NO.	DESCRIPTION	PATTERN NO.	DRAWING NO.	LINE NO.	COLUMN NO.	MAT'L NO.	HEAT TREAT.	MISC.
1	1	1	HP 3 SHAFT W/8 JHJ KINGSBURY *		D013195		1	57	21	*
		2	COUPLING 4 FAST STD BTWN PUMP & TUR		A24119	6		11		
		2	COUPLING 2 1/2 FAST STD BTWN RHCHEGEA		A24119	6		11		
1	1	7	RING DEFLECTOR	M6371	D013197			101		
1	1	7	RING DEFLECTOR OUTER	M7297	D013197			101		
1	1	13	HOUSING RADIAL BRG UPPER HALF *	M7282	C16480	2	3	317	60	M
1	1	13	HOUSING RADIAL BEARING LOWER HALF *	M7299	D013192			2		M
1	1	28	HP 2 IMP 1ST STG RPM4000 VT 3/8	M7300	D013193			2		M
1	1	37	HP 1 CASE ELEVATION *SEE PARTL M/L					78		M
1	1	37	HP 1 CS ELE LOWER HALF SEE ITEM A18 *		A24129	6		11		
1	1	47	HP13 BASE PUMP 45768		A24129	6		11		
2	2	48	BAFFLE STATIONARY OIL 2 HALVES		A24124	3		14		
1	1	48	BAFFLE STATIONARY OIL 2 HALVES		C15171	3		277		
1	1	49	RETAINER OIL SEAL RING		LE0100	8				
1	1	51	SLEEVE THRUST BEARING 2 HALVES		A24123	4		11		
1	1	54	BEARING THRUST 8 JHJ LESS COLLAR		D14290	19		15		
1	1	55	RING OIL SEAL		A24126	1		68	16	
1	1	57	COLLAR THRUST 8 JHJ KINGSBURY		B18666			14		
1	1	59	NUT THRUST	M6373	D013198			2		
1	1	61	COVER END	M7298	D013198			2		
1	1	62	HSG THRUST BRG UPPER HALF *		C15171	3		277		
1	1	62	HSG THRUST BRG LOWER HALF *		B19046	1		11		
1	1	63	SLEEVE RADIAL BEARING 2 HALVES		B18100	15	18	14		
1	1	65	BUSH PRESSURE REDUCING		A24121			14		
1	1	76	SPACER THRUST COLLAR		A20218	11	1	14		
1	1	89	PLATE INNER RETAINER		B19047			11		
1	1	165	KEY FLEX CPLG		B19045			11		
1	1	226	WRG RING CASE 2ND STG		A60556			11		
1	1	227	BUSH PKG BOX RAD END 13 SHAFT		A60558	2		42	21	
1	1	228	BUSH PKG BOX THR END		B18259	12		23		
1	1	238	IMP LOCKNUT RAD W/CARTR SEAL		B19047			11		
2	2	246	KEY IMP SPACER SLV		A20209	7	5	23		
1	1	258	WRG RING CASE 1ST STG		A60559			42		
2	2	276	KEY IMP		A24122	3		14		
2	2	317	COLLAR SHAFT SLV		A60555			11		
1	1	326	PLATE OUTER RETAINER		D18856	99	1			
1	1	337	BUSH CASE SPACER		B18856	99	1			
		366	HOLDER UNION TCPLE ASSEMBLY		C15944			23		MI
		366	HOLDER UNION TCPLE ASSEMBLY		A22822	2		42		
2	2	375	HP4 PLATE SEAL		B19044			42	21	
2	2	439	KEY SHAFT SLV		D013196			204		
2	2	443	SLEEVE SEAL SHAFT		A60459	5		11		
1	1	463	CASE SPACER					211		
2	2	594	BUSHING SEAL PLATE					211		
* 2	2	595	GASKET 8IDX8 3/400X1/8					211		
2	2	656	O RING SHAFT SLV ARP 568 241		A60558	1		42	21	
1	1	674	SEAL RING OUTER RET PLT O RG ARP568 2					308		
1	1	676	IMP LOCKNUT THR W/CARTR SEAL					308		
3	3	695	NIPPLE EXTENSION TBE 1/2X2 LG SCH 80							
1	1	695	NIPPLE 2 LG 1/2 NPT SCH 40							

Shop Order No. J46-694
J46-696
J46-698
J46-700

PACIFIC PUMPS, INC.

PARTS LIST

Pump Serial No. 45-768
45-770
45-772
45-774

FOR:

OUR ORDER NO.

FOR UNIT	TOTAL REQ'D	PART NO.	DESCRIPTION	PATTERN NO.	DRAWING NO.	LINE NO.	COLUMN NO.	MATERIAL NO.	HEAT TREAT	PROCESS
1	1	695	NIPPLE 2 LG 1/2 NPT SCH 40					308		
3	3	806	WSHR STP CLR GRIZZLY 3/16IDX1/20DX1/4					229		
1	1	883	RING OIL CONTROL 8 KINGSBURY CCW ROIN		LE4100	8				
3	3	981	SPRING CENTURY STOCK NO 384		A31528	2				
3	3	992	FERRULE 3/16 IMPERIAL NO 760F 8					210		
6	6	993	FLAT WSHR 2 PER ASSY FOR 10 32 BOLT S					210		
3	3	1020	O RING ARP 568 008					211		
1	1	1060	O SEAL RNG PRESS RAD 5 1/2IDX5 3/40DX		LU5680	2	54	211		
1	1	1061	SLV IMP SPACER CLR .013		A60557	1		42	21	
2	2	1065	PLATE RETAINER		A21550	4		42		
1	1	1131	O RING CASE SPCR		B12574	2		211		
1	1	1150	MP2 IMP 2ND STG RPM 4000 VT AC CLR .0	M7281	C15771	2	3	317	60	MP
3	3	1214	HEAD 2 TERMINALS SINGLE		C15666	7	2	342		
1	1	1214	HEAD 2 TERMINALS SINGLE		C15678	7	2	342		
3	3	1248	ELEMENT BY PP		B16751	2	1	342		
1	1	1248	ELEMENT BY PP		B16751	2	1	342		
1	1	1304	COMPR FITTING 3/16 SWAGELOK 300 1 2BT					342		

INSTALLATION, OPERATION AND MAINTENANCE MANUAL FOR PACIFIC TYPE

RHCNDS
REACTOR FEED PUMP

This instruction manual is intended to assist in the realization of maximum service and efficiency from your Pacific Centrifugal Pump. It is important that the instructions are carefully observed for installation operation, maintenance and testing.

Pacific Centrifugal Pumps are designed by experts to give you optimum performance for the service intended. Mechanical and hydraulic features have been incorporated in the design concept to assure you of dependability, economy, and long, trouble free operation.

Pacific's reputation for superior design and construction is backed by service centers throughout the world. Spare parts and engineering assistance are available to you should you need them.

In addition to the instruction manual several supplemental documents are included when applicable, depending on the particular design characteristics of your pump. These may include the following:

- Cross Sectional Drawing
- Seal Drawing (when applicable)
- Material List
- Piping Diagrams (when applicable)
- Alternate thrust bearing arrangement (when applicable)
- Kingsley thrust bearing arrangement (when applicable)
- Foundation Plan
- Orifice drawings (when applicable)

PACIFIC PUMPS

DIVISION OF DRESSER INDUSTRIES

HUNTINGTON PARK, CALIFORNIA

OPERATING/DESIGN CONDITIONS

Main Pump

Flow	4250 GPM
Differential Head	2500 Feet
Speed	4000 RPM
Temperature of Pumpage	40-140°F
BHP @ 1.0 Sp. Gr.	3620 BHP
Max. Working Pressure, Casing	1500 PSIG
Hydrotest Pressure w/o Mechanical Seals	2250 PSIG

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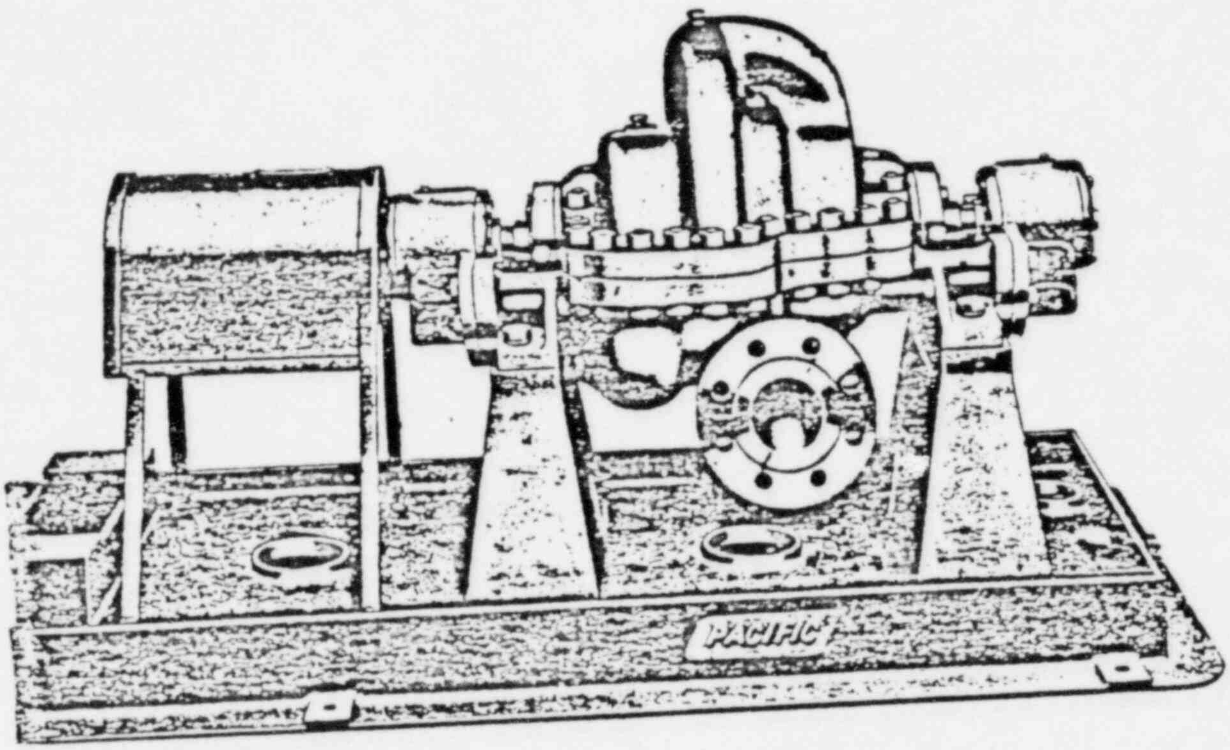


PACIFIC TYPE RHCNDS CENTRIFUGAL PUMPS

The Pacific Type RHCNDS is a horizontal pump constructed with a double volute case, axially split. The impellers may be either the single inlet or double inlet type. Suction and discharge nozzles are cast integral with the lower half pump case. Sleeve radial and Kingsbury thrust bearings are pressure lubricated.

Section I
Installation

A. LOCATION OF PUMP

1. The pump should be located as near to the liquid source as possible.

2. Head room should be provided for the use of hoisting equipment.

3. The unit should be accessible for inspection during operation.

4. It is necessary for satisfactory operation that sufficient net positive suction head (NPSH) be available at the pump suction flange. (Net positive suction head is the total head in feet absolute, determined at the suction nozzle and referred to datum, less the vapor pressure of the liquid in feet absolute.)

B. FOUNDATION (See Fig. 1)

Concrete foundations built on solid ground are the most satisfactory. Foundation bolts of the specified size should be located as shown on the foundation drawing. It is recommended that each bolt be fitted with a pipe sleeve approximately three diameters larger than the bolt and with a washer to support the head of the bolt in the sleeve. After the concrete is poured, the pipe sleeves remain in place while the bolts may be shifted for alignment with the holes in the baseplate.

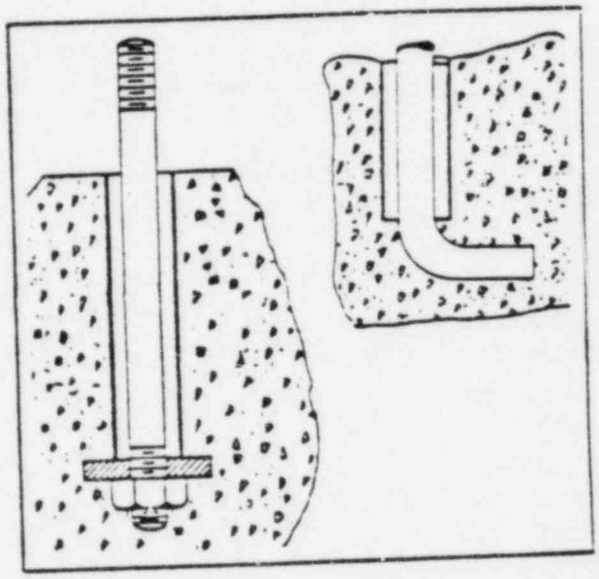


Fig. 1

C. LEVELING BASEPLATE (See Fig. 2)

1. Locate leveling plates and shims on both sides of each foundation bolt and in the center at the pump end of the baseplate. Allow a minimum of one inch between the baseplate and the foundation for grouting.

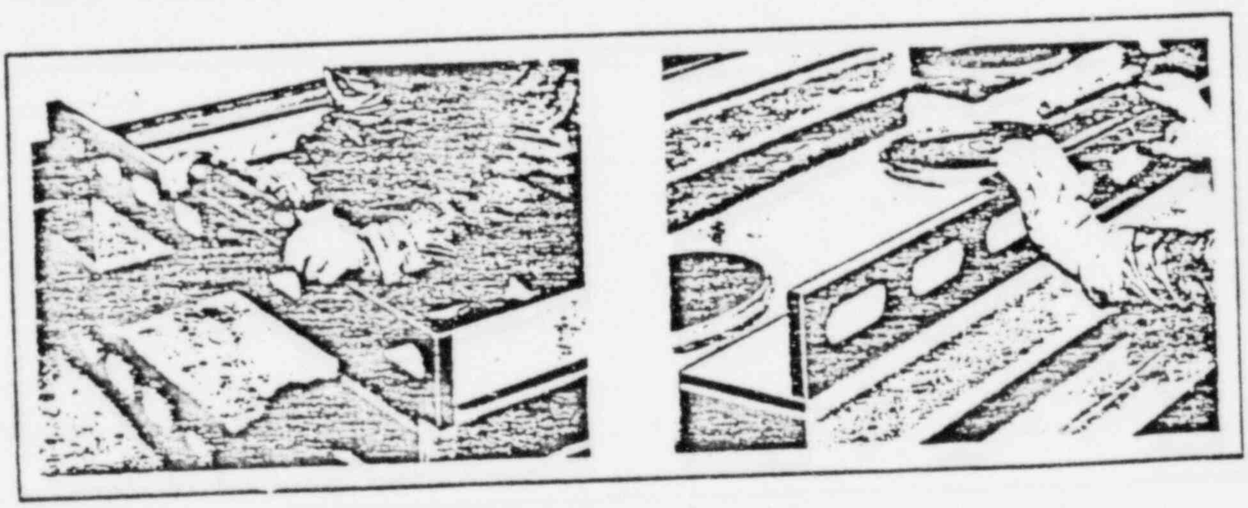


Fig. 2 Leveling Baseplate

2. Level baseplate across driver pads using shims at the foundation bolts on the driver end.

3. Level baseplate across pump pads using shims at the foundation bolts on the pump end.

4. Level baseplate lengthwise using shims at the center on the pump end.

5. Tighten nuts on the foundation bolts evenly but not too firmly.

D. GROUTING

1. Build forms to confine the grout. The forms must be securely anchored and shored.

2. Remove water and waste material from foundation bolt holes and clean off and dampen the foundation slab.

3. Pour grout through holes provided in the baseplate.

A recommended grout mixture is one part iron base aggregate, one part Portland cement and one part coarse, clean sand by weight. Approximately 1-3/4 to 2 gallons of clean water is required for each 100 pounds of mix. Use sufficient water to make the mix placeable.

4. Remove air pockets by working and rodding the grout through holes in the baseplate.

5. After grout is set, tighten nuts on the foundation bolts. Do not remove leveling plates and shims.

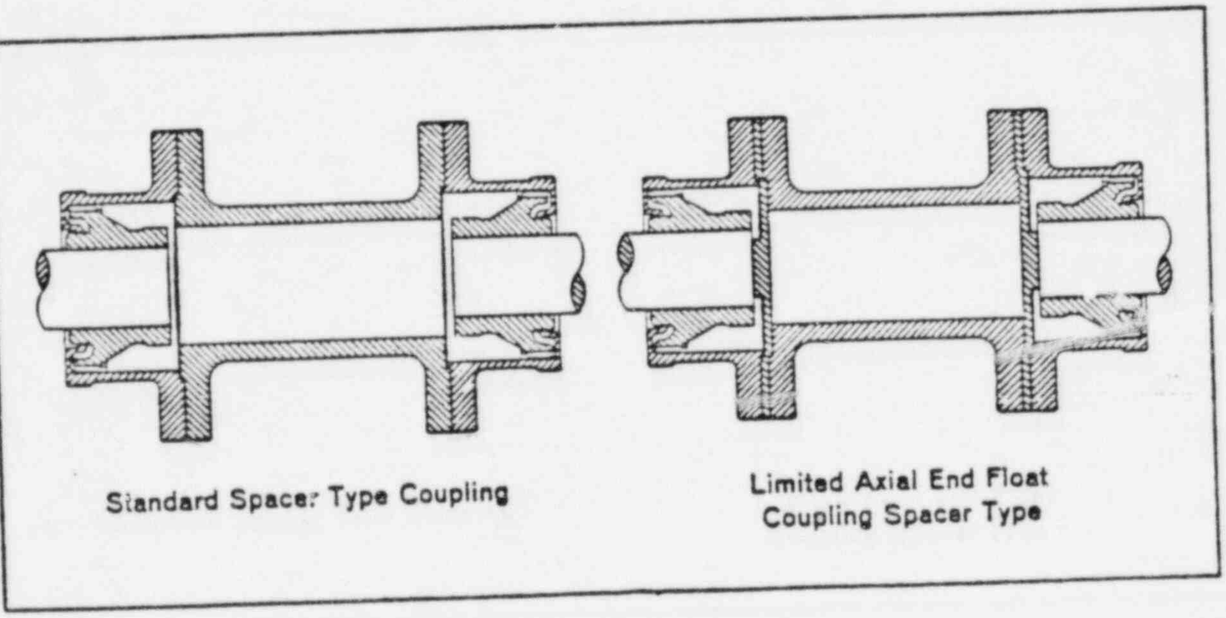


Fig. 3 Spacer Type Couplings

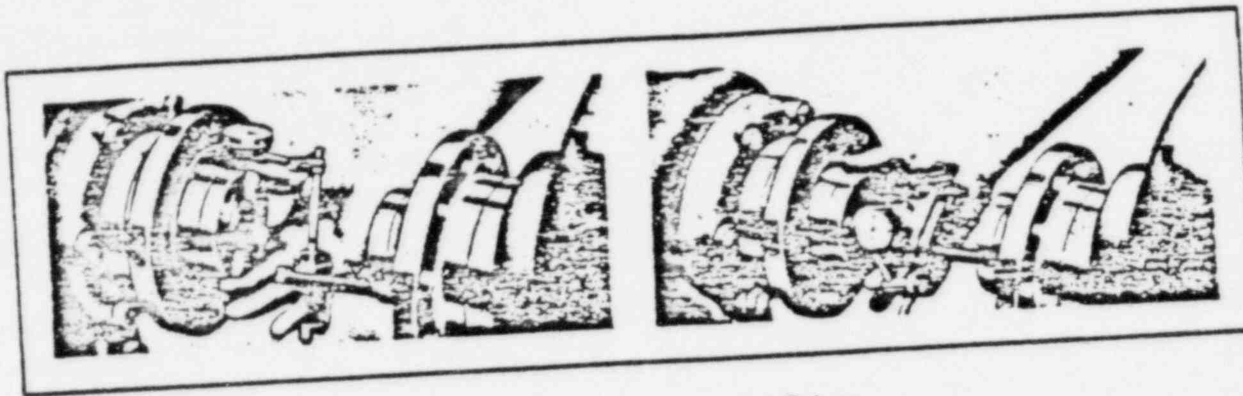


Fig. 4 Aligning Pump and Driver

F. ALIGNING PUMP AND DRIVER(See Fig. 4)
1. Clamp a dial indicator on the driver half coupling. The indicator bracket must be rigid to insure accuracy of the dial indicator reading.
2. Set the indicator button on the face of the hub and align the faces parallel at all points.
3. Set the indicator button on the outside diameter of the pump coupling hub and align the hubs to within .002 inch total indicator reading.

4. To check alignment, clamp the dial indicator to the pump half coupling and take readings on the outside diameter and the face of the driver coupling hub.

NOTE: If a steam turbine is used and is foot mounted, alignment should be made with the turbine hot. If alignment is made with the turbine cold, the turbine should be set low by the distance specified by the turbine manufacturer. A suggested turbine setting is .008 inch low, or .016 inch total indicator reading.

5. Scribe, drill and tap holes in the driver pads for the driver hold down bolts. Install the hold down bolts and draw up snugly, then re-check alignment.

G. PIPING

1. Both suction and discharge piping should be as short and direct as possible. There should be a minimum of bends and fittings and the bends should be made with a long radius, when possible.

2. Piping should be adequately supported near the pump to prevent strains being transmitted to the pump when tightening the flange bolts.

3. Pipes at the suction and discharge nozzles should be as large or larger than the openings in the pump.

H. SUCTION PIPING (See Figs. 5 through 8)

1. Suction lines must be free from pockets or high spots in which gas or vapors may be entrapped.

2. In horizontal lines leading to the pump, only eccentric reducers should be used.

3. The suction line must be free from air leaks and adequate provisions should be made for the

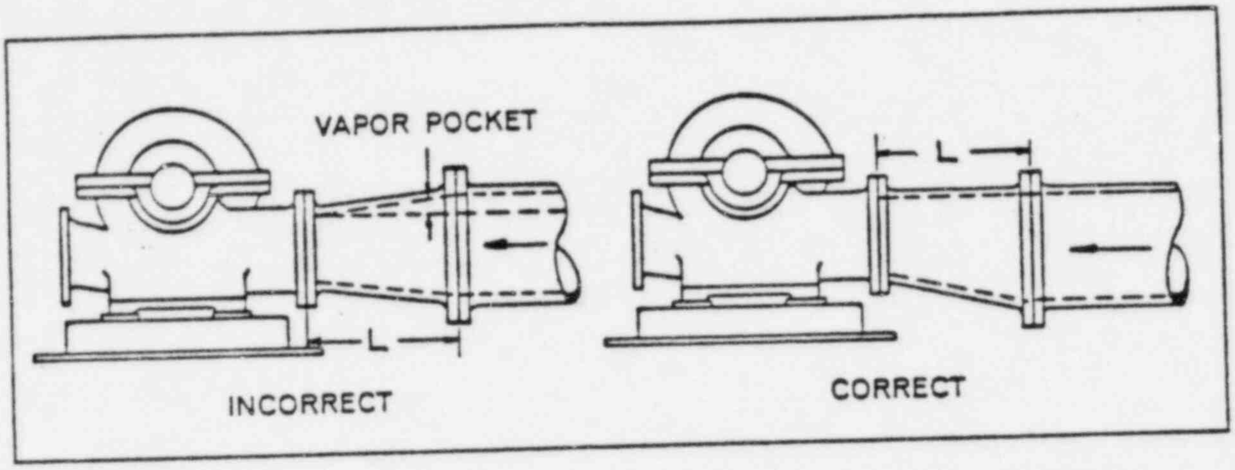


Fig. 5 Suction Line Configuration to Eliminate Pockets or High Spots (Example 1)

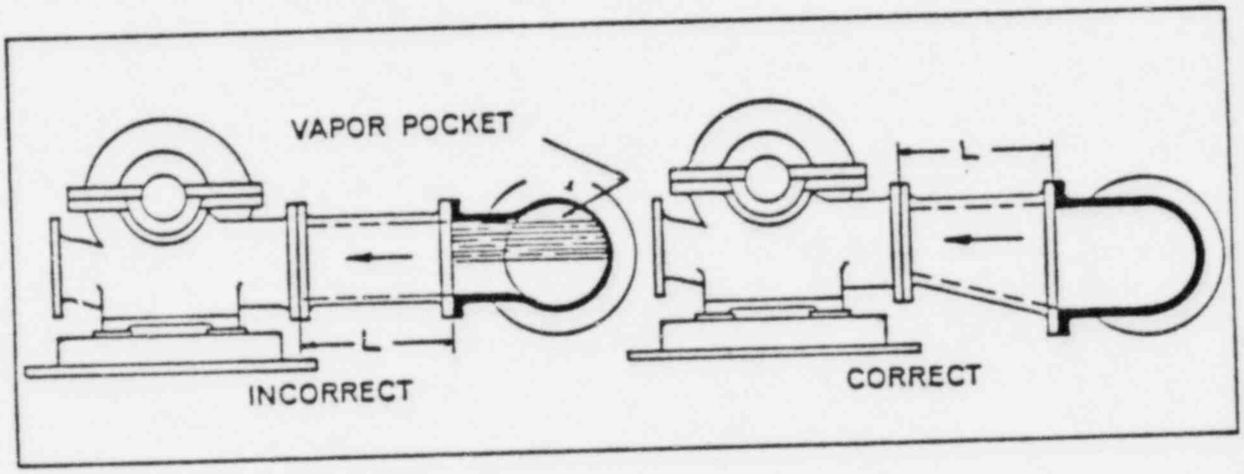


Fig. 6 (Example 2)

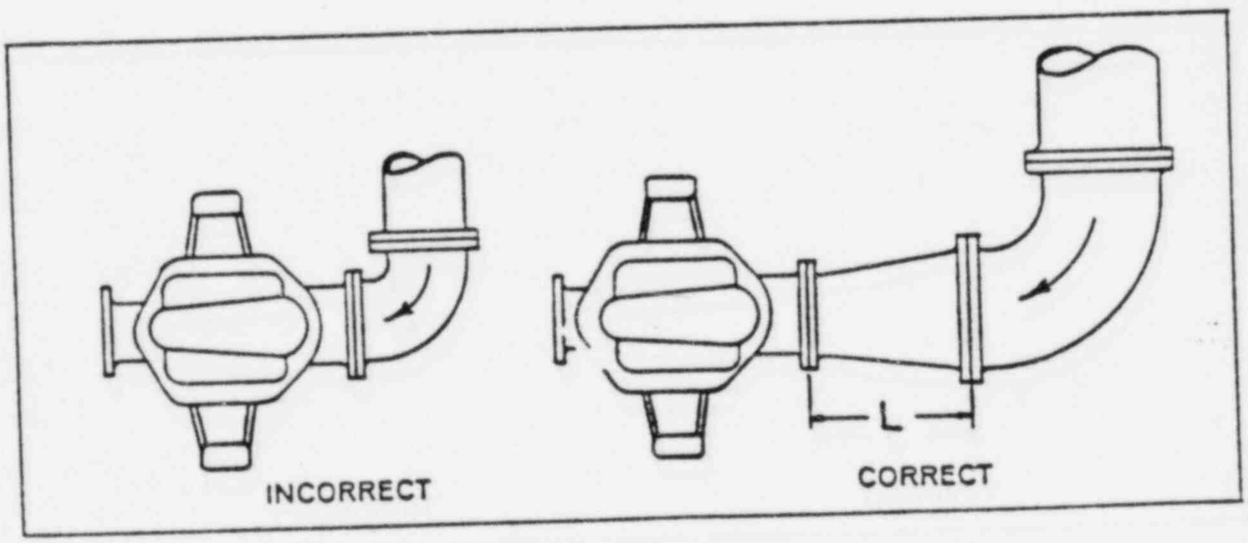


Fig. 7 (Example 3)

expansion of hot lines.

4. It is recommended that a temporary screen be installed in the line at or near the suction nozzle to catch scale or other foreign material. A pressure gauge installed on each side of the screen may be used for measuring pressure drop across the screen.

5. When a strainer or foot valve is used on the inlet end of the suction line, the free area through the strainer or valve should be three to four times the area of the suction pipe.

I. DISCHARGE PIPING

1. On some installations, a check valve and a gate valve may be required in the discharge line. The check valve is used to prevent liquid from running back through the pump in case of failure of the driver. The gate valve is used in priming, starting and when shutting down the pump.

2. When valves are required in the discharge line, they should be located as near as possible to the pump.

3. In all applications, provisions should be made for recirculating a portion of the liquid to prevent overheating of the pump while operating at reduced capacity.

J. AUXILIARY PIPING

When auxiliary piping is to be installed by the customer, the size and location of all pipe openings will be shown on the foundation drawing.

CAUTION

If unit is equipped with breakdown bushing assemblies and condensate is used for sealing, the condensate must be clean and free from scale, abrasive or other material that would either clog the clearance spaces or damage the bore of the breakdown bushings or the surface of the shaft sleeve. A filter or a fine mesh screen should be installed in the condensate feed line to the seals to insure clean condensate.

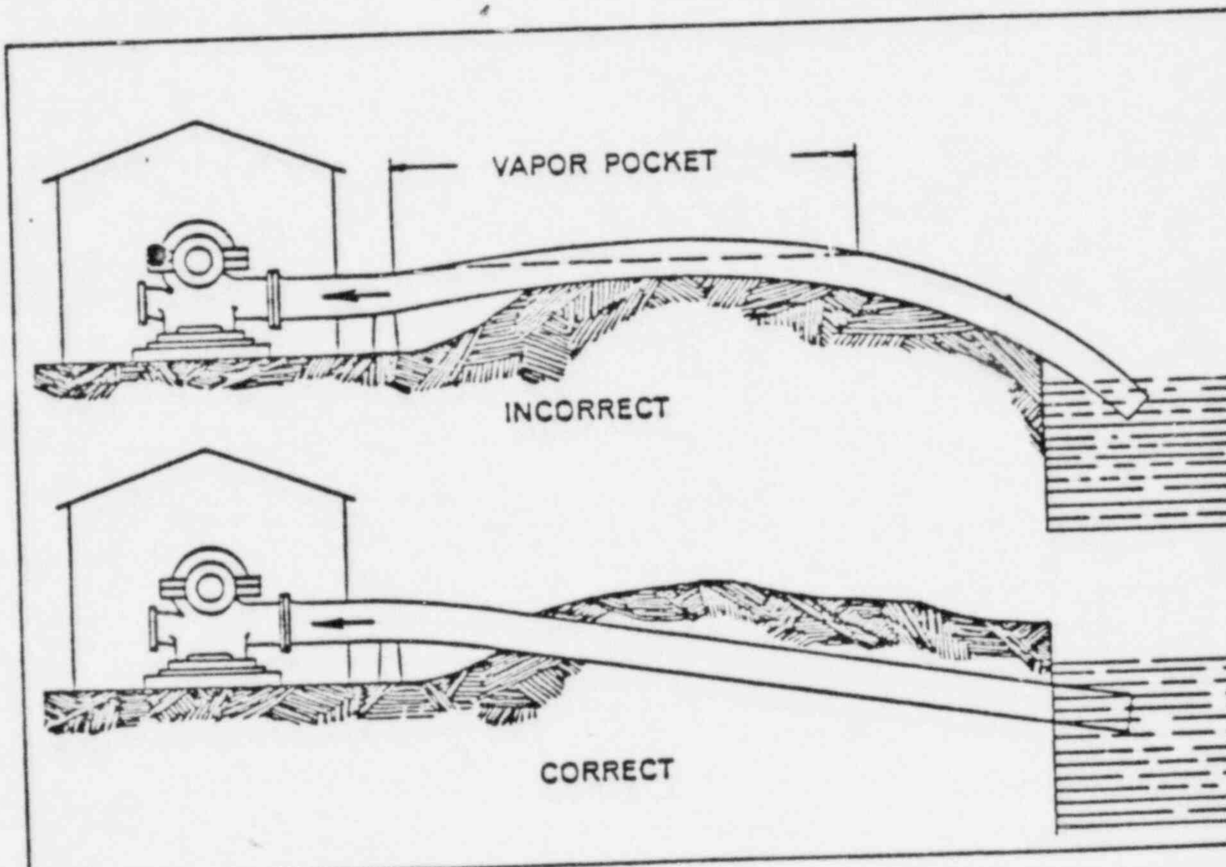


Fig. 8 (Example 4)

K. STUFFING BOXES

When installing packing, carefully read the instruction sheet included in the packing carton. The following procedures are generally recommended for packing installation:

1. Install the first packing ring and tamp it to the bottom of the box. If required, a suitable lubricant may be applied to each ring.

2. Insert a split sleeve or equivalent number of metal rings and compress the packing ring by tightening the stuffing box gland firmly.

3. Back off the gland and remove the sleeve or metal rings. Repeat steps 1 and 2 above for each ring, making sure to stagger the joints 90°. If a lantern ring is used, install the lantern ring as shown on the assembly sectional drawing.

4. After the box is packed, tighten the gland firmly and evenly and let the packing stand for 5 to 10 minutes. Then, loosen the gland nuts and re-tighten finger tight.

5. If possible, rotate the shaft a few times by hand. If a lantern ring is used, make sure it is installed so that adequate lubricating liquid will pass freely to the rings.

6. Refer to Section II - A. Preparation for Operation, for additional stuffing box requirements.

L. CONNECTING PUMP AND DRIVER

1. After piping is connected, check alignment of pump and driver as outlined in Paragraph F.

2. When pump is in alignment, tighten driver hold down bolts.

3. Check rotation of driver to be sure that it agrees with pump rotation.

4. Install spacer between pump and driver half couplings. For couplings which require lubrication, refer to the coupling manufacturer's manual for lubrication instructions.

Section II
Operation

A. PREPARATION FOR OPERATION

1. Fill the oil reservoir to the indicated level with lubricating oil. A high grade turbine oil having a viscosity of 250 SSU at 100°F is recommended.

2. Check metal tags or plates attached to coolers, filters and auxiliary equipment and follow instructions specified thereon.

3. Circulate water through the cooling system, if used. Inlet and drain connections on each pump are identified with metal tags.

4. Admit lubricating liquid to seals or packings that require lubrication.

5. Start the pump following instructions outlined in Paragraph B, below.

6. Check leakage from the seals or packings. If packing leakage is not adequate, a few light taps with a hammer on the gland will usually upset the packing sufficiently to increase the leakage to the required amount.

7. If leakage rate is more than required after the pump has run for 10 to 15 minutes, take up slightly on the gland nuts.

NOTE: Do not overtighten the gland, as this will increase the rate of wear and may cause scoring of the shaft. Leakage will usually decrease after a few days of operation.

8. In high temperature applications, it is advisable to re-check alignment after the pump has been warmed up.

B. STARTING

1. If pump is above the level of the liquid to be pumped, close the discharge valve. If the pump is below the level of the liquid, open the discharge valve 1-1/2 to 2 turns.

2. Prime the pump. All air and vapor must be removed. The pump case and suction pipe must be filled with liquid before the pump is started up.

NOTE: Pumps that are modified to function as hydraulic turbines must also be primed and filled with liquid before starting. If two turbines are used on a single installation, both turbines must be primed.

3. If the pump is fitted with a flushing line, open the line and admit flushing liquid to the seal chamber for 10 to 15 minutes.

4. Start the driver and bring the pump up to speed rapidly.

5. As soon as the pump is up to full speed, open the discharge valve slowly. Do not let the pump run with the discharge valve closed.

6. Check pressure gauges on each side of the temporary screen in the suction line. A pressure drop across the screen indicates it is becoming clogged with dirt or scale. In this case, the pump should be shut down and the screen cleaned or replaced. A clogged screen can cause damage to the pump.

7. The pump should be shut down if it fails to develop its rated discharge pressure at operating speed, or if bearings overheat or there is undue vibration or noise.

C. OPERATING AT REDUCED CAPACITY

If the pump is connected to a constant speed driver, capacity can be reduced by throttling the discharge. If the pump is connected to a variable speed driver, reduction of both the head and the capacity can be accomplished either by reducing the speed or by throttling the discharge.

When throttling the discharge, a by-pass connection may be used to by-pass sufficient liquid to prevent overheating and vaporization of the liquid in the pump.

D. OPERATING ROUTINE

1. Check bearing temperatures periodically. If there is overheating, check the oil level in the reservoir and the oil temperature. When ambient temperature is normal, the sump temperature should not exceed 165°F on pumps equipped with ball bearings. On pumps with Kingsbury or sleeve type bearings, the temperature at the cooler outlet should not exceed 140°F.

2. Check seals or packings for leakage.

3. Check circulation of the cooling system, if used. Cooling requirements will vary according to the ambient temperatures encountered.

4. Check suction and discharge pressure gauges If the differential pressure drops critically, shut down the pump at once.

E. STOPPING

The pump should be shut down rapidly to keep liquid in the pump and prevent parts from seizing. After stopping the driver, close the discharge valve and then the inlet valve, in that order. When Pumps are operating in parallel, it is sometimes necessary to close the discharge valve immediately after stopping the driver to prevent reverse rotation.

Section III
Trouble Shooting Information

Operating troubles and their probable causes are as follows:

A. NO DISCHARGE

1. Wrong direction of rotation
2. Pump not primed.
3. Suction line not full of liquid.
4. Air or vapor in suction line.
5. Suction pipe not submerged enough.
6. Available NPSH not sufficient.
7. Pump not up to rated speed.
8. Too much head.

B. INSUFFICIENT DISCHARGE

1. Wrong direction of rotation.
2. Suction line not full of liquid.
3. Air or vapor in suction line.
4. Air leaks in suction line.
5. Suction line not submerged enough.
6. Available NPSH not sufficient.
7. Pump not up to rated speed.
8. Too much head.

C. INSUFFICIENT PRESSURE

1. Air or vapor in liquid.
2. Pump not up to rated speed.
3. Wrong direction of rotation.
4. Mechanical defects:
   a. Wearing rings worn.
   b. Impeller damaged.
   c. Internal leakage.

D. CAVITATION AND NOISE

1. Air or gas in liquid.
2. Suction line not filled with liquid.
3. Suction line not submerged enough.
4. Available NPSH not sufficient.

E. PUMP LOSES SUCTION AFTER STARTING

1. Suction line not full of liquid.
2. Air leaks in suction line.
3. Air or vapor in liquid.
4. Air or vapor in suction line.
5. Suction line not submerged enough.
6. Available NPSH not sufficient.

F. EXCESSIVE POWER CONSUMPTION

1. Speed too high.
2. Insufficient head.
3. Mechanical defects:
   a. Misalignment
   b. Shaft bent.
   c. Rotating element dragging.
   d. Wearing rings worn.
4. Specific gravity or viscosity of liquid pumped too high.

G. BEARINGS OVERHEAT

1. Oil pressure too low.
2. Improper or poor grade of oil.
3. Dirt in bearings.
4. Dirt or moisture in oil.
5. Failure in oiling system.
6. Bearings too tight.
7. Misalignment.

H. VIBRATION

1. Suction line not full of liquid.
2. Air or vapor in suction line.
3. Misalignment.
4. Worn or loose bearings.
5. Rotating element out of balance.
6. Shaft bent.
7. Foundation not rigid.
8. Vibration in the driver.
9. Wrong location of control valve.

SECTION IV

MAINTENANCE

A. DISASSEMBLY (See Sectional Drawings)

The correct sequence for complete unit disassembly is outlined below:

1. Disconnect auxiliary piping. It is not necessary to disconnect suction and discharge piping.

2. Remove driver coupling spacer and pump half coupling (2), dual drive spacer and coupling (104).

3. Turn mechanical seal retainer plate (1065) into groove in shaft sleeve (443) and lock in position. Loosen or remove set screws and loosen shaft sleeve collar (976) (both seals).

4. Loosen set screws holding deflector rings (7) and slide deflectors back against shaft sleeve collars.

BEARING DISASSEMBLY

THRUST BEARING

5. Dismantle Kingsbury thrust bearing in the following sequence:

   a. Remove end cover-to-bearing housing cap screws and slide end cover (61) with stationary oil baffle (129) and gasket off end of shaft.

   b. Remove thrust bearing housing upper-to-lower cap screws and lift off top half bearing housing (62) with top half stationary oil baffle (48).

   c. Remove outer retainer plate (326) with oil seal ring retainer (49), oil seal ring (55) and seal ring (674).

   d. Remove outer thrust bearing assembly (54) thrust nut cap screw, thrust nut (59), thrust collar (57) with key (309), thrust collar spacer (76), inner thrust bearing assembly (54), oil control ring (883), inner retainer plate (89) and top half sleeve bearing (51) with dowel pin.

   e. Roll out lower half stationary oil baffle (48) and lower half sleeve bearing (51).

   f. Remove dowels, housing-to-case stud nuts and bottom half of bearing housing (62) with gasket.

   g. Slide deflector ring (7) off shaft.

RADIAL BEARING

6. Dismantle radial bearing in following sequence:

   a. Remove upper-to-lower bearing housing cap screws and lift off top half bearing housing (13) with top half of stationary oil baffles (48) and top half bearing sleeve (63) with dowel pin.

   b. Roll-out bottom half oil baffles (48) and bottom half bearing sleeve (63). Remove bearing housing-to-case taper pins and stud nuts. Remove bottom half bearing housing (13) with gasket.

c. Slide deflector ring (7) off shaft.

7. Remove the mechanical seal assemblies as instructed in the seal maintenance section in this manual.

8. Remove top-to-bottom case capnuts and lift off top half of case (37).

9. Lift out rotating element and dismantle in following sequence:

   a. Remove case wear rings (226) and (258).

   b. Remove seal shaft sleeve key (439).

   c. Remove packing box bushing (228) and pressure reducing bushing (65) with "O" ring (1060) and radial end packing box bushing (227).

   d. Remove impeller locknuts (678) and (238).

   e. Remove impellers (28) and (1150) and impeller keys (246) and (276).

   f. Slide off case spacer (463) with bushing (337) and "O" ring (1131), and spacer sleeve (1061).

B. INSPECTION AND REPAIR

1. Clean all parts and inspect for wear or damage. Particular attention should be given to the following:

   a. Check condition of wearing rings (258) and (226).

   b. Check condition of case spacer bushing (337). Replace, if necessary, by removing set screws and pressing out of case spacer. Install new bushing by cooling with dry ice and press into case spacer. Drill and tap at assembly case spacer (463) and bushing (337) for set screws at joint of two parts. Stake all set screws upon replacement.

   c. Inspect spacer sleeve (1061), impeller locknuts (678) and (238), pressure reducing bushing (65), and packing box bushings (227) and (228); replace if worn or damaged.

   d. Check bearing shoes and journals for wear and damage.

   e. Check shaft (1) for straightness by mounting in well oiled sleeve bearing halves and rotating. Use a dial indicator to check. Total indicator reading should be within 0.0015 inch.

C. REASSEMBLY

1. Assemble rotating element parts on shaft in following sequence:

   a. Install center impeller spacer sleeve (1061) and insert impeller and spacer sleeve keys (276) and (246) into keyways.

b. Slide impellers (1150) and (28) into position.

NOTE: THE DIRECTION OF CURVATURE OF THE IMPELLER VANES MUST BE AS SHOWN IN FIGURE NO. 9.

c. Thread on and tighten impeller locknuts (678) and (238).

2. Check concentricity of rotating element by mounting in well oiled sleeve bearing halves and measuring with a dial indicator. Turn shaft slowly by hand and take readings at impeller wearing surfaces, spacer sleeves, and impeller locknuts. Total indicator reading should be within 0.0015 inch at all points.

3. If indicator readings exceed 0.0015 inch, possible causes are:

   a. Shaft not straight.
   b. Abutting (end) faces of impeller hub, impeller locknuts and spacer sleeves not square with shaft centerline.
   c. Burrs or dirt particles on above faces.

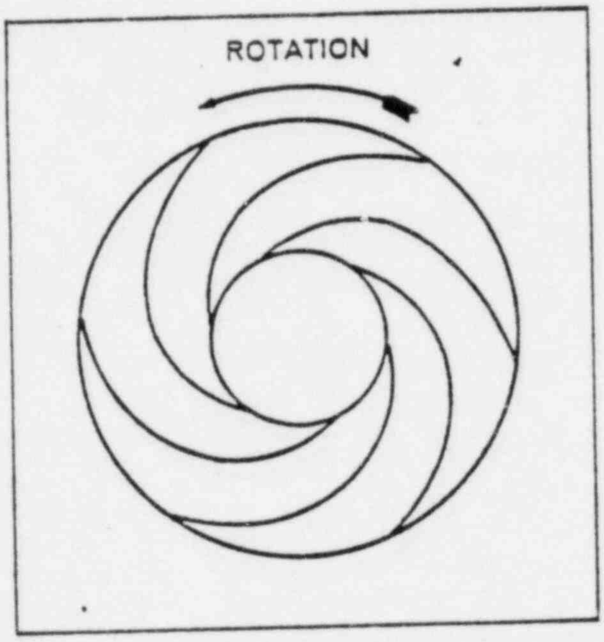


Fig. 9 Direction of Rotation in Relation to Curvature of Impeller Vanes

Fig. 10 Checking Concentricity of Rotating Element

4. When the rotating element checks straight and true:

   a. Remove impeller locknut (238) and suction impeller (28).
   b. Slide case spacer (463) with bushing (337) and "O" ring (1131) over center impeller spacer sleeve (1061).
   c. Install suction impeller (28), impeller locknut (238) and slide pressure reducing bushing (65) with "O" ring (1060) over 2nd stage impeller locknut (678).
   d. Slide case wear rings (226) and (258) over impeller wearing surfaces.
   e. Install shaft sleeve (439) with flat head screws. Stake screws into place.
   f. Slide packing box bushing (227) into position over locknut (238).
   g. Install rotating element in lower half of case (37).

5. The following operations are required to check axial alignment of the impeller and radial alignment of the shaft.

   NOTE: DO NOT INSTALL SEAL ASSEMBLY AT THIS TIME.

   a. Assemble thrust bearing and housing as indicated under thrust bearing assembly section, but do not install top half of sleeve bearing and housing. Tighten bearing housing to casing bolts evenly but not too firmly.

   b. Assemble radial bearing and housing as indicated under radial bearing assembly section, but do not assemble the top half of the sleeve bearing and housing at this point. Tighten bearing housing to casing bolts evenly but not too firmly.

   c. Check to see that impellers (28) and (1150) are centered in case (37) volute. If the impellers are not centered, adjust locknuts (238) and (678) by loosening one and tightening the other, to bring the impellers to center. If impellers are centered, tighten locknuts firmly.

   d. Install top half of case (37). New gaskets should always be used and should be of the same material (1/64" asbestos with Buna Binder) as that originally installed in the pump.

   e. Verify that parting flange studs are clean and install capnuts as indicated on bolting sequence drawing DBC-45768.

   f. Rigidly clamp a dial indicator to the pump shaft and check for concentricity between the shaft and packing box bore at each end of the pump. Make adjustments by tapping the edge of the bearing housing flanges until total indicator reading is within 0.006 inch. When accurate alignment is established tighten the flange bolts firmly.

      NOTE: WHEN DIMENSIONS OF THE PUMP DO NOT ALLOW FOR CONVENIENT USE OF A DIAL INDICATOR A DOWEL PIN OF THE APPROPRIATE SIZE CAN BE USED AS A GAUGE BETWEEN THE SHAFT AND PACKING BOX BORE. ADJUST THE BEARING HOUSING, BY TAPPING, UNTIL THE DOWEL PIN PASSES AROUND THE SHAFT WITH EVEN PRESSURE OR DRAG.

g. Check to see if the dowel holes in the bearing flanges are in line with the holes in the case flanges. If the holes are in line, install the dowels. If the holes are not in line, taper ream the holes to the next larger size and install new taper dowels.

h. Dismantle both bearing housings.

6. Assemble and install mechanical seals at each end of pump as instructed in the mechanical seal maintenance section.

BEARING ASSEMBLY

THRUST BEARING

7. Assemble Kingsbury thrust bearing in following sequence:

NOTE: OIL ALL BEARING SURFACES WHEN ASSEMBLING.

a. Install bottom half bearing housing (62). Line up bearing housing to pump case carefully with taper dowels and tighten bolts firmly. Install bottom half sleeve bearing (51) and bottom half stationary oil baffle (48) by rolling around shaft into housing.

b. Install top half bearing sleeve (51), inner retainer plate (89), oil control ring (883), inner thrust bearing (54), thrust collar spacer (76), thrust collar (57) with thrust collar key (309) and thrust nut (59).

NOTE: THE THRUST COLLAR MUST BE PERPENDICULAR TO THE SHAFT. MAXIMUM TOTAL INDICATOR READING SHOULD BE 0.002 INCH.

c. Install outer thrust bearing (54) and outer retainer plate (326) with retainer (49) oil seal ring (55) and seal ring (674).

d. Install top half bearing housing (62), top half stationary oil baffle (48) with dowel pin and end cover (61) with oil baffle (129).

e. Position deflector ring (7) and tighten set screws to shaft.

f. All thrust bearings require axial end play to allow for oil film and thermal expansion. Normal end play is established at the factory and should not require any adjustment. However, if damage has occurred or a worn condition is suspected, it should be measured.

With the thrust bearing housing assembled, bearing end play can be measured with a dial indicator placed against the coupling end of shaft or a deflector ring (7) which has been set screwed to shaft. Push the shaft firmly one way against the thrust bearing and note the indicator reading. Push the shaft the opposite way and again note the indicator reading. The difference between the two should be within 0.012 to 0.016 inch.

8. When new sleeve bearings are installed, holes must be drilled, reamed, and dowels installed in top half of sleeve. Use the holes provided in top half of bearing housings as a guide for drilling.

RADIAL BEARING

9. Assemble radial bearing in following sequence:

NOTE: OIL ALL BEARING SURFACES WHEN ASSEMBLING.

a. Install bottom half bearing housing (13). Line up bearing housing to casing carefully with taper dowels and tighten bolts firmly. Roll bottom half sleeve bearing and oil baffle (48) into place.

b. Install top half bearing sleeve (63) with dowel and top half bearing housing (13) with top half oil baffles (48) and dowel pin.

10. Position deflector rings (7) on each end of pump shaft by pushing deflector ring tight against stationary oil baffle (48), then pull deflector ring back 1/32 to 1/16 inch and tighten set screws to shaft.

11. Tighten shaft sleeve collar (976) set screws on both ends of pump. Turn retainer (1065) 180° out of shaft sleeve groove and lock into position so that it will not interfere with rotation of the shaft sleeve during normal operation.

12. Press on pump half of flexible drive coupling as shown in coupling instructious at end of manual.

13. Check shaft alignment, correct if necessary, and install coupling spacer.

14. Install auxiliary piping.

D. PARTS ORDERING

When ordering parts for spares or replacement the following information must be given:

1. Pump size, type and serial number as given on nameplate.
2. Quantity of parts.
3. Part name and number as shown on cross sectional drawing.
4. Complete shipping instructions.

E. MECHANICAL SEAL MAINTENANCE

1. Removal of Seal Assembly from Pump

In order to understand the following, reference must be made to the seal assembly drawing C-15962.

To remove mechanical seal for inspection, it is necessary to first remove the complete bearing assembly, including housing. If the seal to be inspected is on the coupling end of pump, the coupling (2) must be removed prior to dismantling the bearing.

Proceed as Follows:

NOTE: WHEN HANDLING SEAL PARTS AND ASSEMBLIES, EXTREME CARE IS REQUIRED TO AVOID DAMAGE.

a. Remove seal flushing piping to seal plate (375).

b. Turn retaining plate (1065) into groove in shaft sleeve (443) and lock in position by tightening cap screw.

c. Loosen set screws in shaft sleeve collar (976).

d. Remove cap screws holding seal plate (375) to casing (37).

e. Slide seal assembly off of shaft and remove to bench for inspection.

2. Disassembly of Seal Parts

a. Remove shaft sleeve collar (976) and "O" Ring (656).

b. Loosen cap screw and turn seal plate retainer (1065) out of shaft sleeve (443) groove and retighten cap screw to keep retainer out of the way.

c. Carefully slide shaft sleeve (443) out of seal plate (375). Lay seal plate on bench with stationary seal insert (2) up. Slide rotating seal ring (3) off of shaft sleeve and place on bench face up. NOTE: DO NOT ALLOW EITHER SEAL RUBBING FACE TO CONTACT ANY OBJECTS, AS THE SLIGHTEST NICK OR CHIP WILL RENDER THEM USELESS.

d. Slide remaining seal parts off of shaft sleeve in the following order after loosening set screws (S) in seal collar (5). Seal "O" ring (P), compression ring (4) and seal collar (5) with springs (C).

e. Carefully slide stationary seal insert (2) out of seal plate with fingers by pulling parallel to seal plate bore, and lay face up on bench. Remove insert "O" ring (6).

3. Inspection

a. Inspect insert (2) and seal ring (3) faces for chipped, nicked scratched, grooved or heat checked surfaces. Surfaces not free of these defects and which are not perfectly flat should be replaced.

b. Inspect insert "O" ring (6), seal "O" ring (P) and shaft sleeve "O" ring for deterioration, scratches, gouges, etc., on all sides. If any of these defects are apparent, or either part is misshapen or crushed, they must be replaced. Best practice is to replace all three parts when seals are disassembled. NOTE: NEW PARTS MUST ALSO BE GIVEN THE SAME CAREFUL INSPECTION.

c. Clean and inspect shaft sleeve (443) for scratches, wear, etc., at the seal "O" ring contact point. If not free of damage or wear, it should be replaced.

d. Clean and inspect bore of seal plate (375) at the insert "O" ring (6) contact points. The surfaces must be free of pitting, gouges, scratches, etc.

e. Inspect parts C, S, 4, 5, 594, and 976 for general appearance. If any appear to be worn irregularly, misshapen, or fit poorly, they should be replaced.

4. Mechanical Seal Assembly

a. Smear a small amount of glycerin in seal plate bore and carefully push seal insert (2) with "O" ring (6) into seal plate (375) until "O" ring bottoms against seal plate. Carefully wipe clean, rubbing face of seal insert (2) with soft, lint free cloth. Using a depth micrometer measure the distance from seal inner plate face to rubbing face of seal insert face at four places around circumference of seat. Readings should all agree within plus or minus 0.0015 inches.

b. Install parts C, 4, 5, and tighten set screws (S) on shaft sleeve (443).

c. Smear a small amount of glycerin on shaft sleeve shoulder and slide "O" ring (P) and seal ring (3) onto shaft sleeve after carefully wiping all seal faces clean with a soft, lint free cloth.

d. Carefully, so as to avoid nicking or chipping, slide shaft sleeve assembly into seal plate (375). Compress complete assembly against seal springs and turn seal plate retainer (1065) into groove on shaft sleeve (443) and lock in place.

e. Insert shaft sleeve "O" ring (656) into groove in bore of shaft sleeve (443).

5. Installation of Complete Seal Assembly to Pump

a. Verify that shaft sleeve key (439) is mounted in shaft with the flat head machine screw. Install new seal plate gasket (595) on seal plate and slide complete seal assembly onto shaft. Insert and tighten equally, the cap screws holding seal plate (375) to casing (37).

b. Install shaft sleeve collar (976) and set screw to four places on shaft sleeve.

DO NOT TIGHTEN LOCK COLLAR SET SCREWS TO SHAFT AT THIS TIME.

c. Install deflector ring (7) and bearing and housing complete as described in manual.

d. Tighten equally all six set screws in shaft sleeve collar (976) against shaft. Stake set screws in place. Turn retainer plates (1065) 180° out of shaft sleeve groove and lock in place with cap screw. NOTE: OPERATION 5.d MUST NOT BE PERFORMED UNTIL BEARING ASSEMBLY IS COMPLETED AT BOTH ENDS OF PUMP.

e. Replace seal piping.

F. SHAFT COUPLING INSTRUCTIONS

(Refer to Koppers form Ø1900-2 attached for complete data)

1. Removal or installation of couplings requires application of heat as they are installed with an interference fit to shaft. An acetylene heating torch and puller assembly must be available at time of dismounting.

REMOVAL

(Read completely before starting)

2. Unbolt and remove coupling spacer. Slide coupling shroud as far back as possible toward bearing housing and remove all grease with solvent.

3. Set up puller assembly so that hook ends of puller may be quickly positioned on back of shroud between coupling and bearing housing after heating.

4. Using a large tip acetylene torch, evenly heat coupling (hub only) by playing torch continuously around circumference. Avoid coupling gear teeth and shaft. It is important to perform this operation quickly to avoid excess heating of shaft and thereby lose the advantage of expanding only the coupling. Heat to approximately 250° to 300° F.

5. Quickly install puller assembly and withdraw coupling hub and shroud from shaft. Do Not Hesitate. Keep the coupling hub sliding off shaft as rapidly as possible to avoid heating of shaft.

INSTALLATION

(Read completely before starting)

6. Thoroughly clean and inspect all coupling parts including keys, bolts and gaskets. Carefully remove any burrs on shaft bore, keyway and key. Do not work on bore except at burrs. Excessive work on bore will destroy the required interference fit.

7. Clean and inspect shaft. Carefully remove all burrs, including any found in keyway. Do not remove any metal except burrs.

8. Oil shaft and key with light oil and dust with a coat of Molybdenum Disulfide.

SHAFT COUPLING INSTRUCTIONS (CONTINUED)

9. Lay coupling shroud, open side up, so that itis immediately ready to receive heated coupling hub. Gloves and lifting devices for picking up heated assembly should be "at ready". NOTE: MAIN PUMP TO TURBINE COUPLING IS A DYNAMICALLY BALANCED ASSEMBLY. ALL SHROUDS, HUBS, AND SPACERS ARE "MATCH MARKED" AND MUST BE MATCHED AT RE-ASSEMBLY.

10. Heat hub with torch as in section #4 preceding.

11. Place heated hub into shroud (observing "matched marks") and immediately lift into position and tap onto shaft with lead mallet. Do Not Hesitate. Shaft will begin to absorb heat from coupling hub and loss of assembly clearance will cause hub to seize if delays occur while positioning.

    Position face of coupling hub flush with end of shaft.

12. After coupling has cooled, check alignment of equipment.

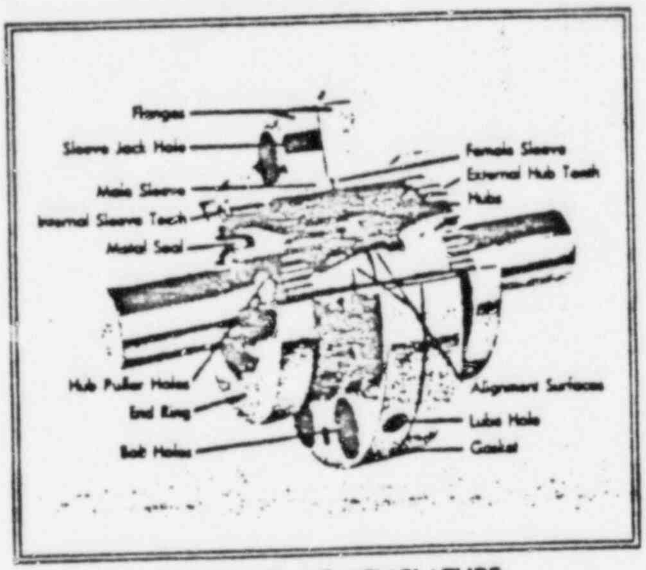
13. Pack coupling with grease per instruction sheet attached and install coupling spacer with gaskets and bolts.

INSTRUCTION DATA SHEET

FOR

FAST'S FORGED STEEL *Couplings*

(SIZES #1½ TO #6 INCLUSIVE)



COUPLING NOMENCLATURE

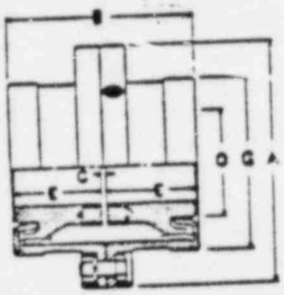
Refer to GENERAL INSTRUCTIONS (Form 1900)
for Installation and Lubrication Instructions

KOPPERS COMPANY, INC.
Fast's Coupling Department
Baltimore 3, Maryland

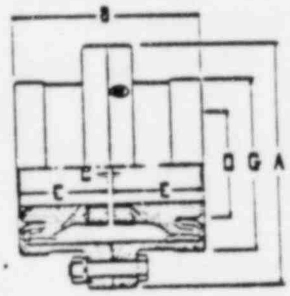
Form 1900-2
Rev. 2

FAST'S FORGED STEEL Couplings

(SIZES #1½ TO #6 INCLUSIVE)



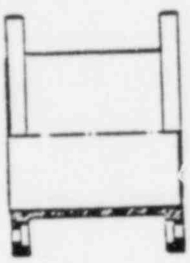
FORGED STEEL COUPLING WITH SHROUDED BOLTS (SIZE #1½ — #5)



FORGED STEEL COUPLING WITH EXPOSED BOLTS (SIZE #1½ — #6)

COL.	1	2	3	4	5	6	7	8	9	10	11	12
	DIMENSIONS—IN INCHES						APPROX. LUBRICANT REQUIRED—PINTS					
							OIL			GREASE		
Size Number	A	B	C	E	G	O	COUPLING ONLY	SPACER ONLY	COUPLING HALF WITH RIGID HALF	COUPLING ONLY	SPACER ONLY	COUPLING HALF WITH RIGID HALF
1½	6	4⅜	⅛	1 11/16	3 11/16	2 5/16	⅛	.03	1/16	⅗	.15	3/16
2	7	5 5/16	⅛	2 7/16	4 11/16	2 ⅞	⅙	.04	1/12	½	.20	¼
2½	8 ⅜	6 7/16	3/16	3 1/16	5 11/16	3 ⅝	5/16	.06	5/32	1	.33	½
3	9 7/16	7 11/16	3/16	3 13/16	7	4 ¼	½	.09	¼	1 ½	.50	¾
3½	11	8 ½	¼	4 ⅛	8 ⅛	5	¾	.10	⅜	2 ¼	.60	1 ⅛
4	12 ½	10 ⅛	¼	4 ¾	9 ⅝	5 ¾	1 ¼	.15	⅝	3 ¾	.80	1 ⅞
4½	13 ⅝	11 ⅜	5/16	5 5/16	10 ⅝	6 ½	1 ½	.18	¾	4 ½	1.0	2 ¼
5	15 5/16	12 ⅝	5/16	6 ⅛	12	7 5/16	2	.22	1	6	1.3	3
5½	16 ¾	13 ⅞	5/16	6 15/16	12 ⅞	8	3 ½	.27	1 ½	9 ½	1.6	4 ¾
6	18	14 ⅞	5/16	7 15/16	14	8 15/16	3 ½	.43	2	12 ½	2.5	6 ¼

Note: Use of excessive amounts of lubricant will not impair operation of the coupling. The excess lubricant will be thrown from the coupling during operation.



SPACER

When a spacer is used (to increase shaft separation), additional lubricant is necessary. To the amount required for the COUPLING ONLY (per column 7 or 10), add the amount required for SPACER ONLY (per column 8 or 11) multiplied by the length of spacer in inches.

example: #2 coupling with 5" spacer

Oil—1/6 plus .04 x 5 = 1/3 pt. (approx.)

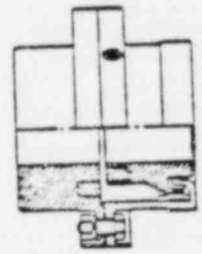
Grease—½ plus .20 x 5 = 1½ pt. (approx.)

When a rigid half is used with a coupling half (for angular misalignment only or floating shaft arrangements), less lubricant is required. Use the quantity specified in columns 9 or 12.

example: #4½ Coupling half with rigid half

Oil— ¾ pt. (approx.)

Grease—2 ¼ pt. (approx.)



COUPLING HALF WITH RIGID HALF

APPROVED LUBRICANTS

Oils

Use a mineral base oil having a viscosity no lighter than 150 SSU (Saybolt Seconds Universal) or heavier than 1000 SSU at 210°F.

DO NOT USE COMPOUNDED OILS

Use grease instead of oil if interval between lubrication exceeds 2 months.

Greases*

Atlantic Refining Company
American Oil Company
Brooks Oil Company
Cities Service Petroleum, Inc.
Continental Oil Company
Esso Standard Oil Company
Fiske Brothers Refining Company
Gulf Oil Corporation
Keystone Lubricating Company
Master Lubricants Company
Phillips Petroleum Company
Pure Oil Company

Atlantic Lubricant #17
Amobar S
Leadolene 375 Light
Trojan Grease A-1
Conoco Super Lube
Fibrax 370 or Nebula 1
Lubriplate #630 AA
Gulf Antifriction Grease #1
Keystone #15 EP XX Light
Lubriko Grease M-54
Philube #1 Stock 401
Poco Fibre Grease #1

Richfield Oil Corporation
Shell Oil Company
Sinclair Refining Company

Socony-Mobil Oil Co., Inc.
Standard Oil Co. of California
Standard Oil Co. of Indiana
Standard Oil Co. of Ohio
Sun Oil Company
Texas Company
Tidewater Associated Oil Co.
Union Oil Co. of California

Rocolube RR
Shell Alvania Grease #2
Sincolube #1, or Litholine Multi-Purpose Grease #2
Sovarex L-O or Kalrex #1
Calol SA #1
Stanobar Grease 'S'
Sohio #77
Sun Oil #901 Grease
Marfak #1
Tycol Alitho #10
Ball Roll #1 or Elnoba #1

*Greases listed are in response to requests for specific recommendations. This list is not complete and is not intended to restrict the use of equivalent lubricants manufactured by companies not listed.

DO NOT USE CUP GREASE

For applications with temperatures exceeding 250°F, contact Koppers Company, Inc., for specific recommendations.

Form 1900-2
Rev. 2

SUPPLEMENTARY INSTALLATION INSTRUCTIONS

(This section supplements pages (1) through (7) of the general manual and requires reference to those pages for effective use.)

1. When leveling the base plate prior to grouting, it is important to observe alignment of pump shafting to the drive turbine shaft.

   Main pump, booster and speed reducing gear, are furnished with 3/16" to 1/4" shims between mounting feet and base plate pedestals. Shims must be in place when leveling base plate and aligning to turbine shaft.

2. The following instructions assume that turbine is set in final position.

   Level and position base plate so that main pump shaft coupling hub is parallel and centered to turbine coupling hub. Use of a straight edge laid parallel to shaft on coupling hubs will be a sufficient preliminary check of centering. Couplings should be centered within 1/64" before grouting base plate.

   All pump and gear reducer shafts should be checked for level before completion of base plate leveling and prior to grouting.

   Check between all equipment shaft ends to assure that spacing is equal to that shown on drawing FC-45768.

3. When base plate is grouted and set, alignment with dial indicators should be made per the general instruction manual page seven. Begin at the main pump to turbine coupling and work back to the booster pump coupling last.

   Set main pump higher than turbine to accommodate turbine thermal growth. Set high by the amount recommended by turbine manufacturer.

   Set speed reducing gearbox lower than both pumps by 0.004" (0.008" total indicator reading) to allow for thermal growth.

4. A realignment with dial indicators must be performed once again after installation of all suction and discharge piping. At completion of this alignment, locating dowels should be installed at all pump mounting feet. A final check of alignment should be made with all equipment at mornal operating temperature.

5. "Bedding In" of the bed plate and relaxation of certain piping stresses will affect alignment of all equipment. A realignment of eqaipment should be made after several months operation. At this time the locating dowels at pump mounting feet will require taper reaming to align both dowel holes. The speed reducing gearbox should be doweled at this time and not before.

LIFTING INSTRUCTIONS

1. Complete unit - Main, Booster and speed reducing Gear (total weight 28,500 lbs.)

   Attach rigging to base plate at four (4) points labeled V-X1 on outline drawing FC-45768.

   Rigging should be positioned for a straight vertical lift only when all equipment is attached to base plate.

2. Booster pump - Type DSK (weight = 4,000 lbs.)

   Detach shaft couplings and common auxiliary piping before lifting pump separate from base plate.

   Booster pump may be lifted separate from other equipment by using two (2) wire rope slings. Position a sling beneath each bearing housing bracket on pump casing, or use lifing lugs VL-3 (two) as shown on drawing FC-45768.

3. Main pump - Type RHC (total weight = 10,680 lbs.)

   Detach shaft couplings and common auxiliary lube oil piping before lifting pump separate from base plate.

   Main pump may be lifted separate from other equipment by four (4) wire rope slings. Position each sling under one of four lifting lugs on pump casing. Lugs are labeled V-L2 on drawing FC-45768.

4. Speed reducing gear - (weight = 920 lbs.)

   Detach shaft couplings and common auxiliary piping before lifting separate from base plate.

   The speed reducing gear may be lifted separate from other equipment by attaching rigging to (2) 5/8" eyebolts located on the top of gear casing.

PACIFIC PUMPS, INC.

PARTS LIST

Shop Order No. J46-694, J46-696, J46-698, J46-700

Pump S/N: 45-768, 45-770, 45-772, 45-774

FOR:

OUR ORDER NO.

PCS. UNIT	TOTAL REQ'D	PART NO.	DESCRIPTION	PATTERN NO.	DRAWING NO.	LINE NO.	COLUMN NO.	MATERIAL NO	HEAT TREAT.	PROCESS
1	1	1	MP 3 SHAFT W/8 JHJ KINGSBURY *		D13195		1	57	21	MP
		2	CPLG 4 FAST STD BTWN PUMPCTUR PUMP 45							
		2	CPLG 2 1/2FAST STD BTWN RHCHCGR PMP45							
1	1	7	RING DEFLECTOR		A24119	6		11		
1	1	7	RING DEFLECTOR OUTER		A24119	6		11		
1	1	13	HOUSING RADIAL BEARING UPPER HALF *	M6371	D13197			101		
1	1	13	HOUSING RADIAL BEARING LOWER HALF *	M7297	D13197			101		
1	1	28	MP2 IMP 1ST STG RPM 4000 VT AC CLR .0	M7282	C15774	2	3	317	60	MP
1	1	37	MP 1 CASE ELEV UPR HLF * SEE PARTL M/	M7299	D13192			2		MP
1	1	37	MP 1 CASE ELEV LOWER HALF SEE ITEM A1	M7300	D13192			2		MP
1	1	47	MP 13 BASE PUMP 45772					78		MP
2	2	48	BAFFLE STATIONARY OIL 2 HALVES		A24129	6		11		
1	1	48	BAFFLE STATIONARY OIL 2 HALVES		A24129	6		11		
1	1	49	RETAINER OIL SEAL RING		A24124	3		14		
1	1	51	SLEEVE THRUST BEARING 2 HALVES		C15171	3		277		
1	1	54	BEARING THRUST 8 JHJ LESS COLLAR		LE0100	8				
1	1	55	RING OIL SEAL		A24123	4		11		
1	1	57	COLLAR THRUST 8 JHJ KINGSBURY		B14290	19		15		
1	1	59	NUT THRUST		A24126	1		68	16	
1	1	61	COVER END		B18666			14		
1	1	62	HOUSING THRUST BEARING UPPER HALF *	M6373	D13198			2		
1	1	62	HOUSING THRUST BEARING LOWER HALF *	M7298	D13198			2		
1	1	63	SLEEVE RADIAL BEARING 2 HALVES		C15171	3		277		
1	1	65	BUSH PRESSURE REDUCING		B19046	1		11		
1	1	76	SPACER THRUST COLLAR		B18100	15	18	14		
1	1	89	PLATE INNER RETAINER		A24121			14		
1	1	165	KEY FLEX CPLG		A20218	11	1	14		
2	2	215	COLLAR SHAFT SLV		A60559			42		
1	1	226	WRG RING CASE 2ND STG		B190[illegible]7			11		
1	1	227	BUSH PKG BOX RAD END 13 SHAFT		B19045			11		
1	1	228	BUSH PKG BOX THR END		A60556			11		
1	1	238	IMP LOCKNUT RAD W/CARTR SEAL		A60558	2		42	21	9
2	2	246	KEY IMP SPACER SLV		B18259	12		23		
1	1	258	WRG RING CASE 1ST STG		B19047			11		
2	2	276	KEY IMP		A20209	7	5	23		
1	1	326	PLATE OUTER RETAINER		A24122	3		14		
1	1	337	BUSH CASE SPACER		A60555			11		
		366	HOLDER UNION TCPLE ASSEMBLY		B18856	99	1			
		366	HOLDER UNION TCPLE ASSEMBLY		B18856	99	1			
2	2	375	MP 4 PLATE SEAL		C15944			23		MP
2	2	439	KEY SHAFT SLV		A22822	2		42		
2	2	443	SLEEVE SEAL SHAFT		B19044			42	21	
1	1	463	CASE SPACER		D13196			264		
2	2	594	BUSHING SEAL PLATE		A60459	5		11		
2	2	595	GASKET 8IDX8 3/4ODX1/16					211		
2	2	656	O RING SHAFT SLV ARP 568 241		LU5680	2	41	211		
1	1	674	SEAL RNG OUTER RET PLT O RNG ARP 568		LU5680	2	6[illegible]	211		
1	1	678	IMP LOCKNUT THR W/CARTR SEAL		A60558	1		42	21	9
3	3	695	NIPPLE EXTENSION TBE 1/2X2 LG SCH 80					308		

LUFKIN

HERRINGBONE GEAR SPEED REDUCERS AND SPEED INCREASERS

INSTRUCTIONS

for

Installing, Lubricating

and

Operating

LUFKIN

COMMERCIAL GEAR UNITS

LUFKIN FOUNDRY & MACHINE CO. LUFKIN, TEXAS

Branch offices: Dallas, Houston, Tulsa, Los Angeles, New York, Oklahoma City, Corpus Christi, Kilgore, Wichita Falls, Casper, Wyo., Great Bend, Kan., Odessa, Tex., Seminole, Okla., El Dorado, Ark., Effingham Ill., Lafayette, La., Sidney, Mont., Edmonton, Alberta, Canada, Bakersfield, Denver, Regina, Pampa, Hobbs, Midland, Natchez

INSTRUCTIONS FOR INSTALLING, LUBRICATING AND OPERATING LUFKIN COMMERCIAL GEAR UNITS

I. General Description

Lufkin Speed Reducers and Increasers of the parallel shaft type are continuous tooth herringbone gears generated by the Sykes process. Gears, shafts, and bearings are designed to withstand 100% overload when starting for momentary operation but should not be run for extended periods of time with a horsepower greater than the service rating on the name-plate. Slow speed shafts are rigidly fixed endwise to position gears and to allow for any external thrust, but high speed shafts are allowed to float for proper gear alignment. It is important that no endwise thrust be exerted on the H.S. shaft for fear of damage to the gear teeth or bearings.

Housings are provided with eyebolts for lifting and care should be taken to prevent damage to the air breather located on the inspection cover when moving.

Test run-in at required speed is conducted on every Lufkin Gear Unit before shipment.

II. Installation

Correct installation is essential for proper operation. The gear should be mounted on a rigid and substantial foundation, preferably on concrete or steel, so that vibration will be at a minimum and proper alignment will be maintained. Foundation bolts should be embedded in concrete foundations when constructed, and if possible some provision should be made for doweling. Foundation bolt-hole and dowel pin hole spacing can be obtained from the base layout.

Power may be transmitted to or from the slow speed shaft by means of flexible coupling, sprocket, pinion, or V-belt. Flexible couplings should be used on all high speed shafts unless approved by Lufkin Engineers. Do not drive coupling on shaft, as an endwise blow may cause damage to the gears and bearings. To avoid trouble, heat the coupling in a bath of oil and shrink on the shaft.

The following steps should be taken when installing a gear unit:

1. Bring the gear unit into a horizontal position and support on broad flat shims located adjacent to and on each side of the foundation bolt holes. Several shim thicknesses may be needed to raise or lower the the unit to bring the gear unit in the same horizontal plane as the connecting shaft.

2. Move the unit on its shims until the gear unit shaft is in the same vertical plane as the connecting shaft with the correct spacing between coupling hubs. For the coupling alignment follow the procedure recommended by the coupling manufacturer. any one of the three units (driver, gear, or driven) may be lined up first and the other two lined up with it in a similar manner mentioned above. Couplings should be lined up within .005".

3. Before tightening the foundation bolts, be sure that the base sets evenly on all shims so that distortion after tightening the

the bolts will not occur. Before starting, check again for alignment with all three units bolted down tight. In case of misalignment correction should be made before unit is put into operation.

4. After complete alignment is obtained, the gear unit should then be doweled to the foundation or base. The base flange of all Lufkin Gear Units is drilled for dowel pins.

Do not mount a Lufkin Gear Unit in any position other than horizontal, unless the the unit has been specially built for this purpose. Special provisions must be made for lubrication, other than horizontal mounting.

III. Starting

Before starting the gear unit, fill the oil sump in the case with the quantity of oil called for on the name-plate and of a viscosity called for in the table on lubrication. The proper level is indicated by a sight gage on one end of the gear unit. The oil should show about half way on the glass. Be sure the pin-hole on top of the gage is always open so that oil will show exact level.

IV. Maintenance

Make a careful inspection of the unit after the first two weeks of operation. Remove inspection cover and inspect gear teeth. A flashlight is useful to see if there has been a gradual smoothing and polishing of working surfaces.

Initial pitting (pits of pin-head size or smaller on tooth surfaces in vicinity of pitch line) may be detected during initial period of gear operation. This is not serious nor detrimental if gradual, and unless it goes beyond initial stage. They will usually disappear with normal wear. If progressive pitting (continuous formation of pits in increasing size and number), scouring (roughened tooth surfaces), or galling (aggravated condition of scouring) should occur, notify the nearest Lufkin Office.

The gear unit under full load and continuous duty might become hot enough to prevent laying the hand on the housing near the bearing for even a few seconds but this is not serious so long as the temperature stabilizes and does not exceed 185°F.

Foundation bolts, housing bolts and fittings should be checked for tightness as vibration tends to loosen them.

V. Spare or Repair Parts

A special parts list assembly is provided for every Lufkin Gear Unit. When ordering spare or repair parts send all information stamped on name plate, and the part name, part number and parts list drawing number from the Parts list Assembly. State number of parts desired and give complete shipping instructions.

If parts are returned to the factory, be sure that each part is tagged with all information necessary to completely identify it.

Lufkin Engineers will gladly advise you on any gear problems you might have. When in doubt contact the nearest Lufkin Office.

LUBRICATION INSTRUCTIONS

The lubricating oils used in Lufkin Gear Units should be high grade, high quality, well refined petroleum oils. It is essential that the oils be clean; they must also be non-corrosive to gears and bearings. They must be neutral in reaction and possess good defoaming properties. When operating temperature is high the oil must have good resistance to oxidation.

Straight mineral type lubricants are to be used under ordinary operating conditions. The tabulation below shows the viscosity of oil to use for all types of Lufkin Gear Units. When Operating in the range of 0 to 40°F ambient temperature, the lubricant should be carefully selected to make certain that the pour point is below the lowest anticipated temperature.

When a new Gear Unit is started in operation the oil should be drained at the end of two weeks and the case thoroughly flushed. The original oil may be used for refilling only if it has been filtered. Under ordinary operating conditions the oil should be changed every 2500 hours of operation or every six months, whichever occurs first.

It is very important to the successful and satisfactory operation of a Gear Unit that careful attention be given to proper lubrication and that the lubricant be kept clean. Every precaution should be taken to prevent water and foreign particles from entering the gear case. In unusually dusty atmospheres and where there is rapid rise and fall in temperatures causing excessive condensation inside the case, it will be necessary to change the oil more frequently than specified above.

RECOMMENDED LUBRICANTS FOR LUFKIN GEAR UNITS

Gear Unit Number	AMBIENT TEMPERATURE 15°F – 60°F		AMBIENT TEMPERATURE 50°F – 125°F	
	AGMA Lubricant No.	Viscosity S.U.V. Secs. at 100°F	AGMA Lubricant No.	Viscosity S.U.V. Secs. at 100°F
S63 and S84	2	280–360	3	490–700
S105 thru S2010; D100 and D120	2	280–360	4	700–1000
S2211 thru S3824; D145 thru D440; T145 thru T195	3	490–700	4	700–1000
T220 thru T720	4	700–1000	5	1000–1500
All Type "M" Units	2	280–360	3	490–700
All Type "N" and "NM" Units	1	180–240	2	280–360

LUFKIN FOUNDRY & MACHINE COMPANY LUFKIN, TEXAS

SPECIAL INSTRUCTIONS FOR STARTING TYPE N HIGH SPEED GEAR UNITS

I. A pressure lubricating system is provided for all Lufkin High Speed Gear Units. This system includes an oil pump, for delivering oil from the sump to gear mesh and bearings; an oil cooler, for cooling the oil after it leaves the pump, an oil strainer to collect sediment and foreign matter in the oil; a check valve to keep the pump primed after initial starting; a pressure relief valve to prevent excessive pressure in the oil lines and cooler; an oil pressure gage to indicate oil pressure in p.s.i. before entering bearings and gear mesh; a sight flow indicator to visually inspect the flow of oil, and a spray nozzle, to spray the oil on the engaging gear teeth.

II. Before starting, fill the sump to the required quantity as called for on the name plate, with the proper lubricant, and observe the following instructions.

1. Unscrew the pipe plug in the vertical oil line near the pump and fill with oil of the same type as used in the unit. This primes the pump and is only necessary for initial starting. The check valve keeps the pump primed on all future shut downs unless the unit has been disassembled.

2. Unscrew the pipe plug located over each high speed bearing and partially fill with oil. This lubricates the bearings while the pump is building up oil pressure to the bearings. This is only necessary for initial starting. The slow speed bearings are self-lubricated from oil reservoirs located within the housing.

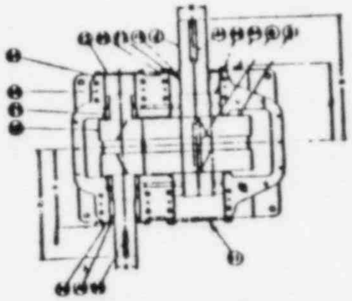
3. Check to see if cooling water circulation is started, and is of sufficient quantity to keep gear unit within proper temperature range.

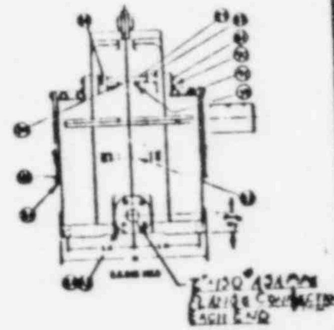
4. Check rotation. Be sure that the gear unit will rotate in the direction for which it is intended. The oil pump is undirectional and must rotate in the direction for which the arrow indicates. If other direction is desired it will be necessary to replace the pump with one of the opposite directions from our Lufkin Plant.

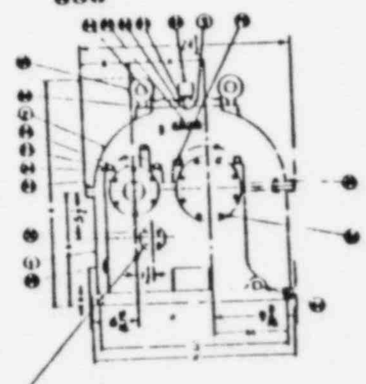
5. If it can be done conveniently turn the unit over a few times by hand before applying the power. After the unit has been running several minutes, check the pressure gage and sight flow indicator to see if oil is flowing to the bearings and gear mesh. The oil pressure should not fall below 5 p.s.i. and the temperature should never exceed 185 degrees F. Remove the cartridge from the oil strainer and wash with gasoline before replacing each time the oil is changed.

6. Couplings on TYPE N units should be as close to perfect alignment as possible. Check with coupling manufacturer for maximum misalignment for speeds involved.

LUFKIN TYPE N GEAR REDUCER







2-150# ASA PIPE FLANGE CONNECTION, EACH SIDE

ITEM NO.	QUAN	PART NO.	NAME
		OM84915	HOUSING ASSEMBLY VIZ:
1	1	OM84915	GEAR HOUSING
2	1	OM84878	GEAR HOUSING CVR.
3	1	BM84858	INSPECTION COVER
19	4	AH0407Z	STUD, S. S. 5/8-4 1/2
23	6	W905010	NUT, 5/8
24	6	W904112	LOCK WASHER, 5/8
44	2	AM04072	STUD, H.S., 5/8-4 1/2
48	2	AM18938	EYE BOLT, 5/8
49	6	W902282	BOLT FLANGE, 1/2-2
50	4	E758704	TAPER PIN, #8-2
54	4	W907172	CAP SCREW, 5/8-1 1/2
60	2	W923807	PIPE PLUG, 1/4
61	2	W923907	PIPE PLUG, 1/2

OIL FLOW REQ'D. 10-12 GPM
150 SSU @100°, HEAT INPUT 21,900 BTU/HR

DIMENSIONS IN INCHES — SHAFT TOLERANCES ± .0005"

SIZE	A	B	C	E	F	G	H	J	LA	M	N	P	Q	R	T	TA	W	X	W KEYWAY	X KEYWAY	Z
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
N8	8	14	26 1/2	6 1/2	[illegible]	21	7 1/4	23 1/4	8 1/4	10	1 1/4	13 1/2	[illegible]	16	10 1/4	[illegible]	3 1/2	2 1/2	1/2 - 1/4 - 3 1/2	1/2 - 1/4 - 2 1/2	[illegible]
[illegible]	10	17	33	12	[illegible]	30 1/4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	10	17	33	12	33	30	11 1/4	35	10 1/4	20	3	19	20 1/4	20	12 1/4	12 1/4	3 1/4		3/4 - 3/8 - 5 1/4		[illegible]
N12	12	20	37	14	36	30	11 1/4	35	10 1/4	20	3	19	20 1/4	20	12 1/4	12 1/4	3 1/4		[illegible]		[illegible]
N14	14	22	43	14	43	35	13 1/4	38	13	27	2 3/4	20 1/4	22	21 1/4	14 1/4	14 1/4	4		1 - 1/2 - 5 1/2		[illegible]
N16	16	24	47 1/4	16 1/2	47	30	15 1/4	43	14	31	3 1/4	23	24 1/4	24 1/4	16 1/4	16 1/4	4 1/2		1 - 1/2 - 7 1/2		[illegible]
N18	18	26	50 1/4	20	50 1/4	33	17 1/4	47	14 1/4	32	3 1/4	33	25 1/4	26 1/4	17	18 1/4	5		1 1/4 - 5/8 - 7 1/2		[illegible]
N21	21	28	55 1/4	22 1/4	60 1/4	24 1/4	19 1/4	53	14 1/4	33	3 1/4	34 1/4	26 1/4	27 1/4	17 1/4	17 1/4	5 1/2		1 1/4 - 5/8 - 8 1/4		[illegible]

LIST OF PARTS

ITEM NO.	QUAN	PART NO.	NAME	SIZE
4	1	BM84864	S S SHAFT	
5	1	BM85465	S S GEAR	
6	1	AM08697	S S KEY	
10	1	BM85466	PINION	
11	1	AM85458	S S END CAP	
12	1	CM84880	S S SEAL CAP	
13	1	AM15043	H S END CAP	
14	1	CM84882	H S SEAL CAP	
20	1	E775935	PIPE FLG, BLIND	1/2"-150#
21	1	BP26455	BREATHER	
25	2	CM84868	H S BEARING	
26	1	AM84836	H S SLINGER	
27	1	AM84367	S S SLINGER	
28				
29	1	AM84857	SPRAY PIPE	
30	1	E775877	SPRAY NOZZLE	1/8-U8050
31	1	E775892	CROSSOVER PIPE	1/2 OD × 9 1/2
32	8	W907250	CAPS SCREWS	1/4 × 1 1/2
34	2	CM84865	S S BEARING	
44	1	AR	S S EXT KEY	1/2-1/2-5 1/2
45	1	AR	H S EXT KEY	3/8-1/4-2 1/2
51	12	W907170	CAPSCREW	1/2-1 1/2
53	8	W907170	CAPSCREW	1/2-1 1/2
57	2	E775887	THERMOCPLE CONN	1/4
58	2	E775893	STD MALE CONN	1/4
59	1	W927901	PIPE PLUG	1/4

ITEM NO.	QUAN	PART NO.	NAME	SIZE
62	1	AR	PIPE FLG, BLIND	2", 150#
63	1	AR	GASKET, FLG	2", 150#
64	1	AR	GASKET, FLG	1/2", 150#
65				
66				
67				
68				
69	1	E775901	SIGHT GAGE	Girs, 1"
70				
71				
72				
73				
83	2	AM07711	"LUFKIN" PLATE	
84	2	AP84906	GASKET, H S	
85	2	AP84904	GASKET, S S	
86	1	AP84905	GASKET, INSP CVR	
87	1	AM08017	BAFFLE	
88	2	W907002	CAPSCREW	1/4 × 1/2
89				
90	2	W923905	PIPE PLUG	1/2
91	2	W923905	PIPE PLUG	1/2

CUSTOMER DRESSER INDUSTRIES CUSTOMER'S ORDER NO. 5122/3/4/5 DATED 9-9-69
NO REQ'D. 1 RIGHT HAND, ROTATION FACING HIGH SPEED SHAFT CCW ACTUAL H.P. 430
PRIME MOVER TURBINE DRIVEN MACHINE CENT. PUMP
HRS. PER DAY ____ TYPE & SIZE CPLG.: HS ____ SS ____
BASE NO. ____ MOTOR NO. ____
ASSEMBLY NO. ____ MOTOR MOUNTED BY ____
INSTALLATION LOCATION ____
CERTIFIED BY RDM DATE 12-9-69
KBH
LUFKIN FOUNDRY & MACHINE COMPANY - LUFKIN, TEXAS

NAME PLATE DATA
REDUCER N800C
ORDER NO. 316343/4/5/6
RATIO 2.22:1 INPUT RPM 4000
CATALOG RATING 831 HP SERVICE RATING 475 HP
SERVICE FACTOR 1.75 OIL CAPACITY GALLONS
PARTS LIST NO. N800C

546-698

Rev.1

COMBINED CURVE PREPARATION DATA

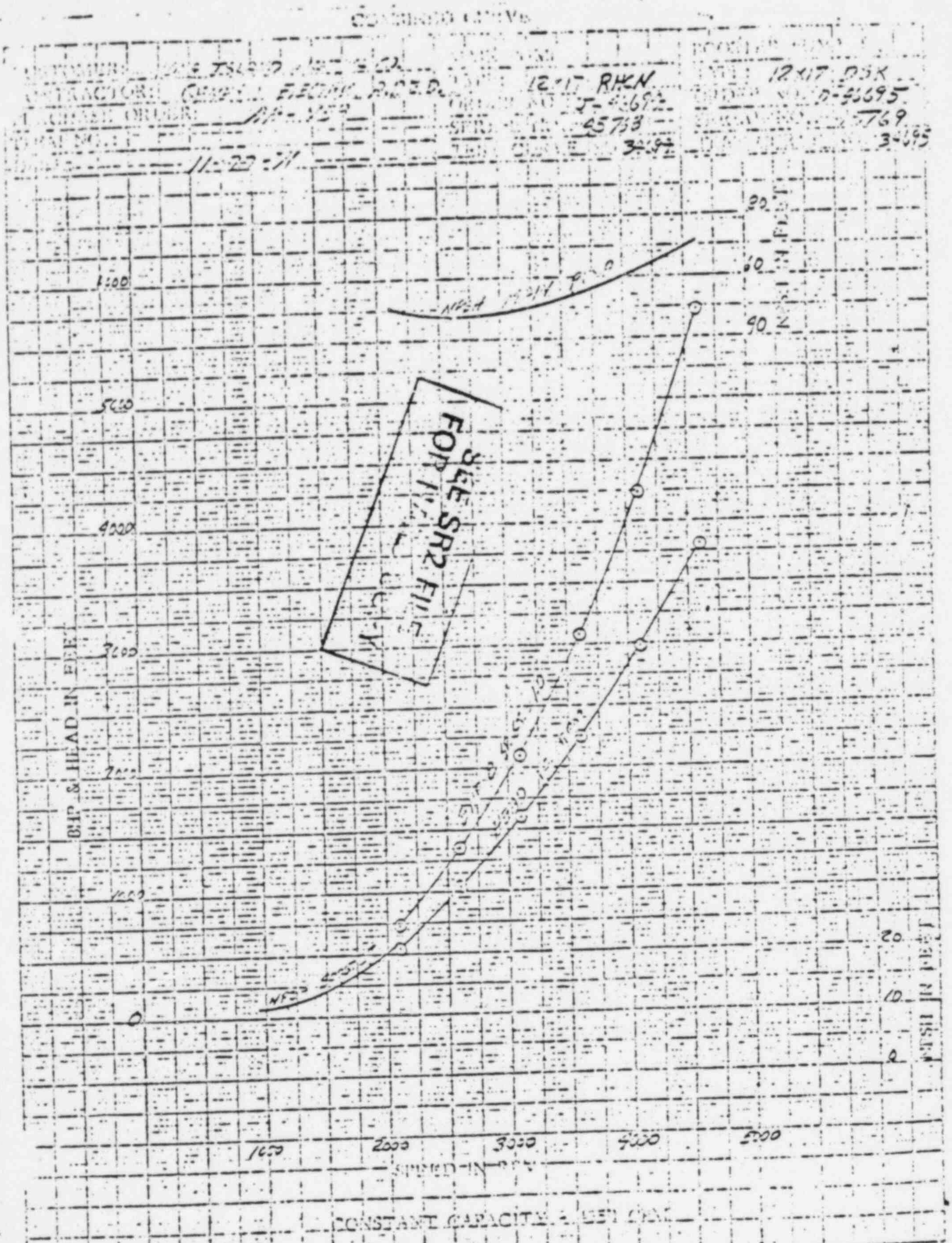
CUSTOMER: LONG ISLAND LIGHTING CO
CONTRACTOR: GENERAL ELECTRIC A.P.E.D.
PURCHASE ORDER: AH-958
ITEM NO.:
DATE: 11-22-71

MAIN PUMP
TYPE: 12x17 RHCN
ORDER NO.: J-46694
SERIAL NO.: 45768
TEST CURVE NO.: 32694

BOOSTER PUMP
TYPE: [illegible]
ORDER NO.: [illegible]
SERIAL NO.: [illegible]
TEST CURVE NO.: [illegible]

No.	Item	1	2	3	4	5	6	7	8	9	10
1	VARIABLE RPM	[illegible]	2600	[illegible]	[illegible]	[illegible]	[illegible]				
2	CONSTANT GPM @ 4250	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4250				
3	EQUIV. GPM @ TEST RPM	[illegible]	[illegible]	[illegible]	[illegible]	1150	[illegible]				
4	HEAD @ EQUIV. GPM	[illegible]	2200	[illegible]	[illegible]	[illegible]	[illegible]				
5	HEAD @ VARIABLE RPM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				
6	BHP @ EQUIV. GPM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				
7	BHP @ VARIABLE RPM	[illegible]	1217	[illegible]	[illegible]	[illegible]	[illegible]				
8	NPSH @ EQUIV. GPM	184	111	83	68	58	54				
9	NPSH @ VARIABLE RPM	50.8	46.9	49.8	[illegible]	61.0	[illegible]				
10	CONSTANT GPM @ 4350	4350	4350	[illegible]	4350	[illegible]	4350				
11	EQUIV. GPM @ TEST RPM [illegible]	[illegible]	6700	5210	[illegible]	[illegible]	3780				
12	HEAD @ EQUIV. GPM	[illegible]	[illegible]	[illegible]	291	278	304				
13	HEAD @ VARIABLE RPM	[illegible]	[illegible]	[illegible]	224.0	[illegible]	[illegible]				
14	BHP @ EQUIV. GPM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	355				
15	BHP @ VARIABLE RPM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5850				
16	BOOSTER GEAR EFF.	97.5	97.5	[illegible]	[illegible]	[illegible]	97.5				
17	GEAR INPUT BHP @ VAR. RPM	[illegible]	[illegible]	222.0	[illegible]	[illegible]	[illegible]				
18	NPSH @ EQUIV. GPM	41.5	21.5	[illegible]	17.5	11.7	16.3				
19	NPSH @ VARIABLE RPM	[illegible]	11.6	[illegible]	15.0	13.6	21.5				
20	OVERALL GPM	4250	4250	4250	4250	4250	4250				
21	TOTAL HEAD	[illegible]	[illegible]	1577	[illegible]	[illegible]	[illegible]				
22	TOTAL BHP	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5725				

SEE SR2 FILE FOR HARD COPY


12x17 RHKN
45733
12x17 DSK
D-45695
5769
11-23-71
NPSH
BHP & HEAD IN FEET
0
1000
2000
3000
4000
5000
20
10
0
SPEED IN RPM
CONSTANT CAPACITY
SEE SR2 FILE FOR

PACIFIC PUMPS, HUNTINGTON PARK, CALIF. — PUMP TEST DATA — TEST CURVE NO. 34694

SIZE 12X17 TYPE RHCH STAGES 2
P.P.I. ORDER NO. J46694 SERIAL NO. 45768

CONTRACTOR:
CUSTOMER: Gen Elect.-APED
CUSTOMER'S P.O. NO. 205-AA958
ITEM NO.
DATE: 12 NOV 1971
TESTED BY: LS & RI FOR P.P.I.
WITNESSED BY: [illegible] -11-12-71
DRIVER: G.E. TURBINE
TEST EQUIPMENT 7338 [illegible]

	ITEM NO.	NO. OF READING	1	2	3	4	5	6	7	8	9	10	11	12
POWER	23	R.P.M.	3998	3997	3998	3998	3998	3997	4005	4000	4001			
	24	TORQUEMETER.-IN. LB.	16320	9900	10190	8300	4920	1210	9720	5450	3140			
	25	ADD TO TORQUE-IN LB.	40m	60m	60m	60m	60m	60m	40m	40m	40m			
	26	TOTAL TORQUE-IN.LB. (INCLUDES TARE)	56320	69900	70190	68300	64920	61210	49720	45450	43140			
	27	NET TORQUE-IN.LB.	56120	69700	69990	68100	64720	61010	49520	45250	42940			
	28													
	29	DHP INPUT TO PUMP	3665	4430	4440	4320	4110	3875	3140	2875	2725			
	30	WATER HORSEPOWER (FROM PAGE 1)												
	31													
	32	PUMP EFFICIENCY-%	75.1	78.9	82.9	83.7	82.0	79.8	64.4	46.9	27.8			
	33													
	34	AVERAGE SP.GR. (FROM PAGE 1)	.999	.997	.997	.997	.996	.996	.996	.996	.996			
	35													
	36													
GPM	37	FLOW INDICATION	3.50	14.45	11.45	8.50	6.55	5.05	1.90	0.82	0.25			
	38	INDICATED GPM												
	39	CORRECTED GPM												
	40													
		CHARACTERISTIC CURVE CONDITIONS @ 4000 R.P.M. @ 1.000 SP. GR.												
	41	G.P.M.	4190	8500	7579	6510	5720	5030	3080	2025	1120			
	42	TOTAL HEAD FT.	2541	1635	1931	2212	2357	2457	2615	2655	2700			
	43	B.H.P.*	3570	4440	4450	4330	4120	3885	3150	2885	2735			

REMARKS:

TAKE = 200 IN LBS.

15 x 10 VENTURI [illegible]

$GPM = 2235.3 \sqrt{{}^{h}Hg. \times \frac{F.C.}{SG.}}$

PAC 138-2

PACIFIC PUMPS, HUNTINGTON PARK, CALIF. — PUMP TEST DATA — TEST CURVE NO. 34694

SIZE 12X17 TYPE RHCM STAGES 2

P.P.I. ORDER NO. J46-694 SERIAL NO 45768

	SUCTION IMPELLER	RADIAL IMPELLER	CLEARANCES	
NO	M-7282	M-7281	WRG. RING	·017
TEST DIA.	16 3/8 X 11°	16 3/8 X 11°	SPACER SLV.	·014
FINAL DIA.	16 3/8 X 11°	16 3/8 X 11°	DRUM	—

GUARANTEED PUMPING CONDITIONS

	RPM	GPM	T.D. HEAD	EFF	NPSH	BP 60
FIELD SPEED / TEST SPEED		NPSH				

DIFFUSER MAT'L:

IMPELLER MAT'L:

BAROMETER: 30.00 "Hg

CONTRACTOR:

CUSTOMER: Gen Elect APED

CUSTOMER'S ORDER NO 205-AB153

ITEM NO

DATE: 12 NOV 1971

TESTED BY: RHP, L.S., EK. FOR P.P.I.

WITNESSED BY: [illegible]

DRIVER: G.E. TURBINE

ITEM NO	NO. OF READING	1	2	3	4	5	6	7	8	9	10	11	12
1	DISCHARGE GEAR	830	810	795		1110	1078		1152	1113	1058		
2	DISCHARGE PRES.-PSIG												
3	SUCTION GAGE	79	68	62		29	12.5		19.2	4.0	2.0		
4	SUCTION PRES.-PSIG												
5	DIFFERENTIAL PRES-PSI	751	742	733		1081	1065		1133	1109	1056		
6	SUCTION TEMP.-°F	111	113	115		114	115		116	118	120		
7	SUCTION SP. GR.	.992	.992	.992		.992	.992		.991	.991	[illegible]		
8	DISCHARGE TEMP.-°F												
9	DISCHARGE SP. GR.												
10	AVERAGE SP. GR.												
11	DIFFERENTIAL HEAD-FT	1750	1729	1705		2520	2480		2640	2580	2460		
12	DIFF. VEL. HEAD-FT.	2.8	2.8	2.8		0.8	0.7		—	—	—		
13	TOTAL HEAD-FT.	1753	1732	1708		2521	2481		2640	2580	2460		
14	WATER HORSEPOWER												
15	FLOW-CPS	13.2	13.1	13.1		3.8	3.6		1.0	1.0	1.0		
16	GPM	5110	5100	8100		4360	4240		2235	2235	2235		
17	RPM	3998	3996	3997		3997	3997		3998	3997	3997		
18													
19	NPSH			174.5			59.7			39.8			
20	hv			5.7			1.6			0.5			
21	NPSHR			180.2			61.3			40.3			
22													

HEAD

TEST EQUIPMENT 7338

TEST GAGE: SR-4

TEST GAGE: BFI-2&3

DIFF. GAGE ELEV. 0 FT.

PACIFIC PUMPS, HUNTINGTON PARK, CALIF. — PUMP TEST DATA — TEST CURVE NO. 34094

SIZE 12X17 TYPE CHCH STAGES 2

P.P.I. ORDER NO. J46694 SERIAL NO. 15768

	SUCTION IMPELLER	RADIAL IMPELLER
NO	M-7282	M-7281
TEST DIA.	11-3/8 x 11°	11-3/8 x 11°
FINAL DIA.	11-3/8 x 11°	11-3/8 x 11°

CLEARANCES	
WEAR RING	.017
SPACER SLV.	.014
DRUM	—

GUARANTEED PUMPING CONDITIONS

	RPM	GPM	T.D. HEAD	EFF	NPSH	SP. GR.
RATED SPEED	4000	4250	2500	74.0	60	1.003
TEST SPEED	4000	4250	2500	74.0	60	—

CASE MAT'L: [illegible] STEEL

IMPELLER MAT'L: 11.5-13% CHROME STL

BAROMETER: —

CONTRACTOR: —

CUSTOMER: Gen Elect - A.P.E.D

CUSTOMER'S ORDER NO. 205-AA958

ITEM NO. —

DATE: 12 NOV 1971

TESTED BY: [illegible] FOR P.P.I.

WITNESSED BY: [illegible] 11-12-71

DRIVER: G.E. TURBINE

ITEM NO.	NO OF READING	1	2	3	4	5	6	7	8	9	10	11	12
1	DISCHARGE GAGE	1188	784	922	1048	1110	1154	1223	1246	1263			
2	DISCHARGE PRES.-PSIG												
3	SUCTION GAGE	90	79	90	93	95	96	99	101	102			
4	SUCTION PRES.-PSIG												
5	DIFFERENTIAL PRES.-PSI	1098	705	832	955	1015	1058	1123	1145	1166			
6	SUCTION TEMP.-°F	85	96	100	100	101	102	102	101	103			
7	SUCTION SP. GR.	.997	.995	.995	.995	.994	.994	.994	.994	.994			
8	DISCHARGE TEMP.-°F	86	95	99	100	102	102	102	103	104			
9	DISCHARGE SP. GR.	1.001	.999	.998	.999	.998	.998	.998	.998	.998			
10	AVERAGE SP. GR.	.999	.997	.997	.997	.996	.996	.996	.996	.996			
11	DIFFERENTIAL HEAD-FT	2540	1632	1929	2210	2350	2450	2615	2655	2700			
12	DIFF. VEL. HEAD-FT.	0.7	3.0	2.4	1.7	1.4	1.0	0.4	0.2	—			
13	TOTAL HEAD-FT.	2541	1635	1931	2212	2351	2451	2615	2655	2700			
14	WATER HORSEPOWER												
15	FLOW-CPS												
16	GPM	4190	8500	7570	6510	5720	5030	3080	2025	1130			
17													
18													
19													
20													
21													
22													

HEAD

TEST EQUIPMENT 7338

TEST GAGE: SR-[illegible]

TEST GAGE: RF1-2

DIFF. GAGE ELEV. 0 FT.

1930/1'

PAC 178

CONTRACTOR GENERAL ELECTRIC A.PED.

CUSTOMER L.L.L.C.O.

ITEM NO. - P.O. AA 958

IMPELLER PATTERN M-7232 M-7261

MAXIMUM DIAMETER 17 17

RATED DIAMETER 16 3/8 X 11° 16 3/8 X 11°

MINIMUM DIAMETER 15 15

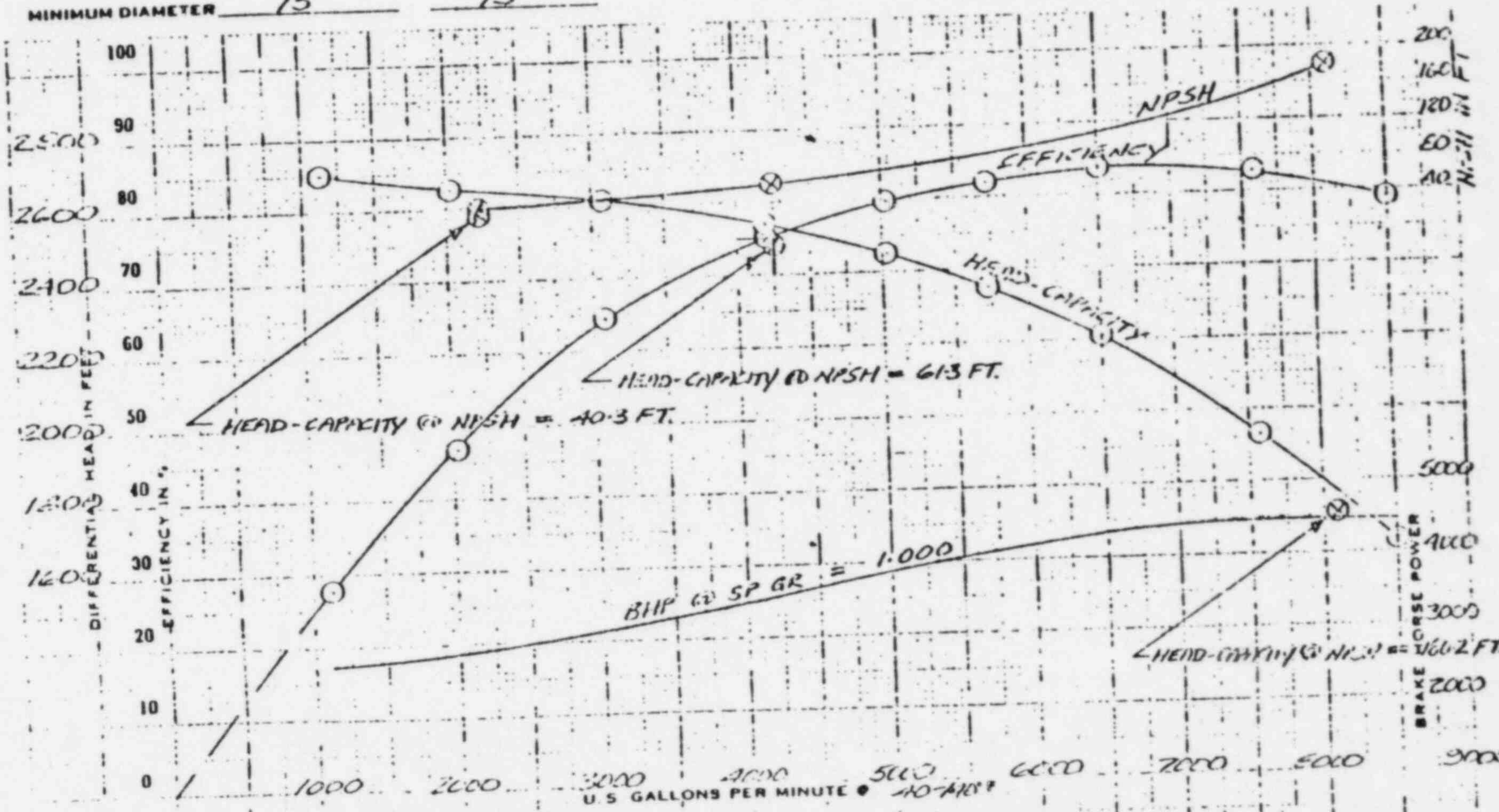
TEST PERFORMANCE CURVE NO. 34694

SIZE 12X17 TYPE RHCH STAGES 2

R.P.M. 4000 DATE 11-12-71

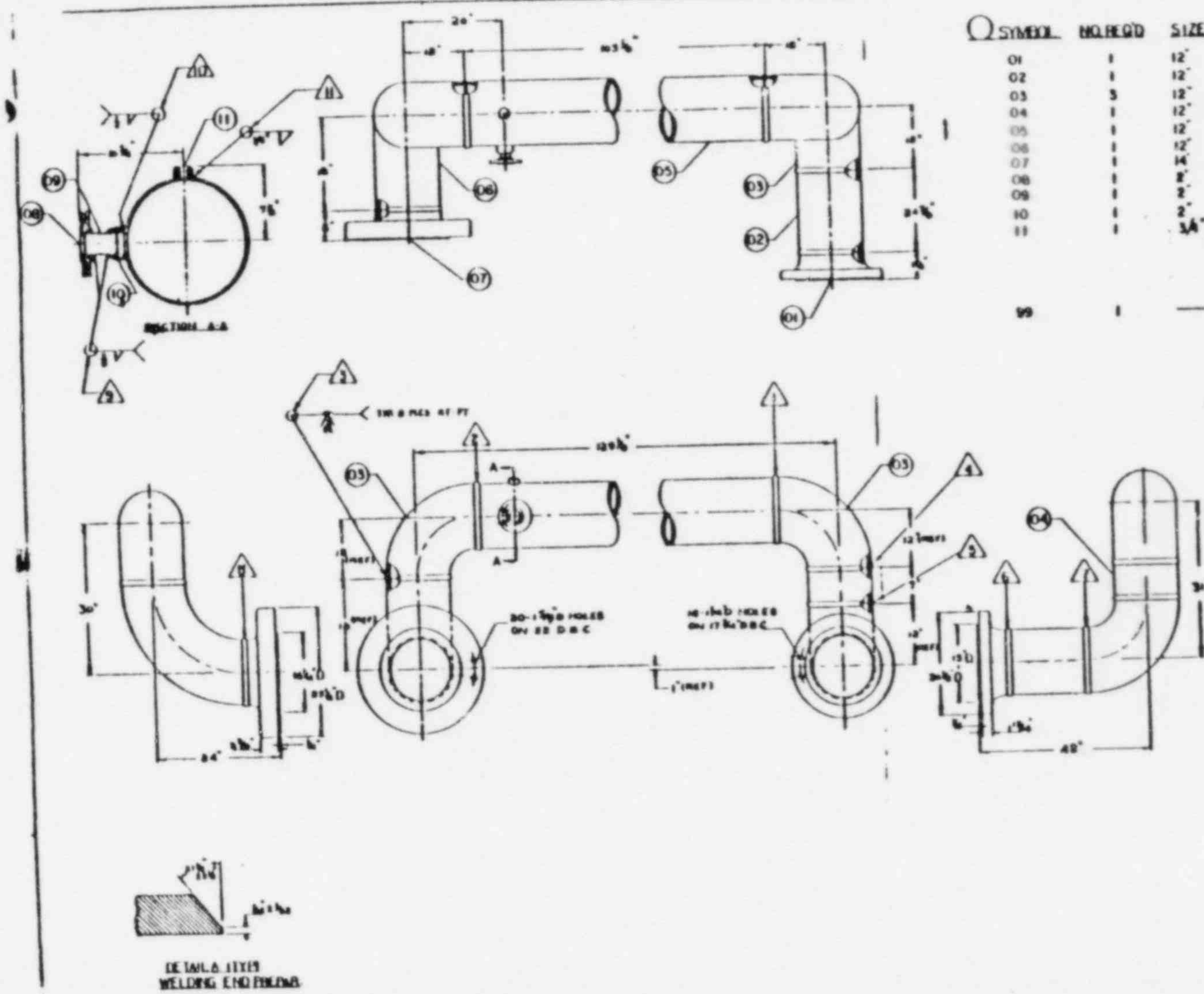
PUMP NUMBER 45766

PERFORMANCE ALSO APPLIES TO PUMP NUMBER -



PACIFIC PUMPS. HUNTINGTON PARK, CALIFORNIA

PAC 240

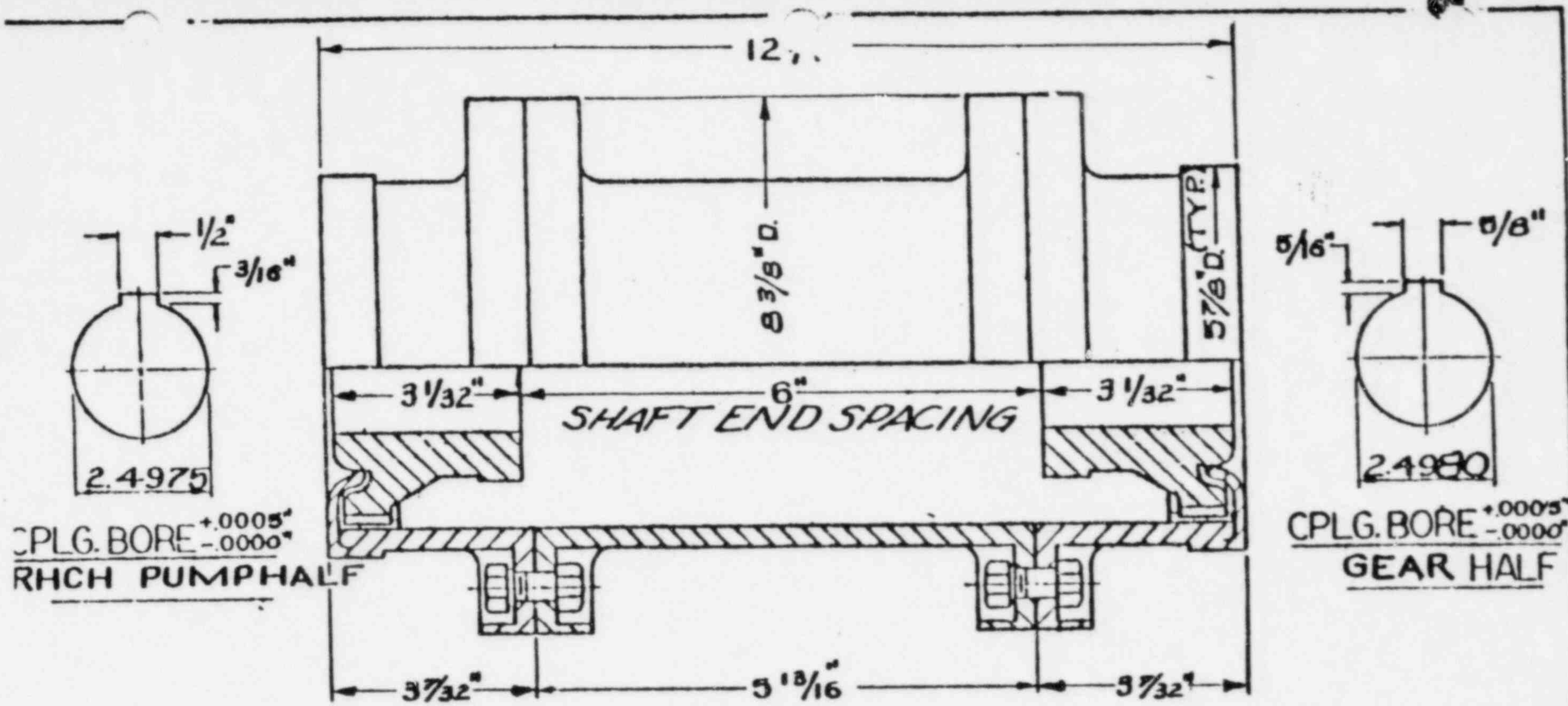


○ SYMBOL	NO. REQ'D	SIZE	DESCRIPTION	MAT'L		
01	1	12"	12"-600#ASA STD RF WELD NECK FLG (SCH 40S)	ASTM	A-105	GR II
02	1	12"	PIPE – SCH 40S (.375 WALL)	ASTM	A-106	GR B
03	3	12"	ELL 90° SHORT RAD W/WELD END (STD .375)	ASTM	A-234	WPB
04	1	12"	PIPE – SCH 40 S (.375 WALL)	ASTM	A-106	GR B
05	1	12"	PIPE – SCH 40S (.375 WALL)	ASTM	A-106	GR B
06	1	12"	ELL 90 – LONG RAD. W/WELD END (.375 WALL)	ASTM	A-234	WPB
07	1	14"	14"-900#ASA STD RF FLG W/SPECIAL WELD NECK	ASTM	A-105	GR II
08	1	2"	2"-300#ASA STD RF FLG	ASTM	A-105	GR II
09	1	2"	PIPE – C.T.S – SCH 160	ASTM	A-106	GR B
10	1	2"	SOCKOLET – RUN PIPE 12"	ASTM	A-181	GR II
11	1	3/4"	THREDOLET – RUN PIPE 12"	ASTM	A-181	GR II
99	1	—	ASSEMBLY			

△ SYMBOL	DESCRIPTION
1	RADIOGRAPH
2	RADIOGRAPH
3	RADIOGRAPH
4	RADIOGRAPH
5	RADIOGRAPH
6	RADIOGRAPH
7	RADIOGRAPH
8	RADIOGRAPH
9	LIQUID PENETRANT
10	LIQUID PENETRANT
11	LIQUID PENETRANT

CERTIFIED CORRECT
BY [signature] DATE

PACIFIC PUMPS
CONNECTING PIPING



J-44698

CPLG. TYPE - FAST STD.

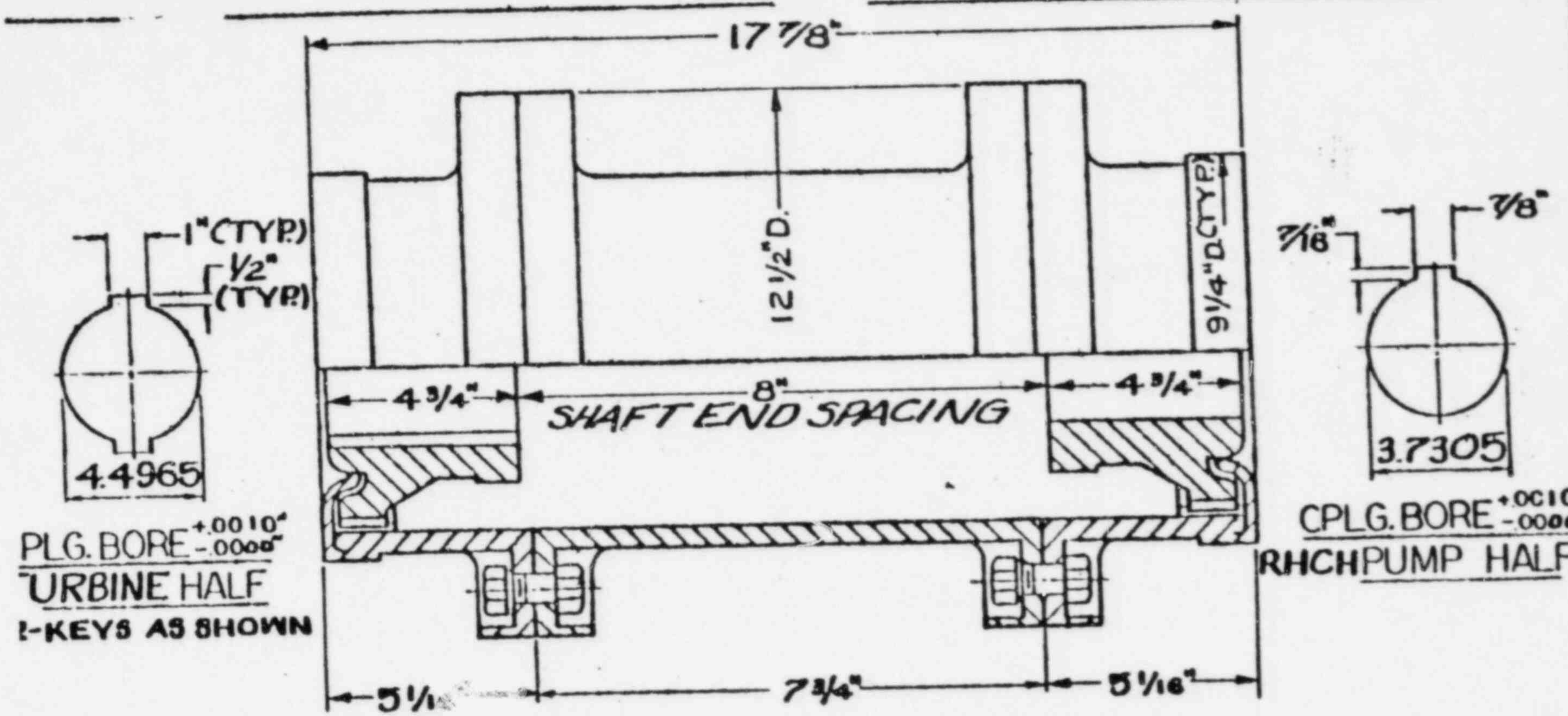
CPLG. SIZE - #2 1/2

430 H.P 4000 R.P.M

CERTIFIED CORRECT

BY [signature] DATE 1-14-70

PACIFIC PUMPS INC.			
COUPLING SHEET			
DWN. [initials]	CHK. RDB	DATE 1-70	ACG 45768



V-46698

CPLG. TYPE - FAST STD. - DYN. BALANCED

CPLG. SIZE - #4

4100 H.P. 4000 R.P.M.

CERTIFIED CORRECT

BY [signature] DATE 1-14-70

PACIFIC PUMPS INC.

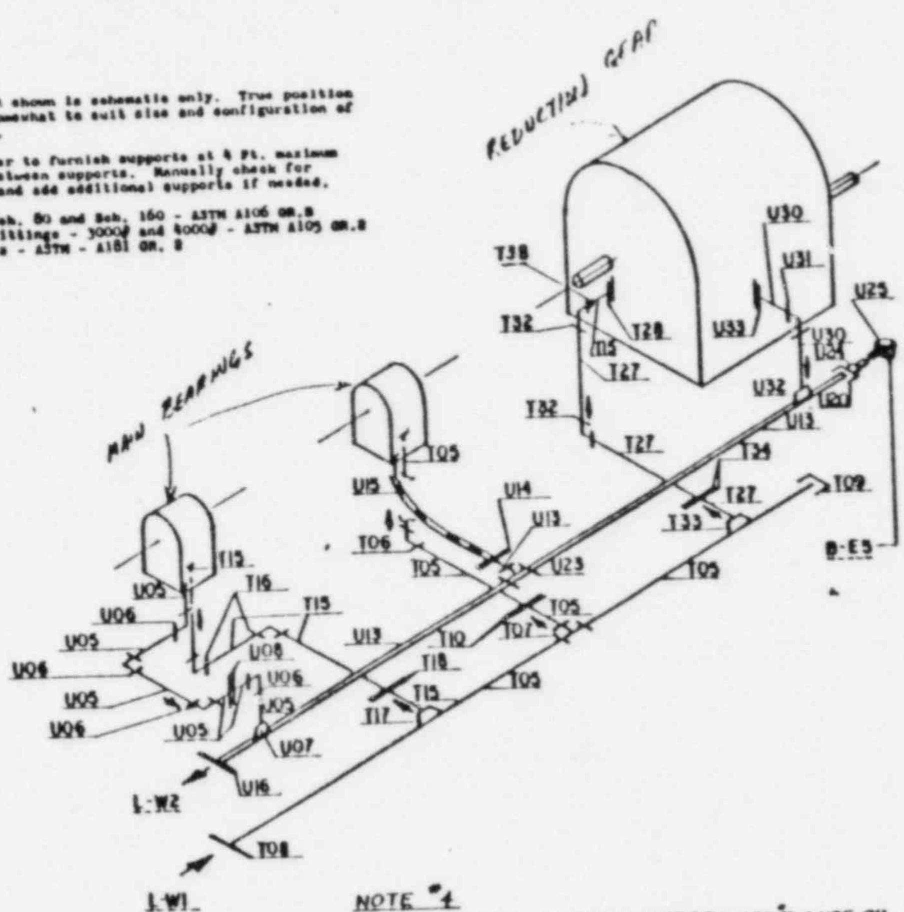
COUPLING SHEET

DWN.	CHK. R.D.B.	DATE 1-12-70	ACP-45768

NOTE #1 Arrangement shown is schematic only. True position may vary somewhat to suit size and configuration of components.

NOTE #2 Manufacturer to furnish supports at 4 Ft. maximum distance between supports. Manually check for vibration and add additional supports if needed.

NOTE #3 All pipe Sch. 80 and Sch. 160 - ASTM A106 GR.B
All pipe fittings - 3000# and 4000# - ASTM A105 GR.II
All flanges - ASTM - A181 GR. II



NOTE #4

INLET LUBE OIL TEMP. APPROX. 150°F. LUBE OIL CHARACTERISTICS 250 S.S.U. @ 100°F

BEARING	LUBE OIL REQ'D-GPM	BTU/HR HEAT INPUT
PUMP THRUST	12-15	38,100
RAD SLV. BRG.	3-5	12,700
GEAR	10-12	21,900
TOTAL SYSTEM	25-32	72,700

ITEM NO.	NO. REQ'D	SIZE	DESCRIPTION
		PRESSURE LINE TO BRGS	
T05	AS REQ'D	1-1/4" P.E.	PIPE - O.T.S. - SCH. 160
T06	1	1-1/4" S.W.	ELBOW-90°-4000#
T07	1	1-1/4" S.W.	TEE - 4000#
T08	1	1-1/2"	FLANGE-SLIP-ON - ASA STD. 1-1/2"-150# R.F. (FOR 1-1/4" PIPE)
T09	1	1-1/4" S.W.	CAP - 4000#
T10	2	1-1/4" S.W.	FLANGE - 150#
T15	AS REQ'D	3/4" P.E.	PIPE - O.T.S. - SCH. 160
T16	2	3/4" S.W.	ELBOW - 90° - 4000#
T17	1	3/4" X 1-1/4 S.W.	WELDOLET - SCH. 160
T18	2	3/4" S.W.	FLANGE - 150#
		PRESSURE LINE TO GEAR	
T27	AS REQ'D	1" P.E.	PIPE - O.T.S. - SCH. 160
T28	1	3/4" S.W.	FLANGE - 150#
T32	2	1" S.W.	ELBOW - 90° - 4000#
T33	1	1" X 1-1/4 S.W.	WELDOLET - SCH. 160
T34	2	1" S.W.	FLANGE - 150#
T38	1	1" S.W. X 3/4" S.W.	REDUCER INSERT-FOOT DSCS. TYPE 1
		RETURN LINE FROM BRGS	
U05	AS REQ'D	1-1/2" P.E.	PIPE - O.T.S. - SCH. 160
U06	4	1-1/2" S.W.	ELBOW - 90° - 4000#
U07	1	1-1/2" X 3" S.W.	WELDOLET - SCH. 160
U08	2	1-1/2" S.W.	FLANGE - 150#
U13	AS REQ'D	3" P.E.	PIPE - O.T.S. - SCH. 80
U14	1	3"	FLANGE - SLIP-ON - 150#
U15	1	3"	FLEXIBLE HOSE ASSEMBLY
U16	1	3"	FLANGE-SLIP-ON - 150#
U20	1	3" S.W.	CAP - 3000#
U23	1	3"	TEE - BUTT WELD - SCH. 80
U24	1	1/2" NPT	COUPLING-HALF - 3000#
U25	1		THERMOCOUPLE DWG. 015077-07-00
		RETURN LINE FROM GEAR	
U30	AS REQ'D	2" P.E.	PIPE - O.T.S. - SCH. 160
U31	1	2" S.W.	ELBOW - 90° - 4000#
U32	1	2" X 3" S.W.	WELDOLET - SCH. 160
U33	1	2" S.W.	FLANGE - 150#

CERTIFIED CORRECT

BY [signature] DATE

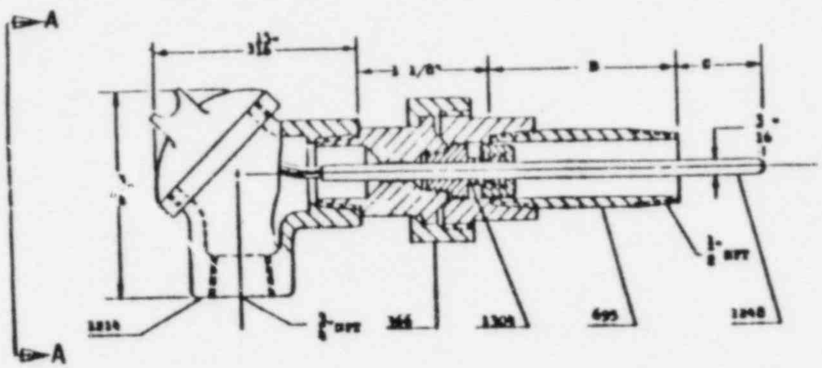
346-698

1	NOTE #4 ADDED	
2	ITEM T38 REVISED	
	CERTIFIED ADDED	
3		
4		

PACIFIC PUMPS INC.

LUBE OIL PIPING

CLO-45768-3



B - 8", OR AS REQUIRED

C - AS REQUIRED

NOTE: HEAD ASSEMBLY INCLUDES SCREWED AND GASKETED COVER CHAINED TO BODY.

PART NO.	DESCRIPTION	MATERIAL
366	UNION	304 S.S.
695	EXTENSION NIPPLE	304 S.S.
1214	HEAD ASSEMBLY	[illegible]
1848	ELEMENT	SELECT
1304	COMPRESSION FTG	304 S.S.

VIEWS A-A

FIGURE 1

TERMINAL BLOCK FOR SINGLE ELEMENT

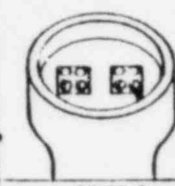
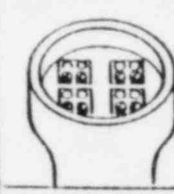


FIGURE 2

TERMINAL BLOCK FOR DUAL ELEMENT



MAXIMUM

THERMOCOUPLE

LINE NO.	SELECT ONE	WIRE MATERIAL	WIRE GA	TUBE MAT'L	TUBE PACKING	SINGLE/ DUAL	GROUNDED OR UNGROUNDED	HEAD
1								
2								
3								
4								
5								
6								
7		COPPER CONSTAN	20	18-8SS	MG OXIDE	SINGLE	GROUNDED	FIG 1
8		IRON CONSTAN						
9		CHROMEL ALUMEL						
10		CHROMEL CONSTAN						
11								
12								
13		COPPER CONSTAN					UNGROUNDED	
14		IRON CONSTAN						
15		CHROMEL ALUMEL						
16		CHROMEL CONSTAN						
17								
18								
19		COPPER CONSTAN	24			DUAL	GROUNDED	FIG 2
20		IRON CONSTAN						
21		CHROMEL ALUMEL						
22		CHROMEL CONSTAN						
23								
24								
25		COPPER CONSTAN					UNGROUNDED	
26		IRON CONSTAN						
27		CHROMEL ALUMEL						
28		CHROMEL CONSTAN						
29								
30								
31								
32								

RESISTANCE TEMPERATURE DETECTOR

LINE NO.	SELECT ONE	OHMS RESIST	SINGLE/ DUAL	TUBE MAT'L	TEMP LIMIT	HEAD	EQUAL TO
51		150 @ 32°F (EDISON NO. 7)	SINGLE	18-8SS	450°F	FIG 1	EDISON 8708 OR 166HQ
52		507.5 @ 32°F	SINGLE	18-8SS	450°F	FIG 1	HONEYWELL "[illegible]" BULB
53		100 @ 32°F (EDISON NO. 7)	DUAL	18-8SS	450°F	FIG 2	EDISON 315N OR 347-[illegible]

SERVICE: HPCI MAIN PUMP
REF: "B-E5" ON FC 45768

*LILCO PROJECT ONLY

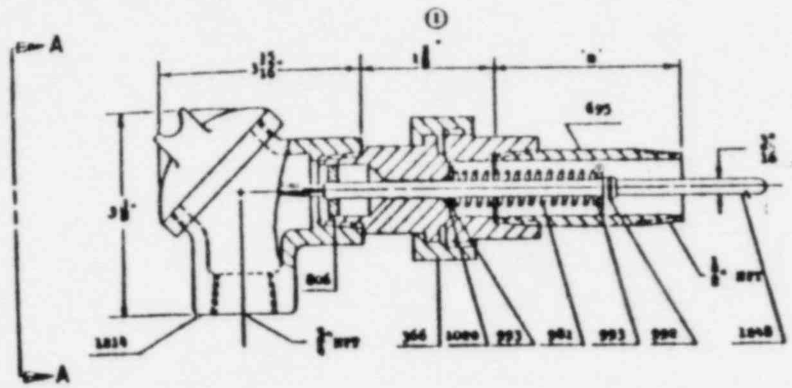
FOR DIMENSIONS, SEE DWG C-15678

PATENT PENDING

PACIFIC PUMPS INC.

TEMPERATURE DETECTOR ASSY. & DATA

C-15677



B - 2", OR AS REQUIRED.

NOTE: HEAD ASSEMBLY INCLUDES SCREWED AND GASKETED COVER CHAINED TO BODY.

PART NO.	DESCRIPTION	MATERIAL
366	T.D. HOLDER UNION	CARBON STEEL
695	EXTENSION NIPPLE	CARBON STEEL
806	STOP COLLAR	NEOPRENE
981	SPRING	STEEL
992	FERRULE	BRASS
993	WASHER	BRASS
1020	"O" RING	HI-CAR
1214	HEAD ASSEMBLY	IRON/CAD. PLT.
1848	ELEMENT	SELECT

VIEWS A-A

FIGURE 1

TERMINAL BLOCK FOR SINGLE ELEMENT

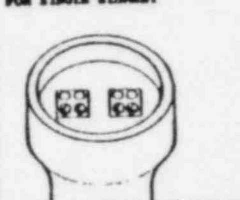
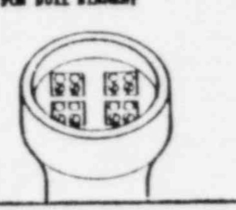
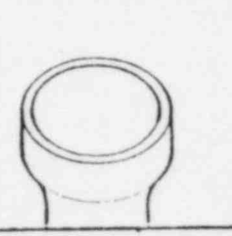


FIGURE 2

TERMINAL BLOCK FOR DUAL ELEMENT





THERMOCOUPLE

LINE NO.	SELECT ONE	WIRE MATERIAL	WIRE GA.	TUBE MAT'L	TUBE PACKING	SINGLE DUAL	GROUNDED UNGROUNDED	HEAD
1		COPPER-CONSTAN.	20	COPPER	NONE	SINGLE	GROUNDED	FIG 1
2		IRON-CONSTAN.						
3		CHROMEL-ALUMEL						
4								
5								
6								
7		COPPER CONSTAN.		18-8SS	MG.OXIDE			
8		IRON-CONSTAN.						
9		CHROMEL-ALUMEL						
10		CHROMEL-CONSTAN						
11								
12								
13		COPPER-CONSTAN.					UNGROUNDED	
14		IRON-CONSTAN.						
15		CHROMEL-ALUMEL						
16		CHROMEL-CONSTAN.						
17								
18								
19		COPPER-CONSTAN.	24			DUAL	GROUNDED	FIG 2
20		IRON-CONSTAN.						
21		CHROMEL-ALUMEL						
22		CHROMEL-CONSTAN.						
23								
24								
25		COPPER-CONSTAN.					UNGROUNDED	
26		IRON-CONSTAN.						
27		CHROMEL-ALUMEL						
28		CHROMEL-CONSTAN.						
29								
30								
31								
32								

RESISTANCE TEMPERATURE DETECTOR

LINE NO.	SELECT ONE	OHMS RESIST.	SINGLE DUAL	TUBE MAT'L	TEMP LIMIT	HEAD	EQUAL TO
51		120 @ 32°F (EDISON 7)	SINGLE	18-8SS	450°F	FIG 1	EDISON F308 OR 8646
52		507.5Ω @ 32°F	SINGLE			FIG 3	HONEYWELL "A" BULB
53		120 @ 32°F (EDISON 7)	DUAL			FIG 2	EDISON 3138 OR 387-7
54							
55							

SERVICE: HPCI MAIN PUMP
REF: "B-E1"; "B-E2"; "B-E3" ON PC-45768

*LILCO PROJECT ONLY

THIS DWG SUPERSEDES C-14801

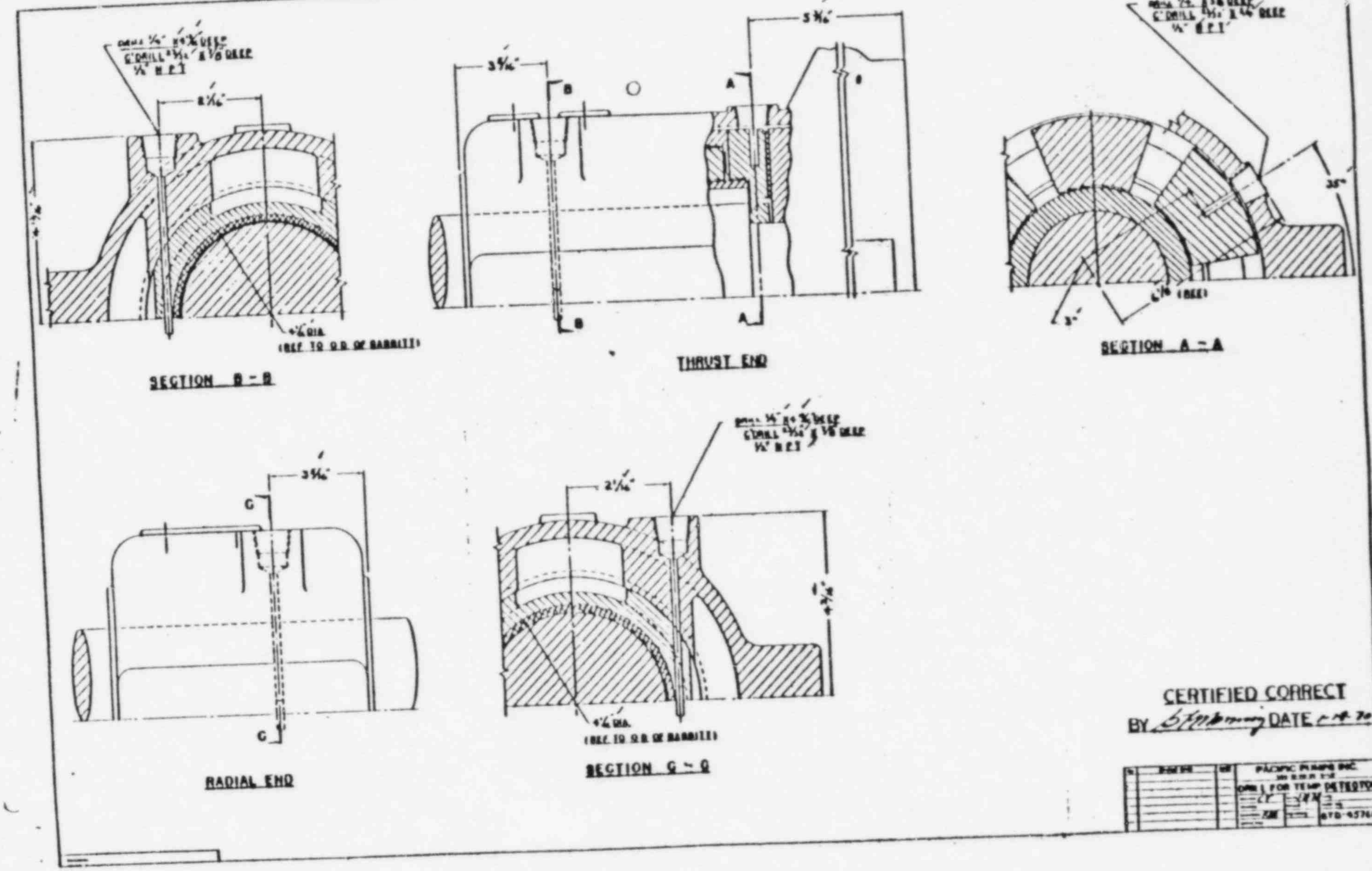
(PATENT PENDING)

PACIFIC PUMPS INC.

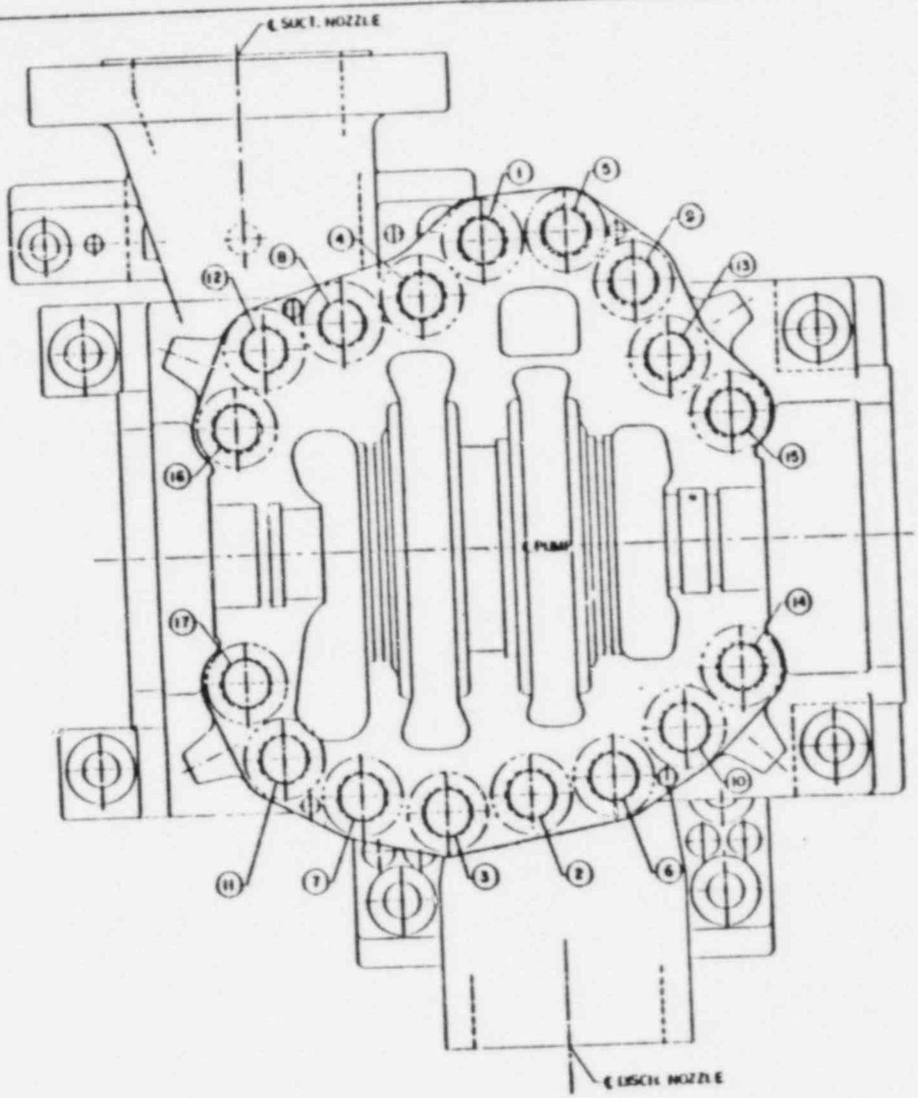
TEMPERATURE DETECTOR ASSEMBLY & DATA

[illegible]

C-15665


SECTION B - B
THRUST END
SECTION A - A
RADIAL END
SECTION G - G
(REF TO O.D. OF BABBITT)
CERTIFIED CORRECT
BY
DATE
PACIFIC PUMPS INC.
DRILL FOR TEMP DETECTOR

J-46698



NOTE

1. TORQUE LOAD FOR 3"-12N CAPNUT IS 8000 FT.LBS.
2. NUMBERS SHOWN (FROM 1 TO 17) INDICATE THE TIGHTENING SEQUENCE OF CASE PARTING FLANGE BOLTING.
3. INDIVIDUAL NUTS AND BOLTS TO BE TIGHTENED IN A SERIES OF 2 PROGRESSIVE STEPS OF 75% AND 100% OF FINAL TORQUE LOAD.
4. ⚠ NUT AND BOLT THREAD LUBRICANT SHALL BE "NEOLUBE" WHICH IS MANUFACTURED BY: HURON INDUSTRIES P.O. BOX 104 PORT HURON, MICH.
   THOROUGHLY LUBRICATE ALL STUD THREADS AND FACES OF ALL CAPNUTS

CERTIFIED CORRECT

BY [signature] DATE

PACIFIC PUMPS

BOLTING SEQUENCE

DBC-45768

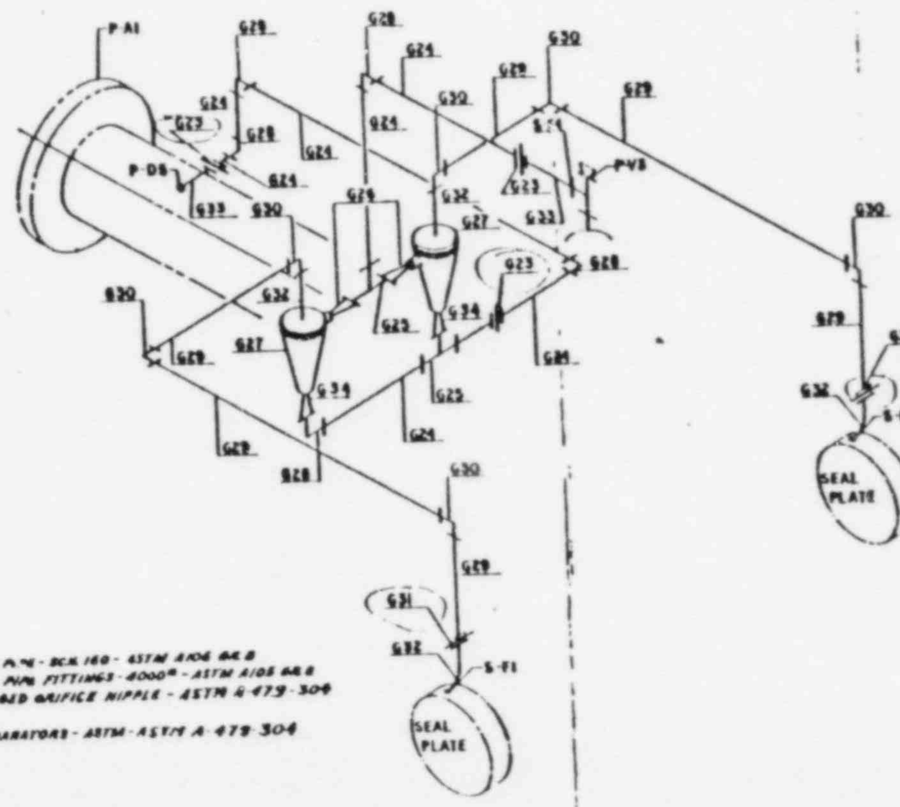
NOTE #1
ARRANGEMENT SHOWN IS SCHEMATIC ONLY
TRUE POSITION MAY VARY SOMEWHAT TO
SUIT SIZE AND CONFIGURATION OF
COMPONENTS.

NOTE #2
MANUFACTURER TO FURNISH SUPPORTS AT 4 FT. MAXIMUM
DISTANCE BETWEEN SUPPORTS. MANUALLY CHECK FOR
VIBRATION AND ADD ADDITIONAL SUPPORTS IF NEEDED.

NOTE #3
ALL THREADED CONNECTIONS TO BE SEAL WELDED,
EXCEPT VENT P-V3 - PLUGGED.

ITEM NO.	NO. REQ'D	SIZE	DESCRIPTION
G22	2	3/4" S.W.	UNION
G23	AS REQ'D	3/4" A.E.	PIPE - C.T.S.
G24	2	3/4" S.W.	TEE
G25	2	3/4" x 1/2" T.O.E.	SWAGED NIPPLE - ORIFICE
G26	2	1/2" NPT	PACIFIC "CENTRI-CLEAN" SEPARATOR
G27	2	[illegible]	ELBOW - 90°
G28	AS REQ'D	1/2" A.E.	PIPE - C.T.S.
G29	6	1/2" S.W.	ELBOW - 90°
G30	2	1/2" S.W.	UNION
G31	AS REQ'D	1/2" T.O.E.	PIPE - C.T.S.
G32	AS REQ'D	3/4" T.O.E.	PIPE - C.T.S.
G33	2	3/4" x 1/2" T.O.E.	SWAGED NIPPLE

GENERAL ELECTRIC ATOMIC POWER EQUIPMENT DEPARTMENT

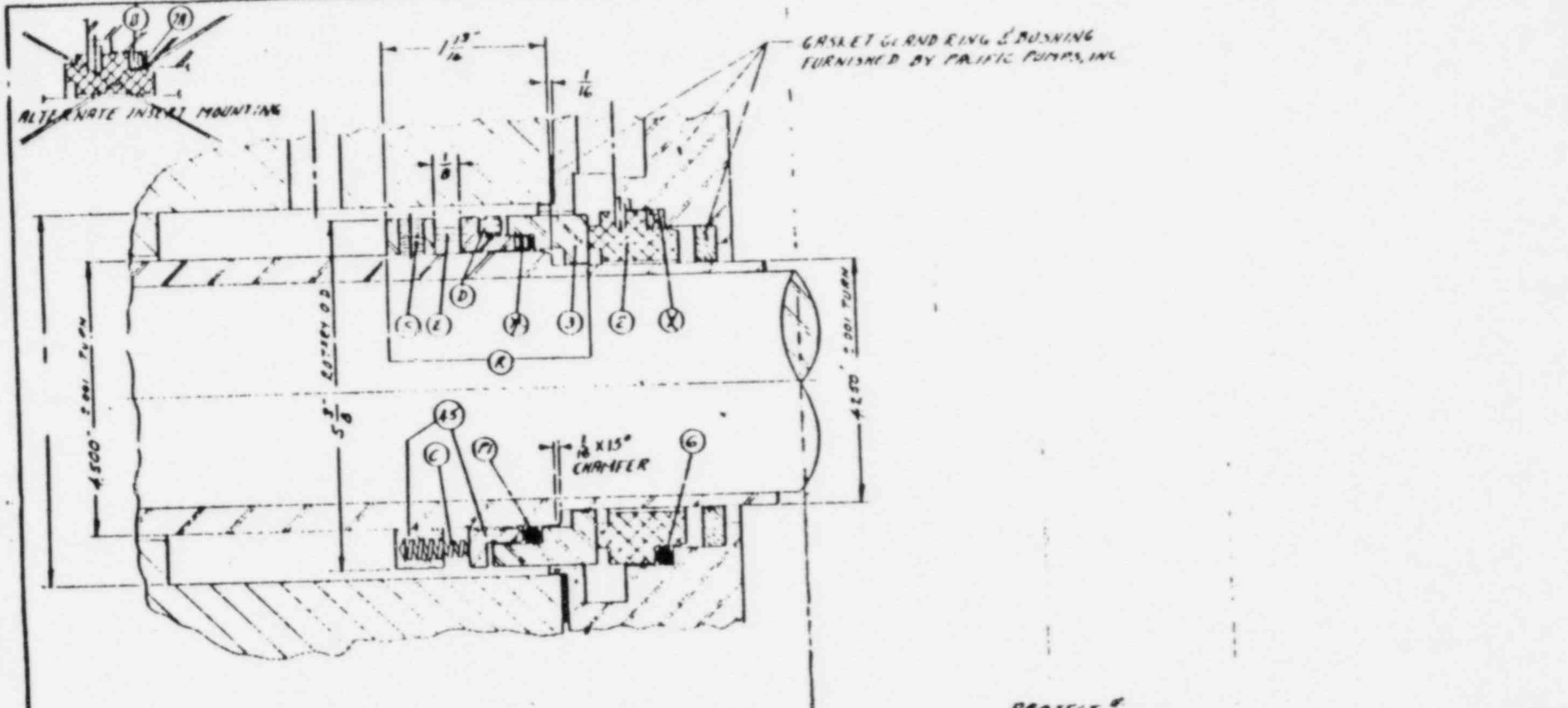


CERTIFIED CORRECT
BY [signature] DATE 12-11-69

NOTE #4
ALL PIPE - SCH. 160 - ASTM A106 GR. B
ALL PIPE FITTINGS - 6000# - ASTM A105 GR. B
SWAGED ORIFICE NIPPLE - ASTM A 479 - 304

SEPARATORS - ASTM - ASTM A 479 - 304

PACIFIC PUMPS INC.
SEAL FLUSH PIPING
CSF-45768 4



MFG.

PROJECT #

R	ROTARY UNIT CONSISTING OF		2	INSERT	# 5 CARBON
3	SEAL RING	316 STAIN	6	"O" RING	BUNA "N"
45	COMP UNIT	316 STAIN	7	"H" RING	—
			P	SHAFT PACK	—
C	SPRINGS	20 STAIN	P1	SHAFT PACK	BUNA "N"
D	DRIVE PINS	20 STAIN	7B	"V" RING	—
E	SPRING PINS	20 STAIN	8	RETAINER RING	~
S	SET SCREWS	20 STAIN			

PARTS: 2, 3, 6 or 7, C, P or P1, 7, 8, S TO BE KEPT IN STOCK AS SPARES

BUYER: PACIFIC PUMPS, INC. HUNTINGTON PARK, CALIF.
ORDER NO.: 18034
USER: GENERAL ELECTRIC A.P.E.D.

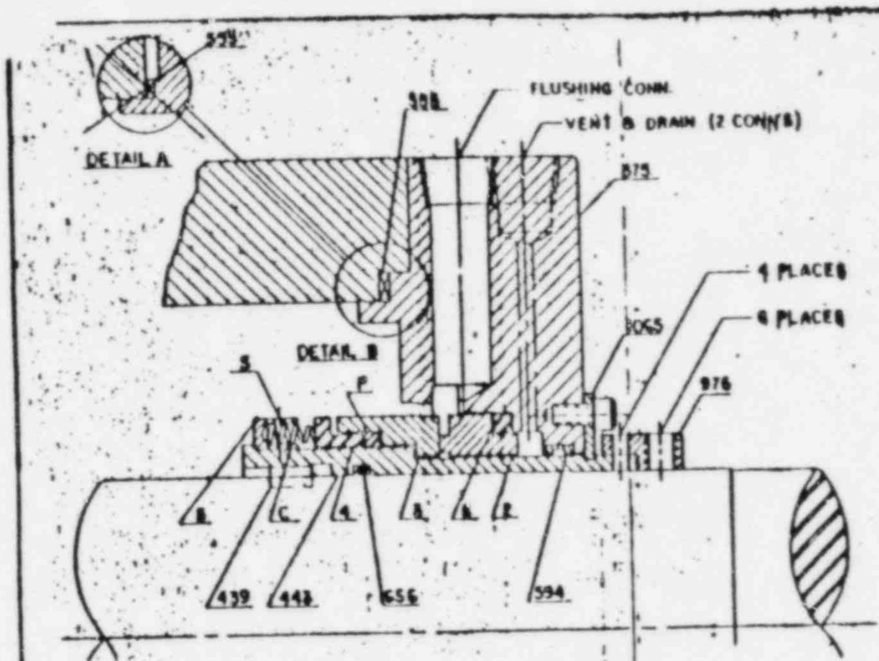
PUMP TYPE & SIZE	PUMP ITEM NO	PUMP SERIAL NO	REFERENCE DRAWING NO	FLUID	PRESSURE BOX	PRESSURE DISCH	R.P.M.	TEMP	SP. GR.
PACIFIC 2x13 RHON			3-K 2D 45688-A	WATER	150 PSIG		6000	60-180	1.0

DURA SEAL TYPE
INSIDE "HSPTO"
ORDER PARTS BY D/M NO. 51743

DURAMETALLIC CORPORATION
KALAMAZOO, MICH.

T.O. 36498-70	SCALE NTS
DATE 6-30-70	
DRAWN L AYARD	DWG. NO.
TORIS 2F-73098	2D-36345
CHECKED L	

J-46698



PACIFIC PUMPS SEAL PARTS

PART NO.	NO. REQ'D.*	NAME OF PART	MATERIALS
375	1	SEAL PLATE	ASTM A 479 TP 304 -①
443	1	SHAFT SLEEVE	ASTM A-276 TP416 - RC 97-38
594	1	SEAL PLATE BUSHING	ASTM B-145-4A
595	1	SEAL PLATE GASKET	BY CAR
656	1	SHAFT SLEEVE "O" RING	BY CAR
976	1	SHAFT SLEEVE COLLAR	ASTM A276 TP416 - NOTE A
1065	1	RETAINER PLATE	ASTM A276 TP416 - NOTE A
①439	1	SHAFT SLEEVE KEY	ASTM A276 TP410 - NOTE A

NOTE: A - LESS THAN 30 RC

DURAMET. PTO SEAL PARTS

PART NO.	NO. REQ'D.*	NAME OF PART	MATERIALS
[illegible]	1	INSERT	CARBON
[illegible]	1	SEAL RING	TUNG. CARB. "N"
[illegible]	1	COMPRESSION RING	AISI 316
[illegible]	1	COLLAR	AISI 316
① [illegible]	1	INSERT "O" RING	BUNA N
C	1 SET	SPRINGS	CARPENTER #20
① F	1	SEAL "O" RING	BUNA N
[illegible]	[illegible]	SET SCREWS	CARPENTER #20

*NOTE: QUANTITIES SHOWN ARE FOR EACH SEAL ASSEMBLY.

SYM NO	DESCRIPTION
01	DETAIL A
02	DETAIL B

CERTIFIED CORRECT
BY [signature] DATE 12-12-69

DURAMETALLIC PTO-SIZE 4.500

PACIFIC PUMPS INC.
LOS ANGELES, CALIF.
SEAL ASSEMBLY
C-15962

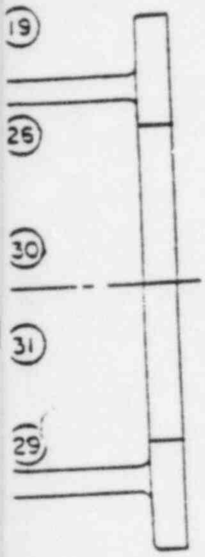
5246-658

NOTE ✱1. TORQUE LOAD FOR 1 1/8"-12N CAPNUT IS 400 FT. LBS.

2. NUMBERS SHOWN (FROM 1 TO 34) INDICATE THE TIGHTENING SEQUENCE OF CASE PARTING FLANGE BOLTING.

3. INDIVIDUAL NUTS AND BOLTS TO BE TIGHTENED IN A SERIES OF 2 PROGRESSIVE STEPS OF 75% AND 100% OF FINAL TORQUE LOAD.

⚠4 4. NUT AND BOLT THREAD LUBRICANT SHALL BE "NEOLUBE"- WHICH IS MANUFACTURED BY:
HURON INDUSTRIES
P.O. BOX 104
PORT HURON, MICH.
THOROUGHLY LUBRICATE ALL STUD THREADS AND FACES OF ALL CAPNUTS



CERTIFIED CORRECT
BY [signature] DATE 12-8-[illegible]

NO.	REVISION	BY	DATE	CKD
3	ADDITIONAL [illegible] ADDED	[illegible]	[illegible]	
2	NOTE NO 4 ADDED	[illegible]	[illegible]	
1	REMOVE PROJECT TITLE	[illegible]	[illegible]	

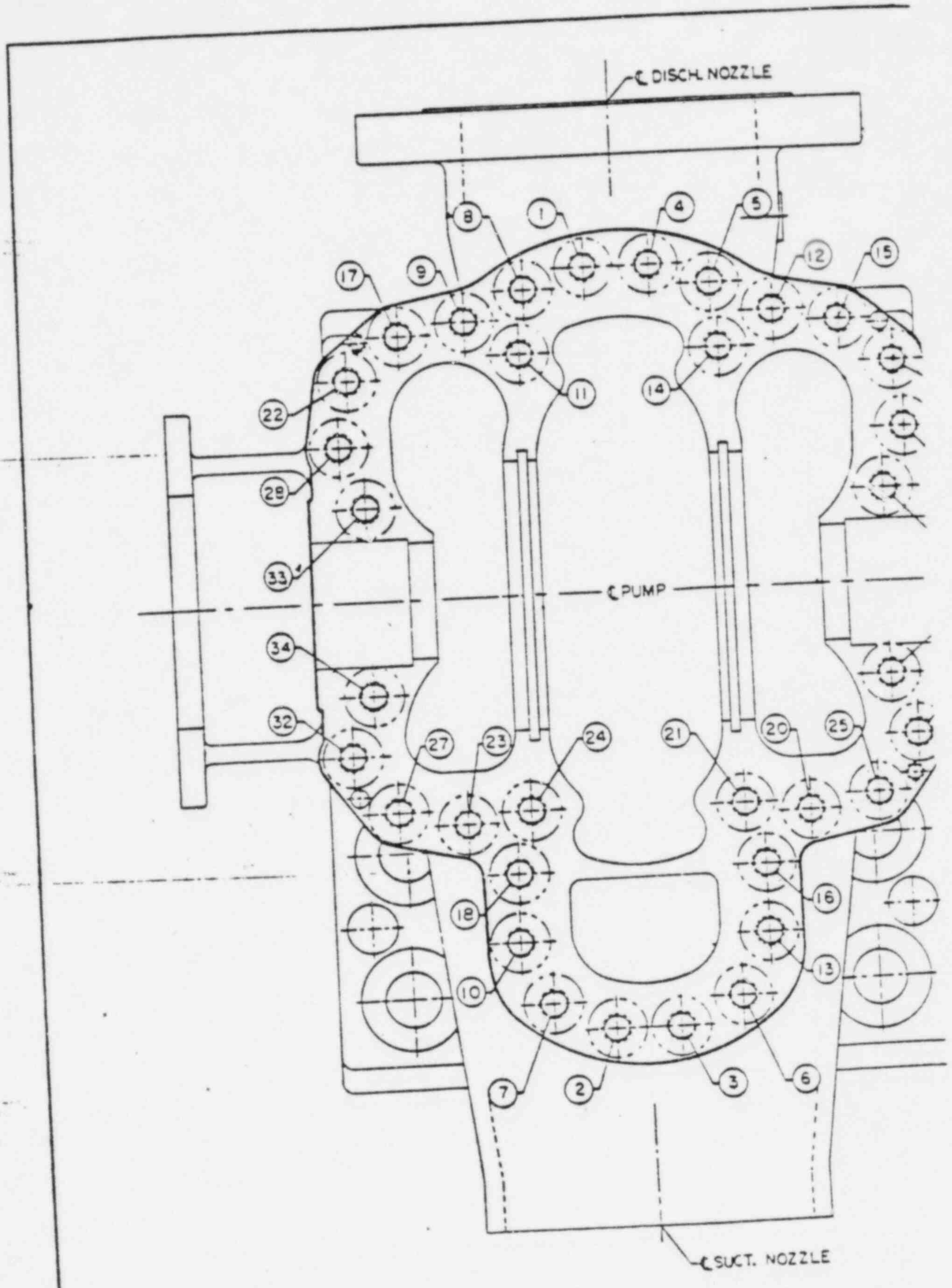
LIMITS ON ALL FINISH DIMENSIONS UNLESS OTHERWISE SPECIFIED:
FRACTIONAL ± 1/64
ANGULAR ± 1/4°
PARALLEL ± .002 IN 10"
CONCENTRIC WITHIN .002 FIR
BREAK OR BURR ALL MACHINED SHARP CORNERS APPROX .010 x 45°
UNLESS OTHERWISE SPECIFIED

PART NO.

PACIFIC PUMPS
DIVISION OF DRESSER INDUSTRIES

BOLTING SEQUENCE

DWN A.K.M. DATE [illegible] TRC'D [illegible]
CKD [illegible] APPROVED SHEET OF
SCALE —
08C 45769-[illegible]



℄ DISCH. NOZZLE
℄ PUMP
℄ SUCT. NOZZLE
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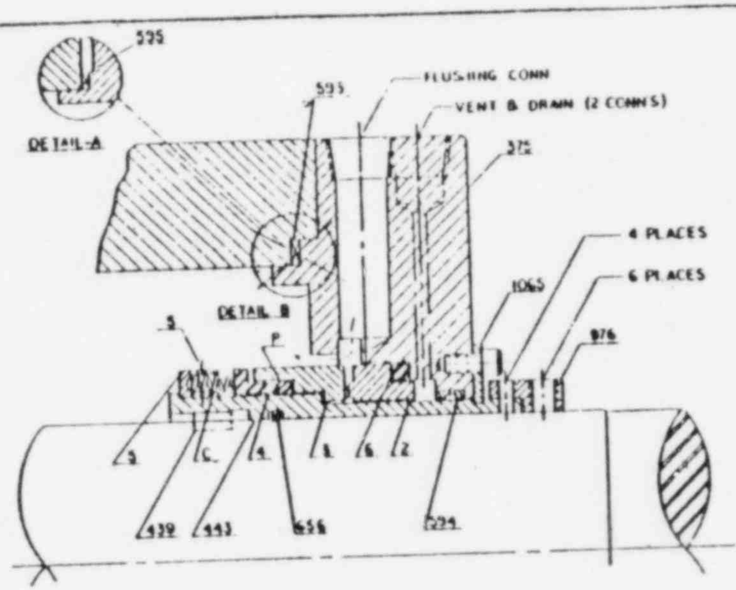


PACIFIC PUMPS SEAL PARTS

PART NO.	NO. REQ'D.*	NAME OF PART	MATERIAL
375	[illegible]	SEAL PLATE	ASTM A-418 TP 304 ①
441	[illegible]	SHAFT SLEEVE	ASTM A-276 TP316 ... 27-38
594	[illegible]	SEAL PLATE BUSHING	ASTM B 145 4A
[illegible]	[illegible]	SEAL PLATE GASKET	316 ...
[illegible]	[illegible]	SHAFT SLEEVE "O" RING	BY CAR
976	[illegible]	SHAFT SLEEVE COLLAR	ASTM A276 TP316 - [illegible]
1065	[illegible]	RETAINER PLATE	ASTM A276 TP316 - [illegible]
②455	[illegible]	SHAFT SLEEVE KEY	ASTM A276 TP310 - [illegible]

NOTE: A - LESS THAN 3000

DURAMET. PTO SEAL PARTS

PART NO.	NO. REQ'D.*	NAME OF PART	MATERIAL
[illegible]	[illegible]	INSERT	CARBON
[illegible]	[illegible]	SEAL RING	TUNG. CARB. "N"
[illegible]	[illegible]	COMPRESSION RING	AISI 316
[illegible]	[illegible]	COLLAR	AISI 316
① [illegible]	[illegible]	INSERT "O" RING	BUNA N
[illegible]	1 SET	SPRINGS	CARPENTER #20
① [illegible]	[illegible]	SEAL "O" RING	BUNA N
[illegible]	[illegible]	SET SCREWS	CARPENTER #20

*NOTE: QUANTITIES SHOWN ARE FOR EACH SEAL ASSEMBLY.

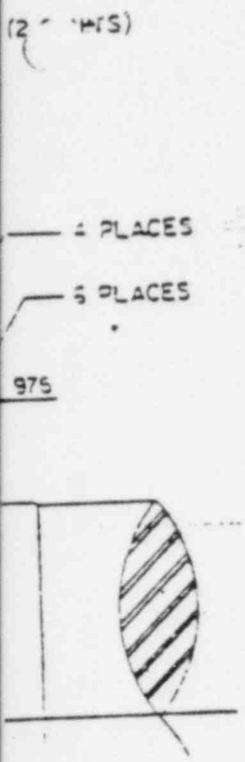
CDL NO.	DESCRIPTION
01	DETAIL A
02	DETAIL B

CERTIFIED CORRECT
BY [signature] DATE 12-12-89

Booster

DURAMETALLIC PTO SIZE 3.625

PACIFIC PUMPS INC.
SEAL ASSEMBLY
C15962



PACIFIC PUMPS SEAL PARTS

PART NO.	NO. REQ'D.*	NAME OF PART	MATERIAL
375	1	SEAL PLATE	ASTM A-479-TP 304-(2)
443	1	SHAFT SLEEVE	ASTM A-276 TP416-RC27-32
594	1	SEAL PLATE BUSHING	ASTM B-145-4A
595	1	SEAL PLATE GASKET	ASBESTOS
656	1	SHAFT SLEEVE "O" RING	BY CAR
975	1	SHAFT SLEEVE COLLAR	ASTM A276 TP416 - NOTE A
1065	1	RETAINER PLATE	ASTM A276 TP416 - NOTE A
(2) 439	1	SHAFT SLEEVE KEY	ASTM A275 TP410 - NOTE A

NOTE: A - LESS THAN 32RC

DURAMET. PTO SEAL PARTS

PART NO.	NO. REQ'D.*	NAME OF PART	MATERIAL
2	1	INSERT	CARBON
3	1	SEAL RING	TUNG. CARB. "N"
4	1	COMPRESSION RING	AISI 316
5	1	COLLAR	AISI 316
(1) 6	1	INSERT "O" RING	BUNA N
C	1 SET	SPRINGS	CARPENTER #20
(1) P	1	SEAL "O" RING	BUNA N
S	2	SET SCREWS	CARPENTER #20

*NOTE: QUANTITIES SHOWN ARE FOR EACH SEAL ASSEMBLY.

CERTIFIED CORRECT

BY S T Money DATE 12-12-69

Booster

DURAMETALLIC PTO-SIZE 3.625

NO.	CHANGE MADE	DATE
(1)	PART NO. 6 & P WAS TEFLON	2-9-70
(2)	PART NO. 375 MATL WAS ASTM A-182	
	& F 304; PART NO. 439 WAS 1045	2-15-?
	NOTE A CLARIFIED	

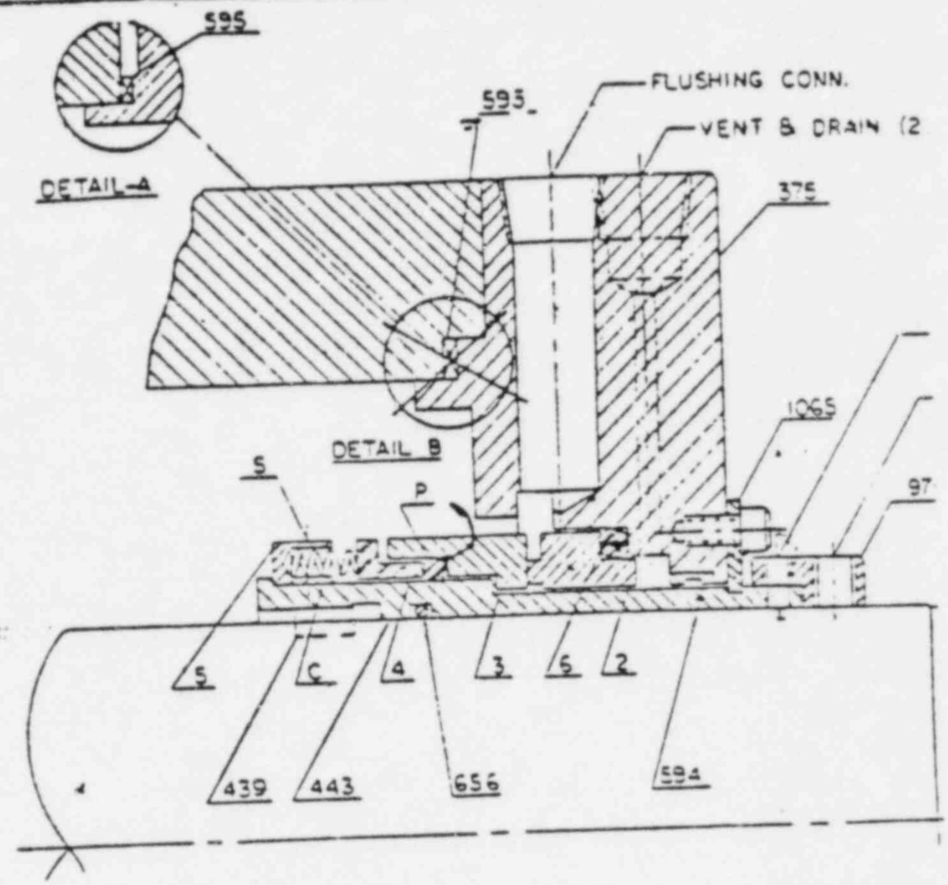
PACIFIC PUMPS INC.
LOS ANGELES, CALIF

SEAL ASSEMBLY

DRAWN CT	DATE 12-12-69	TYPE DSK
TRACED	SCALE ✓	PART NO.
CHECKED R.P.	NO. SHEETS	C-15962
APPROVED		

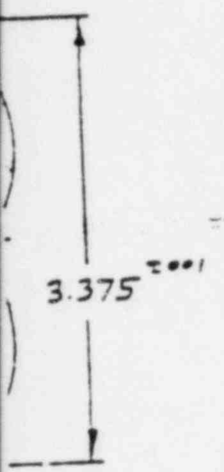
11-20-63 CT/

5J46-655



COL. NO	DESCRIPTION
01	DETAIL A
02	DETAIL B

GASKET, GLAND RING & BUSHING
FURNISHED BY PACIFIC PUMPS, INC.



PROJECT #

PUMPS, INC., HUNTINGTON PARK, CALIF.

ELECTRIC CO.

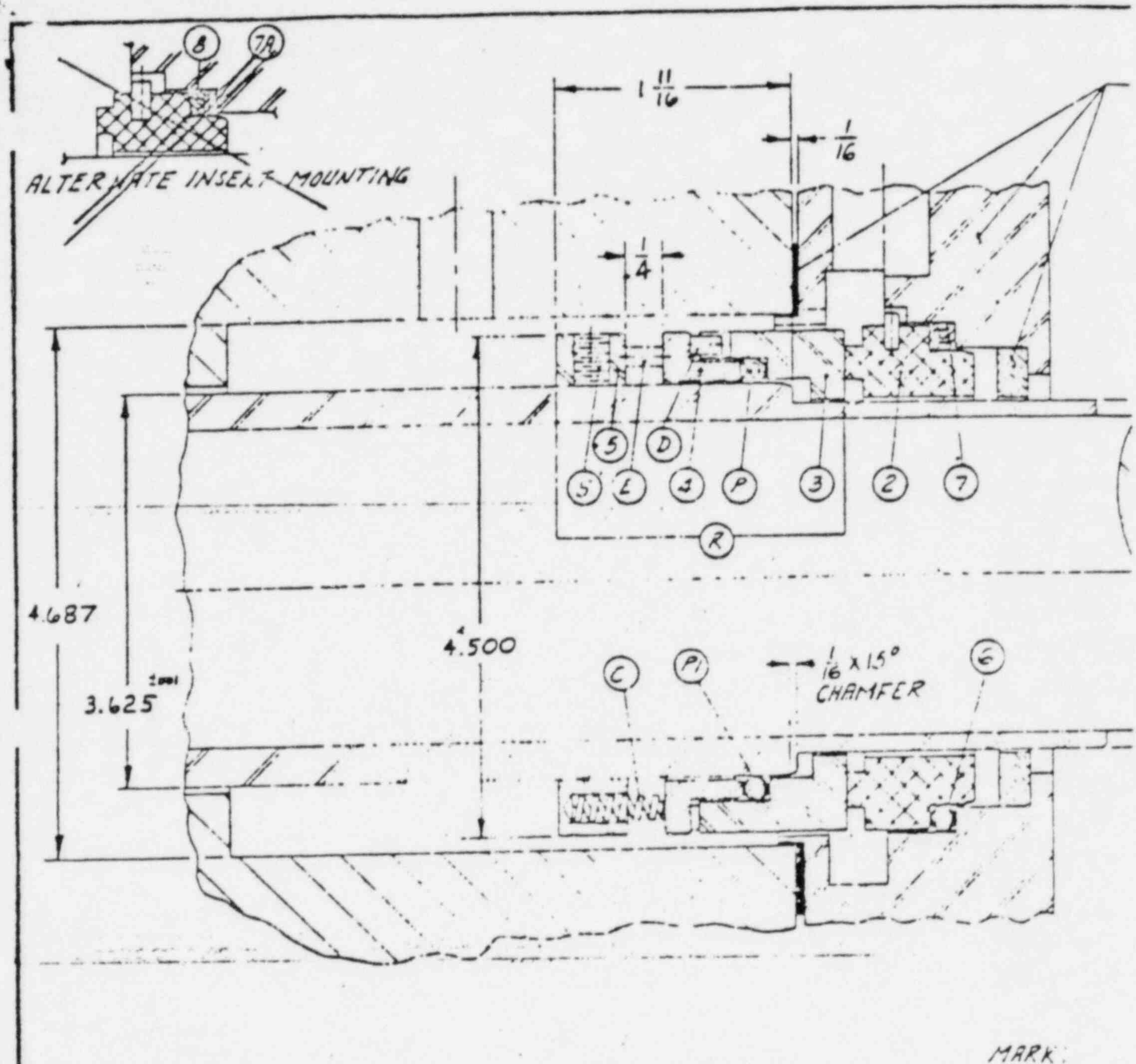
	REFERENCE DRAWING NO	FLUID	PRESSURE BOX	PRESSURE DISCH	R.P.M.	TEMP °F	SP GR
	DMC 2D-45632	WATER			1800	40-140	1.0

DURA SEAL TYPE
INSIDE PTO

ORDER PARTS BY B/M NO. 51750

DURAMETALLIC CORPORATION
KALAMAZOO, MICH.

F.O. 36486
DATE 6-30-70
DRAWN SB
FORM 2F-73098
CHECKED K.
SCALE N.T.S.
DWG. NO. 2D-96354



MARK:

R	ROTARY UNIT CONSISTING OF		2	INSERT	5 CARBON
3	SEAL RING	316 SS/TUNG CARM	6	"O" RING	BUNA N
4	COMP RING	316 SS	~~7~~	~~"V" RING~~	
5	COLLAR	316 SS	~~P~~	~~SHAFT PACK~~	
C	SPRINGS	20 SS	P1	SHAFT PACK	BUNA N
D	DRIVE PINS	20 SS	~~7A~~	~~"V" RING~~	
E	SPRING PINS	20 SS	~~8~~	~~SCREW?? RING~~	
S	SET SCREWS	20 SS			

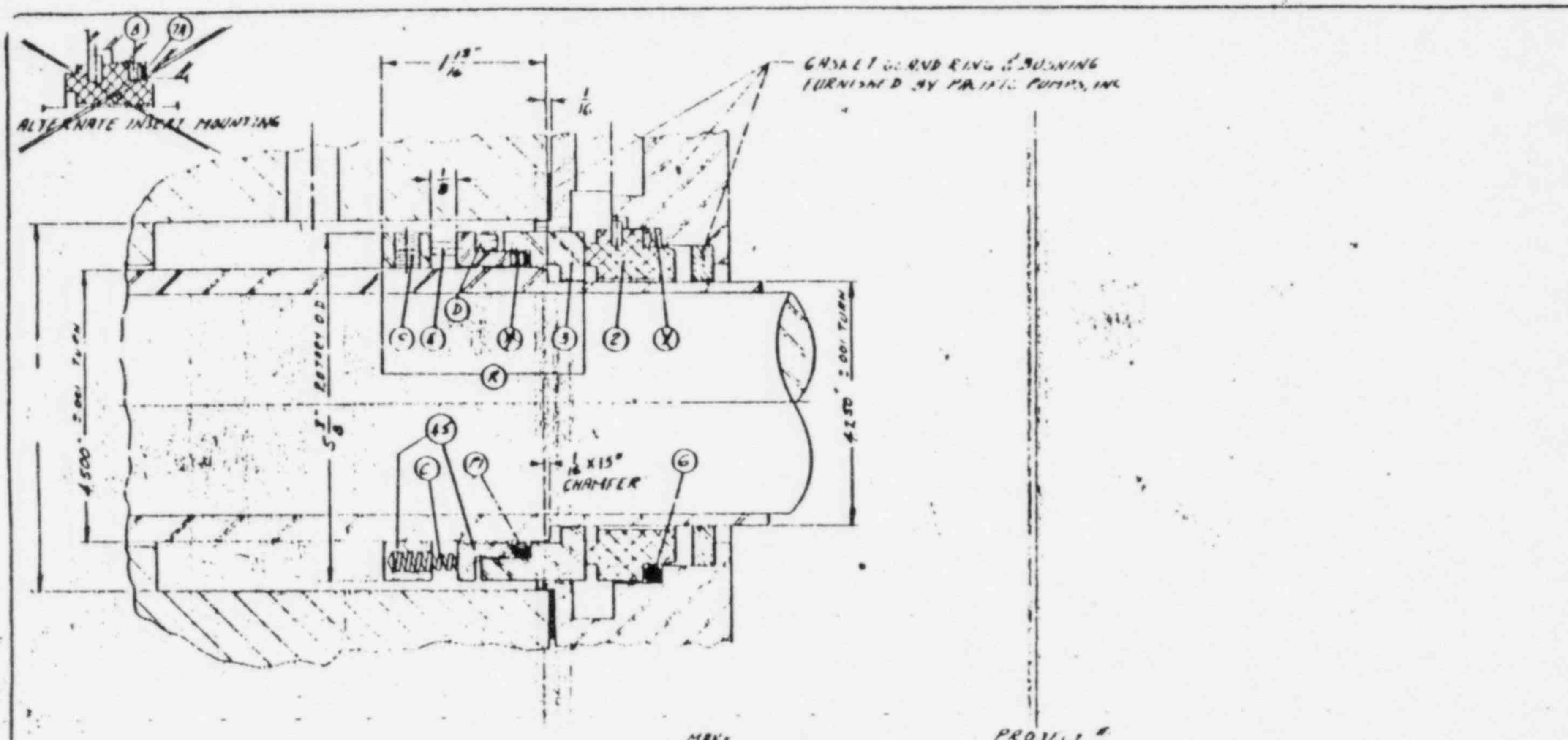
PARTS: 2. 3. 6 or 7. C. P or P1. 7. 8. S TO BE KEPT IN STOCK AS SPARES

BUYER - PACIFI

ORDER NO. - 18 0

USER - GENERA

PUMP TYPE & SIZE	PUMP ITEM NO	
PACIFIC 12 x 17 DSK		



R	ROTARY UNIT CONSISTING OF		2	INSERT	* 5 CARBON
3	SEAL RING	316 STAIN	6	"O" RING	BUNA "N"
15	COMP UNIT	316 STAIN	7	"H" RING	—
			1	SHAFT PACK	—
C	SPRINGS	20 STAIN	17	SHAFT PACK	BUNA "N"
D	DRIVE PINS	20 STAIN	19	"L" RING	—
E	SPRING PINS	20 STAIN	8	SPACER RING	—
5	SET SCREWS	20 STAIN			

PARTS: 2 3 6 or X C Y or 17 X A 5 TO BE KEPT IN STOCK AS SPARES

BUYER - PACIFIC PUMPS, INC., HUNTINGTON PARK, CALIF

ORDER NO. 18094

USER GENERAL ELECTRIC ARED

PUMP TYPE & SIZE	PUMP ITEM NO	PUMP SERIAL NO	REFERENCE DRAWING NO	FLUID	PRESSURE BOX	PRESSURE DISCH	R P M	TEMP	SP GR
PACIFIC 3x13 RHOW			3-16 2D-[illegible]	WATER	150 PSIG		[illegible]	60-160	1.0

DURA SEAL TYPE INSIDE "HSPTO"

ORDER PARTS BY B/M NO. 51748

DURAMETALLIC CORPORATION
KALAMAZOO MICH.

F.O. 36438-70
DATE 6-30-70
DRAWN C. AYARD
[illegible] 2F-73090
CHECKED [illegible]

SCALE NTS

DWG NO 2D-96345

MECHANICAL SEAL MAINTENANCE

17

Bearing Align.

1. Removal of Seal Assembly from Pump

In order to understand the following, reference must be made to the seal assembly drawing C-15962.

To remove mechanical seal for inspection, it is necessary to first remove the complete bearing assembly, including housing. If the seal to be inspected is on the coupling end of pump, the coupling (2) must be removed prior to dismantling the bearing.

Proceed as Follows:

NOTE: WHEN HANDLING SEAL PARTS AND ASSEMBLIES, EXTREME CARE IS REQUIRED TO AVOID DAMAGE.

a. Remove seal flushing piping to seal plate (375).

b. Turn retaining plate (1065) into groove in shaft sleeve (443) and lock in position by tightening cap screw.

c. Loosen set screws in shaft sleeve collar (976).

d. Remove cap screws holding seal plate (375) to casing (37).

e. Slide seal assembly off of shaft and remove to bench for inspection.

2. Disassembly of Seal Parts

a. Remove shaft sleeve collar (976) and "O" Ring (656).

b. Loosen cap screw and turn seal plate retainer (1065) out of shaft sleeve (443) groove and retighten cap screw to keep retainer out of the way.

c. Carefully slide shaft sleeve (443) out of seal plate (375). Lay seal plate on bench with stationary seal insert (2) up. Slide rotating seal ring (3) off of shaft sleeve and place on bench face up. NOTE: DO NOT ALLOW EITHER SEAL RUBBING FACE TO CONTACT ANY OBJECTS, AS THE SLIGHTEST NICK OR CHIP WILL RENDER THEM USELESS.

d. Slide remaining seal parts off of shaft sleeve in the following order after loosening set screws (S) in seal collar (5). Seal "O" ring (P), compression ring (4) and seal collar (5) with springs (C).

e. Carefully slide stationary seal insert (2) out of seal plate with fingers by pulling parallel to seal plate bore, and lay face up on bench. Remove insert "O" ring (6).

3. Inspection

a. Inspect insert (2) and seal ring (3) faces for chipped, nicked, scratched, grooved or heat checked surfaces. Surfaces not free of these defects and which are not perfectly flat should be replaced.

b. Inspect insert "O" ring (6), seal "O" ring (P) and shaft sleeve "O" ring for deterioration, scratches, gouges, etc., on all sides. If any of these defects are apparent, or either part is misshapen or crushed, they must be replaced. Best practice is to replace all three parts when seals are disassembled. NOTE: NEW PARTS MUST ALSO BE GIVEN THE SAME CAREFUL INSPECTION.

c. Clean and inspect shaft sleeve (443) for scratches, wear, etc., at the seal "O" ring contact point. If not free of damage or wear, it should be replaced.

d. Clean and inspect bore of seal plate (375) at the insert "O" ring (6) contact points. The surfaces must be free of pitting, gouges, scratches, etc.

e. Inspect parts C, S, 4, 5, 594, and 976 for general appearance. If any appear to be worn irregularly, misshapen, or fit poorly, they should be replaced.

4. <u>Mechanical Seal Assembly</u>

a. Smear a small amount of glycerin in seal plate bore and carefully push seal insert (2) with "O" ring (6) into seal plate (375) until "O" ring bottoms against seal plate. Carefully wipe clean, rubbing face of seal insert (2) with soft, lint free cloth. Using a depth micrometer measure the distance from seal inner plate face to rubbing face of seal insert face at four places around circumference of seat. Readings should all agree within plus or minus 0.0015 inches.

b. Install parts C, 4, 5, and tighten set screws (S) on shaft sleeve (443).

c. Smear a small amount of glycerin on shaft sleeve shoulder and slide "O" ring (P) and seal ring (3) onto shaft sleeve after carefully wiping all seal faces clean with a soft, lint free cloth.

d. Carefully, so as to avoid nicking or chipping, slide shaft sleeve assembly into seal plate (375). Compress complete assembly against seal springs and turn seal plate retainer (1065) into groove on shaft sleeve (443) and lock in place.

e. Insert shaft sleeve "O" ring (656) into groove in bore of shaft sleeve (443).

5. <u>Installation of Complete Seal Assembly to Pump</u>

a. Verify that shaft sleeve key (439) is mounted in shaft with the flat head machine screw. Install new seal plate gasket (595) on seal plate and slide complete seal assembly onto shaft. Insert and tighten equally, the cap screws holding seal plate (375) to casing (37).

b. Install shaft sleeve collar (976) and set screw to four places on shaft sleeve.

DO NOT TIGHTEN LOCK COLLAR SET SCREWS TO SHAFT AT THIS TIME.

c. Install deflector ring (7) and bearing and housing complete as described in manual.

d. Tighten equally all six set screws in shaft sleeve collar (976) against shaft. Stake set screws in place. Turn retainer plates (1065) 180° out of shaft sleeve groove and lock in place with cap screw. NOTE: OPERATION 5.d MUST NOT BE PERFORMED UNTIL BEARING ASSEMBLY IS COMPLETED AT BOTH ENDS OF PUMP.

e. Replace seal piping.

GENERAL ELECTRIC
NUCLEAR ENERGY DIVISION
ATOMIC POWER EQUIPMENT DEPARTMENT
San Jose, California

DOCUMENT NO. 21A9223 REV. 3

APPLICATION See Transmittal

☒ SPECIFICATION ☐ DRAWING

TYPE PURCHASE

DOCUMENT TITLE STANDARD REQUIREMENTS FOR HIGH PRESSURE COOLANT INJECTION (HPCI PUMPS)

REVISIONS

2	Revision per ECN #HX20736. Sheet 9 is affected. Revisions are indicated by "♦"		RECEIVED 6/11/82
3	Revised per ECN HX28763 General Revision - all sheets affected		

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REVISION STATUS SHEET

3.1.1.5. One copper-constantan thermocouple shall be supplied per bearing outlet, including the gear reducer.

3.1.1.6. All necessary accessories such as piping, coolers, fittings, etc. which form an integral part of the pump sealing, cooling, thrust balancing, and lubricating systems.

3.1.1.7. One set of any special tools required for the erection, dismantling, replacement or maintenance of any part of the pump assembly.

4. DESIGN REQUIREMENTS

4.1. General

4.1.1. The pumping arrangement shall consist of a main pump and a booster pump. The main pump shall be directly connected to a steam turbine, with the booster pump driven through a gear reducer off the main pump shaft. The booster pump shall be used to furnish NPSH for the main pump.

4.1.2. The pumps shall be variable speed machines with an operating range from ~2100 rpm to ~4000 rpm.

4.1.3. The pump must be capable of accelerating to full speed within five seconds.

4.1.4. The steam turbine shall be controlled, within a specified speed range, from pump discharge flow so that a constant flow volume is delivered against a varying back pressure in the reactor.

4.1.5. At low pressure limit, pump speed shall be approximately one-half its full pressure speed.

4.1.6. The pumps shall be mounted so that expansion of the connecting pipe (Para. 3.1.1.2.) and other components can be accommodated when operating temperatures change from standby to maximum operating conditions.

4.2. Lubrication and Cooling

4.2.1. Lube oil for the pumping unit will be supplied from the turbine oil tank.

4.2.2. Cooling water for the turbine auxiliaries will be taken from the booster pump discharge. The Seller shall provide a place to connect a supply line to the booster pump discharge line.

4.2.3. The Seller shall indicate in his proposal whether seal and/or lube oil cooling is required and shall indicate flow requirements where applicable.

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GENERAL ELECTRIC
ATOMIC POWER EQUIPMENT DEPARTMENT

PURCHASE SPECIFICATION

SPEC. NO. 21A9223 REV. —
SH. NO. 2 CONT ON SHEET .

STANDARD REQUIREMENTS FOR HIGH PRESSURE COOLANT INJECTION (HPCI PUMPS)

1. SCOPE

1.1. This specification defines the engineering requirements of the equipment specified herein.

1.2. The work done by the Seller in accordance with this specification shall include all necessary design, development, analysis, drawings, fabrication, shop testing, inspection and preparation for shipment.

1.3. The Seller shall accept full responsibility for his work and for compliance with this specification. Review or approval of drawings, data or specification by the Buyer with regard to general design and controlling dimensions, does not constitute acceptance of any designs, materials or equipment which will not fulfill the functional or performance requirements established by the purchase contract.

2. APPLICABLE DOCUMENTS

2.1. A Purchased Part Drawing (PPD), and Data Sheet shall be used in conjunction with this specification. The data sheet shall take precedence over both this specification and the Purchased Part Drawing.

3. GENERAL DESCRIPTION

3.1. Supplied by Seller

3.1.1. The equipment to be furnished in accordance with this specification and accompanying purchase part drawing shall be as follows:

3.1.1.1. Booster and main stage split case centrifugal pumps with mechanical seals equipped with cyclone separators and mounted with an appropriate gear reducer on a common base plate.

3.1.1.2. A demountable pipe connection between boost pump discharge and main pump suction.

3.1.1.3. A lube oil supply manifold and return manifold, each of which is brought out to a single connection at the turbine end. Threaded oil connections are to be avoided.

3.1.1.4. Pumps shall be mounted on a common base plate complete with gear reducer, complete couplings including both pieces that fasten to the shafts plus spacer, to fasten the pumping unit to the turbine, all coupling guards, and a base drip rail which drains toward the turbine end.

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4.3. Design Life

4.3.1. The design objective shall be to design the casing for a useful life of
40 years, accounting for corrosion, erosion and material fatigue. The system will be
on static standby except that it will be tested once a month and may undergo one or
two real starts during its lifetime.

4.3.2. The corrosion allowance for carbon steel for static water conditions for
40 years life is .080 inch.

4.3.3. The pump impeller, volute, wear rings, shaft and seals shall be designed
for as long a life as is practical. The design objective shall be to provide a
unit which will not require removal from the system for rework or overhaul at
intervals of less than five years.

4.4. Construction/Fabrication

4.4.1. General. Impellers shall be keyed to pump shafts. Unless otherwise
specified, all impellers and shafts as subassemblies shall be dynamically balanced
before incorporation into the pump. Pump rotating assemblies shall be designed
so that satisfactory operation is obtained throughout the operating range regardless
of the critical speed. The pump shall be designed to withstand a possible 25 per-
cent overspeed.

4.4.2. Seals. Mechanical shaft seals shall be used. Leakage through or over the
seals under any normal operating or malfunction condition shall be carefully con-
trolled by the design of the seal. Provision shall be made to drain away separately
any seal leakage, including leakage from serious failure of the seal. Mechanical
seals shall be designed for easy replacement.

4.4.3. Vents and Drains. All passages of the pump shall be designed to permit
complete drainage with the pump in the normal operating position. Low point drain
and high point vent shall be provided. Threaded water connections shall be avoided.

4.4.4. Small Diameter Piping. All small diameter piping (2 inches and under)
shall be socket or seal welded except at maintenance points where dryseal or
tap sealed threads, flanges, or ground joint unions may be used. All piping
2 inches and under shall be Schedule 160 minimum. All welds of water lines
under 4 inches nominal shall be fabricated and inspected per Paragraphs 512.3.4
and 512.3.5 of the ASME Code for Nuclear Pumps and Valves.

4.4.5. Lifting Lugs. The lifting lugs shall be made so that a lifting sling may
be used during installation or removal of the pump or pump casing.

4.4.6. Bolts, Nuts, and Studs. Bolts, nuts and studs shall conform to USAS Standards
and shall be positively locked in such a manner that no possibility of loosening of
internal bolts, nuts and studs in service will exist. Bolt heads in high fluid
velocity regions shall be retained in case they break off.

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4.4.3. Maintenance. As far as possible, maintenance of the unit shall entail no special skills. All parts susceptible to wear shall be capable of removal without cutting heavy structural members or main strength welds.

4.5. Fabricating Pressure Containing Parts

4.5.1. Qualification. All welding including fillet, seal, repair, and attachment welds shall be performed in accordance with written welding procedures. Procedure qualification and weldor performance qualification shall be in accordance with the requirements of Section IX of the ASME Boiler and Pressure Vessel Code.

4.5.2. Qualification Records. Qualification records shall be in accordance with USAS B31.1.0, Code for Power Piping. Application of weldor's identification symbols shall be within the limitations on marking as specified therein. As an alternate, a record of the joint and the weldor's mark may be kept.

4.5.3. Weld End Preparation. The preparation of weld ends for matching ends of pipe or correction of out of roundness shall not result in a wall thickness less than the specified minimum thickness.

4.5.4. Socket Welds

4.5.4.1. Socket welds may be employed for nominal pipe size two inches and smaller.

4.5.4.2. Socket welds shall have a gap of approximately 1/16 inch between the bottom of the socket and the end of the pipe prior to welding. The minimum engagement within the socket after welding shall be as follows:

Pipe Size	Minimum Engagement
1/8 to 1/2 inch	1/4 inch
1/2 to 1-1/2 inch	3/8 inch
1-1/2 inch and larger	1/2 inch

4.5.4.3. A marking technique shall be employed to verify minimum engagement after welding.

4.5.4.4. Socket welds shall have a minimum of two weld layers for nominal pipe wall thickness of 3/16 inch and larger.

4.5.5. Inspection and Repair of Pump Casings

4.5.5.1. Pump casings shall be non-destructively examined and the defects eliminated or repaired in accordance with the requirements of Paragraph 314.5 of the ASME Nuclear Pump and Valve Code with the following exemptions:

4.5.5.1.1. Radiographic examination shall be confined to the area of nozzle preparations from the end of the preparation backward for a distance of at least 2 inches, and any girth or longitudinal pressure-containing welds.

4.5.5.1.2. Magnetic particle or liquid penetrant examination shall be performed after any process-required heat treatment, and shall include all pressure-retaining machined faces, and all external and accessible internal surfaces which comprise the pressure-containing boundary of pump casings, and final machined surfaces of nozzle weld end preparation. Accessible internal surfaces shall be defined as any surface which may be repaired without cutting windows.

4.5.5.1.3. Post-weld magnetic particle or liquid penetrant acceptance criteria shall be as required by Paragraph 512.3.2(f) 2 and 3 of the ASME Nuclear Pump and Valve Code.

4.5.6. Major Weld Repair

4.5.6.1. The Buyer or Quality Control Representative shall receive prior notification of all major repairs.

4.5.7. Attachment Welds

4.5.7.1. Non-pressure parts which are welded to and become an integral part of pump pressure parts shall conform to the requirements of Paragraph 512.3.7 of the ASME Nuclear Pump and Valve Code.

4.5.8. Base Welds

4.5.8.1. Pump bases which are not welded to pressure boundary materials shall be welded by welders qualified to Section IX of the ASME Boiler and Pressure Vessel Code.

4.6. Materials for Pressure Containing Parts

4.6.1. Materials according to the following ASTM specifications shall be used for pressure containing parts: A 15[illegible] [illegible] 70, A 106B, A 324, A 105 Gr. II, A 234 WPB, A 216, A 516, A 233, A 318, A 53c, A 554. Low hydrogen electrodes shall be used for shielded metal arc welding.

4.6.2. Acceptable Materials for Bolting Exposed to Water - A 193-B8, A 194-8 A 453, A 461 Gr. 688.

4.6.3. Acceptable Materials for Pressure Containing Bolting Not Exposed to Water - A 193-B7, B8, B16, A 194-7, 8; A 540-B23, B24; A 461 Gr. 688.

4.6.4. Martensitic stainless steels, if used, shall have a maximum hardness of Rockwell C32.

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4.6.5. When cast martensitic stainless steels are used for operation at temperature below 250°F, silicon contents of 0.50 percent maximum are recommended to reduce the probability of brittle fracture.

4.6.6. 17-4 pH stainless steel, if used, shall be in accordance with ASTM A-564, Type 630, precipitation hardened at 1085± 15°F.

4.6.7. Shafts and impellers shall be made of materials which meet ASTM specifications.

4.6.8. Pump casings, shaft, and impellers shall be serialized for permanent identification. Bolts, nuts, and studs over 1 in. shall be marked per ASTM Material Standard. The method of serialization shall not degrade the part below its functional requirements.

4.7. Alternate Materials

4.7.1. Materials other than those specified shall not be used without the concurrence of the Buyer. For consideration of alternate materials, the Seller shall demonstrate that they comply with applicable codes and that they are compatible with the conditions of use.

4.8. Design Analysis

4.8.1. All equipment shall be so anchored or fastened that it would not be displaced if friction forces did not exist.

4.8.2. The equipment and supports shall be designed to withstand the specified seismic forces applied at the mass center assuming the pump to be flooded and maximum allowable nozzle loads.

4.8.3. The stresses due to horizontal and vertical seismic forces shall be considered to act simultaneously and shall be added directly.

4.8.4. The stresses in the supports and the anchor bolts due to seismic loads shall be combined with the stresses due to other dynamic and static loads. The allowable stress for this combination of loads shall be based on the ordinary allowable stress as set forth in the applicable codes. The one third increase in stress which is normally allowed when considering earthquake loadings shall not be used. Allowable nozzle loads shall also be included.

4.8.5. The allowable shear on anchor bolts set in concrete shall be in accordance with Table No. 26-I of the Uniform Building Code (International Conference of Building Officials).

4.8.6. The pump nozzles shall be capable of withstanding 6000 psi maximum fiber stress from combined torsion and bending loads.

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5. CODES AND STANDARDS

5.1. General

5.1.1. The following standards and codes of the issue in effect on the date of request for quotation form a part of this specification to the extent specified herein.

5.2. Design and fabrication of the pressure-loaded parts of the pump casing shall be in accordance with Section III, Class C and Section VIII of the ASME Boiler and Pressure Vessel Code.

5.3. Pumps shall be tested in accordance with Section B of the Standards of the Hydraulic Institute.

5.4. Materials selected for pump components shall be in accordance with the American Society for Testing and Materials (ASTM) as specified herein.

5.5. USAS B31.1.0

5.6. ASME Code for Nuclear Pumps and Valves.

5.7. ASME Boiler and Pressure Vessel Code, Section IX.

6. TESTING AND QUALITY CONTROL

6.1. Performance Testing

6.1.1. The pump shall be tested in the Seller's shop to demonstrate that it fulfills the requirements of this specification. These tests shall be conducted in accordance with Section B of the Hydraulic Institute Standards. At least five points shall be tested, including full capacity, shut-off and 125 percent of capacity.

6.2. Hydrostatic Testing

6.2.1. The pump casing shall be hydrostatically tested in accordance with Section III, Class C of the ASME Boiler and Pressure Vessel Code.

6.3. Quality Control

6.3.1. The Seller shall be responsible for the quality of the equipment fabricated to this specification regardless of whether such fabrication is in his own shop or that of a subvendor. The Seller shall provide the procedures and records required regardless of where the work is performed.

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6.3.1.1. The Seller shall obtain material certification, and chemical and physical test reports for pressure boundary material, pump shaft, and impellers. These records shall be identified by part name, part number, drawing number, and serial number.

6.3.1.2. A report shall be written showing the results of each non-destructive test performed. Each report shall reference an accepted examination procedure, part name, part serial number.

6.3.1.3. Each major defect repair shall require the records called out in 314.1.8 of the ASME Nuclear Pump and Valve Code.

6.3.1.4. The Seller shall prepare and maintain a quality control summary sheet or equivalent for pressure boundary material which provides for but is not limited to the following:

6.3.1.4.1. Heat treat or post weld heat treating procedure number and date accomplished.

6.3.1.4.2. Fabrication and repair weld procedures and dates accomplished for the particular operation called out.

6.3.1.4.3. Radiographic inspection report number and date accomplished.

6.3.1.4.4. Magnetic particle or liquid penetrant inspection report number and date accomplished.

6.3.1.4.5. Hydrostatic report number and date accomplished.

6.3.1.4.6. Seller's quality control personnel shall initial or stamp each dated entry. Space shall be provided for the General Electric Quality Control Representative to do likewise.

6.3.1.5. Measuring instruments and the accuracy thereof shall be assured by the Seller to be within the tolerance specified for the measurement to be made.

6.3.1.6. In addition, the Seller shall prepare in quantities defined in the Purchase Order consolidated binders of the documents listed below for each item of equipment prior to shipment. Each binder will be submitted to the Buyer. It shall be index tabbed for each major section that it contains for easy reference. The binder itself shall be a standard hard fiber type for 8-1/2 x 11 paper and labeled on the front with the equipment description, General Electric Purchase Order Number, Project Name and Item Mark Number.

6.3.1.6.1. Material certifications.

6.3.1.6.2. Certificate of compliance

6.3.1.6.3. Non-destructive test reports.

6.3.1.6.4. Major repair charts.

6.3.1.6.5. Heat treat charts.

6.3.1.6.6. Hydrostatic test report.

6.3.1.6.7. Performance test report.

7. CLEANING, PAINTING AND PREPARATION FOR SHIPMENT

7.1. Carbon and Low Alloy Steel

7.1.1. Carbon and low alloy steel surfaces shall be in the mechanically cleaned, blast cleaned or pickled condition. The surfaces shall be free of scale and organic contaminants such as grease and oil. Blast cleaned surfaces shall be free of residual quantitites of the cleaning media such as aluminum oxide and silica. After cleaning, inside surfaces shall be coated with a readily water-soluble corrosion inhibitor such as a water solution mixture of one-half of one percent sodium nitrite, one-fourth of one percent mono-sodium phosphate, and one-fourth of one percent di-sodium phosphate. Exterior surfaces shall be painted with the Seller's standard metal primer.

7.2. Machined Surfaces

7.2.1. Machined surfaces may be coated with a corrosion preventative preparation, provided they are accessible and the preparation is readily removable by solvent wiping.

7.3. Capping

7.3.1. Immediately following the completion of shop cleaning and the application of corrosion inhibitors, all pipe ends and equipment openings shall be capped with metal or plywood caps suitable to protect the surfaces and to limit entry of foreign materials or moisture. Caps shall be securely anchored and taped in place and shall be expected to remain intact during normal storage, shipment, and handling. Completed pumps may be stored for periods up to 12 months.

7.4. Identification

7.4.1. All boxes, crates and shipments shall be identified with the parts list number.

7.5. Maintenance Tools

7.5.1. Maintenance tools shall be shipped in a separate container.

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8. SUBMITTALS TO BUYER

8.1. Drawings

8.1.1. Outline Drawing - This drawing shall illustrate the equipment arrangement; detail centerline dimensions, interface dimensions, mounting dimensions; and over-all dimensions, show coupling details and location of lifting supports; and list equipment component weights and those interface or mounting parts supplied by the Seller and by others.

8.1.2. Assembly and Cross-Section Drawing - A sectioned drawing of each type of pump assembly to be supplied, a parts list and material designation.

8.1.3. Piping Drawing - A drawing showing all seal, bearing jacket, lubrication, and thrust balance piping contained in the unit and any interface details on the piping. This drawing shall contain the functional requirements of any system supplied from an external source; i.e., lube oil supply and scavenge capacity; maximum oil supply temperature, and btu input to the lube oil at maximum rpm.

8.2. Engineering Schedule

8.3. Fabrication Schedule

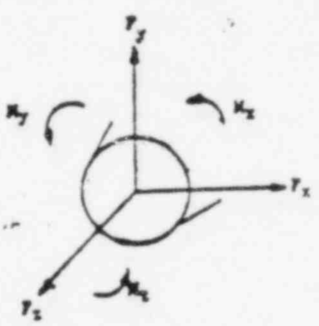
8.4. Design Items

8.4.1. Code calculations for pressure-containing parts.

8.4.2. Calculations to determine the suitability of the design to withstand seismic forces.

8.4.3. A statement as to the calculated critical speed of the design.

8.4.4. A tabulation of the allowable nozzle loadings per the following diagram, which were used to determine the 6000 psi maximum fiber stress.



8.4.5. A curve of required torque vs rpm for the proposed pump system with a statement of the polar moment of inertia for each size unit.

8.5. Procedures

8.5.1. Performance Tests

8.5.2. Hydrotest and Leak Check

8.5.3. Cleaning, Preserving and Painting

8.5.4. Packaging and Marking

8.5.5. Welding Procedures

8.5.6. Weld Repair Procedures

8.5.7. Heat Treatment Procedures

8.5.8. Magnetic Particle Examination

8.5.9. Liquid Penetrant Examination

8.5.10. Radiographic Examination

8.5.11. Torquing of bolts, nuts and studs.

8.6. Test Reports

8.6.1. Hydrostatic

8.6.2. Performance data and curves shall be submitted for certification.

8.7. Certificate of Compliance

8.7.1. The Seller shall furnish certification of compliance with all applicable electrical and mechanical construction codes, together with copies of pertinent test data. The Seller shall supply the drawings, calculations and materials samples required for submittal to the appropriate code and/or license bodies for approval.

8.8. Instruction Manuals

8.8.1. Instruction manuals shall present the following basic categories of information in a practical, complete and comprehensive manner, prepared for use by operating and/or maintenance personnel:

a. Storage maintenance
b. Initial installation
c. Initial testing and adjustment
d. Maintenance, repair and periodic tests
e. Ordering instructions for all replaceable parts, gaskets, etc.

8.8.2. The information shall be orgainized in a logical and orderly sequence. A general description of the equipment, including significant technical characteristics, shall be included to familiarize operating and maintenance personnel with the equipment.

8.8.3. Necessary drawings and/or other illustrations shall be included, or copies of appropriated certified drawings may be bound into the manual. Test, adjustment and calibration information, as appropriate, shall be specified, and identified to the specific equipment. Safety and other warning notices and installation, maintenance and operating cautions shall be emphasized.

8.8.4. A parts list shall be included showing part nomenclature, manufacturer's part number and/or other information necessary for accurate identification and ordering of replacement parts. Common hardware items or other parts to be locally procured shall be adequately identified by technical description.

8.8.5. Instructions and parts lists shall be clearly legible and prepared on good quality paper; carbon copies and tissue copies or other flimsy materials are not acceptable. Multiple page instructions shall be securely bound.

8.8.6. If a standard manual is furnished covering more than the specific equipment purchased, the applicable model (or other identification) parts and other information for the specific equipment purchased shall be clearly identified.

6.3.1.1. The Seller shall obtain material certification, and chemical and physical test reports for pressure boundary material, pump shaft, and impellers. These records shall be identified by part name, part number, drawing number, and serial number.

6.3.1.2. A report shall be written showing the results of each non-destructive test performed. Each report shall reference an accepted examination procedure, part name, part serial number.

6.3.1.3. Each major defect repair shall require the records called out in 314.1.6 of the ASME Nuclear Pump and Valve Code.

6.3.1.4. The Seller shall prepare and maintain a quality control summary sheet or equivalent for pressure boundary material which provides for but is not limited to the following:

6.3.1.4.1. Heat treat or post weld heat treating procedure number and date accomplished.

6.3.1.4.2. Fabrication and repair weld procedures and dates accomplished for the particular operation called out.

6.3.1.4.3. Radiographic inspection report number and date accomplished.

6.3.1.4.4. Magnetic particle or liquid penetrant inspection report number and date accomplished.

6.3.1.4.5. Hydrostatic report number and date accomplished.

6.3.1.4.6. Seller's quality control personnel shall initial or stamp each cated entry. Space shall be provided for the General Electric Qualtiy Control Representative to do likewise.

6.3.1.5. Measuring instruments and the accuracy thereof shall be assured by the Seller to be within the tolerance specified for the measurement to be made.

6.3.1.6. In addition, the Seller shall prepare in quantities defined in the Purchase Order consolidated binders of the documents listed below for each item of equipment prior to shipment. Each binder will be submitted to the Buyer. It shall be index tabbed for each major section that it contains for easy reference. The binder itself shall be a standard hard fiber type for 8-1/2 x 11 paper and labeled on the from with the equipment description, General Electric Purchase Order Number, Project Name and Item Mark Number.

6.3.1.6.1. Material certifications.

6.3.1.6.2. Certificate of compliance

GENERAL ELECTRIC
NUCLEAR ENERGY DIVISION
ATOMIC POWER EQUIPMENT DEPARTMENT
San Jose, California

DOCUMENT NO. [illegible] REV. 1

APPLICATION Long Island Lighting

☒ SPECIFICATION ☐ DRAWING

TYPE PURCHASE - DATA SHEET

DOCUMENT TITLE HIGH PRESSURE COOLANT INJECTION (HPCI) PUMP

REVISIONS

1	Revision per ECN HE27704. Sheet affected: 2. Revisions identified with a spade (♠).		

PERMANENT RECORD

ON MICRO-FILM

1 DRFT [illegible]	BY [illegible] R.T. Baird 5/21/69	[illegible] 2	[illegible] 1
APR 2 8 1971			

REVISION STATUS SHEET

GENERAL ELECTRIC

ATOMIC POWER EQUIPMENT DEPARTMENT

PURCHASE SPECIFICATION

SPEC. NO. 21A9223AB REV. NO. 1

SH. NO. 2 CONT ON SHEET ?

-elk

TITLE HIGH PRESSURE COOLANT INJECTION (HPCI) PUMP - DATA SHEET

1. SCOPE

1.1. This data sheet shall take precedence over the purchased part drawing and purchase specification, and shall be used as the means to add to, delete from, or modify the basic information given in these two documents.

2. APPLICABLE DOCUMENTS

2.1. The following documents form a part of this data sheet. The purchase order or its superceding revisions shall specify which revision of these base documents is to be used for this project.

2.2. Standards and Specifications

Purchase Specification - High Pressure Coolant Injection (HPCI) Pump - 21A9223

2.3. Drawings

Purchased Part Drawing, High Pressure Coolant Injection (HPCI) Pump - 117C3524P2

3. DESCRIPTION

3.1. Except as amended by this data sheet, a complete description of the equipment to be supplied is contained in the base documents.

4. REQUIREMENTS

4.1. Nozzles

4.1.1. Pipe schedules for nozzle preparation have been specified for information only. The schedules and weld preparations that shall be required will be transmitted to the Seller by the Buyer prior to machining of the casting.

4.1.2. Thermocouples (in lieu of copper-constantan per Paragraph 3.1.1.5.)

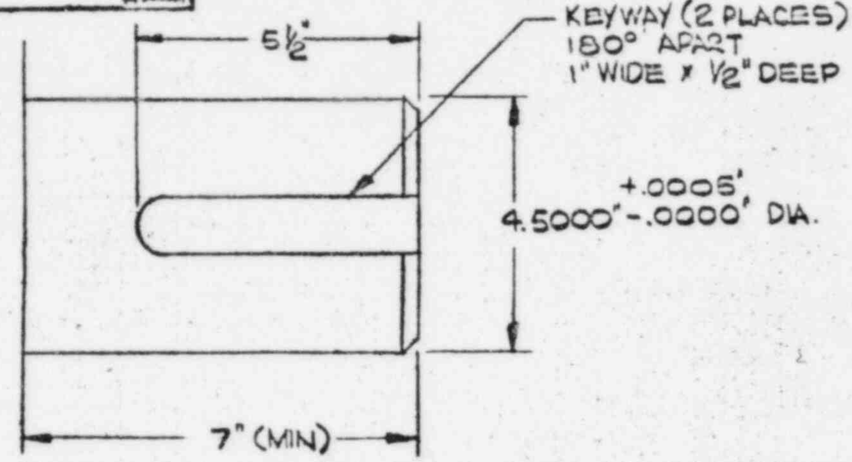
Use: Chromel-Constantan Thermocouples

4.2 Cross over pipe welds shall be radiographically inspected in accordance with the requirements of Paragraph N624 of Section III of the ASME Boiler and Pressure Vessel Code.

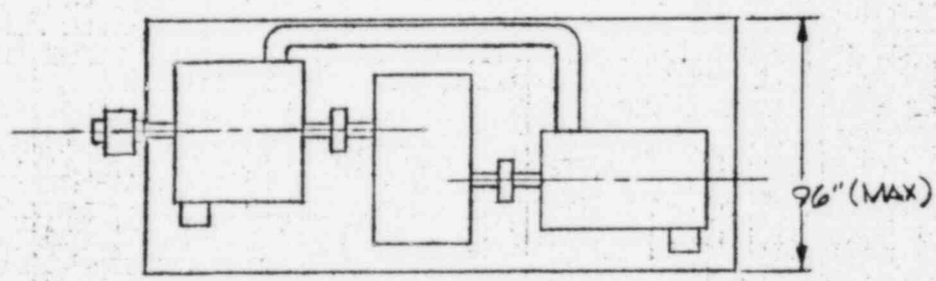
ON MICRO-FILM

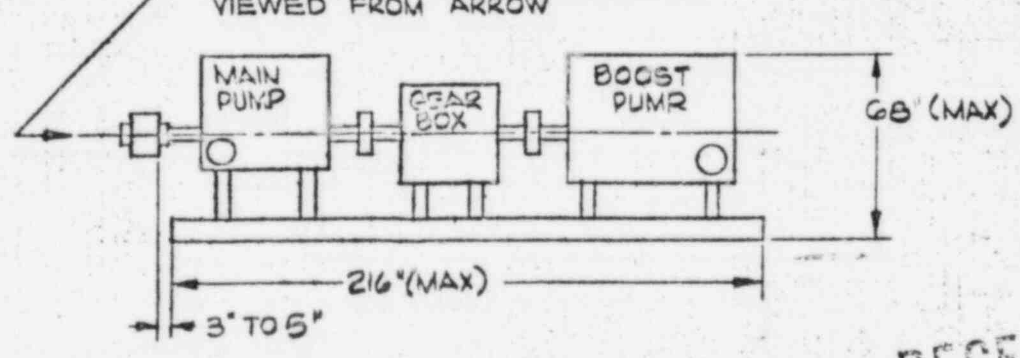
PERMANENT RECORD

APR 2 6 1971



TURBINE SHAFT DETAIL





RECEI

GENERAL ELECTRIC

117C3524 CONT ON SHEET F SH NO 1

UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING:

APPLIED PRACTICES	SURFACES	FRACTIONS	DECIMALS	ANGLES
	✓	±.03 [1]	±	±

TITLE PUMP

FIRST MADE FOR HPCI SYSTEM

PURCHASED PART

FCF. E 41 C001 & 23-1 [1]

4	3	2	1		
[illegible]	[illegible]	[illegible]	[illegible]	PART NUMBER	
LATER	LATER	LATER	LATER	VDF NUMBER	
[illegible]	5100	4350	5100	BOOST GPM.	CONSTANT VOLUME FLOW RATE
[illegible]	5000	4250	5000	MAIN GPM.	
[illegible]	2500	2500	2500	HIGH SPEED	TOTAL HEAD, FT.
[illegible]	525	525	525	LOW SPEED	
[illegible]	[illegible]	3300	3400	SHUTOFF HEAD FT. MAX.	
[illegible]	21	21	21	NPSH AVAILABLE, FT.	
[illegible]	450	450	450	BOOST	DESIGN PRESSURE
[illegible]	1500	1500	1500	MAIN	
[illegible]	40-140	40-140	40-140	DESIGN TEMPERATURE RANGE, °F	
[illegible]	100	100	100	COOLING WATER TO TURBINE, GPM	
[illegible]	40-100	40-100	40-100	NORMAL OPERATING TEMP. °F	
[illegible]		BRONZE/ST. STL.		IMPELLER	MATERIALS
[illegible]		CAST STL.		CASE	
[illegible]		ST. STL.		SHAFT	
[illegible]		BRONZE/ ST. STL.		WEAR RINGS & TRIM	
[illegible]			[illegible]	MECHANICAL SEAL TYPE	
[illegible]			[illegible]	COUPLING TYPE	
[illegible]			[illegible]	SEAL WATER FILTER	
[illegible]	[illegible]	[illegible]	[illegible]	LUBE OIL SUPPLY, GPM, MAX.	
14" SCH. 20	10" SCH. 20	14" SCH. 20	14" SCH. 20	SUCTION NOZZLE, BOOST PUMP, MIN.	
10" SCH. 100	8" SCH. 100	10" SCH. 100	10" SCH. 100	DISCHARGE NOZZLE, MAIN PUMP, MIN.	
[illegible]	[illegible]	1.50	1.50	HORIZONTAL	SEISMIC COEFF.
0.10	0.10	0.10	0.10	VERTICAL	
[illegible]	[illegible]	[illegible]	23000	TOTAL WEIGHT LBS., MAX.	
[illegible]	[illegible]	[illegible]	148	TEMP. °F	AMBIENT COND.
[illegible]	[illegible]	[illegible]	100	[illegible] HUMIDITY %	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible] RATED RANGE	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible] R.P.M.	
[illegible]	[illegible]	[illegible]	[illegible]	HI, MAX	SHAFT HORSEPOWER
[illegible]	550	750	1000	LOW, MAX	

[1]

NOTES:

1. DEMINERALIZED WATER PROPERTIES:
   pH = 6 TO 8
   CHLORIDES = 0.1 PPM. MAX.
2. FOR TURBINE INTERFACE DETAILS CONTACT THE BUYER AT GENERAL ELECTRIC APED.
3. [1] REFERENCE DOCUMENTS:
   21A9223 HPCI PUMP; GEN. REQ.
   209A4288 & 731E224 WELD END PREP., PUMPS & COMPONETS
   21A9825 SPARE PARTS REQ.

LILCO
MPL ITEM NO. E41-C001
PART OR GROUP NO. P002

ED 6/11/82

E41

117C3524

[illegible] COMPANY
[illegible]
175 CURTNER AVENUE
[illegible], CALIFORNIA [illegible]

Z0-AA958

THIS PURCHASE ORDER [illegible] THE STATE OF CALIFORNIA AND IS SUBJECT TO THE TERMS AND CONDITIONS ON THE FACE AND REVERSE HEREOF AND ANY SUPPLEMENTAL SPECIFICATIONS OR OTHER DOCUMENTS EXPRESSLY INCORPORATED BY REFERENCE.

001977270	34	X		6/12/[illegible]	1 of [illegible]

SHIP TO: TO BE DEVELOPED

DRESSER INDUSTRIES, INC.
MACHINERY GROUP
5715 BICKETT STREET
HUNTINGTON PARK, CALIF. 90255

ATTENTION: D. JENSEN

(HEREIN CALLED "SELLER")

TERMS	F.O.B.	SHIP VIA
NET 30 DAYS	DESTINATION	MOTOR FREIGHT

HUNTINGTON PARK, CALIFORNIA

[illegible]	[illegible]	[illegible]	SHIPPING DATE	DELIVERY DATE
LILCO	TO BE ASSIGNED	"AA958" AND ITS REVISION (1)		1-6-72

DESCRIPTION OF GOODS OR SERVICES

SELLER SHALL PROVIDE BY 6-30-69 AN "INSTALLATION DRAWING" OF THE PUMP BELOW DESCRIBED. SUCH DRAWING SHALL BE LESS COMPLETE THAN THE OUTLINE DRAWING CODED "AL" ON ATTACHMENT A TO SPECIFICATION 21A9223, BUT SHALL PROVIDE THE FOLLOWING INFORMATION:

A. OVERALL DIMENSIONS
B. WEIGHT
C. ANCHOR BOLT LOCATIONS AND SIZES
D. NOZZLE LOCATIONS AND SIZES
E. CONDUIT BOXES LOCATION AND SIZES
F. DISTANCE FROM PUMP SHAFT CENTERLINE TO SIDE EDGE OF THE BASE
G. DISTANCE FROM PUMP SHAFT CENTERLINE TO BOTTOM OF BASE
H. DISTANCE OF THE END OF THE PUMP SHAFT - EXTENDS PAST THE END OF THE BASE

TIME IS OF THE ESSENCE IN THE COMPLETION OF THIS INSTALLATION DRAWING AND ITS SUBSEQUENT TECHNICAL ACCEPTANCE BY BUYER.

BUYER'S TECHNICAL REPRESENTATIVES SHALL BE AVAILABLE AS SELLER MAY REQUIRE, TO PARTICIPATE IN THE PREPARATION OF THIS INSTALLATION DRAWING.

/CONTINUED ON PAGE 2/

SHIP NO.	DATE RECD	1	2	3	4	5	6	7	8	9	10	CONTAINERS NO.	KIND	C	RECEIVED BY
1	[illegible]		[illegible]								[illegible]	[illegible]	[illegible]		[illegible]
2															
3															

	VIA	CARRIER'S NAME	FREIGHT BILL NO.	FRT. BILL DATE	PPD. C-COLL.	AMOUNT	REMARKS
1							
2							
3							
4							

RECEIVING REPORT

GENERAL ELECTRIC COMPANY
NUCLEAR ENERGY DIVISION

PURCHASE ORDER 205-AA950

CONTINUATION SHEET

SHEET OF SHEETS

THIS CONTINUATION SHEET IS SUBJECT TO THE TERMS AND CONDITIONS ON THE FACE AND REVERSE SIDE OF THE FIRST SHEET AND ALL OTHER CONTINUATION SHEETS OF THIS ORDER AND ANY SUPPLEMENTS, SPECIFICATIONS OR OTHER DOCUMENTS EXPRESSLY INCORPORATED HEREIN BY REFERENCE.

ITEM	QUANTITY	DESCRIPTION OF GOODS OR SERVICES	UNIT PRICE	TOTAL PRICE

SHOULD SELLER FAIL TO DELIVER THE INSTALLATION DRAWING BY 6-30-69, OR SHOULD BUYER NOTIFY SELLER BY TELEGRAPH BY 7-2-69 THAT THE INSTALLATION DRAWING IS TECHNICALLY UNACCEPTABLE, SUCH FAILURE OR SUCH NOTICE SHALL CONSTITUTE THE CANCELLATION OF THIS PURCHASE ORDER AT NO CHARGE TO THE GENERAL ELECTRIC COMPANY.

PROJECT - - - LILCO

ARTICLE I - SCOPE OF SUPPLY

SELLER SHALL PROVIDE ALL MATERIALS AND SERVICES NECESSARY TO DESIGN, FABRICATE, TEST AND DELIVER THE FOLLOWING:'

1 1 EA HIGH PRESSURE COOLANT INJECTION /HPCI/ PUMP LESS DRIVER, IN ACCORDANCE WITH THE FOLLOWING:

DOCUMENT NO.	REV. NO.	DATE	DOCUMENT TITLE
21A9223	3	6-23-69	STANDARD REQUIREMENTS FOR HIGH PRESSURE
AND ITS ATTACHMENT A	2	5-23-69	COOLANT INJECTION /HPCI/ PUMP
117C3524,P2	1	3-19-69	PUMP, HPCI SYSTEM, PURCHASED PART DRAWING
209A4208	1	12-3-68	BUTT-WELD END PREPARATION
21A9223A4	0	[illegible]	DATA SHEET
21A9025	2	3-13-68	SPARE PARTS REQUIREMENTS
21A1150	2	2-10-69	GENERAL REQUIREMENTS FOR VENDOR DRAWINGS
I	0	6-10-69	QUALITY CONTROL PLAN
QSI 7.2.19	3	12-5-68	DEVIATION DISPOSITION REQUEST PROCEDURE
731E224	0	3-21-68	DIMENSIONS OF SAFE ENDS
E		3-69	PURCHASE ORDER SUPPLEMENT

ARTICLE II SHIPPING

SIXTY DAYS BEFORE SHIPPING DATE, BUYER SHALL NOTIFY SELLER WHETHER THE GOODS REQUIRED IN THIS PURCHASE

/CONTINUED ON PAGE 3/

GENERAL ELECTRIC COMPANY — PURCHASE ORDER NO. 205-AA950

NUCLEAR ENERGY DIVISION

CONTINUATION SHEET — SHEET 3 OF SHEETS

THIS CONTINUATION SHEET IS SUBJECT TO THE TERMS AND CONDITIONS ON THE FACE AND REVERSE SIDE OF THE FIRST SHEET AND ALL OTHER CONTINUATION SHEETS OF THIS ORDER AND ANY SUPPLEMENTS, SPECIFICATIONS OR OTHER DOCUMENTS EXPRESSLY INCORPORATED HEREIN BY REFERENCE.

ITEM	QUANTITY	DESCRIPTION OF GOODS OR SERVICES	UNIT PRICE	TOTAL PRICE

ORDER ARE TO BE PUT INTO OPERATION WITHIN ONE YEAR OR PUT INTO STORAGE FOR A LONGER PERIOD UP TO THREE YEARS. SELLER SHALL NOTIFY BUYER OF MANNER IN WHICH GOODS ARE TO BE DELIVERED AND STORED IF THEY ARE NOT TO BE PUT INTO SERVICE FOR MORE THAN ONE YEAR. ANY MODIFICATIONS IN GOODS CAUSED BY SELLER'S RECOMMENDATION SHALL BE MADE AT SELLER'S EXPENSE. SPECIAL HANDLING METHODS DURING STORAGE SHALL BE SPECIFIED BY SELLER. COMPLIANCE WITH SUCH INSTRUCTIONS SHALL BE AT BUYER'S EXPENSE.

MARKING

ALL ITEMS ARE TO BE MARKED AS FOLLOWS:

MARK	P.O.-NO.	QTY.	PROJECT	GE-ACCT.-NO.
23-1	AA950	1	LILCO	/TO BE ASSIGNED/

DELIVERY REQUIRED BY

PUMP - 1-5-72

DOCUMENTS - ON THE DATES SHOWN IN ATTACHMENT A TO SPECIFICATION 21A9223.

ARTICLE III FABRICATION SCHEDULE

THE FABRICATION SCHEDULE ATTACHMENT A, SHALL BE PRESENTED IN THE FORM OF A HORIZONTAL BAR CHART.

BARS SHALL BE PROVIDED TO SHOW THE MAJOR FABRICATION OPERATIONS SUCH AS MACHINING, NON-DESTRUCTIVE TESTING, OPERATIONAL TESTS, ETC. FOR EACH MAJOR COMPONENT AND SUB-ASSEMBLY FOR EACH ITEM IN THE PURCHASE ORDER FROM RECEIPT OF MATERIAL TO SHIPMENT. INCLUDED SHALL BE IDENTIFICATION ON THE SCHEDULE OF EVENTS FOR WHICH THE APPROPRIATE QUALITY CONTROL PLAN REQUIRES HOLD OR NOTIFICATION OF THE QC REPRESENTATIVE.

AFTER APPROVAL OF THE INITIAL SUBMITTAL OF THE FABRICATION SCHEDULE, IT SHALL BE INCLUDED AS AN ATTACHMENT TO EACH MONTHLY PROGRESS REPORT. A VERTICAL LINE REPRESENTING THE STATUS OF FABRICATION OF EACH OF THE MAJOR COMPONENTS AND SUB-ASSEMBLIES AS OF THE DATE OF THE PROGRESS REPORT SHALL BE ADDED. PREVIOUS VERTICAL STATUS LINES SHALL REMAIN ON EACH SUBMITTAL OF THE FABRICATION SCHEDULE ATTACHED TO THE MONTHLY PROGRESS REPORT.

/CONTINUED ON PAGE 4/

ITEM	QUANTITY	DESCRIPTION OF GOODS OR SERVICES	UNIT PRICE	TOTAL PRICE

REVISIONS TO THE FABRICATION SCHEDULE SHALL NOT BE MADE WHEN SLIPPAGES IN SHOP SCHEDULES OCCUR. REVISIONS SHALL ONLY BE MADE WHEN SHOP OPERATIONS ARE ADDED OR DELETED, OR AT THE REQUEST OF GENERAL ELECTRIC.

ARTICLE IV TRANSMITTALS

ALL DOCUMENT SUBMITTALS ARE TO BE MADE USING THE TRANSMITTAL FORMS NED 705 SUPPLIED BY BUYER, AND SHALL BE SENT DIRECTLY TO:

GENERAL ELECTRIC COMPANY
ENGINEERING RELEASES
175 CURTNER AVENUE
SAN JOSE, CALIFORNIA 95125

ATTN: L.L. KLEINHESSELINK - M/C 630

ONE /1/ COPY OF EACH TRANSMITTAL FORM ONLY SHALL BE MAILED DIRECTLY TO THE BUYER.

ARTICLE V MONTHLY-PROGRESS REPORTS

MONTHLY PROGRESS REPORTS, ATTACHMENT A, SHALL BE SUBMITTED THE FIRST DAY OF EACH MONTH, STARTING WITH THE MONTH FOLLOWING AWARD OF THE PURCHASE ORDER. THE REPORT SHALL INCLUDE THE STATUS OF ENGINEERING, MATERIAL, PARTS, FABRICATION, ASSEMBLY, TEST AND ANY PROBLEM AREAS. ACTION BEING TAKEN IN EACH PROBLEM AREA AND/OR TO RECOVER SCHEDULE DELAYS SHALL BE STATED.

ARTICLE VI INSPECTION FOLLOWING PROLONGED-STORAGE-

**SHOULD THE GOODS BE HELD IN STORAGE FOR A PERIOD EXCEEDING ONE YEAR AFTER THE DATE OF THEIR DELIVERY, SELLER SHALL HAVE THE RIGHT TO MAKE A REASONABLE INSPECTION OF THE GOODS AT A TIME TO BE MUTUALLY AGREED UPON BETWEEN BUYER AND SELLER IN ORDER TO DETERMINE WHETHER THE GOODS HAVE BEEN DAMAGED DURING STORAGE OR INSTALLATION. SELLER SHALL NOTIFY BUYER IN WRITING OF ANY SUCH DAMAGE WITHIN TWENTY-FOUR HOURS AFTER COMPLETION OF SUCH INSPECTION OR NONE SHALL BE DEEMED TO HAVE OCCURRED.

BUYER SHALL PAY FOR SUCH INSPECTION AT THE FOLLOWING RATES:

1. AT THE RATE OF - - - - - - - - - - - - - - - - -

/CONTINUED ON PAGE 5/

ITEM	QUANTITY	DESCRIPTION OF GOODS OR SERVICES	UNIT PRICE	TOTAL P

FOR EACH NORMAL EIGHT HOUR DAY WORKED PLUS ALL APPROPRIATE AND REASONABLE TRAVEL AND LIVING EXPENSES OF SELLER'S INSPECTING REPRESENTATIVE FROM THE TIME OF LEAVING SELLER'S BASE LOCATION UNTIL RETURN, AT ACTUAL INVOICED PRICE TO SELLER AND PROVIDED THAT ANY NECESSARY AIR TRAVEL BE LIMITED TO COACH ACCOMODATIONS.

2. AT THE RATE OF - - - - - - - - - - - - - - - $7.00/HR FOR TIME SPENT IN TRAVEL TO AND FROM THE JOB SITE DURING THE NORMAL WORKING HOURS OF THE DAY.

3. TRAVELING IS TO BE DONE WITHIN THEPPERIOD MONDAY THROUGH FRIDAY ONLY.

4. NO OVERTIME SHALL BE EMPLOYED.

5. THE MINIMUM BILLING FROM HOURS WORKED OR SPENT IN TRAVEL SHALL BE FIFTY PERCENT OF THE DAILY RATE.

6. SHOULD SELLER'S REPRESENTATIVE PRESENT HIMSELF FOR THIS WORK AT THE AGREED TIME BUT BE DETAINED FROM SUCH WORK BY ACTS OF FAILURES TO ACT ON THE PART OF BUYER, THE TIME OF THE DELAY SHALL BE DEEMED WORKING HOURS.

A SEPARATE PURCHASE ORDER SHALL BE WRITTEN FOR THIS SERVICE AT THE TIME IT IS REQUIRED.

ARTICLE VII F.O.B. DESTINATION

PRICE DOES NOT INCLUDE SHIPPING CHARGES. SELLER TO SHIP PREPAID TO DESTINATION. SELLER THEN TO SUBMIT REQUEST FOR PAYMENT SUBSTANTIATED BY A COPY OF ACTUAL PREPAID FREIGHT BILL ON THE FINAL INVOICE INDICATING ACTUAL SHIPPING CHARGES.

ARTICLE VIII PAYMENT

AFTER SUBMITTAL OF AN INVOICE BUT BEFORE FINAL PAYMENT IS MADE, THE FOLLOWING IS REQUIRED:

1. THE BUYER MUST HAVE EITHER A DESTINATION RECEIVING INSPECTION REPORT OR SHIPPING POINT RECEIPT INSPECTION ON AN OVERSEAS SHIPMENT.

2. DETERMINATION BY THE BUYER THAT ALL REQUIREMENTS OF THE ORDER, INCLUDING DOCUMENTATION AND RECORDS, HAVE BEEN MET.

/CONTINUED ON PAGE 6/

THIS CONTINUATION SHEET IS SUBJECT TO THE TERMS AND CONDITIONS ON THE FACE AND REVERSE SIDE OF THE FIRST SHEET AND ALL OTHER CONTINUATION SHEETS OF THIS ORDER AND ANY SUPPLEMENTS, SPECIFICATIONS OR OTHER DOCUMENTS EXPRESSLY INCORPORATED HEREIN BY REFERENCE.

ITEM	QUANTITY	DESCRIPTION OF GOODS OR SERVICES	UNIT PRICE	TOTAL PRICE

IN THE EVENT THAT DOCUMENTATION SUBMITTALS HAVE NOT BEEN COMPLIED WITH AT THE TIME OF SHIPMENT AS DETERMINED BY THE BUYER, THEN 5 PERCENT OF THE TOTAL PURCHASE ORDER PRICE MAY BE WITHHELD BY BUYER UNTIL DOCUMENT SUBMITTALS ARE COMPLETE.

INVOICES, INCLUDING THOSE FOR PARTIAL PAYMENT, SHALL BE FORWARDED TO THE ADDRESS SHOWN ON THE FACE OF THE PURCHASE ORDER. BILLS OF LADING AND SHIPPING MANIFESTS MUST BE ATTACHED TO INVOICES.

REGARDING THE PRINTED TERMS AND CONDITIONS

THE ONE YEAR EXTENSION OF WARRANTY SET FORTH IN SUBJECT 13. /D/ OF PURCHASE ORDER SUPPLEMENT E IS TO BE INTERPRETED AS APPLYING TO THE REPAIRED OR REPLACED COMPONENTS OR SERVICES ONLY, AND NOT APPLICABLE TO THE REMAINING GOODS OR SERVICES WHICH HAD NOT BEEN REPAIRED OR REPLACED ON THAT OCCASION.

OTHER THAN DOCUMENTS SPECIFIED IN ATTACHMENT A TO SPECIFICATION 21A0223, THE FIRST SENTENCE OF SUBJECT 21 OF PURCHASE ORDER SUPPLEMENT E IS TO BE INTERPRETED AS NOT REQUIRING SELLER TO RELEASE TO BUYER FOR BUYERS POSSESSION DOCUMENTS REVEALING SELLER'S MANUFACTURING METHODS.

ARTICLE IX ENTIRE AGREEMENT

THE PROVISIONS OF THIS PURCHASE ORDER AND ALL OTHER DOCUMENTS INCLUDED THEREIN BY REFERENCE SHALL CONSTITUTE THE ENTIRE AGREEMENT BETWEEN THE PARTIES HERETO AND SUPERSEDES ALL PRIOR AGREEMENTS, VERBAL OR WRITTEN, RELATING TO THE SUBJECT MATTER HEREOF AND CAN BE AMENDED ONLY IN WRITING.

ARTICLE X PURCHASE ORDER AMOUNT

THE TOTAL AMOUNT OF THIS PURCHASE ORDER IS - - - -

6/20/69 HY

DRESSER INDUSTRIES INCORPORATED

PACIFIC
pumps division
5715 bickett st.
huntington park
california • 90[illegible]
213 588 • [illegible]

May 10, 1972

CERTIFICATE OF COMPLIANCE

Pump, serial numbers 45768 and 45769 was designed, fabricated and tested in accordance with the requirements of General Electric Company purchase order AA958.

All welding procedures and welders used in repair or fabrication of this pump were qualified in accordance with A.S.M.E. Section IX.

All Nondestructive testing was performed by personnel qualified in accordance with SNT-TC-1A or other applicable specifications as required by the purchase order.

DRESSER INDUSTRIES, INC.
PACIFIC PUMPS DIVISION

R. J. Bauman
Quality Engineer

APPENDIX B

ANALYSES

CALCULATION/PROBLEM COVER SHEET

Calculation/Problem No: 0630-001-044

Title: Materials Analysis of Pacific Pumps (HPCI Pump)

Client: LILCO   Project: NSSS Equipment Qualification

Job No: 0630-001-671

Design Input/References:

Refer to Table of Contents on Page 2.

Assumptions:

Refer to Table of Contents on Page 2.

Method:

Refer to Table of Contents on Page 2.

Remarks:

The purpose of this calculation is to determine the temperature and radiation tolerance of the materials of construction of Pacific Pumps High Pressure Coolant Injection Pump.

REV. NO.	REVISION	PERFORMED BY	CHECKED	APPROVED	DATE
0	Original	[signature]	[signature]	N K Woodward	8/24/82

TABLE OF CONTENTS

LIST OF TABLES

APPENDICES

1.0 PURPOSE

1. To determine the radiation tolerance of this device by examination of the materials of construction.

2. To determine the temperature tolerance of this device by examination of the materials of construction.

2.0 SCOPE

This calculation applies to the Pacific Pumps High Pressure Coolant Injection Pumps exposed to environmental conditions at Shoreham Nuclear Power Station, Unit 1.

3.0 REFERENCES

1. Pacific Pumps Drawing C-15962, Type DSK "Seal Assembly," Revision 2, dated 9/15/70.

2. Durametallic Corporation Drawing 2D-96354, dated 6/30/70, Dura Seal Type "Inside PTO."

3. Pacific Pump Drawing C-15962, Type RHCH "Seal Assembly," Revision 2, dated 9/23/70.

4. Pacific Pumps, Inc. Parts List for Pump Serial No. 45-768.

5. Pacific Pumps, Inc. Parts List for Pump Serial No. 45-769.

6. ROC, K. Trotta (EDS) to J. Gruseke (Pacific Pumps), dated 8/13/82.

7. Handbook of Plastics and Elastomers, Charles A. Harper, McGraw-Hill Book Company, New York, copyright 1978.

8. Parkinson & Sisman, "The Use of Plastics and Elastomers in Nuclear Radiation," Oak Ridge National Laboratory, 10/19/70.

9. ROC, K. Trotta (EDS) to P. Pizzarillo (LILCO), dated 8/10/82.

10. ROC, K. Trotta (EDS) to R. Roberton/F. Sayles (Mobil Oil), dated 8/17/82.

4.0 METHOD OF ANALYSIS

The temperature and radiation tolerance of all materials contained within this device was determined by a document search of published materials and other EDS calculations. The sensitivity of the "weak link" component is then assumed to be the temperature tolerance or radiation tolerance of the entire device.

5.0 BASIC DATA AND ASSUMPTIONS

5.1 Only non-metallic materials have been evaluated since they will be the most sensitive to potential heat or radiation damage.

6.0 SUMMARY RESULTS

The limiting material with respect to temperature is Vapor Tech Light with a maximum operating temperature of 160°F. The limiting materials with respect to radiation are BUNA-N (HYCAR) and Neoprene with a radiation tolerance of 1×10^7 rads.

7.0 BODY OF CALCULATION

See Table 1.

Calculation No. 0603-001-044
Revision No. 0

Prepared by: Kenneth [signature] Date: 8-18-82
Checked by: [signature] Date: 8-18-82

TABLE 1

COMPONENT MATERIALS EVALUATION WORKSHEET

Manufacturer: Pacific Pumps Model No. RHCH

Component	Material	Reference	TEMPERATURE Maximum Operating	TEMPERATURE Reference	RADIATION Acceptable Dose	RADIATION Reference
Pacific Pumps Part No. 656 Shaft Sleeve "O" Ring	Hycar	3	250°F	7	1×10^7 rads	8
Part No. 595 Seal Plate Gasket	Hycar	3	250°F	7	1×10^7 rads	8
Part No. 6 Insert "O" Ring	BUNA-N	3	250°F	7	1×10^7 rads	8
Part No. P Seal "O" Ring	BUNA-N	3	250°F	7	1×10^7 rads	8
Part No. 2 Insert	Carbon	3	Not Sensitive		Not Sensitive	
Part No. 674 Seal Ring Outer Ret. Plt. "O" Ring ARP5682	BUNA-N	4, 6	250°F	7	1×10^7 rads	8
Part No. 806 Wshr. Stp. Clr. Grizzly 3/16IDX1/2ODX1/4	Neoprene	4, 6	240°F	7	1×10^7 rads	8
Part No. 1020 "O" Ring ARP 568 008	BUNA-N	4, 6	250°F	7	1×10^7 rads	8
Part No. 1060 "O" Seal Ring Press. Rad 5 1/2IDX5 3/4ODX	BUNA-N	4, 6	250°F	7	1×10^7 rads	8

Calculation No. 0603-001-044
Revision No. 0

Prepared by: Kenneth [signature] Date: 8-18-8[illegible]
Checked by: [signature] Date: 8-18-8[illegible]

TABLE 1

COMPONENT MATERIALS EVALUATION WORKSHEET

Manufacturer: Pacific Pumps Model No. DSK

Component	Material	Reference	TEMPERATURE Maximum Operating	TEMPERATURE Reference	RADIATION Acceptable Dose	RADIATION Reference
Pacific Pumps Part No. 595 Seal Plate Gasket	Asbestos	1	Not Sensitive		Not Sensitive	
Part No. 656 Shaft Seal "O" Ring	Hycar	1	250°F	7	1×10^7 rads	8
Part No. 2 Insert	Carbon	1	Not Sensitive		Not Sensitive	
Part No. 6 Insert "O" Ring	BUNA-N	1, 2	250°F	7	1×10^7 rads	8
Part No. P Seal "O" Ring	BUNA-N	1, 2	250°F	7	1×10^7 rads	8

Calculation No. 0603-001-044
Revision No. 0

Prepared by: [signature] Date: 5-18-82
Checked by: [signature] Date: 8-15-82

TABLE 1

COMPONENT MATERIALS EVALUATION WORKSHEET

Manufacturer: Mobil

Model No. Vapor Tech Light, Savarex L-O

Component	Material	Reference	TEMPERATURE Maximum Operating	TEMPERATURE Reference	RADIATION Acceptable Dose	RADIATION Reference
Bearing Lubrication Oil	Mobil, Vapor Tech Light	9	160°F	10	1×10^8 rads	10
Speed Reducer Gear Oil	Mobil, Savarex L-O	9	230°F	10	3×10^7 rads	10

APPENDIX A
MATERIALS ANALYSIS
CALC. No. 0630-001-344

eds nuclear

RECORD OF CONVERSATION

FILE: 0630-001-672

COPY: N. Woodward
I. Zebrak
[illegible]

☒ Telephone ☐ Meeting ☐ Other ____________

TO: Joe Gruseke FROM: Ken Trotta KT DATE August 13, 1982

COMPANY: Pacific Pumps PHONE NO.: (201) 382-4400

SUBJECT: High Pressure Coolant Injection (HPCI) Pump Material Code Explanation

Summary of Conversation:

Mr. Gruske was most helpfull in identifying the materials of construction not previously identified in the parts list included in the Pacific Pumps Instruction Manual for Serial Nos. 45768 and 45769, Revision 1 dated 5/25/72.

The materials identified were as follows: Material No. 211 - Buna-N; Material No. 229 - Neoprene; Material No. 281 - Teflon; Material No. 347 - Asbestos. Mr. Gruske also identified many metallic material codes not previously identified.

APPENDIX A
MATERIALS ANALYSIS
CALC. No. 0630-001-044

eds nuclear

EDS Nuclear Inc.
445 Broad Hollow Road
Melville, New York 11747
(516) 454-0200

August 19, 1982
0630-001-NY-102

Pacific Pumps Division
136 Central Avenue
Clark, New Jersey 07066

ATTENTION: Mr. Joe Gruseke

SUBJECT: Verification of Record of Conversation

Gentlemen:

Thank you for the information which you supplied to EDS with respect to material code explanation. EDS Quality Assurance Procedures require that you re~eive the enclosed record of our conversation of August 13, 1982.

If this is an accurate account of our conversation, no action is requested of you. Should there be any errors or misunderstandings in this record, please contact me at (516) 454-0579.

Very truly yours,

Kenneth Trotta

Kenneth Trotta - Engineer
Systems Engineering Division

KT/jm

Enclosures

SHEET 9 OF 12

APPENDIX A
MATERIALS ANALYSIS
CALC. No. 0630-001-044

edis nuclear

FILE: 0630-001-671

COPY: N. Woodward
I. Zebrak
P. Lynches
[redacted]

RECORD OF CONVERSATION

[x] Telephone [ ] Meeting [ ] Other ____________

TO: Reggie Roberton/ Francis Sayles FROM: Ken Trotta KT DATE August 17, 1982

COMPANY: Mobil Oil Corporation PHONE NO.: (609)737-3000

SUBJECT: Vapor Tech Light and Saverex L-O Radiation and Temperature Tolerance

Summary of Conversation:

In response to my letter (EDS Letter No. 0630-001-NY-093) of August 13, 1982, Mr. Roberton and Mr. Sayles provided me with the following information:

Vapor Tech Light is tolerant of radiation up to a value of $1x10^8$ rads.

Vapor Tech Light can be used up to a bulk temperature of 160°F.

Saverex L-O is tolerant of radiation up to a value of $3x10^7$ rads.

Saverex L-O can be used up to a bulk temperature of 230°F.

A letter confirming the above information will be sent to me shortly.

SHEET 12 of 12

APPENDIX A
MATERIALS ANALYSIS
CALC. No. 0630-001-044

eds nuclear

RECORD OF CONVERSATION

FILE: 0630-001-671

COPY: N. Woodward
I. Zebrak

[X] Telephone   [ ] Meeting   [ ] Other

TO: Phil Pizzariello   FROM: Ken Trotta KT   DATE August 10, 1982

COMPANY: LILCO   PHONE NO.: 929-8300 x-234

SUBJECT: High Pressure Coolant Injection Pump Lubricants

Summary of Conversation:

Phil informed me that Vapor Tech Light is used to lubricate the pump bearings and Saverex L-O is used to lubricate the speed reducer. Both lubricants are manufactured by Mobil Oil Corporation. The maintainance schedule requires the pump bearing lubricant to be replaced every 12 months. At this point he could provide no maintainance schedule information for the speed reducer.

SHEET 1 of 1

APPENDIX A
MATERIAL ANALYSIS
CALC. NO. 0630-001-C-4

edis nuclear

EDS Nuclear Inc.
445 Broad Hollow Road
Melville, New York 11747
(516) 454-0200

August 19, 1982
0630-001-NY-101

Long Island Lighting Company
Shoreham Nuclear Power Station
O & S Building
P.O. Box 628
Wading River, New York 11792

ATTENTION: Mr. Phil Pizzariello

SUBJECT: Verification of Record of Conversation

Gentlemen:

Thank you for the information which you supplied to EDS with respect to High Pressure Coolant Injection Pump lubricants. EDS Quality Assurance Procedures require that you receive the enclosed record of our conversation of August 10, 1982.

If this is an accurate account of our conversation, no action is requested of you. Should there be any errors or misunderstandings in this record, please contact me at (516) 454-0579.

Very truly yours,

Kenneth Trotta

Kenneth Trotta - Engineer
Systems Engineering Division

KT/jm

Enclosures

SHEET 12 of 12

REFERENCE LIBRARY
OF
MATERIALS AGING REFERENCES

TITLE	NO.
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L. Small and E. Sheer, "1000 Hour Heat Aging Study," B. F. Goodrich Co., unpublished report	2
M. H. Van De Voorde, "Effects of Radiation on Materials and Components," CERN 70-5, European Organizations for Nuclear Research, February 26, 1970	3
Modern Plastics Encyclopedia, 1979-1980, "Selecting Plastics for Elevated Temperature Performance," pages 481-488, 536-570, and 616-639	4
"Nuclear Engineering Handbook," Harold Elherington, editor, 1st edition, McGraw-Hill, 1958	5
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Boston Insulated Wire & Cable Test Report No. 73C212, Prototype LOCA Simulation Test, 6/18/73	7
Component Aging Due to Accident Environments (EDS Calculation 0630-001-002, Rev. 0)	8
Arrhenius Model for BUNA-N (EDS Calculation 0630-001-003, Rev. 0)	9
Arrhenius Model for Cross-Linked Polyethylene (EDS Calculation 0630-001-004, Rev. 0)	10
Arrhenius Model for Neoprene (EDS Calculation 0630-001-005, Rev. 0)	11
Arrhenius Model of Viton Gaskets (EDS Calculation 0630-001-006, Rev. 0)	12
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Bruce, M.B., and M.V. Davis, "Radiation Effects On Organic Materials in Nuclear Plants," Electrical Power Research Institute Report No. NP-2129 (Nov., 1981)	14
C.A. Harper, "Handbook of Plastics and Elastomers", Mc-Graw Hill Book Comp., N.Y., 1978	15

NUCLEAR ENGINEERING AND DESIGN 17 (1971) 247–280. NORTH-HOLLAND PUBLISHING COMPANY

THE USE OF PLASTICS AND ELASTOMERS IN NUCLEAR RADIATION *

W. W. PARKINSON and O. SISMAN
Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, USA

Received 19 October 1970

Common plastics and elastomers are described in general with emphasis on the relation between chemical structure and engineering properties and applications. The interaction of radiation with organic materials is presented very briefly and radiation-induced crosslinking and scission, which lead to changes in physical properties, are discussed.

The radiation-induced changes in specific plastics are described. Polyethylene, which can be regarded as a prototype for the more complex polymers, develops crosslinks at the rate of 1 to 1.5 for every 100 eV of radiation energy absorbed. The hardness and elastic modulus increase and the flexibility and ductility decrease until the usefulness at doses above 10^9 rads is uncertain for some applications. Polystyrene demonstrates stabilization by the aromatic ring, undergoing change at a lower rate than polyethylene. Polymethyl methacrylate exemplifies polymers containing the quaternary carbon atom, which leads to chain scission and rapid loss of strength properties. Polymers with a high content of strongly electronegative elements also degrade rapidly.

Elastomers are discussed separately because elasticity and flexibility are affected very rapidly by the crosslinking and scission produced by radiation. Finally, various applications of plastics and elastomers in reactor systems or their vicinity are discussed. The properties which are important to the application are presented along with the radiation-induced changes in these properties.

1. The nature and characteristics of plastics and elastomers

The familiar plastics and rubbers of household and industrial use are organic materials that gain their unusual physical and mechanical properties from their large molecular size. These long-chain molecules are made up of numerous repeating (monomer) units, giving such materials the name high polymers. The engineering classification of these materials is based on characteristics which are important in their fabrication and uses.

One class is *thermoplastics*. These materials may be liquefied reversibly at high temperatures, and thus are especially adaptable to molding operations. Intricate shapes can be fabricated economically at high production rates. However, the low softening temperature of these materials puts a limit on the conditions of service, with the consequence that they must be carefully selected if they are to be used at temperatures much above ordinary atmospheric levels. Examples of this class of plastics are polyethylene, polystyrene, polymethyl methacrylate, and the nylons.

Another class is *thermosetting plastics*. These materials solidify at high temperatures, although raw material for molding may be solid at room temperature and may liquefy temporarily upon heating. The softening, which is not reversible in the case of the thermosets, obviously has great utility in the molding of complex objects. Some thermosets are available as liquids in a partially polymerized form and can be used with reinforcing materials and solidified at room temperatures by the addition of chemical curing agents. These variations in initial form and curing temperatures permit an extremely wide latitude in manufacturing processes employing these materials. The irreversible hardening allows many of these materials to be used at temperatures much higher than the limit for most thermoplastics.

* Chapter 69 of the projected third edition of the USAEC Reactor Materials Handbook.

Examples of thermosets are the phenol formalde-hydes, the alkyl polyesters, the epoxies, and the film-forming ingredients in many paints and coatings.

Finally, there are the *rubbers* or *elastomers*. These materials are characterized by high elasticity and are usually soft and easily extensible. There are similarities between the elastomers and the thermoplastics at temperatures well above their softening temperatures; indeed, the rubbers solidify and behave as thermoplastics at low temperatures (below their glass transition points). An essential difference, however, between the rubbers in their cured state and the thermoplastics is the resistance of the rubbers to plastic flow. Although they are subject to high deformation at low stresses, light cross-linking prevents flow, and the soft liquid-like structure permits rapid recovery upon removal of stress, thus conferring the high elasticity characteristic of these materials.

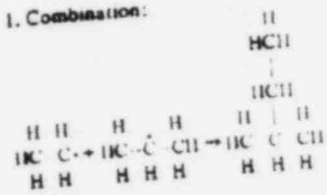
Cross-linking in the rubbers is analogous chemically to curing in the thermosets. It is termed vulcanization and has a long history in the development of rubbery materials. Vulcanization can be brought about by chemical reactions of a number of reagents, but sulfur is the usual one. Obviously, the physical properties of these materials depend strongly on the degree of vulcanization, and the same base polymer can be almost liquid, or hard and glassy, depending on the degree of vulcanization. Examples of elastomers are natural rubber (polyisoprene), butyl (polyisobutylene), NBR (nitrile butadiene rubber), silicone rubber (polymethylsiloxane), and neoprene (polychloroprene).

2. Radiation effects

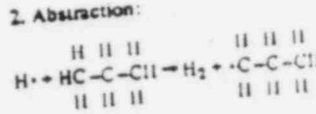
2.1. *Interaction of radiation with organic materials*

The interaction of both gamma radiation and fast neutrons with matter yields energetic particles, which interact with the orbital electrons of the atoms of the absorbing medium to ionize or excite them to higher energy levels. This ionization and excitation disrupts the valence bonds in organic compounds. In hydrocarbons the carbon-hydrogen bonds are broken most frequently, but carbon-carbon bonds are also ruptured, so that a variety of free radicals as well as hydrogen atoms are produced. The charged species resulting from ionization will also be highly reactive both before and after neutralization. Thus, the reactions to produce final products can be quite complex and may be ion reactions as well as free-radical reactions. The major types of reactions involving the radicals are listed below.

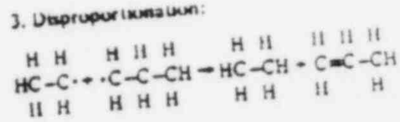
1. Combination:



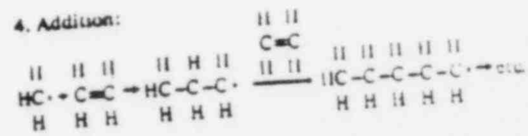
2. Abstraction:



3. Disproportionation:



4. Addition:



Ionic reactions may also proceed through decomposition or combination steps to yield similar final products. Another type of reaction is molecular decomposition, yielding products of lower molecular weight. Complex mixtures of products result from these reactions and some of the products can arise from several different mechanisms. The chemical structure of the starting material will determine the rates of the intermediate reactions and the yields of the individual products.

It is possible to generalize the yields of the major products according to the type of hydrocarbon irradiated. Saturated hydrocarbon (alkane) liquids having straight chains give the largest *G*-values * for hydrogen, i.e. $G \approx 5$.

* The *G*-value is the yield of a radiation-induced reaction expressed as the number of molecules produced or destroyed per 100 eV of radiant energy absorbed.

The other major product is the bimolecular coupling compound produced with a yield of about $G=2$. Gaseous, low-molecular-weight hydrocarbons are produced at about one-tenth the rate of hydrogen. The products with molecular weights intermediate between those of the starting material and the bimolecular products are produced with G of 0.2 to 0.5. Branched alkanes give lower yields of hydrogen and higher yields of products from rupture at the branch points. Cyclic alkanes show a different product pattern, with unsaturated products becoming appreciable ($G = 2.4$ to 3.3), while low-and intermediate-molecular-weight products from fragmentation of the parent compound occur in very low yields.

Unsaturated aliphatic hydrocarbons (olefins or alkenes) produce much less hydrogen than the saturated ones (alkanes) – about $G=1$ – and the yields of other gaseous products are also low. On the other hand, the yield of high-molecular-weight products resulting from coupling can be quite high if the carbon-carbon double bond is in an accessible position (near the chain end).

Aromatic compounds (e.g., benzene) are of special interest because of their resistance to radiation. These compounds are characterized by the resonance-stabilized aromatic ring, which apparently can absorb energy in going to an excited state and can dissipate this excitation energy through a process which does not disrupt the molecule. Benzene, for example, has a very low yield of $G_{H_2} = 0.04$. Coupling reactions consume about 1 molecule/100 eV absorbed. An important characteristic of aromatics in mixtures is their protective ability. Gaseous products from mixtures of alkanes and benzene have been found to be far below the yield predicted from the fractional composition. The aromatic either dissipates excitation energy without decomposition or it acts as a free-radical scavenger. Other substances which may serve as free-radical scavengers and reduce the effects of radiation on alkanes are the antioxidants and aging stabilizers used in plastics, rubbers, and oils. The protective effect of additives is less marked in the radiation-resistant aromatics. Radiation-induced processes in solid hydrocarbons will be qualitatively similar. Certainly, the initial events in the reactions will be identical. The rates of secondary reactions will depend on the mobility of reactive fragments. Hydrogen yields from paraffin wax are found to be almost as high as those from liquid alkanes.

2.2. *Reactions of polymers in a radiation field*

Plastics and rubbers are much more easily damaged by radiation than ceramics or metals. This susceptibility to change by radiation limits the nuclear use of these materials more than any other property. The effects of radiation, however, are different for the various chemical structures, and the degree of radiation stability may vary over several orders of magnitude.

The rupture of chemical bonds, subsequent to the ionization and excitation produced by high-energy radiation, yields fragments of the large polymer molecules. The free radicals thus produced may react to change the chemical structure of the molecule. The polymer molecule may undergo scission (breakup into small molecules), or cross-linking (recombination into a network structure). The free radicals may also recombine into their original form, with no net change. The cross-linking and scission reactions result in a change in physical properties of the material. The type and rate of change depend on the competition between the scission, cross-linking, and recombination reactions. Net scission will cause one kind of property change, while net cross-linking will have a much different effect. If the recombination reaction predominates, the change will be slower. The rate of change depends to a large extent on the chemical structure but is also affected by the physical state.

2.3. *Changes in physical structure and properties*

Cross-linking increases the molecular weight of a polymer, decreases the solubility, and increases the softening temperature. When enough cross-links have formed to bind the material into essentially one large molecule, the material is completely insoluble, and only swells when placed in a solvent. Further irradiation will bind the polymer into a three-dimensional network, the network becoming more rigid. The properties of the polymer are now a function of the density of cross-links in the network structure, and are little governed by the chemical structure. By this process a liquid-like, soft, amorphous polymer will change to a rubbery material and then to a hard glassy substance.

The effects of scission are, in most respects, opposite to those of cross-linking. Here the molecules are broken into smaller fragments. The molecular weight is decreased, solubility is increased, and the softening point is lowered. The shortened chains and greater number of chain ends lead to weakening and often to embrittlement even though the material may have become somewhat softer. In some materials the softening effect is so large that it results in a great increase in viscous flow.

Crystallinity is an important property in polymers, and it also is affected by radiation. Cross-linking tends to destroy crystallinity, as evidenced by an increase in transparency in nylon and polyethylene. Crystallinity can be increased in polymers that undergo scission because there is less restraint on the shortened molecules and they are more easily oriented into the crystal structure. The impact strength of polytetrafluoroethylene, which scissions, is markedly increased after a small irradiation dose, presumably because of an increase in crystallinity. Most polymers that scission, however, are reduced in both impact strength and tensile strength.

Important side reactions to scission and cross-linking are the production of low-molecular-weight fragments and the creation of unsaturation. Many of the low-molecular-weight fragments are gases. Some polymers such as polyethylene produce a gas high in hydrogen, which escapes readily. Other polymers produce gas of higher molecular weight (e.g., CH_4, C_2H_4 etc.) which will be retained in the solid polymer, eventually causing swelling, cracking, or even foaming if the temperature is high enough. Gas yields are given in table 1.

Reactions involving free radicals (e.g., cross-linking and scission) are affected by temperature change because of the change in mobility of the molecules. The rate of production of free radicals by radiation is, however, independent of temperature. With a given irradiation rate, if, for example, the temperature is lowered and the cross-linking rate is decreased, then the competing recombination reaction may use up a greater fraction of the free radicals. The result is greater net energy required per cross-link. Both the rate of cross-linking in polyethylene and the rate of scission in polymethyl methacrylate and polyisobutylene are strongly dependent on temperature. The temperature dependence of radiation damage for most plastics and rubbers is, unfortunately, not well known.

For very many plastics and rubbers the effect of oxygen on the rate of radiation damage is not known. One expects, however, that the reactive species must be sensitive to the presence of oxygen. Scission may be increased by the termination of a free radical with oxygen, or cross-linking might be enhanced by the formation of peroxide links. In the materials studied, however, the net result appears to be predominantly an increase in scission rate when oxygen is present. The amount of oxygen ordinarily dissolved in the material is not enough to change the reaction rate very

Table 1

Gas yields from irradiated plastics and elastomers [1]

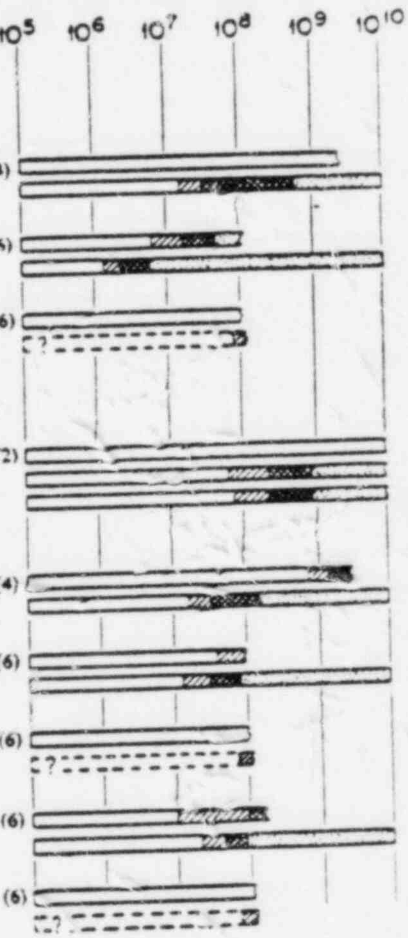
Material	Gas evolved (a): G, or molecules/100 eV	Gas evolved (a): ml/g (STP) at 10^9 rads
Polyethylene	3.1	70
Polystyrene	0.08	1.5
Poly(α-methylstyrene)	0.08	1.5
Natural rubber (b)	0.3	7
Styrene-butadiene rubber (b)	0.15	4
Styrene-butadiene plastic	~0.08	~2
Polyisobutylene rubber (b)	0.8	17
Polyamide-nylon	1.1	25
Aniline-formaldehyde polymer	~0.08	~2
Melamine-formaldehyde polymer (cellulose filler)	0.45	10
Urea-formaldehyde polymer (cellulose filler)	0.8	17
Nitrile-butadiene rubber (b)	0.15	5.0
Casein plastic	0.15	4
Poly(methyl methacrylate)	1.5	35
Poly(ethylene terephthalate)	0.15	3
Allyl diglycol carbonate	1.9	40
Polyesters (general)	0.08 to 1.9	2 to
Cellulose acetate polymer	0.08	17
Cellulose acetate-butyrate polymer	1.2	28
Cellulose propionate polymer	1.5	35
Cellulose nitrate polymer	4.6	105
Ethyl cellulose polymer	1.5	35
Phenolic plastic (no filler)	0.1	3
Phenolic plastic (cellulose filler)	0.8	17
Phenolic plastic (mineral filler)	<0.08	<2
Silicone elastomer	0.9	20
Ethyl acrylate rubber (b)	1.2	28
Chloroprene rubber (b)	0.15	4
Poly(vinyl formal)	~4.3	~100 at 10^9 rads
Triallyl cyanurate polymer	~0.08	~2.0
Polysulfide rubber (b)	0.23	6

(a) Energy absorbed by polymer, excluding any filler.

(b) Rubbers are compounded and vulcanized. Doses to base polymer are less accurate for these materials.

Table 2. Effects of Radiation on Mechanical Properties of Plastics
(Irradiated in air at 25°C unless otherwise noted)

Material	Initial Value[b]	Dose Rate Mrads/hr	Thickness (in.)	Percent of Initial Value Retained at Given Dose (rads)[a,c]
Thermoplastic Polymers				
A. Hydrocarbon Polymers				
1. High-density (linear) polyethylene				
a. Super Dylan:				
Tensile Strength, psi	3000	2	0.12	(4)
Elongation at Break, %	170			
b. Marlex-50:				
Tensile Strength, psi	4290	1	0.007	(6)
Elongation at Break, %	600			
Irradiated in vacuum:				(6)
Tensile Strength, psi				
Elongation at Break, %				
Low-density (branched) polyethylene				
a. Alathon:				
Tensile Strength, psi	1400	2	0.19	(2)
Elongation at Break, %	250			
Notch Impact Strength, ft-lb/in.	11.2			
b. Alathon 10:				
Tensile Strength, psi	1820	2	0.13	(4)
Elongation at Break, %	450			
c. Alathon 3:				
Tensile Strength, psi	1915	1	0.003	(6)
Elongation at Break, %	380			
Irradiated in vacuum:				(6)
Tensile Strength, psi				
Elongation at Break, %				
d. Irrathene 101:				
Tensile Strength, psi	2390	1	0.010	(6)
Elongation at Break, %	525			
Irradiated in vacuum:		1		(6)
Tensile Strength, psi				
Elongation at Break, %				

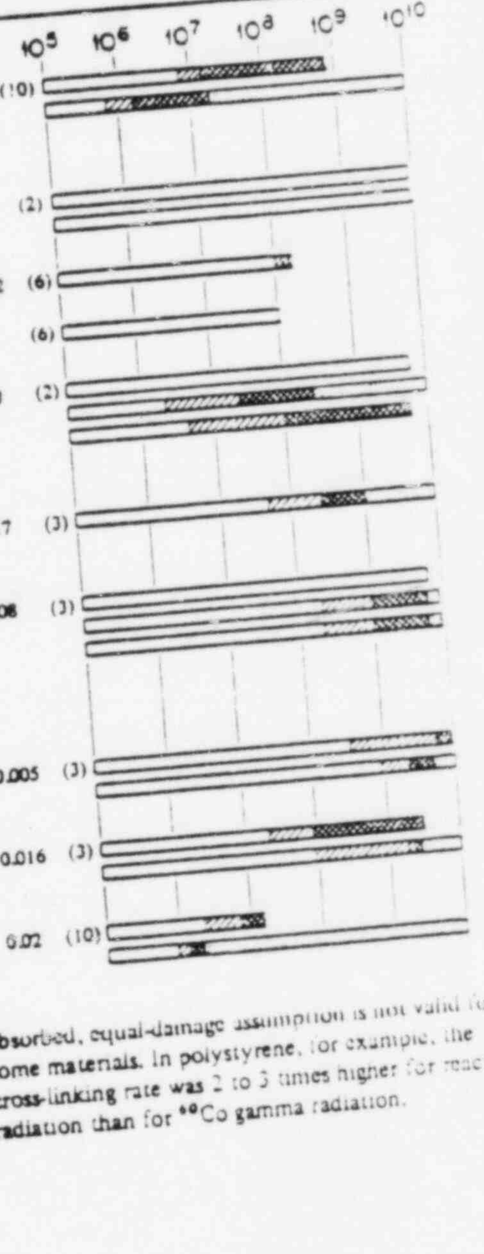


much; for the change to be significant, oxygen must diffuse into the specimen from the surrounding atmosphere. For thin specimens this can be enough to change the reaction rate by a large amount (about a factor of 10 in polytetrafluoroethylene), but for thick specimens the diffusion will be limited to the surface and may not affect the bulk properties of the material. These effects are indicated, where known, in table 2.

The amount of radiation damage in a given radiation atmosphere is proportional to the energy absorbed, usually given in rads. When estimating damage from different kinds of radiation it is often assumed that the radiation source or the dose rate is not important. For gamma radiation and neutrons from a nuclear reactor this may be a reasonable assumption for engineering purposes. For dose rates much higher or much lower than those used in the experiments,

Table 2. (continued)

Material	Initial Value(b)	Dose Rate Mrads/hr	Thickness (in.)	Ref.	Percent of Initial Value Retained at Given Dose (rads)(a,c)
2. Polypropylene (Profax)				(10)	
Tensile Strength, psi	4560				
Elongation at Break, %	70				
3. Polystyrene					
a. Clear Polystyrene:		2	0.12	(2)	
Tensile Strength, psi	1800				
Elongation at Break, %	0.32				
b. Polyflex:		1	0.002	(6)	
Tensile Strength, psi	11300				
Irradiated in vacuum:				(6)	
Tensile Strength, psi					
c. High-impact Polystyrene:		2	0.10	(2)	
Tensile Strength, psi	3100				
Elongation at Break, %	20				
Notch Impact Strength, ft-lb/in.	0.67				
4. Poly alpha-methyl styrene		2	0.17	(3)	
Shear Strength, psi	6000				
5. Butadiene-Styrene Copolymer Rubber Blend (Pliotuf)		2	0.08	(3)	
Tensile Strength, psi	4300				
Elongation at Break, %	3.8				
Notch Impact Strength, ft-lb/in.	0.8				
B. Oxygen-containing Polymers					
1. Polyvinyl formal		2	0.005	(3)	
Tensile Strength, psi	7400				
Elongation at Break, %	2				
2. Polyvinyl butyral		2	0.016	(3)	
Tensile Strength, psi	2200				
Elongation at Break, %	220				
3. Polyformaldehyde (Delrin)			0.02	(10)	
Tensile Strength, psi	10450				
Elongation at Break, %	70				



the radiation damage for equivalent total dose might be different. For high LET * rates the equal-energy-absorbed, equal-damage assumption is not valid for some materials. In polystyrene, for example, the cross-linking rate was 2 to 3 times higher for reactor radiation than for ^{60}Co gamma radiation.

* LET = linear energy transfer, the rate at which energy is transferred to the material per unit path length.

Table 2. (continued)

Material	Initial Value(b)	Dose Rate Mrads/hr	Thickness (in.)	Percent of Initial Value Retained at Given Dose (rads)(a,c)
4. Polymethyl methacrylate				
a. Lucite				(2)
Tensile Strength, psi	10700	2	0.13	
Elongation at Break, %	4.5			
Notch Impact Strength, ft-lb/in.	0.37			
b. Plexiglass II				(1)
Notch Impact Strength, ft-lb/in.	1.0	0.5	0.25	
5. Polycarbonate (Macrofol):				(6)
Tensile Strength, psi	6800	1	0.003	
Elongation at Break, %	75			
Irradiated in vacuum:				(6)
Tensile Strength, psi				
Elongation at Break, %				
6. Polyethylene terephthalate				
Mylar "A"				(3)
Tensile Strength, psi	25000	2	0.002	
Elongation at Break, %	50			(6)
Tensile Strength, psi	20300	1		
Elongation at Break, %	150			
Irradiated in vacuum:		1		(6)
Tensile Strength, psi				
Elongation at Break, %				
7. Cellulosics:				
a. Ethyl Cellulose				(2)
Tensile Strength, psi	6000	2	0.125	
Elongation at Break, %	40			
Notch Impact Strength, ft-lb/in.	2.0			
b. Cellulose Propionate				(2)
Tensile Strength, psi	2600	2	0.62	
Elongation at Break, %	1.6			
Notch Impact Strength, ft-lb/in.	1.1			

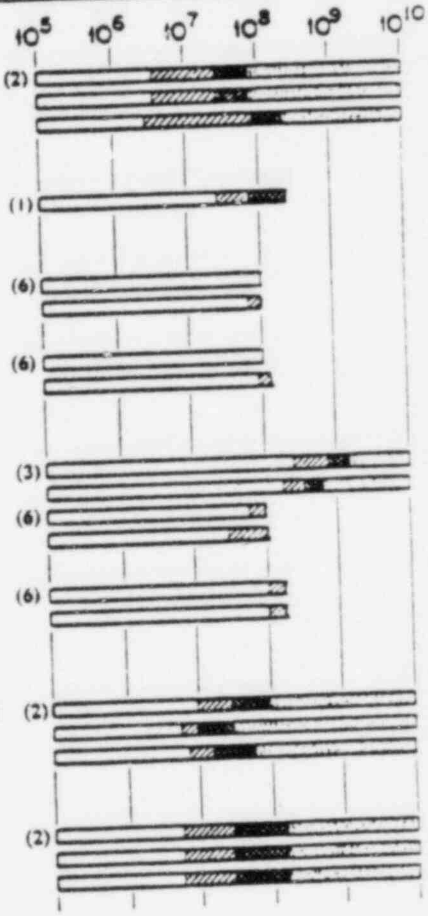


Table 2. (continued)

Material	Initial Value[b]	Dose Rate Mrads/hr	Thickness (in.)	Percent of Initial Value Retained at Given Dose (rads)[a,c]
c. Cellulose Acetate		2	0.125	(2)
Tensile Strength, psi	5300			
Elongation at Break, %	20			
Notch Impact Strength, ft-lb/in.	1.37			
d. Cellulose Nitrate		2	0.125	(2)
Tensile Strength, psi	7600			
Elongation at Break, %	30			
Notch Impact Strength, ft-lb/in.	2.75			
e. Cellulose Acetate-Butyrate		2	0.180	(2)
Tensile Strength, psi	4200			
Elongation at Break, %	60			
Notch Impact Strength, ft-lb/in.	3.3			
C. Halogen-Containing Polymers				
1. Rigid polyvinyl chloride		0.2	0.17	(8)
Tensile Strength, psi	8100			
Notch Impact Strength, ft-lb/in.	0.5			
2. Plasticized polyvinyl chloride				
a. (Geon 8630)		1	0.004	(6)
Tensile Strength, psi	2555			
Elongation at Break, %	245			
b. (Geon 8630)		1	0.02	(6)
Tensile Strength, psi	2735			
Elongation at Break, %	300			
c. (Geon 8640)		1	0.004	(6)
Tensile Strength, psi	3150			
Elongation at Break, %	225			
Irradiated in vacuum:		1		(6)
Tensile Strength, psi				
Elongation at Break, %				
3. Polyvinyl chloride with special plasticizers (70 parts plasticizer per 100 parts polymer):				

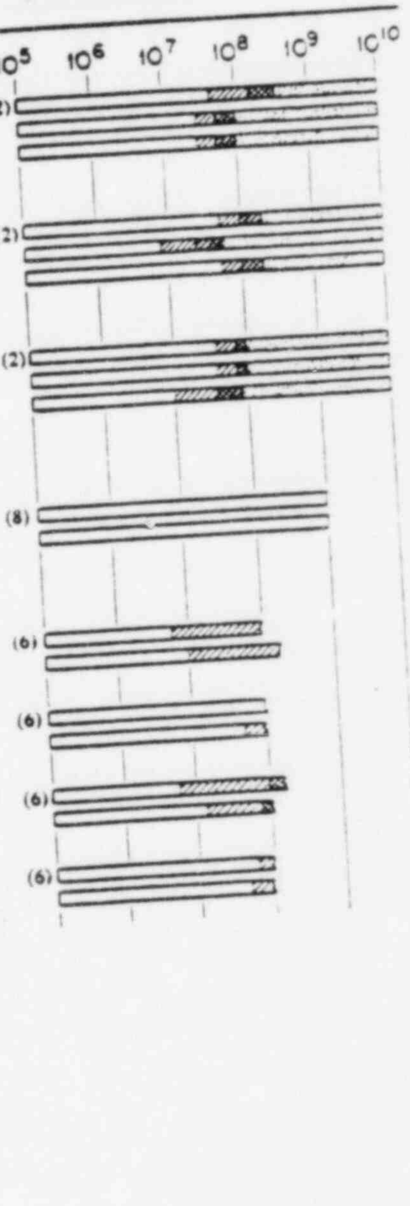


Table 2. (continued)

Material	Initial Value(b)	Dose Rate Mrads/hr	Thickness (in.)	Percent of Initial Value Retained at Given Dose (rads)(a,c)
a. Tritoyl phosphate		0.2	0.06	(7)
Tensile Strength, psi	2100			
Elongation at Break, %	318			
b. Di-2-ethylhexyl phthalate		0.2	0.06	(7)
Tensile Strength, psi	1900			
Elongation at Break, %	364			
c. Di-2-ethylhexyl sebacate		0.2	0.06	(7)
Tensile Strength, psi	1300			
Elongation at Break, %	318			
d. Polypropylenyl sebacate (Reoplex 100)		0.2	0.06	(7)
Tensile Strength, psi	2000			
Elongation at Break, %	342			
e. Polypropylenyl sebacate modified (Reoplex 110)		0.2	0.06	(7)
Tensile Strength, psi	2000			
Elongation at Break, %	234			
4. Vinyl Chloride-vinylidene chloride copolymer		2	0.13	(2)
Tensile Strength, psi	3700			
Elongation at Break, %	200			
Notch Impact Strength, ft-lb/in.	1.6			
5. Polyvinyl chloride acetate		2	0.13	(2)
Tensile Strength, psi	9000			
Elongation at Break, %	3.1			
Notch Impact Strength, ft-lb/in.	0.5			
6. Polyvinyl fluoride (du Pont R-20)		—		(10)
Tensile Strength, psi	8830			
Elongation at Break, %	160			
7. Polychlorotrifluoroethylene (Kel-F)		1	0.12	(2)
Tensile Strength, psi	4900			
Elongation at Break, %	50			
Notch Impact Strength, ft-lb/in.	1.9			

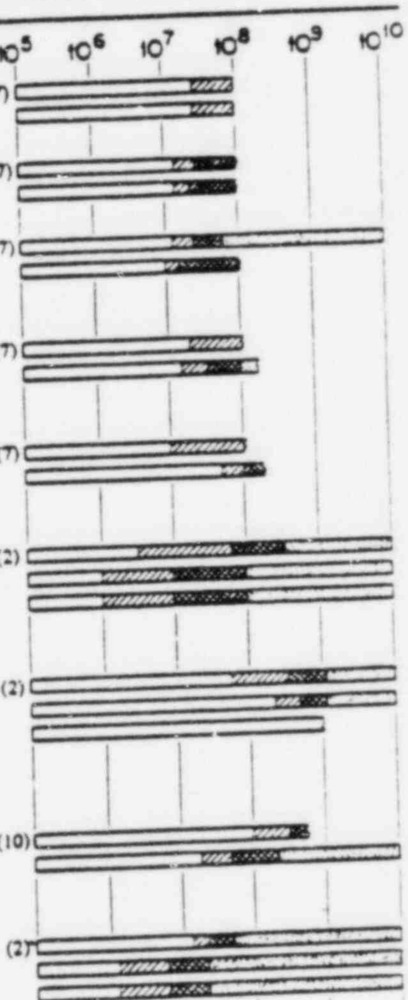


Table 2. (continued)

Material	Initial Value[b]	Dose Rate Mrads/hr	Thickness (in.)	Percent of Initial Value Retained at Given Dose (rads)[a,c]
8. Polytetrafluoroethylene (Teflon)				
Tensile Strength, psi	4800	1	0.06	(5)
Elongation at Break, %	400			
Tensile Strength, psi	3900	1	0.02	(5)
Elongation at Break, %	400			
Irradiated in vacuum:				
Tensile Strength, psi	4650	1	0.06	(5)
Elongation at Break, %	345			
D. Nitrogen-containing Polymers				
1. Polyvinyl Carbazole				
Tensile Strength, psi	1800	2	0.15	(5)
Elongation at Break, %	0.32			
Notch Impact Strength, ft-lb/in.	0.27			
2. Nylon				
Tensile Strength, psi	7600	2	0.10	(5)
Elongation at Break, %	62			
Notch Impact Strength, ft-lb/in.	2.8			
3. Casein Resin				
Tensile Strength, psi	8500	2	0.24	(2)
Elongation at Break, %	20			
Notch Impact Strength, ft-lb/in.	0.5			
4. Styrene-Acrylonitrile Copolymer (Royalite)				
Tensile Strength, psi	4000	2	0.06	(3)
Elongation at Break, %	10			
E. Miscellaneous Polymers				
1. Silicone-glass cloth laminate				
Shear Strength, psi	13500	1	0.07	(3)

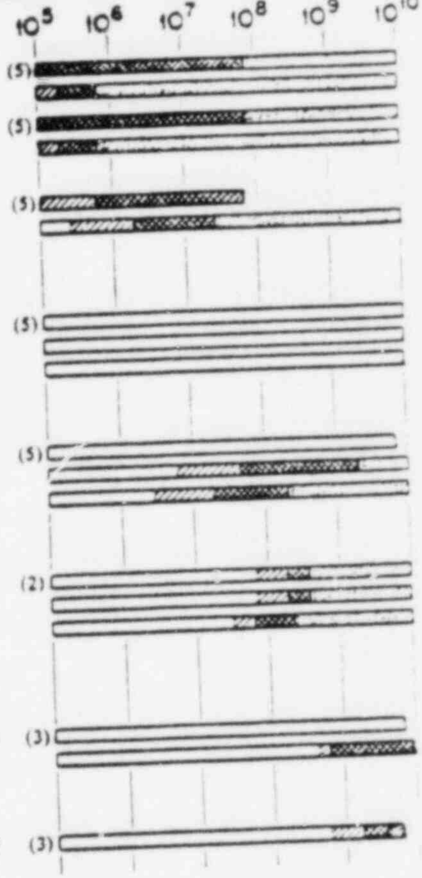


Table 2. (continued)

Material	Initial Value(b)	Dose Rate, Mrads/hr	Thickness, (in.)	Percent of Initial Value Retained at Given Dose (rads)(c,d)
Thermosetting Polymers				
A. Oxygen-containing Polymers				
1. Cast polyester (Selectron 5038)		2	0.26	(2)
Tensile Strength, psi	2000			
Elongation at Break, %	20			
Notch Impact Strength, ft-lb/in.	0.7			
2. Mineral-filled polyester (Plaskon Alkyd)		1	0.13	(2)
Tensile Strength, psi	4700			
Elongation at Break, %	0.2			
Notch Impact Strength, ft-lb/in.	0.4			
3. Allyl diglycol carbonate Resin		2	0.12	(2)
Tensile Strength, psi	6700			
Elongation at Break, %	2.4			
Notch Impact Strength, ft-lb/in.	0.35			
4. Triallyl Cyanurate Resin		2	0.25	(3)
Shear Strength, psi	2000			
5. Cast Phenolic		2	0.18	(2)
Tensile Strength, psi	11000			
Elongation at Break, %	2			
Notch Impact Strength, ft-lb/in.	0.5			
6. Asbestos fabric-filled phenolic		1	0.12	(2)
Tensile Strength, psi	11000			
Elongation at Break, %	1.3			
Notch Impact Strength, ft-lb/in.	3.9			
7. Linen fabric-filled phenolic		2	0.25	(2)
Tensile Strength, psi	11000			
Elongation at Break, %	4.0			
Notch Impact Strength, ft-lb/in.	2.75			

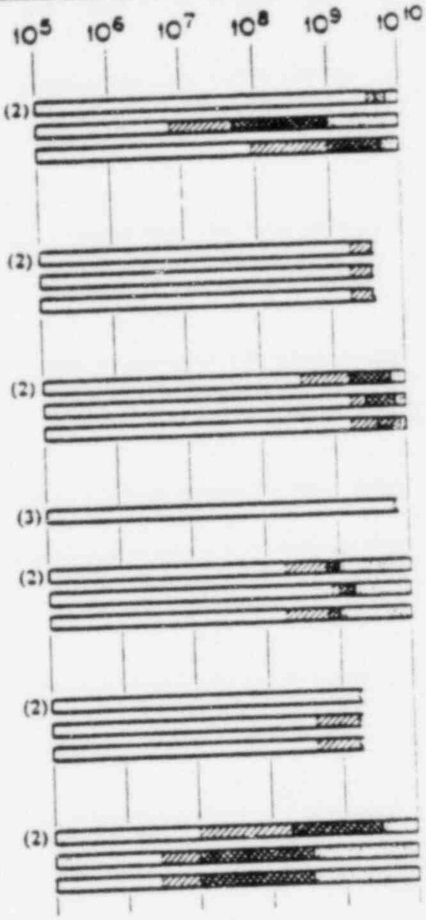


Table 2. (continued)

Material	Initial Value(b)	Dose Rate Mrads/hr	Thick-ness, (in.)	Percent of Initial Value Retained at Given Dose (rads)(a,c)
8. Furane Resin-graphite filled		1	0.37	(2)
Tensile Strength, psi	2200			
Elongation at Break, %	0.39			
Notch Impact Strength, ft-lb/in.	0.31			
9. Epoxy Polymer				
a. Aromatic amine-cured (diamino diphenyl methane) Flexural Strength, psi	17000	3	0.12	(9)
b. Aliphatic amine-cured (piperidine) Flexural Strength, psi	18500	3	0.12	(9)
c. Acid anhydride-cured (hexahydrophthalic anhydride) Flexural Strength, psi	18000	3	0.12	(9)
d. Acid anhydride-cured (dodecenyl succinic anhydride) (long side chain) Flexural Strength, psi	11500	3	0.12	(9)
e. Araldite Type B Casting Shear Strength, psi	8000	2	0.16	(3) ?
B. Nitrogen-containing Polymers				
1. Polyurethane (Estane VC)				(10)
Tensile Strength, psi	6390			
Elongation at Break, %	500			
2. Cellulose pulp-filled urea-formaldehyde		2	0.12	(2)
Tensile Strength, psi	7800			
Elongation at Break, %	0.5			
Notch Impact Strength, ft-lb/in.	0.3			
3. Aniline-Formaldehyde Polymer		2	0.20	(2)
Tensile Strength, psi	9200			
Elongation at Break, %	1.8			
Notch Impact Strength, ft-lb/in.	0.2			

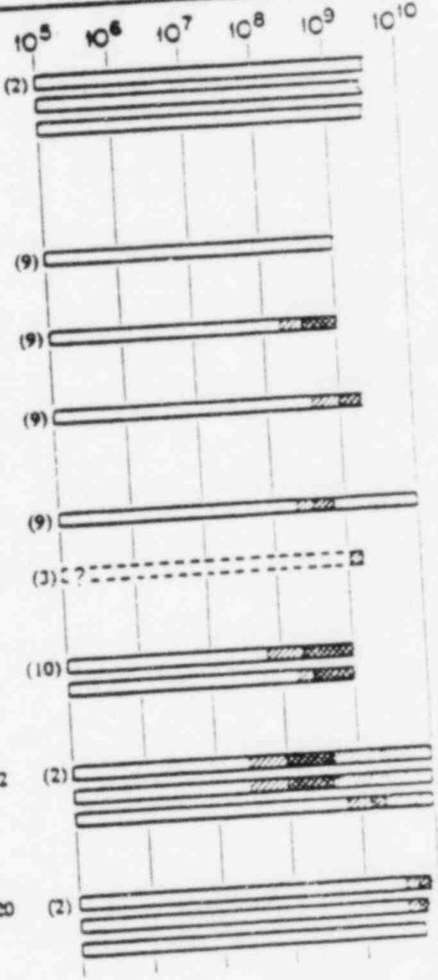
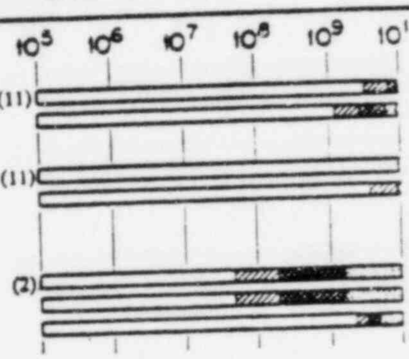


Table 2. (continued)

Material	Initial Value[b]	Dose Rate, Mrads/hr	Thickness, (in.)	Percent of Initial Value Retained at Given Dose (rads)[a,c]
4. Polyimide Polymer "H" Film		2	0.002	(11)
Tensile Strength, psi	26000			
Elongation at Break, %	65			
Irradiated in Vacuum:		6	0.002	(11)
Tensile Strength, psi				
Elongation at Break, %				
5. Cellulose pulp-filled melamine-formaldehyde		2	0.25	(2)
Tensile Strength, psi	9100			
Elongation at Break, %	0.65			
Notch Impact Strength, ft-lb/in.	0.29			



[a] Key for radiation effects:
- (open bar) 100 to 80% of initial value retained.
- (hatched bar) 80 to 50% of initial value retained.
- (solid bar) 50 to 10% of initial value retained.
- (stippled bar) 10 to 0% of initial value retained.

[b] To convert lb/in² to Kg/mm², divide by 1422 so that 14220 lb/in² equals 10 Kg/mm². To convert ft-lb to Kg-m/cm, divide by 18.36 so that 0.3672 ft-lb/in equals 0.02 Kg-m/cm.

[c] rad equals 100 ergs/gram of sample material.

3. The properties of specific materials and the effects of radiation

3.1. *Plastics*

3.1.1. Introduction

This chapter follows the widely used convention of designating the material by the chemical name or class of the monomer or monomers, usually with the prefix "poly-" to distinguish the plastic from the chemical raw material. Although this is a generally accepted convention, it is a poor basis for arranging plastics and rubbers in an orderly listing because it involves so many ambiguities with common materials and so many unfamiliar names with newer materials. Therefore, chemical composition has been adopted as a basis for arrangement since it is independent of nomenclature systems, and since elemental composition is frequently important to the reactor engineer.

On the basis of composition the plastics containing only carbon and hydrogen are listed first. Next are materials containing these elements plus oxygen, followed by polymers containing halogens. Within each class, the polymers are generally listed in the order of increasing complexity.

In the text, the polymeric materials are separated into the plastics and the rubbers because of their wide difference in physical properties and technical applications. Similarly, the plastics are further subdivided into thermoplastics and thermosetting plastics because of differences in fabrication methods and in properties of the finished product. Physical properties of the plastics which are significant in their selection for various applications are summarized in ref. [12].

3.1.2. Polyethylene

Polyethylene is the simplest of the polymeric materials, essentially a linear hydrocarbon with a main chain of carbon–carbon linkages.

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     H   H
- - - C - C - - -
     H   H
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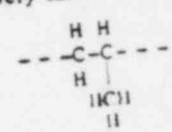
Variations in manufacturing processes yield polymers of different degrees of branching which have varying degrees of crystallinity and, consequently, a range of mechanical properties. Polyethylene polymerized at high pressure has about 30 branches per thousand carbon atoms and a density near 0.92 g/cm^3, and is about 50% crystalline. At the other end of the spec- trum, linear material polymerized at low pressure has very few branches, a density of 0.96 g/cm^3, and crys- tallinities up to 95%. As shown in table 1, the tensile strength of polyethylenes is relatively low, but varies over a factor of 2 for the different types of this poly- mer. Elongation at break is also highly dependent on polymer type, and is relatively high for plastics. The molecular-weight distribution is generally broad for this polymer, and variations permit some control over impact strength and melt properties. The physical and chemical properties, the ease of processing, and the moderate cost of polyethylene make it among the most common of the plastics in industrial and house- hold use. Large quantities are used in sheet, film, and molded items. Its softening temperature and strength limit it to moderate-temperature and nonload-bearing service. Within these limitations it is used widely. Since the electrical properties are unusually good, large quantities are used in electrical apparatus as in- sulation for wiring and coaxial cables. Because of the simplicity of its chemical structure, polyethylene can serve as a prototype for the action of radiation on polymers, and the literature is replete with data on the effects of radiation on this material – both from a basic and an engineering viewpoint. The radiation- induced changes in the physical properties are illus- trative of the results of cross-linking; the material be- comes hard and finally brittle (glassy). The tensile strength increases for mild radiation doses and then decreases for larger exposure. The elastic modulus is increased, and the plastic-flow region of the stress- strain curve is decreased as the material becomes more rigid. The softening temperature is increased. The changes at low dose levels constitute very real im- provements in material for electrical insulation, food packaging, containers, etc. Consequently, polyethyl- ene cross-linked by irradiation is presently being mar- keted at the rate of several million pounds annually.

Polyethylene is a relatively radiation-resistant poly- mer; it is more resistant than the polymers undergoing scission, but not so resistant as those containing arom- atic groups. Although some of the properties begin changing at moderate doses, polyethylene may be us- able up to about 10^{10} rads if the application does not require that it remain soft and pliable. The radiation- induced reactions produce much gas, 90 to 95% of which is hydrogen.

The rates of the fundamental radiation-induced reactions may be useful for comparison purposes. The cross-link yield is $G = 1.0$ to 1.5, the main-chain-yield is 0.2 G, and the hydrogen yield is $G = 3.3$ to 3.7. Very recent studies have shown that the rate of cross-link- ing in very pure polyethylene increases after moderate doses.

3.1.3. Polypropylene

Polypropylene is very similar to polyethylene and although it is not made from ethylene, can be regard- ed as derived from polyethylene by substituting a methyl group on every carbon atom of the main chain



Polypropylene is made from refinery by-product pro- pylene, which allows it to be competitive with poly- ethylene for some purposes. The methyl groups (branches) may be a right-hand or left-hand con- figuration on the main chain. If the arrangement is random (atactic), the polymer is amorphous and is soft and rubbery. On the other hand, if the branches are all in one configuration or the other (isotactic), the regularity of the polymer chain permits a high de gree of crystallinity with high tensile strength and toughness.

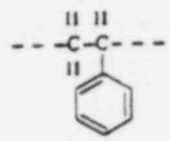
Only the isotactic polymer is commercially im- portant at present. The melting point and the glass- transition temperature of polypropylene are higher than those of polyethylene, and it is used in applica- tions similar to those of polyethylene where the great- er strength and higher softening temperature justify its higher cost. Stretching of films and fibers produce an oriented crystalline structure that has unusual strength and toughness. Such films are used in large volume in packaging applications, while the fibers are very useful in carpeting, rugs, and cordage.

Surprisingly, upon irradiation, polypropylene shows predominant scission at nearly as high a rate as polyisobutylene, $G = 4.9$. At higher doses (10^8

scission appears to decrease while the cross-linking yield increases until they have similar rates at $G = \sim 1$. These changing yields appear to be related to the increase in vinylidene unsaturation, which results from scission and appears at the new chain ends. Consequently, the radiation stability of polypropylene is considerably less than that of polyethylene. At moderate doses there is a loss in impact strength, tensile strength, and elongation at break. At high radiation doses (over 10^9 rads) polypropylene becomes increasingly softer and more flexible, apparently indicating the dominance of the scission process again.

3.1.4. Polystyrene

Polystyrene can be pictured as polyethylene with side groups of phenyl rings on alternate main-chain carbons.

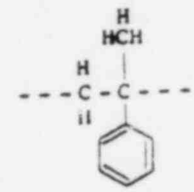


The phenyl groups are bulkier than the methyl groups of polypropylene and the electronic arrangement in the aromatic ring gives much stronger attractive forces between neighboring molecules. Only the atactic material is marketed commercially, and the molecular structure of this form gives an amorphous material in which the strong intermolecular forces raise the glass-transition temperature above 100 C. Polystyrene is a rigid, glassy, transparent plastic at ordinary temperatures, is among the cheapest, and is easy to extrude, mold and color. Its mechanical properties can be improved by adding rubbery polymers or copolymerizing with butadiene or acrylonitrile. The opaque modified polystyrenes have upper temperature limits of 60 C and impact strengths sufficient for appliances, etc. Reinforced grades show still higher impact strengths.

As explained earlier, the phenyl rings stabilize polystyrene against radiation. It cross-links slowly ($G =$ 0.03 to 0.04) with the rate of scission corresponding to $G < 0.01$. The yield of gas from polystyrene, mostly hydrogen and methane, is also very low. These low cross-linking and scission rates mean that the mechanical properties of polystyrene change very little up to doses exceeding 10^{10} rads. Plasticizers and copolymers generally reduce the radiation resistance of polystyrene. The effect of air and oxygen on the radiation damage to thick specimens appears to be slight but there is a small postirradiation oxidation in air which depends on radiation dose and thickness. For thin film or sheet stock, irradiation in air at low dose rates may permit oxidation scission to dominate over cross-linking. The radiation damage is two to three times as great for fast neutrons as for equivalent doses of gamma radiation.

3.1.5. Poly-α-methylstyrene

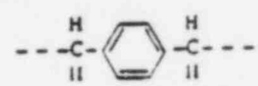
The additional methyl side group of poly-α-methylstyrene gives it a main chain stiffer than that of polystyrene, which results in higher softening temperatures but greater brittleness.



It is difficult and expensive to polymerize, and its former applications as a hard, high-temperature plastic have been taken over by improved or modified polystyrenes. The addition of the methyl group opposite the benzene ring on the main chain produces a quaternary carbon atom, which leads to scission under irradiation. Consequently, the material is relatively sensitive to radiation, as evidenced by a very rapid decrease in shear strength. It has not been studied extensively.

3.1.6. Poly-para-xylylene

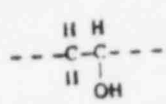
This new material is interesting because of its simple structure and aromatic ring. It is marketed as



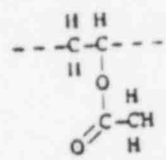
Parylene N, and its chlorinated derivatives as Parylene C and D. The phenyl ring in the main chain gives these materials a stiff molecular structure with moderately strong intermolecular forces and high softening temperatures, for example 1000-hr use temperature above 95 C, and short-time use temperature above 270 C in inert atmospheres. The expensive preparation, vapor polymerization, limits it to high-cost applications where its superior physical and dielectric properties are in demand, e.g. thin-film dielectrics for capacitors, and supporting elements for very small, quick-acting electronic components. Radiation testing has not been extensive, but the aromatic rings appear to lend stability. On the other hand, weathering tests show that the material is not resistant to UV radiation, so the radiation resistance should not be assumed to exceed that of polyethylene. The halogenated derivatives would be expected to lose their electrical resistance at considerably lower radiation doses than polyethylene.

3.1.7. Polyvinyl alcohol and its derivatives

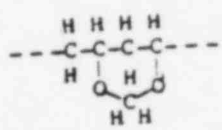
These polymers are polyethylene with the corresponding substituent group on alternate main-chain carbon atoms.



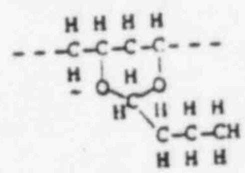
Polyvinyl alcohol



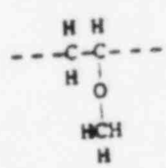
Polyvinyl acetate



Polyvinyl formal



Polyvinyl butyral



Polyvinyl methyl ether

Polyvinyl acetate is prepared by the reaction of acetylene with acetic acid. Hydrolysis of the acetate yields polyvinyl alcohol, but usually about 5% of the ester groups remain unreacted. Decomposition of polyvinyl acetate with formaldchyde, butyraldchyde, or methanol produces the corresponding formal, butyral, or ether.

None of these materials is widely used as a plastic in itself. The hydroxyl groups on polyvinyl alcohol confer water solubility, and it is used in coatings, textile sizes, and as an adhesive. The hydroxyl groups also render it resistant to organic solvents, and useful in solvent-resistant hoses, diaphragms, gaskets, and other flexible components. The effect of radiation on polyvinyl alcohol has not been investigated extensively but it appears to undergo scission in both air and vacuum with $G \sim 3$. The carbonyl content increases during irradiation in vacuum as well as in air, and secondary reactions of liberated hydroxyl radicals may be responsible for the main-chain scission. Since the rate of scission is higher than that of polymethylmethacrylate, the mechanical properties of polyvinyl alcohol probably deteriorate more rapidly.

Polyvinyl acetate has a low softening point, is soft and flexible, and is soluble in aromatic, oxygenated, and chlorinated solvents, but not in water or aliphatic hydrocarbons. It too is used in adhesives, coatings, and textile sizing. Radiation studies have been made mostly with the copolymer with vinyl chloride in which the acetate was a minor constituent. The effect of radiation on the mechanical properties has not been studied.

Polyvinyl formal is widely used in coating electrical wire and as a varnish, since it has superior flexibility and abrasion resistance. The effects of radiation have been studied only on a formulation containing 10% plasticizer in thin sheet form with limited access to air during irradiation. The observed property changes indicate that chain scission is the predominant reaction. Tensile strength and elastic modulus were reduced 50% at about 10^8 rads, while elongation at break was increased about the same fraction.

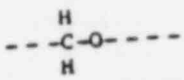
Polyvinyl butyral is a tough, high-strength plastic used as the interlayer in safety glass; it is especially adapted in that about 18% of the ester groups of the parent polyvinyl acetate are left unreacted with butyraldehyde, but are subsequently hydrolyzed to hydroxyl groups. These polar groups impart adhesion to glass layers without additional bonding agents. The elastic modulus of polyvinyl butyral increases upon

...ation, indicating a dominance of cross-linking; in ...st the elongation at break decreases. The tensile ...th drops to 50% at 10^8 rads, a more rapid de... than shown by polyvinyl formal.

The commercial uses of polyvinyl methyl ether re... those of the acetate, and there is little use for ... solid polymer itself. The low-molecular-weight ... polymer cross-links.

...11. Polyformaldehyde

The acetal polymers, products of polymerizing the ...dehyde group, have a main-chain of alternating car... and oxygen atoms. Polyformaldehyde homopoly... and acetal copolymers with formaldehyde are ...eted as Delrin, while the copolymer is available ...Celcon.

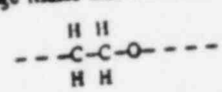


... homopolymer is among the strongest and stiffest ... the thermoplastics, and has outstanding creep and ...ue resistance. With its dimensional stability ... usefulness over a wide temperature range, it finds ...ications as replacement for metals.

The acetal resins are resistant to organic solvents ... to water, but strong acids and bases may induce ...emical decomposition. The regular structure per... high crystallinity, which contributes to the good ...hanical properties and chemical resistance, suit... for gears, bearings, and other mechanical and elec... components. With radiation, polyformaldehyde ...expected to degrade by chain scission at a little ...er rate than the chemically similar polyethylene .... Delrin has poor radiation stability at 10^5 rads.

...19. Polyethylene oxide

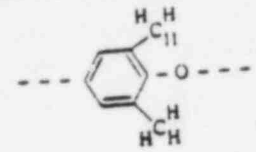
The simple, regular chain and the polar forces of ... ether linkage make this material crystalline, waxy,



...d fibrous. The high fraction of ether linkages con... solubility in water, so that it is used as a plastic...er and as an additive in nonpolymeric materials rath... than as a base polymer. Effects of radiation on the ...gineering porperties of this material are not known. ...adiation in vacuum gives about ¼ the cross-linking yield of polyethylene. The scission rate could be appreciable and would make the net cross-linking rate somewhat higher than reported. The apparent cross-linking rate is higher in air, than in vacuum because of the formation of peroxy cross-links.

3.1.10. Polyphenylene oxide.

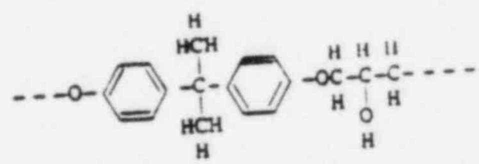
Polydimethyl phenylene oxide, usually called polyphenylene oxide commercially, contains both oxygen linkages and aromatic rings in the main chain.



It has good strength and toughness and unusually good electrical properties – low loss tangent and dissipation factor from −170 to +190 C. Its dimensional stability and resistance to moisture and atmospheric agents make it useful in electrical and electronic applications, as a replacement for glass and stainless steel in medical and surgical devices, and in food processing and handling equipment. It should behave similarly to polyethylene terephthalate under irradiation.

3.1.11. Phenoxy plastics

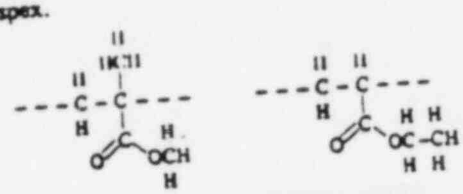
The phenoxy thermoplastics are ethers of bisphenol A and glycerine. The chemical structure is similar to that of the prepolymer of epoxy thermosetting resins, but has more (~100) repeating units per molecule and no unreacted cyclic epoxide units.



The phenoxies have good mechanical and electrical properties and long-term thermal-aging characteristics. They can be processed by injection and blow molding for containers, packaging, etc. Extrusion into film or sheet gives heat-sealable materials of high strength and clarity that are useful for packaging foodstuffs and other items. The ether linkage makes the polymer soluble in polar solvents such as ketones, while the pendant hydroxy group gives good adhesion. Consequently, the material is used for coating paper and textiles and as a structural adhesive, including joining of metals. Behavior under irradiation should be similar to that of the epoxies.

3.1.12. Acrylics and modified acrylics

The widely used acrylic plastics and resins, for practical purposes, can be regarded as polymethyl methacrylate, and variations through copolymerization or blending. Trade names are Lucite, Plexiglass and Perspex.



Polymethyl methacrylate Polyethyl acrylate

Acrylic resins are 90% or more methyl methacrylate copolymerized with a higher alcohol ester of methacrylic acid or with an ester of acrylic acid. The modified acrylics are polymethyl methacrylate, copolymerized with small amounts of styrene, α-methyl styrene, butadiene, or similar monomers, or they are blends of acrylics with polyvinyl chloride or some other flexible, rubbery polymer. The polyacrylate esters are more flexible and ductile. The polyacrylate esters are not widely used as plastics themselves, but the softness and flexibility of the ethyl ester (polyethyl acrylate) lead to its use as an elastomer (see under the rubbers).

Polymethyl methacrylate, with both a methyl and a bulky ester side group on every second main-chain carbon, has a relatively stiff main chain. The ester group also generates intermolecular attraction. Consequently, the methacrylate esters are hard, glassy, and abrasion resistant, and have a fairly high maximum-service temperature of about 100 C.

To increase the impact resistance, methyl methacrylate is copolymerized with an acrylate to give a more flexible polymer chain, or with a higher ester of methacrylic acid to impart a degree of internal plasticization, or with butadiene, or blended with PVC. Copolymerization with α-methyl styrene further stiffens the main chain, raising the service temperature limit. Copolymerizing with styrene reduces the cost of the final products.

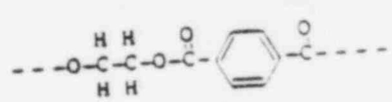
The acrylics are clear and stable to weathering, and suitable for outdoor signs, etc.

The quaternary carbon atom alternating along the main chain of polymethyl methacrylate yields fairly rapid scission under irradiation. Along with scission there is decomposition of the ester group to yield the gases, H_2, CH_4, CO, and CO_2. The chain scission and side-chain decomposition lead to embrittlement and loss of tensile strength at fairly low radiation doses. The optical properties are also degraded by the generation of colored decomposition products and presumably by the formation of free radicals and trapped electrons. Upon standing in air, the oxidation of the reactive species or their spontaneous decomposition results in slow bleaching and recovery of transparency. The radiation-induced changes in engineering properties are shown in table 1. The scission yield is $G = 1.7$, and the gas yield corresponds to the decomposition of 1 ester side group per scission. If bulk polymethyl methacrylate is heated after irradiation, the radiation-produced gases cause foaming.

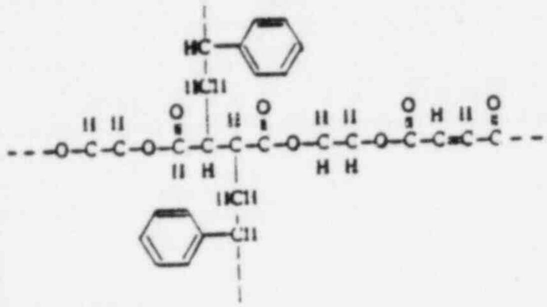
The behavior of polyacrylates under irradiation ha[s] been studied only from a basic standpoint. The absence of quaternary carbon atoms in the main chain results in net cross-linking in contrast to the polymethacrylates; giving them better resistance to radiation. The protective effect of the phenyl group was observed in a series of phenyl polyacrylates which required higher radiation doses for cross-linking than alkyl esters.

3.1.13. Polyester, alkyd and allylic resins

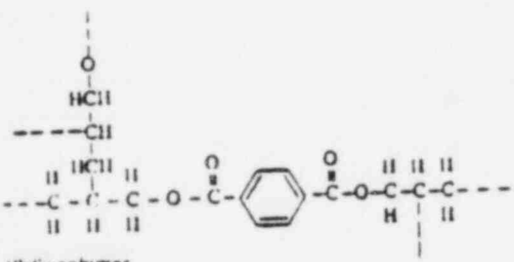
Polyesters are condensation polymers formed fro[m] difunctional alcohols and dicarboxylic acids. These polymers are widely used in the form of both therm[o]plastic and thermosetting resins. The polar ester grou[p] gives strong intermolecular forces that confer toughness and strength to the polymers even at relatively low molecular weights. The thermoplastic polymers having a relatively regular molecular structure (i.e., those prepared largely from ethylene glycol and terephthalic acid) have a high degree of crystallinity.



Polyethylene terephthalate



Alkyd polyester



Allylic polymer

and consequently are strong, tough, and resistant to chemicals, water, and weathering. Stretching or drawing increases the crystallinity and orients the crystallites to give films and fibers of unusual strength.

The thermoplastic polyesters are marketed very widely as fibers and fabrics, originally with the trade name Dacron but now under trade names of several manufacturers (Kodel, Forticel). In film and sheet form, the plastic is marketed as Mylar and Terelene. It is especially useful in electrical items where its dielectric properties, its high softening temperature, and its toughness are needed. Capacitor and insulating sheet stock are notable applications.

The radiation stability of the thermoplastic polyesters ranks somewhat lower than that of polyethylene. While the measured rates of gas formation, cross-linking, and scission are low, the changes in mechanical properties are relatively rapid. The evolved gases are mostly CO_2 and CO, with G from 0.1 to 0.15; rates of cross-linking and scission are also within this range. The elongation at break decreases at about the same rate as for polyethylene but the tensile strength, usually much greater, decreases much faster.

Oriented films appear to have radiation stability greater than that of the unoriented product. Other factors that appear to influence the rate of radiation-induced change are atmosphere, the thickness of the specimen, and radiation dose rate. Irradiated Mylar appears to be unaffected by thermal aging up to 200 C except at radiation doses above 10^8 rads.

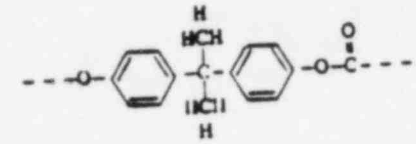
The thermosetting polyesters are made up of two distinctly different groups. One group, the alkyds, is prepared from saturated dihydroxy alcohols and dibasic acids, all or part of which must be unsaturated. A second system of thermosetting polyesters, the allylic resins, utilizes dibasic acids (usually phthalic acid) and the unsaturated monohydroxy alcohol, allyl alcohol. An amorphous, hard structure results from three-dimensional cross-linking which is usually employed in filled or fiber-reinforced formulations to give rigid, strong, and impact-resistant structures.

The alkyd thermosets are used for the most part in the heavily filled condition. The ability of these polyesters to wet treated glass fibers and to form structures of high strength-to-weight ratio with properly oriented and distributed fibers has permitted the replacement of metals in many applications.

For the heavily filled or reinforced materials, the effect of radiation on the filler itself will be the determining factor. Cellulosic fillers will be readily degraded by radiation. Inorganic materials are generally resistant to radiation, and common formulations high in asbestos or fiber glass will be much more resistant. The unfilled resin will vary considerably in sensitivity to radiation, depending on the fraction of aromatic rings or phthalic acid in their makeup and the nature of the cross-linking monomer employed, and the extent of cure, or unreacted unsaturated groups. Thus, unfilled polyesters may show increases in tensile strength and hardness at moderate radiation doses and will retain useful mechanical properties to 2×10^9 rads, while filled formulations are useful considerably beyond this dose. Their behavior under irradiation is very similar to that of the phenolics, described below.

3.1.14. Polycarbonate

Polycarbonate resins are polyesters synthesized by condensation of phosgene with bisphenol A, or by ester exchange of a carbonate with a dihydroxy aromatic compound. They are usually modified with glass reinforcement and chemical stabilizers. The carbonate ester group has strong polar forces, making

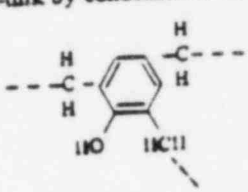


the resin hard, tough, and giving it moderately high softening temperatures. It also has low mold shrinkage and consequently is used for appliance parts, molded gears, pump impellers, etc. Sheet stock with fiberglass reinforcement makes strong appliance and tool housings. The unfilled material is transparent, can be steam sterilized, and can be used at temperatures in excess of 100°C.

The quaternary carbon atom and the carbonate ester group probably lead to chain scission under irradiation. Polycarbonates have been found relatively sensitive to radiation, degradation of mechanical properties being comparable to that of polymethyl methacrylate.

3.1.15. Phenolic resins

The phenolics are thermosetting resins prepared from formaldehyde and various phenols that polymerize and cross-link by condensation reactions. They

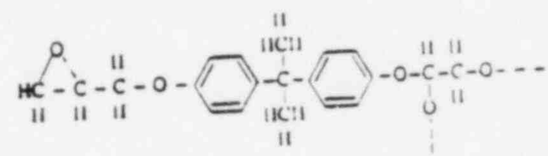


are the oldest plastics and among the most important industrially since they are low cost and properties and fabricating techniques can be varied through changes in the chemical structure and in the reinforcing materials. Furthermore, they have high strength, good chemical and heat resistance, and are easily molded. They are supplied as liquids for coating or impregnating and as molding powder or pellets. In both instances, they set to hard, strong, but sometimes brittle, final products. They are most frequently used with fillers or reinforcing materials, which may be wood powder, cellulose fiber or fabric, calcium carbonate, silica, glass, asbestos, etc.

Unfilled phenol-formaldehyde shows intermediate radiation resistance, not as good as that of polystyrene or polyethylene but much better than that of the polymers which scission. The unfilled and organic-filled plastics swell and become brittle at high radiation doses, and a soluble product is formed which may cause disintegration of the plastic in water. However, the inorganic-filled material shows much better resistance to radiation and is affected only slightly at 3×10^9 rads. For unfilled resin, the tensile strength increases but the impact strength decreases. Phenolics containing inorganic fillers rank among the most radiation-resistant plastics.

3.1.16. Epoxy resins

The epoxy polymers are thermosetting resins based on polyethers formed in condensation reactions between bisphenol A and epichlorohydrin as indicated below. They require relatively large portions of curing agents, most of which are amines, thereby incorporating nitrogen into the molecular structure.

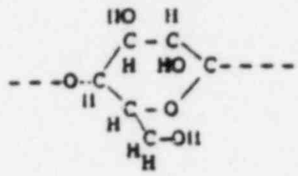


In general, the high concentrations of residual hydroxy and other polar groups in the molecular structure give the epoxies very strong adhesive forces. The wide range in flexibility, hardness, strength, and other properties, leads to applications in coatings, adhesives, encapsulation, impregnation and reinforcement.

The radiation resistance of the epoxies is roughly comparable to that of the phenolics. Aromatic curing agents yield products that are much more resistant than those obtained with aliphatic curing agents. Substantial differences between the effects of accelerated electrons and gamma and reactor radiation have been explained by the difference in dose rate in air. Oxygen plays an important part in the degradation of epoxies and at high dose rates it may be depleted faster than it can diffuse in. For this reason thickness is also important when specimens are irradiated in air.

3.1.17. Cellulose and its derivatives

Cellulose is a partly crystalline natural polymer of carbon, hydrogen, and oxygen arranged in a complex linear structure of cyclic glucose repeating units. The



three hydroxy groups per glucose ring permit the dissolution of cellulose in reactive agents. Substitution of the hydroxy groups by ethyl groups gives the thermoplastic ethyl cellulose, while treatment with aliphatic acids yields the cellulose esters which are useful as molding compounds and, in the case of the acetate, as a textile fiber (acetate rayon). The moisture resistance and weather resistance of these cellulose derivatives are generally poorer than those of most plastics. The upper service temperature is about 70 C. These properties limit the uses to those where exposure to severe environment conditions will not be encountered. Their good molding and strength characteristics, as well as their appearance and low cost, give them wide usage as decorative household items, novelties, toys, and packaging items.

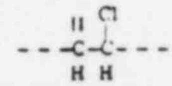
The acetate, propionate, and mixed acetate butyrate are the esters in common use. The variations among the esters and the ether, along with differences in plasticizers, provide a wide range of properties. The polar carbon-oxygen linkage results in strong intermolecular forces which contribute to the crystallinity and strength of these polymers. The large fraction of the chemical structure made up of such electronegative atoms contributes to fairly rapid radiation-induced decomposition. Cellulose undergoes scission rapidly ($G = 10$), but cellulose derivatives appear to be somewhat more resistant than cellulose itself.

Radiation-effects data are available on ethyl cellulose, cellulose acetate (rayon), cellulose propionate, cellulose acetate-butyrate, and cellulose nitrate from tests on sheet stock with limited oxygen. The tensile properties are reduced at least ten times as fast as for polyethylene, but not as fast as for polymethyl methacrylate.

Natural cellulose (cotton, wood, etc.) undergoes scission quite rapidly and takes on a charred appearance. Cellulose nitrate is flammable, which precludes its use as a molding material, but its unique toughness makes it useful as a coating and as extruded sheet and tubing. It differs from the other cellulose esters under irradiation in its production of large quantities of gas. Irradiated sheet and thicker stock warmed to the softening temperature give a spectacular release of gas which inflates the specimen to several times its original volume.

3.1.18. Polyvinyl chloride

Polyvinyl chloride (PVC) has a regular main-chain structure, and polar forces associated with the carbon-



chlorine bond give the pure polymer high crystallinity and high strength and rigidity. Its low cost and the range of properties possible with filler and plasticizer loadings up to 50% have made it one of the most abundantly used of all thermoplastics.

Exposure to either light or ionizing radiation releases HCl from this polymer. Fortunately, in the case of light, this reaction can be stopped by stabilizers. Other radiation-induced changes vary greatly, depending on the additives.

The unplasticized hard, strong form shows little change in tensile and impact strength up to 10^8 rads. Some plasticized formulations harden and show about the same radiation resistance as the unplasticized material, while others are more sensitive by at least an order of magnitude. The liberated HCl rapidly reduces the electrical resistance.

3.1.19. Polyvinyl chloride-acetate

Copolymerization of 5 to 20% vinyl acetate with vinyl chloride yields a plastic that is basically polyvinyl chloride, but less rigid and softer, with internal plasticization. Under radiation, scission predominates in the unfilled polymer, and HCl is produced. It blackens at relatively low doses and drops severely in electrical resistivity. Before the color changes, however, a large increase in the plastic-flow region of the stress-strain curve is observed, the elongation at break increasing up to 200% at 5×10^6 rads. After this the plastic softens and weakens gradually.

3.1.20. Polivinylidene chloride

Another halogenated vinyl polymer that has enjoyed industrial use for a number of years is polyvinyl-

```
   H Cl
- - -C-C- - -
   H Cl
```

idene chloride, used largely as a copolymer with vinyl chloride or acetate. It forms partly crystalline, strong, hard resins. Both plasticized and unplasticized polyvinylidene chloride copolymers find application as flexible hoses, film, molded pipe fittings, etc.

Irradiation of polyvinylchloride with limited access of air produces predominantly chain scission and a rapid loss in strength and electrical resistance, with evolution of HCl.

3.1.21. Polyvinyl fluoride

Polyvinyl fluoride, the fluorine counterpart of polyvinyl chloride (Tedlar) is available in film form and is tough, flexible, and has high tensile strength.

```
H F
C C
H H
```

Polyvinyl fluoride is similar to polyvinyl chloride in that it has good resistance to most chemical agents, but also has outstanding weather resistance as surface panels and house siding, and for coating fabrics. Radiation stability is probably similar to that for polyvinyl chloride.

3.1.22. Fluorocarbon polymers

Completely halogenated ethylene forms two widely used polymers, polytetrafluoroethylene (TFE) (Teflon, Halon, and Thiokol-TFE) and polychlorotrifluoroethylene (CTFE) (Kel-F and Plaskon-CTFE). The copolymer of fluoroethylene with perfluoro propylene (Teflon-FEP) is also coming into increasing use. The TFE and CTFE homopolymers have a simple molecular structure and moderately strong intermolecular forces.

```
   F F              F Cl
- - -C-C- - -    - - -C-C- - -
   F F              F F
```

All have good tensile strength and are tough, also extremely inert chemically and useful to exceptionally high temperatures (250 C in the case of TFE). Hot pressing of powder compacts are required for TFE, but the other resins are more suitable for conventional fabrication. They are used for tubing, gaskets, seals, containers, and for electrical coatings, where their inertness and high-temperature resistance justify their cost. Their low coefficient of friction, makes them useful for unlubricated bearings and sliding surfaces.

These materials undergo scission under irradiation and in spite of their resistance to atmospheric oxidation, they degrade much more rapidly when irradiated in air than when irradiated in a vacuum or inert atmosphere. The effect of oxygen during irradiation is less in CTFE than in TFE. CTFE is more resistant to radiation damage than is TFE but both materials lose strength and electrical resistance and eventually crumble at moderate radiation doses.

The importance of oxygen with regard to radiation stability indicates that the effects of both dose rate and thickness are also likely to be very important when fluorocarbon polymers are irradiated in air.

3.1.23. Chlorinated polyether (penton)

The linear structure with polar groups of this halogen-containing polymer gives a high degree of

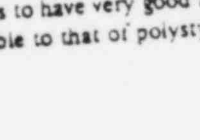
```
          H
        HCCl
      H   |   H
- - - C - C - C - O - - -
      H   |   H
        HCCl
          H
```

crystallinity and moderately high service temperatures, with good corrosion resistance and strength, and low mold shrinkage. Radiation stability is probably very poor.

3.1.24. Polyvinyl carbazole

Polyvinyl carbazole is a nitrogen-containing, linear, thermoplastic addition polymer with a bulky aromatic

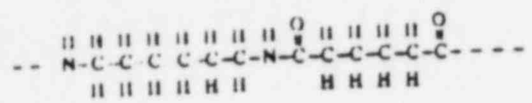
```
   H H
- - -C-C- - -
   H
```



side group on alternate carbon atoms of the main chain. It is thus a very hard, rigid material with rather low impact strength. It has not been extensively tested, but appears to have very good resistance to radiation, comparable to that of polystyrene.

3.1.25. Polyamides

The condensation polymerization of diamines with dicarboxylic acids or of amino acids with themselves leads to a group of thermoplastics now generically termed nylons. The most common member of this group, nylon-66, has six carbon atoms in both the diamine and dicarboxylic acid. The amino acid with six carbon atoms yields nylon-6. Polyamides with up to 12 carbon atoms between amide linkages are manufactured. The amide group has strong intermolecular



forces which produce crystalline-structured, chemically resistant plastics having moderately high service temperatures (150 C for nylon-66). On the other hand, the amide group is subject to attack by acids and alkalies, and these plastics are somewhat more susceptible to these reagents than are the hydrocarbon polymers. The crystallinity and strong intermolecular forces impart high strength to the polyamides drawn into fibers. Thus, these polymers are widely used as high-performance fibers and textile fabrics.

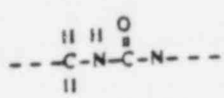
The most pronounced effect of radiation is hardening from cross-linking, but the polyamides have a higher ratio of scission to cross-linking than polyethylene. Thus their retention of strength and elongation is poorer. Thin sheets of nylon and nylon fibers irradiated in air have been found to deteriorate much faster than thick stock. The addition of antioxidants improves the radiation stability of nylon fibers. The polyamides do not harden as fast as polyethylene.

3.1.26. Polyurethanes

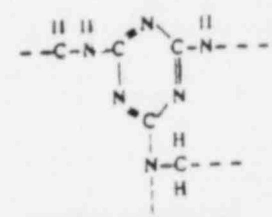
Polyurethane plastics are either thermosetting or thermoplastic condensation polymers, fundamentally only slightly different from the elastomeric polyurethanes discussed under rubbers. Their good adhesion characteristics, toughness, and abrasion resistance make them useful for coatings and adhesives. They are also widely used as rigid foams, which are identical to the elastomeric foams except that different curing agents impart the desired rigidity. Rigid polyurethanes under irradiation should show radiation stability at least as good as that of the elastomers. No change was found in the flexural strength and flatwise compressive strength of a polyurethane-foam sandwich irradiated to 10^9 rads.

3.1.27. Urea formaldehyde and amine formaldehyde resins

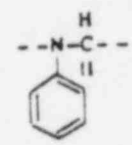
Urea, melamine and aniline condense with formaldehyde to give complex nitrogen-containing resins. Proper reaction conditions lead to cross-linking (thermosetting) since the urea and amines can behave as polyfunctional monomers.



Urea formaldehyde



Melamine formaldehyde



Aniline formaldehyde

In the aniline polymers, such cross-linking requires the reaction of the hydrogens of the phenyl ring, and this resin is frequently used in the non-cross-linked, thermoplastic form, and has good electrical properties.

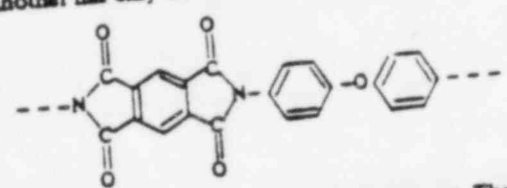
The urea and melamine resins are thermosetting molding, coating and adhesive materials. The urea resins require fibrous fillers for good tensile strength and are usually formulated with wood fillers or cellulose. They are hard, glassy, and solvent and stain resistant, and withstand intermittent exposure to boiling water.

Melamine resins cost more but have greater strength and temperature resistence, withstanding 100 C continuously. Furthermore, reinforcing with asbestos fiber increases their temperature resistance further.

The radiation behavior of this whole group of formaldehyde condensation polymers is similar to that of phenol-formaldehyde resins. The aniline-formaldehyde resins are the most radiation resistant of the group, probably because of the benzene ring in their structure.

3.1.28. Polyimides

The polyimides are condensation polymers of the anhydrides of tetracarboxylic acids and primary diamines. One commercial product structure is shown here (aromatic polyimides of pyromellitic acid). Another has only the imide linkages in common.



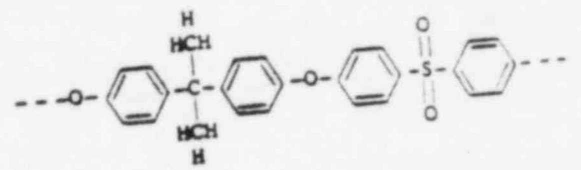
The polyimides are high temperature resistant. The aromatic pyromellitimides (Vespel, Kapton) resist air to 270 C and for short exposures to 450 C. Another product (Cyanamide XPI) is usable to 260 C and is soluble and thermoplastic. Since molding, extrusion, and other methods of thermoforming are difficult for high-temperature materials, the aromatic pyromellitimides are available at present only in billets, shaped forms, and film stock.

The polyimides are used in high-temperature electrical insulating sheet and components, gears, sleeve bearings, housings, and as enamel. They have frictional characteristics similar to nylon and even better strength and wear resistance.

The polyimides are relatively resistant to radiation. Little change occurs in strength after irradiation of thick specimens to 10^{10} rads. But 0.002-in films irradiated in air at $\sim 2 \times 10^{6}$ rads/hr had lost over half their initial tensile strength at 10^{10} rads, and the elongation at break was less than 10% of the initial value.

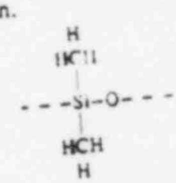
3.1.29. Polysulfone

Polysulfone has good strength and electrical properties from −100 to +165 C. The molecular chain consists of phenylene rings linked alternately by quaternary carbon atoms, oxygen, and sulfone groups. The phenylene ring and the sulfone group confer resonance stabilization, but the quaternary carbon in the chain leads to scission. Radiation stability would be expected to be only moderate at best.



3.1.30. Silicone plastics

Silicone resins contain no carbon-carbon links in the polymeric chain.



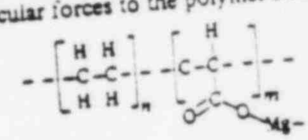
An alkyl trichlorosilane in the polymerizing mixture introduces cross-linking and allows high-temperature curing. Their outstanding characteristics are inertness, resistance to solvents, moisture repellancy, retention of properties at high and low temperatures, and low coefficient of friction.

Uses are high-temperature coatings for metallic components and electrical insulating varnishes, frequently with alkyd resins for convenient curing properties. Silicone resins are used in large volume as molding compounds, usually with fillers of silica, fiber glass or asbestos.

Radiation stability is about intermediate for polymeric materials; the aliphatic silicones are less resistant than those containing the phenyl group in their structure. Glass and asbestos laminates and phenolic resin laminates modified with silicones all show exceptionally good radiation stability compared to the unfilled materials.

3.1.31. Ionomers

By copolymerizing olefins with vinyl carboxylic acids (for example, ethylene and methacrylic acid), "ionomers" that have a hydrocarbon main chain with acidic side groups are obtained. These groups can be neutralized with common metallic cations (sodium, potassium, magnesium, zinc) to impart strong, ionic intermolecular forces to the polymer structure.



At ordinary temperatures ionomers have properties similar to cross-linked polyethylene, though transparency is high. At high temperatures the ionic interchain bonds are broken and the ionomers can be processed by the usual methods. They are tough, solvent- and craze-resistant, but are limited in creeps strength.

Radiation-induced changes should be similar to those in polyethylene unless the carboxylic fraction of the polymer is substantial; it tends to decompose, while methacrylate groups undergo scission.

3.2. *Rubbers*

3.2.1. Introduction

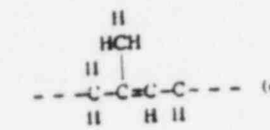
The base polymers for rubbers are "elastomers", which do not differ substantially from thermoplastic and thermosetting resins. It is the formulating and processing, the introduction of reactive ingredients, and the subsequent chemical reactions which impart the properties differentiating rubbers from plastics. The essential characteristic of an elastomer molecule is mobility of the segments of the polymer chain. Consequently, the intermolecular forces must be weak and crystallization must not occur. Pinning points along the polymer chain are also needed to prevent flow and to provide forces opposing external stress.

In practical rubbers, the pinning points are provided by chemical bonds linking polymer chains either directly or through solid particles. The formation of these links during vulcanization or curing and the control of their distribution are accomplished by a host of different additives and a wide range of curing conditions. The properties of the final product are altered further by the incorporation of a wide variety of additives. Reinforcing additives produce a stiffer stock. Plasticizing additives produce a softer stock. Pigments are added for specific colors and antioxidants to improve life. Carbon is a pigment-reinforcement additive. Physical properties of rubbers are given in ref. [3, 10, 13–16].

Rubbers refer to formulated, processed and cured materials ready for use. The irradiation properties and behavior may depend strongly on the additives, particularly the reinforcing fillers, and on the cure or extent of vulcanization. The action of radiation will be influenced by the fillers and additives. Furthermore, radiation cross-linking is analogous to additional vulcanization, while scission may be the inverse. Irradiation properties of the rubbers are given in table 3 and gas yields on irradiation are in table 1.

3.2.2. Natural rubber

Natural rubber, polyisoprene, is a simple hydrocarbon having a four-carbon main-chain repeating unit with a methyl side group and a double bond at the second carbon atom of the monomer unit. Natural rubber has the chain segments on the same (cis) sides of the double-bonded carbons, while gutta-percha and balata are trans, and are largely crystalline and leathery instead of rubbery.



Radiation-induced cross-linking reduces the elasticity and tensile strength (fig. 1); the material becomes hard and brittle, then the strength increases again, the rubber has become a glass.

Natural rubber is not high-temperature resistant and often cannot be used around reactors for this reason. However, for moderate radiation doses, it retains its resilience and resistance to permanent set when under stress or cyclic strain. Radiation damage is much greater when stressed, particularly when oxygen is present because of ozone damage.

3.2.3. Ethylene-propylene rubber (EPR)

The simplest elastomer is the copolymer ethylene-propylene. It differs structurally from polyethylene only in having frequent methyl side groups.

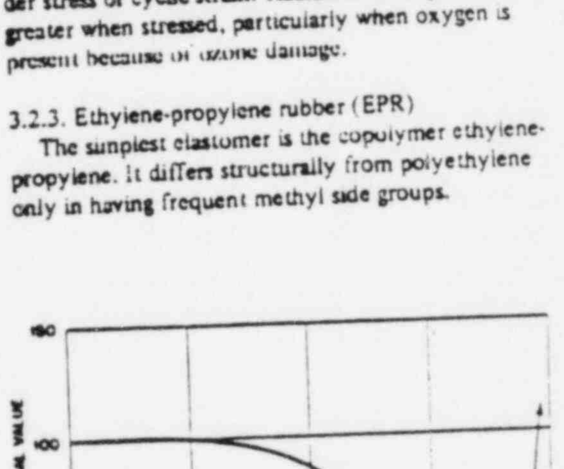


Fig. 1. Tensile strength of an irradiated natural rubber [1].

Table 3. Effects of Radiation on Rubbers

Material	Initial[b,d,e] Value	Percent of Initial Value Retained at Given Dose (rads)[a,c]
Hydrocarbon Rubbers		
Natural Rubber		(3)
Tensile Strength, psi	2600	
Elongation at Break, %	420	
Shore Hardness, Scale A	60	
Compression Set, recovery, %	93	
Ethylene-Propylene Rubber (EPR)		(13)
Tensile Strength, psi	1320	
Elongation at Break, %	275	
Shore Hardness, Scale A	97	
Butyl Rubber GR-150		(3)
Tensile Strength, psi	1100	
Elongation at Break, %	525	
Shore Hardness, Scale A	66	
Compression Set, recovery, %	91	
Butadiene Rubber		(13)
Tensile Strength, psi	2380	
Elongation at Break, %	525	
Styrene-Butadiene Rubber (SBR) (GRS-50)		(3)
Tensile Strength, psi	1700	
Elongation at Break, %	270	
Shore Hardness, Scale A	62	
Compression Set, recovery, %	90	
Oxygen-containing Rubbers		
Polyacrylic Rubber Hycar PA-21		(3)
Tensile Strength, psi	2000	
Elongation at Break, %	230	
Shore Hardness, Scale A	62	
Compression Set, recovery, %	92	
Nitrogen-containing Rubbers		
Nitrile Rubber Hycar OR-15		(3)
Tensile Strength, psi	1900	
Elongation at Break, %	250	
Shore Hardness, Scale A	72	
Compression Set, recovery, %	92	

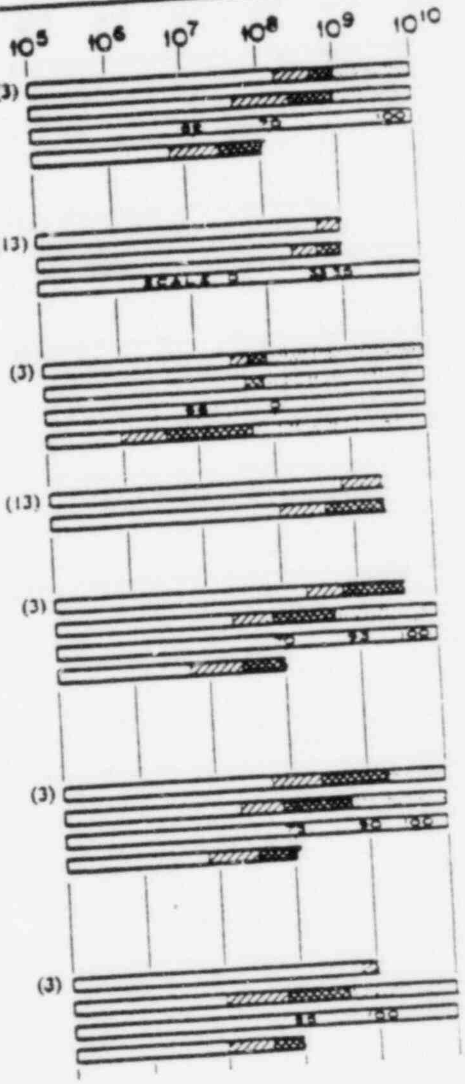
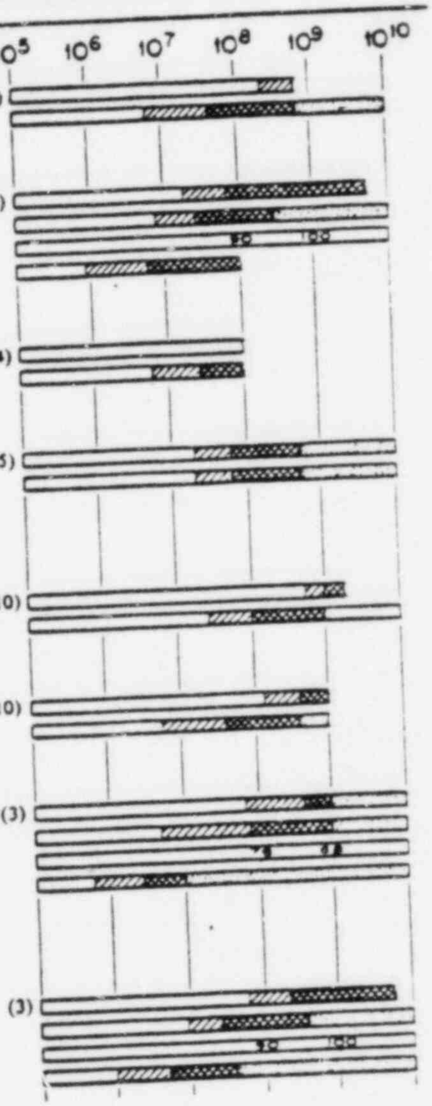


Table 3. (continued)

Material	Initial[b,d,e] Value	Percent of Initial Value Retained at Given Dose (rads)[a,c]
Vinyl Pyridine (Philprene VP-15-1)		(15)
Tensile Strength, psi	2790	
Elongation at Break, %	405	
Polychloroprene Rubber Neoprene W		(3)
Tensile Strength, psi	2900	
Elongation at Break, %	450	
Shore Hardness, Scale A	78	
Compression Set, recovery, %	62	
Fluororubber Viton A		(14)
Tensile Strength, psi	1875	
Elongation at Break, %	160	
Polyurethane Rubber (Genthane)		(15)
Tensile Strength, psi	4040	
Elongation at Break, %	500	
Sulfur-containing Rubbers		
Adduct Rubber (92% Saturation)		(10)
Tensile Strength, psi	2660	
Elongation at Break, %	490	
Chlorosulfonated Polyethylene Rubber (Hypalon)		(10)
Tensile Strength, psi	1980	
Elongation at Break, %	350	
Polysulfide Rubber Thiokol ST		(3)
Tensile Strength, psi	800	
Elongation at Break, %	162	
Shore Hardness, Scale A	74	
Compression Set, recovery, %	90	
Miscellaneous Rubbers		
Silicone Rubber Silastic 7-170		(3)
Tensile Strength, psi	525	
Elongation at Break, %	95	
Shore Hardness, Scale A	59	
Compression Set, recovery, %	97	



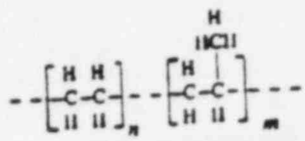
(a) Key for radiation effects:
- 100 to 80% of initial value retained.
- 80 to 50% of initial value retained.
- 50 to 10% of initial value retained.
- 10 to 0% of initial value retained.

(b) To convert lb/in² to Kg/mm², divide by 1422 so that 14220 lb/in² equals 10 Kg/mm².

(c) rad equals 100 ergs/gram of sample material.

(d) Shore Durometer Hardness, described in ASTM-D676-49T.

(e) Compression set, Test B, described in ASTM-D395-49T.

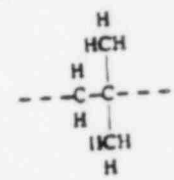


The side groups inhibit crystallization, thus conferring chain mobility, while the saturated structure provides resistance to sunlight, heat, and ozone. This elastomer resists acids and alkalies, but not organic solvents and oils. Saturation prevents vulcanization, so most commercial products are polymerized with a small quantity of a diolefinic monomer: cyclopentadiene, butadiene, etc. Both vulcanizing and reinforcement with carbon black fillers are facilitated.

There are no data on the effects of radiation on commercial materials. Experimental samples soften after irradiation, as does polypropylene. Large losses in tensile strength and gain in the percent compression set occur.

3.2.4. Butyl rubber

Butyl rubber (polyisobutylene) has a saturated carbon–carbon chain with two methyl groups on alternate carbon atoms. Usually a little isoprene is copolymerized to give some unsaturation for vulcanization.

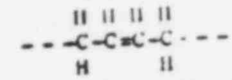


The side groups are adequate to inhibit crystallization and the hydrocarbon molecular structure is stable to oxidative aging and to chemical agents. The gas and vapor barrier properties are also good. Furthermore, the raw material is a low-cost refinery product. Consequently, Butyl rubber finds high-volume use in tubes for automobile tires, in hoses, gaskets, seals, and similar applications.

Radiation induces high rate of chain scission in Butyl rubber because of the quaternary carbon atoms in the molecular structure, with rapid degradation. Butyl rubber becomes soft and loses strength, becoming a tarry, viscous liquid at relatively low radiation doses.

3.2.5. Polybutadiene rubber

Polybutadiene differs from polyethylene in having one double bond in every four–carbon repeating unit.

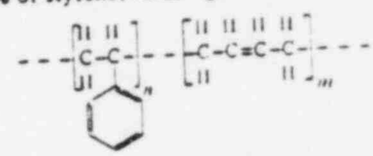


The all-cis polymer is soft and elastomeric, while the all-trans polymer has a more compact, spiral configuration and is crystalline.

The homopolymer cross-links readily and has poor radiation resistance.

3.2.6. Styrene-butadiene rubber (SBR)

The styrene-butadiene copolymer rubber, SBR, formerly GR-S (Government Reserve [Buna] S), with 20 to 40% of styrene, finds high-volume use in tires.

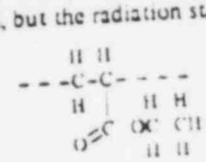


Its resistance to radiation is better than that of most synthetic rubbers, but not quite as good as for natural rubber.

The radiation-induced changes are due to cross-linking. Stability results from the phenyl ring. Most of the radiation-induced change is due to degradation of the butadiene unit, and environmental factors such as oxygen are important.

3.2.7. Polyacrylate rubber

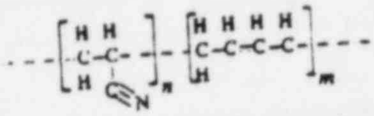
The polyacrylic rubbers, polyethyl acrylate, have higher heat resistance than natural rubber, are not damaged by ozone, and may be used in most oils at elevated temperatures, but the radiation stability is some-



what lower. Tensile strength and elongation generally decrease for moderate radiation exposure. The properties behave as expected for a polymer which cross-links, but the behavior depends somewhat on the type of acrylate. Polyethyl acrylate shows similar property changes to natural rubber.

3.2.8. Butadiene-acrylonitrile rubber (NBR-nitrile butadiene rubber, GR-N)

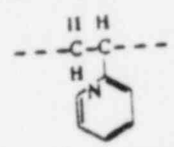
The acrylonitrile content in commercial materials varies from 20 to 45%. The nitrile group increases oil and solvent resistance, and this rubber is used for seals, gaskets, and hoses exposed to lubricants, hydraulic fluids, etc.



The radiation stability is somewhat poorer than that of natural rubber. At low doses the material softens, due to scission, but at high doses cross-linking predominates and hardening is observed. Tensile strength increases at moderate doses, then decreases, and finally increases again for high acrylonitrile contents (see fig. 1). Acrylonitrile content appears to have no effect on the increase in hardness, but the rate and percent decrease in tensile strength is greater with larger amounts of acrylonitrile.

3.2.9. Vinylpyridine rubbers

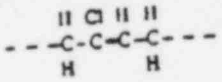
The pyridine ring, like the benzene ring, lends radiation stability, and the vinylpyridine rubbers are near-



ly as resistant to radiation as natural rubber. Hardness increases and elongation decreases because of cross-linking. Irradiation up to 10^8 rads did not show stress cracking.

3.2.10. Polychloroprene rubber (Neoprene)

Neoprene has wide application because of good resistance to weathering, aliphatic oils, and stress-cracking by ozone, and moderately good resistance to

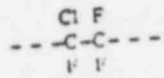


heat. Resistance to aromatic oils, and chlorinated and polar solvents is poor.

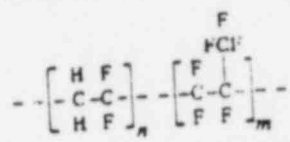
Radiation resistance is not as good as that of natural rubber because of the chlorine, but is as good as that of most synthetic rubbers. Cross-linking at high radiation doses increases hardness and decreases elasticity as in natural rubber. It is much superior to natural rubber when irradiated in oxygen under stress because it resists ozone.

3.2.11. Fluorocarbon rubber

Two base polymers are used in formulating fluorocarbon rubbers. One, largely a polymer of chlorotrifluoroethylene (CTFE), is marketed under the trade name Kel-F.



The other fluororubber is a copolymer of vinylidene fluoride and perfluoropropylene (VFFP), and is marketed as Viton and Fluorel.



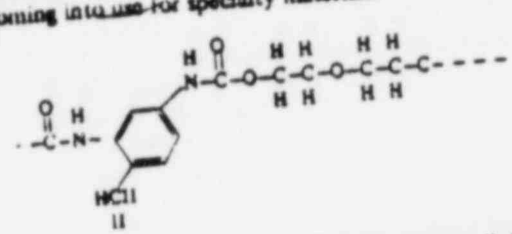
Variations in the monomer ratio are employed to optimize different properties.

Both types of fluorocarbon rubber are flexible and resistant to oxidation, hydraulic fluids, lubricants, and solvents up to 200 C. CTFE formulations are more rapidly damaged by radiation than the other type; in air at room temperature Kel-F loses 25% of its original properties at $\sim 5 \times 10^6$ rads, but is more resistant in silicate ester fluids and in inert atmospheres.

The VFFP copolymers tolerate 10 times higher radiation doses. However, neither type is suitable for long-term use in radiation in air above 125 C. Viton-A in air at 200 C disintegrated at 10^6 rads, but remained usable to much higher doses in argon or diester oil. The more resistant Viton-B retained its tensile strength but lost half its elongation at 10^8 rads at 200 C in polyphenyl ether. "Antirads" and filler material have not improved radiation stability.

3.2.12. Polyurethane rubber

Urethane polymers, both plastics and elastomers, are made from diisocyanates, usually aromatic, by condensation reactions with cross-linking agents having two or more functional groups that provide reactive hydrogen atoms. The reactive hydrogen compounds are usually polyethers or polyesters with unreacted hydroxyl groups. The isocyanate is usually tolylene diisocyanate or diphenylmethane diisocyanate, although aliphatic and polymeric isocyanates are coming into use for specialty materials.



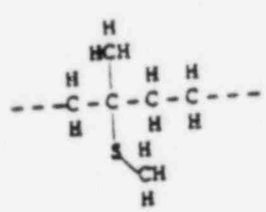
A common feature of urethanes is the urethane linkage in the polymer chain derived from the isocyanate ingredient. Within this structural characteristic, different starting materials yield a manifold assortment of properties. Consequently, polyurethanes range from the more common soft, flexible rubbers to hard, abrasion-resistant coatings and adhesives.

Polyurethane rubbers show radiation stability as good as or better than natural rubbers. Hardness, tensile strength and elongation decrease slightly up to about 10^9 rads, which indicates a balance between cross-linking and chain scission. At higher doses the material becomes harder, weak, and brittle, but may still be useful for some applications up to 10^{10} rads.

Polyurethane rubbers are sensitive to moisture and show poor radiation stability when irradiated wet. They are resistant to most organic solvents, and are therefore often used as seals and gaskets with hydraulic fluids, etc. The temperature of continuous service is not as high as for natural rubber.

3.2.13. Adduct rubbers

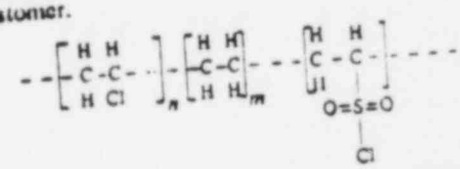
Unsaturated polymers are subject to ozone damage at the double bonds when under stress. The adduct rubbers eliminate most of the double bonds by reacting the polymer with a low molecular-weight alkyl mercaptan.



Most of the radiation-damage data available are for a methyl mercapran adduct of polybutadiene, which has better properties than the unsaturated material, and much better radiation resistance particularly at high temperatures. Radiation stability equals or betters that of natural rubber, and resistance to attack by ozone is better than that of neoprene. The 95% saturated polymer is better than less-saturated material.

3.2.14. Chlorosulfonated polyethylene (hypalon)

Chlorosulfonation of polyethylene yields a non-crystalline polymer flexible enough to serve as an elastomer.

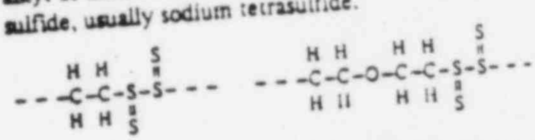


It finds application at higher and lower temperatures than many rubbers and resists oils and greases except aromatic and chlorinated types. Radiation resistance is not quite as good as that of most rubbers, but is quite satisfactory for many applications. Hardness increases and elongation decreases with radiation exposure.

In air at room temperature, it retains its tensile strength, and 75% of its original elongation and undergoes only 60 to 70% compression set to doses of 3×10^7 rads. Anti rads increase the radiation resistance, but data are lacking at high temperatures.

3.2.15. Polysulfide rubber

Polysulfide rubbers are prepared by condensing an alkyl or similar organic dichloride with an alkali polysulfide, usually sodium tetrasulfide.



The elastomer that results can be processed on rubber-fabricating machinery, cured with zinc oxide, and reinforced with carbon black. The vulcanized products are more resistant to oils and solvents than the hydrocarbon rubbers, but have lower tensile strengths and abrasion and heat resistance.

Radiation stability has been studied for thiokol ST and thiokol FA polysulfide rubbers. Radiation resis- tance is only a little better than that of Butyl rubber. Tensile strength begins to decrease at low radiation doses, while the elongation and hardness remain rela- tively unchanged, due to balancing of cross-linking and chain scission. Finally, scission predominates and the property changes are as expected. The compres- sion set is greatly increased under irradiation and the material eventually softens to a tarry consistency.

3.2.26. Silicone rubbers

Silicone polymers are unique in that they do not contain carbon in the main chain. Their silicon-oxygen backbone imparts unusually high operating temperatures (> 270 C) as well as flexibility at low temperatures and resistance to oils and chemical agents. They can be made with many variations in the organic groups at- tached to the main-chain silicon atoms, but dimethyl and methyl-phenyl polysiloxanes are usual. Vinyl, ha- logenated alkyl, and nitrile side groups are substituted for special purposes. The elastomers are generally compounded with finely divided silica or lime for de- sirable mechanical properties. Liquid silicones which cure quickly at room temperature (room temperature vulcanizing, RTV) furnish a convenient means of pre- paring flexible molded items and replicas.

Silicone rubbers are less resistant to radiation than most elastomers, but more resistant than polysulfide rubbers and butyl rubber. Fluorine-containing sili- cones are the most sensitive, while compositions con- taining the phenyl ring withstand doses an order of magnitude higher than those for the more common di- methyl polymer. The silicone rubbers harden rather quickly when irradiated. The tensile strength of many formulations increases under irradiation in air up to 10^7 rads, then decreases rapidly. Elongation is the most sensitive property, usually decreasing to half the original value at 5×10^7 rads at room temperature and at 5×10^6 rads when irradiated at 200 C.

4. The use of plastics and elastomers around reactors

4.1. *Introduction*

The use of plastics and elastomers around reactors is limited to areas of relatively low radiation intensity. Therefore, except for very low power reactors, their use is generally outside the core. For high-flux regions ceramics or metals which can withstand much higher radiation doses must be substituted, though this often causes design problems.

For most applications, most polymeric materials can be used to radiation environment of at least 10^7 rads. Some are useful to 10^{10} or 10^{11} rads in limited applications. Probably none are much better than this, even with large amounts of mineral filler.

High dose rates cause heating, and properties of plastics and rubbers may be strongly temperature de- pendent. Also, the radiation-induced change may de- pend on the temperature, atmosphere, kind of radia- tion, dose rate, and conditions of stress on the mate- rial, and varies widely with chemical structure. Phys- ical property changes are usually more severe in the chemical structures which undergo chain scission.

4.2. *Gaskets and seals*

Plastic and elastomeric materials are the most pop- ular for gaskets, O-rings, and other seals. Where soft, resilient materials are required, rubbers and some of the softer plastics (such as polyethylene and polyvi- nyl chloride) are used. For temperatures below 150 C there is a wide selection of rubbers and plastics in a variety of hardnesses, with or without fillers and with many different additives to give the desired proper- ties.

For high-temperature application the silicones, flu- orocarbons, and polyamides are used, or various rela- tively new polymeric materials. Some may be used up to 300 C or above, as previously described.

Properties of most importance for this application are hardness, tensile strength, elongation, compression set, plastic flow, and resistance to solvents or chemi- cals.

Some polymers are much more resistant to change by radiation in the absence of oxygen, such as when immersed in oil, which must be considered as well as compatibility, for gaskets and seals in submerged operation.

Radiation-induced chemical reactions in these po- lymers often produce gas and corrosive compounds, such as HCl, which may limit their use. Also the seal may become less compatible with the fluid because of radiation damage to the fluid.

Both cross-linking and chain scission destroy the elastomeric properties of organic polymers. The cross-linking reaction makes the material hard and brittle, while the scission reaction softens the polymer and produces flow. Generally speaking, the scission reaction is the most detrimental. In some applications a seal which is gradually becoming hard and brittle may last for a long time if it remains undisturbed. Compression set is increased drastically in rubbers which scission, and this is especially bad for seals used intermittenty.

4.3. *Hoses, flexible tubing and diaphragms*

Soft plastics (polyethylene, fluorocarbons, polyvinyl chloride, etc.) and rubbers are widely used for flexible tubing, hoses, and diaphragms. The choice of material is generally governed by the fluid, the atmosphere, and the temperature.

It is always required that the hose retain strength, but not necessarily flexibility. Since radiation will usually destroy the flexibility much sooner than it will the tensile strength, one need not be too concerned about the early phases of radiation damage in applications where the hose is placed in a permanent configuration. However, cross-linking usually increases the temperature at which the polymer changes from a flexible to a hard material, so when flexibility is required at a relatively low temperature, the useful life of a material that cross-links may be quite short.

Many hoses incorporate a filler with the polymeric material to add strength or resistance to damage by weather. Inorganic fillers such as fiber glass, asbestos, and carbon will increase the resistance to radiation, and may greatly increase the useful life of the hose.

The gas yields from a number of irradiated materials are given in table 1. Gas generation is undesirable in evacuated systems and hydraulic pressure systems.

4.4. *Electrical insulation*

Electrical insulating materials can vary from soft flexible coatings for wires, to rigid sheets or blocks forming terminal strips, or to supports for circuit components themselves. In general, most plastics and elastomers have adequate electrical resistivity unless compounded with fillers which have high electrical conductivity, not used in normal formulation unless conductivity is required.

Commonly used wire insulation at moderate temperatures and mild environments are rubber (both natural and synthetic), polyethylene and polyvinyl chloride. Where high temperature or exposure to corrosive liquids or solvents dictates the use of more expensive material, fluorocarbon elastomers, silicone rubbers, or polyurethanes are used. If high flexibility is not a consideration but abrasion is a problem, then the wire covering commonly employs a reinforcing fabric composed of either fiber glass or textile materials. This is impregnated or covered with a varnish or enamel layer, which may be an alkyd polyester or epoxy. Alternatively, a plastic or rubber sheath may cover the reinforcing fabric. A final type of wire covering is that for solenoids or motor windings where flexibility is not required but compactness, reliability and overload (temperature) resistance are. Some examples are enamels and varnishes composed of phenolics, epoxies, alkyd polyesters, silicones, and, recently, the high-temperature polyimides.

For rigid, structural components requiring mechanical strength (for example, terminal strips, connector plugs), phenolics and other low-cost thermosets are widely used. Fiber- and powder-filled epoxy and alkyd resins are in very common use where their lower molding temperatures and their superior impact strength justify their higher cost, for instance, printed-circuit boards, vacuum-tube bases, and wafer boards for switches. Components which have specialized functional or fabrication requirements may be made of one of the newer thermoplastics having dimensional stability and good moldability. Components such as connector sections, coil forms, covers, and housings are molded from polyphenylene oxide, polysulfone, polyformaldehyde (Delrin), polycarbonate (Lexan), and polyether (Penton). Obviously, where the electrical characteristics are outweighed by other considerations, components may be produced from almost any of the innumerable polymeric materials.

The effect of radiation on the electrical properties of these insulators is generally slight except on the halogen-containing polymers, e.g., polyvinyl chloride, fluorocarbons, and chlorinated polyethers. In these materials, radiation evolves the halogen or hydrogen halide acid which, with moisture, forms a good electrolytic conductor, and electrical resistivity degrades at moderate doses. For the other polymers, the electrical resistivity is more resistant to radiation than are the mechanical properties, and it is chiefly the strength properties that will determine the service lifetime. The radiation-induced changes in the strength of polymeric materials are discussed in other parts of this chapter and presented in tables 2 and 3.

4.5. Thermal insulation

Polymeric materials are widely used for thermal insulation, at times in the form of fibrous packing but primarily as very efficient low-density foams. Polyurethanes, polystyrene, natural and synthetic rubbers, and polyvinyl chloride are common, but almost any plastic or elastomer can be formulated with foaming or blowing agents at some stage of its production. The essential property, thermal conductivity, depends on the density of the foam more than on the polymer itself. Minimum densities consistent with acceptable mechanical properties are about 2 lb/ ft³ (0.03 g/cm³), where the thermal conductivity approaches a minimum, independent of density.

At these low densities the thermal conductivity of the bulk material approaches that of the gas in the cells. In polyurethane foams fluorocarbon blowing agents give conductivities as low as 0.01 Btu/ft-hr-°F (4×10^{-4} cal/cm-sec-°C). Other blowing agents yield thermal conductivities about twice as high. However, fluorocarbon-containing foams gradually increase in conductivity during their aging due to progressive replacement of the fluorocarbon gas with air by diffusion.

Irradiation of polymeric insulation first may slightly increase the evolution of gas and thus the thermal conductivity (as in the case of fluorocarbon-containing foams). Also, cross-linking and scission will alter the compressive and tensile strength of the foam, and where operation of a device depends upon support by a foamed component polymers which undergo scission can limit the radiation tolerance severely.

4.6. Potting or encapsulating compounds

Many polymeric systems can be formulated to provide the electrical resistance, moisture resistance, and mechanical properties required for coating electrical components. However, methods of application restrict bulk potting to relatively few polymers, since compounds that cure at moderate temperatures are desirable. Consequently, epoxy resins and silicone elastomers and resins are the most used.

Filler loadings of silica, calcium carbonate, talc, etc. as high as 50% by weight can be incorporated to increase thermal conductivity and reduce mold shrinkage and cost without loss of good electrical properties.

Silicone potting materials have the greatest flexibility and moisture resistance, and are available in formulations ranging from room-temperature vulcanizing (RTV) rubbers to thermosetting resins. They should not show great sensitivity to radiation, as strength is more than adequate. However, radiation-generated gas may be important. For high-frequency use, the service lifetime is likely to be limited by loss tangent and dielectric breakdown strength.

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NBRs are Hycar 1041 1091-50

1000 HOUR HEAT AGING STUDY

By

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Ev Scheer

Introduction

In its myriad of applications, rubber many times has to withstand heat. Temperature performance requirements for elastomers are becoming more demanding. This need for greater heat resistance is critical in the automotive industry, where the trend for higher under-the-hood temperatures has been escalating due to; smaller engines, more power equipment and emission control devices. Because of these factors more and more rubber parts are operating at temperatures very close to current accelerated heat aging test temperatures.

The convergence of service and accelerated test temperatures is creating difficulties in predicting rubber part life based on currently accepted, historically adequate, 70-hour test methods. Consequently, rubber chemists and engineers are beginning to use longer test times, up to 1000 continuous hours, at elevated temperatures to select properly-formulated rubber compounds. Automotive engineers have estimated that 1000 hours of continuous testing relates to the time required by the average motorist to accumulate 50,000 miles over three to five years; however, an exact correlation with on-car performance has not been established.(1)

This report was initiated to find the service temperatures of many common elastomers. The recipes chosen were representative of good heat resistant recipes for the elastomer used.

After testing, the question arises, when is a polymer no longer serviceable. This requires a person to define a fail point; however, an exact fail point can only be determined by testing actual parts in service. Therefore, this author chose not to define a fail point but to present the data in an objective and a comparatively new way. In this manner the reader is welcomed and encouraged to use his own criteria in defining service temperature life. (In the Appendix the reader can find the test recipes, actual results and a number of different presentations of this data.)

Discussion

Changes in the nature of a rubber vulcanizate during aging are reflected in the changes in stress-strain properties. These are used to compare the heat resistance of different vulcanizates. It would be useful if the changes in tensile strength and elongation could be combined in a single number so that compounds could be readily compared. This has led to the concept of the Retention Index:

$$\text{Retention Index} = \frac{(\%\ \text{Tensile retained})\ X\ (\%\ \text{Elongation retained})}{100}$$

This gives a value of 100 for no change and 0 for complete failure of either property. It was decided, that although some elastomers may show an increase in tensile or elongation after aging, that this increase should not be reflected in the index and therefore a 100 would be the highest possible index. Some examples will, perhaps, explain how it works.(1)(2)

Tensile Change	Tensile Retained	Elongation Change	Elongation Retained	Calculation		Retention Index
%	%	%	%			
-10	90	-20	80	$\frac{90X80}{100}$	=	72
-20	80	-40	60	$\frac{80X60}{100}$	=	48
-20	80	+20	100	$\frac{80X100}{100}$	=	80
+20	100	+20	100	$\frac{100X100}{100}$	=	100
+20	100	-20	80	$\frac{100X80}{100}$	=	80

Six types of elastomers were tested:

1) Polyacrylates
2) Epichlorohydrin
3) Ethylene Propylene
4) Nitrile
5) Chloroprene
6) Chlorosulfonated polyethylene

Temperatures from 250°F to 375°F were used, with exposure times of 70 hours, 3 weeks (504 hours) and 6 weeks (1008 hours). Three types of tests were run:

1) Air Test Tube; tested at room temperature
2) Air Test Tube; tested at elevated temperatures
3) ASTM #3 Oil ; tested at room temperature

The results of these tests appear in Tables 1, 2 and 3. The recipe for each elastomer listed can be found in the Appendix Tables 4 thru 9 and the raw data in chart form can be found in Tables 10 thru 25. Also, for those more comfortable with data presented in a more traditional form, the author would like to draw your attention to Tables 26 thru 28.

A look at Tables 1, 2 and 3 show Hycar 4041 to be the superior heat resistant elastomer tested. The author would like to reiterate that the compounds chosen were only representative of good heat resistant recipes and with proper compounding techniques all indices could be improved. These recipes were designed for commercial use, not to just withstand heat. Also, this data has shown that the concept of a Retention Index is a valuable concept by listing the elastomers in the traditional and expected order of heat resistance.

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TABLE 1

RETENTION INDEX

AIR TEST TUBE AGED AT GIVEN CONDITIONS; TESTED AT ROOM TEMPERATURE

	250°F			275°F			302°F			325°F			350°F			375°F		
	70 Hrs.	3 Wks.	6 Wks.	70 Hrs.	3 Wks.	6 Wks.	70 Hrs.	3 Wks.	6 Wks.	70 Hrs.	3 Wks.	6 Wks.	70 Hrs.	3 Wks.	6 Wks.	70 Hrs.	3 Wks.	6 Wks.
Hycar 4041							93	94	89	100	96	81	81	57	26	83	42	10
Hycar 4043				83	77	71	73	70	47	87	54	24	58	11	0			
Hydrin 200/Hycar 4021							89	38	35	46	22	-						
Hydrin 100				62	58	35	72	30	17	39	2	-						
Hydrin 100/Hydrin 200				59	44	17	63	9	5									
Hydrin 200/Non Black				44	22	10	34	9	2									
Hydrin 200	58	69	56	65	45	5												
Epcar 545/Peroxide				64	49	24	53	11										
Epcar 545/Sulfur				54	44	36	58	34										
Hypalon 40	96	67	46	100	32	7												
Hycar 1041	71	14	4	46	0	-												
Hycar 1041/Hycar 1091-50	61	26	5	64	0	-												
Neoprene W	86	10	0															

TABLE 2

RETENTION INDEX

AIR TEST TUBE AGED AND TESTED AT THE GIVEN ELEVATED TEMPERATURES

	250°F			275°F			302°F			325°F			350°F		
	70 Hrs.	3 Wks.	6 Wks.	70 Hrs.	3 Wks.	6 Wks.	70 Hrs.	3 Wks.	6 Wks.	70 Hrs.	3 Wks.	6 Wks.	70 Hrs.	3 Wks.	6 Wks.
Hycar 4041							100	100	84	100	77	54	100	41	14
Hycar 4043				100	84	69	97	78	68	60	31	18			
Hydrin 200/Hycar 4021										44	39	12			
Hydrin 100				87	53	40	86	25	8	18	-	-			
Hydrin 100/Hydrin 200				75	43	13	63	14	-						
Hydrin 200 Non Black				44	26	21	49	22	-						
Hydrin 200				86	53	2									
Epcar 545/peroxide				95	-	64	94	49	1						
Epcar 545/Sulfur Donor				90	-	78	100	80	1						
Hypalon 40	83	70	61												
Hycar 1041	86	24	-	50	-	-									
Hycar 1041/Hycar 1091-50	68	34	-	63	-	-									
Neoprene W	100	10	4												

TABLE 3

RETENTION INDEX

ASTM #3 OIL AGED AT GIVEN CONDITIONS: TESTED AT ROOM TEMPERATURE

	250°F			275°F			302°F		
	70 Hrs.	3 Wks.	6 Wks.	70 Hrs.	3 Wks.	6 Wks.	70 Hrs.	3 Wks.	6 Wks.
Hycar 4041							83	82	73
Hycar 4043				65	53	55	62	60	54
Hydrin 200/Hycar 4021				57	37	43	46	-	17
Hydrin 100				70	42	34	62	29	5
Hydrin 100/Hydrin 200				63	44	17	56	29	4
Hydrin 200/Non-Black				44	22	10	40	8	3
Hydrin 200				100	58	22	58	25	1
Epcar 545/Peroxide		N.A.							
Epcar 545/Sulfur Donor		N.A.							
Hypalon 40	78	52	50						
Hycar 1041	89	49	6						
Hycar 1041/Hycar 1091-50	74	9	2						
Neoprene W									

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APPENDIX

APPENDIX

TABLES 4 thru 9 show the recipes used. They were mixed according to standard procedures.

TABLES 10 thru 25 show the raw data. All tests were done in accordance with ASTM methods.

TABLE 10 shows Original Properties and Mooney Viscosities.

TABLE 11 shows Original Properties tested at elevated temperatures.

TABLES 12 thru 17 show the Air Test Tube data.

TABLES 18 thru 22 show the Air test tube tested at elevated temperature data.

TABLES 23 thru 25 show the ASTM #3 Oil data.

TABLES 26 thru 28 are summary charts of the preceeding 15 tables shown in a more traditional manner. The author would suggest that these three tables be referred to when you are trying to decide the best elastomer to use for your particular application.

Finally, TABLE 29 is a listing of compounding ingredients.

TABLE 4

HYCAR POLYACRYLATE RECIPES

Hycar 4041	100	-
Hycar 4043	-	100
Acrawax C	2	-
Stearic Acid	-	2
TE-80	2	2
N 550 Black	65	-
N 326 Black	-	75
Admex 760	10	5
Stalite S	1	2
Santowhite Crystals	1	-
Spider Sulfur	0.4	0.3
Sodium Stearate	4	1
Potasium Stearate	-	3
	185.4	190.3

TABLE 5

HYDRIN RECIPES

Hydrin 100	100	-	40	-	-
Hydrin 200	-	30	60	100	100
Hycar 4021	-	70	-	-	-
Stearic Acid	-	1.5	-	-	-
Magnesium Stearate	1	-	1	1	1
Red Lead	-	5	-	-	-
Dyphos	5	-	4	5	5
Dythal	7	-	6	7	7
Niclate	1	-	1	1	1.5
NBC	-	-	0.6	0.6	0.7
Stalite S	-	1	-	-	-
Cumate	0.1	-	-	-	-
N 770 Black	90	35	90	90	3
N 550 Black	-	40	-	-	-
DOP	7	7	7	7	7
Paraplex G50	5	5	5	5	5
ZO-9	1	-	1	1	1
Vanacure C	1.2	1.4	1.2	1.2	1.5
Hi Sil 233	-	-	-	-	35
Zeolex 23	-	-	-	-	20
Silane A-189	-	-	-	-	0.5
	218.3	195.9	216.8	218.8	188.2

TABLE 6

EPCAR RECIPE

Epcar 545	100	100
N 550	75	50
Sunpar 2280	25	15
Zinc Oxide	5	7
Sulfur	0.5	0.3
Stearic Acid	1	-
MBT	3	-
TMTD	0.8	-
NBC	2	-
Butyl Zimate	1.5	-
Sulfasan R	0.8	-
Age Rite Resin D	-	1
Varox	-	8
	214.6	181.3

TABLE 7

HYPALON RECIPE

Hypalon 40	100
Litharge	20
Maglite D	5
N 991	50
Laminar	100
LMW Polyethylene	4
Coldflex 1000	20
Sundex 890	25
NBC	1.5
Kenflex A	5
Tetrone A	1
EVA-2	2.5
	334.0

TABLE 8

HYCAR NITRILE RECIPES

Hycar 1041	100	40
Hycar 1091-50	-	60
Zinc Oxide	5	5
Naugard 445	2	1.5
Agerite Stalite	-	1.5
Stearic Acid	1	1
N 550	40	-
N 991	80	80
Hi Sil 233	-	40
Admex 760	15	15
Flexricin P-4	10	10
TE-80	2	2
Witco 127	-	2
Sulfur	0.5	0.5
CBTS	-	1.0
TMTD	1.5	1.5
TETD	1.5	1.5
	258.5	262.5

TABLE 9

NEOPRENE RECIPE

Neoprene W	100
Aranox	1
Octamine	4
Dodecyl Mercaptan	1.5
Maglite D	4
Stearic Acid	0.5
FEF	20
Laminar	90
Linseed Oil	15
Zinc Oxide	10
NA-22	1
	247.0

TABLE 10

MOONEY VISCOSITY LARGE ROTOR-121°C (250°F)

	HYCAR 4041	HYCAR 4041	HYDRIN 200 HYCAR 4021	HYDRIN 100	HYDRIN 100 HYDRIN 200	HYDRIN 200 NON BLACK	HYDRIN 200	EPCAR 545 PEROXIDE	EPCAR 545 SULFUR DONOR	HYPALON 40	HYCAR 1041	HYCAR 1641 HYCAR 1091-50	NEOPRENE W
Mooney Viscosity													
Minimum	30	39	56	43	46	80	74	46	56	25	28	38	29
T5	>31	13	8.5	10.5	10	7	7.5	>30	7	14	5.5	7	9.5
Cure Conditions													
Time (min.)	20	20	30	30	30	30	30	60	6	20	9	13	10
Temp. (°C)	160	160	175	160	160	160	160	160	160	160	160	160	160
Temper Conditions													
Time (hrs.)	8	8											
Temp. (°C)	170	170											
Original Properties													
100% Modulus	800	460	750	900	920	470	720	460	450	500	550	225	260
300% Modulus						1350		1900	1100			750	920
Tensile	1350	1260	1570	1370	1540	2210	1450	2440	1600	1130	1700	1325	1520
Elongation	200	250	280	260	270	610	260	490	500	280	280	580	410
Hardness	73	66	69	80	75	68	75	68	72	63	65	65	65
Gehman Torsional Stiffness (ASTM D1053)													
θ°	165	170	161	147	145	151	155			170	163	164	160
T2 (°C)	+2.5	-3	-16	-7.5	-17.5	-24.5	-20	-15	-9.5	-19	-13	-11	-30
T5 (°C)	-5.5	-20	-22	-21	-26.5	-33.5	-32	-35	-30	-28	-23	-22.5	-35
T10 (°C)	-8.5	-25	-24.5	-25	-30	-35.5	-36	-40	-38	-30	-25	-25	-36
T50 (°C)	-12.5	-33.5	-30	-29	-34.5	-40	-41.5	-47.5	-47	-36	-27	-29	-38
T100 (°C)	-35	-36.5	-31	-31	-35	-41	-43.5	-50	-50	-37	-29.5	-31	-39
Fr (°C)	-36	-39	-32.5	-31	-36	-41.5	-42	-50.5	-50.5	-39	-31	-30	-40.5

TABLE 11

ORIGINAL PROPERTIES TESTED AT ELEVATED TEMPERATURES

	HYCAR 4041	HYCAR 4043	HYDRIN 200 HYCAR 4021	HYDRIN 100	HYDRIN 100 HYDRIN 200	HYDRIN 200 NON BLACK	HYDRIN 200	EPCAR 545 PEROXIDE	EPCAR 545 SULFUR DONOR	HYPALON 40	HYCAR 1041	HYCAR 1041 HYCAR 1091-50	NEOPRENE W
ORIGINAL PROPERTIES AT ROOM TEMPERATURE													
100% Modulus	800	460	750	980	920	470	720	460	450	500	550	225	260
Tensile	1350	1260	1570	1370	1540	2210	1450	2440	1680	1130	1700	1325	1520
Elongation	200	250	280	260	270	610	260	490	450	280	280	580	410
Hardness	73	66	69	80	75	68	75	68	71	63	65	65	65
ORIGINAL PROPERTIES AT 250°F													
Tensile										400	910	610	450
Elongation										230	290	500	480
Hardness										59	57	51	60
ORIGINAL PROPERTIES AT 275°F													
Tensile		650		760	920	900	930	620	860		760	510	
Elongation		290		150	200	350	220	210	200		250	410	
Hardness		45		75	75	65	73				60	56	
ORIGINAL PROPERTIES AT 300°F													
Tensile	475	630		720	830	780	960	620	790		640	480	
Elongation	190	280		140	170	270	210	190	200		190	310	
Hardness	53	45		75	75	67	73				61	59	

TABLE 11

ORIGINAL PROPERTIES TESTED AT ELEVATED TEMPERATURES

	HYCAR 4041	HYCAR 4043	HYDRIN 200 HYCAR 4021	HYDRIN 100	HYDRIN 100 HYDRIN 200	HYDRIN 200 NON BLACK	HYDRIN 200	EPCAR 545 PEROXIDE	EPCAR 545 SULFUR DONOR	HYPALON 40	HYCAR 1041	HYCAR 1041 HYCAR 1091-50	NEOPRENE W
ORIGINAL PROPERTIES AT 325°F													
Tensile	450	600	620	830				645	750				
Elongation	170	260	110	150				170	210				
Hardness	53	50	64	77									
ORIGINAL PROPERTIES AT 350°F													
Tensile	475												
Elongation	180												
Hardness	53												
ORIGINAL PROPERTIES AT 375°F													
Tensile													
Elongation													
Hardness													

TABLE 12

AIR TEST TUBE AGED AT 121°C (250°F) TESTED AT ROOM TEMPERATURE

	HYCAR 4041	HYCAR 4043	HYDRIN 200 HYCAR 4021	HYDRIN 100	HYDRIN 100 HYDRIN 200	HYDRIN 200 NON BLACK	HYDRIN 200	EPCAR 545 PEROXIDE	EPCAR 545 SULFUR DONOR	HYPALON 40	HYCAR 1041	HYCAR 1041 HYCAR 1091-50	NEOPRENE W
70 HRS AGED 121°C													
Ultimate Tensile, psi							1700			1200	1900	1250	1420
% Tensile Change							+17			+6	+12	-6	-7
% Ultimate Elongation							150			270	200	380	380
% Elongation Change							-42			-4	-29	-35	-7
Shore Hardness							78			64	72	74	-4
Points Hardness Change							+3			+1	+7	+9	+9
180° Bend							P			P	P	P	P
~~**3 WEEKS AGED 121°C**~~													
Ultimate Tensile, psi							1650			1200	2475	[illegible]	1600
% Tensile Change							+14			+6	+46	[illegible]	+5
% Ultimate Elongation							180			190	40	[illegible]	40
% Elongation Change							-31			-33	-86	[illegible]	-90
Shore Hardness							83			69	93	[illegible]	88
Points Hardness Change							+8			+6	+28	[illegible]	+23
180° Bend							P			P	F	[illegible]	F
6 WEEKS AGED 121°C													
Ultimate Tensile, psi							1320			1310	2875	2450	1250
% Tensile Change							-10			+16	+70	+85	-18
% Ultimate Elongation							160			130	10	30	0
% Elongation Change							-38			-54	-96	-95	-100
Shore Hardness							85			74	96	95	96
Points Hardness Change							+10			+11	+31	+30	+31
180° Bend							P			P	F	F	F

TABLE 13

AIR TEST TUBE AGED AT 135^{o}C (275^{o}F) TESTED AT ROOM TEMPERATURE

	HYCAR 4041	HYCAR 4043	HYDRIN 200 HYCAR 4021	HYDRIN 100	HYDRIN 100 HYDRIN 200	HYDRIN 200 NON BLACK	HYDRIN 200	EPCAR 545 PEROXIDE	EPCAR 545 SULFUR DONOR	HYPALON 40	HYCAR 1041	HYCAR 1041 HYCAR 1091-50	NEOPRENE W
70 HRS AGED 135^{o}C													
Ultimate Tensile, psi		1190		1920	1950	1930	1780	2400	1890	1420	1870	1400	
% Tensile Change		-6		+40	+27	-13	+22	-2	+5	+26	+10	+6	
% Ultimate Elongation		220		160	160	310	170	320	240	300	130	370	
% Elongation Change		-12		-38	-41	-49	-35	-35	-46	+7	-54	-36	
Shore Hardness		68		87	83	73	82	67	75	67	79	73	
Points Hardness Change		+2		+7	+8	+5	+7	-1	+3	+4	+14	+8	
180^{o} Bend		P		P	P	P	P	P	P	P	P	P	
Ultimate Tensile, psi		1160		1830	1620	1270	1140	2190	1920	1300	2500	2150	
% Tensile Change		-8		+34	+5	-43	-22	-10	+6	+15	+47	+62	
% Ultimate Elongation		210		110	120	230	150	270	200	90	0	0	
% Elongation Change		-16		-42	-56	-62	-42	-45	-56	-68	-100	-100	
Shore Hardness		72		90	87	74	84	69	77	73	97	96	
Points Hardness Change		+6		+10	+12	+6	+9	+1	+5	+10	+32	+31	
180^{o} Bend		P		P	P	P	P	P	P	P	F	F	
6 WEEKS AGED 135^{o}C													
Ultimate Tensile, psi		1120		1500	720	880	260	1550	1950	1360			
% Tensile Change		-11		+9	-53	-60	-82	-36	+8	+20			
% Ultimate Elongation		200		90	100	150	70	180	160	20			
% Elongation Change		-20		-65	-63	-75	-73	-63	-64	-93			
Shore Hardness		73		92	86	75	80	71	80	89			
Points Hardness Change		+7		+12	+11	+7	+5	+3	+8	+26			
180^{o} Bend		P		P	P	P	P	P	P	F			

TABLE 14

AIR TEST TUBE AGED AT 150°C (302°F) TESTED AT ROOM TEMPERATURE

	HYCAR 4041	HYCAR 4043	HYDRIN 200 HYCAR 4021	HYDRIN 100	HYDRIN 100 HYDRIN 200	HYDRIN 200 NON BLACK	HYDRIN 200	EPCAR 545 PEROXIDE	EPCAR 545 SULFUR DONOR	HYPALON 40	HYCAR 1041	HYCAR 1041 HYCAR 1091-50	NEOPRENE W
70 H S AGED 150°C													
Ultimate Tensile, psi	1250	1100	1800	1860	1860	1620		2190	2000				
% Tensile Change	-7	-13	+14	+36	+21	-27		-10	+19				
% Ultimate Elongation	200	210	250	160	170	280		290	260				
% Elongation Change	0	-16	-11	-28	-37	-54		-41	-42				
Shore Hardness	73	68	73	90	87	73		68	78				
Points Hardness Change	0	+2	+4	+10	+12	+5		0	+6				
180° Bend	P	P	P	P	P	P		P	P				
3 WEEKS AGED 150°C													
Ultimate Tensile, psi	1270	1160	1050	1180	370	830		1090	1930				
% Tensile Change	-6	-8	-33	-14	-76	-62		-55	+15				
% Ultimate Elongation	200	190	160	90	100	150		170	160				
% Elongation Change	0	-24	-43	-65	-63	-75		-76	-64				
Shore Hardness	75	77	80	88	81	75		71	81				
Points Hardness Change	+2	+11	+11	+8	+6	+7		+3	+9				
180° Bend	P	P	P	P	P	P		P	P				
6 WEEKS AGED 150°C													
Ultimate Tensile, psi	1330	1000	1180	610	180	50							
% Tensile Change	-1	-21	-25	-55	-88	-98							
% Ultimate Elongation	180	140	130	100	10	70							
% Elongation Change	-10	-40	-54	-62	-96	-89							
Shore Hardness	75	81	85	93	75	64		88	91				
Points Hardness Change	+2	+15	+16	+13	0	-4		+20	+19				
180° Bend	P	P	P	P	F	P		F	F				

TABLE 15

AIR TEST TUBE AGED AT 163°C (325°F) TESTED AT ROOM TEMPERATURE

	HYCAR 4041	HYCAR 4043	HYDRIN 200 HYCAR 4021	HYDRIN 100	HYDRIN 100 HYDRIN 200	HYDRIN 200 NON BLACK	HYDRIN 200	EPCAR 545 PEROXIDE	EPCAR 545 SULFUR DONOR	HYPALON 40	HYCAR 1041	HYCAR 1041 HYCAR 1091-50	NEOPRENE W
70 HRS AGED 163°C													
Ultimate Tensile, psi	1400	1190	1440	1810									
% Tensile Change	+4	-6	-8	+32									
% Ultimate Elongation	200	230	140	100									
% Elongation Change	0	-8	-50	-61									
Shore Hardness	73	71	78	94									
Points Hardness Change	0	+5	+9	+14									
180° Bend	P	P	P	P									
3 WEEKS AGED 163°C													
Ultimate Tensile, psi	1290	1130	900	370									
% Tensile Change	-4	-10	-43	-73									
% Ultimate Elongation	200	150	110	20									
% Elongation Change	0	-40	-61	-92									
Shore Hardness	77	84	88	91									
Points Hardness Change	+4	+18	+19	+11									
180° Bend	P	P	P	F									
6 WEEKS AGED 163° C													
Ultimate Tensile, psi	1220	1300											
% Tensile Change	-10	+3											
% Ultimate Elongation	180	60											
% Elongation Change	-10	-76											
Shore Hardness	81	88	94										
Points Hardness Change	+8	+22	+25										
180° Bend	P	P	F										

TABLE 16

AIR TEST TUBE AGED AT 177°C (350°F) TESTED AT ROOM TEMPERATURE

	HYCAR 4041	HYCAR 4043	HYDRIN 200 HYCAR 4021	HYDRIN 100	HYDRIN 100 HYDRIN 200	HYDRIN 200 NON BLACK	HYDRIN 200	EPCAR 545 PEROXIDE	EPCAR 545 SULFUR DONOR	HYPALON 40	HYCAR 1041	HYCAR 1041 HYCAR 1091-50	NEOPRENE W
70 HRS AGED 177°C													
Ultimate Tensile, psi	1100	930											
% Tensile Change	-19	-27											
% Ultimate Elongation	200	200											
% Elongation Change	0	-20											
Shore Hardness	76	74											
Points Hardness Change	+3	+8											
180° Bend	P	P											
3 WEEKS AGED 177°C													
Ultimate Tensile, psi	900	1180											
% Tensile Change	-33	-6											
% Ultimate Elongation	170	30											
% Elongation Change	-15	-88											
Shore Hardness	80	97											
Points Hardness Change	+7	+31											
180° Bend	P	F											
6 WEEKS AGED 177°C													
Ultimate Tensile, psi	1000	1750											
% Tensile Change	-26	+28											
% Ultimate Elongation	70	0											
% Elongation Change	-65	-100											
Shore Hardness	92	98											
Points Hardness Change	+19	+32											
180° Bend	P	F											

TABLE 17

AIR TEST TUBE AGED AT 191°C (375°F) TESTED AT ROOM TEMPERATURE

	HYCAR 4041	HYCAR 4043	HYDRIN 200 HYCAR 4021	HYDRIN 100	HYDRIN 100 HYDRIN 200	HYDRIN 200 NON BLACK	HYDRIN 200	EPCAR 545 PEROXIDE	EPCAR 545 SULFUR DONOR	HYPALON 40	HYCAR 1041	HYCAR 1041 HYCAR 1091-50	NEOPRENE W
AGED													
Ultimate Tensile, psi	1120												
% Tensile Change	-17												
% Ultimate Elongation	200												
% Elongation Change	0												
Shore Hardness	77												
Points Hardness Change	+4												
180° Bend	P												
AGED													
Ultimate Tensile, psi	1130												
% Tensile Change	-16												
% Ultimate Elongation	100												
% Elongation Change	-50												
Shore Hardness	87												
Points Hardness Change	+14												
180° Bend	P												
AGED													
Ultimate Tensile, psi	2830												
% Tensile Change	+109												
% Ultimate Elongation	20												
% Elongation Change	-90												
Shore Hardness	93												
Points Hardness Change	+20												
180° Bend	F												

TABLE 18

AIR TEST TUBE AGED AT 121°C (250°F) TESTED AT 121°C

	HYCAR 4041	HYCAR 4043	HYDRIN 200 HYCAR 4021	HYDRIN 100	HYDRIN 100 HYDRIN 200	HYDRIN 200 NON BLACK	HYDRIN 200	EPCAR 545 PEROXIDE	EPCAR 545 SULFUR DONOR	HYPALON 40	HYCAR 1041	HYCAR 1041 HYCAR 1091-50	NEOPRENE W
70 HRS AGED AND TESTED AT 121°C													
Ultimate Tensile, psi							1040			500	1040	670	570
% Tensile Change										+25	+14	+10	+26
% Ultimate Elongation							200			190	250	340	520
% Elongation Change										-17	-14	-32	+8
180° Bend							P			P	P	P	P
3 WEEKS AGED AND TESTED AT 121°C													
Ultimate Tensile, psi							880			620	1030	820	780
% Tensile Change										+55	+13	+14	+73
% Ultimate Elongation							170			160	70	170	50
% Elongation Change										-30	-76	-44	-90
180° Bend							P			P	F	P	F
6 WEEKS AGED AND TESTED AT 121°C													
Ultimate Tensile, psi							800			710			200
% Tensile Change										+77			-55
% Ultimate Elongation							180			140			20
% Elongation Change										-39			-96
180° Bend							P			P			F

TABLE 19

AIR TEST TUBE AGED AT 135°C (275°F) TESTED AT 135°C

70 HRS AGED AND TESTED AT 135°C

	HYCAR 4041	HYCAR 4043	HYDRIN 200 HYCAR 4021	HYDRIN 100	HYDRIN 100 HYDRIN 200	HYDRIN 200 NON BLACK	HYDRIN 200	EPCAR 545 PEROXIDE	EPCAR 545 SULFUR DONOR	HYPALON 40	HYCAR 1041	HYCAR 1041 HYCAR 1091-50	NEOPRENE W
Ultimate Tensile, psi		680		840	930	700	930	770	770	580	730	620	
% Tensile Change		+5		+11	+2	-22	0	+24	-10	0	-4	+21	
% Ultimate Elongation		300		130	150	200	190	200	200	230	130	260	
% Elongation Change		+3		-13	-25	-43	-14	-5	0		-48	-37	
180° Bend		P		P	P	P	P	P	P	P	P	P	

3 WEEKS AGED AND TESTED AT 135°C

	HYCAR 4041	HYCAR 4043	HYDRIN 200 HYCAR 4021	HYDRIN 100	HYDRIN 100 HYDRIN 200	HYDRIN 200 NON BLACK	HYDRIN 200	EPCAR 545 PEROXIDE	EPCAR 545 SULFUR DONOR	HYPALON 40	HYCAR 1041	HYCAR 1041 HYCAR 1091-50	NEOPRENE W
Ultimate Tensile, psi		635		870	800	580	670			440			
% Tensile Change		-2		+14	-13	-35	-28						
% Ultimate Elongation		250		80	100	140	160			90			
% Elongation Change		-14		-47	-50	-60	-27						
180° Bend		P		P	P	P	P			P			

6 WEEKS AGED AND TESTED AT 135°C

	HYCAR 4041	HYCAR 4043	HYDRIN 200 HYCAR 4021	HYDRIN 100	HYDRIN 100 HYDRIN 200	HYDRIN 200 NON BLACK	HYDRIN 200	EPCAR 545 PEROXIDE	EPCAR 545 SULFUR DONOR	HYPALON 40	HYCAR 1041	HYCAR 1041 HYCAR 1091-50	NEOPRENE W
Ultimate Tensile, psi		540		820	330	520	90	520	840	560			
% Tensile Change		-17		+8	-64	-42	-90	-16	-2				
% Ultimate Elongation		240		60	70	130	50	160	160	50			
% Elongation Change		-17		-60	-65	-63	-77	-24	-20				
180° Bend		P		P	P	P	P	P	P	P			

TABLE 20

AIR TEST TUBE AGED AT 150°C (302°F) TESTED AT 150°C

	HYCAR 4041	HYCAR 4043	HYDRIN 200 HYCAR 4021	HYDRIN 100	HYDRIN 100 HYDRIN 200	HYDRIN 200 NON BLACK	HYDRIN 200	EPCAR 545 PEROXIDE	EPCAR 545 SULFUR DONOR	HYPALON 40	HYCAR 1041	HYCAR 1041 HYCAR 1091-50	NEOPRENE W
70 HRS AGED AND TESTED AT 150°C													
Ultimate Tensile, psi	520	610	720	920	750	650		580	830				
% Tensile Change	+9	-3		+28	-10	-17		-6	+5				
% Ultimate Elongation	200	280	110	120	120	160		220	260				
% Elongation Change	+5	0		-14	-29	-41		+16	+30				
180° Bend	P	P	P	P	P	P		P	P				
3 WKS AGED AND TESTED AT 150°C													
Ultimate Tensile, psi	540	570	520	420	240	470		430	810				
% Tensile Change	+14	-9		-42	-71	-40		-31	+3				
% Ultimate Elongation	200	240	160	60	80	160		130	160				
% Elongation Change	+5	-14		-57	-53	-63		-31	-20				
180° Bend	P	P	P	P	P	P		P	P				
6 WKS AGED AND TESTED AT 150°C													
Ultimate Tensile, psi	500	460	550	260		60		140	90				
% Tensile Change	+5	-27		-64		-92		-77	-89				
% Ultimate Elongation	160	260	120	30		30		10	10				
% Elongation Change	-16	-7		-79				-95	-95				
180° Bend	P	P	P	F	F	F		F	F				

TABLE 21

AIR TEST TUBE AGED AT 166°C (325°F) TESTED AT 166°C

	HYCAR 4041	HYCAR 4043	HYDRIN 200 HYCAR 4021	HYDRIN 100	HYDRIN 100 HYDRIN 200	HYDRIN 200 NON BLACK	HYDRIN 200	EPCAR 545 PEROXIDE	EPCAR 545 SULFUR DONOR	HYPALON 40	HYCAR 1041	HYCAR 1011 HYCAR 1091-50	NEOPRENE W
70 HRS AGED AND TESTED AT 166°C													
Ultimate Tensile, psi	510	550	375	550									
% Tensile Change													
% Ultimate Elongation	140	170	80	40									
% Elongation Change													
180° Bend	P	P	P	P									
3 WKS AGED AND TESTED AT 166°C													
Ultimate Tensile, psi	490	510	325										
% Tensile Change													
% Ultimate Elongation	130	100	80										
% Elongation Change													
180° Bend	P	P	P	F									
6 WKS AGED AND TESTED AT 166°C													
Ultimate Tensile, psi	410	560	340										
% Tensile Change													
% Ultimate Elongation	100	50	30										
% Elongation Change													
180° Bend	P	P	F										

TABLE 22

AIR TEST TUBE AGED AT 177°C (350°F) TESTED AT 177°C

	HYCAR 4041	HYCAR 4043	HYDRIN 200 HYCAR 4021	HYDRIN 100	HYDRIN 100 HYDRIN 200	HYDRIN 200 NON BLACK	HYDRIN 200	EPCAR 545 PEROXIDE	EPCAR 545 SULFUR DONOR	HYPALON 40	HYCAR 1041	HYCAR 1041 HYCAR 1091-50	NEOPRENE W
70 HRS AGED AND TESTED AT 177°C													
Ultimate Tensile, psi	440	440											
% Tensile Change													
% Ultimate Elongation	180	150											
% Elongation Change													
180° Bend	P												
3 WKS AGED AND TESTED AT 177°C													
Ultimate Tensile, psi	350	175											
% Tensile Change													
% Ultimate Elongation	100	20											
% Elongation Change													
180° Bend	P												
6 WKS AGED AND TESTED AT 177°C													
Ultimate Tensile, psi	290	140											
% Tensile Change													
% Ultimate Elongation	40	10											
% Elongation Change													
180° Bend	P												

TABLE 23

ASTM 3 OIL AGED AT 121°C (250°F) TESTED AT ROOM TEMPERATURE

	HYCAR 4041	HYCAR 4043	HYDRIN 200 HYCAR 4021	HYDRIN 100	HYDRIN 100 HYDRIN 200	HYDRIN 200 NON BLACK	HYDRIN 200	EPCAR 545 PEROXIDE	EPCAR 545 SULFUR DONOR	HYPALON 40	HYCAR 1041	HYCAR 1041 HYCAR 1091-50	NEOPRENE W
70 HRS AGED 121°C													
Ultimate Tensile, psi										1120	2050	1425	
% Tensile Change										0	+21	+8	
% Ultimate Elongation										220	250	430	
% Elongation Change										-22	-11	-26	
Shore Hardness										53	68	73	
Points Hardness Change										-10	+3	+8	
% Volume Weight Change										+28	+2.3	0.7	
180° Bend										P	P	P	
3 WEEKS AGED 121°C													
Ultimate Tensile, psi										1030	1550	700	
% Tensile Change										-9	-9	-47	
% Ultimate Elongation										160	150	100	
% Elongation Change										-43	-46	-83	
Shore Hardness										50	74	78	
Points Hardness Change										-13	+9	+13	
% Volume Weight Change										+30	+4.5	+0.2	
180° Bend										P	P	P	
6 WEEKS AGED 121°C													
Ultimate Tensile, psi										1000	700	450	
% Tensile Change										-12	-59	-66	
% Ultimate Elongation										160	40	30	
% Elongation Change										-43	-86	-95	
Shore Hardness										50	84	88	
Points Hardness Change										-13	+19	+23	
% Volume Weight Change										+30	3.6	-1.2	
180° Bend										P	P	P	

TABLE 24

ASTM 3 OIL AGED AT 135°C (275°F) TESTED AT ROOM TEMPERATURE

	HYCAR 4041	HYCAR 4043	HYDRIN 200 HYCAR 4021	HYDRIN 100	HYDRIN 100 HYDRIN 200	HYDRIN 200 NON BLACK	HYDRIN 200	EPCAR 545 PEROXIDE	EPCAR 545 SULFUR DONOR	HYPALON 40	HYCAR 1041	HYCAR 1041 HYCAR 1091-50	NEOPRENE W
70 HRS AGED 135°C													
Ultimate Tensile, psi		970	2040	2160	2030	1920	1900			1350	2075	1400	
% Tensile Change		-23	+30	+58	+42	-13	+31			+19	+22	+6	
% Ultimate Elongation		210	160	180	170	310	180			280	250	420	
% Elongation Change		-16	-43	-30	-37	-49	+31			0	-11	-28	
Shore Hardness		45	73	82	77	72	78			42	70	71	
Points Hardness Change		-21	+4	+2	+2	+4	+3			-21	+5	+6	
% Volume Weight Change		+24	+3.3	+3.6	+2.3	0.7	+2.0			+35	+1.[illegible]	+0.4	
180° Bend		P	P	P	P	P	P				P	P	
3 WEEKS AGED 135°C													
Ultimate Tensile, psi		830	1510	1870	1680	1450	1580			1280	1175	350	
% Tensile Change		-34	-4	+36	+9	-34	+9			-42	-31	-74	
% Ultimate Elongation		200	110	110	120	200	150			200	100	70	
% Elongation Change		-20	-61	-58	-56	-67	-42			-29	-64	-88	
Shore Hardness		42	75	87	80	73	76			39	76	86	
Points Hardness Change		-24	+6	+7	+5	+5	+1			-24	+11	+21	
% Volume Weight Change		+26	+5								+4	+0.3	
180° Bend		P	P	P	P	P	P			P	P	P	
6 WEEKS AGED 135°C													
Ultimate Tensile, psi		960	1370	1120	770	1020	859			1160	750	450	
% Tensile Change		-24	-13	-18	-50	-54	-41			+3	-56	-66	
% Ultimate Elongation		180	140	110	100	130	100			170	60	50	
% Elongation Change		-28	-50	-58	-63	-79	-62			-39	-78	-91	
Shore Hardness		48	75	82	76	70	73			41	86	90	
Points Hardness Change		-18	+6	+2	+1	+2	-2			-22	+21	+25	
% Volume Weight Change		+26	+6	+9.7	+7.3	+6.0	+9.1			+48	+4.6	-0.7	
180° Bend		P	P	P	P	P	P			P	F	F	

TABLE 25

ASTM 3 OIL AGED AT 150°C (302°F) TESTED AT ROOM TEMPERATURE

	HYCAR 4041	HYCAR 4043	HYDRIN 200 HYCAR 4021	HYDRIN 100	HYDRIN 100 HYDRIN 200	HYDRIN 200 NON BLACK	HYDRIN 200	EPCAR 545 PEROXIDE	EPCAR 545 SULFUR DONOR	HYPALON 40	HYCAR 1041	HYCAR 1041 HYCAR 1091-50	NEOPRENE W
70 HRS AGED 150°C													
Ultimate Tensile, psi	1120	930	2060	2350	2100	1890	1880						
% Tensile Change	-17	-26	+31	+70	+36	-14	+30						
% Ultimate Elongation	200	210	130	160	150	280	150						
% Elongation Change	0	-16	-54	-38	-44	-54	-42						
Shore Hardness	56	42	75	84	77	73	77						
Points Hardness Change	-17	-24	+6	+4	+2	+5	+2						
% Volume Weight Change	+14	+28	+4	+5.0	+3.2	1.6	+4						
180° Bend	P	P	P	P	P	P	P						
3 WEEKS AGED 150°C													
Ultimate Tensile, psi	1230	950	1390	1020	1070	920	870						
% Tensile Change	-9	-25		-25	-30	-58	-40						
% Ultimate Elongation	180	200	100	100	110	120	110						
% Elongation Change	-10	-20		-61	-59	-80	-58						
Shore Hardness	60	43	73	83	77	70	70						
Points Hardness Change	-13	-23		+3	+2	+2	-5						
% Volume Weight Change	+13	+29		+8									
180° Bend	P	P	P	P	P	P	P						
6 WEEKS AGED 150° C													
Ultimate Tensile, psi	1320	1000	1020	300	140	430	10						
% Tensile Change	-2	-21	-35	-78	-91	-81	-99						
% Ultimate Elongation	150	170	70	80	110	110	20						
% Elongation Change	-25	-32	-73	-79	-59	-82	-93						
Shore Hardness	63	49	81	80	64	65	50						
Points Hardness Change	-10	-17	+12	0	-9	-3	-25						
% Volume Weight Change	+13	+27	+6	+9	+5.1	+7.8	+12						
180° Bend	P	P	P	F	P	P	F						

TABLE 26

AIR TEST TUBE TESTED AT ROOM TEMPERATURE

	HYCAR 4041	HYCAR 4043	HYDRIN 200 HYCAR 4021	HYDRIN 100	HYDRIN 100 HYDRIN 200	HYDRIN 200 NON BLACK	HYDRIN 200	EPCAR 545 PEROXIDE	EPCAR 545 SULFUR DONOR	HYPALON 40	HYCAR 1041	HYCAR 1041 HYCAR 1091-50	NEOPRENE W
Hours until 180° Bend Failure @ 225°F													
250°F							>1000			>1000	>70	>500	>70
275°F		>1000		>1000	>1000	>1000	>1000	>1000	>1000	>500			
302°F	>1000	>1000	>1000	>1000	>500	>1000		>500	>500				
325°F	>1000	>1000	>500	>70									
350°F	>1000	>70											
375°F													
ORIGINAL TENSILE	1350	1260	1570	1370	1540	2210	1450	2440	1800	1130	1700	1325	1520
% Tensile Change After 1000 Hours @ 225°F													
250°F						-10				+16	+70	+85	-18
275°F		-10		+9	+53	-60	-82	-36	+8	+20			
302°F	-1	-21	-25	-55	-88	-98							
325°F	-10	+3											
350°F	-26	+28											
375°F													
ORIGINAL ELONGATION	200	250	280	260	270	610	260	490	500	280	280	510	410
% Elongation Change After 1000 Hours @ 225°F						-38				-54	-96	-95	-100
275°F		-20		-65	-63	-75	-73	-63	-64	-93			
302°F	-10	-40	-54	-62	-96	-89							
325°F	-10	-76											
350°F	-65	-100											
375°F													
ORIGINAL HARDNESS	71	66	69	80	75	68	75	68	72	63	65	65	65
Hardness Change After 1000 Hours @ 225°F													
250°F						+10				+11	+31	+30	+31
275°F		+7		+12	+11	+7	+5	+3	+8	+26			
302°F	+2	+15	+16	+13	0	-4		+20	+19				
325°F	+8	+22	+25										
350°F	+19	+32											

TABLE 27

AIR TIGHT TUBE TESTED AT ELEVATED TEMPERATURES

		NYCAR 4041	NYCAR 4043	HYDRIN 200 NYCAR 4021	HYDRIN 100	HYDRIN 100 HYDRIN 200	HYDRIN 200 NON BLACK	HYDRIN 200	EPCAR 545 PEROXIDE	EPCAR 545 SULFUR DONOR	HYPALON 40	NYCAR 1052	NYCAR 1042 NYCAR 1092-5	NEOPRENE W
Hours until 180° Bend Failure @	225°F							>1000			>1000	>70	>500	>70
	250°F				>1000	>1000	>1000	>1000	>1000	>1000	>500	>70	>70	
	275°F		>1000		>500	>500	>500		>500	>500				
	300°F	>1000	>1000	>1000	>70									
	325°F	>1000	>500	>500										
	350°F	>500												
	375°F													
ORIGINAL TENSILE														
% Tensile Change After 1000 Hours @	225°F										+77			-55
	250°F				+8	-64	-42	-90	-16	-2				
	275°F		-17		-64		-92		-71	-89				
	302°F	+5	-27											
	325°F													
	350°F													
	375°F													
ORIGINAL ELONGATION														
% Elongation Change After 1000 Hours @	225°F				-60	-65	-63	-77	-24	-20	-39			-96
	275°F		-17		-79				-95	-95				
	302°F	-16	-7											
	325°F													
	350°F													
	375°F													
ORIGINAL HARDNESS														
Hardness Change After 1000 Hours @	225°F													
	250°F													
	275°F													
	302°F													
	325°F													
	350°F													

TABLE 4

ASTM #3 OIL TESTED AT ROOM TEMPERATURE

		NYCAR 4041	NYCAR 4043	HYDRIN 200 NYCAR 4021	HYDRIN 100	HYDRIN 100 HYDRIN 200	HYDRIN 200 NON BLACK	HYDRIN 200	EPCAR 545 PEROXIDE	EPCAR 545 SULFUR DONOR	HYPALON 40	HYCAR 1042	NYCAR 1041 HYCAR 1051-50	NEOPRENE W
Hours until 180° Bend Failure @	225°F													
	250°F										>1000	>1000	>500	
	275°F		>1000	>1000	>1000	>1000	>1000	>1000			>1000	>500	>70	
	302°F	>1000	>1000	>1000	>500	>1000	>1000	>500						
	325°F													
	350°F													
	375°F													
ORIGINAL TENSILE		1350	1260	1570	1370	1540	2210	1450			1130	1700	1325	1520
% Tensile Change After 1000 Hours @	225°F													
	250°F										-12	-59	-66	
	275°F		-24	-13	-18	-50	-54	-41			+3	-56	-66	
	302°F	-2	-21	-35	-78	-91	-81	-99						
	325°F													
	350°F													
	375°F													
ORIGINAL ELONGATION		200	250	280	260	270	610	260			200	200	580	410
% Elongation Change After 1000 Hours @	225°F										-43	-86	-95	
	275°F		-28	-50	-58	-63	-79	-62			-39	-78	-91	
	302°F	-25	-32	-73	-79	-59	-82	-93						
	325°F													
	350°F													
	375°F													
ORIGINAL HARDNESS		73	66	69	80	75	68	75			63	65	65	65
Hardness Change After 1000 Hours @	225°F													
	250°F										-13	+19	+23	
	275°F		-18	+6	+2	+1	+2	-2			-22	+21	+25	
	302°F	-10	-17	+12	0	-9	-3	-25						
	325°F													
	350°F													

TABLE 29

COMPOUNDING INGREDIENTS

NAME	SUPPLIER	FUNCTION
Acrawax C	Glyco Cehmicals	Finishing Agent
Admex 760	Ashland Chemical	Plasticizer.
Age Rite Resin D	Vanderbilt	Antioxidant
Age Rite Stalite	Vanderbilt	Antioxidant
Aranox	Uniroyal	Antioxidant
Butyl Zimate	Vanderbilt	Accelerator
CBTS	B. F. Goodrich	Accelerator
Coldflex 1000	C. P. Hall	Plasticizer
Cumate	Vanderbilt	Accelerator
Dodecyl Mercaptan	Pennwalt	Modifier
DCP	B. F. Goodrich	Plasticizer
Dyphos	National Lead	Heat Stabilizer
Dythal	National Lead	Heat Stabilizer
Epcar 545	B. F. Goodrich	Ethylene Propylene Elastomer
FEF	Phillips	Reinforcer
Flexricin P-4	Baker Castor Oil	Plasticizer
Hi Sil 233	PPG Industries	Reinforcer
HVA-2	DuPont	Activator
Hycar 1041 (1091-50)	B. F. Goodrich	Nitrile Elastomer
Hycar 4021 (4041, 4043)	B. F. Goodrich	Polyacrylate Elastomer
Hydrin 100 (200)	B. F. Goodrich	Epichlorohydrin Elastomers
Hypalon 40	DuPont	Chlorosulfonated Polyethylene
Kenflex A	Kenrich Petrochemicals	Plasticizer
Laminar	H. M. Royal	Filler
Linseed Oil	Woburn Chemical	Activator

TABLE 29

NAME	SUPPLIER	FUNCTION
Litharge	National Lead	Activator
LMW Polyethylene	Merck	Activator Lubricant
Magnesium Stearate	Proctor and Gamble	Activator Lubricant
MBT	Royal	Accelerator
N-326	Cabot	Reinforcer
N-550	Philblack	Reinforcer
N-770	Cabot	Reinforcer
N-991	R. T. Vanderbilt	Reinforcer
NA-22	DuPont	Accelerator
Naugard 445	Uniroyal	Antioxidant
NBC	DuPont	Antiozonant
Neoprene W	DuPont	Polychloroprene Elastomer
Niclate	Vanderbilt	Antiozonant
Octamine	Uniroyal	Antioxidant
Paraplex G-50	Rohm and Haas	Plasticizer
Potassium Stearate	Proctor and Gamble	Activator
Red Lead	Eagle Picher	Activator
Santowhite Crystals	Monsanto	Antioxidant
Silane A-189	Union Carbide	Coupling Agent
Sodium Stearate	Nopco Chemical	Dispersant
Stalite S	Vanderbilt	Antioxidant
Stearic Acid	National Bureau Standards	Activator
Sulfasan R	Monsanto	Vulcanizing Agency
Sulfur (Spider)	C. P. Hall	Vulcanizing Agent
Sundex 890	Sun Oil	Plasticizer
Sunpar 2280	Sun Oil	Plasticizer
TZ-80	Technical Processing	Processing Aid
TETD	Vanderbilt	Accelerator

TABLE 29

NAME	SUPPLIER	FUNCTION
Tetrone A	DuPont	Accelerator
TMTD	Royal	Accelerator
Varox	Vanderbilt	Vulcanizer
Warecure C	Ware Chemical	Accelerator
Witco 127	Witco	Antiozonant
Zeolex 23	J. M. Huber	Reinforcer
Zinc Oxide	New Jersey Zinc	Activator
ZO-9	Harwick Chemical	Accelerator

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ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE
CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

EFFECTS OF RADIATION ON MATERIALS AND COMPONENTS

I. Radiation effects on polymeric materials*)

II. Radiation problems relating to high-energy accelerators*)

M.H. Van de Voorde

Lectures given in the
Academic Training Programme of CERN 1968-1969

GENEVA
1970

*) Parts of a series of lectures by B. Vittoz (Ecole Polytechnique Fédérale, Lausanne) and M.H. Van de Voorde.

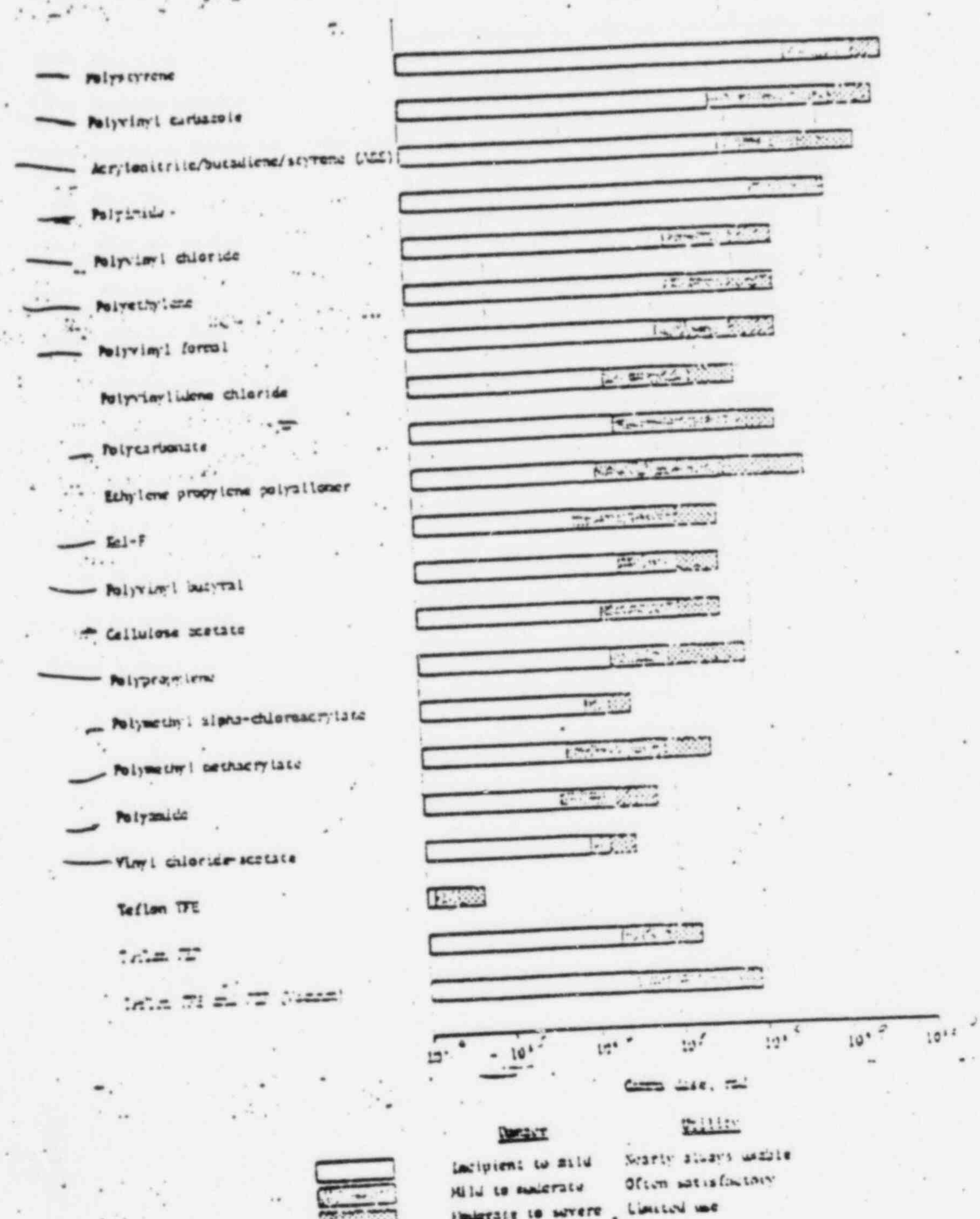

Fig. I.1 Radiation stability of thermoplastic resins (Ref. 93).

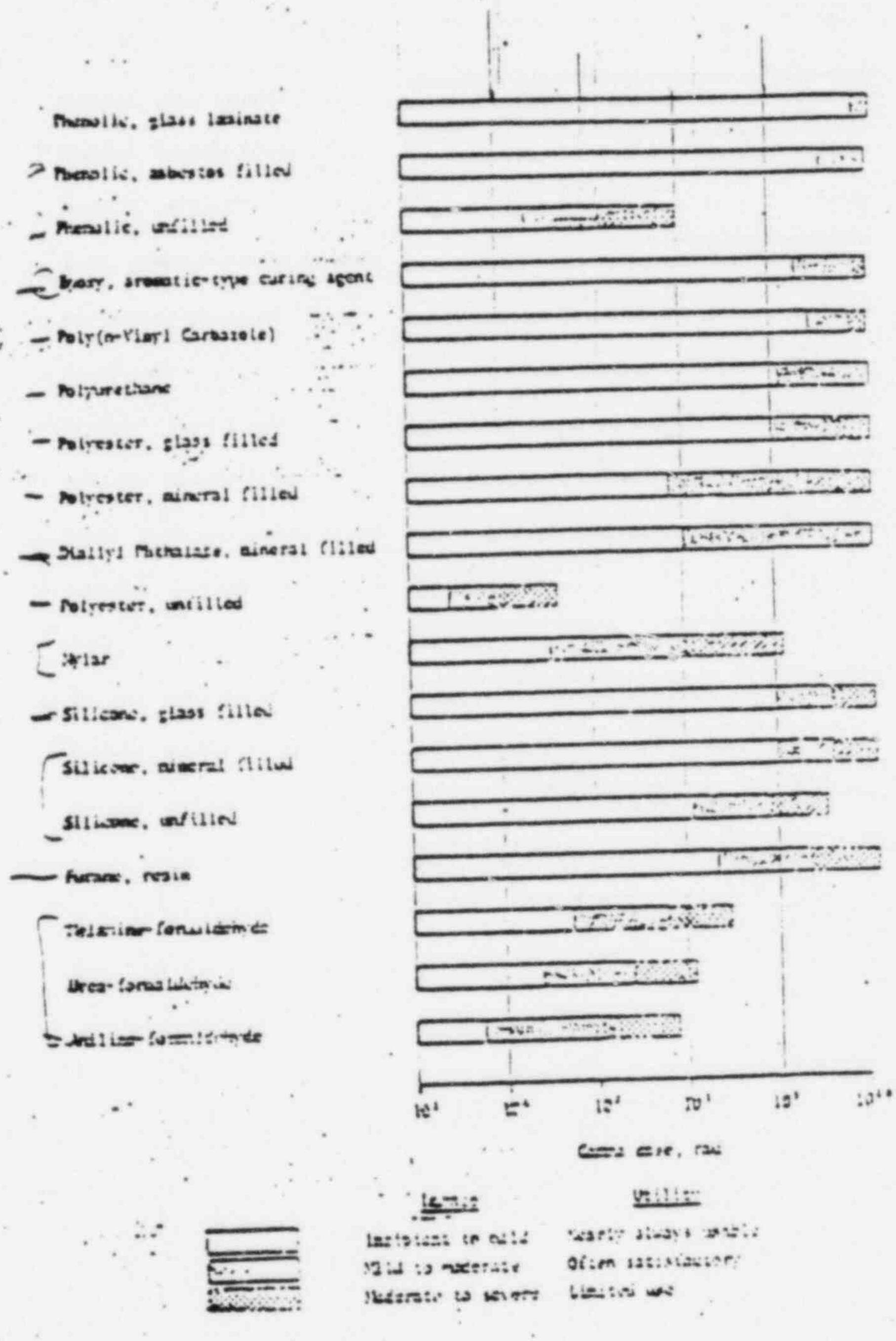

Fig. 1.2 Radiation resistance of thermosetting resins (Ref. 73).

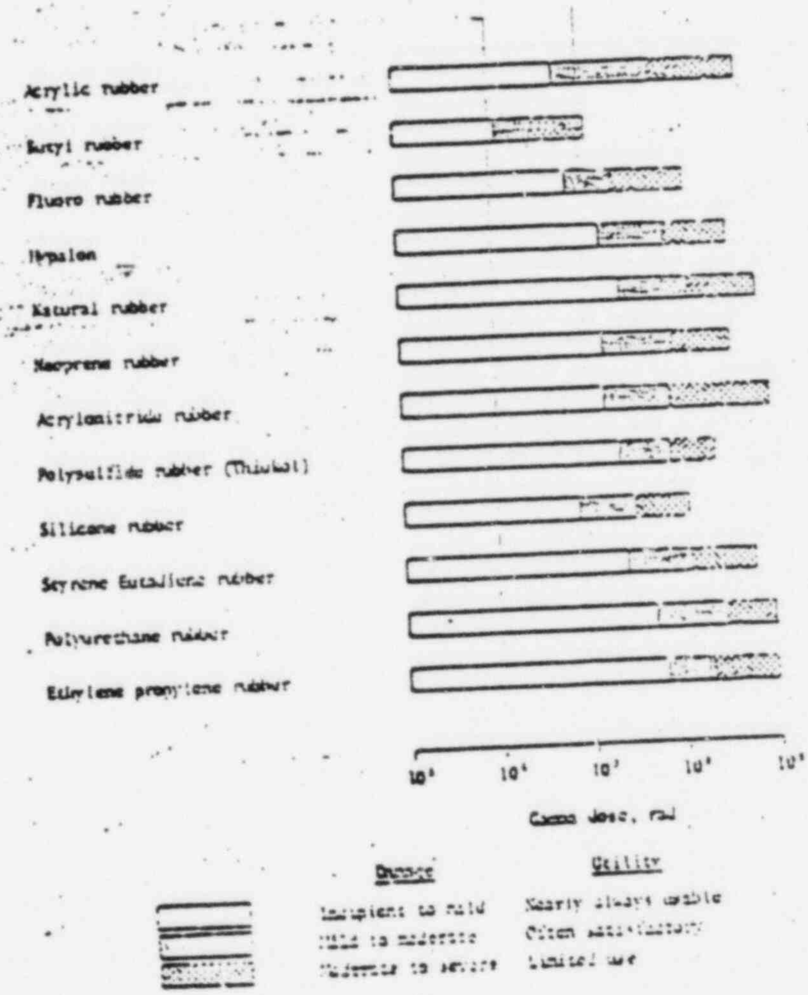

Fig. 1.3 Radiation stability of elastomers.

a value corresponding to the design life selected in ... This is the *design modulus*.

...pply a safety factor to the design modulus to calculate *working modulus*. This is rarely necessary in metal ...m but is in plastics design to correct for any uncertainties arising from extrapolations or other compromises that may have been made. Safety factors of 0.5 to ... are typical.

5) Substitute the calculated working modulus in the ...art design equation. For example, to calculate the width ... a simple rectangular beam required to limit the maximum deflection to a specified value when the span and depth of the beam are fixed, the working modulus would be substituted for E in the following design equation.

$$b = \frac{P}{E\Delta}\,\frac{L^3}{4d^3}$$

where b = width of beam; d = depth of beam; L = span; P = load; Δ = maximum deflection allowed; and E = modulus.

VIII: Limits on Extrapolation of Creep and Creep Rupture Curves

There are several important limitations on the extrapolation of creep and creep rupture curves that the designer should constantly bear in mind.

1) In general, creep and creep rupture curves should not be extrapolated more than one decade of time. Thus 100-hr. creep should not be extrapolated beyond 1000 hr.; 1000 hr. curves not beyond 10,000 hr., and so on.

2) Creep rupture curves at elevated temperatures should be extrapolated with caution because of the danger of downturnings which have been discussed above.

3) Some experiments have been conducted to verify the accuracy of creep extrapolations. They indicate that creep data in the range of 1000 to 5000 hr. when extrapolated one decade or more can be expected to yield creep modulus values that are from 10 to 35% higher than the actual values. This deviation should be taken into account in the safety factor applied to the design modulus.

Selecting plastics for elevated temperature performance

Choosing a plastic for elevated temperature performance is one of the more important and complex tasks facing the designer and materials engineer. It is important, of course, because of the limited temperature range of plastics compared to structural metals and because the different families and grades of plastics vary widely in their elevated temperature capabilities. These differences in capabilities are one of the principal characteristics that distinguish engineering plastics (epoxy, nylon, polycarbonate, thermoplastic polyester, etc.) as a class and certain specialty plastics (PTFE, polyimide, etc.) from the relatively low-temperature volume plastics (polyethylene, polystyrene, PVC, etc.), and their selling prices tend to reflect these differences. Obviously, the designer and material selector need reliable criteria for elevated temperature performance to make an economically optimum material choice.

I: Selecting Criteria for Maximum Use Temperature

Such criteria tend to be complex for two reasons. First, there are a number of different properties that must be ... to consideration for most elevated temperature ap... of plastics and these properties tend to vary with ... are in a nonregular manner. Thus it is necessary to work with properties as *functions of temperature* rather than as single valued constants. Second, different properties of plastics usually do not vary with temperature in the same way. For example, the dielectric loss properties (dielectric constant and dissipation factor, for example) of a particular plastic may change only modestly at elevated temperatures while the rigidity and strength (creep modulus and creep rupture) are reduced drastically; and vice versa.

From the foregoing, it can be seen that there can be *no simple maximum use temperature* for a plastic that is likely to apply to all or even most of the properties that are important in elevated temperature applications. Moreover, certain key properties of plastics are time-dependent; for example, rigidity (creep modulus), strength (creep rupture), and aging resistance. As it was explained in the previous section, Designing for Strength and Rigidity under Static Load, these time-dependent properties cannot be predicted from short-time tests. Therefore, such simple tests as Vicat softening temperature or deflection temperature under load (DTUL), formerly called heat distortion temperature, are not meaningful in judging material suitability in applications where exposure to elevated temperature is more than momentary. Even in momentary exposure situations, such tests have very limited significance and, as we shall see, are more often misleading than helpful.

To judge the elevated temperature performance of a plastic with respect to a particular application, the material selector must consult the values of all the properties germaine to the application at the maximum temperature of the application. For example, if long-term deformation under static load is one of the critical design considerations, then the creep modulus at the design temperature will be one of the properties upon which selection will be based. This concept is simple to state, but fairly complex to carry out because of the possibility and often necessity of making compromises between the different critical properties, part cost, and part design.

To minimize the cost and time required for prototyping and tooling, the designer or project engineer should carry out a systematic material selection analysis as early as possible in the development of an application. Such a program consists of the following steps:

1) Identify all the elevated temperature-sensitive properties that are critical to the application (see below for a discussion of these properties).

2) Estimate the minimum performance values required by the application or the range that might be acceptable at the design temperature.

3) Make a preliminary list of candidate materials by comparing their properties at the design temperature to the application requirements.

4) Screen the preliminary list further by eliminating materials that do not meet other essential requirements of the application, such as fastenability, colorability, fabricatability, etc. Generally, if an application requires elevated temperature performance, this will be controlling in material selection and therefore should be the basis of initial screening.

II: General Effects of Elevated Temperature on Plastics

Virtually all properties of plastics are affected by raising temperature but in different ways and to different degrees. Therefore, an independent approach to each one is required from the standpoint both of understanding behavior and application to material selection. In the following discussion, the major properties involved in elevated temperature applications of plastics will be taken up from both standpoints. For convenience, we can group these properties into four categories.

Category 1, Short-term effects:
Properties in this group are affected simply by the fact of raising the temperature. They include the following:

Form Stability (Melting).

Dimensional Stability—Reversible (Thermal Expansion).

Dimensional Stability—Irreversible (Shrinkage).

Impact. (Always improved at elevated temperature and so not necessary to consider in this context.)

Most Electrical Properties.

Stress-Strain. (Discussed in the section on Rigidity and Strength under Static Load.)

Category 2, Short- and Long-Term Effects:
Properties in this category show both short-term effects like those in Category 1 plus long-term effects. These include the following:

Creep.
Creep Rupture.
Chemical Resistance.

Category 3, Long-Term Effects:
Properties in this category respond only to long-term exposure to elevated temperature. They include the following:

Heat Aging Resistance.
UL Temperature Index.

Category 4, Self-Generating Temperature Effects:
Properties in this category involve physical a… chemical changes in the plastic that generate heat. In… bly, these properties are inherently complex, and … special treatment. They include the following, and … discussed in a later edition of the MPE Design Guide.

Fatigue.
Friction and Wear Resistance.
Flammability.
Arc-Track Resistance.

III: Category 1 Properties — Short-Term Effects

Form Stability: Transitional Behavior of Plastics
The best way to form an instantaneous and meanin… picture of the overall effect of elevated temperature on … plastic is to look at a plot of its short-time modulus … temperature up to the onset of melting or degradation. … particular significance is the in-phase or elastic modu… derived from a dynamic test, such as the Torsion Pe… dulum, ASTM D2236. (There are several methods … measuring dynamic moduli vs. temperature of plastics; … the Torsion Pendulum has the advantage of a simple … tangular specimen that is readily fabricated from a… plastic by realistic commercial fabrication process… whereas other test methods generally are limited to … films or monofilaments. See ASTM D2236 for test deta…) The significance of the dynamic test lies in its ability … separate the response to load of elastic mechanisms wit… the plastic, such as chemical bonds, crosslinks a… crystallinity, from viscous mechanisms, which give … creep and other viscoelastic effects. Consequently, a plo… the elastic modulus vs. temperature reflects changes in … principal loadbearing mechanisms in a plastic and he… its performance under any mechanical stress.

From such plots we can make two very impor… generalizations. One, virtually all plastics fall into one … four different patterns of temperature-property behav… amorphous thermoplastic, semicrystalline thermopla… thermoset with transition, and thermoset without tran… tion. Two, all but a handful of plastics are dominated … large and fairly broad transition, called the *glass transi…* which has a profound effect on all mechanical and therm… properties.

Typical examples of each of the four types of temper… ture-property patterns are shown in Fig. 11. Their m… features are summarized in the following.

1) Amorphous Thermoplastic:
Example—PMMA (Polymethyl Methacrylate)
In this class, which also includes PVC, SAN, ABS, polysty… phenylene oxide-based plastics, polycarbonate, … polysulfone, mechanical properties decrease at a relat… modest rate with increasing temperature until the ons… *their glass transition.* This temperature marks the lim… *their ability to bear continuous load and to remain dim… sionally stable.* However, they remain reasonably form… ble, i.e., retain fabricated shape without external … through most of the transition, which may cover a ran… 20 to 50° C. Above their glass transitions they are visc… melts, although substantially higher temperat… generally are required to reduce the melt viscosity to … point where the materials flow readily in extruders … molding machines. There is no simple test for the ons… the glass transition: The DTUL test, marked by an x fo…

…terials graphed in Fig. 11, generally indicates a …perature close to the upper end of the transition. …wever, the onset can be closely estimated from a plot of …mpanion property also derived from the dynamic test, … log decrement or damping factor. Creep modulus and …ep rupture data also clearly show the disappearance of …ctical loadbearing ability at the beginning of the glass …nsition.

…emicrystalline Thermoplastic: Example—Nylon

…is class, which also includes polyolefins, acetals, …ropolymers, and thermoplastic polyesters, differs from … amorphous plastics principally in the *ability to retain …ificant mechanical properties above their glass transi…*…s. This is due to their *crystalline bonds* and the fact … the crystalline melting point of a polymer always is …stantially higher than its glass transition. However, the …s transition does cause a reduction of as much as 50 to … in both short-term and time-dependent mechanical …perties (except impact, which is improved). This …atly reduces the usefulness of unfilled semicrystalline …stics in loadbearing applications. To overcome that …itation, reinforced grades containing from 5 to 40% of …s fiber, mineral particles, or mixtures have been …eloped. The effect of the fillers, shown in Fig. 12, is to …stantially raise the level of mechanical properties of the …s… …ver its whole temperature range but without … the temperature or the effect of its glass transi… n ar… …elting point. In the case of an amorphous plastic …lycarbonate in Fig. 12) this results simply in a gain in ri…ity with no significant increase in temperature range. …wever, in the case of a semicrystalline plastic this …quently raises its loadbearing ability in the region above …glass transition to the point where it is useful in many …dbearing applications. Thus, the fillers have the effect … extending upwards the useful temperature range of the …stic.

The limit of form stability for semicrystalline plastics is …onset of the crystalline melting point, which is readily …asured by a Differential Scanning Calorimeter (DSC) or …ilar analytical test. For filled grades, the DTUL yields a …newhat lower approximation of this value. However, for …filled grades, the DTUL indicates a temperature …newhere around the midpoint of the glass transition if it …urs above room temperature, for example, nylon in Fig. … If the transition occurs at or below room temperature, …for example with polyethylene, polypropylene, …ybutylene, and acetal, the DTUL yields an arbitrary …nperature somewhere below the melting point. Both of …se cases are different from those of amorphous thermo…stics where DTUL approximately measures the upper …it of the glass transition for both filled and unfilled …des. This confusion in what the DTUL really means …troys its usefulness in relative comparisons of different …stics as well as its value in predicting elevated tempera… … performance and its use can lead to misjudgments. … example, as illustrated in Fig. 11, it incorrectly makes … appear to be a higher-temperature material than …

… important effect of the glass transition is a sig…antly higher thermal coefficient of expansion above … as much as two or three times the value below it. This … be taken into account in selecting a coefficient for … dimensioning. It also leads to increased vulnerability … semicrystalline plastics to thermal oxidation above the …ition. As the plastic expands more rapidly, it becomes … permeable to oxygen. It is the effect of heat-aging on … properties such as creep, creep rupture, and …

…per temperature limit when elevated temperature exposure is of long duration or continuous.

3) Thermoset With Transition: Example—Epoxy

This class, which also includes urea, alkyd, thermosetting polyesters, and diallyl phthalate, is similar in some respects to semicrystalline plastics and very different in others. The similarities lie in the effect of the glass transition on mechanical and thermal properties and the retention of significant mechanical properties above the transition (see epoxy in Fig. 11). In this case, the retention is due to chemical crosslinks rather than crystallinity. The primary difference, of course, is that thermosets do not melt and therefore do not have clearly defined form-stable limits. At high temperatures they gradually oxidize and

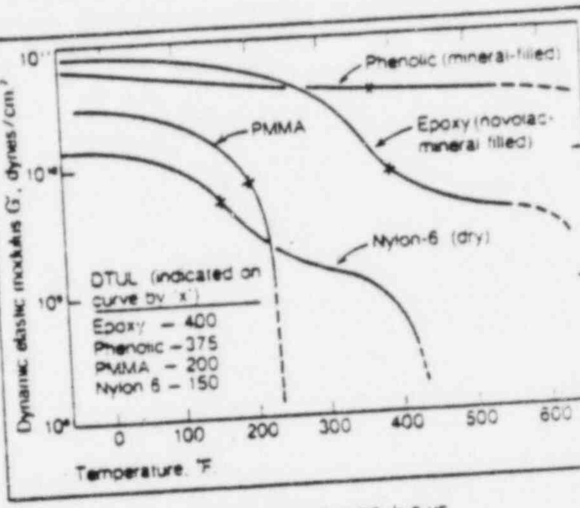

Fig. 11. Dynamic shear (torsion) modulus vs. temperature for representative thermosets and thermoplastics, showing deflection temperature under load (DTUL) at 264 p.s.i.

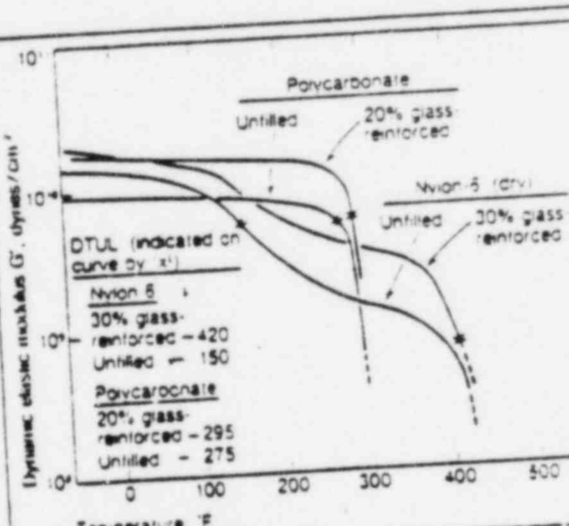

Fig. 12. Dynamic shear (torsion) modulus vs. temperature for amorphous and semicrystalline glass-rein… … plastics, showing de… …

degrade thermally, usually accompanied by surface deterioration, cracking, and/or warping. There is no precise method for measuring the onset of deterioration. Thermogravimetric Analysis (TGA) measures weight loss as a function of steadily increasing temperature and graphically indicates the temperature at which degradation becomes rapid. However, no consistent relationship between TGA data and loss of performance properties has yet been developed. The Torsion Pendulum test can indicate when deterioration has proceeded far enough to affect the dynamics modulus, but this presents some practical testing problems with respect to ventilation and equipment fouling.

One of the principal values of dynamic modulus plots, such as Fig. 11, is the pinpointing of the midpoint and temperature range of the glass transition, both of which for this class of thermosetting plastics can be varied readily by resin chemistry to produce very significant differences in elevated temperature performance. This is particularly true of polyesters and epoxies where the range of grades in

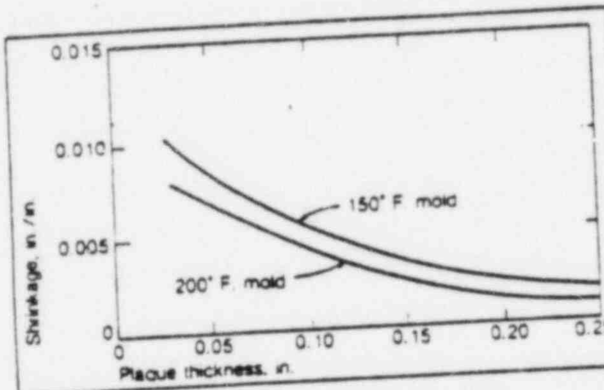

Fig. 13. Effect of thickness and mold temperature on shrinkage of injection molded nylon 6/6 plaques (annealed for 1 hr. at 325° F.).

a single thermoset family represents a shift in the glass transition of nearly 100° C. The dynamic modulus plot also indicates one of the principal property advantages of this class of plastics, namely significantly higher rigidity over a wide range of elevated temperatures.

4) Thermoset Without Transition. Example—Phenolic. This small class, which also includes melamine and silicone, differs from other thermosets only in the absence of a glass transition.

Summary of Transitional Behavior. The elevated temperature performance of most plastics is dominated by the temperature of occurrence and temperature range of the glass transition and, in the case of semicrystalline plastics, by the crystalline melting point. The glass transition has a profound negative effect on all mechanical properties, except impact, and on certain thermal properties, such as coefficient of expansion. Therefore, a knowledge of the transitional behavior of plastics is necessary to understand their elevated temperature capabilities. This knowledge is best derived from a full temperature-modulus plot, especially a dynamic modulus plot, since elevated temperature behavior of plastics is too complex and too varied to be described by simple tests, such as Vicat and DTUL. It is important to note, however, that although the transitions in plastics affect both short-term and time-dependent properties, the short-term modulus, whether it be dynamic or stress-strain, cannot predict the values of time-dependent properties such as creep modulus and creep rupture strength. Therefore, comparisons between dynamic moduli of different materials at a given temperature may not indicate how they would compare under a time-dependent stress.

Dimensional Stability: Reversible Effects

Plastics in general are subject to much larger dimensional changes at elevated temperatures than metals. Thermal coefficients of expansion vary from two to ten times those of typical structural metals. Moreover, the expansion of plastics is subject to a number of variables that should

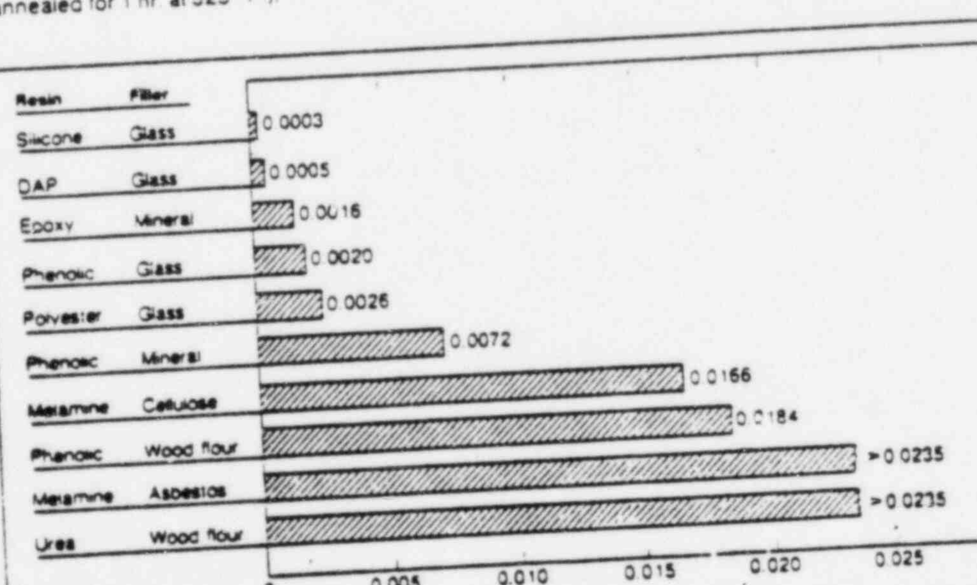

Fig. 14. Post molding shrinkage of thermosetting molding compounds after 500 hr. at 300° F.

into account in the selection of design data.

Coefficients of expansion frequently are not linear temperature, especially for unfilled or lightly filled compounds.

Coefficients of expansion increase significantly in going through a glass transition. For example, a 75% filled epoxy molding compound will undergo such a change in coefficient of thermal expansion from 30 to 90 micro-inches per inch per degree C. and this is a compound optimized for low thermal expansion.

Consequently, it is necessary to measure coefficients of expansion as a function of temperature and to use those that correspond to the temperature of the application.

Dimensional Stability: Irreversible Effects

At elevated temperatures, plastics parts are subject to irreversible shrinkage in addition to that which occurs as a result of processing. This must be taken into account when designing parts that will be used at elevated temperatures and when designing the molds and dies from which the parts are made. Plastic parts also at times are subject to warpage, which usually involves shrinkage, along with a number of other factors.

Three mechanisms are responsible for most post-processing irreversible dimensional change.

1) Relaxation of molded-in stresses. In any plastics process, but especially in injection molding, adjacent sections of a part may shrink at different rates setting up internal stresses between them, leading to differential shrinkage. The most common cause is simply different rates of cooling by different thicknesses of wall. It can also be caused by orientation of the polymer molecules, which is promoted by high rates of flow through orifices, narrow channels, and thin sections, and by the presence of fibrous reinforcements, such as chopped glass. Warpage usually occurs when the internal stresses relax either as the part is cooling immediately after molding or, if the part is not effectively annealed after fabrication, later when the part is subject to elevated temperature in use.

The polymer properties that control orientation are complex and involve interactions with part and mold design. They usually must be evaluated empirically. In general, however, plastics with high solidification shrinkage, such as the semicrystalline thermoplastics (15 to 30 mils/in.), tend to be worse than the amorphous thermoplastics and thermosets (1 to 10 mils/in.).

2) Post-process crystallization. Semicrystalline plastics usually solidify and cool in commercial processes to an incomplete degree of crystallinity. The degree will depend greatly on the particular plastic, the processing conditions including melt temperature and flow rate, on mold or die design, and especially on the quenching conditions. Upon heating, a fabricated part can crystallize further and this will be accompanied by additional shrinkage. An example is shown in Fig. 13 where the very significant annealing shrinkage of a nylon 6/6 is plotted against wall thickness at two different mold temperatures. The thinner plaques at the lower mold temperature are quenched more during processing, have a lower as-molded crystallinity, and therefore have a greater potential for recrystallizing and shrinkage during annealing or heating in use. It should be noted that annealing of a semicrystalline thermoplastic, especially if it is conducted above the glass transition temperature, will usually produce a stable degree of crystallinity in the time required to bring the part to equilibrium. Once annealed, the part will cease shrinking as long as the end-use temperature is below the annealing temperature.

3) Post-process curing. Thermosetting plastics can continue to crosslink and consequently shrink irreversibly

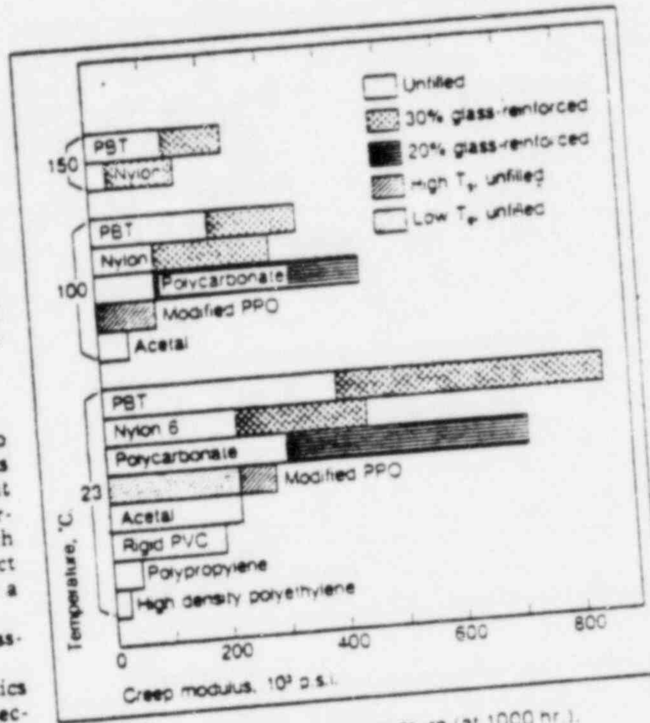

Fig. 15. Creep modulus vs. temperature (at 1000 hr.).

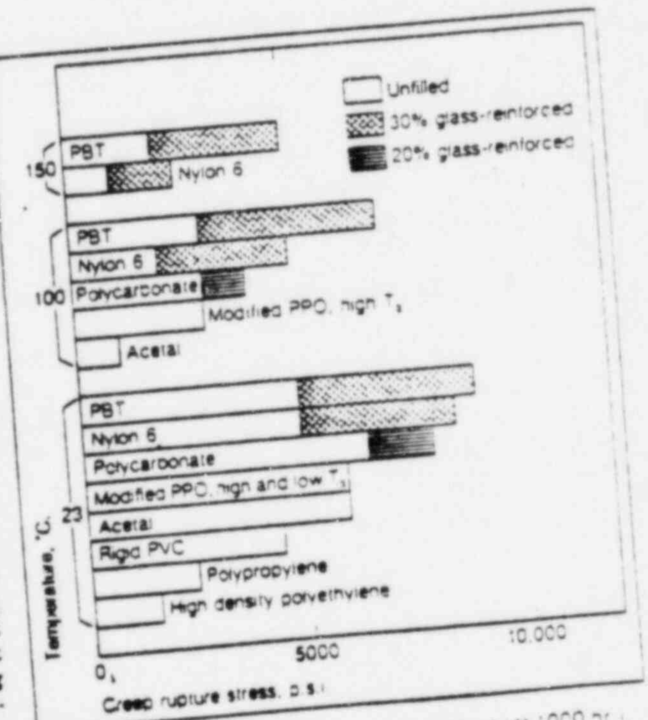

Fig. 16. Creep rupture strength vs. temperature (at 1000 hr.).

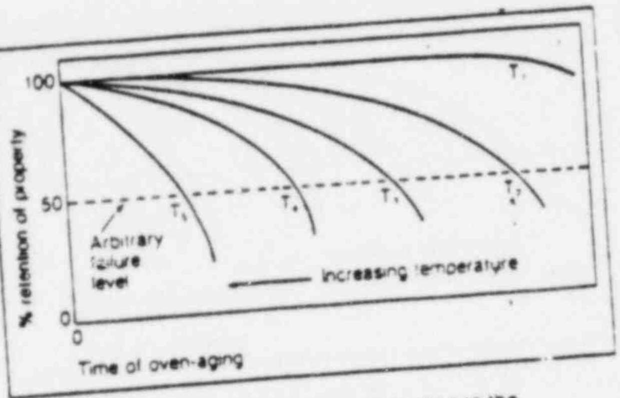

Fig. 17. Typical heat-aging curves, according to the Underwriters Laboratories' temperature index system.

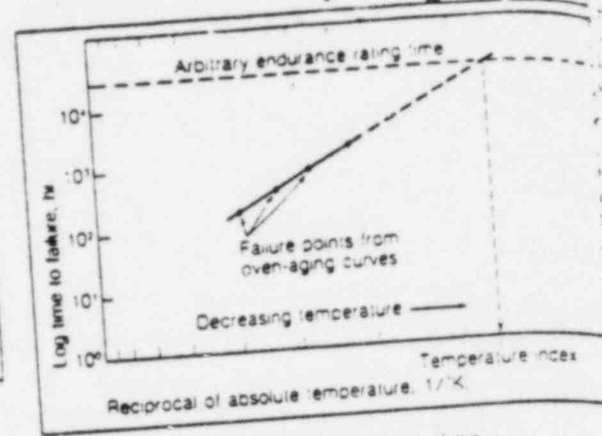

Fig. 18. Simplified model for derivation of the temperature index from Arrhenius plots derived from heat-aging curves, according to the Underwriters Laboratories' temperature index system.

after processing. As in the case of thermoplastics, such shrinkage must be taken into account in part and mold design and in the judgment of suitability of a material for a particular application. The amount of shrinkage will vary with the inherent reactivity of the resin, the formulation, the concentration and type of filler, mold temperature, mold cycle, and the temperature to which the part is heated in use. In general, thermoset parts can be normalized in the same way as thermoplastics, i.e., by annealing at or above the expected maximum use temperature. However, the tendency of some thermosets to post cure is so strong that normalization may be impractical. Examples that show the wide range (less than 1 to greater than 20 mils/in.) of post-process curing encountered in different thermosetting resins and filler systems are graphed in Fig. 14.

IV: Category 2 Properties— Short- and Long-Term Effects

Creep Modulus and Creep Rupture

In the section on Designing for Rigidity and Strength under Static Load we developed the principle that the primary design properties of plastics are *creep modulus* or *creep strain* and *creep rupture strength*. We also illustrated how these properties varied with increasing temperature. The numerical values of these properties, then, are the proper measures for judging the loadbearing ability of a plastic at any particular elevated temperature and should be used as the primary basis for material selection in elevated temperature loadbearing applications. An example of how this can be done is shown in Figs. 15 and 16. Fig. 15 is a bar chart comparing the *creep modulus* at 1000 hr. of a group of thermoplastics at three different temperatures—23° C., 100° C., and 150° C. The length of the bars represents the values of the modulus for unfilled and glass-reinforced grades. Fig. 16 is a similar bar chart of *creep rupture strength* for the same materials. The bar charts show that while most of these thermoplastics have substantial rigidity and strength at room temperature, only a few retain enough of those properties at elevated temperatures to bear significant loads. This is in spite of the fact that the elevated temperatures may be lower than their ultimate melting temperatures.

Creep properties are particularly powerful tools for judging elevated temperature performance for two reasons. One, they measure performance in a very realistic way th... is directly related to the design requirements of the ... plications. Two, they span both short-term (hours, da... and long-term (months, years) performance. Thus, ... charts similar to those in Figs. 15 and 16 can be generated at both at shorter and longer times, depending on the de... life of the application or duration of the applied stress.

The distinction between the dynamic modulus pl... described above and creep data primarily is one of purpo... The dynamic modulus presents an overall picture of th... complex elevated temperature behavior of a plastic a... locates the all-important transitions that dominate ... properties including creep. Because it is a short-term te... however, the dynamic modulus cannot predict the actu... loadbearing capability at any particular temperature. T... creep data not only supply the load capability numerically ... but indicate over what portion of a plastic's temperatu... span it is useful for bearing significant loads.

V: Category 3 Properties— Long-Term Effects

Heat-Aging Resistance

Under long-term (months, years) exposure to elev... temperatures in air, plastics are subject to attack ... oxygen and ozone which can with time degrade ... polymer through a series of chemical reactions and ... about failure. The endurance of plastics under this ... posure depends on many factors including ... temperature, presence of pollutants in the air, presence ... ultraviolet radiation, and whether temperature-gener... stresses, such as fatigue, are involved. However, the ... proach required to measure the basic response of ... plastic without regard to complicating factors depend... one principal factor which is derived from the intended ... plication. That factor is whether or not the plastic will ... under continuous significant load during the elevated tem... perature exposure.

If the plastic will be under continuous significant ... then endurance must be measured by means of creep ... ture. The reason for this, as developed in the section ... Designing for Rigidity and Strength under Static Load...

…ss, elevated temperature, and oxidation interact in … way and it is necessary to test in a way that realis… simulates this interaction in order to determine …ble loads and expected life at any particular ex… temperature. In the preceding section, the example … Plastic Pipe Design System was used to explain …chnique and illustrate typical behavior. In a situation … there is no significant load during the time of ex… typical of many electrical applications where the … serves mainly as a passive insulator, it is possible to … a simpler but more time-consuming way. (One of …dvantages of creep rupture testing at elevated temper… is that although testing for endurance requires long … the strength levels of the plastic at different tem…tures can be developed in a relatively short time— … to 2000 hr.). Such a system has been devised and …ced by the Underwriters Laboratories for many years … The following is a simplified description of it.

Temperature Index

…his system, specimens of plastic are oven-aged at …al temperatures, usually considerably higher than the …pated use temperature to accelerate degradation, for …od of one year. At regular intervals during this period, …ples are withdrawn and tested at room temperature for …le stress-strain, impact, and electrical properties, such …le tensile strength, flexural strength, Izod impact strength, …nsile strength, flexural strength, and dielectric strength. A plot is …le impact strength, and dielectric strength. A plot is …e at each temperature for each property of the percent …ntion of the original (control) value vs. oven aging time …n in Fig. 17. The time required to produce a 50% re… of the original value is selected as an arbitrary …oint and these times are used to make a linear Ar… plot of log time to failure vs. the reciprocal of the …olute exposure temperature as shown in Fig. 18. (The …henius relationship is a rate equation followed by many …mical reactions.) The linear Arrhenius plot is then …rapolated to predict the temperature at which failure …ld be expected at an arbitrary time that depends on the …terial's heat-aging behavior (usually about [redacted]).

This is then considered to be the temperature index of the plastic for that property. (As practiced by UL, the procedure for selecting the index from the Arrhenius plots usually involves comparison to a control standard material and other steps to correct for random variations, oven temperature variations, etc.).

The stress-strain properties, impact properties, and electrical properties frequently do not degrade at the same rate. Therefore, there is a separate temperature index for each of them (see Temperature Index Chart, 1978-79 edition, p. 616). Moreover, thicker specimens usually take longer to reach the failure point at a given temperature. This requires a temperature index for each thickness (standardized at approximately 1/32, 1/16, 1/8, and 1/4 in.) as well. The result is a matrix of temperature indices with three different properties and several levels of thickness as the elements.

UL uses the temperature index as a guideline in qualifying materials for many of the standard appliances and other electrical devices that it regulates but in a conservative manner and qualified by judgments based on long experience with such devices. In other words, they do not apply the indices automatically. In general, the temperature indices, particularly the one in the column headed "Both electrical and mechanical properties" (see Temperature Index Chart), which is usually the most conservative, can be used as a safe continuous use temperature for low load mechanical applications.

It should be noted that not all the indices in the chart are the result of oven-aging programs. Based on experience, UL will grant a generic rating, which is always much lower than the indices based on testing, simply on the basis of the identity of the plastic (nylon, phenolic, polystyrene, etc.). This permits a supplier to qualify his material for certain low-temperature applications without incurring the expense of an oven-aging program. Such ratings are arbitrary and not necessarily an indication of the capability of the grade or the generic material. A list of the generic ratings of all the plastics that UL has recognized is contained in the appendix to the chart.

Dynamic mechanical properties of plastics by torsion pendulum

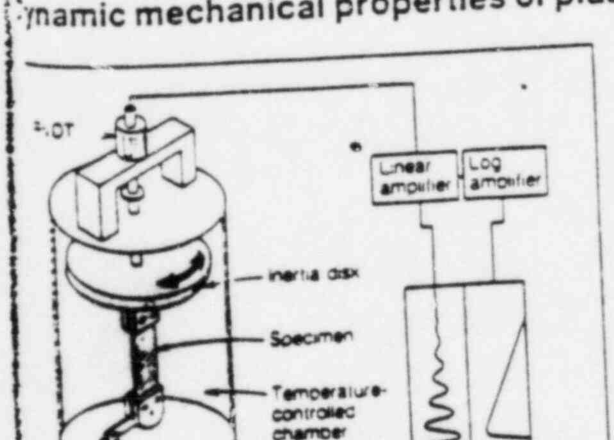

Fig. 1 Torsion Pendulum test equipment.

Dynamic mechanical tests have important advantages over analytical tests (Differential Thermal Analysis, Dilatometry, Clash-Berg, etc.) in measuring the transitions that dominate the temperature dependence of plastics. These advantages include direct measurement of mechanical properties (modulus, loss factor) and measurement of both the range and onset of transitions. Of several available dynamic test methods, the *Torsion Pendulum* (Dynamic Mechanical Properties of Plastics by Means of a Torsional Pendulum—ASTM D2236) has the additional advantages of being applicable to virtually all plastics and of using a simple specimen readily fabricated by all commercial processes or cut from parts.

Fig. 1 is a schematic drawing of a Torsion Pendulum showing the form of the data it produces. In the test, a simple rectangular specimen is clamped in a jaw that is attached to the lower end of a vertical rod which is held and supported by low friction bearings near its upper end. The bearings hold the rod upright but permit it to rotate freely. The lower end of the test specimen is held in a yoke that is fixed rigidly and permanently to the base of the test machine. Thus when the rod is rotated the specimen is twisted and in effect becomes a torsion spring. The yoke (lower clamp) permits the specimen to move freely in a vertical direction thus keeping the stress one of pure shear and permitting a stress analysis to be made that yields the desired dynamic properties. Other important parts of the apparatus are the following: 1) a differential transformer (RVDT) and strip chart recorder that generate a continuous graph of angular displacement of the rod (and specimen) vs. time while it is oscillating; 2) an inertia disk mounted on the rod to increase or decrease the moment of inertia of the system and thus extend the range of the instrument over a wide

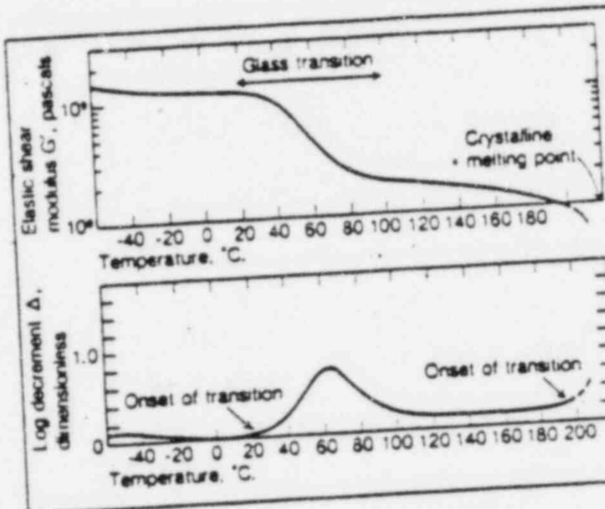

Fig. 2. Dynamic mechanical properties by Torsion Pendulum vs. Temperature of a typical semicrystalline thermoplastic (nylon 6, dry), showing effects of glass transition and crystalline melting transition and method of determining their onsets.

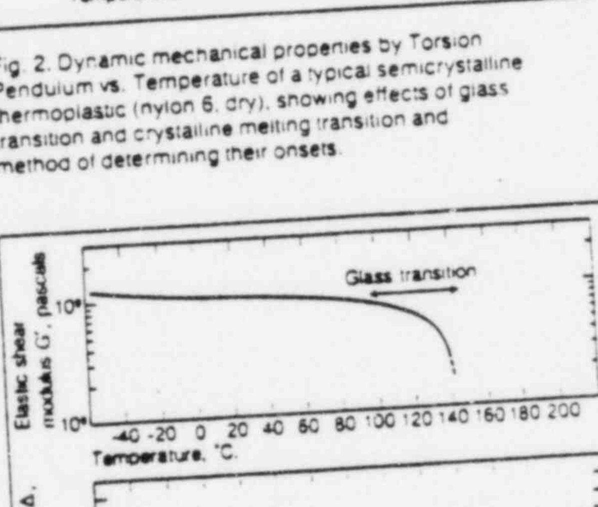

Fig. 3. Dynamic mechanical properties by Torsion Pendulum vs. Temperature of a typical amorphous thermoplastic (modified polyphenylene oxide, high T_g), showing effect of glass transition and method of determining its onset.

range of plastics while keeping the specimen geometry same; and 3) an insulated chamber equipped with a h ing and cooling system that permits variation of the temperature from cryogenic to over 300° C. A single sp men normally is tested over the whole temperature ra in successive steps.

In the test, after temperature equilibrium is establi the specimen is put into oscillation by manually or m anically twisting and releasing the rod. The specimen cillates freely for a few seconds gradually being dampe rest by its internal friction. This produces a typ damped oscillation trace on the recorder chart show Fig. 1. Frequency of the oscillation reflects the el mechanisms in the plastic and from it is calculated *elastic shear modulus*. The envelope curve that defines successively decreasing amplitudes of oscillation refl the viscous mechanisms in the polymer and from it is culated the *logarithmic (log) decrement* which is analog to the loss tangent in sinusoidal tests. This property also be obtained directly from the test electronically if pendulum is equipped with a log amplifier (see Fig Like the loss tangent, the log decrement relates the el modulus to the loss modulus. Therefore, from these properties the *loss shear modulus* can be calcula Usually the elastic shear modulus and log decrement sufficient to characterize the dynamic behavior of a plast

Calculations:

Elastic Shear Modulus, pascals:

$$G' = \left(\frac{6.4\,\pi^2 I L f^2}{\mu\, b t^3}\right)$$

Note: When Δ is larger than 1.0, a correction factor must be added to G'. (See ASTM D2236.)

Log Decrement (dimensionless):

$$\Delta = \ln\left(\frac{A_n}{A_{n+1}}\right)$$

Loss Modulus, pascals:

$$G'' = \left(\frac{G'\Delta}{\pi}\right)$$

where:

I = moment of inertia, g/cm.²
f = frequency, Hz.
L = length of specimen, cm.
b = width of specimen
t = thickness of specim cm.
A_n = amplitude of any oscillation.
μ = shape factor for rectangular cross sections. (See ASTM D2236.)

1 pascal = 10 dynes/cm. = 1.45 × 10^{-4} p

Typical torsion pendulum data are plotted in Figs 3 for semicrystalline and amorphous thermoplastics upper curve in each figure is the *elastic modulus* vs. perature, which clearly shows the dramatic effects of glass transition on the mechanical properties of both tics and on the melting of the amorphous resin. Fig shows the crystalline melting transition of the semi talline plastic. The lower curve in each figure is th *decrement* vs. temperature on the same temperature as the elastic modulus. The dramatic rise in this pro as a result of the glass transition and the crystalline ing point permits a fairly close estimate of the onset peratures and thus the effective maximum loadbe temperatures.

Dimensional stability at elevated temperatures

Material				Dimensional change due to heat aging—ASTM D1299					Coefficient of thermal expansion—ASTM D696				
Type of plastic	Supplier*	Trade name and grade designation	Description	Overall dimensions of test specimen, in.	Nominal dimension measured, in.	Aging temp., °C.	Aging time, hr.	Dimensional change (+ for expansion, − for shrinkage), %	Overall dimensions of test specimen, in.	Nominal dimension measured, in.	Annealing temp. if annealed before test, °C.	Test temp. range, °C.	Coeff. of linear thermal expansion (avg.), 10^{-6}/°C.
													43
ABS	Abtec	Abson 89116, 89200	Injection molding, medium impact										45
		Abson 89120	Injection molding, medium impact										47
		Abson 89130	Injection molding, medium impact										52
		Abson 89140	Injection molding, high impact										58
		Abson 89161	Injection molding, extra high impact										43
		Abson 89163	Extrusion, medium impact										43
		Abson 89165	Extrusion, appliance grade										58
		Abson 89170	Extrusion, high impact										58
		Abson 89171	Extrusion, extra high impact										40
		Abson 89030	Flame retarded, injection molding										40
		Abson 89035	Flame retarded, extrusion										46
		Abson 89129	Flame retarded, molding and extrusion						2 × ¼ × ¼	2		−30 to 30	20
	LNP	Thermocomp AF 1004	20% glass fiber reinforced						2 × ¼ × ¼	2		−30 to 30	16
		Thermocomp AF 1006	30% glass fiber reinforced						2 × ¼ × ¼	2		−30 to 30	12
		Thermocomp AF 1008	40% glass fiber reinforced						5 × ¼ × ¼	5		−30 to 30	47
Acetal	Celanese	Celcon M 90	Copolymer, injection molding						5 × ¼ × ¼	5		−30 to 30	47 (flow direction)
		Celcon GC-25A	Copolymer, 25% glass coupled injection molding							¼		−30 to 30	22 (transverse direction)
	LNP	Thermocomp KFX 1006	30% coupled glass fiber reinforced						2 × ¼ × ¼	2		−30 to 30	24
		Fulton 404	20% PTFE lubricated						2 × ¼ × ¼	2		30 to 30	54
Acrylic	Rohm & Haas	Plexiglas VS	Polymethyl methacrylate MC	9¼ × ½ × ¼ tensile bar		70 80 90 100	2 48 2 48 2 48 2 48	−0.1 −0.6 −8.0 −11 −13 −21 −18 −30	9¼ × ½ × ¼ tensile bar		50	−40 −29 −18 −7 4 15 27 38	52 54 58 61 65 68 74 83
		Plexiglas VM	Polymethyl methacrylate MC	9¼ × ½ × ¼ tensile bar		70 80 90 100	2 48 2 48 2 48 2 48	0.0 −0.2 −0.2 −0.5 −3.5 −8.0 −6.0 −13	9¼ × ½ × ¼ tensile bar		50	−40 −29 −18 −7 4 15 27 38	50 54 58 59 63 67 72 81
		Plexiglas V (811)	Polymethyl methacrylate MC	9¼ × ½ × ¼ tensile bar		70 80 90 100 110	2 48 2 48 2 48 2 48 2 48	0.0 −0.1 0.0 −0.1 −0.1 −0.3 −0.3 0.5 −4.0 −8.0	9¼ × ½ × ¼ tensile bar		50	−40 −29 −18 −7 4 15 27 38	49 52 56 58 61 65 70 76
		Plexiglas V (920)	Polymethyl methacrylate MC	9¼ × ½ × ¼ tensile bar		70 80	2 48 2 48	0.0 −0.1 0.0 −0.2	9¼ × ½ × ¼ tensile bar		50	−40 −29 −18 −7	49 52 [illegible] [illegible]

						80 100 110	2 48 2	-0.8 -1.0 -8.0				16 27 38	29 43
Acrylic (Cont'd)		Plexiglas V (811), V (920), V (052), V (600)	Polymethyl methacrylate MC						8½ × ½ × ½ tensile bar		50	-40 -29 -18 -7 4 15 27 38	49 52 56 58 61 65 70 77
		Implex A	Modified acrylic MC						8½ × ½ × ½ tensile bar		50	-40 -29 -18 -7 4 15 27 38	86 90 92 93 97 103 104 108
		Implex B	Modified acrylic MC						8½ × ½ × ½ tensile bar		50	-40 -29 -18 -7 4 15 27 38	72 74 77 81 85 88 92 94
		Implex C and F	Modified acrylic MC						8½ × ½ × ½ tensile bar		50	-40 -29 -18 -7 4 15 27 38	65 68 71 75 77 80 83 86
Alkyd MC	Am. Cyanamid	Glaskyd 1904	Glass reinforced, extruded						5 × ½ × ½	5	None	-30 to 30 30 to 100 100 to 150	15.9 11.0 7.7
		Glaskyd 3500	Glass reinforced, extruded						5 × ½ × ½	5	None	-30 to 30 30 to 100 100 to 150	16.8 24.7 18.3
CTFE	3M	Kel F 81	Molding and extrusion resin						5 × ½ × ½	5	None	-80 to 20 20 to 150	46 70
Nylon	Allied	Capron 8200	Type 6, g. p. injection molding	5 × ½ × ½	5	100	0.5	-0.07					83
		Capron 8202	Type 6, g. p. injection molding										83
		Capron 8202C	Type 6, fast cycle injection molding										81
		Capron 8230	Type 6, 6% glass, injection molding										59
		Capron 8231	Type 6, 15% glass, injection molding	5 × ½ × ½	5	180	0.5	-0.08					50
		Capron 8233	Type 6, 33% glass, injection molding	5 × ½ × ½	5	180	0.5	-0.06					38
		Capron 8266	Type 6, 60% glass and mineral, injection molding										31
	Belding	BCI Moleculoy 66 01	Type 6/6						5 × ½ × ½	5	105	30 to 80	80
		BCI 808/818	Type 6/6						5 × ½ × ½	5	70	20 to 50	81
		BCI 653	Copolymer						5 × ½ × ½	5	70	20 to 50	82
	Celanese	Celanese 1000	Type 6/6 injection molding						5 × ½ × ½	5	None	-30 to 30	50
	LNP	Thermocomp PF 1004	Type 6, 20% glass, injection molding						2 × ½ × ½	2		-30 to 30	22
		Thermocomp PF 1006	Type 6, 30% glass, injection molding						2 × ½ × ½	2		-30 to 30	17
		Thermocomp PF 1008	Type 6, 40% glass, injection molding						2 × ½ × ½	2		-30 to 30	12
		Thermocomp RF 1004	Type 6/6, 20% glass, injection molding						2 × ½ × ½	2		-30 to 30	23

* For full names and addresses of suppliers, see page 540

Dimensional stability at elevated temperatures (Cont'd)

Material				Dimensional change due to heat aging—ASTM D1299					Coefficient of thermal expansion—ASTM D696				
Type of plastics	Supplier*	Trade name and grade designation	Description	Overall dimensions of test specimen, in.	Nominal dimension measured, in.	Aging temp., °C.	Aging time, hr.	Dimensional change (+ for expansion, − for shrinkage), %	Overall dimensions of test specimen, in.	Nominal dimension measured, in.	Annealing temp. if annealed before test, °C.	Test temp. range, °C.	Coeff. of linear thermal expansion (avg.), 10^{-6}/°C.
Nylon (Cont'd)	LNP (Cont'd)	Thermocomp RF 1006	Type 6/6, 30% glass, injection molding						2 × ¼ × ¼	2		−30 to 30	18
		Thermocomp RF 1008	Type 6/6, 40% glass, injection molding						2 × ¼ × ¼	2		−30 to 30	14
		Thermocomp QF 1004	Type 6/10, 20% glass, injection molding						2 × ¼ × ¼	2		−30 to 30	27
		Thermocomp QF 1006	Type 6/10, 30% glass, injection molding						2 × ¼ × ¼	2		−30 to 30	15
		Thermocomp QF 1008	Type 6/10, 40% glass, injection molding						2 × ¼ × ¼	2		−30 to 30	12
		Thermocomp IF 1004	Type 6/12, 20% glass, injection molding						2 × ¼ × ¼	2		−30 to 30	27
		Thermocomp IF 1006	Type 6/12, 30% glass, injection molding						2 × ¼ × ¼	2		−30 to 30	15
		Thermocomp IF 1008	Type 6/12, 40% glass, injection molding						2 × ¼ × ¼	2		−30 to 30	12
		Thermocomp XF 1004	Amorphous, 20% glass, injection molding						2 × ¼ × ¼	2		−30 to 30	23
		Thermocomp XF 1006	Amorphous, 30% glass, injection molding						2 × ¼ × ¼	2		−30 to 30	18
		Thermocomp XF 1008	Amorphous, 40% glass, injection molding						2 × ¼ × ¼	2		−30 to 30	13
		Thermocomp VF 1004	Type 6/6 impact modified, 20% glass, injection molding						2 × ¼ × ¼	2		−30 to 30	25
		Thermocomp VF 1006	Type 6/6 impact modified, 30% glass, injection molding						2 × ¼ × ¼	2		−30 to 30	18
		Thermocomp VF 1008	Type 6/6 impact modified, 40% glass, injection molding						2 × ¼ × ¼	2		−30 to 30	16
Modified PPO	LNP	Thermocomp ZF 1004	20% glass, injection molding						2 × ¼ × ¼	2		−30 to 30	20
		Thermocomp ZF 1006	30% glass, injection molding						2 × ¼ × ¼	2		−30 to 30	14
		Thermocomp ZF 1008	40% glass, injection molding						2 × ¼ × ¼	2		−30 to 30	10
Polycarbonate	LNP	Thermocomp DF 1004	20% glass, injection molding						2 × ¼ × ¼	2		−30 to 30	15
		Thermocomp DF 1006	30% glass, injection molding						2 × ¼ × ¼	2		−30 to 30	13
		Thermocomp DF 1008	40% glass, injection molding						2 × ¼ × ¼	2		−30 to 30	10
Polyester, thermoplastic	LNP	Thermocomp WF 1004	PBT, 20% glass, injection molding						2 × ¼ × ¼	2		−30 to 30	13.5
		Thermocomp WF 1006	PBT, 30% glass, injection molding						2 × ¼ × ¼	2		−30 to 30	12.0
		Thermocomp WF 1008	PBT, 40% glass, injection molding						2 × ¼ × ¼	2		−30 to 30	10.5
Polyester, thermoset	Am. Cyanamid	Cyglas 605	Glass reinforced MC, extruded						5 × ¼ × ¼	5	None	−30 to 30 30 to 100 100 to 150	21.5 26.5 24.3
		Cyglas 610	Glass reinforced MC, extruded						5 × ¼ × ¼	5	None	−30 to 30 30 to 100 100 to 150	20.8 28.4 20.0
		Cyglas 820	Glass reinforced MC, bulk						5 × ½ × ½	5	None	−30 to 30 30 to 100 100 to 150	19.1 20.[illegible] 11.5
Poly[illegible]	LNP	Thermocomp FF 1004	20% glass, injection molding						2 × ¼ × ¼	2		−30 to 30	30
		Thermocomp FF 1006	30% glass, injection molding						2 × ¼ × ¼	2		−30 to 30	22
		Thermocomp FF 1008	40% glass, injection molding						2 × ¼ × ¼	2		−30 to 30	24

Polyimide, thermoset	Rhodia	Kerimid 601	Laminate, 181 E type glass fabric						8 × 4	4	250	20 to 250	50
		Kinel 4516	Injection molding, 3 mm. glass fiber reinforced						4 × ½ × ¼	4	200	0 to 300	40
		Kinel 5516	Compression and transfer molding, 3 mm. glass fiber reinforced						4 × ½ × ¼	4	200	0 to 300	15-30
		Kinel 5514	Compression molding, 3 mm. glass fiber reinforced						4 × ½ × ¼	4	250	0 to 300	13
		Kinel 5504	Compression molding, 6 mm. glass fiber reinforced						4 × ½ × ¼	4	250	0 to 300	14
		Kinel 5505	Compression molding, 25% graphite powder filled						4 × ½ × ¼	4	250	25 to 300	24
		Kinel 5508	Compression molding, 40% graphite powder filled						4 × ½ × ¼	4	250	25 to 300	24
		Kinel 5511	Compression molding, graphite powder and asbestos filled						4 × ½ × ¼	4	250	25 to 300	14
		Kinel 5517	Compression molding, graphite powder and M_0S_2 filled						4 × ½ × ¼	4	250	25 to 300	30
		Kinel 5518	Compression molding, PTFE filled						4 × ½ × ¼	4	250	25 to 300	48
PPS	LNP	Thermocomp OF 1006	30% glass, injection molding						2 × ½ × ¼	2		- 30 to 30	13
		Thermocomp OF 1008	40% glass, injection molding						2 × ½ × ¼	2		- 30 to 30	15
Poly-propylene	LNP	Thermocomp MFX 1004$_1$5	20% glass, chemically coupled, injection molding						2 × ½ × ¼	2		- 30 to 30	25
		Thermocomp MFX 1006$_1$5	30% glass, chemically coupled, injection molding						2 × ½ × ¼	2		- 30 to 30	21
		Thermocomp MFX 1008$_1$5	40% glass, chemically coupled, injection molding						2 × ½ × ¼	2		- 30 to 30	15
Poly-styrene	LNP	Thermocomp CF 1004	20% glass, injection molding						2 × ½ × ¼	2		- 30 to 30	22
		Thermocomp CF 1006	30% glass, injection molding						2 × ½ × ¼	2		- 30 to 30	18
		Thermocomp CF 1008	40% glass, injection molding						2 × ½ × ¼	2		- 30 to 30	16
Poly-urethane, TP	LNP	Thermocomp TF 1004	20% glass, injection molding						2 × ½ × ¼	2		- 30 to 30	45
		Thermocomp TF 1006	30% glass, injection molding						2 × ½ × ¼	2		- 30 to 30	25
		Thermocomp TF 1008	40% glass, injection molding						2 × ½ × ¼	2		- 30 to 30	15
SAN	LNP	Thermocomp BF 1004	20% glass, injection molding						2 × ½ × ¼	2		- 30 to 30	21
		Thermocomp BF 1006	30% glass, injection molding						2 × ½ × ¼	2		- 30 to 30	18
		Thermocomp BF 1008	40% glass, injection molding						2 × ½ × ¼	2		- 30 to 30	15
Sulfone polymers	ICI America	Victrex 200P, 300P, natural	Polyethersulfone, injection molding and extrusion	8½ × ½ × ¼	8½ ¼	200 200	7400 7400	None None	4 × ½ × ¼	¼	None	20 to 200	57
	LNP	Thermocomp GF 1004	Polysulfone, 20% glass, injection molding						2 × ½ × ¼	2		- 30 to 30	17
		Thermocomp GF 1006	Polysulfone, 30% glass, injection molding						2 × ½ × ¼	2		- 30 to 30	14
		Thermocomp GF 1008	Polysulfone, 40% glass, injection molding						2 × ½ × ¼	2		- 30 to 30	12
Urea MC	Plaskon	Plaskon SMG FLG	Compression molding, alpha cellulose filled	5 × ½ × ¼	5	77	98	- 0.8 to - 0.8				- 30 to 30	27

* For full names and addresses of suppliers, see page 510

Names and addresses of suppliers listed in Dimensional stability chart

Abbes Chemical Co., Wattersen Towers, 1930 Bishop Lane, Suite 916, Louisville, Ky., 40218 (502-456-1660)

Allied Chemical Corp., Specialty Chemicals Div., P.O. Box 1087R, Morristown, N.J., 07960 (201-455-2000)

American Cyanamid Co., Industrial Chemicals Div., 12600 Eckel Rd., P.O. Box 148, Perrysburg, Ohio 43551 (419-874-7941)

Borg Chemical Industries, Research Center, Putnam, Conn. 06260 (212-244-6040)

Celanese Plastics Co., P.O. Box 1000, Summit, N.J., 07901 (201-273-6600)

ICI Americas Inc., Concord Pike & New Murphy Rd., Wilmington, Del. 19897 (302 575-3000)

LNP Corp., 412 King St., Malvern, Pa., 19355 (215-644-5200)

Plaskon Products Inc. 2829 Glendale, Toledo, Ohio (419 382 5611)

Rhone-Poulenc Inc., Chemical Div., P.O. Box 125, Monmouth Junction, N.J. 08852 (201-297-0100)

Rohm and Haas Co., Independence Mall West, Philadelphia, Pa. 19105 (215 592 3000)

3M Co., 3M Center, 223-SW, St. Paul, Minn. 55101 (612-733-1110)

NOTE: Boldface listings identify advertisers in this issue.

Names and addresses of suppliers listed in Laminates chart, p. 530.

(1) American Acrylic Corp., 173 Marine St., Farmingdale, N.Y., 11735 (516-249-1129)
(2) Bergquist Co., 5300 Edina Industrial Blvd., Minneapolis, Minn. 55435 (612-835-2322)
(3) Brandywine Fibre Products Co., 15th and Poplar St., Wilmington, Del., 19801
(4) Budd Co., Plastics Div., 32055 Edward Ave., Madison Heights, Mich. 48071 (313-588-3200)
(5) CTL Dixie Inc., 1240 Glendale-Milford Rd., Cincinnati, Ohio 45215 (513-771-3200)
(6) Chomerics Inc., Dept. TR, 77 Dragon Ct., Woburn, Mass. 01801 (617-935-4850)
(7) **Cincinnati Milacron Chemicals Inc., West St., Cincinnati, Ohio, 45215 (513-554-1554)**
(8) Consoweld Corp., 700 Dura Beauty Lane, Wisconsin Rapids, Wis. 54494 (715-423-2900)
(9) Dodge Fluoroglas, Dodge Industries Inc., Oak Materials Group, McCaffrey St., Hoosick Falls, N.Y. 12090 (518-686-7301)
(10) Fibercast Co., Div. Youngstown Sheet & Tube Co., 25 South Main, P.O. Box 968, Sand Springs, Okla. 063 (918-245-6651)
(11) **General Electric Co., Laminated and Ins. ing Materials Business Dept., Coshocton, Ohio 412 (614-622-5310)**
(12) **General Electric Co., Silicone Products Dept., Waterford-Mechanicville Rd., Waterford, N.Y., 12188 (518-237-3330)**
(13) Gill, M.C., Corp., 4056 Easy St., El Monte, Calif. 91731 (213-283-4786)
(14) Glassteel Inc., 1727-T Buena Vista, Duarte, Calif. 91010 (213-357-3321)
(15) Glastic Corp., 4321 Glenridge Rd., Cleveland, Ohio 44121 (216-486-0100)
(16) Hexcel Tecna Corp., Precision Structures Div., 19819 84th Ave. South, Kent, Wash. 98031 (206-852-9500)
(17) Industrial Dielectrics Inc., 407 S. 7th St., P.O. Box 357, Noblesville, Ind. 46060 (317-773-1766)
(18) Keene Corp., Chase-Foster Div., 200 Amaral, East Providence, R.I., 02914 (401-434-2340)
(19) Lunn Industries Inc., Straight Path, Wyandanch, N.Y. 11798 (516-643-8900)
(21) Masonite Corp., Dept. TR-10, 29 N. Wacker, Chicago, Ill. 60606 (312-372 5642)
(22) Mer-L-Wood Corp., 8757 W. 55th St., Chicago, Ill. 60638 (312-585-7575)
(23) Morrison Molded Fiber Glass Co., 400 Common Wealth Ave., P.O. Box 508, Bristol, Va. 24201 (703-669-1181)
(24) NVF Co., Primary Products Div., Yorklyn Rd., Yorklyn, Del. 19736 (302-239-5281)
(25) Pioneer Plastics Corp., Pionite Rd., Auburn, Me. 04210 (207 784 9111)
(26) Plastic Fabrication Inc., 10300 Royalton Rd., Cleveland, Ohio 44133 (216-237-7951)
(27) Polyply Inc., RD #1, Amsterdam, N.Y. 12010 (518-843-3900)
(28) Quin-T Corp., P.O. Box 458, Joliet, Ill. 60434
(29) R/M Friction Mat'ls Co., Div. Raybestos-Manhattan Inc., 123 E. Stiegel St., Manheim, Pa. 17545
(30) SWS Silicones Corp., Sutton Rd., P.O. Box 428, Adrian, Mich. 49221 (517-263-5711)
(31) Schramm Plastic Products Inc., 8770 S.W. Burnham St., Tigard, Ore. 97223
(32) Spaulding Fibre Co., 310 Wheeler St., Tonawanda, N.Y. 14150 (716-692 2000)
(34) Swedlow Inc., 12122 Western Ave., Garden Grove, Calif. 92645 (714-893-7531)
(35) Synthane-Taylor Corp., an Alco Standard Co., P.O. Box 835, Valley Forge, Pa. 19482 (215-666-0300)
(36) Universal Oil Products Co., Route 17, East Rutherford, N.J. 07073
(37) Westinghouse Electric Corp., Hampton, S.C. 29924

NOTE: Boldface listings identify advertisers in this issue.

Temperature index[1]

Underwriters Laboratories elevated temperature index of plastic compounds, sheets, and laminates

Type	Material: Supplier[b]	Material: Trade name, grade designation, and color[1,4]	Material: Description	UL Temperature Index[1] — Maximum continuous use temperature under very low continuous or low intermittent stresses in applications requiring maximum retention of the properties indicated in the column headings below[1]: Both electrical and mechanical properties[1] — Temp. index, °C.	Thickness,[1] in.	Electrical properties and strength but not impact resistance[1] — Temp. index, °C.	Thickness,[1] in.	Electrical properties only[1] — Temp. index, °C.	Thickness,[1] in.
				70	0.080	80	0.080	80	0.060
ABS	Abtec	Abson—89125 (nc)		70	0.125	80	0.125	50	0.125
		Abson—89129 (ac)		50	0.062	50	0.062	50	0.062
		Abson—89130 (ac)		70	0.060	75	0.060	75	0.060
		Abson—89140 (ac)		50	0.058	50	0.058	50	0.054
	BASF Wyandotte	Terluran—877T (nc)		50	0.120	50	0.120	50	0.120
		Terluran—848S, 858T (nc)		50	0.055	50	0.055	50	0.065
		Terluran—967K (ac)		70	0.058	70	0.058	70	0.058
	Uniroyal	Kralastic—MHA, MHB, MV, MH, MVS K-2938 (ac)		75	0.120	75	0.120	75	0.120
				50	0.058	50	0.058	50	0.064
		Kralastic—SRS (nc), Arylon T (ac)		50	0.120	50	0.120	50	0.150
		Kralastic—MP-2603 (nc)	For electroplating	50	0.058	50	0.058	50	0.054
		Kralastic—FVM, FVJ (ac)	ABS/PVC blend	50	0.062	50	0.062	50	0.062
		Kralastic—MTA (nc)		70	0.058	70	0.058	70	0.064
	Borg-Warner[1]	Cycolac—GSE, GSM (ac)		50	0.058	50	0.058	50	0.054
		Cycolac—OH, T, TD, AH, DFA, X11, X17, LS, CIT, AM, DFA-R (ac)		50	0.058	50	0.058	50	0.054
		Cycolac—EP—3510, EPB—3570 (nc)	For electroplating	50	0.090	50	0.090	50	0.090
		Cycolac—KJA, KJAZ (ac)		50	0.120	50	[illegible]	50	0.120
		Cycolac—KJT, KJTZ (ac)		80	0.058	85	[illegible]	85	0.058
		Cycolac—KJB, KJB-Z (ac)		50	0.240	50	[illegible]	50	0.240
		Cycolac—Z-11, FBK, Z-77 (ac)	Rigid foam MC density 46.8 and 78.2 lb./cu. ft./min.						
				50	0.123	50	0.123	50	0.123
		Cycolac—KJD (ac)		50	0.064	50	0.064	50	0.064
		Cycoloy—X-37 (ac)		95	0.058	95	0.058	95	0.054
		Cycoloy—KHP, KHS (ac)	ABS/polycarbonate blend	50	0.058	50	0.058	50	0.058
		Cycoloy—800 (ac)	ABS/polycarbonate blend	80	0.058	80	0.058	80	0.058
		Cycovin—KA, KAF (ac)	ABS/PVC blend	75	0.058	75	0.058	75	0.058
		Cycovin—KAB (ac)	ABS/PVC blend	80	0.058	90	0.058	90	0.058
	Rexene	Rexene—500-FR-1 (ac), 504ESG, 505ESG, 707K, 727K, 808K, 810K (nc)		75	0.058	90	0.058	90	0.058
		Rexene—500-[illegible] (ac)		80	0.120				
				50	0.079	50	0.079	50	0.079
	Schuman	Polyman—RABS-90 680 (nc)		50	0.058	50	0.058	50	0.058
		Polyman—RABS-680 (nc)		50	0.067	50	0.067	50	0.067
		Polyman—511 (ac)	ABS/PVC alloy	65	0.062	95	0.062	95	0.062
		Polyman—506 (ac), 509 (gy)	ABS/PVC alloy	65	0.066	95	0.066	95	0.066
		Polyman—507 (ac)	ABS/PVC alloy	80	0.090	95	0.090	95	0.090
		Polyman—509 (ac)	ABS/PVC alloy	50	0.058	50	0.058	50	0.058
	Monsanto[1]	Lustran—240, 440, 640, 64, 740, 743, 461, 774, QE-507 (ac)		50	0.058	50	0.058	50	0.058
		Lustran—PG-299, PG-300, PG-298 (ac)	For electroplating	50	0.062	50	0.062	50	0.062
		Lustran—610, 630 (ac)		50	0.058	50	0.058	50	0.058
	Mobay	Novodur—PH/AT, PM, PMT		50	0.062	50	0.062	50	0.062
ABS film and sheet	Uniroyal[1]	Royalite—50							
	[redacted]								
Acetal	Celanese[1]	[redacted]							
				85	0.058	90	0.058	105	0.058
	Du Pont	Delrin—100, 150, 500, 550, 900, 907 (ac)		50	0.028	50	0.028	50	[illegible]
		Delrin—8010, 8020 (ac)		85	0.058	90	0.058	105	0.058
		Delrin—570, 577 (ac)	Glass-reinforced	85	0.058	90	0.058	105	0.058
		Delrin—AF (ac)	Acetal/TFE blend						

a—Abstracted from Underwriters Laboratories Recognized Components Index.

b—For full names and addresses of suppliers, see page 639

NOTE: Superior numbers refer to the explanatory notes on page 638

Material				UL Temperature Index[a]					
				Maximum continuous use temperature under very low continuous or low intermittent stresses in applications requiring maximum retention of the properties indicated in the column headings below[4]					
				Both electrical and mechanical properties[5]		Electrical properties and strength but not impact resistance[6]		Electrical properties only[7]	
Type	Supplier[b]	Trade name, grade designation, and color[1, 2]	Description	Temp. index, °C.	Thickness,[3] in.	Temp. index, °C.	Thickness,[3] in.	Temp. index, °C.	Thickness,[3] in.
Acrylic	Du Pont	Lucite—OKE-450 (nc, wh)	Acrylic/PVC blend	60	0.058	85	0.058	85	0.058
				70	0.120				
				50	0.058	50	0.058	50	0.058
	Rohm & Haas	Plexiglas—VS, VM, V-044, -045, -052, -415, -647-10, -811, -820 (al), DR (ct)		50	0.060	50	0.060	50	0.060
		Plexiglas—G (ct)		50	0.058	50	0.058	50	0.058
Acrylic film and sheet	Rohm & Haas	Plexiglas—VS, VM, V-044, -045, -052, -415, -647-10, -811, -820 (al), DR (ct)	Cast sheets	50	0.060	50	0.060	50	0.060
		Plexiglas—G (ct)	Cast sheet	50	0.062	50	0.062	50	0.062
		Kydex—100 (ac)	PVC alloy cast sheet	130	0.058	130	0.058	130	0.058
Alkyd	Allied[7]	Plaskon-AMC—422, 428, 446, 940 (nc)	Compression, injection, and transfer MC	130	0.020	130	0.020	130	0.020
		Plaskon-AMC—482 (nc)	Compression, injection, and transfer MC	130	0.028	130	0.028	130	0.028
		Synres—2560 (gn)	MC	130	0.058	130	0.058	130	0.058
		Synres—2103, 2152, 2250, 2259 (nc)	MC	130	0.030	130	0.030	130	0.030
	Am. Cyanamid[7]	Glaskyd—4001, 4001S (rd), 2001 (tn)		130	0.028	130	0.028	130	0.028
		Glaskyd—4000, 4000B, 1933, 1933-A, -C (wh)		130	0.058	130	0.058	130	0.058
		Glaskyd—1300, 1901, 1901-C, -D, -E, -F, 1901-1, 1907, 1907A (gn), 1902 (gy), 1904, 1904A (tn), 1910, 1910A (bl), 3510, 3510-A, -C (bk), 2601-C, (bl), -E, -F (tn), 1996, 2101, 2101-B, 2201-A (nc), 3001, 3001-C, -F, -G (rd), 3500, 3500-A, -C (wh)	Compression, injection, and transfer MC	130	0.020	130	0.020	130	0.020
	Durez	Durez—24150 (bk, bn)	MC	180	0.120	180	0.120	180	0.120
				130	0.058	130	0.058	130	0.058
		Durez—24525 (bk, bn)	MC	170	0.120	170	0.120	170	0.120
				130	0.058	130	0.058	130	0.058
		Durez—24337, 29276 (bk, bn)	MC	130	0.058	130	0.058	130	0.058
		Durez—24480 (bk, bn)	MC	155	0.120	155	0.120	155	0.120
				130	0.020	130	0.020	130	0.020
		Durez—27962 (bk, bn)	MC	130	0.058	130	0.058	130	0.058
	Plastics Eng. Co.	Plenco—1500 (tan, bk, bz)	MC	170	0.120	170	0.120	155	0.120
				130	0.020	130	0.020	130	0.020
		Plenco—1511, 1512 (bk), 1529 (tn)	MC	130	0.058	130	0.058	130	0.058
		Plenco—1505 (bk), 1522 (ac)	MC	130	0.058	130	0.058	130	0.058
	U. S. Polymeric	Polyal—3020, 3020F, 3036 (nc)	MC	130	0.060	130	0.060	130	0.060
DAP	Allied	Plaskon-Diall—52-70-70-VO, 73-70-70-VO (ac)	MC	130	0.065	130	0.065	130	0.065
		Plaskon-Diall—FS-10-VO (ac)	MC	130	0.062	130	0.062	130	0.062
		Plaskon-Diall—FS-40-VO (ac)	MC	130	0.058	130	0.058	130	0.058
		Synres—5201, 5251, 5501, 5551, 5805, 6101, 6651 (gn), 5553 (gy), 6601 (bl)	MC	130	0.058	130	0.058	130	0.058
	Durez	Durez—22781, 24778, 29429 (gn, bl, bk, gy)	MC	130	0.058	130	0.058	130	0.058
	Rogers	Rogers—RX-1360, -1360FR, -1365, -1365FR, -1366, -1366FR (nc)	MC	130	0.058	130	0.058	130	0.058
		Rogers—RX-1-540 (nc), -3-2-520 (bn), -3-501 (bl), -3-1-540 (gn), -3-1-525, -3-520 (bl), -1-501, -1-502 (bl), -2-520 (bn), -3-1-535 (bl)	MC	130	0.058	130	0.058	130	0.058
	U. S. Polymeric	Poly Dap—1M20F (nc)	Isophthalate MC	130	0.058	130	0.058	130	0.058
		Poly Dap—4120F, 6130F, 6160D, 6220 (nc)	Orthophthalate MC	85	0.058	85	0.058	55	0.028
Elastomers	Du Pont	Hytrel—5555 (nc)	Polyester elastomer	85	0.058	85	0.058	50	0.028
		Hytrel—5555HS (nc)	Polyester elastomer	55	0.058	75	0.058	55	0.028
		Hytrel—5556 (nc)	Polyester elastomer			80	0.120		

a—Adapted from Underwriters Laboratories Recognized Components Index

b—For full names and addresses of suppliers, see page 630.
NOTE: Superior numbers refer to the explanatory notes on page 638.

Temperature index[a] (Cont'd)

Type	Supplier[b]	Trade name, grade designation, and color[1,2]	Description	UL Temperature index[3]: Both electrical and mechanical properties[4] — Temp. index, °C.	Thickness,[5] in.	Electrical properties and strength but not impact resistance[6] — Temp. index, °C.	Thickness,[5] in.	Electrical properties only[7] — Temp. index, °C.	Thickness,[5] in.
				Maximum continuous use temperature under very low continuous or low intermittent stresses in applications requiring maximum retention of the properties indicated in the column headings below[3]					
Elastomers (Cont'd)	Monmouth	Em-Pee—E19-22 (gy) [redacted]	Thermoplastic rubber	50	0.058	50	0.058	50	0.058
				50	0.028	50	0.028	50	0.028
	Shell	Bexar—6011-1000 (nc), 6011-9001 (bk), X6021-1000 (nc)	Thermoplastic rubber	130	0.058	1?0	0.058	130	0.058
Epoxy	Allied[7]	Plaskon-Epoxy—1960 (nc)	MC	130	0.058	130	0.058	130	0.058
		Synres—3506 (bk)	MC	90	0.070	90	0.070	90	0.070
	Ampliflone	AC—70-1007 (nc)	Casting and encapsulant compound	130	0.058	130	0.058	130	0.058
	Ciba-Geigy	Araldite—XB-2728 (bk), NU-471, 475, NU-480 (bl, bk)	MC	90	0.058	90	0.058	90	0.058
		Ciba—XN1076/1077, NX1065/1066 (nc), XN1062/1038 (bk), XN1063/1075 (nc)	Casting compounds	90	0.047	90	0.047	90	0.047
		Ciba—XN1061/1038 (nc)	Casting compound	90	0.064	90	0.054	90	0.064
		Ciba—XN1042B/1043 (wh)	Casting compound	90	0.052	90	0.052	90	0.052
		Ciba—XN1078/1079 (bk)	Casting compound	130	0.058	130	0.058	130	0.058
	Fiberite	Fiberite—E-3810, E-3824, E-2748, -3838, -4353, -4354 (bk)	Glass-reinforced MC [redacted]	90	0.120	90	0.120	90	0.120
	Epic	Epic—R1000/H5000, R1008/H5000 (nc), R1009/H5003, R1022/H5010, R1024/H5011 (bk)	Casting resin	130	0.120	130	0.120	130	0.120
		Epic—P6000, P6002, P6003 (bk)	MC	130	0.058	130	0.058	130	0.058
	Gulf Oil	Gulf—1067, 1083, 1235, 1355 (nc)	Glass-reinforced SMC	90	0.131	90	0.131	90	0.131
	Hightemp Resins	Hightemp—5600 (wh)	Casting compound	105	0.031	105	0.031	105	0.031
	Hysol	Hysol—MH8F (bk)	MC	130	0.067	130	0.067	130	0.067
		Hysol—MH8-W588 (bk)	MC	130	0.062	130	0.062	130	0.062
		Hysol—MG8F (bk)	MC	105	0.058	105	0.058	105	0.058
		Hysol—ES-0306 (bk)	Casting compound	130	0.060	130	0.060	130	0.060
	Rostone[7]	Rosite—3350-A, -B, -C, -D, -E, -F, -FM (gy)	Glass-reinforced MC	130	0.058	130	0.058	130	0.058
	Morton	Polyset—150, 160, 170, 707, 707-1, -2, -4 (bk)	MC	130	0.062	130	0.062	130	0.062
		Polyset—115, 526 (bk)	MC	90	0.058	90	0.058	90	0.058
	Wakefield Eng.	Wakefield—152, 153 (bl)	Potting compounds	130	0.005	130	0.005	130	0.005
Epoxy coating resin	Armstrong Prod.[7]	Vibro-Flo—E-201, E-291, E-6051	Powder coating resins	105	0.004	105	0.004	105	0.004
		Vibro-Flo—E-7010	Powder coating resin	105	0.003	105	0.003	105	0.003
	Wakefield Eng.	Delta Coate—151	Coating resin[13]	110	0.003	110	0.003	110	0.003
		Delta Bond—152	Bonding resin; for use with Delta Coate 151[14,15]	130	0.003	130	0.003	130	0.003
				130	0.008	130	0.008	130	0.008
	Hysol	Dri-Kote—OK-4, -03, OK-7, -01, -R744, -W682 (gn)	Coating resins[9]	130	0.007	130	0.007	130	0.007
		Dri-Kote—OK12, -02, -03 (bl)	Coating resins[10]	120	0.007	120	0.007	120	0.007
		Dri-Kote—OK8 (bl)	Coating resin[11]	130	0.007	130	0.007	130	0.007
		Dri-Kote—OK15-0295, -0497, -0632 (bk, bn, gn)	Coating resins[12]	130	0.007	130	0.007	130	0.007
		Dri-Kote—OK15, -01, -02 (rd, bl)	Coating resins[12]	105	0.008	105	0.008	105	0.008
		Dri-Kote—OK1-02, OK-10 (rd, bl)	Coating resins[9]	130	0.007	130	0.007	130	0.007
	Mid-American	Micoron—611 (nc, bk, gn), 670 (bn)	Coating resins	130	0.008	130	0.005	130	0.005
	Polymer Corp.	Corvel—ECA-77, ECA-1283, ECB-1383, ECB-1363A, ECC-1363, 82031, 82038, 82038A, 82038B, 82063	Coating resins	130	0.006	130	0.005	130	0.005
		Corvel—LC-1368	Patching resin; for use with Corvel ECC-1363, ECB-1363A, 82038, 82063	130	0.006	130	0.005	130	0.005
	3M	Scotchcast—260, 261, 270, 271, 275, 5229, 5230, 263	Coating resins	130	—	130	—	130	—
		[illegible]—5096	Patching resin; for use with Scotchcast 260, 261, 263, 270						
	[redacted]								

a—Abstracted from Underwriters Laboratories Recognized Components Index

b—For full names and addresses of suppliers, see page 639.
NOTE: Superior numbers refer to the explanatory notes on page 638.

Material				UL Temperature index[a]					
				Maximum continuous use temperature under very low continuous or low intermittent stresses in applications requiring maximum retention of the properties indicated in the column headings below[1]					
				Both electrical and mechanical properties[1]		Electrical properties and strength but not impact resistance[1]		Electrical properties only[1]	
Type	Supplier[b]	Trade name, grade designation, and color[1,2]	Description	Temp. index, °C.	Thickness,[1] in.	Temp. index, °C.	Thickness,[1] in.	Temp. index, °C.	Thickness,[1] in.
Epoxy laminate	Cincinnati Milacron[1]	Cuniclad—2G (cr)	Glass mat	130	0.024	130	0.024	135	0.024
				105	0.004	105	0.004	105	0.004
	Sony	Sony-Flex—CF-2-0311 (nc)	Glass/epoxy film, sheet; also Cu-clad	105	0.008	105	0.008	105	0.008
		Sony-Flex—CF-2-0321 (nc)	Glass/epoxy film, sheet; also Cu-clad	105	0.062	105	0.062	105	0.062
	Universal Oil	UOP—G-1010-FRT (nc)	Epoxy/glass, sheet, rod, tube	150	0.120	150	0.120	150	0.120
Inorganic material	Rostone	Rosite—G, GCD, GM (gy), R, RCD, RM (bk)	MC	1093	0.120	1093	0.0120	1093	0.120
	Babcock & Wilcox	Kaowool (wh)	High and regular density inorganic	982	0.120	982	0.120	982	0.120
		Hi-R-Form—632-98-4 (wh)	Low density inorganic	150	0.131	150	0.131	150	0.131
	Garfield	Hemit (gy)	Cold MC	982	0.900	982	0.900	982	0.900
	Johns-Manville	Cerad (nc)	Low density inorganic	1232	0.240	1232	0.240	1232	0.240
	Quartz	Quartz—JCX31 (wh)	Low density inorganic	1038	0.250	1038	0.250	1038	0.250
	Rex Roto	Pyrasite	Low density inorganic	705	0.250	705	0.250	705	0.250
		Pyrowool	Low density inorganic	130	0.062	130	0.062	130	0.062
Melamine	Allied[1]	Plaskon—MIG-120 (bk)	MC	150	0.120	150	0.120	150	0.120
	Garfield	Kleemite (ac)	Cold MC	150	0.120	150	0.120	150	0.120
	Rostone	Rosite—2150 (wh), 2151 (bk)	Cold MC	150	0.058	150	0.058	150	0.058
	Plastics Eng. Co.	Plenco—744 (bn), 801 (wh)	MC	130	0.058	130	0.058	130	0.058
		Plenco—850, 852 (bn)	MC	150	0.040	150	0.040	150	0.040
		Plenco—757 (bn)	MC	130	0.058	130	0.058	130	0.058
Melamine phenolic	Plastics Eng. Co.	Plenco—701, 702 (rd), 706 (gn), 711 (bl), 712 (bn), 713, 718 (gy), 773 (gn), 777 (gy), 783 (bz)	MC	150	0.058	150	0.058	150	0.058
		Plenco—704, 705 (yl), 709 (bl), 714 (bn), 732, 741 (gy), 742 (bl), 755 (bn), 780, 782 (tn), 787 (wh), 785 (bl)	MC						
Nylon	Allied[1]	Capron—8200 HS-1, 8202 HS-1, 8203 HS-1, 8220 (ac)	Type 6 general-purpose, heat-stabilized MC	95	0.028	95	0.028	105	0.028
				105	0.050	105	0.050		
				95	0.028	95	0.025	105	0.028
		Capron—8202 C HS-1, 8203 C HS-1 (ac)	Type 6 fast-cycle, high-softness, heat-stabilized MC	105	0.050	105	0.050		
				95	0.028	95	0.025	105	0.028
		Capron—8253 HS-1 (ac)	Type 6 heat-stabilized, high-impact copolymer	105	0.058	105	0.058		
				75	0.058	85	0.058	105	0.028
		Capron—8200, 8202, 8202F, 8203 (ac)	Type 6 general-purpose MC	75	0.058	85	0.058	105	0.025
		Capron—8202C, 8203C (ac)	Type 6 fast-cycle, high-softness MC	75	0.058	85	0.058	105	0.025
		Capron—8253 (ac)	Type 6 high-impact copolymer	95	0.028	95	0.025	105	0.025
		Capron—8230 HS-1 (ac)	Type 6, 8% glass-reinforced, heat-stabilized MC	105	0.050	105	0.050		
				95	0.028	105	0.028	105	0.025
		Capron—8231 (ac)	Type 6, 14% glass-reinforced MC	105	0.058				
				95	0.028	130	0.028	130	0.028
		Capron—8233 (ac)	Type 6, 33% glass-reinforced MC	105	0.058	140	0.058	140	0.058
				75	0.058	85	0.058	105	0.028
		Capron—XP-788 (nc)	Type 6, 33% glass-reinforced MC	65	0.058	65	0.058	65	0.056
		Capron—8258 (ac)	Type 6 glass-reinforced copolymer	80	0.120	80	0.120	105	0.025
	Adell	Adell—AS-10-SW, AR-18-N (nc)	Type 6/6 MC	70	0.120	70	0.120	105	0.025
		Adell—AS-10-N, AS-10-N-1, AM-10 (ac)	Type 6/6 MC	65	0.028	65	0.028	65	0.028
		Adell—AG-18-882 (ac), AF-10-887, -887A, 887B (nc)	Type 6/6 MC	65	0.058	80	0.058	65	0.058
		Adell—AF-10-880 (ac), AI-10-N, AT-18-N (nc)	Type 6/6 MC	650	0.058	65	0.058	130	0.058
		Adell—BS-10-N (nc)	Type 6 MC	65	0.058	65	0.058	130	0.058
		Adell—BH-18 (ac)	Type 6 MC	70	0.058	65	0.058	130	0.025
	Schulman	Akulon—K2-ZG340, B3-X387, M2-ZG340 (nc)	Type 6	65	0.058	65	0.058	65	0.058
		Akulon—R600, R602, R700 (nc)	Type 6/6	100	0.058	100	0.058	110	0.025
		Akulon—R600W, R602W, R700W (nc)	Type 6/6	110	0.120	110	0.120		
		Akulon—K2-82V (nc)	Type 6 glass-reinforced	65	0.058	65	0.058	65	0.058

a—[illegible] Underwriters Laboratories Recognized Components Index.

b—For full names and addresses of suppliers, see page 639.
NOTE: Superior numbers refer to the explanatory notes on page 638.

Temperature index[a] (Cont'd)

Type	Material			UL Temperature index[f]					
				Maximum continuous use temperature under very low continuous or low intermittent stresses in applications requiring maximum retention of the properties indicated in the column headings below[g]					
				Both electrical and mechanical properties[h]		Electrical properties and strength but not impact resistance[i]		Electrical properties only[j]	
Type	Supplier[b]	Trade name, grade designation, and color[1,2]	Description	Temp. index, °C.	Thickness,[k] in.	Temp. index, °C.	Thickness,[k] in.	Temp. index, °C.	Thickness,[k] in.
Nylon (Cont'd)	Schuman (Cont'd)	Akulon—K2-62VW (nc)	Type 6 glass-reinforced	110	0.058	120	0.058	120	0.058
				120	0.120	130	0.120		
		Akulon—RV35W (nc)	Type 6/6 glass-reinforced	115	0.058	120	0.058	120	0.058
				125	0.120	130	0.120	130	0.120
		Akulon—RV35 (nc)	Type 6/6 glass-reinforced	65	0.058	65	0.058	65	0.058
	BASF Wyandotte	Ultramid—B3K (nc)	Type 6	75	0.058	85	0.058	105	0.028
		Ultramid—A3K (nc)	Type 6/6	75	0.058	85	0.058	105	0.028
		Ultramid—B3S, B3W (nc)	Type 6	65	0.058	65	0.058	65	0.058
		Ultramid—A3W (nc)	Type 6/6	65	0.058	65	0.058	65	0.058
		Ultramid—B3WG5, B3WG8 (nc)	Type 6 glass-reinforced MC	75	0.058	85	0.058	105	0.028
		Ultramid—B3WG7 (nc)	Type 6 glass-reinforced MC	90	0.058	105	0.058	105	0.028
		Ultramid—B3G7 (nc)	Type 6 glass-reinforced MC	65	0.058	65	0.058	65	0.058
		Ultramid—A3G7, A3HG5 (nc)	Type 6/6 glass-reinforced MC	65	0.058	65	0.058	65	0.058
		Ultramid—A3WG5, A3WG8 (nc)	Type 6/6 glass-reinforced MC	75	0.058	85	0.058	105	0.028
		Ultramid—A3WG7 (nc)	Type 6/6 glass-reinforced MC	90	0.058	105	0.058	105	0.028
		Ultramid—A3XG5, A3XG7 (nc)	Type 6/6 glass-reinforced MC	70	0.058	75	0.058	105	0.028
						80	0.120		
		Ultramid—A4H (nc)	Type 6/6	65	0.030	65	0.030	65	0.030
		Ultramid—A3KG21 (nc)	Type 6/6	65	0.058	65	0.056	65	0.056
	Mobay	Durethan—BK31SK, BK30S, BK40SK, BKV-30-N-1 (nc), BKV30, BKV35 (ac)	Type 6 molding resin	65	0.058	65	0.058	65	0.058
		Durethan—BKV30H (nc)	Type 6 molding resin	95	0.058	130	0.058	120	0.058
		Durethan—BKV35H (nc)	Type 6 molding resin	95	0.058	140	0.058	120	0.058
	Celanese[1]	Celanese—1000, 1000-4, 1200, 1300, 1310, N-224, N-186, 1310-4 (nc)	Type 6/6	75	0.058	85	0.058	105	0.028
		Celanese—1003 (nc)	Type 6/6	105	0.058	105	0.058	105	0.028
		Celanese—1500 (nc)	Type 6/6	75	0.058	85	0.058	105	0.028
		Celanese—1503, 1603 (nc)	Type 6/6	105	0.058	130	0.058	105	0.028
								130	0.120
		Celanese—1503 (nc, rd)	Foamed, type 6/6, minimum density 65.0 lb./cu.ft.	65	0.121	65	0.121	65	0.121
		Celanese—1603 (nc, rd)	Foamed, type 6/6, minimum density 68.6 lb./cu.ft.	65	0.121	65	0.121	65	0.121
	Custom Resins[1]	Custom—CRI-454, -601 (ac)	Type 6 MC	105	0.058	105	0.058	105	0.058
		Custom—CRI-401, -406 (ac)	Type 6 MC	80	0.058	80	0.058	130	0.028
		Custom—CRI-404, -409 (ac)	Type 6 MC	105	0.058	105	0.058	130	0.028
		Custom—CRI-451, -600 (ac)	Type 6 MC	80	0.058	80	0.058	80	0.058
	Du Pont[1]	Zytel—103HS1-L, E103HS-L (ac)	Type 6/6 heat-stabilized MC	95	0.028	95	0.028	130	0.028
				105	0.058	105	0.058		
						110	0.120		
		Zytel—42, 101, 101L, E101L, E101, 105, 106, 113, 122L, 131, 131L, E131L, FE-3073, -3117, -2887L (ac)	Type 6/6 molding and extrusion compounds	75	0.058	85	0.058	105	0.025
		Zytel—151, 151L, 153HS-L, 157HS-L, 158, 158L (nc)	Type 6/12	65	0.058	65	0.058	105	0.028
		Zytel—91HS1-L, 109L, 408, 211 (nc), 408HS (nc, bk), FE-4049BK-10 (bk)	Type 6/10 and copolymers	65	0.058	65	0.058	65	0.058
		Zytel—70G-13HS1-L, 70G-13L, 70G-13L8, 70G-33L, 70G-33HR-L, 70G-43L (nc)	Type 6/6 glass-reinforced MC	65	0.028	105	0.028	105	0.028
				105	0.058	120	0.058	120	0.058
		Zytel—70G-33HS1-L (nc)	Type 6/6 glass-reinforced MC	95	0.028	115	0.028	115	0.028
				105	0.058	125	0.058	125	0.058
						130	0.120	130	0.120
		Zytel—71G-13L, 71G-33L (nc)	Type 6/6 glass-reinforced MC	65	0.028	110	0.028	55	0.028
		Zytel—FE-5076 (nc, rd)	Type 6/6 glass-reinforced MC foamed, minimum density 60.7 lb./cu. ft.	65	0.247	65	0.247	65	0.247
		Zytel—E79G-13L (nc)	Type 6/6 glass-reinforced MC	65	0.058	90	0.058	90	0.058
		Zytel—FE-8008HS (ac)	Type 6/6	65	0.031	65	0.031	65	0.031

a—Abstracted from Underwriters Laboratories Recognized Components Index.

b—For full names and addresses of suppliers, see page 639
NOTE: Superior numbers refer to the explanatory notes on page 638

Type	Supplier[8]	Trade name, grade designation, and color[1, 2]	Description	UL Temperature Index[1]: Maximum continuous use temperature under very low continuous or low intermittent stresses in applications requiring maximum retention of the properties indicated in the column headings below[2] — Both electrical and mechanical properties[2]: Temp. index, °C.	Thick-ness,[3] in.	Electrical properties and strength but not impact resistance[2]: Temp. index, °C.	Thick-ness,[3] in.	Electrical properties only[2]: Temp. index, °C.	Thick-ness,[3] in.
Nylon (Cont'd)				65	0.028	65	0.028	65	0.028
	Du Pont[7] (Cont'd)	Zytel—FE-5081 (nc)	Type 6/6 glass-reinforced MC	65	0.058	65	0.058	110	0.058
		Minlon—10A-40 (nc)	Type 6/6 mineral-filled MC	65	0.028	65	0.028	105	0.028
		Minlon—10B-40, 10B1-40 (nc)	Type 6/6 mineral-filled MC	106	0.054	115	0.053	120	0.058
				115	0.120				
				65	0.028	65	0.028	105	0.028
		Zytel—FE-3016 (nc)	Type 6/10 and copolymers	85	0.058	90	0.058		
				65	0.032	65	0.032	65	0.032
		Zytel—ST-801 (ac)	Type 6/10 and copolymers	65	0.028	65	0.028	105	0.028
		Zytel—77G-33L, 77G-43L (nc)	Type 6/12 glass-reinforced MC			120	0.058	120	0.058
				80	0.031	85	0.031	105	0.031
	Fiberfil[7]	Xylon—FR (ac)	Type 6/6 molding resins	130	0.031	130	0.031	130	0.031
		Nylafil—G-1/30 (nc)	Type 6/6 glass-reinforced MC	85	0.062	65	0.062	65	0.062
		Nylafil—J-4/30/FR (ac)	Type 6/6 glass-reinforced MC	130	0.031	130	0.031	130	0.031
		Nylafil—G1/(10 to 34), J1/(10 to 34), G10/(35 to 45), J10/(35 to 45) (nc)	Type 6/6 glass-reinforced MC	140	0.031	140	0.031	140	0.031
		Nylafil—J-1/15/FR, J-1/16 to 19/FR, J-1/20-29/FR, J-1/30/FR (ac)	Type 6/6 glass-reinforced MC	105	0.058	105	0.058	105	0.028
	Firestone Synth. Fibers	Firestone—213-001, 415-001-HS	Type 6	106	0.054	130	0.058	130	0.028
		Firestone—430-001-HS	Type 6	95	0.028	95	0.028	130	0.028
	Am. Hoechst, Leominster	Fosta—457, 513, 1047, 1408, 1481 (nc)	Type 6	106	0.068	106	0.058		
				70	0.054	80	0.028	130	0.028
		Fosta—399, 436, 438, 446, 471, 475, 512, 578, 589, 851, 961 (nc)	Type 6			85	0.054		
				70	0.028	80	0.028	130	0.028
		Fosta—1016 (nc)	Type 6			85	0.058		
				66	0.058	65	0.058	65	0.058
	ICI Americas[7]	Maranyl—F114 (nc)	Type 6	75	0.058	65	0.054	105	0.028
		Maranyl—A100, A150, AD146, AD148, AD129, A125, AD153, AD225 (nc)	Type 6/6 molding resins	115	0.054	130	0.054	105	0.028
		Maranyl—A192/X/047, A190/X/047, A192/X/917-S (X = ac)	Type 6/6 glass-reinforced MC	120	0.120			130	0.058
				75	0.058	105	0.054	105	0.028
		Maranyl—A190/X/010 (X = ac)	Type 6/6 glass-reinforced MC	80	0.120				
				95	0.058	105	0.058	105	0.028
		Maranyl—A101, A127 (nc)	Type 6/6			110	0.120	110	0.120
				75	0.054	65	0.058	105	0.028
		Maranyl—A192/X/010, AD290 (X = ac)	Type 6/6 glass-reinforced MC	80	0.120				
				106	0.058	130	0.058	105	0.028
		Maranyl—AD197 (nc)	Type 6/6 glass-reinforced MC	110	0.120			130	0.058
				66	0.032	65	0.032	65	0.032
		Maranyl—AD407 (nc)	Type 6/6 MC	68	0.032	65	0.032	65	0.065
		Maranyl—AD447 (nc)	Type 6/6 glass-reinforced MC	75	0.058	85	0.058	105	0.028
		Maranyl—F193 (nc)	Type 6 glass-reinforced MC	50	0.031	50	0.031	100	0.031
	Kay-Fries	Trogamid T (nc)	Transparent, injection and blow molding extrusion	90	0.062	85	0.062		
				85	0.125	90	0.125		
				70	-0.062	85	0.062	130	0.062
	LNP[7]	Thermocomp—PF-100 (2 to 6), PF-1007, -1008 (ac)	Type 6 glass-reinforced MC	95	0.031	106	0.031	130	0.031
		Thermocomp—PF-100 (2 to 6) HS (nc)	Type 6 glass-reinforced, heat-stabilized MC	106	0.062	115	0.062		
				66	0.071	65	0.071	65	0.071
		Thermocomp—PD (2 to 6) 76-252 (nc)	Type 6/6 glass-reinforced MC	66	0.062	65	0.062	65	0.062
		Thermocomp—PD (2 to 6) 77-80 (1 to 8) (ac)	Type 6/6 glass-reinforced MC	115	0.061	115	0.061	130	0.061
		Thermocomp—RF100(1 to 6)-HS (nc)	Type 6/6 glass-reinforced, heat-stabilized MC	115	0.061	115	0.061	130	0.061
		Thermocomp—RF100(7 to 10)-HS (nc)	Type 6/6 glass-reinforced, heat-stabilized MC	125	0.120	125	0.120		
				65	0.061	65	0.061	65	0.061
		Thermocomp—QF 1008 (nc)	Type 6/10 glass-reinforced MC	96	0.023	65	0.028	105	0.028
	Monsanto[7]	Vydyne—R100, R106 (ac)	Mineral-reinforced MC						

1—Abstracted from Underwriters Laboratories Recognized Components Index

8—For full names and addresses of suppliers, see page 639
NOTE: Superior numbers refer to the explanatory notes on page 638

Type	Supplier[b]	Trade name, grade designation, and color[1,4]	Description	Both electrical and mechanical properties[5]: Temp. index, °C.	Both electrical and mechanical properties[5]: Thickness,[3] in.	Electrical properties and strength but not impact resistance[6]: Temp. index, °C.	Electrical properties and strength but not impact resistance[6]: Thickness,[3] in.	Electrical properties only[7]: Temp. index, °C.	Electrical properties only[7]: Thickness,[3] in.
				UL Temperature index[2] — Maximum continuous use temperature under very low continuous or low intermittent stresses in applications requiring maximum retention of the properties indicated in the column headings below[a]					
Nylon (Cont'd)	Monsanto[1] (Cont'd)	Vydyne—R220, R240, RP260 (nc)	Mineral-reinforced MC	90	0.028	105	0.028	105	0.028
		Vydyne—R200, R208 (ac)	Mineral-reinforced MC	85	0.028	95	0.028	105	0.028
				90	0.058	105	0.058		
		Vydyne—10C, 10H, 20H, 22H (ac)	Type 6/6 heat-stabilized MC	95	0.028	95	0.028	125	0.028
				105	0.058	105	0.058		
		Vydyne—10V, 20M, 20N, 20V, 21, 21X, 20NL, 21L (ac)	Type 6/6 molding and extrusion	75	0.058	85	0.058	105	0.028
		Vydyne—31A, 32A, 80X (ac)	Modified type 6/6 MC	75	0.058	85	0.058	105	0.028
		Vydyne—M-340, M-344 (ac)	Modified type 6/6 flame-retarded MC	75	0.058	85	0.058	105	0.028
		Vydyne—909 (bk)	Modified type 6/6 glass-reinforced MC	75	0.058	75	0.028	105	0.028
				80	0.120	95	0.058		
						105	0.120		
	North Sea Oil	Pozmlon—P9000 (nc, bk)	Type 6/6	95	0.058	105	0.058	105	0.028
		Pozmlon—1200E (nc)	Type 6/6	65	0.058	65	0.058	65	0.058
	Key-Fries	Trogamid—T (nc)	Molding resin	50	0.031	50	0.031	100	0.031
				80	0.062	85	0.062		
				85	0.125	80	0.125		
				65	0.063	65	0.063	65	0.062
	Nypel[1]	Nypel—1125FR (nc)	Type 6/6	70	0.125	50	0.125	80	0.125
				95	0.062	95	0.062	105	0.031
		Nypel—1114NC (nc)	Type 6/6	65	0.062	85	0.062	105	0.031
		Nypel—1125 SN, 1125 LU (nc)	Type 6/6	75	0.125				
				65	0.062	65	0.062	65	0.062
	Polymer Corp.	Nylatron—GS (nc)	Type 6/6 antifriction MC	65	0.058	65	0.058	65	0.058
	Rhodia	RPI—A-216 (nc)	Type 6/6	75	0.028	85	0.028	65	0.028
		RPI—A-217 (nc)	Type 6/6					105	0.058
				95	0.028	95	0.028	105	0.028
		RPI—A-218 (nc), A-218NOIR16 (bk)	Type 6/6	105	0.058	105	0.058	110	0.120
						110	0.120		
				65	0.062	65	0.062	65	0.062
		RPI—A-221, FE50279 (nc), FE50279NOIR (bk)	Type 6/6	65	0.058	65	0.058	65	0.058
		RPI—A-216V30, A-216V20 (nc)	Type 6/6 glass-reinforced MC	65	0.062	65	0.062	65	0.062
		RPI—FE50274 (nc), FE50274NOIR (bk)	Type 6/6 glass-reinforced MC	65	0.058	55	0.058	65	0.058
		RPI—B-216, B-217 (nc)	Type 6/66 copolymer MC	65	0.058	65	0.058	65	0.058
		RPI—[illegible]-216V30 (nc)	Type 6/66 copolymer glass-reinforced MC	65	0.060	65	0.060	55	0.060
		RPI—C-3116, C-216 (nc)	Type 6 MC	65	0.061	65	0.061	55	0.061
		RPI—C-216V20 (nc)	Type 6 glass-reinforced MC	65	0.058	65	0.058	55	0.058
		RPI—D-316, D-317 (nc)	Type 6/10 MC	65	0.058	65	0.058	55	0.058
	Rilsan[1]	Rilsan—BECN, BECN-TL, BESN, BESN-TL, BMN, BMN-TL (nc), BMN, BECN (bk)	Type 11	65	0.058	65	0.058	65	0.058
		Rilsan—BECN-P40, BMN-P20, BMN-P40 (nc)	Type 11	65	0.031	65	0.031	105	0.031
	Texapol	Texalon—6XX (X = color code) (ac)	Type 6	75	0.062	85	0.062		
				65	0.031	65	0.031	105	0.031
		Texalon—12XX (X = color code) (ac)	Type 6/6	75	0.062	95	0.062		
				65	0.031	65	0.031	105	0.031
	Wellman	Wellamide—66-22D-H, 66-22L-H, 66-21-L-H (nc)	Type 6/6 glass-reinforced MC	75	0.062	85	0.062		
				95	0.031	95	0.031	105	0.031
		Wellamide—66-22LH-H (nc)	Type 6/6 glass-reinforced MC	105	0.062	105	0.062	110	0.125
						110	0.125		
				65	0.016	65	0.016	65	0.016
		Wellamide—FR22F-H (nc)	Type 6/6 glass-reinforced MC					105	0.031
		Wellamide—GS25-66, GS40-66 (nc)	Glass sphere-reinforced MC	65	0.062	65	0.062	65	0.062

a—Abstracted from Underwriters Laboratories Recognized Components Index

b—For full names and addresses of suppliers, see page 639

NOTE: Superior numbers refer to the explanatory notes on page 634

Material				UL Temperature Index[1]					
				Maximum continuous use temperature under very low continuous or low intermittent stresses in applications requiring maximum retention of the properties indicated in the column headings below[2]					
				Both electrical and mechanical properties[2]		Electrical properties and strength but not impact resistance[2]		Electrical properties only[2]	
Type	Supplier[5]	Trade name, grade designation, and color[3,4]	Description	Temp. index, °C.	Thick-ness,[2] in.	Temp. index, °C.	Thick-ness,[2] in.	Temp. index, °C.	Thick-ness,[2] in.
Nylon (Cont'd)	Wellman (Cont'd)			65	0.062	65	0.062	65	0.062
		Wellamide—GS25-6/66 (nc)	Type 6-66 glass bead-reinforced MC	65	0.062	65	0.062	65	0.062
		Wellamide—FRGS25-66/6, FRGS25-66 (nc)	Glass-reinforced MC	65	0.032	95	0.032	105	0.032
		Wellamide—GF33-66 (nc)	Type 6/6 glass-reinforced MC	75	0.059	105	0.125		
				65	0.033	65	0.033	90	0.033
		Wellamide—FRGF25-66 (nc)	Type 6/6 glass-reinforced MC			105	0.125	95	0.125
				65	0.058	65	0.058	65	0.058
		Wellamide—42L-N, 42LH-N (nc)	Type 6 MC	220	0.002	220	0.002	220	0.002
Nylon film and sheet	Du Pont	Nomex—410 (nc)	Insulating paper	220	0.003	220	0.003	220	0.003
		Nomex—M (nc)	Insulating paper	220	0.006	220	0.006	220	0.006
		Nomex—411 (nc)	Insulating paper	220	0.007	220	0.007	220	0.007
		Nomex—414 (nc)	Insulating paper						
Other polymeric material	Molex	Molex	Bituminous MC	90	0.125	90	0.125	90	0.125
	Amoco	Torlon—4203, 4301 (nc) [redacted]	Polyamide-imide molding resins	50	0.046	50	0.046	50	0.046
	3M	Scotchcast—221, 222	Polyurethane potting resin	50	0.062	50	0.062	50	0.062
Phenolic	Durez			150	0.020	150	0.020	150	0.020
		Durez—11864 (bk, bn)	MC	170	0.120	170	0.120	170	0.120
				150	0.058	150	0.058	150	0.058
		Durez—19089, 21326, 22262, SI-56, 1329 (bk, bn)	MC	155	0.120	155	0.120	155	0.120
				150	0.60	150	0.060	150	0.060
		Durez—145, 30814 (bk, bn)	MC	150	0.020	150	0.020	150	0.020
		Durez—16090, 22065, SI-42, SI-45 (bk, bn), 156 (bk)	MC	150	0.040	150	0.040	150	0.040
		Durez—1306, SI-51 (bk, bn)	MC	[redacted]					
	DUREZ-791	[redacted] 792, 1544, 13527, 16274, [redacted] 18441, 22042, 22486, 22532, 22787, 30129, 123, 298, 21206, 22197, 22829, 23570, 27280, 26189, 29650, 29053, 29737, SI-11, -12, -16, -23, -28, -52, -54, -53, 13656, 111, 118, 161, 165, 21026, 30189 (bk), 740, 22257, 152, 153 (bk, bn)	MC	150 Am					
				150	0.020	150	0.020	150	0.020
	GTE Sylvania	GTE—UI-400-17 (gn), Sylvania 500 (bk, bn)		105	0.375	105	0.375	105	0.375
	Nicolet	Ebonized—Electrical board	Cold MC	150	0.058	150	0.058	150	0.058
	Fiberite	Fiberite—FM-4003 (bk, gn), FM-510, -3510 (bk)	MC	150	0.058	150	0.058	150	0.058
		Fiberite—FM-5064, -4649M, -1132, -1132P, -7700 (bk)	MC	150	0.058	150	0.054	150	0.058
		Fiberite—FM-4002, -4004, -4005, -4005M, 4005X4638, -4006, -4007, -4008, -4009, -4014, -4015, -4016 (bk, gn)	MC	150	0.138	150	0.138	150	0.136
	Garfield	Tegit (bn)	Cold MC	150	0.058	150	0.058	150	0.058
	General Electric, Pittsfield	GE—12899, 12968, 12977, 12979, 14013, 14016, 14019, 14020 (bk)	General-purpose MC						
		Genal—4000, 4050, 4200, 4000A, 4001 (bk), 6202, 4202 (bk, bn)		150	0.058	150	0.058	150	0.058
		GE—12983E, 12989E (bk, bn)	Medium heat-resistant MC	160	0.120	160	0.120	160	0.120
		Genal—4300E (bk, bn)		150	0.058	150	0.054	150	0.058
		GE—12583E, 12898 (bk)	Medium heat-resistant MC						
		Genal—4301E, 4310, 4304E, 4311 (bk)		150	0.058	150	0.058	150	0.058
	Plaskon	Plaskon—M-5303, S-5303, M-5440, S-5440, 201, 401, 504 (bk)		150	0.064	150	0.064	150	0.064
		Plaskon—202, 7990 (bk)		150	0.047	150	0.047	150	0.047
	Plastics Eng. Co.	Plenco—666 (bk)	MC	165	0.120	165	0.120	165	0.120
				150	0.020	150	0.020	150	0.020
		Plenco—586, 597, 586-AF (bn) (bk)	MC	150	0.058	150	0.054	150	0.058
		Plenco—343, 450, 509, 527, 582, 584 (bk), 558 (bn)	MC						

3. Abstracted from Underwriters Laboratories Recognized Component Index

5—For [illegible] name and address [illegible] see [illegible] 833
NOTE: S[illegible] numbers [illegible]

Temperature index[a] (Cont'd)

Material				UL Temperature index[a]					
				Maximum continuous use temperature under very low continuous or low intermittent stresses in applications requiring maximum retention of the properties indicated in the column headings below[c]					
				Both electrical and mechanical properties[c]		Electrical properties and strength but not impact resistance[c]		Electrical properties only[c]	
Type	Supplier[b]	Trade name, grade designation, and color[1,2]	Description	Temp. index, °C.	Thickness,[3] in.	Temp. index, °C.	Thickness,[3] in.	Temp. index, °C.	Thickness,[3] in.
Phenolic (Cont'd)	Plastics Eng. Co. (Cont'd)	Plenco—414, 466, 475, 485, 599, 685 (bk)	MC	150	0.058	150	0.058	150	0.058
		Plenco—649 (bk)	MC	150	0.058	150	0.058	150	0.058
				170	0.120	170	0.120	175	0.120
		Plenco—106, 300, 304, 307, 308, 321, 348, 349, 344, 369, 386, 397, 400, 417, 433, 440, 467, 478, 480, 482, 500, 503, 507, 512, 523, 528, 535, 544, 548, 557, 567, 564, 571, 582, 58½, 587, 2080, 5495 (bk), 317 (rd), 350 (gn), 328, 364, 384, 407, 411, 419, 549 (bn)	MC	150	0.058	150	0.058	150	0.058
	Reichhold	Reichhold—25000, 25001, 25040, 25041, 25346, 25347, 25348, 25378, 25379, 25406, 25407, 25010, 25011, 251128, 251138, 25002, 25114, 25170, 25171, 25018 (ac), 25005, 25151, 25157, 25397, 25207 (bn), 25150, 25156, 25388, 253100, 25116, 92518 (bk), 25004, 25006, 25008, 25408, 25158, 25202 (ac)	MC	150	0.058	150	0.058	150	0.058
				150	0.120	150	0.120	150	0.120
		Reichhold—25400 (bk)	MC	150	0.028	150	0.028	150	0.028
		Reichhold—25396, 92508M, 92938 (bk)	MC	150	0.020	150	0.020	150	0.020
		Reichhold—25506 (bk)	MC	150	0.058	150	0.058	150	0.058
	Resinoid Eng.	Resinoid—7001, 70035, 7005 (bk, gn)	MC	150	0.058	150	0.058	150	0.058
	Rogers	Rogers—RX-466, -468 (bk), -468A (bk, bn), -525, -950, -429, -444, -431, -462 (bk), 610HFR, -611FR, 650FR, -660FR (nc), -625, -611, -610H, -650, -680 (bk, gn), RX-630 (gn)		150	0.120	150	0.120	150	0.120
	Rostone	Rosite—2000 (bn), 2001, 2012 (bk), 2090 (tn)	Cold MC	150	0.060	150	0.060	150	0.060
	Valite	Valite—1246, 4100 (bk)	MC	105	0.125	105	0.125	105	0.125
Phenolic laminate	Masonite	Benelex—404	Ligno-cellulose laminate	90	0.125	90	0.125	90	0.125
		Benelex—401	Ligno-cellulose laminate	90	0.028	90	0.028	90	0.028
	Colonial Fiber	Colonial—S-350 (ac)	Cellulose fiberboard, sheet	90	0.010	90	0.010	90	0.010
	Cottrell	Copaco (nc)	Rag paper sheet	75	0.010	75	0.010	90	0.010
		Copaco—FR (nc)	Rag paper sheet	105	0.028	105	0.028	105	0.028
	Quin-T	Gardboard—V5 (nc)	Fiberboard, sheet	105	0.028	105	0.028	105	0.028
	Rogers	Duroid—800 (tn)	Cellulose fiberboard, sheet	90	0.028	90	0.028	90	0.028
		Duroid—225 (rd), 700 (gy), 100FR (gy, bk)	Cellulose fiberboard, sheet	90	0.015	90	0.015	90	0.015
		Duroid—100 (gy), 225FR (rd)	Cellulose fiberboard, sheet, roll	80	0.032	80	0.032	80	0.032
		Duroid—380TV (bg)	Cellulose fiberboard, sheet, roll	90	0.028	90	0.028	105	0.028
		Duroid—800FR (tn, bk)	Cellulose fiberboard, sheet, roll	105	0.028	105	0.028	105	0.028
		Duroid—850 (bn)	Cellulose fiberboard, sheet	80	0.062	80	0.062	80	0.062
		Duroid—2310 (bg)	Cellulose fiberboard, sheet	80	0.015	80	0.015	80	0.015
		Duroid—2310FR (bg)	Cellulose fiberboard, sheet	80	0.015	90	0.015	80	0.015
	Stevens	Grey Hites—H3-FR (gy)	Wood cellulose sheet	110	0.015	110	0.015	115	0.015
		Hites—VHR-115 (gy)	Wood cellulose sheet	105	0.028	105	0.028	105	0.028
	Johns-Manville	JM—T V Bord (nc)	Fiber insulation board	90	0.010	90	0.010	95	0.010
	Spaulding	Spauldo (bl)	Cotton fiberboard, sheet, roll	95	0.015	95	0.015	110	0.015
		Spaulding—29 (nc)	Cellulose fiberboard, sheet, roll	90	0.030	90	0.030	105	0.030
		Spaulding—29FR (nc)	Cellulose fiberboard, sheet, roll	75	0.030	75	0.030	90	0.030
		Spaulding—238FR (nc)	Cellulose fiberboard, sheet, roll	75	0.030	75	0.030	90	0.030
		Spaulding—238 (nc)	Cellulose fiberboard, sheet, roll	90	0.125	80	0.125	95	0.125
				90	0.031	90	0.031	90	0.031
		Spaulding—201, 201FR (nc)	Cellulose fiberboard, sheet, roll	80	0.015	80	0.015	80	0.015
		Spaulding—L, LFR (gy)	Cellulose fiberboard, sheet, roll	80	0.031	80	0.031	80	0.031
		Spaulding—200, 200FR (bl), XL25, XL25FR (nc)	Cellulose fiberboard, sheet, roll	90	0.020	90	0.020	90	0.020
		Spaulding—Electrite (nc)	Cellulose fiberboard, sheet, roll						

a—Abstracted from Underwriters Laboratories Recognized Components Index.

b—For full names and addresses of suppliers, see page 639

NOTE: Superior numbers refer to the explanatory notes on page 638

Type	Supplier	Trade name, grade designation, and color	Description	UL Temperature index: Both electrical and mechanical properties — Temp. index, °C.	Thickness, in.	Electrical properties and strength but not impact resistance — Temp. index, °C.	Thickness, in.	Electrical properties only — Temp. index, °C.	Thickness, in.
			Material — UL Temperature index: Maximum continuous use temperature under very low continuous or low intermittent stresses in applications requiring maximum retention of the properties indicated in the column headings below						
Phenolic laminate (Cont'd)			[redacted]	300	0.003	300	0.003	300	0.003
	Manning Paper	Manniternp—111 (nc)		130	0.003	130	0.003	300	0.003
		Manniternp—115 (nc)		105	0.062	105	0.062	105	0.062
	Universal Oil	UOP—XXXP-385-O (nc)	Paper/phenolic laminates—one side thermoplastic film-coated	105	0.031	105	0.031	105	0.031
		UOP—X-108 (nc)	Paper/phenolic laminates—semicured for post forming	105	0.030	110	0.030	110	0.030
Phenylene oxide-based resin	General Electric, Selkirk	Noryl—SEI-N, SEI-GFN1, SEI-GFN2N, SEI-GFN3N, EN-V125 (gy)	Modified MC	105	0.030	110	0.030	110	0.030
		Noryl—SE-1, SE-1-GFN2, SE-1-GFN3, EN-265 (ac)	Modified MC	90	0.058	105	0.028	105	0.025
		Noryl—731, ENG-265 (ac)	Modified MC	90	0.058	90	0.058	90	0.058
		Noryl—GFN2, GFN3 (ac)	Modified MC	80	0.120	95	0.058	95	0.058
		Noryl—SE-100N, EN-V100 (ac)	Modified MC	50	0.058	50	0.058	50	0.058
		Noryl—1005, MN-240, PX-1313 (ac)	Modified MC	50	0.249	50	0.249	50	0.249
		Noryl—PX-1193 (i)	Foamed, minimum density 53.1 lb./cu. ft.	50	0.248	50	0.248	50	0.248
		Noryl—PX-1270 (or)	Foamed, minimum density 53.1 lb./cu. ft.	65	0.240	65	0.240	65	0.240
		Noryl—FN-215 (gy)	Foamed, minimum density 46.9 lb./cu. ft.	80	0.090	95	0.060	95	0.060
		Noryl—N-225, SE-100, EN-212 (ac)	Modified MC	80	0.064	95	0.058	95	0.058
		Noryl—1005, N-190 (ac)	Modified MC	110	0.058	110	0.058	110	0.058
Polycarbonate	Fiberfil	Polycarbafil—G 50/40 (nc)	Glass-reinforced MC	115	0.058	125	0.058	125	0.058
		Polycarbafil—J50/10 to 30/FR/A to I (nc)	Glass-reinforced MC	125	0.058	125	0.058	115	0.058
		Polycarbafil—J54/10 (bk, nc)	Glass-reinforced MC	65	0.031	65	0.031	65	0.031
		Plastube—PC-50/TF/22 (nc)		125	0.062	125	0.062	115	0.062
				115	0.058	125	0.058	125	0.058
	General Electric, Plastics	Lexan—100, 101, 101R, 104, 121, 121R, 130, 124, 124R, 131, 140, 141, 141R, 144, 104R, 144R (nc, ac)		100	0.058	100	0.058	100	0.058
		Lexan—103, 103R, 123R, 143, 143R, 123 (nc, ac)		110	0.058	125	0.058	125	0.058
		Lexan—2014, 2014R (nc), ML-1665, 940 (ex, ct)		120	0.058	130	0.058	120	0.058
		Lexan—3412, 3413, 3414 (nc)	Glass-reinforced MC	115	0.058	125	0.058	125	0.055
		Lexan—500, 500R (ac)	Glass-reinforced MC	65	0.058	65	0.058	65	0.058
		Lexan—2814 (ac)	Glass-reinforced MC	65	0.120	65	0.120	65	0.120
		Lexan—943 (nc)		110	0.058	120	0.058	120	0.058
		Lexan—503 (ac)	Glass-reinforced MC	65	0.240	65	0.240	65	0.240
		Lexan—FL-910, FL-920 (nc)	Foamed, minimum density 51.2 lb./cu. ft.	65	0.240	65	0.240	65	0.240
		Lexan—FL-830 (nc)	Foamed, minimum density 54.7 lb./cu. ft.	65	0.240	65	0.240	65	0.240
		Lexan—MI-4028 (nc)	Foamed, minimum density 53.4 lb./cu. ft.	110	0.240	110	0.240	110	0.240
		Lexan—FL-900 (ac)	Foamed, minimum density 46.9 lb./cu. ft.	115	0.061	125	0.061	125	0.061
	LNP	Thermocomp—DF100 (1 to 6), DF1007, DF1008 (nc)	Glass-reinforced MC	115	0.058	125	0.058	125	0.058
	Mobay	Merlon—M-40, M-50, M-60, 6400, 6405, 6600, 6603, 6605 (ac)	General-purpose, flame-retarded	65	0.058	65	0.058	65	0.058
		Merlon—8310, 8313, 8315 (ac)	10% glass-reinforced MC	65	0.240	65	0.240	65	0.240
		Merlon—SF-600 (ac)	Foamed, minimum density 54.9 lb./cu. ft.	90	0.058	95	0.058	95	0.058
		Merlon—6410, 6415, 6417, 6610, 6615 (ac)	Flame-retarded	110	0.120	115	0.120	115	0.120
				115	0.058	130	0.058	130	0.058
		Merlon—9310, 9313, 9315 (ac)	10% glass-reinforced MC	65	0.067	65	0.067	65	0.067
	Fiberite	Fiberite—RTP-301, -307, -302, -303, -304, -305, -306 (ac)	Glass-reinforced MC						

a—Abstracted from Underwriters Laboratories Recognized Components Index

B—For full names and addresses of suppliers, see page 639
NOTE: Superior numbers refer to the explanatory notes on page 638

Temperature index[a] (Cont'd)

Type	Supplier[b]	Trade name, grade designation, and color[1,2]	Description	UL Temperature index[4]: Maximum continuous use temperature under very low continuous or low intermittent stresses in applications requiring maximum retention of the properties indicated in the column headings below[5] — Both electrical and mechanical properties[6]: Temp. index, °C.	Thickness,[3] in.	Electrical properties and strength but not impact resistance[7]: Temp. index, °C.	Thickness,[3] in.	Electrical properties only[8]: Temp. index, °C.	Thickness,[3] in.
Polycarbonate film and sheet	General Electric, Pittsfield	Lexan—9440 (nc)	Sheet	115	0.058	125	0.058	125	0.058
		Lexan—9600 (nc), F6000 (ex. ct)	Sheet	110	0.054	125	0.058	125	0.058
		Lexan—9030 (nc)	Sheet	100	0.058	100	0.058	100	0.058
		Lexan—GF-3000 (ac)	Sheet	65	0.058	65	0.058	65	0.058
		Lexan—8030 (ac)	Sheet	65	0.020	65	0.020	65	0.020
	Rohm & Haas	Tuffak (rd)	Sheet	65	0.011	65	0.011	65	0.011
		Tuffak (ct)	Sheet	65	0.031	65	0.031	65	0.031
		Tuffak (bk)	Sheet	65	0.065	65	0.065	65	0.065
Polyester (thermoplastic)	BASF Wyandotte	Ultradur—B4500, B4510 (nc)	PBT MC	50	0.058	50	0.058	50	0.058
		Ultradur—B4300-G2, -G4, -G6 (nc)	PBT glass-reinforced MC	50	0.054	50	0.056	50	0.054
		Ultradur—B4306G6 (ac)	PBT glass-reinforced MC	50	0.030	50	0.030	50	0.030
	Celanese[7]	Celanex—3300 (ac)	PBT MC	130	0.058	140	0.058	130	0.028
		Celanex—3211 (ac)	PBT MC	130	0.056	130	0.020	130	0.028
		Celanex—3311 (ac)	PBT MC	115	0.054	140	0.028	130	0.028
		Celanex—3310 (ac)	PBT MC	115	0.054	140	0.058	130	0.028
		Celanex—3210 (ac)	PBT	130	0.058	130	0.058	130	0.028
		Celanex—2011 (ac)	PBT	115	0.054	120	0.058	130	0.028
		Celanex—3200, 2005 (ac)	PBT MC	120	0.058	130	0.058	130	0.028
		Celanex—3310, 3210 (ac)	Foamed PBT, minimum density 68.0 lb./cu. ft.	50	0.120	50	0.120	50	0.120
	Ciba-Geigy	Ciba—5600, SK605 (ac)	PBT	50	0.058	50	0.058	50	0.058
	General Electric,[7] Pittsfield	Valox—310, -E, -M, -R (nc)	PBT MC	120	0.028	140	0.028	120	0.028
		Valox—420-SEO, -E, -M, -R (nc)	PBT MC	130	0.030	140	0.030	130	0.030
		Valox—310-SEO, -E, -M, -R (nc)	PBT MC	120	0.030	140	0.030	120	0.030
		Valox—DR-51, -E, -M, -R (nc), DR-451, -467 (nc)	PBT MC	120	0.028	140	0.028	120	0.028
				120	0.028	140	0.028	140	0.028
		Valox—POR-353, -E, -M, -R (nc)	PBT MC	120	0.028	140	0.028	120	0.028
		Valox—DR-48, -E, -M, -R (nc)	PBT MC	130	0.015	130	0.015	130	0.015
		Valox—420, 420-E, 420-M, 420-R (nc)	PBT MC	140	0.028	140	0.028	140	0.028
				110	0.058	125	0.058	125	0.028
		Valox—POR-353, -E, -M, -R (nc)	PBT foamed, minimum density 68.8 lb./cu. ft.	50	0.240	50	0.240	50	0.249
		Valox—FV-600 (wh)	PBT MC	115	0.031	[illegible]	0.031	140	0.031
				120	0.062				
	GAF	Gafite—140 (0, 1, 2) F, 150 (0, 1, 2) F, 180 (0, 1, 2) F (ac)	PBT MC	120	0.032	130	0.032	140	0.032
		Gafite—1400A, 140 (0, 1, 2), Z, 150A, 150 (0, 1, 2) Z, 1800A, 180 (0, 1, 2) Z (ac)	PBT MC	115	0.031	130	0.031	130	0.031
				120	0.062				
		Gafite—14 (1 to 5) (0, 1, 2) F, 15 (1 to 5) (0, 1, 2) F, 18 (1 to 5) (0, 1, 2) F (ac)	PBT MC	130	0.031	130	0.031	130	0.031
		Gafite—146 (0, 1, 2) F, 156 (0, 1, 2) F, 186 (0, 1, 2) F (ac)	PBT MC	120	0.032	130	0.032	130	0.032
		Gafite—14 (1 to 5) (0, 1, 2) Z, 15 (1 to 5) (0, 1, 2) Z, 18 (1 to 5) (0, 1, 2) Z (ac)	PBT MC	130	0.032	140	0.032	130	0.032
		Gafite—146 (1 to 5) Z, 156 (1 to 5) Z, 186 (1 to 5) Z (ac)	PBT MC	120	0.062	140	0.062	130	0.031
	LNP[7]	Thermocomp—WF100 (1 to 6) FR (nc, bk)	PBT MC	50	0.061	50	0.061	50	0.061
	Mobay	Pocan—B-4235, B-1505, B-2505, B-3235 (ac)	PBT	130	0.054	130	0.058	130	0.054
	Grace	Marco—E3000-2, E3000-3, E4000-2, E4000-3 (ac)	Glass-reinforced MC	130	0.054	130	0.058	130	0.058
	Cincinnati Dev. & Mfg.[7]	Insulrus—P-1001FR, P-3003FR (ac), P-5000G,P (nc, bk), P-6000FR, P-5003FR (ac)	MC	130	0.058	130	0.058	130	0.058
	Budd Plastics	Durez—LS-425-1 (ch. gy)	Glass-reinforced MC	130	0.054	130	0.058	130	0.058
	Fiberite	Fiberite—2660 (db)	Glass-reinforced MC	150	0.063	150	0.063	150	0.063
		Fiberite—FM-21288 (db)	Glass-reinforced MC	120	0.058	130	0.058	130	0.058
	Allied Mold. Prod.	Allied Molded—FRP-12002 (nc), -8 (bk)	Glass-reinforced MC bulk						

a—Abstracted from Underwriters Laboratories Recognized Components Index.

b—For full names and addresses of suppliers, see page 639.
NOTE: Superior numbers refer to the explanatory notes on page 634.

Type	Material			UL Temperature Index[2]					
				Maximum continuous use temperature under very low continuous or low intermittent stresses in applications requiring maximum retention of the properties indicated in the column headings below[7]					
				Both electrical and mechanical properties[7]		Electrical properties and strength but not impact resistance[7]		Electrical properties only[7]	
	Supplier[8]	Trade name, grade designation, and color[1,5]	Description	Temp. index, °C.	Thickness,[3] in.	Temp. index, °C.	Thickness,[3] in.	Temp. index, °C.	Thickness,[3] in.
				130	0.058	130	0.058	130	0.058
	Am. Cyanamid	Cyglas—501, 501E, 615, 620 (bk), 600, 2883 (nc)	Glass-reinforced MC	130	0.058	130	0.058	130	0.058
		Cyglas—303 (tn), 506, 506B (gy, 630 (rd), 605 (wh)	Glass-reinforced MC	130	0.028	130	0.028	130	0.028
		Cyglas—610 (bk, nc)	MC	130	0.070	130	0.070	130	0.070
	General Electric, Pittsfield	GE—1236-15, -22, -25, -28 (bk, rd,)	Sheet MC	130	0.058	130	0.058	130	0.058
	Glastic	Glastic—1401-A (ac), 1402-BE (rd), 1402-AR (bk), 1403-DO, -DE, -DF, -ED (bk, rd, gy), 1403F (ac), 1404-JF (tn), 1406-BE, -CE (rd), -DO, -DF, -ED, -EF, -GD, -GF (bk, gy), -DA (wh), 1410-BB, -DD (tn, bk), -FD, -FE, -FF (bk, rd, bl), -E (ac), 1411-A (bk), 1412-A (ac), -BF (gn), 1423A (ac), 1603-G (ac)	Reinforced MC	100	0.090	100	0.090	100	0.090
	Goodyear	Goodyear—J-3550 (ew), J-6168 (ac)	Sheet MC[14]	130	0.034	130	0.034	130	0.034
	Durez	Durez—BC100/-30179, BC200/-30249, BC202/-30339 (ac)	Bulk MC	130	0.028	130	0.028	130	0.028
		Durez—BC201/-30287, BC204/-30300 (ac)	Bulk MC	130	0.062	130	0.062	130	0.062
	Guardian Elec.	Guardian—S-PRC-112, -119	Glass-reinforced MC	130	0.062	130	0.062	130	0.062
	Haveg	Haveg—HM-9300-22, -30 (ac)	MC	130	0.060	130	0.060	130	0.060
		Haveg—HM-9310-22, -30 (nc)	MC	130	0.058	130	0.058	130	0.058
	Armco	Haveg—8000, 8001, 8002, 8003 (nc), 8033, 74202, 8041, 74203 (gy)	Glass-reinforced MC	130	0.120	130	0.120	130	0.120
	Haysite	Haysite—133, 136-1F (nc)	Glass-reinforced MC	130	0.058	130	0.058	130	0.058
		Haysite—200-FR, -FRWR, 250-FR, -FRWR, 260-FR, -FRWR, 141-SE, -SEWR, -158, -15 BWR, -308, -308WR, 166, 167 (bk)	Glass-reinforced premix MC	130	0.058	130	0.058	130	0.058
		Haysite—400, 405, 408, 420, 425, 428, 511, 515, 518, 480WR, 485WR, 488WR, 500WR, 505WR, 508WR (rd)	Glass-reinforced sheet MC	100	0.060	100	0.060	100	0.060
		Haysite—170, 470 (all nonmetallic colors)	Glass-reinforced MC[14]	130	0.058	130	0.058	130	0.058
	Int'l Dielectrics	Dielectrite—4850 (ac), 46-3, 46-0 (ac), 44-1 (nc)	Reinforced MC	130	0.062	130	0.062	130	0.062
		Dielectrite—46-12 (bk, nc)	Bulk MC	130	0.052	130	0.052	130	0.052
		Dielectrite—46-12 (wh)	Bulk MC	130	0.120	130	0.120	130	0.120
		Dielectrite—44-10 (ac)	Bulk MC	130	0.066	130	0.066	130	0.066
		Dielectrite—48-56 (ac)	Bulk MC	130	0.062	130	0.062	130	0.062
	Kenro	Kenrac—37-5000	Glass-reinforced MC	130	0.050	130	0.050	130	0.050
	Koppers	Koppers—SP-325 (nc)		130	0.058	130	0.058	130	0.058
	LOF Eng. Prod.	LOF—600-B2 (ac), -B3 (gy, rd), 700-B2, -B3 (ac)	Reinforced MC	130	0.058	130	0.058	130	0.058
	Marred	Marred—LA Grey	Glass-reinforced MC	130	0.058	130	0.058	130	0.058
	PPG Industries	Selectron—SR-6118 (ac)	Glass-reinforced MC	130	0.068	130	0.068	130	0.068
	Perstorp U.S.	Perapal—HP A-200 (nc), -220 (nc, gy)	MC	130	0.058	130	0.058	130	0.058
	Plastics Eng. Co.	Plenco—1523 (bk, wh)	MC	130	0.100	130	0.100	130	0.100
	Plasgage	Hether-Lite—802-5588, 802-5874 (nc)	Glass-reinforced compound	160	0.120	160	0.120	130	0.120
	Plumb	Fibercore—F5010, F5010A (nc)	Glass-reinforced compound	130	0.058	130	0.058	130	0.058
		Fibercore—F4012, F8002 thru 8 (nc), F8802 thru 14 (ac), F8005, LX530M (nc), F6802A thru F8514A (ac)	Glass-reinforced compound	156	0.005	156	0.005	156	0.005
	Polymer Corp.	Carvel—1003 (nc)	Coating resin	130	0.058	130	0.054	130	0.058
	Polyply	Polyply—SM-530 (rd)	Sheet MC	130	0.062	130	0.062	130	0.062
	Premix	Prem-Glas—2000-Y-CR-SX (ac) (Y = 10 to 30 glass content)	Glass-reinforced bulk MC	130	0.060	130	0.060	130	0.060
		Prem-Glas—2100-Y-CR-SX (ac) (Y = 10 to 30 glass content)	Glass-reinforced bulk MC	130	0.060	130	0.060	130	0.060
		Prem-Glas—2200-Y-CR-SX (ac) (Y = 10 to 30 glass content)	Glass-reinforced sheet MC	130	0.062	130	0.062	130	0.062
		Prem-Glas—3100-Y (nc) (Y = 10 to 30 glass content)	Glass-reinforced bulk MC						

[illegible] Underwriters Laboratories Recognized Components Index

8—For full names and addresses of suppliers, see page 639
NOTE: Superior numbers refer to the explanatory notes on page 625

Temperature index[a] (Cont'd)

Material				UL Temperature index[1]					
				Maximum continuous use temperature under very low continuous or low intermittent stresses in applications requiring maximum retention of the properties indicated in the column headings below[2]					
				Both electrical and mechanical properties[6]		Electrical properties and strength but not impact resistance[6]		Electrical properties only[6]	
Type	Supplier[b]	Trade name, grade designation, and color[1,4]	Description	Temp. index, °C.	Thickness,[3] in.	Temp. index, °C.	Thickness,[3] in.	Temp. index, °C.	Thickness,[3] in.
[illegible]	Promix (Cont'd)	Promi-Glas—3200-Y (nc) (Y = 10 to 30 glass content)	Glass-reinforced sheet MC	130	0.062	130	0.062	130	0.062
		Promi-Glas—3000-Y (ac) (Y = 10 to 30 glass content)	Glass-reinforced bulk MC	130	0.062	130	0.062	130	0.062
		Promi-Glas—2102-Y-CR-SX (ac) (Y = 10 to 30 glass content)	Glass-reinforced bulk MC[14]	100	0.060	100	0.060	100	0.060
		Promi-Glas—2103-Y-CR-SX, 2104-Y-CR-SX (ac) (Y = 10 to 30 glass content)	Glass-reinforced bulk MC[14]	100	0.100	100	0.100	100	0.100
		Promi-Glas—2202-Y-CR-SX (ac) (Y = 10 to 30 glass content)	Glass-reinforced sheet MC[14]	100	0.060	100	0.060	100	0.060
		Promi-Glas—2203-Y-CR-SX, 2204-Y-CR-SX (ac) (Y = 10 to 30 glass content)	Glass-reinforced sheet MC[14]	100	0.100	100	0.100	100	0.100
	Quality Control Ind.	Q-Mat—700-20 (ac), 700-30 (nc, rd, gy)	Glass-reinforced sheet MC	130	0.070	130	0.070	130	0.070
	Reichhold	Polylite—90661, 90662, 90695 (bk)	Molding powder	130	0.058	130	0.058	130	0.058
	Rostone[7]	Rostite—3200-A, -B, -C, -D, -E, -F, -FM, 3250-A, -B, -C, -D, -E, -F, -FM, 3255-A, -B, -C, -D, -E, -F, -FM, 3400-A, -B, -C, -D, -E, -F, -FM, 3450-A, -B, -C, -D, -E, -F, -FM, 3500-A, -B, -C, -D, -E, -F, -FM, 3550-A, -B, -C, -D, -E, -F, -FM, 3658-A, -B, -C, -D, -E, -F, -FM (gy), 3240-C (bk), 3550-LWR (bk, nc, wh), 3458-A, -B, -C, -D, -E, -F, -FM (gy), 3650D (wh, bk, rd), 3660FM (gy, rd)	Glass-reinforced MC	130	0.060	130	0.060	130	0.060
				130	0.028	130	0.028	130	0.028
	Singer	Singer—SRC-1 (ac)		130	0.037	130	0.037	130	0.037
		Singer—SRC-2, -3 (ac)		130	0.055	130	0.055	130	0.055
	Somerville	Somerville—E-6001-22 (ew), E-6022-22 (gy), E-6006-22 (bk)		130	0.062	130	0.062	130	0.062
	Midland Ross	Unit—P4015-I	Glass-reinforced MC	130	0.054	130	0.058	130	0.054
	Westinghouse	Westinghouse—MS3836-RB (gy), -RF (gy, nc), RG (gy, bk), -RH (gy, bk), -RJ (bk)	Glass-reinforced MC	160	0.058	160	0.058	130	0.058
	Westinghouse	Micarta—SM120 (gy)	Glass-reinforced MC	130	0.058	130	0.058	130	0.058
		Micarta—SM-152, -153, -154, -155, -163 (ac)	Glass-reinforced MC	100	0.090	100	0.090	100	0.090
	Woodall	Formadall—1415 to 1422, 1415A to 1422A (ex. bk)	Bulk MC[14]	130	0.054	130	0.058	130	0.058
	Zehrco	Zehrco—Z-3800 (nc), Z-6000-15, -22, -28 (ac)	Glass-reinforced MC	130	0.031	130	0.031	130	0.031
		Zehrco—Z-3920 (nc)	Glass-reinforced MC	100	0.060	100	0.060	100	0.060
		Zehrco—3800-20 (nonmetallic colors)	Glass-reinforced MC[14]	105	0.040	105	0.040	105	0.040
Polyester (thermoset) laminate	Cincinnati Milacron[7]	Cimclad—M, M-1, M-7 (ac), M (FR) (lg), M-7 (FR) (cr, bk), M-71 (FR), M8-(FR) (cr), C, C-7 (ac)	Glass-reinforced sheet	105	0.028	105	0.028	105	0.028
	Cincinnati Dev. & Mfg.	Industrue—X-3 (nc)	Reinforced sheet	130	0.058	130	0.058	130	0.058
				105	0.028	105	0.028	105	0.028
		Industrue—X2FR, X2FR-PG (ac)	Reinforced sheet	160	0.058	160	0.058	130	0.058
				105	0.028	105	0.028	105	0.028
		Industrue—XTRK (nc)	Reinforced sheet	130	0.058	130	0.058	130	0.058
	Budd Plastics	Durastic—OSM-725 (wh), 725-1 (bg, gy)	Glass-reinforced sheet	130	0.090	130	0.090	130	0.090
		Durastic—OSM-745 (gy)	Glass-reinforced sheet	50	0.028	50	0.028	50	0.028
	Polygon	Polygon—EG-10-GL	Glass filament, rod	130	0.057	130	0.057	130	0.057
				105	0.056	105	0.056	105	0.056
	Haysite	Haysite—ESA-5 (bl)	Glass-reinforce.	95	0.028	95	0.028	95	0.028
	Morrison	Morrison—1352 (rt, wh, rd), 1363 (rt, wh)	Glass fiber-reinforced	105	0.058	105	0.058	105	0.058
		Morrison—525	Pultruded glass-reinforced, sheet, parts	130	0.058	130	0.058	130	0.058
	General Electric,[7] Coshocton	GE—PC-75 (tn)	Glass-reinforced	115	0.028	115	0.028	115	0.028
				120	0.058	120	0.058	120	0.058
		GE—PC-75G (bl, tn)	Glass-reinforc.	140	0.028	140	0.028	140	0.028

a—Abstracted from Underwriters Laboratories Recognized Components Index.

b—For full names and addresses of suppliers, see page 639.
NOTE: Superior numbers refer to the explanatory notes on page 638.

Material				UL Temperature index[2]					
				Maximum continuous use temperature under very low continuous or low intermittent stresses in applications requiring maximum retention of the properties indicated in the column headings below[7]					
				Both electrical and mechanical properties[4]		Electrical properties and strength but not impact resistance[5]		Electrical properties only[6]	
Type	Supplier[b]	Trade name, grade designation, and color[1,8]	Description	Temp. index, °C.	Thickness,[3] in.	Temp. index, °C.	Thickness,[3] in.	Temp. index, °C.	Thickness,[3] in.
Polyester (thermoset) laminate (Cont'd)				130	0.062	130	0.062	130	0.062
	Pultrusions	Glasspul—GFP-1, GFP-1A	Pultruded glass-reinforced	90	0.031	90	0.031	[illegible]	0.031
	Universal Oil	UOP—TL-1528 (nc)	Glass-reinforced sheet	140	0.062	140	0.062	105	0.062
				130	0.120	130	0.120	130	0.120
	Westinghouse	Westinghouse—FR, FM (gr), TR, TM (wh)	Pultruded glass-reinforced	130	0.125	130	0.125	130	0.125
	B.B.I.	BBI—180	Pultruded high density glass-reinforced	50	0.050	50	0.050	50	0.050
PE	Chemplex	Chemplex—6001 HDPE (nc)	High density MC	50	0.062	50	0.062	50	0.062
	USI	Flamolin—511, 855	Molding and extrusion high density compounds	50	0.010	50	0.010	50	0.010
		Flamolin—711	Crosslinked, rotational molding, high density compound	150	0.007	150	0.007	150	0.007
PE-CTFE	Allied[7]	Halar—100, 200, 300, 400, 500, 5001, 5032 (nc)				180	0.058	180	0.058
				180	0.062	170	0.062	170	0.062
PE-TFE	Du Pont	Tefzel—200, 280, 210 (nc)	Film, sheet, rod	105	0.0005 to 0.007	105	0.0005 to 0.007	105	0.0005 to 0.007
Polyethylene terephthalate film and sheet	Celanese	Celanar, Celanar 2000 (nc)		105	—	105	—	105	—
	Am. Hoechst, Somerville	Hostaphan—RN, WN	Film, sheet	105	—	105	—	105	—
	ICI Americas	Melinex—0.284, S, 377, 288 (nc)	Film, sheet	105	—	105	—	105	—
	Du Pont	Mylar—A, C, EL, EB-11, MO, WC, WCT, WC-11, WC-22, T, HS (nc)	Film	105	0.007	105	0.007	105	0.007
			Film, sheet	106	0.007	106	0.007	105	0.007
	Rhodia	Terphane	Film	106	0.003	105	0.003	105	0.005
	3M	Scotchpar—2570	Film	210	0.002	210	0.002	240	0.002
	Sheldahl	Sheldahl—GT5500, GT5575	Film	210	0.003	210	0.003	240	0.003
Polyimide film and sheet	Du Pont	Kapton—200F919 (nc)	Film	210	0.005	210	0.005	240	0.005
		Kapton—300F929 (nc)	Film	210	0.006	210	0.006	240	0.006
		Kapton—500F131, 500H (nc)	Film	200	0.0015	200	0.0015	240	0.0015
		Kapton—800F051 (nc)	Film	200	0.002	200	0.002	240	0.002
		Kapton—150F019 (nc)	Film	200	0.003	200	0.003	240	0.003
		Kapton—200F011 (nc)	Film	200	0.004	200	0.004	240	0.004
		Kapton—300F021 (nc)	Film	200	0.001	200	0.001	230	0.001
		Kapton—400F022, 400F031 (nc)	Film	200	0.002	200	0.002	230	0.002
		Kapton—100H (nc)	Film	200	0.003	200	0.003	230	0.003
		Kapton—200H (nc)	Film						
		Kapton—300H (nc)		170	0.058	170	0.058	170	0.058
Polyphenylene sulfide	Phillips	Ryton—R-4 (bn)	Glass-reinforced MC	50	0.015	50	0.015	50	0.015
		Ryton—R-8 (bn)	Glass-reinforced MC	200	0.065	200	0.054	200	0.058
				115	0.028	115	0.025	115	0.028
Polypropylene	ARCO/Polymers	ARCO—PPSX21 (nc) (X = 5 to 8)		115	0.028	115	0.028	115	0.028
		ARCO—PPSX22 (nc) (X = 5 to 8)		120	0.058	120	0.054	120	0.054
				110	0.028	110	0.028	110	0.028
		ARCO—PPSX0T2 (nc) (X = 5 to 8)	Talc-filled	105	0.028	105	0.028	105	0.028
		ARCO—PPSX0T4 (nc) (X = 5 to 8)	Talc-filled	100	0.058	100	0.054	100	0.058
		Plaskon—FR-1083 (nc)	Flame-retarded MC	105	0.058	105	0.058	105	0.058
	Allied	Plaskon—FR-1083 (nc)	Flame-retarded MC	80	0.020	80	0.020	80	0.020
				90	0.048	90	0.046	90	0.046
	Amoco	Amoco—6014, 6114 (nc)		100	0.051	100	0.051	100	0.051

a—Abstraction from Underwriters Laboratories Recognized Component Index

b—For full names and addresses of suppliers, see page 639

NOTE: Superior numbers refer to the explanatory notes on page [illegible]

Temperature index[a] (Cont'd)

Type	Supplier[b]	Trade name, grade designation, and color[1,2]	Description	Both electrical and mechanical properties: Temp. index, °C.	Both electrical and mechanical properties: Thickness,[3] in.	Electrical properties and strength but not impact resistance: Temp. index, °C.	Electrical properties and strength but not impact resistance: Thickness,[3] in.	Electrical properties only: Temp. index, °C.	Electrical properties only: Thickness,[3] in.
Material				UL Temperature index[3]: Maximum continuous use temperature under very low continuous or low intermittent stresses in applications requiring maximum retention of the properties indicated in the column headings below[4]					
				95	0.046	95	0.046	95	0.046
Polypropylene (Cont'd)	Amoco (Cont'd) [redacted]	Amoco—1011, 1014, 1016 (nc)		100	0.096	100	0.096	100	0.096
				85	0.020	85	0.020	85	0.020
		Amoco—2626 (nc)		95	0.096	95	0.096	95	0.096
				50	0.046	50	0.046	50	0.046
		Amoco—2226, 1046 (nc)		95	0.051	95	0.051	95	0.051
		Amoco—8011 (nc)		95	0.033	95	0.033	95	0.033
	Rexene	Rexene—11H-3, -5, -7, -10, -15, 11W-3, -5, -7, -10, -18, 14W-3, -5, -7, -10, -15, 18H-3, -4, -5, -7, -10, -15, 18W-3, -4, -5, -7, -10, -18 (nc)		105	0.058	105	0.058	105	0.058
	Exxon[1]	Exxon—E185, CD486, CD486A, E187, D-569 (nc)		115	0.058	115	0.058	115	0.058
		Exxon—CD300, CD350, CD87A (nc)		95	0.058	95	0.058	95	0.058
		Exxon—CD280C, CD347, CD280CX, CD207C, E622, 803HC, 805HC, 806MC (nc)		90	0.058	90	0.058	90	0.058
		Exxon—CD1190 (nc)		80	0.058	80	0.058	80	0.058
		Exxon—CD396 (nc)		110	0.028	110	0.028	110	0.028
		Exxon—D-570 (nc)		115	0.058	115	0.058	115	0.058
				105	0.028	105	0.028	105	0.028
		Exxon—CD484 (nc)		115	0.031	115	0.031	115	0.031
		Exxon—CD-577 (nc)		90	0.031	90	0.031	105	0.031
		Exxon—CD-594 (nc)		105	0.062	105	0.062		
				50	0.058	50	0.058	50	0.058
	Fiberite	Fiberite—RTP-178 (ac) [redacted]	Glass-reinforced MC	95	0.058	95	0.058	95	0.058
	Am. Hoechst, Leominster	Hostalen—PP-996, -998 (nc)		115	0.120	115	0.120	115	0.120
				110	0.040	110	0.040	110	0.040
		Hostalen—PP-842 (nc)		115	0.120	115	0.120	115	0.120
	Hercules[1]	Pro-fax—6X23 (X = 3 to 8) (nc)		105	0.040	105	0.040	105	0.040
				110	0.120	110	0.120	110	0.120
		Pro-fax—SA586 (nc)		85	0.040	85	0.040	85	0.040
		Pro-fax—6XF3 (X = 3 to 8) (nc)		105	0.040	105	0.040	105	0.040
		Pro-fax—PC-072-3, 6X81 (X = 3 to 8) (nc)		85	0.058	85	0.058	85	0.058
		Pro-fax—PC-307 (nc)		115	0.040	115	0.040	115	0.040
		Pro-fax—6X24 (X = 3 to 8) (nc)		105	0.058	105	0.058	105	0.058
		Pro-fax—7X24 (X = 3 to 8) (nc)		50	0.058	50	0.058	50	0.058
		Pro-fax—PC-072-1, PD-451 (nc)		110	0.057	110	0.057	110	0.057
	Novamont[1] [redacted]	Moplen—CY-X, CRA-X, (X = 007, 015, 025, 040, 080, or 120) (nc)		105	0.057	105	0.057	105	0.057
		Moplen—CWA-X (X = see above), CX-W (nc)		100	0.057	100	0.057	100	0.057
		Moplen—CY-X, CHY-X, C-663, C-X, CR-X CW-X (nc) (X = see above)		105	0.062	105	0.062	105	0.062
		Moplen—CRVO-4 (nc)		105	0.028	105	0.028	105	0.028
	ICI Americas[1]	Propathene—GXM-43, GX543M, GYM-202, GY702M, GWM101, GW601M, GYM-45, GY545M (nc)		110	0.028	110	0.028	110	0.028
		Propathene—HWM-25, HW525M, HWM107, HW807M (nc)		105	0.031	105	0.031	105	0.031
	LNP[1]	LNP—MF-100 (1 to 6)-HB (nc)	Glass-reinforced MC	105	0.028	105	0.028	105	0.028
	Venmouth	EM-PEE—PP-401, PP-401CS (ac)	MC	50	0.058	50	0.058	50	0.058
	[redacted]	EM-PEE—PP-204 (nc)	MC	50	0.062	50	0.062	50	0.062
		Pamonn—227 [redacted]	MC	105	0.028	105	0.028	105	0.028
	USI	Polyflam—APP-956 (nc)		50	0.058	50	0.058	50	0.058
	Schulman [redacted]	Polyflam—APP-975 (nc)		50	0.031	50	0.031	50	0.031
		Polyflam—APP-962, -1021, -1066, -1156 (nc)		115	0.028	115	0.028	115	0.028
	Shell[1]	Shell—5X24, 5X80, PX80 (X = 0.5-12.0) (nc)							

a—Abstracted from Underwriters Laboratories Recognized Components Index.

b—For full names and addresses of suppliers, see page 639.
NOTE: Superior numbers refer to the explanatory notes on page 634.

Material				UL Temperature Index[a]: Maximum continuous use temperature under va[illegible] continuous or low intermittent stresses in applic[illegible]s requiring maximum retention of the properties indicated in the column headings below[4]					
				Both electrical and mechanical properties[5]		Electrical properties and strength but not impact resistance[6]		Electrical properties only[7]	
Type	Supplier[b]	Trade name, grade designation, and color[1,4]	Description	Temp. index, °C.	Thickness,[3] in.	Temp. index, °C.	Thickness,[3] in.	Temp. index, °C.	Thickness,[3] in.
				105	0.028	105	0.028	105	0.028
Polypropylene (Cont'd)	Shell[1] (Cont'd)	Shell—XMT6100-02LP (nc)		105	0.028	105	0.028	105	0.028
		Shell—7X21, 7X26, 7X27, 7X25, 7X28, 7X29 (nc), PX20, SX20 (ac), (X = 0.5-12.0)		95	0.028	95	0.028	95	0.028
		Shell—GST1, MST1, GST2, MST2, XM6100-02LP (nc)		100	0.025	100	0.025	100	0.028
		Shell—GST3 (nc)		80	0.028	80	0.025	80	0.028
		Shell—TC813 (nc)		100	0.075	100	0.075	50	0.075
	Eastman[1]	Tenite—4232 (nc)		95	0.075	95	0.075	50	0.075
		Tenite—4231 (nc)		50	0.050	50	0.050	50	0.050
		Tenite—4P31 (nc)		50	0.120	50	0.120	50	0.120
Polystyrene	ARCO/Polymers	Dylene—KPD-1439H (nc)		50	0.058	50	0.058	50	0.058
	Amoco	Amoco—G2, G3, R5 (nc)		50	0.046	50	0.046	50	0.046
		Amoco—H4, H4R, M9, H6M, H4E, M6 (nc)		50	0.056	50	0.056	50	0.056
	BASF Wyandotte	Luran—4328 (nc)		50	0.040	50	0.040	50	0.040
	Dow	Styron—430U, 475D, 492U, 6021, XP7000.00 (ac)		50	0.062	50	0.062	50	0.062
		Styron—420D, 470D, 686, 6850 (ac)		50	0.061	50	0.061	50	0.061
	Eastern Sterling	Eastern—HM-12 (nc)	Styrene-butadiene copolymer	50	0.058	50	0.058	50	0.058
	Am. Hoechst, Leominster	Tuf-Flex—271, 326, 474, 721M, 329, 885, 730 (ac)	MC	50	0.058	50	0.058	50	0.058
		Fosterene—50, 58 (ac)	MC	50	0.062	50	0.062	50	0.062
	Hammond	Hammond—505-13 (nc), 550-11 (rd)		50	0.058	50	0.058	50	0.058
	Monsanto[1]	Lustrex—65, HT-65, 3350 (ac), 6400 (nc)	Butadiene-styrene resin	50	0.063	50	0.063	50	0.063
		Lustrex—4200, 4220 (ac)	Butadiene-styrene resin	50	0.124	50	0.124	50	0.124
	Polysar	Polysar—520FR (ac)	Styrene-butadiene resin	50	0.058	50	0.058	50	0.058
	Rexene	Rexene—PS-414 (bk), PS-444, PS-510TG (nc)		50	0.058	50	0.058	50	0.058
	Schulman	Polyflam—RMS-415, -424 (nc)		50	0.079	50	0.079	50	0.079
		Polyflam—HSF-13 (nc)		50	0.062	50	0.062	50	0.062
	Shell	Shell—324A, 325A, 331, 333, 335, 336, 339 (nc)	Styrene-butadiene MC	50	0.062	50	0.062	50	0.062
	Union Carbide	UCC—TMDB-6800, -6840, -9040 (nc)		50	0.086	50	0.086	50	0.086
		UCC—TMDH-5171 (nc)		170	0.018	180	0.018	180	0.018
Polysulfone	ICI Americas[1]	ICI—200P, 300P (ac)	Polyethersulfone	140	0.020	150	0.020	150	0.020
	Union Carbide	Udel—P1700, P1710, P1720, P3500, P3510 (nc)		140	0.020	150	0.020	150	0.020
	LNP[1]	Thermocomp—GF100X, GF100X—FR (X = 1 to 8) (nc)	Glass-reinforced MC	50	0.063	50	0.063	50	0.063
SAN	BASF Wyandotte	Luran—368R (nc)		90	0.058	90	0.058	90	0.058
		Luran—S776S, S757R (nc)	Acrylate-SAN	50	0.058	50	0.058	50	0.058
	Thermofil	Thermofil—B-2020FG, B-2008 (nc, gy)	Glass-reinforced MC	105	0.055	105	0.055	105	0.055
Silicone	Ampsitone	Ampsitone—AC-100-1326 (nc)	Casting, encapsulant compound	105	0.060	105	0.060	105	0.060
		Ampsitone—AC-100-1526 (nc)	Casting, encapsulant compound	140	0.075	140	0.075	150	0.075
	General Electric, Waterford	GE-102 (wh), 103 (bk), 108 (cl), 109 (bl), 112 (wh), 118 (cl), CRTV-132 (wh), CRTV-5110 (cl), M & R-30 (cl)	RTV-type rubber sealant	200	0.075	200	0.075	200	0.075
		GE—106, 116 (rd)	RTV-type rubber sealant	105	0.028	105	0.028	105	0.028
		GE—133 (bk)	RTV-type rubber sealant	105	0.031	105	0.031	105	0.031
		GE—161 (wh)	RTV-type rubber sealant	105	0.036	105	0.036	105	0.036
		GE—162 (wh)	RTV-type rubber sealant	230	0.015	230	0.015	230	0.015
		GE—SE9058	Appliance wire insulation					250	0.075
				140	0.075	140	0.075	140	0.075
	Dow Corning	Silastic—731, 732, 734, 96-081 (ac)	RTV-type sealant[11]	180	0.075	180	0.075	180	0.075
		Silastic—3140 (cl, gy)	RTV-type sealant	220	0.060	220	0.060	220	0.060
		Silastic—738, 3120 (gy)	RTV-type sealant	200	0.060	200	0.060	200	0.060
		Silastic—3145 (gy)	RTV-type sealant	170	0.060	170	0.060	170	0.060
		Silastic—170, 96-082 (bk)	Rubber						

a—Abstracted from Underwriters Laboratories Recognized Components Index

b—For full names and addresses of suppliers, see page 639

NOTE: Superior numbers refer to the explanatory notes on page 638

Temperature index[a] (Cont'd)

Type	Supplier[b]	Trade name, grade designation, and color[1,2]	Description	UL Temperature index — Maximum continuous use temperature under very low continuous or low intermittent stresses in applications requiring maximum retention of the properties indicated in the column headings below: Both electrical and mechanical properties — Temp. index, °C.	Both electrical and mechanical properties — Thickness, in.	Electrical properties and strength but not impact resistance — Temp. index, °C.	Electrical properties and strength but not impact resistance — Thickness, in.	Electrical properties only — Temp. index, °C.	Electrical properties only — Thickness, in.
Silicone (Cont'd)	Dow Corning (Cont'd)			130	0.060	130	0.060	130	0.060
		Silastic—182, 184 (wh)	Rubber	140	0.060	140	0.060	140	0.060
		Silastic—186 (wh)	Rubber	105	0.014	105	0.014	105	0.014
		Silastic—3140 (nc)	Rubber, conformal coating	105	0.008	105	0.008	105	0.008
		Silastic—R4-3117 (nc)	Rubber, conformal coating	260	0.062	260	0.062	260	0.062
		Dow Corning—302, M-81-121 (rd)	MC	240	0.062	240	0.062	240	0.062
		Dow Corning—304, 305, 306, 307, 308, 480, QM81-086, QM81-134, Q1-5021 (ac)	MC	105	0.075	105	0.075	105	0.075
	SWS Silicones	SWS—820, 831, 832, 930, 931, 934, 960, T-47, V-54	RTV-type rubber	140	0.075	140	0.075	140	0.075
	3M	3M—8661, 8662 (cl, bk)	RTV-type rubber[17]	150	0.075				
				105	—	105	—	105	—
	Wakefield Eng.	Wakefield—120	Grease, joint compound[14,15]	110	—	110	—	110	—
				105	0.010	105	0.010	105	0.010
Silicone laminate	Bergquist	Sil-Pad—100 (rd), 200, 400 (gy)	Rubber, sheet	105	0.018	105	0.018	105	0.018
	Chomerics	Che-Therm—1661 (wh)	Rubber insulation, sheet	105	0.008	105	0.008	105	0.008
		Che-Therm—1663 (wh), 1665 (gn)	Rubber insulation, sheet	105	0.005	105	0.005	105	0.005
		Che-Therm—1666 (bn)	Rubber insulation, sheet	105	0.004	105	0.004	105	0.004
		Che-Therm—1664 (bl)	Rubber insulation, sheet	105	0.015	105	0.015	105	0.015
		Che-Therm—1671 (wh)	Rubber insulation, sheet	105	0.011	105	0.011	105	0.011
		Che-Therm—1673 (gn)	Rubber insulation, sheet	105	0.010	105	0.010	105	0.010
		Che-Therm—1674 (bl)	Rubber insulation, sheet	105	0.073	105	0.073	105	0.073
	General Electric, Waterford	GE —SE-5558 (bn)	Rubber, sheet	200	0.005	200	0.005	200	0.005
	Keene	Keene—7580 (ac)	Rubber sheet	200	0.008	200	0.008	200	0.008
		Keene—49561, 49581-006 (ac)	Rubber sheet	200	0.010	200	0.010	200	0.010
		Keene—48580-010, 48586, 51580-010 (ac)	Rubber sheet	200	0.012	200	0.012	200	0.012
		Keene—51581 (ac)	Rubber sheet	200	0.024	200	0.024	200	0.024
		Keene—53586 (ac)	Rubber sheet	200	indicated by 3 digit suffix	200	indicated by 3 digit suffix	200	indicated by 3 digit suffix
		Keene—49561-015, 49581-032, 51580-015, 51586-015, 51580-020, 51586-020, 55580-025, 55580-030, 43580-020, 43580-030, 43580-040, 55589-030 (ac)	Rubber sheet	100	0.058	100	0.058	100	0.058
Urea	Allied[7]	Plaskon—HGFCG-39, -42, -46, -48, -54, -93, HG-50, -390, SMG (ac)	MC			105[14]	0.058	105[14]	0.058
				100	0.058	100	0.058	100	0.058
		Plaskon—FCG, FCG-130, -21, -36, -144 (ac), -300, -310 (bk)	MC			105[14]	0.058	105[14]	0.058
				100	0.058	100	0.058	100	0.054
	Am. Cyanamid	Beetle—72, 78, 75, 77, WE-1342, -8006, -8023, -1343, -8795, -8080, -8083 (ac)		100	0.120	100	0.120	100	0.120
	Budd Chem.	Budd—B-200, -300 (nc)	MC	100	0.059	100	0.059	100	0.059
	Perstorp U.S.	Skanopal—151 (ac)	MC	100	—	100	—	100	—
	Plastics Mfg.	Plastics Mfg.—MUP-00 (wh), -32 (l)	MC	50	0.058	50	0.058	50	[illegible]
Vinyl	Air Products	Staflow—2016, 2003A, 2025, 2029, 5011, 7021 (nc)	Propylene/PVC copolymers	50	0.068	50	0.068	50	0.068
		Staflow—2027 (nc)	Propylene/PVC copolymers			80	0.080		
	Diamond Shamrock	Dacovin—4401-A (gy)		50	0.058	50	0.058	80	0.058
	Ethyl	Ethyl—7042 (ac)		50	0.028	50	0.028	50	0.028
	Goodrich	Geon—8700A, 82036 (ac)		50	0.028	50	0.028	50	0.028
	Schulman	Polyvin—8614 (nc)	Flexible	50	0.030	50	0.030	50	0.030
		Polyvin—4820-01 (nc)	Flexible	85	0.020	85	0.020	85	0.020
	Polymer Corp.	Polymer—VCA-1218, VCA-1384	Vinyl coating resins	105	0.020	105	0.020	105	0.020
		Polymer—8788 (gy, bk)	PVC coating resin	50	0.039	50	0.039	50	0.039
Vinyl film and sheet	Kay-Fries	Ascroon—T	Sheet	50	0.009	50	0.009	50	0.009
	Sangreen	Sanseal—110 (ct)	Sheet	50	0.030	50	0.030	50	0.030
		Sanseal—180 (wh)	Sheet	50	0.010	50	0.010	50	0.010
	Union Carbide[7]	UCC—VCA 3803-L, VSA 3803-L (bk, wh), VCA/VSA 3310-L, QCA/QSA 3817-L (ct)	PVC/acetate sheet						

a—Abstracted from Underwriters Laboratories Recognized Components Index.

b—For full names and addresses of suppliers, see page 639.
NOTE: Superior numbers refer to the explanatory notes on page 634.

Elevated temperature indices of industrial laminates[a]

NEMA/ANSI grades[1]	Temperature index, maximum[7], °C. Electrical[1]	Mechanical[1]	Laminate thickness, minimum[2], in.	Supplier[b] grade designation, and color (sheet, rod, and tube, except as noted)
A	155	155	0.055	NVF A-703-P (nc); Insurok T-739, NEMA-A (nc); Spaulding A (nc)
	140	140	0.025	
AA	155	155	0.044	Insurok T-727, NEMA-AA (nc), Spaulding AA (nc)
	140	140	0.025	
C	115	125	0.057	General Electric, Coshocton' 113 (nc), Iten C (nc); S[illegible] (nc); Universal Oil C (nc)
	85	85	0.028	
	115	125	0.055	Insurok T-801 (nc)
	85	85	0.025	
CE	115	125	0.055	Insurok T-806 (nc)
	85	85	0.025	
	115	125	0.057	General Electric, Coshocton' 2013 (nc); Iten CE (nc); NVF CE-578 (nc); Spaulding CE, CEF (nc); Synthane-Taylor' CB, CE, CEF (nc)
	85	85	0.028	
L	115	125	0.057	Insurok T-733, NEMA-L (nc)
	85	85	0.028	
LE	115	125	0.057	General Electric, Coshocton' 1841 (nc); Iten LE (nc); NVF LE-875 (nc); Insurok T-827, NEMA-LE (nc); Spaulding LE (nc); Synthane-Taylor' LB, LE (nc)
	85	85	0.028	
FR2	105	105	0.043	Westinghouse 65MO5 (Cu-clad 65MO5), 65MO5A (tn)
	75	75	0.028	
	105	105	0.357	Kay-Fries DN3033 (Cu-clad DN7033), 3034 (Cu-clad 7034), DN4021 (Cu-clad 8021), 4025 (Cu-clad 8025), 4026 (Cu-clad 8026), 4027 (Cu-clad 8027), 4029 (Cu-clad 8029), 4033 (Cu-clad 8033) 4034 (Cu-clad 8034), 4035 (Cu-clad 8035), 4036 (Cu-clad 8036), 4037 (Cu-clad 8037), 4038 (Cu-clad 8038), 4041 (Cu-clad 8041) (nc); General Electric, Coshocton' 11673, 11676, ADLOZ (nc), 11800 (Cu-clad 11800), 11800S, ADFR2 (bn); NVF XXXPC-475, XXXPC-476, (Catabond) XXXPC-476 (FR-2), (Cu-clad Catabond) XXXPC-476 (FR-2) (nc), Perstorp U.S. PF317, PF324 (tn); Synthane-Taylor' FR2; (mr); Universal Oil' XXXP-395 (Cu-clad XXXP-395), XXXP-395-R (nc)
	75	75	0.025	
	105	105	0.057	Westinghouse (Catalized) 65MO5 (tn)
	105	105	0.065	Atlantic Laminates OPL-FR-2-1 (Cu-clad OPL-FR-2-1) (tn)
	75	75	0.025	
	75	75	0.028	Universal Oil (Cu-clad XXXP-395) (nc)
	100	100	0.057	Kay-Fries DN3019 (Cu-clad DN7019) (nc)
	70	70	0.028	
	95	95	0.057	Kay-Fries DN4043 (Cu-clad DN8043) (nc)
	85	85	0.028	
FR3	110	110	0.057	Kay-Fries DN5302 (Cu-clad 9302) (nc); NVF EP-492, (Catabond) EP-492, EP-492-SEO, SR-492-SEC (Cu-clad EP-492) (nc); Spaulding EXXXP-645 (wh); Synthane-Taylor' FR3 (tn); Universal Oil' 1201 (Cu-clad 1201) (nc), Westinghouse 65M24, 65M41, 65M42, (Cu-clad 65M41) (i)
	90	90	0.028	
	110	110	0.057	General Electric, Coshocton' 11574, ADFR3 (nc)
	90	90	0.031	Westinghouse (Catalized) 65M41, 65M42 (i)
	110	110	0.057	Universal Oil G-10FR (nc)
FR4	130	140	0.008	
	105	105	0.002	Mica' EG-618 (nc), -644 (bl), -648 (gn), -668 (bk), -683 (wh), -899 (tn), -848 (gn)
	130	140	0.025	
	130	130	0.007	
	130	140	0.025	Atlantic Laminates AE3137FR, AL3137FR (c), AL500 (tr gn) Century Laminates CLGFR (nc); Du Pont DS-200, DS-600 (gn); Electrofy' GEE-101, (Cu-clad GEC-101) (bk, bl, rd, nc); Fortin B-30, -31, -32, -34, -40, -41 (gn); Hewe Technology FR (nc, wh, bk); IBM 19-700 (nc); Janco FR-4; Lamination Tech. LT-GF, LT-GFO (nc, gn); Mica' EG-810, (Catalized-618), -218 (nc); NVF EG-872, -873, -873-SEO, (Catabond) EG-872, -874, -874-SEO (nc); N. E. Laminates N-105 (gn, nc, bl, tn), -205 (gn, nc); Perstorp U.S. GE-313 (gn); Polyply L-4 (gn); Prec. Laminates G-10FR4 (gn); Spaulding G-10-900, FR-4-10 (gn); Synthane-Taylor FB-400, -800, -800S, -420, -802, -866 (gn); U.S. Polymeric E-731C (gn), E-731 (nc), E-7149 (gn, nc); Universal Oil (Catalized) G-10FR, (Cu-clad G-10FR) (nc); Westinghouse 65M25S, 65M35 (tn), 65M25S, 65M38, (Catalized) 65M28 (gn); Youngblood FR-4 (ac), (Catalized) FR-4 (gn)
	130	140	0.028	General Electric, Coshocton' 11635, 11635G, 11637 (gn), 11730, 11740 (nc), ADFR4 (gn); Kay-Fries DN5520 (Cu-clad DN9020), DN5521 (Cu-clad DN9021) (nc); IBM 70-19-700/280, -700/594
				General Electric, Coshocton' (Cu-clad 11635) (gn); Kay-Fries (Cu-clad DN9020) (nc)
	130	130	0.028	Fortin' EG-2028-FR, -FR-402 (gn); Perstorp U.S. GE-383, GE-313UT (gn)
	130	140	0.031	Mica' EG-802 (nc)
	130	130	0.008	Hewe (Cu-clad FR) (nc); Lamination Tech. (Cu-clad LT-GF, LT-GFO) (nc, gn); Mica' (Cu-clad EG-810T) (nc); Universal Oil (Cu-clad G-10FR) (nc), Westinghouse (Cu-clad 65M28S, 65M38) (gn); Youngblood (Cu-clad-catalized FR-4) (gn)
	130	130	0.025	
				Fortin' (Cu-clad EG-2028-FR) (gn); Westinghouse (Cu-clad 65M25S, 65M35) (ac)
	130	130	0.031	Fortin' B-30, -31, -33, -34, -40, -41, (gn); IBM 19-700 (nc) 70-19-700/280, -700/594
	130	130	0.015	
	120	90	0.004	Fortin' (Cu-clad B-30, -31, -33, -34) (gn)
	130	130	0.015	
	90	90	0.004	
	130	130	0.025	Atlantic Laminates (Cu-clad AL 3137FR) (ac); Century Laminators (Cu-clad CLGFR) (nc); Du Pont (Cu-clad DS-600) (gn); NVF (Cu-clad EG-873, -873-SEO) (nc); N.E. Laminates (Cu-clad N-105, -205); Polyply (Cu-clad L-41) (gn) Prec. Laminates (Cu-clad G-10FR4) (gn); Synthane-Taylor (Cu-clad FB-400, -800, -802, -800S) (gn)

a—Abstracted from Underwriters Laboratories Recognized Components Index.

b—For full names and addresses of suppliers, see page 639.

NOTE: Superior numbers refer to the explanatory notes on page 635.

Temperature index[a] (Cont'd)

NEMA/ANSI grades[a]	Temperature index, maximum, °C. Electrical	Mechanical	Laminate thickness, minimum, in.	Supplier[b] grade designation, and color (sheet, rod, and tube, except as noted)
FR4 (Cont'd)	120	130	0.025	IBM 19-700C (nc)
	130	130	0.015	N.E. Laminates N-3105 (nc), (Cu-clad N-3105/N-3025); Perstorp U.S. GE-313UT (gn); Youngblood FR-4 (gn)
	120	120	0.015	N.E. Laminates N-4105 (nc), (Cu-clad N-4105/N-4205)
	130	130	0.015	Synthane-Taylor FB-450, -451 (gn)
	120	130	0.004	
	130	130	0.015	Youngblood (Cu-clad FR-4, 1226FR) (gn)
	120	120	0.010	
	130	130	0.030	U.S. Polymeric (Cu-clad E-731, -C, E7149) (nc)
	130	130	0.007	U.S. Polymeric E-731-C (gn), E-731 (nc), E-7149 (gn, nc)
	110	—	0.003	
	120	120	0.007	Youngblood FR-4 (gn)
	120	105	0.008	Synthane-Taylor FB-600 (gn)
	105	105	0.002	General Electric, Coshocton 11730, 11740 (nc); Mica EG-402 (Cu-clad EG-402T) (nc); Universal Oil (1139)(Cu-clad G-10FR) (nc)
	130	130	0.013	Mica EG-202, -218, (Cu-clad EG-818T (nc), -844T (bl), -848T (gn), -868T (bx), -883T (wn), -899T (tn))
	120	—	0.008/0.029	Atlantic Laminates AE3247-B4, AL3247-B4 (Prepregs) (nc); Century Laminators CLGFT (nc), (Prepregs CLGF-15, -16) (gn); Lamination Tech. LT-GF-TL, LT-GFO-TL (Prepregs LT-FR416, LT-FRO416) (nc, gn)
	105	—	0.003/0.025	Atlantic Laminates AE3247 (nc); Polyply L-4, (Prepreg L-4) (gn)
	105	105	0.007	Mica (Cu-clad EG-816T) (nc), -844T (bl), -848T (gn), -868T (bx), -883T (wn), -899T (tn)
	105	—	0.004/0.008	Mica EG-402T, (Prepregs 102-21, -22, -321, -322) (nc)
	120	—	0.015	IBM 19-700C (nc)
	110	—	0.004/0.025	
	130	130	0.016/0.030	General Electric, Coshocton 11730, 11740 (nc)
	120	120	0.0045/0.014	
	105	105	0.002/0.007	
	130	130	0.015/0.029	Du Pont DS-400, DS-600 (gn); Electrocy GEE-101UT (Cu-clad GEC-101UT) (bk, bl, rd, nc); Howe FR (nc); Lamination Tech. LT-GF-TL, LT-GFO-TL (nc, gn)
	90	—	0.020/0.015	Perstorp U.S. (Prepreg GE-313-P/108) (gn)
	90	—	0.002/0.025	IBM 19-700C (Prepreg) (nc)
	120	—	0.008/0.025	Lamination Tech. LT-GF-TL, LT-GFO-TL, (Prepregs LT-FR437, LT-FRO437) (nc, gn)
	120	—	0.007/0.025	Century Laminators CLGFT (nc), (Prepreg CLGF28) (gn); Lamination Tech. LT-GF-TL, LT-GFO-TL (Prepregs LT-FR428, LT-FRO428) (nc, gn)
	120	120	0.004/0.023	Howe Technology (Cu-clad FR), (Prepreg Cu-clad FR-p) (nc)
	130	130	0.015/0.031	IBM 70-19-700/280, -/584
	120	—	0.004/0.031	
	130	130	0.015/0.007	U.S. Polymeric E-731-a, -C, -P, E-7149, (Prepregs E-731-A, -C, -P, E-7149) (gn); E-731, E-7149 (Prepregs E-731, E-7149) (nc)
	120	130	0.007/0.007	U.S. Polymeric E-731-C, E-7149, (Prepregs E-731-C, E-7149) (gn); E-731, E-7149, (Prepregs E-731, E-7149) (nc)
	120	—	0.004/0.007	U.S. Polymeric E-731-A, -P, (Prepregs E-731-A, -P, -C, -C, E-7149) (gn); E-731, E-7149 (nc)
	130	—	0.003/0.015	N.E. Laminates N-3105 (nc), (Prepregs N-3205, NS-3205) (nc)
	90	—	0.003/0.019	Perstorp U.S. GE313UT, (Prepreg GE-313-P/112) (gn)
	120	—	0.004/0.018	N.E. Laminates N-4105, (Prepregs N-4205, NS-4205) (nc); Perstorp U.S. GE-313UT, (Prepreg GE-313-P/116) (gn)
	105	—	0.003/0.007	U.S. Polymeric E-731, -A, -C, -P, E-7149 (gn, nc), (Prepregs E-731-A, -P) (gn)
	105	105	0.004/0.010	Fortin (Cu-clad 8-30, -31, -33, -34) (Prepregs Cu-clad 8-10, -13) (gn)
	120	120	0.004/0.010	Fortin (Prepregs 810, 813), 8-30, -31, -33, -34, -40 (gn)
	110	110	0.0035/0.010	Youngblood (Prepreg 1226FRP) (gn)
	120	—	0.004/0.031	IBM (Prepregs 70-19-700/280, -/584)
	90	—	0.002/0.031	
	120	—	0.004/0.029	Atlantic Laminates AL3247 (nc); Century Laminators CLGFT, (Prepregs CLGF12, CLGF13), (Cu-clad CLGFT) (nc); Du Pont (Cu-clad DS-600) (Prepreg Carter 5150 FR-4), DS-400, -600, (Prepregs Carter 5104, -5150) (gn); Electrocy GEE-101UT, (Cu-clad GEC-101UT) GEP-101 (Prepreg) (bk, bl, rd, nc); Kay-Fries DN-9020ML, (Prepreg DN-9020MP) (gn); Howe FR (Prepreg FR-P) (nc); IBM 19-700 (Prepreg 19-700) (nc); Lamination Tech. LT-GF-TL, (Prepregs LT-FR-412, -413, -425), LT-GFO-TL (Prepregs LT-FRO-412, -413, -425), (Cu-clad LT-FRO-412, -413, -425) (nc, gn)
	110	—	0.004/0.025	IBM 19-700C, (Prepreg 19-700C) (nc)
	105	105	0.0025/0.008	Synthane-Taylor FB-680, (Prepreg 8F-527) (gn)
	110	110	0.003/0.010	Youngblood 1226FR (gn)
	105	105	0.013/0.008	Universal Oil BG-1FR
	105	105	0.016/0.008	Universal Oil BG-1.5FR
	105	105	0.0025/0.008	Universal Oil BG-2FR
	105	105	0.0035/0.008	Universal Oil BG-3FR

a—Abstracted from Underwriters Laboratories Recognized Components Index.

b—For full names and addresses of suppliers, see page 635.
NOTE: Superior numbers refer to the explanatory notes on page 638.

NEMA/ANSI grades	Temperature index, maximum[a], °C. Electrical	Mechanical	Laminate thickness, minimum, in.	Supplier[b] grade designation, and color (sheet, rod, and tube, except as noted)
FR4 (Cont'd)	105	105	0.0045/0.008*	Universal Oil BG-4FR
	105	105	0.007/0.008*	Universal Oil BG-7FR
	105	105	0.0035/0.025*	Fortin' (Prepregs B10, B13), B-30, -31, -33, -34, -40 (gn)
	105	105	0.002/0.028*	Westinghouse 65M28, (Prepreg HT-11841) (gn)
	105	—	0.002/0.025*	Howe FR (nc)
	90	—	0.002/0.025*	Century Laminators CLGFT (nc) (Prepreg CLGF08) (gn); Du Pont (Prepregs Conar 5104, -5150) (gn); Electroply' (Prepreg GEP-101) (bk, bl, rd, nc); Kay-Fries (Prepreg DN-9020-MP) (gn); Electroply' GEP-101 (Prepreg); Howe FR-P (Prepreg) (nc), BM 19-700 (Prepreg) (nc); Du Pont Conar 5104, 5150, (Prepregs) (gn); Lamination Tech. LT-GF-TL, -GTO-TL (Prepregs LT-FR408, -FR0408) (nc, gn)
	90	90	0.002/0.010*	Fortin' (B10, B13 Prepregs) (gn)
	105	—	0.002/0.008*	Mica' EG-602, -818, (Cu-clad EG-602T, -818T), (Prepregs 102-28, 102-328, 102-29, 102-329) (nc)
	105	—	0.005/0.008*	Mica' EG-602, (Cu-clad EG-602T), (Prepregs 102-26, 102-326), (nc)
	105	—	0.006/0.008*	Mica' (Prepregs 102-23, 102-323) (nc), (Cu-clad EG-818T, -844T, -848T, -868T, -883T, -899T), EG-818 (nc), -844 (bl), -848 (gn), -868 (bk), -883 (wh), -899 (tn)
FR5	170	180	0.057	Kay-Fries DN5504, (Cu-clad DN-9004) (nc)
	140	160	0.028	
	170	180	0.053	General Electric, Coshocton' FR-45 (nc); Mica' EG823 (wh), EG824 (nc); Polyply L-5 (gn); Synthane-Taylor' FB1011 (gn)
	140	160	0.025	Universal Oil G-11FR (nc); Westinghouse 66M50 (wh)
	130	130	0.025	General Electric, Coshocton' (Cu-clad FR-45) (nc)
	170	170	0.055	Westinghouse (Cu-clad 65M50) (wh)
	140	140	0.025	Synthane-Taylor' (Cu-clad FB1011) (gn); Westinghouse (Cu-clad 65M50) (wh)
G3	140	170	0.025	Spaulding G-3-788, G-3 (nc); Synthane-Taylor' G-3 (nc), Universal Oil G-3 (nc)
G5	50'	140	0.025	General Electric, Coshocton' 11508 (nc); NVF G-5-813 (nc); Insurok T-859, NEMA G-5 (nc); Spaulding G-5 (gy); Synthane-Taylor' G5 (nc)
	—	140	0.028	Ilen G5 (nc)
G7	170	220	0.025	General Electric, Coshocton' 11617; NVF G-7-832 (nc); Synthane-Taylor' GSC, GSCF (nc)
G9	130	130	0.065	General Electric, Coshocton' 11628 (nc)
	50	140	0.025	General Electric, Coshocton' 11628 (nc), Universal Oil G-9 (nc)
	50'	140	0.025	NVF G-9-818 (nc); Spaulding G-9, G-9-851 (gy); Insurok T-888, NEMA-G-9 (nc), Synthane-Taylor' G9 (nc)
G10	130	140	0.025	Atlantic Laminates 2037-1 (lt gn); Du Pont DS-100 (gn); Electroply' GEE-100, (Cu-clad GEC-100) (nc); General Electric, Coshocton' 11546, 11556, 11558G, 11710 (nc); Howe G-10 (nc); Janco G-10; Mica' EG-710, -770 (nc); NVF EG-864, G-10-863, (Catabond) EG-867, G-10-865 (nc); N.E. Laminates N-100 (gn); Polyply L-10 (gn); Prec. Laminates G-10 (gn); Spaulding G-10, G-10-773 (gn); Insurok T-525, NEMA-G-10 (nc); Synthane-Taylor' GEC-500S (gn); U.S. Polymeric E-730K, E-730O, E-7148 (gn); Westinghouse 65M27S 65M37 (gn)
	130	140	0.028	Ilen G-10 (nc); Kay-Fries DN5510, (Cu-clad DN9010) (nc)
	130	140	0.031	Fortin' A-40, EG-2028 (gn)
	130	140	0.025	Fortin' A-30, A-31, A-33, A-34, A-40 (gn); Mica' EG-758 (nc), -788 (bk); Youngblood G-10 (gn)
	130	130	0.015	
	120	50	0.007	
	130	140	0.025	Synthane-Taylor' GEC-500 (gn)
	120	105	0.009	
	110	50	0.002	Fortin' A-30, A-31, A-33, A-34, A-40 (gn)
	130	120	0.025	Fortin' (Cu-clad EG-2028) (gn), General Electric, Coshocton' (Cu-clad 11558G) (nc), Howe (Cu-clad G-10) (nc); Mica' (Cu-clad EG-710T, -770T) (nc); Synthane-Taylor' (Cu-clad GEC-500) (gn); Universal Oil (Cu-clad G-10) (nc), Westinghouse (Cu-clad 65M27S, 65M37) (gn)
	130	130	0.015	Fortin' (Cu-clad A-30, -31, -33, -34) (gn); Mica' (Cu-clad EG-758T) (nc), -788T (bk); U.S. Polymeric E-730K (gn)
	50	50	0.002	
	130	130	0.015	Youngblood (Cu-clad G-10) (gn)
	120	120	0.010	
	130	130	0.002	Sheldahl GT8500; Universal Oil (Cu-clad G-10) (nc)
	110	50	0.002	Mica' EG-752 (nc)
	110	—	0.003/0.025*	Atlantic Laminates AE2147 (nc)
	110	—	0.006/0.025*	Atlantic Laminates AE2147-B1 (Prepreg) (nc)
	130	140	0.025	Universal Oil G-10 (nc)
	105	105	0.002	
	130	130	0.015/0.025*	Du Pont DS-300 (gn), Electroply GEE-100UT, (Cu-clad GEC-100UT) (nc), Howe G-10 (nc), U.S. Polymeric E-730-K, -Q, E-7148 (gn)
	120	—	0.007/0.025*	Du Pont DS-300 (gn), Electroply GEE-100UT, (Cu-clad GEC-100UT) (nc), Howe G-10 (nc)
	110	—	0.002/0.025*	Du Pont DS-300, (Prepreg Conar 5146) (gn); Kay-Fries DN-9010-ML, (Prepreg DN-9010-MP) (gn); Electroply GEE-100UT, (Cu-clad GEC-100UT), (Prepreg GEP-100) (nc), Howe G-10, (Cu-clad G-10), (Prepreg G-10-P) (nc)

a—Abstracted from Underwriters Laboratories Recognized Components Index.

b—For full names and addresses of suppliers, see page 639.
NOTE: Superior numbers refer to the explanatory notes on page 638.

Temperature index[a] (Cont'd)

NEMA/ANSI grades	Temperature index, maximum, °C. Electrical	Temperature index, maximum, °C. Mechanical	Laminate thickness, minimum, in.	Supplier[b] grade designation, and color (sheet, rod, and tube, except as noted)
G10 (Cont'd)	120	—	0.007/0.007	U.S. Polymeric E-730-K, E-730-Q, E-7148 (gn)
	110	—	0.004/0.007	U.S. Polymeric (Prepreg E-730-K) (gn)
	110	—	0.003/0.015	N.E. Laminates (Prepreg N-1200) (nc)
	110	—	0.003/0.007	U.S. Polymeric E-730-K, -Q, E-7148, (Prepregs E-730-Q, E-7148) (gn)
	110	105	0.0025/0.009	Synthane-Taylor GEC-550, (Prepreg EF-526) (gn)
	110	110	0.002/0.007	Fortin A-30, -31, -33, -34, -40 (gn)
	105	105	0.002/0.007	Fortin (Prepregs A-10, -11, -13), (Cu-clad A-30, -31, -33, -34) (gn)
	105	105	0.0013/0.008	Universal Oil BG-1
	105	105	0.0018/0.008	Universal Oil BG-1.5
	105	—	0.0025/0.008	Mica EG-600, (Cu-clad EG-600T), (Prepregs 102-66, -68), EG-752 (Prepregs 102-18, 102-318) (nc), (Cu-clad EG-752T), (Prepregs 102-18, -318) (nc)
	105	105	0.0025/0.008	Universal Oil BG-2
	105	105	0.0035/0.008	Universal Oil BG-3
	105	—	0.004/0.008	Mica EG-752, (Cu-clad EG-752T), (Prepregs 102-11, 102-12, 102-311, 102-312) (nc)
	105	105	0.0045/0.008	Universal Oil BG-4
	105	—	0.005/0.008	Mica EG-752, (Cu-clad EG-752T), (Prepregs 102-16, 102-216) (nc)
	105	—	0.006/0.008	Mica EG-758, (Cu-clad EG-758T), (Prepregs 102-13, 102-313) (nc), EG-768, (Cu-clad EG-768T) (bk)
	105	105	0.007/0.008	Universal Oil BG-7
	105	105	0.002/0.028	Westinghouse 65M27, (Prepreg HT-11907), (gn)
G11	170	180	0.084	Mica EG-723 (wh), EG-724 (nc); NVF G-11-861, (Catabond) G-11-861 (nc); Polyply G-11 (gn); Prec. Laminates G-10 (gn); Spaulding G-11-963 (gn); Synthane-Taylor GEC-111 (gn); Universal Oil G-11 (nc)
	140	180	0.025	
	170	180	0.067	Ilen G11 (nc); Kay-Fries DN5503, (Cu-clad DN9003) (nc)
	140	180	0.028	
	140	140	0.025	Synthane-Taylor (Cu-clad GEC-111) (gn)
	140	180	0.025	General Electric, Coshocton 11695 (nc)
X	130	130	0.028	Insurok T-300, T-615, NEMA X (nc); Spaulding X (nc); Synthane-Taylor FBX (mr); Universal Oil X, 88X, 99-X (nc)
	130	130	0.067	Synthane-Taylor X-115, X-116 (tn), X-215 (bn)
	115	125	0.028	
XP	130	130	0.028	General Electric, Coshocton 11660 (nc); Ilen 100, 100FR, 118P; NVF XN-152, XP-214-8, XP-240 (nc); Spaulding 456, XPK-20, X-598, X-913 (nc); Insurok T-610, T-737 (nc)
XPC	130	130	0.028	Ilen 310L, 120FR; Spaulding XPC-470 (nc), 477 (nc); Insurok T-414 (nc); Synthane-Taylor XPC (tn); Universal Oil XPC, 106, 106-FR (nc)
	130	130	0.025	Atlantic Laminates OPL-XPC-1, -2, -FR-1 (Cu-clad OPL-XPC-1) (tn)
XX	140	140	0.067	NVF XX-324 (nc); Insurok T-301, T-304, T-312, T-643, NEMA-XX (nc); Spaulding 688, X-631, X-903, XX, XX-633, EHV-60, XXX-598 (nc), X-786 (mr); Synthane-Taylor XX (tn)
	130	130	0.028	
	130	130	0.028	Ilen 200 (nc)
XXP	140	140	0.067	General Electric, Coshocton 11563 (nc); Kay-Fries DN2033, (Cu-clad DN6033) DN2034, (Cu-clad DN6034), DN3024, (Cu-clad DN7024) (nc); Insurok T-740, NEMA-XXP (nc); Spaulding 785 (nc); Synthane-Taylor XXP-241 (tn)
	130	130	0.028	
	130	130	0.028	Ilen 205 (nc)
XXX	140	140	0.067	General Electric, Coshocton 2029 (nc); Insurok T-303, T-308, T-640, NEMA-XXX (nc); Spaulding XXX (nc); Synthane-Taylor XXX (tn); Universal Oil XXX (nc)
	130	130	0.028	
	130	130	0.028	Ilen 214, 215 (nc)
XXXP	125	125	0.028	General Electric, Coshocton 11573; Ilen 220, 215FR; Kay-Fries (Cu-clad DN7024) (nc); NVF E-469, E-2041, XXXP-219 (nc); Insurok T-725, T-777, T-927, T-929 (nc); Spaulding XXXP-229FR (rd); Synthane-Taylor XXXP749, 320, XXXP (tn); Universal Oil XXXP-925 (Cu-clad XXXP-925) (nc)
	140	140	0.067	Synthane-Taylor 320 (tn)
XXXPC	125	125	0.028	NVF XXXPC-473, (Catabond) XXXPC-473 (nc); Insurok T-787 (nc); Synthane-Taylor XXXPC (tn); Westinghouse 65M03, (Cu-clad 65M03) (bn)
	125	125	0.025	Atlantic Laminates OPL-XXXPC-1 (tn) (Cu-clad OPL-XXXPC-1) (tn); General Electric, Coshocton 11571, 11572, (Cu-clad 11571) (nc)
Vulcanized fibre (commercial/electrical insulation)	115	110	0.028	NVF Forbon bone/Forbon comml./Forbon Peerless; Spaulding Supergrav/Comml./Armite (gy); Synthane-Taylor Taylorite bone/Taylorite comml./Taylorite ins. (gy); Ilen Bone/Commercial
FW-G-10	180	190	0.067	NVF G-12-3737 (nc); Polygon AFW-G-10; Spaulding FW-G-10-AX-1003 (nc); Westinghouse HY-1054 (bl/gn)
	180	180	0.029	
	180	190	0.067	Spaulding FW-AS-1006, FW-WS-1006 (nc, wh) FW-AW-1006 (nc)
	180	190	0.029	Spaulding FW-AU-1006, FW-AX-1006 (nc)
	180	190	0.062	Janco JAA-G-10
	180	180	0.031	
FW-G-11	180	170	0.067	NVF G-12-3731 (nc); Polygon BFW-G-11; Spaulding FW-G-11-AH-1003 (nc)
	170	170	0.029	

a—Abstracted from Underwriters Laboratories Recognized Components Index.

b—For full names and addresses of suppliers, see page 639.
NOTE: Superior numbers refer to the explanatory notes on page 638.

NEMA/ANSI grades[1]	Temperature index, maximum[1], °C. Electrical[1]	Mechanical[1]	Laminate thickness, minimum[1], in.	Supplier[8] grade designation, and color (sheet, rod, and tube, except as noted)
GPO1[1]	105	160	0.055	Zehrco GR1 (nc)
	90	160	0.025	Polyply L-45 (rd, tn)
	105	160	0.025	Eagle-Picher Ep-900 (tn)
	105	105	0.055	
	90	90	0.025	Glasloc G200FR, G200 (tn)
GPO2	180	180	0.067	Haysite ETS-FR, -150, -150DE, -150DF (rd)
	130	160	0.028	N.E. Laminates 505 PGM (tn); Westinghouse H-7896 (rd)
	130	160	0.056	NVF GP-9206 (rd); Westinghouse H-24947 (rd)
	130	160	0.055	
	120	150	0.028	Ind'l Dielectrics 4800 (ac)
	130	160	0.115	
	105	160	0.065	
	90	90	0.028	N.E. Laminates (Cu-clad 505PGM) (tn)
	130	130	0.054	Zehrco GR2 (rd)
	130	160	0.025	Glasloc UTS (rd
	130	160	0.025	Polyply L-40, (Cu-clad L-40 max. 105°C.) (rd)
	105	160	0.025	Isola (580) G-1-FR (nc)
	105	160	0.055	
	90	90	0.028	Eagle-Picher EP-910 (ac)
	105	105	0.065	
	90	90	0.025	Molded Fiber Glass Cos. 2-202
	105	105	0.067	Glastic 1580, 1582 (wh, gn)
GPO3	120	140	0.028	
	85	85	0.025	Westinghouse H-23583 (rd)
	120	140	0.028	NVF GP-9306 (rd)
	120	140	0.065	
	105	105	0.028	Glastic UTR (rd); Westinghouse H-23583 (rd)
	130	180	0.067	Westinghouse H-23333 (rd)
	130	150	0.067	Ind'l Dielectrics 4800 (rd, nc, wh)
	120	140	0.065	
	90	90	0.028	Haysite ETR-FR-C, -V, 151 (rd)
	110	150	0.064	
	100	150	0.028	Cincinnati Mesacron 40 (nc)
	105	140	0.064	Polyply L-50 (rd)
	105	140	0.025	Isola G-1-TR (nc)
	105	140	0.055	
	90	90	0.028	Molded Fiber Glass Cos. 3-201
	105	105	0.067	Eagle-Picher EP-920 (ac)
	105	105	0.065	Eagle-Picher EP-920 (ac); Zehrco GR3 (rd)
	90	90	0.025	Zehrco GR3 (rd)
	105	140	0.065	Haysite HST (bn)
Non-NEMA/ANSI industrial	160	180	0.064	Rogers RA4100 (bk)
	150	150	0.064	Spaulding Stratoclad 101 (nc), -102 (rd)
	140	140	0.067	Synthane-Taylor FB-100 (nc)
	130	140	0.031	Synthane-Taylor X-116-2 (nc)
	120	120	0.028	Spaulding XP-FR (nc), XPC-FR (nc, bk)
	130	130	0.067	Spaulding XP-FR (nc), XPC-FR (nc, bk), Stratoclad 103 (rd)
	125	125	0.028	Universal Oil (Catalized NP-424) (tn)
	125	140	0.024	Universal Oil (Cu-clad NP-424) (tn, br)
	105	105	0.028	Insurok T115 (nc)
	120	105	0.067	
	120	100	0.028	Dodge Fluorglas' 8660-2 (Cu-clad 8801-2) (gy)
	105	105	0.015	Rogers RA 4100WM (bk)
	105	105	0.064	Westinghouse H-23925 (nc)
	115	120	0.067	
	115	110	0.028	Synthane-Taylor CFMB (nc)
	115	125	0.067	
	85	85	0.028	

5—Abstracted from Underwriters Laboratories Recognized Components Index

8—For full names and addresses of suppliers, see page 639
NOTE: Superior numbers refer to the explanatory notes on page 631

Temperature index[1] (Cont'd)

NEMA/ANSI grades[1]	Temperature index, maximum[2], °C.		Laminate thickness, minimum[3], in.	Supplier[8] grade designation, and color (sheet, rod, and tube, except as noted)
	Electrical[4]	Mechanical[4]		
Non-NEMA/ANSI industrial (Cont'd)	65	65	0.028	Universal Oil C-FR (nc)
	90	90	0.025	Ien 816 (ac)
	90	90	0.050	Ien 817 (ac)
	50	50	0.028	Universal Oil 399 (nc); NP-424 (tn, bl)
	110	110	0.057	Universal Oil 1001 CL (nc)
	90	90	0.028	
	115	120	0.062	Spaulding 154 (wh)
	115	110	0.031	
	115	115	0.064	Atlantic Laminates OPL-XPC, OPL-XPC-FR (bn)
	110	110	0.063	Atlantic Laminates OPL-XXX-PC (bn)
	50	50	0.031	NVF MCB-532 (nc)
	105	105	0.003/0.007[7]	General Electric, Coshocton[7] 11387 (nc)
	105	105	0.0035/0.007[7]	General Electric, Coshocton[7] 11388 (nc)
	105	105	0.005/0.007[7]	General Electric, Coshocton[7] 11389 (nc)
	130	140	0.025	Spaulding PEGFR (gn); Westinghouse 65M62, (Cataized 65M62) (ac); IBM 19-700-142 (gn); Synthane-Taylor[7] FS670P (gn), FB-700 (nc); Universal Oil NP-424 (tn, bl)
	130	130	0.025	Spaulding PEG10FR (gn); Synthane-Taylor[7] (Cu-clad FS670P) (gn)
	130	130	0.032	Universal Oil 77, 78 (nc); Westinghouse (Cu-clad 65M62) (ac)
	130	130	0.028	Atlantic Laminates AL-910, (Cu-clad AL-910) (an); Spaulding Stratoclad 101 (nc), -102 (rd)

1—Grade designation may have additional suffix numbers and/or letters to denote specific modifications, such as color, filler content, and viscosity, that have been approved by UL.

2—The temperature index is an arbitrary, elevated temperature limit for specific grades of commercial plastics. It is derived from long-term oven-aging test programs on test specimens according to a standard Underwriters Laboratories procedure. (See "The temperature index—a necessary guide to safety evaluation of plastics," by Howard Reymers, Modern Plastics, Sept. 1970.) The primary purpose of the Temperature index is to assist UL engineers in judging the acceptability of individual plastics in specific applications involving long-term exposure to elevated temperatures. In applying temperature indices to such judgments, UL engineers take into account the stress and temperature involved in the application, the detail part design, hazard and safety factors, and the specific heat-aging patterns of the different properties, such as electrical, mechanical (strength) and impact of a plastic. This procedure recognizes that upper temperature limits of plastics depend very much on how they are used (stressed) in specific applications. Consequently, the temperature index of a particular plastic qualifies it only for those UL applications where UL has specifically approved it for the application. In addition, temperature indices are useful in applications of new materials, whose long-term heat-aging behavior can be compared to older materials whose performance is known from experience.

By correlation of oven-aging test data with field experience, Underwriters Laboratories has established fundamental temperature indices on certain plastics with which they have had extensive experience. These fundamental temperature indices apply to the basic plastic generically and are awarded to specific commercial grades upon application of the supplier to UL usually after minimal testing. Higher temperature indices require the standard UL temperature index test program. The following generic temperature indices are current:

Generic plastic	Temperature index, °C.
Alkyd molding compounds[a] *	130
CTFE	150
DAP molding compounds[a]	130
Epoxy molding compounds[a] *	130
FEP (TFE-HFP copolymer)	150
Melamine molding compounds[a] * B	130
Melamine/phenolic molding compound[a] * B	130
Nylon (6, 6/6, 6/10), including glass fiber-reinforced compounds	65
Phenolic molding compound[a] *	150
Polycarbonates, including glass fiber-reinforced compounds	65
Polyester molding compound (thermoset)[a] *	130
PET (thermoplastic) film	105
Silicone rubber	105
TFE	150
Urea molding compound[a]	100

a Heat and pressure molding compound only; does not include formulations intended for casting or pouring.

* Compounds filled with other than synthetic organic fibers but not fiber-reinforced liquid resins.

B Compounds, including cellulose-filled, that have a specific gravity of 1.58 or greater.

3—The long-term heat-aging resistance of plastics is quite dependent on the thickness of the part or test specimen. The thicker the part, the slower are the effects of thermal degradation on properties. For this reason, Underwriters Laboratories requires temperature index testing over a range of thicknesses or, in the case of a particular application, at the thickness specific to the application. In the chart each temperature index is listed alongside the minimum thickness to which it applies.

4—Not all properties of a given plastic are affected by heat aging at the same rate. Thus, for example, the temperature to produce loss of electrical insulation function of a plastic in a certain time may be higher, lower, or the same as that required for a corresponding loss in mechanical function. Consequently, for plastics whose properties show significant variations in resistance to heat aging, a separate temperature index is assigned to each property.

The properties that UL measures on heat-aged test specimens to judge the effect of heat aging are grouped into three main categories: 1) Electrical properties (principally dielectric strength and, in some cases, arc/track resistance); 2) General mechanical strength (flexural strength, tensile strength, modulus); 3) Resistance to impact (Izod and tensile impact strength). In its rating system UL determines for each material grade a temperature index for each of these three property categories. (The index is the temperature at which a material will retain 50% of the properties in question after heat aging for a fixed period of time. See note 3.) In addition, the three temperature indices are determined over a range of thicknesses (see note 3) usually 1/32, 1/16, 1/8 and 1/4 in.

UL publishes this data on its yellow cards and in its annual Recognized Components index in the form of a table for each material grade organized by thickness and by property category. The following is a typical example:

Thickness, in.	Temperature index, °C.		
	Electrical properties	Mechanical properties	
		With impact	Without impact
1/32 (0.031)	115	95	115
1/16 (0.062)	125	105	125
1/8 (0.125)	130	105	130

The Encyclopedia chart has followed essentially the same system except for the following two minor differences, which were adopted to improve clarity and understanding of the significance of these indices: 1) In the chart the temperature index column headings have been expanded and modified somewhat compared to the UL column headings, which are very cryptic in UL publications such as yellow cards. The purpose of this change is to be more expressive about what the indices stand for as shown below:

UL headings	Encyclopedia headings
Electrical properties	Electrical properties only
Mechanical properties with impact	Both electrical and mechanical properties
Mechanical properties without impact	Electrical properties with strength but not impact resistance

Thus the Encyclopedia headings point up the fact that UL temperature indices are primarily criteria for retension of electrical properties under heat aging with and without certain combinations of mechanical properties, namely strength and impact resistance. 2) The column order from left to right in the Encyclopedia chart is the reverse of that found in UL publications, i.e., in the chart Electrical properties only is on the right and Mechanical properties is on the left.

5—National Electrical Mfrs. Assn.—Standards on Industrial Laminated Thermosetting Products, LI1-1965.

6—For use in multilayer printed circuit wiring boards. Ratings apply to laminate thickness X when built up to total thickness Y, expressed in table as X/Y.

7—Not for use in electrical applications at temperatures greater than 50°C.

8—Where colors have been included in the UL Recognized Component index, the color abbreviation in parentheses follows the grade or series of grades. For example: Grade —XYZ-123, -124, -125 (ac), -128 (bk) indicates that the first three grades are listed for all colors (ac) and grade XYZ-128 for black (bk). Color code is as follows: ac = all colors; bg = beige; bl = blue; blgn = blue green; al = aluminum; at = clear transparent colors; bk = black; bn = brown; bz = bronze; ch = charcoal; cr = cream; ct = clear transparent; db = dark brown; ew = eggshell white; gn = green; gy = gray; iv = ivory; lg = light green; mr = maroon; nc = natural color; or = orange; pk = pink; rd = red; rs = rust; tn = tan; tl gn = translucent green; wh = white; yl = yellow.

9—Substrate materials are steel, steel/cadmium, brass plated copper.

10—Substrate materials are steel, copper, aluminum.

11—Substrate materials are electroless nickel-plated steel, cadmium plated steel, tin-plated steel.

12—Substrate material is steel.

13—Substrate materials are copper, aluminum.

14—Substrate material is copper.

15—Substrate material is aluminum.

16—105°C is permitted in wire connector applications only.

17—Except 150°C where elongation is not essential.

18—For use in structural parts in room air conditioners at temperatures not exceeding 100°C.

Names and addresses of suppliers listed in Temperature index chart

APCO Polymers Inc., 1500 Market St., Centre Sq., Philadelphia, Pa. 19101
& Chemical Co., Wattersen Towers, 1930 Bishop Lane, Suite 916, Louisville, Ky., 40218
Plastics Inc., 4530 Annapolis Rd., Baltimore, Md. 1227
Products and Chemicals Inc., Plastics Div., P.O. Box 538, Allentown, Pa., 18105
Allied Chemical Corp., Specialty Chemicals Div., P.O. Box 1087R, Morristown, N.J., 07960
Allied Molded Products Inc., N. Union St., P.O. Box 623, Bryan, Ohio 43506
American Cyanamid Co., Industrial Chemicals Div., Wayne, N.J. 07470
American Hospital Corp., Plastics Div., 289 N. Main St., Leominster, Mass., 01453
American Hospital Corp., Plastics Div., Route 202-206 North, Somerville, N.J., 08876
Amoco Chemicals Corp., P.O. Box 8640A, Mail Code 4102, Chicago, Ill., 60680
Ampolone Corp., P.O. Box 3297, Brownsville Compress Bldg. No. 900, Brownsville, Tex., 78520
Armco Composites, 333 N. Sixth St., St. Charles, Ill. 60174
Armstrong Products Co. Inc., P.O. Box 657, Warsaw, Ind. 46580
Atlantic Laminates Div., Oak Materials Group Inc., 174 N. Main St., Franklin, N.H. 03235
BASF Wyandotte Corp., 100 Cherry Hill Rd., Parsippany, N.J. 07054
B.B.I. Inc., P.O. Box 146, Glenshaw, Pa. 15116
Babcock & Wilcox Co., Refractories Div., P.O. Box 923, Old Savannah Rd., Augusta, Ga. 30903
Bergquist Co. Inc., 4350 W. 78th St., Minneapolis, Minn. 55435
Borg Warner Chemicals, Plastics, Borg-Warner Corp. International Center, Parkersburg, W. Va. 26101
Budd Chemical Co., 272 Rockaway St., Boonton, N.J. 07005
Budd Co., Plastics Div., 3207½ Edward Ave., Madison Heights, Mich., 48071
Celanese Plastics Co., 26 Main St., Chatham, N.J., 07928
Century Laminators Inc., 1225 Knollwood Circle, Anaheim, Calif. 92810
Chemplast Co., Rolling Meadows, Ill., 60008
Chomerics Inc., Dept. TR, 77 Dragon Court, Woburn, Mass. 01801
Ciba-Geigy Corp., Plastics & Additives Div., Saw Mill River Rd., Ardsley, N.Y. 10502
Cincinnati Development & Mfg. Co., 5814 Wooster Pike, Cincinnati, Ohio 45227
Cincinnati Milacron Chemicals Inc., West St., Cincinnati, Ohio, 45215
Colonial Fiber Co., 615 Parker St., Manchester, Conn., 06040
Cottrell Paper Co., P.O. Box 35, Rock City Falls, N.Y., 12863
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Diamond Shamrock Chemical Co., General Headquarters, 1100 Superior Ave., Cleveland, Ohio, 44114
Dodge Fluorglas, Dodge Industries Inc., Oak Materials Group, McCaffrey St., Hoosick Falls, N.Y. 12090
Dow Chemical Co., 2020 Dow Center, Midland, Mich., 48640
Dow Corning Corp., P.O. Box 1767, Midland, Mich., 48640
Du Pont de Nemours, E. I., & Co., 1007 Market St., Wilmington, Del., 19898
Durez Div., Hooker Chemicals & Plastics Corp., 1024-8 Royal Ave., Niagara Falls, N.Y., 14302
Eagle-Picher Industries Inc., 580 Walnut St., Cincinnati, Ohio, 45202
Eastern Sterling Plastics Co., P.O. Box 316, Windsor, N.J. 08561
Eastman Chemical Products Inc., Sub. Eastman Kodak Co., P.O. Box 431, Kingsport, Tenn., 37662
Electroply Inc., 140 Washington St., El Segundo, Calif. 90245
Epic Resins, Div. of RTE Corp., 1900 E. North St., Waukesha, Wis. 53186
Ethyl Corp., Vaqueen Div., 451 Florida Blvd., Baton Rouge, La. 70801
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Fortin Laminating Corp., Div. Monogram Industries Inc., 1323 Truman St., San Fernando, Calif. 91340
GAF Corp., 140 W. 51st St., New York, N.Y. 10020
GTE Sylvania Inc., 520 Lexington Ave., Warren, Pa. 16365
Garfield Mfg. Co., P.O. Box 40, Garfield, N.J. 07026
General Electric Co., Laminated & Insulating Materials Business Dept., Coshocton, Ohio 43812
General Electric Co., Noryl Operations, 1 Noryl Ave., Selkirk, N.Y., 12158
General Electric Co., Plastics Div., 1 Plastics Ave., Pittsfield, Mass., 01201
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Goodrich, B. F., Chemical Co., 6100 Oak Tree Blvd., Cleveland, Ohio, 44131
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Somerville Industries Ltd., 20 Bertrand Ave., Scarborough, Ontario, Canada, M1L-2P4
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Spaulding Fibre Co., Industrial Plastics Div., 310 Wheeler St., Tonawanda, N.Y. 14150
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Westinghouse Electric Corp., Insulating Materials Div., Chemical Products Plant, Manor, Pa. 15665
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4.3 Mechanisms for Removal of Damage, Recovery

Thermally activated movement of defects permits their removal. It has been estimated on theoretical grounds[11] that the activation energy for motion of *interstitials* is between 0.1 and 0.2 ev in a typical face-centered-cubic crystalline solid, copper. The activation energy for motion of a *vacancy* is significantly higher in most solids. An unequivocal assignment of activation energy and frequency factors for movement of these primary defects in solids is impossible at the present time. In Table 13 are

Table 13. Temperature Ranges for Recovery

Solid	Type of irradiation	Temperature of irradiation	Temperature range for significant recovery of electric resistivity
Graphite	Electron*	10°K	80–110°K; 150–300°K; no studies at higher temperatures
	Proton†	103°K	150–300°K; no studies at higher temperatures
		30°C	100–130°C; 1000–1400°C; 1800°C
		150°C	100–130°C; 1000–1400°C; 1800°C
	Fast neutron¶	120°K‡	150–300°K
		30°C	100–130°C; 1000–1400°C; 1800°C
		80°K	213°K
Al	Fast neutron§	10°K	35°K; 223°K
Ni	Electron**	80°K	30°C; 300°C
Cu	Electron**	10°K	35°K; 40–200°K (very gradual); 300°C
	Deuteron††	80°K	243°K; 300°C
	Fast neutron††	10°K	30°K (sharp); 30–200°K (gradual); 200–230°K
Ag	Deuteron††	10°K	10–230°K (gradual); 230–260°K (rapid)
Au	Deuteron††		

* R. R. Austerman and J. K. Hove, Irradiation of Graphite at Liquid Helium Temperatures, *Phys. Rev.*, 100: 1214–1215 (1955).

† G. Hennig and J. E. Hove, Interpretation of Radiation Damage to Graphite, P/751, *Proc. Intern. Conf. on Peaceful Uses of Atomic Energy*, August, 1955.

‡ W. P. Eatherly, *Bull. Am. Phys. Soc.*, 30: 8 (1955); also T. J. Neubert, *ibid*.

¶ W. K. Woods, L. P. Bupp, and J. F. Fletcher, "Irradiation Damage to Artificial Graphite," P/746.

§ A. W. McReynolds, W. Augustyniak, M. McKeown, and D. B. Rosenblatt, Neutron Irradiation Effects in Cu and Al at 80°K, *Phys. Rev.*, 98: 418–425 (1955).

** C. J. Meechan and J. A. Brinkman, Electrical Resistivity Study of Lattice Defects Introduced in Copper by 1.25 Mev Electron Irradiation at 80°K, *Phys. Rev.*, 103: 1193 (1956).

†† J. W. Corbett, J. M. Denney, M. D. Fiske, R. M. Walker, Electrical Irradiation of Copper Near 10°K, *Phys. Rev.*, 108: 954–964 (1957).

A. Sosin, C. J. Meechan, Defect Production and Migration in Copper and Nickel, NAA-SR-2062, Nov. 15, 1957.

11 F. Seitz and J. S. Koehler, "The Theory of Lattice Displacements Produced During Irradiation," P/749.

given the temperature ranges in which recovery of changes in electrical resistivity occurs and which must be related to thermally activated motion of primary defects observed in several solids studied to date. It may be noted that complete recovery requires heating to temperatures associated with the usual annealing of metals.

The case of graphite may be somewhat clearer than that for metals in that single interstitial atoms lie between the planes and move at approximately 80 to 100°K. Vacant sites move near 1800°C. The possible reactions of the primary defects in graphite are discussed later.

After apparently complete removal of interstitial-vacancy pairs, defects remain that increase the resistance of metals to flow. These defects are thought to be either jogs in dislocations or aggregates of interstitials or vacancies forming the equivalent of stacking faults or both.

Fission fragment damage anneals only partially at temperatures below those at which atomic diffusion occurs. Depending on the activation energy for diffusion in the material in which the fission products find themselves, there will be a temperature range in which the atoms are sufficiently mobile that further diffusion to metastable or stable configurations is possible. Certain of the fission-product atoms, particularly the inert gases, are far too large to fit in ordinary metallic lattice. The

initial lattice strains are probably relieved by diffusion of vacancies to the region of the inert gas atom; subsequently, the region of vacant sites along with the gas atom may diffuse out of the crystal, first to grain boundaries and then along or with grain boundaries out of the solid. While this is proceeding, if the concentration of fission-product atoms is sufficiently high, agglomeration and bubble formation are possible. At temperatures too low for diffusion, fission-product atoms will influence the physical and mechanical properties of solids in all the ways generally pictured for the effects of impurities. Because of the large mismatch in atom size, large effects at very low concentration may be expected.

4.4 Ionic Crystals

Displacements occur in ionic crystals in the way described above. In addition, two other sources of point defects exist.

Vacancies may evaporate from jogs in dislocations,[16] the energy being supplied by excitons[16] or by thermal activation.

Interstitial atoms may be produced[17] by ionization of an anion by γ radiation or fast electrons followed by movement of the anion itself under coulomb repulsion or of a cation pushed by the anion. The cross section for the process is approximately $10^{-(18+n)}$ cm², where n is the number of electrons removed.

The interaction of crystal defects with one another and with electrons and holes is covered in the references cited.[14,18]

5 CHANGES PRODUCED IN MACROSCOPIC PROPERTIES OF MATERIALS

5.1 Nonfissionable Metals

The effects of radiation on nonfissionable metals are generally relatively small as far as the engineering applications of the materials are concerned. The results observed, however, are of considerable interest in basic studies on the properties of imperfect materials.

5.11 Mechanical Properties. The effects on mechanical properties require some consideration in the practical application of metals to structures in a strong radiation field. The changes in electrical properties have been extensively explored also but are probably of lesser engineering significance.

The mechanical properties investigated have been of considerable variety. Table 14 summarizes the results on numerous metals.*,[18]

5.12 Electrical Properties. The changes in electrical properties of metals have been studied primarily as a tool for the fundamental investigation of radiation-damage phenomena. In general, the resistivity near room temperature in samples exposed at such temperatures changes very little, less than 1 per cent. At lower temperatures of exposure and measurement, significant changes are observed, and the study of these changes and their annealing behavior at higher temperatures has been of considerable importance to the subject. Other electrical or magnetic properties have been investigated in special instances, including magnetic permeability and thermoelectric power. Table 15 summarizes results on the electrical resistivity changes observed in various metals.

The thermal conductivity of metals generally follows the behavior of the electrical conductivity. Measurements have been made in a few materials, e.g., Inconel and stainless steels, at elevated temperatures in the range 300 to 800°C with no changes observed.

The thermoelectric power of several materials has been studied[19] as a function of irradiation. The data appear in Table 16.

5.13 Effects of Radiation on Reactions in Solid Metals (Metallurgical Processes). Several major types of reactions in solid metals (metallurgical processes) induced or

* These data have been collected from numerous unpublished AEC reports. A useful summary is given in Ref. 18.

Table 15. Electrical Resistivity

Metal	Exposure	Change observed	Remarks
Aluminum, high purity annealed	2.2×10^{17}/cm² (36 Mev α particles)	+40%	Exposed at ~ −100°C, measured at ~ −170°C
	4×10^{19}/cm² fast neutrons	+10%	Exposed at 50°C, measured at −190°C
Aluminum, 2S	[illegible]	+0.7%	Exposed at 50°C, measured at + 20°C
AlSi alloy (2.3% Si, in solution)	4.8×10^{19}/cm² fast neutrons	Negligible	Exposed at 50°C
Copper OFHC	2.2×10^{17}/cm² (36 Mev α particles)	+30%	Exposed at −100°C, measured at −170°C
	1.5×10^{19}/cm² fast neutrons	+0.2%	Exposed at 60°C, measured at 20°C
CuBe alloys: 1% Be	1.7×10^{19}/cm² fast neutrons	+0.39%	Exposed at ~50°C
5.4% Be	1.7×10^{19}/cm² fast neutrons	+0.01%	Exposed at ~50°C
CuZn alloys: 1.35% Zn	1.5×10^{19}/cm² fast neutrons	+0.3%	Exposed at ~50°C
6.3% Zn	1.5×10^{19}/cm² fast neutrons	−0.65%	Exposed at ~50°C
12.6% Zn	1.5×10^{19}/cm² fast neutrons	−1.8%	Exposed at ~50°C
Iron	1.7×10^{19}/cm² fast neutrons	Negligible	Exposed at ~50°C
Iron alloys: Type 304 SS	4×10^{19}/cm² fast neutrons	+5%	Exposed at 200°C, measured at ~20°C
	7×10^{17}/cm² (10 Mev deuterons)	+4%	Exposed and measured near −150°C
Type 347 SS	25×10^{19}/cm² fast neutrons	−1%	Exposed at 260°C, measured at 25°C
Type 347 SS	25×10^{19}/cm² fast neutrons	−7%	Exposed at 260°C, measured at 25°C
Type 322W SS	2×10^{19}/cm² fast neutrons	Negligible	Exposed at ~50°C
Nickel, type A	2.2×10^{17}/cm² (36 Mev particles)	+60%	Exposed at ~ −100°C, measured at −170°C
Zirconium	1.4×10^{20}/cm² thermal neutrons (~ 2×10^{19}/cm² fast)	+6%	Exposed at ~30°C, measured at 20°C
	25×10^{19}/cm² fast neutrons	Negligible	Exposed at 260°C, measured at 25°C

Table 16. Thermoelectric Power

Metal	Exposure	Thermoelectric power vs. unirradiated metal	Remarks
Copper	1.2×10^{17}/cm² 35-Mev α particles	−0.03 μv/°C	Exposed, measured at −120°C
Iron	2×10^{16}/cm² 9 Mev protons	−0.3 μv/°C	Measured near 30°C
Chromel vs. Alumel	6×10^{17} neutrons/cm² fast neutron flux	Negligible	Exposed, measured near 100°C

affected by radiation have been studied extensively: order-disorder tr[illegible]mations, precipitation from solid solution, phase change from austenitic to ferritic structure, and diffusion.

Order-Disorder. In the alloy Cu_3Au, neutron exposures have been observed to disorder initially well-ordered specimens at temperatures near 50°C. In a somewhat higher temperature range, radiation has been observed to accelerate the ordering of initially disordered specimens.

Similar disordering effects have been observed in Ni_3Mn from measurements of changes in the magnetic properties.

In the alloy β brass, which normally exists only in the ordered states below its transition temperatures, exposure to 4×10^{17}/cm² of 36-Mev α particles at −150°C produced a 100 per cent increase in resistivity. This is much greater than is observed in other brasses and anneals out rapidly below room temperature. This change has been interpreted as disordering of the β-brass structure at low temperatures.

All these results can be described qualitatively in terms of enhanced local diffusion on a microscale. The exact mechanism required to account for the rapidity of the effects is not yet clear. Several hypotheses, described as "thermal," "displacement," or "replacement" spikes, have been proposed.*

Precipitation from Solid Solution. The system that has been studied most extensively is copper containing about 2 per cent beryllium. The changes in electrical resistance during and subsequent to exposure, the changes in hardness after varying exposures, and the subsequent alteration of these changes during annealing were investigated. In summary, a correspondence between effects produced by neutron irradiation and by low-temperature (~100°C) aging was observed. The results suggest that radiation can produce precipitate nuclei and that these form because of the accelerated microdiffusion which takes place in the presence of radiation.

The decrease in resistivity observed in type 322W stainless steel (Table 15) has also been attributed to precipitation induced by radiation.

Phase Transformation. Austenitic stainless steels, alloys of iron, chromium, and nickel, are metastable only at ordinary temperatures; the stable state is a mixture of austenitic and ferritic. The ferritic phase is ferromagnetic, and magnetic measurements have been used as a sensitive means for detecting the presence of transformed material. A slight increase in ferritic content after neutron bombardment of type 347 stainless steel has been observed, but of a magnitude probably below practical significance.

Diffusion. The effects of radiation on the several processes discussed in earlier paragraphs suggest that microdiffusion is accelerated in metals when they are exposed to particle radiation. Direct experiments on this phenomenon have not yielded positive results, however.

Detailed experiments on the effect of radiation on the diffusion rate in the copper-gold, copper-nickel, and lead-tin systems and on self-diffusion in silver have been made.

Copper-gold and copper-nickel samples were exposed in a fast-neutron flux of ~5×10^{11} neutrons/(cm²)(sec) in the temperature range 280 to 380°C, with no observable change in diffusion rate compared with control samples at the same temperature.

Lead-tin samples, exposed in a much lower flux, also gave negative results.

Silver self-diffusion was studied using cyclotron beams of 3×10^{11} neutrons/(cm²)(sec) of 10-Mev protons. The temperature range was 700 to 850°C. No detectable change was observed.

5.2 Moderator Materials

5.21 Graphite. Information concerning changes in the following properties of graphite is of direct use in the design and operation of reactors: (1) linear dimensions, (2) thermal conductivity, (3) enthalpy (stored energy), and (4) Young's modulus. Of engineering importance but not of direct use are changes in (1) strength and (2)

*Revised by D. S. Billington in Ref. 21.

Table 14. Change in Mechanical Properties of Metals and Alloys

Metal	Property*	Exposure†	Change observed	Remarks†
Aluminum, high purity annealed	Offset yield strength Ultimate strength Fractional elongation	2 × 10[illegible]/cm² thermal neutrons, 5 × 10[illegible]/cm² fast neutrons	+100% +60% −67%	Exposed at about 50°C for all properties given
Aluminum, high-purity half hard	Offset yield strength Ultimate strength Fractional elongation	2 × 10[illegible]/cm² thermal neutrons, 5 × 10[illegible]/cm² fast neutrons	+10% +6% 0	Exposed at about 50°C for all properties given
Aluminum	Creep rate	~10[illegible]/(cm²)(sec) thermal neutrons	Negligible	Tested at 150°C, 27 kg/cm²
Aluminum	Creep rate	~10[illegible]/(cm²)(sec) 9 Mev protons	Negligible	Tested between 170–335°C, 45–100 kg/cm²
Aluminum alloys:		10[illegible]/cm² fast neutrons		Exposed at 70°C for all properties given
Type 61S0	Yield strength Tensile strength		+290% +150%	
Type A54S	Yield strength Tensile strength		+6% +6%	
Type 52S0, 61STS	See above		~50–100% for both Y.S and T.S	
Beryllium	Various	~3 × 10[illegible]/cm² fast neutrons	Negligible	Exposed at ~30°C
Copper Ann. (OFHC)	Hardness	2 × 10[illegible]/cm² fast neutrons 6 × 10[illegible]/cm² fast neutrons	41 → 57 DPH +33 Brinell numbers	Exposed at 60°C Exposed at 80°C
Copper, single crystals	Critical shearing stress Creep	2 × 10[illegible]/cm² fast neutrons 10[illegible]/(cm²)(sec), 16 Mev deuterons	0.4 → 2.0 kg/mm² Negligible	Exposed at 60°C, measured at 20°C At 360°C, 700 kg/cm²
Copper 2% Be alloy: Quenched from 800°C	Hardness—Rockwell G	9 × 10[illegible] neutrons/cm² thermal neutrons, 2 × 10[illegible] neutrons/cm² fast neutrons	R_G18 → R_G90	Exposed at 30°C, alloy originally in solution annealed state
Quenched for 2 hr at 315°C			R_G100 → R_G105	Exposed at ~30°C, alloy near maximum hardness originally
Quenched for 16 hr at 450°C			R_G67 → R_G85	Exposed at ~30°C, alloy originally overaged thermally
Copper manganese:	DPH hardness	1.4 × 10[illegible]/cm² fast neutrons		All exposed at ~30°C
1.0% Mn 5.0% Mn			+13.7 DPH numbers +16.8 DPH numbers	
12.4% Mn			+11.6 DPH numbers	
Copper zinc	Hardness	1.5 × 10[illegible]/cm² fast neutrons		
1.35% Zn			26 → 60 R_F	Exposed at ~30°C
14% Zn			65 → 71 R_F	Exposed at 30°C, annealed 1 hr at 250°C before exposure

Table 14. Change in Mechanical Properties of Metals and Alloys. (Continued)

Metal	Property*	Exposure†	Change observed	Remarks†
34% Zn (Cont.)	Hardness (Cont.)	1.5 × 10[illegible]/cm² fast neutrons (Cont.)	100 → 101 R_F	Exposed at 30°C, cold rolled before exposure
Iron	Hardness	2 × 10[illegible]/cm² fast neutrons	84 → 90 R_B	Exposed at 40°C
Iron alloys: Type 304 SS	Hardness Fatigue strength	1.3 × 10[illegible]/cm² thermal neutrons, 10[illegible]/cm² fast neutrons 2 × 10[illegible]/cm² fast neutrons	Negligible Insignificant	300°C during exposure Irradiated at 100°C, tested at 1,700 cpm
Type 316 SS	Hardness Ultimate strength Elongation at rupture	5 × 10[illegible]/cm² fast neutrons	83 → 98 R_B +90% −15%	Exposed at 25°C
Type 347 SS	Hardness Yield point Ultimate tensile strength Hardness Hardness Elongation at rupture Elongation at rupture Creep rate	6 × 10[illegible]/cm² fast neutrons 1.1 × 10[illegible]/cm² 36-Mev α particles 6.7 × 10[illegible]/cm² 36-Mev α particles 6 × 10[illegible]/cm² fast neutrons 7 × 10[illegible]/cm² fast neutrons ~10[illegible]/(cm²)(sec) fast neutrons	75 → 93 R_B 2300 → 5400 kg/cm² 600 → 7300 kg/cm² 190 → 230 DPH 190 → 260 DPH 57 → 34% Negligible Decreased 25%	Exposed at 100°C Exposed at ~20°C, measured at 20°C Exposed at 160°C Exposed at 200°C Tested in reactor at ~200°C under 8,000 psi stress
BA-212 pressure vessel steel	Fatigue endurance limit	1 × 10[illegible]/cm² fast neutrons	46,000 → 42,000 psi	Sample without notch exposed at 40°C
BA-201 pressure vessel steel	Tensile strength (2% offset) Elongation at rupture	4 × 10[illegible]/cm² fast neutrons	+60% 12 → 3%	Exposed under load of 1,000 kg/cm²
Molybdenum	Hardness Yield strength (2% offset) Fracture strength Ductile to brittle transition temperature	10[illegible]/cm² fast neutrons	+35 Brinell numbers 100,000 → 140,000 psi 130,000 → 160,000 psi −30 → +70°C	Exposed at 80°C
Nickel	Hardness Ultimate strength Elongation at rupture	10[illegible]/cm² fast neutrons	41 → 96 R_B 4400 → 6600 kg/cm² 47 → 26%	Exposed at 30°C
Zirconium	Hardness Yield strength (2% offset) Elongation Creep rate	2 × 10[illegible]/cm² fast neutrons ~10[illegible]/(cm²)(sec) thermal and fast neutrons	+10 DPH numbers 17,000 → 24,000 psi Negligible change Rate decreased by factor of 20	Exposed at 260°C Tested in reactor at 260°C in stress range 1,000–2,500 kg/cm²

* Creep rates are "in beam" or "in pile"; other properties are before and after measurements.

† In "Exposure" and "Remarks" columns conditions are not repeated. Initial conditions govern all entries for a given metal in "Metal," "Property," and "Change observed" columns until a changed condition is indicated by a new entry.

approximate calculations of the energy absorbed by a material from each of the principal components of a normal pile radiation, namely, fast neutrons, γ's, and thermal neutrons.

2.1 Absorption Energy from Fast Neutrons

The amount of energy K_s absorbed per gram of an organic material from a fast-neutron dosage ϕ_s with an average neutron energy K_n is

$$K_s = \phi_s \frac{\Sigma_s}{\rho} \frac{1}{2} K_n$$

where ρ is the density of material, ½ is the fraction of the initial energy of the neutron transferred to the hydrogen* atom per collision, and Σ_s is the macroscopic scattering cross section of hydrogen in the material being considered; Σ_s is equal to $\sigma_s N_H$ where σ_s is the microscopic scattering cross section for hydrogen, and N_H is equal to the number of hydrogen atoms per cubic centimeter of material. To determine more exactly, but still not rigorously, the total energy absorbed from a fast-neutron dosage, the energies absorbed from neutrons over each small incremental energy range would have to be calculated, using the dose and scattering cross section corresponding to each energy range. These energies would then need to be summed to obtain the total energy K_s^{total}. On the basis that 0.01-Mev neutrons are the lowest energetic neutrons above thermal that contribute any appreciable energy to the medium through the scattering process, the total energy absorbed would be

$$K_s^{total} = \sum_{0.01} K_s^{0.01-1.0} + K_s^{1.0-2.0} + K_s^{2.0-3.0} + \cdots$$

where

$$K_s^{0.01-1.0} = \phi_s^{0.01-1.0} \sigma_s^{0.01-1.0} \frac{N_H}{\rho} \frac{1}{2} K_n^{0.01-1.0}$$

2.2 Absorption Energy from γ Radiation

The energy absorption from a γ photon dosage ϕ_γ can be approximated by the following equation:

$$K_\gamma = \phi_\gamma \mu_\gamma E_\gamma$$

where K_γ is the energy absorbed per gram of material from γ radiation and E_γ is the average energy of the γ photons. The term μ_γ is the energy absorption coefficient (in square centimeters per gram) of the material for γ radiation of energy E_γ, and it is the fraction of energy dissipated by a narrow beam of γ rays in traversing an absorber. It is obtained by multiplying the probability of each interaction process by the probable fraction of the photon energy actually dissipated in the absorber as a result of the process.

The energy absorption coefficients of various materials are given as μ_a/ρ in Table 2 of Sec. 7-3. In many cases where the μ_γ value for a particular material being considered cannot be found, the μ_γ value for an analogous material can be readily substituted. The value for water can generally be used for ordinary organic materials.

2.3 Absorption Energy from Thermal Neutrons

For the H(n,γ)D reaction, which is the main source of energy deposition in organics by thermal neutrons, the energy absorbed per gram can be crudely approximated by the following equation:

* The deposition of energy in an ordinary organic compound by fast neutrons and thermal neutrons is due primarily to its hydrogen content, since hydrogen has a much larger scattering and absorption cross section than carbon.

$$K_s^{th} = \phi_s \frac{\Sigma_a}{\rho\sigma_\gamma} \sigma_\gamma K_\gamma$$
$$= \phi_s \frac{\Sigma_a}{\rho} K_\gamma$$

where ϕ_s is the thermal-neutron dose, ρ is the density of the material, K_γ is the average energy of the photons generated by the n-γ reaction, and Σ_a is the macroscopic absorption cross section of hydrogen in the material being considered; Σ_a is equal to $\sigma_a N_H$, where σ_a is the microscopic absorption cross section for hydrogen and N_H is the number of hydrogen atoms per cubic centimeter.

2.4 Average Energy in Breaking a Bond

The average energy required to break a chemical bond is approximately 25 ev, and the average energy difference between successive electronic levels is about 5 ev. It is obvious that the Mev energies possessed by ordinary pile fast neutrons and γ photons constitute large sources of energy that can be transferred via secondary processes and cause extensive electronic excitation and ionization in a chemical compound. Although the average energy of a thermal neutron at normal temperatures is 0.025 ev and is insufficient to cause electronic excitation or ionization, the capture of these low-energy neutrons by matrix nuclei results in secondary radiation from n-γ, n-p, and n-α reactions which involves energy in the Mev range.

Two different methods have been frequently used in the past to relate the rate of reaction of liquids and gases as a function of the irradiation energy involved. In gases, the ion-pair yield has been used as a reaction rate measure, the energy required to produce an ion pair varying in different gases from approximately 28 to 38 ev. This energy range is approximately 18 to 22 ev greater than the ionization potential range of the gases, and this difference represents the energy necessary for the formation of electronically excited states.

In liquids, since it is difficult to measure the number of ions produced by radiation, it has been frequently customary to determine the rate of reaction by the amount of material reacting for a given energy input. The term G has been used for this purpose, and it is defined as the number of molecules reacting per 100 ev of energy absorbed. For general covalent materials, it is useful to remember that the normal value of G is approximately 4.

In this article, the changes in physical and chemical properties of the various materials listed have been related to the amount of energy absorbed per gram weight of irradiated material.

3 CALCULATION OF RADIATION DAMAGE

3.1 Radiation Damage to Water, Aqueous Solutions, and Fused Salts

Excellent reviews of the effects of radiation on water and aqueous solutions and many other materials have been written. These reviews have appeared under the general title of Radiation Chemistry in the "Annual Reviews of Physical Chemistry" from 1950 through 1954[a] and in the same "Annual Review" for 1955 under the title of Radiation and Hot Atom Chemistry. These reviews are concerned with the fundamental aspects of the effects of radiation on various materials.

The general mechanism of the effects of radiation on water has received rather exhaustive treatment in these reviews. It is generally agreed that the decomposition of pure water proceeds to a limited extent and then comes to a standstill because of the back reaction. The main initial decomposition reactions of irradiation are

$$H_2O \rightarrow H + OH \quad (1)$$
$$2H_2O \rightarrow H_2 + H_2O_2 \quad (2)$$

Although the H_2O_2 formed decomposes to oxygen in a secondary reaction, the back reaction involving the combination of the reaction products to re-form water can be formulated as follows:

$$H + H_2O_2 \rightarrow H_2O + OH \quad (3)$$
$$OH + H_2 \rightarrow H_2O + H \quad (4)$$
$$\text{Net reaction: } H_2 + H_2O_2 \rightarrow 2H_2O \quad (5)$$

The decomposition of irradiated aqueous solutions proceeds according to Eqs. (1) and (2), but the presence of solutes protects the initial decomposition products by destroying the free radicals by oxidation-reduction reactions. Thus, hydrogen can evolve and the hydrogen peroxide can decompose. Since solute molecules vary considerably in specificity of reaction, appreciable differences in results can be obtained when various aqueous solutions are irradiated.

The data in Table 1 are concerned primarily with the engineering aspects of the radiation damage to water, aqueous solutions, and fused salts. As can be seen from this table, the reaction of water with pile radiation is reversible, and relatively low equilibrium pressures are obtained. However, when borated water is irradiated, an irreversible reaction occurs and the gas evolution is a linear function of the combined energy absorption from neutron scattering and neutron capture minus the γ-energy absorption. In other words, the γ-energy absorption appears to favor the back reaction, whereas the energy absorbed from neutron scattering and the n-α reaction with boron appears to favor the forward reaction.

Even without the presence of boron, antifreeze solutions will tend to decompose extensively under radiation; the presence of boron simply accelerates this effect. As would be expected from the mechanism of reaction, fused salts are not detectably affected by the pile radiation. In the liquid state, they are not even affected by that portion of the fast-neutron energy (2 to 5 per cent) deposited in the liquid by momentum losses, since the ions are then in a less ordered state than they would be in the solid form.

A fairly extensive review of the unclassified data available on the decomposition of water by radiation has been made.[5] This review is divided into four main parts: (1) General Considerations—an approximate picture of the gross process of radiation-induced decomposition of water, (2) The Mechanism—the role of ionization and the principal chemical reactions involved, (3) Major Factors—the major variables and their effects upon decomposition, and (4) Practical Considerations—general observations on decomposition that are of interest to the reactor designer, general rules for minimizing decomposition, and specific decomposition data obtained from in-reactor experiments and from full-sized reactors are presented.

Four major conclusions have been made in this review:

1. "Under the average neutron-gamma flux levels existing in cooling water or moderating water of present reactors, both the instantaneous decomposition rates and the maximum concentrations of decomposition products are very close to zero for initially gas-free, relatively pure water." Relatively pure water is defined in Monson's review in a very approximate manner as having a minimum specific resistance of 200,000 ohm-cm and a maximum gas content of 0.1 ml/liter.

2. "In general, increased temperature results in reduced decomposition rates and equilibrium concentrations of decomposition products." Above 300°F, the recombination rate is high and essentially independent of temperature.

3. "In general, the presence of some impurities results in increased decomposition rates and equilibrium concentrations of decomposition products, some impurities producing slight increases and others producing very large increases." At low temperatures, solutions of some ionic impurities such as KBr, KI, and $CuSO_4$ may produce partial pressures of 1,500 psi under radiation conditions that produce only a partial pressure of less than 10 psi for relatively pure water. At high temperature, i.e., above 400°F, exploratory work has shown that certain impurities strongly catalyze the backward reaction. Such impurities are copper, rhodium, palladium, platinum, silver, and iodine; and tin, iron, and titanium to a lesser extent.

4. "At low temperature, decomposition is so repressed by excess hydrogen that virtually no decomposition occurs at average neutron and gamma irradiation levels

Table 1. Radiation Damage to Water, Aqueous Solutions, and Fused Salts

No.	Class of material	Specific material tested	Temperature of irradiation, °F	Irradiation source[a]	Type of reaction[b]	Gas evolution, ml/ml (STP)	Dosage, 10^9 rads	Particle dosages each equivalent to 10^9 rads: Thermal[c] neutrons, 10^{20} neutrons/cm²	Fast[d] neutrons, 10^{17} neutrons/cm²	Gamma energy: Photons[e], 10^{20} γ/cm²	Gamma energy: Roentgens, 10^9 r	Container	Remarks
1	Water	Demineralized	220–250	WR	Rev., equil. pressure: 1.27 psi H_2, 0.25 psi O_2	None	20	3.37	2.78	2.81	1.06	AL series 300 Stainless steel	Terminated ad libitum. Equilibrium should continue with increasing dosage
2		Distilled	220–250	WR	Rev., equil. pressure: 6 psi H_2, 2 psi O_2	None	30	3.37	2.78	2.81	1.06	AL series 300 Stainless steel	Same as above
3	Antifreeze solutions	60% Prestone in 4% H_3BO_3 water solution	200–220	GR	Irrev.	Not measured	0.0002	0.016	2.92	2.84	1.06	Al	No change in freezing point (−80 to −85°F)
4		60% Prestone in 4% H_3BO_3 water solution	220–275	GR	Irrev.	Not measured	0.2	0.016	2.92	2.85	1.06	Al	Completely carbonized; moist and black
5	Aqueous acid solutions	0.095% boron[f]	220	WR	Irrev.	0.30[g]	0.011	0.099	2.78	2.02	1.06	AL series 300 Stainless steel	The system was operated at pressures up to 60 psi. No indication of equilibrium conditions was observed
6		1.90% boron[f]	220	WR	Irrev.	1.9[g]	0.040	0.0032	2.84	2.82	1.06	AL series 300 Stainless steel	Same as above
7		Ortho-phosphoric	77–330	VG	Irrev.	Extensive	1.8	4.10[h]	0.72	2.16	1.13	Series 300 Stainless steel	Extensive decomposition, darkening, and heavy frothing
8	Fused salts	Sodium hydroxide	1300	GR	Rev.	Not detected (<1%)	.22	0.62	10.2	2.22	1.17	Ni	No evidence of damage. No change in freezing point, determined in situ. No pressure was detected.
9		Sodium hydroxide	1000	VG	Rev.	Not detected (<1%)	20	0.62	10.2	2.22	1.17	Ni	Same as above

[a] WR—water reactor, GR—graphite reactor, VG—van de Graaff—2-Mev electrons.
[b] Rev.—reversible, Irrev.—irreversible.
[c] Thermal-neutron dosage equivalents calculations based on geometric configuration of a 1.25-cm radius cylinder.
[d] Fast neutrons ≥ 1.0 Mev.
[e] Gamma photon average energy—1.0 Mev.
[f] USP boric acid in demineralized water.
[g] A series of tests using concentrations of 0.095, 0.59, 0.94, and 1.90 per cent boron was run. The gas evolution was found to be a linear function of the rad dosage calculated as $E_n - E_\gamma$ where E_n = the combined energy absorption from neutron moderation and the neutrons reaction with boron and E_γ = the γ energy absorption.
[h] This dosage includes not only the energy absorbed from the $H(n,\gamma)D$ reaction but that absorbed from the $P(n,\beta)$. The energy from the $P(n,\beta)$ reaction was calculated from average disintegrations per second with a build-up of five half-lives.

in present reactors if hydrogen equivalent to 5 to 10 psi partial pressure is initially dissolved (and maintained) in otherwise relatively pure water." The same statement is essentially true for water used at high temperature.

In general, the reactor designer should consider the following steps in attempting to minimize water decomposition: (1) Initially remove all the oxygen economically feasible, and dissolve a small amount of hydrogen in the water before subjecting it to irradiation; (2) maintain a partial pressure of a few pounds per square inch of hydrogen (or deuterium for heavy water) in the system; and (3) maintain the water relatively pure (10^6 ohm-cm or higher) by installation of a bypass, mixed-bed, ion-exchange system.

3.5 Radiation Damage to Organic Fluids

In a nuclear power plant, organic liquids, in general, can be used in many different ways, such as for greases, lubricants, coolants or heat-transfer media, moderating materials, and allied usages. Two of the most striking effects occurring in an organic liquid as the result of exposure to radiation are gas evolution and changes in viscosity. The viscosity usually increases upon continual exposure to radiation until the liquid has polymerized into a solid form.

Several broad generalizations can be made regarding the effect of radiation on organic fluids. The gas evolution is not dependent upon the dosage rate, but it is a linear function of the total dose of energy applied. The per cent viscosity increase is also a function of the radiation dosage rather than the dosage rate, and a marked threshold of reaction appears to exist. The viscosity gradually increases initially with radiation damage until a definite amount of radiation has been absorbed; at this point there is an exponential increase in viscosity with small incremental amounts of radiation energy. Generally, there is considerable difference between the behavior of aromatic compounds and other organic compounds under radiation. Aromatics are far more resistant to radiation damage than aliphatics, the radiative energy absorbed presumably being taken up primarily by excitation of the shielded system of π electrons in the aromatic nucleus.*

In a more definitive manner, the difference in susceptibility of various aromatic structures to radiation damage can be considered and explained on the basis of their ability to assume several different electronic configurations, that is, on their ability to resonate. The higher the resonance energy of the aromatic structure, the more resistant it should be to radiation. The resonance energy of a compound being defined as the difference between the experimentally determined energy of formation and the calculated energy of formation as determined by adding up the individual bond energies, the following values in terms of kilocalories per mole are obtained in order of decreasing resonance energy for various organic materials: anthracene, 105; naphthalene, 75; quinoline, 69; stilbene, 54; indole, 54; diphenyl, 47; styrene, 46; pyridine, 43; and benzene, 39. The values given for diphenyl, styrene, and stilbene include 8, 7, and 15 kcal/mole of resonance energy, respectively, in addition to the 39 kcal/mole for the benzene ring. The experimental radiation-damage data obtained to date on various homologues of benzene, naphthalene, and diphenyl are in good general agreement with the rule that "the higher the resonance energy of the aromatic structure being tested, the greater the resistance to radiation damage." This is a good general rule to remember in predicting the effects of radiation on a new aromatic-type material, and this rule should be of assistance in synthesizing or developing a new material to meet certain radiation-resistant requirements.

By using the general law that equivalent damage to organic materials is obtained for equivalent energy absorption, the engineer can utilize the experimental data presented in Table 2 (also Tables 3 and 4) to estimate the radiation stability of a given material under any mixed pile flux. For example, the life of a material such as

* If the symbol means (π) is used to represent the pair of electrons that goes to make up the single bond between the carbon to carbon atoms and the carbon to hydrogen atoms of an aromatic nucleus, then pi (π) can be arbitrarily used to represent the pair of electrons that goes to make up the second bond between the carbon to carbon atoms. However, each pair of these pi (π) electrons should be considered as being distributed over the entire aromatic ring structure and should not be considered as belonging to any particular carbon to carbon atoms.

hexadecane (item 4, Table 2) subjected to a radiation field of 10^{12} thermal neutrons/(cm²)(sec), 10^8 fast neutrons/(cm²)(sec), and 10^{11} γ photons/(cm²)(sec) is estimated as follows:

$$\frac{10^{12}\ (\text{th.n.})/(\text{cm}^2)(\text{sec})}{2.82 \times 10^{13}\ (\text{th.n.})/(\text{cm}^2)(\text{sec})} \times 1.0 \times 10^6\ \text{rads} = 0.4\ \text{rad/sec}$$

$$\frac{10^8\ (\text{f.n.})/(\text{cm}^2)(\text{sec})}{2.05 \times 10^{13}\ (\text{f.n.})/(\text{cm}^2)(\text{sec})} \times 1.0 \times 10^6\ \text{rads} = 4.8\ \text{rads/sec}$$

$$\frac{10^{11}\ \gamma/(\text{cm}^2)(\text{sec})}{1.95 \times 10^{12}\ \gamma/(\text{cm}^2)(\text{sec})} \times 1.0 \times 10^6\ \text{rads} = 51\ \text{rads/sec}$$

$$\text{Total} = 56.2\ \text{rads/sec}$$

From Table 2, a dosage of 5.0×10^8 rads for hexadecane causes an increase in the 100°F viscosity of 135 per cent and an increase in the 210° viscosity of 55 per cent. Therefore, the time necessary to increase the viscosity to these values is

$$\frac{5.0 \times 10^8\ \text{rads}}{56.2\ \text{rads/sec}} = 8.9 \times 10^6\ \text{sec}$$

$$= \text{approx. } 2{,}470\ \text{hr}$$

If the 135 and 55 per cent increases in viscosity can be tolerated, hexadecane would have a useful life of at least 2,470 hr under the assumed pile flux conditions. Closer scrutiny of the table will reveal that an asymptotic increase in viscosity of hexadecane occurs at 20.0×10^8 rads; this rad dosage is equivalent to 9,880 hr of operation under the assumed pile flux conditions.

Much of the data in Table 2 have been adapted from the experimental results originally obtained by Bolt and Carroll of the California Research Corporation.* These experimental results have been modified to conform to the particular format used in this table.

3.3 Radiation Damage to Elastomers

Many different usages can be found for elastomers in a nuclear power plant, e.g., as gaskets, flexible connecting tubes, hoses, and elasticlike electrical insulating material and for many other allied functions that necessitate the use of a material which is elastic enough to be pressed to fit a given contour or which has a large amount of vibration resistance. For such uses in a nuclear power plant, elastomers could be subjected to various degrees of radiation flux, depending upon their site of application in the power plant.

Although elastomers are of a specialized nature, they are organic solids, and as such, they are subject to considerable damage by radiation. The effects of radiation on five different physical properties of eight well-recognized elastomers are given in Table 3. As organics, the amount of damage is proportional to the energy absorbed by each material. Since the atoms and molecules of organic solids are in general in a far more ordered and restrained state with less degrees of freedom than those of organic liquids, it would be expected that damage to solids would occur at lower radiation dosages than for liquids. Comparison of the data in Tables 2 and 3 verifies this observation.

Examination of the data in Table 3 shows that the tensile strength, set-at-break, and the compression set values decreased initially for some of the elastomers and increased initially for other elastomers. In considering such changes, it should be borne in mind that the effects of irradiation on elastomers would necessarily depend upon the curing states of these materials, the curing states in turn being dependent upon the fabrication processes used. As a corollary to this statement, it should be likewise true that ionizing radiation might prove very beneficial as a means to develop and control desirable curing processes for such materials.

*The service life of any of the elastomers listed in Table 3 can be estimated for any mixed pile flux conditions in the same manner as previously described for organic

Table 2. Radiation Damage to Organic Fluids

No.	Material	Temperature of evaluation, °F	Type of evaluation	Gas evolution, ml/g (10⁹ rads) (STP)	Per cent viscosity increase as a function of radiation dose (kinematic viscosity measured in centistokes at 100 and 210°F): Unirradiated, centistokes 100°F	Unirradiated 210°F	1.0 × 10⁸ rads 100°F	1.0 × 10⁸ rads 210°F	5.0 × 10⁸ rads 100°F	5.0 × 10⁸ rads 210°F	10.0 × 10⁸ rads 100°F	10.0 × 10⁸ rads 210°F	20.0 × 10⁸ rads 100°F	20.0 × 10⁸ rads 210°F	40.0 × 10⁸ rads 100°F	40.0 × 10⁸ rads 210°F	Particle dosage equivalent to 1.0 × 10⁸ rads: Thermal neutrons, 10¹⁶ neutrons/cm²	Fast neutrons, 10¹⁶ neutrons/cm²	Gamma rays: Previous, 10¹⁶ γ/cm²	Recent, 10¹⁶ γ
	I. Aliphatic Series																			
	A. Hydrocarbons																			
1	Hexane	125–175	VG	3.75	0.55	ND	2	ND	10	ND	22	ND	55	ND	100	ND	2.96	1.95	1.96	1.02
2	Dodecane	140	VG	5.85	1.50	ND	5	ND	20	ND	95	ND	557	ND	AR	ND	2.81	2.02	[illegible]	[illegible]
3	1-Decene	275	GR	ND	1.40	1.10	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid	2.97	2.14	[illegible]	[illegible]
4	Hexadecane	158–284	GR	9.80	3.10	1.20	18	9	135	55	1000	435	AR	AR	AR	AR	2.82	2.05	1.95	1.02
5	Heptadecane	167	GR	ND	3.60	1.40	19	11	175	115	2200	685	AR	AR	AR	AR	2.95	2.05	1.95	1.02
6	Formulation SAE-30 [illegible] base	167	GR	ND	185	14.0	53	21	1360	235	AR	AR	AR	AR	AR	AR	4.26	2.06	2.03	1.08
7	Gasoline	240–260	VG	0.90	1260	ND	−5	ND	−7	ND	−17	ND	−40	ND	ND	ND	3.47	3.38	2.06	1.08
8	2-Butanone	130–170	VG	6.00	0.525	ND	3	ND	11	ND	33	ND	166	ND	2185	ND	3.86	2.49	2.01	1.06
9	2-Heptanone	150–150	VG	4.20	0.90	ND	62	ND	130	ND	210	ND	650	ND	AR	ND	3.32	2.46	2.00	1.05
10	n-Butyl ethyl ether	130–170	VG	6.00	0.615	ND	2.5	ND	10	ND	37	ND	190	AR	3285	AR	3.20	2.23	1.97	1.03
11	n-Amyl ether	284	GR	11.30	1.02	0.54	10	11	80	60	150	148	AR	AR	AR	AR	3.08	2.20	1.95	1.02
12	Isoamyl ether	86–254	GR	9.00	1.22	0.34	2	9	37	24	90	80	580	320	ND	ND	3.04	2.70	1.95	1.02
13	n-Hexyl ether	150–150	VG	5.30	2.11	ND	14	ND	80	ND	234	ND	1450	ND	AR	ND	3.14	2.19	1.96	1.03
14	Dipropyleneglycol-methyl ether	284	GR	9.60	0.93	0.46	7	8	50	48	140	160	ND	ND	ND	ND	3.45	2.71	2.02	1.05
15	Diethyleneglycol-ethyl ether	284	GR	11.60	1.20	0.58	2	3	62	41	275	141	ND	ND	ND	ND	3.45	2.71	2.02	1.05
16	Diethoxytetraglycol	153	GR	ND	2.50	1.10	28	Boils	380	Boils	15,990	Boils	AR	Boils	AR	Boils	3.92	3.18	2.05	1.07
17	Polypropylene oxide	160	GR	6.10	57.0	9.60	26	8	354	140	>1800	650	Solid	Solid	Solid	Solid	5.23	3.92	2.09	1.10
18	Poly(butoxyethylene)	150	GR	ND	22.6	5.00	19	18	440	300	ND	ND	ND	ND	ND	ND	4.14	2.98	2.03	1.07
19	2-Ethylhexyl acetate	284	GR	8.80	1.29	0.62	5	6	115	70	608	335	ND	ND	ND	ND	3.39	2.59	2.01	1.05
20	n-Butyl benzoate	284	GR	8.50	1.10	0.67	16	3	328	94	3300	914	AR	AR	AR	AR	3.34	2.54	2.01	1.05
21	iso-Butyl benzoate	86–	GR	8.80	1.30	0.64	12	6	77	40	193	145	>1400	>600	AR	AR	3.39	2.54	2.01	1.05
22	Diethyl adipate	155	GR	ND	2.30	1.10	26	12	422	154	AR	AR	AR	AR	AR	AR	3.97	3.28	2.05	1.09
23	Di-(2-ethylhexyl) sebacate	150	GR	4.50	13.0	3.40	54	29	2360	365	Solid	Solid	Solid	Solid	Solid	Solid	2.92	2.49	2.01	1.05
24	Di-(2-ethylhexyl) sebacate + inhibitor	86–356	GR	ND	13.0	3.40	26	20	423	235	7600	2840	AR	AR	AR	AR	2.92	2.49	2.01	1.05
25	16,19-Dioxa-13,22-dimethyltetra-[illegible]	155	GR	ND	55.0	7.30	12	7	−40	−27	−62	−47	ND	ND	ND	ND	2.90	2.28	1.98	1.04
	II. Cyclic Series																			
	A. Alicyclic hydrocarbons																			
26	9-(3-Cyclopentylpropyl) heptadecane	165	GR	ND	12.0	2.70	27	22	633	437	20,730	25,815	AR	AR	AR	AR	2.94	2.32	1.98	1.04
27	9-(2-Cyclohexylethyl) heptadecane	150	GR	ND	15.0	3.20	27	19	513	290	>7000	>4500	AR	AR	AR	AR	3.36	2.40	1.99	1.04
	B. Aromatic hydrocarbons																			
	1. Benzene derivatives																			
28	n-Butylbenzene	284	GR	1.50	0.92	0.53	8	7	165	70	175	140	3230	1200	AR	AR	3.84	2.82	2.03	1.06
29	sec-Butylbenzene	284	GR	1.50	0.89	0.50	6	4	135	26	100	64	556	290	AR	AR	3.84	2.82	2.05	1.06
30	tert-Butylbenzene	284	GR	1.90	1.02	0.60	6	3	143	30	95	66	553	250	AR	AR	3.84	2.82	2.05	1.06
31	iso-Butylbenzene	284	GR	1.60	0.82	0.53	8	6	165	20	132	70	733	334	AR	AR	3.84	2.82	2.03	1.05
32	Alkylbenzene 250+	150–355	GR	ND	6.7	1.70	4	9	108	53	470	192	AR	AR	AR	AR	3.26	2.44	2.00	1.05
33	Alkylbenzene 250+	300	VG	1.30	7.3	1.90	3	2	12	4	140	20	160	70	1500	300	3.26	2.44	2.00	1.05
34	Alkylbenzene 250+	145–266	GR	ND	101	7.10	4	13	179	83	909	322	AR	AR	AR	AR	3.60	2.36	2.00	1.06
35	Alkylbenzene 350+	300	VG	1.70	23.8	3.72	4	5	21	8	185	140	150	90	>1800	AR	3.60	2.36	[illegible]	[illegible]
36	Octadecylbenzene	86–425	GR	3.50	12.0	2.80	8	14	230	115	3240	615	AR	AR	AR	AR	2.73	2.37	[illegible]	[illegible]
37	9-(Phenylethyl) heptadecane	171	GR	ND	10.0	2.40	20	19	220	129	2200	492	AR	AR	AR	AR	3.22	2.36	1.98	1.04
38	1-Phenyl-2-Butene	284	GR	1.70	1.00	0.54	10	4	60	35	150	113	3500	1000	AR	AR	3.21	3.16	2.01	1.07
39	1,2 Diethylbenzene	284	GR	2.00	0.94	0.49	2	10	49	39	104	100	1390	575	AR	AR	3.84	2.82	2.01	1.06
40	1,3 Diethylbenzene	284	GR	2.60	0.82	0.48	5	4	58	33	138	83	1730	690	AR	AR	3.84	2.82	2.03	1.06
41	1,4 Diethylbenzene	284	GR	2.00	0.82	0.37	5	3	52	32	130	89	1730	972	AR	AR	3.84	2.82	2.03	1.06
42	1-Methyl-4-isopropylbenzene	284	GR	2.30	0.75	0.45	7	4	60	33	179	82	1235	545	AR	AR	3.84	2.82	2.05	1.06
43	1,3-Dimethyl-5-ethylbenzene	284	GR	2.40	0.81	0.47	5	4	50	28	160	91	2245	730	AR	AR	3.84	2.82	2.05	1.06
44	1,2,4,5-Tetramethylbenzene	284	GR	1.90	Solid	0.58	Solid	5	Solid	52	Solid	105	Solid	960	Liquid	AR	3.85	2.82	2.03	1.06
45	Phenylcyclohexane	300–400	GR	1.50	2.10	0.92	9	5	55	40	400	100	2400	335	AR	AR	3.79	2.92	2.05	1.07
46	Diphenylmethane	160	GR	ND	2.40	1.00	8	ND	79	Boils	ND	Boils	ND	Boils	ND	Boils	3.80	3.85	2.05	1.08
47	Biphenyl	284–700	GR	0.30	Solid	1.00	Solid	15	Solid	40	Solid	160	Solid	200	Solid	9200	3.62	4.16	2.08	1.08
48	3-Methylbiphenyl	284–700	GR	0.50	3.20	1.11	7	4	65	27	160	175	ND	ND	ND	ND	3.95	3.83	2.08	1.08
49	Amylbiphenyl	144–425	GR	1.80	10.8	2.20	11	4	100	50	310	154	AR	AR	AR	AR	4.95	3.21	2.16	1.12
50	o-Diphenylbenzene	86–700	GR	2.00	Solid	4.50	Solid	7	Solid	48	Solid	134	Solid	782	Solid	AR	5.03	4.37	2.11	1.11
51	m-Diphenylbenzene (oxygenated)	86–700	GR	0.50	Solid	4.30	Solid	4	Solid	46	Solid	125	Solid	AR	Solid	AR	5.03	4.37	2.11	1.11
52	Biphenyl — Diphenyl Oxide, "Dowtherm A"	150–700	GR	0.17	2.60	1.01	10	19	77	44	275	108	AR	585	AR	AR	6.31	4.94	2.12	1.12
53	Dowtherm A + Alkylbenzene 250 (1:1 by wt.)	300	VG	0.50	3.90	1.19	3	7	21	17	42	54	110	64	535	227	4.15	3.29	2.94	1.08
54	n-Butyl phenyl ether	86–264	GR	2.00	1.58	0.66	8	3	45	27	140	99	~2500	~900	AR	AR	4.00	3.11	2.84	1.07
55	n-Butyl benzoate	86–254	GR	2.90	2.50	0.93	12	8	65	50	205	125	~3150	~1500	AR	AR	4.55	3.68	2.87	1.09

Table 2. Radiation Damage to Organic Fluids. (*Continued*)

No	Material	Temperature of irradiation, °F	Type of irradiation	Gas evolution, ml (10⁸ rads) (STP)	Unirradiated, centistokes 100°F	Unirradiated, centistokes 210°F	1.0 × 10⁸ rads 100°F	1.0 × 10⁸ rads 210°F	5.0 × 10⁸ rads 100°F	5.0 × 10⁸ rads 210°F	10.0 × 10⁸ rads 100°F	10.0 × 10⁸ rads 210°F	20.0 × 10⁸ rads 100°F	20.0 × 10⁸ rads 210°F	40.0 × 10⁸ rads 100°F	40.0 × 10⁸ rads 210°F	Thermal neutrons, 10¹⁶ neutrons/cm²	Fast neutrons, 10¹⁶ neutrons/cm²	Gamma rays: Photons, 10¹⁸ γ/cm²	Gamma rays: Roentgens, 10⁸ r
56	Diethylhexyl phthalate	284	GR	4.70	7.20	1.90	21	8	100	84	1260	?21	AR	AR	AR	AR	3.00	4.16	2.10	1.10
57	Di-2 Ethylhexyl phthalate	163	GR	ND	6.80	1.70	91	47	>5000	>950	AR	AR	AR	AR	AR	AR	3.28	3.06	2.09	1.06
58	Dioctyl terephthalate	165–356	GR	ND	54.0	6.90	26	22	222	185	>1500	>1350	AR	AR	AR	AR	2.75	2.86	2.05	1.06
59	Dioctyl terephthalate + inhibitor	68–284	GR	4.40	34.2	6.90	29	16	360	185	>1900	>1330	AR	AR	AR	AR	2.75	2.86	2.03	1.06
60	Phenyl n-propyl ketone	273	GR	ND	133	9.00	20	17	100	100	~300	~510	AR	AR	AR	AR	5.00	3.64	2.06	1.09
61	Tetraaryl silicate	158	GR	ND	12.4	2.90	45	28	1110	350	AR	AR	AR	AR	AR	AR	8.41	5.32	2.09	1.10
	Halogenated																			
62	Dichlorobiphenyl	158	GR	ND	47.3	1.60	9	8	60	25	155	62	730	243	AR	AR	0.10	7.00	2.20	1.15
63	Difluorobiphenyl	300	GR	ND	Solid	1.07	Solid	10	Solid	115	Solid	900	Solid	AR	Solid	AR	6.04	5.83	2.16	1.14
	2. Naphthalene derivatives:																			
64	Naphthalene	295–700	GR	0.60	Solid	0.80	Solid	3	Solid	20	Solid	160	Solid	225	Solid	AR	5.43	4.28	2.10	1.10
65	1-Methylnaphthalene	150	GR	ND	2.00	0.80	9	5	50	37	150	90	ND	ND	ND	ND	4.95	3.88	2.09	1.10
66	Dodecylnaphthalene	248	GR	ND	20.0	3.00	14	12	130	73	650	235	AR	AR	AR	AR	3.25	2.73	2.02	1.06
67	Octadecylnaphthalene	150	GR	ND	29.0	5.50	21	4	280	120	2485	66	AR	AR	AR	AR	3.30	2.58	2.01	1.05
68	Phenylnaphthalene	86–700	GR	0.54	17.0	2.43	15	8	95	41	370	115	AR	775	AR	AR	6.04	4.47	2.26	1.19
69	Pentalene 95	400	VG	0.73	15.1	3.28	7	1	16	9	30	15	80	33	260	87	3.94	2.99	2.04	1.07
70	Pentalene 195	165	GR	1.00	23.0	3.30	17	8	170	87	~770	~500	AR	AR	AR	AR	3.63	2.84	2.03	1.06
71	Pentalene 290	300	VG	0.70	95.2	2.50	3	3	20	12	165	135	125	60	415	135	3.57	2.80	2.02	1.08
72	Pentalene 290	400	VG	0.65	95.2	2.50	1	1	18	9	161	121	119	42	459	130	3.57	2.80	2.02	1.06
73	Pentalene 290	500	VG	0.65	95.2	2.50	0.5	0.5	15	7	147	120	76	28	135	50	3.57	2.80	2.32	1.06
74	Pentalene 290	600	VG	0.62	95.2	2.50	1	1	15	7	143	120	72	32	182	64	3.57	2.80	2.02	1.06
75	1, 2, 3, 4-Tetrahydronaphthalene	284	GR	6.00	1.90	0.84	10	5	52	43	145	96	11370	495	AR	AR	4.05	3.15	2.05	1.08
76	Octadecyltetralin	150–275	GR	ND	29.0	4.10	14	22	348	241	~3700	~2565	AR	AR	AR	AR	2.83	2.41	1.99	1.05
	Halogenated																			
77	α-Fluoronaphthalene	284–700	GR	0.65	1.55	0.71	15	7	61	30	520	125	AR	780	AR	AR	6.26	5.32	2.14	1.12
	3. Anthracene derivatives:																			
78	9-(1-Dodecyl) anthracene	172	GR	ND	77.5	7.10	7	15	56	110	150	605	ND	AR	ND	AR	3.25	2.90	1.96	1.05
79	9, 10-Dibenzyl-9, 10-dihydroanthracene	275	GR	ND	130	9.10	23	10	285	98	>800	~450	AR	AR	AR	AR	3.28	2.73	2.02	1.06
	III. Silicones																			
80	Dimethyl Silicone (DC-200)	153	GR	6.00	280	132	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid	4.25	3.72	1.78	0.95
	IV. Lubricants																			
81	Motor oil No. 10	140	GR	ND	49.0	6.60	18	11	150	77	715	295	AR	AR	AR	AR	2.99	2.07	1.95	1.03
82	Motor oil No. 20 #1	190–350	GR	ND	83.0	6.70	-5	0	110	29	502	72	AR	AR	AR	AR	2.63	2.10	1.95	1.03
83	Motor oil No. 20 #2	140	GR	ND	127	12.5	21	12	56.6	175	>1300	250	AR	AR	AR	AR	2.63	2.10	1.95	1.03
84	Motor oil No. 20 #3	140	GR	ND	61.0	9.60	129	15	240	172	AR	537	AR	AR	AR	AR	2.63	2.10	1.95	1.03

These materials were tested not only at various temperatures but, also, in various containers such as aluminum, stainless steel, magnesium, quartz, and glass.

GR-graphite reactor. VG-van de Graaff—2-Mev electrons.

Values are given in milliliters of gas per milliliter of liquid per 10⁸ rads. In general, gas evolution from organic liquids is a linear function of the radiation dosage and the reaction of the radiation on organics is irreversible in nature.

ND indicates that the item was not determined.

AR represents an asymptotic viscosity increase.

Fast neutrons ≥ 1.0 Mev.

Gamma photons, average energy—1.0 Mev.

Mixture of mono- and di-alkylated benzene having an average molecular weight of 250 (product of California Research Corporation).

Mixture of mono- and di-alkylated benzene having an average molecular weight of 350 (product of California Research Corporation).

Mixture of mono- and di-alkylated benzene having ... diphenyl oxide (product of Dow Chemical Company).

Mixture of 25 per cent biphenyl and 75 per cent diphenyl oxide (product of Dow Chemical Company).

Dosage 2.0 × 10⁸ rads.

Undistilled mixture of Polyamylnaphthalenes (product of Sharples Chemicals, Inc.).

Distilled mixture of 25 per cent mono-, 55 per cent di-, 20 per cent poly amylnaphthalenes (product of Sharples Chemicals, Inc.) after distillation to remove fractions boiling below 625°F. The number 290 approximates the molecular weight.

Distilled mixture of the residue of pentalene 195 (product of Sharples Chemicals, Inc.)

Arbitrary designation of the number of pentalene ...

Based on single experimental values, therefore considered as tentative.

Oxidation inhibitor—2 per cent dilauryl selenide.

Viscosity measured at 68°F.

Table 3. Radiation Damage to Elastomers

No.	Class of material	Specific material tested[a]	Tensile strength −25%	Tensile strength −75%	Elongation[b] −25%	Elongation[b] −75%	Set-at-break[c] −25%	Set-at-break[c] −75%	Compression set −25%	Compression set −75%	Strain at 400 psi −25%	Strain at 400 psi −75%	Thermal neutrons, 10^{17} neutrons/cm²	Fast neutrons,[d] 10^{16} neutrons/cm²	Gamma energy: Photons,[e] 10^{16} γ/cm²	Gamma energy: Roentgens, 10^7 r
			Damage to give 25 and 75% decrease in listed properties, 10^7 rads										Particle dosages each equivalent to 1×10^7 rads			
1	Rubber	Natural rubber	13	65	3.4	25	2.6	15	4.8	31	10	110	3.3	2.5	2.0	1.1
2	Chloroprene rubber	Neoprene W	6.3	120	1.8	11	1.8	11	0.6	30	3.4	21	0.12	3.0	2.1	1.1
3	Butadiene styrene rubber	Buna S (GRS-50)	28	[f]	1.9	17	1.9	17	1.3	27	1.8	31	6.0	2.9	2.1	1.1
4	Butadiene acrylonitrile rubber	Hycar OR-15	17[g]	[h]	1.6	14	0.4	36	0.7	10	2.6	22	1.5	3.1	2.1	1.1
5	Silicone rubber	Silastic 7-170	4.9	[i]	0.7	3.1	ND[j]	ND[j]	0.4	2.1	1.1	7.5	6.0	3.8	2.1	1.1
6	Isobutylene rubber	Butyl (GR-150)	2.2	5.0	4.3	ND[j]	0.6	[illegible]	0.4	0.8	2.1	4.2	4.4	2.2	2.1	1.1
7	Polyacrylonitrile rubber	Hycar PA-21	5.2	57	1.7	9.9	0.3	2.0	0.6	[m]	3.2	37	7.7	3.6	2.1	1.1
8	Polysulfide rubber	Thiokol ST	7.3	42	0.3	34	0.3	5.4	0.1	0.3	6.7	12	3.8	0.01	2.2	1.1

[a] These materials were irradiated in a water-cooled facility of a graphite reactor using water temperatures of 75 to 105°F. The reactions are irreversible. Since the properties shown in the table were the primary subject of study, gas evolution as such was not measured. Some evolution does accompany the changes in physical properties noted, and such evolution not only contributes to these changes but could also present a corrosion problem, e.g., when chlorine is evolved from neoprene rubber.

[b] Percentage elongation was calculated by dividing the change in distance at the moment of rupture between a set of gauge marks on the specimen by the original distance between the marks and multiplying by 100. The per cent change shown in the table was calculated by dividing the per cent elongation value of the irradiated specimen by the value of the unirradiated specimen and multiplying by 100.

[c] Percentage set-at-break was determined in the same general way as percentage elongation except that the broken pieces of the specimen were carefully fitted together and the change in distance between the set of gauge marks was measured 10 min after rupture of the specimen instead of at the moment of rupture. The delay in the measurement allows the material some time for restoration.

[d] Fast neutron ≥ 1.0 Mev.

[e] Average energy = 1.0 Mev.

[f] The tensile strength decreased to a minus 25 per cent value down to a minimum value of minus 50 per cent at 100 × 10^7 rads; then as brittleness increased, the tensile strength increased exponentially and approached a 300 × 10^7 rad asymptote.

[g] This dosage gave a positive change in the value of the property measured; all dosages not so annotated gave a negative change.

[h] The tensile strength continued to increase from the plus 25 per cent change value up to a maximum of plus 42 per cent at 30 × 10^7 rads, then decreased to a minimum value of minus 37 per cent at 120 × 10^7 rads, then increased exponentially and approached a 300 × 10^7 rad asymptote.

[i] The tensile strength decreased from the minus 25 per cent value down to a minimum of minus 60 per cent at 40 × 10^7 rads, then increased exponentially and approached a 300 × 10^7 rad asymptote.

[j] N.D.—not determined.

[k] The set-at-break continued to increase from the plus 25 per cent change to a maximum of plus 48 per cent at 1.3 × 10^7 rads, then decreased exponentially and approached a 6 × 10^7 rad asymptote.

[l] The set-at-break continued to increase from the plus 25 per cent change value up to a maximum of plus 50 per cent at 0.7 × 10^7 rads, then decreased exponentially to the minus 25 per cent change value at 2.6 × 10^7 rads.

[m] The compression set increased from the plus 25 per cent change value up to a maximum of plus 55 per cent at 2 × 10^7 rads, decreased to a minimum value of minus 65 per cent at 50 × 10^7 rads, and then increased exponentially and approached a 300 × 10^7 rad asymptote.

However, the nature of the curing state of the elastomer , ,ocation would liquids. However, the nature of the curing state of the elastomer need to be considered in order to evaluate its radiation stability.

Most of the radiation-damage-rad-dosage and particle-equivalence data given in Tables 3 and 4 are based upon the experimental results of Bisman and Bopp;[1,8] these published results were previously presented primarily in graphical form by plotting the changes in physical properties as a function of the accumulated radiation dose in terms of thermal-neutron flux times the irradiation time (nvt).

3.4 Radiation Damage to Plastics

There are multitudinous applications for plastics in various parts of a nuclear power plant. For example, in that portion of an electrical system involving motors and selsyns, plastics are used as brush holders, grease seals, insulating tapes, spacers, slot insulation, shaft insulation, electrical-wire insulation, and end punchings.

Data have been compiled in Table 4 on the effects of radiation on five different properties for 38 plastics. As in the case of elastomers, the plastics exhibit radiation damage at lower dosage levels than do the organic liquids, this higher susceptibility to radiation again being explained on the basis that the atoms of a solid possess less degrees of freedom than those of a liquid. Since plastics are covalent materials, the equivalent-energy–equivalent-damage generalization can be applied, and the service life of these materials under a mixed pile flux can be calculated in a manner analogous to that described previously for organic liquids.

3.5 Radiation Damage to Electrical, Electronic, and Mechanical Systems

In Table 5, an attempt has been made to utilize the experimental radiation-damage data compiled in the preceding tables, particularly Tables 2, 3 and 4. These data have been applied to various systems of a nuclear power plant in order to analyze and evaluate the effects that radiation-induced changes in individual materials might have on the systems in which such materials are employed. Since electrical, electronic, and mechanical systems constitute a major portion of a nuclear power plant in which organic materials might be widely used, these three systems have been chosen for analysis and evaluation of their probable radiation stability.

The various electrical, electronic, and mechanical systems are listed in the second column of Table 5, and the corresponding radiation-susceptible components of each of these systems are listed in the third column. In the fourth column, some of the more common materials that are actually used in the construction of these components are listed, and the most radiation-susceptible properties of the materials used in these components are listed in the fifth column. In the sixth column, a dosage level is listed that would give a 25 per cent change in the various properties listed for each particular material. The dosage level listed is based upon experimental data recorded in preceding tables, and the 25 per cent change that has been selected as a conservative value should be safely below that per cent change associated with an exponential rise in damage with small additional increments of radiation. In the seventh and last column, references are given to preceding tables for respective materials in order to calculate the thermal-neutron, fast-neutron, and γ-radiation dosages that are equivalent to the rad dosages given in the sixth column.

This table is based in part on the premise that the stability of a given system is a function of its most radiation-susceptible materials. Certainly, the operational stability of a system might be endangered by any change appreciably greater than a 25 per cent change in any of the physical properties of one or more of its materials of construction, but the system may still be operable, depending upon the vital function of the affected material.

For most materials, the 25 per cent change in one or more physical properties represents a good engineering reference value, but this is not true for certain electronic materials, particularly semiconductors. Not only can changes in semiconductor properties occur frequently at very low neutron and γ dosages,* but in addition, small

* Experimental data indicate that even a single photon can sometimes apparently affect the properties of a semiconductor.

Table 4. Radiation Damage to Plastics

No.	Class of material	Specific material tested[a]	Tensile strength −25%	Tensile strength −75%	Elongation −25%	Elongation −75%	Elastic modulus −25%	Elastic modulus −75%	Shear strength −25%	Shear strength −75%	Impact strength −25%	Impact strength −75%	Thermal neutrons, 10^{17} neutrons/cm²	Fast[b] neutrons, 10^{16} neutrons/cm²	Photons,[c] 10^{18} γ/cm²	Roentgens, 10^8 r
			Dosages to give 25 and 75% decrease, 10^6 rads										Particle dosages each equivalent to 1×10^6 rads		Gamma energy	
1	Allyl diglycol carbonate	CR-39	24	170	8.2	26	21	*	94	301	94	301	4.4	4.2	2.0	1.1
2	Aniline formaldehyde unfilled	Cibanite	240	456	240	450	>500	>500	240	450	1.3	140	0.86	4.1	2.1	1.1
3	Casein	Ameroid	4.7	14	4.7	14	>13	>13	4.7	14	2.0	3.4	1.1	4.4	2.2	1.1
4	Cellulose acetate	Plastacele	2.5	111	1.6	3.4	>4.0	>4.0	2.5	11	1.6	3.4	5.2	4.8	2.1	1.1
5	Cellulose acetate butyrate	Tenite II	2.3	4.2	2.3	4.2	>4.0	>4.0	2.3	4.2	0.71	3.5	4.8	4.2	2.1	1.1
6	Cellulose nitrate	Pyralin	2.1	3.4	0.4	1.6	2.3	/	2.1	5.4	2.1	5.4	1.8	7.2	2.1	1.1
7	Cellulose propionate	Forticel	0.4	4.2	0.4	4.2	ND	ND	0.4	4.2	0.4	4.2	5.0	4.3	2.1	1.1
8	Ethyl cellulose	Ethocel R-2	1.0	14.0	0.5	1.3	>5.0	>5.0	1.3	10	0.6	2.5	4.1	3.5	2.0	1.1
9	Furan, asbestos and carbon-black filler	Duraloa	>500	>500	>500	>500	>500	>500	>500	>500	>500	>500	4.2	3.5	2.3	1.2
10	Melamine formaldehyde cellulose filler	Melmac and Plaskon Melamine	6.4	53	6.4	53	120	>140	40	200	200	*	2.3	3.5	2.2	1.2
11	Methyl methacrylate	Lucite	1.0	3.3	1.0	3.3	>4.0	4.0	3.7	9.8	3.7	9.8	3.8	3.5	2.1	1.1
12	Monochlorotrifluoroethylene	Fluorothene	8.5	17	1.7	8.7	>11.0	11.0	15	*	1.7	8.7	0.85	3.5	2.3	1.2
13	Phenol formaldehyde unfilled	Catalin	17	70	1.0	3.2	17	70	17	70	17	70	5.1	4.6	2.1	1.1
14	Phenol formaldehyde asbestos fabric laminate filler	Bakelite	240	>500	53	>70	>80	>80	240	>500	53	>70	4.0	4.7	2.1	1.1
15	Phenol formaldehyde asbestos fiber filler	Bakelite	>100	>100	>100	>100	>500	>500	>500	>500	>100	>100	4.8	4.6	2.2	1.1
16	Phenol formaldehyde asbestos filler	Haveg 41	>400	>400	>400	>400	>400	>400	ND	ND	>400	>400	4.4	4.6	2.1	1.1
17	Phenol formaldehyde graphite filler	Karbate	210	>500	6.3	>600	210	>500	210	>500	>500	>500	4.0	4.7	2.1	1.1
18	Phenol formaldehyde linen fabric laminate filler	Bakelite	1.4	65	0.3	2.4	110	230	ND	ND	0.3	2.4	3.0	4.6	2.1	1.1

No.	Class of material	Specific material tested[a]	Tensile strength −25%	Tensile strength −75%	Elongation −25%	Elongation −75%	Elastic modulus −25%	Elastic modulus −75%	Shear strength −25%	Shear strength −75%	Impact strength −25%	Impact strength −75%	Thermal neutrons	Fast neutrons	Photons	Roentgens
19	Phenol formaldehyde paper laminate filler	Micarta	2.5	110	0.8	36	70	>500	ND	ND	0.8	36	5.4	4.6	2.1	1.1
20	Phenol formaldehyde paper filler	Bakelite	2.2	40	2.2	40	25	>300	2.2	40	2.2	40	5.0	4.6	2.1	1.1
21	Polyalphamethyl styrene	Experimental plastic Q-817	ND	ND	ND	ND	ND	ND	4.0	44	ND	ND	4.0	3.3	2.1	1.1
22	Polyamide	Nylon FM-10001	470	>500	0.9	21	36	150	>500	>500	8.4	5.7	0.81	3.0	2.0	1.1
23	Polyamide	Nylon FM-3003	160	>500	0.4	14	60	>500	ND	ND	0.5	500	0.81	3.0	2.0	1.1
24	Polyester	Selectron 5038	0.14	0.2	0.7	13	0.09	0.2	0.14	0.3	9.0	180	6.2	4.7	2.2	1.1
25	Polyester, mineral filler	Plaskon alkyd	360	>500	360	>500	360	>500	360	>500	360	>500	3.6	4.9	2.2	1.1
26	Polyethylene	Polythene	600	>1000	9.0	37	130	220	11	9.0	9.0	37	2.7	2.2	1.9	1.1
27	Polyethylene terephthalate	Mylar film	19	65	12	29	ND	ND	ND	ND	ND	ND	6.7	6.0	2.2	1.3
28	Polystyrene, black pigment filler	Styron 475	100	300	0.5	7.6	>600	>600	>500	>500	1.0	>500	4.5	3.5	2.1	1.1
29	Polystyrene	Amphenol	>600	>600	>600	>600	>600	>600	>600	>600	>600	>600	4.5	3.5	2.1	1.1
30	Polystyrene white pigment filler	Styron 411C	>500	>500	>500	>500	>500	>500	>500	>500	>500	>500	4.5	3.5	2.1	1.1
31	Polytetrafluoroethylene	Teflon	0.01	5.5	0.003	0.02	>2.0	>2.0	0.04	5.5	0.04	0.06	10	28	2.4	1.2
32	Polyvinyl butyrate	Butacite film	1.9	200	10	54	ND	ND	ND	ND	ND	ND	3.3	3.0	2.1	1.1
33	Polyvinyl carbazole	Polectron	>500	>500	>500	>500	>500	>500	>500	>500	>500	>500	1.4	4.7	2.2	1.1
34	Polyvinyl chloride	Geon 2046	160	370	12	83	ND	ND	ND	ND	ND	ND	0.068	5.0	2.2	1.1
35	Polyvinyl formal	Formvar	25	>1900	9.7	>12	11	85	ND	ND	ND	ND	4.0	3.6	2.1	1.1
36	Vinylidene chloride	Saran	14	220	4.3	53	80	220	51	220	4.3	53	0.027	8.9	2.2	1.2
37	Urea formaldehyde cellulose pulp pigment	Beetle plaskon urea	3.8	20	3.0	20	>24	>24	3.0	20	60	110	0.31	5.9	2.2	1.1
38	Vinyl chloride acetate	Vinylite	67	420	0.2	0.4	67	420	67	420	>500	>500	0.09	5.2	2.2	1.1

[a] These materials were irradiated in a water-cooled facility of a graphite reactor using water temperatures of 75 to 105°F. The reactions are irreversible. Since the properties shown in the table were the primary subject of study, gas evolution as such was not measured. Some evolution will occur, and in the plastics containing halides, the evolved halide gas may present some corrosion problems.

[b] Fast neutrons ≥ 1 Mev.

[c] Average energy = 1 Mev.

[d] This dosage gives a positive change in the value of the property measured; all dosages not so annotated gave a negative change.

[e] The elastic modulus decreased from the minus 25 per cent change to a minimum of minus 63 per cent at 100×10^6 rads, then increased exponentially to approach the 200×10^6 rad asymptote.

[f] The elastic modulus increased from the plus 25 per cent change to a maximum at plus 27 per cent and then leveled off until a dosage of 5×10^8 rads had been received by the specimen.

[g] The impact strength decreased exponentially from the minus 25 per cent change to approach the 400×10^6 rad asymptote.

[h] The shear strength decreased exponentially from the minus 25 per cent change to approach the 30×10^6 rad asymptote.

Table 5. Radiation Damage to Electrical, Electronic, and Mechanical Systems

No.	Type of system	Radiation-susceptible components	Actual materials used	Most radiation-susceptible properties[a]	Damage levels to give 25% change, 10^7 rads	Reference for particle-rad damage equivalents[b]
			Electrical			
1	Connectors	Base insulation	Paper filled phenolformaldehyde	T, K, B, I	2.2	4-20
2			Asbestos filled phenolformaldehyde	T, K, I	100	4-16
3		Gasket (pressure type)	Buna S	K, SAB, C, SAF	1.3	3-3
4			Natural rubber	SAB	2.6	3-1
5	Fuse holders	Base insulation	Linen filled phenolformaldehyde	K, I	0.3	4-18
6			Paper filled phenolformaldehyde	K, I	0.8	4-19
7	Light bulbs	Glass envelope	Glass	Light transmission	0.1	
8	Magnetic amplifiers	Core damping fluid	Silicone oil	Viscosity	>50	2-13[d]
9		Core insulation	Nylon	I	0.6	4-22
10		Interwinding insulation	Kraft paper	K, T, I	0.5	4-8[d]
11			Mylar	K, T	12	4-27
12		Potting compound	Silastic	C	0.4	3-5[d]
13		Terminal board	Paper filled phenolformaldehyde	K, I	0.8	4-19,
14			Unfilled phenolformaldehyde	K	1.0	4-13
15		Wire insulation	Formvar	K	9.7	4-35
16			Teflon	K	0.003	4-31
17	Motors and relays	Brush holders	Linen filled phenolformaldehyde	K, I	0.3	4-18
18			Paper filled phenolformaldehyde	K, I	0.8	4-19]
19		Grease seal	Neoprene	C	0.6	3-2
20			Buna N	SAB, C	0.4	3-4
21			Felt	K, T, I	0.5	4-04c
22			Leather	I	0.4	4-22[d]
23		Insulating tapes	Rubberized cloth	K, T, I (cloth)	0.5	4-8[d]
24			Polyvinyl chloride	K	12	4-34
25			Natural rubber	SAB, C	2.6	3-1
26			Teflon coated fiberglas	K (Teflon)	0.003	4-31
27			Fiberglas and silicone resin	Pliability	>50	2-13[d]
28			Acetate cloth	K, I	1.6	4-4
29			Buna N treated fiberglas	SAB, C (Buna N)	0.4	3-4
30			Teflon coated fiberglas	K (Teflon)	0.003	4-31
31		End punchings and slot insulation	Fiberglas and amine	T, K	6.4	4-10
32		Shaft insulation, etc.	Mylar	K, T	12	4-27
33			Teflon	K	0.003	4-31
34			Mica with shellac	I	0.4	4-22[d]
35			Mica with mylar	K, T (Mylar)	12	4-27
36			Paper filled phenolformaldehyde	K, I	0.8	4-19
37			Asbestos filled phenolformaldehyde	K, I	53	4-14
38			Kel-F	K, I	1.7	4-12
39			Fiberglas with silicone rubber	C	0.4	3-5

Table 5. Radiation Damage to Electrical, Electronic, and Mechanical Systems. (Continued)

No.	Type of system	Radiation-susceptible components	Actual materials used	Most radiation-susceptible properties[a]	Damage levels to give 25% change, 10^7 rads	Reference for particle-rad damage equivalents[b]
40		Wire insulation	Fish paper	K, T, I	0.5	4-8[d]
41			Varnished cambric	K, T, I	0.5	4-8[d]
42			Polyvinyl chloride	K	12	4-34
43			Cellulose acetate	K, I	1.6	4-4
44			Teflon	K	0.003	4-31
45			Formvar	K	9.7	4-35
46			Fiberglas and silicone resin	Pliability	>50	2-13[d]
47			Nylon	K, I	0.4	4-23
48			Neoprene	C	0.6	3-2
49			Paper	K, T, I	0.5	4-8[d]
50	Relays and switches	Base insulation and shell	Paper filled phenolformaldehyde	K, I	0.8	4-8[d]
51			Linen filled phenolformaldehyde	K, I	0.5	4-18
52			Asbestos filled phenolformaldehyde	T, K, I	>100	4-15
53			Unfilled phenolformaldehyde	K	1.0	4-13
54	Thermocouples	Wire insulation	See Motors (Wire insulation)			
55	Transformers	Wire insulation	See Motors (Wire insulation)			
56		Oils	Chlorinated hydrocarbons	Viscosity	>100	2-37
57			Dichlorobiphenyl	Viscosity	>100	2-37
58		Gaskets	Buna N rubber	SAB, C	0.4	3-4
59			Hycar PA	SAB	0.3	3-7
60		Base insulation	Paper filled phenolformaldehyde	K, I	0.8	4-19
61			Paperboard	K, T, I	0.5	4-8[d]
			Electronic			
62	Capacitors	Dielectric	Paper	K, T, I	0.5	4-8[d]
63			Paraffin	K, I	9.0	4-26[d]
64		Base insulation	See Relays (Base insulation)			
65	Coaxial cables	Wire insulation	Polystyrene	T, K, KM, B, I	>500	4-30
66			Polythene	K, I	9.0	4-26
67			Rayon	K, I	1.6	4-4c
68			Polyvinyl chloride	K	12	4-34
69			Neoprene	C	0.6	3-2
70	Connectors	Base insulation	Polystyrene	T, K, KM, B, I	>600	4-29
71			Polyethylene	K, I	9.0	4-26
72			Paper filled phenolformaldehyde	K, I	0.8	4-19
73			Asbestos filled phenolformaldehyde	K, I	53	4-14
74			Unfilled phenolformaldehyde	K	1.0	4-13
75	Ion chamber	Base insulator	Polystyrene	T, K, KM, B, I	600	4-29
76			Polyethylene	K, I	9.0	4-26
77			Teflon	K	0.003	4-31
78			Methyl methacrylate	T, K	1.0	4-11
79	Printed circuits	Base insulation	Urea formaldehyde	T, K, B	3.0	4-37

Systems. (*Continued*)

No.	Type of system	Radiation-susceptible components	Actual materials used	Most radiation susceptible properties[a]	Damage levels to give 25 % change, 10^7 rads	Reference for particle-rad damage equivalents[b]
80	Printed circuits (continued)	Base insulation (continued)	Melamine formaldehyde	T, K	6.4	4-18
81			Paper filled phenolformaldehyde	K, I	0.8	4-19
82		Conductor binder	Epoxy resin	S	100	
83	Resistors	Base insulation	Paper filled phenolformaldehyde	K, I	0.8	4-19
84			Asbestos filled phenolformaldehyde	T, K, I	>100	4-15
85			Paperboard	K, T, I	0.5	4-8[d]
86	Thermistors	Wire insulation	See Electric Motors (Wire)			
87	Transducers	Wire insulation	See Electric Motors (Wire)		>50	2-13[d]
88		Damping fluid	Silicone oil	Viscosity	0.8	4-19
89	Vacuum tubes	Tube bases	Paper filled phenolic	K, I	1.0	4-13
90			Unfilled phenolic	K		
			Mechanical			
91	Combustion engines	O rings	Neoprene	C	0.6	3-2
92		Shaft seals	Leather	I	0.4	4-22[d]
93		Fan belts	Cloth backed neoprene	K, T, I	0.5	4-8[d]
94		Lubricant	SAE-20	Viscosity	>100	2-51
95		Antifreeze	Prestone	Viscosity	>.02	1-3[d]
96		Gaskets	Cork	K, T, I	0.5	4-8[d]
97			Cork impregnated cloth	K, T, I	0.5	4-8[d]
98			Neoprene	C	0.6	3-2
99			Thiokol	C	0.1	3-8
100		Filter	Cloth	K, T, I	0.5	4-8[d]
101			Paper	E, T, I	0.5	4-8[d]
102		Hoses	Neoprene	C	0.6	3-2
103			Cloth backed neoprene	K, T, I (cloth)	0.5	4-8[d]
104		Starter generator	See Electric Motors		1.3	3-3
105	Fluid disconnects	O rings	Buna S	E, SAB, C, SAF	0.6	3-2
106		Gaskets	Neoprene	C	0.1	3-8
107			Thiokol	C	0.4	3-5
108			Silicone rubber	C	0.6	3-2
109	Gauges	Diaphragm	Neoprene	C	0.4	4-22[d]
110			Leather	I	>50	2-12[d]
111	Hydraulic system	Hydraulic fluid	Di(2 Ethylhexyl) sebacate	Viscosity	0.4	4-22
112		Seals, O rings	Nylon	I	0.6	3-2
113			Neoprene	C	1.3	3-3
114			Buna S	E, SAB, C, SAF	0.4	3-4
115			Buna N	SAB, C	0.6	3-2
116		Hoses	Neoprene	C	1.3	3-3
117			Buna S	E, SAB, C, SAF	0.4	3-4
118			Buna N	SAB		
	Hydraulic system (continued)		Cloth-backed neoprene	K, T, I (Cloth)	0.5	4-8[d]
119		Cylinder cups	Leather	I	0.4	4-22[d]
120			Neoprene	C	0.6	3-2
121		Couplings	Leather	I	0.4	4-22[d]
122			Neoprene	C	0.6	3-2
123		(Similar to Hydraulic System except hydraulic fluid is replaced by air)				
124	Pneumatic systems	Diaphragm	Neoprene	C	0.6	3-2
125	Pressure switches		Nylon	I	0.4	4-22
126			Leather	I	0.4	4-22[d]
127			Neoprene	C	0.6	3-2
128	Pumps	Packings, shaft seals, gaskets	Natural rubber	SAB	2.6	3-1
129			Buna N	SAB, C	0.4	3-4
130			Thiokol	C	0.1	3-8
131			Silicone rubber	C	0.4	3-5
132			Teflon	K	0.008	4-31
133			Cotton	K, T, I	0.5	4-8[d]
134			Rayon	K, I	1.6	4-8
135			Paper	K, T, I	0.5	4-8[d]
136			Leather	I	0.4	4-22[d]
137			Kel F	K, I	1.7	4-12
138			Butyl rubber	C	0.4	3-6
139						
140	Valves	Packing, seals, gaskets	See pumps			

[a] T = tensile strength, E = elongation, S = shear strength, I = impact strength, SAB = set-at-break, C = compression set, SAF = strain at 400 psi, and EM = elastic modulus.

[b] Reference is made to table number and item, e.g., 4-19 refers to item 19 of Table 4.

[c] Decrease in foot candle output.

[d] The equivalent dosage for this material has been estimated on the basis of chemical and physical similarity to a material actually tested.

[e] This is one of several materials which may be used in this application.

percentage changes in such properties can render a given instrument useless. For these materials, the 25 per cent change represents a very high upper limit value; a radiation-damage threshold value is frequently needed, i.e., that radiation dosage at which the semiconductor properties just begin to change.

Based upon the premise that a system is no more stable under radiation than its most radiation-susceptible materials, the service life of each of the systems listed in Table 5 can be estimated for any pile flux conditions in the same manner as previously described for organic liquids. In evaluating the behavior of electronic components under radiation conditions, it should be remembered that although radiation damage to organic-type materials is, in general, a function of total dosage and not dosage rate, it is still entirely possible that the ionization produced in an electrical insulation system during irradiation will cause the resistivity of radiation-sensitive insulating materials to be changed in situ as a function of dosage rate. It could therefore be possible for a given electrical insulation material or system to receive the same total dosage under different fluxes or dosage rates and yet exhibit somewhat different radiation-induced changes.

the engineering properties of VITON* fluoroelastomer

*Reg. U.S. Pat. & Tm. Off.

product description

VITON* fluoroelastomer, a fluorine-containing hydrocarbon polymer, is a high-performance synthetic rubber with exceptional resistance to oils and chemicals at elevated temperatures. Since its commercialization in 1958, Du Pont has developed a variety of types of VITON possessing specific property improvements, notably in the areas of polymer processing and end product resistance to compression set.

Among the earliest uses of VITON were O-rings for severe service conditions. This continues to be an important application, while sharing its original prominence with a growing number of uses detailed in a later section of this booklet.

VITON is marketed as a raw materia to the rubber manufacturing industr by the Elastomer Chemicals Department of Du Pont. No finishec products are made from VITON by the Elastomer Chemicals Departmer

Our customers offer a variety of solid and cellular products, solvent solutions and coated fabrics, all based on VITON. The compounded product can be molded, extruded, or calendered using standard rubbe processing equipment.

table of contents

*Reg. U.S. Pat. & Tm. Off.

properties

VITON® fluoroelastomer is an exceptional rubber. It possesses the traditional rapid recovery from deformation, or resilience, of a true elastomer. It also exhibits mechanical properties of the same order of magnitude as those of conventional synthetic rubbers. However, the resistance properties of VITON are, in many respects, far beyond the range of those of ordinary rub`ers. Mechanical and resistance properties of Du Pont VITON will be discussed in that order.

MECHANICAL PROPERTIES

General-purpose formulations of VITON were used for the measurements reported herein, except as specifically noted. The values cited should be taken as representative of what you might expect of a product supplied by a reputable rubber manufacturer. Exact duplication of every figure, however, should not be expected. As is the case with all elastomers, VITON may be compounded to [redacted]

[redacted]ength and elongation
[redacted]ents from −65 to 400°F.
[redacted]4°C.) may be made on VITON
[redacted]mally controlled enclosure of
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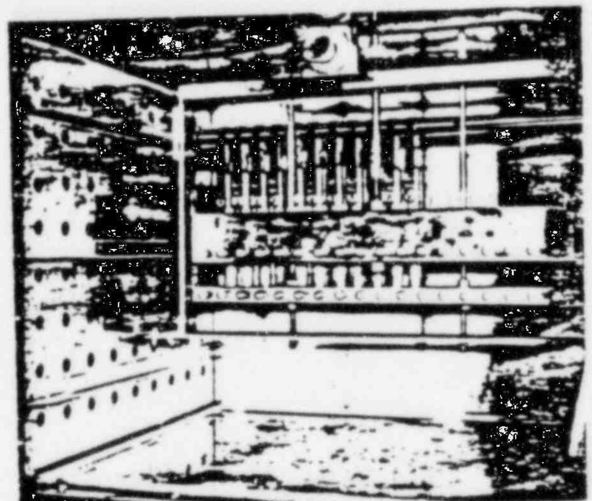
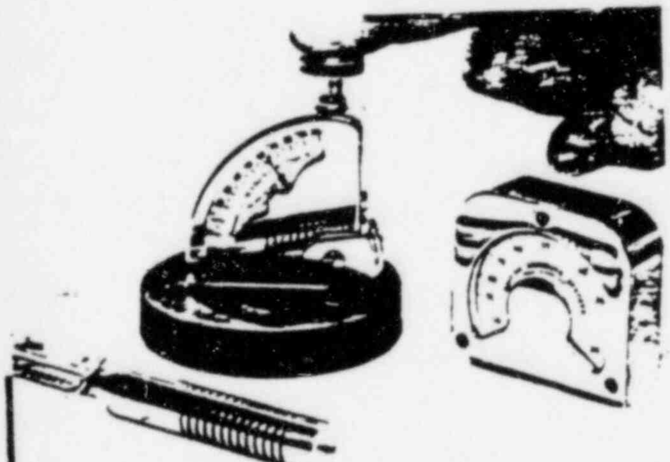


^ The mechanical properties of VITON are evaluated in a variety of equipment, including this dynamic flex tester.

MECHANICAL PROPERTIES



HARDNESS

The durometer A hardness of general-purpose compounds of VITON* fluoroelastomer is approximately 70. Harder and softer formulations (50 to 95) can be furnished and products with great apparent softness may be obtained by the use of cellular VITON.

Depending upon polymer and formulation, hardness may change very little or may decrease 5 to 15 points at temperatures between 250 and 500°F. (121 and 260°C.) Such variations must be taken into consideration in specifying hardness of products used at elevated temperatures.

TENSILE STRENGTH

Compounds of VITON have good tensile strengths, adequate for most applications. A typical value, when tested at 75°F. (24°C.), is 2,000 psi (140.6 kg./cm.²). And, measured at 300°F. (149°C.), the tensile strength of VITON remains in the vicinity of 600 psi (42.2 kg./cm.²).

ELONGATION AT BREAK

Percent elongation at break is a common yardstick for evaluating a rubber's durability in service. The performance of VITON at 75°F. (24°C.) normally ranges from 150 to 300 percent elongation at break. At 300°F. (149°C.) the elongations of typical compounds of VITON range from 75 to 150 percent.

COMPRESSION SET

Figure 1 illustrates the exceptionally good compression set shown by a typical compound of VITON after test compressions for various periods of time at 300°F. and 392°F. (149 and 200°C.). These values become more meaningful when it is realized that most rubbers have a service temperature ceiling less than 250°F. (121°C.)

FABRIC COATING

Coatings of VITON are commonly employed on fabrics to confer necessary heat or fluid resistance to the end product. Adhesion to the fabrics is generally good and, depending upon the heat resistance of the fabric used, temperatures up to 550°F. (288°C.) cause no problems.

Heat stabilities of three representative fluoroelastomer coatings on glass fabric are shown in Figure 2. As can be seen, all three compounds exhibit excellent heat aging properties and are useful for more than 100 hours at 550°F. (288°C.)

Above 500°F. (260°C.) single plies of coated fabrics are more stable than multiple plies. This is because at these high temperatures the decomposition products of VITON cannot escape as readily from multi-ply construction. Their entrapment causes faster deterioration.

Asbestos fabric coated with VITON is used on jet aircraft for firewall sleeves and seals. >

*Reg. U.S. Pat. & Tm. Off.

Figure 1
Long-Term Compression Set of VITON

Compression set, %*

Time, hr.	At R.T.	At 300°F. (149°C.)	At 392°F. (200°C.)
1,000	—	12	50
2,000	—	16	65
4,000	21	22	79
8,000	21	32	98

*ASTM D395, Method B. (O-rings)

Figure 2
Heat Stability of Glass Fabric Coated with VITON

	Compound A		Compound B		Compound C	
	1 ply	2 ply	1 ply	2 ply	1 ply	2 ply
Original grab tensile strength, lb./linear in. (kg./cm.)	91 (16.2)	194 (34.6)	80 (14.3)	190 (33.9)	109 (19.5)	185 (33.0)
After 50 hr. oven aging at 550°F. (288°C.)	93 (16.6)	123 (22.0)	57 (10.2)	121 (21.6)	94 (16.8)	128 (22.9)
After 100 hr. oven aging at 550°F. (288°C.)	78 (13.9)	98 (17.5)	54 (9.6)	102 (18.2)	74 (13.2)	107 (19.1)
% Weight Loss						
After 50 hr. oven aging at 550°F. (288°C.)	6.7	7.4	8.0	8.7	7.8	8.4
After 100 hr. oven aging at 550°F. (288°C.)	12.2	15.2	13.9	19.8	13.8	18.2

Figure 3
Adhesion of VITON to Metals*

Metal	Original Measured at 75°F. (24°C.)	Aged 64 hr. at 500°F. (260°C.) Measured at 75°F. (24°C.)	Aged 64 hr. at 500°F. (260°C.) Measured at 400°F. (204°C.)
Aluminum	160 (28.6)	20 (3.6)	6 (10.7)
Brass	160 (28.6)	20 (3.6)	6 (10.7)
Steel	160 (28.6)	20 (3.6)	6 (10.7)

*180° peel adhesion in lb./linear in. (kg./cm.). All failures were by stock tearing.

RESILIENCE

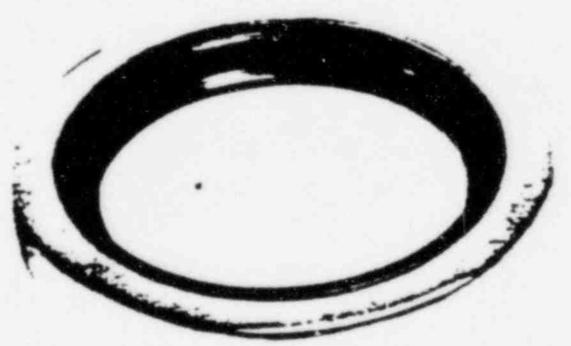
The dynamic properties of VITON* fluoroelastomer make it suitable for use as a vibration isolator at high temperatures and as a vibration damper (energy absorber) at room temperature. In the latter case, however, it would normally be employed only in very corrosive environments.

ADHESION TO METALS

VITON can be adhered to a variety of metals, using special adhesive formulations also based on VITON. Assemblies do not fail at the bond. Bond strength exceeds the tear strength of cured VITON, both at [illegible]F. (24°C.) and at temperatures [illegible]igh as 400°F. (204°C.). The [illegible]sive bonds also endure 500°F. ([illegible]°C.) heat aging. Figure 3 lists representative peel adhesion values between VITON and some common metals.

SPONGE PROPERTIES

Cellular VITON, in densities from 10 to 95 lb./ft.³, (0.16 to 1.52 g./cm.³), offers the advantages of extreme softness and compressibility while retaining to a high degree the exceptional heat and fluid resistance of solid fluoroelastomer products. Both open and closed cell materials can be produced.



*Reg. U.S. Pat. & Tm. Off.

RESISTANCE PROPERTIES

Again we point out the influence of compounding upon specific properties; like acid resistance, electrical characteristics, water absorption, etc. General-purpose formulations of VITON* fluoroelastomer will be referred to throughout unless otherwise indicated.

It is important to note that if you require a high degree of resistance to a specific exposure you should stress this fact to your rubber supplier. He can furnish you with a product specially compounded to suit your purpose. For instance, volume swell of VITON in hot water can be reduced by two-thirds without significant sacrifice in overal performance. Similar improvement of other resistance properties can be achieved through special compounding.

HIGH TEMPERATURE

VITON withstands high temperature and simultaneously retains its good mechanical properties better than any other elastomer. Oil and chemical resistance also are relatively unaffected by elevated temperatures. Compounds of VITON remain usefully elastic indefinitely when exposed to laboratory air oven aging up to 400°F. (204°C.). Continuous service limits are generally considered to be:

- >3,000 hours at 450°F. (232°C.)
- 1,000 hours at 500°F. (260°C.)
- 240 hours at 550°F. (288°C.)
- 48 hours at 600°F. (315°C.)

For fleeting exposures to 1,000 plus °F. (538°C.), where a rubber part must perform a function and then is destroyed, VITON often can provide the necessary temporary protection.

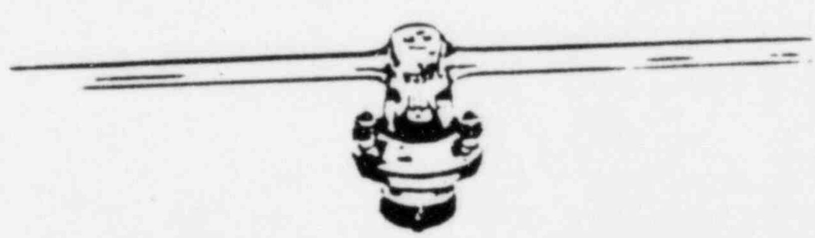
LOW TEMPERATURE

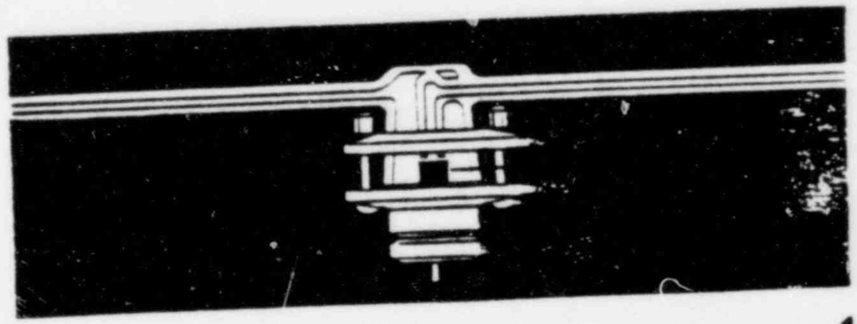
Especially in aircraft and space equipment, both low and high temperature conditions must be satisfied. VITON is generally serviceable in dynamic applications down to −10°F. (−23°C.).

Thickness of the sample has a marked effect upon tests of flexibility at low temperature; the thinner cross sections, of course, exhibiting less stiffness than thicker ones at every temperature. The brittle point of VITON, at a thickness of 0.075 in. (1.9 mm.), is in the neighborhood of −50°F. (−45°C.). Depending upon thickness and hardness, this value may range from −25 to −75°F. (−32 to −59°C.). Under certain conditions, some of these fluoroelastomer products perform satisfactorily in dynamic applications at temperatures approaching their brittle points.

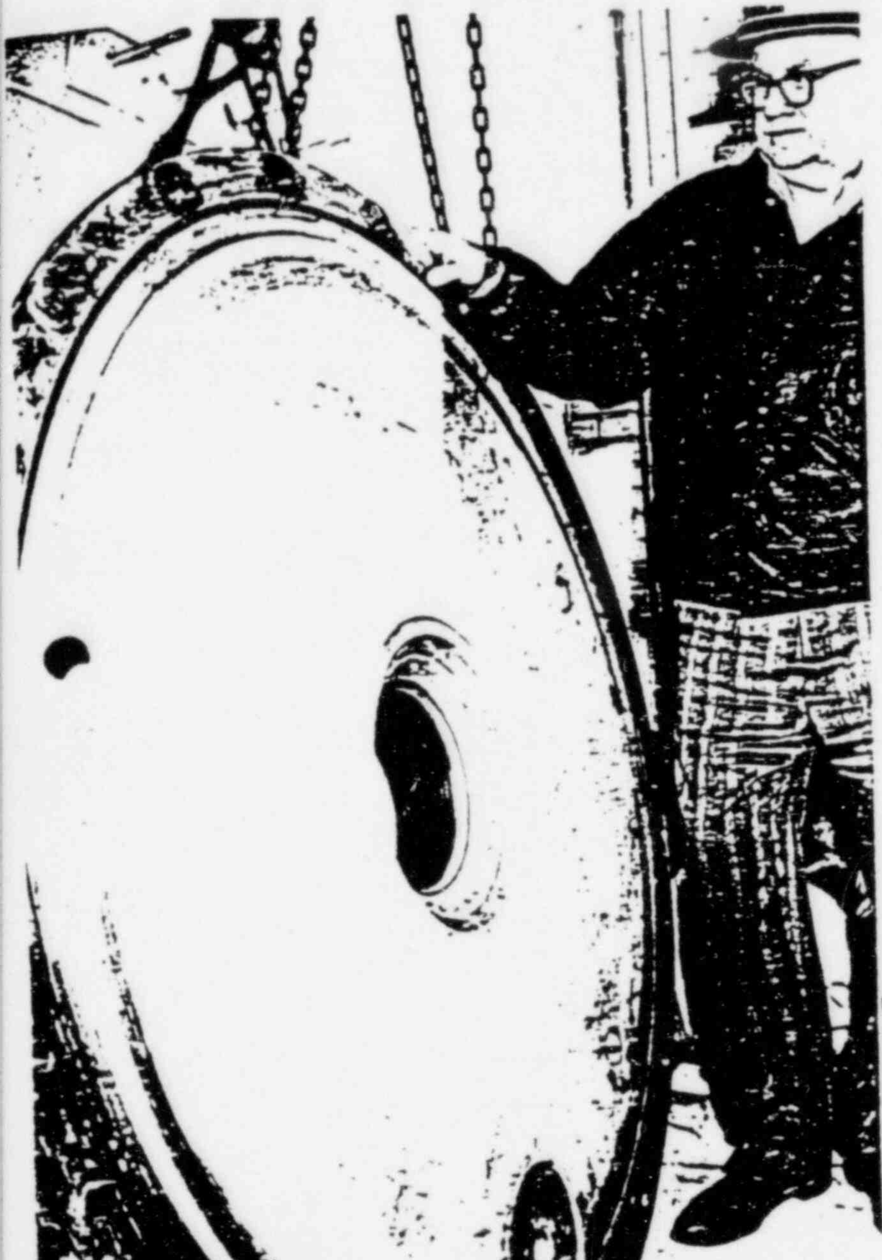
Although VITON has limitations at very low temperatures when dynamic service is required, static applications are readily handled. As a matter of fact, general-purpose O-rings made of VITON have proven satisfactory as static seals under cryogenic conditions approaching absolute zero.

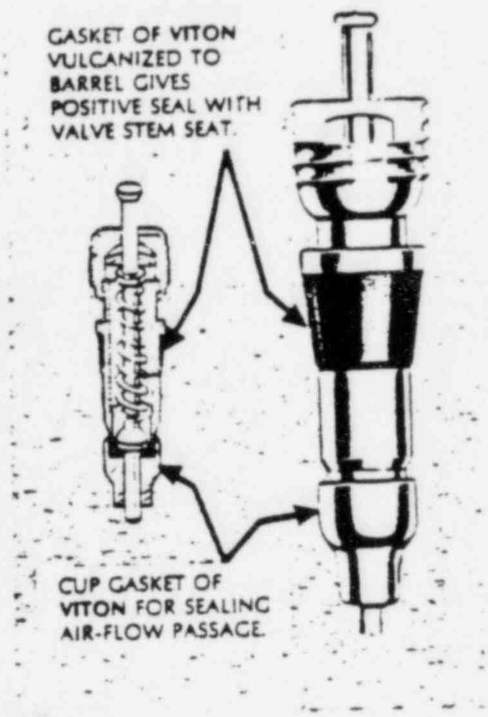
Greaseless stopcock for high-vacuum (1×10^{-4}mm. Hg) service up to 450°F. (232°C.) is closed by a resilient diaphragm of outgassing- and radiation-resistant VITON.





*Reg. U.S. Pat. & Tm. Off.





^ Valve inside jet aircraft wheels uses gaskets of VITON* fluoroelastomer. Specification calls for operation from −65 to 500°F. (−54 to 260°C.) plus pressures over 300 psi (21.1 kg./cm.²).

< The flange seal of VITON on this vacuum drier cover was in place for 12 years. Estimated temperatures within the jacketed stainless steel vessel ran 460–480°F. (238–249°C.) and the contents were acidic organics. Seal replacement was made only when the drier had to be mechanically overhauled. At no time had the seal shown any evidence of leaking.

*Reg. U.S. Pat. & Tm. Off.

RESISTANCE PROPERTIES

FLUID RESISTANCE

VITON* fluoroelastomer has the best proven fluid resistance characteristics of any commercial rubber available to date. It has excellent resistance to oils, fuels, lubricants, most mineral acids, and resists many aliphatic and aromatic hydrocarbons (carbon tetrachloride, benzene, toluene, xylene) that act as solvents for other rubbers.

On the other hand, VITON is not recommended for service in low molecular weight esters and ethers, ketones, certain amines, hot anhydrous hydrofluoric or chlorosulfonic acids, and a few proprietary fluids such as Skydrol 500A. The solubility of VITON in low molecular weight ketones is, of course, useful in producing solution coatings of VITON.

Tabulated on pages 18-19 are evaluations of VITON versus a representative list of nearly 200 fluids.

GAS PERMEABILITY

VITON is relatively impermeable to air and gases, ranking about midway between the best and the poorest elastomers in this respect. These comparative measurements were made using standard-sized specimens (1 sq. cm. by 1 cm. thick) of typical compounds, each exposed to a pressure differential of one atmosphere at 176°F. (80°C.)

The permeability of VITON can be modified considerably by the way it is compounded. But, in all cases, permeability increases rapidly with increasing temperature. Additional data on the permeability of VITON are tabulated in Figure 4.

▲
High-temperature fluid resistance tests in the laboratory confirm that products of VITON, such as those shown at right, will successfully perform in the field where other rubbers fail completely.

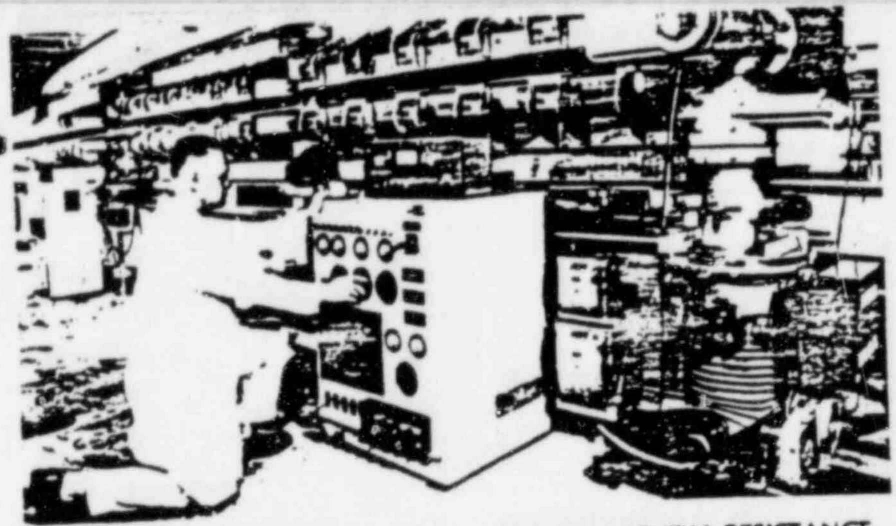
Figure 4
Permeability* of Compounded VITON

	75°F. (24°C.)	86°F. (30°C.)	250°F. (121°C.)	400°F. (204°C.)
Air	0.0099×10^{-7}	—	—	—
Carbon dioxide	—	0.59×10^{-7}	—	—
Helium	0.892×10^{-7}	—	17.4×10^{-7}	67.0×10^{-7}
Nitrogen	0.0054×10^{-7}	—	—	—
Oxygen	—	0.11×10^{-7}	—	—

*c.c./cm.²/cm./sec./atm.

*Reg. U.S. Pat. & Tm. Off.

Vacuum chamber of giant proton accelerator, one-half mile (800 m.) in circumference, was gasketed with radiation-resistant, non-volatilizing VITON to improve the vacuum to x 10^{-7} in. Hg.



FLAMMABILITY

VITON* fluoroelastomer, like Neoprene and HYPALON* synthetic rubber, is a halogen-containing polymer and thus is more resistant to burning than are exclusively hydrocarbon rubbers.

In laboratory tests, products made of normally compounded VITON will burn if directly exposed to flame but will go out when the flame is removed. Natural rubber and many synthetics will, under the same conditions, continue to burn. However, despite its advantage over other materials in such laboratory tests, VITON will burn if involved in an actual fire situation.

Special compounding can enhance the flame resistance of VITON. One formulation, specifically developed for the Space Program, will not ignite under conditions of the NASA test, which specify 100 percent oxygen at 6.2 psi (absolute).

FOOD AND DRUG CONTACT

The U.S. Food and Drug Administration has amended its regulations to provide for the use of vulcanizates of VITON in the formulation of rubber articles intended for repeated food contact use.

More details are available in the Federal Register, Vol. 33, No. 5, Tuesday, January 9, 1968, Part 121—Food Additives. Subpart F—Food Additives Resulting From Contact With Containers or Equipment and Food Additives Otherwise Affecting Food—Rubber Articles Intended for Repeated Use.

ABRASION RESISTANCE

End products made from VITON are tough and long wearing. In the Taber abrasion test a loss per revolution of 0.1-0.2 milligrams, with a H-22 wheel and 1,000-gram load was measured on a typical compound of VITON.

RADIATION RESISTANCE

Exposure of VITON to gamma radiation from a cobalt-60 isotope source brings about an increase in hardness and stiffness. This seems to be as a result of an increased state of cure induced by the radiation. For dynamic applications, VITON should not be exposed to radiation exceeding 1 x 10^7 roentgens. For static applications, higher dosages are permissable. VITON gives no evidence of radiation-induced stress cracking.

VITON ranks about midway among commonly available elastomers with respect to radiation resistance alone. However, since high temperature is frequently involved simultaneously with exposure to radiation, the practical effectiveness of VITON correspondingly increases. In many cases, the temperatures will rule out most other elastomers and plastics.

ELECTRICAL PROPERTIES

The electrical properties of VITON suggest its use as a wire insulation for low voltage, low frequency applications requiring unusual heat and fluid resistance. It normally has a D.C. resistivity on the order of 2 x 10^{13} ohm-cm., a dielectric constant around 10, dissipation factor of about 0.05 and a dielectric strength of 500 volts per mil (2,000 volts per mm.).

ENVIRONMENTAL RESISTANCE

VITON has excellent resistance to atmospheric oxidation, sun and weather. Samples weathered in direct sunlight showed little or no change in properties or appearance after 13 years' exposure in Florida. The same is true for samples exposed to various tropical conditions in Panama for ten years.

Articles produced with VITON are unaffected by ozone concentrations as high as 100 ppm. No cracking occurred in a bent loop test after one year's exposure to 100 ppm of ozone in air at 100°F. (38°C.).

The biological resistance of VITON also is excellent. A typical compound tested against specification MIL-E-5272C showed no fungus growth after 30 days. This spec covers four common groups of fungi.

Under extreme vacuum conditions VITON exhibits a weight loss of only 2-3 percent, indicating that it is virtually completely immune to outgassing. Products of VITON are commonly baked at 400-500°F. (204-260°C.) for 16-24 hr. in order to post-cure them. This procedure removes virtually all volatiles before the item goes into service.

Figure 5

Electrical Properties of VITON at Various Temperatures (Tested in air)

	75°F. 24°C.	300°F. 149°C.	390°F. 199°C.
Dissipation Factor, (1,000 Hz.)	0.034	0.273*	0.39 to 1.19*
Dielectric Constant, (1,000 Hz.)	10.5	7.1	9.1

*Indicator drifting.

*Reg. U.S. Pat. & Tm. Off.

applications

AUTOMOTIVE

Many opportunities exist for the incorporation of VITON* fluoroelastomer in parts for the engine and drive train of modern passenger vehicles and trucks. Cost is a major factor in this industry and any use of a high-priced elastomer like VITON is an exceptional testimonial to its premium performance. However, the long-term value provided by VITON is being increasingly recognized as justifying its use in place of cheaper materials as performance insurance for certain automotive parts. This is true not only for extreme exposure conditions but, in some cases, also where only moderate conditions are normally encountered.

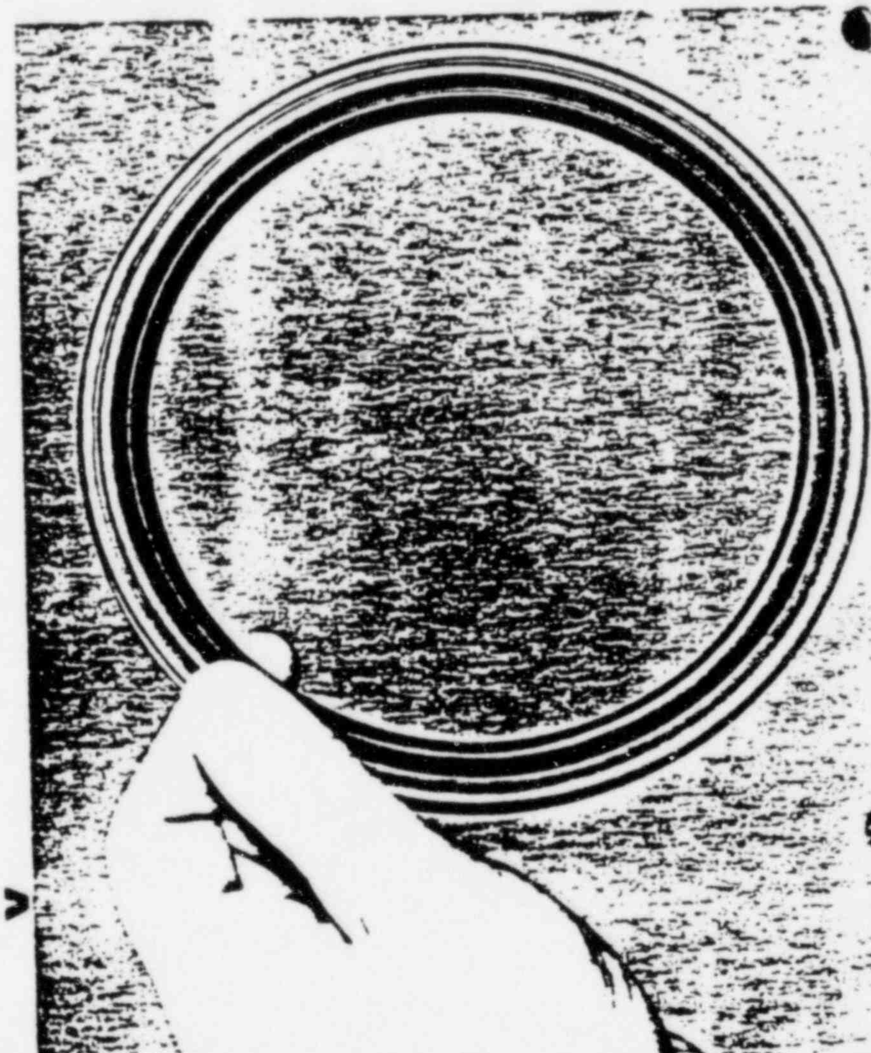
In carburetors, needle valves tipped with VITON provide a resilient, fuel-resistant, abrasion-resistant seating material that is the key to a non-flooding carburetion system. A component of VITON on truck carburetors is the accelerator pump cup which must remain dimensionally stable within close tolerances in order to function properly.

Valve stem oil seals made of VITON have been used for a number of years on one line of heavy-duty truck engines designed for 100,000 miles (160,930 km.) of maintenance-free operation. And many have run over 150,000 miles (241,395 km.) without incident—a severe test of heat and oil resistance.

Since 1962, VITON has been the standard seal material on diesel engine brake solenoids. These devices have been installed in more than 50,000 vehicles ranging from city buses to logging trucks. The O-ring seals of VITON were purchased against MIL-R-25897 specification and hold against hot lube oil at up to 60-70 psig (4.2-4.9 kg./cm^2.) in the truck engine.

Off-the-road equipment also uses VITON. A major manufacturer has standardized on VITON for rear crankshaft lip seals in its heavy-duty diesel engines used on certain of its earthmoving machines. Some of these engines have run 8,000 hr. between overhauls as a result. Hydraulic fittings in automotive service are reliably sealed against vibration-induced leakage by sleeves of VITON which absorb angular displacement and withstand hot oils. And automatic transmission front pump seals of VITON have proven their worth after years of successful service.

Other automotive uses for VITON include an axle pinion shaft seal, diesel cylinder liner seals, solenoid plunger tips, seals for automatic transmissions in buses, vacuum tubing and diaphragm for a spark advance mechanism.

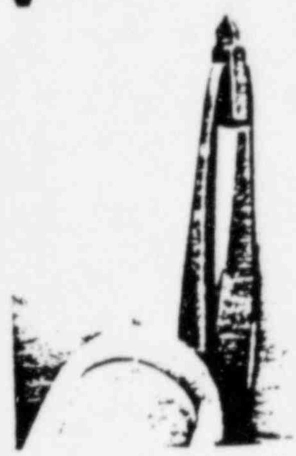


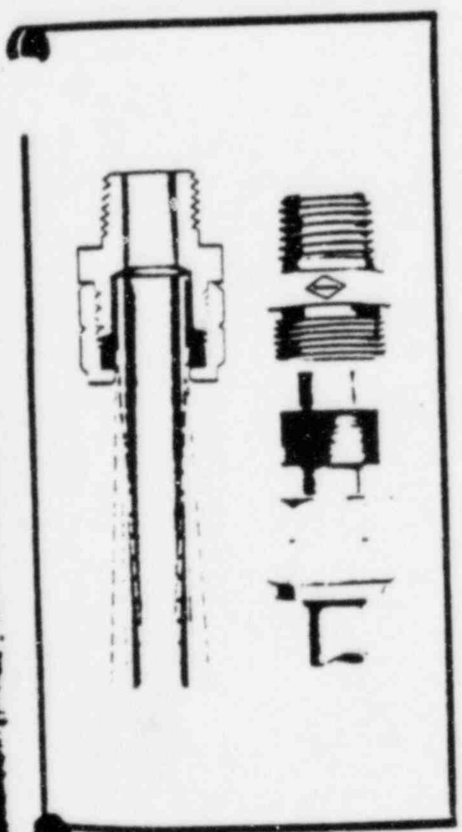
Rear crankshaft seal of VITON on earthmovers' diesels has reduced maintenance and prolonged engine life.

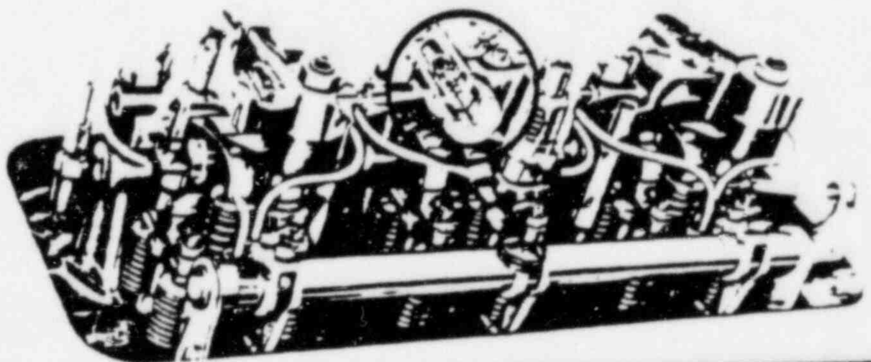
*Reg. U.S. Pat. & Tm. Off.

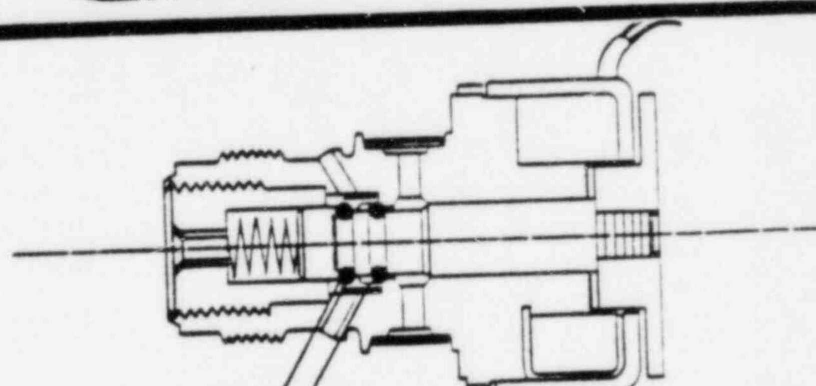
< Engine brakes sealed with VITON* fluoroelastomer are giving truckers lower maintenance costs per mile.

VITON on tip of carburetor needle valve prevents flooding, does not swell in aromatic fuels.
V









ON keeps hydraulic fittings th-tight.

^
Solenoids controlling hydraulic operation of diesel engine brakes have seals of hot oil-resistant VITON.

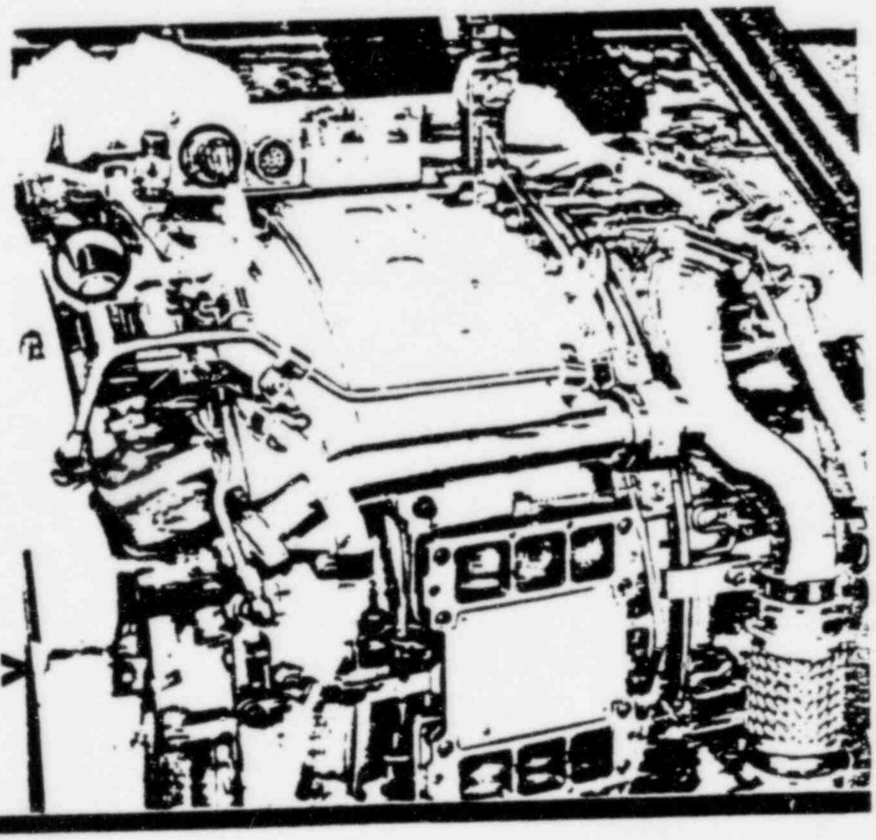
*Reg. U.S. Pat. & Tm. Off.

applications

AIR AND SPACE

Piston-type as well as jet engines employ VITON* fluoroelastomer for resistance to heat, lubricants and fuels. Seals of VITON are now standard on major airlines.

Commercial jetliners use VITON in many critical applications where exceptional heat and oil resistance are necessary requirements.



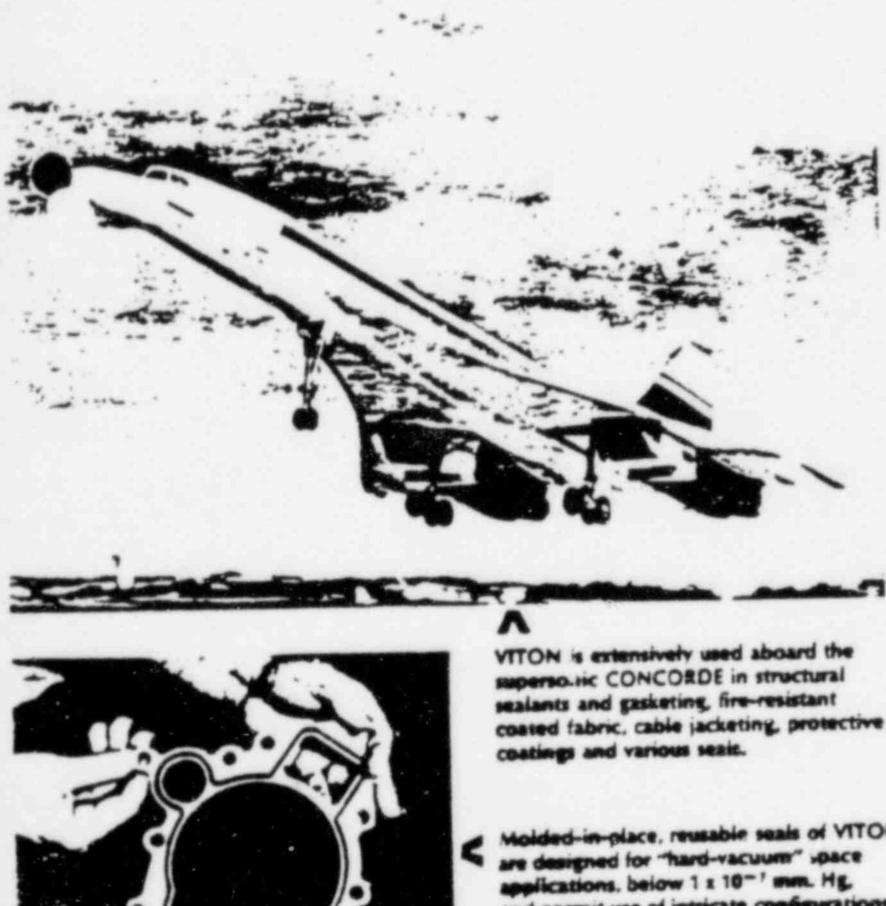
Connector seals on jet engine wiring harnesses are VITON for heat, oil, weather and vibration resistance.

*Reg. U.S. Pat. & Tm. Off.

Stability of materials under extreme exposure conditions is a prime requisite in this field. The high and low temperature properties of VITON* fluoroelastomer have been well demonstrated in a number of aircraft and missile components; manifold gaskets, coated fabrics, firewall seals, heat-shrinkable tubing and fittings for wire and cable, mastic adhesive sealants, protective coatings and numerous O-ring seals. An additional characteristic of VITON pertinent to space components is its ability to seal against "hard" vacuum, down to a range of 10^{-9}mm. Hg by actual test.

Aircraft designers have reported O-rings of VITON have a usable thermal range of −65 to +600°F. (−54 to +315°C.); and at 680 to 730°F. (360 to 388°C.) tests have been successful but service life is reduced to about 30-40 hours. They further report that VITON has excellent abrasion resistance and resistance to thermal cycling, a common condition encountered in rapid ascent to, and descent from, the stratosphere or higher. In several tests, VITON sealed just as well at room temperature, and also at reduced temperatures, after 40 thermal cycles as it did when new. Other elastomers, after two or three thermal cycles, would no longer maintain their seals at room temperature. One study on the service life of O-rings, run by an aircraft manufacturer, involved dynamic tests at elevated temperatures. O-rings of VITON, properly designed and installed according to their recommendations, proved capable of successfully completing 50,000-cycle compression tests at 500°F. (260°C.)

Among other applications of VITON in aviation are its uses as an abrasion-resistant solution coating over braid-sheathed ignition cable; heat-resistant connector seals on jet engine wiring harnesses; flexible, impregnated fiber glass sheathing for electric wire; coated fabric covers for jet engine exhausts between flights; and syphon hose for hot engine lubricants.



VITON is extensively used aboard the supersonic CONCORDE in structural sealants and gasketing, fire-resistant coated fabric, cable jacketing, protective coatings and various seals.

Jet engine exhaust covers are made of glass fabric coated with VITON to stand 500-700°F. (260-371°C.)

Molded-in-place, reusable seals of VITON are designed for "hard-vacuum" space applications, below 1×10^{-7} mm. Hg, and permit use of intricate configurations.

*Reg. U.S. Pat. & Tm. Off.

CHEMICAL INDUSTRY

A "universal" material of construction is the ideal sought by harried production and maintenance engineers in this rough-on-equipment industry. The high costs involved in dismantling and replacing failed components, to say nothing of the production losses, far outweigh any materials cost factor. Standardization on VITON* fluoroelastomer is becoming more common as its economic justification in longer production runs between maintenance shutdowns is being more widely demonstrated. In two documented instances, chemical piping and equipment seals have remained in uninterrupted service for over 10 years.

VITON is very close to being a universal seal for chemical process equipment. One example is a pumping station handling more than 80 different solvents, oils and chemicals. Seals of VITON used in the piping's swivel joints and telescoping joints were inspected after two years' service and found to be as good as the day they were installed.

Another example is a door gasket for a wood impregnation autoclave. Temperatures to 245°F. (118°C.), steam pressures of 150 psig (10.5 kg./cm.²), and exposure to cresol oils and other phenolics are involved. VITON overcame the permanent set deficiency of the original woven asbestos gasketing and gave much longer service than previously tried synthetic rubber seals.

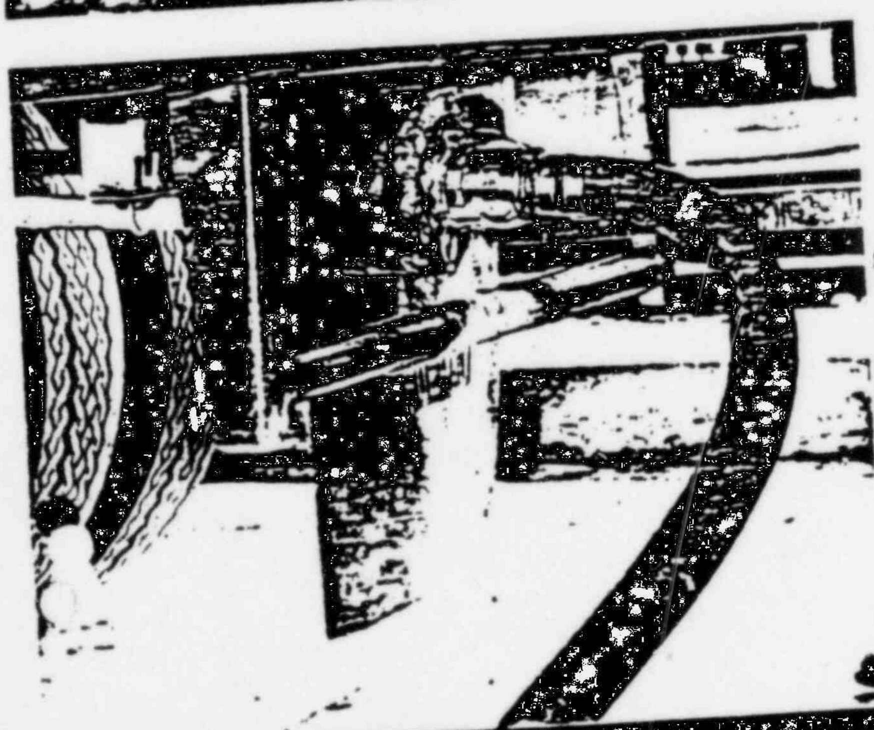
A third example is the rotameter manufactured by a leading supplier of measurement and control equipment. All of its rotameters intended for metering chemicals are furnished with O-ring seals of VITON. This adoption of a "universal" seal has simplified the production and markedly reduced the number of customer service calls on the instrument.

But VITON serves the chemical industry in more ways than as seals alone. Fluoroelastomer lined valves eliminate heat and corrosion worries in many a plant. Transfer hose for solvents and reactive petrochemicals is in daily use for both processing and distribution facilities. Included are installations on ocean tankers as well as highway trailers. Proportioning pumps handling highly reactive chemicals are equipped with diaphragms of VITON. Processing rolls for hot or corrosive service are covered with VITON. And aerosol-propelled solvent solutions of VITON are sprayed on as multi-purpose maintenance coatings throughout the chemical industry.

Packing of pipeline swivel joint is heavily encrusted with deposits after years of handling a variety of solvents, yet it remains as leak-free as when first installed because it's made of VITON.

*Reg. U.S. Pat. & Tm. Off.

^ Door of wood impregnation autoclave is sealed against hot phenolic preservatives by an O-ring of VITON* fluoroelastomer. The improved steam/vacuum sealing system replaced woven asbestos gaskets.



< Severe chemical attack destroyed tank truck transfer hose after only one delivery. Then a hose lined with VITON was tried. Now the hose lasts over a year in routine tanker use.

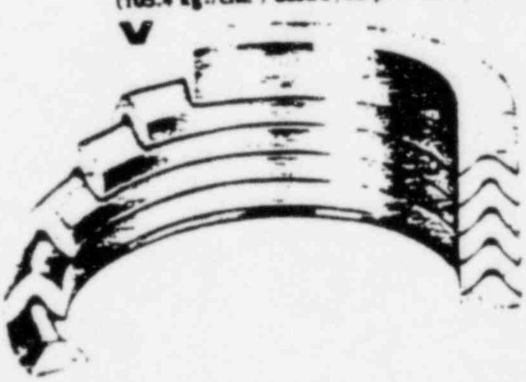
*Reg. U.S. Pat. & Tm. Off.

MISCELLANEOUS INDUSTRIAL USES

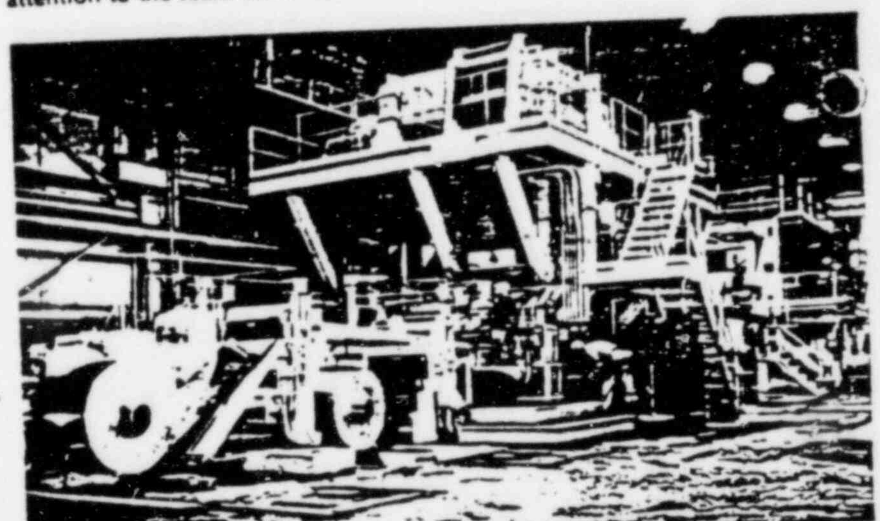
Cutting across all industry lines are a wealth of additional applications where the good mechanical properties of VITON* fluoroelastomer have permitted it to replace conventional elastomers. To cite a few: stable-dimensioned O-ring seals in the meters of automatic gasoline blending pumps, high-vacuum seals for a proton accelerator, a heat- and corrosion-resistant expansion joint for a utility company's stack gas exhaust ducts, tubing and seals for a variety of premium-grade industrial instruments, conveyor tires for hot plate glass, packing rings for hydraulic activators on steel mill ladles, jacketing for steel mill signal cable, deflector rolls on high-speed tinplating lines, precision-molded balls for check valves in oil or chemical service, and an assortment of O-ring seals for test equipment in an automotive manufacturer's experimental lab.

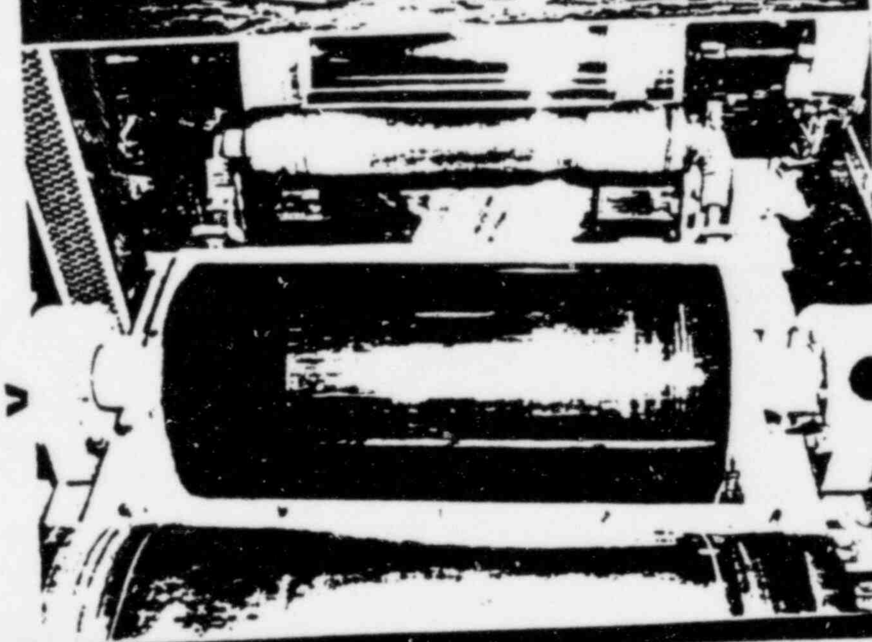
The lattermost example well illustrates the general principle that we have been stressing in this booklet. Previously, various test machines had to be dismantled every few days to repair leaks. Use of VITON permits the units to run continuously for three months without attention to the seals. Seals now are customarily replaced only during periodic maintenance overhauls. Exposure is to a variety of hydraulic fluids at temperatures up to 325°F. (163°C.) and pressures, in some cases rapidly alternating, up to 2,000 psi (140.6 kg./cm.²).

According to the lab's mechanical design engineer, their previous seals "baked so hard they snapped like pretzels" when removed after a short time because of leakage. The switch to VITON eliminated a real maintenance headache and, he feels, has come very close to providing the long-sought "universal seal."



Molded packing rings, made of VITON reinforced with asbestos cloth, seal hydraulic actuators of steel mill ladles. Reactive, nonflammable hydraulic fluids at 550°F. (288°C.) and 1,500 psig (105.4 kg./cm.²) destroyed previous packings.





On a continuous tinplating line a deflector roll covered with VITON has outlasted the previous roll by more than 12 to 1.

*Reg. U.S. Pat. & Tm. Off.

applicable specifications

MIL-R-83248

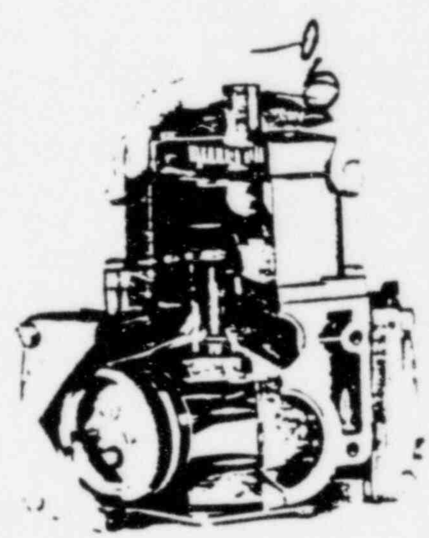
	Spec	VITON
Original		
Tensile Strength, psi	1,600	1,735
, kg./cm.[2]	112.5	122.0
Elongation, %	125	190
Hardness, Durometer		
A points	75 ±5	79
T_R °F., max.	+5	−4
T_R °C., max.	−15	−20
Compression Set—ASTM D395, Method B 70 hr. at 75°F. (24°C.), %	15	12
Aged 70 hr. at 75°F. (24°C.) in Reference Fuel B		
Tensile Strength, % change	−20	−15
Elongation, % change	−20	−10
Hardness, points change	±5	−2
Volume, % change	0 to +10	+1.6
...ged 70 hr. at 347°F. (175°C.) in ...uffer Blend 7700		
...nsile Strength, % change	−25	−22
...ngation, % change	−20	−5
...rdness, points change	0 to −15	−7
Volume, % change	0 to +20	+16.4
Compression Set—ASTM D395, Method B		
Standard Measurement, %	10	0
Measurement After 18-hr. Cooling, %	15	7
Aged 70 hr. at 528°F. (275°C.) in Air		
Tensile Strength, % change	−35	−20
Elongation, % change	−15	+42
Hardness, points change	−5 to +10	+1
Weight, % change	−10	−5.06
Compression Set—ASTM D395, Method B		
22 hr. at 392°F. (200°C.), %	15	8
Compression Set—ASTM D395, Method B Aged 166 hr. at 347°F. (175°C.)		
Standard Measurement, %	20	15
Measurement After 18-hr. Cooling, %	35	24

AMS-7278D

	Spec	VITON
Original		
Tensile Strength, psi	1,200	1,735
, kg./cm.[2]	84.4	122.0
Elongation, %	125	190
100% Modulus, psi	350	880
, kg./cm.[2]	24.6	61.9
Hardness, Durometer		
A points	75 ±5	79
T_R °F., max.	+5	−4
T_R °C., max.	−15	−20
Aged 70 hr. at 75°F. (24°C.) in Reference Fuel B		
Tensile Strength, % change	−15	−15
Elongation, % change	−15	−10
Hardness, points change	−5 to +5	−2
Volume, % change	0 to +10	+1.6
Aged 70 hr. at 392°F. (200°C.) in Anderol L-774		
Tensile Strength, % change	−40	−13
Elongation, % change	−20	+11
Hardness, points change	−15 to +5	−7
Volume, % change	0 to +20	+11.3
Aged 70 hr. at 482°F. (250°C.) in Air		
Tensile Strength, % change	−30	−2
Elongation, % change	−40	−10
Hardness, points change	0 to +15	+1
Weight, % change	−8.0	−0.94
Compression Set—ASTM D395, Method B		
70 hr. at 392°F. (200°C.),%	50	13

AMS-7280

	Spec	VITON
Original		
Tensile Strength, psi	1,600	1,735
, kg./cm.[2]	112.5	122.0
Elongation, %	125	190
Hardness, Durometer		
A points	75 ±5	79
T_R °F., max.	+5	−4
T_R °C., max.	−15	−20
Aged 70 hr. at 75°F. (24°C.) in Reference Fuel B		
Tensile Strength, % change	−15	−15
Elongation, % change	−15	−10
Hardness, points change	−5 to +5	−2
Volume, % change	0 to +10	+1.6
Aged 70 hr. at 392°F. (200°C.) in Stauffer Blend 7700		
Tensile Strength, % change	−40	−26
Elongation, % change	−20	−16
Hardness, points change	−15 to +5	−9
Volume, % change	0 to +25	+19.5
Aged 70 hr. at 482°F. (250°C.) in Air		
Tensile Strength, % change	−20	−2
Elongation, % change	−20	−10
Hardness, points change	0 to +10	+1
Weight, % change	−5	−0.94
Compression Set—ASTM D395, Method B		
70 hr. at 392°F. (200°C.), %	30	13
336 hr. at 392°F. (200°C.), %	55	32



Gasoline pump metering shaft seal—VITON* fluoroelastomer since 1958.

*Reg. U.S. Pat. & Tm. Off.

fluid resistance of VITON fluoroelastomer

Products made from VITON* fluoroelastomer are successfully used in contact with a great variety of fluids, in many instances at temperatures far higher than are practical with other elastomers. The choice of premium-priced VITON is justified by its trouble-free service which saves far more expensive maintenance and downtime costs.

To assist design engineers concerned with specifying rubber components exposed to severe chemical environments, the accompanying tabulation has been prepared. It includes evaluations of the fluid resistance of VITON versus a selection of materials whose influences, at various temperatures and for certain exposure times, range from virtually no effect on, to complete solution of, products made from properly compounded VITON.

We emphasize that it should be used as a *guide only*. The tabulation is based on laboratory tests and records of actual service performance. But an elastomer's degree of compatibility with a particular fluid also depends on such variables as temperature, time, velocity of flow, aeration, stability of the fluid, degree of contact, nature of suspended solids, etc.

It is always advisable to test the product under actual service conditions before specification. If this is impractical, then tests should be devised which simulate actual service conditions as closely as possible. Obviously, your rubber supplier should be provided with complete detai s on the conditions involved, since correct compounding and processing are important to the success of any resilient part where chemical resistance is one of the service requirements.

Rating Key

- A—Little or no effect
- B—Minor to moderate effect
- C—Severe effect, ranging to complete destruction
- T—No data—likely to be compatible
- X—No data—not likely to be compatible

Chemical	Ratin
Acetaldehyde	C
Acetic acid, 20%	C
Acetic acid, 30%	C
Acetic acid, glacial	C
Acetic anhydride	C
Acetone	C
Acetylene	A
Aluminum chloride solutions	A
Aluminum sulfate solutions	A
Ammonia, anhydrous	C
Ammonium chloride solutions	A
Ammonium hydroxide solutions	A
Ammonium sulfate solutions	A
Amyl acetate	C
Amyl alcohol	A(212°
Aniline	A-B
Aniline	B(158°
Aniline	C(300°
ASTM oil #1	A(300°
ASTM oil #3	A(350°
ASTM reference fuel A	A
ASTM reference fuel B	A
ASTM reference fuel C	A
Asphalt	A(400°
Barium hydroxide solutions	[illegible]
Beer	[illegible]
Benzaldehyde	C
Benzene	B(158°
Benzoyl chloride	B
Borax solutions	A
Boric acid solutions	A
Bromine, anhydrous liquid	A(212°
Butane	A
Butyl acetate	C
Butyraldehyde	C
Butyric acid	T
Calcium bisulfite solutions	A
Calcium chloride solutions	A
Calcium hydroxide solutions	A
Calcium hypochlorite, 5%	A
Calcium hypochlorite, 20%	B(158
Carbon bisulfide	A
Carbon dioxide	A
Carbon monoxide	T
Carbon tetrachloride	A(158
Castor oil	A
Chlorine gas, dry	A(212
Chlorine gas, wet	A
Chloroacetic acid	C
Chlorobenzene	A
Chloroform	A
Chlorosulfonic acid	C
Chromic acid, 10-50%	A
Citric acid solutions	A
Copper chloride solutions	A

*Reg. U.S. Pat. & Tm. Off.

Chemical	Rating
Copper sulfate solutions	A
Cottonseed oil	A(300°F.)
Creosote oil	A(212°F.)
Cyclohexane	A
Dibutyl phthalate	B
Diethyl sebacate	B
Dioctyl phthalate	B
DOWTHERM A	A(212°F.)
DOWTHERM A	B(400°F.)
Epichlorohydrin	C(122°F.)
Ethyl acetate	C
Ethyl alcohol	A
Ethyl chloride	A
Ethyl ether	B
Ethylene dichloride	A-B(120°F.)
Ethylene glycol	A(250°F.)
Ethylene oxide	C(158°F.)
Exxon 2380 turbo oil (lubricant)	A(392°F.)
Ferric chloride solutions	A
Fluosilicic acid	T
Formaldehyde, 40%	A
Formic acid	C(158°F.)
FREON-11	B
FREON-11	T(130°F.)
FREON-12	A-B
FREON-12	B(130°F.)
FREON-22	C
FREON-22	X(130°F.)
FREON-113	A
FREON-113	T(130°F.)
FREON-114	A
FREON-114	T(130°F.)
Furfural	C(158°F.)
Fyrquel 220 (hydraulic fluid)	A(212°F.)
Gasoline	A
Glue	A
Glycerin	A(250°F.)
n-Hexane	A
Hydrazine	C
Hydrochloric acid, 20%	A
Hydrochloric acid, 20%	A(230°F.)
Hydrochloric acid, 37%	A(158°F.)
Hydrochloric acid, 37%	B(230°F.)
Hydrocyanic acid	A
Hydrofluoric acid, 48%	A(212°F.)
Hydrofluoric acid, 75%	B(158°F.)
Hydrofluoric acid, anhydrous	A
Hydrogen	A
Hydrogen peroxide, 90%	A
Hydrogen peroxide, 90%	C(270°F.)
Hydrogen sulfide	B(270°F.)
Isooctane	A
Isopropyl alcohol	A
Isopropyl ether	C
JP-4	A(400°F.)
JP-5	A(400°F.)
JP-6	A(100°F.)
JP-6	B(550°F.)
Kerosene	A(158°F.)
Kerosene	B(400°F.)
Lacquer solvents	C
Lactic acid	A
Linseed oil	A
Lubricating oils	A(158°F.)
Magnesium chloride solutions	A
Magnesium hydroxide solutions	A
Mercuric chloride solutions	A
Mercury	A
Methyl alcohol	A-B
Methy[illegible]hyl ketone	C
Methylene chloride	B(100°F.)
Mineral oil	A
Mobil XRM 206A (aircraft eng. lube)	A(350°F.)
Naphtha	A(158°F.)
Naphthalene	A(176°F.)
Nitric acid, 10%	A
Nitric acid, 30%	A
Nitric acid, 60%	A
Nitric acid, 70%	A
Nitric acid, 70%	B(100°F.)
Nitric acid, red fuming	B
Nitric acid, red fuming	C(158°F.)
Nitrobenzene	B
Oleic acid	B
Oleum, 20-25%	A
Palmitic acid	A
Perchloroethylene	A(212°F.)
Phenol	A(212°F.)
Phenol	B(300°F.)
Phosphoric acid, 20%	A
Phosphoric acid, 60%	A(212°F.)
Phosphoric acid, 70%	A
Phosphoric acid, 85%	A
Pickling solution (20% nitric acid, 4% HF)	A
Pickling solution (17% nitric acid, 4% HF)	A
Pickling solution (17% nitric acid, 4% HF)	C(225°F.)
Picric acid	A
Potassium dichromate solutions	A
Potassium hydroxide solutions	A
Pydraul 312C	A
Pyridine	C
QFI-2023 (silicone brake fluid)	A(392°F.)
SAE #10 [illegible]	A
Sea wa[illegible]	A
Shel[illegible] 30[illegible]	B(392°F.)
Silicone grease	A
SKYDROL 500	C
SKYLUBE 450	C(392°F.)
Soap solutions	A
Sodium chloride solutions	A
Sodium dichromate, 20%	A
Sodium hydroxide, 20%	A
Sodium hydroxide, 46½%	A
Sodium hydroxide, 46½%	C(100°F.)
Sodium hydroxide, 50%	C
Sodium hydroxide, 73%	C
Sodium hypochlorite, 5%	A
Sodium hypochlorite, 20%	B(158°F.)
Sodium peroxide solutions	A
Soybean oil	A(250°F.)
Stannic chloride	A
Stannous chloride, 15%	A
Steam (see water)	B(300°F.)
Stearic acid	T
Styrene	A
Sulfur, molten	A(250°F.)
Sulfur dioxide, liquid	A
Sulfur dioxide, gas	A
Sulfur trioxide	A
Sulfuric acid, up to 5%	A
Sulfuric acid, 5-10%	A
Sulfuric acid, 10-50%	A
Sulfuric acid, 50-80%	A
Sulfuric acid, 60%	A(250°F.)
Sulfuric acid, 90%	A(158°F.)
Sulfuric acid, 95%	A
Sulfuric acid, 95%	A(158°F.)
Sulfuric acid, fuming (20% oleum)	A
Sulfurous acid	A
Sunoco XS-820 (EP lubricant)	A(300°F.)
Tannic acid, 10%	A
Tartaric acid	A
Tetrahydrofuran	C
Toluene	B(100°F.)
Tributyl phosphate	C(212°F.)
Trichlorethylene	A
Trichloroethylene	B(158°F.)
Tricresyl phosphate	A(300°F.)
Triethanolamine	C
Trisodium phosphate solutions	A
Tung oil	A
Turpentine	A(158°F.)
Water	A(158°F.)
Water	A(212°F.)
Xylene	A
Xylene	B(158°F.)
Zinc chloride solutions	A

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[illegible]VERSIONS FOR EXPOSURE TEMPERATURES INDICATED IN TABLE

°F.	°C	°F.	°C	°F.	°C	°F.	°C
100	38	158	70	230	110	350	176
120	49	176	80	250	121	392	200
122	50	212	100	270	132	400	204
130	54	225	107	300	149	550	288

FOR FURTHER INFORMATION

Du Pont supplies raw VITON* fluoroelastomer to leading rubber manufacturers throughout the world. They, in turn, fabricate stock items as well as custom parts of VITON and sell through local rubber goods suppliers or direct to end users.

To obtain more information on VITON, contact your normal source of supply for rubber products or write to Du Pont for a list of manufacturers who produce these items. (Please be sure to indicate the particular products in which you are interested.)

If you wish to evaluate VITON for a custom rubber product or for a new application, contact the Elastomer Chemicals Department District Office nearest you. A sales-service engineer will welcome the opportunity to discuss your application and can refer you to a rubber manufacturer with the facilities and experience required to follow your project to completion.

*Reg. U.S. Pat. & Tm. Off.

U.S. Sales Offices

Boston, MA 02110
140 Federal Street (617) 423-7120

Chicago, IL
7250 N. Cicero Avenue
Lincolnwood, IL 60646 (312) 982-4000

Detroit, MI
29201 Telegraph Road
P. O. Box 985
Southfield, MI 48037 (313) 559-6000

Los Angeles, CA 90022
5717 E. Ferguson Drive (213) 685-6851

Menlo Park, CA 94025
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P. O. Box 2707
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ELASTOMER CHEMICALS DEPARTMENT
WILMINGTON, DE 19898

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REF. V-7A

BOSTON
INSULATED
WIRE & CABLE CO.

65 BAY STREET · BOSTON · MASSACHUSETTS 02125 · (617) 265-2102 · ... 94 0604

October 30, 1975

Bechtel Company
P.O. Box 607
15740 Shady Grove Road
Gaithersburg, Maryland 20760

Attention: Mr. Peter Anas

Subject: The Toledo Edison Company
Davis-Besse Nuclear Power Station
Bechtel Job 7749
Instrumentation Wire and Triaxial Cable
P.O. #Q1598
BIW Orders #1000 and B148

Gentlemen:

This is in reply to questions by your Mr. R. Vatsan concerning LOCA simulation tests on the subject cable.

We wish to clarify that prototype LOCA test on Item 1, 2/C #16 AWG shielded cable, was performed in an autoclave at our Boston facility. The test was conducted in accordance with Specification 7749-E-17, para. 11.2.3, including air oven aging, irradiation, energizing at 240V, 7-day steam/temperature cycle, and a borated water spray of at least 1800 ppm boron throughout the test. The required IR measurements (para. 11.2.3.4) and physical and electrical measurements (para. 11.2.3.5) were all reported in our Test Report 73C212.

Regarding the triaxial cable, our Part Number 9660-C-G20, we refer you to our letter dated July 17, 1975 to Mr. R. J. Haas of The Toledo Edison Company. A copy of this letter, along with the LOCA test data, is enclosed.

We trust that the above information will satisfy your LOCA test requirements. Please contact us if you have any further questions.

Very truly yours,

BOSTON INSULATED WIRE & CABLE CO.

Richard Kruger
Richard Kruger
Applications Engineer

RK/rhc
encl.
cc: Mr. R. Vatsan

bcc: J. E. Rat.
T. Russell
R. Kruger (2)

BOSTON
INSULATED
WIRE & CABLE CO.

65 BAY STREET · BOSTON · MASSACHUSETTS 02125 · 617 265 2107

July 17, 1975

Mr. R. J. Haas
Supervisor, Electrical Purchasing
Purchasing Department for Davis Besse - Unit 1 Construction
The Toledo Edison Company and
The Cleveland Electric Illuminating Company
P.O. Box 929
Toledo, Ohio 43601

Re: Triaxial Cable for Toledo Edison
P.O. No. Q1598D
BIW Order B148

Dear Mr. Haas:

This is to confirm the information discussed in our telephone conversation with your Mr. Calcamuggio on July 15, 1975 and to furnish documentation on the subject cable.

The subject cable is BIW Part Number 9660-C-G20. Although your purchase order did not originally require documentation on LOCA simulation, we have furnished this same cable for several other applications requiring LOCA, and we have shown the cable passes LOCA tests.

Test Report 75C008 is furnished to show the results of a recently completed test on Part Number 9660-C-G20. This report shows excellent performance after a 104 day LOCA simulation test. The radiation conditioning and duration of test greatly exceed those required by your Specification 7749-E-17.

We are also furnishing Figure III showing the results of a LOCA simulation test on a similar 75-ohm coaxial cable conducted at the Franklin Institute Research Laboratories (excerpts from Report F-C3859-1). This report demonstrates excellent performance after a double thermal aging cycle of 168 hours at 121C, one of which included simultaneous irradiation. This thermal conditioning is in excess of the single cycle required by Specification 7749-E-17. The LOCA cycle (IEEE Std 323-1974) is also considered much more severe than your 7-day test.

Mr. R. J. Haas
Supervisor, Electrical Purchasing
Purchasing Department for Davis Besse - Unit 1 Construction

We trust that the data presented will demonstrate the cable's excellent ability to withstand LOCA conditions and will satisfy all your requirements. Please do not hesitate to contact us if you have any further questions.

Very truly yours,

BOSTON INSULATED WIRE & CABLE CO.

Richard Kruger
Richard Kruger
Applications Engineer

RK/rhc
cc: Mr. M. D. Calcamuggio
Mr. E. C. Novac

STON INSULATED WIRE & CABLE

General Date Sheet

TEST: LOCA SIMULATION SPEC: Special Test PAR: for Westinghouse Reactor	TEST NO. 75C008
CONDITIONING: 2 x 10^8 rads gamma prior to LOCA cycle	DATE 5/13/75
	TESTED BY W. Barnes
PART. TYPE NO.: 9660-C-G20	LAB. SUP. CHECK R. Kruger
CUSTOMER:	

TEST REQUIREMENTS. 2 x 10^8 rads prior to LOCA cycle
290F (in 12 sec) and 300F (in 25 sec), 53 psig -- Hold for 15 minutes.
Reduce to 252F and 16.5 psig over 30 min period. Hold @ 252F for 10 days.
Straighten, give 40x bend, test @ 80 volts/mil for 5 minutes in water.
Spray cable with 2,000 ppm boric acid adjusted to pH 8-8.5 with NaOH throughout the test.
L = 20 feet

Time	Temp °F	Press. psig Steam	IR Cond-Shld M /L	IR Shl-Shld M /L
0	75	0	20 x 10^5+	8 x 10^5
15 min	300	60	2.5 x 10^4	1 x 10^4
1 day	252	16	6 x 10^5	3 x 10^4
5 days	252	16	20 x 10^5+	1 x 10^3
9 days	252	16	20 x 10^5+	2 x 10^4
13 days	252	16	20 x 10^5+	2 x 10^4
17 days	200	0	20 x 10^5+	20 x 10^5+ (1)
51 days	200	0	20 x 10^5+	20 x 10^5+
104 days	200	0	20 x 10^5+	20 x 10^5+

2300 volts applied between conductor and inner shield throughout the test. After 16 days and again after 37 days, the cable was removed from the test chamber, straightened, given a 40x bend, and passed a 7500 volt ac (80 V/mil) proof test in water (5 minutes). Cable returned to chamber for further testing at 200F. At the conclusion of 104 days, the cable withstood a Post LOCA test, including a 40x bend and a 5 minute ac proof test in water: 11,000 volts cond-inner shield and 1,000 volts shield-shield.

9660-C-G20 CABLE CONSTRUCTION

Conductor -- #20 AWG 10/32 tinned copper
Insulation -- Crosslinked polyethylene
Inner Shield -- #33 AWG tinned copper braid, 90% min coverage
Insulation between Shields -- Crosslinked polyethylene
Outer Shield -- #33 AWG tinned copper braid, 90% min coverage
Jacket -- Bostrad 7 CSPE chlorosulfonated polyethylene
OD -- .460"

(1) Boric acid spray discontinued.

BIW

FRANKLIN INSTITUTE RESEARCH LABORATORIES TESTS

A 75-ohm coaxial cable, similar to the proposed cable with the same crosslinked polyethylene insulation but a neoprene jacket in place of Bostrad 7 (CSPE) passed the "Qualification Testing of Electrical Cables Under Simultaneous Exposure to Radiation, Steam and Chemical Spray" program conducted by Franklin Institute Research Laboratories. The testing included the following conditions. (Note the double aging cycle.)

1. Aged -- 168 hours at 121C (without radiation)

2. Aged 168 hours at 121C with simultaneous irradiation of 50×10^6 rads (50 megarads)

3. IEEE 323 LOCA cycle, including two excursions from normal conditions to 340F and 110 psig, for a duration of 30 days with simultaneous irradiation of 150×10^6 rads (150 megarads). Total irradiation -- 200×10^6 rads (200 megarads).

The cable was energized at 600 volts throughout the 30 day LOCA cycle, and passed a 2200 volt ac test at the conclusion of the LOCA cycle.

Upon completion of the above tests at Franklin Institute Research Laboratories, the cable was returned to BIW. It was then subjected to a post LOCA test consisting of a 40x bend. Following the bend, the cable withstood 5000 volts ac for 5 minutes while immersed in water.

C LITY CONTROL PROGRAM & PRO JRES
TRANSMITTAL FORM

Bechtel Company

Post Office Box 607
15740 Shady Grove Road
Gaithersburg, Maryland 20760

TO: Mr. J. E. Rath
Boston Insulated Wire & Cable
65 Bay Street
Boston, Mass. 02125

VIA: J. D. Lenardson
TECo QAE

DATE: June 18, 1973
FILE NO: 1535, E-17

COPIES TO:
- [x] TECo QAE 1 W/A
- [x] PROJ. CONST. MGR. 1 W/A
- [x] SHOP INSP. SUPV. 1 W/A

(1) APPROVAL WITHOUT COMMENTS.
2 APPROVAL WITH COMMENTS, RELEASED FOR INTERIM USE, RESUBMIT WITHIN 20 DAYS PER ED 6058.
3 NOT APPROVED. SEE COMMENTS MARKED ON PROCEDURES. RESUBMIT FOR APPROVAL WITHIN 30 DAYS PER ED 6058.

PROCEDURE NO.	REV.	TITLE	APPROVAL STATUS
7749-E-17Q-10-1	-	Prototype Test Report No. 73C212	(1)

NOTE: This satisfies requirement (3) and (5) of Form ED6058 and the prototype test results portion of requirement (6).

WHM/EMS/mma

cc: S. N. Saba w/o
E. M. Steudel w/o
W. E. Wilson w/o

VERY TRULY YOURS,

W. H. MABLE, PROJECT ENGINEER

TECo QAE 6-21-73 ACCEPTANCE DATE

T. E. - D. B.
JUN 21 1973
Q. A. ENGR.

ATTACHMENT I

ISOMEDIX

RADIATION CERTIFICATION

Part No.: LSS 1885 A Boston Insul Wire & Cable

Dose Rate: 1.0 Mrad/h

Total Dose: One piece - 35 Mrad ; One piece - 100 Mrad

Date Radiation Completed: 4-23-73

Source: Cobalt-60

Conditions: Irradiation performed in air at ambient temperature (70°F) and slight negative pressure (-1/2" water).

Max. Temp. of Sample During Irradiation: 110 °F

Dosimetry System: Dosimetry was performed using a Victoreen Model 555 Integrating Dose Rate Meter and Probe. The unit was calibrated on January 15, 1971 by the Victoreen Instrument Company, using Cobalt-60 and Cesium-137 sources whose calibrations are traceable to the U.S. National Bureau of Standards. A copy of the calibration certificate is available.

Other: Samples were rotated and turned during exposure to achieve a more uniform dose distribution.

Post-Irradiation Defects Observed: None

This is to certify that the subject product was radiation processed in the aforementioned manner.

George R Dietz
George R. Dietz
Manager, Radiation Services

GRD:mg

ATTACHMENT II

BOSTON INSULATED WIRE & CABLE CO.

General Data Sheet

Name Test	SPEC. Bechtel 7749-E-17	PAR. 11.2.2.2 a	TEST NO. 73D258
CONDITIONING: none			DATE 4/12/73
PART. TYPE NO.: LSS-1885-A Horizontal			TESTED BY W. Barnes
CUSTOMER: Toledo Edison			LAB. SUP. CHECK
TEST REQUIREMENTS: According to above specification			

Ignition Time 30 sec.

Insulation failure time

1. No failure after 10 min.
2. No failure after 10 min.
3. No failure after 10 min.
4. No failure after 10 min.
5. No failure after 10 min.
6. No failure after 10 min.
7. No failure after 10 min.
8. No failure after 10 min.
9. No failure after 10 min.
10. No failure after 10 min.

Continued to burn 0 sec.

Cable damage 20 inches, approximately 3½" on either side of burner.

Did cotton ignite? No

Thermocouple Readings:

1. Temperature of flame at that point which would be in contact with the cable was measured as 1450°F prior to test.

2.

Thermocouple # & Position	3 Min.	6 Min.	9 Min.
#1. (center) *	500°F	1460°F	1380°F
#2. (left)	140°F	150°F	160°F
#3. (right)	180°F	200°F	220°F

* Thermocouple repositioned after 1st measurement so as to be directly over flame.

PAGE ______ OF ______ PAGES

BOSTON INSULATED WIRE & CABLE CO

General Data Sheet

TEST: Flame Test	SPEC: Bechtel 7749-E-17	R: 11.2.2.2.b	TEST NO.: 73D258
			DATE: 4/12/73
CONDITIONING: none			TESTED BY: W. Barnes
PART. TYPE NO.: LSS-1685-A	Vertical		LAB. SUP. CHECK:
CUSTOMER: Toledo Edison			
TEST REQUIREMENTS: According to above specification			

Ignition Time

Insulation failure time

1. Failed after 10 minutes
2. Failed after 10 minutes
3. 9 min. 25 sec.
4. Failed after 10 minutes
5. 9 min. 25 sec.
6. No failure
7. 9 min. 30 sec.
8. 9 min. 15 sec.
9. No failure
10. No failure

Continued to burn 4 min. 55 sec. very small contained flicker.

Cable damage 39 inches from point of impingement.

Cotton did not ignite.

Thermocouple Readings:

1. Temperature of flame, at that point which would be in contact with the cable, was measured as 1450°F prior to test.

2.

Thermocouple # & Position	Thermocouple Readings °F									
	1 Min.	2 Min.	3 Min.	4 Min.	5 Min.	6 Min.	7 Min.	8 Min.	9 Min.	10 Min.
#1. (burner location)	900	860	910	840	940	900	900	1000	880	900
#2. (18" above burner)	500	660	820	820	900	880	800	760	800	800
#3. (36" above burner)	400	580	660	640	620	600	620	700	600	600

ATTACHMENT IV

B[illegible]TON INSULATED WIRE & CABLE

General Date Sheet

TEST: Post Accident Environmental Test Bechtel SPEC: PAR: 7749-E-17-11.2.3	TEST NO.: 136212
CONDITIONING: Air oven aged 168 hrs@121°C, radiation dose 1x10⁸ rads	DATE: 4-30-73
PART. TYPE NO.: LSS-1885A (Sample 1/ft in length 12 ft exposed to cycle)	TESTED BY: W. Barnes
ORDER NO.:	LAB. SUP. CHECK:
CUSTOMER: Toledo Edison Co.	
TEST REQUIREMENTS: According to above spec.	

Record Insulation Resistance

a. At beginning of test room temp.

b. Once an hour @ high press. & temp.

c. Once a day at low press. & temp.

240 V applied continuously between readings

@ end of test cable O.K. @ 1.0 KVAC 5 mins.

Insulation Resistance

		Conductor #1	Conductor #2	
Initial		5100 meg Ω/M'	34x10³ meg Ω/M'	
	45 psi 290°	.155 " " "	.162 " " "	once every hour for 12 hours
		.153 " " "	.162 " " "	
		.204 " " "	.204 " " "	
		.273 " " "	.239 " " "	
		.306 " " "	.324 " " "	
		.304 " " "	.391 " " "	
		.425 " " "	.442 " " "	
		.510 " " "	.561 " " "	
		.661 " " "	.679 " " "	
		.765 " " "	.765 " " "	
		.935 " " "	.935 " " "	
		.935 " " "	.935 " " "	

Reduced Temperature & Pressure

		Conductor #1	Conductor #2	
	5 psi 220°F	28.9 meg Ω/M'	32.4 meg Ω/M'	1 day
		42.5 " " "	39.1 " " "	2 day
		51 " " "	39.1 " " "	3 day
		52.6	40.8	4 day
		Saturday & Sunday no reading taken		5 day
				6 day
		51 " " "	40 " " "	7 day
After Cooling		1000 " " "	340 " " "	

3A×10" per ft OK

EMS

PAGE ______ OF ______ PAGES

RECEIVED JUN - 8 1973

JOB No. 7749

PROJ. ENG.	
ST. P.E.	
ADM. ASST.	
CIVIL	
ELECT.	✓
LAYOUT	
MISC.	
NUCLEAR	
C & I	
Q A E	
ARCHITECT	
PURCHASING	
ESTIMATING	
SWITCH YARD	
CONSTRUCTION	
PLAN & SCD	
FILE NO.	E-17

6 - 73

VENDOR'S QA PROGRAM REVIEW

1 X Approval without comments

2 ☐ Approval with comments, released for interim use, resubmit within 10 days per EB 4054

3 ☐ Not approved. See comments marked on Procedure. Resubmit for approval within 10 days.

Approval of this QA Program does not relieve supplier from full compliance with contract or purchase order requirements.

By EMS Date 6/15/73

7749 ... R-002

Job No. 7749 (L S BECHTEL CORP.)

CUSTOMER: Toledo Edison Lab Test #

Customer PO# Q1590 BIW Job #

Customer Item# 1 BIW P/N

Spec. # 7749-E-17, Rev.0

Prototype test report per letter sent to Mr. W. H. Mable of Bechtel Company by J. Learn of Boston Insulated Wire on January 12, 1973

---

(1) Para 11.2.1 Radiation Resistance Test

Conditioning: (a) Samples air oven aged for 168 hrs at 121°C

(b) Aged samples irradiated to a total dose of 3.5×10^7 rads (See attached radiation certificate - Attachment #1)

Tests	Spec. Para	Results
High Voltage a-c	11.3.1.1 a	pass 1 KV a-c for 5 min, c-c
Insulation Resistance	11.3.1.1 b	I.R.Const=35,200
Continuity	11.3.1.3	O.K.
Tensile Strength	11.3.2.1	2365 psi
Elongation	11.3.2.1	200%
Gravimetric Water Absorption	11.3.2.3b	5.24 mg /in^2
Electrical Water Absorption (EM 60)	11.3.2.3a	diel. const = 3.8

RECORD PRINT

FILE COPY

*Change in capacitance (1-14 day & 7-14 day) could not be obtained due to sample failure at stress of 80 volts/mil on 7th day of test

7749-E-17Q-10-7

2. Para 11.2.2 Flame Resistance Test

a.

Test	Spec.Para.	Conditioning	Result
Vert.Flame	11.2.2.1 (IPCEA S-19-81, sec 6.196)	none	pass
Vert. Flame	"	168 hrs @121°C	pass

b. The results of the horizontal and vertical tray tests, performed per para 11.2.2.2 a and b, are included as attachments II and III of this report. These tests were witnessed by both Toledo Edison and Bechtel Company personnel and have test Number 73D258.

3. Para 11.2.3 Post Accident Environment Test

Conditioning: a. Sample was aged for 168 hrs @ 121°C

b. Aged sample was irradiated to a dose 10^8 rads (See attachment I for radiation certificate)

The results of the autoclave test cycle as specified in para 11.2.3.3 is included as Attachment IV. The I.R. readings required by para 11.2.3.4 are also given in this attachment.

At the conclusion of the autoclave test cycle the tests specified in para 11.2.3.5 c & d were performed. These tests are considered to be part of the autoclave test and as such the results will be found in Attachment IV.

The physical and electrical tests as specified in para 11.3.1 and 11.3.2 were also performed after removal from the autoclave and the results are listed below:

TEST	SPEC PARA	RESULTS
Tensile Strength Elongation	11.3.2 11.3.2	2400 psi 185%
Gravimetric Water Absorption	11.3.2.3 b	1.43 mg/in^2
Electrical Water Absorption (E.M.60)	11.3.2.3 a	diel const=3.04 1-14 day: 2.4% 7-14 day: 0.3% Stability Factor:0.4%

CALCULATION/PROBLEM COVER SHEET

Calculation/Problem No: 0630-001-002

Title: Component Aging Due to Accident Environments

Client: LILCO Project: NSSS Equipment Qual. Program

Job No: 0630-001-671

Design Input/References:

Refer to Table of Contents on Page 2 of 9.

Assumptions:

Refer to Table of Contents on Page 2 of 9.

Method:

Refer to Table of Contents on Page 2 of 9.

Remarks: The purpose of this Calculation is to extend the qualified operating time of components which are qualified to higher peak temperatures than seen during a postulated LOCA/HELB but for a shorter time than required.

REV. NO.	REVISION	PERFORMED BY	CHECKED	APPROVED	DATE
0	Original	[signature]	[signature]	[signature]	9/30/81

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APPENDICES

1.0 PURPOSE

The purpose of this calculation is to equate the aging degradation experienced by a component during an environmental qualification temperature test to the aging it will experience due to the variable temperatures it will be exposed to during postulated accident conditions.

2.0 SCOPE

This method applies to the qualification of components which are qualified for peak accident temperatures but not for a sufficient length of time.

3.0 REFERENCES

1. A Review of Equipment Aging Theory and Technology, EPRI Report No. NP-1558, September, 1980.

4.0 ASSUMPTIONS

1. The degradation due to aging is an irreversible process. Therefore, all effects on materials due to aging should be cumulative in nature.

2. An activation energy of 0.5 eV will be assumed for all materials. According to Reference 1, Page 4-10, the apparent activation energy of the aging process may vary from 0.5 to 1.5 eV or more. Since the smaller the actuation energy, the less time is required to degrade the material to a specified point, using 0.5 eV is considered conservative.

3. Material degradation is dominated by a single chemical process which has a temperature dependent reaction rate. This allows for utilization of the Arrehnius Model.

4. Component will respond instantaneously to the accident environment (i.e.; temperature of entire component is equal to the environmental temperature at any given time).

5.0 **DEVELOPMENT OF METHOD**

The aging model generally accepted by the NRC and industry is the Arrhenius Model:

$$t = Be^{\frac{\phi}{kT}} \quad (\text{Ref. 1, Eq 4-1}) \qquad \text{Eq. 1}$$

t = TIME TO REACH A SPECIFIED ENDPOINT
B = CONSTANT (USUALLY DETERMINED EXPERIMENTALLY)
ϕ = ACTIVATION ENERGY
k = BOLTZMANN'S CONSTANT = 8.617×10^{-5} eV/°K
T = ABSOLUTE TEMPERATURE (°K)

A special form of the equation is:

$$\ln\left(\frac{t_s}{t_a}\right) = \frac{\phi}{K}\left(\frac{1}{T_s} - \frac{1}{T_a}\right) \quad (\text{Ref 1, Eq 4-16}) \qquad \text{Eq. 2}$$

WHERE THE SUBSCRIPTS "s" AND "a" DESCRIBE SERVICE AND TEST CONDITIONS RESPECTIVELY.

This equation states that heating a material or component at temperature T_a for time t_a will produce the same amount of degradation as will be produced at the service temperature T_s over time t_s.

Equation 2 can be rewritten.

$$t_s = t_a \exp\left[\frac{.5}{8.617 \times 10^{-5}}\left(\frac{1}{T_s} - \frac{1}{T_a}\right)\right]$$

$$\Rightarrow t_s = t_a \exp\left[5.8 \times 10^{3}\left(\frac{1}{T_s} - \frac{1}{T_a}\right)\right] \qquad \text{Eq. 3}$$

Because most accident temperature profiles are not constant like the test profiles, but rather spike to a peak temperature which then decreases with time, a more accurate aging model can be developed which takes advantage of the decrease in temperatures. This can be done by dividing the environmental profiles into N number of steps such that you define some fixed time interval t_f such that $t_f = \frac{t_a}{N}$.

This t_f will replace t_a in Eq. 3. Since aging is considered a cumulative effect, the sum of all these t_f test times will produce the same degrees of degradation incurred by the test at the same T_a but for time t_a.

For the first iteration, the peak accident temperature is substituted into Eq. 3 along with the assumed test time t_f and the reported test temperature T_a. The result will be a service time t_s for which the component has undergone similar degradation but at the lower temperature T_s.

The temperatures for the next iterations are obtained by using the environmental profile temperature t_s corresponding to the t_s calculated for the previous interval. The qualified time will be the sum of all the t_s for each interval.

$$t_s = \sum_{i=1}^{N} \frac{t_a}{N} \exp\left[5.8\times10^3 \left(\frac{1}{T_s(t_{s_{i-1}})} - \frac{1}{T_a(t_{a_i})}\right)\right] \quad \text{Eq. 4}$$

WHERE ① $N = 1, 2, 3, \ldots$
② $T_S = T_S(t)$
③ $T_a = T_a(t)$. T_a Is Ussually A Constant

A sample problem is provided as Appendix A.

0	SRP	9/11/81	[illegible]	9/14/81	Component Aging Due To Accident Environments
					eds nuclear — JOB NO 0630-001-671 — CALC NO 0630-001-003 — PAGE 5 OF 9
REV	BY	DATE	CHECKED	DATE	

APPENDIX A

PROBLEM: A COMPONENT HAS BEEN QUALIFIED FOR 4 HRS @ 212 °F. IT WILL SEE THE ACCIDENT PROFILE GIVEN IN FIGURE 1, WITH A PEAK TEMPERATURE OF 194 °F. THE PROBLEM ARISES IN THAT THE COMPONENT IS REQUIRED TO OPERATE FOR 1 DAY BUT HAS BEEN TESTED FOR ONLY THE 4 HRS.

SOLUTION: THE TEST TIME OF 4 HOURS WILL BE DIVIDED INTO N= 8 INTERVALS .5 HOURS LONG. USING EQUATION 3 WITH:

$t_A = .5$ HRS

$T_A = 212°F = 373°K$

$T_S = 194°F = 363°K$

A $t_S = .8$ HRS IS COMPUTED.

FOR THE NEXT INTERATION, T_S IS TAKEN FROM THE GIVEN ACCIDENT PROFILE CORRESPONDING TO $t_S = .8$ HRS.

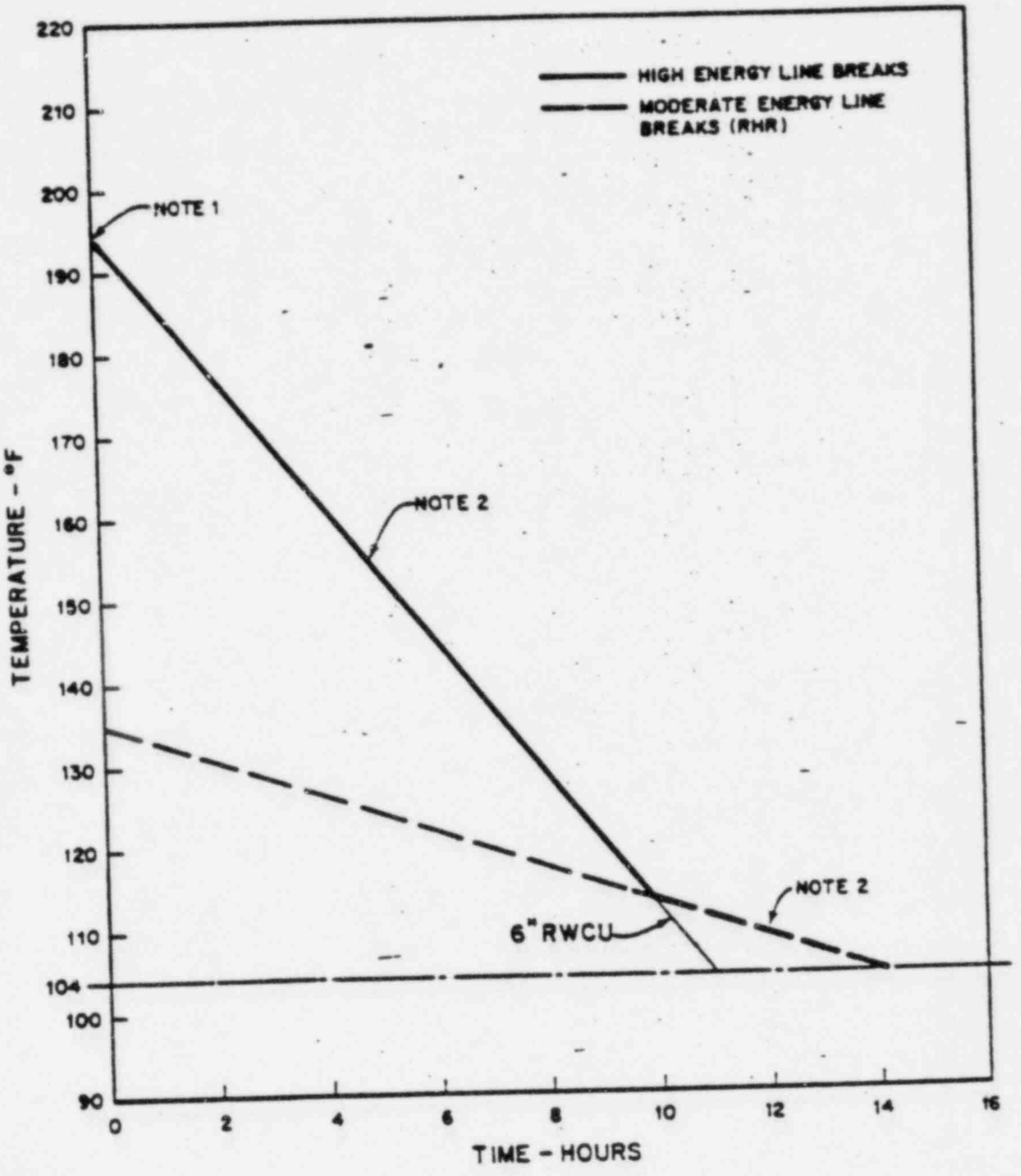
AT $t_S = .8$ HRS, $T_S = 188°F$.

THE RESULTS OF THE ITERATIONS ARE PRESENTED IN TABLE 1.

TABLE 1 : SAMPLE PROBLEM RESULTS

N	T_S, °F	t_S, HRS	$t_{CUMULATIVE}$, HRS
1	194	.8	—
2	188	.9	1.7
3	180	1.1	2.8
4	171	1.4	4.2
5	159	1.9	6.1
6	144	2.9	9
7	120	5.9	14.9
8	104	9.8	24.7 = t_S

THESE RESULTS ARE SHOWN GRAPHICALLY IN FIG 2. WHAT THE RESULTS MEAN IS THAT THE AMOUNT OF DEGRADATION EXPERIENCED BY THE COMPONENT IN 4 HRS @ 212°F IN APPROXMATELY EQUAL TO 24.7 HRS OF EXPOSURE TO THE ACCIDENT PROFILE TEMPERATURES. THE COMPONENT CAN THEREFORE BE QUALIFIED FOR ITS SPECIFIED OPERATING TIME OF 1 DAY. AND COMPLETELY ENVELOPE THE ACCIDENT PROFILE (AT THE VERY LEAST UNTIL THE TEMPERATURE RETURNS TO AMBIENT)



NOTES

1. PEAK TEMPERATURE RISE WITHIN 15 SECONDS FROM TIME ZERO.
2. LIMITING PROFILE FOR HELB, ALSO ENVELOPES MELB.

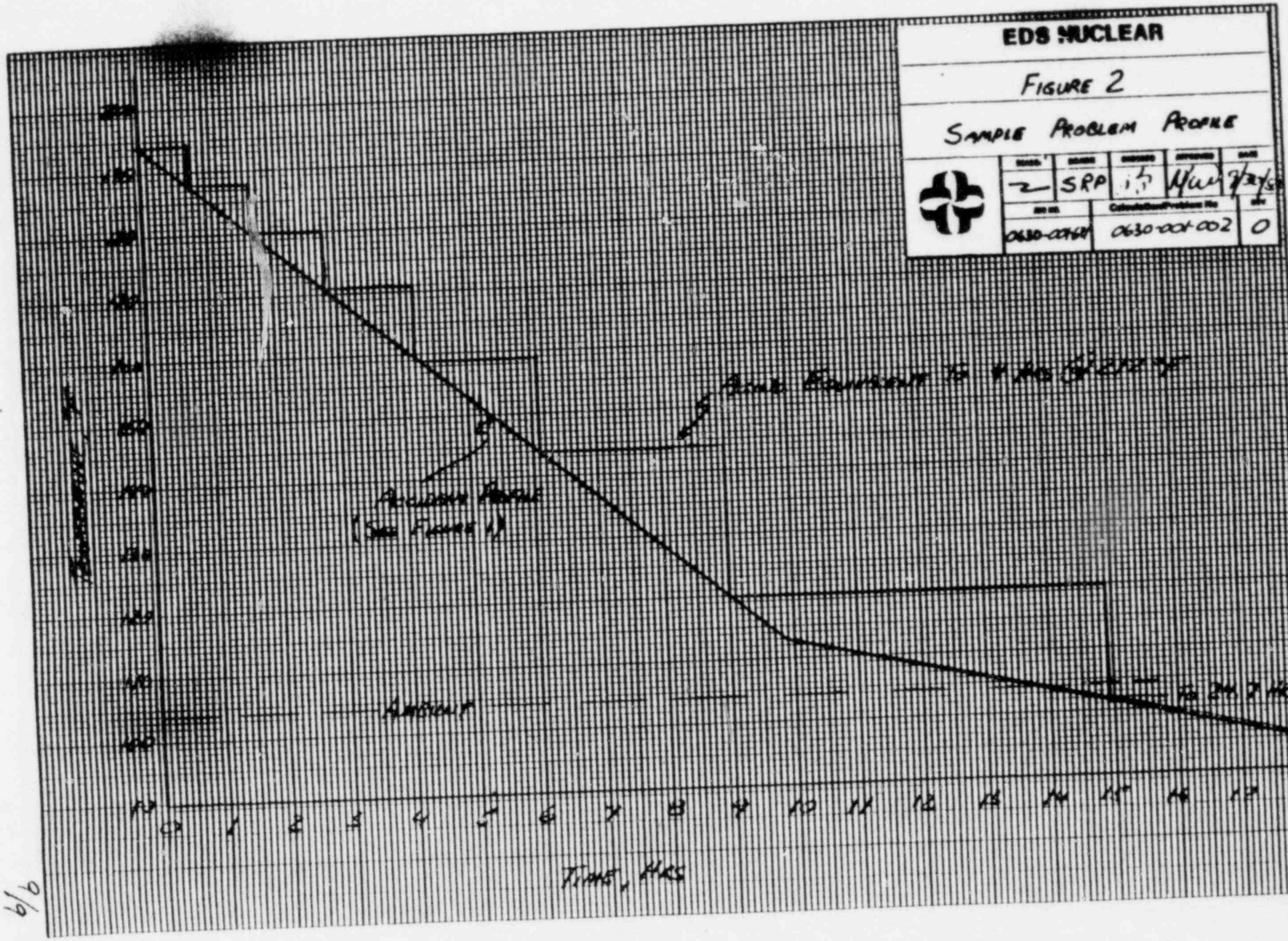
REACTOR BUILDING, SECONDARY CONTAINMENT TEMPERATURE LEVELS FOR ZONE 12

FIGURE 1

CALCULATION NUMBER 0630-001-002

K·E 10 X 10 TO ½ INCH 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A.

46 1326



9/9

CALCULATION/PROBLEM COVER SHEET

Calculation/Problem No: 0630-001-003

Title: Arrhenius Model of Buna-N Gaskets

Client: LILCO   Project: NSSS Equipment Qualification

Job No: 0630-001-671

Design Input/References:

Refer to Table of Contents on Page 2 of 6.

Assumptions:

Refer to Table of Contents on Page 2 of 6.

Method:

Refer to Table of Contents on Page 2 of 6.

Remarks:

The purpose of this calculation is to determine the maximum service temperature for Buna-N Gaskets for a service life of 40 years.

REV. NO.	REVISION	PERFORMED BY	CHECKED	APPROVED	DATE
0	Original	W. P. Thurman	Ken Trotter	N. K. Woodward	2/11/82

EDS 0008 5/79

TABLE OF CONTENTS

LIST OF APPENDICES

1.0 PURPOSE

The purpose of this calculation is to determine the maximum temperature that can be maintained on BUNA-N gaskets for a service life of 40 years.

2.0 SCOPE

This calculation applies to the qualification of equipment at the Shoreham Nuclear Power Station containing BUNA-N gaskets.

3.0 REFERENCES

1. A Review of Aging Theory and Technology, EPRI Report No. NP-1558, September, 1980.

2. 1000 Hour Heat Aging Study by Larry Small and Ev Scheer (BF Goodrich) Table 18.

3. ROC, AD Sawyer to Ev Scheer (BF Goodrich), dated December 16, 1980.

4.0 METHOD OF ANALYSIS

The aging model generally accepted by the NRC and industry is the Arrhenius Model;

$$t = B e^{\frac{\phi}{KT}} \quad \text{(REF. 1, EQ 4-1)}$$

t = Time to reach a specified endpoint
B = Constant (usually determined experimentally)
ϕ = Activation energy
T = Absolute temperature (°K)

A special form of the equation is:

$$\ln\left(\frac{t_s}{t_a}\right) = \frac{\phi}{K}\left(\frac{1}{T_s} - \frac{1}{T_a}\right) \quad \text{(REF. 1, EQ 4-1)}$$

Where the subscripts "s" and "a" describe service and test conditions respectively.

5.0 BASIC DATA AND ASSUMPTIONS

1. HYCAR 1041 is assumed representative of BUNA-N (Ref. 3).

2. Tensile stength and/or compression set are the critical properties required by a gasket material. Tensile stength is required in order to maintain a pressure boundary against the force of pressure transients.

3. BUNA-N rubber was tested at 121°C for 3 weeks and the tensile strength was found to have increased 13% (Ref. 2).

6.0 SUMMARY RESULTS

BUNA-N gaskets can withstand a maximum temperature of 104°F for a service life of 40 years.

7.0 BODY OF CALCULATION

$$\ln\left(\frac{t_s}{t_a}\right) = \frac{\phi}{K}\left(\frac{1}{T_s} - \frac{1}{T_a}\right)$$

$t_s = 40 \text{ yrs} = 2080 \text{ wks}$

$t = 3 \text{ wks}$

$\phi = 0.86 \text{ eV}$ (REF. 1)

$K = 8.617 \times 10^{-5} \text{ eV}/{}^{\circ}K$

$T_a = 121\,^{\circ}C = 394\,^{\circ}K$

$$\ln\left(\frac{2080 \text{ WKS}}{3 \text{ WKS}}\right) = \frac{0.86 \text{ eV}}{8.617 \times 10^{-5} \frac{eV}{{}^{\circ}K}}\left(\frac{1}{T_s} - \frac{1}{394\,^{\circ}K}\right)$$

$$6.54 = 9980.2\left(\frac{1}{T_s} - 0.00254\right)$$

$$T_s = 313\,^{\circ}K = \underline{104\,^{\circ}F}$$

					LILCO - NSSS EQUIPMENT QUALIFICATION ARRHENIUS MODEL OF BUNA-N GASKETS
					eds nuclear — JOB NO 0630-001-671 — PAGE 4
0	9WPD	12/15/81	KT	1-22-82	CALC NO 0630-001-003 — OF 6
REV	BY	DATE	CHECKED	DATE	

APPENDIX A

CORRESPONDENCE

					LILCO - NSSS EQUIPMENT QUALIFICATION ARRHENIUS MODEL OF BUNA-N GASKETS
					JOB NO 0630-001-671 / PAGE 5
0	[illegible]	12/15/81	KT	1-22-82	eds nuclear / CALC NO 0630-001-003 / OF 6
REV	BY	DATE	CHECKED	DATE	

0570-010-681
FILE: 0370-025-681

eds nuclear

RECORD OF CONVERSATION

COPY: J Ironfield
J Mankevish
P Stowe
M. Ballard

[x] Telephone   [ ] Meeting   [ ] Other

TO: Ev Scheer   FROM: ~~A Sawyer~~ AAS   DATE 12/16/80

COMPANY: BF Goodrich   PHONE NO.: 216-447-6000

SUBJECT: BUNA-N Specific Name

Summary of Conversation:

I called Mr. Scheer to verify which elastomers listed in his 1000 hour heat aging study were classified as BUNA-N.

BUNA-N type elastomers are:

HYCAR 1041   HYCAR 1041/HYCAR 1091-50

These type elastomers would be representative of general BUNA-N mechanical characteristics. Furthermore, BUNA-N generic name is synonymous with GR-N and NBR type rubber which stands for ACRYLONITRILE BUTADIENE Rubber. Also, Mr. Scheer identified the difference between BUNA-N and BUNA-S. BUNA-S is also called GR-S and SPR which stands for Styrene Butadiene Rubber.

AS/cjc

CALCULATION/PROBLEM COVER SHEET

Calculation/Problem No: 0630-001-004

Title: Arrhenius Model of Cross-Linked Polyethylene

Client: LILCO Project: NSSS Equipment Qualification

Job No: 0630-001-671

Design Input/References:

Refer to Table of Contents on Page 2 of 4

Assumptions:

Refer to Table of Contents on Page 2 of 4

Method:

Refer to Table of Contents on Page 2 of 4

Remarks:

The purpose of this calculation is to determine the maximum service temperature for cross-linked polyethylene for a service life of 40 years.

REV. NO.	REVISION	PERFORMED BY	CHECKED	APPROVED	DATE
0	Original	W.P. Turnari	Ken Fetter	N.K. Woodward	2/11/82

EDS 0004 873

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1.0 PURPOSE

The purpose of this calculation is to determine the maximum temperature that can be maintained on Cross-Linked Polyethylene for a service life of 40 years.

2.0 SCOPE

This calculation applies to the qualification of equipment at the Shoreham Nuclear Power Station containing Cross-Linked Polyethylene materials.

3.0 REFERENCES

1. A Review of Aging Theory and Technology, EPRI Report No. NP-1558, September, 1980.

2. Boston Insulated Wire & Cable Test Report 73C212.

4.0 METHOD OF ANALYSIS

The aging model generally accepted by the NRC and industry is the Arrhenius Model:

$$t = B e^{\frac{\phi}{KT}} \qquad \text{(REF. 1, EQ. 4-1)}$$

t = Time to reach a specified endpoint
B = Constant (usually determined experimentally)
ϕ = Activation energy
T = Absolute temperature (°K)

A special form of the equation is:

$$\ln\left(\frac{t_s}{t_a}\right) = \phi/K \left(\frac{1}{T_s} - \frac{1}{T_a}\right) \qquad \text{(REF. 1, EQ. 4-16)}$$

Where the subscripts "s" and "a" describe service and test conditions respectively.

					LILCO - NSSS EQUIPMENT QUALIFICATION ARRHENIUS MODEL OF CROSS LINKED POLYETHYLENE
					eds nuclear — JOB NO 0630-001-671 — PAGE 3
0	WPD	12/15/81	KT	1-22-82	CALC NO 0630-001-003 — OF 4
REV	BY	DATE	CHECKED	DATE	

5.0 BASIC DATA AND ASSUMPTIONS

1. Cross-Linked Polyethylene was thermally aged for 168 hours at 121°C. Following this aging, it was irradiated to a dose of 1 x 10^8 rads and was subjected to a high temperature saturated steam test. At the conclusion of these tests, the material maintained its resistance and integrity (Ref. 2).

6.0 SUMMARY RESULTS

Cross-Linked Polyethylene can withstand a maximum temperature of 117°F for a service life of 40 years.

7.0 BODY OF CALCULATION

$$\ln\left(\frac{t_s}{t_a}\right) = \frac{\phi}{K}\left(\frac{1}{T_s} - \frac{1}{T_a}\right)$$

t_s = 40 YRS = 350,400 HRS

t_a = 168 HRS

ϕ = 1.13 eV

$K = 8.617 \times 10^{-5}$ eV/°K

T_a = 121 °C = 394 °K

$$\ln\left(\frac{350{,}400\ \text{HRS}}{168\ \text{HRS}}\right) = \frac{1.13\ \text{eV}}{8.617\times10^{-5}\ \frac{\text{eV}}{°\text{K}}}\left(\frac{1}{T_s} - \frac{1}{394°\text{K}}\right)$$

$$7.64 = 13113.6\left(\frac{1}{T_s} - 0.00254\right)$$

$$T_s = 320.2°\text{K} = \underline{117°\text{F}}$$

REV	BY	DATE	CHECKED	DATE	
0	WPD	12/15/81	KT	1-22-82	

LILCO - NSSS EQUIPMENT QUALIFICATION

ARRHENIUS MODEL OF CROSS LINKED POLYETHYLENE

eds nuclear

JOB NO 0630-001-671

CALC NO 0630-001-003

CALCULATION/PROBLEM COVER SHEET

Calculation/Problem No: 0630-001-005

Title: Arrhenius Model of Neoprene

Client: LILCO Project: NSSS Equipment Qualification

Job No: 0630-001-671

Design Input/References:

Refer to Table of Contents on Page 2 of 5

Assumptions:

Refer to Table of Contents on Page 2 of 5

Method:

Refer to Table of Contents on Page 2 of 5

Remarks:

The purpose of this calculation is to determine the maximum service temperature for neoprene for a service life of 40 years and the qualified life at a service temperature of 104°F.

REV. NO.	REVISION	PERFORMED BY	CHECKED	APPROVED	DATE
0	Original	W.P. Iurnoni	Ken Trotta	N.K. Woodward	2/11/82

XDS 1008 372

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1.0 PURPOSE

The purpose of this calculation is to determine the maximum temperature that can be maintained on Neoprene for a service life of 40 years and the qualified life at a service temperature of 104°F.

2.0 SCOPE

This calculation applies to the qualification of equipment at the Shoreham Nuclear Power Station containing Neoprene.

3.0 REFERENCES

1. A Review of Aging Theory and Technology, EPRI Report No. NP-1558, September, 1980.

2. 1000 hour Heat Aging Study by Larry Small and Ev Scheer (BF Goodrich) Table 18.

4.0 METHOD OF ANALYSIS

The aging model generally accepted by the NRC and industry is the Arrhenius Model:

$$t = B e^{\phi / KT} \qquad \text{(REF. 1, EQ. 4-1)}$$

t - Time to reach a specified endpoint
B - Constant (usually determined experimentally)
ϕ - Activation energy
T - Absolute temperature (°K)

A special form of the equation is:

$$\ln\left(\frac{t_s}{t_a}\right) = \phi/K \left(\frac{1}{T_s} - \frac{1}{T_a}\right) \qquad \text{(REF. 1, EQ. 4-16)}$$

Where the subscripts "s" and "a" describe service and test conditions respectively.

					LILCO - NSSS EQUIPMENT QUALIFICATION ARRHENIUS MODEL OF NEOPRENE
					JOB NO 0630-001-671
0	MPA	12/15/81	KT	1-22-82	eds nuclear — CALC NO 0630-001-005 — PAGE 2 OF 5
REV	BY	DATE	CHECKED	DATE	

5.0 BASIC DATA AND ASSUMPTIONS

1. Neoprene rubber was tested at 121°C for 70 hours and was found to have changed in the following manner (Ref. 2):

   1. Tensile strength increased 26%.
   2. Elongation increased 8%.

6.0 SUMMARY RESULTS

1. Neoprene Rubber can withstand a maximum temperature of 72.5°F for a service life of 40 years.

2. Neoprene rubber is qualified for 6 years at a service temperature of 104°F.

7.0 BODY OF CALCULATION

$$\ln\left(\frac{t_s}{t_a}\right) = \frac{\phi}{K}\left(\frac{1}{T_s} - \frac{1}{T_a}\right)$$

$$t_s = 40\ \text{YRS} = 350{,}400\ \text{HRS}$$
$$t_a = 70\ \text{HRS}$$
$$\phi = 0.87\,eV \quad \text{(REF. 1)}$$
$$K = 8.617\times10^{-5}\ eV/°K$$
$$T_a = 121\,°C = 394\,°K$$

$$\ln\left(\frac{350400\ \text{HRS}}{70\ \text{HRS}}\right) = \frac{0.87\,eV}{8.617\times10^{-5}\,\frac{eV}{°K}}\left(\frac{1}{T_s} - \frac{1}{394\,°K}\right)$$

$$8.52 = 10096.3\left(\frac{1}{T_s} - 0.00254\,°K\right)$$

$$T_s = 295.5\,°K = \underline{72.5\,°F}$$

					LILCO - NSSS EQUIPMENT QUALIFICATION		
					ARRHENNK MODEL OF NEOPRENE		
					eds nuclear	JOB NO 0630-001-671	PAGE 4
0	[illegible]	12/15/81	KT	1-22-82		CALC NO 0630-001-005	OF 5
REV	BY	DATE	CHECKED	DATE			

7.0 BODY OF CALCULATION (CON'T)

FOR A SERVICE TEMPERATURE OF 104°F (40°C) THE SERVICE LIFE CAN BE CALCULATED AS:

$$\ln\left(\frac{t_s}{t_a}\right) = \frac{\phi}{K}\left(\frac{1}{T_s} - \frac{1}{T_a}\right)$$

t_a = 70 HRS

ϕ = 0.87 eV

$K = 8.617 \times 10^{-5}$ eV/°K

T_s = 104°F = 313°K

T_a = 121°C = 394°K

$$\ln\left(\frac{t_s}{70\,HRS}\right) = \frac{0.87\,eV}{8.617\times10^{-5}\,\frac{eV}{°K}}\left(\frac{1}{313°K} - \frac{1}{394°K}\right)$$

$$\ln\left(\frac{t_s}{70}\right) = 6.63$$

$$\frac{t_s}{70} = e^{6.63}$$

t_s = 53,024 HRS = 6.05 YEARS

REV	BY	DATE	CHECKED	DATE	LILCO - NSSS EQUIPMENT QUALIFICATION ARRHENIUS MODEL OF NEOPRENE eds nuclear	JOB NO 0630-001-671 CALC NO 0630-001-005	PAGE 5 OF 5
0	WPA	12/15/81	KT	1-22-82			

CALCULATION/PROBLEM COVER SHEET

Calculation/Problem No: 0630-001-006

Title: Arrhenius Model of Viton Gaskets

Client: LILCO

Project: NSSS Equipment Qualification

Job No: 0630-001-671

Design Input/References:

Refer to Table of Contents on Page 2 of 7.

Assumptions:

Refer to Table of Contents on Page 2 of 7.

Method:

Refer to Table of Contents on Page 2 of 7.

Remarks:

The purpose of this calculation is to determine the maximum service temperature for Viton fluoroelastomer gaskets for a service life of 40 years.

REV. NO.	REVISION	PERFORMED BY	CHECKED	APPROVED	DATE
0	Original	John M. DeCosta	Ken Trotter	N. Klinedienst	2/11/82

EDS 2008 9/78

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LIST OF APPENDICES

1.0 PURPOSE

The purpose of this calculation is to determine the maximum temperature that can be maintained on Viton fluoroelastomer gaskets for a service life of 40 years.

2.0 SCOPE

This calculation applies to the qualification of equipment at the Shoreham Nuclear Power Station containing Viton fluoroelastomer.

3.0 REFERENCES

1. The Engineering Properties of Viton, E.I. Dupont De Nemours and Co. (Inc.).

2. A Review of Aging Theory and Technology, EPRI Report No. NP-1558, September, 1980.

4.0 METHOD OF ANALYSIS

The aging model generally accepted by the NRC and industry is the Arrhenius Model;

$$t = B e^{\phi/KT} \quad \text{(REF. 2, EQ. 4-1)}$$

t = Time to reach a specified endpoint
B = Constant (usually determined experimentally)
ϕ = Activation energy
T = Absolute temperature (^{o}K)

A special form of the equation is:

$$\ln\left(\frac{t_s}{t_a}\right) = \phi/K \left(\frac{1}{T_s} - \frac{1}{T_a}\right) \quad \text{(REF. 2, EQ 4-16)}$$

Where the subscripts "s" and "a" describe service and test conditions respectively.

5.0 BASIC DATA AND ASSUMPTIONS

1. Tensile strength and/or compression set are the critical properties required by a gasket material. Tensile strength is required in order to maintain a pressure boundary against the force of pressure transients.

2. Viton was aged for 70 hours at 275°C (528°F) and the tensile strength was found to have decreased 20% (Ref. 1).

6.0 SUMMARY RESULTS

Viton can withstand a maximum temperature of 129.2°C (264.6°F) for a service life of 40 years.

7.0 BODY OF CALCULATION

$$\ln\left(\frac{t_s}{t_a}\right) = \frac{\phi}{K}\left(\frac{1}{T_s} - \frac{1}{T_a}\right)$$

$$t_s = 40 \text{ YRS} = 350{,}400 \text{ HRS}$$

$$t_a = 70 \text{ HRS}$$

$$\phi = 1.11 \text{ eV} \quad \text{(REF. 2)}$$

$$K = 8.617 \times 10^{-5} \text{ eV/°K}$$

$$T_a = 275 °C = 548 °K$$

$$\ln\left(\frac{350{,}400 \text{ HRS}}{70 \text{ HRS}}\right) = \frac{1.11 \text{ eV}}{8.617 \times 10^{-5} \frac{\text{eV}}{°K}}\left(\frac{1}{T_s} - \frac{1}{T_a}\right)$$

$$8.52 = 12{,}882\left(\frac{1}{T_s} - 0.00182\right)$$

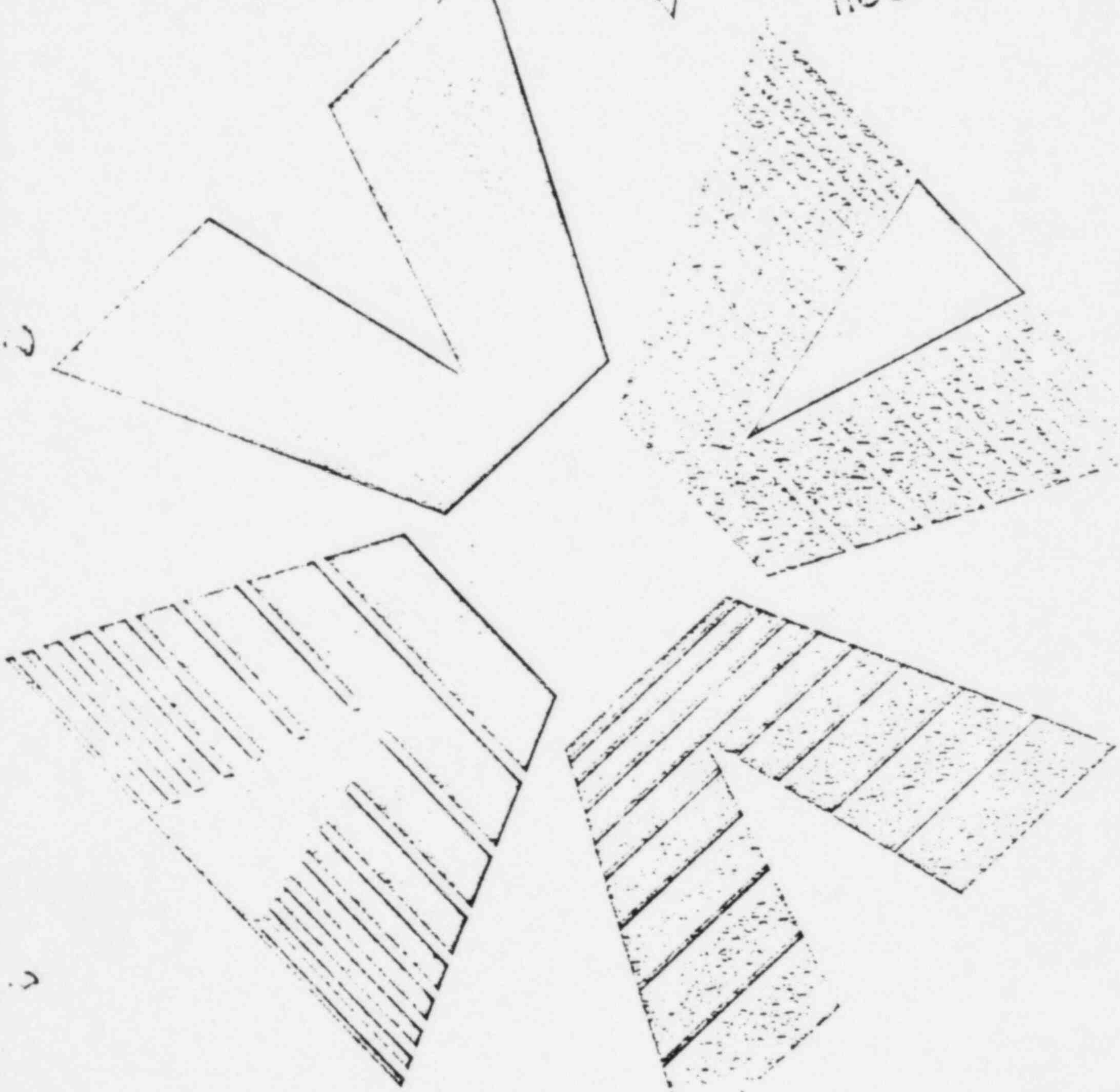
$$T_s = 402.2 °K = \underline{264.6 °F}$$

REV	BY	DATE	CHECKED	DATE			
0	JE	12/15/81	KT	1-22-82	LILCO - NSSS EQUIPMENT QUALIFICATION ARRHENIUS MODEL OF VITON eds nuclear	JOB NO 0630-001-671 CALC NO 0630-001-006	PAGE 4 OF 7

APPENDIX A

ADDITIONAL REFERENCES

the engineering properties of VITON* fluoroelastomer



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*Reg. U.S. Pat. & Tm. Off.

applicable specifications

MIL-R-83248

	Spec	VITON
Original		
Tensile Strength, psi	1,600	1,735
, kg./cm.²	112.5	122.0
Elongation, %	125	190
Hardness, Durometer		
A points	75 ±5	79
T_R °F., max.	+5	−4
T_R °C., max.	−15	−20
Compression Set—ASTM D395, Method B 70 hr. at 75°F. (24°C.), %	15	12
Aged 70 hr. at 75°F. (24°C.) in Reference Fuel B		
Tensile Strength, % change	−20	−15
Elongation, % change	−20	−10
Hardness, points change	±5	−2
Volume, % change	0 to +10	+1.6
Aged 70 hr. at 347°F. (175°C.) in Stauffer Blend 7700		
Tensile Strength, % change	−25	−22
Elongation, % change	−20	−5
Hardness, points change	0 to −15	−7
Volume, % change	0 to +20	+16.4
Compression Set—ASTM D395, Method B		
Standard Measurement, %	10	0
Measurement After 18-hr. Cooling, %	15	7
Aged 70 hr. at 528°F. (275°C.) in Air		
Tensile Strength, % change	−35	−20
Elongation, % change	−15	+42
Hardness, points change	−5 to +10	+1
Weight, % change	−10	−5.06
Compression Set—ASTM D395, Method B		
22 hr. at 392°F. (200°C.), %	15	8
Compression Set—ASTM D395, Method B Aged 166 hr. at 347°F. (175°C.)		
Standard Measurement, %	20	15
Measurement After 18-hr. Cooling, %	35	24

AMS-7278D

	Spec	VITON
Original		
Tensile Strength, psi	1,200	1,735
, kg./cm.²	84.4	122.0
Elongation, %	125	190
100% Modulus, psi	350	880
kg./cm.²	24.6	61.9
Hardness, Durometer		
A points	75 ±5	79
T_R °F., max.	+5	−4
T_R °C., max.	−15	−20
Aged 70 hr. at 75°F. (24°C.) in Reference Fuel B		
Tensile Strength, % change	−15	−15
Elongation, % change	−15	−10
Hardness, points change	−5 to +5	−2
Volume, % change	0 to +10	+1.6
Aged 70 hr. at 392°F. (200°C.) in Anderol L-774		
Tensile Strength, % change	−40	−13
Elongation, % change	−20	+11
Hardness, points change	−15 to +5	−7
Volume, % change	0 to +20	+11.3
Aged 70 hr. at 482°F. (250°C.) in Air		
Tensile Strength, % change	−30	−2
Elongation, % change	−40	−10
Hardness, points change	0 to +15	+1
Weight, % change	−8.0	−0.94
Compression Set—ASTM D395, Method B		
70 hr. at 392°F. (200°C.), %	50	13

AMS-7280

	Spec	VITON
Original		
Tensile Strength, psi	[illegible]	1,735
, kg./cm.²	[illegible]	122.0
Elongation, %	[illegible]	190
Hardness, Durometer		
A points	75 ±[illegible]	79
T_R °F., max.	[illegible]	−4
T_R °C., max.	[illegible]	−20
Aged 70 hr. at 75°F. (24°C.) in Reference Fuel B		
Tensile Strength, % change	[illegible]	−15
Elongation, % change	[illegible]	−10
Hardness, points change	−5 to [illegible]	−2
Volume, % change	0 to [illegible]	+1.6
Aged 70 hr. at 392°F. (200°C.) in Stauffer Blend 7700		
Tensile Strength, % change	[illegible]	−26
Elongation, % change	[illegible]	−16
Hardness, points change	−15 to [illegible]	−9
Volume, % change	0 to [illegible]	+19.5
Aged 70 hr. at 482°F. (250°C.) in Air		
Tensile Strength, % change	[illegible]	−2
Elongation, % change	[illegible]	−10
Hardness, points change	0 to [illegible]	−1
Weight, % change	[illegible]	−0.94
Compression Set—ASTM D395, Method B		
70 hr. at 392°F. (200°C.), %	30	13
336 hr. at 392°F. (200°C.), %	55	32

Gasoline pump metering shaft seal—VITON* fluoroelastomer since 1958.

*Reg. U.S. Pat. & Tm. Off.

CALCULATION/PROBLEM COVER SHEET

Calculation/Problem No: 0630-001-007

Title: Arrhenius Model of Ethylene Propylene Rubber

Client: LILCO Project: NSSS Equipment Qualification

Job No: 0630-001-671

Design Input/References:

Refer to Table of Contents on Page 2 of 6

Assumptions:

Refer to Table of Contents on Page 2 of 6

Method:

Refer to Table of Contents on Page 2 of 6

Remarks:

The purpose of this calculation is to determine the maximum service temperature for Ethylene Propylene rubber for a service life of 40 years.

REV. NO.	REVISION	PERFORMED BY	CHECKED	APPROVED	DATE
0	Original	W.P. Iusmari	Ken Trotta	N Kleemlund	2/11/82

EDS 1004 8/78

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LIST OF APPENDICES

1.0 PURPOSE

The purpose of this calculation is to determine the maximum temperature that can be maintained on Ethylene Propylene for a service life of 40 years.

2.0 SCOPE

This calculation applies to the qualification of equipment at the Shoreham Nuclear Power Station containing Ethylene Propylene rubber.

3.0 REFERENCES

1. A Review of Aging Theory and Technology, EPRI Report No. NP-1558, September, 1980.

2. 1000 hour Heat Aging Study by Larry Small and Ev Scheer (BF Goodrich) Table 19.

3. ROC, AD Sawyer to Ev Scheer (BF Goodrich), dated January 5, 1981.

4.0 METHOD OF ANALYSIS

The aging model generally accepted by the NRC and industry is the Arrhenius Model;

$$t = B e^{\phi / KT} \quad \text{(REF. 1, EQ. 4-1)}$$

t = Time to reach a specified endpoint
B = Constant (usually determined experimentally)
ϕ = Activation energy
T = Absolute temperature (°K)

A special form of the equation is:

$$\ln\left(\frac{t_s}{t_a}\right) = \frac{\phi}{K}\left(\frac{1}{T_s} - \frac{1}{T_a}\right) \quad \text{(REF. 1, EQ. 4-1)}$$

Where the subscripts "s" and "a" describe service and test conditions respectively.

					LILCO - NSSS EQUIPMENT QUALIFICATION ARRHENIUS MODEL, ETHYLENE PROPYLENE RUBBER
					JOB NO 0630-001-671
0	WPJ	12/15/81	KT	1-22-82	eds nuclear — CALC NO 0630-001-007 — PAGE 3 OF 6
REV	BY	DATE	CHECKED	DATE	

5.0 BASIC DATA AND ASSUMPTIONS

1. EPCAR 545/Peroxide is assumed representative of EPR (Ref. 3).

2. EPR was tested at 135°C for 6 weeks and was found to have changed in the following manner (Ref. 2):

   1. Tensile strength decreased 16%.
   2. Elongation decreased 24%.

6.0 SUMMARY RESULTS

Ethylene Propylene rubber can withstand a max. service temperature of 144.5°F for a service life of 40 years.

7.0 BODY OF CALCULATION

$$\ln\left(\frac{t_s}{t_a}\right) = \frac{\phi}{K}\left(\frac{1}{T_s} - \frac{1}{T_a}\right)$$

t_s = 40 YRS = 2080 WKS

t_a = 6 WKS

ϕ = 0.95 eV (REF. 1)

$K = 8.617 \times 10^{-5}$ eV/°K

T_a = 135°C = 408°K

$$\ln\left(\frac{2080 \text{ WKS}}{6 \text{ WKS}}\right) = \frac{0.95 \text{ eV}}{8.617\times10^{-5} \frac{\text{eV}}{°K}}\left(\frac{1}{T_s} - \frac{1}{408°K}\right)$$

$$5.85 = 11024.7\left(\frac{1}{T_s} - 0.00245\right)$$

$$T_s = 335°K = \underline{144.5 °F}$$

REV	BY	DATE	CHECKED	DATE	LILCO - NSSS EQUIPMENT QUALIFICATION / ARRHENIUS MODEL, ETHYLENE PROPYLENE RUBBER
0	[illegible]	12/15/81	KT	1-22-82	eds nuclear — JOB NO 0630-001-671; CALC NO 0630-001-007; PAGE 4 OF 6

APPENDIX A

CORRESPONDENCE

eds nuclear

FILE: 0370-025-671

RECORD OF CONVERSATION

COPY: J Ironfield
P Stowe
A ~~Sawyer~~
J Haverly
M Ballard
N Woodward
Qual. File

[X] Telephone ☐ Meeting ☐ Other

TO: Ev Scheer FROM: Alan Sawyer DATE 1/5/81

COMPANY: BF Goodrich PHONE NO.: 216-447-7712

SUBJECT: 1000 Hour Heat Aging Study

Summary of Conversation:

Ev Scheer was contacted in order to identify which polyner tested was representative of EPR (Ethylene Propylene Rubber).

Mr. Scheer stated EPCAP 545/Peroxide was most representative of EPR. He also stated EPCAP 545/Peroxide and EPCAP 545/Sulfur are both EPDM rubbers which can be cured with both sulfur and peroxide while EPR polyner cannot be sulfur cured, which is why EPDM rubbers are easily tested but still representative of EPR.

AS/cjc

Radiation Effects on Organic Materials in Nuclear Plants

NP-2129
Research Project 1707-3

Final Report, November 1981

Prepared by

GEORGIA INSTITUTE OF TECHNOLOGY
Nuclear Engineering Department
Neely Nuclear Research Center
900 Atlantic Drive, N.W.
Atlanta, Georgia 30332

Principal Investigators
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EPRI Project Manager
G. Sliter

Risk Assessment Program
Nuclear Power Division

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NOTICE

Prepared by
Georgia Institute of Technology
Atlanta, Georgia

EPRI PERSPECTIVE

PROJECT DESCRIPTION

Equipment in nuclear plants must be qualified to perform safety-related functions after long periods of exposure to low-level radiation during operation and after short periods of high-level radiation during accidents postulated for design. The effects of radiation on materials is therefore one of the topics addressed in the EPRI Equipment Qualification Supplementary Program (RP1707). This report by the Georgia Institute of Technology presents the results of a literature search for data concerning the radiation resistance of organic materials. The data are intended eventually to be included in the computerized Equipment Qualification Data Bank (RP1707-2).

PROJECT OBJECTIVE

The main objective of this project was to determine, to the extent possible, a low-level threshold dose for radiation damage to organic materials in plant equipment. Equipment located in a benign plant environment and exposed to less than the threshold dose during its design life could be excluded from the general qualification requirement for radiation testing or further analysis of radiation effects. The information compiled can also assist in the design and qualification of equipment subjected to high-level radiation doses.

PROJECT RESULTS

The report includes an overview of radiation effects and an extensive list of organic materials in order of increasing resistance to radiation damage. An important finding is that a total dose of less than 10^5 rads produces no significant degradation of mechanical or electrical properties. (Notable exceptions are equipment that contain Teflon® or semiconductor devices.) Also, at this level, no significant synergistic effects of radiation combined with other environmental stresses, such as elevated temperatures, were identified. The results of this work will be of interest to utility engineers, architect-engineers, equipment manufacturers, and regulatory staff involved in the qualification of equipment for radiation effects.

George Sliter, Project Manager
Nuclear Power Division

ABSTRACT

A literature search was conducted to identify information useful in determining the lowest level at which radiation causes damage to nuclear plant equipment. Information was sought concerning synergistic effects of radiation and other environmental stresses.

Organic polymers are often identified as the weak elements in equipment. Data on radiation effects are summarized for 50 generic name plastics and 15 elastomers. Coatings, lubricants, and adhesives are treated as separate groups.

Inorganics and metallics are considered briefly. With a few noted exceptions, these are more radiation resistant than organic materials.

Some semiconductor devices and electronic assemblies are extremely sensitive to radiation. Any damage threshold including these would be too low to be of practical value. With that exception, equipment exposed to less than 10^4 rads should not be significantly affected. Equipment containing no Teflon should not be significantly affected by 10^5 rads.

Data concerning synergistic effects and radiation sensitization are discussed. The authors suggest correlations between the two effects.

ACKNOWLEDGMENTS

A number of individuals have provided useful information, discussions, and/or assistance in the preparation of this report. We wish to specifically acknowledge James F. Gleason, Wyle Laboratories, for many helpful criticisms and suggestions. John Wanless, NUS Corporation, assisted EPRI in technical management of the work.

CONTENTS

CONTENTS (Continued)

CONTENTS (Continued)

ILLUSTRATIONS

TABLES

SUMMARY

Much of the equipment used in nuclear power generating stations will be subjected to low-level irradiation over the life of the plant. In accordance with applicable industry standards and regulatory requirements regarding equipment qualification, the effects of such "benign" environments must be addressed either by test or by detailed analysis for all safety related equipment (including equipment not classified 1E). Additionally synergistic effects of irradiation concurrent with other environmental stresses must be considered.

A comprehensive literature search was conducted to identify information useful in determining a low level radiation threshold for nuclear plant materials, components, and assemblies. Additional detail on the type and extent of damage possible under various conditions was sought to provide guidance in the selection of materials and components which must function in high-level or "harsh" environments.

Data bases consulted in this search included NTIS (National Technical Information Service), ERA (Energy Research Abstracts), Science Abstracts, EDB (Energy Information Data Base) and INSPEC. These were computer searched through the Georgia Tech Library and Oak Ridge National Laboratory. Applicable information from miscellaneous sources is also included. Equipment qualification reports usually provide little information relating to damage thresholds and were not specifically sought.

Two principal processes which occur in the interaction of radiation with matter are considered. Ionization and excitation of absorber atoms is the principal process leading to damage of organic materials through chemical reaction of the excited ions and/or free radicals. Damage to inorganic/metallic materials is primarily related to physical displacement of electrons and/or atoms and consequent disruption of the crystal lattice structure of the absorbing material.

With certain very notable exceptions, inorganics/metallics are much less susceptible to radiation damage than organics. Semiconductor devices function through designed imperfections in crystal structure and are quite sensitive to further disruption of those structures by displacement processes. Any all-inclusive threshold identifiable from existing data would be too low to be of practical value to the industry. Additionally the optical properties of glasses may be affected at radiation levels approximately equal to those which affect the most sensitive organic materials.

A separate review of the extensive theoretical information and test data available on displacement effects would be useful in establishing guidelines for the selection and use of semiconductor devices and complex electronic components.

This study addresses organic materials; no further consideration of inorganic/metallic materials is made here. Additionally, simple organic compounds, generally not used in nuclear plant equipment, are excluded from consideration.

Information presented in this report concerning organic materials used in plant equipment suggests an exclusion from test or further analysis should be allowed for nonelectronic equipment subjected to 10^4 rads or less. Nonelectronic equipment which contains no teflon and is subjected to less than 10^5 rads should likewise be excluded. At these levels there is no significant degradation of mechanical or permanent electrical properties of the listed materials. Also at this level no indications were found in the literature search of significant synergistic effects of radiation combined with other environmental stresses or sensitization to subsequently imposed stresses. In general, equipment failures occur at some higher level involving considerably more than threshold degradation of component materials.

While each manufacturer's formulation(s) of a particular generic material is sufficiently different to preclude statistical treatment of test data, theoretical considerations supported by test data indicate that a specific threshold must exist for each material. In all cases, the lowest identified damage threshold is reported here. Many materials have not been studied in great detail and estimates of their thresholds may be reduced on the basis of further tests and analysis. Fortunately, the most sensitive materials have been studied extensively and reduction of the exclusion levels stated above is not anticipated.

The term "synergistic effect" is used here when comparative data for simultaneously and sequentially applied multiple stresses indicate nonequal changes in a given material. The term "sensitization" is used when application of one stress changes the material so that the rate (or type) of response to a subsequent stress is different from the original material. "Sensitization" and "synergistic effects" are different manifestations of the changes that occur in materials under stress and are recognized as interrelated.

Direct data identifying synergistic effects for materials is extremely limited but data identifying sensitization effects is available for many materials. Inferences are made based on these sensitization effects concerning the synergistic effects that occur in multiple stress environments. Tables identifying materials for which strong, moderate, and minor sensitization effects are known are included.

From the limited information available it appears that selection of sequential test programs which maximize "sensitization" effects will result in the best achievable simulation of the synergistic effects that would occur in real environments.

Section 1

INTRODUCTION

Any equipment which performs a safety related function in a nuclear plant application must be proven capable of performing the necessary function(s) throughout its installed life (including normal life and any accident conditions through which it must function). That proof is provided by equipment qualification. The effects of a number of environmental stresses including temperature, oxidizing atmosphere, mechanical stress (including vibration and seismic effects), hostile chemical environments, electrical stress, and radiation must be considered. As pointed out by Carfagno[19] and others, the exact duplication of the effects of long term, low level and multiple stress environments is not technically feasible.

Exact duplication is not the intention of equipment qualification. Industry standards (IEEE, ANSI) identify methods which can be expected to provide at least equal degradation of the type(s) that could impair performance of a safety related function. Substantial efforts are made to provide assurance that effects which are not well understood are adequately simulated.

Among the requirements of NUREG 0588[60] and IE Bulletin 79-01B[61] is an assessment of the effects of radiation environments previously considered benign (creating no significant stress on equipment). An additional requirement is that synergistic effects of radiation in combination with other environmental stresses be evaluated.

The stated objective of this work is to provide a technical basis for determining a low level threshold for radiation damage to nuclear plant materials, components and assemblies. An additional implied objective is to provide information useful in identifying synergistic effects.

A comprehensive literature search was conducted to identify information useful in achieving these objectives. Data bases consulted included NTIS (National Technical Information Service), ERA (Energy Research Abstracts), INSPEC, EDB (Energy Information Data Base) and Science Abstracts. These were computer searched using facilities at the Georgia Tech Library and Oak Ridge National Laboratory. References published prior to 1960 were excluded from the search but much significant test data from early work is referenced in more recent publications. Some selective judgment was used to exclude summaries of summaries and treatments too general to provide new or significant information. Investigations of chemical reaction mechanisms are numerous but are cited here only as they appeared relevant to the objectives of this study. Many manufacturers have conducted radiation damage tests in various environments. Radiation resistant formulations with damage thresholds far above those of the identified generic materials are known. It is unfortunate that much such information is not published because of proprietary considerations. Also, regrettably, most articles for which no English translations were available were excluded.

Results of a somewhat similar but more limited survey are published as Appendix C of Reference 61. The few conflicts are discussed in Section 4 and identified for specific materials in Section 3.

Preliminary data searches indicated that the proposed method of treatment (to provide a statistical treatment of radiation damage thresholds for a few materials and equipment items including complex electronic components) would not be feasible. Specifically, little threshold information is available for complete component/equipment items. Also "threshold" in that context implies impaired function of the equipment and does not include consideration of the fact that many equipment items function acceptably with degraded materials. While a number of materials have been tested extensively, test environments vary as do formulations of generically similar materials. An identification of the lowest reported change in any property of a given material with identification of test parameters whenever possible is a conservative and technically justifiable approach to this study.

Organic polymers are most often identified as the weak element(s) in operating equipment and so as a group were selected for detailed study.

Inorganics and metallics are generally little affected by radiation environments that cause considerable degradation in organic materials. Important exceptions are identified in Section 2 which is a general discussion of radiation effects.

Table 1-1 provides definitions for a number of the terms and units used in this review.

Section 3 summarizes and references detailed test data for specific materials. Materials are categorized on the basis of most frequent use as thermoplastic, thermosetting plastic, or elastomeric material. A few materials are identified in more than one category, though a specific formulation would best fit a single category. Further subgroupings are on the basis of chemical similarity. Materials are identified by generic name; an alphabetic index of some familiar trade names is provided in the appendix.

Section 4 provides the authors' conclusions concerning the data reviewed along with a table of radiation damage thresholds (4-1) and summary data concerning sensitization effects (Tables 4-2 through 4-4). Some of the higher thresholds cited in Table 4-1 are based on limited information and may be accurate only for a single specific material and set of test conditions.

A user seeking information for a specific material(s) should first locate its generic name through the appendix or an outside source such as the manufacturer's data. Applicable information concerning radiation effects can then be located in Section 3 and Section 4.

Selection of materials for service in radiation environments on the basis of threshold information only is not recommended. Consideration of the type and extent of degrading effects of radiation and other environmental stresses on specific materials along with the operational requirements of a particular equipment design should result in selection of equipment with a high potential for qualification.

Table 1-1

DEFINITIONS

absorbed dose	the amount of energy absorbed from the radiation field per unit mass of irradiated material
aliphatic	organic compounds characterized by open chain structures
aldehyde	organic compounds characterized by the presence of the H-C=O radical
alkane	saturated aliphatic hydrocarbon compounds characterized by single carbon-carbon bonds
alkenes	unsaturated aliphatic hydrocarbons characterized by at least one carbon-carbon double bond
alpha	a massive positively charged particle (He^{++}) emitted by certain radioactive materials; particle energy depends on the parent material; penetrating ability is limited
aromatic	organic compounds characterized by closed ring structure and resonance stabilized (shifting/shared) unsaturation
beta	a particle emitted by certain radioactive materials. A negatively charged beta has the characteristics of an electron; a positively charged beta particle is a positron (positrons are not a significant consideration for power plant environments)
bremsstrahlung	electromagnetic radiation (photon) emitted when energetic electrons or betas lose energy due to the influence of the electric field of absorber atoms
covalent	a chemical bond formed by the sharing of electrons between adjacent atoms so that both remain electrically neutral (neither is an ion)
crosslink	chemical bond formed between separate polymer elements; crosslinking may be intermolecular (between molecules) or intramolecular (between parts of the same molecule)
Curie	the basic unit of intensity of radioactivity; equal to 3.7×10^{10} disintegrations per second
depth-dose	the absorbed radiation dose at a particular depth in a specific absorber; depth-dose curves show the distribution of absorbed energy in a specific material
displacement	physical relocation of atoms/electrons of an absorber, through collision processes, resulting in disruption of the material's crystal structure

Table 1-1 (Continued)

DEFINITIONS

dose rate effects	an effect on a material which is different in magnitude or type (for the same total dose), depending on the irradiation rate; effects may be transient or permanent
elastomers	natural and synthetic rubbers; elastomers should be able to undergo stretching to twice original length and retract rapidly, when released, to near original length
excitation	a process by which energy is supplied to electrons, atoms, or radicals, rendering them chemically more reactive
free radical	an atom or radical group of atoms having one electron not involved in bond formation; free radicals are highly reactive and usually highly mobile
gamma	electromagnetic radiation (photons) emitted by certain radioactive materials; gammas are more penetrating than comparable energy particulate radiation
Gray (Gy)	the SI recommended unit of absorbed dose which represents an absorption by a specified material of 1×10^4 ergs/gram; 1 Gray = 100 rads
G-value	the number of molecules of a specified type formed or consumed per 100 electron volts of energy absorbed by a system; it is also used to specify the number of reactions that occur per 100 eV absorbed
ion	an electrically charged atom, radical, or molecule resulting from the addition or removal of electrons by any of a number of possible processes
ionization	the process of ion formation
irradiation	exposure to radiation
ketone	organic compounds characterized by the presence of the carbonyl group -C=O
LET	Linear Energy Transfer - the radiation energy lost per unit length of path through a material, usually expressed in kiloelectron volts per micron of path; a higher LET value indicates more effective ionization of the absorber
neutron	an uncharged elementary particle present in the nucleus of every atom heavier than hydrogen. Neutrons are released during fission
neutron activation	a process by which absorber atoms become radioactive through capture of a neutron by the nucleus of the absorber

Table 1-1 (Continued)

DEFINITIONS

polymers	organic compounds characterized by a repeating structural unit
rad	the traditional unit of absorbed dose representing the absorption by a specified material of 100 ergs per gram of that material. 1 rad = 10^{-2} Gy
radiation	the emission and propagation of energy through matter or space; also, the energy so propagated; the term has been extended to particles, as well as electromagnetic radiation
radical	a group of atoms which take part in chemical reactions as a unit
radiolysis	decomposition of materials induced by irradiation
Roentgen	the historical unit of exposure to radiation; one Roentgen (R) produces an absorbed dose in air of 0.87 rads (air); the absorbed dose in other materials depends on the energy of the radiation and the composition of the absorber
scission	the process by which chemical bonds are broken; also, the number of bonds broken by the process
sensitization effect	an effect on a material by a particular stress such that the rate or type of response to a subsequent separate stress is different than it would have been for the original material
synergistic effect	an effect on a material of two or more stresses applied simultaneously which is different in magnitude or type than that of the same stresses applied separately
thermoplastic	an organic material which will soften on heating, but will revert to its starting properties on cooling
thermosetting plastic	an organic material which hardens permanently on heating or curing
threshold	(as radiation damage threshold) the lowest radiation dose which induces permanent change in a measured property(s) of a material; also, the first detectable change in a property of a material due to the effect of radiation

Section 2

DISCUSSION OF RADIATION EFFECTS

Radiation interacts with matter by two principal processes which are of interest here. Physical displacement of the atoms/electrons of a material result in disruption of the material's crystal structure. Ionization/excitation processes result in highly mobile and/or energetic atoms and ions. Though both processes occur for all materials, damage to metals/inorganics is principally related to displacement effects.

Chemical bonding of inorganics is ionic and so further ionization does not usually induce chemical reactions within the material. Chemical bonding of organics is covalent and damage to organic materials occurs via chemical reaction resulting from ionization/excitation processes. Displacement effects are generally not significant for organics because of their less rigid molecular structure. The effects of either process may be subdivided into transient effects and permanent effects. This brief discussion of complex effects is not intended to be complete. References 22, 25, and 37 treat basic concepts in some detail and cite more rigorous treatments.

Whether a displacement occurs is determined by the masses of the colliding particles and the energy available for a given collision. This implies that chemical composition, radiation type, and energy spectrum are of primary importance. Whether a displacement is permanent (or damaging) depends on the structure and physical state of the material. Much of the total dose absorbed by inorganics/metallics does not produce displacements and is dissipated with no net effect.

Much less of the total dose absorbed by organic materials is dissipated. Most is used to initiate or accelerate chemical reactions through ionization and excitation of absorber atoms. The type of reaction is determined by the material. The extent of reaction is determined by the total energy available. The effects of radiation type and energy spectrum in modifying the total energy available is usually minor. This is a statement of the classical "equal dose-equal damage" approximation for organics.

Also, Cannot Duplicate Variable Dose Rate

Most equipment items in nuclear plant environments are exposed to gamma radiation of various energies over their normal lifetimes. Some are also exposed to beta and neutron radiation of various energies. Only equipment in close contact with radioactive materials might be exposed to alpha radiation. Accident environments would contain particularly high levels of beta and gamma radiation. In short, the radiation environment is complex.

Test facilities are not available to duplicate such complex environments. Concurrent neutron and gamma exposure can be provided by experimental reactor facilities. Gamma exposures can be provided by concentrated isotope sources such as Cobalt-60 or Cesium-137. Beta exposures can be provided by electron accelerator facilities.

Exposure to radiation types separately may be possible but the matching of energy spectrums is not. Additionally, both practical and technical considerations limit the feasibility of this approach. Radiation simulation is most often performed by providing equal or greater total absorbed dose to sensitive materials and components with an isotope source of gamma radiation and utilization of the "equal dose-equal damage" concept.

"Equal dose-equal damage" does not apply to inorganics/metallics so the effects of plant radiation environments may not be well simulated. This is usually not important because most inorganics/metallics show no significant damage even in the most extreme equipment environments. Special cases occur which require further consideration. Though no detailed treatment of these was made in this study, some noted in the documents referenced by this study include:

1. Increased fragility of some glasses and ceramics at exposures greater than 10^5 rads.
2. Changes in the optical properties of some glasses are noted at 10^4 rads.
3. Transient changes in electrical properties occur, the significance of which is application dependent. In benign environments it appears that only complex electronic components and semiconductor devices might be affected.
4. At least some semiconductor devices are very susceptible to radiation damage. Avery[2] noted radiation induced failures at less than 300 rads.

Semiconductor devices have imperfect crystal structure by design and some of these are very much affected by any further disruption of the crystal structure. Transient changes in electrical properties which are unimportant for insulations may be significant to the proper function of complex electronic components. Radiation tolerances depend on design considerations and applications.

An in-depth study of such special cases would provide guidance for avoiding use of the most sensitive devices/components. Criteria might be identified which, if met, would be proof of some minimum radiation resistance greater than the lowest value found.

Further discussion of radiation effects herein are limited to those that pertain to organic polymers.

EFFECTS OF RADIATION TYPE AND ENERGY SPECTRUM

A test radiation environment must provide at least equal radiation dose to the most sensitive materials in an equipment as would occur in its real plant environment.

The energy of any radiation source is degraded as it travels through a material. The absorbed dose at some finite depth in the material will be different from the absorbed dose at the surface (the amount depends on incident radiation energy and absorbing material). A "depth dose" profile will result.[10] Different radiation types may produce very different profiles in a given material or component.

Consideration of the LET (linear energy transfer) and penetrating ability of radiation types is useful in determining whether test radiation environments are adequate. LET is defined as the amount of energy deposited in a material per unit path length of the radiation and is usually expressed in keV/micron.

For alpha particles, LET values are many times as high as for other radiation types. Penetrating ability is very limited. The energy of a 5.3 MeV alpha is totally absorbed by a 35 micron layer of water. If alpha radiation is a part of a particular equipment environment, the effects are significant only for thin films or material surfaces in direct contact. Damage to such films or surfaces might be greater than from equal doses of beta or gamma radiation.[58]

Beta particles have LET values in organic materials approximately equal to those of comparable energy gamma photons. The penetrating ability of beta radiation

Exhibit
Enclosure

is strongly dependent on the density of the absorbing material. Very dense materials are quite effective in stopping beta radiation. The maximum penetration of a 1 MeV beta particle in lucite plastic is about 3 millimeters while in iron the range is reduced to about 0.5 mm.[62]

Beta interactions also produce some Bremsstrahlung (photon) radiation which is effectively low energy gamma radiation.[37] The ratio of energy deposited as Bremsstrahlung to the energy deposited as beta is:

$$E_{Bremsstrahlung}/E_{beta} \approx EZ/800$$

E = beta energy in MeV   Z = atomic number of material

The dose from Bremsstrahlung is usually less than 10% of the incident beta dose.

Neutrons penetrate more effectively than alpha or beta particles of comparable energy because they carry no electronic charge. Neutron interactions with material are complex and no simple approximation of penetration depth was located. Usually, neutron effects are simulated by gamma radiation. Neutron activation of absorber atoms produces radioactive materials. The effects are often not large for organic polymers but for components with metallic parts, contamination problems may be serious. LET values are higher than those of comparable energy gamma or beta radiation.

Gamma radiation is most effective in penetrating material. Energy is deposited at an exponentially decreasing rate given by:

$$D = D_o e^{-\mu X}$$

D_o = incident dose
D = dose at depth X
X = depth of interest
μ = energy dependent absorption coefficient of material

It is certainly apparent from consideration of the penetrating ability of radiation types that considerably different depth dose profiles can occur. For organic materials shielded from direct exposure to the radiation environment, gamma radiation is usually the only type that penetrates to the material.

For organic materials or components directly exposed to mixed radiation environments further consideration is necessary. Colwell (under Sandia Laboratories sponsorship) generated comparable depth dose profiles for Cobalt-60 and for the mixed beta, gamma radiation environments hypothesized for a loss of coolant accident.[23,10] It was concluded that ^{60}Co is an adequate simulator of the chemical and physical degradation that might occur in a particular reactor cable. Adequacy for other organic components is implied by considering that LET values are approximately equal for gamma photons and beta particles in organic polymers[3,52] and, therefore, should produce approximately equal damage in materials that are not thicker than the effective penetration depth of beta particles (gamma simulation would then be more than adequate).

Neutron effects may not be as well simulated since LET values are higher. Effects seem to be minor except for highly unsaturated polymers. Parkinson noted crosslinking of polystyrene by neutron irradiation to be about three times as great as with an equal dose of gamma radiation.[42] Smaller effects have been observed for highly unsaturated aliphatics.[17] Most nuclear plant equipment will not be exposed to a significant neutron dose.

EFFECTS ON POLYMER CHEMISTRY

Absorbed radiation provides the energy necessary to initiate chemical reactions. The direct effect is ionization and/or excitation of the molecules of a material. In solid polymers free radicals are the most frequent result; in liquid systems the production of molecular ions becomes more common. A number of competing chemical reactions may then occur, the most important of these being crosslinking (bonding between molecules or parts of a molecule) and scission (breaking of molecular side or main chains). The formation of low molecular weight gaseous by-products may be an important consideration in either type of reaction. Irradiation of materials in hermetically sealed devices may induce significant internal pressures from the expansion of such gases. Higher mole weight gaseous products may be "trapped" in thick polymeric materials and induce significant internal stress.

Empirically determined G values are useful in making radiation damage predictions. G values are used to specify the number of reactions of a particular type induced per 100 eV absorbed. If the G value for the reaction of interest is known, an "order-of-magnitude" estimate of the radiation damage threshold can be made. The following treatment is as suggested by Charlesby.[30]

A certain amount of chemical change is required to produce measurable change in the physical properties of a material. Most polymers require roughly one change per molecule. Defining a theoretical damage threshold, X, as the number of rads required to produce one change per molecule a value can be calculated by:

$$X = (100/G) \; / \; M(1.0365 \times 10^{-10}) \qquad \text{(Eq. 1)}$$

M = polymer mole weight and G = G value (as defined above)

The equation is derived from:

1 erg = 6.24×10^{11} electron volts (eV)
1 rad = 100 ergs/gm absorber = 6.24×10^{13} eV/gm
m = the weight of one polymer molecule
= Mole weight polymer/6.02×10^{23} (Avogadro's number)
(100/G) = number of eV/reaction since G = number of reactions per 100 eV

Then by definition:

$$X = \frac{(100/G)}{m} \cdot \frac{1 \text{ rad}}{6.24 \times 10^{13} \text{ eV/gm}}$$

which gives Equation 1. Substituting typical values of G = 2 and $M = 1 \times 10^{6}$ gm in Equation 1 gives:

$$X = 4.8 \times 10^{5} \text{ rads}$$

G values are effectively chemical reaction rate constants and like rate constants will vary somewhat with environmental conditions. The radiation damage threshold is then partially dependent on environmental conditions. If this dependence is significant, conflicting estimates of the threshold value will be found for the same material tested in different environments.

Any specific material has a number of measurable properties which don't change at the same rate and so the property selected for measurement substantially affects the radiation resistance found. Differences in formulation can result in "same generic name" materials with significantly different resistance to radiation. Further, substantial quantities of long lived free radicals persist in some materials after irradiation. This will result in radiation sensitization and/or dose rate effects.

The types of reaction which can occur depend primarily on the chemical composition of the absorbing material. Table 2-1 identifies whether the dominant reaction mechanism is cross linking or scission for many of the polymers treated in this study. It must be recognized that environmental conditions and variations in formulation influence the dominance of a particular mechanism for most materials. Materials identified in both parts of Table 2-1 are particularly susceptible to such influences. Some effects of crosslinking and scission on material properties are indicated in Table 2-2.

Radiation damage thresholds and overall radiation resistance are dependent on the polymer's basic structure. An approximate order of radiation stability is:

substituted aromatics > aromatics > aliphatics

Among aliphatics the approximate order is:

alkanes > ethers > alcohols > esters > ketones

This order is approximate only and does not imply that every polymer in one class is more resistant than all polymers in a lower class. Also, basic compounds are generally more stable than comparable acidic compounds. Saturated aliphatics are more stable than corresponding unsaturated aliphatics. Unbranched chains are less reactive than branched chains. Compounds containing quaternary carbon atoms are particularly sensitive to scission processes and are damaged by fairly low radiation levels. Teflon, butyl, rubber, polymethyl methacrylate and cellulose are included in this group.

Physical mixtures of polymers will usually result in a product with radiation resistance between that of the most and least resistant component and directly related to the percent of each component present. Simple dilution is inferred. Nonhomogeneous mixtures would show nonuniform damage.

Copolymers frequently show much better radiation resistance than comparable physical mixtures of the components. Since changes in chemical structure are involved, a polymer with greater or less resistance than either component is a possibility. Usually the copolymer has an intermediate resistance not greatly less than the most stable component. Copolymers often incorporate the most desirable characteristics of the components.

Most commercially available materials contain additives and fillers which influence their radiation resistance. Inorganic fillers are not susceptible to damage at the levels of interest here and are usually effective in increasing radiation resistance by dilution. Carbon black is usually least effective and is thought to transmit most of the energy it absorbs to surrounding polymer molecules.

Organic additives are often used to improve the mechanical properties of the base polymer (plasticizers, flame retardants, etc.). Most contain antioxidants. Many antioxidants are used up by chemical reactions with oxygen. Others have been developed which do not change permanently but catalyze reactions of the base polymer which result in less degradation than the reactions which would occur in their absence. "Antirad" additives, including but not limited to antioxidants, are those which have been found to be particularly effective in increasing the radiation resistance of base polymers. Dramatic improvements in the radiation resistance of the most sensitive polymers are possible. Crosslinking polymers are often rendered quite sensitive to oxidative degradation by radiation and the use of effective antioxidants can significantly improve their radiation resistance.

Additives can also have a detrimental effect. This is usually not of concern for plastics and elastomers although some halocarbon flame retardants are known to reduce the radiation resistance of some cable insulations.[35,10] It is a significant concern for most lubricants. A number of the additives necessary for other desirable properties result in a final product which is often much less radiation resistant than the base polymer.[9]

Physical form can influence the extent of degradation. Highly crystalline solid polymers may trap reactive chemical species and inhibit or delay their reaction. One polyethylene containing crystalline and amorphous regions showed roughly three times as much crosslinking in the amorphous region.[38] The crystalline region contained high concentrations of free radicals. Surface area/volume ratios of test samples may impact the effectiveness of competing reaction mechanisms.[27]

Radiation excited chemical species are stored to some extent in many solid polymers, including those which are nearly amorphous. Free radical "storage" occurs to a lesser extent for thin films and for semifluid and fluid polymers such as adhesives and lubricants. For these, access to both internal and external co-reactants is less limited. In any case the presence of trapped radicals implies a potential for delayed reaction. The mechanism(s) of such delayed reaction will depend on environmental conditions.

Table 2-1

DOMINANT PROCESSES IN IRRADIATED POLYMERS

Crosslinking	Scission
Polyethylene	Polyisobutylene
Polystyrene	Poly-a-methylstyrene
Polyacrylates	Polymethacrylates
Polyacrylamide	Polymethacrylamide
Polyamides	Cellulose
Polyesters	Cellulose acetate
Natural rubber	Polytetrafluoroethylene
Synthetic rubbers (except polyisobutylene)	Polychlorotrifluoroethylene
Polysiloxanes	Polymethacrylic acid
Polyvinyl alkyl ethers	Poly-a-methacrylonitrile
Polyvinyl methyl ketone	Polyethylene terephthalate
Chlorinated polyethylene	
Chlorosulfonated polyethylene	
Polyacrylonitrile	
Polyethylene oxide	
Polyvinyl chloride	Polyvinyl chloride
Polypropylene	Polypropylene
Polyvinylidene chloride	Polyvinylidene chloride
Polyvinylidene fluoride	Polyvinylidene fluoride

Adapted from Reference 58 (and others)

Table 2-2

EFFECTS OF CROSSLINKING AND SCISSION

Scission	Crosslinking
CAUSES	CAUSES
Decreased molecular weight	Increased molecular weight
Decreased Young's modulus	Increased Young's modulus
Reduced yield stress for viscous flow	Impeded viscous flow
USUALLY CAUSES	USUALLY CAUSES
Decreased tensile strength	Increased tensile strength
Increased elongation	Decreased elongation
Decreased hardness	Increased hardness
Increased solubility	Increased softening temperature
Decreased elasticity	Decreased solubility
	Gas formation
	Embrittlement
	Decreased elasticity
SOMETIMES CAUSES	
Embrittlement	
Gas formation	
Decreased melting temperature	

Adapted from Reference 9

EFFECTS OF COMBINED ENVIRONMENTS

As previously indicated, only the initial ionization/excitation of polymer molecules is independent of environmental factors. The chemical composition of the polymer determines possible reaction mechanisms. Environmental conditions determine which of these possible reactions will occur and at what rates.

This implies that changes in a material subjected simultaneously to radiation and other environmental stresses could be different from the changes that would occur in the material if subjected to the stresses separately and sequentially. A "synergistic" effect could occur.

Few simultaneous (combined environment) tests have been performed to investigate synergistic effects quantitatively but a good deal of information is available concerning radiation "sensitization" of various materials to subsequent exposure to other environmental stresses.

NOTE: IN NUCLEAR PLANTS HIGH RADIATION LEVELS OCCUR AFTER HIGH ENVIRONMENTAL STRESSES HAVE SUBSIDED

For many polymers radiation significantly accelerates oxidative degradation. This is clearly demonstrated by many comparative tests of identical materials irradiated in air and in inert atmosphere or vacuum. For a few polymers more "radiation damage" occurs in nitrogen or vacuum than in air. This implies that oxidative reactions can inhibit other more damaging reactions. For some materials "radiation damage" is about the same in either environment. Oxidation is apparently not a significant reaction degradation mechanism for these. Problems occur in providing sufficient oxygen to more than the surface layer of solid polymers because oxygen diffusion is a slow process. Carefully prepared thin films are often used for comparative tests. Post irradiation acceleration of oxidative degradation is often observed for thicker solid polymer samples and is thought to be related to the reaction of "trapped" radicals as oxygen becomes accessible to them.

Enhancement of "radiation degradation" at elevated temperatures is qualitatively well established for many polymers. For most this may be simply an acceleration of oxidative reactions which would occur over a longer time at lower temperatures. For others radiation may result in significant changes in the thermal resistance of the polymers. Crosslinked materials have higher mole weights and elevated melting points may occur. Polymers which undergo dominant scission will have reduced mole weights and may show significantly lower melting points.

Some polymers appear to be more resistant to radiation plus elevated temperature than to elevated temperature alone. Radiation induced crosslinking appears to inhibit oxidative degradation in some such materials, for others the effect may be related to an increased melting point of the polymer.

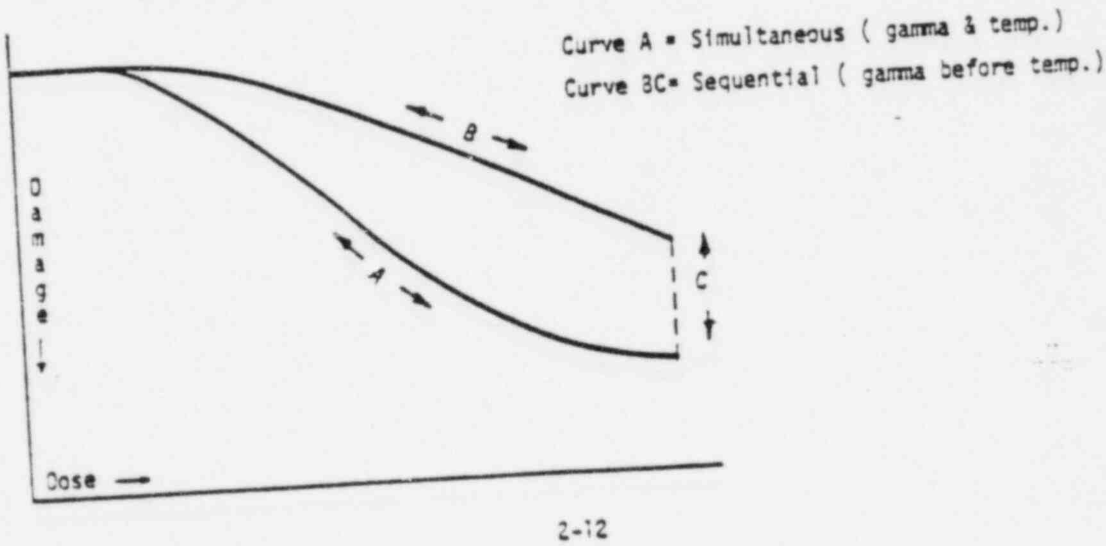
Many materials and components show reduced radiation resistance when mechanical stress is applied during irradiation, with intermittent stress more damaging than constant stress. This may be due in part to the production of free radicals by mechanical stress.[27] Crystallization effects have also been suggested as significant to mechanical effects.[55] Exceptions occur, a number of lubricants show better radiation resistance in dynamic than in static tests. Most elastomeric seals exhibit less increase in compression set when irradiated under dynamic stress.

Materials for which sensitization effects are known are indicated in Tables 4-2 through 4-4 of Section 4.

In equipment qualification, combined stress effects are simulated by sequential testing. The first test is usually irradiation. Sensitization to subsequent environmental stress occurs (if the material is subject to sensitization). This is intended to simulate synergistic effects as can be seen in the suggested dose-damage profiles of Figure 2-1. The degradation indicated by section C would not be instantaneous, but appears to be because time is not a coordinate.

Figure 2-1

SUGGESTED DAMAGE PROFILES FOR SIMULTANEOUS/ SEQUENTIAL TESTS



Clough's investigation of low dose rate oxidation effects for two materials known to be susceptible to the combined influence of radiation, oxidation, and temperature[10] is of particular interest. From graphical test data (reproduced in Figures 2-2 and 2-3) it is clear that the strongest synergistic effect is related to oxidation; degradation is blocked in nitrogen atmosphere. Ten to fifteen percent decrease in elongation (most sensitive property) is noted for PE irradiated in air at 83°C at ~ 1×10^6 rads. This compares well with damage thresholds indicated by higher dose rate tests at ambient temperatures for thin films.[36] PE and PVC formulations with both higher and lower thresholds are reported in the literature (See Section 3).

These tests provide an opportunity to compare simultaneous and sequential test data. Samples were subjected to 83 days of thermal stress and 83 days of irradiation (~ 10 megarads for PE and ~ 8.7 megarads for PVC), as indicated by points e and f in Figures 2-2 and 2-3. Though each sequential test actually required two 83 day periods, a better comparison of effects is achieved by adding an equal stress line to Clough's figure and shifting the sequential test points to that line, as indicated by points e' and f'. It then becomes apparent that sequential testing approximately simulates the synergistic effects of the combined environment if radiation is the first test and if dose rates are equal.

It is further possible that points e represent radiation sensitized states for both materials and that further thermal stress would result in degradation profiles similar to curve BC of Figure 2-1. It is not possible to address dose rate effects analytically from this data since only one dose rate was used for each material.

It should be noted that efforts to provide simultaneous stress environments don't always result in more realistic estimates of equipment or material service life. Reference 44 (coatings) and Reference 59 (insulations) report comparable sequential and simultaneous stress test results. Unfortunately, in both cases there does not appear to be adequate access of air to the simultaneous test facility (small airtight chambers). This is probably more serious in the insulation study which involves materials known to be sensitive to oxidative degradation.

Radiation induced transient increases in electrical conductivity are known at levels below the threshold damage levels given here.[1] There appears to be no significant effect for equipment in low dose rate and low total dose (benign) radiation environments.

Figure 2-2

POLYETHYLENE DEGRADATION
(Adapted from Reference 10)

Dose Rate=4.5 x 10^3 rads/hr

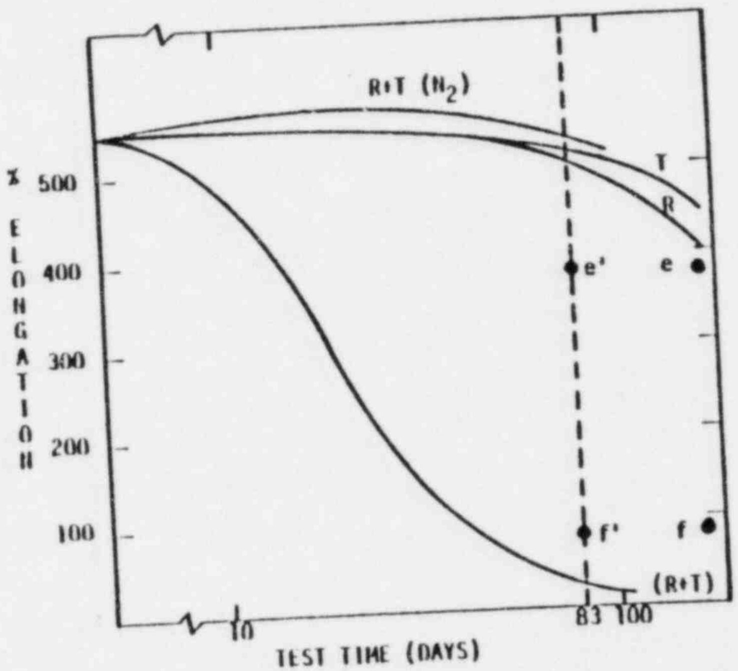
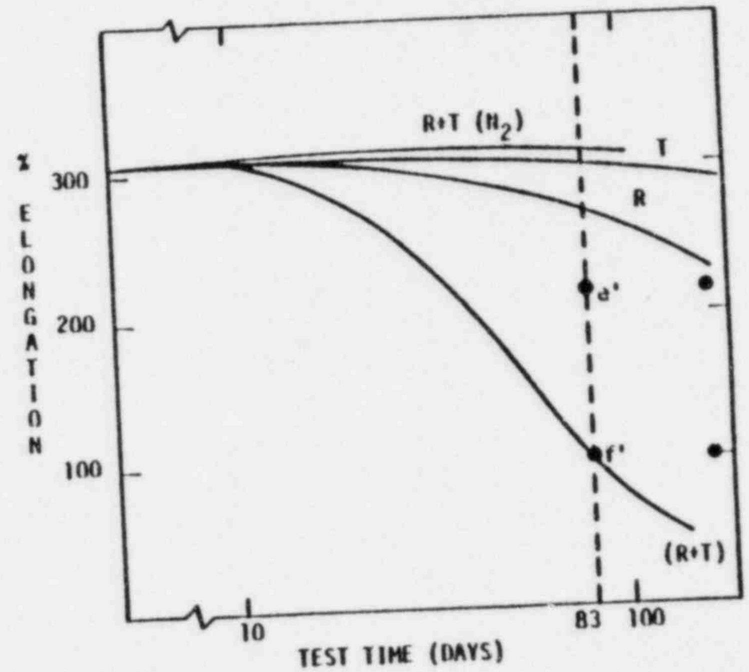


Figure 2-3

POLYVINYL CHLORIDE DEGRADATION
(Adapted from Reference 10)

Dose Rate = 4 x10^3 rads/hr



e, e' = 83 days at 80°C followed by 83 days radiation at 25°C in air

f, f' = 83 days radiation in air at 25°C followed by 83 days at 80°C

R = radiation at 25°C in air

T = 80°C, no radiation

R+T(N_2) = radiation at 80°C in nitrogen

R+T = radiation at 80°C in air

At higher dose rates transient changes in breakdown voltage, dielectric strength, etc. may seriously affect equipment operation but usually degradation of mechanical properties is the limiting effect.

Permanent changes in the electrical properties of most materials will occur at some level above threshold. The presence or absence of electrical load during irradiation does not appear to affect the type or extent of permanent "radiation damage" to any significant degree. Permanent failure mechanisms induced by and during transient changes in electrical properties are excluded.

The presence or absence of moisture does not appear to impact the "radiation resistance" of most materials. Cellulose was the only material treated here for which such an effect was clearly demonstrated. "Radiation damage" to polyurethanes may be greater in moist environments but these are easily degraded by moisture alone and comparative tests were not found. A number of materials exhibit increased water absorption in harsh radiation environments[55] but this generally occurs only at levels where the mechanical properties are greatly degraded.

AGING EFFECTS/DOSE RATE EFFECTS

The least well understood and the most difficult effects to duplicate are those that result from a combination of long term, low level stresses. Acceleration of "radiation aging" effects is as much "state-of-the-art" as is acceleration of other aging effects. Defining adequate techniques requires careful consideration of known dose rate effects including:

- Transient electrical effects are dose rate dependent but are usually most severe at high dose rates.
- Dose rates of 10^4-10^7 rads/hr result in approximately equal degradation for equal total dose to a given material if other environmental stresses are equal (Reference 3).
- Enhanced degradation occurs following irradiation for many polymers; inhibited degradation occurs for a few materials. These may be termed sensitization effects.
- The most significant enhanced degradation is usually associated with oxidative reactions. Degradation from other delayed reactions is usually minor.
- Little comparable test data is available for most materials concerning synergistic effects of dose rates.

Chapiro,[21] Gillen,[28] and others have conducted dose rate studies for specific materials which are of interest. Unfortunately, only comparisons of immediate, rather than delayed, effects were found. The extent to which sensitization effects compensate for the less damaging direct effects is probably adequate (based on inference), but comparative studies would be helpful.

Section 3

RADIATION EFFECTS FOR SPECIFIC MATERIALS

Data for specific materials is presented in six distinct groups on the basis of similar properties or applications. These are:

- Thermosetting Plastics
- Thermoplastics
- Elastomers
- Lubricants
- Adhesives
- Protective Coatings

Within each group, materials with similar chemical structures are presented together. The lowest threshold identified is indicated to the right of the generic name unless there is good evidence that the value is not generally applicable. In that case, the lowest value found is discussed in the summary data. The property first affected is indicated beside the threshold value.

The dose unit most often used by the nuclear industry is rads (air). The unit used in most of the data reviewed was rads (carbon). This is within about 1% of rads air for Cobalt 60, the most commonly used radiation source. For some data, dose was specified as rads (polymer), which is within 5% of rads (air) for most polymers. Gamma dose units are expressed here simply as rads, ignoring the small differences among these units. Neutron and beta doses are expressed as they were in the cited references. Some calculations and conversion factors are presented at the end of this section.

THERMOSETTING PLASTICS

Thermosetting polymers harden permanently during heating or curing. Many of these rigid plastics are quite radiation resistant, but are less versatile than thermoplastics.

Aminoplast Resins

These are reaction products of aldehydes and certain amine compounds. They are most often used as molding materials but to some extent in adhesives and coatings.

Aniline Formaldehyde/threshold - 6.7×10^5 rads/impact strength. Impact strength of Cibanite increased above threshold dose with a 25% increase at 1.3×10^7 rads but 50% loss at 1.2×10^8 rads. Tensile and shear strength and elongation decreased at approximately the same rate with threshold, 25% decrease, and 50% decrease occurring at 9.1×10^7, 2.4×10^9, and 3.6×10^9 rads, respectively. Elastic modulus was unchanged at the highest dose.[36]

Melamine Formaldehyde/threshold - 6.7×10^6 rads/tensile/elongation. Melmac (cellulose filler) displayed approximately equal decrease in tensile strength and elongation with threshold, 25%, and 50% decrease at doses of 6.7×10^6, 6.6×10^7, and 1.6×10^8 rads. Shear strength exhibits the same threshold, but is reduced more slowly. A 25% decrease occurs at 3.9×10^8 rads and 50% at 9.1×10^8 rads. Impact strength was little affected.[36]

Urea Formaldehyde/threshold - 7.5×10^6 rads/tensile/elongation. Plaskon Urea showed decreasing tensile and shear strength and elongation. Threshold, 25% decrease and 50% decrease in these properties were observed at 7.5×10^6, 3×10^7, and 7.3×10^7 rads, respectively. Elastic modulus decreased slightly after 3.2×10^7 rads. Impact strength decreased initially at 3.2×10^7 rads and was reduced 25% at 5.8×10^8 rads.[36]

Casein Resin/threshold - 4×10^6 rads/impact strength. A 50% reduction in impact strength of the protein-based resin, Ameroid, was induced by 3×10^7 rads. Tensile and shear strength and elongation were initially changed at approximately 10^7 rads and reduced to 50% of the original value at approximately 10^8 rads. Elastic modulus was unchanged.[36]

Epoxy Resins/threshold - 2×10^8 rads or greater/varies

References 26 and 42 report detailed investigations of the mechanical and electrical properties of various epoxies. Novalac and glycidyl amine types are even more radiation resistant than standard epoxies (DGEBA). With some curing agents, doses of 4×10^9 rads have resulted in no loss of mechanical properties. Reference 48 reports that standard epoxy resins cured with aromatic amines were more radiation resistant than those cured with aliphatic amines or acid anhydrides; threshold damage occurred at 10^9 rads and 2×10^8 rads, respectively. Novalac has been found to be quite resistant to oxidation while many others are not. A combined environment of heat and radiation was found to be less severe than heat alone for one epoxy laminate.[36] Electrical properties show some variation from exposure to radiation environments, but are of adequate stability for use in most electronic circuits.[36]

Phenoxy Resins/threshold - unknown

Though chemically similar to epoxy formulations, radiation resistances of phenoxy resins appear to be generally less than that of epoxies. One test indicated a loss of 75% of the initial tensile strength after 3×10^8 rads with most of the material's ductility also lost.[55]

Furane Resin/threshold - 3×10^8 rads/tensile/elongation.

Duralon, an asbestos and carbon black-filled, furane-based resin, shows very good radiation resistance. The properties measured (tensile and impact strength, elongation, and elastic modulus) showed initial degradation at 3×10^8 rads and 25% damage at 3×10^9 rads.[37]

Phenolic Resins/threshold - 3×10^5 to 3.9×10^8 rads/elongation

Unfilled and cellulose-filled phenolics are not particularly radiation resistant and after irradiation become more susceptible to moisture damage and disintegration. Phenolic laminates and mineral-filled phenolics exhibit very good stability in radiation fields. Phenolic laminates irradiated at temperatures as high as 900°F retain flexural strength as good as or better than nonirradiated controls. Oxidation may be inhibited by radiation-induced reactions in this case.[36] Electrical properties are generally stable to high doses. Transient increases in leakage resistance of a factor of 10 have been noted in connectors utilizing phenolics, but recovery to original values was rapid.[33] The least resistant phenolic resin reported was linen fabric-filled, with 25% damage shown at 3×10^6 rads. The most resistant was asbestos-filled (Haveg 41), with 25% damage after 3.9×10^9 rads.[36] Graphite fillers do not appear to be effective with phenolics. Graphite-filled Karbate exhibited threshold damage at 8×10^5 rads. Some phenolic laminates have been found unaffected by as much as 8×10^9 rads.

Polyester Resins (Excluding Phthalates)/threshold -10^5 to 10^6 rads/elongation

Polyester resins (allylic and alkyds) vary in radiation resistance, depending on the aromatic content and the nature of the crosslinking monomer. Threshold for radiation damage to most nonfilled resins are 10^5 to 10^6 rads.[37] Elongation of Selectron 5038 (unfilled) was reduced approximately 20% at 8 x 10^6 rads, and 50% after 10^9 rads. One mineral-filled polyester (Plaskon Alkyd) showed damage thresholds for tensile, shear, and impact strength, and elongation at 7.9 x 10^7 rads; 25% decreases occurred around 3.5 x 10^9 rads.[36]
Polyesters may be quite sensitive to degradation by ultraviolet radiation and by oxidation. Like the phenolics, they show dramatic increases in radiation resistance with inorganic fillers.

One polyester-glass laminate exhibited no change in tensile strength or elastic modulus after 4 x 10^8 rads. Electrical properties (permanent) of one mineral-filled polyester were unchanged after 2.5 x 10^9 rads.[55] Reference 61 reports a threshold for GPO-2 and GPO-3 laminates of 10^7 rads, but test data for those materials was not located.

Diallyl Phthalate, Glass-Filled/threshold - 1.8 x 10^9 rads/tensile/elongation

Though technically a polyester, this material is treated separately because of its stability. Only minor changes in physical and electrical properties have been noted for glass-filled DAP after doses up to 10^{10} rads. Ultimate elongation and tensile strength increased (improved) after a beta dose of 1.8 x 10^9 rads at 60°C (5.8 x 10^{16} e/cm^2, E = 1 MeV). Transient increases in insulation resistance were followed by rapid recovery.[33] At a neutron dose of 1 x 10^9 rads (1.67 x 10^{16} n/cm^2, E $\geq$ 2.9 MeV), diallyl phthalate was found suitable as connector insulation material.[33] The 10^6 rad threshold indicated in Reference 61 is probably based on the threshold of the orlon filler.

Polyimide/threshold - 10^7 rads/elongation/tensile strength

One polyimide film was initially affected at 10^7 rads. Tensile strength increased, then dropped gradually, but was still greater than 50% of the original value after 10^9 rads. Elongation decreased gradually beyond threshold and was reduced by half at 10^9 rads. DuPont H-film shows threshold loss of elongation at 4 x 10^8 rads, but retained 50% of the original at 3 x 10^9 rads. Tensile strength was initially changed at 10^9 rads, in air. In vacuum, elongation was first affected by 10^9 rads and retained better than half its initial value at 10^{10} rads.[47] Electrical (permanent) and physical properties of Kapton were stable to 10^9 rads and were not greatly degraded after 10^{10} rads. Dielectric breakdown during electron irradiations have been observed to increase with increasing dose rate and/or elevated temperature.[33] No documentation was found to support the 10^6 rad threshold indicated by Reference 61.

Polyurethane Resins/threshold - approximately 10^7 rads/tensile strength

Polyurethanes are polyester or polyether diisocyanates. Thermoplastics and elastomeric forms are also available. Various curing agents and additives result in a range of susceptibility to radiation and to radiation-sensitized oxidation.

STA-Foam AA-402 (urethane foam insulation) was reduced in compressive strength to 34% of the original value by 8×10^7 rads when irradiated in air at 27°C. Vacuum irradiation of the same material at 40°C to 9×10^7 rads resulted in only a 17% loss of compressive strength.[4]

Reference 36 reports that CPR-20 and CPR-1021 thermal insulations showed little change in compressive strength at 10^9 rads. A urethane laminate exhibited initial weight loss at 1.75×10^8 rads and 1% weight loss after 7×10^8 rads. Minor decreases in flexural strength and elastic modulus were noted at 7×10^8 rads.[36]

An electron irradiation of one polyurethane to 1.8×10^9 rads (5.8×10^{16} e/cm^2, E = 1.0 MeV) at 60°C resulted in serious physical degradation, including 67% increase in hardness, 76% increase in stiffness in flexure, 59% decrease in tensile strength, and 99% decrease in ultimate elongation. A separate study, including exposure to 1.2×10^{14} n/cm^2, E > 0.5 MeV, and 1.4×10^6 rads gamma resulted in insignificant physical degradation. Permanent changes in volume resistivity and insulation resistance were less than one order of magnitude for both studies. A polyurethane foam encapsulating compound showed transient decreases in insulation resistance of nearly 10^3 during radiation exposure at a rate of 1.5×10^{11} n/cm^2/second (E > 0.1 MeV) and 6×10^4 rads/hour gamma. Full recovery occurred within 3 days after a total exposure of 1.5×10^{15} n/cm^2 (E>0.1 MeV) and 1.8×10^6 rads gamma.[33]

Silicone Resins/threshold - approximately 10^6 rads/varies

Kirsher[37] suggests thresholds on the order of 10^6 rads for silicone formulations except glass-reinforced resins.

Threshold loss of tensile strength for one unfilled silicone resin was noted at 7 x 10^6 rads and 50% decrease in that property after 7 x 10^7 rads.[55]

Reference 25 reports post-irradiation degradation of silica-filled polysiloxanes in air. The effectiveness of colloidal sulphur and benzophenone additive in reducing crosslinking and gas evolution are discussed. Phenyl methyl silicones are more stable than dimethyl silicones.

Elevated temperatures usually result in reduced radiation resistance. Reference 37 estimates damage thresholds for silicone insulations at 4.5 x 10^7 to 1.8 x 10^8 rads at 25°C, or 4.5 x 10^6 to 1.6 x 10^7 rads at 200°C in air. Reference 33 notes satisfactory performance of one silicone-alkyd wire insulation after 5.3 x 10^7 Roentgens at 150°C. Reference 59 compares damage to silicone insulations exposed to simultaneous and sequential radiation and elevated temperature (oxidation effects may not be adequately reproduced in the simultaneous test).

One silicone-glass fabric laminate subjected to simultaneous temperature (500°F) and irradiation showed tensile strength 110% of that of a control specimen subjected to temperature only after 2.1 x 10^7 rads and 70% of the control value after 8.3 x 10^7 rads. One heat-resistant laminate retained approximately 50% of its original flexural strength after 8.3 x 10^8 rads and 2 hours in boiling water (tensile and compressive strength were greater than the original value).[36] A silicone-asbestos laminate showed only minor changes in physical properties after 6 x 10^8 rads at room temperature in air.[37]

Pyrrone/threshold - approximately 10^8 rads/flexural strength/elastic modulus

Pyrrones are polyimidazopyrrolone polymers. The condensed aromatic ring structure is quite stable in radiation fields. Reference 55 reports threshold changes in flexural strength and elastic modulus at 1 x 10^8 rads. Both increased gradually to 10^{10} rads. Electron irradiations to 1 x 10^{10} rads (E = 1 MeV) and 5 x 10^9 rads (E = 2 MeV) resulted in insignificant degradation of mechanical and permanent electrical properties. At 10^{10} rads yield strength increased by about 70%; tensile strength was unaffected; and elongation decreased by two-thirds of the original value. Dielectric breakdown induced by electron irradiations have been observed to increase with increasing electron flux and to decrease with increasing temperature. No dielectric breakdowns were observed for proton irradiations with similar particle fluxes.

THERMOPLASTICS

Thermoplastics soften when heated, but return to their original properties when cooled. These are the most versatile plastics. Crosslinking can transform them into thermosetting materials.

Acetal Resins/threshold - 6×10^5 rads/tensile/elongation

Acetal resin is chemically polyformaldehyde. Test data was located only for the homopolymer, Delrin. Reference 61 lists a 10^5 rad threshold, which may have been derived from Reference 4, which gives an "order-of-magnitude" threshold of 10^5 rads, but referred to data showing a 7×10^5 initial change. Reference 48 reported 20% loss in tensile strength at 3×10^6 rads and 50% loss at 8×10^6 rads concurrent with 20% loss in elongation at 1×10^6 rads, 50% loss at 2×10^6 rads, and 90% loss at 3×10^6 rads for a 0.02-inch thick specimen. Reference 55 reported a 6×10^5 rad threshold for tensile strength and elongation for a Delrin with lower initial tensile strength and elongation. A 25% loss of tensile strength was observed at 1×10^6 rads, 50% at 4×10^6 rads, and 75% at 6×10^6 rads. Loss in elongation was 25% at 0.9×10^6 rads, 50% at 2×10^6 rads, and 75% at 3×10^6 rads. Reference 36 reports poor retention of physical properties at 4.4×10^6 rads. Tests reported were static, in air, at ambient temperature. The acetal copolymer is sold as Celcon. Some other copolymers are Alkon, Durathon, Ertacetal, and Hostaform C. Chain scission is probably dominant. Acetals are often used as gears, bearings, or other molded-plastic parts.

Acrylic Resin/threshold - 7×10^5 rads/tensile/elongation

Acrylic resin is generally 90% or more polymethyl methacrylate. Test data for Lucite and Plexiglass give fairly similar estimates of radiation resistance. Reference 36 reports initial changes in tensile strength and elongation for Lucite at 7.5×10^5 rads, with 25% loss in elongation at approximately 10^7 rads and 50% loss at 2×10^7 rads. Tensile strength was reduced by 25% at approximately 10^7 rads and by 50% at 2×10^7 rads. Loss in light transmission was approximately 50% at 5.5×10^6 rads. Shear strength and impact strength were first affected at approximately 10^7 rads. Both these properties were reduced by 25% at 4 x 10^7 rads and 50% at 6.2 x 10^7 rads. The elastic modulus began increasing at 1 x 10^7 rads and was 12% higher at 5 x 10^7 rads. Increased oxidation has been noted following irradiation, but heating at 80°C in air for 1-6 hours shows about the same degradation as 500 hours of room temperature storage.[37] About 35 ml/gm of gas is evolved at a total dose of 10^9 rads, G_{gas} is approximately 1.5. A portion of the gaseous products are trapped in the polymer. Heating during irradiation causes foaming and expansion of the material to 5 to 10 times the original volume by trapped gases. G(S) = 1.1 -1.9 at room temperature in air, but increases at higher temperatures.

The softening temperature of polymethyl methacrylate is greatly reduced by large radiation doses. Reference 21 reports a distinct decrease in softening temperature after 7.0 x 10^5 rads.

<u>Polyacrylonitrile</u>/threshold - approximately 1 x 10^6 rads/tensile strength

Reference 25 gives a tensile strength threshold of 1 x 10^6 rads for fibers subjected to neutron irradiation in air. Reference 9 reports significant loss in tensile strength for Orlon fibers after 8 x 10^6 rads and suggests a maximum use level of 5 x 10^7 rads. Dolan and Dynel are other commercial names for polyacrylonitrile fibers.

<u>Polymethyl Alpha-Chloroacrylate</u>/threshold - approximately 7 x 10^5 rads/unknown

Reference 36 reports a damage threshold of 8.2 x 10^5 rads and 25% damage at 1.1 x 10^6 rads, but does not specify the properties tested. Reference 37 reports radiation resistance similar to polymethyl methacrylate and the threshold is assumed to be the same as that of PMMA. Tests were performed on commercial samples of Gafite.

<u>Cellulose</u>/threshold - 1 x 10^5 rads/tensile strength

Reference 9 found threshold radiation damage for cotton fibers irradiation in air at about 10^5 rads and a 23% loss in tensile strength at 4.4 x 10^6 rads. Reference 58 reports a decrease in breaking strength of 5 to 7% for 1 x 10^6 rads. The basic component of electrical insulating papers is cellulose.

Reference 21 reports that post-irradiation degradation occurs only if the moisture content of irradiated samples is quite low. Degradation at higher doses is rapid. Decreases in crystallinity and increases in hydrolysis rates are noted. G(S) may be as high as 11. Reference 33 reports a failure threshold for capacitors using paper dielectrics of 1.04×10^{14} neutrons/cm^2 ($E > 2.9$ MeV) and 3.96 Mrads gamma at 85ºC.

Cellulose Derivatives

Chemical derivatives show better radiation resistance than the base polymer.

Cellulose Acetate/threshold - approximately 8×10^5 rads/tensile strength. Reference 9 reports the 8×10^5 rad threshold for Rayon fibers and suggested use limits of 2×10^7 rads. Reference 21 reports some reduction in thermal resistance. Temperature at break of specimens under constant stress was gradually reduced from 170ºC for the unirradiated samples to 135ºC for samples which had received 2×10^7. The effect was the same in air or N_2 and at various dose rates. Reference 36 reports initial changes in shear strength of Plasticele at 2×10^6 rads, 25% decrease at 2×10^6 rads, and 50% loss at 3×10^7 rads. Impact resistance and elongation were degraded at about the same rate. Tensile strength was 50% at the original value of 6×10^7 rads.

Reference 37 notes that dielectric properties of cellulose acetate are stable to higher radiation doses than are the physical properties. Reference 48 reports G_{gas} =0.08 after 10^9 rads with 17 ml/gm evolved.

Cellulose Acetate Butyrate/threshold - 3.4×10^5 rads/elastic modulus. Tenite II has been tested in fiber and thin film form. Elastic modulus is the first property affected. Reported thresholds are $3.4 - 5 \times 10^5$ rads with an increase of approximately 20% at 3.2×10^7 rads. Impact resistance is affected above doses of $6.8 - 8 \times 10^5$ rads. A 25% loss in impact resistance occurs at 6.6×10^6 rads or more and 50% loss is noted at 19 - 30 megarads. Shear strength, elongation, and tensile strength are affected at approximately 1.5×10^6 rads, reduced 25% at 2.3×10^7 rads and 50% at 3.3×10^7 rads. Oxidation effects occur. Reference 48 reports better radiation resistance at high dose rates for 125-mil thick samples.

Cellulose Nitrate/threshold - 5×10^5 rads/elongation. Elongation of Pyralin samples was affected at 5×10^5 rads with a 25% reduction of that property at 3.5×10^6 and 50% loss at 1×10^7 rads. Impact resistance showed a threshold of 1×10^6

rads with rapid degradation above threshold. The value at 3×10^6 rads was 50% of the original. Tensile and shear strength was affected at 1×10^6 rads, but these properties were not degraded quickly. At 2×10^7 rads, tensile and shear strength were 75% of original values and 50% at 3×10^7 rads. Large quantities of gas are evolved.

Cellulose Propionate/threshold - 3×10^5 rads/impact resistance. Impact resistance of Forticel samples was affected above 3×10^5 rads,[36] but was still 75% of the initial value after 4.4×10^6 rads and 50% at 1.5×10^7 rads. Tensile strength was reduced 25% at 5×10^6 rads and 50% at 1.5×10^7 rads. Elongation was reduced 25% at 3.5×10^6 rads and 50% at 1.5×10^7 rads. Shear strength was affected by 4×10^5 rads, but was still 50% of the original value at 3×10^6 rads. Higher values are observed for thick samples[48] and $G_{gas} = 1.5$ with 35 ml/gm evolved at 10^9 rads.

Ethyl Cellulose/threshold - 1.5×10^6 rads/impact resistance. Ethocel R-2 shows initial reduction in impact resistance at 1.5×10^6 rads, 25% reduction at 5×10^6 rads, and 50% loss at 1×10^7 rads.[36] Elongation and shear strength are affected at 2×10^6 rads. Elongation is reduced 25% at 4×10^6 and 50% at 4×10^7 rads. Tensile strength is affected above 3×10^6 and reduced to 50% at 2×10^7 rads. Tests reported were for static irradiations in air at ambient temperature. Reference 48 gives G_{gas} approximately 4.6 with 105 ml/gm evolved at 10^9 rads.

Halogenated Polymers

Many of the commercial halogenated polymers are chloride or fluoride substituted vinyls; others are substituted polyolefins.

Polyvinyl Chloride, Rigid/threshold - greater than 10^6 rads. Reference 48 reports 80% or better retention of tensile and notch impact strength of a 0.17-inch thick sample irradiated in air at 2×10^5 rads/hour and ambient temperature to a total dose of approximately 10^9 rads. Reference 33 reports very serious degradation at 1.3×10^9 rads for rigid PVC irradiated at 60°C with 1 MeV electrons. Radiation resistance is undoubtedly dependent on thermal and oxidizing conditions, as is the resistance of plasticized PVC.

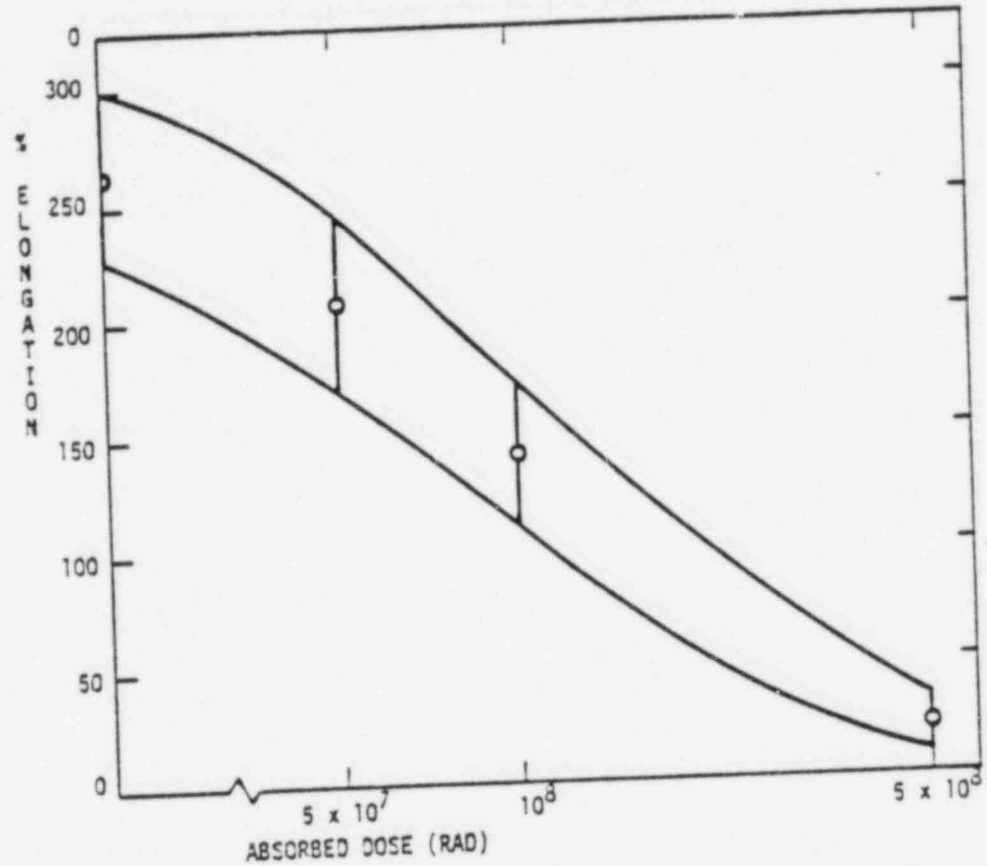
Polyvinyl Chloride, Plasticized/threshold - 5×10^5 rads/temperature at break. Reference 8 reports that DC resistivity of one PVC cable insulation was affected after 5×10^6 rads and sensitivity to hot water and steam was increased above this value. Large decreases in oxidation resistance were noted above 5×10^6.

Scission or crosslinking may predominate, depending on temperature and oxidizing conditions. Plasticizers and additives are not generally known for commercial materials, but a fairly large range of radiation resistances occur for different materials (Figure 3-1). Reference 48 reports results for 4 and 20-mil samples of Geon 8630 irradiated in air at room temperature. The 4-mil sample lost approximately 20% of original tensile strength after 7×10^6 rads, but retained less than 50% after 1×10^8 rads. The 20-mil sample lost less than 20% of original tensile strength at 1×10^8 rads. Elongation of the 4-mil sample was reduced 20% by 1×10^7 rads. 7×10^7 rads were required for the same change in elongation of the 20-mil sample. Similar indications of extensive oxidation effects were observed with 4-mil samples of Geon 8640 irradiated in air and vacuum. In air, tensile strength was decreased approximately 20% by 7×10^6 rads and 50% by 1×10^8 rads. Elongation decreased 20% at 2×10^7 rads and 50% at 8×10^7 rads. In vacuum, tensile strength was reduced 20% by 7×10^7 rads and elongation was reduced 20% by 6×10^7 rads. References 21 and 39 note marked differences in thermal properties of irradiated PVC. A reduction in the melting temperature of the polymer occurs in air (but not in vacuum). Reduction of the temperature at break of samples heated under constant stress was noted for samples after 5×10^5 rads. After 1.1×10^7 rads, a 30-40°C reduction in temperature at break was achieved. The rate of HCL evolution is affected by the temperature during and subsequent to irradiation. $G_{HCL} = 5.41$ (-90°C), = 13 (30°C), = 23 (70°C) after 2×10^7 rads. Diffusion and permeability constant are increased by irradiation but may decrease again at higher doses. Crosslinking is inhibited in air, but may be enhanced by inclusion of polyfunc-tional materials, such as polyethylene glycol dimethacrylate. The temperature-oxidation resistance of commercial materials will vary with the effectiveness of free radical scavengers and antioxidants.

Polyvinyl Fluoride/threshold approximately 10^7 rads/elongation. DuPont R-20 exhibits approximately 20% loss of elongation at 2×10^7 rads and 50% loss at 5×10^7 rads. Tensile strength was not appreciably affected below 1×10^8 rads. Sample thickness and dose rate were not given.[48] Polyvinyl fluoride is also marketed as Tedlar. Radiation resistance is probably less at elevated temperatures. One electron irradiation at 60°C to 1.3×10^9 rads resulted in severe physical

Figure 3-1

"SIMILAR" PVC CABLES IRRADIATED AT 20-40°C



Data for cables from 38 manufacturers

(From Reference 50)

degradation but unchanged insulation resistance and a 7% decrease in dielectric constant. Dissipation factor increased one decade.[33]

Polytetrafluoroethylene/threshold - 1.5×10^4 rads/elongation. Reference 47 reports a threshold change of elongation at 1.5×10^4 rads for Teflon (TFE) in air, of tensile strength at 2.1×10^4 rads, of shear and impact strength and elastic modulus at 1.8×10^5 rads. A 25% decrease was noted at 3.4×10^4 rads for elongation, 1.2×10^5 rads for tensile strength, and 4×10^5 rads for shear strength. Impact strength increased 25% at 3.6×10^5 rads. Oxidation effects are quite large. Radiation resistance is approximately ten times greater in vacuum or fluid. Teflon hoses tested under simulated operating conditions failed, by leakage, at 1×10^5 rads when exposed to intermittent fluid pressure of 1,000 psig and at approximately 1×10^6 rads when subjected to 1,200 psig static pressure. The radiation exposure-damage relation was relatively insensitive to temperature in the range of 100 to 350°F in that test. Teflon back-up rings (in fluid) have been found serviceable in some applications to approximately 4×10^7 rads, although physical degradation occurs.[36]. Sharp decreases in melting temperature were noted for irradiations above 330°C.

Teflon-FEP (copolymer of fluoroethylene and perfluoropropylene) is more resistant that Teflon-TFE. Teflon-FEP shows ten times greater radiation resistance in vacuum and sixteen times greater resistance in air for 10-mil films.[46] Temperature effects have been noted. Damage at cryotemperatures was negligible for a dose that produced 40% loss of tensile strength at 73°F and 60% damage at 350°F.

Electrical properties are affected differently for irradiation in air and vacuum. TFE volume resistivity has been observed to drop by a factor of 10^2-10^3 in vacuum radiation and to drop an additional factor of 10-10^2 after irradiation (gradual recovery may occur). One Teflon-insulated wire is reported to show slightly reduced flexibility at 10^3 rads in a 5 psia O_2 atmosphere at 90°C. A similar Teflon wire lacking a polyimide coating present on the first wire did not show reduced flexibility under the same conditions.[33] This indicates that the materials were incompatible, not that the radiation level was significant.

Tetran, Fluorlon, and Hostaflon FT are a few of the other commercial names for polytetrafluoroethylene. Main chain scission is dominant and there is little evidence of any crosslinking during irradiation.

Polychlorotrifluoroethylene/threshold - 1.2×10^6 rads/shear strength/elastic modulus. Reference 9 reports approximately 50% loss of elongation and impact strength with negligible change in tensile strength at 1×10^7 rads for a 0.3 cm sample of Kel-F irradiated in air. Reference 33 gives a 47% loss of elongation, 16% decrease in impact strength, and unchanged tensile strength at 2.4×10^7 rads. Decreases in surface and volume resistivity by a factor of $10\text{-}10^2$ have been noted in the irradiation of Kel-F to 2.1×10^7 rads with no post-irradiation recovery. A concurrent decrease in dissipation factor occurred. (Reference 37 gives a threshold of 1.2×10^6 rads for shear strength and elastic modulus, 3.6×10^6 rads for elongation and impact strength, and 3.6×10^7 rads for tensile strength of Fluorothene. Fifty percent (50%) damage levels were 1.1×10^8 rads for tensile strength, 4.1×10^7 rads for elongation and impact strength, and 2×10^8 rads for shear strength (initially increases above threshold, then decreases). Reference 55 notes return to original values of volume resistivity, dielectric strength, and arc resistance for PCTFE after 2×10^8 rads in air. Oxidation effects are not as dramatic as with Teflon, but radiation resistance is better in vacuum or inert atmosphere. Scission is dominant. Hostaflon and Trithene are additional trade names.

Polyvinylidene Chloride/threshold - 3.7×10^6 rads/elongation. Reference 37 reports initial change in elongation and impact strength at 3.7×10^6 rads. Tensile strength and elastic modulus are affected at 6.4×10^6 rads and shear strength begins to decrease at 4.1×10^7 rads. A 25% loss occurs for elongation and impact strength at 4.1×10^7 rads, for tensile strength at 1.6×10^8 rads, and for shear strength at 5.5×10^8 rads. Reference 36 provides supporting data and notes general darkening and evolution of HCL. Tests were in air at ambient temperatures on commercial samples of Saran. Data on comparable materials, such as Vestan, Velon, and Diorit were not found. Reference 48 reports lower radiation resistance for a vinyl chloride-vinylidene chloride copolymer with an approximate 20% decrease in elongation and impact strength at 1×10^6 rads and a 50% decrease at 1×10^7 rads.

Polyvinylidene Fluoride/threshold - approximately 8×10^6 rads/not specified. Kynar 400 showed only color change after 10^7 rads in air or vacuum, but was brittle and lost flexural and tensile strength at 10^8 rads. Volume resistivity was reduced by approximately 10^5 after 2×10^8 rads in air. Dissipation factor increased by less than a factor of 10. The dielectric constant was unchanged. No physical damage was noted after 10^8 rads at cryotemperatures. Elevated temperatures would be expected to increase radiation sensitivity. Reference 13 indicated the lowest value, but did not indicate property changes at that level.

Tefzel Fluoropolymer (Copolymer of Ethylene/Tetrafluoroethylene)/threshold ?/elongation. Tefzel insulation exhibits a decrease in elongation of approximately 25% at 2×10^7 rads and 50% at 3×10^7 rads. Dose rate effects were noted with higher rates leading to less damage for a given total dose. This is probably due to greater oxidative effects at lower dose rates.[28] Electrical properties are reported to be stable at much higher radiation doses. The manufacturer's data shows serious reduction in flex life after 1×10^8 rads. Samples irradiated in nitrogen were not as much affected as those irradiated in air.

Polyvinyl Chloride Acetate/threshold - 1.4×10^6 rads/elongation. Reference 36 reports softening and darkening of this material with evolution of HCL. Elongation increases rapidly above threshold with a 50% increase noted for vinylite at ˜ $\times 10^7$ rads. Other physical properties are not affected until much higher radiation doses have occurred. Shear strength of vinylite is affected initially at 5×10^7 rads, tensile strength at 5×10^8 rads, and impact strength at 4×10^9 rads. Reference 55 notes increased water absorption after 1.5×10^7 rads. One polyvinyl chloride acetate sample irradiated at 60°C to 1.8×10^9 rads (with electrons) showed little change in hardness and tensile strength while flexibility increased approximately 30%. Dielectric constant and dissipation factors were unchanged while insulation resistance decreased by 10^2.[33] Reference 48 reports a 200% increase in elongation at 5×10^6 rads, followed by gradual softening and weakening of the plastic.

Aliphatic Polyamide (Nylon Fiber)/threshold - 8.7×10^4 rads/flex life

Reference 36 reports reduced flex life of nylon tire cords (nylon 6, 66, and 66HT) at 8.7×10^4 rads, but also notes that tests on tires containing these cords did not show as pronounced an effect. Irradiation of the same fibers in vacuum showed only a 10-15% reduction in flex life after 8.7×10^6 rads. Sensitivity to radiation in air is estimated at four to five times greater than in vacuum. A number of effective "antirads" are available. Doubling of radiation resistance is reported with Arcoflex C and a four-fold increase has been observed with quinone or pyrogallol. Nylon fiber with an age resistor and phenothiazine showed little change in tensile strength and 1.5 times original elongation after 1.7×10^7 rads in air. Reference 21 reports similar behavior of nylon (polycaprolactam) irradiated at temperatures of -80°C, room temperature, and 100°C.

Reports of transient electrical effects were not found, but Reference 33 reports permanent effects from electron irradiation to 1.8 x 10^9 rads (5.8 x 10^{16} e/cm^2, E = 1.0 MeV) at 60°C. Insulation resistance increased about one order of magnitude, dissipation factor decreased less than an order of magnitude, and dielectric con- stant at 1 KHz decreased a maximum of 32%.

Aramid/threshold - 7 x 10^6 rads/elongation

Aromatic polyamides show considerably better radiation resistance than aliphatic types and are less sensitive to oxidation. Kevlar and Nomex nylon are better known trade names. Nomex yarns have been reported to be unaffected by 3.3 x 10^8 rads at ambient temperature. At 500°F and 1.4 x 10^7 rads, the yarn retained 45% of original elongation and 62% of its initial tensile strength.[36] Reference 13 classes Kevlar as similar in radiation resistance to polyimides. The value indicated for Nomex, Reference 61 (24% loss of elongation at 10^8 rads), was probably determined at elevated temperatures.

Polycarbonate/threshold - 7 x 10^5 rads/elongation

Reference 55 reports initial changes in elongation of polycarbonate film at 7 x 10^5 rads. This property increased, then decreased to approximately 50% of original at 7 x 10^7 rads. Tensile strength first increased at 3 x 10^6 rads, then decreased gradually. It was still greater than 50% of original at 1 x 10^8 rads. Reference 48 notes an approximate 20% loss in elongation and less than 20% loss in tensile strength at 1 x 10^8 rads for 3-mil Macrofol film irradiated in air or vacuum. Reference 36 notes that Lexan was too brittle to test after 2.6 x 10^8 rads at 25°C in air. The 10^6 rad threshold given by Reference 61 is probably an "order of magnitude" value and is in good agreement with the value noted above.

Polyolefins

These are aliphatic alkene polymers. Only ethylene, propylene, and isobutylene-based materials are useful commercially.

Polyethylene/threshold - 3.3 x 10^5 rads/increased elongation under stress. This threshold value does not indicate damage, but, rather, an improvement of original properties.

Reference 36 gives data for the irradiation of Alathon 3 films (various thicknesses) and for a 2-mil Marlex 50 sample. The Marlex lost approximately 90% of the original elongation at 4.4 x 10^6 rads, but less than 15% of original tensile strength. The 3-mil Alathon sample retained more than 90% of its original elongation and tensile strength at 8.7 x 10^6 rads, but rapidly lost strength above that dose. At 4.4 x 10^7 rads, tensile strength was approximately 33% less than the original value and elongation was decreased by approximately 87%. Radiation resistance in vacuum is quite good, with approximately 50% loss in elongation and an increase of tensile strength of nearly 50% after 8.7 x 10^8 rads. Effective antioxidants are known and may greatly improve radiation resistance (Figures 3-2 and 3-3), but are not always used in commercial formulations. Many antioxidants are relatively insoluble in PE and may migrate from the polymer (particularly at elevated temperatures), leaving it subject to rapid oxidative degradation. Reference 50 notes that, of 40 polyethylene insulations tested, only 3 demonstrated adequate radiation and fire resistance for nuclear applications.

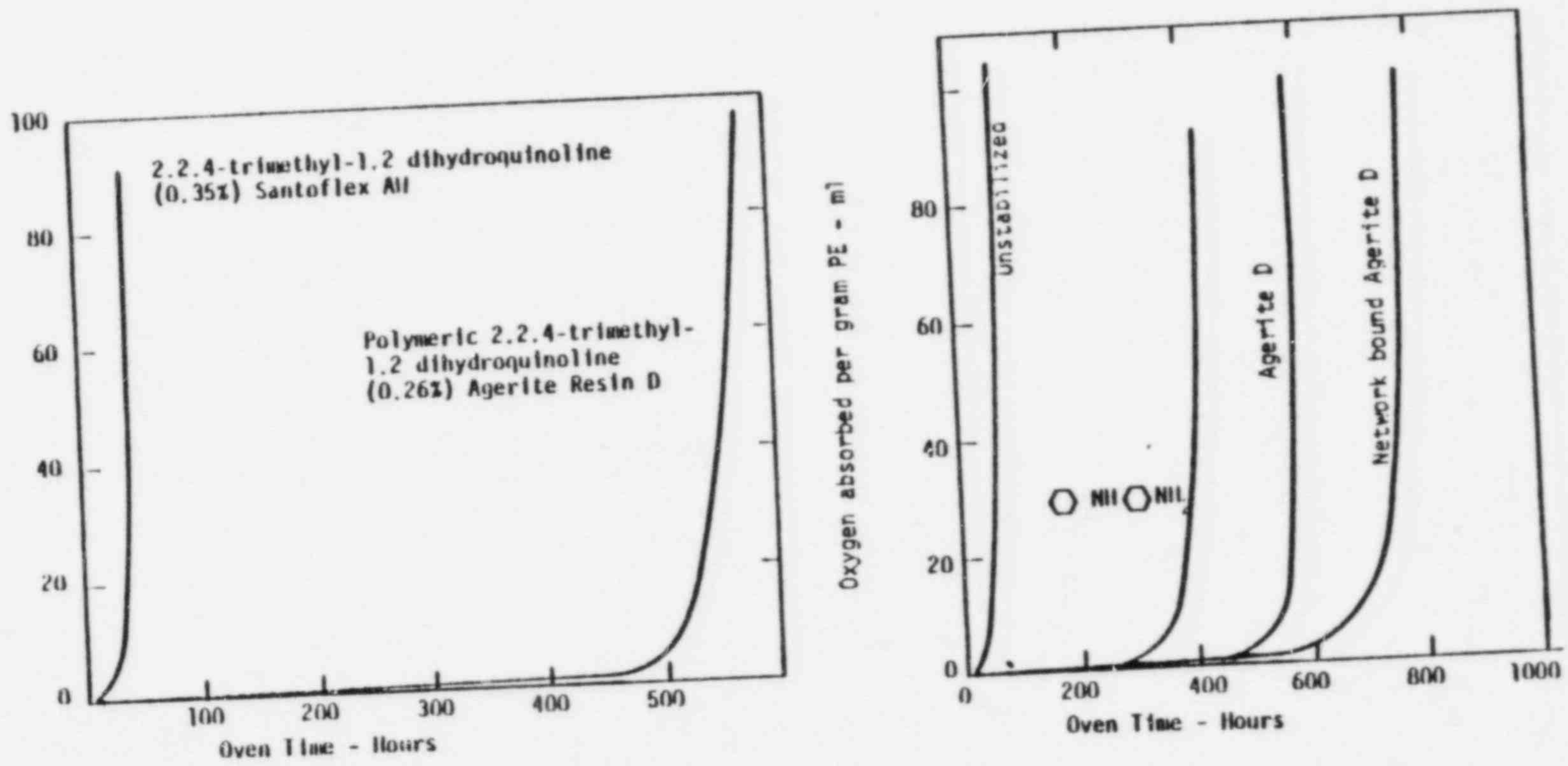
Reference 8 reports detailed tests of commercial cable insulation and jacket materials, including HDPE (high-density PE), NF-CLPE, and CB-CLPE (nonfilled and carbon black-filled chemically crosslinked PE) cable insulations. They noted that dielectric loss was observed at 5 x 10^6 rads and oxidation resistance was greatly reduced at that dose. They recommended service limits of 1 x 10^8 rads. Chapiro[21] reports detailed investigations of oxidation-related dose rate effects and thermal effects. Increased melting points and other beneficial effects of radiation crosslinking of polyethylene are discussed (also see Reference 52). Outgassing of PE is extensive during irradiation. Data from Reference 10 is discussed in the preceding section. An appropriate damage threshold for most cable materials is about 10^6 rads.

Polypropylene/threshold - less than 4 x 10^5 rads - no specific data. This threshold is determined on the basis of its more susceptible chemical structure and general similarity to polyethylene. Though the damage threshold in air may appear to be as high as 10^7 rads, References 52 and 32 report extensive post-irradiation oxidation of polypropylene syringes after sterilization doses of 2 - 2.5 megarads. Reference 32 also notes that this sensitization to oxidative degradation is totally blocked by beta-activated thioether additives.

Ionomer Resins/threshold - 2 x 10^6 rads/elongation/tensile strength. Reference 55 reports this threshold value, but does not report dose rate or sample thickness.

Figure 3-2 and 3-3

EFFECT OF VARIOUS ANTIOXIDANTS ON OXIDATION RESISTANCE OF CROSSLINKED PE (20 MEGARADS)



(Both Figures From Reference 52)

A lower threshold would probably be noted if oxidation effects were maximized. Greater than 50% of original tensile strength was retained at 9×10^8 rads. Fifty percent(50%) of original elongation was reported at 7×10^7 rads. Radiation resistance would be dependent on the effectiveness of antioxidants, as are the polyolefins. Vacuum irradiations to 5-10 megarads result in improved properties. Lichtenberg electron discharge effects are less for sodium ionomers than zinc ionomers.[30] No other data was found for organometallics.

Propylene-Ethylene Polyallomer/threshold - 1×10^6 rads/tensile strength/elongation. The polyallomer suffix indicates a unique bonding mechanism. This material is neither a physical mixture nor a true copolymer. Data for ethylene-propylene elastomers would not be applicable.

A reduction to half the original tensile strength occurs at 4×10^7 rads and half the initial elongation is noted at 7×10^6 rads.[55] Reference 36 reports results of irradiation at room temperature, 205°F, and 250°F. The overall radiation resistance is not good. Oxidation effects have not been investigated.

Irradiation-Modified Polyolefin/no threshold reported. Reference 33 reports that wire insulated with this material (from Raychem Corporation) completed a wet dielectric strength test after a radiation dose of 500 megarads. No serious degradation in physical or electrical properties was noted at this radiation level. This formulation must contain very effective antioxidant/-antirad additives. Reference 61 indicates a 10^8 rad threshold for polythermaleze.

Polyethylene Terephthalate/threshold - 4.4×10^6 rads/tensile/elongation

Dacron fibers are not significantly degraded below 2.5×10^7 rads.[9] Dacron tire cords irradiated in air and vacuum showed similar flex life, tensile strength, and elongation. Quinone and quinhydrone are effective antirads. Mylar (oriented PET film) appears to be more radiation resistant than nonoriented fibers. Reference 55 notes threshold changes in tensile strength and elongation at 4×10^7 rads. A 50% reduction in elongation is observed at 3×10^8 rads and a 50% decrease in tensile strength after 6×10^8 rads. Only slight reduction in melting temperature of PET occurs with increasing radiation dose. Greater scission rates (degradation) occur at lower dose rates, but it is not certain whether oxidation is involved.[25]

No thermal acceleration of radiation damage has been noted up to 200°C.[36] Degradation of electrical properties is insignificant at 10^7 rads.[33] Mylar film capacitors have been found serviceable after 10^8 rads.[36] Outgassing during irradiation is minimal (mostly H_2). Mylar is susceptible to ultraviolet radiation and to combined heat and vacuum.

Parylene/threshold - unknown

Poly-para-xylyenes and derivatives show better electrical, optical, and thermal properties than Mylar (applications are similar), but mechanical properties are not as good and radiation resistance is considerably less than that of Mylar. No specific data was cited.[55, 48]

Polyphenylene Oxide/threshold - approximately 10^5 rads/tensile strength

Reference 55 reports a slight increase in tensile strength at 10^5 rads. The material maintains slightly greater than original strength to approximately 10^9 rads. Other properties are not reported. Noryl, PPO, and Alphalux 400 are commercial names for this polymer.

Polysulfone/threshold - approximately 5×10^7 rads/flexural strength

Reference 16 reports this threshold and reduction of tensile and flexural strength to half the original value after 1.7×10^8 rads (in air) for one aromatic polysulfone. Irradiation in vacuum to 3.5×10^8 caused little reduction in flexural strength. Increased sensitivity to radiation at elevated temperatures is noted. SO_2 is evolved during irradiation. Reference 61 indicates an "allowable" dose of 10^7 rads, but no supporting test data was located by this search.

Polystyrene/threshold - approximately 2×10^7 rads/tensile strength

Bowmer[14] found reduction of tensile and flexural strength to approximately 50% of original values for unstabilized polystyrene sheets (3 mm) in air at 30°C at 1×10^8 rads, gamma. Only 25% of initial values were retained after 2×10^8 rads. A 5×10^8 rad vacuum irradiation produced negligible changes in the same material. Commercial products contain various antioxidants and stabilizers. Reported thresholds range from 10^8 to greater than 10^9 rads. Reference 36 notes post-irradiation oxidation effects for commercial materials. Permanent decreases in volume resistivity and insulation resistance of one or two orders of magnitude occur after doses as low as 4×10^6 rads.[33] Styrene is approximately three times more sensitive to neutron irradiation than to gamma irradiation.

Acrylonitrile-Butadiene-Styrene/threshold - approximately 10^7 rads. Tensile strength increases above threshold, but decreases after about 2×10^8 rads. Slightly more than half the original value was retained after 10^9 rads.[55] Other styrene copolymers also exhibit radiation resistances less than commercial polystyrenes. The extent of radiation protection achieved will depend on the relative proportions of the polymer components. Styrene-acrylonitrile and styrene-butadiene survived electron irradiation to 1.8×10^9 rads at 60°C, but electrical properties were degraded. Styrene-divinyl benzene was little affected under the same conditions.[33] Poly-alpha-methyl styrene also shows radiation resistance somewhat less than polystyrene.[48] Since polystyrene shows post-irradiation oxidation effects, copolymers probably also do, but no reports of this effect were found. ABS and SAN are common trade names. The 10^7 rad threshold indicated in Reference 61 may be an order of magnitude value, but it is used since oxidation effects might reduce the 2×10^7 rad value (Reference 55) identified in this search.

Vinyl Polymers

Vinyl polymers contain a high degree of unsaturation and may be susceptible to both scission and crosslinking processes (see Table 2-1).

Polyvinyl Butyral/threshold - approximately 3×10^6 rads/elastic modulus. Elastic modulus increases during radiation (indicates crosslinking). Elongation at break decreases. Reference 36 estimates a 25% damage level of 1.9×10^7 rads. Reference 55 indicates a 50% change in tensile strength after 1×10^8 rads and in elongation after 3×10^8 rads. Butacite and Saflex are trade names for this material.

Polyvinyl Formal/threshold - approximately 1.6×10^7 rads/tensile/elastic modulus. Irradiation of Formvar resulted in decreased tensile strength and elastic modulus. Reference 36 reports 1.2×10^8 rads as a 25% damage level. References 55 and 48 indicate 50% damage levels at about 10^9 rads. Scission appears to be dominant as it is in polyvinyl alcohol and polyvinyl acetate. Reference 61 indicates an order of magnitude threshold of 10^7 rads, which is in good agreement.

Polyvinyl Carbazole/threshold - 8.8 x 10^7 rads/impact strength. All physical properties appear to be quite insensitive to radiation and are reported as unchanged at 2 x 10^9 rads.[48, 55] Reference 36 indicates 25% damage to Grinlan F at 4.4 x 10^9 rads. Other commercial names are Luvican and Polectron. The threshold value cited was determined for Polectron.[36]

ELASTOMERS

This term includes natural rubber and a number of synthetics with similar elasticity. ASTM designations for most materials are provided in parentheses following the generic name.

Polyacrylate (ACM)/threshold - approximately 10^6 rads/set at break

Chapiro[21] discusses crosslinking and scission rates for various esters of acrylic acid. Similar crosslinking rates were noted for methyl, n-butyl, and isobutyl acrylates. Phenyl acrylate was more resistant to radiation-induced change. It was also more resistant than phenylethyl acrylate. Reference 37 notes that scission is dominant for lower radiation doses, but that crosslinking is more pronounced above 8.7 x 10^7 rads. Reference 9 suggests a 25% damage level at 3 x 10^6 rads. Reference 36 reports results of a number of separate tests. One test of set at break revealed threshold change after 10^6 rads and 25% increase after 3 x 10^6 rads for Hycar PA. Another study reported threshold change in compression set at 1.5 x 10^6 rads and 25% increase at approximately 10^7 rads. Elongation decreased, with threshold, 25% and 50% decrease at 3, 15, and 30 megarads, respectively. Tensile strength also decreased, indicating threshold damage at 4 x 10^6 rads and 25% at 6 x 10^7. Reduction of compression set through the addition of antirads was better than with most other rubbers. Hycar PA-21 with UOP-88 antirad exhibited approximately 50% compression set at 3.7 x 10^7 rads. The same formulation without the antirad showed 50% compression set after 8.4 x 10^6 rads. Unirradiated controls took on only about 13% compression set. Alpha-napthyl amine and FLX (N-phenyl-N'O-tolyethylene diammine) are also recommended antirads.

Adduct Rubbers/threshold - approximately 4 x 10^6 rads/tensile strength/elongation

Adduct rubbers are made by reacting diene rubbers (polybutadine, isoprene, etc.) with alkyl mercaptans to remove unsaturations. Data was found only for methyl mecaptans of polybutadiene and one butadiene-acrylonitrile adduct. Reference 9 notes that better initial properties often result from the reduced unsaturation and that adduct rubbers show better radiation resistance (particularly at elevated temperatures) than natural or neoprene rubbers. Radiation resistance appears to increase with increasing saturation. Small changes in tensile strength and elongation (less than 10%) were noted for 86% and 92% saturated (methyl mercaptan) adducts of polybutadine at 4.4 x 10^6 rads. Decreases in elongation of approximately 20% were noted at 1.9 x 10^7 rads. Tensile strength increased for both. A 65% saturated adduct of butadiene-acrylonitrile showed slightly less radiation resistance, but more than its corresponding butadienacrylonitrile. Mechanical property changes at 4.4 x 10^6 rads were small. One study, including irradiation of an 88% saturated adduct of polybutadine at 75°F and 200°F, indicated that radiation resistance was about the same at both temperatures.[36] Data on compression set characteristics was not found.

Butyl Rubber/threshold - less than 7 x 10^5 rads/tensile strength

Butyl rubbers are copolymers of polyisobutylene with small percentages of isoprene. Butyls are the least radiation-resistant rubbers known. Reference 25 discusses reaction mechanisms. Degradation is almost exclusively by chain scission (quaternary carbon structure) with G(S) = 4.1 - 5.0. If crosslinking occurs, it is with G(X) less than 0.05. Polymercaptans and t-butyl-dichloro-benzene additives were found to inhibit degradation somewhat.

Reference 36 reports one observation of a 25% loss of tensile strength for butyl rubber at 7 x 10^5 rads and a 50% loss at 3 x 10^6 rads. A 25% decrease in elongation occurred at 5 x 10^6 rads and a 50% decrease at 7 x 10^6 rads. Higher dose levels were noted for another butyl rubber (tested at a different facility), with threshold changes in tensile strength and elongation at 7 x 10^6 rads. A 25% decrease in elongation occurred after 4 x 10^7 rads and in tensile strength after 2 x 10^7 rads. A 20% decrease in compression set recovery was noted at 9 x 10^5 rads for one material and a use limit of approximately 4 x 10^6 rads for butyl gaskets and seals (at temperatures below 300°F) was suggested in Reference 37. Reference 8 suggests use limits for a butyl-based insulation of 5 x 10^6 rads. Changes in oxidation resistance were not found at that level. References 51 and 53 indicate degradation of mechanical properties at 1 x 10^6 rads, and Reference 54 indicates "severe" damage to butyl rubber hoses in service at an accelerator facility at 5 x 10^6 rads.

Ethylene-Propylene/threshold - 1×10^6 rads/compression set

Although some experimental formulations showed poor radiation resistance, a number of commercial materials appear to be comparable to crosslinked polyethylene. As with other polyolefins, radiation resistance will depend on the effectiveness of antioxidant systems (especially at elevated temperatures). Reference 28 reports dose rate effects with greater degradation at low dose rates when the total dose exceeded about 2×10^7 rads for one ethylene-propylene cable insulation. Reference 8 details effects of radiation on cable insulation and jacket materials, including EPDM-based and EPM-based insulations (both mineral filled). No changes in oxidation resistance were found following total dose up to 10^8 rads (dose rate was 5×10^5 rads/hour). Elongation of the EPDM insulation was not significantly changed after 5×10^6 rads, but was reduced to 48% of the initial value after 5×10^7 rads and 37% after 1×10^8 rads. The EPM insulation retained 81% of its unirradiated value after 5×10^6 rads, 41% after 5×10^7 rads, and 26% following 1×10^8 rads. Reference 39 also reports very good radiation resistance of EP rubber (EPDM base) and that cables using special chloroprene jackets and EP insulation passed IEEE-383 tests.

EPDM retained 79% and EPM retained 90% of the original tensile strength after 10^8 rads. Changes in permanent electrical properties were relatively unimportant. Reference 35 reports similar results for ethylene propylene cable insulations, but reports that a fire-retardant additive appeared to cause instability of electrical properties in an EPDM-based material at exposures above 10^7 rads. Reference 55 reports minor reductions in mechanical properties of EP-F234 after 5×10^4 rads, but less than 25% decrease in those properties at 10^6 rads. A 50% decrease in elongation was noted after 2×10^7 rads and in tensile strength after 2×10^8 rads. The 5×10^4 rad value is not cited above, since it is not generally applicable and does not represent significant change to the material.

Barbarin[6] recommended an EP compound (Parker-Hannifin E740-75) as exhibiting the best known combination of radiation, fluid, and temperature tolerance. He warned that variations in compounding can cause wide difference in properties. One EP compound showed 28.5% increase in compression set after 10^7 rads and would be acceptable as a dynamic seal, while one (Parker-Hannifin E515-80) exhibited 46.5% increase in that property under the same test conditions. He recommended that no dynamic seals be used after radiation doses greater than 10^7 rads due to excessive compression set. Reference 61 indicates a 10^7 rad "allowable" dose for EP as for polyethylenes.

Fluoroelastomers/threshold - 10^5 to 10^6 rads/compression set (most)

The use of fluoroelastomers for O-rings, sealants, and gaskets is often desirable because of their high temperature resistance and compatibility with diester fluids, but in radiation environments, outgassing of corrosive acids and high compression set can occur. References 4 and 13 report "threshold" property changes between 10^5 and 10^6 rads (no specific data). Barbarin[6] suggests that fluoroelastomers not be used as dynamic seals beyond 10^6 rads and points out their tendency to degrade in water or steam. He reports changes in mechanical properties after irradiation to 10^7 and 10^8 rads in air at room temperature. Both Fluorocarbon V747-75 and Fluorosilicone L 677-70 took on excessive compression set after 10^7 rads (greater than 65%). Threshold changes in tensile strength, elongation, and hardness were noted for fluorosilicone after 1 x 10^6 rads and for Kel-F Elastomer (trifluorochloroethylene-vinylidine fluoride) after 2 x 10^6 rads.[55] Viton A exhibits a radiation damage threshold of 5 x 10^6 rads in air at ambient temperature.[36] At elevated temperatures, radiation resistance of fluoroelastomers is reduced, particularly in air. Reference 37 reports disintegration of Viton A (vinylidine fluoride-hexafluoropropylene) samples irradiated to 8.7 x 10^5 rads at 400°F in air. Resistance in argon was still extremely poor, with a 75% decrease in tensile strength noted after 5 x 10^6 rads at 400°F. Viton A irradiated in MIL-L-7800 oil (diester base) at 400°F showed only minor changes in tensile strength and elongation after 4.4 x 10^6 rads and approximately 40% decrease in elongation and approximately 10% loss of tensile strength after 1.7 x 10^7 rads. Of the fluoroelastomers, Kel-F and fluorosilicones (methyl silicone base) are probably the least resistant. Viton A and Poly FBA (1F4) appear to be about equal in radiation resistance. A modification of Viton A, known as Viton B or LD234, appeared to be about twice as resistant, with about 50% decrease in elongation and negligible reduction in tensile strength after 1 x 10^8 rads at 400°F in bis-phenoxy-phenyl ether. Viton B sealant formulations also demonstrated better retention of mechanical properties than Viton A. Two fluorinated polyester elastomers manufactured by Hooker Chemical, HA-1 and HA-2, were also recommended as among the most resistant fluoroelastomers.[36] Dynamic tests have shown Viton A able to retain sealing ability in Versilube F50 and MLO-8200 at 83 megarads in one test, but allowed some leakage during the final stages of a 380-hour test at 200°F and pressure of up to 3,000 psi in Oronite 8200 after a total radiation exposure of 5 x 10^7 rads. Static seals performed acceptably under those conditions.[37] Viton B irradiated in vacuum has shown post-irradiation degradation during 2 weeks storage in air.[4] Long-term effects may be about the same as for Viton A.

Use limits will depend strongly on application, but caution must be used in selection of fluoroelastomers above approximately 10^6 rads in dynamic applications and 10^7 rads as static seals.

A radiation crosslinked fluoroelastomer (copolymer of tetrafluoroethylene and propylene) discussed in Reference 52 should be investigated as potentially useful in nuclear applications. Properties appeared to be better than those of chemically similar tefzel material.

Hypalon (CSM)/threshold - 5×10^5 rads/elongation

Chlorosulfonated polyethylene is often recommended for electrical cable jackets in nuclear environments. Its resistance to radiation, temperature extremes, fire, oxidation, and oils and greases (except aromatic and chlorinated) is quite good.

Though some CSPE formulations show early decreases in elongation,[8, 28] others show threshold changes in that property above 10^7 rads. Reference 28 reports a very rapid drop in ultimate elongation for one CSPE insulation to approximately 40% of the original value after less than 1.5×10^7 rads. Further decreases were gradual and the material retained greater than 100% ultimate elongation after 1.8×10^8 rads. Two cable jackets showed much more gradual decline, with approximately 50% decrease after 75-100 megarads. Both retained slightly less than 100% ultimate elongation after 1.8×10^8 rads.

Data from Reference 8 includes an 11% decrease in ultimate elongation for one CSPE jacket after 5×10^5 rads and a 41% decrease after 5×10^7 rads. At that radiation level, tensile strength was increased, oxidation resistance was not changed, and electrical properties were good. A recommended service limit was set at 5×10^7 rads (as for all jacket materials tested), but it appears that a higher limit could be acceptable.

One chlorosulfonated polyethylene exposed to 3.1×10^7 rads (gamma) and 1.2×10^{15} n/cm^2, $E > 0.33$ MeV, showed only 15% decrease in elongation and no significant change in tensile strength. After 1.1 to 1.4×10^8 rads and 5.5 to 7.0×10^{15} n/cm^2, this material still retained approximately 40% of the original elongation.

Reference 55 reports threshold changes in tensile strength and elongation at 10^7 rads with 50% decrease in elongation after 6×10^7 rads, and in tensile strength after 6×10^8 rads.

Reference 39 indicates some of the variations in resistance of chlorosulfonated polyethylene to radiation, thermal aging, and high-temperature steam in relation to variations in formulations.

Hydroquinone has been found effective in increasing radiation resistance. Irradiation in air usually results in greater degradation than in vacuum. Actual values for radiation-induced compression set were not found (not generally used in sealing applications), but it is thought to be less resistant than most elastomers in that respect.[37] Reference 61 indicates a 10^7 rad "allowable" dose for CSPE, which seems overly conservative.

Natural Rubber (NR)/threshold - 2×10^6 rads/compression set

The resistance of natural polyisoprene to radiation alone is good, but resistance to ozone and elevated temperatures is poor, and rapid degradation occurs for samples irradiated above threshold under stress. Antiox 4010 (N-cyclohexyl-N-phenyl-p-phenylenediammine) was found to be effective in increasing the radiation resistance.[37] Threshold changes in compression set were noted after 2×10^6 rads, in elongation after 5.5×10^6 rads, and in tensile strength after 2.4×10^7 rads.[36] Reference 55 reports threshold change in compression set after 5×10^6 rads. Elongation was first affected by 9×10^6 rads and tensile strength by 2×10^7 rads. A 50% decrease in elongation and tensile strength occurred after 1×10^8 and 5×10^8 rads, respectively. Reference 25 provides information on reaction mechanisms. Retention of Yerzley resilience is excellent and resistance to changes in permanent set during flexing of irradiated natural rubber was good.[36]

Neoprene (CR)/threshold - approximately 8×10^5 rads/compression set

Several neoprene cable jackets have been investigated for nuclear applications. Blodgett[8] reported decreased resistance to oxidation above 5×10^6 rads (resistance was reduced by half after 5×10^7 rads). Ultimate elongation was 93% of the initial value after 5×10^6 rads, but only 46% after 5×10^7 rads. Reference 28 reports greater degradation from simultaneous irradiation and thermal aging than from sequential testing. Reference 39 reports the effect of ketone-amine and thiocarbonate antioxidants on chloroprene rubber. One neoprene material showed greater degradation in vacuum than in air. Tensile strength decreased by 94% after only 1.9×10^7 rads. Samples irradiated in air decreased 16% in tensile strength for the same total dose. Both air and vacuum irradiation resulted in an approximate 50% decrease in elongation at the 1.9 x 10^7 rad level. Another test indicated that two of three commercial neoprene compounds examined exhibited post-irradiation degradation after storage in air.[36]

Reference 13 rates neoprene as a preferred elastomer for space applications. Reference 37 notes only minor changes in mechanical properties of one neoprene (aromatic plasticizer) after 8.7 x 10^7 rads in air. Reference 55 indicates threshold changes in compression set after 2 x 10^6 rads, in elongation and set at break after 5 x 10^6 rads, in strain at 26 Kg/cm^2 after 7 x 10^6 rads, and in tensile strength after 1 x 10^7 rads.

Neoprene seals used in a simulated turbojet accessory system did not fail in a 200-hour test. Temperatures were 190°F to 300°F, hydraulic pressure was 0 to 1,000 psig, and radiation dose was 1.75 x 10^6 rads. Neoprene O-rings used in a gauging system for reactor pressure tubes were found serviceable to 10^8 rads, though hardened.

Excessive compression set and loss of flexibility may occur at radiation doses above a few megarads. Reference 48 reports changes in compression set recovery at 8-9 x 10^5 rads.

<u>Nitrile (NBR)</u>/threshold - approximately 10^6 rads/compression set

Various copolymers of acrylonitrile and butadiene are commercially available. The nitrile group provides increased oil and solvent resistance and thermal resistance is good. Nitriles are resistant to ozone cracking, but tend to stress crack. Some generalizations can be made concerning variations in radiation resistance. Polymers with higher acrylonitrile content tend to show better retension of tensile strength. Elongation of high acrylo polymers is initially high, but may decrease more rapidly than low acrylo compounds at moderate radiation exposures. This trend in elongation may reverse at higher doses. In general, the absolute elongation value remains higher for the high acrylo compounds and overall radiation resistance is slightly better.

In a series of tests varying curing agents and acrylonitrile content (50, 40, 33, and 20%), a peroxide-cured 50% copolymer showed the best overall resistance. With radiation curing, a 40% acrylonitrile was more stable than higher or lower percentage acrylo compounds. A 20% acrylonitrile was most stable of the sulfur-cured polymers. Stability of high and medium percentage acrylo compounds to air irradiation is not greatly affected by carbon black fillers (strength and elongation), though better flexibility seems to be retained with minimum carbon black. Resistance to irradiation in JP-4 fuel was greatly reduced by carbon black in both high and medium percentage acroly polymers. A large number of antirads have been found to improve overall radiation stability and compression set characteristics. One nitrile rubber with Antiox 4010 was not stiff or brittle until exposures reached 5 x 10^6 rads.[36] Reference 6 mentions two Nitrile formulations which show little compression set at 10^7 rads (N674-70 and N741-75), but does not give specific values. Reference 41 reports extensive tests of the physical properties of a commercial NBR O-ring compound. No significant difference was noted from irradiation in air or oil. Nitriles with antirads are highly recommended for dynamic seal application at low temperatures. Resistance to elevated temperatures is less than that of most other elastomers. Reference 13 classifies NBR as a "preferred" elastomer.

Some formulations are probably not suitable for vacuum applications. Reports of softening, tackiness, and rapidly decreasing tensile strength of specimens irradiated in vacuum have been noted. This would indicate predominant scission.

The same materials irradiated in air exhibited predominant crosslinking. One report of pronounced oxidation after exposures above 4.3 x 10^7 rads was noted. Other tests indicated approximate equal radiation resistance in air, vacuum, or inert atmospheres. Reference 55 notes threshold changes for Buna-N (probably no antirad). Tensile strength was affected at 5 x 10^7 rads, increased to approximately 4 x 10^8 rads, then decreased rapidly. Elongation was affected at approximately 2 x 10^6 rads and decreased by 50% after 7 x 10^7 rads. Set at break and compression set were affected at approximately 2 x 10^6 rads. Strain (at 26 Kg/cm^2) was affected by 5 x 10^6 rads. The threshold noted above is given in Reference 36. Reference 37 reports static and dynamic tests of Buna-N hoses at temperatures up to 350°F and static pressures up to 1,200 psig and one intermittent pressure test with 0 to 1,000 psig. Buna-N was all right up to about 4 megarads in the static test and at least one megarad in the dynamic test. The elevated temperature was probably more significant than the radiation level in that test. Reference 61 also cites a 10^6 rad threshold for nitrile rubber.

Butadiene (BR)/threshold - approximately 10^6 rads/compression set

References 21, 25, and 30 report various investigations of the chemical reactions induced in polybutadiene (and copolymers) by ionizing radiation. The all-cis polymer is soft and elastomeric, the all-trans polymer is crystalline. The homopolymer is less radiation resistant than its corresponding acrylonitrile and styrene copolymers. Resistance to compression set during irradiation is less than that of natural rubber. Specific data is cited in Reference 37 for mass polymerized polybutadiene containing 50 phr of HAF black. It retained 70% of the original tensile strength and 31% of the initial elongation after 1.7×10^8 rads, but hardness increased 20 Shore A units.

Polyisoprene, Synthetic/threshold - 10^6 rads (?)

Radiation resistance should be similar to natural rubber, but no specific data on physical properties was found. Reference 25 gives some information on chemical reaction mechanisms.

Polyurethane (ALL)/threshold - approximately 10^6 rads/compression set

Polyurethane is usually rated with natural rubber in radiation resistance. Balanced crosslinking and scission appear to occur in both air and vacuum for most formulations with about equal damage in either environment. One compound, Vulkolla, Grade 2018/40, did show more degradation in vacuum. Chain scission was dominant in that environment and a complete loss of strength was noted after 10^8 rads. Irradiation at temperatures up to 260°F indicated that tensile strength was degraded about equally by radiation at ambient or elevated temperatures. Ultimate elongation of samples irradiated at higher temperatures was generally greater than that of specimens irradiated at ambient temperature. Compression set is greatly increased by elevated temperatures with or without radiation. Extreme moisture sensitivity limits application. Irradiation in the presence of moisture may lead to more rapid degradation. Estane VC cured with dicumyl peroxide has shown good radiation resistance with 60% compression set after 5.5×10^7 rads. Adiprene C, sulfur cured with carbon black reinforcement, showed poor radiation resistance. Polyester-based urethanes are more resistant than polyether-based materials. Both p-phenylene diisocyanate and diphenyl methene-4-4'-diisocyanate are effective antirads. One Estane, VC, retained 30% of its initial tensile strength at 6 x 10^7 rads and 50% at 2 x 10^8 rads. A 20% decrease in elongation occurred after 1 x 10^8 rads and a 50% drop at 3 x 10^8 rads.[48]

Reference 37 reports threshold damage at 8.7 x 10^6 rads and 25% damage after 4.3 x 10^7 rads. A tendency to soften (scission) was noted to about 4 x 10^8 rads, with hardening above that dose. Tensile strength and elongation both decreased gradually.

Reference 55 provides data for a urethane cable insulation without details of the formulation. Tensile strength was decreased by 50% after 10^7 rads and by slightly greater than 75% after 10^8 rads. Elongation was approximately 90% of the original value after 10^7 rads and approximately 50% after 2 x 10^8 rads. Hardness was slightly greater than the initial value after 10^7 rads and about 125% of the unirradiated value at 10^8 rads.

Reference 6 reports data for polyurethane P642-70 O-rings. Hardness was unaffected by 10^8 rads, tensile strength was unaffected by 10^7 rads, but decreased by 60% after 10^8 rads; elongation was reduced 16% by 10^7 rads and 65% by 10^8 rads. One-hundred percent (100%) flexural modulus was increased 30% after 10^7 rads and tear strength increased 22% after 10^7 rads, but was 52% less than the initial value after 10^8 rads. Compression set was 55.5% at 10^7 rads and greater than 90% after 10^8 rads.

<u>Styrene-Butadiene (SBR)</u>/threshold - 2 x 10^6 rads/compression set/elongation

The most radiation-resistant SBR rubbers are those with the highest styrene content. Crosslinking is dominant. Stress cracking has been noted after doses as low as 4.3 x 10^7 rads. No data was found comparing air irradiation with vacuum or inert atmosphere irradiation, nor was any information found concerning the effect of elevated temperatures during irradiation. Ozone resistance is poor and limits application in radiation environments.Threshold changes in hardness were observed in GR-S-50 after 5 x 10^4 rads in one test, but 7 x 10^6 rads was required to increase the hardness from 62 to 67 Shore A units. Threshold changes in elongation, compression set, set at break, and strain at 400 psi/in^2 were noted after 2 x 10^6 rads. A 25% change in those properties occurred at 10^7 rads. Tensile strength was unchanged at that dose.[36] The low dose change in hardness is not consistent with other data of the same test or with other tests and is probably an error.

Reference 55 reports slightly higher thresholds for mechanical properties of Buna-S. No change in hardness was noted below 10^7 rads. A 50% damage level was indicated for elongation, set at break, compression set, and strain at 28 Kg/cm^2 at 6 x 10^7 rads. Tensile strength exhibited threshold changes at that level and hardness was less than 125% of the original value.

Radiation resistance of Sympol 1500 was increased when acridine, pyrene, or fluoranthene plasticizers were used. The best antirads found for Synpol 1500 were derivatives of p-phenylene diamine or phenyl naphthyl amine.

Reference 41 reports investigations of the radiation-induced changes for a commercial SBR O-ring formulated specifically for radiation resistance. Hardness was unaffected below 1.8 x 10^7 rads. Stress strain effects were minor below 3.6 x 10^7 rads and "good" tensile properties were maintained after 1.2 x 10^8 rads. Elongation was still 20% after 1.6 x 10^9 rads. Compression set was the most sensitive property and was 50% after 3 x 10^7 rads. That compound would be effective as a dynamic seal at least to 10^7 rads and be useful for some applications at higher doses.

Silicones (UMO)/threshold - 5 x 10^5 rads/oxidation resistance

Silicones exhibit excellent resistance to extreme temperatures. Inorganic fillers, such as silica, are generally needed to achieve good initial tensile properties. The silicone rubbers are more resistant to radiation than butyls and polysulfides, but a broad range of radiation resistances occurs, depending on the structure of the silicone molecule, the vulcanizing system, and the presence of additives, such as fillers and antirads. Environmental parameters, such as elevated temperatures, oxidizing conditions, and mechanical stress, may greatly affect radiation resistance. Reference 36 provides details for the irradiation of dimethyl, methyl vinyl, methyl phenyl, and other commercially available siloxanes. Reference 25 discusses comparative stability and chemical reaction mechanisms.

Oil and fuel resistance is usually less than that of neoprene or nitrile rubbers. Radiation-induced compression set becomes excessive for many formulations. Outgassing during irradiation is less than with hydrocarbon rubbers.

Reference 8 reports data for one dimethyl silicone cable insulation. After 5 x 10^7 rads, tensile strength was 100% of the original value. Elongation was reduced to 90% of the initial value after 5×10^6 rads and to 34% after 5×10^7 rads. Oxidation resistance appeared to be greatly reduced (by a factor of 10^4 after 5×10^6 rads and by a factor of 10^6 after 5×10^7 rads). Despite this, the cable was suggested as usable up to 5×10^7 rads at 70°C or below. In view of more recent data on low dose rate effects, following such a suggestion would seem imprudent.

Peroxide curing agents may leave residues which render silicone rubber more susceptible to oxidation. Radiation curing usually results in better resistance to compression set.[36]

Reference 6 notes that two silicone O-ring formulations showed acceptable resistance to compression set after 10^7 rads. S 455-70 had 31.4% compression set and S 604-70 had 20% compression set. Resistance of those formulations to silicone fluids and moisture was rated as poor.

Connectors employing silicone rubber insulations can withstand exposures to as much as 10^{15} to 10^{16} neutrons/cm^2 and 10^7 Roentgens at 55°C and still provide reasonable electrical performance. Transient decreases in insulation resistance occur during irradiation with minimums of less than 10^7 ohms. Encapsulating compounds RTV-501 and Sylgard 182 and 183 were not seriously degraded by exposure to 2×10^{13} to 7.5×10^{15} n/cm^2 and 2×10^6 to 10^8 Roentgens gamma. Dow Corning R-7521 maintained good physical and permanent electrical properties after 5×10^8 rads at 23°F or 1×10^8 rads @ 200°C.[33]

Reference 48 notes that one dimethyl silicone rubber lost 50% of its initial tensile strength after 5×10^7 rads at room temperature, or after 5×10^6 rads at 200°F. Silastic 50-480 was found to be an acceptable seal material in 450°F oil after 3×10^6 rads.[36] Reference 61 also suggests a 10^6 rad threshold for silicone rubber.

Thiokol (PTR)/threshold - 3×10^5 rads/hardness

The radiation resistance of Thiokol ST and Thiokol FA polysulfide rubbers is comparable to that of butyl rubber. Though considerable crosslinking occurs, scission is dominant and a "tarry" texture will be observed after high radiation doses. Thiokol rubbers show better retention of ultimate elongation than neoprene and polyacrylate elastomers, though tensile strength is rapidly degraded. Thiokol ST containing alpha naphthylamine or N-phenyl-N-O-tolylenediamine and Thiokol FA containing beta naphthol (antirads) both showed ultimate elongations of 260 to 280% after 1.3 x 10^8 rads.[37]

Reference 36 reports that one Thiokol ST formulation showed a 50% decrease in tensile strength and elongation after only 1 x 10^6 rads. Another Thiokol ST tested at a different facility exhibited threshold changes in elongation and set at break after 5 x 10^5 rads, but only 25% decrease in those properties after 4 x 10^6 rads. Tensile strength and strain at 400 psi were only slightly decreased after 5 x 10^6 rads. Threshold changes in compression set were noted after 6 x 10^5 rads and in hardness after 3 x 10^5 rads during that test.

Three Thiokol sealants (PR 1201-HT, EC 801, and EC 1373), top coated with nitrile rubber, were irradiated in air and JP-4 fuel. Though somewhat degraded, they were found serviceable after 2.5 x 10^7 rads. Another sealant (PR-1422) was found to maintain satisfactory stress-strain values after 8.7 x 10^7 rads and 24 hours of post-irradiation aging at 275°F. Only minor differences have been noted for comparable irradiations in air and vacuum.[36]

Lead peroxide, dichromate, and manganese dioxide-cured polysulfides show similar radiation resistance, though the dichromate curing might be slightly better for overall radiation resistance and lead peroxide curing is noted as yielding polysulfides with generally poor heat resistance.[36]

Vinylpyridines/threshold - greater than 10^6 rads

Though specific data is limited, the radiation resistance is indicated as quite similar to that of natural rubber. Carbon black-filled stock showed little change in tensile strength below 4 x 10^7 rads. Elongation was not much affected at 4.3 x 10^6 rads, but was decreased by more than 25% after 4.3 x 10^7 rads. Silica-loaded stock lost tensile strength at doses of less than 5 x 10^6 rads, but increased again at doses above 1 x 10^8 rads.[37] No stress cracking was observed in tests at exposures up to 8.7 x 10^7 rads.[36]

PROTECTIVE COATINGS

The radiation resistance of protective coatings varies with a number of factors, including pigments, plasticizers, solvents, catalysts, curing agents, and additives. Damage thresholds are seldom established from the tests performed, but References 9, 44, and 56 provide discussions of considerations necessary in the selection of coating systems for specific applications. Reference 13 provides guidelines in the selection of thermal control coatings, as well as general purpose coatings.

Reference 44 presents the following generalized statements drawn from a number of sources:

1. Pigmented coatings are more resistant to radiation than those containing little or no pigments. Carbon black inhibits damage, while some grades of titanium dioxide accelerate damage. Extender pigments appear to contribute to color change.

2. Realistic comparisons of different coating systems can be made only if the same pigment compositions are used for all vehicles.

3. The choice of primer is important when a coating to be subjected to radiation is applied to metal substrates.

4. The degree of cure for any specific system can influence apparent radiation resistance.

5. Residual solvents can influence radiation resistance.

6. To a point, gamma radiation (and heat) initially improves the physical properties of many organic coatings. Exposure to radiation beyond a given point tends to excessively crosslink and/or degrade organic coatings. This leads to coating embrittlement which develops into failure. For epoxies applied to steel, failure usually occurs at the metal-coating interface.

Data is presented which indicates that for the systems tested (including phenolic and epoxy-polyamide formulations), sequential simulation of nuclear environments and accident conditions results in greater degradation of coatings than simultaneous tests.

The influence of the surface to which the coating is applied is often quite significant. For example, one vinyl coating (Amercoat 33) failed on an aluminum panel after 2×10^8 rads, but failed on a concrete panel only after 1×10^9 rads. Coating on concrete were, in general, more stable.[9] Further data on specific mounted coatings in that test are given in Table 3-1.

As indicated in Reference 13, many coating systems are not greatly affected by radiation exposures below 10^8 rads. Phenolic alkyd enamels, silicone alkyd enamels, and alkyd-epoxy formulations may be useful above 10^9 rads.

Table 3-1

RADIATION RESISTANCE OF MOUNTED PROTECTIVE COATINGS

Polymer Base	Trade Names	Surface	Gamma Dose 10^8 Rads	Appearance[a]
Furan	Alkaloy-550[b]	Concrete	9.4	No failure
		Steel Rod	8.4	No failure
Modified Phenolic	Amphesive-801[b]	Concrete	9.4	No failure
		Steel Rod	8.7	Drastically embrittled
Silicone Alkyd	Solar Silicone[c] Alkyd	Concrete	6.7	No failure
		Steel	6.7	No failure
Epoxy	Epon-395[d]	Steel	6.7	No failure
Vinyl Chloride	Amercoat-33[e]	Aluminum	2.1	Failed; blistered
		Concrete	10.5	Failed; blistered
		Steel	8.7	Failed; blistered
Styrene	Prufcoat[f]	Concrete	8.7	Failed; blistered
		Steel	8.7	Failed; cracked
		Steel (Wet)	0.8	Failed; cracked
Vinyl	Corrosite-22[g]	Aluminum	2.1	Failed; blistered
		Concrete	11.0	Borderline failure

a Examined for blisters, cracking, hardening, tackiness, etc.

b Atlas Mineral Products Company

c Solar Division, Gamble Skogmo, Inc.

d The Glidden Company

e Amercoat Corporation

f Prufcoat Laboratories, Inc.

g Corrosite Corporation

Source - Reference 9

Reference 56 indicates three coating systems (two epoxy-based and one modified phenolic-based) that did not fail after 5×10^9 Roentgens in demineralized water. Evidence of greater radiation resistance in air is also cited.

Thermal control coatings are more susceptible to radiation damage. Threshold change is indicated for one silicone coating, S13G, after only 10^5 rads, with appreciable damage after 10^6 rads. Another silicone, Thermatrol 6A-100, was the best indicated in Reference 13, with threshold change at about 10^7 rads and appreciable damage slightly below 10^8 rads. Inorganics and acrylics were also indicated as preferred thermal coatings.

LUBRICANTS

Radiation resistance of base oils is the dominant factor controlling the radiation resistance of lubricants. Finished lubricants may be more resistant than base oils, but are commonly less resistant due to the influence of additives necessary to achieve other desirable properties. Static tests may be quite misleading. Dynamic tests can result in dramatic decreases (or increases) in apparent use limits. References 9, 13, 24, 36, and 37 present data for many lubricants, including some dynamic test results. Some useful generalizations taken from Reference 9 are presented below.

1. The identity of the organic base fluid is the most important factor in resistance to irradiation. Base materials vary a thousandfold in their susceptibility to radiolysis. An approximate decreasing order of stability is polyphenyls, poly (phenyl ethers), alkyl aromatics, aliphatic ethers, mineral oils, aromatic esters, silicones, aromatic phosphates.

2. Oil lubricants, in general, can be classified according to dose ranges, as follows:

   a. 10^6 rads or below: No unusual problem from radiation noted.

   b. 10^6 to 10^7 rads: Methyl silicones, aliphatic diesters, and phosphate esters become affected; polymers in solution degrade. For most other cases, other environmental factors are controlling.

   c. 10^7 to 10^8 rads: Radiation effects on physical properties render diesters and certain mineral oils marginal in performance. Oxidation stability and thermal stability are adversely affected for all fluids. Some lubricants are usable; some are marginal in this range.

d. 10^8 to 10^9 rads: Oxidation and thermal stability of most lubricants are seriously impaired. Major changes occur in most physical properties. Aliphatic ethers, aromatic esters, and certain mineral oils (carefully selected) may be used.

e. 10^9 to 10^{10} rads: Polyphenyls, poly (phenyl ethers), or alkyl aromatics are recommended.

f. 10^{10} rads or above: Radiation damage becomes extremely limiting. Lubrication with even the best organic oils is very restricted.

3. Additives normally used in lubricants, e.g., antioxidants, anti-wear agents, EP agents, and antifoam agents, suffer radiation damage. Their depletion during irradiation, or their radiolysis products, can cause complications below radiation levels at which the base oil degrades.

4. Selected additives reduce radiation damage in base oils. They are most effective in the least stable fluids.

5. Oxidation drastically reduces the life of a lubricant. Radiation accelerates oxidation.

6. The role of temperature is interrelated to that of oxygen, additives, and radiation dose. Radiation damage is generally a minor function of temperature below about 300°F.

7. Under irradiation, greases first soften because of damage to the gel structure and then harden because of crosslinking of the oil. Conventional greases are usable to about 10^7 rads. Special products are available for use from 10^9 to 5×10^9 rads.

8. Many machine elements have some tolerance for degraded lubricants.

   In some cases, a system will function for a higher radiation dose than would be predicted from the static radiolytic changes in a critical physical property.

Bonded dry film lubricants are generally most stable (with or without radiation) and their use is recommended whenever possible.

ADHESIVES

Reference 15 provides data on the radiation stability of many adhesives, though most are based on static tests in air at room temperature. A number of epoxy phenolic, vinyl phenolic, and modified nylon phenolic adhesives retained useful properties after 10^9 rads.

Epoxy, epoxy-Thiokol, nitrile-phenolic, and nitrile-epoxy-phenolic adhesives retained useful properties after 5×10^8 rads. After 10^8 rads, neoprene-phenolics exhibited useful properties and neoprene-nylon-phenolic adhesives maintained useful properties after 5 x 10^7 rads. Reference 13 suggests that use of neoprene-nylon-phenolics and cellulosics (which would be even more sensitive) be generally avoided.

Oxidation is an important factor in the degradation of adhesives at elevated temperatures. Most show better thermal resistance in vacuum or inert atmospheres, but one epoxy-phenolic adhesive, Hexcell 422-J, retained better shear strength after exposure to 10^9 rads at 350°F in air than after exposure to the temperature-air environment alone.[36]

DOSE CALCULATIONS/CONVERSIONS

The ICRU recommended unit of exposure for X or gamma radiation is the Roentgen (R) which produces an absorbed dose in dry air under charged particle equilibrium of 0.869 rads:

1 Roentgen = 0.869 rads (air)

The absorbed dose in any other medium can be calculated if the energy of the exposing radiation and the composition of the absorber is known. The following equation and values for mass energy absorption coefficients ($\mu en/\rho$) and for equilibrium factor (A_{eq}) are taken from Reference 63.

$(\mu en/\rho)$ - carbon = 0.02670

$(\mu en/\rho)$ - air = 0.02660

A_{eq} (1.25 MeV CO-60) = 0.985

Then:

$$\text{rad (medium)} = \frac{(\mu en/\rho)\ \text{medium}}{(\mu en/\rho)\ \text{air}}\ .985\ \text{rad (air)}$$

$$\text{rad (carbon)} = \frac{(.02670)}{(.02660)}\ .985\ \text{rad (air)}$$

$$\text{rad (carbon)} = 0.989\ \text{rad (air)}$$

Reference 3 provides information on appropriate methods for measuring and calculating absorbed dose in specific materials resulting from exposure to various radiation sources. Factors that influence the total absorbed dose include radiation type and energy spectrum as well as chemical composition and thickness of the absorber.

Occasionally, it is not possible to determine the absorbed dose from the information available. The following conversion factors taken from Reference 36 can then be used to make some estimate of the absorbed dose in organic polymers.

For exposure to:

1 M eV electrons

$$e/cm^2 \times 4.5 \times 10^{-8} \cong \text{rads}$$

1 M eV photons

$$\gamma/cm^2 \times 5.0 \times 10^{-8} \cong \text{rads}$$

Thermal neutrons -- 0.025 eV

$$n/cm^2 \times 1.06 \times 10^{-9} \cong \text{rads}$$

Fast neutrons -- average of 1 M eV

$$n/cm^2 \times 4.17 \times 10^{-9} \cong \text{rads}$$

These values appear to be based on assuming a thick sample of material with a chemical composition similar to tissue. They are indicated as rads (carbon) in Reference 36, but this is misleading. Although accurate within a factor of 2 or 3 for most polymers, the neutron conversion factors would be in error by more than an order of magnitude for pure carbon.

Section 4

SUMMARY AND CONCLUSIONS

The summary threshold listing of Table 4-1 supports the suggestion that radiation effects are not a significant concern for organic polymers at or below 10^4 rads. It is, therefore, suggested that nonelectronic equipment containing these materials will not be affected. It is further suggested that nonelectronic equipment without Teflon will not be affected at 10^5 rads or less. Further explanation is provided here for the few cases where radiation-induced change was indicated below 10^5. A threshold of 5×10^4 rads was noted for one ethylene-propylene formulation, but the property changes were minor and commercial materials show thresholds of 10^6 rads or greater (10^6 is the cited threshold in Table 4-1). A threshold change in hardness was determined for styrene-butadiene rubber at 5×10^4 rads by one investigation . As indicated in Section 3, that value is probably in error; the lowest threshold reported elsewhere is 2×10^6 rads. The change in hardness (if real) would not significantly affect mechanical performance. The 8.7×10^4 rad threshold for nylon fibers is of more concern. Roughly 25% reduction in flex life was noted for nylon 6, 66, and 66 HT fibers. This test appears to have maximized synergistic effects. The fiber form provided maximum availability to oxygen and the flexural cycling test provided a very sensitive damage indicator. Further degradation was gradual; 8.7×10^5 rads resulted in a 40-60% decrease in flex life. Nylon sheets showed a damage threshold greater than 10^5 rads.

In summary, the suggested exclusion levels are felt to be quite conservative. In literature reviewed for this report, the lowest dose indicated as making a substantial contribution to equipment failure was about 10^5 rads for Teflon hoses subjected to the additional stress of elevated temperatures and pressures. Other radiation induced equipment failures are associated with doses of 10^6 rads or more.

One polyethylene/polyvinyl chloride cable insulation, containing a nylon inner sleeve, did show serious deterioration after 10 years in service at ambient temperature of 30-40°C and an estimated radiation dose of about 2 x 10^6 rads.[10] The nylon in this case was exposed to more than 20 times the threshold damage level and more than twice the 40-60% damage level. This may have contributed greatly to the overall component performance (see Section 3 data for PE and PVC for other pertinent information).

No threshold is suggested for electrical equipment which might fail due to transient effects of high radiation dose rates; for normal "aging" dose rates, transient changes in electrical properties are indicated as negligible.

No threshold is suggested for semiconductor devices or electronic assemblies.

Appendix C of Reference 61 treats a number of the materials treated by this study and identifies equipment types in which those materials are commonly found. The two reviews are basically in agreement, but a few exceptions are worthy of note:

- A 10^9 allowable level is indicated for most laminates. Data considered in this review indicates that cellulose (paper or cotton)-filled laminates would be seriously degraded by 10^9 rads.
- Diallyl phthalate (glass-filled) is indicated as an exceptionally good electrical insulating material. The threshold cited is probably for unfilled material, which is not generally used.
- A 10^7 rad allowable dose is indicated for most cable insulating materials. While accurate, it fails to indicate that specific materials are available which tolerate much higher doses.

Table 4-1 identifies the lowest threshold found for each material, the reference which provided that value, and the material property first affected.

Tables 4-2 through 4-4 identify materials for which sensitization effects were found for irradiation above threshold and the nature of that effect. It is suggested that test programs which maximize such sensitization effects will best simulate the synergistic effects that could occur for the materials in an operating environment.

Sandia Laboratories and CERN (European Organization for Nuclear Research) have a number of active programs involving radiation effects and are continuing to supply new information. The Radiation Effects Information Center of Battelle Memorial Institute supplied much of this information reviewed here, but is not currently active in the field. Two of their major studies are not cited in the reference section. REIC 46 was neglected since that information is included in Reference 33. REIC 38 was neglected because it deals principally with electronic components; information on organic materials is included in referenced works.

A substantial effort was made to include and reference all pertinent information from the literature. One report identified too late to be included in the references was UD-NEMA Technical Report No. 708 (1964), which provides data for the irradiation of a number of plastic laminates. Omission of that and any other as yet unidentified work was unintentional.

TABLE 4-1

SUMMARY LIST OF THRESHOLD DOSES

Generic Name Material	Lowest Reported Threshold (Rads)	Report Ref.	Property Changed
Polytetrafluoroethylene	1.5×10^4	47	Elongation
Aliphatic polyamide (nylon)	8.7×10^4	36	Flex life
Cellulose	1×10^5	9	Tensile strength (increase)
Polyphenylene oxide	10^5	55	Tensile strength
Polyester resins (unfilled)	10^5 to 10^6	36	Elongation (most)
Fluoroelastomers	10^5 to 10^6	4, 13	Compression set (most)
Cellulose propionate	3×10^5	36	Impact strength
Cellulose-filled phenolics	3×10^5	36	Hardness
Cellulose acetate butyrate	3.4×10^5	55	Elastic modulus
Polypropylene	Approx. 3×10^5	None	Similar to polyethylene
Polyethylene	3.8×10^5	21	Elongation increase
Cellulose nitrate	5×10^5	55	Elongation
PVC (plasticized)	5×10^5	21	Thermal resistance
Chlorosulfonated polyethylene	5×10^5	8, 28	Elongation
Silicone elastomers	5×10^5	8	Oxidation resistance
Acetal resin	6×10^5	55	Tensile strength/ elongation
Aniline formaldehyde	6.7×10^5	36	Impact strength
Polycarbonate	7×10^5	55	Elongation
Acrylic resin (PMMA)	7×10^5	21	Tensile/ elongation
Polymethyl alphachloroacrylate	7×10^5	37	Tensile elongation
Butyl rubber	7×10^5	55	Tensile strength

Table 4-1 (Continued)

Generic Name Material	Lowest Reported Threshold (Rads)	Report Ref.	Property Changed
Cellulose acetate	8×10^5	9	Tensile strength
Graphite-filled phenolic	8×10^5	36	Elongation
Neoprene	8×10^5	48	Compression set
Polyacrylonitrile (fiber)	1×10^6	25	Tensile strength
Propylene-ethylene polyallomer	1×10^6	55	Tensile/ elongation
Polyacrylate elastomer	10^6	36	Set at break
Silicones	1×10^6	37	Tensile/ elongation/ hardness
Ethylene propylene elastomer	10^6	55	Compression set
Butadiene rubber	10^6	37	Compression set
Nitrile rubber	10^6	36	Compression set
Urethane rubber	10^6	55	Compression set
Polychlorotrifluoroethylene	1.2×10^6	55	Shear strength/ elastic modulus
Polyvinyl chloride acetate	1.4×10^6	55	Elongation
Ethyl cellulose	1.5×10^6	36	Impact strength
Parylene	None established	55, 48	
Styrene butadiene rubber	1.8×10^6	37	Compression set/elongation
Vinyl pyridine rubber	2×10^6	36	Compression set
Natural rubber	2×10^6	36	Compression set
Ionomer resins	2×10^6	36	Tensile/ elongation
Polyvinyl butyral	3×10^6	55	Tensile st.

Table 4-1 (Continued)

Generic Name Material	Lowest Reported Threshold (Rads)	Report Ref.	Property Changed
Polyvinylidene chloride	3.7×10^6	37	Elongation
Casein resin	4×10^6	36	Impact strength
Polyethylene terephthalate	4.4×10^6	36	Tensile/ elongation
Melamine formaldehyde (cellulose-filled)	6.7×10^6	36	Impact strength
Aromatic polyamides	7×10^6	36	Elongation
Urea formaldehyde	7.5×10^6	36	Tensile/ elongation
Tefzel	None established	28	Elongation
Polyvinylidene fluoride	8×10^6	13	Not given
Polyimide	10^7	47	Elongation/ tensile
Polyvinyl fluoride	10^7	36	Elongation
Polyvinyl formal	1.6×10^7	36	Elastic modulus
Acrylonitrile butadiene	10^7	61, 55	Tensile strength
Polystyrene	2×10^7	14	Tensile strength
Polysulfone	5×10^7	16	Flex strength
Polyurethane resin	6×10^7	37	Tensile strength
Polyester resin (mineral-filled)	7.9×10^7	37	Elongation (most)
Polyvinyl carbazole	8.8×10^7	36	Impact strength
Pyrrone resin	10^8	55	Flexural strength
Epoxy resin	2×10^8 or more	26, 42	Varies
Furan resin (asbestos and CB-filled)	3×10^8	37	Tensile/ elongation
Polyester glass laminate	4×10^8	38	Flexural st.
Silicone-asbestos laminate	6×10^8	36	Flexural st.
Asbestos phenolic laminate	10^9	36	Flexural st.
Glass-filled diallyl phthalate	1.3×10^9	33	Tensile strength/ elongation

Table 4-2

MATERIALS FOR WHICH STRONG SENSITIZATION EFFECTS HAVE BEEN DEMONSTRATED

MATERIAL	EFFECTS RELATED TO* O_2	Heat	Other	DEMONSTRATED BY	COMMENT
Acrylic Resins	X			Increased oxidation rate following irradiation	80°C in air for 1-6 hrs gave about the same damage as 500 hr air storage
(PMMA) (Lucite) (Plexiglass) (Perspex)		X		Decreased "softening" temperature of irradiated acrylics ("softening" = increasing elongation under constant stress)	Initial softening temperature 260°C detectable change after 7×10^5 rads After 2.3×10^6 rads softening temp. was 150°C
			X (gas)	Gaseous degradation products cause "foaming" at high temperatures-gas diffusion is limited	At lower temperatures cracking and crazing would be expected
Cellulose (paper) (plant fibers)	X			Increased oxidation rate following irradiation	Does not occur if radiation was in inert atmosphere, nor if moisture content was above 3%
			X (H_2O)	Increased H_2O absorption and H_2O solubility.	
Polyvinyl Chloride (PVC)	X			Lower radiation resistance in air than in vacuum (same formulation) Lower radiation resistance of thin films in air than thick samples (same formulation) Lower radiation resistance at lower dose rates in air	Heating in air following irradiation produces approximately the same damage as thin film or low dose rate tests

* X - effect is related to environment marked
No - effect is not related to environment marked
blank- no data to indicate whether an effect related to that environment occurs

Table 4-2 (Continued)

MATERIALS FOR WHICH STRONG SENSITIZATION EFFECTS HAVE BEEN DEMONSTRATED

MATERIAL	EFFECTS RELATED TO O_2	Heat	Other	DEMONSTRATED BY	COMMENT
(PVC)		X		Reduced melting temperature after irradiation in air (but not in vacuum) Increased outgassing rates at elevated temperature (air or vacuum)	Total of 30-40°C reduction after 11 X 10^6 rads Outgassing is principally HCL
* Polytetra-fluoroethylene Teflon (PTFE)	X			Lower radiation resistance in air than in vacuum (same formulation) Lower radiation resistance for thin films in air than thick samples (same formulation)	FEP teflon shows better oxidation resistance and better total radiation resistance
		X		Temperature resistance not greatly affected in the range 100-350°F	Sharp reductions in melting point when irradiated at high temperature
Aliphatic Polyamide (Polycaprolactam) (Nylon)	X			Reduced flex life of fibers irradiated in air Lower radiation resistance in air than in vacuum	4 - 5X better resistance in vacuum
		NO		Melting point unchanged after 8.7 X 10^6 rads Similar results at temperatures to 100°C	

Table 4-2 (Continued)

MATERIALS FOR WHICH STRONG SENSITIZATION EFFECTS HAVE BEEN DEMONSTRATED

MATERIAL	EFFECTS RELATED TO O_2	Heat	Other	DEMONSTRATED BY	COMMENT
Polyethylene	X			Lower radiation resistance in air than in vacuum Lower radiation resistance of thin films than thick samples (in air) Lower radiation resistance at low dose rates	
		X		Greatly increased heat resistance if irradiated in vacuum Some increase in temperature resistance when irradiated in air Limit of 150°C in air	Related to peroxide formation
Polypropylene	X			Increased oxidation rate following irradiation Lower radiation resistance in air than in vacuum	Radiation resistance generally less than polyethylene
		X		Crosslinking rates reduced above 35°C	
Polystyrene	X			Increased oxidation rate following irradiation Lower radiation resistance in air than in vacuum	
			X (LET)	Approximately 3 times as much damage from neutron radiation as from gamma or electron	LET effects for highly unsaturated organics

Table 4-2 (Continued)

MATERIALS FOR WHICH STRONG SENSITIZATION EFFECTS HAVE BEEN DEMONSTRATED

MATERIAL	EFFECTS RELATED TO O_2	Heat	Other	DEMONSTRATED BY	COMMENT
Polyester Resins (excluding Phthalates)	X			Decreased oxidation resistance	Little detail located. Effect should be greatest with longest most unsaturated ester base
Fluoroelastomer	X			Lower radiation resistance in air than vacuum, inert atmosphere or oil	Viton A "disintegrated" after 8.7 X 10^5 rads at 400°F in air
				Increased oxidation rate after irradiation	"OK" after 4.4 X 10^6 rads at 400°F in oil
		X		Some decrease in radiation resistance at elevated temperature in inert atmosphere	Moisture resistance generally not good
Neoprene	X			Lower radiation resistance at lower dose rates. Increased oxidation rates following irradiation (2 out of 3 formulations tested)	Probable temperature effects
			X	Lower radiation resistance in vacuum	Apparently little to no crosslinking for that formulation in vacuum (some in air)

Table 4-3

MATERIALS FOR WHICH "MODERATE" SENSITIZATION EFFECTS HAVE BEEN DEMONSTRATED

MATERIAL	EFFECTS RELATED TO O_2	Heat	Other	DEMONSTRATED BY	COMMENT
Cellulose Acetate	NO			No dose rate influence over range of 9.2 rad/sec to 0.9 rad/sec Same results air/vacuum	
		X		Temperature at break under constant load decreased from 170°C unirradiated to 135°C after 2×10^7 rads	
Tefzel	X			Lower radiation resistance at low dose rates Reduced flex life in air (not in N_2)	Reductions in thermal resistances probable
Polysulfone	X			Lower radiation resistance in air than in vacuum	
		X		Lower radiation resistance at elevated temperature	

Table 4-3 (Continued)

MATERIALS FOR WHICH "MODERATE" SENSITIZATION EFFECTS HAVE BEEN DEMONSTRATED

MATERIAL	EFFECTS RELATED TO O_2	Heat	Other	DEMONSTRATED BY	COMMENT
Epoxy Resins	X			Results are variable - depends on curing agent Novalac is rated as especially oxidation resistant	
		X		Some greater resistance to heat plus radiation than to heat alone	Oxidation may be blocked by radiation crosslinking
Phenolic Resins			X (H_2O)	Cellulose filled and unfilled resins show increased sensitivity to moisture after irradiation	
	X	X		Temperature plus radiation less damage than temperature alone for some	Oxidation may be blocked by radiation crosslinking
Polyurethane Plastics	X			Variable oxidation resistance from "minor" to ~ four times as sensitive to radiation in air as in vacuum	Moisture sensitivity is application limiting
Silicone Resins	X			Increased oxidation rate following irradiation for silica filled polysiloxanes	
		X		Lower radiation resistance at elevated temperatures	
				Silicone-alkyd insulations and glass filled laminates are more resistant to temperature plus radiation than to temperature alone	Oxidation may be blocked by crosslinking

Table 4-3 (Continued)

MATERIALS FOR WHICH "MODERATE" SENSITIZATION EFFECTS HAVE BEEN DEMONSTRATED

MATERIAL	EFFECTS RELATED TO O_2	Heat	Other	DEMONSTRATED BY	COMMENT
Ethylene Propylene	X			Lower radiation resistance at low dose rates	Cable insulation
			X	One formulation showed unstable electrical properties after irradiation	Incompatibility with fire-retardant additive
Chlorosulfonated Polyethylene	X			Lower radiation resistance at low dose rates	
				Lower radiation resistance in air than in vacuum	
Buna N	X			Some show greater degradation in air than vacuum	Overall aging resistance may be poor
Rubber (Nitrile)			X (Mechanical stress)	Dynamic Pressure Test 350°F	Passed 350°F dynamic test after 1 X 10^6 rads
Silicone rubber	X		X	Increased oxidation rates following irradiation -- peroxide cured	Peroxide residues involved
		X		Minor changes in thermal properties	

Table 4-4

MATERIALS FOR WHICH TESTS INDICATE MINOR TO NO SENSITIZATION EFFECTS

MATERIAL	EFFECTS RELATED TO O_2	Heat	Other	DEMONSTRATED BY	COMMENT
Polyvinylidene Fluoride (Kynar)	X			Equal radiation resistance in air or vac[illegible]	No comparative test at elevated temperatures found
Polycarbonate (Macrofoil) (Lexan)	X			Equal radiation in air or vacuum of 3 mil Macrofoil film	No comparative test at elevated temperature found
Polyethylene Terephthalate (Dacron) (Mylar)	X			Flex life of Dacron fibers same for air or vacuum irradiation (other properties also)	
		X		Minor reduction in melting point Radiation resistance unaffected up to temperatures of 200°C	
			X	Low dose rate test shows greater scission rates	Reasons uncertain, occurs in air or vacuum
Polyimide (H-Film) (Kapton)	X			Radiation resistance in air is about half as much as in vacuum	

Table 4-4 (Continued)

MATERIALS FOR WHICH TESTS INDICATE MINOR TO NO SENSITIZATION EFFECTS

MATERIAL	EFFECTS RELATED TO O_2	Heat	Other	DEMONSTRATED BY	COMMENT
Adduct Rubber			X	Higher saturated adducts show greater radiation resistance	
		X		Equal radiation resistance at 75°F to 200°F	
Butyl Rubber	X			No decrease in oxidation resistance	Poor radiation resistance Scission dominant
Polyurethane Rubber	X			Equal radiation resistance in air or vacuum	Moisture sensitive
		X		Tensile strength retention same to 260°F	
Thiokol Rubber	X			Comparable radiation resistance in air or vacuum	Scission dominant
				Radiation followed by thermal aging no significant change	
Aramid (Nomex) (Kevlar)	X			Better resistance to elevated temperatures following irradiation. About equal resistance to temperature alone as to simultaneous temperature/radiation	Radiation induced crosslinking appears to block oxidative degradation

Section 5

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APPENDIX

(ADAPTED FROM REFERENCE 55 AND OTHERS)

Alphabetic Index Of Plastics by Trade Name

(A)

TRADE NAME	CHEMICAL NAME
ABCOLITE	Polystyrene (PST)
ABSON	Acrylonitrile butadine styrene (ABS)
ACETOPHANE	Cellulose acetate
ACROLITE	Urea formaldehyde
ACRILAN	Acrylic resin
ACRYLOID	Polyacrylester
ACRYSOL	Polyacrylester
ACRYTEX	Polyacrylacid
AFCOLENE	Polystyrene
AGILENE	Polyethylene
AGILIDE	Polyvinyl chloride
AKULON	Polyamide
ALATHON	High-pressure polyethylene
ALBAMIT	Melamine formaldehyde
ALGOFLON	Polytetrafluoroethylene (PTFE)
ALKATHENE	Polyethylene
ALKON	Polyacetal
ALKYLDALE	Polyester
ALPHALUX 400	Polyphenylene Oxide (PPO)
ALTUGLAS	Acrylic resin
AMEROID	Casein resin
AMPACET	Polystyrene
ARALDITE	Epoxy resin
ARNITE	Polyethylene terephthalate
AROPOL	Polyester
ASTRALIT	Polyvinyl chloride (PVC)
ALTAC	Polyester

(B)

TRADE NAME	CHEMICAL NAME
BAKELITE	Phenolics
	Polyvinyl chloride
	Polystyrene
	Phenoxy
	Polysulfone
BENVIC	Polyvinyl chloride
BEXOID	Cellulose acetate
BEXTRENE	Polystyrene
BLENDEX	Acrylonitrile butadiene styrene (ABS)
BONOPLEX	Polymethacrylester
BUTACITE	Polyvinylbutyral
BUTOFAN	Copolymer butadine styrene

(C)

CALADENE	Phenolic
CAMPCO C119	Polycarbonate
CAPRAN (Film)	Polyamide (Nylon 6)
CARDURA	Epoxy resin
CARINA	Polyvinyl chloride
CARINEX	Polystyrene
CARLONA	Polyethylene
CARLONA P	Polypropylene
CASCO RESINS	Urea formaldehyde, phenolic
CATABOND	Polyester
CATALIN	Phenolic
CEAPREN	Polyester
CELLIDOR	Cellulosics
CELLIT	Cellulosics
CELLOFOAM	Polystyrene
CELLOPHANE	Cellulosics
CELSON	Polyoxmethylene
CIBANITE	Aniline formaldenyde
COVISIL	Silicone

TRADE NAME	CHEMICAL NAME
CR 39	Diallyl-polycarbonate
CRYSTIC	Polyester
CYCOLAC	Acrylonitrile butadiene styrene (ABS)
CYMEL	Melamine formaldehyde

(D)

DACRON	Polyethylene terephthalate
DAPLEN	Polypropylene
DAPON	Diallylphthalate
DAPCEN	Polyester
DARVIC	Polyvinyl chloride
D.C. RESINS	Silicone
DEDERSON	Polyamide
DELRIN	Acetal
DESMODENE	Polyester
DESMODUR	Polyurethane
DESMOPHEN	Polyurethane
DEVCON	Epoxy Resin
DIAFLON	Polytetrafluoroethylene (PRFE)
DIAKON	Polymethylmethacrylate
DIORIT	Polyvinylidene chloride
DOLAN	Polyacrylonitrile
DOWEXSON	Polystyrene (sulfonated)
DRALON	Polyacrylonitrile
DURALON	Furan resin
DURATHON	Polyacetal
DURETHANE	Polyurethane
DUREZ	Phenolic
DURITE	Phenolic
DYLAN	Polyethylene
DYLENE	Polystyrene
DYNAPOL	Polyester
DYNEL	Polyacrylonitrile

(E)

TRADE NAME	CHEMICAL NAME
EKAVYL	Polyvinyl chloride
ELVAZET	Polyvinyl acetate
EMULTEX	Polyvinyl acetate
EPIALL	Epoxy resin
EPIKOTE	Epoxy resin
EPON	Epoxy resin
EPOPHEN	Epoxy resin
EPOXYLITE	Epoxy resin
ERINOLD	Casein resin
ERTALON	Polyamide
ERTALYTE	Polyethylene terephthalate
ERTAPHENYL	Polyphenylene oxide
ERVALKYD	Alkyd resin
ESTANE	Polyurethane
ETHOCEL	Ethyl cellulose

(F)

FLEXON	Polyvinyl chloride
FLUON	Polytetrafluoroethylene (PTFE)
FLUORLON	Polytetrafluoroethylene (PTFE)
FLUOROTHENE	Polychlorotrifluoroethylene (PCTFE)
FORMICA	Melamine-formaldehyde
FORMVAR	Polyvinyl formal
FORTICEL	Cellulosics

(G)

GABRASTER	Polyester
GABRITE	Urea formaldenyde
GANSOLITE	Casein resin
GEDEX	Polystyrene
GELVA	Polyvinyl acetate
GEON	Polyvinyl chloride

TRADE NAME	CHEMICAL NAME
GLIDPOL	Polyester
GRILON	Polyamide
(H)	
H FILM and HT FILM	Polyimide
HALON	Polytetrafluoroethylene (PTFE)
HAVEG	Phenolic
HERCULON	Polypropylene
HETRON	Polyester
HIFAX	Polyethylene
HOSTAFLON	Polychlorotrifluoroethylene (PCTFE)
HOSTAFLON TF	Polytetrafluoroethylene
HOSTAFORM C	Polyoxymethylene
HOSTALEN G	Polyethylene
HOSTALEN PPH	Polypropylene
HOSTALIT	Polyvinyl chloride
HOSTYREN	Polystyrene
HYDEFLON	Polytetrafluoroethylene (PTFE)
(I)	
IGAMID U	Polyurethane
IGELIT	Polyvinyl chloride
IXAN	Polyvinylidene chloride
(K)	
KAPTON (FILM)	Polyimide
KARBATE	Phenolic
KEL F	Polychlorotrifluoroethylene (PCTFE)
KOROSEAL	Modified polyvinyl chloride
KRALASTIC	Acrylonitrile butadiene styrene (ABS)
KYNAR	Polyvinylidene fluoride

(L)

TRADE NAME	CHEMICAL NAME
LACQRENE	Polystyrene
LACTOPHANE	Cellulosics
LAMINAC	Polyester
LEGUVAL	Polyester
LEKUTHERM	Epoxy resin
LEXAN	Polycarbonate
LORKALENE	Polystyrene
LUCITE	Polymethyl methacrylate
LUCOVYL	Polyvinyl chloride
LUPOLEN	Polyethylene
LURAN	Styrene acrylonitrile (SAN)
LUSTRAN	Acrylonitrile butadiene styrene (ABS)
LUSTREX	Polystyrene
LUVICAN	Polyvinyl carbazole

(M)

MAKROLON	Polycarbonate
MARAGLAS	Epoxy resin
MARBLETTE	Phenolic
MARCO MR	Polyester
MARFOAM	Polyurethane
MARLEX	Polyethylene
MARVINOL	Polyvinyl chloride
MELINEX	Polyethylene terephthalate
MELMAC	Melamine formaldehyde
MELOX	Melamine formaldehyde
MERAKLON	Polypropylene
MERLON	Polycarbonate
MOPLEN	Polypropylene
MOWILTH	Polyvinyl acetate
MYLAR	Polyethylene terephthalate
MULTRON	Polyester

(N)

TRADE NAME	CHEMICAL NAME
NAILONPLAST	Polyamide
NOMEX YARN	Polyamide (aromatic)
NORYL	Polyphenylene oxide
NOVODUR	Acrylonitrile butadiene styrene (ABS)
NOVOLAC	Epoxy resin
NUCLON	Polycarbonate
NYLON	Polyamide

(O)

OLETEMP	Polypropylene
OPALON	Polyvinyl chloride
ORGAMID	Polyamide
ORIZON	Polyethylene
ORLON	Polyacrylonitrile
OROGLAS	Polymethacrylester

(P)

PARAPLEX	Polyester
PARLENE N,C,D	Parylene
PERLON	Polyurethane
PERLON L	Polyamide
PERSPEX	Polymethyl methacrylate
PHENOLINE	Phenolic
PLASTISSUE	Polyethylene film
PLASKON ALKYD	Polyester
PLASTACELE	Cellulose acetate
PLEOGEN	Polyester
PLEXIDUR	Polymethyl methacrylate
PLEXIGLAS	Polymethyl methacrylate
PLEXILEIM	Polyacrylacid
PLIOVIC	Polyvinyl chloride
PLYOPHEN	Phenolic
POLECTRON	Polyvinylcarbazole

TRADE NAME	CHEMICAL NAME
POLYDUR	Polyethylene
POLYFLON	Polytetrafluoroethylene
POLYOX	polyethylene
POLYSTYROL	Polystyrene
POLYTHENE	Polyethylene
POLYTHERM	Polyvinyl chloride
POLYVIOL	Polyvinyl alcohol
PPO	Polyphenylene oxide
PROFAX	Polypropylene
PROPATHENE	Polypropylene
PROPIOFAN	Polyvinyl acetate
(R)	
RAYOLIN	Polyolefin
RAYON	Cellulosics
RESIMENE	Melamine formaldehyde
RESINOL	Phenolic
RESINOX	Phenolic
RESOCEL	Phenolic
RESOFIL	Phenolic
RHODANITE	Cellulose acetate
RHODOPAS	Polyvinyl acetate
RHODORSIL	Styrene acrylonitrile (SAN)
RILSAN	Polyamide
ROSITE 2000	Phenolic
(S)	
SAFLEX	Polyvinylbutyral
SAN	Styrene-acrylonitrile
SARAN	Polyvinylidene chloride
SARAN F	Polyvinyl chloride
SELECTRON	Polyester
SICRON	Polyvinyl chloride
SILMAR	Polyester
SODETHANE	Polyurethane
SOLITHANE	Polyurethane

TRADE NAME	CHEMICAL NAME
SOLVIC	Polyvinyl chloride
SOMOPLAS	Polyvinyl chloride
SOREFLON	Polytetrafluoroethylene
STRUX	Cellulose acetate
STYROFOAM	Polystyrene
STYRON	Polystyrene
STYROPOR	Polystyrene
SURLYN	Ionomer resin
SUSTONAT	Polycarbonate
SYLGARD	Silicone
SYNVAREN	Phenolic
SYNVARITE	Phenolic
SYNVAROL	Urea formaldehyde

(T)

TRADE NAME	CHEMICAL NAME
TEDLAR	Polyvinyl fluoride
TEFLON	Polytetrafluoroethylene
TEFLON FEP	Copolymer of hexafluoropropylene and tetrafluoroethylene
TENITE	Polypropylene
TENITE BUTYRATE	Cellulose acetate butyrate
TERLURAN	Styrol polymer
TERPLEX	Polymethacrylester
TERYLENE	Polyethylene terephthalate
TETRAN	Polytetrafluoroethylene
TEXIN	Polyurethane
TORTULEN P	Polypropylene
TREVIRA	Polyethylene terephthalate
TRIACEL	Cellulose acetate
TRITHENE	Polychlorotrifluoroethylene
TROGAMID	Polyamide
TROLEN P	Polypropylene
TROLITUL	Polystyrene
TRULON	Polyvinyl chloride
TUFNOL	Phenolic

TRADE NAME	CHEMICAL NAME
TYBRENE	Acrylonitrile butadiene styrene (ABS)
TYGON	Polyvinyl chloride
(U)	
UDEL	Polysulfone
UKAPON	Polyester resins
ULTRAMID	Polyamide
ULTRON	Polyvinyl chloride
UROX	Urea formaldehyde
(V)	
VARCUM	Phenolic
VELON	Polyvinylidene chloride
VESPEL	Polyimide
VESTAMID	Polyamide
VESTAN	Polyvinylidene chloride
VESTOLEN	Polyethylene
VESTOLITE	Polyvinyl chloride
VESTYRON	Polystyrene
VIBRATHANE	Polyester
VIBRAIN	Polyester
VINAROL	Polyvinyl alcohol
VINAVIL	Polyvinyl acetate
VINIDUR	Polyvinyl chloride
VINNAPAS	Polyvinyl acetate
VINNOL	Polyvinyl chloride
VINOFLEX PC	Polyvinyl chloride
VINYLITE A	Polyvinyl acetate
VINYLITE	Polyvinyl chloride
VIPLA	Polyvinyl chloride
VISCOSE	Cellulosics
VYBAK	Polyvinyl chloride

(W)

TRADE NAME	CHEMICAL NAME
WELVIC	Polyvinyl chloride
WOPALON	Cellulose acetate

(X)

XYLONITE	Cellulosics
XYNEL	Polyvinyl chloride

(Z)

Z FOAM	Polyurethane
ZETAFIN	Polyethylacrylate
ZYTEL	Polyamide

Alphabetic Index for Elastomers by Popular Name

POPULAR NAME	CHEMICAL DESIGNATION	TRADE NAMES
Acrylics	Polyacrylate	Acrylon Angus HR, SH Hycar Lactaprene Paracil OHT Precision acrylics Thiacril Vyram
Butyl GRI	Isobutylene-isoprene	Bucar butyl Enjay butyl Hycar I.I. rubber Oppanol B Petro-Tex butyl Polysar butyl Precision butyl Vistanex MM
EPR	Ethylene propylene	Angus KR APK C 23 Dutral N Enjay EPR Nordel Olethene
Fluoroelastomers	Vinylidene fluoride hexafluoropropylene	Angus VA, SV Fluorel Precision fluoro Viton
	Fluoro-silicone	Precision fluoro silicone
	Trifluorochloro-ethylene-vinylidene-fluoride	Silastic LS 53
Hypalon	Chlorosulfonated polyethylene	Angus HN Hypalon Precision hypalon
Natural Rubber	Natural polyisoprene	Coral DRP Natsyn Okolite Shell isoprene Trans P.R.

POPULAR NAME	CHEMICAL DESIGNATION	TRADE NAMES
Neoprene GRM	Chloroprene	Angus G Neoprene Okoprene Perbunan C Precision neoprene Sovprene U.S. rubber neoprene
Nitrile; Buna-N; G.R.A.; N.B.R.	Acrylonitrile-butadiene	Angus DS, WR, FR,LR, E, P Butacril Butraprene Chemigum Chemivic FR-N Herecrol Hycar OR Parker Nitrile Perbunan Polysar Krynao Precision Nitrile Royalite Tylac
Polybutadiene; Buna; S.K.A.	Butadiene	Ameripol CB BR rubber Budene Cisdene Diene Duradene Duragen Polysar tacktene S.K.B. Texus synpol EBR Trans 4 or cis 4
Polyisoprene Synthetic	Synthetic polyisoprene	Ameripol SN Coral DPR Natsyn Philprene Shell IR Trans PIP Cariflex
Polyurethane	Diisocyanate-polyester or polyether	Adiprene Chemigum XSL Conathene Contilan Cyanoprene Desmodur Desmolin Disogrim Elastocast Elastolan Elastothane Estane Genthane

POPULAR NAME	CHEMICAL DESIGNATION	TRADE NAMES
		Guidfoam Lamigom Mearthane Microvon Multrathane Pagulan Phoenolan Polyvon Precision urethane Solithane Texin Vorylen Vulcarprene Vulkollan
SBR; Buna-S; GRS; SKB	Styrene-butadiene	Ameripol Angus R.G. ASRC Polymers Butaprene S Carbonix Cariflex Chemigum IV Copo Darex Duradene Flosbrene FR-S Gen-flow Gentro Hycar OS, E, TT Krylene Kryflex Navgapol Naugatex Philprene Plioflex Pliolite S Pliotuf Polysar S S Polymers Solprene Synpol Tylac
Silicone	Polysiloxane	Angus SIL, SIS Arcosil Conrlastic Fairprene General Electric SE HW Parker Silicone Rhodorsils RTV Silastene Silastic Union Carbide K.Y.

POPULAR NAME	CHEMICAL DESIGNATION	TRADE NAMES
Thiokol; GRP	Organic polysulfide	Alkylene polysulfide F.A. polysulfide rubber Perduren Precision Thiokol S.T. polysulfide rubber Thioplasts Vulcaplas
Vinylpyridine	Butadiene-2-methyl-5-vinyl pyridine	Philprene

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Handbook of Plastics and Elastomers

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Chemical resistance Vinyl esters are unaffected by aliphatic hydrocarbons, strong bases, and dilute acids, bases, and salt solutions. They exhibit fair resistance to strong oxidants and strong acids. They are attacked by aromatic solvents, chlorinated solvents, esters, and ketones (see Table 7).

Chief corrosive-environment services The vinyl esters are employed to build all types of chemical processing equipment and are used in about all the corrosive environments in which the epoxy and polyester resins see service. As glass-fiber-reinforced resin structures they are used in piping, ducts, tanks, hoods, vent stacks, bins, feeders, chutes, scrubbing towers, fans, blowers, jets, pumps, valves, etc. Reinforced with glass flake, the vinyl esters are used as protective linings in steel tanks.

Flammability The vinyl-ester resins are classified as burning resins by ASTM D 635. Some modified vinyl esters are fire-retardant, however.

ELASTOMERS

Fundamentals

Relationship to plastics Closely related to the thermoplastic and thermosetting polymeric compounds are the synthetic elastomers. In many instances the same building block monomers, such as styrene and acrylonitrile, may be found as part of their structure.

ASTM definition of elastomer The term *elastomer* has been defined by the American Society for Testing and Materials as meaning "a polymeric material which at room temperature can be stretched to at least twice its original length and upon immediate release of the stress will return quickly to approximately its original length."

In this section we will be reviewing the general physical properties and chemical resistivity of natural rubber, for comparison, and the chief synthetic elastomers of commercial value.

Natural Rubber

Preparation and composition Natural rubber is obtained principally from the latex of *Hevea brasiliensis*, a tree. This elastomer is based upon natural *cis*-polyisoprene. The principal repeating unit is $(-CH_2-\underset{\underset{CH_3}{|}}{C}=CH-CH_2-)_n$.

Natural rubber is generally classified into soft, semihard, and hard rubber depending upon the degree of its curing. Vulcanization is accomplished by reaction with sulfur and/or sulfur-bearing compounds and additional organic accelerators in the presence of certain inorganic oxides at temperatures in the range of 212 to 400°F. The degree of vulcanization (hardness) is dependent upon the amount of sulfur contained in the final product. Soft rubbers have a maximum of about 0.5 to 4.0 percent sulfur, with a durometer Shore A reading of 20 to 30. Hard rubber (Ebonite) contains about 32 percent sulfur with a Shore D durometer between 50 and 100. Semihard rubber falls somewhere between these ranges. Neither semihard nor hard rubber meets the ASTM definition of elastomers; only soft rubber may be so considered. Thus chemical-resistance information is included only for soft rubber (see Table 8).

Natural rubber has outstandingly high tensile strength and excellent resiliency, and it retains its mechanical properties to a great extent at both elevated and low temperatures. However, it is susceptible to high-temperature degradation under prolonged exposure (see Table 9).

Chemical resistance Natural rubber is affected by mineral and vegetable oils, gasoline, benzene, toluene, and chlorinated hydrocarbons. It is severely attacked by strongly oxidizing materials such as nitric acid, concentrated sulfuric acid, dichromates, permanganates, sodium hypochlorites, and chlorine dioxide. It is not affected by most inorganic salt solutions, alkalies, and nonoxidizing acids. Hydrochloric acid reacts with soft rubber to form rubber hydrochloride. The reaction of hydrochloric ... semihard and hard rubber is quite slow, and they are acceptable for such ... see Table 8).

Synthetic Rubber (IR)

This is synthetic *cis*-polyisoprene, which is chemically and physically similar to natural rubber. Its chemical resistance is identical to that of natural rubber.

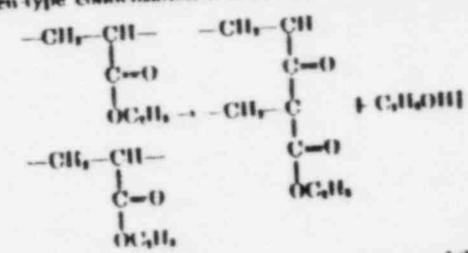
Acrylonitrile Butadiene (NBR)

Preparation and composition These elastomers are familiar as nitrile rubber or Buna N. Their properties and chemical resistance can be varied by changing the ratio of acrylonitrile to butadiene. These polymers usually contain between 20 and 40 percent acrylonitrile. A decrease in acrylonitrile results in a decrease in fuel and oil resistance. However, lowering the acrylonitrile content results in an elastomer with improved low-temperature flexibility and resiliency. Proper compounding can result in products with high tensile strength, excellent abrasion resistance, and good aging characteristics (see Table 10).

Chemical resistance The nitrile rubbers have good resistance to oils and solvents. They exhibit good resistance to alkalies and aqueous salt solutions. They swell very slightly in aliphatic hydrocarbons, fatty acids, alcohols, and glycols. The reduction in physical properties as a result of swelling is small, making the NBR elastomers especially suitable for gasoline and oil-resistant applications. NBR is attacked by strong oxidizing agents, ketones, ethers, and esters (see Table 8).

Polyacrylic Rubber

Preparation and composition The class of elastomers known as polyacrylic rubbers are polymers of acrylic acid esters prepared from alcohols of intermediate weight. Typical of this group are polyethyl acrylate and polybutyl acrylate, as well as the copolymer of ethyl acrylate and 2-chloroethyl vinyl ether. Vulcanization of these polymers is quite difficult inasmuch as they are saturated materials. Sulfur and sulfur-bearing compounds in fact act as curing retardants, and perform more as aging deterrents. These polyacrylic rubbers are cured with amines, such as triethylenetetramine. Alkaline reagents such as sodium metasilicate, potassium hydroxide, or lead oxide have been used used satisfactorily too. Cross-linking is said to occur by a Claisen-type condensation reaction with the splitting-out of alcohol:



Chemical resistance The fully cured polyacrylic rubbers exhibit good resistance to petroleum products, to hot oils and air up to 350°F. They have good resistance to animal and vegetable fats and oils. They will swell in aromatic hydrocarbons, alcohols, and ketones. Solvents frequently employed with polyacrylic rubbers are methylethyl ketone, toluene, xylene, or benzene. The polyacrylic rubbers deteriorate when subjected to aqueous media, steam, glycols, and caustic environments. Copolymers of acrylates and acrylonitrile produce acrylic rubbers with improved water and steam resistance. The acrylic rubbers are unaffected by oxygen and ozone (see Table 11).

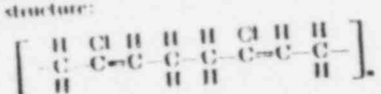
Physical properties The polyacrylic rubbers have good flex resistance and low permeability to hydrogen, helium, and carbon dioxide. They have fairly poor weathering characteristics, since they are affected by water. Discoloration in direct sunlight is negligible.

Butyl Rubber (IIR)

Preparation and composition A general-purpose synthetic rub... is obtained through the copolymerization of isobutylene with 1 to 35 percen... ...rene in the

Chloroprene Rubber (CR)

Preparation and composition More familiarly known as neoprene, this compound is prepared by polymerization of chloroprene, 2-chlorobutadiene-1, 3. It has the following repeating structure:



Neoprene has excellent resistance to permeation by gases. Depending upon the gas, permeability is one-fourth to one-tenth that of natural rubber (see Table 13).

Chemical resistance Neoprene is unaffected by aliphatic hydrocarbons, alcohols, glycols, and fluorinated hydrocarbons. It is not resistant to chlorinated hydrocarbons, organic esters, aromatic hydrocarbons, phenols, and ketones (see Table 8). It is unaffected by dilute mineral acids, concentrated caustics, and aqueous inorganic salt solutions. It is severely attacked by concentrated oxidizing acids like nitric acid and sulfuric acid, as well as strong oxidizing agents such as potassium dichromate

TABLE 13 General Properties of Chloroprene (Neoprene)

Property	Value
Specific gravity	1.28
Tensile strength, lb/in.²	3,000-4,000
Elongation, %	800-900
Hardness (durometer)	A40-95
Tear resistance	Fair
Abrasion resistance	Good
Recommended operating temp:	
Min °F	−40
Max °F	240
Chemical resistance:	
Acids, dilute	Excellent
Acids, concentrated	Good
Aliphatic solvents	Good
Aromatic solvents	Fair
Chlorinated solvents	Fair
Alcohols	Good
Alkalies	Good
Esters, ethers, ketones	Good
Resistance to (heat) aging	Excellent
Resistance to oxidation	Excellent

and peroxides. Neoprene is slightly inferior to nitrile rubber in oil resistance but is markedly better than natural, Buna S, or butyl rubber. This elastomer has good resistance to sunlight and general weathering.

Abrasion resistance Neoprene synthetic rubber is a tough, strong, resilient elastomer with excellent resistance to abrasive wear under severe service conditions. It has better abrasive-resistant properties than natural rubber at elevated temperatures.

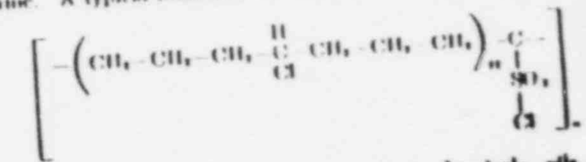
Hardness range Hardness of products made of neoprene generally ranges from 45 to 95 durometer A. Neoprene products are also available in open- or closed-cell sponge form.

Temperature resistance Neoprene is able to withstand continuous-exposure conditions at 200 to 225°F for long periods. There are specially compounded formulas of neoprene which can operate in intermittent service at temperatures up to 250°F. Conventional neoprene compounds can operate at temperatures down to −40°F, while specially formulated compounds have performed satisfactorily at temperatures as low as −67°F.

Flammability Neoprene will not propagate a flame. It burns in the presence of a fl[illegible] self-extinguishing when the flame is removed.

Chlorosulfonated Polyethylene (CSM)

Preparation and composition More familiarly known as Hypalon, this elastomer is prepared by reacting polyethylene with chlorine and sulfur dioxide. The process converts the thermoplastic polyethylene into an elastomer which can be compounded and vulcanized. The final product can be slightly varied in its properties; these depend upon the degree of chlorination, which is generally in the range of 25 to 30 percent chlorine. A typical molecular structure may be considered as follows:



Chemical resistance Extremely resistant to most chemicals, oils, and greases (see Table 8), Hypalon is particularly unaffected by aqueous salt solutions, alcohols, weak and concentrated alkalies, and concentrated sulfuric acid. It experiences good performance with hypochlorites. The resistance is poor to aliphatic and aromatic

TABLE 14 General Properties of Chlorosulfonated Polyethylene (Hypalon)

Property	Value
Specific gravity	1.12-1.28
Tensile strength, lb/in.²	4,000
Elongation, %	250-500
Hardness (durometer)	A45-95
Tear resistance	Fair
Abrasion resistance	Excellent
Recommended operating temp:	
Min °F	−40
Max °F	325
Chemical resistance:	
Acids, dilute	Excellent
Acids, concentrated	Excellent
Aliphatic solvents	Fair
Aromatic solvents	Poor
Chlorinated solvents	Poor
Alcohols	Good
Alkalies	Excellent
Esters, ethers, ketones	Poor
Resistance to (heat) aging	Excellent
Resistance to oxidation	Excellent

hydrocarbons, gasoline, jet fuels, chlorinated solvents, aldehydes, ketones, and fuel oils. The elastomer is resistant to microorganisms and underground environments. It has excellent resistance to moisture, high-humidity conditions, and ozone.

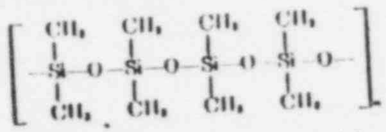
Flammability Hypalon is classified as self-extinguishing by ASTM D 635.

Weatherability Hypalon exhibits excellent resistance to ultraviolet radiation and atmospheric oxidation. It has excellent resistance to outdoor weathering by the elements and is unaffected by prolonged immersion in water.

Physical properties This elastomer has excellent abrasion resistance and good retention of physical properties to temperatures as low as 0°F and as high as 300°F. Special formulations can resist temperatures to 350°F. Hardness may be varied from 50 to 95 durometer A. The elastomer's excellent electrical properties make it well suited for insulation in low-voltage applications. Hypalon has excellent resistance to fatigue, cracking, and impact (see Table 14).

Silicone Rubber (VMQ)

Preparation and composition Silicone rubber is an organo silicone oxide polymer characterized by exceptional heat resistance. Chemically it is a linear-chain dimethyl siloxane polymer containing several thousand units of this structure:



Although the polymer is saturated, it can be vulcanized by heating with a source of free radicals such as benzoyl peroxide. It is postulated that the free radicals derived from the benzoyl peroxide abstract hydrogen atoms from the polymer molecules. The unsatisfied valences on the polymer molecules then give rise to cross links which result in a vulcanized product (see Table 18).

Temperature range The silicone rubbers have an extremely broad useful temperature range from −100 to 500°F. Their flexibility, resilience, and tensile strength are retained in this temperature range to an amazing degree.

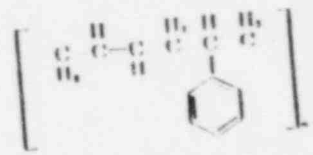
TABLE 18 General Properties of Silicone Rubber (Polysiloxane)

Property	Value
Specific gravity	1.1–1.6
Tensile strength, lb/in.²	600–1,300
Elongation, %	100–800
Hardness (durometer)	A30–90
Tear resistance	Fair
Abrasion resistance	Poor
Recommended operating temp:	
Min °F	−175
Max °F	600
Chemical resistance:	
Acids, dilute	Good
Acids, concentrated	Good
Aliphatic solvents	Excellent
Aromatic solvents	Excellent
Chlorinated solvents	Good
Alcohols	Good
Alkalies	Good
Esters, ethers, ketones	Good
Resistance to (heat) aging	Fair
Resistance to oxidation	Good

Chemical resistance Silicone rubbers are quite resistant to lubricating, animal, and vegetable oils, alcohols, dilute acids, and alkalies. They are excessively swollen by aromatic solvents, such as benzene and toluene, gasoline, and chlorinated solvents. They are not resistant to steam at elevated temperatures. The silicone polymers exhibit excellent resistance to ozone and weathering. They are particularly desirable in many aircraft applications such as jet-engine components, aircraft ducting, gaskets, seals, and diaphragms.

Styrene-Butadiene (SBR)

Preparation and composition This product, known also as GR-S rubber and Buna S rubber, is made by copolymerizing 75 parts of butadiene to 25 parts of styrene b... water at 50°C. It is compounded in much the same manner as natural ... can be vulcanized to soft, semihard, or hard rubber. It has the following molecular structure:



Chemical resistance Its compounds are similar to natural rubber in physical properties and in chemical resistance. Like natural rubber, SBR formulations deteriorate quickly in contact with oils and solvents. They are unaffected by water, alcohol, dilute acids, or alkalies. However, they are soluble in ketones, esters, and many hydrocarbons. They resist atmospheric deterioration slightly better than natural rubber (see Table 19).

Physical and mechanical properties SBR has lower tensile strength, is less resilient, and has lower heat resistance than natural rubber. The SBR products are more flexible than natural rubbers, especially at temperatures down to −120°F.

TABLE 19 General Properties of Styrene Butadiene

Property	Value
Specific gravity	0.94
Tensile strength, lb/in.²	200–300
Elongation, %	400–600
Hardness (durometer)	A40–90
Tear resistance	Fair
Abrasion resistance	Good
Recommended operating temp:	
Min °F	−60
Max °F	180
Chemical resistance:	
Acids, dilute	Good
Acids, concentrated	Fair
Aliphatic solvents	Poor
Aromatic solvents	Poor
Chlorinated solvents	Poor
Alcohols	Good
Alkalies	Good
Esters, ethers, ketones	Poor
Resistance to (heat) aging	Good
Resistance to oxidation	Good

Polysulfide Rubbers (T)

Preparation and composition These elastomers are prepared by reacting different organic dihalides with polysulfides. Typical is Thiokol B, which is prepared from di-2-chloroethyl ether, $Cl-(CH_2)_2-O-(CH_2)_2Cl$, and sodium polysulfide, Na_2S_x.

Chemical resistance Thiokol polymers are outstanding in solvent, gasoline, and oil resistance. The resistance to solvent swelling depends significantly upon the weight percent of sulfur in the polymer. The polysulfides have good resistance to aging and exceptional resistance to ozone, oxidation, and weathering. The polysulfides can be used within the temperature range of −60 to 250°F; it also has short-term uses up to 300°F without loss of properties (see Tables 8 and 20).

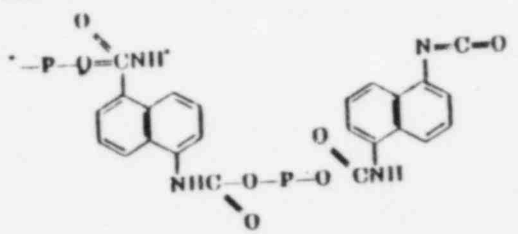
Polyurethane Diisocyanate Elastomers (AU)

Preparation and composition These are commonly referred to by the names urethane and/or polyester rubbers. The urethane solid elastomers are made with various isocyanates. The chief ones employed are tolylene diisocyanate (TDI) 4,4'-diphenylmethane diisocyanate (MDI), and 1,5-naphthalene diisocyanate. Typical starting point is the polyester obtained from the reaction of ethy... propylene

TABLE 20 General Properties of Polysulfide (Thiokol)

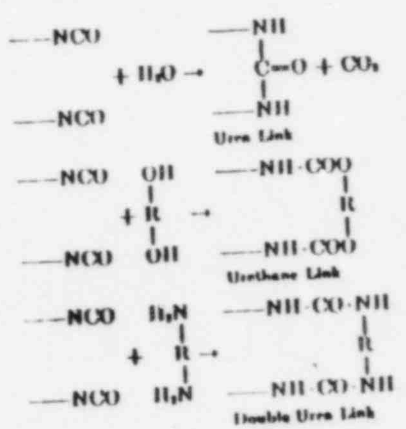
Property	Value
Specific gravity	1.35
Tensile strength, lb/in.²	250-400
Elongation, %	450-650
Hardness (durometer)	A40-85
Tear resistance	Poor
Abrasion resistance	Poor
Recommended operating temp:	
Min °F	−60
Max °F	250
Chemical resistance:	
Acids, dilute	Good
Acids, concentrated	Good
Aliphatic solvents	Excellent
Aromatic solvents	Excellent
Chlorinated solvents	Very good
Alcohols	Good
Alkalis	Good
Esters, ethers, ketones	Fair
Resistance to (heat) aging	Fair
Resistance to oxidation	Good

glycol with adipic acid. This product is reacted with 1,5-naphthalene diisocyanate to produce a prepolymer with a structure along these lines:



P = polyester group

This prepolymer can be chain-extended with water, glycols, or amines through linkage across terminal isocyanate groups:



Chemical resistance The solid polyurethane elastomers are clear, flexible plastics with excellent resistance to most mineral and vegetable oils, greases, and fuels. They exhibit good to excellent resistance to aliphatic, aromatic, and chlorinated hydrocarbons. Resistance to esters, ethers, and ketones is generally only fair. They are softened and swollen by alcohols. They have limited service in weak acid solutions and are completely unacceptable for use in concentrated acids. Caustics severely degrade the urethane rubbers. They are not resistant to steam. They show good resistance to oxygen and ozone (see Tables 8 and 21).

Weathering Urethanes have good weathering properties, being unaffected by extremes of weather. Prolonged exposure to ultraviolet light will darken the elastomers and somewhat diminish their physical properties. Pigmentation or use of ultraviolet absorbers can minimize such effects. Standard urethane elastomers do not support fungus growth and are generally quite resistant to microbiological attack. Some of the urethane rubbers offer outstanding resistance to the damaging effects of gamma-ray radiation.

TABLE 21 General Properties of Urethane Elastomer

Property	Value
Specific gravity	1.1-1.3
Tensile strength, lb/in.²	4,000-8,000
Elongation, %	400-750
Hardness (durometer)	Shore A90-D70
Tear resistance	Good
Abrasion resistance	Excellent
Recommended operating temp:	
Min °F	−65
Max °F	240
Chemical resistance:	
Acids, dilute	Fair
Acids, concentrated	Poor
Aliphatic solvents	Excellent
Aromatic solvents	Good
Chlorinated solvents	Good to fair
Alcohols	Good to fair
Alkalies	Fair to poor
Esters, ethers, ketones	Poor
Resistance to (heat) aging	Excellent
Resistance to oxidation	Good

Physical properties These elastomers have excellent abrasion resistance, impact resistance, and load-bearing properties. They can be processed by conventional thermoplastic methods, i.e., injection molding, extrusion, and solution application. They can be used safely for prolonged periods at temperatures above the boiling point of water, and retain much of their physical properties as low as −45 to 60°F (see Table 21).

Flammability The urethane rubbers are classified as slow-burning to self-extinguishing by ASTM D 635. Compounding with flame retardants can result in nonburning products.

PLASTIC TESTING AND EVALUATION

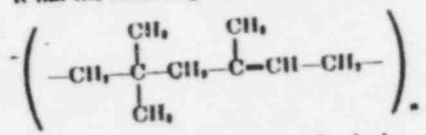
General Considerations

It is particularly interesting to note that plastic evaluations in many laboratories, as recorded throughout the literature, generally do not follow typical cookbook standards or set patterns of procedures which we associate with the testing of alloys. The standard expression "mils per year attack" referring to metals and alloys exposed to corrosive environments is obviously lacking from reports on plastic ... dies.

TABLE 9 General Properties of Natural Soft Rubber

Property	Value
Specific gravity	0.93
Tensile strength, lb/in.²	2,500-3,500
Elongation, %	750-850
Hardness (durometer)	A30-90
Tear resistance	Excellent
Abrasion resistance	Excellent
Recommended operating temp:	
Min °F	−60
Max °F	180
Chemical resistance:	
Acids, dilute	Good
Acids, concentrated	Fair
Aliphatic solvents	Poor
Aromatic solvents	Poor
Chlorinated solvents	Poor
Alcohols	Good
Alkalies	Good
Esters, ethers, ketones	Poor
Resistance to (heat) aging	Good
Resistance to oxidation	Good

presence of aluminum chloride as a catalyst, maintaining the reaction temperature at −125 to −140°F. It has the following molecular structure:



Physical properties Butyl rubber exhibits exceedingly low permeability to gases such as oxygen and nitrogen. It was this characteristic that enabled it to replace natural rubber for pneumatic-tire inner liners. Butyl rubber is about equal in tear resistance and abrasion resistance to natural rubber. Its electrical properties are about the same as those of natural rubber also. While the resilience of butyl rubber is relatively low at room temperature, significant increase in resilience is noted at elevated temperature (212°F) (see Table 12).

Chemical resistance Butyl rubber is quite resistant to many acidic and alkaline media. Unlike natural rubber it is very resistant to swelling by animal and vegetable oils (see Table 8). Vulcanized butyl rubber swells and deteriorates rapidly when exposed to aliphatic and aromatic solvents. Butyl rubber may be used at service temperatures in the range of 200 to 240°F. Heat has a tendency to soften the material over a period of time rather than to harden it as with natural rubber.

TABLE 10 General Properties of Butadiene-Acrylonitrile (Buna N)

Property	Value
Specific gravity	1.00
Tensile strength, lb/in.²	500-900
Elongation, %	450-700
Hardness (durometer)	A40-95
Tear resistance	Good
Abrasion resistance	Excellent
Recommended operating temp:	
Min °F	−60
Max °F	250
Chemical resistance:	
Acids, dilute	Good
Acids, concentrated	Good
Aliphatic solvents	Excellent
Aromatic solvents	Good
Chlorinated solvents	Fair
Alcohols	Good
Alkalies	Good
Esters, ethers, ketones	Poor
Resistanc[illegible] aging	Excellent
Resistan[illegible]tion	Good

TABLE 11 General Properties of Polyacrylate

Property	Value
Specific gravity	1.09
Tensile strength, lb/in.²	250-400
Elongation, %	450-750
Hardness (durometer)	A40-90
Tear resistance	Fair
Abrasion resistance	Good
Recommended operating temp:	
Min °F	−20
Max °F	350
Chemical resistance:	
Acids, dilute	Fair
Acids, concentrated	Fair
Aliphatic solvents	Good
Aromatic solvents	Fair
Chlorinated solvents	Fair
Alcohols	Poor
Alkalies	Fair
Esters, ethers, ketones	Poor
Resistance to (heat) aging	Excellent
Resistance to oxidation	Good

TABLE 12 General Properties of Butyl Rubber

Property	Value
Specific gravity	0.90
Tensile strength, lb/in.²	2,000-3,000
Elongation, %	750-950
Hardness (durometer)	A40-90
Tear resistance	Good
Abrasion resistance	Good
Recommended operating temp:	
Min °F	−50
Max °F	300
Chemical resistance:	
Acids, dilute	Excellent
Acids, concentrated	Excellent
Aliphatic solvents	Poor
Aromatic solvents	Poor
Chlorinated solvents	Poor
Alcohols	Good
Alkalies	Excellent
Esters, ethers, ketones	Poor
Resistance to (heat) aging	Excellent
Resistance to oxidation	Excellent

Ethylene Propylene (EPM)

Preparation and composition There are two ethylene propylene compounds of commercial value. The first, known as EPR rubber, is a completely saturated ethylene-propylene copolymer made by solution polymerization. This product employs a peroxide or peroxide-sulfur modified curing system. EPR has excellent resistance to ozone and weathering. It can be used at temperatures up to 325°F without appreciable loss in properties (see Table 15).

A second type of ethylene-propylene elastomer, designated EPDM, is a sulfur-curing terpolymer.

Chemical resistance The ethylene propylene elastomers exhibit good to excellent chemical resistance to water, acids, and caustics. They are essentially unaffected by alcohols. They are quite resistant to the phosphate-based hydraulic fluids. They show only mild resistance to the aromatic hydrocarbons, and are attacked by aliphatic and halogenated hydrocarbons. They are poorly resistant to diester-type synthetic lubricants. They exhibit excellent resistance to oxidation and ozone (see Table 8).

TABLE 15 General Properties of Ethylene Propylene

Property	Value
Specific gravity	0.86
Hardness (durometer)	A30-90
Tear resistance	Fair
Abrasion resistance	Good
Recommended operating temp:	
Min °F	−60
Max °F	300
Chemical resistance:	
Acids, dilute	Excellent
Acids, concentrated	Good
Aliphatic solvents	Poor
Aromatic solvents	Fair
Chlorinated solvents	Poor
Alcohols	Good
Alkalies	Good
Esters, ethers, ketones	Poor
Resistance to (heat) aging	Good
Resistance to oxidation	Excellent

Weatherability EPDM exhibits excellent weathering properties, suffering no significant deterioration under prolonged exposure to direct sunlight.

Flammability The ethylene propylene elastomers are classified as burning by ASTM D 635.

Fluoroelastomers

Preparation and composition Typical members of this elastomer family are produced as:

1. A copolymer of chlorotrifluoroethylene and vinylidene fluoride
2. A trifluoropropyl siloxane polymer
3. A perfluorobutyl acrylate elastomer
4. A copolymer of vinylidene fluoride and hexafluoropropylene
5. Hexafluoropentamethylene adipate

There are a number of other compositions of merit.

Chemical resistance The fluoroelastomers all have excellent chemical and solvent resistance. They are extremely resistant to aliphatic hydrocarbons, chlorinated solvents, animal, mineral, and vegetable oils, gasoline, jet fuels, dilute acids, alkaline media, an[illegible] inorganic salt solutions. They exhibit fair to poor resistance to oxygenated solvents, alcohols, aldehydes, ketones, esters, and ethers (see Tables 16 and 17).

TABLE 16 General Properties of Fluorosilicone

Property	Value
Specific gravity	1.4
Tensile strength, lb/in.²	1,000
Elongation, %	200-500
Hardness (durometer)	A40-78
Tear resistance	Fair
Abrasion resistance	Poor
Recommended operating temp:	
Min °F	−90
Max °F	400
Chemical resistance:	
Acids, dilute	Excellent
Acids, concentrated	Very good
Aliphatic solvents	Excellent
Aromatic solvents	Excellent
Chlorinated solvents	Excellent
Alcohols	Good
Alkalies	Good
Esters, ethers, ketones	Good
Resistance to (heat) aging	Good
Resistance to oxidation	Excellent

Physical properties These elastomers have a practical application and retain their physical properties over a wide temperature range of from −90 to 400°F. They have low permeability rates with air and extremely low water absorption. This resistance to moisture makes them highly desirable for use in electrical and electronic equipment requiring excellent insulation. They have excellent aging characteristics. They exhibit good tensile strength and tear resistance but generally are compounded with such fillers as finely divided silica or carbon black when these are of added importance.

TABLE 17 General Properties of Vinylidene Fluoride Hexafluoropropylene

Property	Value
Specific gravity	1.8
Tensile strength, lb/in.²	2,000
Elongation, %	[illegible]
Tear resistance	Poor
Abrasion resistance	Good
Recommended operating temp:	
Min °F	−10
Max °F	<500
Chemical resistance:	
Acids, dilute	Good
Acids, concentrated	Good
Aliphatic solvents	Excellent
Aromatic solvents	Excellent
Chlorinated solvents	Good
Alcohols	Excellent
Alkalies	Fair
Esters, ethers, ketones	Poor
Resistance to (heat) aging	Good
Resistance to oxidation	Excellent

RESPONSE TO NRC VERBAL COMMENTS ON MECHANICAL EQUIPMENT ENVIRONMENTAL QUALIFICATION SHOREHAM NUCLEAR POWER STATION - UNIT 1 LONG ISLAND LIGHTING COMPANY

1. What safety related mechanical equipment has not been environmentally qualified, and when can interim justifications be supplied?

   A: Qualification has been completed on all but a few items of equipment. Justification for utilizing the balance of the equipment until the first refueling outage will be provided prior to fuel load.

2. NRC's concern is that LILCO response to Item 270.2 (SNRC-737) regarding the maintenance and surveillance program to ensure operability appears to be committing to less than the original Chapter 5 commitment in the EQ Report.

   A: The conceptual approach to using this data to improve plant reliability and safety envisions using the recent availability of remote accessing of the NPRDS data base by the maintenance group and the Independent Safety Engineering Group (ISEG). LILCO has participated in NPRDS Report Writer User Training and has obtained the logon and password capabilities. Additionally, operational feedback received from the following will be factored into the maintenance program; NRC via LER's Bulletins, Circulars, and Information Notices; General Electric and other NSSS vendors; NSAC/INPO through its Nuclear Notepad and other programs, and other service contracts such as NOMIS. Specific data requirements may be identified by LILCO Office of Nuclear personnel including Shoreham Nuclear Power Station, Nuclear Engineering Department, Nuclear Operations Support Department, as well as other Company departments and INPO.

RESPONSES TO OPEN ITEM FROM

NRC ENVIRONMENTAL QUALIFICATION AUDIT

JUNE 2 and 3, 1982

SHOREHAM NUCLEAR POWER STATION - UNIT 1
LONG ISLAND LIGHTING COMPANY

NRC issues raised in the NRC trip report have been excerpted, and the LILCO answer is provided following each NRC issue. A number of attachments are mentioned in the LILCO answers. These are provided at the end of this issue and answer format along with additional useful data.

An index of the material provided follows this introduction. In order to aid in locating the material, the item numbers in the index are cited in the responses, such that item 2 of the index is referred to as (2*).

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ENVIRONMENTAL QUALIFICATION AUDIT OPEN ITEM RESPONSES

1. NRC issues raised and LILCO responses
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   a. Stone & Webster SNPS-1-UR-22-F Rev. 1
   b. GE Appendix B, Gamma Exposure, from TR 74-502-2
3. General Electric Documentation
   a. GE Dwg. 133D9636 Medium Voltage Penetration
   b. GE Parts List No. 378x193AC
   c. GE Installation DWG. 130D9627AC Elect. Pen. Low Voltage (2 pcs.)
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4. General Electric Specification 262A7076
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5. G.E. Letter to SWEC, April 29, 1981, JWB-T-2084
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7. 100 Series Containment Electrical Penetrations
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   a. DWG. & Parts List No. PL 195B9474, Rev. 0
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8. G.E. Letter to SWEC, September 24, 1976

Subject: Qualification Tests - Progress Report (EMR 300 & 301 Test Summary)

9. Test 107-76-05, Use of EMR-300 Epoxy

10. Letter SNRC-250, February 8, 1978

Subject: IE Bulletin 77-07

a. Table 1, Conditions of service

b. Attachment 1, GE Recommendations on Leak Testing

11. Letter LIL-8795, May 11, 1976

Subject: Reactor Containment Electrical Penetrations (G.E. Testimony before Joint Congressional Committee on Atomic Energy)

100 Series Medium Voltage Electric Penetrations

NRC Issue

"Two radiation calculations, one in the test report and another (SNPS-1-UR-22-F) in the file were performed to reduce the required dose to 3.9×10^7 rads. Both of these should be provided to the staff for verification of the postulated dose."

Answer

The radiation calculations are attached herein (2*) for NRC staff evaluation.

NRC Issue

"The limiting material for containment isolation was EPR. The applicant, however, should identify to the staff other materials which are required for containment integrity."

Answer

The attached parts lists and drawings (3*) show the 100 series medium voltage penetration. The only other non-metallic component in the 100 series penetration is item 28 SEALANT part No.262A7076 P001 (see specification No. 262A7026) (4*). This item provides a support function only, preventing the cable from moving inside the sleeve; it does not perform a containment isolation function. The EPR rubber is the only item which performs a containment isolation function. (Refer to GE letter to SWEC dated April 29, 1981) (5*).

NRC Issue

"The most recent revision to the EQSR indicates that these penetrations perform a safety function for line breaks outside of the drywell. Qualification for the environmental conditions of these breaks was not addressed. Previous submittals, however, had prescribed functionability for a LOCA only. Clarification in this area is therefore required."

Answer

All 23 GE Penetrations were assigned a generic Operating Code, Duration, and Safety Functions, that were considered most limiting for plant operation.

The 100 series medium voltage electrical penetrations perform a passive function only for the duration of an accident. They do not function in any way for a PBOC, but must maintain containment integrity to allow proper isolation and electrical properties.

Environmental conditions are not addressed because a PBOC provides a less severe transient than is postulated during a LOCA. Primary and Secondary seals of the General Electric Penetrations (Series 100) are located in Zones G&H in the RBS; the environmental conditions (6*) are as follows:

Normal Radiation (Zones G & H)	1.8×10^3 Rad
Duration	40 yrs
6 months Accident Dose (Zones G & H)	5.75×10^6 Rads for LOCA 3.45×10^4 Rads for PBOC
Temp. Zone (11)	190°F within 29 sec Decreasing to 120°F in 9 hrs Decreasing to 104°F in 16 hrs
Pressure (peak)	0.9 psig within 10 sec Decreasing to 0 within 17 hrs
Humidity (RH)	100 %

Because the 100 series penetrations consist of two redundant, identical seals and the primary seal was successfully environmentally tested with no failures at much higher temperature, pressure and radiation levels, it is anticipated that the penetrations will perform their function during a PBOC without failure.

NRC Issue

"The applicant committed to Type B testing as described in Appendix J of 10CFR Part 50 for periodically verifying the leaktight integrity of these penetrations. The applicant should confirm that epoxy or rubber seals in the conductor modules will be subjected to leak testing in this program, and should describe the corrective action to be taken if unacceptable leak rates are obtained in service."

Answer

Electrical Penetrations 1T23-Z-WA2, 1T23-Z-WA3 and 1T23-Z-EA2 (GE Series 100 medium voltage) will be type B leak tested in accordance with the frequency and acceptance criteria prescribed in Appendix J of 10CFR Part 50. During this testing the EPR rubber seal will see a test pressure of 48 psig dry nitrogen. If unacceptable leak rates are obtained during this testing, the cause of the excessive leakage will be investigated and if found to be due to an EPR rubber seal degradation, then the degraded seal will be repaired at the first convenient opportunity.

In addition to the above leak rate testing program, these electrical penetrations will be maintained at a pressure of 25 psig, (i.e. each electrical penetration will be pressurized to 25 psig of dry Nitrogen). Each electrical penetration's Nitrogen pressure will be checked at an interval of once per every three months (this interval may be gradually increased to a maximum of once per every twelve months based upon an evaluation of each electrical penetration's past performance with respect to its capability to maintain 25 psig of dry Nitrogen). If during these periodic checks of the electrical penetration pressure it is discovered that a seal is not able to maintain a positive Nitrogen pressure due to a small leak, then consideration will be given to periodically purging the penetration in question with dry Nitrogen until the affected seal is repaired.

200 Series Low Voltage Electrical Penetrations:

NRC Issue

"The applicant did not address, however, high energy line break conditions outside containment and their effect on secondary seal integrity..... In addition, the radiation dose on the secondary seal was only 1.3×10^5 Rads, compared with a postulated value of 4×10^7 rads."

Answer

The 200 series penetration also has two redundant identical seals and both seals are located on the Primary Side of the containment wall, for Groups 6, 10, 11, 13, and 14. Therefore, a PBOC will have a negligible effect on the primary seals of these penetrations.

Page 3 of Test Report 994-76-018 Rev. 1, states:

"Test Hardware Configuration"

"The test penetration was a standard 200 Series design with an additional Shield Building Module Seal installed on the end of the penetration outside the reactor. This additional seal had no effect on the Primary 200 Series seal. The Shield Building Module was positioned approximately 8 ft from the primary seal and consisted of epoxy sealant being poured around the cables which were supported in a 2.50 inch sleeve."

The standard 200 Series design does not have a Shield Building Module Seal installed, and therefore, the radiation dose received by it is not relevant to the Shoreham Plant.

Page 4 of Test Report 994-76-018 Rev. 1 states: "All modules were installed in a header assembly during each phase of testing except for Gamma Exposure.

The Gamma test facility required the modules be removed from the header and each module was exposed independently. The modules were reinstalled in the header assembly following the gamma exposure."

The header assembly is not affected by a radiation dose, since it is a metallic assembly and no degradation will take place. Test report 994-76-018, Rev. 1, defines the maximum allowable containment integrated gamma dose as 1×10^8 Rads and analytically apportions this containment dose to the epoxy by considering the protection afforded by the geometry of the penetration. Each module was subjected to the exposure shown below:

Modules	Serial No.	Primary Seal	Shield Bldg. Seal (N/A to Shoreham)
4/0 AWG	TG-8	$5.3x10^7$ Rads	$1.3x10^5$ Rads
2 AWG	TG-7	$9.8x10^7$ Rads	$1.3x10^5$ Rads
8 AWG	TG-6	$6.7x10^7$ Rads	$1.3x10^5$ Rads
12 AWG	TG-5	$6.0x10^7$ Rads	$1.3x10^5$ Rads
T/C	TG-3	$5.0x10^7$ Rads	$1.3x10^5$ Rads
SRM/IRM	TG-1	$5.1x10^7$ Rads	$1.3x10^5$ Rads

The shield building seal, which is not applicable to Shoreham, received a lower exposure due to a shielding effect by the primary side seal during the gamma exposure.

The following penetrations have the epoxy modules located inside the containment (RBP) and therefore the primary side of the epoxy module receives the $3.9x10^7$ Rad exposure (TR 994-76-018, Rev. 1, pages 9-13) calculated in the test report.

SWEC ID No.	GE Group No.
1T23-Z-WB1	6
1T23-Z-WC4	10
1T23-Z-WD1	11
1T23-Z-WB6	13
1T23-Z-WC6	14

All other 200 series low voltage electrical penetrations have the epoxy seal modules located in zones G and H of the Reactor Building Secondary (RBS).

The required limiting radiation for these zones is:

5.75×10^6 Rad Gamma for LOCA
3.45×10^4 Rad Gamma for PBOC

which is much less than the equipment exposed to during the testing.

The required limiting temperature is:

194F decreasing to 120F in 9 hrs., and decreasing to 104F in 16 hrs.

The required limiting pressure is:

0.9 psig decreasing to atmospheric in 17 hrs.

as opposed to equipment testing parameters:

340F at 103 psig for 4.5 hrs.
328F at 80 psig for 3.5 hrs.
275F at 26 psig for 17.5 hrs.
210F at 20 psig for 12 days, 6.5 hrs.,

and a minimum tested value of 5×10^7 Rads as listed above.

PBOC conditions were not originally addressed, because the penetrations successfully passed a much more severe accident profile without failure for a longer period of time.

NRC Issue

"Unlike the 100 Series penetrations, the 200 Series penetrations supply power to 1E equipment in the drywell. The referenced test report and analysis performed by the applicant are insufficient for demonstrating that the penetrations can carry rated current and voltage under accident conditions."

Answer

Page 2 of test report 994-76-018, Rev. 1 states:

"This test report documents objective evidence for design verification of the 200 Series Electric Penetration, Low Voltage Design for both integral and free-standing containment applications. As the 200 Series design is similar to the 100 Series in most respects, the objective evidence herein is supplemented by the qualification test report for the 100 Series design."

Since a similarity to the 100 Series penetration can be shown, please see Addendum 1 to the LOW VOLTAGE QUALIFICATION TEST REPORT for 100 Series Containment Electrical Penetrations, attached (7*).

Additional evidence of successful testing is presented in the Nuclear Regulatory Commission's findings on the electrical penetrations at Diablo Canyon. (Ref. Diablo Canyon SER., Supp. 9, Sec. f).

"The applicant in Section 3.11.3-6 of the FSAR indicated that electrical penetrations have been successfully type tested. The type tests included temperature pressure and relative humidity. It appeared, from this information, that exposure to chemical spray, radiation preconditioning, and energizing of the penetration during simulated LOCA testing may not have been included as part of the qualification type tests as required by IEEE Standard 317-1971.

Subsequently, the applicant provided, in submittal dated October 22, 1978, for audit review, an additional test report No. 74-502-3, 100 Series Electrical Containment Penetrations Low Voltage Qualification Test Report, Addendum 1, dated March 1974 (7*).

This report indicated that the low voltage power and control instrument signal and thermocouple penetrations were further tested as follows:

1. Thermally cycled 40 times from 50° to 150° to 50°F at 95 percent relative humidity at the rate of 3 to 4 cycles per day.

2. Exposed to 5×10^7 Rads at 3×10^6 r/h before the penetration was exposed to LOCA environment.

During the subsequent LOCA test, the penetration was exposed to steam environment with pH above 8.2 and 100 percent relative humidity for 193 hours (3 hours at 340°F and 102 psig, 3 hours at 320°F and 81 psig, 18 hours at 260°F and 23 psig, and for 169 hours 250°F and 16 psig. The cable passing through the penetration was energized during this test.

Based on our review of the test report No. 74-502-3, we conclude that the test conditions adequately enveloped the design conditions defined by the Applicant for a LOCA and steam line break accident, that the tests satisfied the qualification test requirements of IEEE Standard 317-1971, and that the GE Series low voltage penetrations have therefore, been acceptably qualified environmentally."

NRC Issue

A greater than 40-year qualified life was established by comparison with data for N229 epoxy used in the 100 series penetration. The staff does not agree with this evaluation. IE Bulletin 77-07 and related reports describe adverse operating experiences with N229 epoxy."

Answer

Please refer to test report 994-76-016 (*8 & 9) Test 107-76-05 - use of EMR-300 Epoxy, dated September 29, 1976. The conclusion of this test report on page eight provides sufficient evidence of acceptable epoxy integrity under the required operating conditions.

The adverse operating experiences, noted in the above question regarding the N229 epoxy, refer to epoxy adherence to the conductor (Farley 1 & 2) and transition connector insulation loss (Millstone 2). The epoxy adherence problem at Farley 1 & 2 was caused by tin plating of the conductors. To increase epoxy adherence at Shoreham, GE Scotchkoted the conductors by a fusion process. (Ref. GE testimony before Joint Congressional Committee on Atomic Energy - 1976(11*). The problem of loss of transition connection insulation was resolved at Shoreham by insulating the entire length of the conductor within the penetration. Therefore, the adverse experiences noted in Bulletin 77-07 are not applicable to the Shoreham penetrations (10*).

Please note that all information, with the exception of Diablo Canyon, SER. 9, Section F, is presently part of the Electrical Penetration Qualification Document submitted at the June 2 and 3, 1982 NRC Site Audit.

NRC Issue

"IE Bulletin 77-07 and related reports describe adverse operating experiences with N229 epoxy. It is, therefore, appropriate that the applicant describe the surveillance program to be utilized for monitoring or detecting inservice degradation of these penetrations, if one is to be established. Although a commitment to Appendix J leak testing for 100 Series penetrations, none has been made for the 200 series."

"If a test program is to be utilized for monitoring inservice degradation it should be submitted to the staff for review and evaluation. The frequency of surveillance, type of testing, minimum acceptable values, and corrective action for unacceptable test results described."

Answer

The following electrical penetrations will be given the same treatment described for the 100 series medium voltage penetrations (i.e., all of the GE 200 series low voltage electrical penetrations listed below will be Type B leak tested in accordance with Appendix J of 10CFR Part 50, maintained at a pressure of 25 psig with dry Nitrogen, periodically checked and purged with dry Nitrogen if required):

1T23-Z-WB1	1T23-Z-EA1
1T23-Z-WB2	1T23-Z-EA3
1T23-Z-WB3	1T23-Z-EB1
1T23-Z-WB4	1T23-Z-EB2
1T23-Z-WB5	1T23-Z-EB3
1T23-Z-WB6	1T23-Z-EB5
1T23-Z-WC4	1T23-Z-EB6
1T23-Z-WC5	1T23-Z-EC3
1T23-Z-WC6	1T23-Z-EC5
1T23-Z-WD1	1T23-Z-EC6
1T23-Z-WD2	1T23-Z-ED5
1T23-Z-WD3	1T23-Z-ED6

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION TITLE PAGE

*SEE INSTRUCTIONS ON REVERSE SIDE

A 5010.54 (FRONT)

CLIENT & PROJECT	PAGE 1 OF 8
LILCO - Shoreham 1	plus A1 & B1
CALCULATION TITLE (Indicative of the Objective): Post-LOCA Upper Limit Gamma and Beta Dose and Dose Rates inside the Primary Cont. with Supp. Pool Water containing 100% Cs, 50% Hal, & 1% Remainder and Airborne source made up of 100% Noble gases and 50% Halogens.	QA CATEGORY (✓) ☑ I - NUCLEAR SAFETY RELATED ☐ II ☐ III ☐ ______ OTHER

CALCULATION IDENTIFICATION NUMBER

J.O. OR W.O NO.	DIVISION & GROUP	CURRENT CALC. NO.	OPTIONAL TASK CODE	OPTIONAL WORK PACKAGE NO.
11600.02	48/88	SWPS-1-VR-22-F rev. 1		

* APPROVALS - SIGNATURE & DATE			REV. NO OR NEW CALC NO.	SUPERSEDES * CALC. NO OR REV. NO.	CONFIRMATION * REQUIRED (✓)	
PREPARER(S)/DATE(S)	REVIEWER(S)/DATE(S)	INDEPENDENT REVIEWER(S)/DATE(S)			YES	NO
[signature] (3/1/82)	M. Hurley 3/3/82	A Aniello 3-9-82		SWPS-1-VR-22-F		✓

DISTRIBUTION *

GROUP	NAME & LOCATION	COPY SENT (✓)	GROUP	NAME & LOCATION	COPY SENT (✓)
RECORDS MGT. FILES (OR FIRE FILE IF NONE) Fire File	Shoreham 1 245/4				

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION SHEET

A 5010.65

CALCULATION IDENTIFICATION NUMBER				PAGE 2
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	
11600 02	48/88	SNPS-1-UR-22-F-rev. 1		

Table of Contents:

Objective: To determine the post-LOCA upper limit gamma and beta dose and dose rate inside the Primary Containment; using a Suppression Pool water source containing 100% Cs, 50% Halogens, and 1% Rmndr.

Basis:

1) The upper limit gamma dose and dose rates within the Primary Containment would be that 'in contact' with the suppression pool water. This was calculated in Ref. 1, pp 7 and 9. The suppression pool water source includes 100% Cs, 50% Halogens, and 1% Rmndr.

2) The DRAGON4 Computer Code will yield results for the dose and dose rate in the Primary containment for both airborne gamma and airborne beta sources. Airborne sources include 100% Noble gases, 50% Halogens.

3) LOCA with reactor containment building and MSIV leakage.

(I) LOCA parameters;

[6]

1) Power level = 2550 MWT

2) Fuel damaged = 100%, Fuel Core Activity (see Appendix A)

3) Activity released from fuel - 100% Noble gases
50% Halogens

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION SHEET

A 5010.65

CALCULATION IDENTIFICATION NUMBER				PAGE 4
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	
11600.02	48/88	SHPT-1-UR-22-F-rev. 1		

Basis: (continued)

[6] ↓

4) Iodine Fractions - Organic = 4%
Elemental = 91%
Particulate = 5%

5) Primary Containment leak rate = 0.5% per day

6) Secondary Containment leak rate = 177% (vol/day) for 50% 'mixing model'. For 100% mixing model (model used for this calc.) leak rate = $\frac{177\%}{2}$ = 86.5%, which is 0.865 vol/day.

7) Iodine filter efficiency = 95%

[7] 8) Reference Breathing Rate = 3.47-04 m^3/sec

(II) MSIV Leakage parameters;

[8] 1) Volume of suppression pool is 1.34+05 ft^3 (gas volume)

[9] 2) Drywell leakage rate at:
t = 0.33 hrs ⇒ 16 hrs is 5.35-03 vol/day
t = 16 hrs. on is 6.31-03 vol/day

[8] 3) Volume of Drywell is 1.925+05 ft^3

Method: The γ dose and dose rate will be the sum of the contributions from both airborne and suppression pool water sources. Table I - 'Primary Containment - γ Dose and Dose Rate Post-LOCA' lists the total dose and dose rates as a function of time from 0 to 2 years.

Method: (continued)

The β^- dose and dose rate result from the airborne contribution in the Primary containment. The β^- contribution from the suppression pool would be insignificant. Table II - 'Primary Containment - β^- Dose and Dose Rates Post-LOCA' lists these values as a function of time from 0 to 2 years.

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION SHEET

5010 65

CALCULATION IDENTIFICATION NUMBER				PAGE 6
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	
11600.02	48/08	SWPS-1-UR-22-F-rev.1		

Table I - 'Primary Containment - γ Dose and Dose Rates Post-LOCA'

	Dose Rates			Integrated Dose		
Time (hrs.)	Airborne* (Rem/hr)	In Contact** w/Suppression Pool Water (Rem/hr)	Total (Rem/hr)	Airborne* (Rem)	In Contact** w/Suppression Pool Water (Rem)	Total (Rem)
0.0	5.82+06	5.67+05	6.39+06	0.0	0.0	0.0
0.1	4.72+06	3.79+05	5.10+06	5.11+05	4.67+04	5.58+05
0.5	3.73+06	2.67+05	4.00+06	2.17+06	1.75+05	2.35+06
1.0	3.10+06	1.98+05	3.30+06	3.86+06	2.90+05	4.15+06
4.0	1.59+06	8.56+04	1.68+06	1.04+07	6.67+05	1.11+07
8.0	9.48+05	5.62+04	1.00+06	1.53+07	9.46+05	1.62+07
10.0	7.85+05	4.88+04	8.34+05	1.70+07	1.05+06	1.81+07
24.0	3.38+05	2.59+04	3.64+05	2.41+07	1.56+06	2.57+07
720	6.38+03	4.05+03	1.04+04	5.38+07	6.54+06	6.03+07
2160	2.92+01	2.86+03	2.89+03	5.54+07	1.13+07	6.67+07
4380	3.35+00	2.53+03	2.53+03	5.54+07	1.72+07	7.26+07
6570	1.85+00	2.39+03	2.39+03	5.54+07	2.26+07	7.80+07
8760	1.02+00	2.33+03	2.33+03	5.54+07	2.78+07	8.32+07
10950	5.66-01	2.29+03	2.29+03	5.54+07	3.28+07	8.82+07
13140	3.13-01	2.26+03	2.26+03	5.54+07	3.78+07	9.32+07
15330	1.73-01	2.24+03	2.24+03	5.55+07	4.28+07	9.83+07
17520	9.59-02	2.23+03	2.23+03	5.55+07	4.77+07	1.03+08

* from Refs. 3 & 4

** from Ref. 2, pp 7 & 9

Table II

'Primary Containment - β^- Dose and Dose Rates Post-LOCA'

Time (hrs)	Airborne* Dose Rate (Rem/hr)	Airborne* Dose (Rem)
0.0	5.50+07	0.0
0.1	3.58+07	4.32+06
0.5	2.34+07	1.53+07
1.0	1.96+07	2.59+07
4.0	1.19+07	7.03+07
8.0	8.79+06	1.11+08
10.0	7.92+06	1.27+08
24.0	4.66+06	2.12+08
720	8.33+04	7.00+08
2160	9.03+03	7.33+08
4380	4.81+03	7.47+08
6570	2.66+03	7.55+08
8760	1.47+03	7.60+08
10950	8.15+02	7.62+08
13140	4.51+02	7.63+08
15330	2.50+02	7.64+08
17520	1.38+02	7.65+08

* from Refs. 3 & 4

STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION SHEET

A 3010 65

CALCULATION IDENTIFICATION NUMBER				PAGE 8
J.O. OR W.O. NO.	DIVISION & GROUP	CALCULATION NO.	OPTIONAL TASK CODE	
11600.02	48/38	SNPS-1-VR-22-F-rev. 1		

References :

[1] Calc # SNPS-1-VR-21-M - "Maximum Dose Rate & Integrated Dose Due to a Nest of Pipes Carrying 100% Cs, 50% Hal, and 1% Rmndr. in Suppression Pool Water using New version of Radioisotope Computer Library" (8/27/81)

[2] DRAGON4 Computer Code, NU115 - V04/L01, QA Cat. I, effective 12/14/81, Users' Manual by J.N. Hamawi

[3] R0801888, 24 Feb 82, Job 718 - DRAGON4 "LOCA + MSIV Leakages for Primary Containment" Time = 0.1, 0.3, 0.5, 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 16.0, 24.0, 30.0, 50.0, 70.0, 96.0, 200, 300, 500, 720, 2160, 4380, and 8760 hrs.

[4] R0801777, 24 Feb. 82, Job 679 - DRAGON4 "LOCA + MSIV Leakages for Primary Containment" Time = 0.0, 0.3, 0.5, 8.0, 16.0, 24.0, 96.0, 720, 2190, 4380, 6570, 8760, 10950, 13140, 15330, 17520, 26280, and 35040 hrs.

[5] General Electric Document No. 22A2703T

[6] SNPS-1, FSAR Table 15.1.34-1, Revision 8, Sept. 1977

[7] US AEC Regulatory Guide 1.3 June 1974

[8] SNPS-1, FSAR Table 6.2-1-1, original page

[9] Calc # SNPS-1-RP-13-W, pb (5/14/78)

[10] Calc # SNPS-1-VR-22-G-rev. 1, 'Post-LOCA Upper Limit Gamma and Beta Dose and Dose Rate inside The Primary Containment using 50% Halogen & 1% Rmndr. for Supp. Pool Water and 100% Noble Gas & 50% Halogens for Airborne Sources' (3/1/82)

J.O. or W.O. No.	Division & Group	Calculation No.		page A1
11600.02	47/78	SNPS-L-UN-22-F-rev. 1		

Appendix A

Core Activity***

Isotope	Curies/Megawatt	Curies*
Kr - 83m	3.0 + 03	7.7 + 06
85m	6.5 + 03	1.7 + 07
85	3.0 + 02	7.7 + 05
87	2.3 + 04	5.9 + 07**
88	3.2 + 04	8.2 + 07**
89	2.0 + 04	5.1 + 07
90	2.0 + 04	5.1 + 07
91	1.3 + 04	3.3 + 07
92	6.6 + 03	1.7 + 07
93	1.6 + 03	4.1 + 06
94	1.1 + 03	2.8 + 06
Xe - 131m	1.8 + 02	4.6 + 05
133m	2.0 + 02	5.1 + 05
133	5.6 + 04	1.4 + 08
135m	1.7 + 04	4.3 + 07
135	5.3 + 04	1.4 + 08**
137	4.7 + 04	1.2 + 08
138	4.8 + 04	1.2 + 08**
139	4.0 + 04	1.0 + 08
140	1.9 + 04	4.8 + 07
141	5.9 + 03	1.5 + 07
142	1.3 + 03	3.3 + 06
Br - 83	3.0 + 03	7.7 + 06
84	4.7 + 03	1.2 + 07
85	6.5 + 03	1.7 + 07
87	1.1 + 04	2.8 + 07
I - 131	2.9 + 04	7.4 + 07
132	4.2 + 04	1.1 + 08
133	4.8 + 04	1.2 + 08
134	6.2 + 04	1.6 + 08
135	4.9 + 04	1.2 + 08
136	2.0 + 04	5.1 + 07

* - at 2550 Mwt

** - these numbers are scaled from AEC values - see telecon by R. Varasse to E. Bernard (AEC) dated 6-12-74 (11:45 am). [ATT. B]

*** - from General Electric Document No. 22A2703T

ATTACHMENT B

SNPS-1-UR-22-F-REV. 1

STONE & WEBSTER ENGINEERING CORPORATION

To M. B. Keane
for Distribution

LICENSING GROUP
TELEPHONE MEMORANDUM

Project/J.O.No. GSU-River Bend 112210 or Generic ______

Call Date June 12, 1974 Time 11:45 Incoming ✓ Outgoing ______

Between Mr. E. Bernard of AEC and RE Varrasse of S&W
______ of Bethesda

Subject ______

SUMMARY

Mr. Bernard said he had looked at the computer outputs (DRAGON and RFM 123 runs) I had provided him to determine the discrepancies between AEC and S&W LOCA dose calculations for a 3039 Mwt BWR. He found the following discrepancies:

Core Inventory (Ci)

Isotope	Kr-87	Kr-88	Xe-135	Xe-138
AEC value	.71+8	.97+8	.16+9	.145+9
S&W (EE) value	.365+8	.517+8	.297+9	.131+9

Average γ Energy Mev

Isotope	Kr-83M	Kr-87	Kr-89	Xe-133	Xe-138	I-134
AEC value	.008	1.374	1.06	0.046	1.52	1.84
S&W value	.005	.856	2.22	.073	.432	2.51

Average β Energy Mev

Isotope	Kr-83m	Xe-138	I-135
AEC value	0.28	0.80	0.51
S&W value	0.101	0.565	0.475

He stated that all other values were in good agreement with his.

Copy to:

F.Riegelhaupt	___	GJCunningham	___	______	X	Job Book ______
KLVener	___	WGCulp	___	______	X	
JRCoombe	___	RGPaine	___	______	X	
LFWalker	___	MJRay	___	______	X	
DMangan	___	GFDave	___	______	X	
AFerror	___	[illegible]	___			

APPENDIX E

GAMMA EXPOSURE

INTRODUCTION

The effects of radiation exposure on the electrical penetrations are directed specifically at the sealant compound and its interface with mating parts; i.e., the ability to maintain an adequate bond adhesion. In qualifying the penetration for service environments described herein, the following constraints are established:

1. The maximum containment integrated dose, both for normal and loss-of-coolant accident, is considered to be isotropic over a 2π solid angle.

2. The objective of the penetration performance is to maintain containment integrity.

3. The maximum integrated dose (gamma) occurs during post-accident conditions.

This report defines the maximum allowable containment integrated gamma dose (1×10^8 R), then analytically apportions this containment dose to the epoxy by considering the protection afforded by the geometry of the penetration.

This analysis was used to determine the actual hardware radiation exposure in order to qualify the electrical penetrations.

REQUIREMENTS

CONTAINMENT INTEGRATED GAMMA DOSE

The maximum containment integrated gamma dose is established, by definition, at 1.0×10^8 Rads.

ENVIRONMENTAL (CONTAINMENT) SERVICE CONDITIONS

The electrical penetration shall maintain containment integrity when the containment environment is subjected to the conditions listed in Table 5-1.

TABLE 5-1

ENVIRONMENTAL EXPOSURE REQUIREMENTS

Event	Temp °F	Pressure psig	Time	% RH	γ Integrated Dose (Accumulative) Rad
Thermal cycle	50 to 150 to 50	0	3 cycles - 24 hr (40 yr normal SVC)	100	1×10^7
LOCA	340	125	6 hr	100	2×10^7
	325	62	5 hr	100	3×10^7
	290	62	240 hr	100	4×10^7
	250	25	24 hr	100	4.5×10^7
	225	20	1 yr	100	1×10^8

RADIATION APPORTIONMENT

INTRODUCTION

This analysis determines the gamma radiation level which would be "seen" by a "detector" located at the epoxy seal of the module assembly.

In summary, the epoxy seal is housed in a steel cylinder, approximately 2.12 inches in diameter. This seal, when installed in the 2.00 inch thick steel header plate, becomes located behind the surface of the header plate. The seal can thus be treated as a detector located in a tunnel, thereby receiving the appropriate radiation shielding, which is detailed in the analysis below.

Two installations are available: (1) the penetration located inside the containment and (2) the penetration located outside the containment at the end of a three foot nozzle. In both cases, barrier protection afforded by cables, junction boxes and other extraneous hardware are ignored.

ANALYSIS, PENETRATION INSTALLED INSIDE CONTAINMENT

Figure 5-1 defines the plan view arrangement of the penetration and detector location relative to the containment environment.

GIVEN: Containment γ dose = 1.0×10^8 R

$$\frac{1.0 \times 10^8 \text{ R}}{2\pi \text{ steradians}} = 1.59 \times 10^7 \text{ R/Ster}$$

From Figure 5-1

Solid angle of each of 4 shielded zones:

$$\psi_1 = \frac{2\pi r h}{r^2} = \frac{2\pi h}{r} \text{ where values are scaled from Figure 5-1.}$$

where:

- l = thickness of material between module header holes.
- d = diameter of the unprotected header hole.
- r = radius of circle = l+d/2
- t = average thickness of the steel header plate in the respective solid angle.
- h = 4 equal lengths of vertical line as shown.

and $\psi_1 = \frac{2\pi (0.92)}{4.250} = 1.35$

$$\psi_1 = A/z^2 = \frac{\pi d^2/4}{Z^2} = \frac{\pi (2.12)^2}{2^2} = 0.88$$

Check ψ_2:

$$\psi_2 = 2\pi - 4 (\psi_1) = 6.28 - 4 (1.35) = 0.88$$

GIVEN: Containment γ dose $(R_o) = 1.0 \times 10^8$ R

γ dose (R_1) at module epoxy (detector D_1)

$$R_1 = \left(\frac{R}{Ster}\right)\left[\psi_2 + \Sigma\psi_1 B_n\right]$$

where B_n = transmission or protection factor of the steel defined by thickness t_n shown on Figure 5-1.

From Figure 5-1	B (Factor)
$t_1 = 0.934$	0.7
$t_2 = 2.50$	0.2
$t_3 = 3.25$	0.12
$t_4 = 3.00$	0.15

$$\therefore R_1 = (1.59 \times 10^7)\left[0.88 + 1.35\,(0.7 + 0.2 + 0.12 + 0.15)\right]$$

$$= (1.59 \times 10^7)(0.88 + 1.58)$$

$$= 3.90 \times 10^7 \text{ R}$$

QUALIFICATION TESTING

LEVEL OF EXPOSURE/ENVIRONMENTAL EXPOSURE

In order to minimize the number of irradiation exposure tests, a conservative minimum value of 4×10^7 R was selected as the integrated dose level applied to the qualification hardware. Table 5-2 lists the qualification hardware and the respective irradiation dose level together with subsequent environmental exposure tests to which the hardware was subjected.

Irradiation exposure was performed at the GE-Vallecitos.

The following summarizes the radiation levels.

Serial No.	6577788
Accumulated dose	5×10^7 R
Rate	3.5×10^5 r/hr

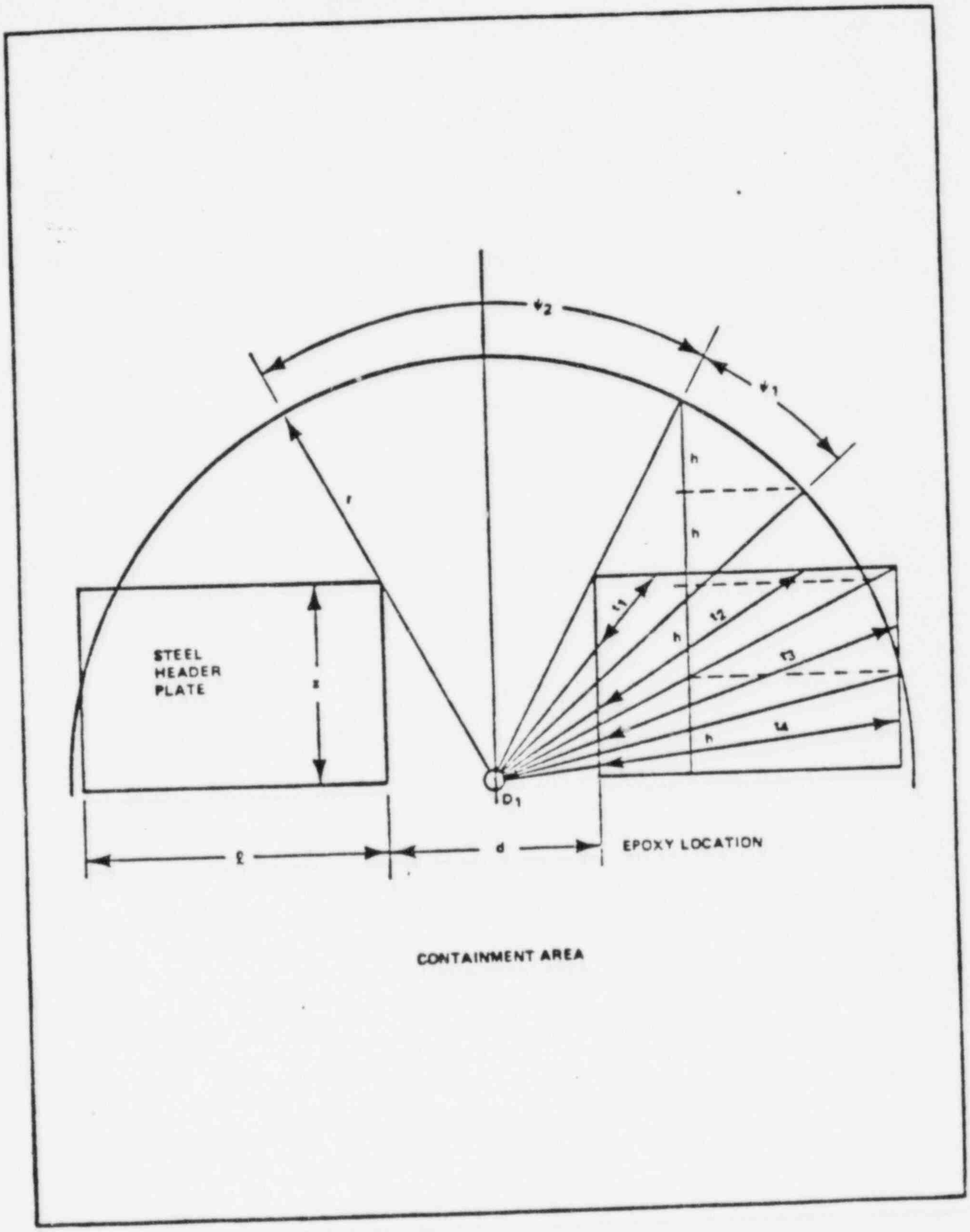
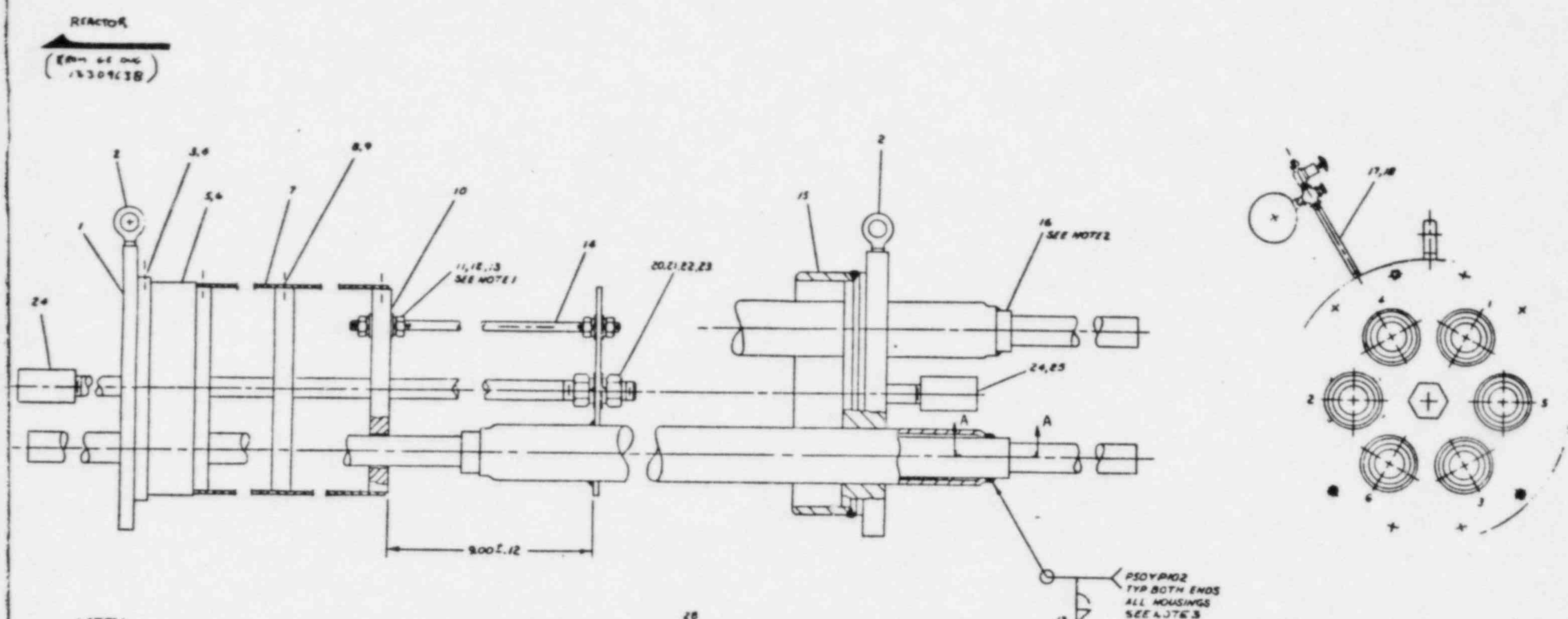


Figure 5-1. 100 SERIES ELECTRICAL PENETRATION GAMMA RADIATION EXPOSURE

CONTAINS ASME CODE PARTS SECTION III CLASS MC

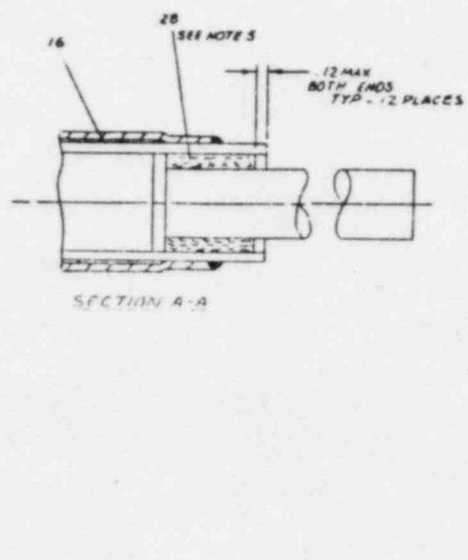
133D9636 | ...ECTRIC PENETRAT...

SEE 226X193 AC FOR PART IDENTIFICATI...



NOTES:

1. TORQUE NUTS TO 640 IN-LBS.
2. ITEM 16 MUST BE CENTERED IN HOUSING.
3. WELD PROCEDURE TO BE QUALIFIED IN ACCORDANCE WITH ASME BOILER & PRESSURE VESSEL CODE - SECTION III CLASS MC. LIQUID PENETRANT INSPECTION IN ACCORDANCE WITH APPENDIX IX.
4. SEALANT (ITEM 28) SHALL BE ADDED AFTER WELDING OPERATION - ALL HOUSINGS.
5. MARK CABLES 1,2,3 ETC APPROX. 10.00 INCHES FROM HEADER PLATE (ITEM 5) & RING (ITEM 1) USING SHRINK TUBING (ITEM 19) 2.00 INCHES LONG (REF WIRE LIST 163C1902AC).

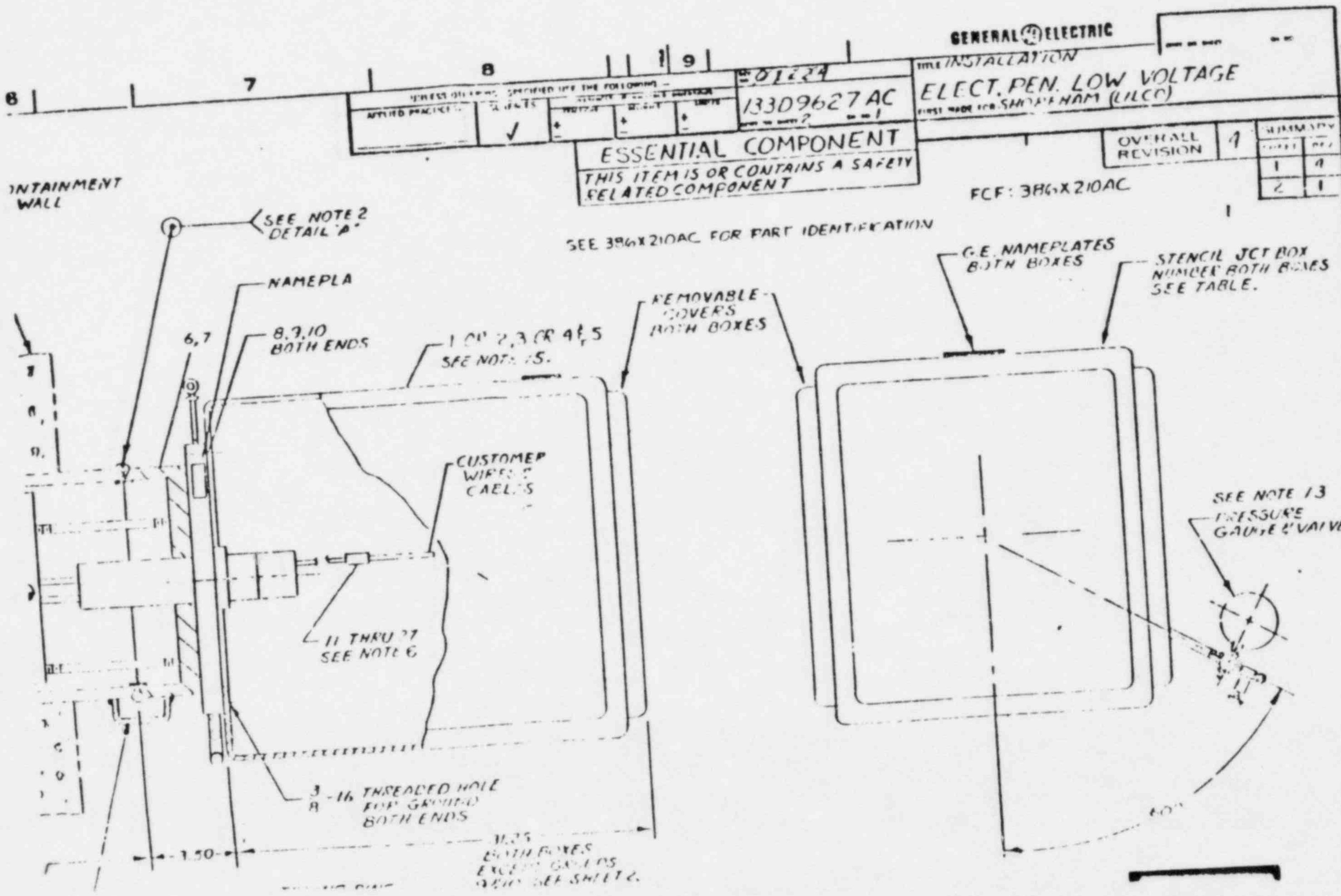


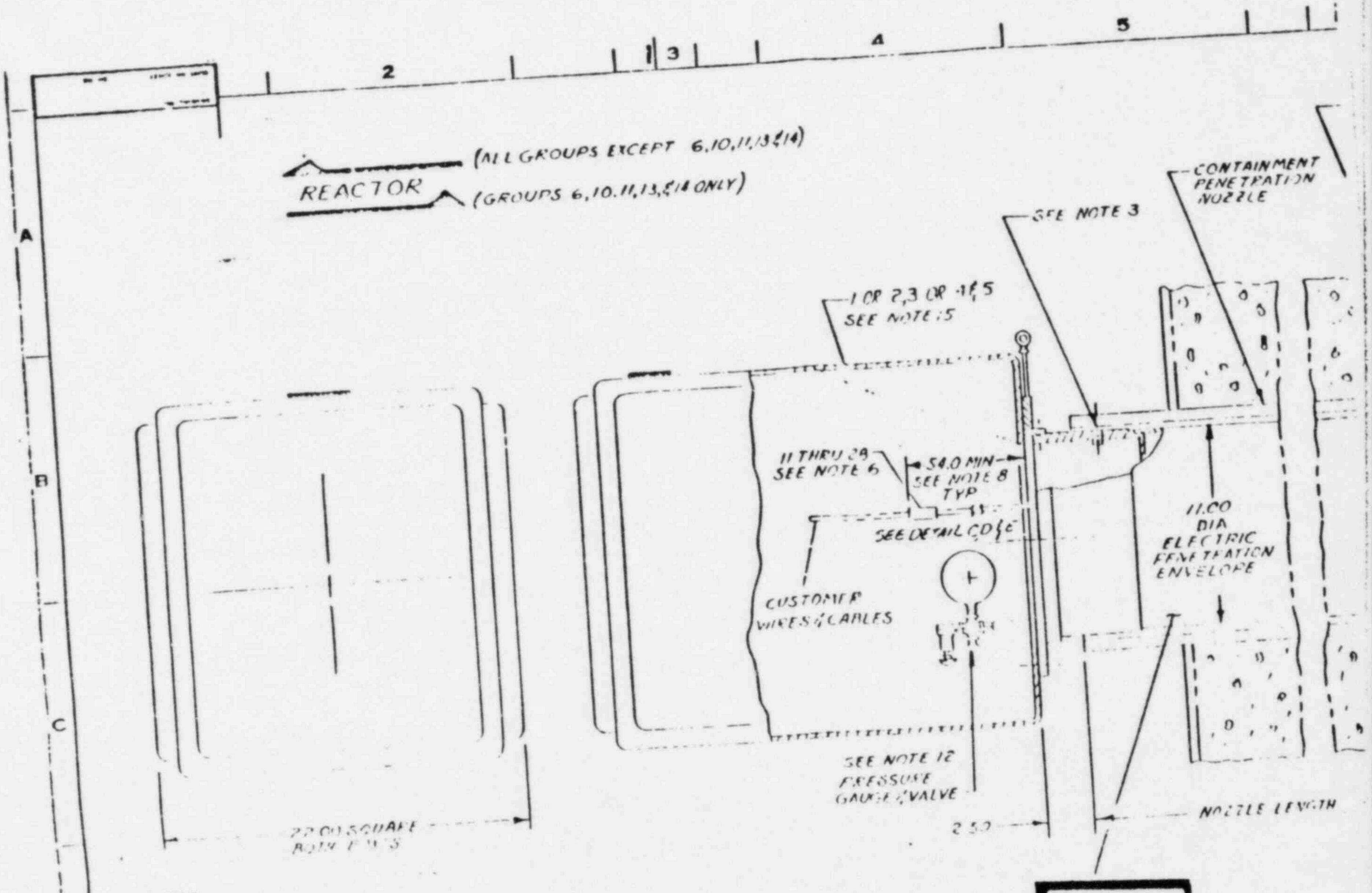
SECTION A-A

SUFFIX NUMBER ? G001 (handwritten above: 328X193AC)

TITLE:ELECTRIC PENETRATION, MV PL REV: 2 DOC REV: CMPL-P:C CMPL-D:

ITEM	NAME	IDENTIFICATION	STAT	QTY	DT	UM	SRC	EC	CC	SP	AC	RC	CD
001	RING, BOX	157C4839P005		1	21					N			
002	BOLT,EYE (SHOULDER)	175A9623P003		2	23					N			
003	SCREW,MACH,PNH	M153P25012		8	23								
004	WASHER,SST SPR LK .375 SST	M406P13		8	23								
005	SHELL	163C1541P001		1	21								
006	SET SCREW,SELF LOCK	209A5043P008		8	23					N			
007	COVER - 12"	195B9746P04025		2	21								
008	WASHER,PLAIN #10	N402P9C		32	23								
009	SCREW,MACH,PNH #10-24X.38 LG	N80P17006C		32	23								
010	SUPPORT-MEDIUM VOLTAGE	204B6267G001		3	16								
011	WASHER,PLAIN	N402P45C		24	23								
012	WASHER,STL SPR LK FOR .50 BOLT C STL	N405P15C		24	23								
013	NUT,HEX .50-13	N203P29C		24	23								
014	STUD, THREADED ROD	176A1570P008		6	23					N			
015	HEADER, MV	204B6184G001		1	16								
016	CONDUCTOR	159C4679G007		6	16					N			
017	THREAD SEALANT	249A1067P001		AR	23								
018	PRESSURE GAUGE & VALVE	174B9475G001		1	16					N			
019	TUBING SHRINKABLE	175A8230P012		AR	23					N			
020	ROD	262A7306P004		1	21								
021	WASHER,PLAIN FOR 1.00 BOLT,SST	N400P20		2	23								
022	WASHER,SST SPR LK FOR 1.00 DIA BOLT	N406P20		2	23								
023	NUT,HEX 1.00-8UNC SST	N227P39		2	23								
024	BLOCK	195B9924P001		2	21								
025	ROD	262A7306P003		1	21								
026	PENETRATION, ELECTRIC	163C1902AC ✓ WIRE LIST		X	CC								
027	M.V. ELECT. PEN.	133D7636 ✓ ASSY		X	16								
028	SEALANT	262A7076P001		AR	1F								


GENERAL ELECTRIC
INSTALLATION
ELECT. PEN. LOW VOLTAGE
SHOREHAM (LILCO)
133D9627AC
ESSENTIAL COMPONENT
THIS ITEM IS OR CONTAINS A SAFETY RELATED COMPONENT
OVERALL REVISION 4
FCF: 386X210AC
SEE 386X210AC FOR PART IDENTIFICATION
CONTAINMENT WALL
SEE NOTE 2 DETAIL 'A'
NAMEPLA
6,7
8,9,10 BOTH ENDS
REMOVABLE COVERS BOTH BOXES
G.E. NAMEPLATES BOTH BOXES
STENCIL JCT BOX NUMBER BOTH BOXES SEE TABLE.
CUSTOMER
11 THRU 27 SEE NOTE 6
SEE NOTE 13
3/8-16 THREADED HOLE FOR GROUND BOTH ENDS
1.50
BOTH BOXES
7



2
3
4
5
A
B
C
(ALL GROUPS EXCEPT 6,10,11,13 & 14)
REACTOR
(GROUPS 6,10,11,13,&14 ONLY)
CONTAINMENT PENETRATION NOZZLE
SEE NOTE 3
1 OR 2,3 OR 4 & 5 SEE NOTE 5
11 THRU 28 SEE NOTE 6
54.0 MIN SEE NOTE 8 TYP
SEE DETAIL C,D & E
11.00 DIA ELECTRIC PENETRATION ENVELOPE
CUSTOMER WIRES & CABLES
SEE NOTE 12 PRESSURE GAUGE & VALVE
NOZZLE LENGTH
2.50
22.00 SQUARE

NOTES:

PARTS LIST NO :

386X110AC

SUFFIX NUMBER ? G001

TITLE:ELEC PENETRATION-LOW VOLT PL REV: 3 DOC REV: CMPL-P:C CMPL-D:

ITEM	NAME	IDENTIFICATION	STAT	QTY DT UM SRC	E C S A R C / C C P C C D
001	BOLT,EYE (SHOULDER)	175A9623P003		2 23	N
002	NUT,HEX	N203P25C		2 23	
003	SHELL	163C1541P001		1 21	
004	WASHER,PLAIN #10	N402P9C		32 23	
005	SCREW,MACH,PNH #10-24X.38 LG	N80P17006C		32 23	
006	SUPPORT-WIRE	157C4/026002		3 16	N
007	COVER - 12"	195B9746P06475		2 21	N
008	STUD, THREADED ROD	176A1570F038		6 23	
009	WASHER,PLAIN	N402P45C		12 23	
010	WASHER,STL SPR LK FOR .50 BOLT C STL	N405P15C		12 23	
011	NUT,HEX .50-13	N203P29C		12 23	
012	HEADER RING-MACHINED	163C1889P001		1 21	
013	O RING	209A4117F029		7 23	B
014	O RING	209A4117P030		7 23	
015	WIRE MODULE	164C5446ACG005		1 16	
016	WIRE MODULE	164C5446ACG005		1 16	
017	WIRE MODULE	164C5446ACG005		1 16	
018	WIRE MODULE	164C5446AC6005		1 16	
019	PLUG, MODULE	198B6099P001		1 21	
020	WIRE MODULE	164C5446ACG005		1 16	
021	WIRE MODULE	164C5446AC6005		1 16	
022	RING	235A1900P001		1 21	N
023	CLAMP	234A9056P001		6 23	N
024	WASHER,PLAIN .938IDX1.500DX.10THK SST	N400P19		12 23	
025	BOLT, HEX HEAD	235A1031P37040		12 23	N
026	LUBRICANT	262A7893P001		AR 23	
027	WIRE,STAINLESS STEEL	175A8866F008		AR 21	N
028	WASHER	262A7003P001		6 21	N
029	PRESSURE GAUGE & VALVE	174B9475G001		1 16	
030	THREAD SEALANT	249A1067P001		AR 23	N
031	RING, BOX	157C4839F005		1 21	
032	WASHER,SST SPR LK .375 SST	N406P13		8 23	
033	SCREW,MACH,PNH	N153P25012		8 23	N
034	SET SCREW,SELF LOCK	209A5043P010		8 23	
036	PENETRATION, ELECTRIC	163C1902AC ✓ [WIRE LIST]		X CC	
037	PENETRATION, ELECTRIC	20466172 ✓ [ASSY-L.V.]		X 16	N
046	GREASE, SILICONE	175A6251P003		AR 23	

PARTS LIST NO ? 386X210AC
SUFFIX NUMBER ? G001

TITLE:REAC CNTMT ELEC PEN, LV   PL REV: 5 DOC REV: CMPL-P:C CMPL-D:

ITEM	NAME	IDENTIFICATION	STAT	QTY	DT	UM	SRC	EC	CC	SP	AC	RC	CD
004	JUNCTION BOX	246A9277G010		2	16					N			
005	GASKET	262A7141P001		2	21								
006	ELEC PENETRATION-LOW VOLT	386X110ACG001 ✓		1	02								
007	RING, BACKING-WELDING	209A6119P010		1	23					N			
008	SCREW,MACH,PNH	N153P25016		16	23								
009	WASHER,PLAIN .38	N402P43C		16	23								
010	WASHER,STL SPR LK FOR .375 BOLT C STL	N405P13C		16	23								
015	SPLICE, CONDUCTOR	209A5010P026		130	23					N			
016	SPLICE, CONDUCTOR	209A5010P009		70	23					N			
032	ELECT PEN LOW V.	133D9627AC ✓ INSTLL.		X	1H								
033	PENETRATION, ELECTRIC	163C1902AC ✓ WIRE LIST		X	CC								

PENETRATION IDENTIFICATION TABLE

PENETRATION NO	INSIDE JCT BOX NO	OUTSIDE JCT BOX NO	GE CATALOG NO	NOZZLE LENGTH
1T23*Z-E-A1	1JBPI*E-A1	1JBPO*-E-A1	386X210AC G001	74.00
1T23*Z-W-B4	1JBPI*W-B4	1JBPO*-W-B4	386X210AC G002	
1T23-Z-W-B2	1JBPI-W-B2	1JBPO-W-B2	386X210AC G003	
1T23-Z-E-A3	1JBPI-E-A3	1JBPO-E-A3	386X210AC G004	
1T23-Z-E-B3	1JBPI-E-B3	1JBPO-E-B3	386X210AC G005	
1T23-Z-W-B1	1JBPI-W-B1	1JBPO-W-B1	386X210AC G006	
1T23-Z-E-B5	1JBPI-E-B5	1JBPO-E-B5	386X210AC G007	
1T23-Z-W-B5	1JBPI-W-B5	1JBPO-W-B5	386X210AC G008	
1T23*Z-E-D5	1JBPI*E-D5	1JBPO*-E-D5	386X210AC G009	
1T23*Z-E-D6	1JBPI*E-D6	1JBPO*-E-D6	386X210AC G009	
1T23*Z-W-D2	1JBPI*W-D2	1JBPO*-W-D2	386X210AC G009	
1T23*Z-W-D1	1JBPI*W-D1	1JBPO*-W-D1	386X210AC G010	
1T23*Z-W-C4	1JBPI*W-C4	1JBPO*-W-C4	386X210AC G011	
1T23*Z-E-B2	1JBPI*E-B2	1JBPO*-E-B2	386X210AC G012	
1T23-Z-W-B6	1JBPI-W-B6	1JBPO-W-B6	386X210AC G013	
1T23-Z-W-C6	1JBPI-W-C6	1JBPO-W-C6	386X210AC G014	
1T23-Z-E-B6	1JBPI-E-B6	1JBPO-E-B6	386X210AC G015	
1T23-Z-E-C6	1JBPI-E-C6	1JBPO-E-C6	386X210AC G016	
1T23-Z-W-C5	1JBPI-W-C5	1JBPO-W-C5	386X210AC G017	
1T23-Z-E-C5	1JBPI-E-C5	1JBPO-E-C5	386X210AC G018	74.00

* CLASS 1E PENETRATIONS

PARTS LIST NO ? [illegible]
SUFFIX NUMBER ? G00?

TITLE:CONDUCTOR   PL REV: 4 DOC REV: 4 CMPL-P:C CMPL-D:C

ITEM	NAME	IDENTIFICATION	STAT	QTY	UM	SRC
001	SUPPORT	225A6004P006		2	23	N
002	RUBBER, UNVULCANIZED	225A5226P002		AR	23	N
003	ADHESIVE, BONDING	246A7103P002		AR	23	N
004	ADHESIVE, BONDING	246A7103P002		AR	23	N
005	ADHESIVE, BONDING	248A7103P001		AR	23	N
006	INSERT	248A4897P001		2	21	N
007	CABLE POWER [illegible] MV	175A[illegible]		14	[illegible]	N
008	SLEEVE	246A9848P001		2	21	N
009	SPLICE	234A9667P002		2	21	N
010	TAPE, INSULATION	209A6265P003		1	23	N
011	EPOXY	225A4967P001		AR	23	N

200 Series MV

PARTS LIST NO ? 328X393AC
SUFFIX NUMBER ? G001

TITLE:REAC CNTMT ELEC PEN, MV   PL REV: 3 DOC REV: CMPL-P:C CMPL-D:

ITEM	NAME	IDENTIFICATION	STAT	QTY	UM	SRC	E C C	C C F	S R C	A C C	R C D	C
001	LUG, COMP TYPE	209A5549P0[illegible]		12	23			N				
002	BOLT,SEMIFIN	N16P29024		26	23			N				
003	WASHER,PLAIN FOR .50DIA BOLT	N423P45		26	23							
004	WASHER,SPR,LOCK	N407P15		26	23							
005	NUT,HEX	N202P29		26	23							
006	SPLICE INSULATING KIT	225A4535G001		12	16			N				
007	90 DEGREE LUG, COMP TYPE	209A5[illegible]11P003		12	21			N				
008	JUNCTION BOX	193B1203G011		2	16			N				
009	GASKET	175A9737P008		2	21			N				
010	WASHER,PLAIN NARROW FOR .50 BOLT SST	N400P15		24	23							
011	WASHER,SST SPR LK .50 SST	N406P15		24	23							
012	BOLT,HEX HD	N24P29010		24	23							
013	COMP LUG	176A1585P00[illegible]		12	23			N				
014	RING, BACKING-WELDING	209A6119P010		1	23			N				
015	ELECTRIC PENETRATION, MV	328X193ACG001 ✓		1	02							
016	WASHER,PLAIN 1.00 OD X .41 ID SST	N400P43		16	23							
017	WASHER,SST SPR LK .375 SST	N406P13		18	23							
018	BOLT,HEX HD .375-16UNCX1.000	N24P25016		18	23							
020	PENETRATION, ELECTRIC	163C1902AC ✓ WIRE LIST		X	CC							
021	ELECT.PEN.MEDIUM VOLTAGE	133D9638 ✓ INSTL		X	TR							

PARTS LIST NO ?

EIS IDENT: SEALANT

GENERAL ELECTRIC

262A7076
CONT ON SHEET 2 SH NO. 1

C	262A7224	TITLE SPECIFICATION SEALANT (ENCAPSULATION COMPOUND)
	262A7076 CONT ON SHEET 2 SH NO. 1	FIRST MADE FOR ELECTRICAL PENETRATION MODULES

OVERALL REVISION	4

SUMMARY	
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8	4

REVISIONS: 3 NE78350 ... 2 NE 60... CHKD ... 1 NJ00U52 CHK'D BY ... 1-8-73 QUANG NG. ... 1260 ...

1.0 SCOPE

This specification covers a two-part, non-flame propagating epoxy resin system which will cure at room temperature. It is suitable for potting and encapsulation of electrical low and high voltage cables and cable splices.

2.0 APPLICABLE DOCUMENTS

Specification Mil-I-16923E: Insulating Compound, Electrical, Embedding.

Fed-Std-406: Plastics, Methods of Testing: Method 4041-Electr. Resistance

Fed-Std-406: Plastics, Methods of Testing: Method 1011-Tensile Strength.

ASTM Spec. D 1706: Indentation Hardness of Plastics by Means of a Durometer.

ASTM Spec. D 149: Dielectric Breakdown Voltage and Dielectric Strength of Electrical Insulating Materials.

ASTM Spec D 618: Conditioning Plastics and Electrical Insulating Materials for Testing.

ASTM Spec. D 1672: Exposure of Polymeric Materials to High Energy Radiation.

3.0 REQUIREMENTS

The resin shall be supplied in the form of two liquids, designated Part A (resin) and Part B (catalyst or hardener). Each component or the resin only shall contain a certain amount of chemically inert filler material. Resin and hardener shall not include any chemical constituents that vaporize easily under vacuum conditions or at elevated temperatures as recommended by the manufacturer of subject resin to prevent casting imperfections, blowholes, and other voids. Each component shall be free from impurities within the limits of best commercial practice. The density of the components as determined after degassing shall be 9.7 ± 0.1 Lbs/Gal for component A and 11.8 ± 0.1 Lbs/Gal for component B.

When mixed in the specified proportions, vacuum degassed, and cured at room temperatures not below 73°F, the resin shall harden with a minimal volatile loss or significant shrinkage to a uniform, solid mass of specified hardness. After completion of the curing period which shall not exceed five days at 73°F temperature the cast resin shall show uniform hardness and no further shrinkage. The specific gravity of the properly prepared and cured resin shall be 1.35 ± 0.05.

PRINTS TO

MADE BY NANCY NEDRY 9-20-74	APPROVALS C.T. Hill 23 Sept 74	NEPD	262A7076
ISSUED E. Margherone 10-1-74		SAN JOSE	CONT ON SHEET 2 SH NO. 1
			CI

EIS

GENERAL ELECTRIC

262A7076

CONT ON SHEET 3 SH NO. 2

TITLE SEALANT (ENCAPSULATION COMPOUND)

FIRST MADE FOR ELECTRICAL PENETRATION MODULES

262A7076

CONT ON SHEET 3 SH NO. 2

3.1 Physical Requirements

3.1.1 Handling and Casting

The resin, after mixing in the proper proportions as called for by the manufacturer, shall have a working life of 20 min. minimum as determined per paragraph 4.4.2 of this specification.

The heat as generated during the initial curing cycle shall not exceed 350°F for a one lb. sample as cast into a thin-walled metal container. This container shall not be attached to parts or devices working as a heat sink for the latter during the curing of the resin as contained therein.

3.1.2 Properties

The individual components and the properly mixed, degassed, cast and cured resin shall conform to the requirements as listed in Table I. The supplier shall be responsible only for conformance to those properties denoted with a "Q".

TABLE I
REQUIREMENTS

PROPERTY	UNITS	REQUIRED FOR *	AVERAGE VALUE	DEVIATION ALLOWED	REFERENCE
Shelf Life	Months	Q	6	Minimum	See para. 4.4.1
Working Life	Minutes	Q	20	Minimum	See para. 4.4.2
Shore D Hardness	Shore D Units	Q	60	MINIMUM	ASTM-D1706
Coefficient of Linear Thermal Expansion	Inch/Inch/°C from 23°C to 113°C	Q	16.8×10^{-5}	$\pm 1.0 \times 10^{-5}$	Mil-I-16923E
Ultimate Tensile Strength	PSI	Q	2,400	Min.	Crosshead speed to be 0.2"/min. Fed-Std-406 Method 1011
Elongation at Break	% of initial	Q	10%	Min.	
			--		

REVISIONS: 1 — NC [illegible] CHKD [illegible] ESM; 2 — NE 60914 CHKD [illegible] ESM; 3 — NE 78350 CHKD [illegible]

PRINTS TO

MADE BY NANCY MERRILL 9-23-74

ISSUED E. [illegible] 11-74

C. [illegible] 23 Sept 74

NEPD SAN JOSE

262A7076

CONT ON SHEET 3

CI

262A7076
CONT ON SHEET 4 SH NO. 3

TITLE SEALANT (ENCAPSULATION COMPOUND)

FIRST MADE FOR ELECTRICAL PENETRATION MODULES

TABLE I: REQUIREMENTS (Cont'd)

PROPERTY	UNITS	REQUIRED FOR	AVERAGE VALUE	DEVIATION ALLOWED	REFERENCE
Dielectric Strength	Volts/ Mil	Q	350	Min	ASTM-D149
Volume Resistivity	Ohm-Cm	Q	$1X10^{12}$ @ 500 V	Min	Method 4041 of Std. #406
Electrical Insulation Resistance	Ohms	I	$1.0X10^{11}$ @ 500 V	Min	G.E. Dwg. # 117C1534 175A1083
Radiation Resistance	Rads	I	$1.0X10^{8}$	Min	ASTM-D1672
Moisture Absorption	%	Q	0.85	Max	See para. 4.4.8

* Q for Vendor Qualification; I for Internal Inspection purposes

3.2 Packaging

The materials for subject compound shall be delivered in suitable containers to allow safe transportation and storage by common and other carriers at the lowest rate to the point of delivery. Each package shall be clearly marked with the net weight, the manufacturer's name, the type, component or chemical designation, the manufacturer's lot number and the actual date of manufacture.

4.0 QUALITY ASSURANCE PROVISIONS

4.1 The supplier shall certify that each individual lot of material conforms to all applicable requirements of this spec. The purchaser will conduct certain tests as stated in para. 4.3 and 4.4 of this spec. so as to verify the acceptability of any particular lot.

4.2 Preproduction Samples

When requested, a preproduction sample shall consist of a one pound minimum sample representative of the identical material and manufacturing process as used for actual production. The preproduction sample shall be subjected to all examinations and tests as specified herein. When stipulated as a pre-negotiated term of the purchase order, prior to shipment the supplier shall submit a certified test report to verify his compliance as per paragraph 4.1.

REVISIONS
1 E. FRASCH 5-9-75 NE 60162 CHKD EGA
2 E. MAGVERONE 6-9-75 NE 60994 CHKD EGA ESM

PRINTS TO

MADE BY NANCY MERRALL 9-23-74
ISSUED E. Margverone Oct 1-74
APPROVALS C. H. Ring 23 Sept 74
NEPD SAN JOSE
C1

4.3 Classification of Tests

As indicated on Table I, all tests shall be conducted for the following purposes:

4.3.1 Qualification Tests: Are those tests initially performed on the resin to approve it as an acceptable product. These tests shall consist of all the ones so identified in Table I and shall be performed in accordance with the appropriate paragraphs of this specification. Failure in any test shall disqualify the resin represented.

4.3.2 Inspection Tests: Are those tests performed on incoming individual lots shipped in fulfillment of a purchase order to audit and verify their compliance with paragraph 4.1 and 4.3.1.

4.3.2.1 Inspection Lot: For the purpose of inspection and testing a lot shall be defined as both components of all the resin of the same type, and submitted for inspection at the same time.

4.3.2.2 Sampling Procedure: One container of each component of each inspection lot shall be selected for sampling. The material in each container shall be thoroughly stirred to insure complete homogeneity with all settled material brought into suspension.

4.3.2.3 Rejection and Retest: Failure of any lot to meet all the applicable requirements of this specification shall be cause for retest. The property in question shall be retested on new specimens prepared from fresh resin. If the average retest value fails to meet the specification requirement, the entire lot shall be rejected.

4.4 Test Procedures

Unless otherwise specified, all tests shall be conducted at standard conditions, i.e., 50°±5% relative humidity and a temperature of 73°±2°F. The samples shall be preconditioned according to ASTM Spec. D618-61.

TITLE SEALANT (ENCAPSULATION COMPOUND)

FIRST MADE FOR ELECTRICAL PENETRATION MODULES

REVISIONS

4.4.1 Shelf Life

Both components of the epoxy resin when properly stored at 73° ± 2°F in their unbroken shipping containers shall have a minimum of six months storage life during which no chemical breakdown or deterioration of the resulting properties as listed in paragraph 3.1.2 shall occur.

4.4.2 Pot Life or Working Life

This shall be the time from completion of the mixing of the components to the onset of rapid increase of the viscosity preventing further casting operations. The mixed resin shall be kept either at room temperature of 73°F ± 2° or a defined elevated temperature as recommended by the manufacturer to better facilitate casting. The time during which the viscosity stays below 100,000 Centipoises shall be determined by periodic measurement preferably using a Brookfield Viscosimeter with a number 4 spindle rotating between 5 and 30 RPM.

4.4.3 Initial Viscosity

The initial viscosity of the properly mixed resin shall be determined using a Brookfield Viscosimeter with a number 4 spindle rotating between 5 and 30 RPM. A 200 ml capacity tall form beaker shall be used for the determination. The resin temperature shall be 73°F ± 2°F or such temperature as recommended by the manufacturer for the proper handling of the resin.

4.4.4 Shore D Hardness

A slab of resin shall be cast and cured according to the resin manufacturer's instructions. The slab shall have a minimum thickness of 3/8" and a size of at least 3 square inches. The tests shall be conducted according to ASTM Spec. D1706-61. An instantaneous reading shall be taken with a Shore D Durometer.

4.4.5 Dielectric Strength

Dielectric strength testing equipment capable of producing at least 75KV conforming to ASTM Spec. D-149-64 shall be used. The cut slab specimens shall be immersed at least 1" below the surface of a bath of high grade transformer oil. The rate of voltage rise shall be 500 volts/sec. The breakdown voltage shall be determined and the dielectric strength in volts/mil shall be calculated for each specimen. The average of four values shall be used to determine the conformance to this specification.

REV	Description
1	F. Rosnick, E.EAMSCH 2-9-25, NE60762, CHKD EGM
2	E. Margherone, E.MARGHERONE, NE60994, CHKD EGM

PRINTS TO

4.4.5.1 Test Electrodes: The electrodes shall consist of two opposed brass rods 1/4" diameter with edges rounded to a radius of 1/32". The electrodes shall be mounted vertically and coaxially within 1/16". The movable top electrode shall press on the specimen with a weight of 0.10 lbs.

4.4.5.2 Test Specimen: Specimens shall be cast in a mold as specified in paragraph 4.5.1 of MIL-I-16923E according to the resin manufacturer's instructions. The size of the test specimen shall be 3"x3"x0.125" ±0.010 inch thickness. The large surfaces of the specimen shall be cast surfaces with a smooth surface condition as attained by the use of polished steel plates and Teflon type mold release agent for the casting process.

4.4.6 Electrical Insulation Resistance

4.4.6.1 Volume Resistivity Tests:

According to the manufacturer's instructions a minimum of three samples shall be cast and conditioned per ASTM-D618 and subsequently be tested per Federal Test Method Std. #406, Method 4041

4.4.6.2 For "In-House" testing:

According to the manufacturer's instructions, three plugs from identical resin lots shall be cast, degassed, and cured in a mold as shown on drawing #117C1534: Part I. Each test plug shall carry a pair of electrodes properly shaped and spaced as shown on drawing #175A1083. An electrode spacing fixture as shon on drawing #117C1534 parts 2 to 10 shall be used to insert and space the electrode wire pairs in the still liquid cast resin. After completion of the curing cycle of the resin, the specimen shall be stabilized at room temperature according to paragraph 4.4. Then the electrodes shall be connected to a picoammeter and a suitable stable power supply to provide 500 volts DC current. The resistance measured over the electrodes at above voltage shall not drop below $1x10^{11}$ ohms under an average of 2 min. of applied voltage.

4.4.7 Coefficient of Linear Thermal Expansion

The linear thermal expansion shall be determined on at least three specimens prepared according to paragraph 4.4.5.2. The

REV 2
262A7076
CONT ON SHEET 8 SH NO. 7

TITLE SEALANT (ENCAPSULATION COMPOUND)

FIRST MADE FOR ELECTRICAL PENETRATION MODULES

REVISIONS

size of the specimens shall be 2" length by 1/2" square and the test method shall be in accordance with paragraph 4.6.8 of MIL-I-16923E.

4.4.8 Moisture Absorption

The moisture absorption shall be determined on three specimens of 1"x3"x1/8" height cut from cast slabs in accordance with paragraph 4.4.5.2. The specimens shall be placed in a desiccator over dry $Ca\ Cl_2$ for 96 hours. After conditioning, the specimens shall be weighed, exposed to 96+1% relative humidity for 240 hours, then weighed again. The average percentage of weight gain due to absorption of humidity shall be reported as follows:

$$\frac{\text{Wet Weight - Dry Weight}}{\text{Dry Weight}} \times 100$$

4.4.9 Ultimate Tensile Strength and Elongation

The ultimate tensile strength and the percentage of elongation at break shall be determined on a minimum of four samples according to Fed. Test Std. 406, Method 1011 with a testing machine crosshead speed of 0.2"/Min.

1 | NE60762 | CHKD EGM
2 | NE60774 | CHKD EGM

PRINTS TO

MADE BY NANCY MERRILL 9-23-74
ISSUED E. Migliore 10-17-74
APPROVED C.H. Kirk 23 Sept. 74
NEPD SAN JOSE
LOCATION CI

GENERAL ELECTRIC

262A7076
CONT ON SHEET F SH NO. 8

SH NO. 04
262A7076
CONT ON SHEET F SH NO. 8

TITLE
SEALANT (ENCAPSULATION COMPOUND)

FIRST MADE FOR ELECTRICAL PENETRATION MODULES

REVISIONS

APPENDIX

QUALIFIED PRODUCT: 4

- Scotchcast Resin XR-5237 in 1 Gal. container

by: Minnesota Mining and Manufacturing Co.
Electrical Products Division
2501 Hudson Rd.
St. Paul, Minnesota 55119

- Each container to be marked to indicate:

1. Manufacturer
2. Manufacturer's Product Identification
3. Manufacturers Lot #
4. The Actual Date of Manufacture

4 QUANG NG NJ0B852 CHK'D BY: K.J.Y.

PRINTS TO

NANCY MERRILL 9-23-74

23 Sept 74

NEPD
SAN JOSE

262A7076
CONT ON SHEET F SH NO. 8

CI

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GENERAL ELECTRIC

NUCLEAR POWER

SYSTEMS DIVISION

GENERAL ELECTRIC COMPANY 175 CURTNER AVE., SAN JOSE, CALIFORNIA 95125
MC 391, (408) 925-3371

April 29, 1981
JWB-T-2084

Project Engineer - J.O. No. 11600.02
Stone & Webster Engineering Corp.
P. O. Box 2325
Boston, MA 02107

Dear Sir:

SUBJECT: SHOREHAM NUCLEAR POWER STATION UNIT 1
ELECTRICAL PENETRATIONS, NUREG-0588 QUALIFICATIONS

Reference: JWB-T-2068, May 6, 1981

We have reviewed information regarding materials used for the Shoreham electrical penetrations. Beyond the information that you already have, we have not found additional useful data to show the penetrations meet the requirements of NUREG-0588.

Data on the metallic structural part were sent to Stone & Webster at the time of equipment delivery as part of ASME Section III Code Package. Other major components which could have a significant effect on containment integrity are the epoxy sealing compound used around the copper rods in the low penetrations, the EPR rubber used is a sealant in the medium penetrations, and the "O" rings on the low voltage wire modules. These materials and the sealing techniques were qualification tested per S&W. the purchase specification and the data previously delivered to you.

The epoxy used was a high temperature rubbery material developed by GE and manufactured by an outside vendor to GE specifications. It is not available as a vendor catalogue item. The pressured seal of the medium voltage units is an EPR rubber which was vulcanized to a cable splice on the conductor and to an outer metal sleeve, which was in turn welded to a tube in the penetration flange. Three adhesives were employed to aid in bonding rubber to the metal and to the cable jacket. The process may be as important as the materials used.

This is presently all the information readily available.

Very truly yours,

J. W. Blakley
Project Manager
Shoreham Project

JWB:hmc/1764 & 1782

cc: W. J. Museler
A. E. Pedersen
J. E. Etzweiler
J. P. Novarro
R. M. Pulsifer

NRC SITE AUDIT OPEN

J.O. No. 11600.02

Attachment to EQREF No. ITEM - REPLY

REQUIRED SERVICE CONDITIONS
SHOREHAM NUCLEAR POWER STATION - UNIT 1

Equipment ID(s): (See Attachment)

Equipment Type: ELECTRIC PENETRATIONS

EQSS Ref: 134-01

Applicable Zone: Temp/Pres. 9, 10, 11, 12

Rad. G and H

NORMAL SERVICE CONDITIONS:		LIMITING ZONE NO.
Time (duration)	40 YRS	SECONDARY CONTAINMENT
Pressure ~~psig~~ In H_2O Vac.	1.0	T/P 12
Temperature, °F (range)	104	
Relative Humidity, %	50%	
Radiation, rads (40 yr. normal integrated dose), gamma	1.8×10^3	G and H

EMERGENCY (DBE) SERVICE CONDITIONS:		
Operating Time (duration)	180 DYS	
Pressure psig	Peak 0.9 psig From 0 within 10 sec. Decrease to 0 psig within 17 hrs	T/P 1-12
Temperature, °F	104 - 194°F within 15 sec decreasing to 120°F in 9 hrs Decreasing to 104°F in 16 hrs.	T/P 12
Humidity, %	100%	
Radiation, rads, gamma (40 yr. integrated dose plus accident dose for the above operating time)	5.08×10^4 - G 5.75×10^6 - H	H

NOTES:

1. This form may be filled for each individual equipment or for each specification. However, the current equipment specification service conditions must agree with this form.
2. Refer to EQSR for the applicable Bldgs., Elev., Zones and operating times.
3. Refer to Appendix E of Shoreham Environmental Qualification Report and FSAR Table 3.11.2-1 for service conditions.
4. "The Operating Time" indicates the longest post accident operating time.
5. If space for Equipment ID's in insufficient, list ID's on an attachment and reference the attachment above.

8/1/81

ATTACHMENT TO RCS 134-01

NRC SITE AUDIT OPEN ITEM REPLY

1T23*Z-EA1
1T23*Z-WB4
1T23-Z-WB2
1T23-Z-EA3
1T23-Z-EB3
1T23-Z-EB5
1T23-Z-WB5
1T23*Z-ED5
1T23*Z-ED6
1T23*Z-WD2
1T23*Z-EB2
1T23-Z-EB6
1T23-Z-EC6
1T23-Z-WC5
1T23-Z-EC5

100 SERIES CONTAINMENT ELECTRICAL PENETRATIONS

LOW VOLTAGE QUALIFICATION TEST REPORT
ADDENDUM 1

Prepared by [signature]
R. M. Schuster

Design Approval [signature]
N. G. Luria

220926

March 1974

TABLE OF CONTENTS

220927

INTRODUCTION

LOW VOLTAGE POWER AND CONTROL

This test supplements the testing performed on units covered in the "Low Voltage Qualification Test Report" in which aging, LOCA and severe electrical loading demonstrated that containment integrity would be maintained for power and control modules.

This report documents the simultaneous voltage and current loading during the LOCA service environment on qualification hardware which was subjected to the necessary aging exposures. The primary objective of the test was to demonstrate that the penetration electrical circuits would perform the necessary functions during a LOCA. The secondary objective was to demonstrate, again, the maintenance of the containment pressure integrity. Both objectives met the specification requirements.

As discussed in the "Low Voltage Qualification Test Report," there are two generic designs in this classification, namely control (No. 10 AWG through No. 18 AWG) and power (No. 4/0 through No. 8 AWG). Because of similarity in construction and configuration, qualification of any one within a generic type will qualify all units within that type. For maximum loading, the 4/0 and No. 10 were selected to qualify these basic generic designs. Other sizes tested merely substantiated this rationale.

SIGNAL

All signal modules are basically of a generic design configuration in that each module employs coax (or triax) cable, glass hermetric seals, coax or triax connectors, all encapsulated with the same resin. Qualification of the unit tested herein qualifies all signal units for use in a Nuclear Containment.

220928

The testing reported herein demonstrates that the signal penetrations, when subjected to the necessary aging and LOCA service environments will maintain the integrity of the containment pressure boundary.

Although not specified to be electrically operable during LOCA, the signal unit maintained a high enough insulation resistance between center conductor and shield (>1 x 10^6 ohms) to be considered electrically acceptable for use during LOCA.

THERMOCOUPLE

The thermocouple penetration is of the same generic design and the No. 18 AWG through No. 10 AWG type penetrations, with the exception that actual thermocouple materials are used in place of copper. This test, therefore, demonstrates that the thermocouple penetration, when subjected to the necessary aging and LOCA service environment, will maintain the containment pressure boundary integrity.

Although not specified for operation during a LOCA, the insulation resistance between conductor and conductor, and conductor to ground was high enough (>1 x 10^5 ohms) to operate during LOCA.

2209?9

REFERENCES

Low Voltage Qualification Test Report dated January 1974

Low Voltage Power, Drawing No. 195B9475

Low Voltage Control, Drawing No. 195B9474

ECN Modification Change ① ⓐ Only, Drawing No. NE47750, Sheet 1

Signal, SRM/IRM, Drawing No. 195B9476

Thermocouple, Drawing No. 163C1068

220930

QUALIFICATION RATING SUMMARY

Based on all testing performed the following operating limits are established on the electrical penetrations.

All low voltage penetrations, which include control, instrumentation, power and signal are qualified for the following service environments.

NORMAL SERVICE (Thermal Cycling)

Low Voltage Power	120 cycles 50 - 150 - 50°F, 100% relative humidity
Low Voltage Control	120 cycles 50 - 150 - 50°F, 100% relative humidity
Low Voltage Thermocouple	60 cycles 50 - 150 - 50°F, 100% relative humidity
Signal	40 cycles 50 - 150 - 50°F, 100% relative humidity

NORMAL SERVICE (Gamma Ray Exposure)

All penetrations	1×10^{8} rad area containment integrated dose (See Section 5.)

LOCA SERVICE

Temperature	340°F	320°F	260°F	250°F
Pressure	103 psig	80 psig	25 psig	16 psig
Humidity, RH	100%	100%	100%	100%
Duration	3 hours	3 hours	18 hours	7 days
pH*	10	10	10	10
Ambient temperature	$\geq$150°F	$\geq$150°F	$\geq$130°F	$\geq$130°F

LOCA ELECTRICAL (Throughout LOCA Service Environment above)

Size	Voltage	Current
No. 16 AWG through No. 18 AWG	1 amp	125 volts
No. 10 AWG through No. 14 AWG	3 amp	460 volts

*Based on evaluations and tests reported in the Epoxy Report, Section 10.

220931

Size	Voltage	Current
No. 8 AWG	16 amps	460 volts
No. 6 AWG	26 amps	460 volts
No. 4 AWG	34 amps	460 volts
No. 2 AWG	45 amps	460 volts
No. 2/0	70 amps	460 volts
No. 4/0	95 amps	460 volts

PRESSURE TRANSIENT

Sp = 80 Δp psig in 10 seconds, all penetrations.

CONTAINMENT INTEGRITY

All penetrations are qualified to meet a leak rate of $<1 \times 10^{-7}$ cc He/sec at design pressure during LOCA.

220932

TEST SETUP

THERMAL CYCLE EXPOSURE

Refer to Section 4 of the "Low Voltage Qualification Test Report."

GAMMA RAY EXPOSURE

Refer to Section 5 of the "Low Voltage Qualification Test Report."

LOCA

The autoclave described in Section 3 of the "Low Voltage Qualification Test Report" was used in this test. All modules were mounted in the 12 inch size header plate with the associated retaining hardware defined by Drawing No. 195B9243.

An environmental hood was placed over the autoclave to achieve the ambient temperatures indicated herein.

The electrical circuits employed during LOCA were as shown on Figures 4-1 through 4-3. A minimum of 30% of all wires in each module were series connected to carry current and voltage.

220933

Temperature, °F	300	250
Pressure, psig	80	20
Relative humidity, %	100	100
Duration, hours	4	168
Steam, pH	>8.2	>8.2
Outside temperature, °F	≥150	≥130

Module

No. 4/0 (S/N Y2257-392)	Current, amps	150	150
	Voltage, volts a-c	600	600

Based on generic design configuration for No. 8 AWG through 4/0, the following ratings are derived:

	I* 30°C amps	Density Derating*	I Derated amps	I Test / I Derated	I Rating amps	V Volts, a-c
4/0	235	0.8	188	150/188	150	600
2/0	185	0.7	130	150/188	104	600
2	120	0.7	84	150/188	67	600
4	90	0.7	63	150/188	50	600
6	70	0.7	49	150/188	39	600
8	50	0.6	30	150/188	24	600

ACCEPTANCE TESTING

LEAK INTEGRITY

All units at the end of the test were leaktight to less than 1×10^{-7} ccHe/sec at 15 psig across the entire module. Both Veeco and GE Mass Spectrometers were used in the measurement test.

220942

*Based on National Electrical Code.

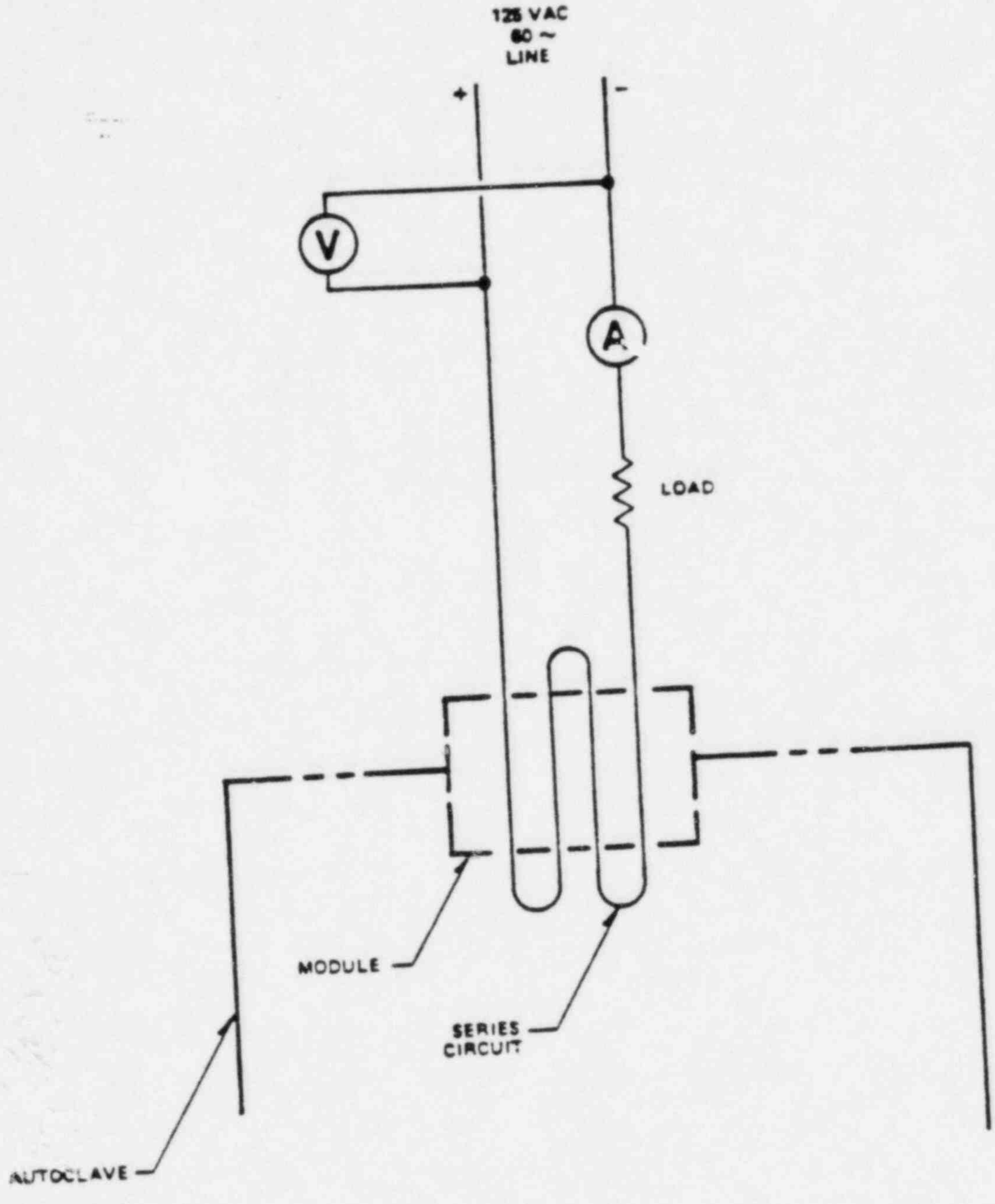
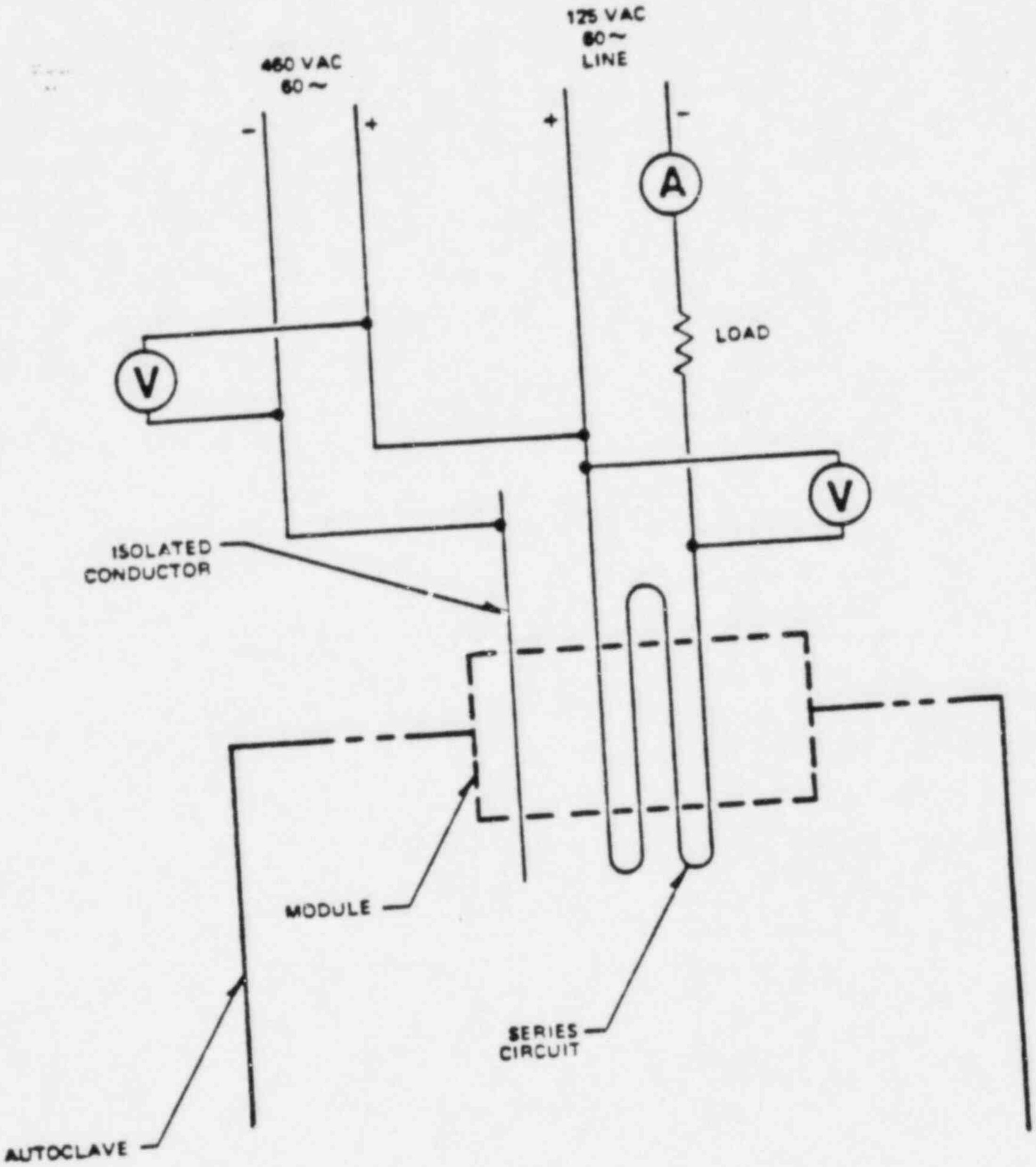


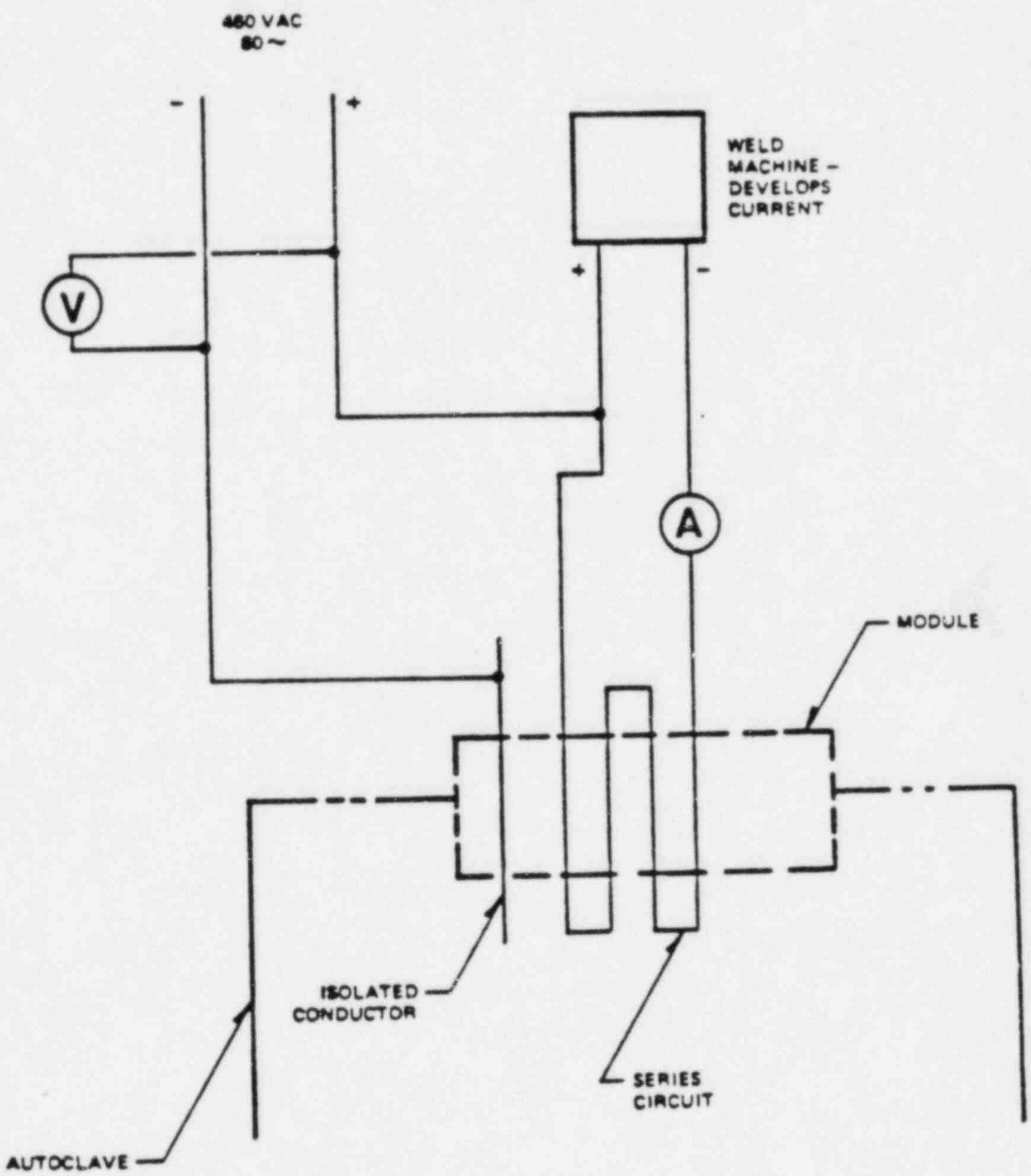
FIGURE 1. ELECTRICAL TEST SET-UP FOR NO. 16AWG CIRCUIT

2?0934



220935

FIGURE 2. ELECTRICAL TEST SET UP FOR NO. 10AWG CIRCUIT



220936

FIGURE 3. ELECTRICAL TEST SET-UP FOR 4/0 CIRCUITS

QUALIFICATION HARDWARE IDENTIFICATION

The following identifies the prototype hardware used in this qualification test program.

Module Name	Drawing No.	Mfg. Serial No.	Drawing Modification	Remarks See Notes 1 - 4
No. 10 AWG	195B9474G002	Y7257-251	None	Vulkene wire
No. 16 AWG	195B9474G001	Y7257-169	None	Vulkene wire
No. 10 AWG	195B9474G002	Y7257-211	ECN NE47750	Vulkene wire
No. 4/0	195B9474G004	Y7257-392	None	Raychem Flamtrol wire
No. 4/0	195B9474G004	Y7257-454	None	Raychem Flamtrol wire
Thermo-couple	(See Notes 5, 6) 163C1068G003	Y7257-381	None	Vulkene wire
Signal	195B9476G001	Y7257-135	None	Raychem Triax cable

NOTES:

1. Vulkene wire, Drawing No. 175A7293
2. Raychem Flamtrol, Drawing No. 174B9404
3. Signal cable, Drawing No. 225A4706
4. Thermocouple, Drawing No. 209A4108
5. Second qualification of the thermocouple module (refer to Section 3 of Low Voltage Qualification Test Report, January 1974)
6. Except for wire length and quantity

The above hardware was fabricated by the Pen Seal Production Shop under the direction of engineering instructions. This qualification hardware is representative of prime hardware being delivered for plant installation.

220937

TEST RESULTS

The following is the sequence of exposures and testing performed on the qualification hardware.

THERMAL CYCLE

Refer to Section 4 of the "Low Voltage Qualification Test Report" dated January 1974 for discussion and requirements.

The qualification hardware was subjected to the environment as shown on the following table. Both primary and secondary seals were subjected to this environment.

After completion of the above exposure, the hardware was helium leak tight at a rate less than 1×10^{-7} cc/sec at 15 psig differential pressure through both primary and secondary seal, using a Veeco Helium Mass Spectrometer (QC production equipment).

DISCUSSION

With the exception of the signal module, the effects of 170 thermal cycles (both primary and secondary seals) on the final outcome of the penetration to maintain containment integrity after LOCA have already been qualified. (See Low Voltage Qualification Test Report, January 1974.) Also, in the same report, under Section 3, Page 3-14 the application of rated current was demonstrated to have no effect on containment integrity.

As this overall test, in this report, is primarily concerned with the additional application of operating voltage, aging exposures were completed to demonstrate that there were no significant changes in dielectric strength of the designed system. A minimum of 40 cycles, representing one plant startup and shutdown per year, was selected, although not essential to the objective of this test.

220938

WIRE TERMINATION SYSTEM

The termination system used in providing the necessary series circuit of the respective modules is shown below.

Module Name	Lug or Crimp Drawing No.	Lug or Crimp Type	Insulation Drawing No.	Insulation Type
No. 4/0	225A4815	Crimp lug	175A8230	Shrink tubing
No. 10, No. 16	209A5010	Nylon insulated panel crimp	175A8230	Shrink tubing

2200939

THERMAL CYCLE EXPOSURE

Cycle temperature	50 to 150 to 50°F
Percent relative humidity	95% to 100%
Cycles per day	3 to 4

Module Name	Serial Number	No. Cycles
Thermocouple	Y7156-381	60
SRM/IRM Signal	Y7257-135	40
No. 16 AWG	Y7257-169	40
No. 10 AWG	Y7257-251	40
No. 10 AWG	Y7257-211	42
No. 4/0	Y7257-454	40
No. 4/0	Y7257-392	40

GAMMA RADIATION EXPOSURE

Refer to Section 5 of the "Low Voltage Qualification Test Report" dated January 1974 for discussion and requirements.

The qualification hardware listed above was subjected to the following environment:

Accumulated dose	5×10^7 Rads
Rate of exposure	3×10^6 r/hr

After completion of the above exposure, the qualification hardware remained helium leaktight to less than 1×10^{-7} cc/sec at 15 psig through both primary and secondary seals, using Veeco Helium Mass Spectrometer (QC production equipment).

LOSS OF COOLANT ACCIDENT TEST

Upon completion of the thermal cycle and gamma radiation exposures, the qualification hardware listed above was subjected to the following environment and electrical loading conditions.

For those modules required to operate electrically during the specified LOCA, the applicable currents and voltages are indicated below.

		Event 1	Event 2	Event 3	Event 4
Temperature, °F		340	320	260	250
Pressure, psig		103	81	25	16
Relative humidity, %		100	100	~100	100
Duration, hours		3	3	18	168
Steam, pH		>9.5	>8.5	>8.2	>8.2
Outside temperature, °F		≥150	≥150	≥130	≥120
Module					
No. 16 AWG (S/N Y7257-169)	Current, amp	1.1	1.1	1.1	1.1
	Voltage, volts a-c	125	125	125	125
No. 10 AWG (S/N Y7257-251)	Current, amps	3.3	3.3	3.3	3.3
	Voltage, volts a-c	500	500	500	500
No. 4/0 AWG (S/N Y7257-454)	Current, amps	95	95	95	--
	Voltage, volts a-c	460	460	460	--
No. 10 AWG (S/N Y7257-211)	Current, amps	3.3	3.3	3.3	3.3
	Voltage, volts a-c	125	125	125	125

For the modules required to operate electrically during the specified LOCA, the applicable current and voltage are listed below. Upon completion of the thermal cycle and gamma radiation exposure the qualification hardware listed below was subjected to the specific environment.

220941

Temperature, °F	300	250
Pressure, psig	80	20
Relative humidity, %	100	100
Duration, hours	4	168
Steam, pH	>8.2	>8.2
Outside temperature, °F	≥150	≥130

Module

No. 4/0 (S/N Y2257-392)	Current, amps	150	150
	Voltage, volts a-c	600	600

Based on generic design configuration for No. 8 AWG through 4/0, the following ratings are derived:

	I* 30°C amps	Density Derating*	I Derated amps	I Test / I Derated	I Rating amps	V Volts, a-c
4/0	235	0.8	188	150/188	150	600
2/0	185	0.7	130	150/188	104	600
2	120	0.7	84	150/188	67	600
4	90	0.7	63	150/188	50	600
6	70	0.7	49	150/188	39	600
8	50	0.6	30	150/188	24	600

ACCEPTANCE TESTING

LEAK INTEGRITY

All units at the end of the test were leaktight to less than 1×10^{-7} ccHe/sec at 15 psig across the entire module. Both Veeco and GE Mass Spectrometers were used in the measurement test.

220942

*Based on National Electrical Code.

CIRCUIT INTEGRITY

All circuits subjected to current and voltage, as specified above, produced no shorting or discontinuity.

LOSS OF COOLANT ACCIDENT - LONG TERM

REQUIREMENT

BWR plants: 100 days at 200°F, 20 psig, 100% relative humidity

PWR Plants: 1 year at 225°F, 15 psig, 100% relative humidity

Acceptance: Leak rate $<1 \times 10^{-2}$ ccN_2/sec through penetration

QUALIFICATION TEST

Temperature	225°F
Pressure	20 psig
% relative humidity	~100%
Duration	1 year

TEST RESULTS (LATER)

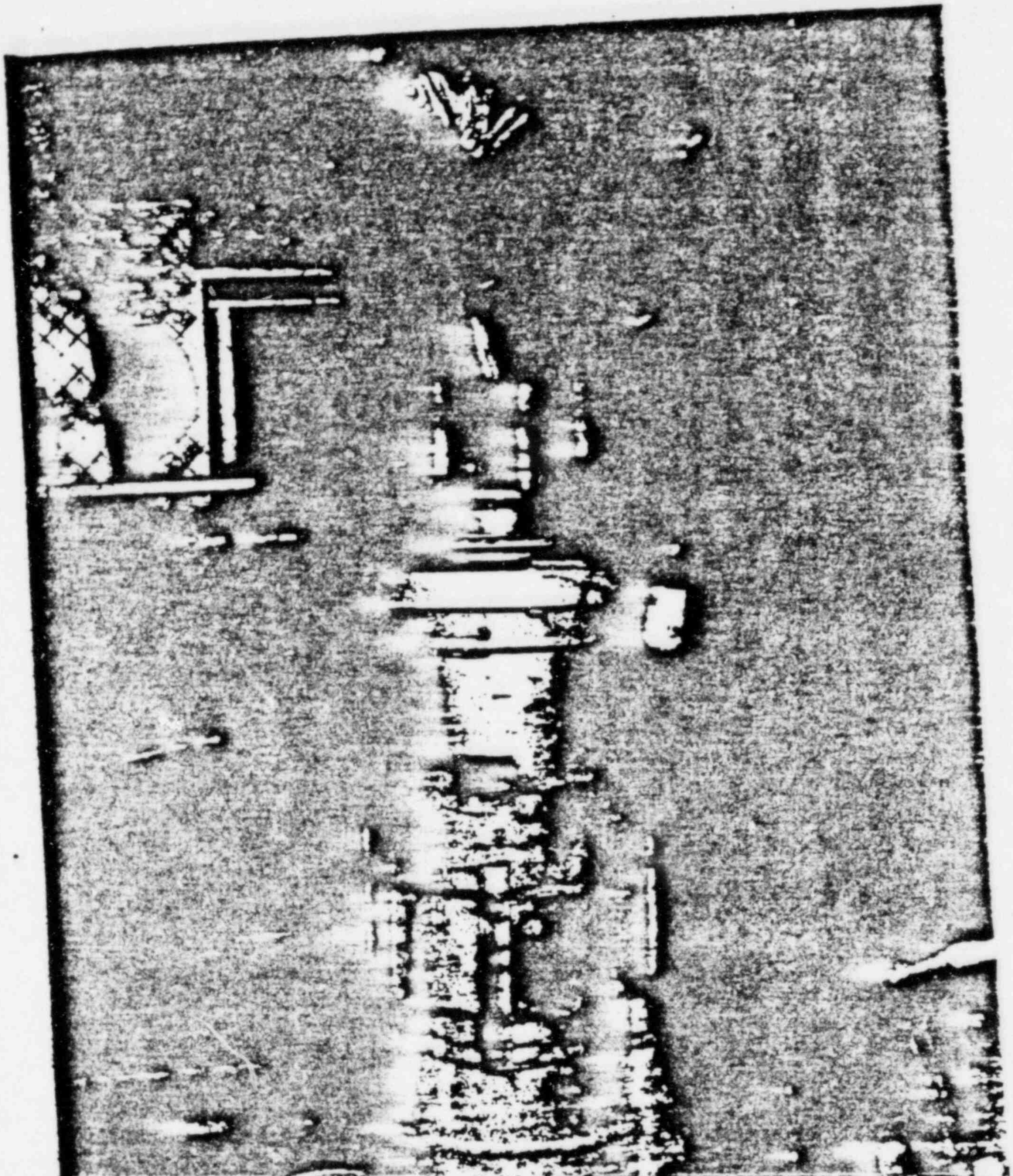
Test in progress.

PRESSURE TRANSIENT TEST

This test demonstrates the ability of the penetration to withstand a pressure rise of 80 psig in 10 seconds.

As a pressure barrier, all penetrations have the same configuration, in that wire and cable are encapsulated in an epoxy resin. The test was therefore performed on two of the modules, which qualifies all configurations. In addition, the 10 second duration will not cause any significant shock loading.

The test setup is the same as that of the LOCA service environment test. With the pressure in the autoclave initially at 12 psig and 250°F, GN_2 was injected into the autoclave and the pressure increased to 92 psig in 10 seconds. Both units remained helium leaktight to $<1 \times 10^{-7}$ ccHe/sec.



LOCA TEST SET-UP

220944

Units Tested	Autoclave Pressure, Initial	Pressure End
No. 10 AWG (S/N Y7257-211)	12 psig	92 psig
Thermocouple (S/N Y7257-381)	12 psig	92 psig

IMPEDANCE MISMATCH TEST RG-11 TRIAX MODULE

SPECIAL INDEPENDENT TEST

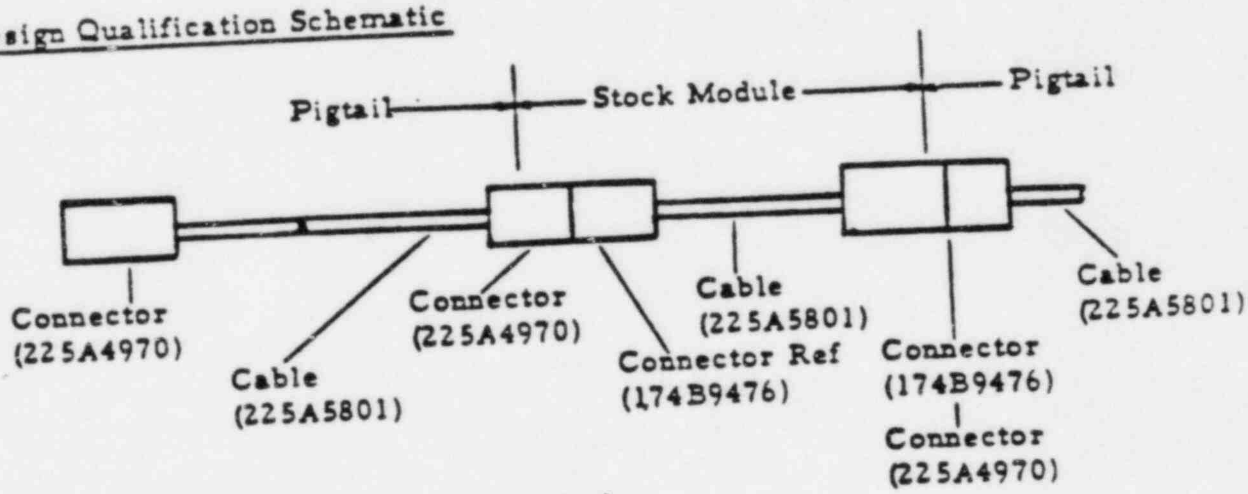
Introduction

This test determines the effect of impedance mismatch on the triax (PG-11) electrical penetration.

Design Qualification, Identification

1. Cable assembly, Drawing No. 174B9476 (Proprietary Design). This drawing defines the design internal to the stock module.
2. Connector, Drawing No. 225A4970, Amphenol Cat. No. 53175
3. Wire Module Assembly, Drawing No. 159C4484
4. Cable, Drawing 225A5801, Amphenol Cat. No. 21-529

Design Qualification Schematic



Results of Test (See Attachment Letter)

2~0945

NUCLEAR POWER GENERATION CONTROL DEPARTMENT
San Jose, California

January 18, 1972

cc: W. Green
C. vonDamm

Subject: TRIAXIAL SIGNAL CABLE FOR CONTAINMENT ELECTRICAL PENETRATIONS

N. Luria
MC 058

A test was run today on the sample cable and connectors provided by you. As you know, the sample consisted of a length of triaxial RG-11 terminated at one end in an Amphenol triaxial connector, a short length of cable terminated at both ends by triaxial connectors, and another long piece of cable terminated at one end by a triaxial connector. The three pieces were connected together and the effect of impedance mismatches was determined.

As a result of the tests it appears that the triaxial cable and connector configuration can perform with a waveform distortion less than that caused by a 65 ohm termination on a 75 ohm cable down to a pulse rise time of 1.0 nanosecond. Since the connectors are 50 ohm, faster rise times will show a larger discontinuity but at 1.0 nanosecond and above the effect is within specification.

The measurement was made using a Hewlett Packard Time Domain Reflectometer and checked using a laboratory pulser and oscilloscope.

L D Test

L. D. Test
MC 014

220946

REVISION STATUS SHEET

DOCUMENT NO. PL 195B9475 REV. 0

GENERAL ELECTRIC

NUCLEAR ENERGY DIVISION

APPLICATION ELEC PENETRATIONS

FCF ltr

TYPE

☐ SPECIFICATION ☒ DRAWING ☐ OTHER

DOCUMENT TITLE LV PWR WIRE MODULE ASSEMBLY

LEGEND:

REVISIONS

0	E. MARGHERONE 4-79	E.M.	
	ISSUED.		

	PRINTS TO
	A13
	24
	41
220947	
DESCRIPTION OF GROUPS	

MADE BY E. MARGHERONE DEC 21, 75	APPROVALS N. LUBIA	BWRS DEPT.	PL 195B9475
ISSUED E. Margherone 4-79	N. Lubia	SAN JOSE LOCATION	CONT. ON SHEET 2 SH. NO. 1

CI

GENERAL ELECTRIC

BOILING WATER REACTOR SYSTEMS DEPARTMENT, SAN JOSE, CA

TITLE: WIRE MODULE, LV PWR

PL 195B9475 | SECT A | REV 0

ITEM NO	ALT	DOCUMENT TYPE	DESCRIPTION: NAME	DESCRIPTION: IDENTIFICATION	DOC STA	EC	CC	G001	G002	G003	G004	U/M	SRC	SPA	ACT
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			TERMINAL LUG	225A4815P002					38					NO	
			TERMINAL LUG	225A4815P004						20				NO	
			TERMINAL LUG	225A4815P008							8				
002			WIRE	174B9404P005				60				FT		NO	
			WIRE	174B9404P006					38			FT		NO	
			WIRE	174B9404P008						20		FT		NO	
			WIRE	174B9404P012							8	FT		NO	
003			SLEEVE	282A6213P001				2	2	2	2				
004			MODULE	174B9103G003	1			1						NO	
			MODULE	174B9103G004					1					NO	
			MODULE	174B9103G006						1				NO	
			MODULE	174B9103G008							1			NO	
005			POTTING COMP	175A8120P001				AR	AR	AR	AR			NO	
006			RUBBER, UNVULCANIZED	225A5226P004				AR	AR	AR	AR				
007			EPOXY-QUICK SETTING	225A4987P001				AR	AR	AR	AR			NO	
008			POTTING BOARD (#8 AWG)	225A6826P002				2						NO	
			POTTING BOARD (#6 AWG)	225A6827P002					2					NO	
			POTTING BOARD (#2 AWG)	225A6837P002						2				NO	
			POTTING BOARD	234A9762P002							2			NO	
009			CONNECTOR	225A5146P001				60						NO	
			CONNECTOR	225A5146P002					38					NO	
			CONNECTOR	225A5146P004						20				NO	
			CONNECTOR	225A5146P008							8			NO	

MAIN BY: EDE | DATE: MO 01 DAY 05 YEAR 74 | CONT ON SHEET 3 | SH NO 2 | PL 195B9475 | SECT A | REV 0

REVISION STATUS SHEET

DOCUMENT NO. PL 195B 9474 REV. 0

GENERAL ELECTRIC

NUCLEAR ENERGY DIVISION

APPLICATION ELEC PENETRATIONS

FCF ltr

TYPE

☐ SPECIFICATION ☒ DRAWING ☐ OTHER

DOCUMENT TITLE LV WIRE MODULE ASSEMBLY

LEGEND:

REVISIONS

0	E. MARGHERONE Jan 4-74	EM	
	ISSUED.		

PRINTS TO
A13
24
41

220949

DESCRIPTION OF GROUPS

MADE BY E. MARGHERONE DEC 21, 73	APPROVALS N. LURIA	BWRS DEPT.	PL 195B 9474
ISSUED E. Margherone Jan 4-74	N. Luria	SAN JOSE LOCATION	CONT. ON SHEET 2 SH. NO. 1

NED 800-14

14 - 22 CI

GENERAL ELECTRIC

BOILING WATER REACTOR SYSTEMS DEPARTMENT, SAN JOSE, CA

PL 19589475 | SECT A | REV 0

TITLE: WIRE MODULE, LV PWR

ITEM NO	ALT	DOCUMENT TYPE	DESCRIPTION: NAME	DESCRIPTION: IDENTIFICATION	DOC STA	EC	CC	G001	G002	G003	G004	U/M	SRC	SPA	ACT
														B	
010			TUBING	175A8230P007				AR	AR					NO	
			TUBING	175A8230P008						AR				NO	
			TUBING	175A8230P010							AR				

220930

MADE BY: EDP | DATE (MO DAY YEAR): 01 05 74 | LAST ITEM NO USED 010 | FINAL SECTION | CONT ON SHEET: FINAL | SH NO 3 | PL 19589475 | SECT A | REV 0

REVISION STATUS SHEET

DOCUMENT NO. PL 195B9476 REV. 0

GENERAL ELECTRIC

NUCLEAR ENERGY DIVISION

APPLICATION ELEC PENETRATIONS

FCF ltr

☐ SPECIFICATION ☒ DRAWING ☐ OTHER ______ TYPE ______

DOCUMENT TITLE SIGNAL WIRE MODULE ASSEMBLY

LEGEND:

REVISIONS

0	E.MARGHERONE Jan 9-74 ISSUED.	EBM	

PRINTS TO
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24
41

220951

DESCRIPTION OF GROUPS

MADE BY	APPROVALS		
E. MARGHERONE DEC 21,73	N. LURIA	BWRS DEPT.	PL 195B9476
ISSUED E. Margherone Jan 9 74	[signature]	SAN JOSE LOCATION	CONT. ON SHEET 2 SH. NO. 1

NED 905 (REV.)

14 - 24

CI

GENERAL ELECTRIC

BOILING WATER RE... TOR SYSTEMS DEPARTMENT, SAN JOSE, CA

PL 195B0474 | SECT A | REV 0

TITLE: ...T WIRE MODULE

ITEM NO	A T	HARDWARE TYPE	NAME	IDENTIFICATION	DOC STA	E C	C C	G001	G002	U/M	SRC	SPA	ACT
001			SPLICE	209A5010P002				307					
			SP...	209A5010P003					170				
002			... ELECTRICAL, INSULATED	175A7293P004				325		F1			
			WIRE, ELECTRICAL, INSULATED	175A7293P010					175	F1		NO	
003			SLEEVE	282A0213P001				7	7				
004			MODULE	174B9103G012				1				NO	
			MODULE	174B9103G013					1			NO	
005			RUBBER, UNVULCANIZED	225A5220P004				AR	AR				
006			POTTING BOARD	225A6747P002				7				NO	
			POTTING BOARD	225A6748P005					7			NO	
007			POTTING COMP	175A8120P001				AR	AR			NO	
008			CONTACT	234A9806P001				307				NO	
			CONTACT	234A9806P002					170			NO	
009			TUBING	175A8230P004				AR				B	
			TUBING	175A8230P005					AR			NO	
010			EPOXY-QUICK SETTING	225A4067P001				AR	AR			NO	

GROUP NUMBER AND QUANTITY

MADE BY: EDP | DATE: MO 01 DAY 05 YEAR 74 | LAST ITEM NO USED - 010 | FINAL SECTION | CONT ON SHEET: FINAL | SH NO 2 | PL 195B9474 | SECT A | REV 0

2209.52

THIS ASSEMBLY CONTAINS ASME CODE PARTS

UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING — SURFACES ✓ ±.50

195B9474

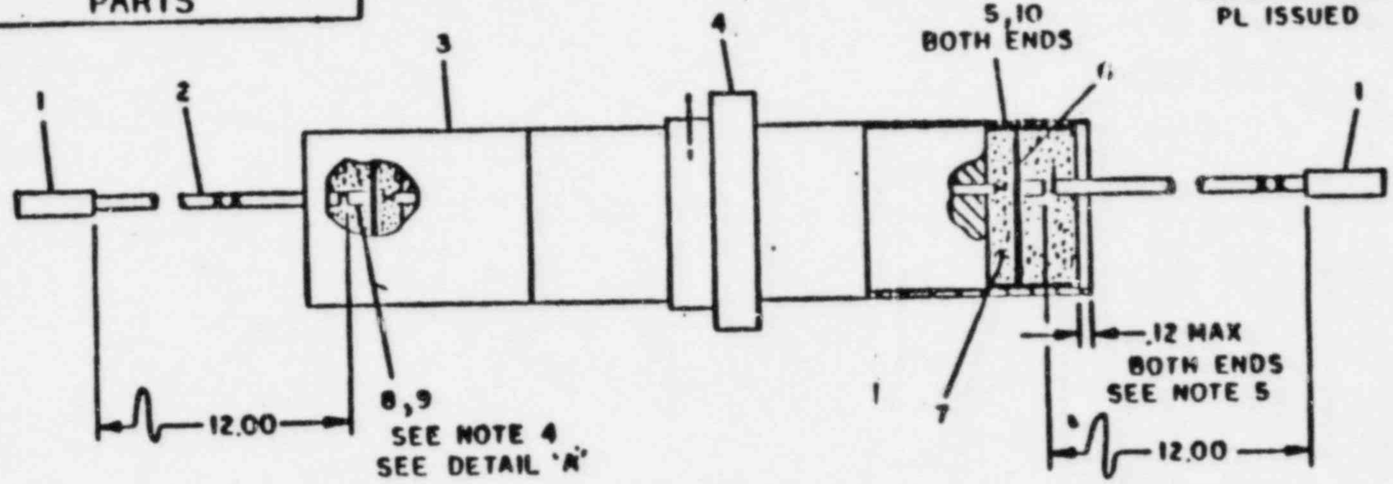
GENERAL ELECTRIC

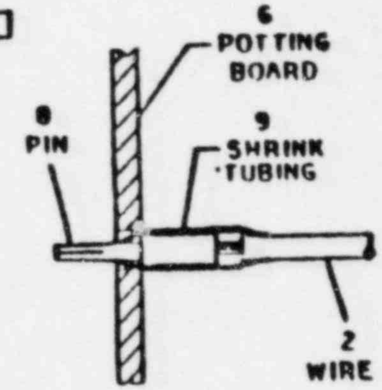
195B9474

ASSY WIRE MODULE, LV

FIRST MADE FOR FO 2 QUAL. ELECT. PENETRATION

PL ISSUED FCF





DETAIL 'A'

NOTES:
1. QUANTITY OF WIRE ON PARTS LIST IS TOTAL QUANTITY REQUIRED PER MODULE.
2. MARK WIRES 1,2,3,4, ETC., ETC. BOTH ENDS.
3. WIRES MAY BE PLACED IN ANY LOCATION & MUST MAINTAIN CONTINUITY.
4. USE SHRINK TUBING (ITEM 9) OVER EACH PIN - SEE DETAIL 'A' BOTH ENDS.
5. EPOXY (ITEM 7) MUST NOT FLOW OVER EPR (ITEM 5).

PRINTS TO
A14
24
41

E. MARGHERONE

BWRS SAN JOSE

195B9474

C!

2?0953

GENERAL ELECTRIC

BOILING WATER REACTOR SYSTEMS DEPARTMENT, SAN JOSE, CA

PL 19589476 | SECT A | REV 0

TITLE: WIRE MODULE, SIGNAL

ITEM NO	ALT	DOCUMENT TYPE	DESCRIPTION: NAME	DESCRIPTION: IDENTIFICATION	DOC STA	EC	G001								U/M	SRC	SPA	ACT
001			CABLE, RADIO FREQUENCY, CNT	225A4706P001			2								FT		NO	
002			TUBING	175A8230P008			2								FT		NO	
003			POTTING COMP	175A8120P001			AR										NO	
004			RUBBER, UNVULCANIZED	225A5226P004			AR											
005			EPOXY-QUICK SETTING	225A4967P001			AR										NO	
006			SLEEVE	262A6213P001			2											
007			MODULE	174B9102G001			1										NO	
008			EPOXY	209A4967P001			AR											
009			POTTING BOARD	234A9809P005			2										NO	
010			CABLE, RADIO FREQUENCY, CNT	225A4706P002			4								FT		NO	
011			PLUG	145A5201P005			6											

220954

MADE BY | NO DAY YEAR | FINAL SECTION | CONT ON SHEET FINAL | SH NO 2 | PL 19589476 | SECT A | REV 0

THIS ASSEMBLY CONTAINS ASME CODE PARTS

GENERAL ELECTRIC 195B9475

ASSY WIRE MODULE LV PWR

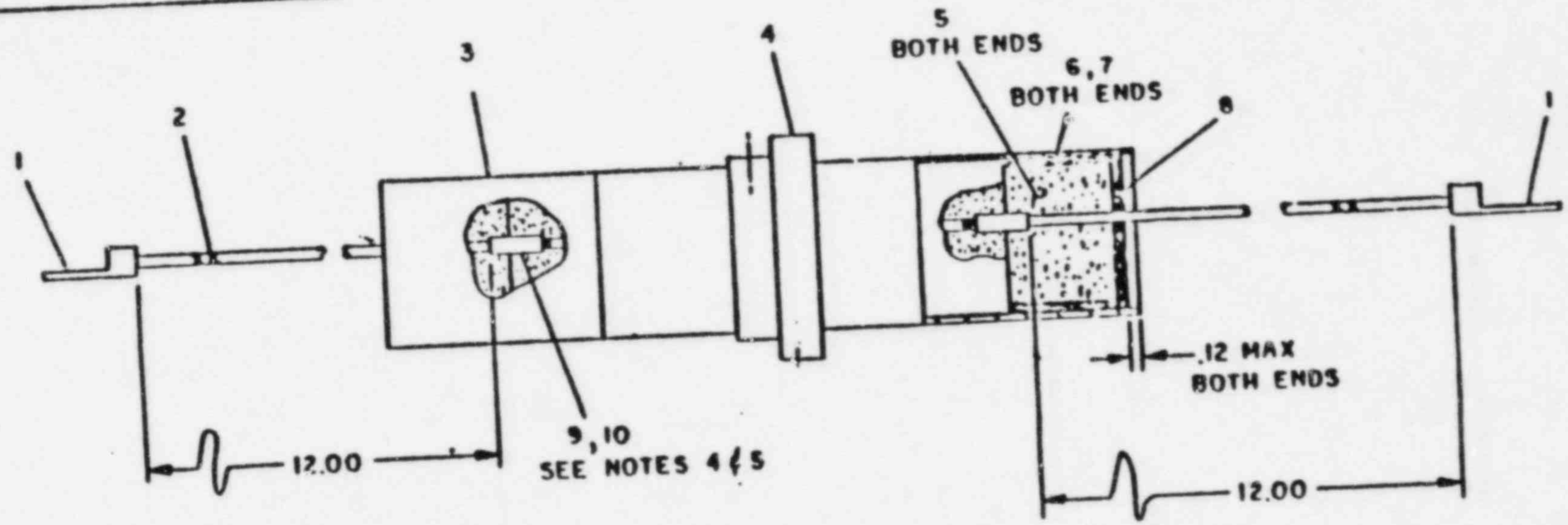
FIRST MADE FOR F02 QUAL. ELECT PENETRATION

195B9475

UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING				
	✓	±	±.50	±

PL ISSUED

F&F



NOTES:

1. QUANTITY OF WIRE ON PARTS LIST IS TOTAL QUANTITY REQUIRED PER MODULE.
2. MARK WIRES 1,2,3,4, ETC., ETC. BOTH ENDS. USE SHRINK TUBING (ITEM 11 - 1.0 LONG) TO MARK 4/0 WIRES APPROX. 4.0 FROM END OF WIRE. BOTH ENDS OF MODULE.
3. WIRES MAY BE PLACED IN ANY LOCATION & MUST MAINTAIN CONTINUITY.
4. THREAD CONNECTOR (ITEM 9) TO FULL THREAD ENGAGEMENT. DO NOT FORCE. (TIGHT FIT IS NOT REQUIRED).
5. USE SHRINK TUBING (ITEM 10) OVER EACH CONNECTOR (ITEM 9) BOTH ENDS. (2 layers)
6. EPOXY (ITEM 5) MUST NOT FLOW OVER EPR (ITEM 6).

REVISIONS

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E. MARGHERONE

BWRS SAN JOSE

195B9475

2205

THIS ASSEMBLY CONTAINS ASME CODE PARTS

UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING —					
DRAWING PRACTICES	SURFACES				
	✓	±	±.50	±	

195B9476

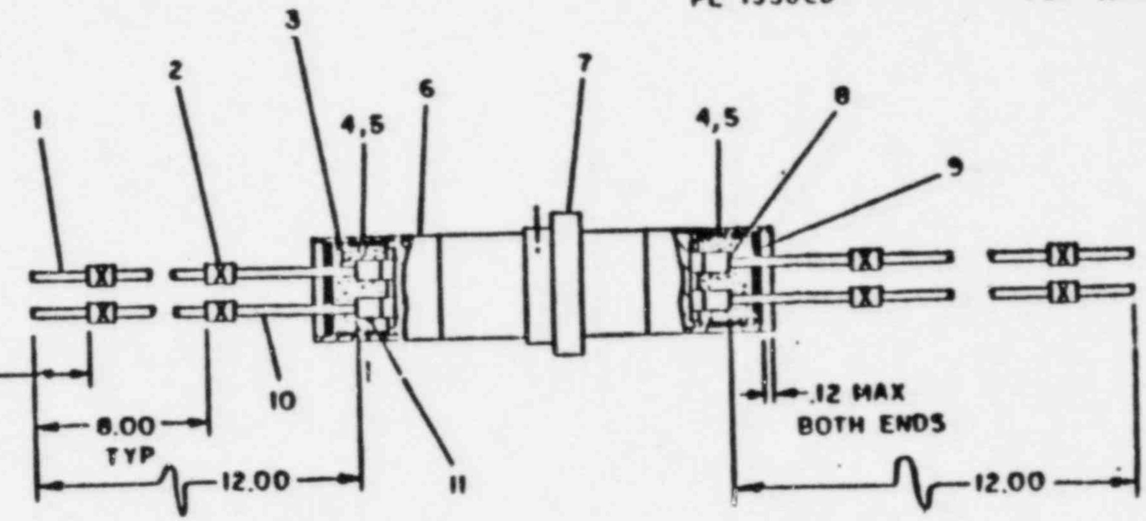
GENERAL ELECTRIC

195B9476

ASSY
WIRE MODULE, SIGNAL
FQ2 QUAL ELECT. PENETRATION

PL ISSUED

FCF



NOTES:

1. QUANTITY OF CABLE ON PARTS LIST IS TOTAL QUANTITY REQUIRED PER MODULE.
2. MARK CABLES (ITEMS 1 OR 10) WITH SHRINK TUBING (ITEM 2 - 2.0 LONG) SRM-1, IRM-1 & IRM-2. BOTH ENDS.
3. APPLY EPOXY (ITEM 8) TO PREVENT POTTING COMPOUND (ITEM 3) FROM ENTERING CONNECTORS. BOTH ENDS.
4. EPOXY (ITEM 3) MUST NOT FLOW OVER EPR (ITEM 4).

REVISIONS

A14
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41

E. MARGHERONE

BWRS
SAN JOSE

195B9476

C1

220956

REASON FOR CHANGE -
A. CORRECTION OF ERROR
B. ADDITION TO COMPLETE DESIGN
C. TO REDUCE COST
D. CUSTOMER'S REQUEST
E. TO USE EXISTING PARTS, MATERIALS OR TOOLS
F. OTHER (EXPLAIN)

ENGINEERING CHANGE NOTICE

APED - CONTROL & INSTRUMENTATION
GENERAL ELECTRIC CO.

NO NE 47750
CONT. ON SH. 2 SH. NO. 1
DATE ISSUED Jan 22 74

PROJECTS & REQ. FARLEY I
EQUIPMENT ELECTRICAL PENETRATIONS

RESPONSIBILITY 941 REASON CODES B

☒ TEMPORARY SUBSTITUTION
☐ DWG., P.L. OR SPEC. CHANGE

DWG., P.L. OR SPEC. NO.	SH. NO.	REV. NO.	DWG., P.L. OR SPEC. TITLE
SEE BELOW →			→

INSTRUCTIONS:

(1) 328X196WE LV PWR ELECT PENETR.

(a) FOR MODULES COMPLETED TO 159C4482 G001, G003, G004, G005 & G006 ONLY —
REWORK BY REMOVING SLEEVE (235A1460P001) ON END THAT DOES NOT FIT INTO HEADER ONLY. REPLACE WITH SST SLEEVE (262A6213P002), SECURE SLEEVE TO BODY WITH LOCTITE & PRIMER (176A1827P004 & P006). PUT (1) LAYER OF RUBBER (225A5226P004) IN SLEEVE WITH QUIK-SET (225A4967P001) THEN FILL WITH 175A8120P001.
NOTE: SST SLEEVE SHOULD HAVE APPROX. .005 CLEARANCE TO MACHINED EPOXY BEFORE POTTING.

(b) FOR MODULES NOT COMPLETED TO ABOVE —
REPLACE BOTH SLEEVES (235A1460P001) WITH SST SLEEVES (262A6213P001) (NO LOCTITE REQ'D), PUT (1) LAYER OF RUBBER (225A5226P004) IN

CLARIFY DISPOSITION BELOW

BUILD TO THIS ECN

RETURN SLEEVES (235A1460) TO STOCK

RECEIVED
JAN 22 1974
ENGINEERING RELEASE

ATTN: PRODUCTION CONTROL. THE FOLLOWING PRINTS ARE ATTACHED TO THIS ECN

220957

RIS
REV
S.C.

STATUS OF EQUIPMENT:
☐ NEW RELEASE
☐ AT MATERIAL ORDER
☐ AT PLANNING
☐ AT VENDOR
☐ AT FAB MACH. SHOP
☐ AT ACCUM.
☒ AT ASSY.
☐ IN STOCK
☐ QC TEST
☐ SHIPPED

DIST. KEY: LURIA 058
·M FRAASCH 139

DISPOSITION — ITEM NO. (SEE INSTRUCTIONS ABOVE)
☐ ORDER PARTS
☐ SCRAP
☒ WORK
☒ RE-WORK
☐ RETURN TO STOCK
☐ NO MATL. AFFECTED
☐ CHG. P.O.
☐ USE AS IS
☐ RESTOCK UNDER NEW DWG. #
☐ OTHER

TEST INSTR. REV. REQ'D. ☐ YES ☒ NO
DESIGN REVIEW REQ'D. ☐ YES ☒ NO

PREPARED BY E. Margherone DATE 1/18/74
RESPONSIBLE ENGINEER N. E. Luria DATE 1/18/74
DFTG. ENDORSEMENTS COMP. 905 INITIAL EJM

JOB NO.: 11600.02

JOB NAME: SHOREHAM - UNIT I

JOB CLIENT: LILCO

COMPILED BY: Louis S. Fiore

DATE: 8/2/82

SHT. NO. ECD-88V-8 REV. 0

MECHANICAL EQUIPMENT ENVIRONMENTAL CONFORMANCE DATA SHEET

Specification No./Vendor: SH1-88V/Velan Engineering Co.

Mark No.	Sub-Component Identification			Environmental Qualification Report Environment			Documented Material Data		Status	Reference	Comments
	Vendor Dwg. No Shoreham File No. (SFN)	Non-Metallic Sub-Components	Material	Zone	Total Radiation (Rads)	Temp. (°F)	Threshold Radiation (Rads)	Service Temperature (°F)			
1E51*MOV041	P2-3287-H-1 SFN6.37-194G	Same as 1B21*MOV031	Same as 1B21*MOV031	D-22	1.2×10^8	340	1×10^{10}	1200	A A	Same as 1B21*MOV031	
1E51*MOV042	P2-3287-H-1 SFN6.37-194G	Same as 1B21*MOV031	Same as 1B21*MOV031	T-08	3.6×10^6	215	1×10^{10}	1200	A	Same as 1B21*MOV031	
1E51*MOV043	P2-3287-H-1 SFN6.37-194G	Same as 1B21*MOV031	Same as 1B21*MOV031	G-01	5.8×10^6	150	1×10^{10}	1200	A	Same as 1B21*MOV031	
1E51*MOV045	P2-3287-H-7 SFN6.37-95J	Same as 1B21*MOV031	Same as 1B21*MOV031	G-01	5.8×10^6	150	1×10^{10}	1200	A	Same as 1B21*MOV031	
1G11*MOV246	P2-3287-H-5 SFN6.37-143J	Same as 1B21*MOV031	Same as 1B21*MOV031	G-02	5.8×10^6	152	1×10^{10}	1200	A	Same as 1B21*MOV031	
1G11*MOV247	P2-3287-H-5 SFN6.37-143J	Same as 1B21*MOV031	Same as 1B21*MOV031	G-02	5.8×10^6	152	1×10^{10}	1200	A	Same as 1B21*MOV031	
1G11*MOV248	P2-3287-H-5 SFN6.37-143J	Same as 1B21*MOV031	Same as 1B21*MOV031	L-02	3.1×10^6	152	1×10^{10}	1200	A	Same as 1B21*MOV031	
1G11*MOV249	P2-3287-H-5 SFN6.37-143J	Same as 1B21*MOV031	Same as 1B21*MOV031	L-02	3.1×10^6	152	1×10^{10}	1200	A	Same as 1B21*MOV031	

GENERAL ELECTRIC

NUCLEAR ENERGY

SYSTEMS DIVISION

GENERAL ELECTRIC COMPANY, 175 CURTNER AVENUE, SAN JOSE, CALIFORNIA 95125
Phone (408) 297-3000 TWX No. 910-338-0116

September 24, 1976

Project Engineer - J. O. 11600.02
Stone & Webster Engineering Corp.
P. O. Box 2325
Boston, MA 02107

Dear Sir:

Subject: Shoreham Nuclear Power Station Unit 1 Electrical Penetrations Qualification Tests - Progress Report

For your information we have successfully completed most of the qualification tests of the Series 200 low voltage electrical penetrations. This is the type of penetration that will be furnished for Shoreham. The design is similar to the Series 100 type that was used in the past, but it uses two epoxies that are improved versions of the previous epoxy. The new formulations are called EMR 300 and EMR 301. The modules for the Series 200 units are shorter, but are interchangeable with the Series 100 modules.

The following qualification tests have been successfully completed:

1. Thermocycle
2. Radiation resistance
3. Short circuit and overload current
4. LOCA (short term)

Tests to be performed are:

1. Seismic - scheduled for November 1 completion
2. Long Term LOCA (100 day) - scheduled for May 1977 completion

The last two tests are not likely to present problems. The long term test conditions for Shoreham are 210° F, 100% RH and 20 psig. This compares with the LOCA conditions of 340° F, 100% RH and 48 psig for four hours which the unit has successfully passed. The low temperature is much easier for epoxy to withstand.

GENERAL ELECTRIC

In summary, the most difficult parts of the qualification test program for the new Series 200 penetration design have been completed, and the results are favorable. The two remaining tests are unlikely to present any problems, and manufacturing of the penetrations for Shoreham is proceeding.

Yours very truly,

E. D. Smith

E. D. Smith, Senior Engineer
Controls Application Engineering
Domestic Projects I & II
M/C 371, Ext. 2393

rgm

cc: E. Colby
Portland, OR

Attach C

SENSOR PRODUCTS

ENGINEERING MEMO

NUMBER 994-76-016

TEST 107-76-05

USE OF EPR-300 EPOXY

BY

N. G. LURIA AND
B. J. NALEZINSKI

DATE

SEPTEMBER 29, 1976

REVIEWED BY:

N. G. LURIA

APPROVED BY:

J. H. TERHUNE

CONTENTS

Abstract

This test report is objective evidence qualifying the use of EMR-300 epoxy in electric penetrations, specifically for Forsmark, TVO and replacement modules.

I.M.E.E.: XR5237/EMR 300
Start Test: 5/27/76
Completed Test: 9/17/76

September 21, 1976

TEST 107-76-05

1.0 INTRODUCTION

The purpose of this test is to reconfirm previous test data incorporating the new EMR 300 resin and the 3M Co. XR5237 into the present 100 series electrical penetration low voltage product. The EMR 300 is used as the stock pot and XR5237 as the customer end pot. A retest schedule was set up using two pen seal modules each undergoing a different test sequence, thereby covering a wide range of in-service conditions.

2.0 REFERENCES

Test report document #74-502-3
Prototype test plan #74-NGL-57
Test report #100 - EMR300/XR5237
Work order - planning card #46 ('T' NO. THB76)
Work order - planning card #59 ('T' NO. THB66)
M.P.I. 27.014

3.0 TEST LOCATION

L.O.C.A. test facility Bldg. W
Engineering lab Room #267 Bldg. A
Vallecitos Nuclear Center, cobalt facility

4.0 TEST EQUIPMENT

a. Hi pot S/N N04282, AR hy pot, Associated Research, Inc.
b. Mass spectrometer helium leak detector, G.E. Co. Model LC 20
c. Autoclave S/N 250 G. E. spec.
d. Pressure gauge S/N 143691
e. Final controller console, model #524
f. Tenney environmental chamber S/N 8723-3
g. V.N.C. cobalt 60 facility
h. A.C. voltage supply
i. D.C. current supply
j. Volt/ohm meter Model #269
k. Insulation resistance measuring rack S/N #5

5.0 TEST HARDWARE

#16 AWG Electrical penetration, low voltage, serial number TGZ79-012
#10 AWG Electrical penetration, low voltage, serial number Y7463-111

6.0 REQUIREMENTS

6.1 TEST ENVIRONMENT

Loss of Coolant Accident

Temp:	@340°F	325°F	260°F
Press:	103 PSIG	81 PSIG	20 PSIG
Duration:	4 hours	3 hours	6 days

A.C. current during L.O.C.A.
A.C. voltage during L.O.C.A.

Thermal Cycle Test

1 cycle, 500°F to 150°F to 50°F
Total of 120 cycles @ 70 to 100% R.H.

Gamma Exposure

@ 5 X 10^7 rads

6.2 TEST SEQUENCE OF TEST HARDWARE

#16 AWG, S/N TGZ79-012

L.O.C.A.
Thermal cycle
Gamma Irradiation
L.O.C.A.

#10 AWG, S/N Y7463-111

Thermal cycle
Gamma Irradiation
L.O.C.A.

7.0 DESCRIPTION

The test set-up for both electrical pen seal modules was the same, however, the test schedule for module S/N TGZ79-012 was different due to the L.O.C.A.- performed prior to the thermal cycling. Final L.O.C.A. - for both modules was performed simultaneously (See 6.2).

8.0 ACCEPTANCE CRITERIA

8.1 Throughout the test, the leak rate through the entire module, including both seals shall not exceed 1×10^{-2} ccH_2/sec.

8.2 During loss of coolant accident test, the modules shall be capable of sustaining the following:

123 VAC
1.5 amps D.C.

8.3 The following information data shall be accumulated:

- o Insulation resistance during L.O.C.A.
- o Insulation Resistance after L.O.C.A.
- o Sample Withstand Voltage (A.C.)

9.0 TEST RESULTS

9.1 Verification of #16 AWG Module, S/N TGZ79-012

9.1.1 Initial L.O.C.A. Test

The test conditions applied to the #16 AWG Module are summarized in Table 1. After the L.O.C.A. test, soap bubble checks were made on the external boundary of the module with no indications of leakage at 160oF and 86 PSIG. The module sustained the indicated current and voltage. There were no anomalies during this part of the test. The insulation resistance from conductors to ground showed the steady values as recorded.

At the conclusion of the test, when temperature returned to ambient the following measurements were recorded.

- o Helium leak rate
  - o Vessel exposed end: 8×10^{-7} cc/sec.
  - o Outside end: 2.4×10^{-6} cc/sec.
- o Withstand voltage (information data)

  50% of wires withstood 2.2 KVAC (60HZ) for 1 minute duration
- o Insulation Resistance (information data)

  81% of wires were in excess of 1×10^6 ohms @ 500 VDC.

9.1.2 Thermal Cycle

Table 2A defines the environment to which the module was subjected. At the conclusion of the test, only one end of the module remained helium leak tight to less than 1 X 10^{-6} cc/sec.

9.1.3 Gamma Exposure

The module was exposed to the radiation conditions of Table 3.

9.1.4 Final L.O.C.A. Test

The module was subjected to the second L.O.C.A. environment of Table 4. At the completion of the test, the modules passed the following tests.

- Helium leak rate: 8.6 X 10^{-10} cc/sec
- 66% of wires were still able to exhibit an insulation resistance greater than 5 X 10^{5} ohms @ 500 VDC

Since this module was subjected to two L.O.C.A. tests, the primary objective was to demonstrate pressure integrity due to the small sample size tested.

9.2 Verification of #10 AWG Module

S/N Y7463-111

9.2.1 Introduction

This module is the design verification unit which demonstrates both electrical and mechanical properties. The sequence of testing covers aging, followed by Loss of Coolant Accident.

9.2.2 Thermal Cycle

Table 2B defines the environment to which the module was subjected. At the conclusion of the test, the entire module remained helium leak tight to less than 1 X 10^{-6} cc/sec.

9.2.3 Gamma Exposure

The module was exposed to the gamma radiation conditions of Table 3.

9.2.4 L.O.C.A. Test

The module was subjected to the L.O.C.A. environment of Table 4.

During the L.O.C.A. environment, 98% of the wires sustained 150 VAC and exhibited an insulation resistance of greater than 1 X 10^4 ohms @ 500 VDC.

At the conclusion of the L.O.C.A. test, the module was helium leak tight to less than 8.6 X 10^{-8} cc/sec. In addition, 100% of the wires were capable of withstanding 2.2 KVAC (60HZ) for 1 minute duration (wire to all other wires and ground) and showed an insulation resistance (wire to all other wires and ground) of greater than 1 X 10^{11} ohms.

In summary, there was virtually insignificant deterioration as a result of the testing program.

10. CONCLUSION

This design verification test was conducted to qualify the EMR-300 epoxy in the 100 series design for Forsmark, TVO and previous requisition replacement modules.

The verification covers the epoxy capability to provide required pressure integrity and electrical characteristics.

The EMR-300 epoxy is basically identical to the previously qualified N229 epoxy with the exception that the former has increased stability when subjected to high pressure steam environment. Both epoxies are used in the "stock" module only and both are protected from any steam environment by the 3M Co. XR5237 epoxy used to encapsulate the pigtail wire and cables. The change to EMR-300 was introduced for the purpose of increasing the long term reliability of the product and in anticipation of any future requirements increase in operating temperature/pressure environment.

This test demonstrates that EMR-300 is acceptable for use in the electrical penetration module design and outperforms the previous N229 epoxy. The increased elongation property of EMR-300 allows for a greater gamma radiation exposure which is one measure of life performance.

TEST CONDUCTOR [signature] 9/23/76
B. J. Nalezinski

TEST REVIEWED BY [signature] 9/27/76
R. M. Schuster

INDEPENDENT TEST CONCURRENCE [signature]
C. Hamasaki

TEST APPROVAL [signature]
N. G. Luria

TABLE 1

INITIAL L.O.C.A. TEST FOR #16 AWG
ELECTRICAL PENETRATION LOW VOLTAGE S/N TGZ79-012

Date of Test: 5/27/76 to 6/2/76

Temperature-	340°F	325°F	260°F
Pressure PSIG-	103 PSIG	81 PSIG	20 PSIG
Duration-	4 hours	3 hours	5 days

TABLE 2

THERMAL CYCLE EXPOSURE TEST

Temp cycle:	50 to 150-50°F
Cycle time	4 hours
# of cycles	120
RH, %	>90%

TABLE 3

GAMMA IRRADIATION

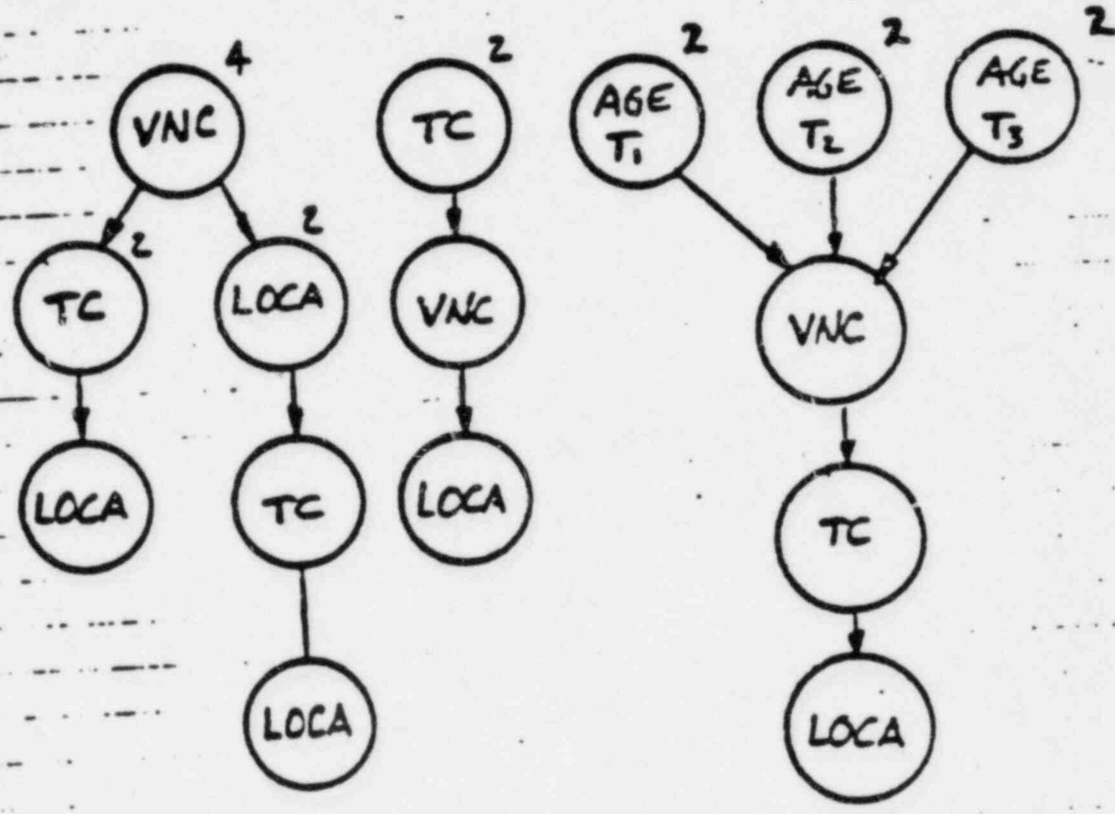
Exposure rate:	@ 3.5×10^5 R/hr
Total exposure:	5×10^7 rads
Date of test:	7/26/76 - 8/1/76

TABLE 4

FINAL L.O.C.A. TEST

Temp.:	340°F	325°F	260°F
Pressure (vessel):	103 PSIG	81 PSIG	20 PSIG
Duration:	3 hours	3 hours	18 hours

PROTOTYPE TEST
EMR 300 / XR 5237

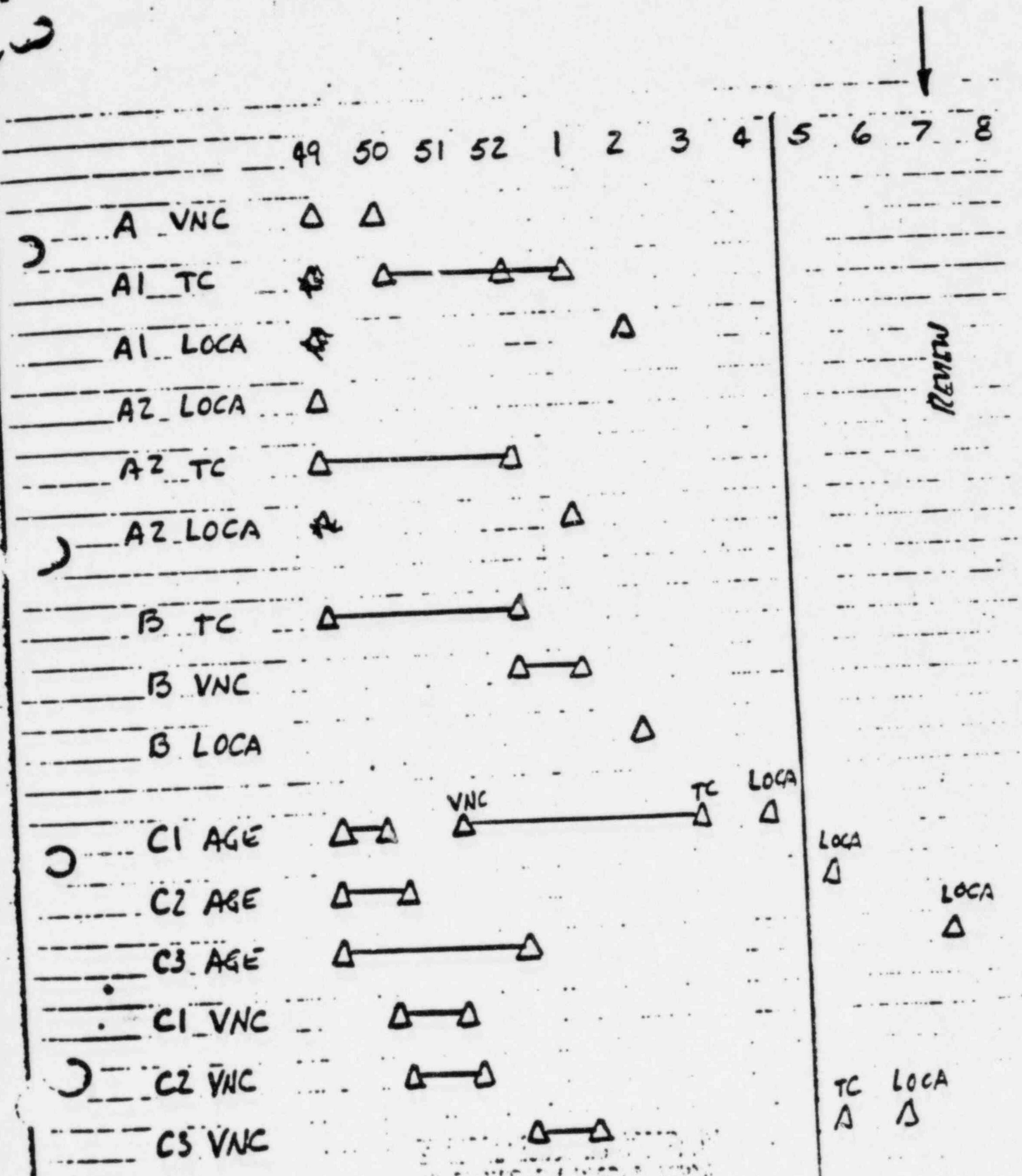


VNC : 1×10^8 R @ 3.5×10^5 r/hr

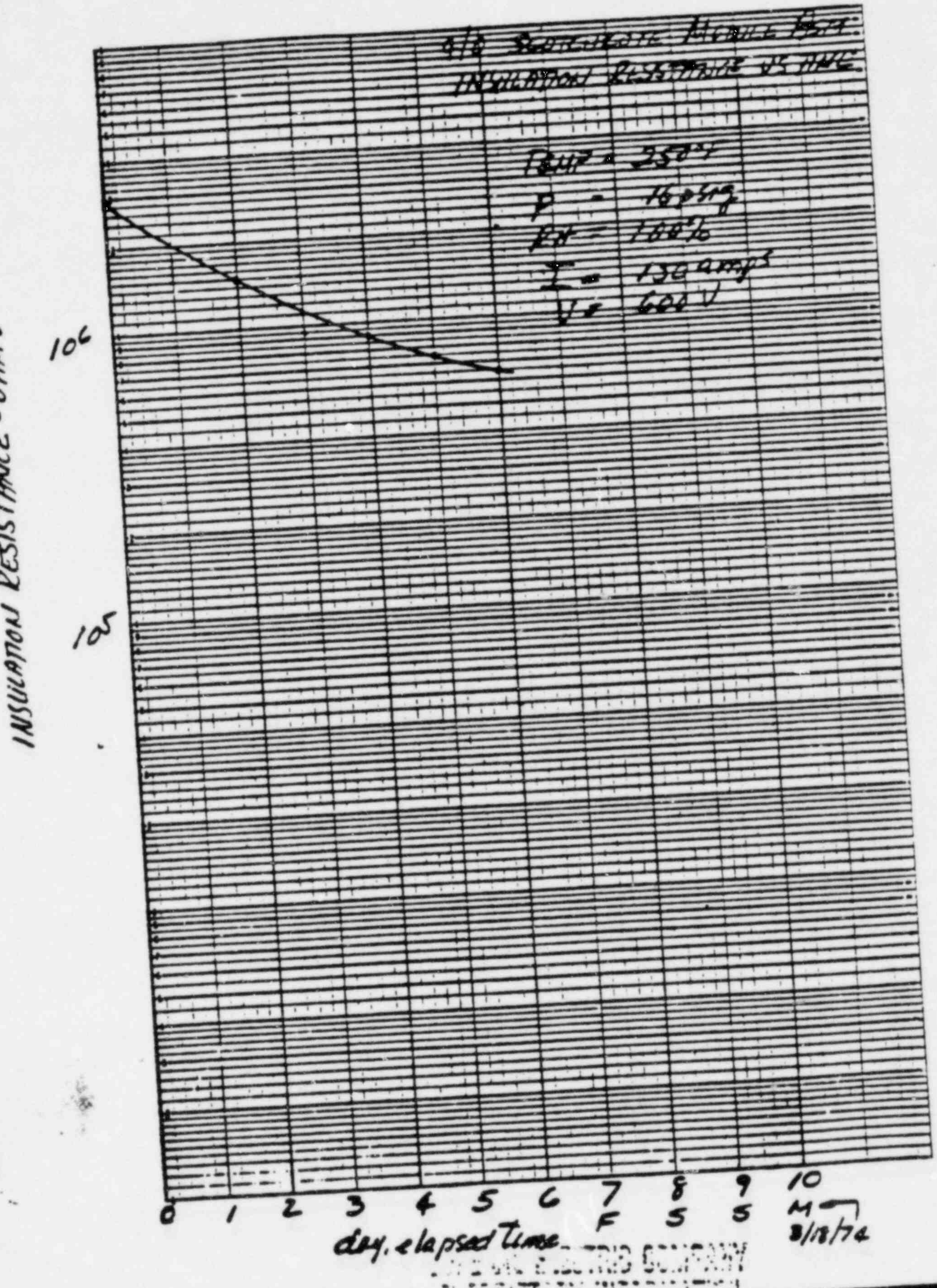
TC : 120 cy 50-150-50°F @ 100% RH

LOCA :				
T	°F	340	325	260
P	psig	103	81	16
t	hrs	6	6	36

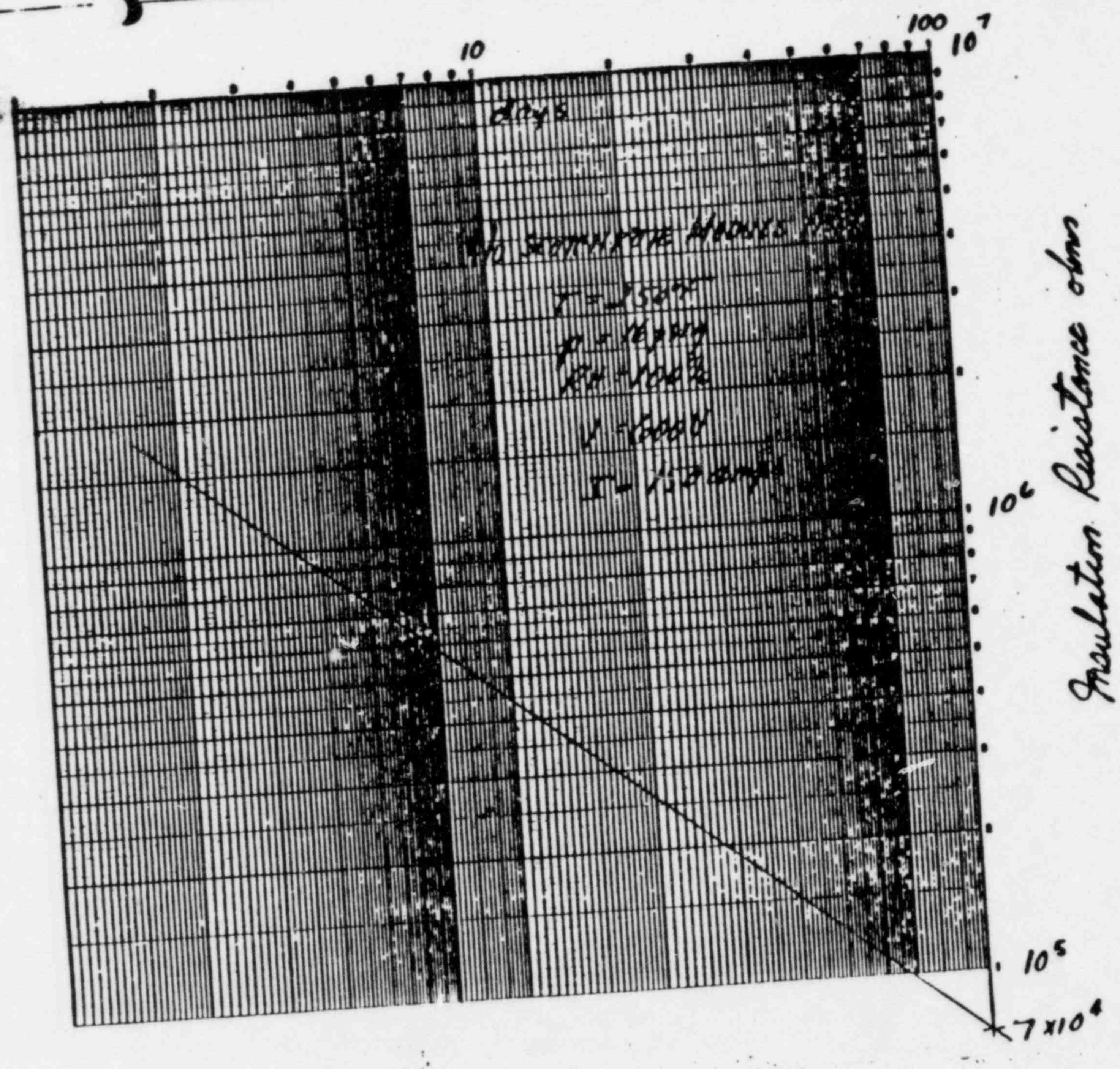
T_1 : 340°F - 7.5 days
T_2 : 320°F 15 days
T_3 : 300°F 30 days



49 50 51 52 1 2 3 4 5 6 7 8
A VNC
A1 TC
A1 LOCA
A2 LOCA
A2 TC
A2 LOCA
B TC
B VNC
B LOCA
VNC
TC
LOCA
C1 AGE
LOCA
C2 AGE
LOCA
C3 AGE
C1 VNC
C2 VNC
TC
LOCA
C3 VNC
REVIEW



TEMP = 250°F
P = 16 psig
RH = 100%
I = 130 amps
V = 600 V
10⁶
10⁵
INSULATION RESISTANCE - OHMS
0 1 2 3 4 5 6 7 8 9 10
F S S M
3/18/74
day, elapsed time


10
100
Days
10^7
10^6
10^5
7×10^4
Insulation Resistance ohms

E.J.R

341.311

SNRC-250

February 8, 1978

Mr. J. P. O'Reilly, Director
Directorate of Regulatory Operations
Region I
U. S. Nuclear Regulatory Commission
631 Park Avenue
King of Prussia, Pennsylvania 19406

IE Bulletin 77-07
Shoreham Nuclear Power Station - Unit 1
Docket No. 50-322

Dear Mr. O'Reilly:

In response to the request contained in Inspection and Enforcement Bulletin 77-07 (December 19, 1977) we have conducted a review of the Shoreham Plant to address the questions contained therein.

As part of the Shoreham specific response we will be referencing generic letters previously sent to the NRC, as part of the manufacturers generic response. The letters we will be referencing are as follows:

Letter 1: November 30, 1977 - Electrical Penetrations
Letter 2: December 2, 1977 - Electrical Penetration-Effects of Radiation Exposure
Letter 3: December 5, 1977 - Electrical Penetration - Leaks

These letters are from G. G. Sherwood, G.E. to D. G. Eisenhut, Assistant Director Oper. Tech. NRC. Letters are attached to response.

The following will serve to answer the specific questions 1.0 through 3.2 contained in the subject bulletin:

Question 1.0 Do you have containment electrical penetrations that are of the G.E. Series 100, or are otherwise similar in that they depend upon an epoxy sealant and a dry nitrogen pressure environment to ensure that the electrical and pressure characteristics are maintained so as to ensure the functional capability as required by the plant's safety analysis report: namely, (1) to ensure adequate functioning of electric safety related equipment and (2) to ensure containment leak tightness. If you do use penetrations of this type at your facility describe the manufacturer and model number of these units.

Answer 1.0 — Yes. The Shoreham Station utilizes General Electric Series 200 electrical penetrations in the containment. Reference letters discuss generic design for this type series.

Question 1.1 — If you do not have penetration assemblies of the type(s) referenced in Item 1.0 above, describe the type(s) of penetrations e.g., manufacturer and model number now in use or planned for use in safety systems at your facility.

Answer 1.1 — Not Applicable.

Question 1.2 — Do the transition connector pins imbedded in the epoxy as discussed in Item 1.0 above, have an insulation jacket?

Answer 1.2 — Yes. Unlike the penetrations utilized at Millstone Unit #2, the transition connector pins have an insulation jacket over the entire length.

Question 2.0 — For those penetrations referenced in Item 1 above, has the manufacturer's prescribed nitrogen pressure been maintained at all times during shipping, storage, and installation?

Answer 2.0 — The instruction manual provided by the vendor makes provisions for maintenance and pressurization during shipping, storage and installation. These prescribed methods have been followed.

Question 3.0 Is there a need, as determined by either the vendor or yourself, to maintain penetrations pressurized during normal operation, to assure functionability during a LOCA.

Answer 3.0 The vendor recommendations regarding pressurization are attached. They will be followed on Shoreham.

Question 3.1 What measures have you taken to ensure that penetrations of this type will perform their design function under LOCA conditions? (design reviews, analysis, or tests)?

Answer 3.1 The Shoreham penetration purchase specification required extensive qualification testing for the electrical properties and for the penetration to withstand the LOCA environment. Table 1 attached gives conditions of service. Penetrations were qualified to these environmental conditions.

Question 3.2 Are the measures that provide this assurance adequate to satisfy the Commission's regulations (General Design Criteria for Appendix A to Part 50; QA Criteria, Appendix B to Part 5)?

Answer 3.2 The measures taken for the design testing of the electrical penetrations assemblies provide adequate assurance to satisfy the Commission's regulations.

If you have any additional questions in this area, please contact us.

Very truly yours,

T. J. Burke,
Project Manager
Shoreham Nuclear Power Station

RMK/cl

Attach.

cc: NRC Office of Inspection and Enforcement
Division of Reactor Inspection Programs
Washington, D. C. 20555

bcc: H. Chau
Dist. List 14
Eng. File A21.200
W. T. Keating
W. Shanks (GE)
E. J. Brabazon (S&W)
J. Blakley (GE)
E. J. Youngling
Karl Kniel (NRC)
Al Toth (NRC)
P. J. Scannell

ATTACHMENT 1

Containment electrical penetrations manufactured by General Electric are ·pplied with pressure gauges and fittings for pressurizing the interior .lume of the penetration seal. This is to facilitate leak testing and to maintain a positive pressure within the penetration during operation. The positive pressure is maintained to reduce the potential for moisture entering the seal which can lead to long term degradation of the seal. The purpose of this Service information letter is to make certain that all users of General Electric containment penetrations are advised of the recommended mode for operating the penetrations with a positive nitrogen (N_2) pressure.

DISCUSSION

General Electric has manufactured three types of electrical penetrations. These are known as 1) Cannister Type, 2) Series 100, and 3) Series 200. All three types have provisions for pressure gauges to show internal pressure. The installation instructions in general require purging and pressurization with N_2 and testing for leaks.

These electrical penetrations are passive equipment and, if properly installed and found to be leak-tight initially, should not need repair or replacement unless mechanically damaged. Thus, N_2 pressure can be applied and held by these penetrations over long periods of time. Penetrations should be pressurized after installation with 15 to 45 psig of N_2 for normal operation. Periodic checks should be made to verify that a positive pressure (with respect to the containment) is being maintained.

·essurization of the penetrations with N_2 is not necessary to assure con-.ainment integrity or electrical integrity if there are no leaks in the penetration. If a leak develops in the penetration, and the nitrogen pressure falls to atmospheric, then the penetration will "breathe" with changes in barometric pressure and penetration temperature. This breathing can draw both moisture and air into the internals of the penetration. This will not have an immediate affect on electrical integrity; however, in the long-term it may lead to gradual deterioration.

RECOMMENDED ACTION

General Electric recommends that all containment electrical penetrations manufactured by General Electric be pressurized to a pressure of 15 to 45 psig with commercially available dry nitrogen and monitored periodically after installation to verify that a positive pressure is being maintained. During commerical operation, a check interval of three to twelve months should be established based on performance. The intent of this recommendation is that the penetration seals should be kept at a positive pressure (with respect to normal containment pressure) to preclude any potential seal degradation from moisture intrusion.

If any seal is not able to hold a positive N_2 pressure due to a small leak, consideration should be given to periodically purging the seal with commercially dry N_2 in an attempt to keep moisture out. The seal should be repaired at the first convenient opportunity.

.f any penetration is found to be leaking (when leak rate testing) in excess of the IEEE Standard 317 limit of 1×10^{-2} cc/sec., the seal should be repaired.

For further information or assistance in repair of electrical penetrations, please contact your local General Electric service representative.

Table 1
CONDITIONS OF SERVICE

Normal Service Environment

The outboard and inboard end of the assemblies will be subject to the following ambient conditions during normal continuous operation:

Outboard End

Maximum pressure	Atmospheric
Maximum temperature	110 F
Maximum relative humidity	90%
Time	Continuous
Radiation level	5.3×10^3 rads

Inboard End

Maximum pressure	2 psig
Maximum temperature	135 F
Maximum relative humidity	100%
Time	Continuous
Radiation level	3.68×10^7 rads

Maximum Emergency Environment

Outboard End

Maximum pressure	15 psig
Maximum temperature, F	212 F for 6 hrs, 150 F for 100 days
Maximum relative humidity	100%
Radiation level	1.7×10^5

Inboard End

Transient Conditions

	1	2	3	4	5
Time	1 hr	3 hr	6 hr	1 day	100 days
Maximum pressure, psig	48	48	48	25	20
Maximum temperature, F	340	340	320	250	210

STONE & WEBSTER ENGINEERING CORPORATION

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AEHecheny
EAPutkonen
BShair
RGBrunner
CSS 245/7
General Files
JPLawrence

Project Engineer
Long Island Lighting Company
Shoreham Nuclear Power Station
P. O. Box 618
Wading River, NY 11792

May 11, 1976
J.O.No. 11600.02
File No. 241.21.1
LIL- 8795

Dear Sir:

PURCHASE ORDER NO. 310578
REACTOR CONTAINMENT ELECTRICAL PENETRATIONS
SH1-134
SHOREHAM NUCLEAR POWER STATION - UNIT 1
W080-48923

As a result of information received concerning General Electric leaving the containment electric penetration supply business, the following information has been gathered.

GE explains that it originally got into the penetration supply business in the early days of reactors as a service to their customers because at that time there were few other suppliers. It now believes there is a sufficient number of suppliers so it intends to drop this line of work. In addition to Shoreham, it has other units in various stages of design and manufacture. GE recognizes its contract obligations with its customers, especially in regard to warrantees. It presently has agreements with licensees in Japan and Germany to manufacture penetration parts. GE is at this time formulating its intended policy in regard to spare parts after manufacturing has stopped. Indications are this will be complete in a few weeks. It will continue manufacturing through 1977 in order to complete its present contracts. At the time of submittal of the recommended spare parts list, we can take a hard look at the requirements and evaluate what parts to purchase, keeping in mind the GE programs.

COPY

In regard to the testimony of the former GE engineers before the Joint Congressional Committee on Atomic Energy, the following information can be given. The former GE engineers stated that the epoxy adherence to the conductors at Farley 1 was deficient and caused five percent of the installed electrical seals to leak under normal environmental conditions.

Mr. Earl Smith of GE, San Jose, states that between Farley 1 & 2, a total of 13 modules out of about 390 were reported leaking. These were detected by a drop in nitrogen gage pressure over a period of time. The leaking modules were returned to GE and tested in the shop. Of the 13 modules, 7 were found to leak at the factory. None of these leaked at a rate of $1x10^{-2}$ cm ^{3}/sec which is the maximum field installed leak rate. They did leak at a rate greater than $1x10^{-6}$ cm ^{3}/sec which is the maximum production leak rate. The explanation provided by GE is that the conductor pins were improperly tin plated. Six of the 7 leakers were from the same manufactured lot. The penetrations to be supplied for Shoreham will not have this tin plating but instead will be Scotch coated by a fusion process. This will increase the epoxy adherance to the conductor rods. In addition, the epoxy to be used for Shoreham is a newer compound that exhibits greater bonding strength. GE will supply the latest fully qualified materials for Shoreham. We have requested GE to submit a letter confirming the above information from Mr. Smith. S&W has experienced no problems with the GE penetrations at the PASNY James A. FitzPatrick Station nor is it aware of any problems at other installations.

The former GE Engineers also stated that during simulated LOCA conditions, the penetration epoxy has in some cases reverted. The GE reply to this is that during the experimental development of epoxy mixtures various compounds were tested. Certain mixtures tested for an installation in Italy did fail the qualification tests. None of the materials that failed were ever installed in working reactors. S&W has a copy of the qualification test reports on the penetrations and these appear satisfactory.

Based on the above information, we believe that there is no significant reason to make any changes regarding the electric penetrations. At this time, we believe there are sufficient installed spare modules and spare assemblies to handle additions which may be necessary as the design develops. If major changes were required in the future, the spare sleeves could accommodate penetrations of other manufacturers, if necessary. We will continue to closely follow the activities of GE in regard to this matter.

If you have any questions, please contact us.

Very truly yours,

J. P. Allen
Project Engineer

JPL:ATN

RESPONSE TO NRC VERBAL
COMMENTS ON ENVIRONMENTAL
QUALIFICATION REPORT SUBMITTAL DATED
MAY - 1982 - REVISION 2

SHOREHAM NUCLEAR POWER STATION - UNIT 1
LONG ISLAND LIGHTING COMPANY

1. Why do the RCIC System Components not have to function?

   A: The Environmental Qualification Status Report (EQSR), included in the Environmental Qualification Report (EQR) classified the RCIC components as "Op Code B" indicating that these components would not function during a postulated accident. However, the EQSR which was submitted in Rev. 3 on August 13, 1982 modified the "Op Code" to "A" for certain RCIC components indicating that those components will function during a postulated accident. The RCIC system does not need to function as a heat removal system during the postulated accidents.

2. Why were Uninterrupted Power, Condensate Transfer and Storage System not included in the Electrical EQ submittal?

   A: On Shoreham, uninterrupted power supply is not safety-related and supplies power to nonsafety-related equipment and instrumentation only.

   Condensate Storage and Transfer (1P11) System is not required for accident mitigation except for the 1E51 and 1E41 level switches located on the condensate tank for automatic transfer of HPCI and RCIC pumps on low condensate storage tank level. These switches are Class 1E, however, are not included in the EQSR because they are not located in a harsh environment.

3. Why was the Suppression Pool Pump Back System not included in the Electrical submittal?

   A: The Suppression Pool Pump Back System is a subsystem of the Radwaste System (1G11) and is addressed in the EQR. Several components included pump 1G11*P270C and flood level elements 1G11*LE645A,B are utilized by this subsystem and have been addressed in the EQ program.

4. Was Regulatory Guide 1.97 Rev. 2 implemented?

   A: All instrumentation exposed to harsh environment which are necessary for safe shutdown have been included in the EQR.

5. Is all EOP display instrumentation included in EQR?

   A: The EOP display instrumentation is included in the EQR as part of Reg. Guide 1.97, Rev. 2 study as type "A" parameters.

6. What is the status of the equipment in the TMI action item program?

   A: The safety-related Class 1E Electrical Equipment required for those system commitments and additions for NUREG-0737 are incorporated in Shoreham's Environmental Qualification Program.

   A review of the Shoreham TMI Action Plan responses (FSAR Volume 16) was conducted. The equipment identified as a result of this revi^w is listed below and included in the EQSR, except mechanical components. Equipment required by R.G. 1.97 is identified by the designation "RG" in the EQSR.

<u>TMI Items Addressed</u>
<u>In Environmental Qualification Program</u>

REF: FSAR Volume 16
(Response to NUREG-0737)

Shoreham responses to the following of NUREG-0737 section reviewed:

I.D.1 Control Room Design Reviews

I.D.2 Plant Safety Parameter Display Console

II.B.3 Post Accident Sampling (1Z96)
No Class 1E harsh environment equipment in these systems.

II.D.3 SRV Position Indication
1B21*PT153A-L

III.D.3.3 In-Plant Radiation Monitoring
1D21*RE085A,B
Other Class 1E equipment is located in a nonharsh environment.

II.F.1 Accident Monitoring Sampling

1Z93*PT003A,B	Containment Pressure Monitoring
1Z93*PT004A,B	
1Z93*LT001A,B	Suppression Pool Level
1Z93*LT012A,B	

II.K.3.13 Reset Logic for RCIC Steam Supply Valve

Equipment located in nonharsh environment

II.K.3.15 Time Delay Relays

Equipment located in a nonharsh environment

II.K.3.22 Auto Switchover of RCIC

No Class 1E harsh environment equipment

III.A.1.2 Emergency Response Facilities

Equipment located in nonharsh environment. Some signals originate in R.G. 1.97 instrumentation.

The Shoreham response to the following section of NUREG-0660 was also reviewed:

II.B.7 Inerting

1T24*AOV001A,B Primary Containment Nitrogen (Mechanical)
1T24*SOV001A,B Supply Valves, Controlling SOVs
1T24*PNS001A,B and PNSs (HCNT, CISL, SAFE)

1T24*AOV004A,B Suppression Chamber Nitrogen (Mechanical
1T24*SOV004A,B Supply Valves, Controlling SOVs
1T24*PNS004A,B and PNSs (HCNT, CISL, SAFE)

7. Scram Discharge Volume (SDV) - Flooding from high energy line breaks:

Did Shoreham address flooding through stairwells and equipment hatches?

A: Shoreham's assessment of a postulated SDV line crack was provided in response to Shoreham SER Open Item No. 61 regarding NUREG 0803. This report concluded that environmental conditions resulting from a postulated break in the SDV were enveloped by the worst case PBOC for all equipment required to mitigate a break in the scram system. (See Section 3.5 of SNRC-703 dated 5/13/82.)

In particular, flooding through stairwells, equipment hatches, and other openings was specifically considered for a postulated SDV line crack in the same fashion that flooding effects were considered for other pipe break/cracks previously analyzed and reported in FSAR Appendix 3C. This includes the effects of dripping and spraying.

8. Why was the equipment replacement program in the EQ program different from that described in classification letter?

   A: The equipment replacement program is described in the "Equipment Environmental Qualification Action Plan" previously submitted in Revision 2 (May 1982) to the Environmental Qualification Report. The replacement program and equipment testing program has been modified based on the refinement of radiation calculations, shielding, or review of additional documentation. The latest status of the action plan will be submitted in early September with Revision 4 to the Environmental Qualification Report.

9. Please advise on the status of interim justification (IJ) submittals.

   A: The interim justifications for Shoreham are being prepared in two phases. The first portion of these justifications are found in Appendix H of Revision 3 to the Environmental Qualification Report submitted on August 13, 1982. The remainder of the interim justifications are scheduled for submittal to the NRC in Revision 4 to the Environmental Qualification Report in early September.