CENTRAL FILE

MECHANICAL EQUIPMENT
QUALIFICATION PROGRAM

M-SNUB

Hydraulic Snubbers

No.	DATE	REVISIONS	BY	CH'K	APPR
1	2/2/83	See Revision Control Sheet	mRL	cRK	PDB
0	1/21/83	Issued for use	mRL	cRK	PDB

nutech

JOB NO. CPC-09-16

SPEC/DES GUIDE No.	REV.
Mechanical M-SNUB	1

REVISION CONTROL SHEET

TITLE: Hydraulic Snubber REPORT NUMBER: M-SNUB

NAME / TITLE	INITIALS
M. Rio Lee / consultant	MRL
C.W. Allen / CONSULTANT	CWA
W R Kelly / PROJECT ENGINEER	WRK
H. Fonticiella / Project Manager	HMF
[signature] / ENGINEERING MANAGER	PDB

PAGE(S)	REV	PREPARED BY / DATE	ACCURACY CHECK BY / DATE	CRITERIA CHECK BY / DATE	REMARKS
1	1				Revised qualification status to thirty (30) day post accident
2	1				Revised CDES for thirty (30) day post accident and revised accident radiation
4	1				Revised MEEQS (2) for thirty (30) day post accident and revised accident radiation
10-23	1				Revised MEEQRFs to include additional design and test data including a thirty (30) day post accident operability
27-30	1	MRL 2/2/83	CWA 2/2/83	WRK 2/2/83	Revised Appendix A to include a thirty (30) day post accident operability period

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Mechanical Equipment File Cover Summary Sheet

Equipment Type: Hydraulic Snubber MEQ Prog No.: M-SNUB

Manufacturer/Model No: ITT Grinnell/Miller Cylinders Model 52 and Model 90

Safety Function:

The primary function of the Hydraulic Snubber is to protect fluid systems and components important to safety from the effects of seismic disturbances and other types of transient dynamic loadings such as water hammer, steam hammer, pipe whip and relief valve actuation while permitting minimal restraint against thermal expansion.

Operation:

Hydraulic Snubbers generally consist of an assembly of a double-acting hydraulic cylinder, a reservoir, and a flow control device, e.g., orifice valves on the ends of cylinder ports. Ideally, under slow movement due to thermal expansion, the system or components supported by snubbers will move freely as if the snubbers do not exist because the hydraulic fluid inside the cylinder flows through one of the valves into the reservoir and then flows into the other end of the cylinder until the imposed force is balanced. When a body or internal force is applied suddenly with the flow restricted by the flow control device, snubbers will limit dynamic responses so the supported system will not be overstressed.

Qualification Status:

The ITT Grinnell Hydraulic Snubbers are qualified for a forty (40) year service period and a thirty (30) day post accident condition provided that periodic inservice inspection and functional test of the hydraulic snubbers and replacement of the hydraulic seals and fluid are performed according to the surveillance and maintenance recommendation developed in Section G.

MIDLAND UNITS 1 AND 2
EQUIPMENT QUALIFICATION SUMMARY
COMPONENT DATA AND ENVIRONMENT SHEET

EQUIPMENT ID NUMBER Generic

DESCRIPTION: Hydraulic Snubber
SERVICE: Reactor Coolant Pump Support

MANUFACTURER: ITT Grinnell
MODEL NO: Miller Cylinder Model 52/90
SYSTEM: N/A **PO NO:** M-SNUB **EEQS NO:** M-SNUB
ROOM NO: 105A **BLDG:** R1 **ELEVATION:** 614'
OPERATING CYCLES: N/A **NONSEISMIC VIBR:** N/A
RESPONSE SPECTRUM FIG: Future use
LOCA: Yes **MSLB:** **SAFE SD:** Hot, Cold
HELB OUTSIDE RB: N/A
NOTES:

PARAMETER	Normal	LOCA	MSLB	
OPERABILITY PERIOD	40 years	30 days	30 days	
SAFETY FUNCTION	Dynamic restraint	Dynamic restraint	Dynamic restraint	
A. TEMPERATURE (F)	50-120	F-1	F-2	
B. PRESSURE	ATM	F-1	F-2	
C. HUMIDITY (PERC RH)	0-100	100	100	
D. RADIATION (RADS)	1.6E07	1.53E08	Env by LOCA	
E. SPRAY	N/A	T-1	T-1	
F. SUBMERGENCE	N/A	N/A	N/A	
G. ACCURACY	N/A	N/A	N/A	
H. RESPONSE TIME	N/A	N/A	N/A	

EQUIPMENT ID NUMBER Generic

DESCRIPTION: Hydraulic Snubber
SERVICE: Reactor Coolant Pump Support

MANUFACTURER: ITT Grinnell
MODEL NO: Miller Cylinder Model 52/90
SYSTEM: N/A **PO NO:** M-SNUB **EEQS NO:** M-SNUB
ROOM NO: 105A **BLDG:** R2 **ELEVATION:** 614'
OPERATING CYCLES: N/A **NONSEISMIC VIBR:** N/A
RESPONSE SPECTRUM FIG: Future Use
LOCA: Yes **MSLB:** Yes **SAFE SD:** Hot, Cold
HELB OUTSIDE RB: N/A
NOTES:

PARAMETER	Normal	LOCA	MSLB	
OPERABILITY PERIOD	40 years	30 days	30 days	
SAFETY FUNCTION	Dynamic restraint	Dynamic restraint	Dynamic restraint	
A. TEMPERATURE (F)	50-120	F-1	F-2	
B. PRESSURE	ATM	F-1	F-2	
C. HUMIDITY (PERC RH)	0-100	100	100	
D. RADIATION (RADS)	1.6E07	1.53E08	Env by LOCA	
E. SPRAY	N/A	T-1	T-1	
F. SUBMERGENCE	N/A	N/A	N/A	
G. ACCURACY	N/A	N/A	N/A	
H. RESPONSE TIME	N/A	N/A	N/A	

2

EQUIPMENT ID NUMBER

DESCRIPTION:
SERVICE:

MANUFACTURER:
MODEL NO:
SYSTEM: **PO NO:** **EEQS NO:**
ROOM NO: **BLDG:** **ELEVATION:**
OPERATING CYCLES: **NONSEISMIC VIBR:**
RESPONSE SPECTRUM FIG:
LOCA: **MSLB:** **SAFE SD:**
HELB OUTSIDE RB:
NOTES:

PARAMETER				
OPERABILITY PERIOD				
SAFETY FUNCTION				
A. TEMPERATURE (F)				
B. PRESSURE				
C. HUMIDITY (PERC RH)				
D. RADIATION (RADS)				
E. SPRAY				
F. SUBMERGENCE				
G. ACCURACY				
H. RESPONSE TIME				

MECHANICAL EQUIPMENT ENVIRONMENTAL QUALIFICATION SHEET (1)

TYPE OF EQUIPMENT: Hydraulic Snubbers

MANUFACTURER: ITT Grinnell Corporation — PROGRAM NO.: M-SNUB

MODEL NO.: Miller Cylinder Model 52/Model 90

EQUIPMENT APPLICABILITY:	ACCEPTANCE	REF.	PAGE(S)
Model Qualified, Configuration and Interfaces Match Installation	Y	Apdx. 14	-

EXTERNAL NORMAL OPERATING CONDITIONS

	REQUIRED	QUALIFIED	ACCEPT.	METHOD (1)	REF.	PAGE(S)
QUALIFIED LIFE (2)	40 years	40 years	Y	AN	Apdx. A No. 1	-
RESPONSE TIME	N/A	N/A	N/A	N/A	N/A	N/A
ACCURACY	N/A	N/A	N/A	N/A	N/A	N/A
TEMPERATURE, MIN.	$50^{o}F$	$50^{o}F$	Y	AN	Apdx. A No. 2	-
TEMPERATURE, MAX.	$120^{o}F$	$120^{o}F$	Y	AN,PC	Apdx. A No. 2	-
TEMPERATURE, AVE.	N/A	N/A	N/A	N/A	N/A	N/A
PRESSURE	ATM	ATM	Y	AN	Apdx. A No. 3	-
HUMIDITY, MAX.	100%	100%	Y	TC	Apdx A No. 4 Ref. 10	2,3
TID (RADS)	1.6E07	1.6E07	Y	TC	Ref. 10	2,3
OPERATING CYCLES	N/A	N/A	N/A	N/A	N/A	N/A

(1) Qualification Method Symbols: TT-Type Test, PT-Partial Type Test, TC-Test of Vital Components, OE-Operating Experience, AN-Analysis

(2) Qualified _____ without exception __X__ with exception (See MEFCSS)

MECHANICAL EQUIPMENT ENVIRONMENTAL QUALIFICATION SHEET (2)

ACCIDENT ENVIRONMENT:	LOCA Yes	MSLB Yes	HELB OUTSIDE RB N/A	PROGRAM NO.: M-SNUB		
	REQUIRED	QUALIFIED	ACCEPT-ANCE	METHOD (1)	REF.	PAGE(S)
OPERATING TIME	30 days	30 days	Y	AN	Apdx. A No. 6	
RESPONSE TIME	N/A	N/A	N/A	N/A	N/A	N/A
ACCURACY	N/A	N/A	N/A	N/A	N/A	N/A
TEMPERATURE	F-1, F-2	F-2	Y	AN	Apdx. A No. 2	
PRESSURE	F-1, F-2	F-1	Y	AN	Apdx. A No. 3	
TID (2) (RADS) γ/β	3.9E07/1.3E08	3.9E07/1.3E08	Y	AN	Apdx. A No. 7	
SPRAY	T-1	T-1	Y	AN	Apdx. A No. 8	
SUBMERGENCE	N/A	N/A	N/A	N/A	Apdx. A No. 13	
LONG TERM FAILURE OF SHORT-TERM USE EQUIP. WAS ADDRESSED	N/A	N/A	N/A	N/A	Apdx. A No. 12	

ACCELERATED AGING TIME/TEMPERATURE 72hrs/268°F (References 10 & 16)

(1) Qualification Method Symbols: TT-Type Test, PT-Partial Type Test, TC- Test of Vital Components, OE-Operating Experience, AN-Analysis

(2) Includes the dose acquired under normal operating conditions over the equipment qualified life.

EQUIPMENT APPLICABILITY EVALUATION SHEET

EQUIPMENT: Hydraulic Snubbers PROGRAM NO.: M-SNUB

SUBSYSTEM	COMPONENT	ESSENTIAL FOR FUNCTION	MFGR./MODEL NO. DATA	C/PSS REF.	REMARKS
Hydraulic Snubber	Cylinder Assembly	Y	ITT Grinnell	A	Pages 1-4, MEEQRF
	Reservoir Assembly	Y	ITT Grinnell	B	Pages 5-8, MEEQRF
	Valves	Y	ITT Grinnell	C	Pages 9-12, MEEQRF
	Hydraulic Fluid	Y	ITT Grinnell	D	Page 13, MEEQRF
	Rod End Connector /End Connector	Y	ITT Grinnell	N/A	Page 14, MEEQRF Appendix A, No. 9

COMPONENT/PART SUMMARY SHEET A

EQUIPMENT: Hydraulic Snubbers COMPONENT: Cylinder Assembly PROGRAM NO.: M-SNUB

NON-METALLIC PART DESCRIPTION	ESSENTIAL FOR FUNCTION	REF. DOC.	MATERIAL	REF. DOC.	REPLACE-MENT INTERVAL	BASIS (1)	REF. DOC.	REQUIRE-MENTS MET	REF. DOC.	REMARKS
O Ring Fill Port Plug	Y	1	EPDM Federal Mogul E-50	4	5 years	OE, AN	4,15, 16	N/A	N/A	Appendix A No. 10
O Ring Fill Port Plug	Y	1	EPDM Federal Mogul E-50	4	5 years	OE, AN	4,15, 16	N/A	N/A	Appendix A No. 10
External Bearing Seal	Y	11	EPDM Acushnet E17018	4	5 years	OE, AN	4,15, 16	N/A	N/A	Apdx. A, No. 10 Mod 52 only
O Ring-End Seal	Y	1	EPDM Acushnet E17018	4	5 years	OE, AN	4,15, 16	N/A	N/A	Appendix A No. 10
Piston Seal	Y	1	EPDM W.H. Salisbury, 80154	4	5 years	OE, AN	4,15, 16	N/A	N/A	Appendix A No. 10
Rod Wiper	Y	1	EPDM Mn. Rubber No. 559-EQ	4	5 years	OE, AN	4,15, 16	N/A	N/A	Appendix A No. 10
Rod Seal	Y	1	EPDM Mn. Rubber No. 559-EQ	4	5 years	OE, AN	4,15, 16	N/A	N/A	Appendix A No. 10

(1) Replacement Interval Basis Abbreviations: OE-Operating Experience, AN-Analysis, MR-Manufacturers Recommendation

COMPONENT/PART SUMMARY SHEET B

EQUIPMENT: Hydraulic Snubbers   COMPONENT: Reservoir Assembly   PROGRAM NO.: M-SNUB

NON-METALLIC PART DESCRIPTION	ESSENTIAL FOR FUNCTION	REF. DOC.	MATERIAL	REF. DOC.	REPLACEMENT INTERVAL	BASIS (1)	REF. DOC.	REQUIREMENTS MET	REF. DOC.	REMARKS
O Ring Outlet Adapter	Y	1	EPDM Federal Mogul E-50	4	5 years	OE, AN	4,15 16	N/A	N/A	Appendix A No. 10
O Ring Filter Adapter	Y	1	EPDM Federal Mogul E-50	4	5 years	OE, AN	4,15 16	N/A	N/A	Appendix A No. 10
O Ring Drain Adapter	Y	1	EPDM Federal Mogul E-50	4	5 years	OE, AN	4,15 16	N/A	N/A	Appendix A No. 10
O Ring Mtg. Studs	Y	1	EPDM Federal Mogul E-50	4	5 years	OE, AN	4,15 16	N/A	N/A	Appendix A No. 10
O Ring Class Gauge	Y	1	EPDM Federal Mogul E-50	4	5 years	OE, AN	4,15 16	N/A	N/A	Appendix A No. 10
O Ring Cap	Y	1	EPDM Federal Mogul E-50	4	5 years	OE, AN	4,15 16	N/A	N/A	Appendix A No. 10

(1) Replacement Interval Basis Abbreviations: OE-Operating Experience, AN-Analysis, MR-Manufacturers Recommendation

COMPONENT/PART SUMMARY SHEET C

EQUIPMENT: Hydraulic Snubbers **COMPONENT:** Valve **PROGRAM NO.:** M-SNUB

NON-METALLIC PART DESCRIPTION	ESSENTIAL FOR FUNCTION	REF. DOC.	MATERIAL	REF. DOC.	REPLACE-MENT INTERVAL	BASIS (1)	REF. DOC.	REQUIRE-MENTS MET	REF. DOC.	REMARKS
Valve Stem Thread Seal	Y	1	EPDM Federal Mogul E-50	4	5 years	OE, AN	4,15 16	N/A	N/A	Appendix A No. 10
Velocity Adjustment Screw Thread Seal	Y	1	EPDM Federal Mogul E-50	4	5 years	OE, AN	4,15 16	N/A	N/A	Appendix A No. 10
O Ring - Valve Male Connector	Y	1	EPDM Federal Mogul E-50	4	5 years	OE, AN	4,15 16	N/A	N/A	Appendix A No. 10
O Ring - Valve Retainer Plate	Y	1	EPDM Federal Mogul E-50	4	5 years	OE, AN	4,15 16	N/A	N/A	Appendix A No. 10
O Ring - Circle Seal Valve	Y	1	EPDM Federal Mogul E-50	4	5 years	OE, AN	4,15 16	N/A	N/A	Appendix A No. 10
O Ring - Circle Seal Valve	Y	1	EPDM Federal Mogul E-50	4	5 years	OE, AN	4,15 16	N/A	N/A	Appendix A No. 10

(1) Replacement Interval Basis Abbreviations: OE-Operating Experience, AN-Analysis, MR-Manufacturers Recommendation

COMPONENT/PART SUMMARY SHEET D

EQUIPMENT: Hydraulic Snubber COMPONENT: Hydraulic Fluid PROGRAM NO.: M-SNUB

NON-METALLIC PART DESCRIPTION	ESSENTIAL FOR FUNCTION	REF. DOC.	MATERIAL	REF. DOC.	REPLACE MENT INTERVAL	BASIS (1)	REF. DOC.	REQUIRE-MENTS MET	REF. DOC.	REMARKS
Hydraulic Fluid	Y	1	GE SF-1154	3	5 years	AN	3,16	Y	N/A	Appendix A No. 11

(1) Replacement Interval Basis Abbreviations: OE-Operating Experience, AN-Analysis, MR-Manufacturers Recommendation

MECHANICAL EQUIPMENT ENVIRONMENTAL QUALIFICATION REVIEW FORM

COMPONENT: Cylinder Assembly	PAGE 1 OF 14
MFGR.: ITT Grinnell	PROGRAM NO.: M-SNUB
DWG./DOC. NO.: PHD-5222-SK-51, PHD-5222-SK-52	MODEL NO.: Sliller Cylinder 52790
of Ref 1, Pages 32,33	LOCATION: RB, Rm 105A, 614FT

SAFETY RELATED: YES X NO ____

DISCUSSION:

The cylinder assembly is a double-ended piston rod design. The end connectors connect the hydraulic cylinder to the attachments of the supporting structure/component. The hydraulic fluid flows into/out of the cylinder through the cylinder fill ports and valves to absorb the displacements due to the thermal expansion and compression. For a sudden dynamic load due to the incompressibility of hydraulic fluid and the velocity limitation of the valve, the cylinder containing hydraulic fluid acts as a dynamic restraint of the supported component/system.

PART DESCRIPTION: O Ring- Fill Port Plug, item 24, PHD-5222-SK-52 of Ref 1

FUNCTION: To prevent leakage of hydraulic fluid through fill port.

SAFETY RELATED: YES X NO ____

Seal failure results in a loss of hydraulic fluid and hence a loss of the restraint function of hydraulic snubber to a dynamic load.

MFGR.: Federal Mogul MODEL NO.: E-50

MATERIAL: Ethylene Propylene REFERENCE(S): 4

DESIGN RATING(S)	REFERENCE(S)	REQUIREMENTS	DEMONSTRATED BY	ACCEPTABLE	REFERENCE(S)
3.0E07 Rads	4	Radiation 2.63E07 Rads (5 year plus 30 day post accident	material Analysis and vital component test	Y	Ref. 4 Apdx. A No. 7
350⁰F	4	321⁰F-maximum suface temperature	Surface temperature analysis and vital component test	Y	Ref. 4, 17 Apdx. A, No. 2

PART DESCRIPTION: O Ring - Fill port plug, Item 23, PHD-5222-SK-51 of Ref 1

FUNCTION: To prevent leakage of hydraulic fluid from fill port.

SAFETY RELATED: YES X NO ____

Seal failure results in a loss of hydraulic fluid and hence a loss of the restraint function of hydraulic snubber to a dynamic load.

MFGR.: Federal Mogul MODEL NO.: E-50

MATERIAL: Ethylene Propylene REFERENCE(S): 4

DESIGN RATING(S)	REFERENCE(S)	REQUIREMENTS	DEMONSTRATED BY	ACCEPTABLE	REFERENCE(S)
3.0E07 Rads	4	Radiation- 2.63E07 Rads (5 year plus 30 day post accident)	Material analysis and vital component test	Y	Ref. 4 Apdx. A No. 7
350°F	4	321°F-maximum surface temperature	Surface temperature analysis and vital component test	Y	Ref. 4,17 Apdx. A No. 2

PART DESCRIPTION: External Bearing Seal, Item 27, PHD-5222-SK 52 of Ref.1

FUNCTION: To prevent leakage of hydraulic fluid from hydraulic cylinder

SAFETY RELATED: YES X NO ____

Seal failure results in a loss of hydraulic fluid and hence a loss of the safety function of hydraulic snubber to restrain a dynamic load.

MFGR.: Acushnet MODEL NO.: E17018

MATERIAL: Ethylene Propylene REFERENCE(S): 4

DESIGN RATING(S)	REFERENCE(S)	REQUIREMENTS	DEMONSTRATED BY	ACCEPTABLE	REFERENCE(S)
3.0E07 Rads	4	Radiation- 2.63E07 Rads (5 year plus 30 day post accident)	Material analysis and vital component test	Y	Ref. 4 Apdx. A No. 7
350°F	4	321°F-maximum surface temperature	Surface temperature analysis and vital component test	Y	Ref. 4, 17 Apdx. A No. 2

PART DESCRIPTION: O Ring - End Seal, Item 14, PHD-5222-SK-51 of Ref.1

FUNCTION: To prevent leakage of hydraulic fluid from hydraulic cylinder.

SAFETY RELATED: YES X NO ____

Seal failure results in a loss of hydraulic fluid and hence a loss of the restraint function of hydraulic snubber to a dynamic load.

MFGR.: Acushnet MODEL NO.: E-17018

MATERIAL: Ethylene Propylene REFERENCE(S): 4

DESIGN RATING(S)	REFERENCE(S)	REQUIREMENTS	DEMONSTRATED BY	ACCEPTABLE	REFERENCE(S)
3.0E07 Rads	4	Radiation - 2.63E07 Rads (5 year plus 30 day post accident)	Material analysis and vital component test	Y	Ref. 4 Apdx. A No.7
350°F	4	321°F-maximum surface temperature	Surface temperature analysis and vital component test	Y	Ref.4,17 Apdx. A No. 2

PART DESCRIPTION: Piston Seal, Item 2, PHD-5222-SK-51 of Ref. 1

FUNCTION: To prevent leakage of hydraulic fluid from hydraulic cylinder.

SAFETY RELATED: YES X NO ____

Seal failure results in a loss of hydraulic fluid and hence a loss of the restrain function of hydraulic snubber to a dynamic load.

MFGR.: W. H. Salisbury MODEL NO.: 80154

MATERIAL: Ethylene Propylene REFERENCE(S): 4

DESIGN RATING(S)	REFERENCE(S)	REQUIREMENTS	DEMONSTRATED BY	ACCEPTABLE	REFERENCE(S)
3.0E07 Rads	4	Radiation - 2.63E07 Rads (5 year plus 30 day post accident	Material analysis and vital component test	Y	Ref. 4 Apdx. A No. 7
350°F	4	321°F-maximum surface temperature	Surface temperature analysis and vital component test	Y	Ref.4,17 Apdx. A No. 2

PART DESCRIPTION: Rod Wiper, Item 15, PHD-5222-SK-51 of Ref. 1

FUNCTION: To prevent leakage of hydraulic fluid from cylinder.

SAFETY RELATED: YES X NO ____

Seal failure results in a loss of hydraulic fluid and hence a loss of the safety function of hydraulic snubber to restrain a dynamic load.

MFGR.: Minnesota Rubber MODEL NO.: 559-EQ

MATERIAL: Ethylene Propylene REFERENCE(S): 4

DESIGN RATING(S)	REFERENCE(S)	REQUIREMENTS	DEMONSTRATED BY	ACCEPTABLE	REFERENCE(S)
3.0E07 Rads	4	Radiation - 2.63E07 Rads (5 year plus 30 day post accident)	Material analysis and vital component test	Y	Ref. 4 Apdx. A No. 7
350°F	4	321°F-maximum surface temperature	Surface temperature analysis and vital component test	Y	Ref. 4,17 Apdx. A No. 2

PART DESCRIPTION: Rod Seal, Item 6, PHD-5222-SK-51 of Ref. 1

FUNCTION: To provide a seal between the cylinder and the rod bushing assembly.

SAFETY RELATED: YES X NO ____

Seal failure results in a loss of hydraulic fluid and hence a loss of the safety function of hydraulic snubber to restrain a dynamic load.

MFGR.: Minnesota Rubber MODEL NO.: 559-EQ

MATERIAL: Ethylene Propylene REFERENCE(S): 4

DESIGN RATING(S)	REFERENCE(S)	REQUIREMENTS	DEMONSTRATED BY	ACCEPTABLE	REFERENCE(S)
3.0E07 Rads	4	Radiation - 2.63E07 Rads (5 year plus 30 day post accident)	Material analysis and vital component test	Y	Ref. 4 Apdx. A No. 7
350°F	4	321°F-maximum surface temperature	Surface temperature analysis and vital component test	Y	Ref. 4,17 Apdx. A No. 2

MECHANICAL EQUIPMENT ENVIRONMENTAL QUALIFICATION REVIEW FORM

COMPONENT: Reservoir Assembly	PAGE 5 OF 14
MFGR.: ITT Grinnell	PROGRAM NO.: M-SNUB
DWG./DOC. NO.: PHD-5222-SK-63, PHD-5222-SK-85	MODEL NO.: Oil-Rite
of Ref. 1, Page 44 & 46	LOCATION: RB, Rm 105A, 614FT

SAFETY RELATED: YES X NO ____

DISCUSSION:

The reservoir attached to the hydraulic cylinder compensates the volume change and allows the piston to freely extend or retract resulting from the thermal expansion and contraction of the hydraulic fluid or the safety related fluid system/components restrained by the hydraulic snubber. The sight glass assembly of reservoir provides the accessibility of the hydraulic fluid level. Any leakage due to the seal failure may compromise the fluid integrity of the hydraulic system and be injurious to the hydraulic snubber's safety function.

PART DESCRIPTION: O-Ring-outlet adapter, Item 9, PHD-5222-SK-63 of Ref. 1

FUNCTION: To prevent leakage of hydraulic fluid from the reservoir outlet adapter.

SAFETY RELATED: YES X NO ____

Seal failure results in a loss of hydraulic fluid and hence a loss of the safety function of hydraulic snubber to restrain a dynamic load.

MFGR.: Federal Mogul MODEL NO.: E-50

MATERIAL: Ethylene Propylene REFERENCE(S): 4

DESIGN RATING(S)	REFERENCE(S)	REQUIREMENTS	DEMONSTRATED BY	ACCEPTABLE	REFERENCE(S)
3.0E07 Rads	4	Radiation - 2.63E07 Rads (5 year plus 30 day post accident)	Material analysis and vital component test	Y	Ref. 4 Apdx. A No. 7
350^oF	4	321^oF-maximum surface temperature	Surface temperature analysis and vital component test	Y	Ref. 4,17 Apdx. A No. 2

PART DESCRIPTION: O-Ring-Filter Adapter, Item 15, PHD-5222-SK-63 of Ref. 1

FUNCTION: To prevent leakage of hydraulic fluid from the reservoir.

SAFETY RELATED: YES X NO ____

Seal failure results in a loss of hydraulic fluid and hence a loss of the restraint function of hydraulic snubber.

MFGR.: Federal Mogul MODEL NO.: E-50

MATERIAL: Ethylene Propylene REFERENCE(S): 4

DESIGN RATING(S)	REFERENCE(S)	REQUIREMENTS	DEMONSTRATED BY	ACCEPTABLE	REFERENCE(S)
3.0E07 Rads	4	Radiation - 2.63E07 Rads (5 year plus 30 day post accident)	Material analysis and vital component test	Y	Ref. 4 Apdx. A No. 7
350°F	4	321°F-maximum surface temperature	Surface temperature analysis and vital component test	Y	Ref.4,17 Apdx. A No. 2

PART DESCRIPTION: O-Ring-Drain Adapter, Item 5, PHD-5222-SK-63 of Ref. 1

FUNCTION: To provide a seal between the drain adapter and the reservoir.

SAFETY RELATED: YES X NO ____

Seal failure results in a loss of hydraulic fluid and hence a loss of the safety function of hydraulic snubber to restrain a dynamic load.

MFGR.: Federal Mogul MODEL NO.: E-50

MATERIAL: Ethylene Propylene REFERENCE(S): 4

DESIGN RATING(S)	REFERENCE(S)	REQUIREMENTS	DEMONSTRATED BY	ACCEPTABLE	REFERENCE(S)
3.0E07 Rads	4	Radiation - 2.63E07 Rads (5 year plus 30 day post accident)	Material analysis and vital component test	Y	Ref. 4 Apds. A No. 7
350°F	4	321°F-maximum surface temperature	Surface temperature analysis and vital component test	Y	Ref. 4,17 Apdx. A No.2

PART DESCRIPTION: O-Ring-Mtg. Studs, Item 33, PHD-5222-SK-63 of Ref. 1

FUNCTION: To prevent leakage of hydraulic fluid from the reservoir sight glass.

SAFETY RELATED: YES X NO ____

Seal failure results in a loss of hydraulic fluid and hence a loss of the safety function of hydraulic snubber to restrain a dynamic load.

MFGR.: Federal Mogul MODEL NO.: E-50

MATERIAL: Ethylene Propylene REFERENCE(S): 4

DESIGN RATING(S)	REFERENCE(S)	REQUIREMENTS	DEMONSTRATED BY	ACCEPTABLE	REFERENCE(S)
3.0E07 Rads	4	Radiation - 2.63E07 Rads (5 year plus 30 day post accident)	Material analysis and vital component test	Y	Ref. 4 Apdx. A No. 7
350°F	4	321°F-maximum surface temperature	Surface temperature analysis and vital component test	Y	Ref. 4,17 Apdx. A No. 2

PART DESCRIPTION: O-Ring-Glass Guage, Item 37, PHD-5222-SK-63 of Ref. 1

FUNCTION: To provide a seal between reservoir and sight glass gauge.

SAFETY RELATED: YES X NO ____

Seal failure results in a loss of hydraulic fluid and hence a loss of the restraint function of hydraulic snubber to a dynamic load.

MFGR.: Federal Mogul MODEL NO.: E-50

MATERIAL: Ethylene Propylene REFERENCE(S): 4

DESIGN RATING(S)	REFERENCE(S)	REQUIREMENTS	DEMONSTRATED BY	ACCEPTABLE	REFERENCE(S)
3.0E07 Rads	4	Radiation - 2.63E07 Rads (5 year plus 30 day post accident)	Material analysis and vital component test	Y	Ref. 4 Apdx. A No. 7
350°F	4	321°F-maximum surface temperature	Surface temperature analysis and vital component test	Y	Ref. 4,17 Apdx. A No. 2

PART DESCRIPTION: O Ring - Cap, Item 33, PHD-5222-SK-63 of Ref. 1

FUNCTION: To prevent leakage of hydraulic fluid from reservoir.

SAFETY RELATED: YES X NO ____

Seal failure results in a loss of hydraulic fluid and hence a loss of the safety function of hydraulic snubber to restrain a dynamic load.

MFGR.: Federal Mogul MODEL NO.: E-50

MATERIAL: Ethylene Propylene REFERENCE(S): 4

DESIGN RATING(S)	REFER-ENCE(S)	REQUIREMENTS	DEMONSTRATED BY	ACCEPT-ABLE	REFER-ENCE(S)
3.0E07 Rads	4	Radiation - 2.63E07 Rads (5 year plus 30 day post accident)	Material analysis and vital component test	Y	Ref. 4 Apdx. A No. 7
$350^{\circ}F$	4	$321^{\circ}F$-maximum surface temperature	Surface temperature analysis and vital component test	Y	Ref.4,17 Apdx. A No. 2

PART DESCRIPTION:

FUNCTION:

SAFETY RELATED: YES ____ NO ____

MFGR.: MODEL NO.:

MATERIAL: REFERENCE(S):

DESIGN RATING(S)	REFER-ENCE(S)	REQUIREMENTS	DEMONSTRATED BY	ACCEPT-ABLE	REFER-ENCE(S)

MECHANICAL EQUIPMENT ENVIRONMENTAL QUALIFICATION REVIEW FORM

COMPONENT: Valves	PAGE 9 OF 14
MFGR.: ITT Grinnell	PROGRAM NO.: M-SNUB
DWG./DOC. NO.: PHD-5222-SK-55, PHD-5222-SK-70,	MODEL NO.: N/A
of Ref 1, Pages 36 and 47	LOCATION: RB, Rm 105A, 614FT

SAFETY RELATED: YES X NO ____

DISCUSSION:

The valves at each end of cylinder ports provide the channel of hydraulic fluid from reservoir to cylinder. Under slow movement due to thermal expansion or contraction, the hydraulic fluid flows through the valves into the reservoir or cylinder to balance the imposed force. When a body force or internal force is applied suddenly, the valves cannot carry the excessive fluid velocity, the hydraulic snubber therefore acts as a restraint to the supported safety related component/fluid system.

PART DESCRIPTION: Valve Stem Thread Seal, Items 9, PHD-5222-SK-55 of Ref.1

FUNCTION: To prevent leakage of hydraulic fluid through valve stem thread

SAFETY RELATED: YES X NO ____

Seal failure results in a loss of hydraulic fluid and hence a loss of the designed safety function of hydraulic snubber.

MFGR.: Federal Mogul MODEL NO.: E-50

MATERIAL: Ethylene Propylene REFERENCE(S): 4

DESIGN RATING(S)	REFER-ENCE(S)	REQUIREMENTS	DEMONSTRATED BY	ACCEPT-ABLE	REFER-ENCE(S)
3.0E07 Rads	4	Radiation - 2.63E07 Rads (5 year plus 30 day post accident)	Material analysis and vital component test	Y	Ref. 4 Apdx. A No. 7
350°F	4	321°F-maximum surface temperature	Surface temperature analysis and vital component test	Y	Ref. 4,17 Apdx. A No. 2

PART DESCRIPTION: O-Ring-Valve Retainer Plate, Item 13, PHD-5222-SK-55 of Ref. 1

FUNCTION: To prevent leakage of hydraulic fluid through the valve retainer plate

SAFETY RELATED: YES X NO ____

Seal failure results in a loss of hydraulic fluid and hence a loss of the safety function of hydraulic snubber to restrain a dynamic load.

MFGR.: Federal Mogul MODEL NO.: E-50

MATERIAL: Ethylene Propylene REFERENCE(S): 4

DESIGN RATING(S)	REFERENCE(S)	REQUIREMENTS	DEMONSTRATED BY	ACCEPTABLE	REFERENCE(S)
3.0E07 Rads	4	Radiation - 2.63E07 Rads (5 year plus 30 day post accident)	Material analysis and vital component test	Y	Ref. 4 Apdx. A No. 7
350°F	4	321°F-maximum surface temperature	Surface temperature analysis and vital component test	Y	Ref. 4, 17 Apdx. A No. 2

PART DESCRIPTION: o Ring-Circle Seal Valve, Item 38, PHD-5222-SK-55 of Ref. 1

FUNCTION: To prevent leakage of hydraulic fluid through valve.

SAFETY RELATED: YES X NO ____

Seal failure results in a loss of hydraulic fluid and hence a loss of the safety function of hydraulic snubber to restrain a dyanmic load.

MFGR.: Federal Mogul MODEL NO.: E-50

MATERIAL: Ethylene Propylene REFERENCE(S): 4

DESIGN RATING(S)	REFERENCE(S)	REQUIREMENTS	DEMONSTRATED BY	ACCEPTABLE	REFERENCE(S)
3.0E07 Rads	4	Radaition - 2.63E07 Rads (5 year plus 30 day post accident)	Material analysis and vital component test	Y	Ref. 4 Apdx. A No. 7
350°F	4	321°F-maximum surface temperature	Surface temperature analysis and vital component test	Y	Ref. 4, 17 Apdx. A No. 2

PART DESCRIPTION: Velocity Adjustment Screw Thread Seal, Items 5, PHD-5222-SK-55 of Ref. 1

FUNCTION: To prevent leakage of hydraulic fluid through velocity adjustment screw

SAFETY RELATED: YES X NO ___

Seal failure results in a loss of hydraluic fluid and hence a loss of the safety function of hydraulic snubber to restrain a dynamic load.

MFGR.: Federal Mogul MODEL NO.: E-50

MATERIAL: Ethylene Propylene REFERENCE(S): 4

DESIGN RATING(S)	REFERENCE(S)	REQUIREMENTS	DEMONSTRATED BY	ACCEPTABLE	REFERENCE(S)
3.0E07 Rads	4	Radiation - 2.63E07 Rads (5 year plus 30 day post accident)	Material analysis and vital component test	Y	Ref. 4 Apdx. A No. 7
350°F	4	321°F-maximum surface temperature	Surface temperature analysis and vital component test	Y	Ref.4,17 Apdx. A No. 2

PART DESCRIPTION: O-Ring - Valve Male Connector, Item 19, PHD-5222-SK-55, of Ref. 1

FUNCTION: To prevent leakage of hydraulic fluid through connector

SAFETY RELATED: YES X NO ___

Seal failure results in a loss of hydraulic fluid and hence a loss of the safety function of hydraulic snubber to restrain a dynamic load.

MFGR.: Federal·Mogul MODEL NO.: E-50

MATERIAL: Ethylene Propylene REFERENCE(S): 4

DESIGN RATING(S)	REFERENCE(S)	REQUIREMENTS	DEMONSTRATED BY	ACCEPTABLE	REFERENCE(S)
3.0E07 Rads	4	Radiation - 2.63E07 Rads (5 year plus 30 day post accident)	Material analysis and vital component test	Y	Ref. 4 Apdx. A No. 7
350°F	4	321°F-maximum surface temperature	Surface temperature analysis and vital component test	Y	Ref.4,17 Apdx. A No. 2

MEEQRF (CONT.)	PAGE 12 OF 14	PROGRAM NO.: M-SNUB

PART DESCRIPTION: O-Ring-Circle Seal Valve, Item 37, PHD-5222-SK-55 of Ref. 1

FUNCTION: To prevent leakage of hydraulic fluid from valve tubing

SAFETY RELATED: YES X NO ____

Seal failure results in a loss of hydraulic fluid and hence a loss of the operability of hydraulic snubber.

MFGR.: Federal Mogul MODEL NO.: E-50

MATERIAL: Ethylene Propylene REFERENCE(S): 4

DESIGN RATING(S)	REFERENCE(S)	REQUIREMENTS	DEMONSTRATED BY	ACCEPTABLE	REFERENCE(S)
3.0E07 Rads	4	Radiation - 2.63E07 Rads (5 year plus 30 day post accident)	Material analysis and vital component test	Y	Ref. 4 Apdx. A No. 7
$350^{\circ}F$	4	$321^{\circ}F$-maximum surface temperature	Surface temperature analysis and vital component test	Y	Ref. 4, 17 Apdx. A No. 2

PART DESCRIPTION:

FUNCTION:

SAFETY RELATED: YES ____ NO ____

MFGR.: MODEL NO.:

MATERIAL: REFERENCE(S):

DESIGN RATING(S)	REFERENCE(S)	REQUIREMENTS	DEMONSTRATED BY	ACCEPTABLE	REFERENCE(S)

MECHANICAL EQUIPMENT ENVIRONMENTAL QUALIFICATION REVIEW FORM

COMPONENT: Rod End Connector/End Connector	PAGE 13 OF 14
MFGR.: ITT Grinnell	PROGRAM NO.: M-SNUB
DWG./DOC. NO.: PHD-5222-SK-51, PHD-5222-SK-52,	MODEL NO.: RB, Rm 105A, 614FT
of Ref. 1, Pages 32 and 33	LOCATION:

SAFETY RELATED: YES X NO ___

DISCUSSION:

The rod end connector/end connector connects the hydraulic cylinder and the fluid system or components important to safety.

There are no non-metallic parts contained in the connector assembly. Therefore, a Component/Part Summary Sheet is not required.

PART DESCRIPTION:

FUNCTION:

SAFETY RELATED: YES ___ NO ___

MFGR.: MODEL NO.:

MATERIAL: REFERENCE(S):

DESIGN RATING(S)	REFERENCE(S)	REQUIREMENTS	DEMONSTRATED BY	ACCEPTABLE	REFERENCE(S)

MECHANICAL EQUIPMENT ENVIRONMENTAL QUALIFICATION REVIEW FORM

COMPONENT: Hydraulic Fluid	PAGE 14 OF 14
MFGR.: General Electric Company	PROGRAM NO.: M-SNUB
DWG./DOC. NO.: N/A	MODEL NO.: SF-1154
	LOCATION: RB, Rm 105A, 614FT

SAFETY RELATED: YES X NO ____

DISCUSSION:

The hydraulic fluid used in the hydraulic snubber is a major load carrying member. The GE SF-1154 fluid is a copolymer containing both methyl and phenyl units. It has high temperature stability and can be used from $-56^{\circ}F$ to $+540^{\circ}F$ (Reference 3). It has radiation resistance up to 5.0E08 rads (Reference 3). The compatibility of SF-1154 to the EPDM based seals used in ITT hydraulic snubbers was demonstrated in Reference 10.

PART DESCRIPTION: Hydraulic fluid

FUNCTION: To carry the sudden dynamic load

SAFETY RELATED: YES X NO ____

Degradation of hydraulic fluid will hinder the operability of hydraulic snubber.

MFGR.: GE MODEL NO.: SF-1154

MATERIAL: Methyl phenyl polysiloxane fluid REFERENCE(S): 3

DESIGN RATING(S)	REFERENCE(S)	REQUIREMENTS	DEMONSTRATED BY	ACCEPTABLE	REFERENCE(S)
5.0E08 Rads	3	Radiation - 2.63E07 Rads (5 year plus 30 day post accident)	Material analysis and vital component test	Y	Ref. 4 Apdx. A No. 7
540°F	3	120°F-maximum environmental temperature	Material design rating	Y	Ref. 3

HYDRAULIC SNUBBERS
MAINTENANCE AND SURVEILLANCE RECOMMENDATIONS
M-SNUB

Frequency	Requirement	Action
Every refueling outage or the scheduled inspection periods (attached on page 3) whichever is earlier	Inservice visual inspection of 1. Any indication of damage or impaired operability. 2. Attachments to the foundation or supporting structure are secure. 3. The snubber has freedom of movement and is not frozen up. 4. Any external signs of leakage or any other conditions which may compromise the operability of the hydraulic system. 5. An adequate reservoir fluid volume is available for operation.	Any unit which fails to pass visual inspection shall be removed from service and subject to functional testing restored or replaced by an operational unit.
At least every 18 months or shutdown	Functional test to verify that 1. Activation (restraining action) is achieved within the specified range of velocity in both tension and compression. 2. Snubber bleed, or release rate, where required, is within the specified range in compression or tension. For snubbers specifically required to not displace under continuous load, displacement shall be verified.	For the snubber found inoperable, an engineering evaluation shall be performed to determine whether or not the snubber mode of failure has imparted a significant effect or degradation on the supported component or system.

Frequency	Requirement	Action
	3. The snubber has freedom of movement and is not frozen up.	All snubbers of the same design shall be functionally tested.
Every five years*	Normal maintenance	Replace all the seals listed on CPSS and the following parts: Hydraulic Fluid Rod Wave Spring Piston Wear Ring Rod Wiper Rod Bushing Rod Seal Cage Rod Pressure Ring Retainer Screws

* This maintenance program follows the manufacturer's recommendation per Reference 1.

The first inservice visual inspection of snubbers shall be during the first COLD SHUTDOWN exceeding 24 hours after four months of power operation and shall include all snubbers. If less than two (2) snubbers are found inoperable during the first inservice visual inspection, the second inservice visual inspection shall be performed 12 months ± 25% from the date or the first inspection. Otherwise, subsequent visual inspections shall be performed in accordance with the following schedule:

No. of Inoperable Snubbers per Inspection Period	Subsequent Visual Inspection Period*
0	18 months ± 25%
2	6 months ± 25%
3,4	124 days ± 25%
5,6,7	62 days ± 25%
8 or more	31 days ± 25%

* The inspection interval shall not be lengthened more than one step at a time.

APPENDIX A

1. The only non-metallic parts of the ITT Grinnell Hydraulic Snubbers are hydraulic fluid and seals at various locations. The operating experience (Pages 84 and 86, Reference 4) and supporting analysis (References 3, 16) have demonstrated that the 5-year life of seals and hydraulic fluid is a conservative projection. With appropriate maintenance and surveillance schedules, developed in the Maintenance and Surveillance Recommendation Section, the qualified life of the Hydraulic Snubber is determined to be in excess of 40 years including a 30 day post accident condition.

2. The hydraulic fluid used in the ITT Grinnell Hydraulic Snubbers is GE SF-1154 silicone fluid which has excellent high temperature stability. It can be used from -56 to +540°F which envelops both the normal and post-accident environmental temperatures (Reference 3). The seal material used in ITT Grinnell Hydraulic Snubbers, EPDM, in general maintains its elastomeric character over a broad temperature range. Typical service temperature range for <u>continuous</u> usage is from -70°F to 350°F (Page 2, Reference 4) which envelops the normal service temperature of the hydraulic snubbers used in the Midland Units 1 & 2. The maximum surface temperature which the hydraulic snubber seals will experience during an MSLB is determined by supporting analysis in Reference 17 to be 321°F since the EPDM has demonstrated performance at temperatures up to 350°F, the qualification is acceptable.

3. The Ethylene Propylene base material used in this seal application can withstand very high pressure environments. In similar applications, EPR seals and O-Rings were exposed to LOCA Simulation Testing (See MEQ Program M.118) with temperatures up to 358°F and pressures up to 45 psig. The seals in the hydraulic snubber are designed to maintain a high pressure differential

(in excess of several thousand pounds) between the internal hydraulic fluid and external pressure. Any increases of environmental pressure actually decreases the pressure differential of internal fluid pressure and external pressure. Pressure qualification is acceptable.

4. The humidity requirement for the hydraulic snubbers is 100% RH as a maximum value. This value does not change for accident conditions. A test of Vital Components - Seals has been included in Reference 10 where the seals were exposed to a 100% RH conditions without remarkable changes in materials properties. Therefore, the humidity qualification is acceptable.

5. The primary function of the hydraulic snubber is to ensure the thermal behavior and the frequency response level of the Reactor Coolant Pump System so that the induced reactions and the resultant stresses at the reactor coolant pumps are within allowable limits. Since carrying nonseismic vibration load is part of the hydraulic snubber's safety function, the qualification is acceptable.

6. The required operating period for a hydraulic snubber is 30 days to maintain the reactor coolant pump integrity for a small LOCA. The non-metallic constituents of the hydraulic snubbers have been evaluated against the postulated environmental conditions over a 30 day post-accident period (See No. 2 and 7 of this Appendix and Reference 17) and found acceptable.

7. The total integrated dose requirement of 1.69E08 rads is for the surface of equipment in a radiation environment of 1.3E08 rads beta and 2.3E07 rads gamma for 30 days post-accident (from EQ Submittal, Rev. 1, Table 1-6) and 1.6E07 rads for a 40 year normal service. Replacement of the seals and hydraulic fluid on a 5-year basis decreases the radiation dose requirement to 1.55E08 rads (2.5E07 rads gamma and 1.3E08 rads beta).

NRC IE Bulletin 79-01B states that the beta surface dose would be reduced by approximately a factor of ten within 30 mils of the surface of equipment. An additional 40 mils of thickness results in another factor of 10 reduction in dose. There are several static seals whose surface is directly exposed to the beta dose field. The rest of the seals are shielded by the metal parts which are much thicker than 70 mils. The thickness of the smallest size of those seals exposed to the air is 0.087 inch (Item 16, Page 26, Reference 4), which is equivalent to 221 mils. Considering that these seals are static seals, loss of one third of seal material (70/221 = 1/3) is unlikely to damage its sealing function. Therefore, the total radiation dose with a 5 year replacement interval can be reduced to 1.3E06 beta (1.3E08/(10 x 10) = 1.3E06) and 2.5E07 gamma. This results in a 2.63E07 total radiation dose which is enveloped by 3.0E07 gamma dose tested. The tests were conducted by ITT Grinnel on all the seals used in the hydraulic snubber for a total dose of 3.0E07 rads gamma (Reference 10) and sufficient resiliency is maintained in all cases to provide adequate sealing. Therefore, the radiation qualification is acceptable.

The GE SF-1154 Hydraulic Fluid has excellent radiation resistance and is capable of absorbing up to 5.0E08 rads before gellation, which is much higher than 2.63E07 Rads. The radiation qualification is acceptable.

8. The required project chemistry is given in T-1. The EPDM has demonstrated an excellent chemical stability (Reference 4, Page 2). In addition, Midland EQ Programs E22A and E22B have demonstrated that the Ethylene Propylene Rubber material is qualified for a spray chemistry which is more severe than the required Midland spray chemistry. Spray chemistry qualification is acceptable.

9. The Rod End Connector/End Connector is a totally metallic part and is not affected by the environmental conditions imposed during a LOCA or MSLB.

10. Seals made of EPDM have lasted 5 years under working conditions and still maintained its safety function (Pages 84 and 89, Reference 4). A test conducted by ITT Grinnell on its hydraulic snubber seals demonstrates that the seals maintain sufficient resiliency to provide adequate sealing after 72-hours of exposure at 268°F. With Arrhenius Methodology a 5-year service life at 120°F is determined in Reference 16. The seal was tested with the GE SF-1154 Hydraulic Fluid. The compatibility of EPDM and the hydraulic fluid has been demonstrated. Therefore, 5 years of replacement interval is adequate for qualifying hydraulic snubber.

11. As stated in No. 2, 7, and 10, GE SF-1154 has an excellent stability against temperature and radiation. The 5-year projected life is conservative.

12. The hydraulic snubber is qualified for a long term 30 day operability period as described in this Appendix. Therefore this category is not applicable.

13. Because all the hydraulic snubbers are located at the level of 614 ft. which is higher than the flood level of 603 ft., both normal and accidental submergence are not considered for snubber qualification. Thus this category is not applicable.

14. The hydraulic snubber subjected to analysis as described in this program is identical to the hydraulic snubber installed at the Midland plant, Units 1 & 2 as noted in References 1, 4.

REFERENCES AND ADDITIONAL DATA

 PROGRAM NO.: M-SNUB

1. ITT Grinnell Co., "Technical Manual for Maintenance Large Bore Hydraulic Snubbers", Report No. PHD-5222-1MBM, January 9, 1979.

2. Letter from Earl Tomlinson of W. H. Salisbury & Co. Linemens Rubber Protective Devices, Subject: Mechanical Properties of Compound #80154, dated December 8, 1982.

3. G.E. "Silicone Fluids in Radiation Environments", G.E. technical information CDS-4176, January 1981.

4. ITT Grinnell Co., "Final Report - Consumers Power Company Contract for Consulting Service for the Reactor Coolant Pump Snubber Seal Study for the Midland Plant", Report No. SPS-ZPR-8014-5, December 24, 1981.

5. ASME Boiler and Pressure Vessel Code, Section III, Division 1, Subsection NF.

6. EPRI, "A Review of Equipment Aging Theory and Technology", Report EPRI NP-1558, September 1980.

7. Federal Mogul Co., "Comparison - National Compound E50-70 to ASTM D200 Specifications 4CA715A25B44EA14F19G21 and 3DA715A26B36EA14F19G21" National O-Rings Technical Report, April 26, 1982.

REFERENCES AND ADDITIONAL DATA

 PROGRAM NO.: M-SNUB

8. Federal Mogul Co., "Comparison Compound E50-70 to TACO Inc./ Underwriters Laboratories UL 778 Requirements" National O-Rings Technical Report, April 26, 1982.

9. Acushnet Co. Laboratory Report No. 4034 for Compound E-17018, page 2.

10. ITT Grinnell Co., "Radiation and Environmental Test of Seal and Fluid materials for Snubbers" Report No. PHD-5347-2R, Revision 1, July 23, 1977.

11. ITT Grinnell Co., "Radiation and Environmental Test of Seal Materials for Snubbers", Report No. PHD-7569-1, Revision 1, July 23, 1977.

12. ITT Grinnell Co., Engineering Parts List MB-5222-31, Revision 3, October 28, 1981.

13. ITT Grinnell Co., Engineering Parts List MB-5222-45, Revision 3, October 28, 1981.

14. EPRI, "Radiation Effects on Organic Materials in Nuclear Plants" Report EPRI NP-2129, November 1981.

15. ITT Grinnell Co. Drawing PHD-5222-5, PHD-5222-6, PHD-5222-7 and PHD-5222-8.

REFERENCES AND ADDITIONAL DATA

PAGE 3 OF 3 PROGRAM NO.: M-SNUB

16. M.R. Lee, "Replacement Interval Calculation for the ITT Grinnell Hydraulic Snubber Seals and Hydraulic Fluid Based on the Thermal Degradation", NUTECH Calculation CPC-09-E.041, January 1983.

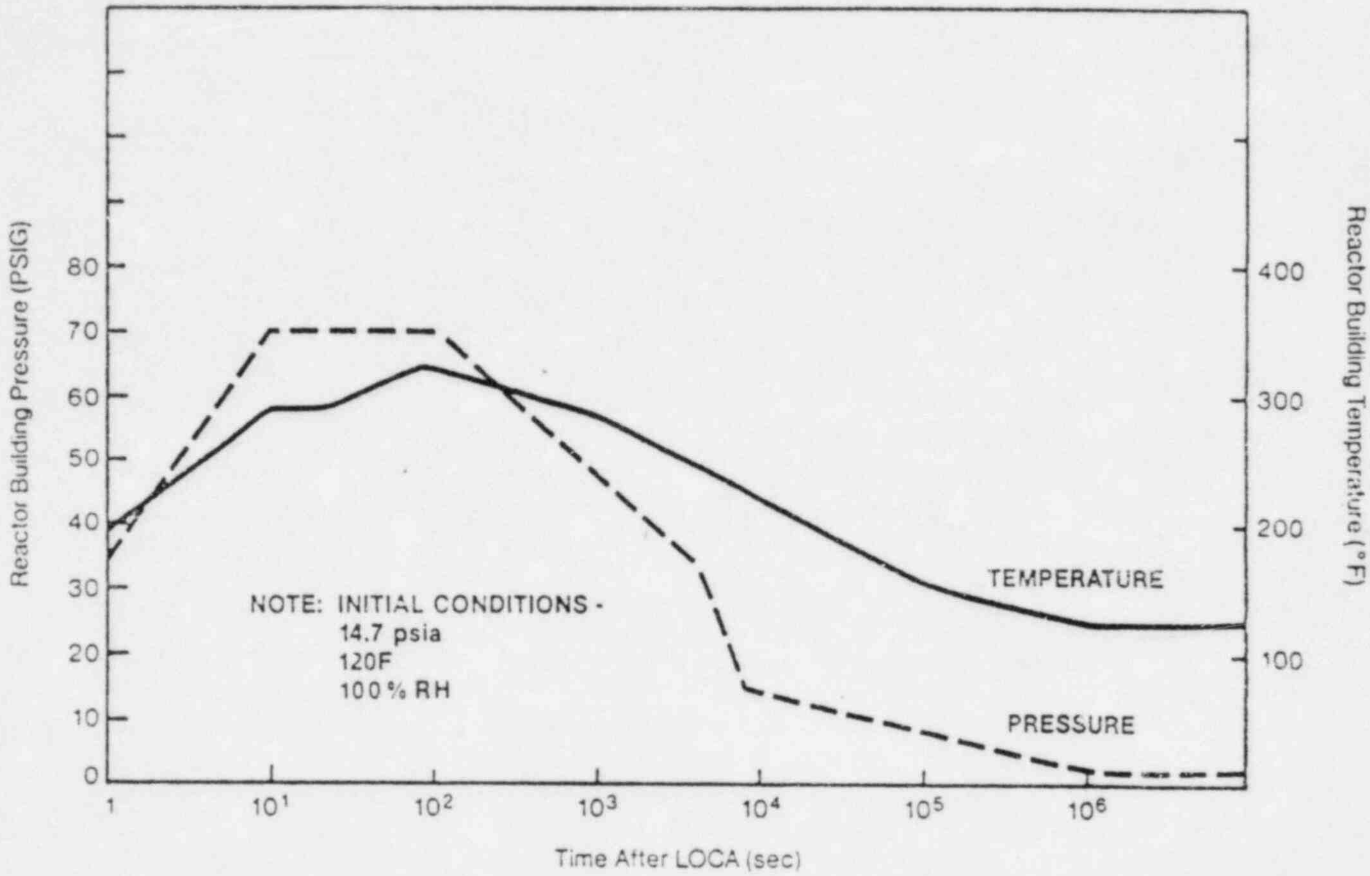
17. M.R. Lee, "Surface Temperature Analysis for the ITT Grinnell Hydraulic Snubbers", NUTECH Calculation CPC-09-E.040, January 1983.

18. Midland Plant, Units 1 & 2 Environmental Qualification Report, Vol. I, Revision 1, December 1982.

GENERIC FIGURES

F-1 and F-2: Reactor Building Temperature and Pressure vs Time after LOCA and MSLB Accidents

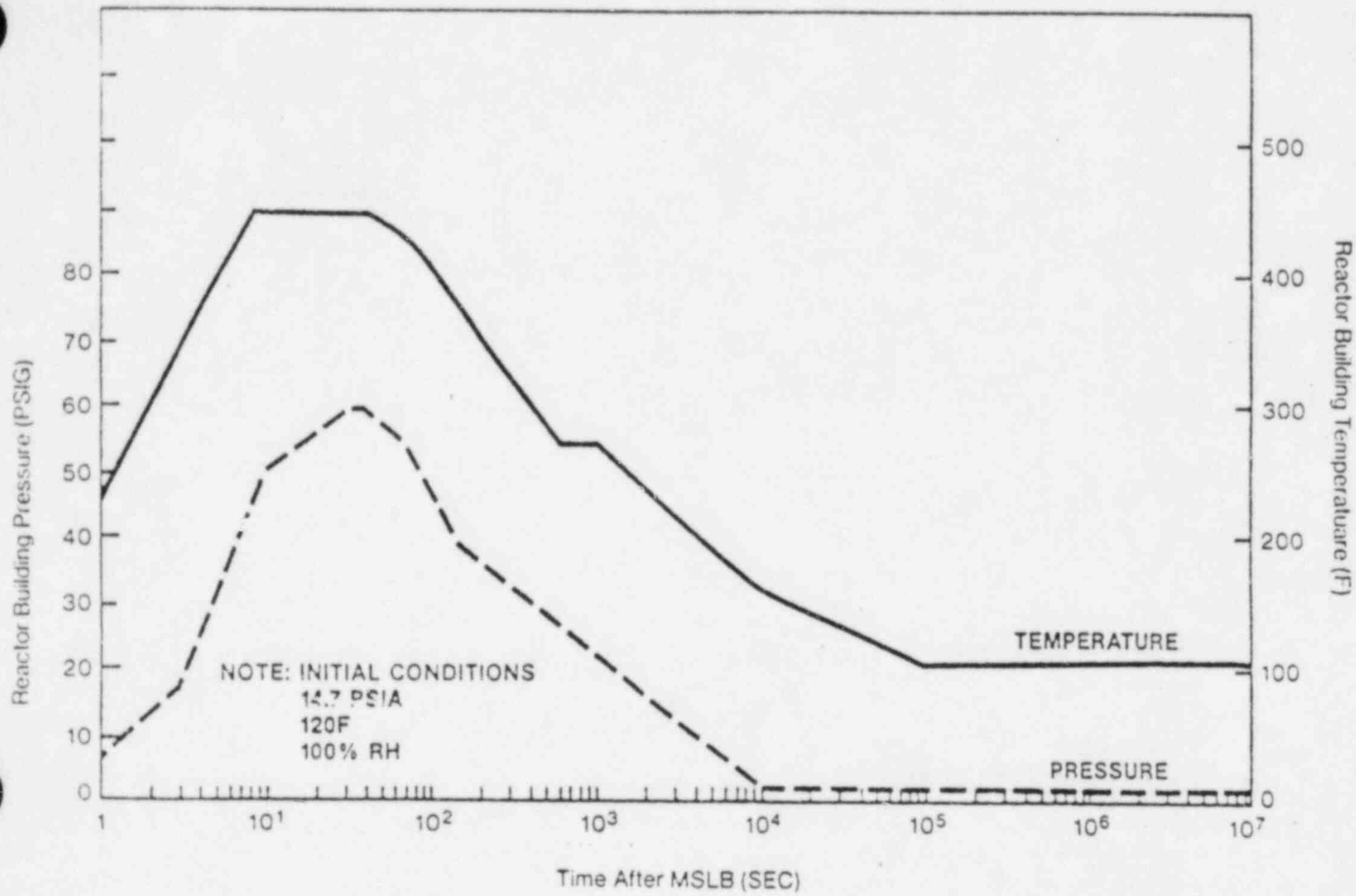
T1 : Present Spray Chemistry



CONSUMERS POWER COMPANY MIDLAND UNITS 1 AND 2
REACTOR BUILDING PRESSURE AND TEMPERATURE VS TIME AFTER LOCA
FIGURE F-1

EO Report Revision 1
12/82

6-G.2536.61



CONSUMERS POWER COMPANY MIDLAND UNITS 1 AND 2
REACTOR BUILDING PRESSURE AND TEMPERATURE VS TIME AFTER MSLB
FIGURE F-2

EQUIPMENT QUALIFICATION REPORT
MIDLAND PLANT UNITS 1 AND 2

T1

PRESENT SPRAY CHEMISTRY

TIME POST-DBA

	0 - 60 MINUTES	60 - 121 MINUTES	121 MINUTES - 30 DAYS
pH	4.5 - 4.6	Increasing	7.0 - 7.5
Boric Acid	13,000 - 14,130 ppm	13,000 - 14,130 ppm	13,000 - 14,130 ppm
Hydrazine	Maintained at 50 - 110 ppm	Maintained at 50 - 110 ppm	Maintenance Stopped
Disodium Phosphate	None	Addition Begun to Control pH to 7.0 - 7.5 at 120 Minutes	Maintain pH to 7.0 - 7.5

ITT GRINNELL CORPORATION
PIPE HANGER DIVISION
RESEARCH, DEVELOPMENT AND
ENGINEERING DEPARTMENT

PHD-5222-1MBM

TECHNICAL MANUAL

FOR MAINTENANCE

LARGE BORE HYDRAULIC SNUBBERS

CONSUMER POWER CO.

MIDLAND PLANT UNITS 1 & 2

JANUARY, 1979

REVISION 3

TECHNICAL MANUAL PHD-5222-1MBM

PREPARED BY: [signature] DATE 1/19/79
Engineer

APPROVED BY: [signature] DATE 1/19/79
Sect. Mgr.

APPROVED BY: [signature] DATE 1/19/79
Dept. Mgr.

TECHNICAL MANUAL PHD-5222-1MBM

REV. SHEET

NO.	DATE	REV.	BY	APPR.	APPR.
1	2/10/81	General Revision	DSS	[illegible]	[illegible]
2	5/14/81	General Revision	DJS	[illegible]	[illegible]
3	7/21/81	Added Note After 7.12.1 and Added Section 7.12.2	DJS	[illegible]	[illegible]

1.0 MAINTENANCE PROCEDURE (14" - 20" HYDRAULIC SNUBBERS)

Maintenance of the Midland Plant Unit 1 & 2 snubbers should be conducted during every normal maintenance or shutdown period. Maintenance need only consist of the following:

1.1 Check cylinder head and cap, valves, fluid line connections and reservoir for signs of fluid leakage. If it is necessary to remove valve covers, procedures contained in the installation manual PHD-5222-2MBI should be followed.

1.2 If leakage is evident at any connections, check for proper tightness. (Ref; PHD-5222- SK 55 and SK 56)

1.2.1 Tighten fractional tube adapter (20) Cajon Fitting, to a torque of 18 ft. lbs.

1.2.2 Tighten fittings (21) and (23) in the following manner. Back off fitting until it can be retightened by hand. Retighten by hand. Tighten fitting by turning 1 1/4 turns.

1.2.3 All other fittings shall be tightened in the following fashion. Back off fitting nut until it can be tightened by hand. Secure nut hand tight and then tighten with a wrench by turning the fitting 1 1/4 turns. If this does not stop leakage, replace fitting - refer to Section 7.0.

1.3 If leakage is evident at valve mounting surface, check torque of valve mounting bolts (18) drawing PHD-5222-SK 55 & 56. Torque on these bolts should be 35 ft. lbs. Torque bolts to this value if required. If this does not stop leakage, refer to Sections 7.0 and 8.0 for inspection or replacement of seals.

1.4 If leakage is evident at any of the following points refer to Section 7.0 for Valve Teardown.

1.4 Cont'd

(Refer to PHD-5222-SK 55 and 56)

a. Velocity adjustment screw (6)

b. Orifice valve stem (2)

c. Between valve body (1) and retainer plate (12)

1.5 If leakage is evident at the valve adjustment screws (See Para. 1.4 a. and b.), any type of modification could result in unit's calibration being affected. (See Section 7.0 for Teardown).

1.6 If leakage is evident at any of the cylinder components, refer to Section 2.0 thru 6.0 for replacement of seals or components.

1.7 Check the fluid level in the reservoir. If the level has dropped below the required level, replenish with GE Silicone Fluid SF-1154. This should be done now only if reservoir is not to be torn down.

1.8 If leakage is evident at any of the reservoir fittings, refer to Section 9.0 for replacement of seals or adjustment.

1.9 Clean exposed portion of piston rod using a non-petroleum based solvent* and clean with a lint free cloth. After cleaning, wipe with a light coat of GE SF-1154 fluid.

1.10 The elastomeric seals used in the snubber assembly can be expected to last for approximately 5 years. Seals should be replaced after this period or at the shutdown preceeding the shutdown which will exceed 5 years.

NOTE: Seals may remain on the shelf for up to five (5) years prior to installation. Once installed and compressed, seal life is five (5) years.

* AVAILABLE NON PETRO BASED SOLVENTS THAT HAVE BEEN USED ARE ZYLENE, ALCOHOL, ETC.

2.0 TEARDOWN FOR REPLACEMENT OF SEALS IN MILLER CYLINDER MODEL 90 PHD-5222-SK 51

This Section covers the following snubbers:

D1, D3, E1B, E3B, F1, B5, B3, B6 & B4

2.1 Disconnect remote reservoir feed tube(s)* from reservoir connection assembly and remove cylinder assembly by reversing the installation procedure as described in PHD-5222-2MBI, to an area where all grime may be removed from external surfaces utilizing a non-petroleum based solvent. Clean exposed threads on tie rods using a wire brush. (*PARALLEL UNITS ARE JOINED TO A COMMON RESERVOIR)

2.2 Units should now be moved to an area that is free of all dust and dirt for disassembly and replacement of seals.

2.3 During disassembly all units shall be cleaned using a non-petroleum based solvent. All seals and wave spring (16) shall be discarded and replaced using new material. Seal and seal cavities shall be wet with clean fresh fluid: Type GE SF-1154 silicone fluid.

2.4 With unit in horizontal position and valves in the top mounted position, remove valves as described in Section 7.0 from the cylinder body and set aside. Pour fluid out of cylinder into a suitable container and discard fluid. Stroking unit will speed this process.

2.5 With the unit still in a horizontal position, the torque on the clevis attachment at the end of the piston rod should be broken.

2.6 Place unit in a (fixture) in the vertical position with piston rod (1) up.

2.7 Remove Clevis Attachment from end of piston rod (1).

2.8 Disassemble cylinder for seal or component replacement as follows:

2.8.1 Removal of Rod Bushing Assembly

2.8.1.1 Remove rod wiper retainer (30) by first removing clip (32) around the retainer screws (21) then washer (31) and then the rod wiper retainer (30).

2.8.1.2 Loosen and remove retainer screws (21) and washers (33) which hold rod bushing (8) and retainer plate (7) to cylinder head (3).

2.8.1.3 Lift retainer plate (7) from cylinder head (3) and remove existing parts from cylinder in the following sequence: (Ref; PHD-5222 SK 54):

Rod Wiper (15) - to be discarded

Rod Bushing (8)

Rod Seal (6) - to be discarded

Rod Pressure Ring (12)

Rod Wave Spring (16) - to be discarded

Rod Seal Cage (13)

2.8.2 Disassembly of Cylinder

2.8.2.1 Loosen and remove tie rod nuts (9) at piston rod (1) end of cylinder.

2.8.2.2 Thread lifting eye rod into threaded holes provided in cylinder head and attach a sling to eye rods. Using an overhead hoist, slowly lift cylinder head (3) above tie rods (11); tapping on the underside of the head (3) with a rubber mallet, while lifting, will aid in freeing the

2.8.2.2 Cont'd

head (3) from the cylinder tube (5) and tie rods (11).

2.8.2.3 Thread a male eye attachment into piston rod (1) end and again using a sling and hoist, slowly raise piston/piston rod (1) from cylinder tube (5), using caution not to bind piston in cylinder tube (5) resulting in damaged components. Place assembly to one side, remove eye attachments and disassemble piston parts as follows:

2.8.2.3.1 Remove piston retaining ring (18) from one side of piston (1). Using a needlenose plier or other suitable means, grasp piston retaining ring (18) and remove from groove in piston (1).

2.8.2.3.2 Slide anti roll ring (17) from piston (1)

2.8.2.3.3 Remove piston seal (2) from piston (1) and discard.

2.8.2.3.4 Remove piston seal back-up ring (10) from piston (1).

2.8.2.3.5 Proceed to remove seals on other side in like manner.

2.8.2.3.6 If scored or severely worn, remove piston wear ring (19). Using snap ring pliers, or other expanding tool, 2.8.2.3.6 Cont'd

expand piston wear ring (19) and slide off piston (1).

2.8.2.4 Remove cylinder tube (5) from cylinder cap (4).

2.8.2.5 Remove cylinder tie rods (11) using vise grips, or other suitable tools. Protect tie rods (11) by wrapping with protective tape, cloth or other methods that will insure tie rods (11) will not be severely scored.

2.8.2.6 Remove cylinder cap (4) from fixture

2.8.2.7 Remove cylinder end seals (14) from O-ring grooves on inner face of cylinder head (3) and cylinder cap (4). Discard seals.

2.8.2.8 Remove fill port plug (23) from cylinder head (3) and cylinder cap (4) and discard O-rings (24).

2.9 Cleaning

2.9.1 Clean all cylinder components using a non-petroleum base solvent and blow dry using oil-free air.

2.9.2 Wire brush all threads and clean thoroughly.

2.10 Inspection

2.10.1 Inspect piston rod (1). If any nicks or scratches are evident on piston rod (1) the vendor shall be notified so that a representative may be present to evaluate the severity of the damage and make recommendation to either rework or replace piston rod.

2.10.2 Inspect additional components for wear that may result in damaged seals or hamper the operation of the units. Replace as required.

2.11 Reassembly of Cylinder

2.11.1 Replacement of Seals

2.11.1.1 Wet all seals and seal cavities with hydraulic fluid (use only type GE SF-1154) prior to installing seals.

2.11.1.2 Insert new O-ring (24) in fill port and replace fill port plug (23)

2.11.1.3 Insert new cylinder end seals (14) into O-ring grooves in the inner-face of the cylinder head (3) and cylinder cap (4).

2.11.1.4 If removed, install a new piston wear ring (19) onto piston (1). Using snap ring pliers or other expanding tool, expand piston wear ring (19) and slide into place on piston (1).

2.11.1.5 Replace piston seal parts (items 2-new, 10, 17, 18)

2.11.1.5.1 Install piston seal back-up ring (10) on piston (1) so that is seats against shoulder.

2.11.1.5.2 Place a new piston seal (2) onto piston (1) flat side of seal to piston seal back-up ring (10)

2.11.1.5.3 Install piston anti-roll ring (17) over piston (1) flat side away from piston seal (2).

2.11.1.5.4 Install piston retaining ring (18) onto piston (1) using needle nose pliers to expand and ensuring that retaining ring (18) seats into groove in piston (1).

2.11.2 Assembly of Components

2.11.2.1 Place cylinder cap (4) back into fixture. Single lug attachment down.

2.11.2.2 Reinstall tie rods (11)

2.11.2.3 Place cylinder tube (5) into groove in cylinder cap (4). Coat tube with a thin layer of GE SF-1154 hydraulic fluid.

2.11.2.4 Next place a tapered starting ring or piston ring compressor over piston seal (2) at the end opposite piston rod (1).

2.11.2.5 Install eye attachment into piston rod (1). Using a sling and overhead hoist, raise piston/piston rod assembly (1) by use of the lifting eye attachment to a position directly above cylinder tube (5).

2.11.2.6 Slowly lower piston/piston rod assembly (1) into cylinder tube (5). When a point is reached where tapered ring or ring compressor interfere, remove from piston (1) and continue lowering assembly into cylinder tube (5). Taking precautions to insure piston assembly (1) does not bind, continue lowering until piston (1) bottoms against cylinder cap (4).

2.11.2.7 Remove lifting eye attachment and sling.

2.11.2.8 Using sling and hoist, lift cylinder head (3) over piston rod (1) align cylinder head (3) to mate tie rod holes to tie rods (11). Insure that snubber valve ports on cylinder head (3) and cylinder cap (4) are on the same side of the unit.

2.11.2.8 Cont'd

Lower cylinder head (4) onto the unit so that the groove on the inner face of the cylinder head mates to cylinder tube (5).

2.11.2.9 Reinstall tie rod nuts (9), applying molycote to tie rod threads.

2.11.3 Replacement of Rod Bushing Assembly

2.11.3.1 Place rod seal cage (13) over piston rod (1) and into counterbore in cylinder head (3).

2.11.3.2 Install new rod wave spring (16) over piston rod (1) and seat into rod seal cage (13).

2.11.3.3 Place rod pressure ring (12) over piston rod (1) so that its flat side bears against rod wave spring (16).

2.11.3.4 Install new rod seal (6) into seal cavity of bushing (8) making sure that the rod seal (6) is properly seated. Place bushing (8) over piston rod (1) and into bushing cavity in cylinder head (3), rod seal (6) down.

2.11.3.5 Place retainer plate (7) over piston rod (1). Align retainer plate (7) with tapped holes in cylinder head (3).

2.11.3.6 Install washer (33) and retainer screw (21) and torque in accordance with Section 8.0.

2.11.3.7 Install new rod wiper (15) over piston rod, insuring that the wiper (15) is secured behind the retaining lip provided in the rod bushing (8).

2.11.3.8 Install wiper rod retainer over piston rod to keep the rod wiper in place.

2.11.4 Remove unit from the fixture and place in a horizontal position.

2.11.5 Torque cylinder tie rod nuts (9) in accordance with Section 8.0

2.11.6 Attach clevis attachment to end of piston rod (1) and torque to a value of 6,000 ft.lbs.

3.0 TEARDOWN FOR REPLACEMENT OF SEALS IN MILLER CYLINDER MODEL 90 - SHORT STROKE - PHD-5222-SK 51

This section covers the following snubbers:

D4, I1, I2, E1A, E3A, F2, G1, G2, J2

3.1 Accomplish steps 2.1 thru 2.7, Section 2.0

3.2 Disassemble cylinder for seal or component replacement as follows:

3.2.1 Removal of Rod Bushing Assembly

3.2.1.1 Mount adapter plate with O-ring over valve port in cylinder cap (4). Install four mounting bolts and secure.

3.2.1.2 Remove rod wiper retainer (3) by first removing clip (32) around the retainer screws (21) then washer (31) and then the rod wiper retainer (30).

3.2.1.3 Using an air hose provide 80 psi filtered air to cylinder at the fill port in the cylinder cap (4). This pressure will provide means to fully extend piston rod (1). Maintaining pressure now remove retaining ring (22) from piston rod (1).

3.2.1.4 Decrease air pressure so that the piston rod (1) now retracts and bottoms out against cylinder cap (4).

3.2.1.5 Loosen and remove retainer screws (21) and washers (33) and lift retainer plate (7) from cylinder head (3). Remove existing parts from cylinder head (3) in the following sequence as shown on drawing PHD-5222-11 SK 54:

Rod Wiper (15) - discard

Bushing (8)

3.2.1.5 Cont'd

Rod Seal (6) - discard

Rod Pressure Ring (12)

Rod Wave Spring (16) - discard

Rod Seal Cage (13)

3.3 Accomplish Steps 2.8.2 thru 2.11.2.9 Section 2.0

3.4 Replacement of Rod Bushing Assembly

3.4.1 Provide 80 psi air to cylinder cap (4) to fully extend piston rod. Maintain pressure while installing rod seal parts.

3.4.2 Accomplish step 2.11.3, Section 2.0

3.4.3 Reinstall retainer ring (22) in groove on piston rod (1)

3.4.4 Release air pressure and allow retainer ring (22) to come to rest against rod bushing (8).

3.5 Torque cylinder tie rod nuts (9) in accordance with Section 8.0

3.6 Remove unit from the fixture and place in a horizontal position.

3.7 Attach clevis attachment to end of piston rod (1) and torque to a value of 6,000 ft. lbs.

4.0 TEARDOWN FOR REPLACEMENT OF SEALS IN MILLER CYLINDER MODEL 52

PHD-5222-SK 52

This Section covers snubbers B1 & B2

4.1 Accomplish Steps 2.1 thru 2.3, Section 2.0

4.2 With cylinder in horizontal position, remove extension piece.

4.3 Accomplish Steps 2.4 thru 2.8.1.3, Section 2.0

4.4 Removal of External Bearing

4.4.1 Loosen and remove retainer screws (26) and washers (33).

4.4.2 Lift external bearing (25) from cavity in cylinder head (3)

4.4.3 Remove and discard external bearing seal (27)

4.5 Accomplish Steps 2.3.2 thru 2.11.2.9, Section 2.0

4.6 Replacement of External Bearing

4.6.1 Install new external bearing seal (27) over hub on rear of external bearing (25)

4.6.2 Install external bearing (25) by placing external bearing, seal down, into counterbore in cylinder head (3).

4.6.3 Install retainer screws (26) and washers (33) and torque in accordance with Section 8.0.

4.7 Accomplish Steps 2.11.3 thru 2.11.6, Section 2.0

4.8 Attach extension piece torquing nuts and bolts in accordance with Section 8.0.

5.0 TEARDOWN FOR REPLACEMENT OF SEALS IN MILLER CYLINDER MODEL 52 SHORT STROKE, PHD-5222-SK 52

This section covers the following snubbers:

C1, C2, D2, E2, E4, A1, A2, H1 & H2

5.1 Refer to Section 4.0 for the sequence of disassembly and assembly of these particular units.

5.2 The only variation will exists in the removal and replacement of the rod seal parts. Air pressure will again be required for extending and maintaining piston rod position. Refer to Section 3.0, 3.2 and 3.4 for this information.

6.0 TEARDOWN FOR REPLACEMENT OF SEALS IN MILLER CYLINDER MODEL 52 SHORT STROKE, PHD-5222-SK 53

Assembly # J1

6.1 These cylinders have the same basic structural characteristics, and are to be worked the same as those in Section 5.0, with the exception of the cylinder tie rods (11).

6.2 As may be noted on procedural drawing PHD-5222-SK 53 the tie rods (11) extend through the cylinder cap (4) and extension Piece (28), threading into the pivot lug attachment (29) rather than threading into the cylinder cap (4) as on other units.

6.3 The only additional precautionary measure to be taken on this unit is during reassembly:

6.3.1 Prior to reassembly as stated in Section 5.0, install the pivot lug attachment (29) into the fixture.

6.3.2 Lift extension piece (28) into place on pivot lug (29) and align tie rod holes. Insure proper orientation of pivot lug (29) to extension piece (28).

6.3.3 Lift cylinder cap (4) into place on extension piece (29) assuring correct location for the valve mounting port in relation to pivot lug (29) and extension piece (28).

6.3.4 Reassemble remaining components as stated in Section 5.0.

7.0 <u>TEARDOWN PROCEDURE FOR THE SNUBBER VALVE/PHD-5222-SK 55 & SK 56</u>

7.1 Drain reservoir as described in Section 9.0

7.2 (Ref; PHD-5222-SK 55) Remove reservoir connection assembly from the valve connection tubing tee (24) by backing off fitting nut (23). Free reservoir connection assembly tee (24) and plug or cap tee (24).

7.3 During disassembly all valve fitting, tubing and components <u>except</u> seals shall be cleaned using a non-petroleum based solvent and blown dry using clean oil free air. All seals used shall be discarded. New seals and seal cavities shall be wet with clean fresh GE silicone fluid #SF-1154 just prior to installation.

7.4 Removal of Valve from Cylinder

7.4.1 Remove tamperproof cover from valve body (1) as described in procedure PHD-5222-2MBI

7.5 Loosen fitting nut (21) located at valve on cap end of cylinder.

7.6 Loosen fitting nut (21) located at valve on head end of cylinder.

7.7 Loosen and remove valve mounting bolts (18) at valve located at cylinder cap.

7.8 Lift valve body (1) free of cylinder cap and connecting tube (22)

7.9 Loosen and remove valve mounting bolt (18) at valve located at cylinder head.

7.10 Making sure connecting tube (consisting of 21, 22, 23 and 24) does not bend or hang, lift valve body (1) free of cylinder head and connecting tube (22).

7.11 Drain snubber valve bodies of fluid. Drain connecting tube (21, 22, 23 and 24) of fluid and place to one side.

7.12 Seal and/or Component Replacement: The following disassembly/assembly sequence should be used for replacement of elastomeric seals or components as required.

7.12.1 Disassembly of Valve

NOTE: All parts to be reused should be marked and kept with the valve from which removed. Parts are not to be interchanged.

7.12.1.1 Removal of fittings

7.12.1.1.1 Loosen and remove fractional tube connector (20)

7.12.1.1.2 Remove and discard O'ring (19)

7.12.1.2 Place valve on table with adjustment screws up.

7.12.1.3 Using a screwdriver hold orifice valve stem (2) and loosen jam nut (3).

7.12.1.4 Remove orifice valve stem (2) from valve body (1). The following components shall be removed from the orifice valve stem:

a. Jam nut (3)

b. Washer (4)

c. Thread seal (5), Discard

7.12.1.5 Using an allen wrench secure velocity adjustment screw (6) and loosen jam nut (7).

7.12.1.6 Remove velocity adjustment screw (6) from valve body (1). The following components shall be removed from the velocity screw (6):

a. Jam Nut (7)

b. Washer (8)

c. Thread seal (9), Discard

7.12.1.7 Invert valve body (1)

7.12.1.8 Remove and discard O'ring (10)

7.12.1.9 Loosen and remove retainer plate screws (11). Lift retainer plate (12) from valve body.

7.12.1.10 The following components shall then be removed in sequence from valve body (1):

a. O'ring (13)

b. Valve seat disc (14)

c. Poppet valve (15)

d. Spring (16)

e. Spring Plunger (17)

7.12.1.11 Repeat Steps 7.12.1.1 thru 7.12.1.10 for the second valve

7.12.2 Cleaning of Valve

7.12.2.1 The valve body should be thoroughly rinsed using pressurized filtered Freon TF solvent. All ports, cavities, blind holes, etc. must be flushed of any particles accumulated during use. Filtered air should then be blown through all areas.

7.12.2.2 All parts to be reused in valve should be thoroughly rinsed using pressurized filtered Freon TF solvent then blown dry with filtered air.

7.12.3 Assembly of Valve (NOTE: All Seals and Mating Valve Surfaces are to be Wet with GE SF-1154 Silicone Fluid Before Installation)

7.12.3.1 Place the valve block (1) inverted on the bench with large hole facing up.

7.12.3.2 Install plunger (17) into the body (1) with the flat side of the plunger (17) facing down.

7.12.3.3 Install spring (16) into the body (1) so it seats over the short stem on the plunger (17).

7.12.3.4 Install valve poppet (15) into the body with hex end facing down and so the short stem on the poppet seats in the spring (16).

7.12.3.5 Slide the valve seat disc (14) over the long stem on the poppet and seat the disc (14) in the valve body (1). (NOTE: The Chamfer Must Face the Poppet).

7.12.3.6 Install retaining plate (12) aw follows:

7.12.3.6.1 Set -125 O'ring (13) in place on top of the valve seat disc (14).

7.12.3.6.2 Push the valve seat disc down (14) until firmly seated.

7.12.3.6.3 Using a small rod, hold the seat disk (14) down against the poppet (15) stem and plate the retaining plate (12) in position, aligning the holes with the threaded holes in the valve body.

NOTE: The retaining plate (12) should be placed directly on the valve body (1) during this operation, with minimum sliding between the two. Sliding can affect the proper seating of the O'ring.

7.12.3.6.4 While holding the retaining plate (12) firmly, release the seat disc (14).

7.12.3.6.5 Install the two retaining plate screws (11) and tighten.

7.12.3.6.5 Cont'd

<u>NOTE</u>: The remaining O'ring (10) will be installed when the valve is assembled to cylinder.

7.12.3.7 Invert the assembly so that it sits on the bench with the retaining plate (10) at the bottom.

7.12.3.8 Install the locking velocity screw (6) as follows:

7.12.3.8.1 Screw the 1/4 thread seal (9) on the socket end of the locking velocity screw (6) so that it is approximately 1/4 in. from the socket end of the screw.

7.12.3.8.2 Slide the washer (8) over the socket end of the screw (6) until it is against the thread seal (9).

7.12.3.8.3 Screw the hex nut (7) on the socket end of screw (6) until the socket end of the screw (6) extends 1/8" beyond the edge of the hex nut (7).

7.12.3.8.4 While holding the hex nut (7) fixed on the screw (6), screw the thread seal (9) toward the hex nut (7) until snug against the washer (8) and hex nut (7).

7.12.3.8.5 Screw the velocity locking screw (6) assembly into the body (1) in the threaded hole, over the plunger (17) and spring assembly, until snug.

7.12.3.8.6 While holding the screw (6) with an allen wrench, tighten the hex nut (7) an additional 1/4 turn.

7.12.3.9 Install the orifice stem screw (2) as follows:

7.12.3.9.1 Screw the 1/4 thread seal (5) over the tapered end of the screw to approximately 3/4 in. from the slotted end.

7.12.3.9.2 Fit the washer (4) over the slotted end of the screw (2) until snug against the thread seal (5).

7.12.3.9.3 Screw the hex nut (3) on the slotted end of the screw (2) until snug against the washer (4) and thread seal (5).

7.12.3.9.4 Screw the orifice stem screw (2) assembly into the remaining threaded hole in the valve body (1) until snug.

7.12.3.9.5 While holding the screw (2) with a screwdriver, tighten the hex nut (3) an additional 1/4 turn with a wrench.

7.12.3.10 Repeat Step 7.12.3 for the second snubber valve.

7.13 Replacement of Fitting

7.13.1 Install new O'ring (19) onto fractional tube adapter (20) and thread into valve port on side of valve.

7.13.2 Install tubing (22) onto fractional tube adapter (20) and engage fitting nut (21). Snug fitting nut (21) hand tight.

7.13.3 Repeat Steps 7.13.1 and 7.13.2 for second snubber valve.

7.14 Disassembly/Assembly Procedure Connecting Tubing

7.14.1 Remove the plug from the tee (24) on valve connection tubing.

7.14.2 Connect reservoir connection assembly to valve connection tubing at the tee (24).

7.15 Mounting Valve on Cylinders

7.15.1 Install O'rings (10) into O'ring grooves in valve retainer plates (12). Mount one valve body (1) on the cap end of cylinder so that the valve port and cap mounting port are aligned, and the fractional tube adapter (20) are facing in the direction of the cylinder head.

7.15.2 Install and engage valve mounting bolts (18) loosely.

7.15.3 Place additional valve body (1) on head end of cylinder.

7.15.4 Install and engage valve mounting bolts loosely.

7.15.5 Torque mounting bolts (18) on both valve bodies to 35 ft/lbs.

7.15.6 Tighten fractional tube adapters (20) at both valve connections.

7.15.7 Carefully check all tubing connections for proper engagement and alignment. Once this is completed, tighten all fitting nuts (Ref; Section 1.0)

7.16 The above procedure may be used for installation of the top mounted valve connection assembly (SK. PHD-5222-SK 56).

8.0 TORQUE REQUIREMENTS - CYLINDERS

8.1 Torque - Cylinder Tie Rods

8.1.1 Attached drawings in this section depict the various bolt patterns for the cylinders on this project.

PHD-5222 SK 57 - quantity of 20 tie rods

PHD-5222 SK 58 - quantity of 24 tie rods

PHD-5222 SK 59 - quantity of 28 tie rods

Each sketch shows numbered tie rod locations which is the sequence in which each tie rod shall be snugged down or torqued.

8.1.2 Check to insure that molycote has been applied to all tie rod threads before installation.

8.1.3 Method - Turn of The Nut

8.1.3.1 Pre-torque tie rod nuts to the value specified in Table 1 in the order shown on one of the above drawings.

8.1.3.2 Mark a point on both the cylinder head and tie rod nut where they join (see detail SK 57). Call mark on head point 1 and mark on tie rod nut point 2.

8.1.3.3. Using available angle measuring device mark on head a third and fourth point counterclockwise from point 1 at 50% and 100% of the degrees shown on Table 1

8.1.3.4 Insert allen wrench into socket head nuts and rotate nut clockwise until point 2 is directly in line with point 3.

8.1.3.5 Continue this process in sequence on chart until all tie rod nuts have been tightened to point 3.

8.1.3.6 Repeat Steps 8.1.3.4 and 8.1.3.5 aligning point 2 with point 4 until all tie rod nuts are tightened.

8.2 Torque Circular Retainer

8.2.1 PHD-5222 SK 60 & 61 contained in this section depict the various bolt patterns for the cylinders on this project.

PHD-5222-SK 60 - quantity of 16 retainer screws

PHD-5222-SK 61 - quantity of 20 retainer screws

Each sketch shows numbered retainer screws locations which is the sequence in which each retainer screw shall be snugged down or torqued. These values are shown on Table 1.

8.2.2 Tighten using the methods of Step 8.1.3.

8.3 Torque External Bearing

8.3.1 PHD-5222 SK 62 contained in this section depicts the bolt patterns for the cylinders on this project. The drawing shows numbered retainer screws locations which is the sequence that each retainer screw shall be snugged down or torqued. These values are shown on Table 1.

8.3.2 Tighten using the methods of Step 8.1.3.

8.4 Torque Extension Piece Nuts and Bolts

8.4.1 Using a torque wrench snug down and torque extension piece nuts and bolts in same sequence as that shown for tie rods (ref. Para. 8.1.1).

8.4.2 Snug all nuts and bolts initially to 100 ft. lbs.

8.4.3 Torque all nuts and bolts initially to 1/3 values shown below in Step 8.4.5 in correct sequence.

8.4.4 Repeat torquing in sequence to 2/3 value and then to full value.

8.4.5 Torque values for extension piece nuts and bolts for units based on pivot pin sizes are as follows:

Pivot Pin Dia. (in.)	Torque (Ft. Lbs.)
4.5	984
5.0	1038
6.0	1061
9.44	1061

NOTE: Bolts and nuts may be retorqued and reused at any time unless upon inspection, a defect in either is determined.

TA[illegible] I

				Tie Rod * 1 1/4-12 Thread		Circular Retainer 5/16-24 Thread		External Bearing (12) 1/2-20 Thread
CYL. NO.	MODEL	BORE DIA.	NO. TIE RODS	TORQUE (FT. LB)	TURN OF NUT (DEGREES)	NO. SCREWS	TORQUE ** (FT. LB)	TORQUE ** (FT. LB)
C1	52	14	20	665	197	16	20	80
C2	52	14	20	665	197	16	20	80
D1, D3	90	14	20	665	122	16	20	--
D4	90	14	20	665	124	16	20	--
I1, I2	90	14	20	665	295	16	20	--
D2	52	16	20	665	151	16	20	80
E1A, E3A	90	16	24	695	226	16	20	--
E1B, E3B	90	16	24	695	226	16	20	--
E2	52	16	24	695	224	16	20	80
E4	52	16	24	695	224	16	20	80
F1	90	16	24	695	156	16	20	--
F2	90	16	24	695	137	16	20	--
G1, G2	90	16	28	715	165	20	20	--
A1	52	18	28	715	168	16	20	80
A2	52	18	28	715	168	16	20	80
B5	90	18	28	715	149	16	20	--
J1	52	18	24	695	327	16	20	80
J2	90	18	24	695	137	16	20	--
B1	52	20	28	715	169	16	20	80
B2	52	20	28	715	168	16	20	80
B3, B6	90	20	28	715	170	16	20	--
B4	90	20	28	715	156	16	20	--
H1	52	20	28	715	209	16	20	80
H2	52	20	28	715	209	16	20	80

* TIE ROD NUT PRETORQUE - 100 FT. LBS (ALL CYLINDERS)

** PRETORQUE TO 50% OF TORQUE VALUES LISTED ABOVE

9.0 TEARDOWN FOR REPLACEMENT OF SEALS, OIL-RITE RESERVOIRS PHD-5222-SK 63 & 64

9.1 This procedure covers reservoirs of 3 gal. capacity (PHD-5222-SK 63) and 5 and 10 gal. capacity (PHD-5222-SK 64) which are essentially identical except for size and mounting brackets.

9.2 During disassembly all fittings and components except seals shall be cleaned using a non-petroleum based solvent and blown dry using clean, oil free air. All seals shall be discarded. New seals and seal cavities shall be wet with clean, fresh G.E. silicone fluid # SF-1154 just prior to installation.

9.3 Drain reservoir into suitable container by removing pipe plug (7) from drain adapter (4).

9.4 Remove steel tubing from 1" NPT male connector (11) by backing off fitting nut (12). Free and secure steel tubing.

9.5 Remove 1" NPT male connector (11).

9.6 Remove cover hold down screws (16) and remove cover (3).

9.7 Secure drain adapter (4) on inside of reservoir and remove jam nut (6). This frees 3 gal capacity reservoir from mounting bracket (2). Drain reservoir of any remaining fluid. Secure mounting bolt and jam nut and discard O'ring (5).

NOTE: The following steps will be accomplished with 3 gal. capacity reservoir removed from mounting bracket.

9.8 Secure filter adapter (14) unscrew filter body (20) and remove it and filter (18) from filter adapter (14). Remove jam nut (13). Discard O'ring (15).

9.9 Secure tube adapter (8) and remove jam nut (10). This frees 5 and 10 gal. capacity reservoirs from mounting bracket (2). Drain reservoir of any remaining fluid. Secure mounting bolt and jam nut and discard O'ring (9).

9.10 Remove two sight glass mounting nuts (17) and remove sight glass assembly (19).

9.11 Disassemble sight glass (ref. Detail PHD-5222-SK 63) as follows:

9.11.1 Unscrew two mounting studs (39) from sight glass body (32). Remove O'rings (33) and discard.

9.11.2 Remove sight glass cap (34). Remove O'ring (38) and discard.

9.11.3 Remove securing screw (35).

9.11.4 Gently pressing inward and upward on sight glass (36) remove it and tap O'ring (37) from sight glass body (32). Discard O'ring.

9.11.5 Remove lower O'ring (37) and discard.

9.12 Clean all components and prepare for reassembly as indicated in 9.2.

9.13 Assembly of sight glass can be accomplished in reverse order of disassembly with the following noted:

9.13.1 Assure that lower and upper sight glass O'rings (37) are properly seated.

9.13.2 Mounting stud O'rings (33) should be carefully assembled over threads leaving approximately 1/4 inch of thread to be threaded into sight glass body.

9.14 Assembly of reservoir can be accomplished in reverse order of assembly making proper assembly to mounting brackets when required.

10.0 FLUID REQUIREMENTS PER SNUBBER

Snubber	Fluid Required (Gallons)
A1	10.38
A2	10.38
B1	8.45
B2	9.53
B3	8.37
B4	8.65
B5	8.08
B6	8.37
C1	15.04
C2	15.02
D1	7.21
D2	11.73
D3	7.21
D4	9.19
E1A	17.78
E1B	17.78
E2	17.87
E3A	17.78
E3B	17.78
E4	17.87
F1	10.71
F2	10.28
G1	12.42
G2	12.42
H1	16.80
H2	16.80
I1	22.90
I2	22.90
J1	12.74
J2	9.92

11.0 SPARE PARTS

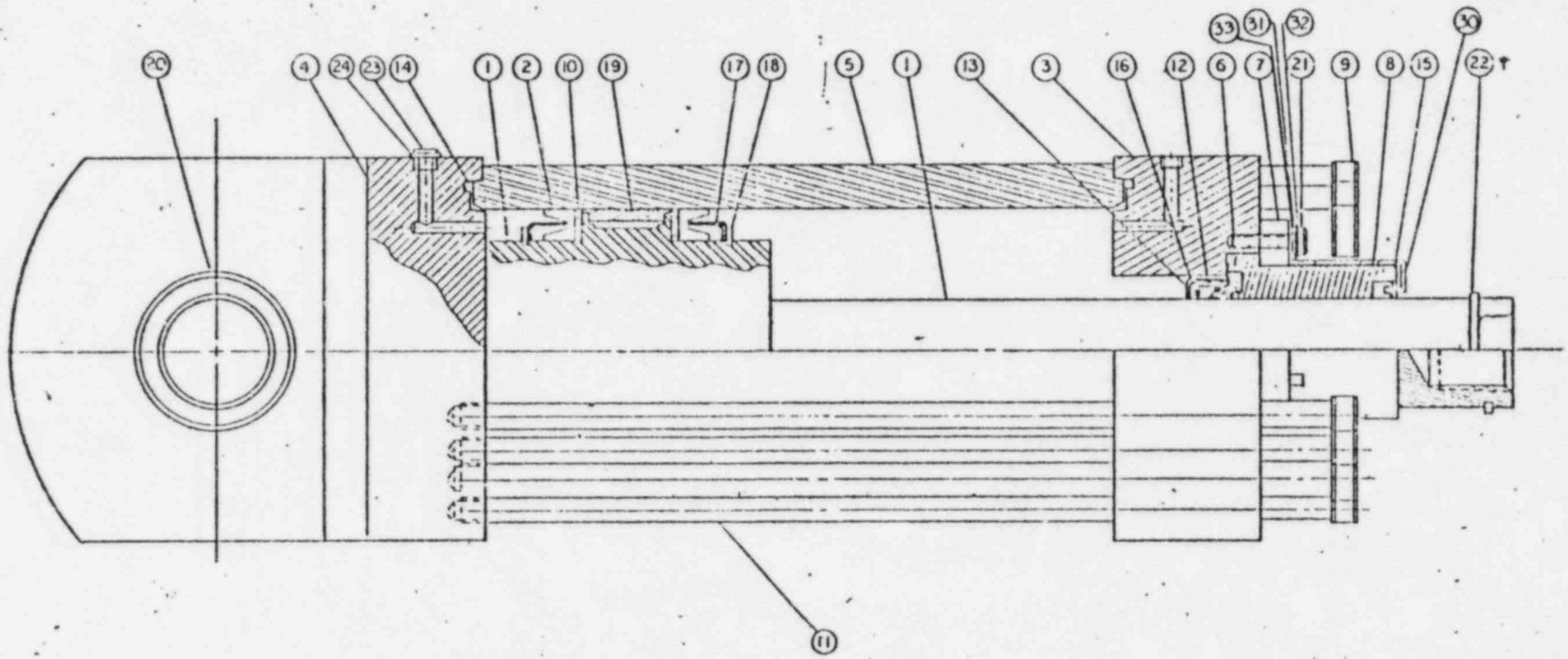
QTY./SNUBBER			
1		Cylinder Seal Kit Including:	
	2	Piston Seals	
	1	Rod Seal	
	1	Rod Wiper	
	2	Cylinder End Seals	
1		Rod Bushing	
1		Rod Seal Cage	
1		Rod PressureRing	
1		Rod Wave Spring	
1		Piston Wear Ring	
16		Retainer Screws	

THE ABOVE AS SHOWN ON MILLER DWG.# D5689H SHTS. 1 & 2

1		Spherical Bearing 4.5 I.D. SKF GEZ-408ES	
1		Spherical Bearing 5.0 I.D. SKF GEZ-500ES	
1		Spherical Bearing 6.0 I.D. SKF GEZ-600ES	
1		Valve Seal Kit Including:	
	4	Thread Seals	-1/4
	6	O'ring (2/Valve; 1/Port plate)	-125
	2	O'ring (male connector)	-916
	2	O'ring (fill ports)	-908
	2	O'ring (plug valve)	-211
	1	O'ring (plug valve)	-113
3		Reservoir Assembly Seal Kit ((1) 3 Gal., (1) 5 Gal., (1) 10 Gal.)	
	6	O'ring (Mtg. Studs)	-112
	3	O'ring (Cap)	-015
	6	O'ring (Sight Glass Gauge)	-109

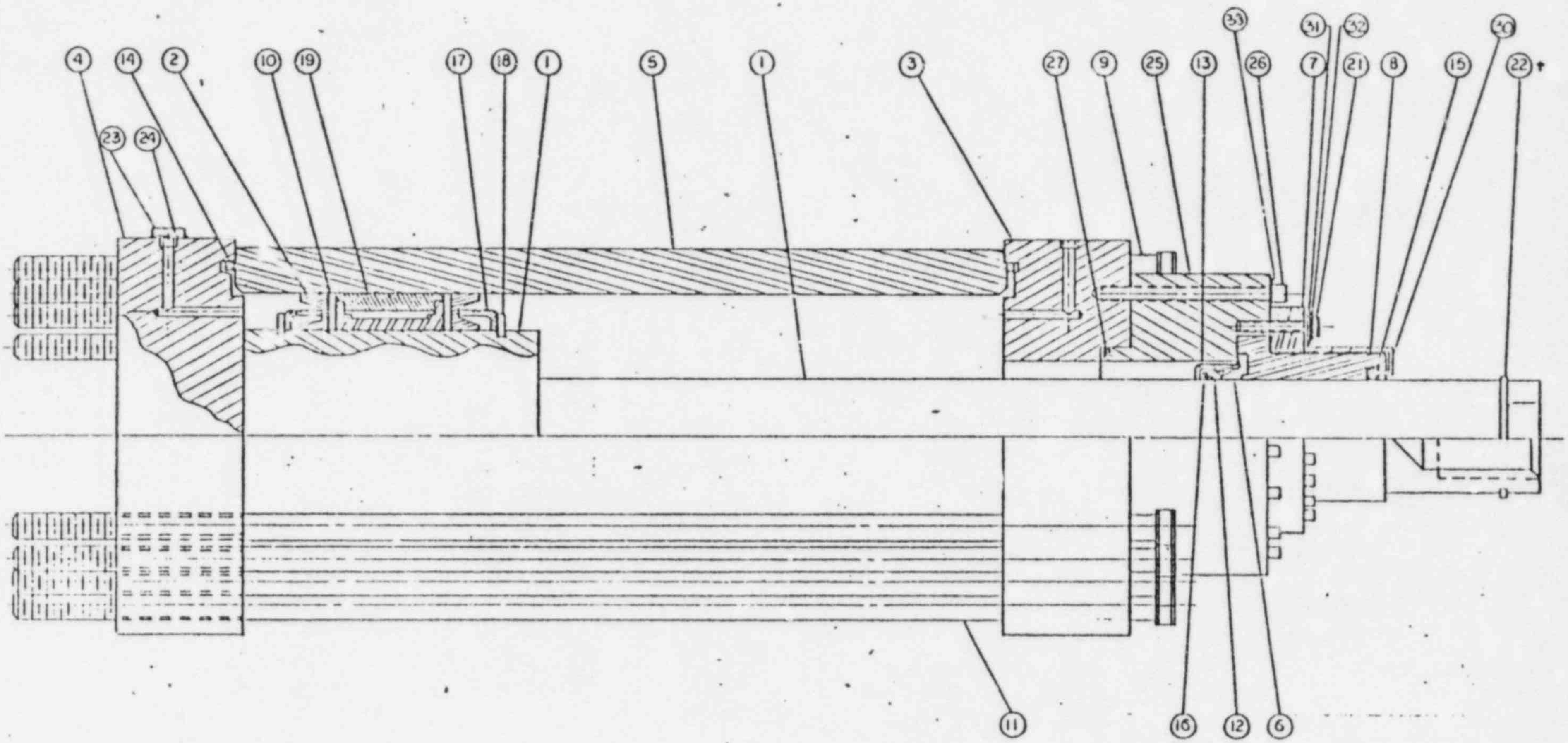
11.0 SPARE PARTS (Cont'd)

	3	O'ring (Outlet Adapter)	-132
	6	O'ring (Drain and Filter Adapter)	-120
10		Sight Glass Assemblies	



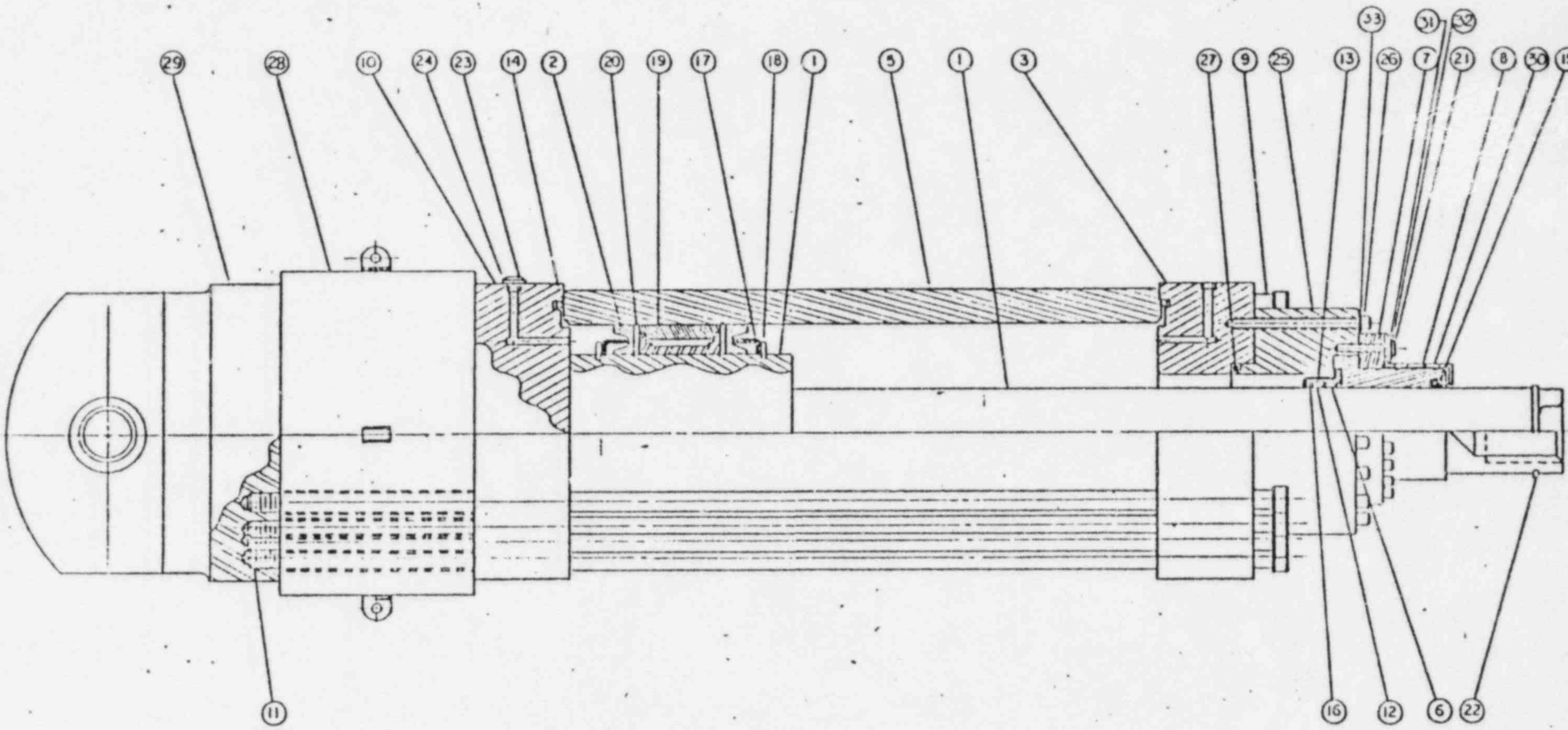
NOTE:
† USED ON SHORT STROKE CYL. ONLY

SCALE: E.P.L.	LIST OF PARTS	ITT Grinnell Corporation PIPE HANGER DIVISION RESEARCH, DEVELOPMENT & ENGINEERING PROVIDENCE, R.I.
MAT'L SPEC.	SUPERSEDES	
FAB. SPEC.	TOLERANCE EXCEPT AS NOTED / DATE 1-27-79	C VILLER CYLFCER W.CEL 50
WELD SPEC.	FRAC. / DEC. / ANG.	DRAWN / CHK'D / APP'D
NDE PROCEDURE		PHD-5222-SK-51
FINISH, EXCEPT AS NOTED		REV
Q.A. REVIEW		

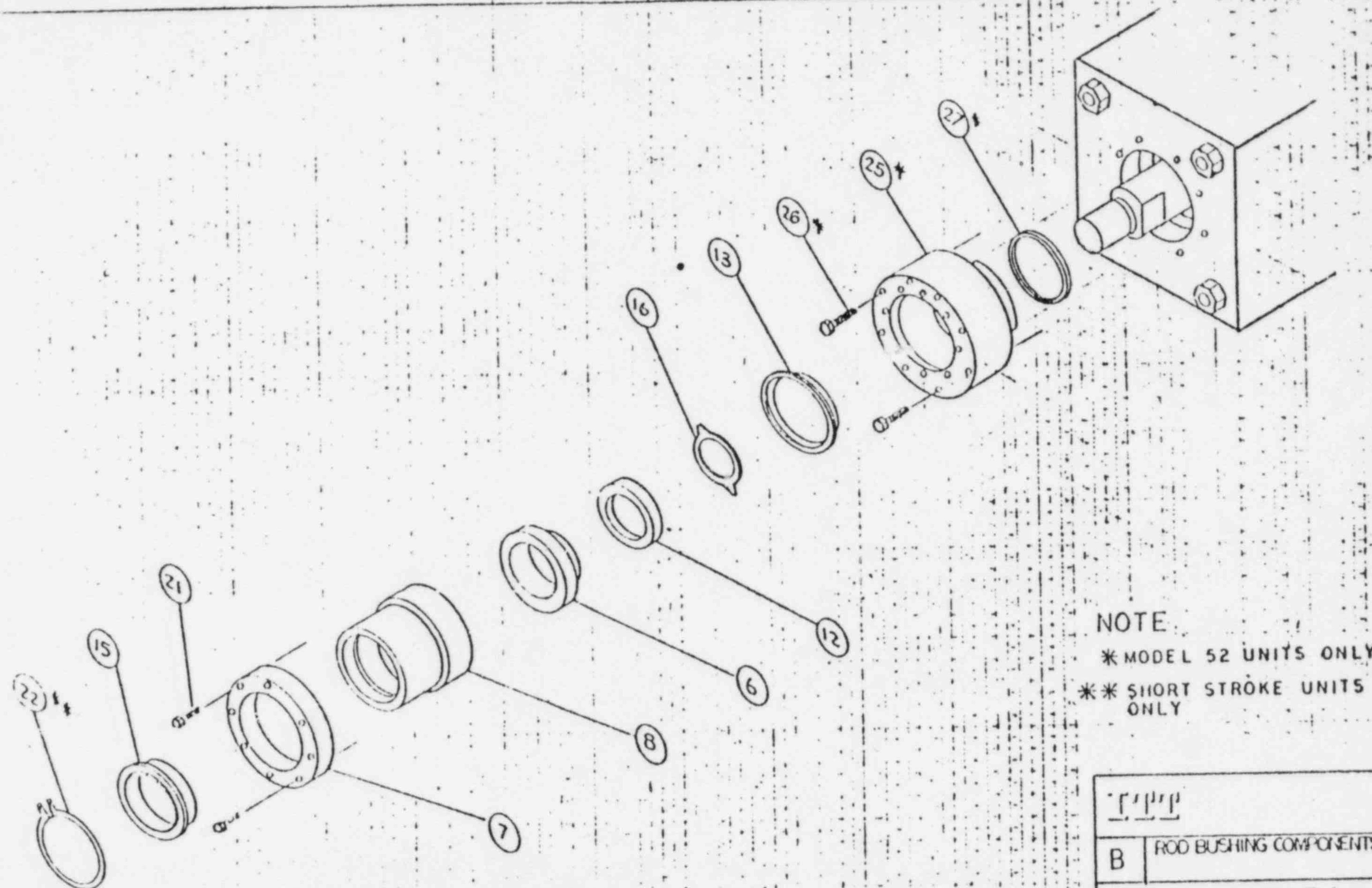


NOTE:
† USED ONLY ON SHORT STROKE CYL.

SCALE: NONE. E.P.L. MAT'L. SPEC. FAB. SPEC. WELD SPEC. NDE PROCEDURE FINISH EXCEPT AS NOTED Q.A. REVIEW	LIST OF PARTS SUPERSEDES TOLERANCE EXCEPT AS NOTED FRAC. DEC. ANG. DATE: 1-27-75 DRAWN: RG CHK'D APP'D	ITT Grinnell Corporation PIPE HANGER DIVISION RESEARCH, DEVELOPMENT & ENGINEERING PROVIDENCE R.I. C VILLER CYLINDER MODEL 52 PHD-5222-SK-52 REV



SCALE: NONE E.P.L.	LIST OF PARTS	ITT Grinnell Corporation PIPE HANGER DIVISION RESEARCH, DEVELOPMENT & ENGINEERING PROVIDENCE, R.I.
MAT'L SPEC. FAB. SPEC. WELD SPEC. NDE PROCEDURE FINISH EXCEPT AS NOTED Q.A. REVIEW	SUPERSEDES TOLERANCE EXCEPT AS NOTED: FRAC. DEC. ANG. DATE 1-27-79 DRAWN S.L. CHK'D APP'D	C MILLER CYLINDER - MODEL 52 SHORT STROKE ~ JI ASSY. PHD-5222-SK-53 REV



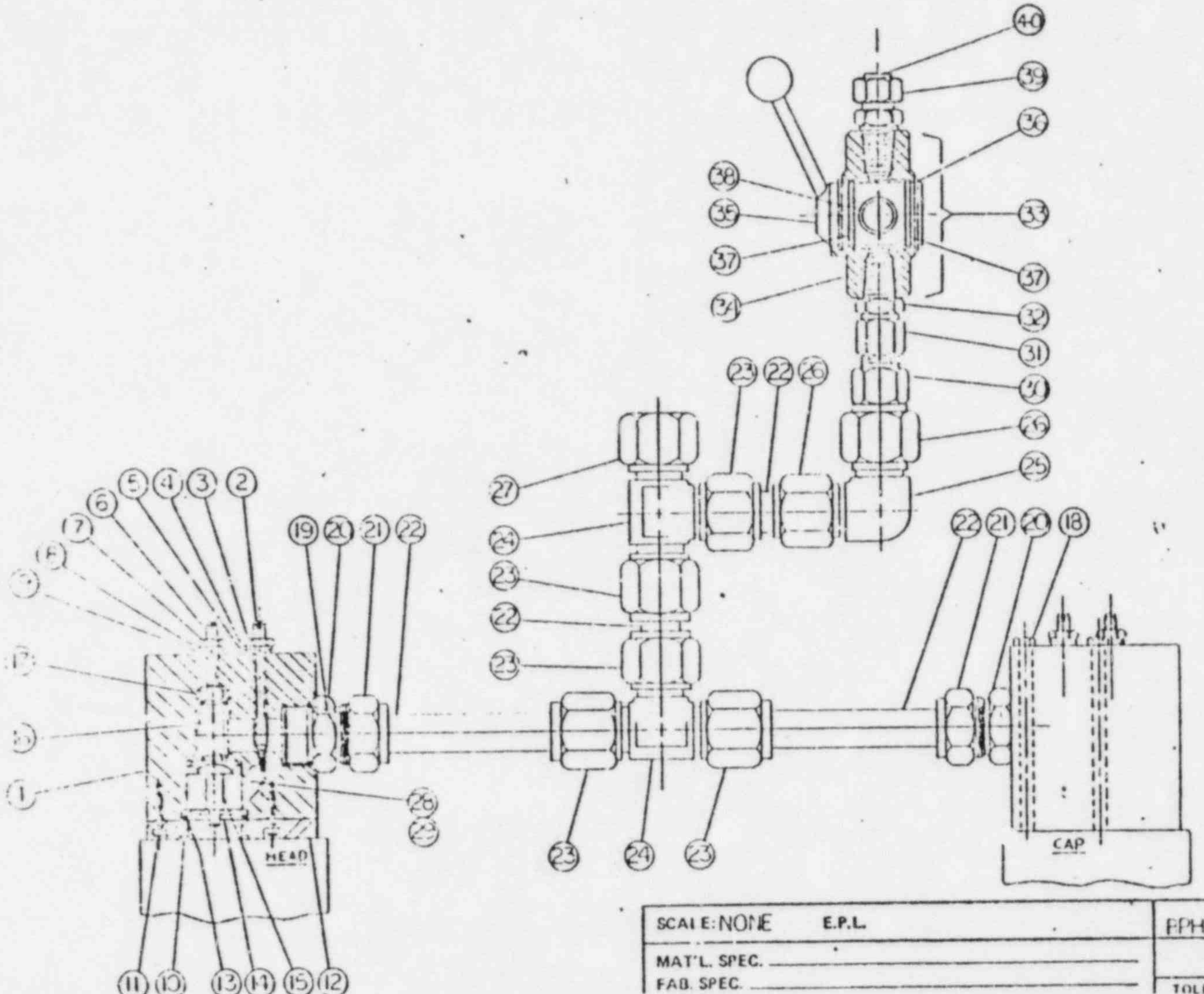
NOTE

✱ MODEL 52 UNITS ONLY

✱✱ SHORT STROKE UNITS ONLY

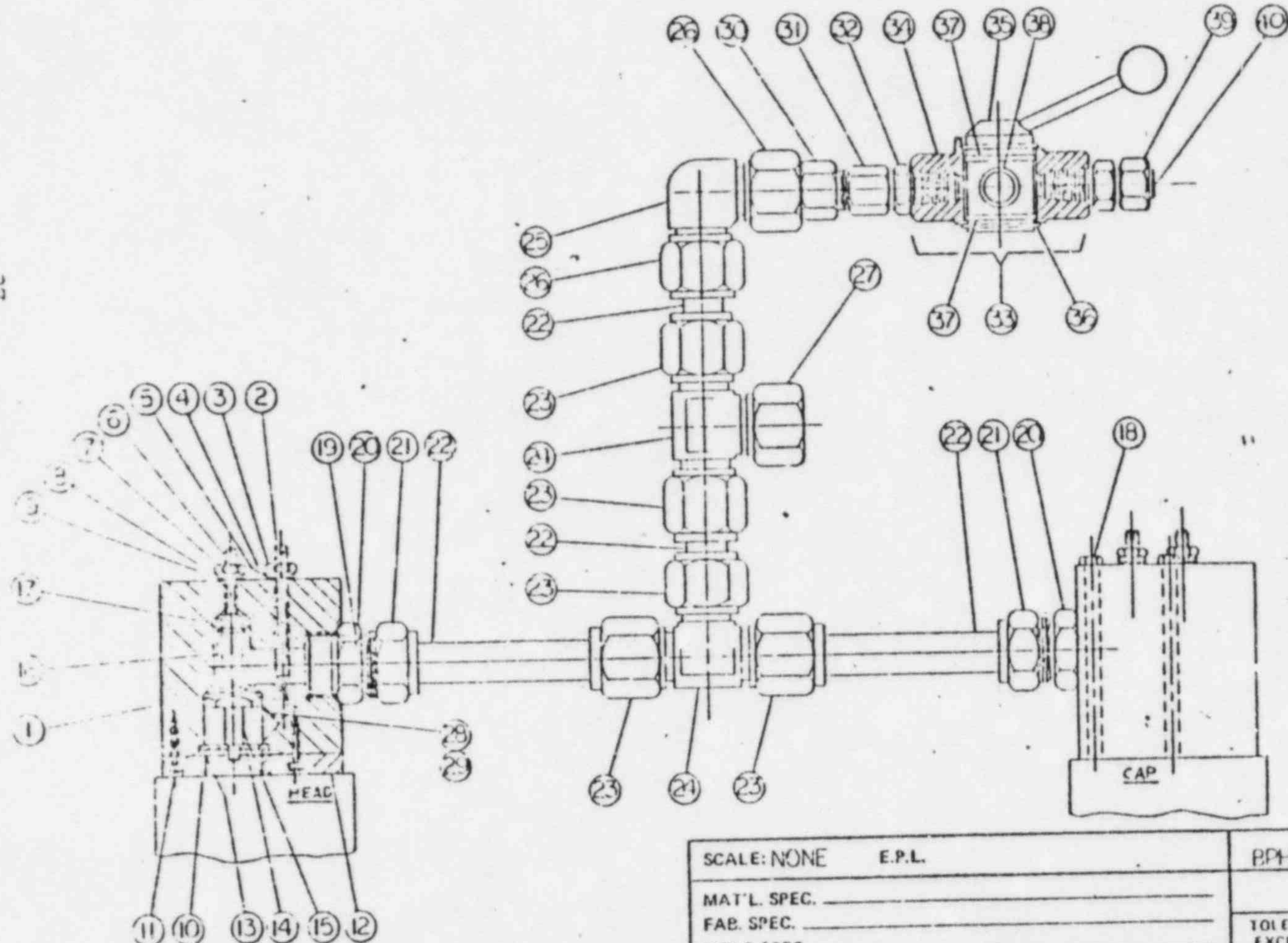
ITT	
B	ROD BUSHING COMPONENTS
PHD-5222-SK-54	

REV.	DESCRIPTION	DCN	BY	APP'D	Q.A.	DATE



SCALE: NONE E.P.L.	LIST OF PARTS BPHD-5222-SKB2		ITT Grinnell Corporation PIPE HANGER DIVISION RESEARCH, DEVELOPMENT & ENGINEERING PROVIDENCE, R.I.	
MAT'L. SPEC.	SUPERSEDES			
FAB. SPEC.	TOLERANCE EXCEPT AS NOTED	DATE	B	VALVE CONNECTION SIDE MOUNTED
WELD SPEC.				
NDE PROCEDURE	FRAC.	DRAWN	PHD-5222-SK55	
FINISH, EXCEPT AS NOTED	DEC.	CHK'D.		
Q.A. REVIEW	ANG.	APP'D.		

REV.	DESCRIPTION	DCN	BY	APP'D	Q A	DATE



SCALE: NONE E.P.L.

MAT'L. SPEC.
FAB. SPEC.
WELD SPEC.
NDE PROCEDURE
FINISH, EXCEPT AS NOTED
Q.A. REVIEW

LIST OF PARTS BPHD-5222-SKP2
SUPERSEDES

TOLERANCE EXCEPT AS NOTED
FRAC.
DEC.
ANG.

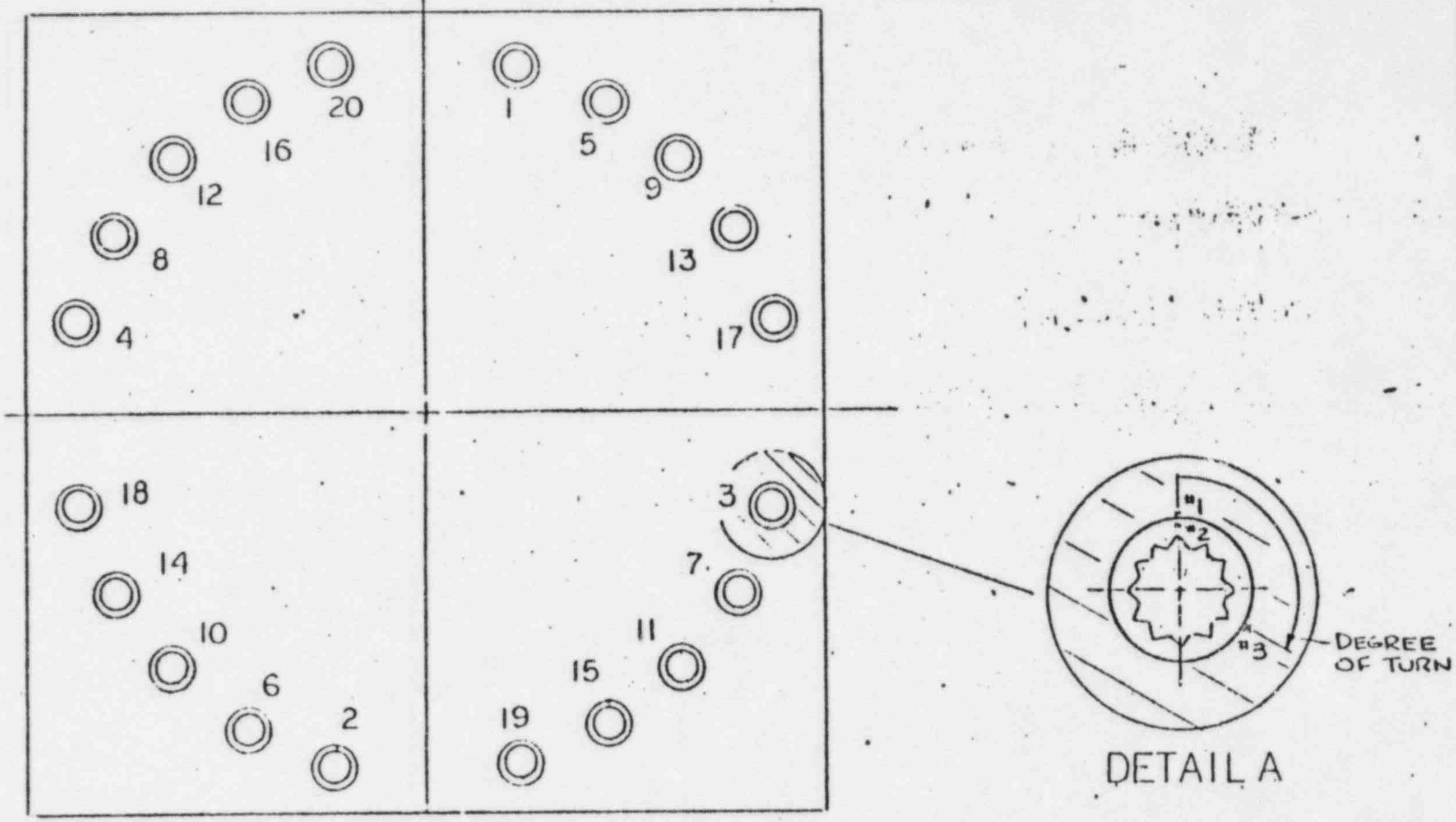
DATE
DRAWN
CHK'D.
APP'D.

ITT Grinnell Corporation
PIPE HANGER DIVISION
RESEARCH, DEVELOPMENT & ENGINEERING
PROVIDENCE, R.I.

B VALVE CONNECTION TOP MOUNTED

PHD-5222-SK56

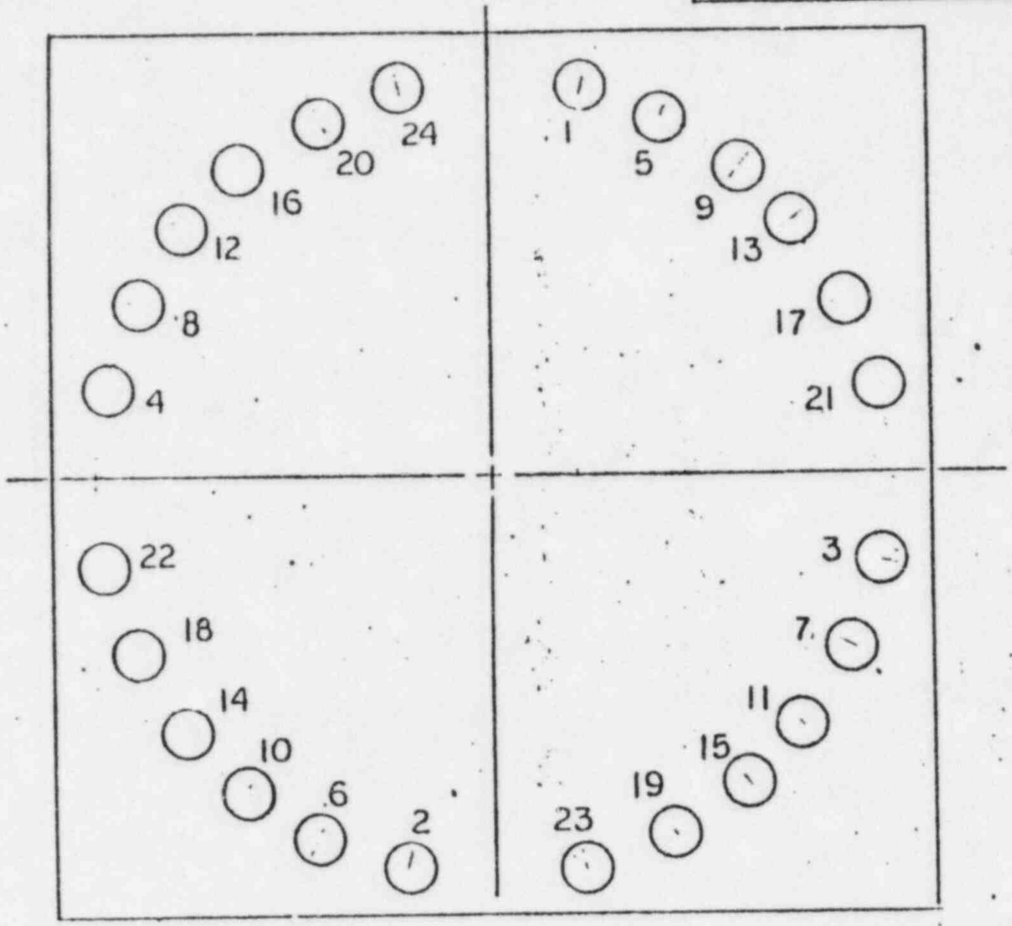
REV



REV.	DESCRIPTION	BY	APP'D	Q.A.	DATE

SCALE: E.P.L.	LIST OF PARTS	ITT Grinnell Corporation PIPE HANGER DIVISION RESEARCH, DEVELOPMENT & ENGINEERING PROVIDENCE, R.I.
MAT'L. SPEC. ______ FAB. SPEC. ______ WELD SPEC. ______ NDE PROCEDURE ______ FINISH, EXCEPT AS NOTED ______ Q.A. REVIEW ______	SUPERSEDES TOLERANCE EXCEPT AS NOTED — FRAC. ___ DEC. ___ ANG. ___ DATE 1-27-79 — DRAWN RL CHK'D. ___ APP'D. ___	A — TORQUING SEQUENCE 20 TIE RODS PHD-5222-SK-57 — REV.

REV.	DESCRIPTION	BY	APP'D	Q.A.	DATE



SCALE: E.P.L.

MAT'L. SPEC. ______

FAB. SPEC. ______

WELD SPEC. ______

NDE PROCEDURE ______

FINISH, EXCEPT AS NOTED ______

Q.A. REVIEW ______

LIST OF PARTS

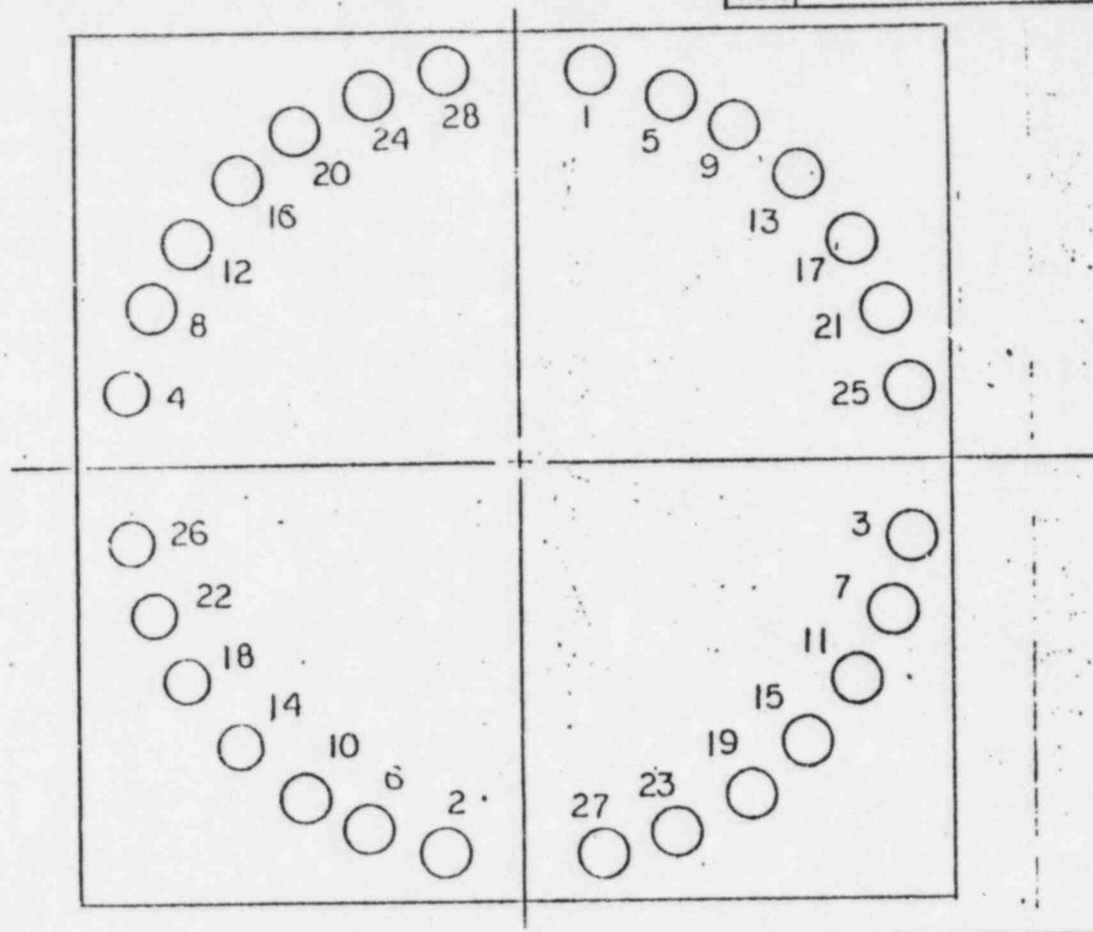
SUPERSEDES

TOLERANCE EXCEPT AS NOTED	DATE 1-27-79
FRAC. ______	DRAWN R.L.
DEC. ______	CHK'D. ______
ANG. ______	APP'D. ______

ITT Grinnell Corporation
PIPE HANGER DIVISION
RESEARCH, DEVELOPMENT & ENGINEERING
PROVIDENCE, R.I.

A — TORQUING SEQUENCE
24 TIE RODS

PHD-5222-SK-58 REV.



REV.	DESCRIPTION	BY	APP'D.	Q.A.	DATE

SCALE: E.P.L.

MAT'L. SPEC.

FAB. SPEC.

WELD SPEC.

NDE PROCEDURE

FINISH, EXCEPT AS NOTED

Q.A. REVIEW

LIST OF PARTS

SUPERSEDES

TOLERANCE EXCEPT AS NOTED

FRAC.

DEC.

ANG.

DATE 1-27-79

DRAWN RL

CHK'D.

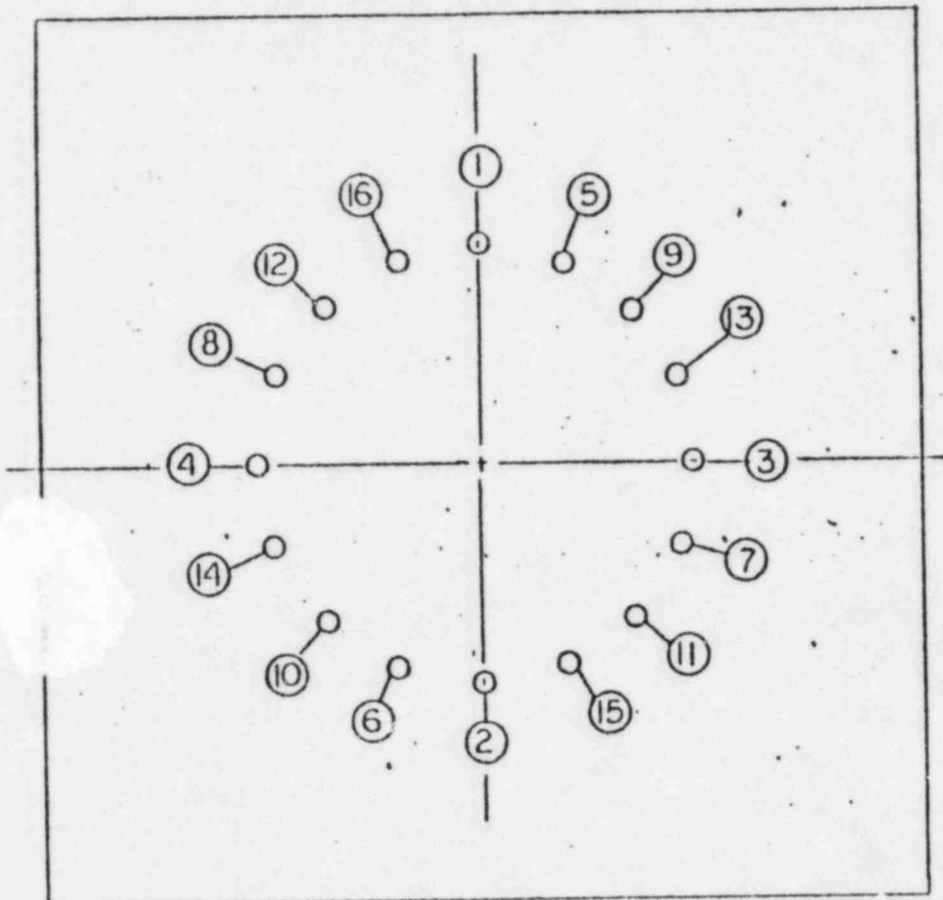
APP'D.

ITT Grinnell Corporation
PIPE HANGER DIVISION
RESEARCH, DEVELOPMENT & ENGINEERING
PROVIDENCE, R.I.

A TORQUING SEQUENCE
28 TIE RODS

PHD-5222-SK-59

REV.



REV.	DESCRIPTION	BY	APP'D.	Q.A.	DATE

SCALE: E.P.L.

MAT'L. SPEC. ______
FAB. SPEC. ______
WELD SPEC. ______
NDE PROCEDURE ______
FINISH, EXCEPT AS NOTED ______
Q.A. REVIEW ______

LIST OF PARTS

SUPERSEDES

TOLERANCE EXCEPT AS NOTED
FRAC. ______
DEC. ______
ANG. ______

DATE 1-27-79
DRAWN RL
CHK'D. ______
APP'D. ______

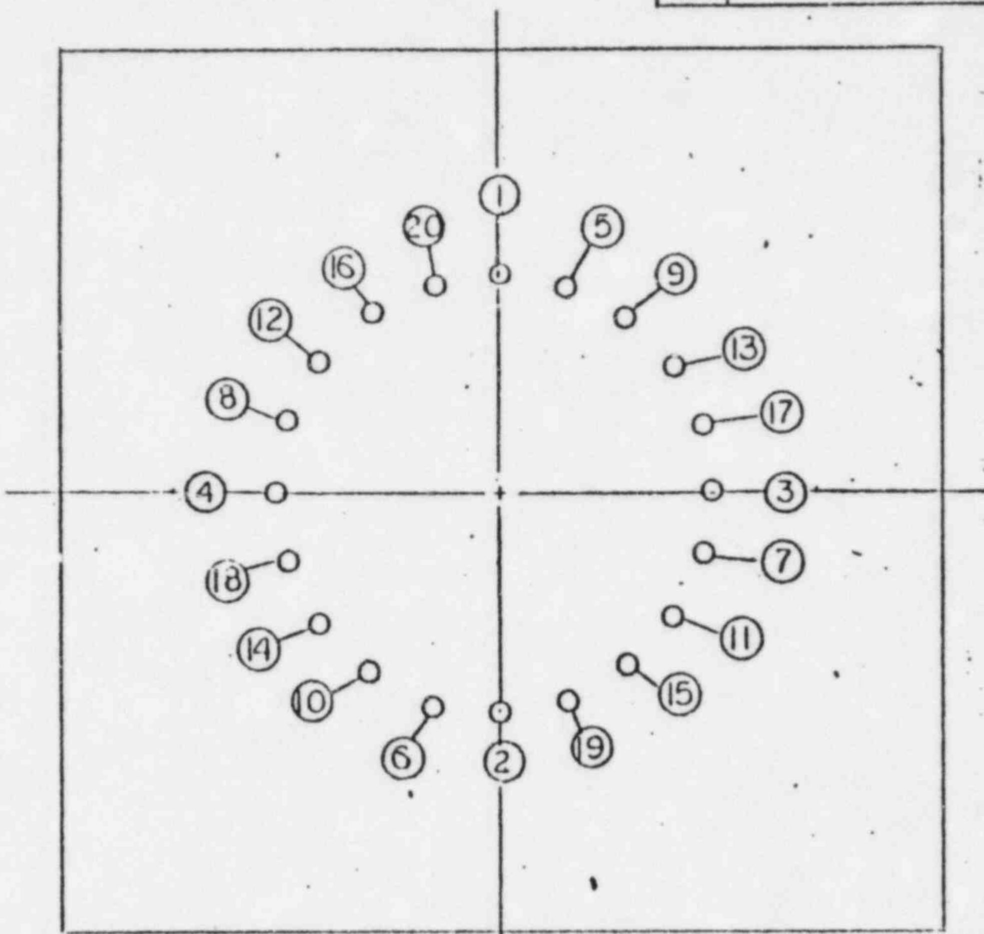
ITT Grinnell Corporation
PIPE HANGER DIVISION
RESEARCH, DEVELOPMENT & ENGINEERING
PROVIDENCE, R.I.

A TORQUING SEQUENCE
CIRCULAR RETAINER-16 SCREWS

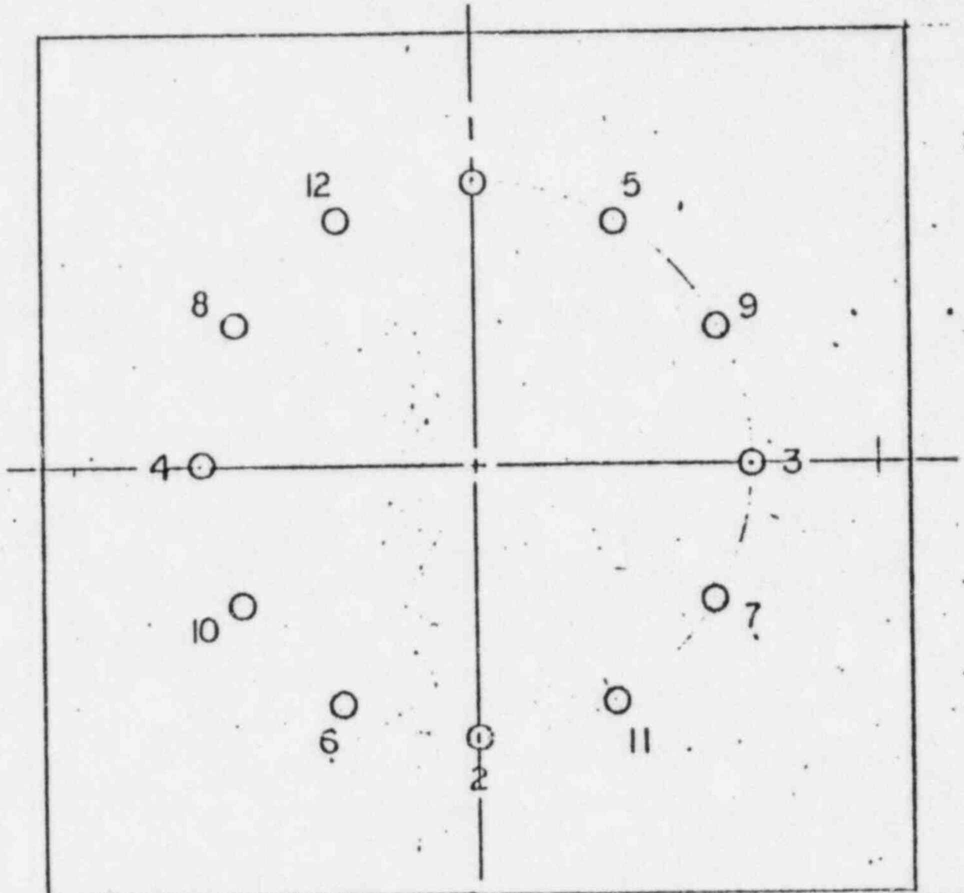
PHD-5222-SK-60

REV.

REV.	DESCRIPTION	BY	APP'D.	Q.A.	DATE



SCALE: E.P.L.	LIST OF PARTS	ITT Grinnell Corporation PIPE HANGER DIVISION RESEARCH, DEVELOPMENT & ENGINEERING PROVIDENCE, R.I.
MAT'L. SPEC. ______ FAB. SPEC. ______ WELD SPEC. ______ NDE PROCEDURE ______ FINISH, EXCEPT AS NOTED ______ Q.A. REVIEW ______	SUPERSEDES TOLERANCE EXCEPT AS NOTED: FRAC.______ DEC.______ ANG.______ DATE 1-27-79 DRAWN RL CHK'D.______ APP'D.______	A — TORQUING SEQUENCE CIRCULAR RETAINER-20 SCREWS PHD-5222-SK-61 REV.



EXTERNAL BEARING HOLE SEQUENCE

REV.	DESCRIPTION	BY	APP'D.	Q.A.	DATE

SCALE: E.P.L.

MAT'L. SPEC.

FAB. SPEC.

WELD SPEC.

NDE PROCEDURE

FINISH, EXCEPT AS NOTED

Q.A. REVIEW

LIST OF PARTS

SUPERSEDES

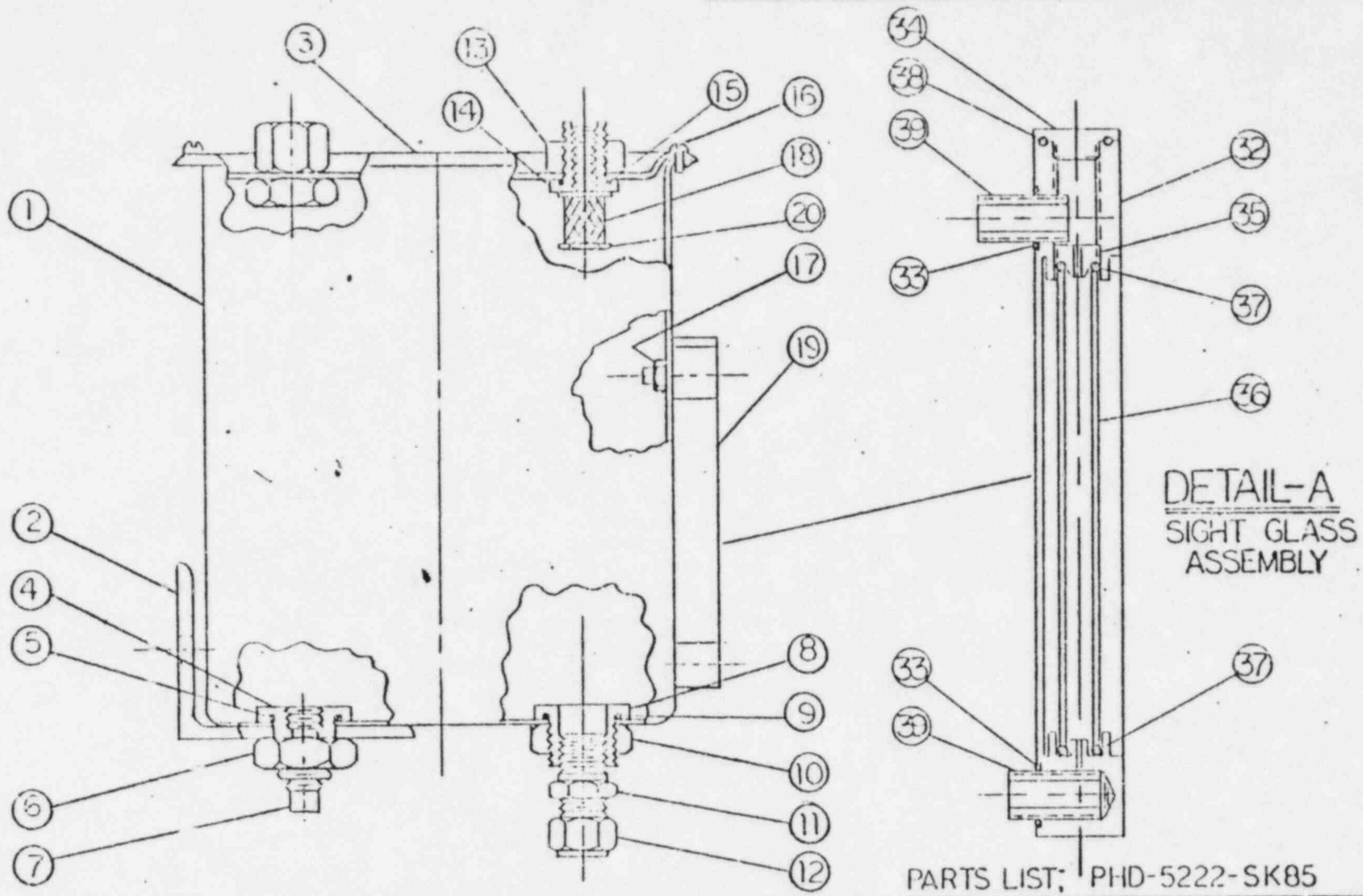
TOLERANCE EXCEPT AS NOTED	DATE 1-27-79
FRAC.	DRAWN RL
DEC.	CHK'D.
ANG.	APP'D.

ITT Grinnell Corporation
PIPE HANGER DIVISION
RESEARCH, DEVELOPMENT & ENGINEERING
PROVIDENCE, R.I.

A TORQUING SEQUENCE EXTERNAL BEARING

PHD-5222-SK-62 REV.

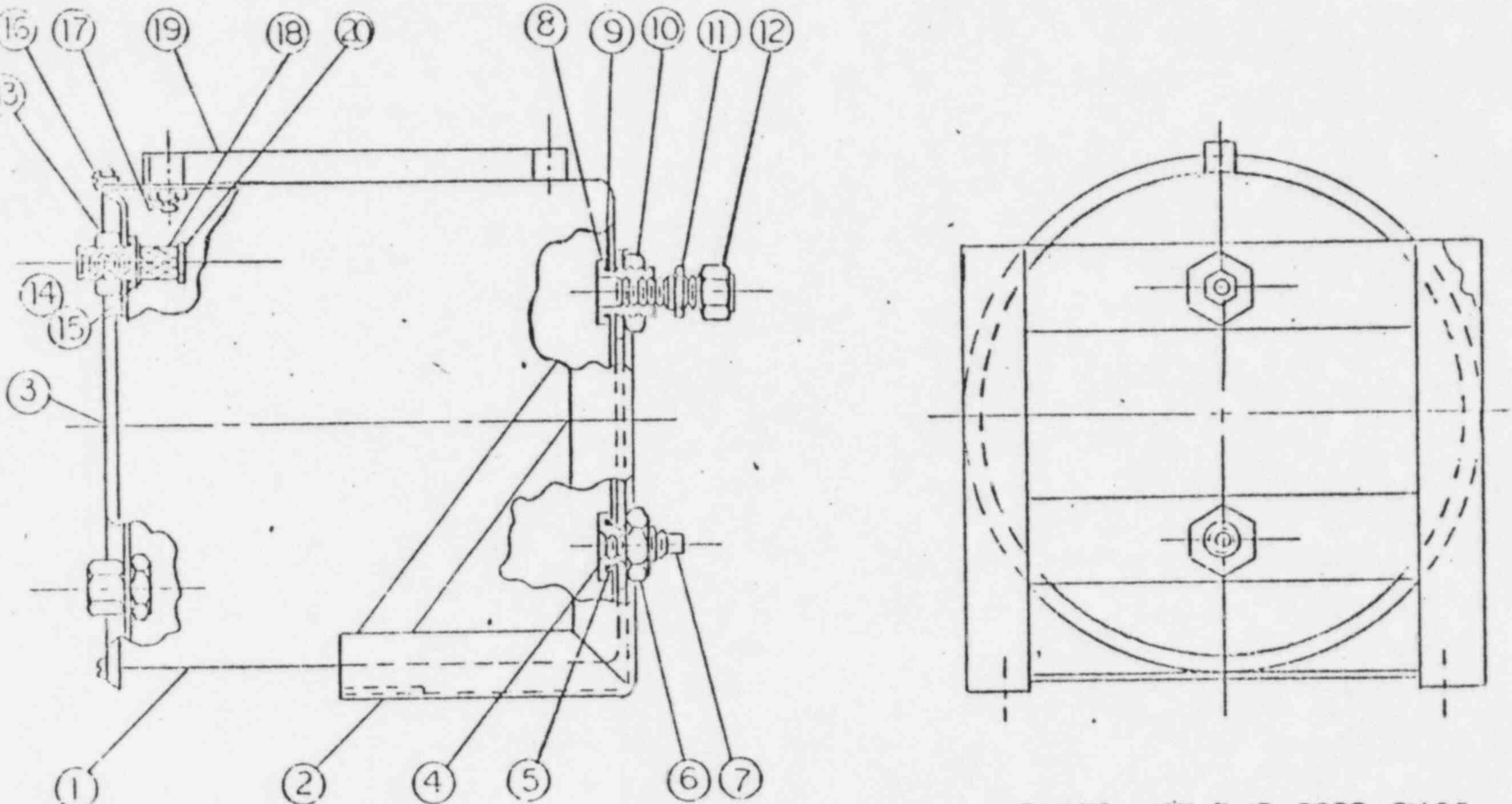
REV.	DESCRIPTION	BY	AP...	DATE



PARTS LIST; PHD-5222-SK85

SCALE: E.P.L.	LIST OF PARTS	ITT Grinnell Corporation PIPE HANGER DIVISION RESEARCH, DEVELOPMENT & ENGINEERING PROVIDENCE, R.I.
MAT'L. SPEC.	SUPERSEDES	
FAB. SPEC.	TOLERANCE EXCEPT AS NOTED / DATE	A — OIL-RITE RESERVOIR 3 GAL. CAPACITY
WELD SPEC.	FRAC. / DRAWN	
NDE PROCEDURE	DEC. / CHK'D.	PHD-5222-SK-63 — REV. A
FINISH, EXCEPT AS NOTED	ANG. / APP'D.	
Q.A. REVIEW		

REV.	DESCRIPTION	BY	APP'D.	Q.A.	DATE



- 45 -

PARTS LIST; PHD-5222-SK85

SCALE: E.P.L.	LIST OF PARTS	ITT Grinnell Corporation PIPE HANGER DIVISION RESEARCH, DEVELOPMENT & ENGINEERING PROVIDENCE, R.I.
MAT'L. SPEC. FAB. SPEC. WELD SPEC. NDE PROCEDURE FINISH, EXCEPT AS NOTED Q.A. REVIEW	SUPERSEDES	A — OIL-RITE RESERVOIR 5 & 10 GAL. CAPACITY
	TOLERANCE EXCEPT AS NOTED: FRAC. DEC. ANG. — DATE: DRAWN CHK'D. APP'D.	PHD-5222-SK-64 — REV. A

REV.	DESCRIPTION	DCN	BY	AP[illegible]	DATE

LIST OF PARTS

ITEM NO.	PART NAME
1	Reservoir
2	Mtg. Bracket
3	Cover
4	Drain Adapter
5	"O" Ring 1" I.D. x .103 W
6	1" - 14 Jam Nut
7	Drain Plug
8	Outlet Adapter
9	"O" Ring 1 3/4" I.D. x .103 W
10	1 3/4" - 12 Jam Nut
11	1" x 1 NPT Male Connector
12	Fitting Nut
13	1" - 14 Jam Nut
14	Filter Adapter
15	"O" Ring 1" I.D. x .103 W
16	#6 x 1/4 Fan Hd. Screw
17	Mounting Nuts
18	Filter #100 Mesh 1" O.D. x 1"
19	Site Glass Ass'y

ITEM NO.	PART NAME
20	Filter Body
32	Sight Glass Body
33	"O" Rings
34	Sight Glass Cap
35	Screws
36	Sight Glass
37	Sight Glass "O" Rings
38	Cap "O" Rings
39	Mtg. Studs

SCALE: E.P.L.	LIST OF PARTS	ITT Grinnell Corporation PIPE HANGER DIVISION RESEARCH, DEVELOPMENT & ENGINEERING PROVIDENCE, R.I.
MAT'L. SPEC. FAB. SPEC. WELD SPEC. NDE PROCEDURE FINISH, EXCEPT AS NOTED Q.A. REVIEW	SUPERSEDES TOLERANCE EXCEPT AS NOTED: FRAC. DEC. ANG. DATE: DRAWN CHK'D. APP'D.	A — PARTS LIST 3-5-10GAL. RESERVOIRS PHD-5222-SK85 — REV.

LIST OF PARTS

ITEM NO.	MFGR STD NO.			PART NAME
1	BPHD-5222-21			BODY WITHOUT RELIEF VALVE
2	APHD-5222-26			ORIFICE STEM VALVE
3	C2-3.2			1/4-28NF HEX JAM NUT
4	C4-4.1			1/4-SAE STEEL WASHER
5				THREAD-SEAL #649027-1/4
6	APHD-5222-25			ADJUSTMENT SCREW 1/4-28-NF X 1 3/8 LG.
7	C2-3.2			1/4-28NF HEX JAM NUT
8	C4-4.1			1/4-SAE STEEL WASHER
9				THREAD-SEAL #649027-1/4
10				O'RING DASH 125
11	C2-2.6			RET. PLATE SCREWS #10-32 X 1/2 LG. SOC. HD. CAP SCR.
12	APHD-5222-27			RETAINER PLATE
13				O'RING DASH 125
14	APHD-5222-23			VALVE SEAT DISC
15	APHD-5222-22			VALVE POPPET
16				SPRING-LEE
17	APHD-5222-24			SPRING PLUNGER
18				MOUNTING BOLTS 3/8-16 X 4.375 LG.
19				O'RING DASH 916
20				MALE CONNECTOR 1" (SWAGELOK)
21				FITTING NUT (MALE CONNECTOR)
22				CONNECTING TUBING (1.00 O.D. X .065 WALL)
23				FITTING NUT (UNION TEE)
24				UNION TEE 1" (SWAGELOK)
25				ELBOW 1" (SWAGELOK)
26				FITTING NUT (ELBOW)
27				PLUG 1" (SWAGELOK)
28	BPHD-5222-			VALVE FILTER SCREEN
29				RETAINER RING (TRUARC)
30				REDUCER 1/2" x 1" (SWAGELOK)

31			REDUCER FITTING NUT
32			TUBE ADAPTER 1/2" [illegible]
33			PLUG VALVE 1/2" CIRCLE SEAL
34			PLUG VALVE BODY
35			PLUG VALVE BARREL
36			RETAINING RING
37			O-RING -2[illegible]
38			O-RING -[illegible]
39			MALE CONNECTOR 1/2" SWAGELOK
40			PLUG 1/2" SWAGELOK

REV.	DESCRIPTION	DCN	BY	APP'D	Q.A.	DATE

REF.: FOR VALVE CONNECTION SEE DRAWING NO. BPHD-5222-SK-55 or 56

SCALE: E.P.L.	LIST OF PARTS		ITT Grinnell Corporation PIPE HANGER DIVISION RESEARCH, DEVELOPMENT & ENGINEERING PROVIDENCE, R.I.
MAT'L. SPEC.	SUPERSEDES		
FAB. SPEC.	TOLERANCE EXCEPT AS NOTED	DATE 4-11-79	B — VALVE CONNECTION LIST OF PARTS
WELD SPEC.			
NDE PROCEDURE	FRAC.	DRAWN [illegible]	FHD-5222-SK-70 — REV.
FINISH, EXCEPT AS NOTED	DEC.	CHK'D.	
Q.A. REVIEW	ANG.	APP'D.	

DEV.	DESCRIPTION	DCN	BY	APP'D	Q A	DATE

LIST OF PARTS

ITEM NO				PART NAME
1				PISTON-PISTON ROD
2				PISTON SEAL
3				CYLINDER HEAD
4				CYLINDER CAP
5				CYLINDER TUBE
6				ROD SEAL
7				RETAINER PLATE
8				ROD BUSHING
9				TIE ROD NUTS
10				BACK UP RING
11				TIE RODS
12				ROD PRESSURE RING
13				ROD SEAL CAGE
14				CYLINDER END SEALS
15				ROD WIPER
16				ROD WAVE SPRING
17				PISTON ANTI-ROLL RING
18				PISTON RETAINING RING
19				PISTON WEAR RING
20				SPHERICAL BEARING
21				RETAINER SCREWS
22*				RETAINING RING
23				FILL PORT PLUG
24				"O" RINGS
[illegible]				WIPER RETAINER PLATE
[illegible]				PUSH NUT
[illegible]				5/16" FLAT WASHER
[illegible]				1/2" FLAT WASHER

NOTE:
* — USED ON SHORT STROKE CYL. ONLY

SCALE: E.P.L.	LIST OF PARTS	ITT Grinnell Corporation PIPE HANGER DIVISION RESEARCH, DEVELOPMENT & ENGINEERING PROVIDENCE, R.I.
MAT'L. SPEC.	SUPERSEDES	B MILLER CYLINDER MODEL 90 LIST OF PARTS
FAB. SPEC.	TOLERANCE EXCEPT AS NOTED	DATE 4-12-79
WELD SPEC.	FRAC.	DRAWN ADL
NDE PROCEDURE	DEC.	CHK'D.
FINISH, EXCEPT AS NOTED	ANG.	APP'D.
Q.A. REVIEW		PHD-5222-SK-71 REV.

REV	DESCRIPTION	DCN	BY	APP'D	Q.A.	DATE

LIST OF PARTS

ITEM NO.				PART NAME
1				PISTON-PISTON ROD
2				PISTON SEAL
3				CYLINDER HEAD
4				CYLINDER CAP
5				CYLINDER TUBE
6				ROD SEAL
7				RETAINING PLATE
8				ROD BUSHING
9				TIE ROD NUTS
10				BACK-UP RING
11				TIE RODS
12				ROD PRESSURE RING
13				ROD SEAL CAGE
14				CYLINDER END SEALS
15				ROD WIPER
16				ROD WAVE SPRING
17				ANTI-ROLL RING
18				PISTON RETAINING RING
19				PISTON WEAR RING
21				RETAINER SCREWS
22 *				RETAINING RING
23				FILL PORT PLUG
24				O RINGS
25				EXTERNAL BEARING
26				RETAINER SCREWS
27				EXTERNAL BEARING SEAL
[illegible]				WIPER RETAINER PLATE
[illegible]				PUSH NUT
32				5/16" FLAT WASHER
33				1/2" FLAT WASHER

NOTE

* — USED ON SHORT STROKE CYL. ONLY

SCALE: E.P.L.	LIST OF PARTS		ITT Grinnell Corporation PIPE HANGER DIVISION RESEARCH, DEVELOPMENT & ENGINEERING PROVIDENCE, R.I.
MAT'L. SPEC.	SUPERSEDES		
FAB. SPEC.	TOLERANCE EXCEPT AS NOTED	DATE 4-12-79	B — MILLER CYLINDER MODEL 52 LIST OF PARTS
WELD SPEC.	FRAC.	DRAWN [illegible]	PHD-5222-SK-72
NDE PROCEDURE	DEC.	CHK'D	REV
FINISH, EXCEPT AS NOTED	ANG.	APP'D	
Q.A. REVIEW			

REV.	DESCRIPTION	DCN	BY	APP'D	Q.A.	DATE

LIST OF PARTS

ITEM NO.				PART NAME
1				PISTON-PISTON ROD
2				PISTON SEAL
3				CYL. HEAD
4				CYL. CAP
5				CYL. TUBE
6				ROD SEAL
7				RETAINING PLATE
8				ROD BUSHING
9				TIE ROD NUTS
10				BACK-UP RING
11				TIE ROD
12				ROD PRESSURE RING
13				ROD SEAL CAGE
14				CYL. END SEAL
15				ROD WIPER
16				ROD WAVE SPRING
17				ANTI-ROLL RING
18				PISTON RETAINING RING
19				PISTON WEAR RING
20				SPHERICAL BEARING
21				RETAINING SCREWS
22				RETAINING RING
23				FILL PORT PLUG
24				"O" RINGS
25				EXTERNAL BEARING
26				RETAINER SCREWS
27				EXTERNAL BEARING SEAL
28				EXTENSION PIECE
29				PIVOT LUG
30				WIPER RETAINER PLATE
31				PUSH NUT
32				5/16" FLAT WASHER
33				1/2" FLAT WASHER

SCALE: E.P.L.	LIST OF PARTS		ITT Grinnell Corporation PIPE HANGER DIVISION RESEARCH, DEVELOPMENT & ENGINEERING PROVIDENCE, R.I.
MAT'L. SPEC.	SUPERSEDES		
FAB. SPEC.	TOLERANCE EXCEPT AS NOTED	DATE 4-12-79	B [illegible] ASSY. LIST OF PARTS
WELD SPEC.	FRAC.	DRAWN TM	
NDE PROCEDURE	DEC.	CHK'D	HL-[illegible]-SK77
FINISH, EXCEPT AS NOTED	ANG.	APP'D.	REV.
Q.A. REVIEW			

W. H. SALISBURY & CO.

Linemen's Rubber Protective Devices

SINCE SALISBURY CHICAGO QUALITY MANUFACTURERS RUBBER PRODUCTS 1855

401 NORTH MORGAN STREET
CHICAGO, ILLINOIS 60622
AREA CODE 312 / 421-4850

Dec. 8, 1982

Mr. Dave Rosenberg
NuTech Engineering
7910 Woodmont Ave
Bethesda, Maryland

Dear Mr. Rosenberg:

The following is the information you wanted concerning compound #80154

Original Properties

Tensile, (psi)	2770
Elongation (%)	270
Shore A Hardness	85

After Heat Aged 70 hrs @ 212°F

Tensile, (psi)	2775
Elongation, (%)	185
Shore A Hardness	87

Since #80154 contains Nordel EPDM, I enclosed some interesting information about Nordel's heat aging resistance I received from DuPont [illegible]

Temperature Range

EPDM insulations maintain their elastomeric character over a broad temperature range. Typical compositions remain flexible at temperatures down to -70°F. and have brittleness temperatures as low as [illegible]0°F. At the other end of the scale, EPDM compositions provide excellent resistance to mechanical stresses and deformation at elevated temperatures. Tests run on a typical medium voltage insulation compound (Table IV) show that modulus is essentially unaffected at temperatures up to 300°F., reflecting the resistance of EPDM compositions to thermal softening. Tensile strength and elongation are reduced as temperature is increased from 75 to 300°F., but are superior to the values obtained with other types of insulation, particularly at 300°F.

TABLE IV

TENSILE PROPERTIES AT ELEVATED TEMPEPATURES

Physical Properties	Test Temperature, °F. 75°	158°	300°
100% Modulus, psi	250	200	210
Tensile Strength, psi	1000	680	400
Elongation at Break, %	310	250	170

Flexibility and Handling

EPDM insulation is inherently very flexible. The extent to which this carries over to the finished cable is, of course, influenced by construction features. Where the insulation wall is heavy relative to conductor size, frequently the case in medium voltage cable, EPDM insulation contributes greatly to cable flexibility. This is of particular importance when splicing and terminating in restricted quarters, such as in manholes.

Ozone Resistance

EPDM compositions are, for all practical purposes, completely impervious to ozone. Ozone resistance is inherent in ethylene-propylene rubbers so that protective waxes, antiozonants, or special compounding are not required to achieve this property. Typical insulations based on EPDM show no sign of cracking when exposed to an ozone concentration of 0.03 percent by volume for 100 hours, using the procedure specified in ASTM D-470.

Radiation Resistance

The increasing number of nuclear generating facilities in recent years has focused attention on the need for elastomeric components with excellent radiation resistance. Ethylene propylene rubbers are particularly resistant to the deteriorating effects of high energy radiation. Results of a series of tests conducted in our laboratories are summarized in Table V. Vulcanized slabs, 75 mils thick, were subjected to several dosage levels of beta radiation using a General Electric Resonant Transformer. Stress-strain properties measured in accordance with ASTM D-412 show that the EPDM insulation under test retained approximately 90% of its original tensile strength and over 40% of its original elongation after exposure to 5.5×10^7 rads of beta radiation. While elongation showed a further decrease as exposure time was lengthened, the EPDM insulation still remained quite flexible even after a total dosage of 10^8 rads.

TABLE V

INSULATION OF NORDEL®
RESISTANCE TO RADIATION

Exposure	Retention of Original Properties, % Tensile	Elongation
5.5×10^7 rads	91	42
1.1×10^8 rads	99	24
5.5×10^7 rads plus 7 days aging in 150°C. oven plus 7 days in 60 psi steam	87	47

Original Tensile Strength, 1030 psi
Original Elongation, 550%

Radiation Conditions:

Vulcanized slabs were placed 30 cm. from radiation source; beam current - 0.5 milliamps, acceleration potential - 2 megavolts, dosage rate - 8.5×10^4 rads/sec.

Blodgett and Fisher, in their paper on the effects of gamma radiation on cable coverings, point out that the total radiation dosage absorbed by a cable within the containment area of a thermal nuclear reactor might approach 5×10^7 rads, assuming a generator life of 40 years(1). The retention of tensile properties after exposure to gamma radiation reported by Blodgett and Fisher is reasonably close to that reported here using beta radiation.

Compositions based on EPDM would also be expected to survive abnormal bursts of energy from a thermal nuclear reactor conceivably involving exposure to a combination of radiation, steam and dry heat. In a laboratory test, an EPDM medium voltage insulation compound retained more than 80% of its original tensile strength and more than 40% of its original elongation after exposure to a sequence of 5.5×10^7 rads of beta radiation, 7 days oven aging at 150°C., and 7 days in 60 psi steam.

Electrically Stable Insulations For Low Voltage Applications

Where dielectric loss is not a prime consideration, such as is the case for low voltage insulation, lower cost EPDM insulations are feasible. This is accomplished primarily by greater extension with oil and filler, and the use of untreated clay in combination with a silane coupling agent. Such insulations possess electrical properties adequate for use in both wet and dry locations at voltages up to at least 5 KV.

The peroxide curing system offers several advantages. Among these are low dielectric loss, electrical stability in water, retention of physical properties after aging at temperatures as high as 300°F., and resistance to deformation during the jacketing operation.

EPDM insulations containing high levels of oil and filler can be peroxide cured without difficulty. In addition, such insulations not only possess excellent original properties, but also show little change on aging. These characteristics are attributable to the inherent properties of EPDM and to the permanence of the low-volatility paraffinic oils.

The physical and electrical properties of two typical, extended insulation compounds are shown in Tables VI and VII. Both possess good original physical and electrical properties, good resistance to heat degradation, and excellent stability in 75°C. water.

Of particular interest is the favorable comparison of physical and electrical properties for Compound B vs. Compound A, even though Compound B is much more highly extended with filler and oil. Compound B, with a pound-volume cost of $.183 is 11% lower in cost than Compound A, and 30% lower than the compound shown in Table I.

THE EFFECTS OF RADIATION, HEAT, AND STEAM ON NORDEL® EPDM

FIGURE 1

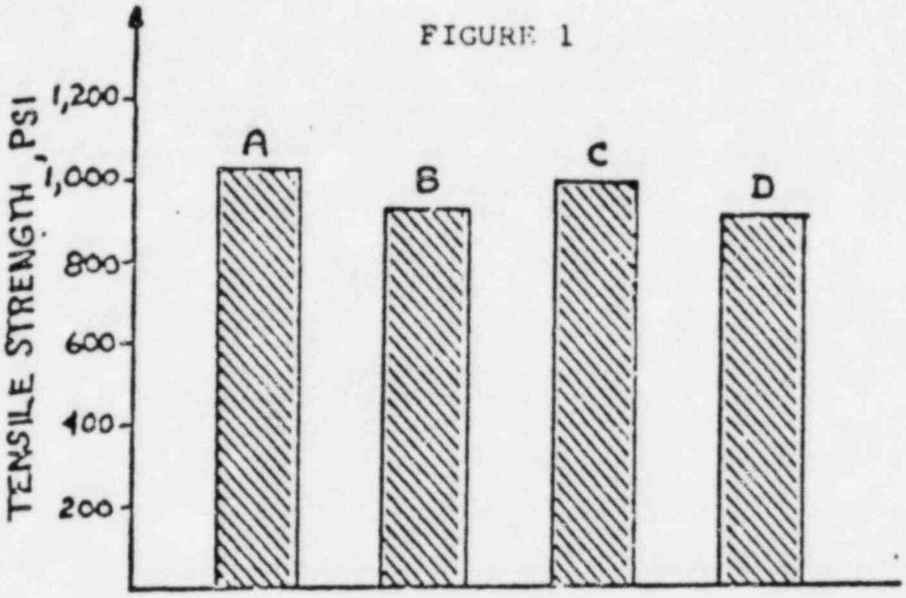
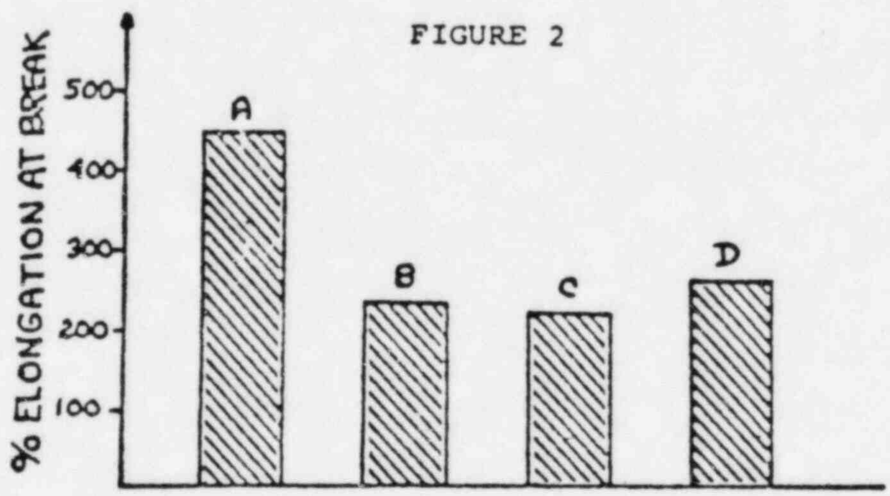


FIGURE 2



KEY

A = ORIGINAL

B = AFTER 5.5 x 10^7 RADS

C = AFTER 5.5 x 10^7 RADS + 7 DAYS AGING @ 150°C.

D = AFTER 5.5 x 10^7 RADS + 7 DAYS AGING @ 150°C + 7 DAYS IN 60 PSI STEAM

Silicone Fluids in Radiation Environments

Silicone fluids have been used for a number of years in environments subject to radiation of various types. They have been used as an hydraulic fluid in nuclear power stations and on nuclear powered ships. They have operated in Van Allen Belt environments and in laboratory and diagnostic apparatus.

Four fluids have seen extensive service.

SF 96 series

Available in many viscosities these fluids are polydimethylsiloxanes.

They have the best viscosity/temperature properties of any known fluid and will operate from −65 to +400F.

The radiation resistance will depend on the viscosity selected.

Fluid	M_o to Gellation
SF96-50	40
SF96-100	20
SF96-500	10
SF96-1000	7

SF 1154

SF 1154 is the most common material used in these applications. SF 1154 fluid is a copolymer containing both methyl and phenyl units. It has excellent high temperature stability and can be used from −56 to +540F. It has excellent radiation resistance and is capable of absorbing up to 5 x 10^8 rads before gellation.

SF 1147

This moderately low viscosity (=50 cs/77F) silicone fluid is the best lubricant of the silicone family and very possibly the best lubricant known for bimetallic contact. It has high radiation stability gelling at 5 x 10^8 rads.

Versilube® F 50

This silicone fluid is a high temperature lubricant capable of operating at temperature extremes (−140F to +500F) and has been used well in radiation environments encountered in space flight. Compared to the above fluids, it has a low radiation tolerance. It contains molecularly bound chlorine which starts to generate acid at 1 x 10^6 rads. This increases with increased dosage. Gellation occurs at 2 to 5 x 10^7 rads.

The effect of radiation on silicones is a cross linking mechanism which gradually increases the viscosity of the fluid eventually resulting in gellation.

Theoretical treatment of these effects will be found in:

A.A. Miller, J. Am. Chem. Soc. 82, 3519 (1950)

A.A. Miller, J. E.C. Product Research and Development 3, 3, 1964, pp. 252-256.

Physical Properties of Non Irradiated Fluids

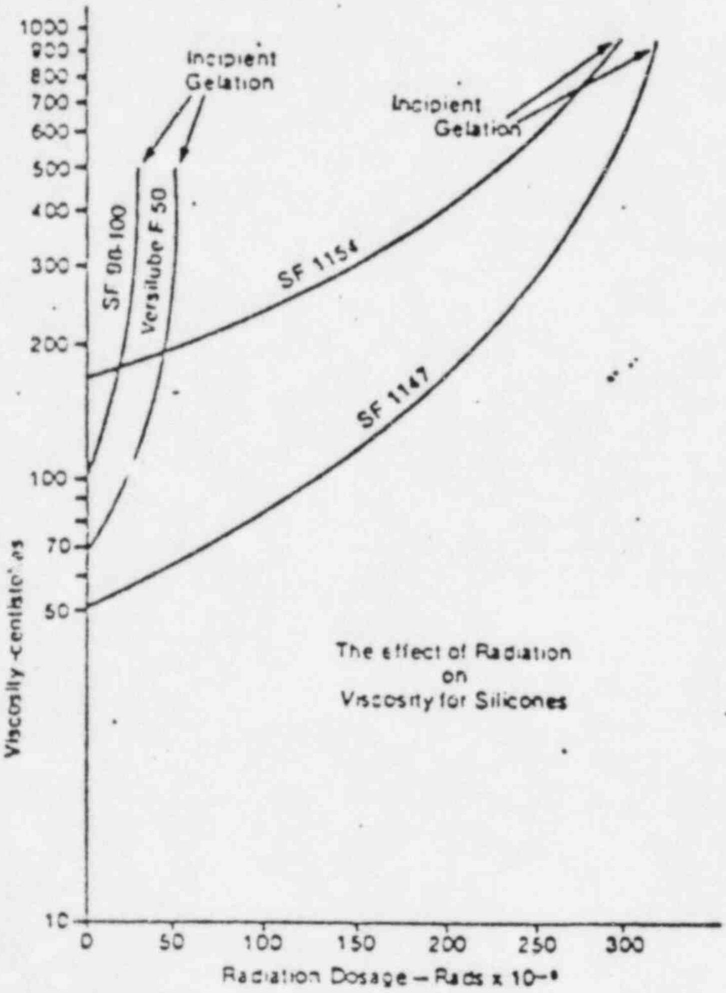
	SF 96-100	SF 1154	SF1147	F 50
Viscosity				
@ −65F				
−40F				2500
0F	600		4500	
77F	300	2500	350	
100F	100	175	49	70
210F	75	110	31	52
350F	30	23	7.5	16
400F		7.5		
450F	12	5.7		4.5
			1.8	
Pour Point	−67	−40	−65	−140
Flash Point COC	>575	>550	>500	>550
Fire Point	>675	>650	>600	>640
Fire Point	>675	>650	>600	>640
Specific Gravity	0.966	1.05	0.89	1.045
Refractive Index	1.4030	1.4960		1.4280
Specific Heat	0.36	0.39	.454	0.34
Thermal Expansion	.000925	7.5×10^{-4}	7.2×10^{-4}	
Bulk Modulus	>110 000	>185 000	>210 000	>110 000
Weight Loss 24 hrs 150C %	<0.5	<5	<5	<0.4
Max. radiation dosage with minimum change	1×10^7	1×10^8	1×10^8	1×10^6

REFERENCE 74

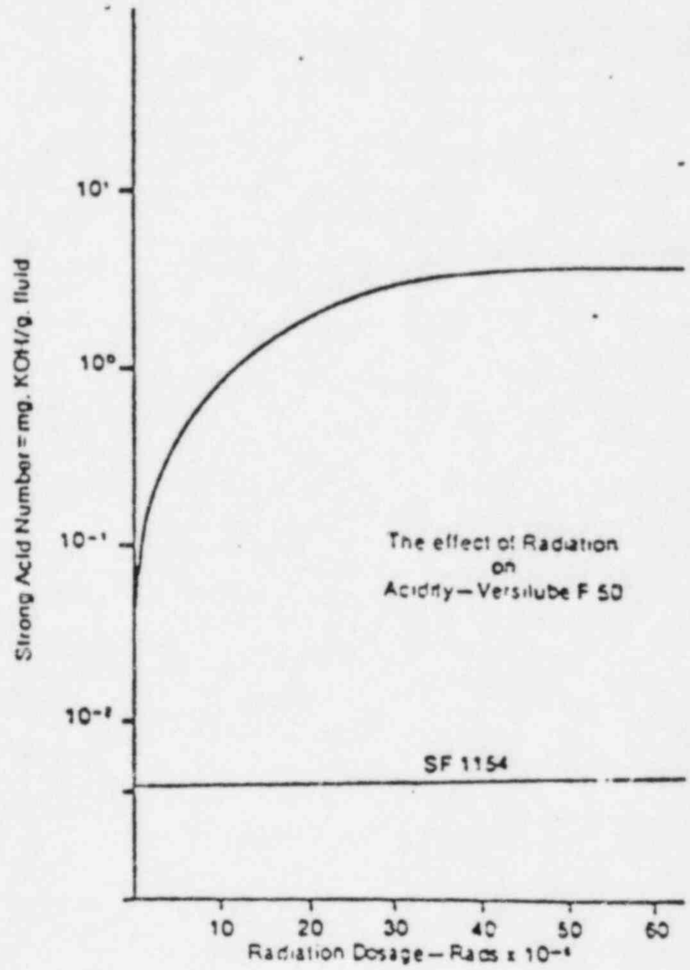
Effect of Radiation

Whereas the major effect of radiation on silicones is that of cross linking to increase viscosity, some of them, notably Versilube F 50 will also release small quantities of HC1.

The two accompanying curves show the effect of radiation on viscosity for all four fluids and the effect on acidity of Versilube F 50 and SF 1154.



The effect of Radiation on Viscosity for Silicones



The effect of Radiation on Acidity — Versilube F 50

GENERAL ELECTRIC COMPANY
SILICONE PRODUCTS DIVISION
RUBBER AND FLUID PRODUCTS DEPARTMENT
WATERFORD NEW YORK 12188
PHONE (518) 237-3330

GENERAL ELECTRIC

1/81

ITT GRINNELL CORPORATION
PIPE HANGER DIVISION
RESEARCH, DEVELOPMENT AND
ENGINEERING DEPARTMENT

FINAL REPORT

CONSUMERS POWER COMPANY

CONTRACT FOR CONSULTING SERVICES

FOR THE

REACTOR COOLANT PUMP SNUBBER SEAL STUDY

FOR THE

MIDLAND PLANT

CONSUMERS POWER P.O. CP10-1101

ITT GRINNELL PROJECT NO. SPS-8014

REPORT NO. SPS-ZPR-8014-5

PREPARED BY: Yolanda Moorehead DATE: Dec. 24, 1981

PREPARED BY: Hakimi S. Belaidi DATE: 12-24-1981

APPROVED BY: David O. Francis DATE: 12/24/81

APPROVED BY: R. B. Malecky DATE: 12/24/81

TABLE OF CONTENTS

ABSTRACT

This report covers all work accomplished by ITT Grinnell Corporation for Consumers Power Company under P.O. CP 10-1101, "Reactor Coolant Pump Snubber Seal Study for the Midland Plant". Results of evaluations based on seal material state-of-the-art, application considerations, failure modes and discussions with consultants knowledgeable in areas of concern are presented. Seal life modeling methodology is considered and an environmental test program to quantitatively define seal life based on overall results of this study is proposed.

SUMMARY

This study was conducted to evaluate the feasibility of extending the life of snubber seals exposed to a defined typical nuclear power plant environment. The primary goal of this study was to generate information in a quantity and level of refinement to provide a technically sound basis for defining, evaluating and finally choosing a means of extending seal life. It was proposed that the actual qualification of seal life extension would be accomplished by a Phase II follow up study and test program.

Initial effort consisted of gathering data and technical reports on seal material in the following categories:

a. EP (ethylene propylene) compounds utilized in present Midland reactor coolant pump snubbers.

b. "Other" elastomeric compounds.

c. Plastic/resin compounds

d. Metallics

An in-depth evaluation of extensive material gathered in each of these categories was conducted.

Further efforts were carried out in the following areas:

a. Snubber seal design considerations and failure modes.

b. Seal life modeling methodology.

c. Testing considerations and requirements.

In carrying out these efforts, it was noted that very little has been done in industry as a whole with respect to dosage rate effects or combined effects of radiation, air, fluid and temperature. To confirm and possibly expand on our consideration of these effects and our overall effort, several prominent persons in the field of elastomeric studies were consulted. These included.

a. Robert Barbarin, Technical Director R & D, Parker Seal Co.

b. Daniel Hertz, President, Seals Eastern.

c. Jerry Sieron, Technical Manager for Elastomers, WPAFB.

d. Lloyd Bonzon, Project Engineer, Sandia Laboratory.

In general, all concurred with our findings and were in agreement with our considerations for testing and final evaluation. Many helpful suggestions were obtained. A summary of discussions with the above is included in Appendix 3 of this report.

CONCLUSION

Based on the overall considerations of environment, design, testing and cost, EPDM material exhibits the highest probability of success.

Due to the fact that many different EPDM compounds exist with a variety of combinations of fillers, extensive testing has to be performed in order to determine the best possible compound. The means by which this is to be accomplished includes, but is not limited to, stress relaxation tests and "bread-board" tests (tensile strength, elongation, durometer, etc.). Because of the nature of these tests and the compounds themselves, the actual testing has to be a minimum of six (6) months. These methods will yield significant results and will enable ITT Grinnell to quantitatively define seal life.

I. Establishing Seal Life State-of-the-Art Baseline

1.1 Screening and Gathering of Technical Data (Materials Survey)

Utilizing the resources of ITT Grinnell RD & E, the New England Research Application Center (NERAC) and a number of seal manufac- -ers, extensive data and publications have been acquired. Resulting from this,an updated file was compiled outlining new manufacturing practices, new materials and test results with respect to various extreme conditions (corrosive fluid, elevated temperature, radiation, and steam). From several in-house sources, a series of articles was obtained detailing failures of snubbers due to fluid leakage at various power plants along with the causes of these failures. It was noted that misinstallation is potentially the highest cause of seal failure in a snubber system. Seal degradation was not attributed as having an influence in any of the cases involving EPDM compounds. Data received was categorized and evaluated under the heading of EPDM, "other" elastomers, plastics/ resinuous compounds and metallic material.

1.2 Evaluation of EPDM Compounds

1.2.1 Overview

In general, EPDM exhibits superior qualities for our environmental parameters. Physical properties will depend on variations in the compounding and the addition of reinforcing materials such as carbon black and silica amine or phenolic antioxidants, processing aids such as stearic acid or plasticizers, and curing agents like peroxide sulfur or sulfur donating accelerators.

EPDM General Characteristics

Durometer Range: 30A-90A

Tensile psi: 500-3500

Modulus (100%) psi: 100-3000

Elongation: 100-700%

Flex Cracking Resistance - very good

Tear Resistance: fair-good

Abrasion Resistance: good-excellent

Impact Resistance: very good

Service Temperatures (for continuous use)

-70 to 350°F

Environmental Resistance:

Ozone	outstanding
Oxidation	excellent
Water	excellent
Radiation	good
Silicate Hydrofluid	good

1.2.2 Parker Compounds

Parker has done extensive testings on its compounds. Both temperature and radiation (separate) testing were performed. Parker compound E740-75 is highly recommended due to its excellent resistance to radiation levels up to 10^8 rads under room temperature (see Table 4). When exposed to temperature, Parker E-740-75 shows a good back stress retention percent (Graphs 1-1A). Percent compression set is relatively low after temperature aging in both fluid and air (Graph 2).

Ranking of the Parker compounds on the approved vendor listing:

a. E740-75 specially formulated for snubber applications.

b. E692-75 high temperature resistant but not recommended for radiation.

1.2.3 Minnesota Rubber Compound

Minnesota Rubber Co. has performed radiation and temperature testing on its EP compound 559 EQ (Graphs 3-7). When temperature tested, this compound exhibited relatively low compression set at high temperature (Graph 8), but not as good as Parker compound E740-75 (Graph 9).

1.2.4 Federal Mogul Compound

Federal Mogul Compound E80 was not radiation tested whereas compound E59 was and exhibited desirable compression set at 10^7 rads. Graphs 10 through 14 compare the physical properties of the compounds investigated. Note that the testing parameters differ which made it hard to draw any concrete conclusions as to what compound is a better one.

1.2.5 Acushnet and W.H. Salisbury Compounds

No data on environmental testing was available from Acushnet and W.H. Salisbury. We were provided with a technical sheet containing basic properties and breadboard test results.

1.2.6 ITT Grinnell Qualification Tests

ITT Grinnell had performed qualification tests on all of the EP compounds included on our approved vendor list. These were accelerated LOCA simulation tests and were judged on a basis of whether after radiation and temperature exposure, the seals leaked under dynamic testing. These tests did not give a true indication of seal life. Copies of these test results are available upon request.

1.3 Evaluation of "Other" Materials

1.3.1 Viton

Viton is a fluorocarbon elastomer which has exhibited very good heat and fluid resistance when compared to other elastomers.

Compounds of Viton have good tensile strength adequate for most applications. The durometer (Shore A) hardness ranges from 50 to 90 depending material used for "O" rings and seals and accounts for about 80 percent of all applications of Kalrez. Table 2 outlines the general physical properties for Compound 1050.

Kalrez can be used continuously at temperatures of 600°F in many mechanical seal fluid environments. It is suitable for service at temperatures of 100°F to 180°F above that of any other commercial elastomer.

Kalrez does not exhibit outstanding compression set qualities with respect to elastomers but does outperform plastics in general. Table 3 represents traditional compression set data for Kalrez 1050 "O" ring (heat aged in air - Figure 3).

Kalrez can withstand 1 megarad (10^6 rads) of radiation with little effect on physical properties. Exposure to 10 megarads (10^7 rads) produces a moderate effect with 40 percent loss of tensile strength and 25 percent loss of elongation at break. At 100 megarads (10^8 rads) there are severe effects with 80 percent loss in tensile strength and 80 percent loss in elongation. Figure 4 shows the effects of radiation on Kalrez. Note that when compared with Viton, Kalrez expresses better sealing force retention at 400°F for long life (Figure 5).

1.3.3 Hycar Nitrile Elastomers

Hycar nitrile rubbers exhibit high tensile strength, good abrasion resistance and low compression set. Hycar rubbers in the medium and medium high acrylonitrile range offer a balance of physical properties between hardness and oil abrasion resistance on one hand and resilience and low temperature flexibility on the other. Medium - high acrylonitrile hycar (1002) has good water-resistance during prolonged service.

Hycar nitrile does not provide outstanding thermal resistance. The maximum service temperature for hycar nitrile is about 300°F. According to manufacturer catalogues and R. Harrington's report on Hycar nitrile rubber, amount and type of fillers are effective on hycar elastomer radiation stability. Data obtained from radiation exposure to gamma radiation (1 x 10^6 rads) in air of 25°C indicates that these compounds show decrease in elongation and increase in hardness with increasing exposure to radiation as the doses are increased. The tensile strength increases. This increase is a very strong indication that crosslinking is predominant. Although not as pronounced as the tensile strength, the hardness appears to be increased with increasing radiation exposure.

According to the evaluated data on nitrile elastomers, the use of these materials in a high dosage radiation environment is not recommended.

1.3.4 Vespel

Vespel parts are suitable for use in a wide range of temperatures with very good resistance to hydraulic fluid. It provides excellent abrasion resistance while maintaining extremely good mechanical properties with respect to temperature.

Radiation resistance of Vespel has not been fully documented. However, being part of the Polyamide family, which exhibits threshold damage at an absorbed dose of 8×10^5 rads and excessive degradation at 9×10^6 rads, Vespel should be carefully examined when and if used in an irradiated field.

Vespel has been compounded to withstand temperatures of up to 500°F (600°F when oxygen free). The major drawback in using Vespel (outside of questionable radiation resistance) is its inability to withstand a steam environment which could be present in a LOCA condition. Poor compression set and close tolerance requirements (for temperature cycling) are a major drawback.

1.3.5 Envex 1115

Envex 1115 is suitable for use in a wide range of temperatures (cryogenics to 550°F) with excellent chemical resistance to most hydraulic fluids. It provides a high compression strength (28000 psi) among other good physical properties.

Radiation resistance:

Being part of the Polyamides, Envex follows the same criteria as stated above (for Vespel). The major drawbacks are very poor compression set and extremely close machining tolerances.

1.3.6 Kel-F

Kel-F plastic is a highly fluorinated resin which offers good mechanical properties. Kel-F plastic is unaffected and therefore compatible with a wide variety of chemicals. It operates over a temperature range of -400°F to +400°F without decomposition or mechanical failure. Furthermore, it exhibits zero moisture absorption and is unaffected by high humidity. Kel-F is a thermoplastic exhibiting high compressive strength and relatively good elastic memory (plastics as a whole usually lack in this respect).

Radiation resistance:

Kel-F is readily susceptible to radiation induced damage. Also under these conditions Kel-F releases gases which may have a corrosive effect on adjacent components. It becomes quite soft and tacky at lower doses. In light of the above, the use of Kel-F thermoplastic is not recommended for our environment.

1.3.7 Metallic Seals

Two differenct types of metallic seals ("K seal" and "helicoflex") have been evaluated.

The "K seal" is an all-metal seal designed for use in "static" application. A "K seal" consists of three basic elements, the body, the lips, and the surface coating (Figure 6).

Basic Helicoflex seals comprise one or two metal linings formed around the toroidal section of helically wound spring (Figure 7).

Metallic seals can perform in all "static" face sealing applications in a wide range of temperatures and in a radiation environment. Metallic seals are available in a wide choice of materials and shapes to meet property and fluid requirements. Because of the inability of a metal seal to readily conform to its cavity dimensions, extremely stringent tolerances must be adhered to. Surface finishes (both gland and seal) are very tightly controlled. Adherence to proper installation procedures would be extremely critical and if done incorrectly may result in an excessive failure percentage. The major drawback of these seals is the high cost of purchasing and remachining (redesign in some cases) of existing glands.

1.4 Summary of Consulting Screening

An agenda of questions was designed to discuss actual state-of-the-art technology of the elastomers. A breakdown of the general points is (see Appendix 3):

a. EPDM is one of the best materials available for our operating environments.

   From their actual experience with EPDM compounds and the physical state of the seals after being exposed for five (5) years in actual operating conditions, a substantial extension over five years is a realistic projection (detailed testing will be required).

b. A mathematical model (life projection) has not been used extensively, if at all. This area needs extensive research work. The Air Force (WPAF) will start such a program in the future. Sandia Laboratory staff have done some work in this area, and based their projection (modeling) on accelerated aging testing. Sandia's concensus is the shorter the extrapolation, the better your life projection. It should be noted that this concept is not shared by the remainder of the industry. All three other consultants do not recommend induced harsh chemical degradation which is non-existent in actual working conditions. It is well known that in a strained elastomer two relaxations exist. These are known as physical and chemical stress relaxations. Physical relaxation involves two physical processes (such as diffusion of polymer units or movement of entanglements) whereas chemical relaxation involves the breaking down of covalent bonds. Both of these processes are expected to have different temperature dependencies. It has been verified that in low temperature range (25°C - 111°C), no appreciable chemical relaxation occurs. This postulate has been verified by J. Sieron, R. Barbarin and D. Hertz (consultants). D. Winkler, of the University of Akron, Applied Research Division of Polymers, (working in this area) also supports this postulate and strongly rejects the accelerated age testings.

c. There is a synergistic effect on Radiation - Thermal degradation.

d. Dosage rate is definitely a consideration that we have to pursue.

e. Metallic seals show a good alternative. They are strongly recommended for static applications, although testing has to determine the degree of limitations for dynamic cases.

f. Thermal cycling is a failure mode. For our temperature range (50°F - 120°F), there is little or no effect on the longevity of the seal.

g. Due to the fact that some of our seals are immersed in a compatible silicone fluid

(GE SF-1154), effects of oxidation are minimized (irradiation of the polymers results in bond cleavage giving free radicals, which, in the presence of oxygen, react by a chain mechanism to form oxidation products that include thermally labile hydroperoxide). It is one parameter working to our advantage.

h. Our testing program (relatively short time testing under actual operating conditions) has been judged adequate for seal life projection by all the consultants with the exception of Sandia Laboratory.

i. Unreinforced plastics are not recommended for use in our snubbers. Consideration was given to procurement costs, dimensional criteria of the seal and gland, testing requirements and availability of the materials. Arrhenius projections and the WLF equations are mathematical interpretations of a chemical and physical (respectively) evaluation of temperature only. They will lose their high correlation when used in conjunction with multiple parameters (fluid, radiation, steam...).

j. Degradation by temperature is highly minimized when $T_{min} + 100^{o}F \leq T_{operating} \leq T_{max} - 100^{o}F$. (T = Temperature)

II Snubber Seal Failure Criteria

2.1 Outline of Purpose

In order to provide a means of life prediction, an in-depth understanding had to be achieved of how a seal could be expected to fail. This was carried out in the manner described below. Dimensional analysis was conducted with respect to gland sizes and percentage squeeze realized by the seal. This information was then applied, in conjunction with the material properties outlined in Section I, to devise a pictoral model (FTA) which would depict areas with the greatest probability of failure. Once this had been determined, a potential seal material could be judged by its strength in these areas.

2.2 Baseline Dimensional Review Design Analysis

ITT Grinnell evaluated the minimum, nominal and maximum seal squeeze with respect to the temperatures existing in the seal environment (50°F - lowest reading based on a shutdown condition, 120°F - normal operating and 316°F - projected highest reading during a LOCA condition). These results (Tables 9.1 through 9.4) have been compared with the applicable vendor recommended squeeze range specified for each seal location (to secure design aspects and sealibility of a seal, all calculated percent squeeze for each specific seal must fall between minimum and maximum range of squeeze required by seal manufacturer).

Available design sealing surface finish requirements and existing extrusion gaps (maximum and minimum) have been defined and depicted in corresponding figures. Results from all evaluation and calculations are summarized in Figure 8 through 20 and corresponding Tables 4 and 9.1 through 9.4.

2.2.1 Federal Mogul

The valve retainer plate O ring (Figure 9) is exposed to system pressures of 5000 psi to 10,000 psi. Since the specified compound (E50) has a durometer of 70 ± 5 (Shore A), standard design practice indicates the use of back up rings or a zero clearance gap. However, since the valve seat disk-to-valve body does not constitute a seal, equal hydrostatic pressure will exist in the valve chamber (including the gap). Therefore, the .003 inch to .009 inch gap does not constitute an extrusion path.

Figures 9, 10, 11, 12, 13, and 14 are all static O rings (EPDM peroxide cured seals manufactured by Federal Mogul Reference Table 4). The Federal Mogul seal squeeze range requirement is .006 inches to 35 percent of cross section diameter. Recommended static seal surface finish requirements are 32 microinches. Figures 9, 10, 12, 13, and 14 comply with the above stated requirements. Figure 11 indicates that both nominal and maximum seal squeeze exceed that standard requirement of 35 percent. However, since initial design squeeze or compression provided for low pressure sealing, and the reservoir sight glass is a low pressure seal only, the maximum squeeze of 41.51 percent will not be a detriment. Figure 15 is a static O ring (EPDM peroxide cured seal manufactured by Federal Mogul reference Table 1). The seal will not be compressed due to mismatched dimensions. Since this seal is not exposed to system high pressure and a leakage problem has not been experienced at this location, the use of this specific O ring does not constitute a major problem. However, change to an alternative "O" ring with a larger cross section is recommended.

2.2.2 Acushnet

Figures 16 and 17 are both static "O" rings (EPDM peroxide cured) manufactured by Acushnet (reference Table 1). The Acushnet seal squeeze range requirement is .010 inch to 35 percent of cross section diameter. Recommended static seal surface finish requirements are up to 64 microinches as indicated by Figures 4 and 5, the squeeze range requirement has been met.

Gap #1, depicted in Figure 17, indicates a .001 inch to .00275 inch intrusion path. Since the specified compound (E17018) has a durometer of 70 $\pm$ 5 (Shore A), and the "O" ring is exposed to system pressures of 6300 psi to 10,000 psi, standard design practice indicates the use of a back up ring. However, cylinder vendor design experience indicates that the use of back up rings in this type of seal gland configuration is not effective and may actually detract from seal functionability. This fact, coupled with the fact that ITT Grinnell has not experienced any leakage problem with the external bearing seal, verifies seal design adequacy.

2.2.3 Minnesota Rubber

The rod seals (Figures 18.1 through 18.4 are dynamic seals (EPDM peroxide cured) manufactured by Minnesota Rubber (reference Table 4). Design configuration of this seal consists of one static and one dynamic portion. For an adequate seal to exist between this seal and the bushing, fit of the static portion of this seal in x direction is the main concern. For the static portion of this seal, the percent of compression in the x and y directions were determined at the temperatures of interest (reference Table 7.1 A through 7.4 A). Manufacturer recommended percent compression for this specific seal is undefined. However, calculated values in x direction do not appear to be inadequate. This is further supported by the fact that ITT Grinnell has not experienced any leakage problems with the rod seal.

Figures 19.1 through 19.2 show the rod wiper (EPDM peroxide cured) manufactured by Minnesota Rubber (reference Table 4). In order to extend life of this wiper some design modification is recommended.

2.2.4 W.H. Salibury

The piston seal (Figure 20) is a dynamic seal (EPDM Sulfur cured) manufactured by W.H. Salisbury (reference Table 1). The percent of deflection at the seal lips has been defined and listed (reference Figure 20). The piston seal will not compress at any point. However, keeping in mind the allowable bypass, the current configuration of piston seal is adequate.

2.3 F.T.A.

The F.T.A. (Fault Tree Analysis) provides an adequate means to identify, document, and analyze potential failure of seals and their overall effects on system performance. The F.T.A. generally starts by identifying an undesirable event at the system level and identifies the event at subsequent lower levels in the system that can cause the undesirable top event. The primary purpose of the F.T.A. is to ensure that the system (seal) will be reliable and safe for its intended use and foreseeable life time. The standard logic symbols used in hardware technology were used to establish the fault tree. Appendix 1 outlines the different symbols and their respective meanings. It was hoped that a quantitative probability would be assigned to lower levels of the F.T.A. and that the final probability of an event taking place would be evaluated using the subsequent logic gate mathematics (Appendix 1).

Due to the scarcity of meaningful data on seal failure in general (in a nuclear snubber environment) a quantitative probability of success could not be determined. The alternative method is to rank the relative probability of a part failure to the other possible failure modes in that system. This method utilized the ways that elastomeric or non-elastomeric seals degrade (data, articles, consultants) see Appendix 4.

III Seal Life Projection and Verification

3.1 Estimation of Life

Resulting from the in-depth study which has been performed, certain conclusions have been reached. EPDM has been determined to be the best candidate for a: extended life. This choice was made taking several conditions into account. Foremost were the environmental considerations. EPDM has withstood this parameter in field use without exhibiting any discernable degree of degradation. In laboratory testing, EPDM consistently outperformed other elastomeric compounds (abrasion resistance, heat resistance, fluid compatability, radiation resistance, etc). Secondly, consideration was given to geometric parameters, not only of the seal itself, but also, to the glands. Our snubber design was intended to be used with elastomers having allowed space for swell and thermal expansion (elastomers have a higher value than do plastics or metals) to name a few. If another material (plastic or metal) was to be used, then remachining or complete redesign of the glands would most likely have to take place. This process would entail a significant cost impact and in the case of certain seal locations (cylinder end seal) may have proven to be very impractical. The third major consideration was the cost and availability of the materials. EPDM is relatively inexpensive, readily available from numerous vendors and has a short turn around time for delivery.

Based on the above stated information and the heavy endorsement that was given EPDM by our consultants who are experts in this field, we determined that EPDM had the highest probability for success. ITT Grinnell feels that the life of these seals could be extended significantly beyond the present seven (7) year period. In order to verify this, extensive testing will have to be performed (outlined in Section 3.2 below).

3.2 Testing

3.2.1 Purpose

This section will outline the test procedures necessary to verify life projections of EPDM seals as used in ITT Grinnell snubber systems under a nuclear power plant environment. Emphasis will be placed on simulated actual conditions and a degradation vs. time graph will be plotted. This will enable ITT Grinnell to state with a high degree of certainty the maximum life expectancy of the system seals.

3.2.2 Method of Testing

As previously stated, the ITT Grinnell test program utilizes simulated operational conditions. Close attention will be paid to radiation levels, temperature, fluid, steam and compression of the seal itself.

Qualification testings will be composed of the general breadboard testings plus the compression stress relaxation. Compression stress relaxation test is a direct representation of the several mechanisms of degradation (relaxation) the seal material will see under actual operation. Coupled with the breadboard tests, stress relaxation should develop adequate data to predict with a high confidence level the suitability and longevity of the polymeric material under the actual operating conditions.

3.2.3 Evaluation Criteria

Seal property data will be recorded in the form of percentage of properties retained or changed. This information will be used as input into a mathematical curve fitting (regression) computer program. Final extrapolations and analytical results (graphs) will then be compared to and checked against known benchmarks (data obtained from testing of five year and eight year exposed seals) for accuracy. Efforts will be made (via sensitivity evaluation, separation of variables, etc) to discern the sphere of influence that each separate parameter contributes to the total degradation of the seal. Based on the above, and in conjunction with the knowledge of potential types of failure modes (brittleness, degree of swell, high set characteristics, etc.), a determination will be made as to how long EPDM seals can safely be used in a nuclear environment.

APPENDIX 1

CHARTS, GRAPHS

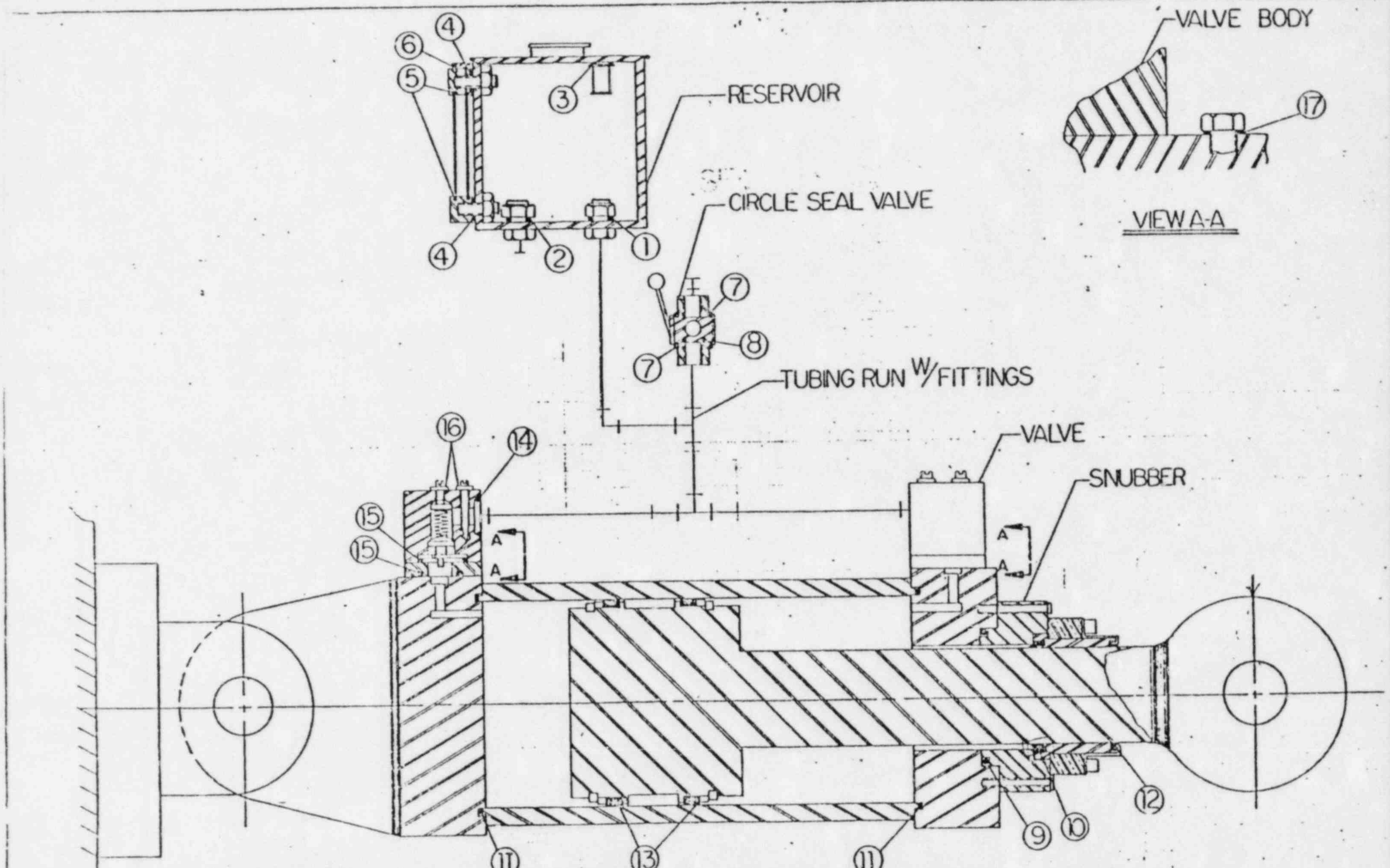
AND FIGURES

MIDLAND SNUBBER SEALS

ITEM	SEAL TITLE	LOCATION	FUNCTION-TYPE	SIZE	MANUFACTURER	COMPOUND	CURE METHOD
1	'O'RING - OUTLET ADAPTER	RESERVOIR	STATIC - 'O' RING	1.737 I.D. X .103W	FEDERAL - MOGUL	E 50	EPDM-PEROXIDE
2	'O'RING - DRAIN ADAPTER	RESERVOIR	STATIC - 'O' RING	.987 I.D. X .103W	FEDERAL - MOGUL	E 50	EPDM-PEROXIDE
3	'O'RING - FILTER ADAPTER	RESERVOIR	STATIC - 'O' RING	.987 I.D. X .103W	FEDERAL - MOGUL	E 50	EPDM-PEROXIDE
4	'O'RING - MTG. STUDS	SIGHT GLASS-RES.	STATIC - 'O' RING	.487 I.D. X .103W	FEDERAL - MOGUL	E 50	EPDM-PEROXIDE
5	'O'RING - GLASS GAUGE	SIGHT GLASS-RES.	STATIC - 'O' RING	.299 I.D. X .103W	FEDERAL - MOGUL	E 50	EPDM-PEROXIDE
6	'O'RING - CAP	SIGHT GLASS-RES.	STATIC - 'O' RING	.551 I.D. X .070W	FEDERAL - MOGUL	E 50	EPDM-PEROXIDE
7	'O'RING - CIR. SEAL VALVE	TUBING RUN	STATIC - 'O' RING	.796 I.D. X .139W	FEDERAL - MOGUL	E 50	EPDM-PEROXIDE
8	'O'RING - CIR. SEAL VALVE	TUBING RUN	STATIC - 'O' RING	.549 I.D. X .103W	FEDERAL - MOGUL	E 50	EPDM-PEROXIDE
9	EXTERNAL BEARING SEAL	MODEL 52 ONLY	STATIC - 'O' RING	VARIOUS	ACUSHNET	E 17018	EPDM-PEROXIDE
10	ROD SEAL	CYLINDER	DYNAMIC - LIP	VARIOUS	MINNESOTA RUBBER	559-EQ	EPDM-PEROXIDE
11	'O'RING - END SEAL	CYLINDER	STATIC - 'O' RING	VARIOUS	ACUSHNET	E 17018	EPDM-PEROXIDE
12	ROD WIPER	CYLINDER	DYNAMIC - LIP	VARIOUS	MINNESOTA RUBBER	559-EQ	EPDM-PEROXIDE
13	PISTON SEAL	CYLINDER	DYNAMIC - U-CUP	VARIOUS	W.H. SALISBURY	80154	EPDM-SULFUR
14	'O'RING - VALVE	TUBE CONN.	STATIC - 'O' RING	1.171 I.D. X .116W	FEDERAL - MOGUL	E 50	EPDM-PEROXIDE
15	'O'RING - VALVE	RETAINER PL.	STATIC - 'O' RING	1.299 I.D. X .103W	FEDERAL - MOGUL	E 50	EPDM-PEROXIDE
16	THREAD SEAL	VALVE	STATIC - THREAD	.644 I.D. X .087W	FEDERAL - MOGUL	E 50	EPDM-PEROXIDE
18	THREAD SEAL	VALVE	STATIC - THREAD	1.299 I.D. X .103W	FEDERAL - MOGUL	E 50	EPDM-PEROXIDE
17	FILL PORT PLUG	CYLINDER	STATIC - 'O' RING	.644 I.D. X .087W	FEDERAL - MOGUL	E 50	EPDM-PEROXIDE
19	FILL PORT PLUG	CYLINDER	STATIC - 'O' RING	.755 I.D. X .097W	FEDERAL - MOGUL	E 50	EPDM-PEROXIDE

CYLINDER MODEL	QUANTITY OF SEALS
52	30
90	29

TABLE: 4


VALVE BODY
RESERVOIR
CIRCLE SEAL VALVE
VIEW A-A
TUBING RUN W/FITTINGS
VALVE
SNUBBER
A
A
A
A
1
2
3
4
4
4
5
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6
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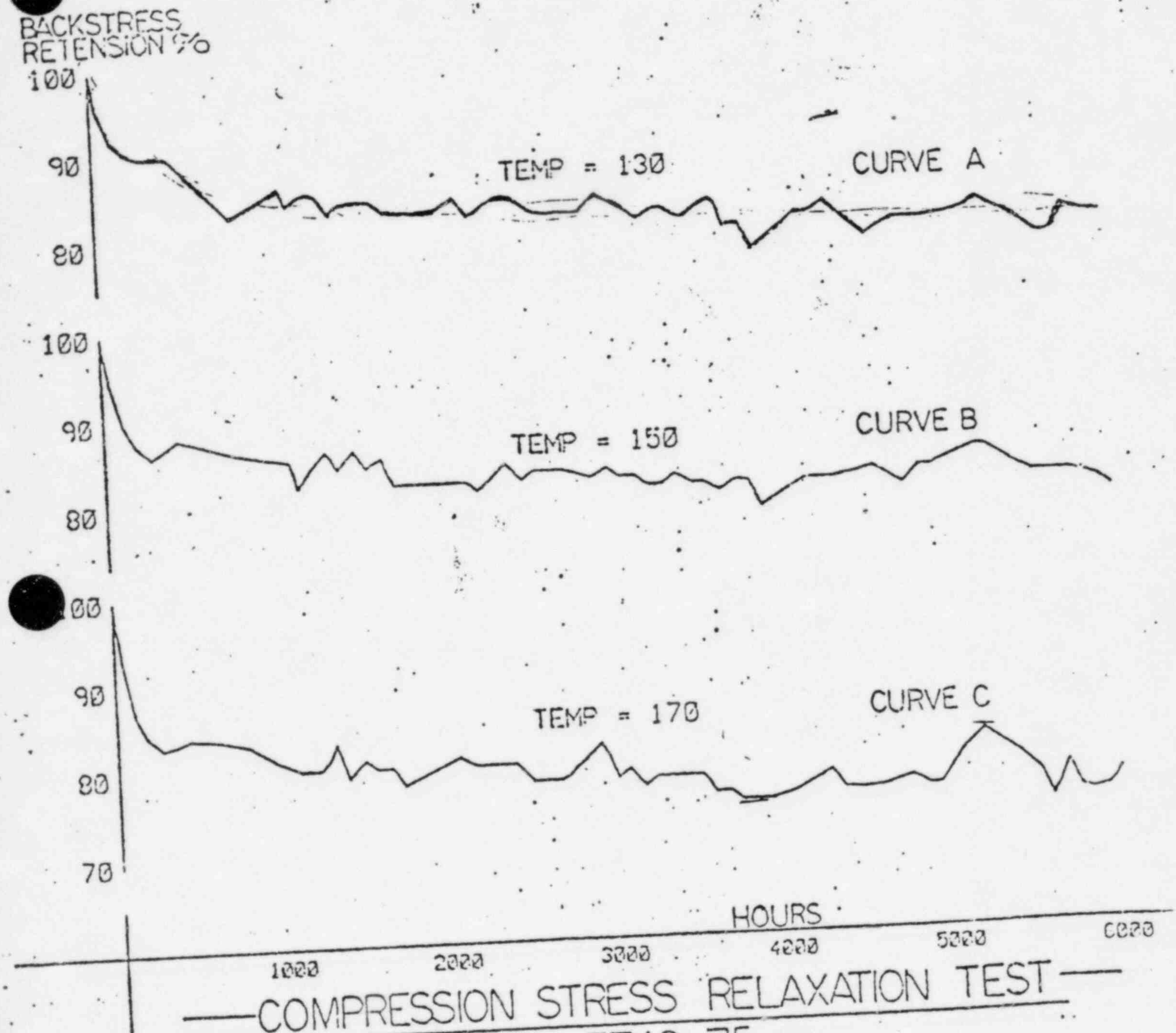
15
16
17



COMPRESSION STRESS RELAXATION TEST

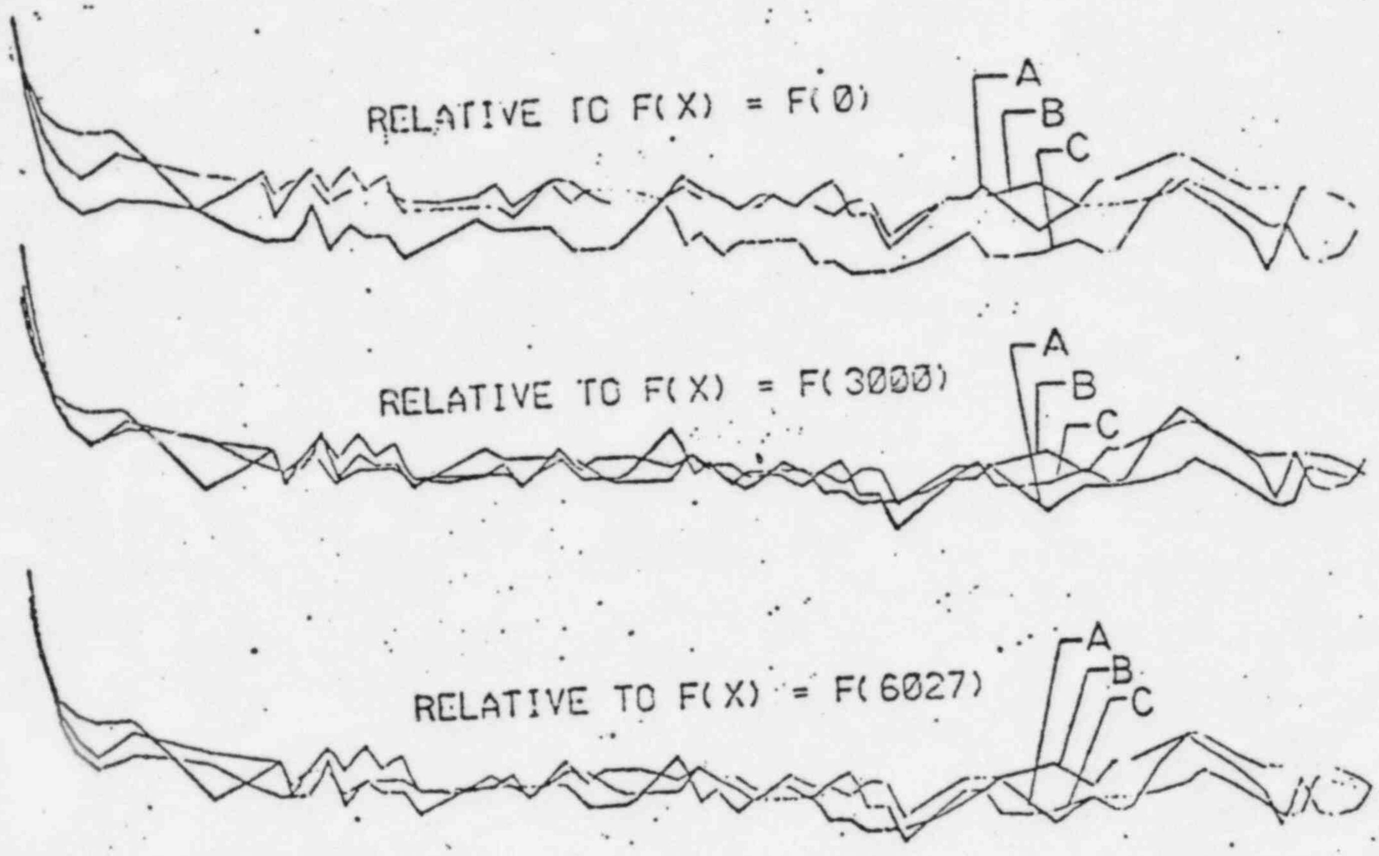
PARKER E740-75

GRAPH 1

BY YM DATE 7-15-81 SUBJECT SEAL STUDY SHEET NO. ...... OF ......

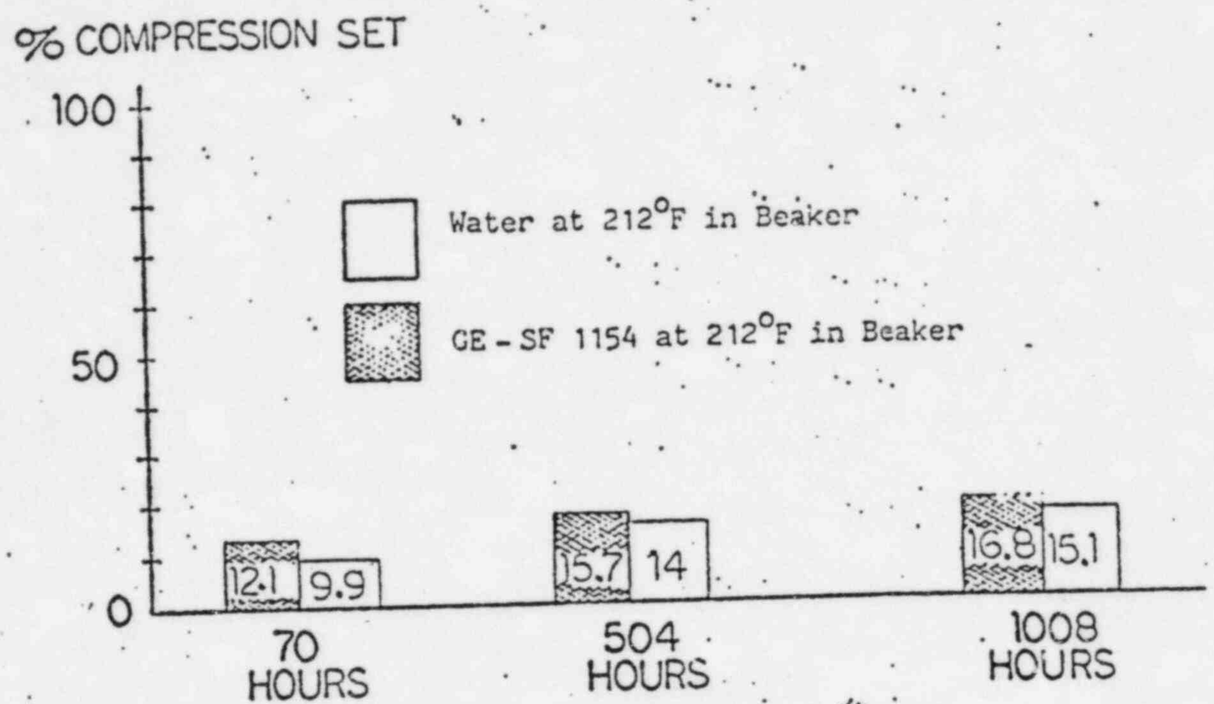
CHKD. BY HB DATE 7-15-81 CUSTOMER CONSUMERS SYSTEM ......

PROJECT MIDLAND PROJECT NO. SPS-8014



BACKSTRESS RETENSION
OVERLAY COMPARISON
PARKER E740-75

—GRAPH 1A—



PARKER-COMPOUND # 740

Hardness varied from -2 to -1 from 75 orig. (insignificant)

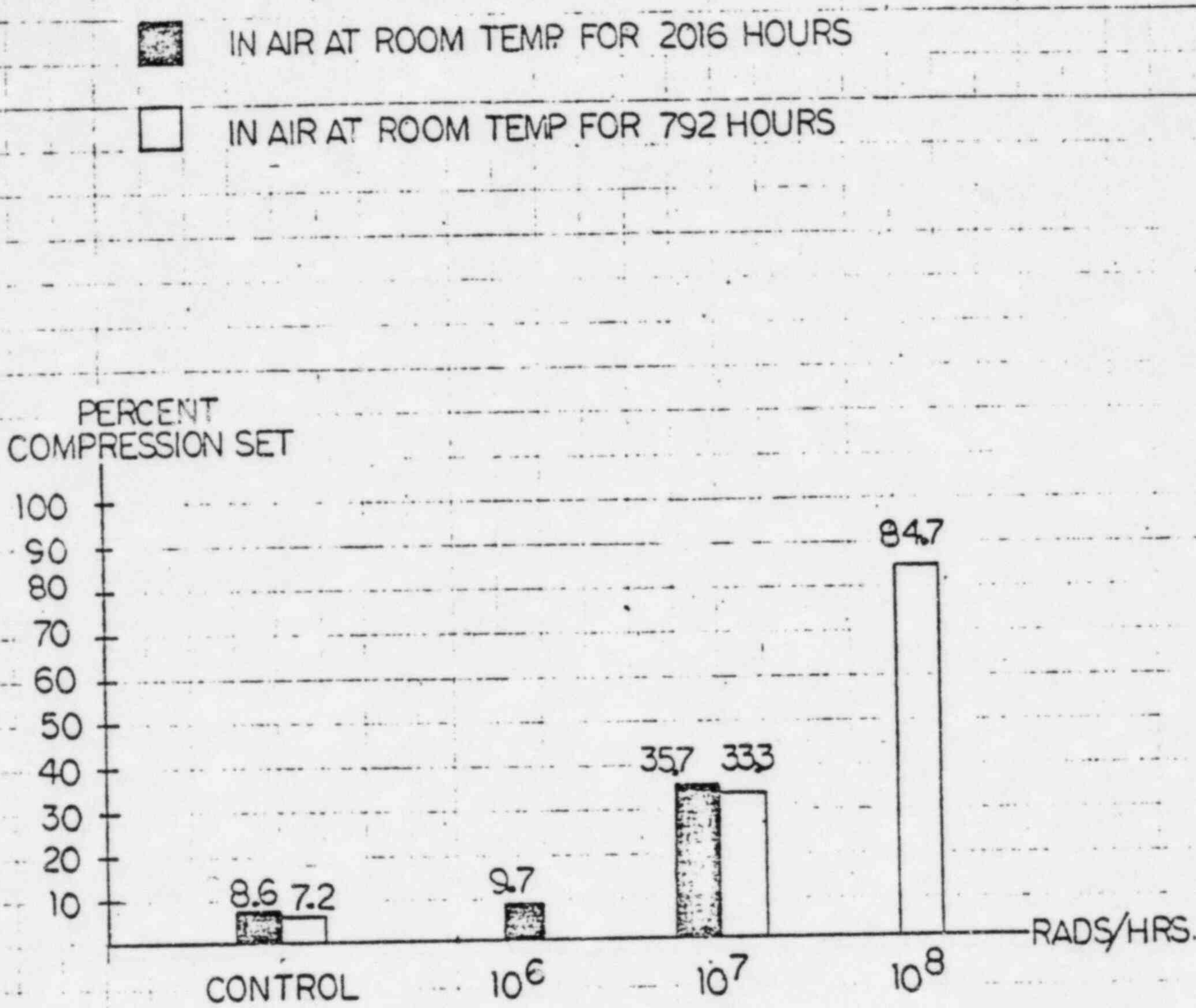
Swell after 1008 Hrs. 1.1% - insignificant
may be due to temp. also

NOTE: Results were similar after Test B immersion
3 hrs. @ 340°F, 3 hrs. @ 320°F & 18 hrs. @ 250°F

	Orig.	Test A (70 hrs)	Test A (504 hrs)	Test A (1008 hrs)	Test B
Hardness	75	73	74	73	72
Tensile Str.	2580	2620	2430	2750	2380
Elong. %	182	183	179	197	177
Mod. @ 100%	928	941	921	878	952
Volume (%)		+.8	+.09	+1.1	1.9

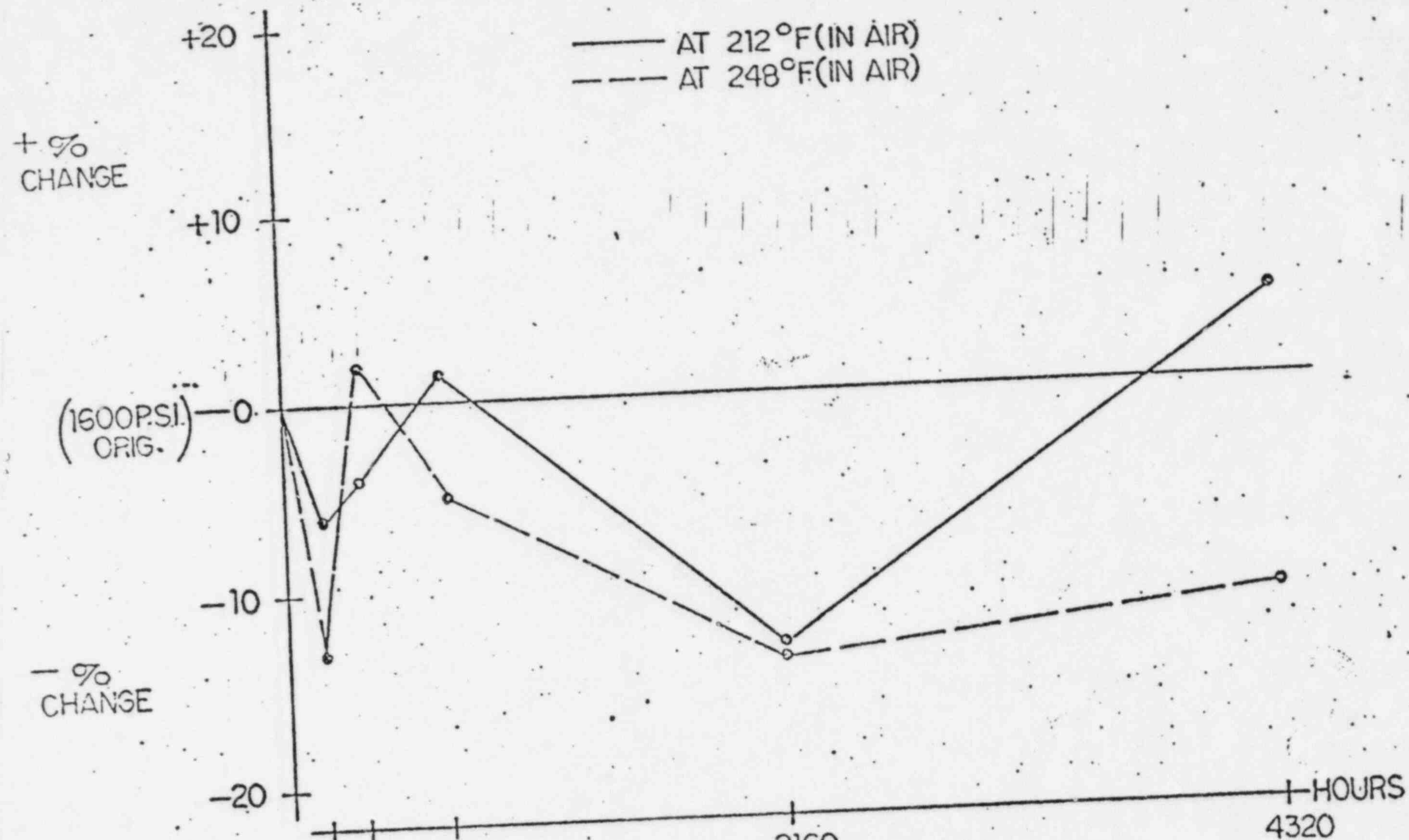
—GRAPH 2—

TESTING DONE



GRAPH 2A - COMPRESSION SET
COMPOUND E740 75

NORDELL - EPDM 1:1 ACTIVADO
ENERGY



TENSILE STRENGTH
MINN. RUBBER-COMPOUND #559EQ
GRAPH 3

*

ITT Grinnell Corporation
BY Y.M. DATE 7-15-81
CHKD. BY H.B. DATE 7-15-81

SUBJECT SEAL STUDY
CUSTOMER CONSUMERS
PROJECT MIDLAND
SYSTEM ....
PROJECT NO. SPS 8014
SHEET NO. .... OF ....

— % DEVIATION —
MINN. RUBBER-COMPOUND #559EQ

— GRAPH 4 —

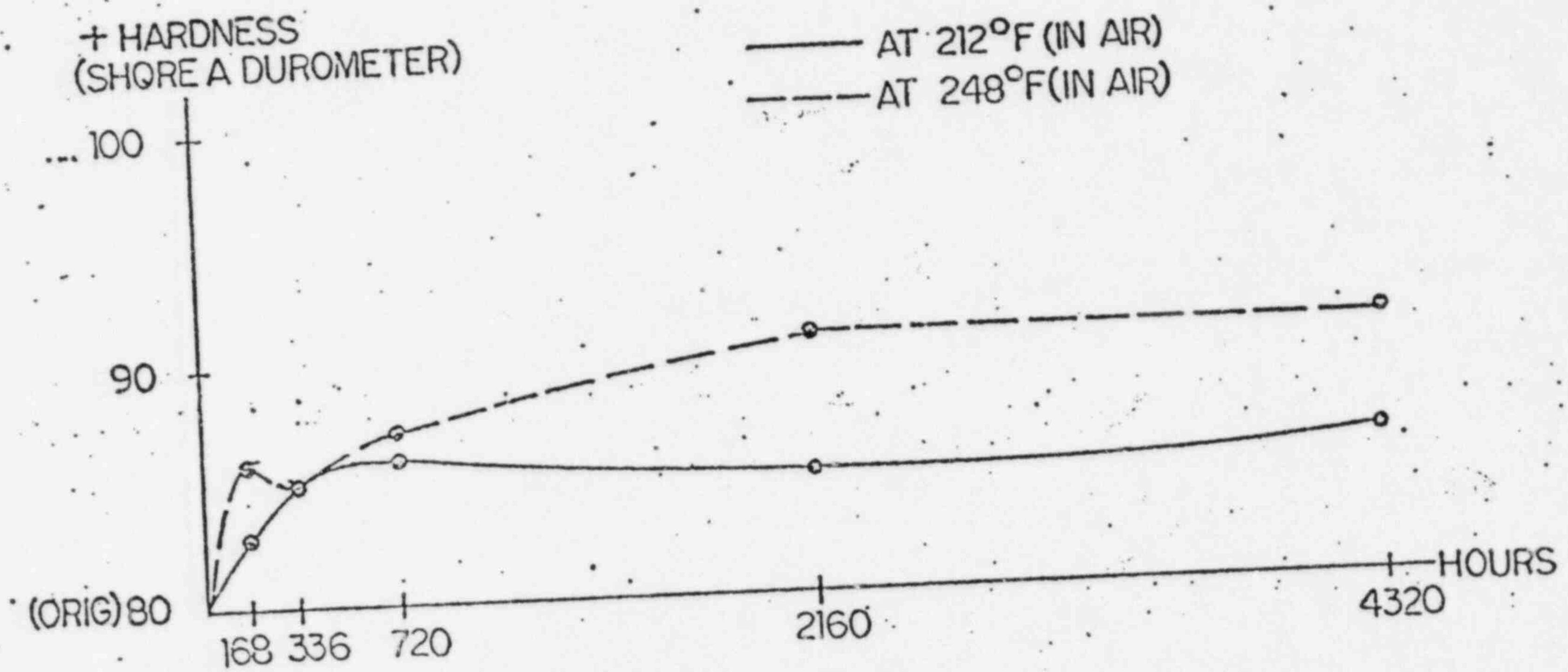
*

ITT Grinnell Corporation

BY Y.M. DATE 7-15-81 SUBJECT SEAL STUDY SHEET NO. .... OF ......

CHKD. BY H.B. DATE 7-15-81 CUSTOMER CONSUMERS SYSTEM ....

PROJECT MIDLAND PROJECT NO. SPS 8014

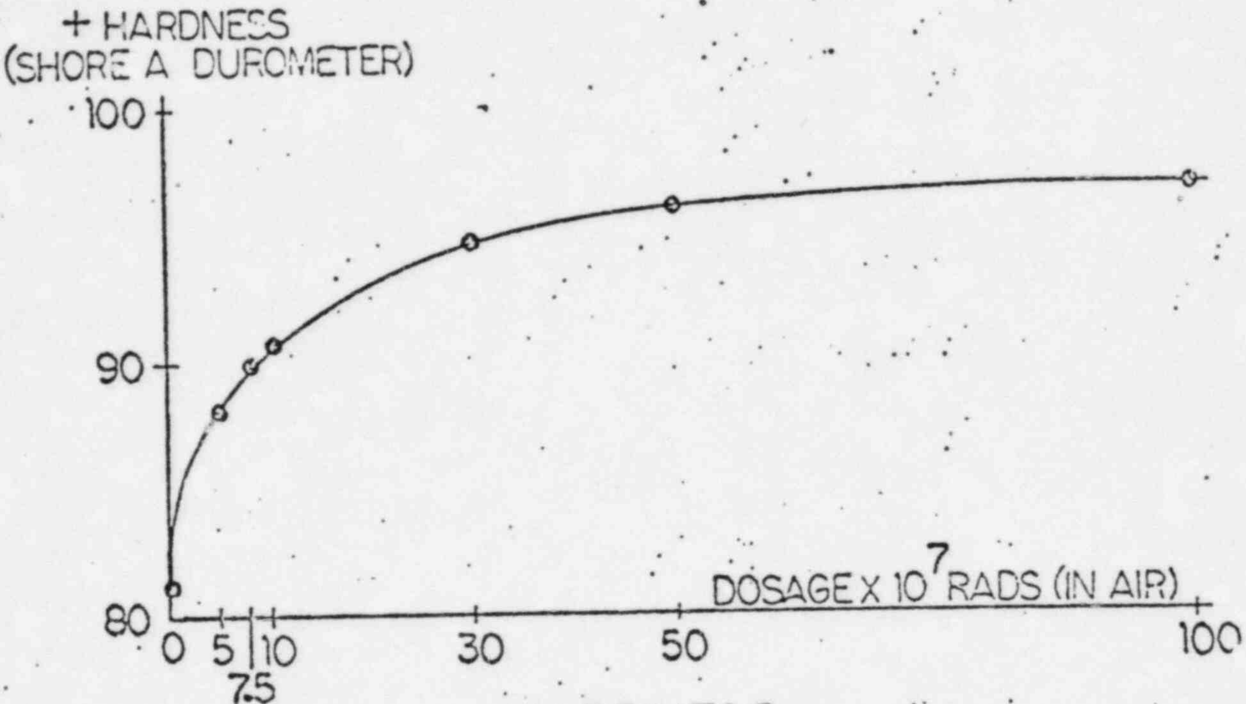


HARDNESS

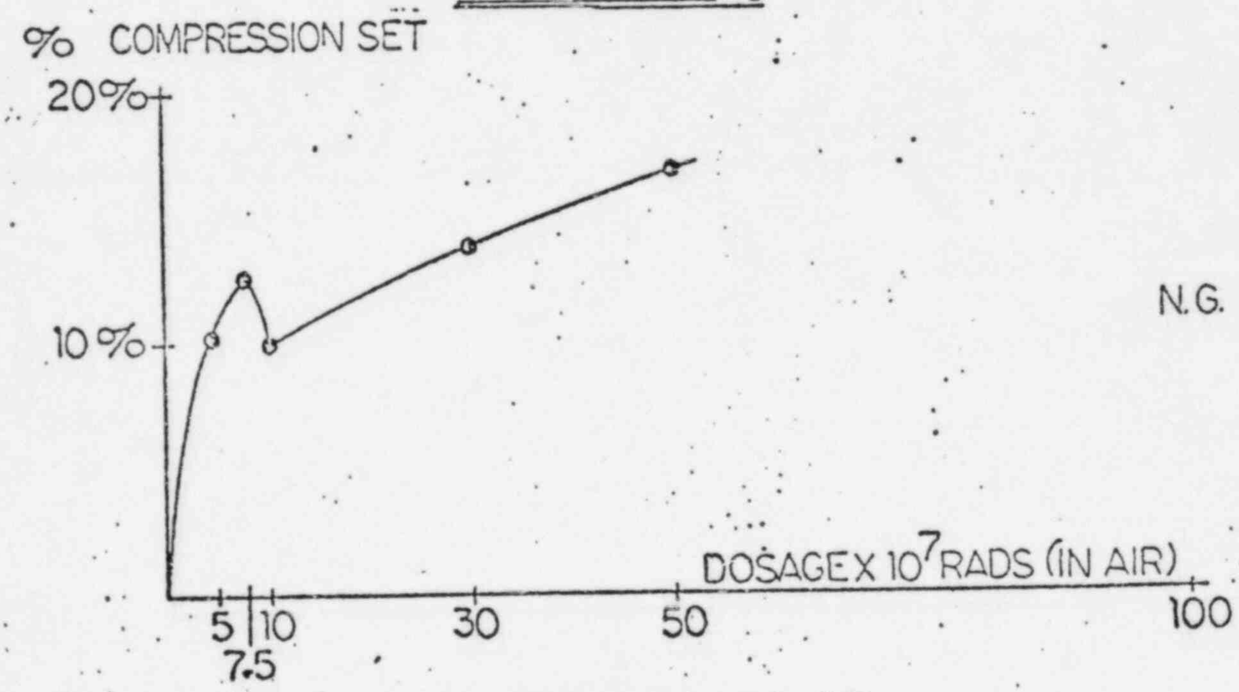
MINN. RUBBER-COMP. #559EQ

GRAPH 5

BY Y M DATE 7-15-81 SUBJECT SEAL STUDY SHEET NO. ..... OF .....
CHKD. BY HB DATE 7-15-81 CUSTOMER CONSUMERS SYSTEM .....
PROJECT MIDLAND PROJECT NO. SPS 8014

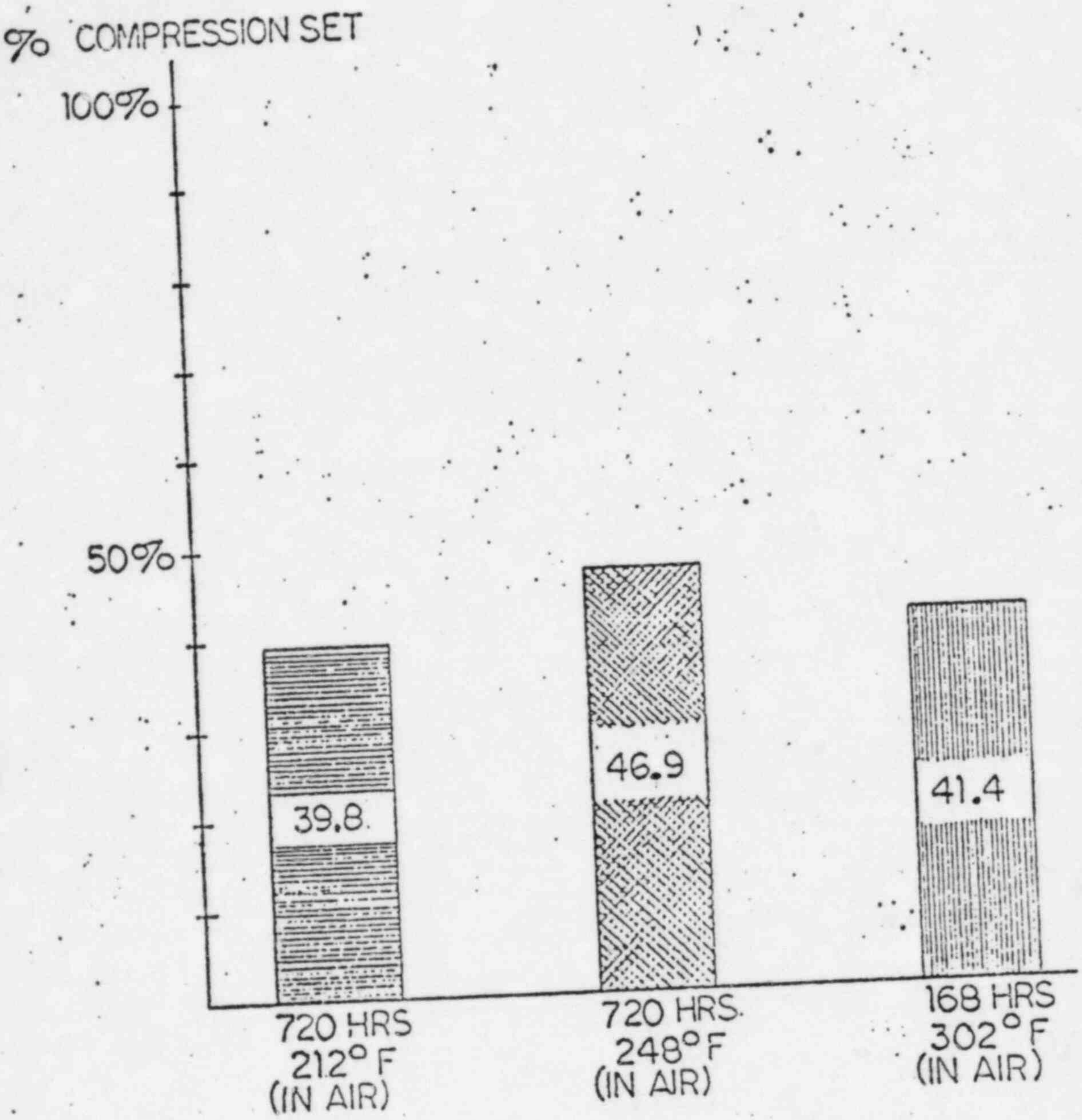


—HARDNESS—
MINN. RUBBER-COMPOUND #559EQ
—GRAPH 6—



—COMPRESSION SET—
MINN. RUBBER -COMPOUND #559EQ
—GRAPH 7—

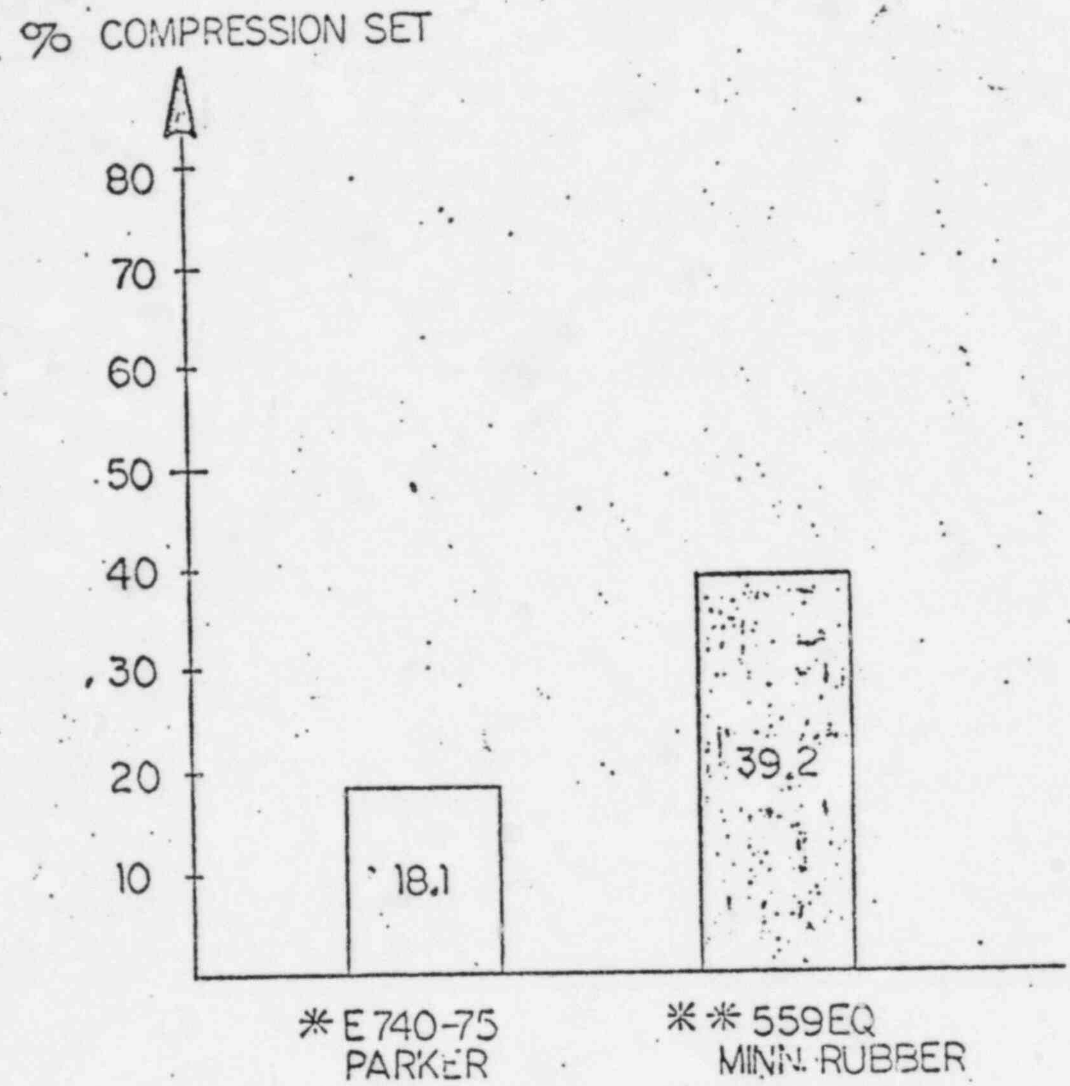
BY Y M DATE 7-15-81 SUBJECT SEAL STUDY SHEET NO.
CHKD. BY HB DATE 7-15-81 CUSTOMER CONSUMERS SYSTEM
PROJECT MIDLAND PROJECT NO. SPS-8014



—METHOD B —COMPRESSION SET—
MINN. RUBBER — COMPOUND #559EQ

—GRAPH 8—

BY YM DATE 7-15-81 SUBJECT
CHKD. BY HB DATE 7-15-81 CUSTOMER CONSUMERS SYSTEM
PROJECT MIDLAND PROJECT NO. SPS-8014

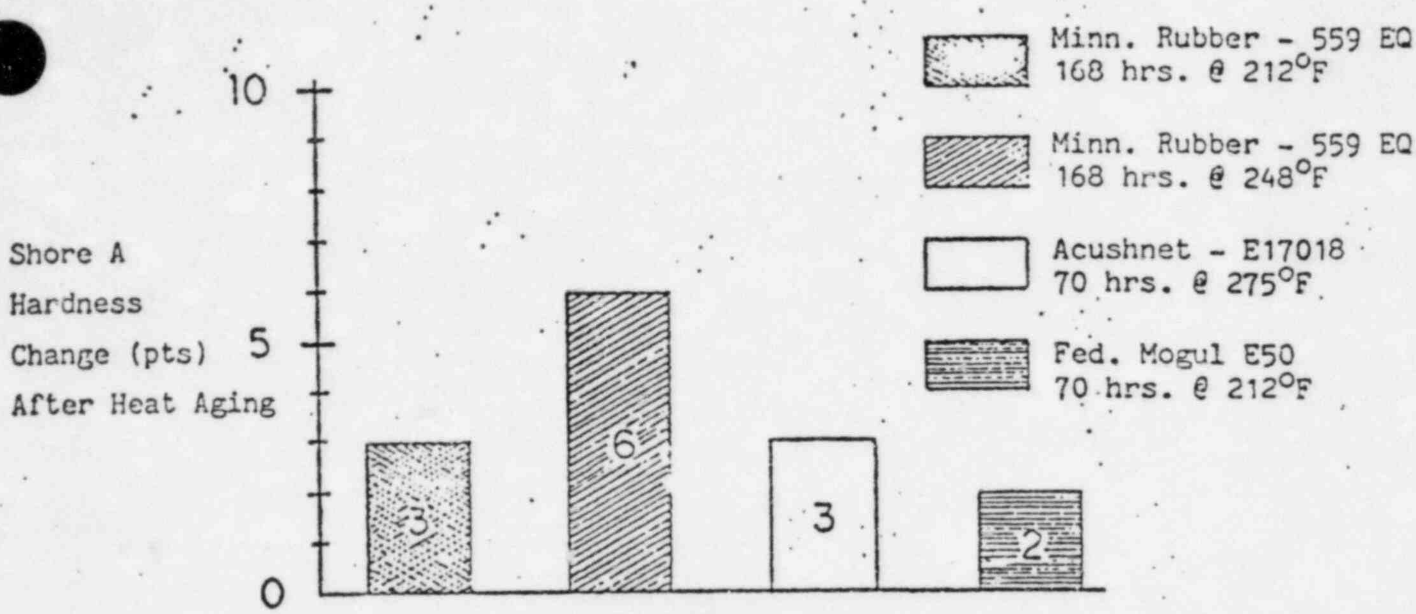


—COMPRESSION SET—

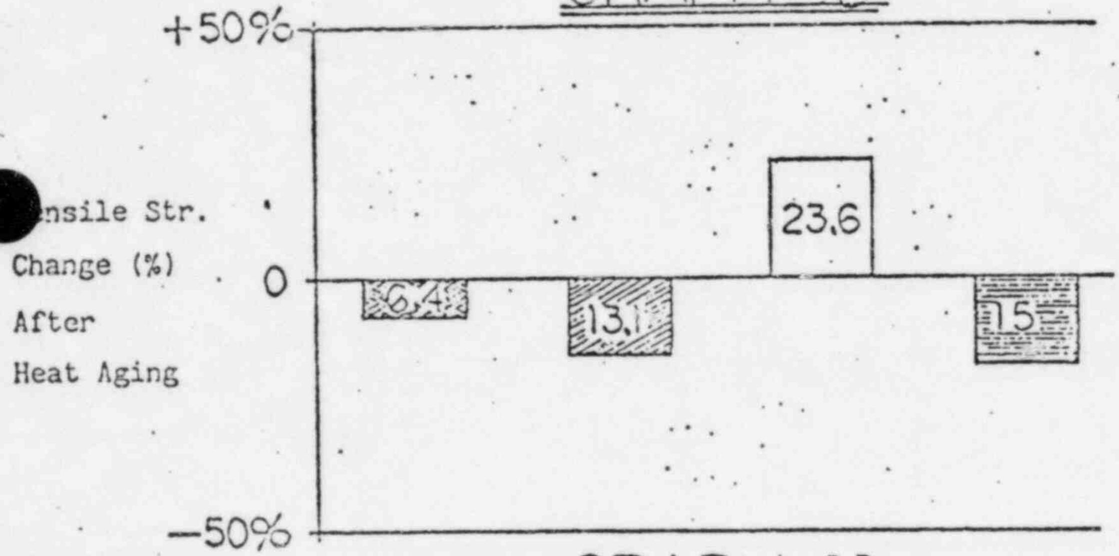
* 3 hrs. @ 340°F, 3 hrs. @ 320°F & 18 hrs. @ 250°F in GE SF 96,200 Fluid (Dimethyl polysiloxane fluid)

** 3 hrs. @ 340°F, 3 hrs. @ 320°F & 18 hrs. @ 250°F in GE SF 1154 Fluid (Methyl phenyl polysiloxane fluid)

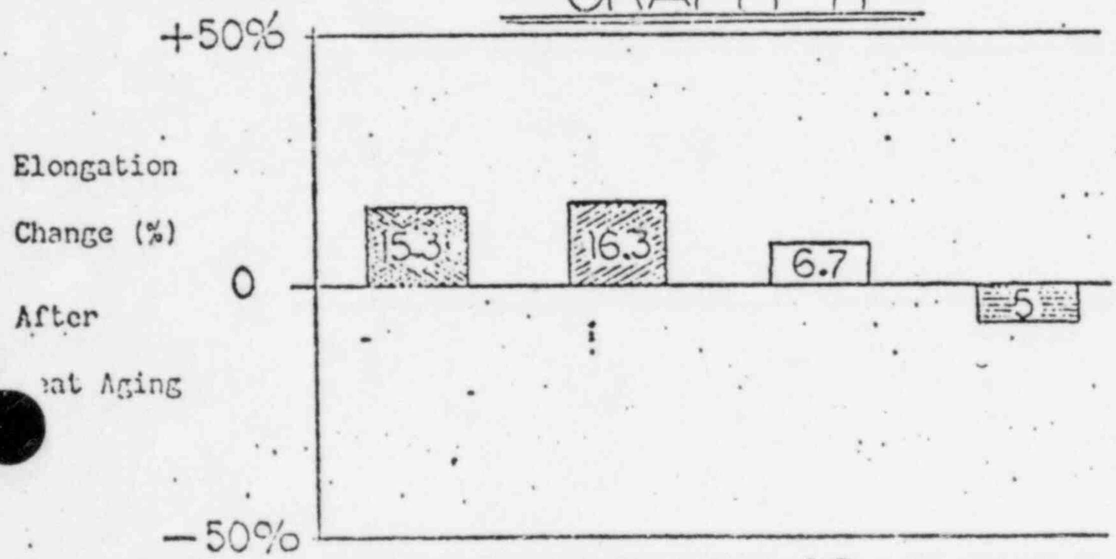
—GRAPH 9—



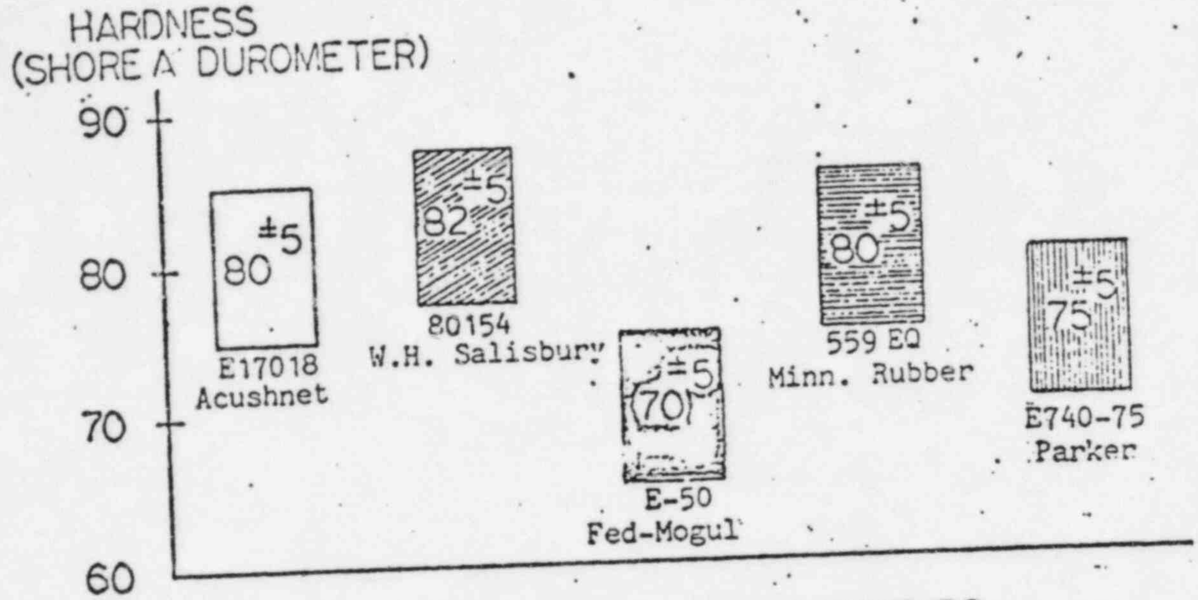
—GRAPH 10—



—GRAPH 11—

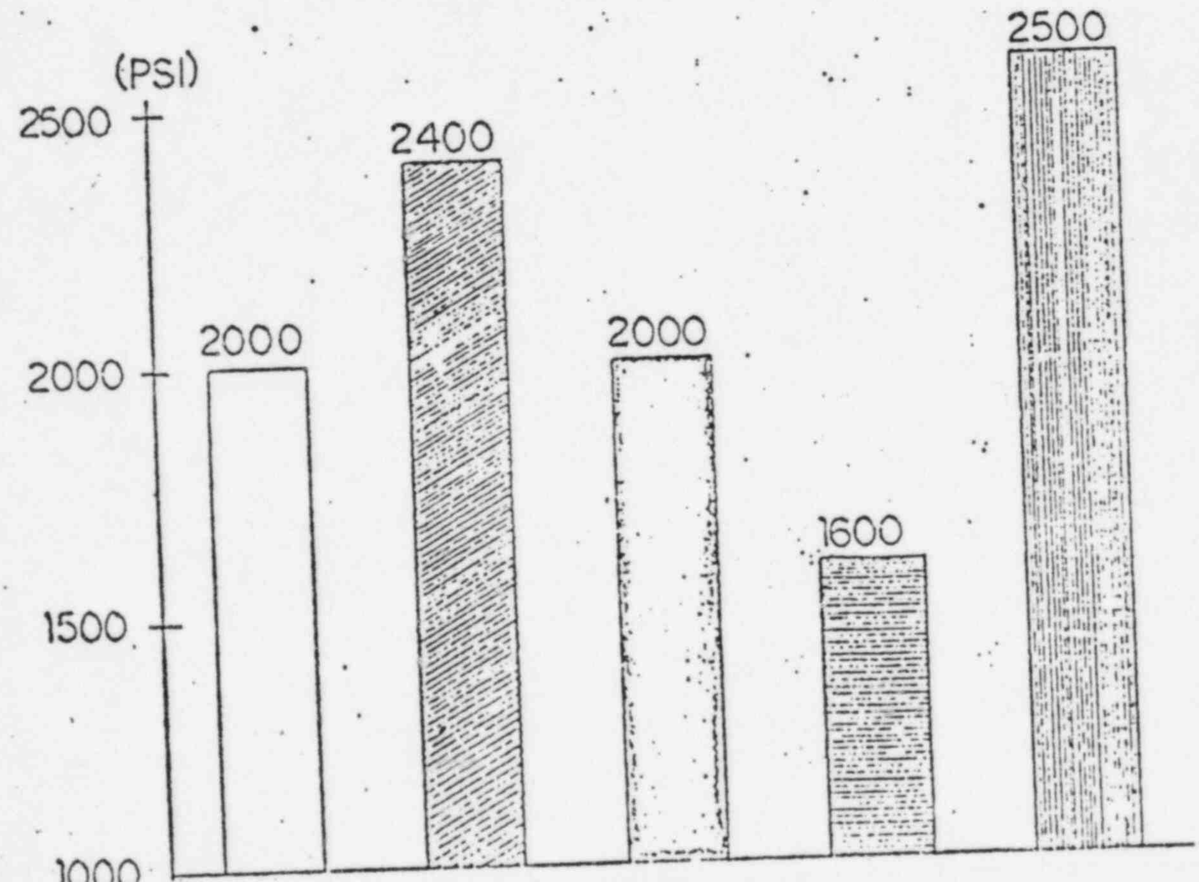


—GRAPH 12—



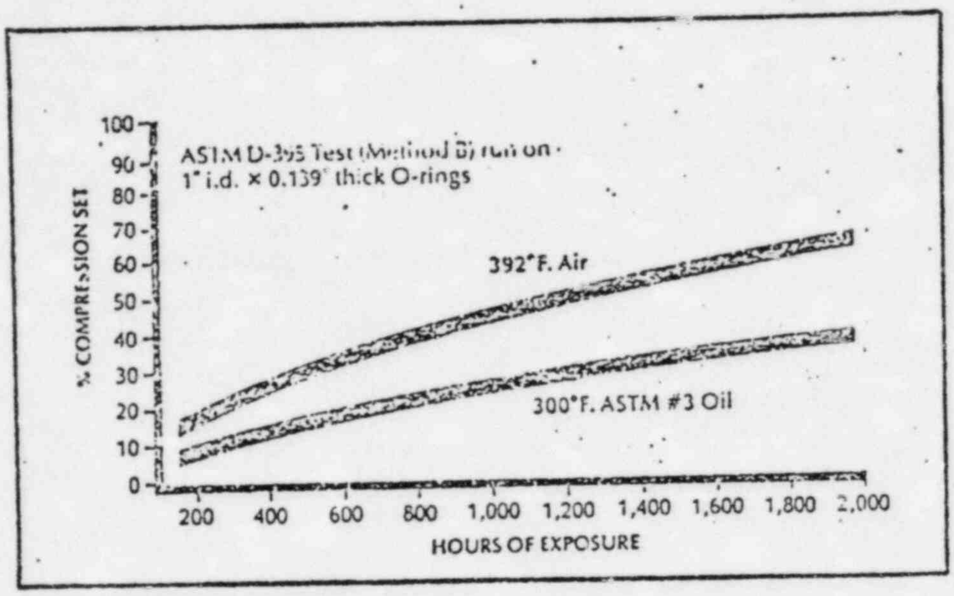
— ORIGINAL PROPERTIES —

— GRAPH 13 —



— TENSILE STRENGTH —

— GRAPH 14 —



PERMANENT DEFORMATION RESISTANCE OF VITON

—FIG. 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)

LONG TERM COMPRESSION SET OF VITON AT DIFFERENT TEMPERATURES

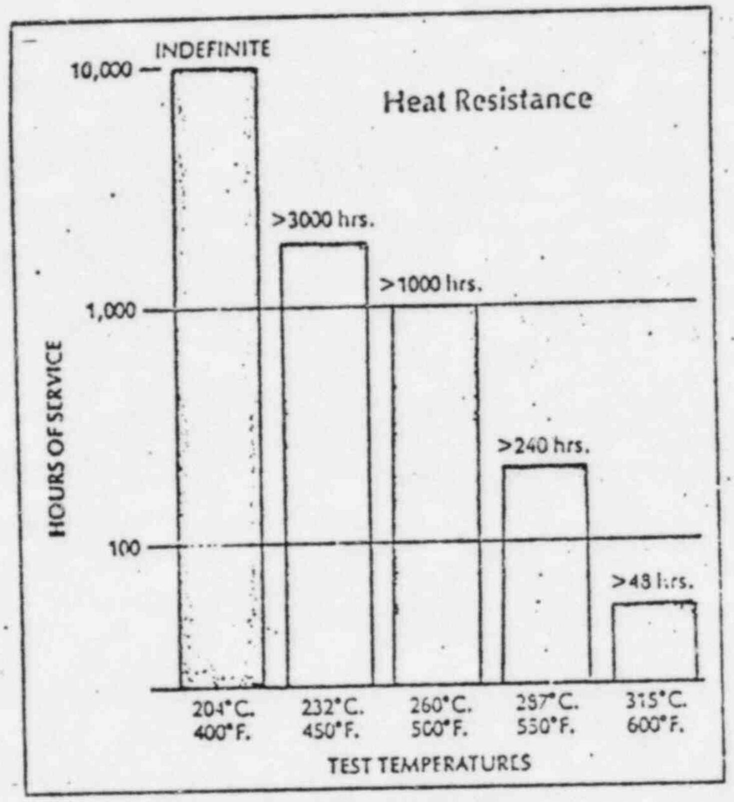
—FIG. 1-A—

Oven Air Aging of VITON

Physical Properties (dumbbell specimens unless otherwise noted)	Original	Temperature, Time				
		212°F. 100°C. 3 months	250°F. 121°C. 3 months	275°F. 135°C. 3 months	300°F. 148°C. 11 months	392°F. 200°C. 11 months
100% modulus, psi	800				1050(131%)	810(101%)
Ultimate tensile strength, psi (O-ring)	1915	1835	1915(100%)	2025(106%)		
Ultimate tensile strength, psi	2200				1700(77%)	1400(64%)
Ultimate elongation, % (O-ring)	210	210	225(107%)	235(112%)		
Ultimate elongation, %	220				145(66%)	150(68%)
Hardness, Durometer A points	76				76(100%)	81(107%)

THE EFFECT OF OVEN AIR AGING ON SPECIFIC MECHANICAL PROPERTIES OF VITON AT VARIOUS TEMPERATURES OVER PROLONGED PERIODS.

— FIG. 2 —



SERVICE LIMITS OF VITON IN AIR AT
VARIOUS TEMPERATURES.

— FIG-2-A —

PHYSICAL PROPERTIES				
ENVIRONMENT	RADIATION DOSAGE ERGS g^{-1} (c)	TENSILE STRENGTH psi	ELONGATION %	HARDNESS
AIR	0	1044	192	66.2
AIR	8.7×10^7		DISINTEGRATED	
ARGON	2×10^8	2145	172	72
ARGON	5×10^8	742	63	76
MIL-L-7808 OIL	8.7×10^7	1112	208	64.8
MIL-L-7808 OIL	4.4×10^8	1028	211	64.4
MIL-L-7808 OIL	1.7×10^9	961	117	64.8

PROPERTY CHANGE IN "VITON" IRRADIATED IN AIR,
ARGON AND JET TURBINE OIL AT 400°F BY COBALT - 60

—FIG. 2-B—

PHE No 4

Hardness, Durometer A	80
100% Modulus*, psi	1,400
MPa	9.65
Tensile Strength*, psi	1,900
MPa	13.10
Elongation at Break*, %	130
Compression Set, ASTM D395B Pellets 70 hr. at 400°F (204°C), %	38
at 550°F (288°C), %	53
Brittle Point, ASTM D746	
°F	−35
°C	−37

*ASTM D412, 10 in./min. (4 2 x 10⁻³ m/s)

GENERAL PHYSICAL PROPERTIES OF KALREZ PERFLUOROELASTOMER

(COMPOUND 1050)

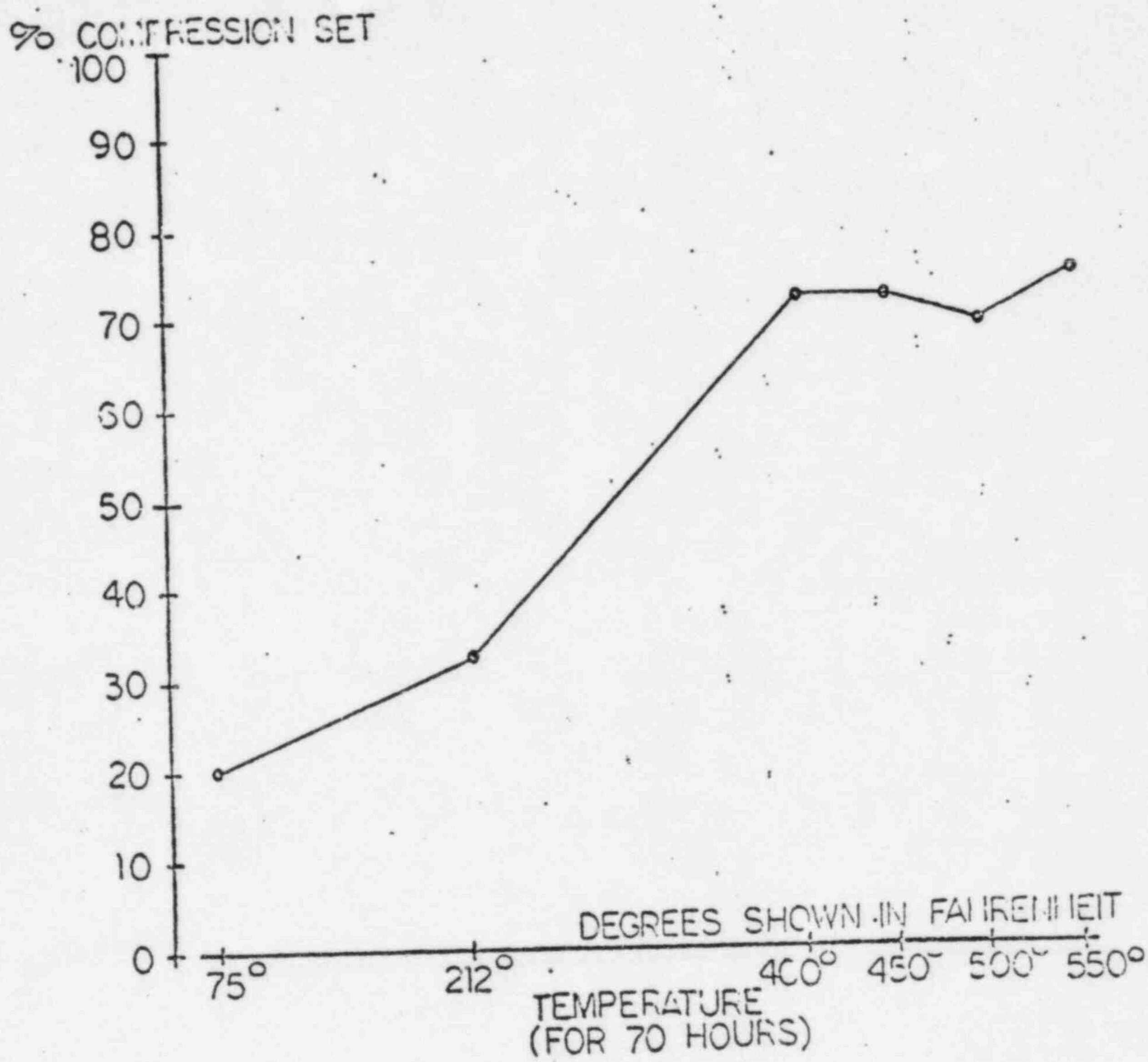
—TABLE-2—

Test Conditions: Temperature	Time	Compression Set % KALREZ 1050
75°F (24°C)	70hr.	20
212°F (100°C)	70hr.	32
400°F (204°C)	70hr.	71
450°F (232°C)	70hr.	71
500°F (260°C)	70hr.	69
550°F (288°C)	70hr.	74

*ASTM D-395B
AS-568A = 214 O-Ring Specimens
Heat Aged in Air

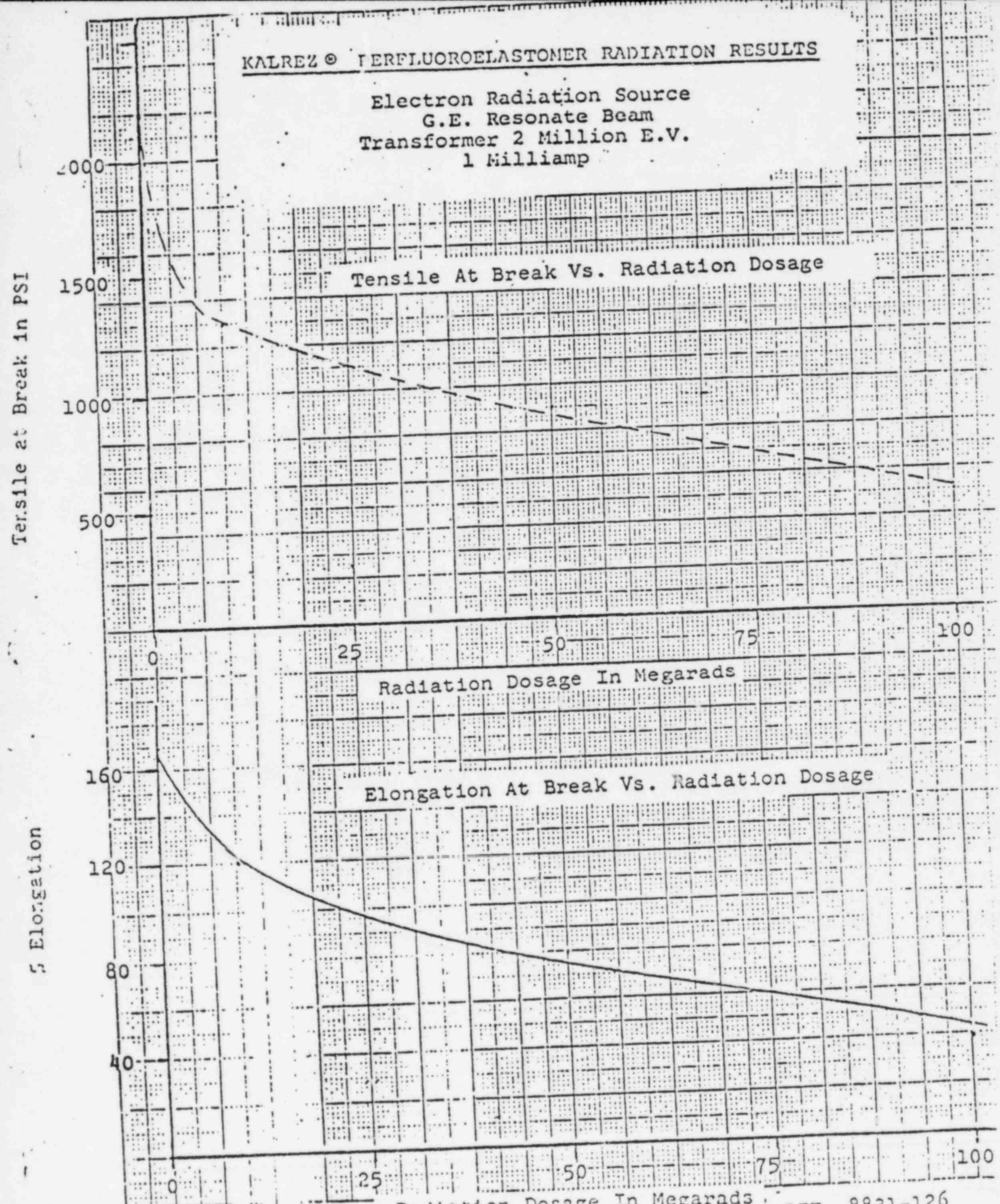
COMPRESSION SET OF KALREZ AT DIFFERENT TEMPERATURES

— TABLE-3 —

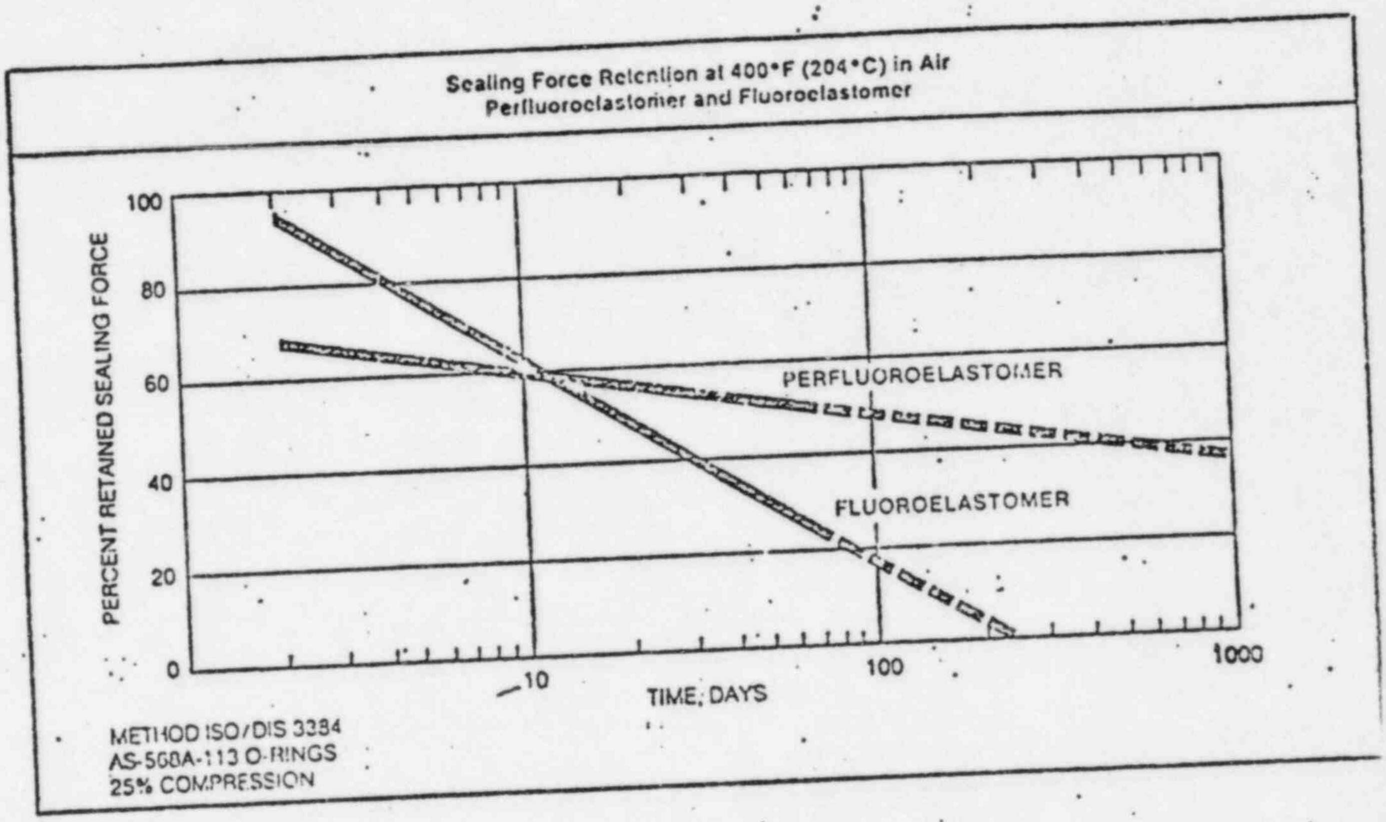


—KALREZ—
(COMPOUND 1050)

— FIG. 3 —


KALREZ © PERFLUOROELASTOMER RADIATION RESULTS
Electron Radiation Source
G.E. Resonate Beam
Transformer 2 Million E.V.
1 Milliamp
Tensile at Break in PSI
2000
1500
1000
500
Tensile At Break Vs. Radiation Dosage
0
25
50
75
100
Radiation Dosage In Megarads
% Elongation
160
120
80
40
Elongation At Break Vs. Radiation Dosage
0
25
50
75
100
Radiation Dosage In Megarads
REF. 8831-126

—FIG.4—



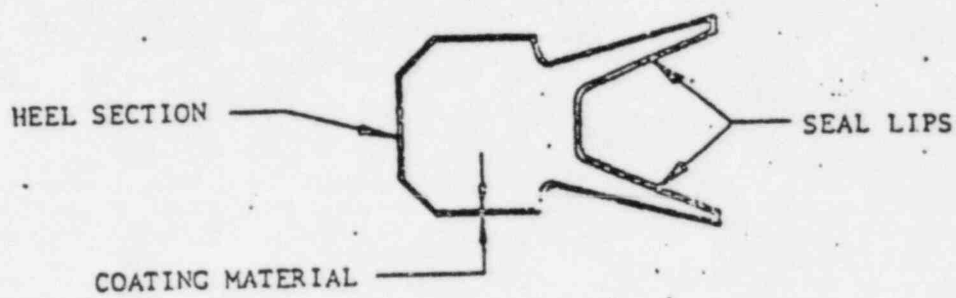
KALREZ
BACKSTRESS RETENTION

FIG. 5

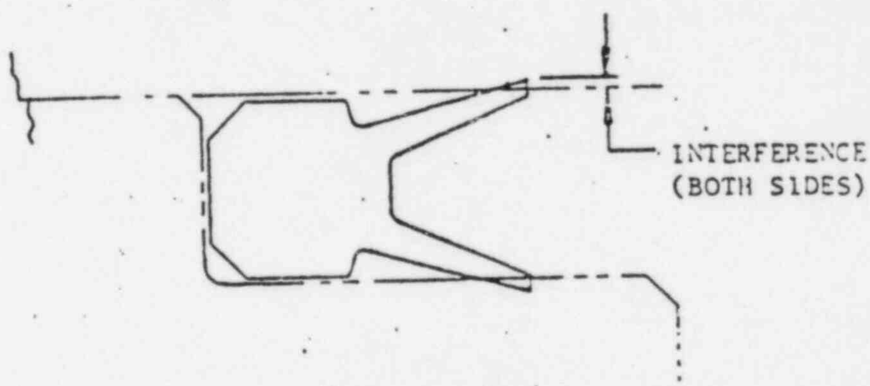
BY... AK ... DATE 9/17/81 SUBJECT... SEAL STUDY ... SHEET NO. .... OF ......

CHKD. BY .... DATE .... CUSTOMER CONSUMER POWER SYSTEM ....

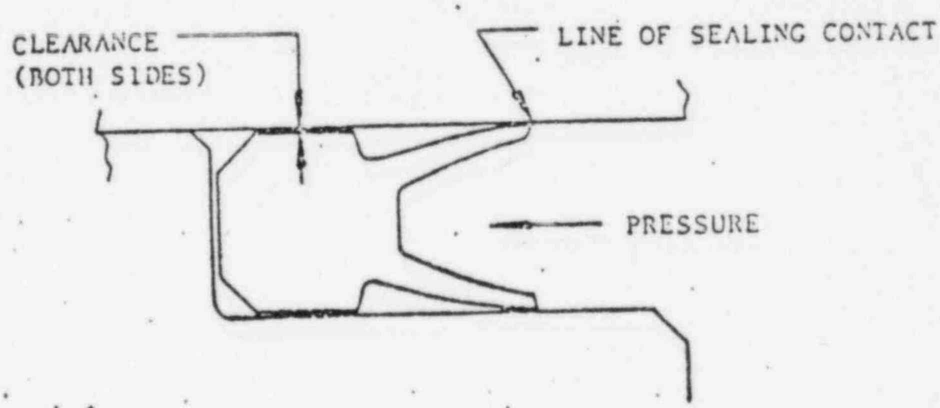
PROJECT ... MIDLAND .... PROJECT NO. SPS-3014 ....



CROSS SECTION of TYPICAL K-SEAL



CROSS SECTION of K-SEAL and SEAL CAVITY SHOWING INTERFERENCE



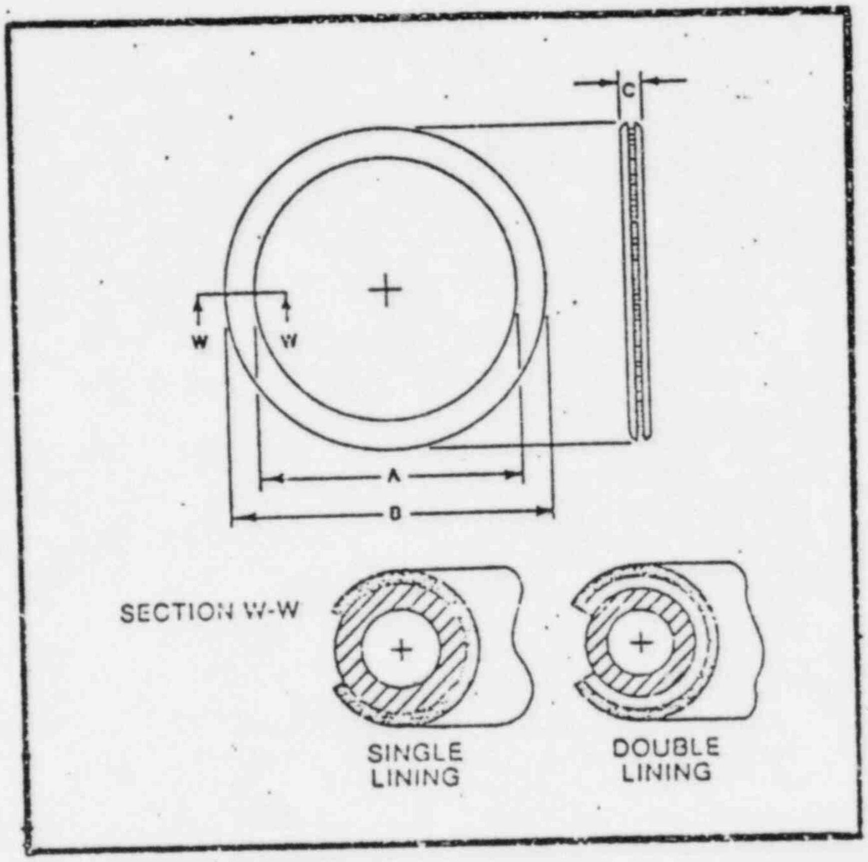
K-SEAL in INSTALLED POSITION

— FIG-6 —

BY AK DATE 9/12/81 SUBJECT SEAL STUDY SHEET NO. ... OF ...

CHKD. BY ... DATE ... CUSTOMER CONSUMER POWER SYSTEM ...

PROJECT MIDLAND PROJECT NO. SPS-3014



— FIG. 7 —

CROSSECTIONAL DIAGRAM

HELICOFLEX SEAL

APPENDIX 2

BASELINE STUDY

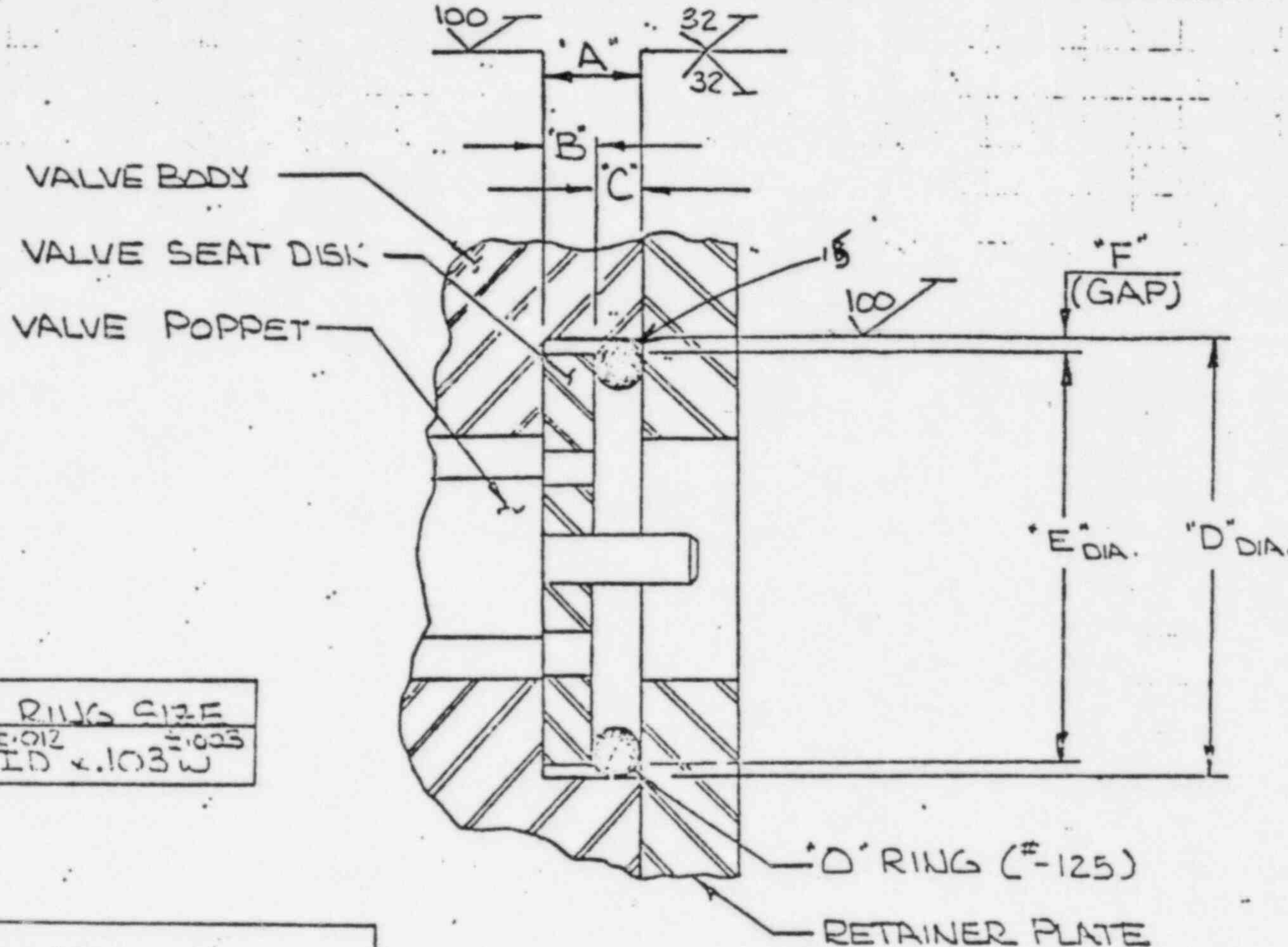
CHARTS, GRAPHS

AND FIGURES

BY ... DATE ... SUBJECT ... SHEET NO. ... OF ...

CHKD. BY AK DATE 5-29-81 CUSTOMER CONSUMERS SYSTEM VALVE-RET. PLATE

PROJECT MIDLAND PROJECT NO. SPS-8014



"O" RING SIZE
1.299 ±.012 ID x .103 ±.003 W

DIMENSIONS		
DIM.	MIN.	MAX.
A	.207	.208
B	.125	.126
C	.081	.083
D	1.446	1.447
E	1.438	1.440
F	.003	.009

COMPRESSION		
MIN.	MAX.	NOMINAL
17%	23.6%	20.38%

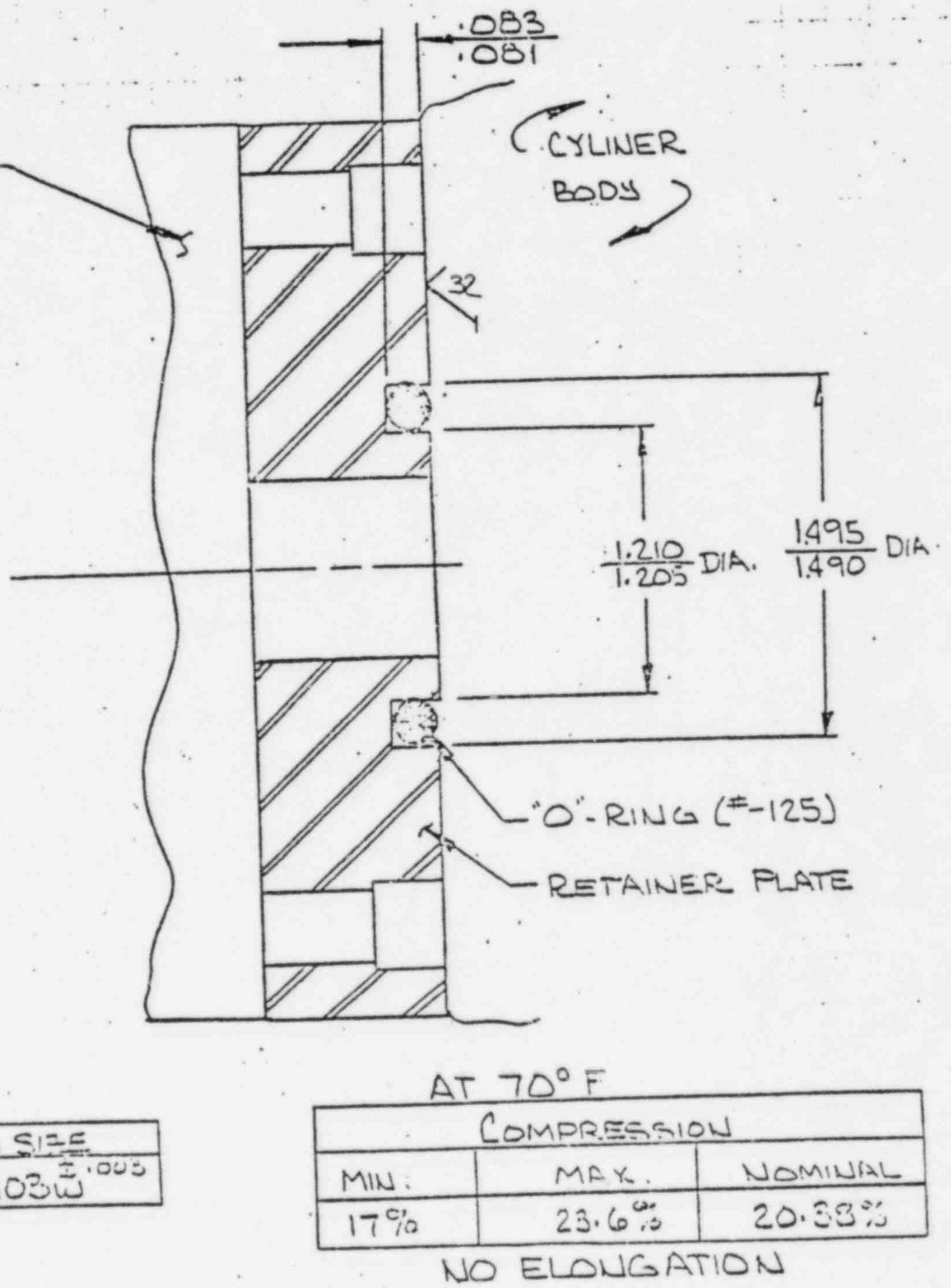
ABOVE AT 70° F

NO SCALE

REF: PHD-5222-21-REV.F
PHD-5222-23-REV.E
PHD-5222-29-REV.C

FIG. 9

BY DL DATE 5-27-81 SUBJECT SEAL STUDY SHEET NO. 2 OF
CHKD. BY A.K. DATE 5-29-81 CUSTOMER CONSUMERS SYSTEM VALVE-RET. PLATE
PROJECT MIDLAND PROJECT NO. SPS-8014



AT 70° F

'O'-RING SIZE
1.299 ±.012 ID x .103 W ±.003

COMPRESSION		
MIN.	MAX.	NOMINAL
17%	23.6%	20.38%

NO ELONGATION

NO SCALE

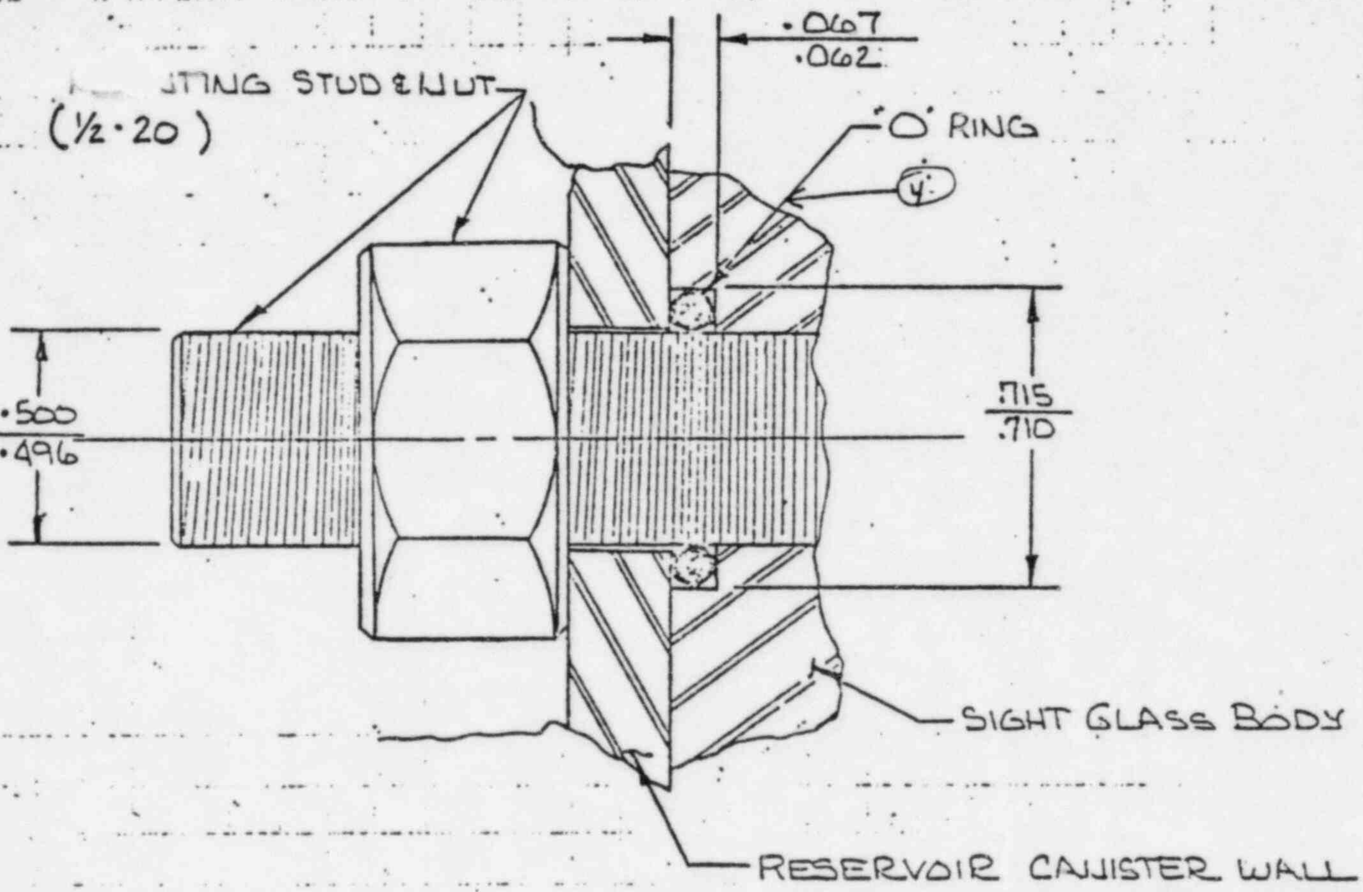
REF: PHD-5222-27-REV.D

FIG. 10

PHL No. 4

CHKD. BY AK ..... DATE .... CUSTOMER CONSUMERS ..... SYSTEM RESERVOIR-MTG.STU'

PROJECT MIDLAND .... PROJECT NO. SPS-8014 ....



"O" RING SIZE
.487 ±.005 I.D. x .103W ±.003

AT 70°F

COMPRESSION		
MIN.	MAX.	NOMINAL
33%	41.51%	37.38%

ELONGATION		
MIN.	MAX.	NOMINAL
.813%	3.73%	2.25%

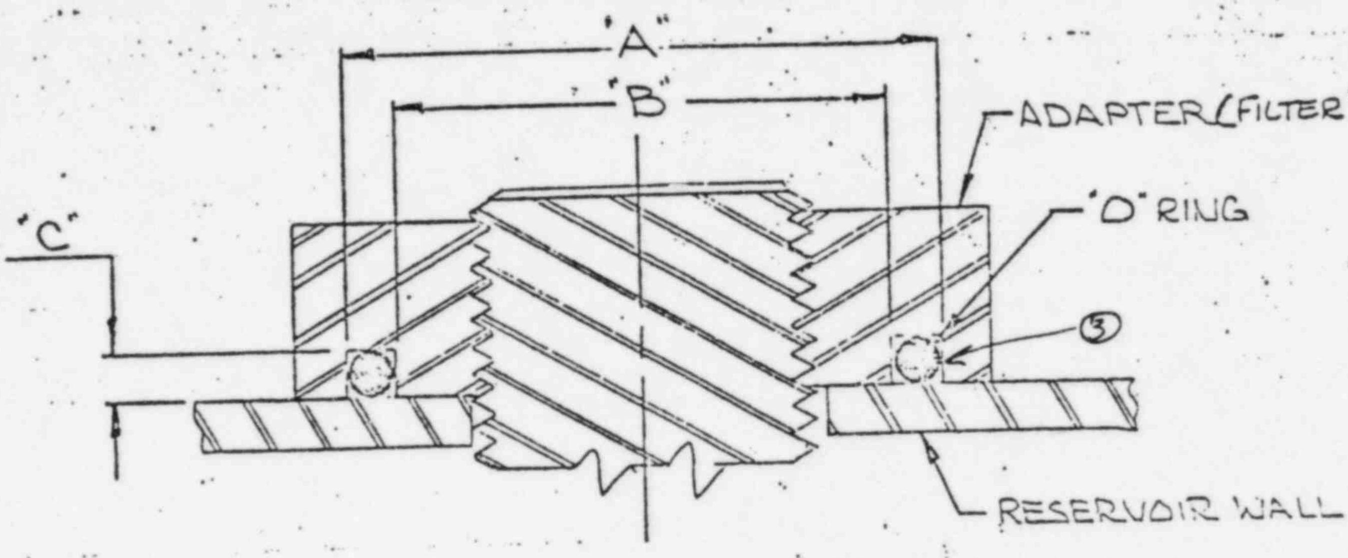
NOTE: "O" RING SIZE USED WAS NAT'L STD PART NO. AS-112 (FOR ACTUAL DIM'S & TOL'S)

FIG. 11

REF: OIL-RITE DRAWINGS
{B-1556 - REV. J
{B-1554-3 REV Q

NO SCALE

PHE No. 4



— FIG. 12 —

DIMENSIONS		
A	B	C
1.255 / 1.250	1 ±1/64	.083 / .078

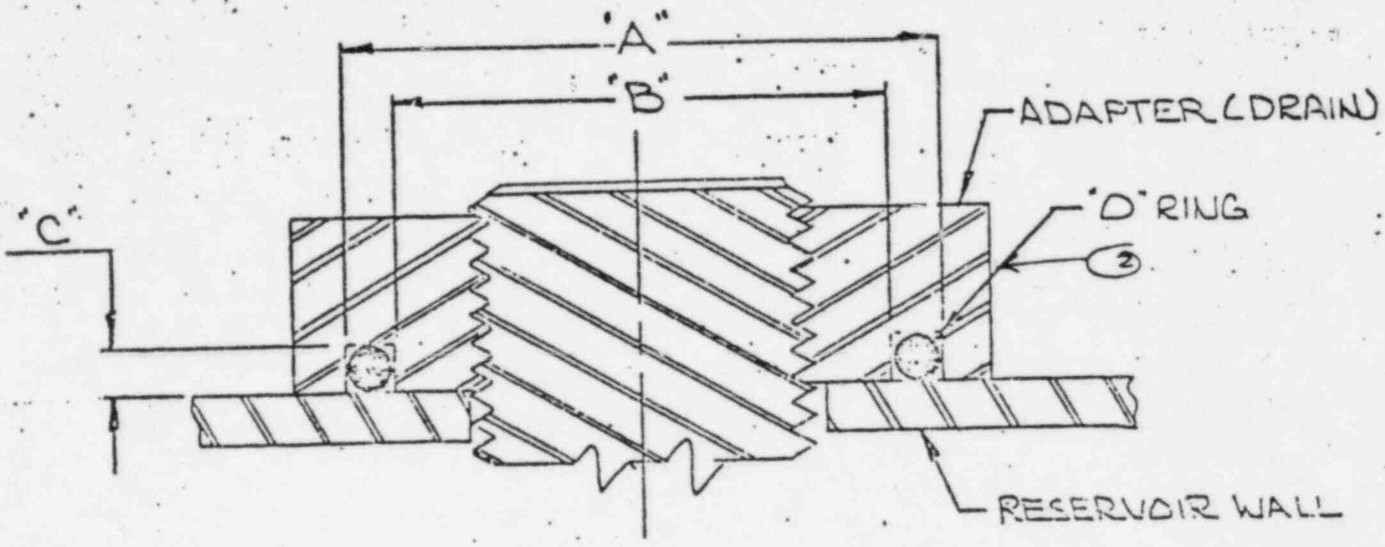
"O" RING SIZE
.987 ±.010 x .103 ±.003

COMPRESSION		
MIN	MAX	NOMINAL
17%	26.42%	21.85%

PHE No 4

CHKD. BY AK DATE 7-7-81 CUSTOMER CONSUMERS SYSTEM RESERVOIR - DRAIN ADAPTER

PROJECT MIDLAND PROJECT NO: SPS 8014



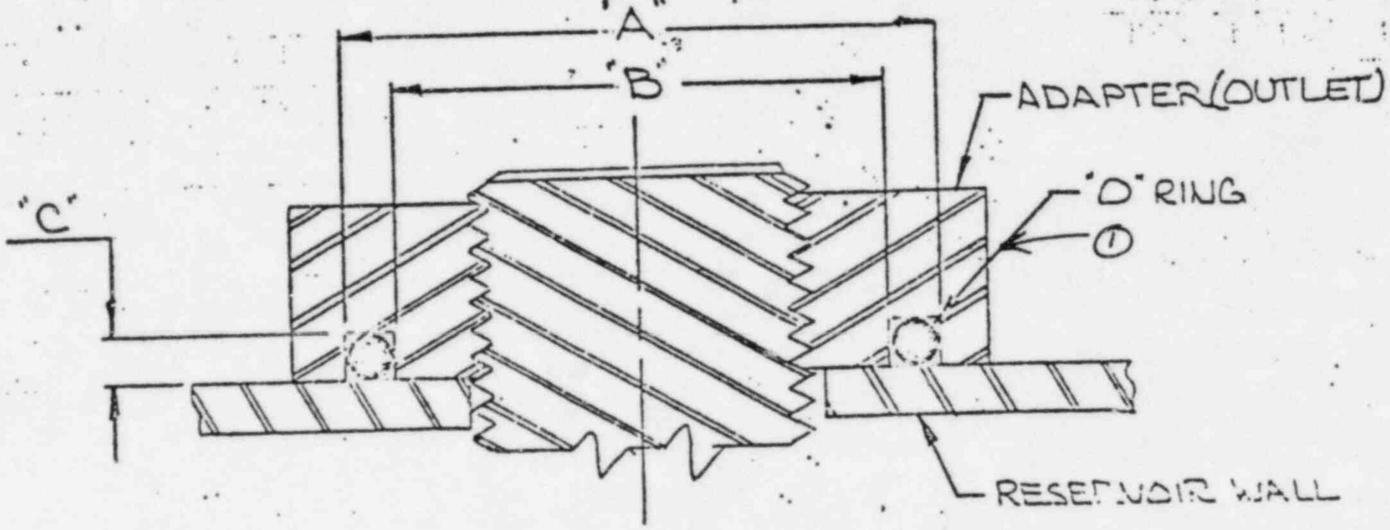
— FIG. 13 —

DIMENSIONS		
A	B	C
1.255 / 1.250	1 ±1/16	.083 / .078

"O" RING SIZE
.987 ±.010 x .103 ±.003

COMPRESSION		
MIN	MAX	NOMINAL
17%	26.42%	21.85%

PHE No. 4



-FIG. 14-

DIMENSIONS		
A	B	C
2.010 / 2.000	1¾ ± 1/64	.083 / .078

'O' RING SIZE	
1.737 ±.015 ID	.103 ±.003 W

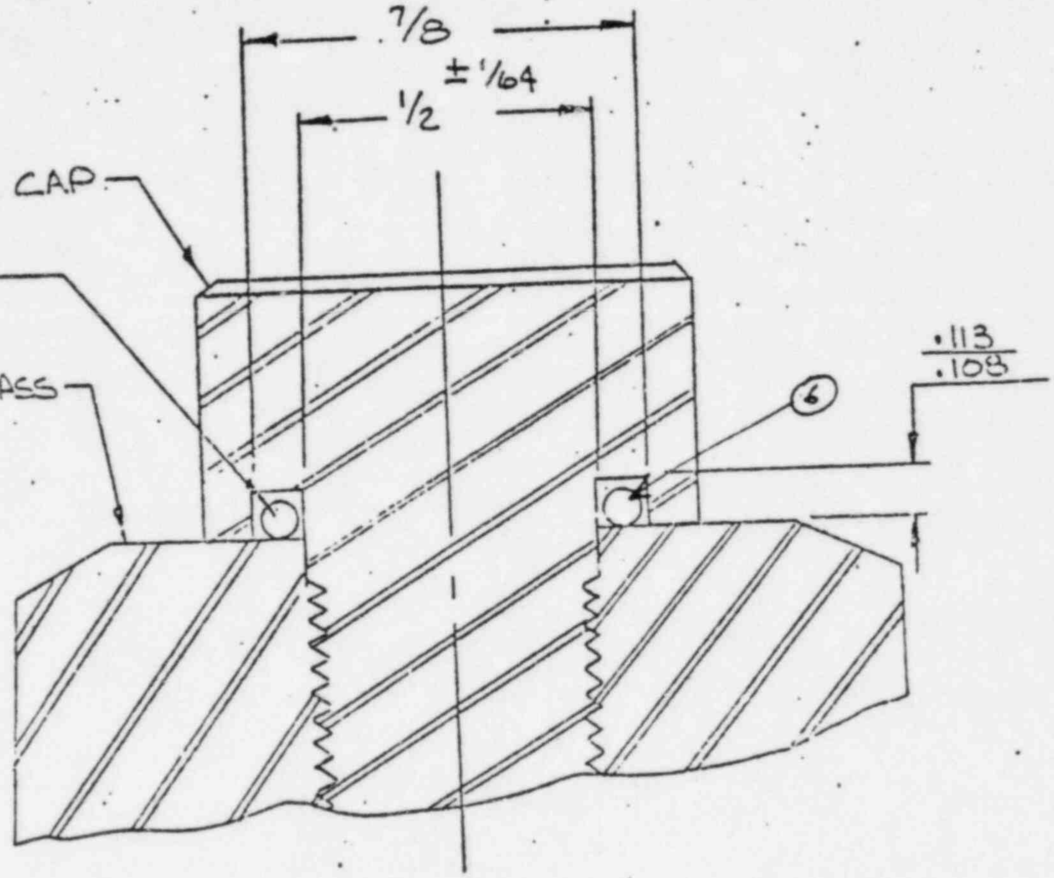
COMPRESSION		
MIN	MAX	NOMINAL
17%	26.42%	21.85%

PHE No. 4

BY. D.L. DATE 7-7-81 SUBJECT SEAL STUDY

CHKD. BY A.K. DATE 7/7/81 CUSTOMER CONSUMERS SYSTEM RESERVOIR - EXTERNAL CAP.

PROJECT MIDLAND PROJECT NO. SPS-8014



— FIG. 15 —

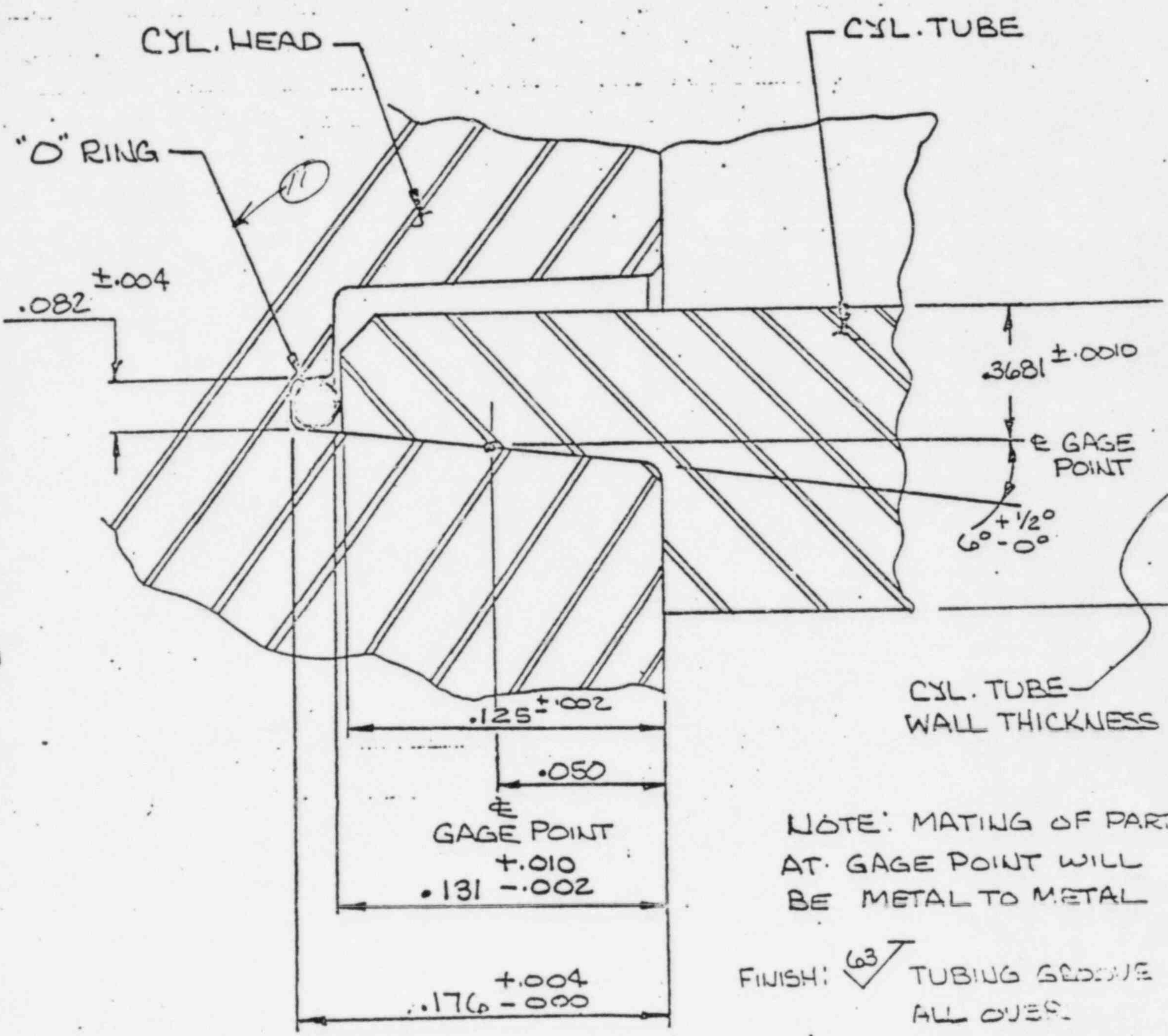
'O' RING SIZE
$.551^{\pm.007} \times .070^{\pm.003}_{W}$

— SEAL SEES NO COMPRESSION —

PHE No. 4

CHKD. BY AK DATE 5-29-81 CUSTOMER CONSUMERS SYSTEM CYL. - END SEALS

PROJECT MIDLAND PROJECT NO. SPS-8014



NOTE: MATING OF PART AT GAGE POINT WILL BE METAL TO METAL

FINISH: 63 TUBING GROOVE ALL OVER

BORE SIZE	"O" RING SIZE I.D. ±.030 W ±.003
14"	14.610 X .070
16"	16.610 X .070
18"	18.610 X .070
20"	20.610 X .070

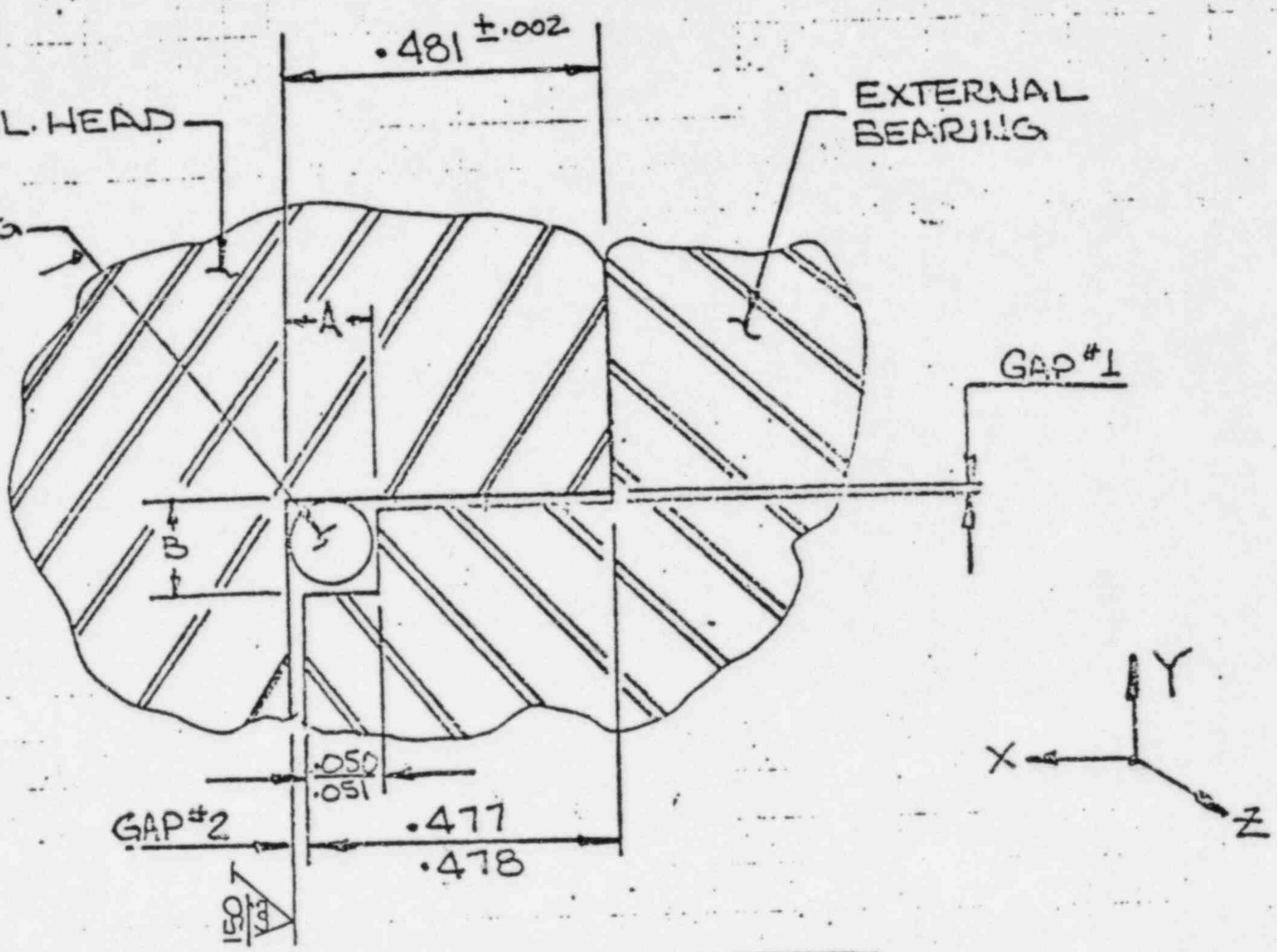
AT 70° F

COMPRESSION		
MIN.	MAX.	NOM.
14.93%	32.87%	24.29%

NO ELONGATION

FIG. 16

PHE No. 4



"A"			"B"		
MIN.	MAX.	NOM.	MIN.	MAX.	NOM.
.051	.057	.054	.09475	.096	.09538

GAP #1			GAP #2		
MIN.	MAX.	NOM.	MIN.	MAX.	NOM.
.001	.00275	.00188	.001	.006	.0035

'O'-RING SIZE	
BORE	SIZE
14"	7.900 ±.030 I.D. x .070 ±.003 W
16"	8.900 ±.030 I.D. x .070 ±.003 W
18"	9.900 ±.030 I.D. x .070 ±.003 W
20"	10.900 ±.030 I.D. x .070 ±.003 W

COMPRESSION ("X" DIR.)		
MIN.	MAX.	NOM.
14.93%	30.14%	22.85%

AT 70° F

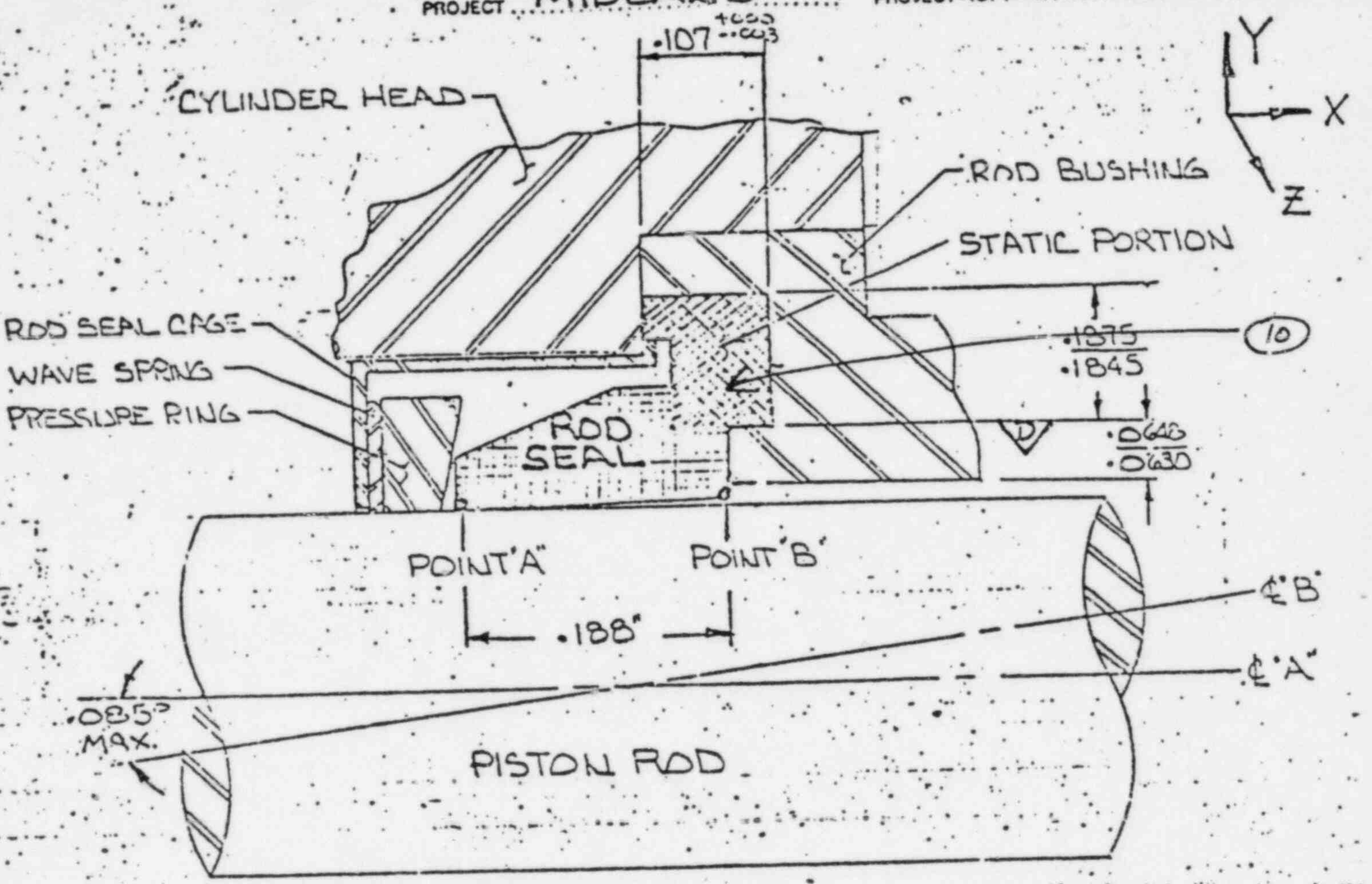
NO COMPRESSION IN "Y" DIR.

NO ELONGATION

REF: MILLER'S FILE A6958 REV. 9
MILLERS' GEN. ASSY MODEL "52 REV.
MILLERS' FILE A7031-REV #1

NO SCALE

FIG. 17



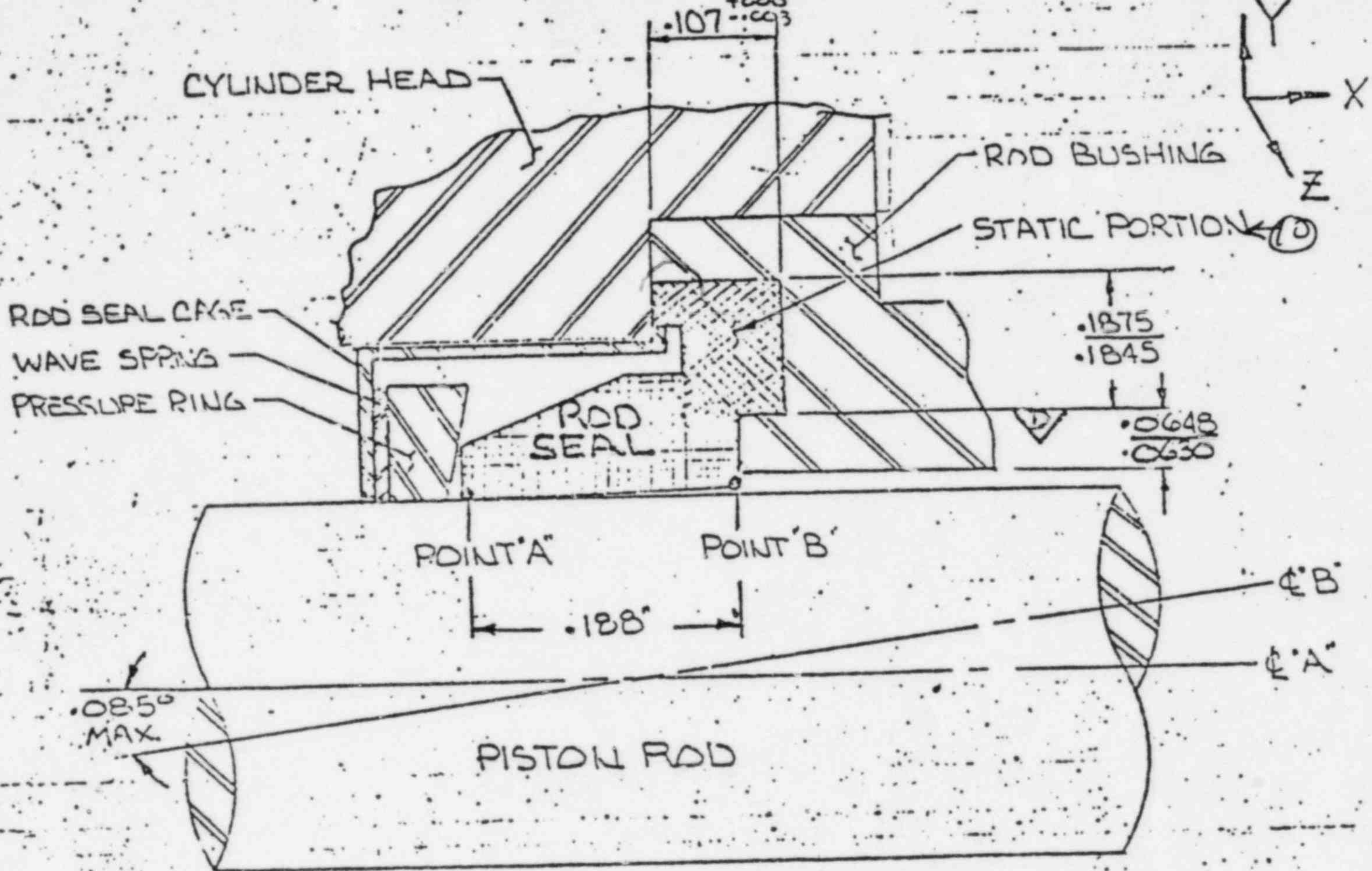
% ELONGATION					
POINT "A"		POINT "B"		SURFACE "D"	
MIN.	MAX.	MIN.	MAX.	MIN.	MAX.
1.71%	2.16°	0%	0%	.54%	.92%

% COMPRESSION (STATIC PORTION)			
'X' DIR.		'Y' DIR	
MIN.	MAX.	MIN.	MAX.
18.22%	22.15%	1.57%	3.91%

— FIG. 18.1 14' BORE ASSEMBLIES —

NOTE: COMPRESSION/ELONGATION RESULTS BASED ON WORST POSSABLE SITUATION W/ ROD ANGLED AT .085° AND W/ SEAL GLAND ECCENTRIC TO ℄ .001. AT 70°F

PHE NO. 1



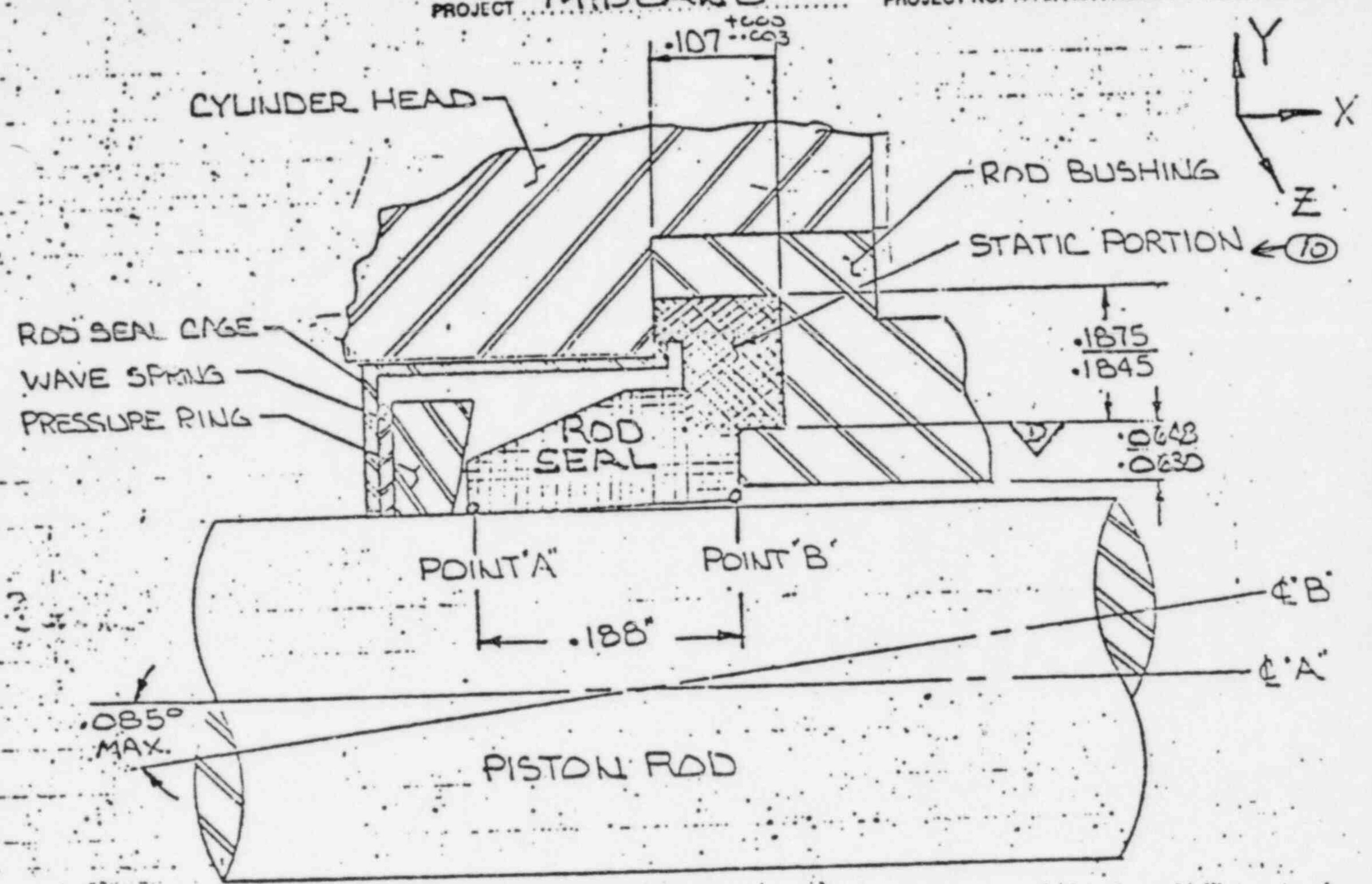
% ELONGATION					
POINT "A"		POINT "B"		SURFACE 'D'	
MIN.	MAX.	MIN.	MAX.	MIN.	MAX
1.71%	2.10%	0%	0%	.54%	.92%

% COMPRESSION (STATIC PORTION)			
'X' DIR.		'Y' DIR	
MIN.	MAX.	MIN.	MAX.
18.22%	22.15%	1.59%	3.91%

– FIG. 18.2 16" BORE ASSEMBLIES –

NOTE: . COMPRESSION/ELONGATION RESULTS BASED ON WORST POSSABLE SITUATION W/ ROD ANGLED AT .085° AND W/ SEAL GLAND ECCENTRIC TO ℄ .001. AT 70°F

PHE NO. 4



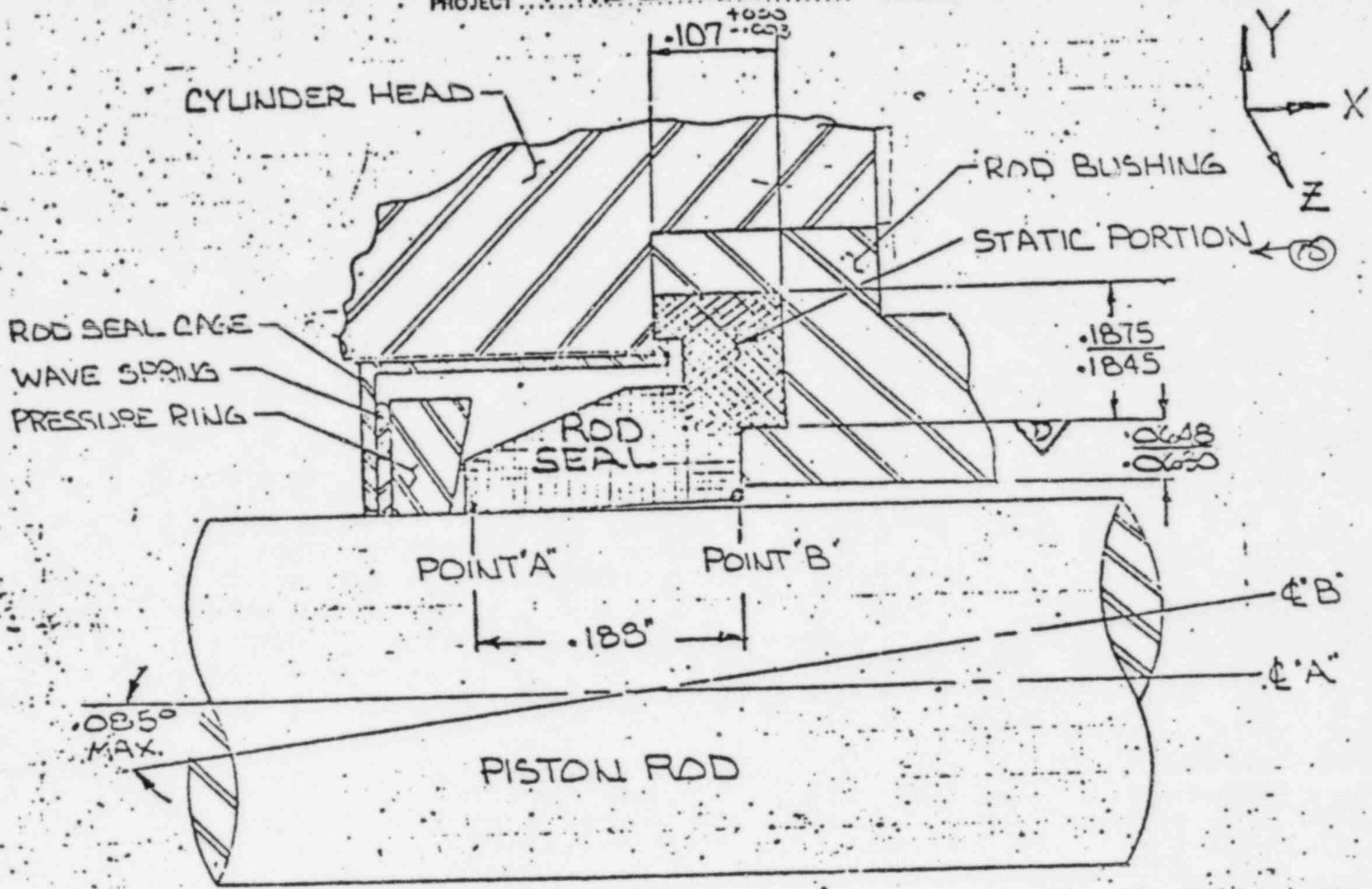
% ELONGATION					
POINT "A"		POINT "B"		SURFACE 'D'	
MIN.	MAX.	MIN.	MAX.	MIN.	MAX
1.69%	2.04%	0%	0%	.54%	.92%

% COMPRESSION (STATIC PORTION)			
'X' DIR.		'Y' DIR	
MIN.	MAX.	MIN.	MAX.
18.22%	22.15%	1.59%	3.91%

—FIG. 18.3 18' BORE ASSEMBLIES —

NOTE: COMPRESSION/ELONGATION RESULTS BASED ON WORST POSSABLE SITUATION W/ ROD ANGLED AT .085° AND W/ SEAL GLAND ECCENTRIC TO ℄ .001 AT 70°F

PHF No. 4

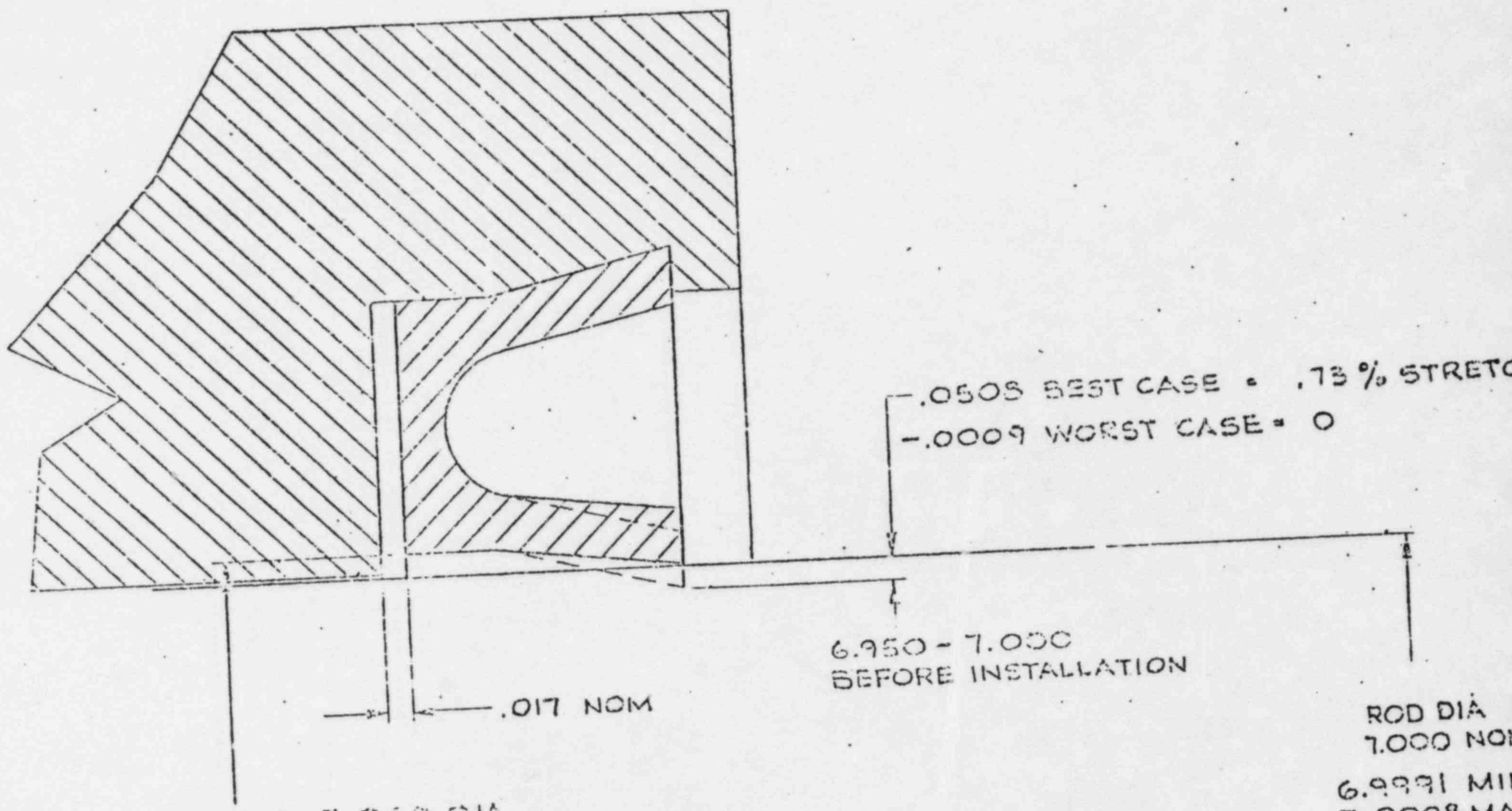


% ELONGATION					
POINT "A"		POINT "B"		SURFACE 'D'	
MIN.	MAX.	MIN.	MAX.	MIN.	MAX
1.68%	2.05%	0%	0%	.54%	.92%

% COMPRESSION (STATIC PORTION)			
'X' DIR.		"Y" DIR	
MIN.	MAX.	MIN.	MAX
18.22%	22.15%	1.59%	3.91%

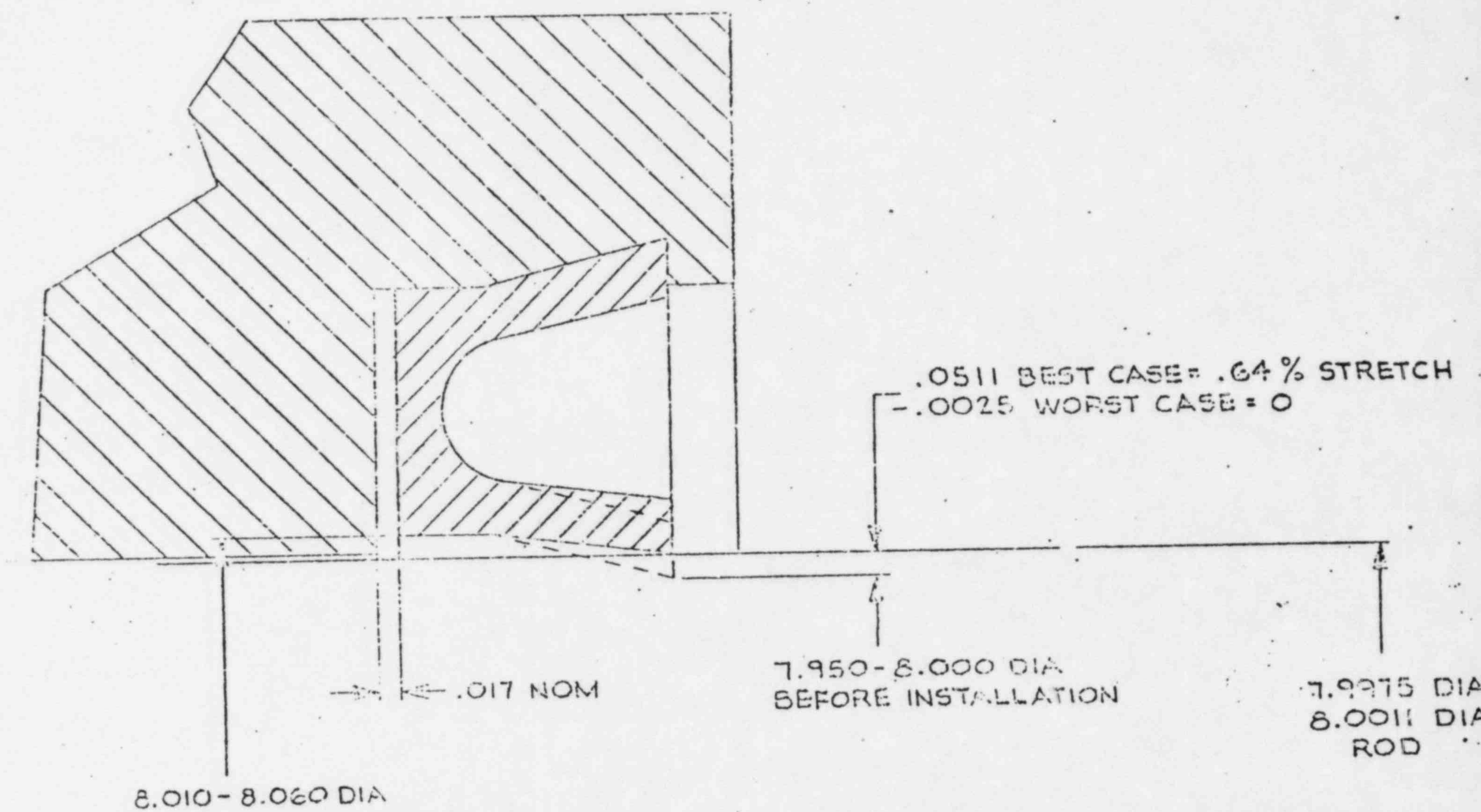
—FIG. 18.4 20" BORE ASSEMBLIES —

NOTE: COMPRESSION/ELONGATION RESULTS BASED ON WORST POSSABLE SITUATION W/ ROD ANGLED AT .085° AND W/ SEAL GLAND ECCENTRIC TO ℄ .001 AT 70°F



—FIG. 19·1—

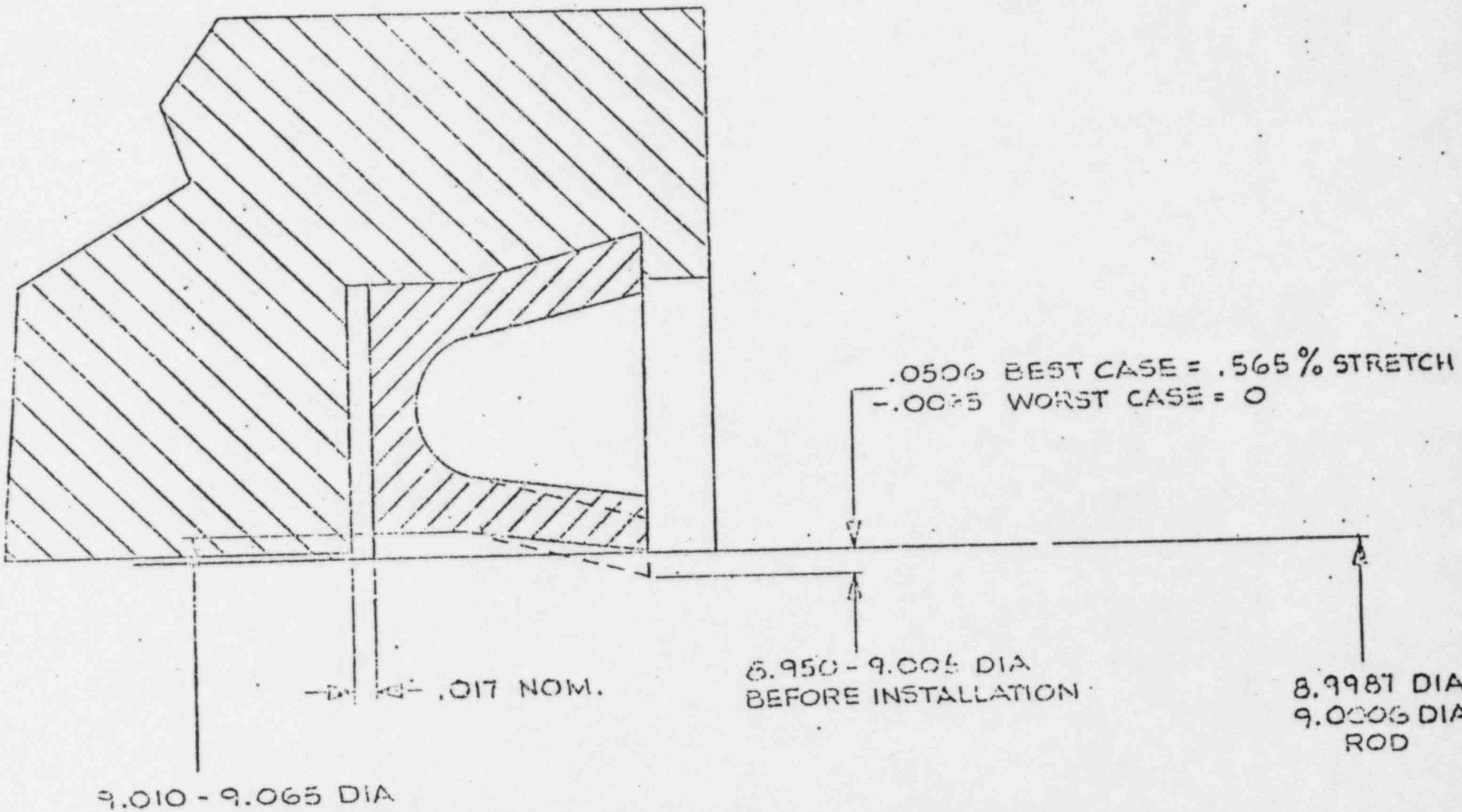
SNUBBERS D1, D3, D4, I1, I2
14" BORE SIZE



SNUBBERS E1A, E3A, E1B, E3B, F1, F2, G1, G2

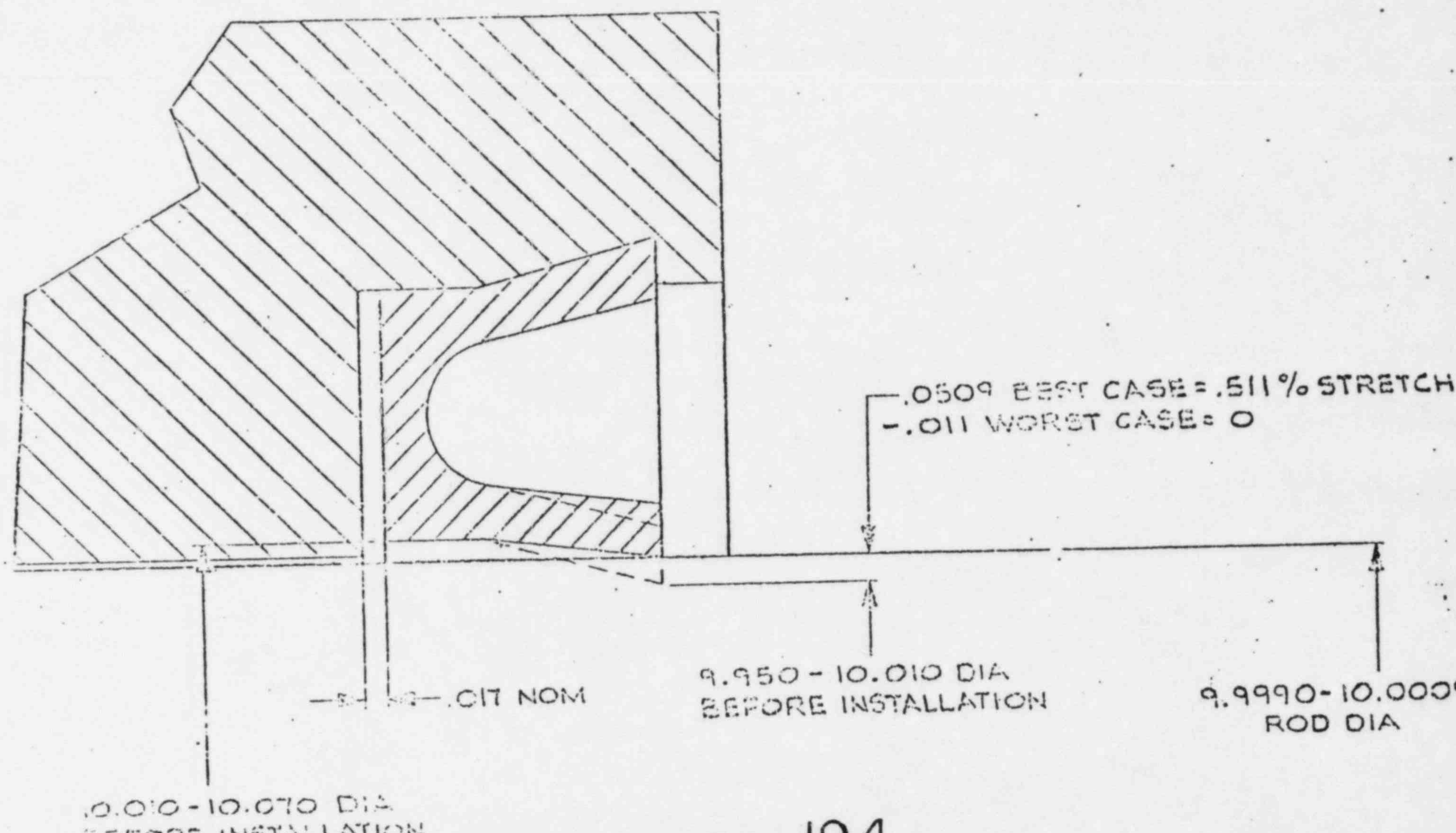
16" BORE SIZE

FIG. 19.2



SNUBBERS B5, J2
18" BORE SIZE

— FIG. 19.3 —

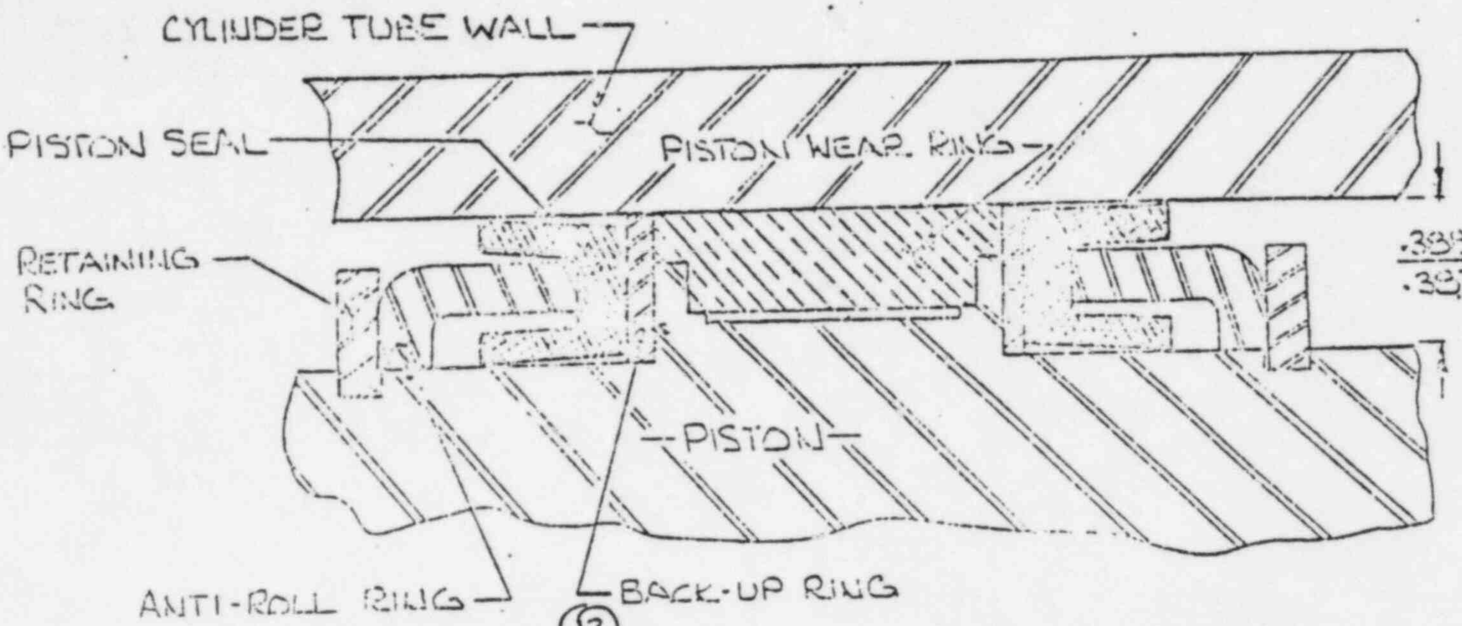


— FIG.- 19.4 —

SNUBBERS B3, B4, B6

20" BORE SIZE

BY E.L. DATE 6-26-81 SUBJECT [illegible]
CHKD BY A.K. DATE 6-26-81 CUSTOMER CONSUMERS SYSTEM CYLINDER-PISTON SEAL
PROJECT MIDLAND PROJECT NO. SPS-8014



(13)

PERCENT DEFLECTION *		
BORE	MIN.	MAX.
14"	25.39%	28.36%
16"	28.12%	30.94%
18"	30.94%	32.16%
20"	31.38%	34.48%

*NOTE: RESULTS SHOWN ARE ENTIRE SEAL DEFLECTION, EACH LIP WILL DEFLECT 1/2 OF RESULTS SHOWN.

FIG. 20- PISTON SEAL

PHE No 4

ITT Grinnell Corporation

PIPE HANGER ENGINEERING DIVISION

BY AK DATE 7/7/81 SUBJECT SEAL STUDY SHEET NO. .... OF ......

CHKD. BY .... DATE .... CUSTOMER CONSUMERS SYSTEM ....

PROJECT MIDLAND PROJECT NO. ....

SEAL TITLE	LOCATION	TEMP.	MANUFACTURER	COMPOUND
ROD SEAL	CYLINDER	70 °F	MINNESOTA RUBBER	559 EQ

COMPRESSION – 14"CYL.			
"X" DIRECTION		"Y" DIRECTION	
NOMINAL	MAX.	NOMINAL	MAX.
18.22 %	22.15 %	1.57 %	3.91 %

COMPRESSION – 16"CYL.			
"X" DIRECTION		"Y" DIRECTION	
NOMINAL	MAX.	NOMINAL	MAX.
18.22%	22.15%	1.59%	3.91%

COMPRESSION – 18"CYL.			
"X" DIRECTION		"Y" DIRECTION	
NOMINAL	MAX.	NOMINAL	MAX.
18.22%	22.15%	1.59%	3.91%

COMPRESSION – 20"CYL.			
"X" DIRECTION		"Y" DIRECTION	
NOMINAL	MAX.	NOMINAL	MAX.
18.22%	22.15 %	1.59%	3.91%

COMPRESSION AT 70 °F

TABLE 9.1 ROD SEALS

ITT Grinnell Corporation

PIPE HANGER ENGINEERING DIVISION

BY AK DATE 7/7/81 SUBJECT SEAL STUDY SHEET NO. .... OF ......

CHKD. BY .... DATE .... CUSTOMER CONSUMERS SYSTEM ....

PROJECT MIDLAND PROJECT NO. ....

SEAL TITLE	LOCATION	TEMP.	MANUFACTURER	COMPOUND
ROD SEAL	CYLINDER	120 °F	MINNESOTA RUBBER	559 EQ

COMPRESSION - 14" CYL.			
"X" DIRECTION		"Y" DIRECTION	
NOMINAL	MAX.	NOMINAL	MAX.
18.97%	22.79%	1.84%	4.2%

COMPRESSION - 16" CYL.			
"X" DIRECTION		"Y" DIRECTION	
NOMINAL	MAX.	NOMINAL	MAX.
18.49%	22.48%	1.69%	4.1%

COMPRESSION - 18" CYL.			
"X" DIRECTION		"Y" DIRECTION	
NOMINAL	MAX.	NOMINAL	MAX.
18.49%	22.79%	1.69%	4.2%

COMPRESSION - 20" CYL.			
"X" DIRECTION		"Y" DIRECTION	
NOMINAL	MAX.	NOMINAL	MAX.
18.79%	22.79%	1.89%	4.2%

COMPRESSION AT 120 °F

TABLE 9.2 ROD SEALS

ITT Grinnell Corporation

BY AK DATE 7/7/81 SUBJECT SEAL STUDY SHEET NO. .... OF ......

CHKD BY .... DATE .... CUSTOMER CONSUMERS SYSTEM ....

PROJECT MIDLAND PROJECT NO. ....

SEAL TITLE	LOCATION	TEMP.	MANUFACTURER	COMPOUND
ROD SEAL	CYLINDER	316 °F	MINNESOTA RUBBER	559 EQ

COMPRESSION – 14" CYL.			
"X" DIRECTION		"Y" DIRECTION	
NOMINAL	MAX.	NOMINAL	MAX.
21.27 %	25.13 %	2.87 %	5.43 %

COMPRESSION – 16" CYL.			
"X" DIRECTION		"Y" DIRECTION	
NOMINAL	MAX.	NOMINAL	MAX.
21.2[illegible] %	[illegible]	2.87 %	4.60 %

COMPRESSION – 18" CYL.			
"X" DIRECTION		"Y" DIRECTION	
NOMINAL	MAX.	NOMINAL	MAX.
21.27 %	[illegible]	2.[illegible] %	5.[illegible] %

COMPRESSION – 20" CYL.			
"X" DIRECTION		"Y" DIRECTION	
NOMINAL	MAX.	NOMINAL	MAX.
21.27 %	24.[illegible] %	[illegible]	[illegible]

COMPRESSION AT 316 °F

TABLE [illegible] ROD SEALS

SEAL TITLE	LOCATION	TEMP.	MANUFACTURER	COMPOUND
ROD SEAL	CYLINDER	50 °F	MINNESOTA RUBBER	559 EQ

COMPRESSION - 14"CYL.			
"X" DIRECTION		"Y" DIRECTION	
NOMINAL	MAX.	NOMINAL	MAX.
17.89%	22.04%	1.46%	3.86%

COMPRESSION - 16"CYL.			
"X" DIRECTION		"Y" DIRECTION	
NOMINAL	MAX.	NOMINAL	MAX.
17.96%	21.90%	1.48%	3.73%

COMPRESSION - 18"CYL.			
"X" DIRECTION		"Y" DIRECTION	
NOMINAL	MAX.	NOMINAL	MAX.
17.96%	21.86%	1.48%	3.75%

COMPRESSION - 20"CYL.			
"X" DIRECTION		"Y" DIRECTION	
NOMINAL	MAX.	NOMINAL	MAX.
17.89%	22.04%	1.46%	3.86%

COMPRESSION AT 50 °F

TABLE 9.4 ROD SEALS

BY.............. DATE.............. SUBJECT.............................
CHKD. BY.............. DATE.............. CUSTOMER.............................. SYSTEM..............................
PROJECT.............................. PROJECT NO..............................

SEAL LOCATION	TYPE	% SQUEEZE	F(DESIGN)	F(REQ'D)	% MARGIN
VALVE-RET.PLATE	"O" RING	20.38%	71.6499#	7.06#	90.15%
VALVE-RET.PLATE	"O" RING	20.38%	71.6499#	7.06#	90.15%
CYL.-END SEAL	"O" RING(14")	24.29%	691.54#	51.72#	92.52%
CYL.-END SEAL	"O" RING(16")	24.29%	785.76#	58.77#	92.52%
CYL.-END SEAL	"O" RING(18")	24.29%	879.97#	65.82#	92.52%
CYL.-END SEAL	"O" RING(20")	24.29%	974.19#	72.86#	92.52%
CYL.-EXT.BEARING	"O" RING(14")	22.85%	337.56#	26.43#	92.17%
CYL.-EXT.BEARING	"O" RING(16")	22.85%	379.91#	29.74#	92.17%
CYL.-EXT.BEARING	"O" RING(18")	22.85%	242.27#	33.06#	92.17%
CYL.-EXT.BEARING	"O" RING(20")	22.85%	464.62#	36.38#	92.17%
RES.MTG. STUDS	"O" RING	37.38%	83.79#	4.71#	94.43%
CYL.-ROD SEAL	SHEF.SEAL	SEE FIG. 7.1THRU7.4	———	———	———
CYL.PISTON SEAL	U-CUP	SEE FIG.8	———	———	———
RES.-OUTLET	"O" RING	21.85%	66.09#	6.88#	89.58%
RES.-DRAIN	"O" RING	21.85%	48.40#	5.04#	89.58%
RES.-FILTER	"O" RING	21.85%	48.40#	5.04#	89.58%
RES.-EXT.CAP	"O" RING	0%	———	———	———

- TABLE 1 -

% SQUEEZE = % Compression of the seal associate with installation condition at room temperature.

F_{DES} = Force associate with backstress developed by installation seal squeeze at nominal room temperature condition.

$F_{REQ'D}$ = Min. Backstress required to seal against steady state low pressure at design requirement of 35 PSI (for nominal room temperature condition).

% MARGIN = $\frac{FD-FR}{FD} \times 100$

PHE No. 4

APPENDIX 3

SUMMARY OF THE

CONSULTANT'S MEETINGS

EPDM DISCUSSION, COMMENTS & SUGGESTIONS

D. L. HERTZ, JR. (ITT GRINNELL VISIT 8/7/81

Submitted 8/20/81

EPDM - TWENTY YEAR SERVICE LIFE PREDICTABILITY

ABSTRACT

Ethylene-propylene terpolymers are base elastomers for seals designed to contain silicone type hydraulic fluids in seismic arresting devices. The preferred useful life expectancy is twenty-plus years in a moderate temperature environment that may also involve continuous low-level radiation. Ethylene and propylene, the two simplest of the alkene series, have been intensively studied. It is highly improbable that a failure mechanism previously unknown might appear in the service environment. The operating temperatures are well within the elastomer's accepted thermal resistance for long-term serviceability, leaving only the complications of stress relaxation and radiation damage to consider. Stress relaxation testing coupled with a modulus (shear or Young's) monitoring program should develop adequate data to predict with a high confidence level the suitability of EPDM seals for twenty year service life.

INTRODUCTION

Adequate references to stress relaxation corroborate the validity of this testing method as an accurate tool in prediction of long-term seal serviceability as a function of retained seal contact stress. The problem of sealing under conditions of long-term low-level radiation exposure encompasses both polymer physics (stress relaxation) and polymer chemistry (elastomer structural damage). Assuming radiation induced free radicals, the elastomer would be first subjected to: a. increasing crosslink density at unsaturated diene sites (which are limited by per cent diene monomer concentration) followed by: b. abstraction of methine hydrogen(1) resulting backbone scission (reversion). Compressive stress relaxation rates would be greatly influenced by b and not noticeable by a.

Condition-a

Condition-a would be indicated by an increase in shear modulus(G), directly related to durometer(2). Conventional durometer measuring devices are operator sensitive. Therefore, the Wallace-Shawbury Microindentor (Testing Machines, Inc.-Mineola, NY) might be a more accurate instrument to consider. Lindley's approach(3) for load compression forces might also be considered to calculate Young's modulus increase. Elastomer sensitivity to radiation-induced crosslinking could be compared by using identically compounded model compounds with the elastomer differing only in per cent third monomer concentrations. (This ranges from 2 to 13%.) Initial crosslink density would be controlled by using Loan's(4) model approach to develop a known level of crosslinks.

Condition-b

Backbone scission would be physically indicated by surface stickiness. Stress relaxation rates would be greatly increased since the test is molecular weight sensitive, and it is assumed chain scission (backbone cleavage) would dominate. Quantitative results could be defined by using Kearsley's(5) approach.

POLYMER SCREENING

Since all elastomers have gaseous precursors, initial degradation by-products in ionizing radiation would be indicated by gas evolution. This test might be as simple as looking for gas bubbles from an elastomer immersed in water (radiation intensity, CO-60 source, would be only slightly diminished)(6).

CROSSLINK TYPES (PEROXIDE, SULFUR)

Peroxide Cure

Bulk of published EPDM data indicate peroxide cured elastomers to have superior compression set and lower stress relaxation rates (notably Meier, et al.)(7). Residual peroxide fragments have been identified as troublesome by numerous sources and techniques known to immobilize such fragments are well known. One reservation on peroxide cured EPDM (99.9% theoretical conversion of curative) was a solenoid valve seat failure in contact with potable water - 206-210°F surrounding the seal and 50-70°F potable water on the valve seating area. Extensive reversion on the cold water side occurred within six months in various parts of the country. Replacing the seal with a sulfur cured EPDM cured the problem. Residual sulfur or its by-product (zinc diethyldithiocarbamate) apparently acted as a free radical trap(8) with the probable mechanism-singlet oxygen, as defined by Kaplan et al.(9).

Sulfur Cure

Development of a monosulfidic crosslink using elemental sulfur, using the technique as developed by Baldwin(10) and verified by Meier, et al.(11) creates a very stable crosslink in the event the peroxide cured crosslink is susceptible to environmental and/or ionizing radiation damage.

THERMAL STABILITY

There is no problem regarding thermal stability of the EPDM. Upper service temperature limits are well below recommended maximum service temperatures and lower temperatures well above the elastomer transition range (point at which the elastomer can increase the shear modulus by one or two orders of magnitude with only a few degrees of temperature shift.)

ALTERNATIVE ELASTOMERS

Propylene-TFE copolymer (AFLAS) as produced by ASAHI Glass-Japan is probably the only other suitable elastomer for ionizing radiation service. It should be considered if oil resistance or a higher temperature environment becomes a design criteria.

SUPPLEMENTAL TESTING INSTRUMENTS

The Yerzley oscillograph (Yerzley Company-744 Broad St., Newark, NJ) should be reviewed. The instrument measures complex dynamic modulus which is strongly influenced by molecular weight and crosslink density.

MODEL COMPOUNDS

There is a strong case for use of model compounds (known compositions) as benchmarks in testing. EPDM's are inherently ozone resistant (therefore not requiring antiozonant protection), but a rubber compounder might incorporate antiozonant in sufficient amounts to act as a free radical trap in a radiation environment. This would mask or offset elastomer damage until the antiozonant is consumed, creating a "time-bomb" radiation effect (12, 14). A very interesting approach for an EPDM model compound is described by Baldwin, Borzel and Makowski(13). This same approach is also useful from a design standpoint as it points out effect of molecular weight on useful properties. Additional background on EPDM serviceability as influenced by compounding can be derived from Auda and Hazelton's paper(14).

CONCLUSIONS

Accurate stress relaxation and modulus-shift testing on EPDM elastomers should develop sufficiently linear data (Arrhenius) to predict long-term serviceability with a high confidence level. The area of least information is the effect of low level radiation on crosslinking and subsequent chain scission of the elastomer. There are sufficient types of EPDM (varying ratios of ethylene-propylene-third monomers) so that crosslinking/scission reactions could be monitored readily over a short time period.

D. L. Hertz, Jr.

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CONSULTING VISIT TO ITT GRINNELL

AUGUST 6, 1981

DISCUSSION, COMMENTS, AND SUGGESTIONS

J.K. SIERON

CONSULTING VISIT TO ITT GRINNELL - August 6, 1981

The following synopsis covers significant points I made during my visit to ITT:

A. Questions (Attachment 1)

1. EPDM is an excellent choice as the base elastomer for hydraulic system seals in the environment identified in Question 1 with the following qualifications: (a) the exact composition of the EPDM elastomer compounds on your qualified supplier list should be identified since an infinite number of possible compounds exists, (your legal department should explore confidential disclosure agreements on material compositions with your seal suppliers); (b) EPDM compounds co-vulcanized by peroxide curing systems with 1, 2 - polybutadiene liquid polymers have outstanding properties and could be superior to your presently used EPDM compounds (a suggested compound is AF-E-411, Parker Seal and others are familiar with this material); (c) clearance tolerances for elastomeric seals subjected to 10,000 psi would have to be very small to prevent seal extrusion and failure, (back-up rings are used in aircraft hydraulic systems at pressures above 1500 psi).

2. It is not likely that EPDM seals exposed to system temperatures ranging from 50°-120°F., silicone fluids and radiation exposure of 52 rad/hour would be severely damaged if the seals are properly formulated and processed. The above parameters should not seriously affect seal properties whether applied individually or collectively. The most reliable test to predict seal performance is compression set under anticipated conditions. It is suggested that compression set of candidate seals be measured on o-rings subjected to static operational conditions after 24 hours, 48 hours, 72 hours, 1 week, 2 weeks, 4 weeks and each month thereafter up to at least 6 months, (a flat curve normally is reached within 1 week for stable materials).

3. Again, in response to Question 3, I have to caution that "EPDM" covers a multitude of possible materials. EPDM base elastomers vary widely in molecular weight and molecular weight distribution. Further, the base EPDM elastomer (starting material) can be compounded with a variety of reinforcing materials such as carbon black and silica, amine or phenolic antioxidants, processing aids such as stearic acid or plasticizers, and curing agents like peroxides, sulfur or sulfur donating accelerators. To reiterate my answer to Question 1, peroxide cured co-vulcanizates of EPDM and 1, 2-polybutadiene liquid resins would probably be superior to conventional EPDM compounds. In addition, a new very stable elastomer called AFLAS which is a copolymer of propylene and tetrafluoroethylene could be superior to EPDM. AFLAS has exceptional oxidative stability and is stable to 500°F. Metal seals and seals based on radiation resistant high Tg polymers such as polyphenylene sulfide could also be superior to EPDM. The major problem with such seals would be machining and installation since they are not forgiving.

4. In response to Question 4, I don't think that PH_3 treatments of EPDM are required to achieve a "blocking" effect against oxidation for your environment. The PH_3 treatment probably was used to neutralize residual hydroperoxides in the EPDM compounds. A preferred and recommended procedure is to post-cure the EPDM seals under a nitrogen atmosphere at temperatures exceeding maximum use temperature, ie - 1 hour each at 250°F., 300°F., 350°F., and 400°F. and cool down to 200°F. or less before removal from the oven.

5. It is hard to beat real time testing! Since your EPDM seals have endured 5 years under working conditions without significant damage, a 10 year life is a conservative projection. My experience indicates that you can expect at least 20 to 30 years lifetime as long as exposure conditions do not change. For example, hydraulic system seals (nitrile rubber) were found to be in excellent

condition after recovery from World War 11 aircraft downed in desert and ice cap regions.

6. Question 6 is a little more difficult to answer. In general, properly compounded classes of elastomers will functionally seal to certain limits; for example, EPDM - 300°F., Viton/Fluorel - 400°F., Silicone - 400°F. In the absence of oxygen or an oxidizing environment, EPDM is stable and has sealed for more than 6 months at 500°F. in a geothermal well environment. Compression set is the usual cause of seal failure and set is always accentuated by high temperatures.

7. In general, I like your test outline because it relies on seal evaluations under operational conditions. Some suggestions to enhance your program are: (a) get the precise composition of the baseline seals exposed to 5 years under reactor conditions and subject similar, but new seals in compression set fixtures along with dumbell specimens or freely suspended seals to your test conditions for at least 6 months; (b) measure compression set and physical properties - tensile strength, elongation, 100% modulus (very important) and hardness on seals or dumbell specimens after 24 hour, 48 hour, 72 hour, 1 week, 2 weeks, 1 month and each month thereafter to at least 6 months (if possible, continue testing to about 2 years; my experience indicates that people believe real time testing) (c) in addition to the standard baseline seals, subject nitrogen post-cured baseline seals to the above tests and also EPDM/ 1, 2 -poly-butadiene seals, preferrably N_2 post-cured, to the above test conditions.

8. Based on the Sandia reports and other data, I feel that low dosage rates of 40-50 rad/hour will not significantly harm properly compounded EPDM seals. However, it is always better to rely on real time testing under simulated operational conditions to accurately assess seal life prediction.

9. We have as yet, not been able to correlate modeling studies with test data to predict seal lifetime. A program to predict seal lifetime as a function of material physical properties and dynamic test results will start in [illegible]ember 1981.

QUESTIONS:

1. What elastomeric material would you consider would be superior in our environment to EPDM (fluid silicone base, temp. range $50^{\circ} - 120^{\circ}$, max. operating pressure 10,000 psi radiation exposure 52 rad/hour)?

2. Some of the physical properties' behavior observed from individual testing (T, Rad, fluid) follow a Maxwellian decay (exponential). This phenomenon is due to the initial bond relaxation. Are we in a position to say that they obey the same chemical degradation? Can the "synergism" of these parameters be an additive effect?

3. Based on # 1 above, is there another type of material (plastic, and/or metal) which would surpass EPDM? What would be the limitations (machining, non-standard sizing, etc.)?

4. Is the usage of PH_3 treatments of EPDM for a "blocking" effect of oxidation necessary (for our operating environment)?

5. Seals made of EPDM have lasted 5 years under working conditions and still remain in good shape. From your expertise, is a 10 year life a conservative projection?

6. Throughout your experience with elastomers have you at anytime been subjected to: if $T_{min} + 100^{\circ}F < T_{operating} < T_{max} - 100^{\circ}F$

   temperature is of little or no effect on sealing capabilities (i.e., stress relaxation) of an elastomer?
   (Address EPDM in particular).

7. After reviewing our testing outline, do you have any thoughts as to what, if anything, should be added to predict an extended life.

8. Is the total energy absorbed in a material which determines the property damages, the rate at which the energy is absorbed or some function of both (address total dosage (1.8×10^{7} rad) vs dosage rate 52 rad/hour)?

9. How have you, in the past, attempted long term life modeling (math. model) from your test data?
   Address: Separation of variables
   Arrhenius Equation
   WLF Method
   Creep Function
   Stress Relaxation

7/17/81
A. KHATAMSAZ
H. BELAIDI

Compression Stress Relaxation Test

Sample # -10-20 O'rings of each EPDM compound (1/2" ID) (all properties originally measured for reference point)

Test Equipment - Shawbury-Wallace compression stress relaxometer (ASTM D.1390)

Test Conditions - Simultaneous rad.(52 rad/Hr.), varying temp. (50°F - 120°F, LOCA @ end) & silicone fluid; each parameter separately. (25% comp.) and in comb. of 2 parameters (i.e. Temp. & fluid, etc.)

Possible Variance - 10 O'rings treated with PH_3 (per Sandia Lab. procedure), 10 O'rings untreated; average results.

Duration - 6 months w/reading every 10 hrs. or continuously if auto. graph readout available.

Data - Determine "best curve fit" for data obtained on % backstress retained vs. time. Extrapolate to 5 yrs., compare with 5 yr. known seals. If accurate, extrapolate for 10 yr., 15 yr. & 20 yr. Determine interaction of parameters as follows:

$$f(t) = a(t) + bt + ct$$

2. Compression set test (ASTM D395 Method B)

From above test: Measure compression set 30 min. after removal from test jig. Compare with known values. Determine if it follows curve.

3. Durometer Test (Shore A)

Check durometer after ABV tests and compare with known values. Determine curve fit accuracy.

4. Tensile Test & Elongation (ASTM D412)

After above 3 tests: Check tensile % change. Compare with known values. Determine curve fit accuracy.

5. Flex Test (ASTM D-430) Rod Seal & Piston Seal to be accomplished after above test #2.

CONSULTING VISIT TO PARKER SEALS

AND SANDIA LABORATORIES

DISCUSSION, COMMENTS,

AND SUGGESTIONS

Hakim Belaidi
September 23, 1981

Minutes of meeting with R. H. Barbarin, 8/12/81, Culver City, Cal.

Introduction: Mr. R. H. Barbarin, technical director, Research and Developement Division of Parker Hannifin Corporation, seal group. He has done extensive work on elastomeric products. He has performed stress relaxation testings for life evaluation of seals exposed to temperature. He has served at different symposiums related to elastomeric and non elastomeric products.

1. For the stated environment, EPDM, is one of the best materials. There might be strong competition from Viton. But for a combined environment, EPDM has shown very good stability (relative).

2. No, the chemical degradation by temperature and radiation does not follow the same mechanism. Their overall trend on the physical properties follows the same pattern (Maxwellian). The industry doesn't have enough information on the synergism effect. I would doubt any additive effects. Extensive testing might provide an answer.

3. Plastics in general are not recommended for the environment specified. After brief description of the dividing element between plastic and elastomer (formation of high level stress rings, etc.), he reiterated that plastics might be good and acceptable for our environment (not harsh). However, EPDM will still perform more effectively. Metal seals are even better than EPDM if careful design tolerances, remachining and actually redesigning of actual glands are being followed. However, in overall picture, EPDM is the "champ".

4. I don't know of such blocking effect. However, post-curing under nitrogen atmosphere has proven to be very effective. Peroxide and sulfur cured are other excellent methods.

5. 10 year life is very conservative projection for EPDM compounds. I would even state that a 20 year is not beyond "Horizons". Testing will show you the confimation.

6. There is minimal degradation that the seal will see under your proposed "rule of thumb". On a relative basis, yes, there is little effect. But I would not say that the life of the seal is not compromised. Again in conjunction with radiation, there might be a pronounced effect. But for your envoronment (52 rad/hr, 120^0 F) not to worry. EPDM has the stability to withstand this environments (saturated backbone).

7. No, except I would include % modulus. Compression stress relaxation should provide with enough information coupled with "Breadboard testings", you will be able to determine as to what is the extent of the seal life.

8. Both dosage rate and total integrated dose provide a combined effect on the seal degradation hich is more destructive I cannot really confirm it. But I am inclined to say that total integrated dose will. However testing should be performed and analysed for it may prove the opposite.

9. Arrhenius projection is somewhat an adequate method when temperature is the only criteria. But using it in a combined environment, it will lose its high correlation. If the effect was additive, you might be lucky because this principle can be superposable. The same evaluation follows for the W.L.F. projection.

Y.G. Moorehead
September 21, 1981

Minutes of meeting with L. Bonzon 8/13/81, Albequerque, New Mexico.

1. Mr. Bonzon stated that, for our operating condition, EPDM is probably the best elastomer to use with Viton ranking as a "maybe".

2. Mr. Bonzon was opposed to the use of the word "physical" (relaxation). He said that chemical degradation is the only way to predict life (and only in an accelerated method).

3. Metal seals were cited as the best solution but that machining, tolerances of installation are extremely vital to the success of these seals.

4. Mr. Bonzon said the PH_3 treatment would be useless in our application (this is 180° from the data presented in the report that Sandia sent us #SAND80-2149). Not effective for EPR though he never tried it.

5. EPDM seals probably good for 10 years, no guarantee. At this point he reiterated that accelerated age tests would be the only way to determine.

6. Agreed to $T_{min} + 100^{\circ}F \leq T_{oper} \leq T_{max} - 100^{\circ}F$

7. This question resulted in the longest discussion. Mr. Bonzon was opposed to our method of testing. Claims that accelerated induced chemical degradation tests are the only way to predict life (Commentary: Industry and academia have proven, per Dave Winkler-University of Akron, that induced chemical degradation is not an accurate way of predicting elastomer life. Sandia has recently been trying to re-instate this type of life study testing. Mr. Bonzon stated that the one thing that Sandia has been missing is a benchmark.) All of their accelerated tests have been done on temperature influence only. Mr. Bonzon said that Sandia is not sure if accelerated tests will be accurate for combined parameters.

8. Stated that degradation is a function of both dosage and dosage rate in conjunction with all the other parameters (heat, humidity, fluid,...). Claims the only way to determine this is by accelerated testing using 50 O rings per point of interest (at this point he was asked if this is due to the fact that it's a manditory scientific procedure or just one that Sandia employs. He said that he recommends this).

9: No math modeling done. After some discussion, it became apparent that he really did not understand the concept behind math models so we dropped the subject (though he professed to kr [illegible] nphatically that math models don't work.)

Note: Tour of facility was provided. Facility is of the nature of wet radiation. No unusual instrumentation is present. Mr. Bonzon was very informative about his installation.

APPENDIX 4

FTA AND PROBABILITY ASSIGNMENTS (RELATIVE)

A random probability number is assigned (.0001) to the very high (VH) relative degree of probability. This number will be equally subdivided and assigned to the relatively lower level of probability.

VH -- .0001

H -- .000086

MH -- .000071

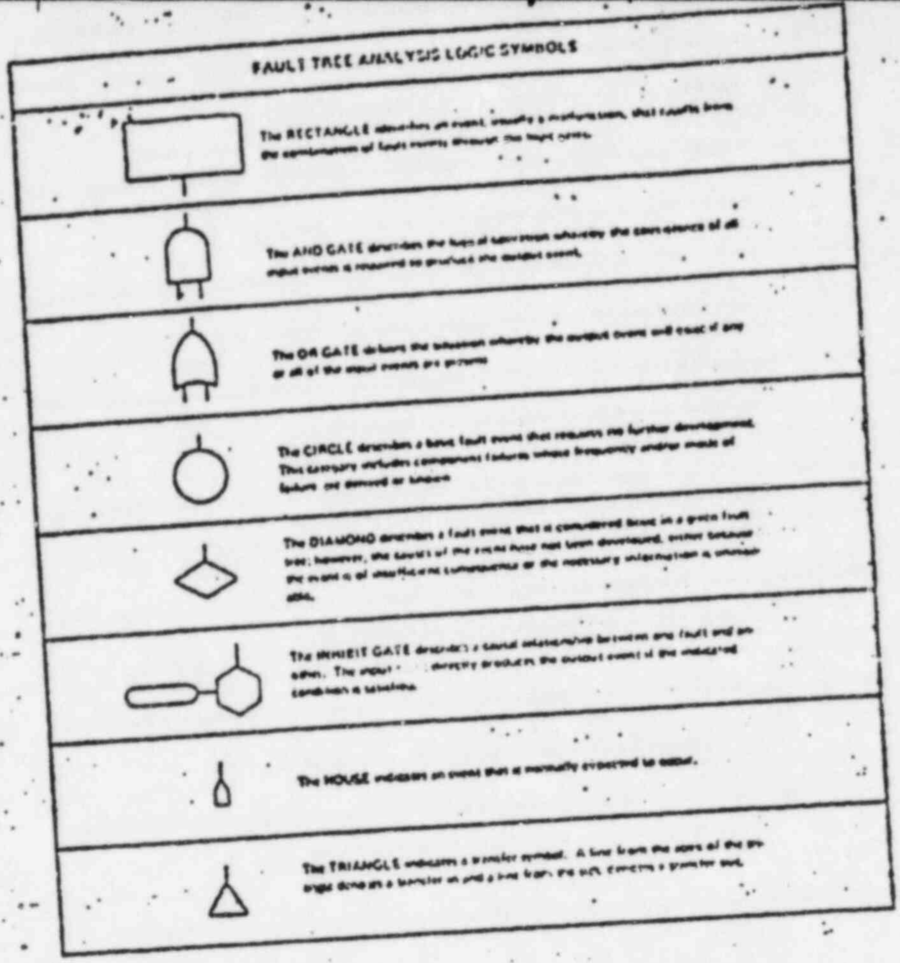
M -- .000057

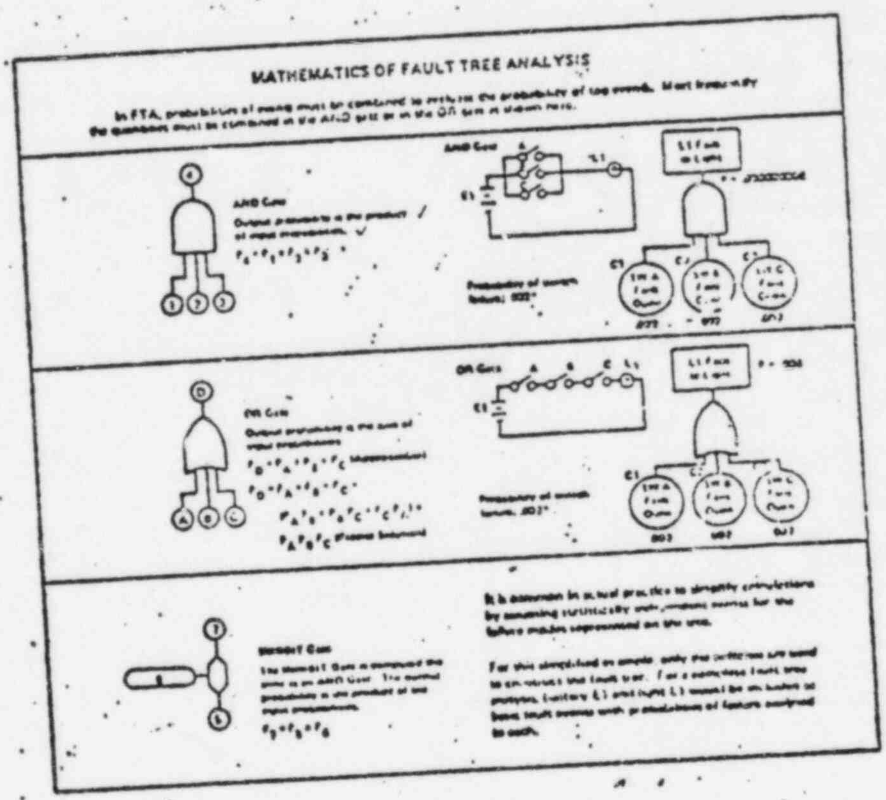
ML -- .000043

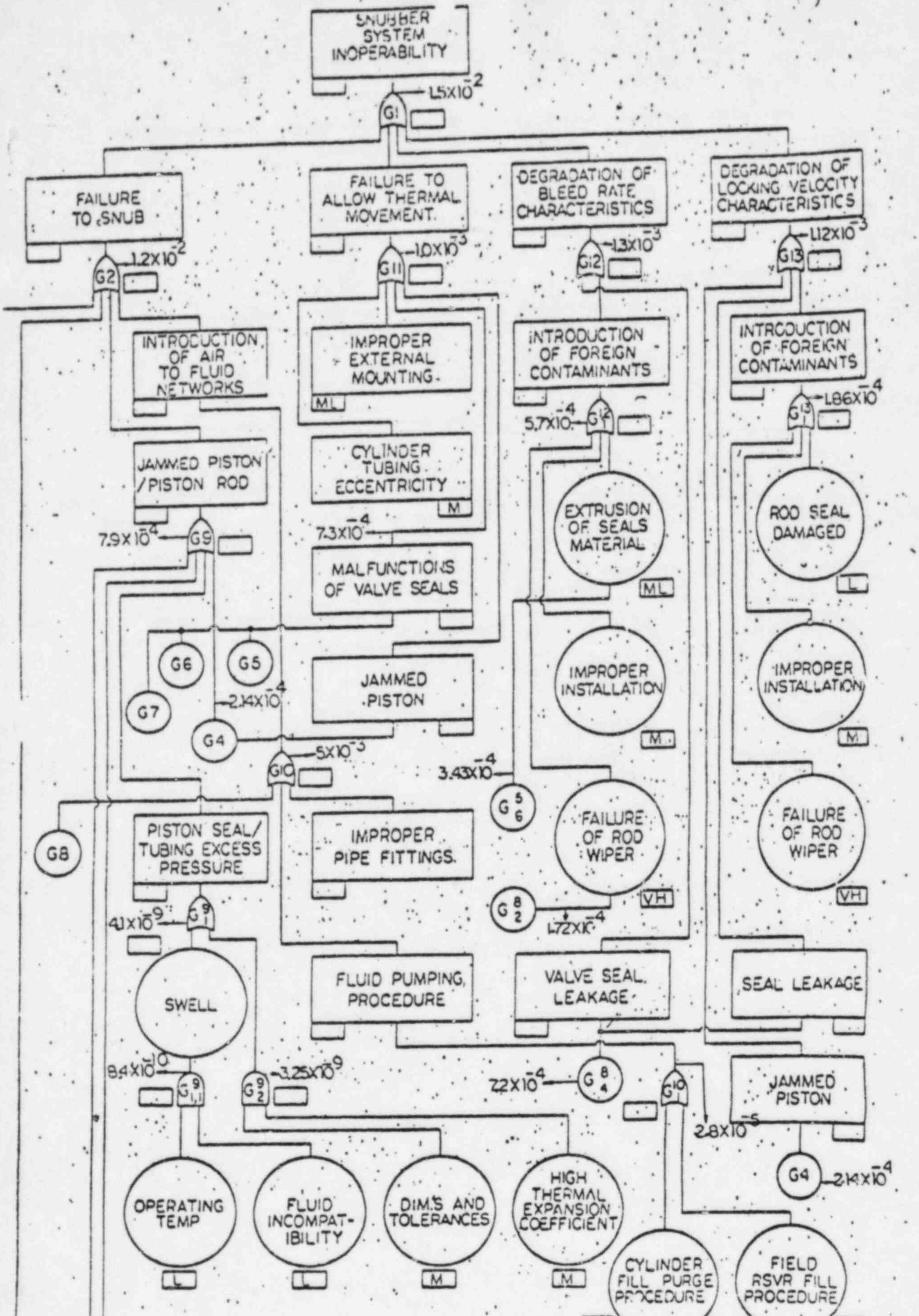
L -- .000029

VL -- .000014 (Very Low)

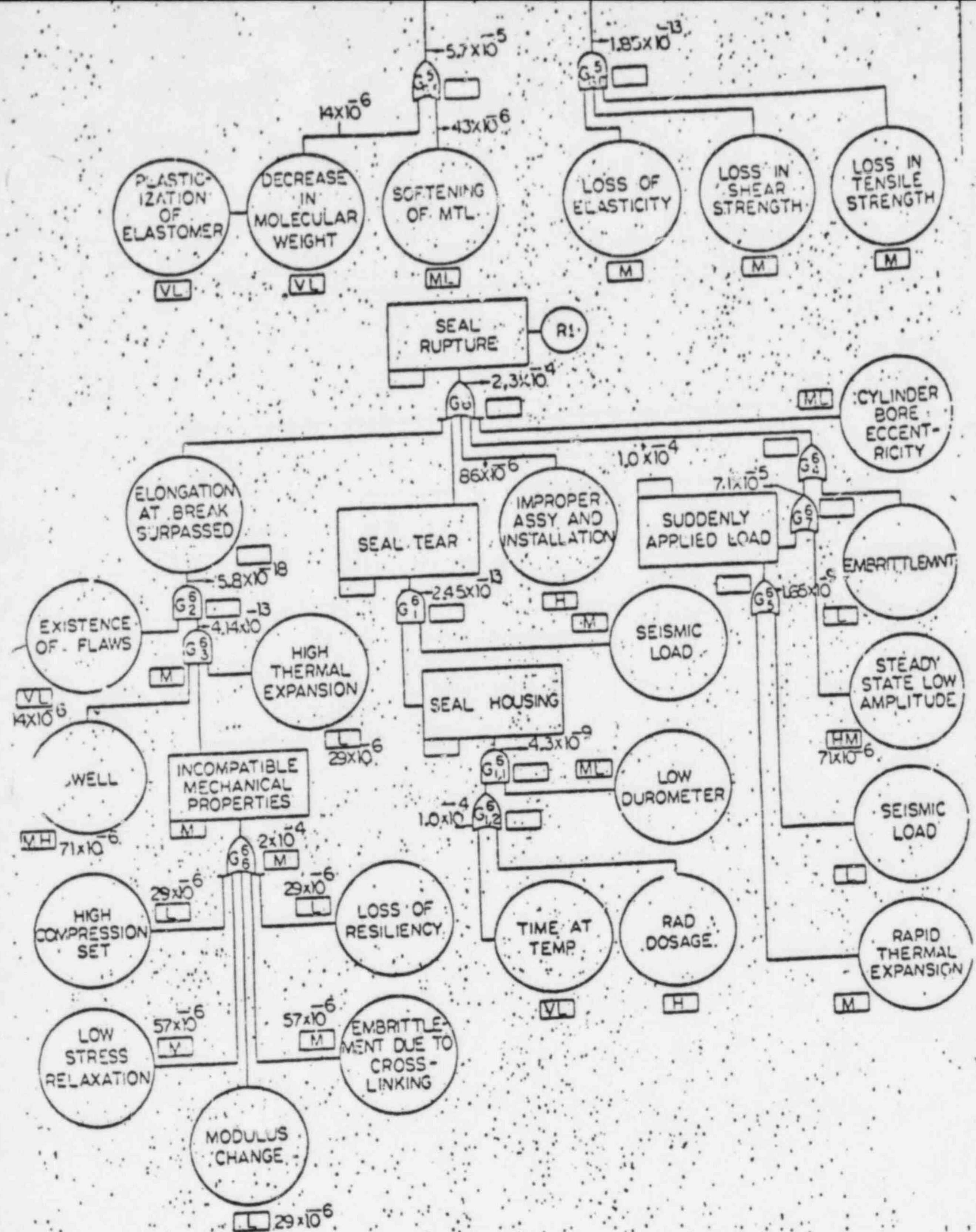
On a relative basis, the F.T.A. will indicate what failure mode has the higher probability of occurence. It will also serve as a verification of the logic designed for such failure.


FAULT TREE ANALYSIS LOGIC SYMBOLS
The RECTANGLE
The AND GATE
The OR GATE
The CIRCLE
The DIAMOND
The INHIBIT GATE
The HOUSE
The TRIANGLE

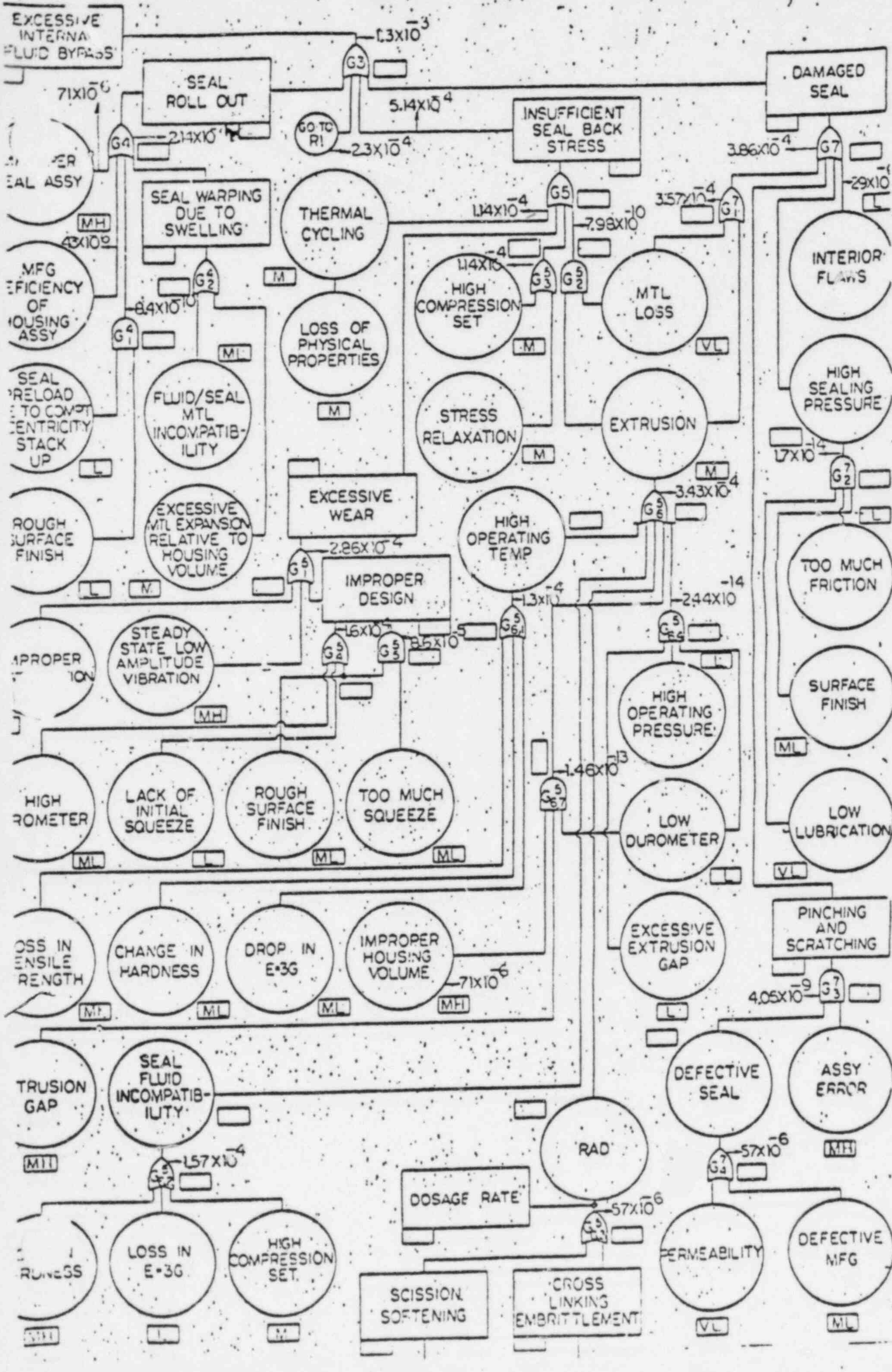

MATHEMATICS OF FAULT TREE ANALYSIS
AND Gate
OR Gate



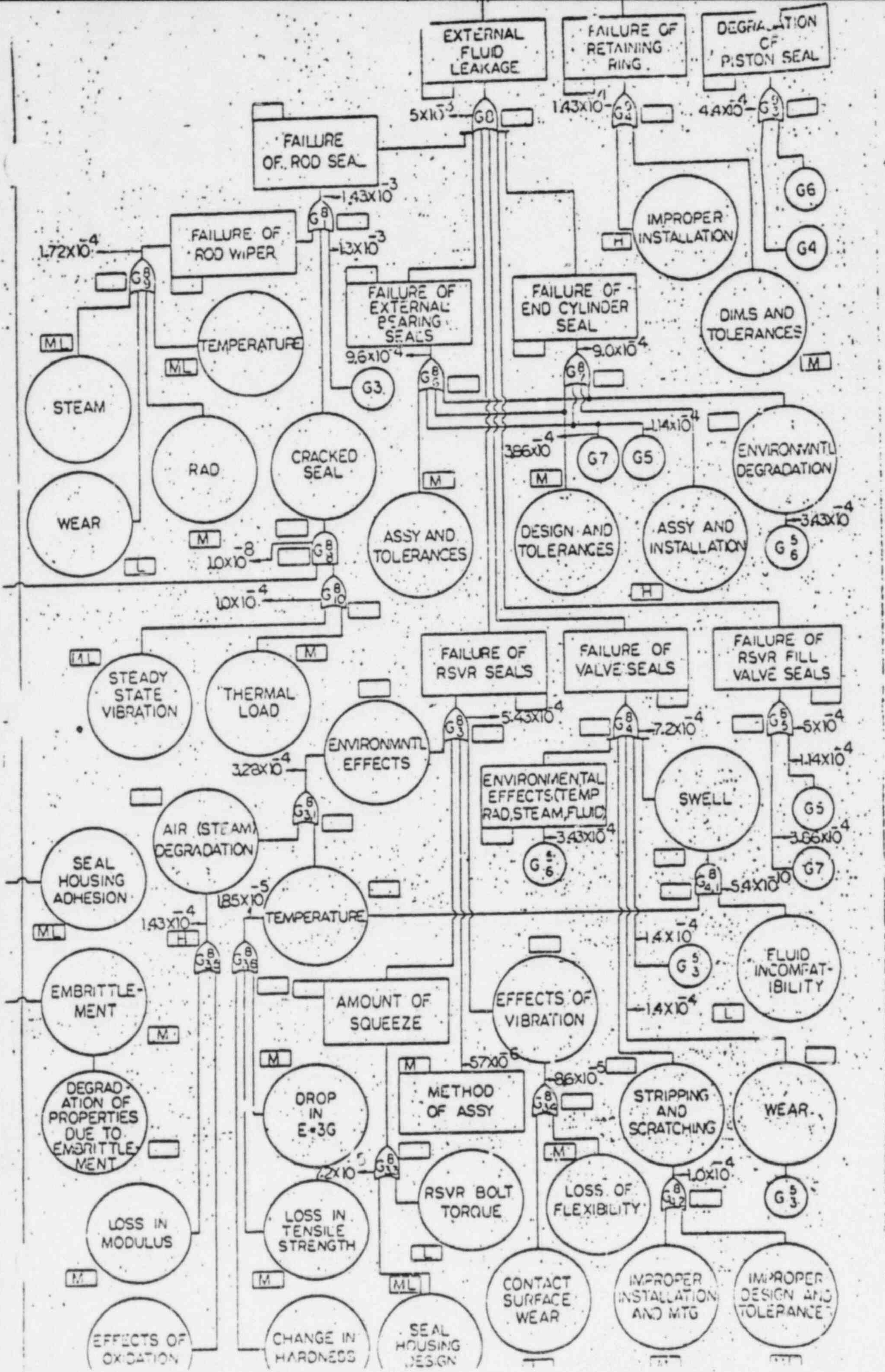
SNUBBER SYSTEM INOPERABILITY
G1
1.5X10^-2
FAILURE TO SNUB
G2
1.2X10^-2
FAILURE TO ALLOW THERMAL MOVEMENT
G11
1.0X10^-3
DEGRADATION OF BLEED RATE CHARACTERISTICS
G12
1.3X10^-3
DEGRADATION OF LOCKING VELOCITY CHARACTERISTICS
G13
1.12X10^-3
INTRODUCTION OF AIR TO FLUID NETWORKS
IMPROPER EXTERNAL MOUNTING
ML
INTRODUCTION OF FOREIGN CONTAMINANTS
INTRODUCTION OF FOREIGN CONTAMINANTS
5.7X10^-4
1.86X10^-4
CYLINDER TUBING ECCENTRICITY
M
JAMMED PISTON /PISTON ROD
7.9X10^-4
G9
7.3X10^-4
MALFUNCTIONS OF VALVE SEALS
EXTRUSION OF SEALS MATERIAL
ML
ROD SEAL DAMAGED
L
G6
G5
G7
2.14X10^-4
G4
JAMMED PISTON
IMPROPER INSTALLATION
M
IMPROPER INSTALLATION
M
5X10^-3
G10
3.43X10^-4
G8
PISTON SEAL/ TUBING EXCESS PRESSURE
IMPROPER PIPE FITTINGS.
FAILURE OF ROD WIPER
VH
FAILURE OF ROD WIPER
VH
4.1X10^-9
1.72X10^-4
SWELL
FLUID PUMPING PROCEDURE
VALVE SEAL LEAKAGE
SEAL LEAKAGE
8.4X10^-10
3.25X10^-9
7.2X10^-4
JAMMED PISTON
2.8X10^-5
G4
2.14X10^-4
OPERATING TEMP
L
FLUID INCOMPATIBILITY
L
DIM.S AND TOLERANCES
M
HIGH THERMAL EXPANSION COEFFICIENT
M
CYLINDER FILL PURGE PROCEDURE
VL
FIELD RSVR FILL PROCEDURE
VL



5.7X10⁻⁵
1.85X10⁻¹³
14X10⁻⁶
43X10⁻⁶
PLASTICIZATION OF ELASTOMER
VL
DECREASE IN MOLECULAR WEIGHT
VL
SOFTENING OF MTL.
ML
LOSS OF ELASTICITY
M
LOSS IN SHEAR STRENGTH
M
LOSS IN TENSILE STRENGTH
M
SEAL RUPTURE
R1
2.3X10⁻⁴
ML
CYLINDER BORE ECCENTRICITY
1.0X10⁻⁴
7.1X10⁻⁵
86X10⁻⁶
ELONGATION AT BREAK SURPASSED
SEAL TEAR
IMPROPER ASSY AND INSTALLATION
H
SUDDENLY APPLIED LOAD
EMBRITTLEMNT
L
5.8X10⁻¹⁸
2.45X10⁻¹³
1.65X10⁻⁹
4.14X10⁻¹³
EXISTENCE OF FLAWS
VL
HIGH THERMAL EXPANSION
M
L
29X10⁻⁶
SEISMIC LOAD
M
STEADY STATE LOW AMPLITUDE
HM
71X10⁻⁶
SEAL HOUSING
4.3X10⁻⁹
ML
LOW DUROMETER
14X10⁻⁶
SWELL
VH
71x10⁻⁶
INCOMPATIBLE MECHANICAL PROPERTIES
M
2x10⁻⁴
M
1.0x10⁻⁴
SEISMIC LOAD
L
HIGH COMPRESSION SET
29x10⁻⁶
L
LOSS OF RESILIENCY
29x10⁻⁶
L
TIME AT TEMP.
VL
RAD DOSAGE
H
RAPID THERMAL EXPANSION
M
LOW STRESS RELAXATION
57x10⁻⁶
V
EMBRITTLEMENT DUE TO CROSS-LINKING
57x10⁻⁶
M
MODULUS CHANGE
L
29x10⁻⁶



EXCESSIVE INTERNAL FLUID BYPASS
1.3X10-3
G3
SEAL ROLL OUT
DAMAGED SEAL
71X10-6
G4
2.14X10
GO TO R1
2.3X10-4
5.14X10-4
INSUFFICIENT SEAL BACK STRESS
3.86X10-4
G7
SEAL ASSY
MH
SEAL WARPING DUE TO SWELLING
THERMAL CYCLING
G5
1.14X10-4
7.98X10-10
3.57X10-4
29X10
MFG DEFICIENCY OF HOUSING ASSY
8.4X10-10
1.14X10-4
INTERIOR FLAWS
HIGH COMPRESSION SET
MTL LOSS
M
VL
LOSS OF PHYSICAL PROPERTIES
SEAL PRELOAD DUE TO COMPT ECCENTRICITY STACK UP
ML
FLUID/SEAL MTL INCOMPATIBILITY
HIGH SEALING PRESSURE
STRESS RELAXATION
EXTRUSION
L
1.7X10-14
ROUGH SURFACE FINISH
EXCESSIVE MTL EXPANSION RELATIVE TO HOUSING VOLUME
EXCESSIVE WEAR
HIGH OPERATING TEMP
3.43X10-4
TOO MUCH FRICTION
2.86X10-4
IMPROPER DESIGN
1.3X10-4
2.44X10-14
1.6X10
8.5X10-5
IMPROPER INSTALLATION
STEADY STATE LOW AMPLITUDE VIBRATION
HIGH OPERATING PRESSURE
SURFACE FINISH
1.46X10-13
HIGH DUROMETER
LACK OF INITIAL SQUEEZE
ROUGH SURFACE FINISH
TOO MUCH SQUEEZE
LOW DUROMETER
LOW LUBRICATION
VL
LOSS IN TENSILE STRENGTH
CHANGE IN HARDNESS
DROP IN E-3G
IMPROPER HOUSING VOLUME
71X10-6
EXCESSIVE EXTRUSION GAP
PINCHING AND SCRATCHING
4.05X10-9
EXTRUSION GAP
SEAL FLUID INCOMPATIBILITY
DEFECTIVE SEAL
ASSY ERROR
1.57X10-4
RAD
57X10-6
DOSAGE RATE
57X10-6
LOSS IN E-3G
HIGH COMPRESSION SET
PERMEABILITY
DEFECTIVE MFG
SCISSION SOFTENING
CROSS LINKING EMBRITTLEMENT


EXTERNAL FLUID LEAKAGE
FAILURE OF RETAINING RING
DEGRADATION OF PISTON SEAL
5X10-3
1.43X10-4
4.4X10-4
FAILURE OF ROD SEAL
1.43X10-3
G6
G4
FAILURE OF ROD WIPER
1.72X10-4
1.3X10-3
IMPROPER INSTALLATION
H
ML
TEMPERATURE
FAILURE OF EXTERNAL BEARING SEALS
FAILURE OF END CYLINDER SEAL
DIMS AND TOLERANCES
M
9.6X10-4
9.0X10-4
ML
STEAM
G3
RAD
CRACKED SEAL
1.14X10-4
3.86X10-4
G7
G5
ENVIRONMNTL DEGRADATION
M
M
WEAR
ASSY AND TOLERANCES
DESIGN AND TOLERANCES
ASSY AND INSTALLATION
3.43X10-4
M
1.0X10-8
L
H
1.0X10-4
ML
M
FAILURE OF RSVR SEALS
FAILURE OF VALVE SEALS
FAILURE OF RSVR FILL VALVE SEALS
STEADY STATE VIBRATION
THERMAL LOAD
5.43X10-4
7.2X10-4
5X10-4
ENVIRONMNTL EFFECTS
1.14X10-4
3.28X10-4
ENVIRONMENTAL EFFECTS (TEMP RAD, STEAM, FLUID)
SWELL
G5
3.43X10-4
3.66X10-4
AIR (STEAM) DEGRADATION
SEAL HOUSING ADHESION
G7
5.4X10-10
1.85X10-5
1.43X10-4
TEMPERATURE
ML
H
1.4X10-4
FLUID INCOMPATIBILITY
EMBRITTLEMENT
AMOUNT OF SQUEEZE
EFFECTS OF VIBRATION
1.4X10-4
L
M
M
5.7X10-6
M
8.6X10-5
DEGRADATION OF PROPERTIES DUE TO EMBRITTLEMENT
DROP IN E•3G
METHOD OF ASSY
STRIPPING AND SCRATCHING
WEAR
M
2X10-5
1.0X10-4
LOSS IN MODULUS
LOSS IN TENSILE STRENGTH
RSVR BOLT TORQUE
LOSS OF FLEXIBILITY
L
M
M
ML
CONTACT SURFACE WEAR
IMPROPER INSTALLATION AND MTG
IMPROPER DESIGN AND TOLERANCE
EFFECTS OF OXIDATION
CHANGE IN HARDNESS
SEAL HOUSING DESIGN

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NATIONAL O-RINGS NATIONAL O-RINGS NATIONAL O-RINGS NATIONAL

NATIONAL O-RINGS TECHNICAL REPORT

NATIONAL O-RINGS

COMPOUND E50-70

DATE APRIL 26, 1982

SPECIFICATIONS ASTM D2000

4CA714A25B44EA14F19G21 AND

3DA715A26B36EA14F19G21

TITLE: COMPARISON - NATIONAL COMPOUND E50-70 TO ASTM D2000 SPECIFICATIONS 4CA715A25B44EA14F19G21 AND 3DA715A26B36EA14F19G21

PURPOSE: To analyze the performance of E50-70 slabs and buttons (70 durometer ethylene-propylene rubber) when tested in accordance with the specified requirements of ASTM D2000.

CONCLUSION: National O-Rings Compound E50-70 complies with all requirements of the above specifications.

DENNIS REICKS
TECHNICAL SERVICES SUPERVISOR

FEDERAL MOGUL

NATIONAL O-RINGS
TECHNICAL REPORT

COMPOUND E50-70

DATE APRIL 26, 1982

SPECIFICATIONS ASTM D2000
4CA715A25B44EA14F19G21 AND
3DA715A26B36EA14F19G21

ORIGINAL PHYSICAL PROPERTIES	LIMITS 4CA715	LIMITS 3DA715	E50-70 RESULTS
Hardness, Shore A, points	70±5	70±5	72
Tensile Strength, psi, min.	1500	1500	2300
Elongation, %, min.	200	200	240
AIR AGE, ASTM D865	A25 70 HRS. @ 125°C(257°F)		
Hardness Change, points, max.	+10		+2
Tensile Change, %, max.	-20		-3.2
Elongation Change, %, max.	-40		-9
		A26 70 HRS. @ 150°C(302°F)	
Hardness Change, points, max.		+10	+6
Tensile Change, %, max.		-20	+1
Elongation Change, %, max.		-20	-16
COMPRESSION SET, ASTM D395, METHOD B	B44 70 HRS. @ 100°C(212°F)		
% of Original Deflection, max.	50		14
		B36 22 HRS. @ 150°C(302°F)	
% of Original Deflection, max.		25	16
FLUID RESISTANCE, 70 HRS. @ 100°C(212°F) IN DISTILLED WATER, ASTM D471	EA14	EA14	
Volume Change, %	±5	±5	+0.7
LOW TEMPERATURE BRITTLENESS, ASTM D2137, METHOD A	F19	F19	
Must Be Non-Brittle @	-55°C(-67°F)	-55°C(-67°F)	Passes
TEAR RESISTANCE, ASTM D624	G21	G21	
Die C, kN/m, min.	26	17	28.9

FEDERAL MOGUL

NATIONAL O-RINGS TECHNICAL REPORT

COMPOUND E50-70

DATE MARCH 31, 1982

SPECIFICATIONS TACO INC./UL 778 REQUIREMENTS

TITLE: COMPARISON - NATIONAL COMPOUND E50-70 TO TACO INC./UNDERWRITERS LABORATORIES UL 778 REQUIREMENTS.

PURPOSE: To analyze the performance of E50-70 ASTM slabs and buttons (70 durometer ethylene-propylene rubber) when tested in accordance with the requirements of Taco Inc./UL 778.

CONCLUSION: National O-Rings Compound E50-70 complies with all requirements of UL 778 specified by Taco Inc. (See attached test data.)

Dennis Reicks

DENNIS REICKS
TECHNICAL SERVICES SUPERVISOR

FEDERAL MOGUL

NATIONAL O-RINGS
TECHNICAL REPORT

COMPOUND E50-70
DATE MARCH 31, 1982

SPECIFICATIONS TACO INC./UL 778 REQUIREMENTS

ORIGINAL PHYSICAL PROPERTIES	LIMITS	RESULTS
Hardness, Shore A, points	55 to 75	75
Tensile Strength, psi. min.	1500	2300
Elongation, %, min.	250	255

AIR AGE, 1440 HRS. @ 250°F		
Tensile Strength Change, % of Original, min.	75	102.61
Elongation Change, % of Original, min.	65	74.51

COMPRESSION SET, 40% OF ORIGINAL THICKNESS, 24 HRS. @ 258°F		
% Set, max.	15	11.8

ELONGATION SET, DUMBBELL STRETCHED FROM 1 INCH TO 2.5 INCHES, HELD FOR 2 MINUTES, AND MEASURED 2 MINUTES AFTER RELEASE		
Acceptable Set, Inches, max.	.250"	.020"

#3865

FEDERAL MOGUL

Laboratory Report No. 4034

RESULTS

Original Properties	Required	E-17018
Hardness, Shore "A"	90 ± 5	82
Tensile Strength, psi	1200 min.	1957
Elongation, %	100 min.	160
Wagner 21B, 70 Hrs. @ 257°F		
Hardness Change	-10	-2
Tensile Change, %	-10 max.	+35.4
Elongation Change, %	-15 max.	0
Volume Change, %	0 to +10	+4.8
Dow Corning 50-4, 70 Hrs. @ 257°F		
Hardness Change	-10	+1
Tensile Change, %	-10 max.	+44.1
Elongation Change, %	-15 max.	0
Volume Change, %	0 to +10	+0.7
Oven Aging, 70 Hrs. @ 257°F		
Hardness Change	0 to +10	+3
Tensile Change, %	-10 max.	+11.1
Elongation Change, %	-20 max.	-6.3
Compression Set, 22 Hrs. @ 257°F		
Plied Discs, % Set	20 max.	3.8
% Recovery	95 min.	99
Low Temperature, 5 Hrs. @ -65°F		
Flexible	Pass	o.k.

Acushnet Co.
P. M. Beattie

ITT GRINNELL CORPORATION
PRODUCT DEVELOPMENT
HANGER DIVISION

RADIATION AND ENVIRONMENTAL TEST OF SEAL AND FLUID MATERIALS FOR SNUBBERS

Revision 1 Approval [signature] Date 7-23-77
Dept. Mgr.

FOR REFERENCE ONLY

Report No. PHD-5347-2R Rev. 1

Prepared by [signature] Date 10/3/75
Prod. Engr.

Approved by [signature] Date 10/2/75
Sec. Mgr.

Approved by [signature] Date 10/3/75
Dept. Mgr.

This report supersedes Report No. PHD-5347-1R, "Radiation Capacity of Snubber Seal Materials at Davis Besse Nuclear Power Station Unit 1" dated 7-29-75. This report contains data previously presented, with the addition of temperature and humidity data on seal material after irradiation and temperature, viscosity, and flash and flame point data on hydraulic fluid. Data previously presented is slightly modified as a result of review of collected data and calculations. These modifications are minor and do not reflect significant changes in results previously reported. There is also a change in method of identification of spacers used to determine precompression of seal material.

Appended to this report is report no. PHD-7569-1 Rev. 1 which tests four additional seal materials for radiation and environmental acceptability.

RESULTS AND CONCLUSIONS

Below is tabulated summary of results obtained on seal materials after exposure to a total integrated radiation dose of 3×10^7 Rads. Tabulation shows percent change in durometer, tensile strength, and compression set.

Compound	Durometer Average % Change	Tensile Strength Average % Change	Average Compression Set - % of Initial Compression
National E-50	+2.4	-23.2	51.9
Acushnet E-17018	-1.8	-41.5	46.4
Parker E740-75	+7.8	-20.3	54.8
Parker E692-75	+5.9	- 4.7	56.4
Salisbury 80154	+4.8	- 3.2	53.3
Minnesota 559EQ	+7.6	- 4.8	71.6
Mantaline 70 Duro EPDM	Not Tested	-19.3	68.3
Parker E515-80	+4.7	-11.3	70.0

Samples of the above materials after having been exposed to irradiation, were then subjected to 100% steam at 268°F for a period of 72 hours. Below is a tabulated summary of results obtained after this exposure. These results are based on original material properties.

Compound	Durometer Average % Change	Average Compression Set - % of Initial Compression
National E-50	-9.6	52.5

Compound	Durometer Average % Change	Average Compression Set - % of Initial Compression
Acushnet E-17018	-1.2	49.5
Parker E740-75	+ .59	58.0
Parker E692-75	-1.8	58.5
Salisbury 80154	+6.0	70.8
Minnesota 559EQ	0.0	77.0
Mantaline 70 Duro EPDM	Not Tested	89.4
Parker E515-80	-4.1	75.1

Data from which the above were obtained, are included in Appendix I of this report.

Changes in durometer are not significant. Changes in tensile strength due to irradiation, can be classified on the average as moderate. Change in compression set can be classified as moderate to appreciable in some cases, however, sufficient resiliency is maintained in all cases to provide adequate sealing. It is noted that the Mantaline seals, which show the greatest degree of compression set, are static seals. In this application, compression set is not as significant a factor as would be in a dynamic seal.

Use of the above compounds are as follows:

1) At Snubber Valve Ports: National Seal Division Federal Mogul Compound No. E-50, Acushnet E-17018, Parker E740-75, Parker E692-75
2) Cylinder Piston Seals: W. H. Salisbury & Co. Compound No. 80154

3) Rod Seal & Rod Wiper: Minnesota Rubber Co. Compound No. 559EQ

4) Cylinder Tube to Head Seals: Mantaline Corporation 70 Durometer EPDM Cord Stock

5) Valve Adjustor Seals: Parker E515-80, Parker E740-75

Documentation on method and level of radiation exposure to seals is included in Appendix I of this report, page 36 and 37. (Code B)

After exposure to 3×10^7 Rads, samples of the hydraulic fluid exhibited a slight increase in viscosity. This increase was no more than would be produced by a 13° temperature drop. Fluid specimens, which did not contain hydraulic seal samples, experienced slightly more change in viscosity than fluid specimens in which seal samples had been immersed during radiation.

Maximum viscosity after exposure is roughly the same as the high limit of normal production viscosity.

Hydraulic fluid is considered suitable for continued use after exposure to 3×10^7 Rads and the presence of seal material does not adversely affect fluid properties.
Samples of fluid which had been exposed to maximum radiation (4.5×10^7) were subjected to flash point and fire point tests with the following results:

Flash Point = 615°F

Fire Point = or greater 720°F

PURPOSE

The purpose of these tests is to demonstrate the ability

PURPOSE (cont'd)

of seal and fluid material used in ITT Grinnell Corporation's Hydraulic Snubbers to meet the requirements of nuclear power plant applications.

PROCEDURE-SEAL IRRADIATION

Test specimens for all molded seals were O-Rings in ARP568-212 size. Test specimens for extruded seals were cut from pieces of the actual extruded stock. Specimens were tested for compression set, change in tensile strength, and change in durometer. The extruded stock was too small in cross-section to permit a meaningful durometer measurement and so only compression set and tensile strength were measured for these specimens.

Compression set indicates the extent to which squeeze initially applied by the gland to the seal is lost as the seal ages. It is measured by compressing a specimen by a given amount (to 75% of its initial thickness for this test); ageing the seal in this compressed state; and then measuring the free thickness of the seal after ageing. The difference between initial and final thickness is expressed as a percent of initial squeeze.

To test for compression set, a test fixture was made for each specimen. The fixture consisted of a series of steel plates ground flat separated by a spacer ground to a predetermined dimension to assure 25% compression. The complete assembly

PROCEDURE-SEAL IRRADIATION (cont'd)

was held together by a bolt running through the center (see Figure 1). The initial thickness of each compression set test specimen was measured at three locations around the O-Ring. The spacer for the test fixture was then ground to give exactly 25% squeeze for the specimen. Specimens were compressed and placed in the hydraulic fluid immediately prior to irradiation and were removed from the fluid and the compression relieved immediately following irradiation. Specimens were exposed to gamma radiation at a rate of .75 Megarads per hour for a period of 40 hours.

Durometer and tensile strength were measured with a separate set of specimens which were not compressed. First a durometer measurement was made, then the O-Ring was cut and mounted in a tensile tester.

Two specimens were used to determine initial tensile strength; another two specimens were used to measure durometer and tensile strength after irradiation; and a third pair of specimens were used to measure compression set.

Tensile strength measurements were made using a 0 - 250 lb. range Scott tensile tester. Durometer measurements were made with a Rex Model A Shore A durometer tester.

PROCEDURE-SEAL TEMPERATURE/STEAM EXPOSURE

After measurements were taken, the specimens used to measure compression set were remounted in the fixture of Figure 1.

PROCEDURE-SEAL TEMPERATURE/STEAM EXPOSURE (cont'd)

The complete assembly was installed in a test chamber as shown in Figure 2. Approximately three inches of water was put into the test chamber and then the complete chamber was placed in a power-o-matic mechanical convection oven. Temperature was determined and monitored for a period of 72 hours using a combination of Type J Thermocouple and Leeds-Northrup Potentiometer Model No. 8693-2. After completion of test, specimens were again measured for durometer and compression set as described in previous procedure.

PROCEDURE-FLUID IRRADIATION

A gallon of fluid was drawn from the production supply at the ITT Grinnell Hanger Division Plant in Warren, Ohio. This supply of fluid had been mixed with blue dye in accordance with normal production procedures. Identity and lot numbers of the fluid and of the dye are recorded in the Data Sheets.

This gallon sample was divided into several specimen containers. One, a small glass vial, contained only hydraulic fluid; a second, a polysulfone tube, contained hydraulic fluid, a steel test fixture, and 40 ethylene-propylene O-Rings. Both of these containers were irradiated to 3×10^7 Rads. After irradiation, fluid from these two containers and a fresh specimen from the gallon sample were

PROCEDURE-FLUID IRRADIATION (cont'd)

placed in polyethylene bottles and sent to the General Electric Silicone Products Department for testing. Test data was transmitted to the ITT Grinnell Corporation for this report.

GRINNELL CORPORATION

HANGER DEVELOPMENT SECTION

BY N.E.W. DATE 7-29-75 SUBJECT SEAL MATERIAL IRRADIATION TEST FIXTURE SHEET NO. 1 OF 1

CHKD. BY D.A.E. DATE 7-29-75 PROJECT NO. PHD-5347

Report No. PHD-5347-2R

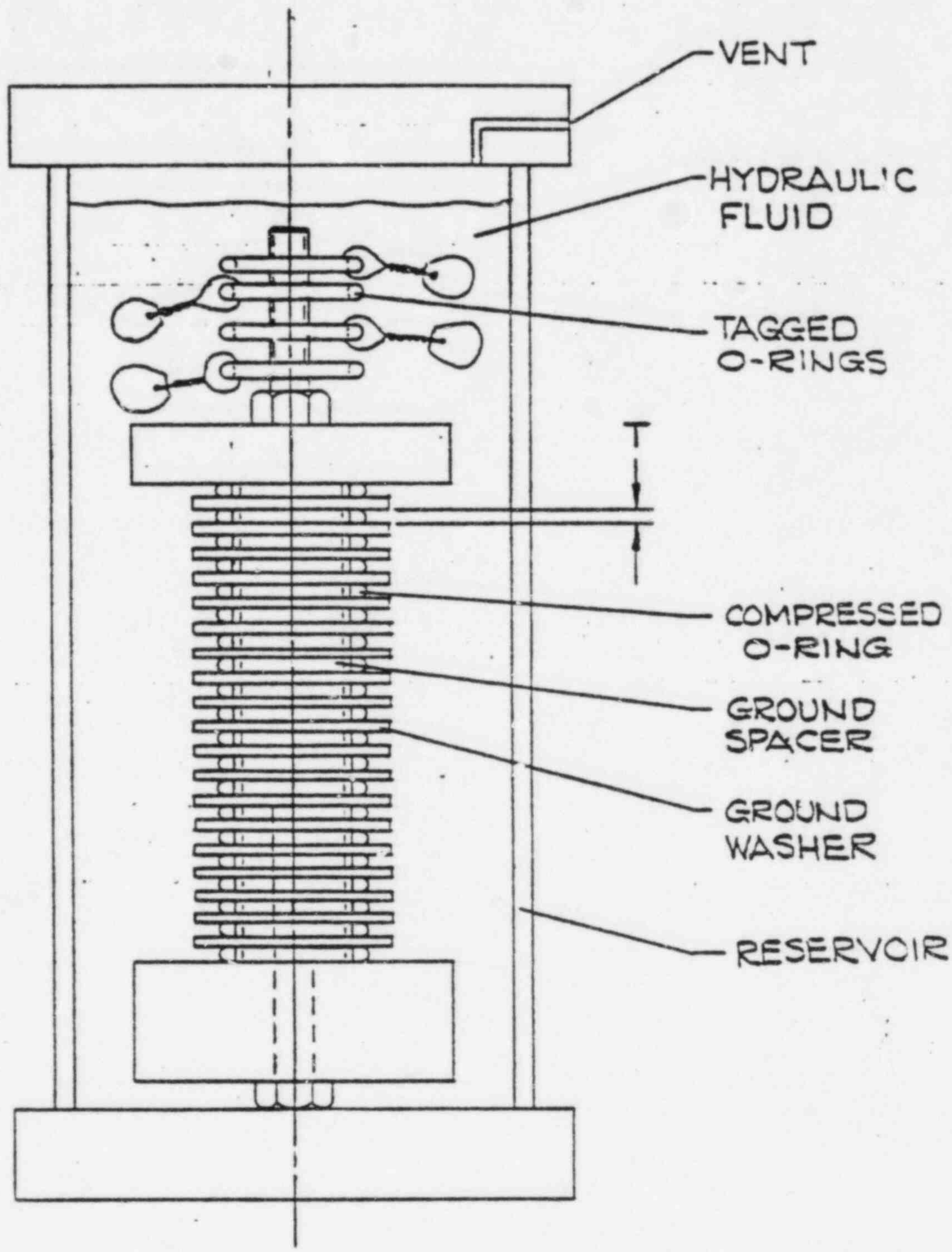


FIG. 1

Printed in U. S. A.

3872 - Hanger

ITT Grinnell Corporation

PRODUCT DEVELOPMENT DEPARTMENT

BY R.D.D. DATE 10-1-75 SUBJECT STEAM TEST CHAMBER - SEALS

CHKD. BY E.M. DATE 10-2-75

SHEET NO. 1 OF 1

PROJECT NO. PHD-534

PHD-5347-2R

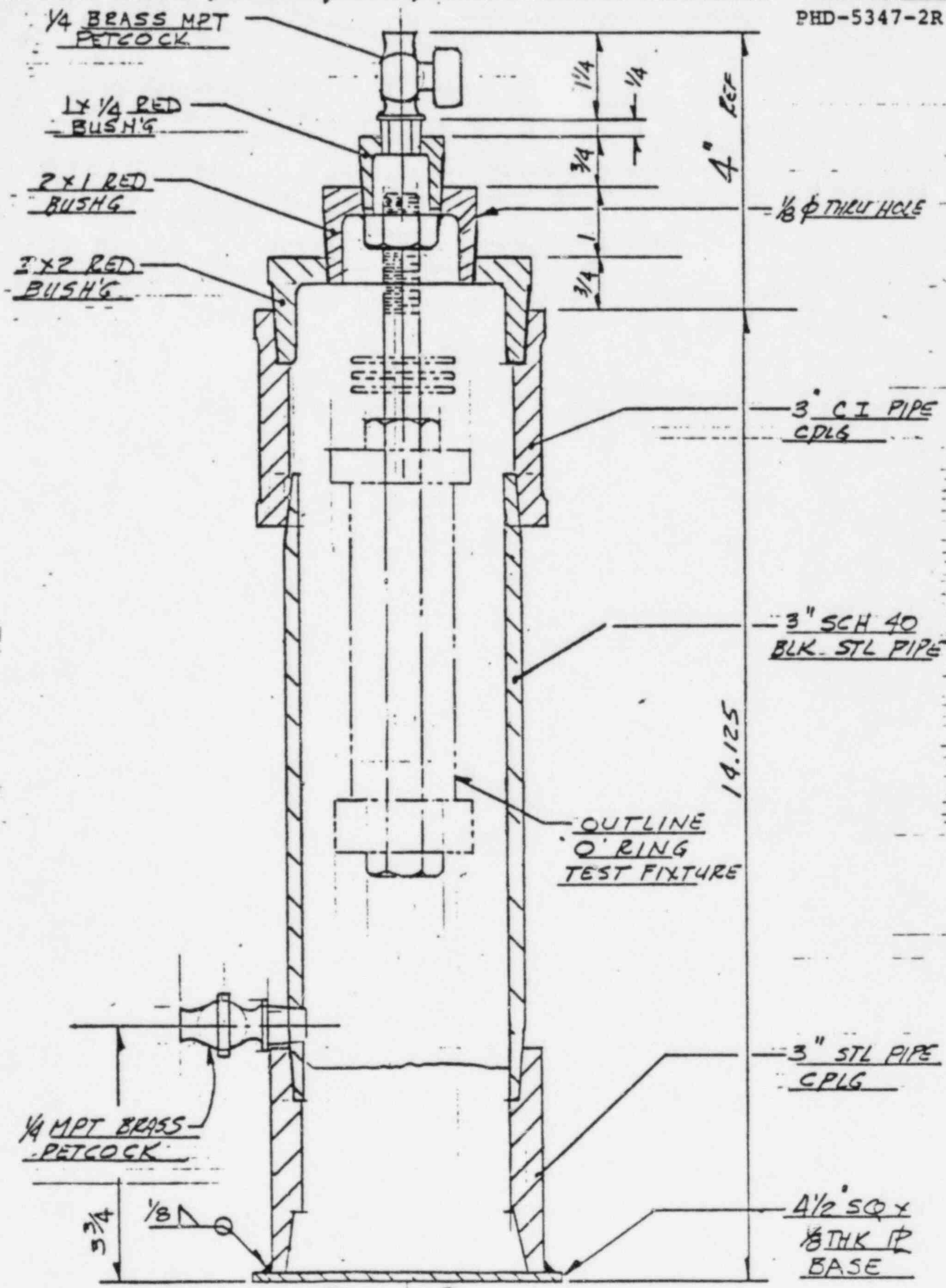


FIG. #2

TEST DATA

TEST REPORT FORM - SEAL MATERIAL IRRADIATION

Initial Data

Specimen Type and Size: O-RING ARP 568-212
Molder: NATIONAL SEAL DIV., FEDERAL MOGUL Compound No. 250
Batch No. 47376 Cure Date 4Q74
Certificate of Compliance BEARINGS INC., CLEVELAND, OHIO No. 102668

Durometer-Shore A:	83	83					81	82
Tensile Strgth-PSI	1746	1696						
Irrad. Test Ident							3	5

Specimen Ident •••
Thickness: T_{01}= .138 T_{02}= .139 T_{03}= .138
$\overline{T}_0$= .1383 .75 $\overline{T}_0$= .104
Fixture Dimension: T = .1034 Ident 103 Container Ident B

Specimen Ident ••••
Thickness: T_{01}= .139 T_{02}= .140 T_{03}= .140
$\overline{T}_0$= .1396 .75 $\overline{T}_0$= .1047
Fixture Dimension: T = .1052 Ident 105 Container Ident B

Speciment Ident ____
Thickness: T_{01}= ____ T_{02}= ____ T_{03}= ____
$\overline{T}_0$= ____ .75 $\overline{T}_0$= ____
Fixture Dimension: T = ____ Ident ____ Container Ident ____

Specimen Ident ____
Thickness: T_{01}= ____ T_{02}= ____ T_{03}= ____
$\overline{T}_0$= ____ .75 $\overline{T}_0$= ____
Fixture Dimension: T = ____ Ident ____ Container Ident ____

Specimen Ident ____
Thickness: T_{01}= ____ T_{02}= ____ T_{03}= ____
$\overline{T}_0$= ____ .75 $\overline{T}_0$= ____
Fixture Dimension: T = ____ Ident ____ Container Ident ____

Specimen Ident ____
Thickness: T_{01}= ____ T_{02}= ____ T_{03}= ____
$\overline{T}_0$= ____ .75 $\overline{T}_0$= ____
Fixture Dimension: T = ____ Ident ____ Container Ident ____

Signature of Test Supervisor Frank Ybarra Date 9/24/75

AFTER IRRADIATION

Radiation Type GAMA
Radiation Dose 3×10^7

Specimen Ident	3	5				
Durometer-Shore A:	85	85				
Tensile Strgth-PSI	1239	1404				

Specimen Ident ••• Radiation Dose 3×10^7
Thickness: T_{11}= .1203 T_{12}= .1192 T_{13}= .1185
$\overline{T}_1$= .1193 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = 54.9%

Specimen Ident ••••
Thickness: T_{11}= .1230 T_{12}= .1223 T_{13}= .1223
$\overline{T}_1$= .1225 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = 48.9%

Specimen Ident ______ Radiation Dose ______
Thickness: T_{11}= ______ T_{12} = ______ T_{13}= ______
$\overline{T}_1$= ______ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ______

Specimen Ident ______
Thickness: T_{11}= ______ T_{12}= ______ T_{13}= ______
$\overline{T}_1$= ______ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ______

Specimen Ident ______ Radiation Dose ______
Thickness: T_{11}= ______ T_{12}= ______ T_{13}= ______
$\overline{T}_1$= ______ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ______

Specimen Ident ______
Thickness: T_{11}= ______ T_{12}= ______ T_{13}= ______
$\overline{T}_1$= ______ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ______

Signature of Test Supervisor Frank Ohms Date 9/24/75

AFTER IRRADIATION
AFTER STEAM

Radiation Type GAMA
Radiation Dose 3×10^7 ____ ____
Specimen Ident 3 5 ____ ____ ____ ____
Durometer-Shore A: 76 74 ____ ____ ____ ____
Tensile Strgth-PSI ____ ____ ____ ____ ____ ____

Specimen Ident ••• Radiation Dose 3×10^7
Thickness: T_{11}= .119 T_{12}= .1196 T_{13}= .1188
$\overline{T}_1$= .1191 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = 55%

Specimen Ident ••••
Thickness: T_{11}= .1228 T_{12}= .1221 T_{13}= .1221
$\overline{T}_1$= .1223 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = 50%

Specimen Ident ____ Radiation Dose ____
Thickness: T_{11}= ____ T_{12}= ____ T_{13}= ____
$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Specimen Ident ____
Thickness: T_{11}= ____ T_{12}= ____ T_{13}= ____
$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Specimen Ident ____ Radiation Dose ____
Thickness: T_{11}= ____ T_{12}= ____ T_{13}= ____
$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Specimen Ident ____
Thickness: T_{11}= ____ T_{12}= ____ T_{13}= ____
$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Signature of Test Supervisor Frank Moore Date 9/24/75

TEST REPORT FORM - SEAL MATERIAL IRRADIATION

Initial Data

Specimen Type and Size: O-RING ARP 568-212
Molder: ACUSHNET RUBBER CO. Compound No. E-17018
Batch No. 41 Cure Date 2Q75
Certificate of Compliance J. ROYAL CO.

Durometer-Shore A: 84 83 81 84 ____ ____ ____ ____
Tensile Strgth-PSI 1704 1981
Irrad. Test Ident A B ____ ____ ____ ____

Specimen Ident 1+1-1+
Thickness: T_{01}= .140 T_{02}= .140 T_{03}= .140
$\overline{T}_0$= .140 .75 $\overline{T}_0$= .105
Fixture Dimension: T = .105 Ident .105 Container Ident B

Specimen Ident 1+11-1+
Thickness: T_{01}= .140 T_{02}= .140 T_{03}= .140
$\overline{T}_0$= .140 .75 $\overline{T}_0$= .105
Fixture Dimension: T = .105 Ident 105 Container Ident B

Speciment Ident ____
Thickness: T_{01}= ____ T_{02}= ____ T_{03}= ____
$\overline{T}_0$= ____ .75 $\overline{T}_0$= ____
Fixture Dimension: T = ____ Ident ____ Container Ident ____

Specimen Ident ____
Thickness: T_{01}= ____ T_{02}= ____ T_{03}= ____
$\overline{T}_0$= ____ .75 $\overline{T}_0$= ____
Fixture Dimension: T = ____ Ident ____ Container Ident ____

Specimen Ident ____
Thickness: T_{01}= ____ T_{02}= ____ T_{03}= ____
$\overline{T}_0$= ____ .75 $\overline{T}_0$= ____
Fixture Dimension: T = ____ Ident ____ Container Ident ____

Specimen Ident ____
Thickness: T_{01}= ____ T_{02}= ____ T_{03}= ____
$\overline{T}_0$= ____ .75 $\overline{T}_0$= ____
Fixture Dimension: T = ____ Ident ____ Container Ident ____

Signature of Test Supervisor Frank Ybsca Date 9/24/75

AFTER IRRADIATION

Radiation Type GAMA

Radiation Dose 3×10^7 ____ ____

Specimen Ident A B ____ ____ ____ ____

Durometer-Shore A: 81 87 ____ ____ ____ ____

Tensile Strgth-PSI 1085 1070 ____ ____ ____ ____

Specimen Ident 1+11-1+ Radiation Dose 3×10^7

Thickness: T_{11}= .124 T_{12}= .124 T_{13}= .124

$\overline{T}_1$= .124 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = 45.97%

Specimen Ident 1+1

Thickness: T_{11}= .1235 T_{12}= .124 T_{13}= .1238

$\overline{T}_1$= .1237 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = 46.83%

Specimen Ident ____ Radiation Dose ____

Thickness: T_{11}= ____ T_{12} = ____ T_{13}= ____

$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Specimen Ident ____

Thickness: T_{11}= ____ T_{12}= ____ T_{13}= ____

$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Specimen Ident ____ Radiation Dose ____

Thickness: T_{11}= ____ T_{12}= ____ T_{13}= ____

$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Specimen Ident ____

Thickness: T_{11}= ____ T_{12}= ____ T_{13}= ____

$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Signature of Test Supervisor Frank Meyer Date 9/24/75

AFTER IRRADIATION
AFTER STEAM

Radiation Type GAMA
Radiation Dose 3×10^7 ____ ____
Specimen Ident A B ____ ____ ____ ____
Durometer-Shore A: 81 82 ____ ____ ____ ____
Tensile Strgth-PSI ____ ____ ____ ____ ____ ____

Specimen Ident 1+11-1+ Radiation Dose 3×10^7
Thickness: T_{11}= .1232 T_{12}= .1227 T_{13}= .1227
$\overline{T}_1$= .1228 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = 49%

Specimen Ident 1+1
Thickness: T_{11}= .1226 T_{12}= .1226 T_{13}= .1226
$\overline{T}_1$= .1226 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = 50%

Specimen Ident ____ Radiation Dose ____
Thickness: T_{11}= ____ T_{12} = ____ T_{13}= ____
$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Specimen Ident ____
Thickness: T_{11}= ____ T_{12}= ____ T_{13}= ____
$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Specimen Ident ____ Radiation Dose ____
Thickness: T_{11}= ____ T_{12}= ____ T_{13}= ____
$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Specimen Ident ____
Thickness: T_{11}= ____ T_{12}= ____ T_{13}= ____
$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Signature of Test Supervisor Frank [signature] Date 9/24/75

TEST REPORT FORM - SEAL MATERIAL IRRADIATION

Initial Data

Specimen Type and Size: O-RING ARP 568-212
Molder: PARKER SEAL Co. Compound No. E740-75
Batch No. 165326 Cure Date 1Q75
Certificate of Compliance ______

Durometer-Shore A:	83	84					85	84
Tensile Strgth-PSI	1263	1289						
Irrad. Test Ident							JJ	VV

Specimen Ident 11+
Thickness: T_{01}= .140 T_{02}= .140 T_{03}= .141
$\overline{T}_0$= .1403 .75 $\overline{T}_0$= .1052
Fixture Dimension: T = .1053 Ident 105 Container Ident B

Specimen Ident 101
Thickness: T_{01}= .142 T_{02}= .143 T_{03}= .143
$\overline{T}_0$= .1426 .75 $\overline{T}_0$= .107
Fixture Dimension: T = .1073 Ident 107 Container Ident B

Speciment Ident ______
Thickness: T_{01}= ______ T_{02}= ______ T_{03}= ______
$\overline{T}_0$= ______ .75 $\overline{T}_0$= ______
Fixture Dimension: T = ______ Ident ______ Container Ident ______

Specimen Ident ______
Thickness: T_{01}= ______ T_{02}= ______ T_{03}= ______
$\overline{T}_0$= ______ .75 $\overline{T}_0$= ______
Fixture Dimension: T = ______ Ident ______ Container Ident ______

Specimen Ident ______
Thickness: T_{01}= ______ T_{02}= ______ T_{03}= ______
$\overline{T}_0$= ______ .75 $\overline{T}_0$= ______
Fixture Dimension: T = ______ Ident ______ Container Ident ______

Specimen Ident ______
Thickness: T_{01}= ______ T_{02}= ______ T_{03}= ______
$\overline{T}_0$= ______ .75 $\overline{T}_0$= ______
Fixture Dimension: T = ______ Ident ______ Container Ident ______

Signature of Test Supervisor Frank Mecca Date 9/24/75

AFTER IRRADIATION

Radiation Type GAMA
Radiation Dose 3x10^7 ____ ____
Specimen Ident JJ VV ____ ____ ____ ____
Durometer-Shore A: 91 89 ____ ____ ____ ____
Tensile Strgth-PSI 947 1086 ____ ____ ____ ____

Specimen Ident 11+ Radiation Dose 3×10^7
Thickness: T_{11}= .1210 T_{12}= .1205 T_{13}= .1210
$\overline{T}_1$= .1208 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = 55.5%

Specimen Ident 101
Thickness: T_{11}= .1232 T_{12}= .1235 T_{13}= .1230
$\overline{T}_1$= .1232 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = 54%

Specimen Ident ____ Radiation Dose ____
Thickness: T_{11}= ____ T_{12} = ____ T_{13}= ____
$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Specimen Ident ____
Thickness: T_{11}= ____ T_{12}= ____ T_{13}= ____
$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Specimen Ident ____ Radiation Dose ____
Thickness: T_{11}= ____ T_{12}= ____ T_{13}= ____
$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Specimen Ident ____
Thickness: T_{11}= ____ T_{12}= ____ T_{13}= ____
$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Signature of Test Supervisor Frank Masa Date 9/24/75

AFTER IRRADIATION
AFTER STEAM

Radiation Type GAMA
Radiation Dose 3×10^7
Specimen Ident JJ VV
Durometer-Shore A: 85 83
Tensile Strgth-PSI

Specimen Ident 11+ Radiation Dose 3×10^7
Thickness: T_{11}= .1203 T_{12}= .1200 T_{13}= .1204
$\overline{T}_1$= .1202 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = 57%

Specimen Ident 101
Thickness: T_{11}= .1216 T_{12}= .1220 T_{13}= .1220
$\overline{T}_1$= .1218 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = 58.9%

Specimen Ident ____ Radiation Dose ____
Thickness: T_{11}= ____ T_{12} = ____ T_{13}= ____
$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Specimen Ident ____
Thickness: T_{11}= ____ T_{12}= ____ T_{13}= ____
$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Specimen Ident ____ Radiation Dose ____
Thickness: T_{11}= ____ T_{12}= ____ T_{13}= ____
$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Specimen Ident ____
Thickness: T_{11}= ____ T_{12}= ____ T_{13}= ____
$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Signature of Test Supervisor: [signature] Date 9/24/75

TEST REPORT FORM - SEAL MATERIAL IRRADIATION

Initial Data

Specimen Type and Size: O-RING ARP 568-212
Molder: PARKER SEAL Co. Compound No. E692-75
Batch No. 165326 Cure Date 2Q75
Certificate of Compliance ______

Durometer-Shore A:	84	84		-	-		85	85
Tensile Strgth-PSI	1098	1217						
Irrad. Test Ident			-				DD	NN

Specimen Ident +011
Thickness: T_{01}= .142 T_{02}= .141 T_{03}= .142
$\overline{T}_0$= .1416 .75 $\overline{T}_0$= .1062
Fixture Dimension: T = .1062 Ident 106 Container Ident B

Specimen Ident 1+0
Thickness: T_{01}= .142 T_{02}= .142 T_{03}= .141
$\overline{T}_0$= .1416 .75 $\overline{T}_0$= .1062
Fixture Dimension: T = .1068 Ident 1066 Container Ident B

Speciment Ident ______
Thickness: T_{01}= ______ T_{02}= ______ T_{03}= ______
$\overline{T}_0$= ______ .75 $\overline{T}_0$= ______
Fixture Dimension: T = ______ Ident ______ Container Ident ______

Specimen Ident ______
Thickness: T_{01}= ______ T_{02}= ______ T_{03}= ______
$\overline{T}_0$= ______ .75 $\overline{T}_0$= ______
Fixture Dimension: T = ______ Ident ______ Container Ident ______

Specimen Ident ______
Thickness: T_{01}= ______ T_{02}= ______ T_{03}= ______
$\overline{T}_0$= ______ .75 $\overline{T}_0$= ______
Fixture Dimension: T = ______ Ident ______ Container Ident ______

Specimen Ident ______
Thickness: T_{01}= ______ T_{02}= ______ T_{03}= ______
$\overline{T}_0$= ______ .75 $\overline{T}_0$= ______
Fixture Dimension: T = ______ Ident ______ Container Ident ______

Signature of Test Supervisor Frank Moore Date 9/24/75

AFTER IRRADIATION

Radiation Type GAMA

Radiation Dose 3×10^7 ____ ____

Specimen Ident DD NN ____ ____ ____ ____

Durometer-Shore A: 90 90 ____ ____ ____ ____

Tensile Strgth-PSI 1086 1120 ____ ____ ____ ____

Specimen Ident +011 Radiation Dose 3×10^7

Thickness: T_{11}= .1226 T_{12}= .1215 T_{13}= .1215

$\overline{T}_1$= .1218 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = 55.9%

Specimen Ident 1+0

Thickness: T_{11}= .1225 T_{12}= .1220 T_{13}= .1210

$\overline{T}_1$= .1218 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = 56.8%

Specimen Ident ____ Radiation Dose ____

Thickness: T_{11}= ____ T_{12} = ____ T_{13}= ____

$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Specimen Ident ____

Thickness: T_{11}= ____ T_{12}= ____ T_{13}= ____

$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Specimen Ident ____ Radiation Dose ____

Thickness: T_{11}= ____ T_{12}= ____ T_{13}= ____

$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Specimen Ident ____

Thickness: T_{11}= ____ T_{12}= ____ T_{13}= ____

$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Signature of Test Supervisor Frank Mosca Date 9/24/75

AFTER IRRADIATION
AFTER STEAM

Radiation Type GAMA
Radiation Dose 3x10^7 ______ ______
Specimen Ident DD NN ______ ______ ______ ______
Durometer-Shore A: 83 84 ______ ______ ______ ______
Tensile Strgth-PSI – – ______ ______ ______ ______

Specimen Ident +011 Radiation Dose 3x10^7
Thickness: T_{11}= .1204 T_{12}= .1209 T_{13}= .1209
$\overline{T}_1$= .1207 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = 59%

Specimen Ident 1+0
Thickness: T_{11}= .1212 T_{12}= .1213 T_{13}= .1212
$\overline{T}_1$= .1212 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = 58%

Specimen Ident ______ Radiation Dose ______
Thickness: T_{11}= ______ T_{12} = ______ T_{13}= ______
$\overline{T}_1$= ______ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ______

Specimen Ident ______
Thickness: T_{11}= ______ T_{12}= ______ T_{13}= ______
$\overline{T}_1$= ______ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ______

Specimen Ident ______ Radiation Dose ______
Thickness: T_{11}= ______ T_{12}= ______ T_{13}= ______
$\overline{T}_1$= ______ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ______

Specimen Ident ______
Thickness: T_{11}= ______ T_{12}= ______ T_{13}= ______
$\overline{T}_1$= ______ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ______

Signature of Test Supervisor Frank Nosc ______ Date 9/24/75

TEST REPORT FORM - SEAL MATERIAL IRRADIATION

Initial Data

Specimen Type and Size: O-RING ARP 568-212
Molder: W.H. SALISBURY CO. Compound No. 80154
Batch No. N.A. Cure Date 1Q 75
Certificate of Compliance ORDER No. 51897-OA

Durometer-Shore A: 83 84 ___ ___ ___ ___ 83 84
Tensile Strgth-PSI 1449 768/468
Irrad. Test Ident ___ ___ ___ ___ II PP

Specimen Ident ++111
Thickness: T_{01}= .142 T_{02}= .142 T_{03}= .141
$\bar{T}_0$= .1416 .75 $\bar{T}_0$= .1062
Fixture Dimension: T = .106 Ident 106 Container Ident B

Specimen Ident ++
Thickness: T_{01}= .142 T_{02}= .142 T_{03}= .142
$\bar{T}_0$= .142 .75 $\bar{T}_0$= .1065
Fixture Dimension: T = .106 Ident 106 Container Ident B

Speciment Ident ____
Thickness: T_{01}= ____ T_{02}= ____ T_{03}= ____
$\bar{T}_0$= ____ .75 $\bar{T}_0$= ____
Fixture Dimension: T = ____ Ident ____ Container Ident ____

Specimen Ident ____
Thickness: T_{01}= ____ T_{02}= ____ T_{03}= ____
$\bar{T}_0$= ____ .75 $\bar{T}_0$= ____
Fixture Dimension: T = ____ Ident ____ Container Ident ____

Specimen Ident ____
Thickness: T_{01}= ____ T_{02}= ____ T_{03}= ____
$\bar{T}_0$= ____ .75 $\bar{T}_0$= ____
Fixture Dimension: T = ____ Ident ____ Container Ident ____

Specimen Ident ____
Thickness: T_{01}= ____ T_{02}= ____ T_{03}= ____
$\bar{T}_0$= ____ .75 $\bar{T}_0$= ____
Fixture Dimension: T = ____ Ident ____ Container Ident ____

Signature of Test Supervisor Frank Meca Date 9/24/75

AFTER IRRADIATION

Radiation Type GAMA

Radiation Dose 3×10^7 ____ ____

Specimen Ident II PP ____ ____ ____ ____

Durometer-Shore A: 88 87 ____ ____ ____ ____

Tensile Strgth-PSI 468 1252 ____ ____ ____ ____

Specimen Ident ++111 Radiation Dose 3×10^7

Thickness: T_{11}= .1229 T_{12}= .1232 T_{13}= .1225

$\overline{T}_1$= .1228 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = 52.8%

Specimen Ident ++

Thickness: T_{11}= .1232 T_{12}= .1222 T_{13}= .1225

$\overline{T}_1$= .1226 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = 53.8%

Specimen Ident ____ Radiation Dose ____

Thickness: T_{11}= ____ T_{12} = ____ T_{13}= ____

$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Specimen Ident ____

Thickness: T_{11}= ____ T_{12}= ____ T_{13}= ____

$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Specimen Ident ____ Radiation Dose ____

Thickness: T_{11}= ____ T_{12}= ____ T_{13}= ____

$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Specimen Ident ____

Thickness: T_{11}= ____ T_{12}= ____ T_{13}= ____

$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Signature of Test Supervisor Frank Abeca Date 9/20/75

AFTER IRRADIATION
AFTER STEAM

Radiation Type GAMA

Radiation Dose 3x10^7 ____ ____

Specimen Ident II PP ____ ____ ____ ____

Durometer-Shore A: 80 77 ____ ____ ____ ____

Tensile Strgth-PSI ____ ____ ____ ____ ____ ____

Specimen Ident ++111 Radiation Dose 3x10^7

Thickness: T_{11}= .1162 T_{12}= .1162 T_{13}= .1162

$\overline{T}_1$= .1162 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = 71%

Specimen Ident ++

Thickness: T_{11}= .1166 T_{12}= .1166 T_{13}= .1166

$\overline{T}_1$= .1166 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = 70.5%

Specimen Ident ____ Radiation Dose ____

Thickness: T_{11}= ____ T_{12} = ____ T_{13}= ____

$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Specimen Ident ____

Thickness: T_{11}= ____ T_{12}= ____ T_{13}= ____

$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Specimen Ident ____ Radiation Dose ____

Thickness: T_{11}= ____ T_{12}= ____ T_{13}= ____

$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Specimen Ident ____

Thickness: T_{11}= ____ T_{12}= ____ T_{13}= ____

$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Signature of Test Supervisor Frank [signature] Date 9/24/75

TEST REPORT FORM - SEAL MATERIAL IRRADIATION

Initial Data

Specimen Type and Size: O-RING ARP 568-212
Molder: MINNESOTA RUBBER Co. Compound No. 559EQ
Batch No. F.O. No. G 2915 Cure Date 4th QUARTER 1974
Certificate of Compliance MINNESOTA INVOICE No. 73580

Durometer-Shore A:	85	84				85	86
Tensile Strgth-PSI	1416	1186					
Irrad. Test Ident						X	S

Specimen Ident 00111
Thickness: T_{01}= .139 T_{02}= .138 T_{03}= .140
$\overline{T}_0$= .139 .75 $\overline{T}_0$= 1042
Fixture Dimension: T = .104 Ident 104 Container Ident B

Specimen Ident 00
Thickness: T_{01}= .139 T_{02}= .139 T_{03}= 138
$\overline{T}_0$= .1386 .75 $\overline{T}_0$= .104
Fixture Dimension: T = .1042 Ident 104 Container Ident B

Speciment Ident ____
Thickness: T_{01}= ____ T_{02}= ____ T_{03}= ____
$\overline{T}_0$= ____ .75 $\overline{T}_0$= ____
Fixture Dimension: T = ____ Ident ____ Container Ident ____

Specimen Ident ____
Thickness: T_{01}= ____ T_{02}= ____ T_{03}= ____
$\overline{T}_0$= ____ .75 $\overline{T}_0$= ____
Fixture Dimension: T = ____ Ident ____ Container Ident ____

Specimen Ident ____
Thickness: T_{01}= ____ T_{02}= ____ T_{03}= ____
$\overline{T}_0$= ____ .75 $\overline{T}_0$= ____
Fixture Dimension: T = ____ Ident ____ Container Ident ____

Specimen Ident ____
Thickness: T_{01}= ____ T_{02}= ____ T_{03}= ____
$\overline{T}_0$= ____ .75 $\overline{T}_0$= ____
Fixture Dimension: T = ____ Ident ____ Container Ident ____

Signature of Test Supervisor Frank Mesa Date 9/24/75

AFTER IRRADIATION

Radiation Type GAMA

Radiation Dose 3×10^7 ____ ____

Specimen Ident	X	S				
Durometer-Shore A:	93	91				
Tensile Strgth-PSI	1235	1235				

Specimen Ident 00111 Radiation Dose 3×10^7
Thickness: T_{11}= .1125 T_{12}= .113 T_{13}= .113

$\bar{T}_1$= .1128 Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{\bar{T}_0 - T}$ = 72.24%

Specimen Ident 00
Thickness: T_{11}= .114 T_{12}= .114 T_{13}= .1145

$\bar{T}_1$= .1141 Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{\bar{T}_0 - T}$ = 71%

Specimen Ident ____ Radiation Dose ____
Thickness: T_{11}= ____ T_{12} = ____ T_{13}= ____

$\bar{T}_1$= ____ Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{\bar{T}_0 - T}$ = ____

Specimen Ident ____
Thickness: T_{11}= ____ T_{12}= ____ T_{13}= ____

$\bar{T}_1$= ____ Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{\bar{T}_0 - T}$ = ____

Specimen Ident ____ Radiation Dose ____
Thickness: T_{11}= ____ T_{12}= ____ T_{13}= ____

$\bar{T}_1$= ____ Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{\bar{T}_0 - T}$ = ____

Specimen Ident ____
Thickness: T_{11}= ____ T_{12}= ____ T_{13}= ____

$\bar{T}_1$= ____ Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{\bar{T}_0 - T}$ = ____

Signature of Test Supervisor Frank Mosca Date 9/24/75

AFTER IRRADIATION
AFTER STEAM

Radiation Type GAMA

Radiation Dose	3×10^7		____		____	
Specimen Ident	X	S	____	____	____	____
Durometer-Shore A:	85	86	____	____	____	____
Tensile Strgth-PSI	____	____	____	____	____	____

Specimen Ident 00111 Radiation Dose 3×10^7
Thickness: T_{11}= .1105 T_{12}= .1105 T_{13}= .1102

$\overline{T}_1$= .1104 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = 79.04%

Specimen Ident 00
Thickness: T_{11}= .1126 T_{12}= .1128 T_{13}= .1128

$\overline{T}_1$= .1127 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = 75%

Specimen Ident ____ Radiation Dose ____
Thickness: T_{11}= ____ T_{12} = ____ T_{13}= ____

$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Specimen Ident ____
Thickness: T_{11}= ____ T_{12}= ____ T_{13}= ____

$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Specimen Ident ____ Radiation Dose ____
Thickness: T_{11}= ____ T_{12}= ____ T_{13}= ____

$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Specimen Ident ____
Thickness: T_{11}= ____ T_{12}= ____ T_{13}= ____

$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Signature of Test Supervisor Frank Mosca Date 9/20/75

TEST REPORT FORM - SEAL MATERIAL IRRADIATION

Initial Data

Specimen Type and Size: CORD STOCK
Molder: MANTALINE Compound No. 70 DURO EPDM
Batch No. N.A. Cure Date ________
Certificate of Compliance ________

Durometer-Shore A: — —
Tensile Strgth-PSI 1432 1527
Irrad. Test Ident NOT TAGGED

Specimen Ident NEXT TO LAST
Thickness: T_{01}= .072 T_{02}= .072 T_{03}= .072
$\overline{T}_0$= .072 .75 $\overline{T}_0$= .054
Fixture Dimension: T = .0578 Ident 057 Container Ident B

Specimen Ident LAST
Thickness: T_{01}= .073 T_{02}= .073 T_{03}= .073
$\overline{T}_0$= .073 .75 $\overline{T}_0$= .0548
Fixture Dimension: T = .0578 Ident 057 Container Ident B

Speciment Ident ____
Thickness: T_{01}= ____ T_{02}= ____ T_{03}= ____
$\overline{T}_0$= ____ .75 $\overline{T}_0$= ____
Fixture Dimension: T = ____ Ident ____ Container Ident ____

Specimen Ident ____
Thickness: T_{01}= ____ T_{02}= ____ T_{03}= ____
$\overline{T}_0$= ____ .75 $\overline{T}_0$= ____
Fixture Dimension: T = ____ Ident ____ Container Ident ____

Specimen Ident ____
Thickness: T_{01}= ____ T_{02}= ____ T_{03}= ____
$\overline{T}_0$= ____ .75 $\overline{T}_0$= ____
Fixture Dimension: T = ____ Ident ____ Container Ident ____

Specimen Ident ____
Thickness: T_{01}= ____ T_{02}= ____ T_{03}= ____
$\overline{T}_0$= ____ .75 $\overline{T}_0$= ____
Fixture Dimension: T = ____ Ident ____ Container Ident ____

Signature of Test Supervisor Frank Nocca Date 9/24/75

AFTER IRRADIATION

Radiation Type GAMA

Radiation Dose 3×10^7

Specimen Ident	–	–				
Durometer-Shore A:	–	–				
Tensile Strgth-PSI	1194	–				

Specimen Ident NEXT TO LAST Radiation Dose 3×10^7
Thickness: T_{11}= .0623 T_{12}= .0627 T_{13}= .0627

$\bar{T}_1$= .0625 Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{\bar{T}_0 - T}$ = 66.9%

Specimen Ident LAST
Thickness: T_{11}= .0623 T_{12}= .0627 T_{13}= .0623

$\bar{T}_1$= .0624 Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{\bar{T}_0 - T}$ = 69.7%

Specimen Ident ______ Radiation Dose ______
Thickness: T_{11}= ______ T_{12} = ______ T_{13}= ______

$\bar{T}_1$= ______ Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{\bar{T}_0 - T}$ = ______

Specimen Ident ______
Thickness: T_{11}= ______ T_{12}= ______ T_{13}= ______

$\bar{T}_1$= ______ Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{\bar{T}_0 - T}$ = ______

Specimen Ident ______ Radiation Dose ______
Thickness: T_{11}= ______ T_{12}= ______ T_{13}= ______

$\bar{T}_1$= ______ Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{\bar{T}_0 - T}$ = ______

Specimen Ident ______
Thickness: T_{11}= ______ T_{12}= ______ T_{13}= ______

$\bar{T}_1$= ______ Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{\bar{T}_0 - T}$ = ______

Signature of Test Supervisor Frank Nkora Date 9/24/75

AFTER IRRADIATION
AFTER STEAM

Radiation Type GAMA

Radiation Dose 3×10^7 ______ ______

Specimen Ident — — ______ ______ ______ ______

Durometer-Shore A: — — ______ ______ ______ ______

Tensile Strgth-PSI ______ ______ ______ ______ ______ ______

Specimen Ident NEXT To LAST Radiation Dose 3×10^7

Thickness: T_{11}= .0593 T_{12}= .0593 T_{13}= .0596

$\overline{T}_1$= .0594 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = 88.7%

Specimen Ident LAST

Thickness: T_{11}= .0592 T_{12}= .0597 T_{13}= .0592

$\overline{T}_1$= .0593 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = 90.1%

Specimen Ident ______ Radiation Dose ______

Thickness: T_{11}= ______ T_{12} = ______ T_{13}= ______

$\overline{T}_1$= ______ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ______

Specimen Ident ______

Thickness: T_{11}= ______ T_{12}= ______ T_{13}= ______

$\overline{T}_1$= ______ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ______

Specimen Ident ______ Radiation Dose ______

Thickness: T_{11}= ______ T_{12}= ______ T_{13}= ______

$\overline{T}_1$= ______ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ______

Specimen Ident ______

Thickness: T_{11}= ______ T_{12}= ______ T_{13}= ______

$\overline{T}_1$= ______ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ______

Signature of Test Supervisor *Frank Mosca* Date 9/24/75

TEST REPORT FORM - SEAL MATERIAL IRRADIATION

Initial Data

Specimen Type and Size: O-RING ARP 568-212
Molder: PARKER SEAL Co. Compound No. E515-80
Batch No. 163993 Cure Date 4Q74
Certificate of Compliance SUPPLIED BY C.E. CONOVER & Co., INC., ASHLAND, MASS.

Durometer-Shore A:	85	84			85	85		
Tensile Strgth-PSI	1302	1263						
Irrad. Test Ident					N	O		

Specimen Ident 30e111
Thickness: T_{01}= .141 T_{02}= .142 T_{03}= .141
$\overline{T}_0$= .1413 .75 $\overline{T}_0$= .106
Fixture Dimension: T = .1062 Ident 106 Container Ident B

Specimen Ident +
Thickness: T_{01}= .141 T_{02}= .142 T_{03}= .143
$\overline{T}_0$= .142 .75 $\overline{T}_0$= .1065
Fixture Dimension: T = .106 Ident 106 Container Ident B

Speciment Ident ____
Thickness: T_{01}= ____ T_{02}= ____ T_{03}= ____
$\overline{T}_0$= ____ .75 $\overline{T}_0$= ____
Fixture Dimension: T = ____ Ident ____ Container Ident ____

Specimen Ident ____
Thickness: T_{01}= ____ T_{02}= ____ T_{03}= ____
$\overline{T}_0$= ____ .75 $\overline{T}_0$= ____
Fixture Dimension: T = ____ Ident ____ Container Ident ____

Specimen Ident ____
Thickness: T_{01}= ____ T_{02}= ____ T_{03}= ____
$\overline{T}_0$= ____ .75 $\overline{T}_0$= ____
Fixture Dimension: T = ____ Ident ____ Container Ident ____

Specimen Ident ____
Thickness: T_{01}= ____ T_{02}= ____ T_{03}= ____
$\overline{T}_0$= ____ .75 $\overline{T}_0$= ____
Fixture Dimension: T = ____ Ident ____ Container Ident ____

Signature of Test Supervisor Frank Mesca Date 9/24/75

AFTER IRRADIATION

Radiation Type GAMA

Radiation Dose 3×10^7 ____ ____

Specimen Ident	N	O	____	____	____	____
Durometer-Shore A:	88	90	____	____	____	____
Tensile Strgth-PSI	1121	1153	____	____	____	____

Specimen Ident 3○E111 Radiation Dose 3×10^7

Thickness: T_{11}= .1170 T_{12}= .1172 T_{13}= .1168

$\bar{T}_1$= .117 Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{\bar{T}_0 - T}$ = 69%

Specimen Ident +

Thickness: T_{11}= .1179 T_{12}= .1159 T_{13}= .1163

$\bar{T}_1$= .1164 Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{\bar{T}_0 - T}$ = 71%

Specimen Ident ____ Radiation Dose ____

Thickness: T_{11}= ____ T_{12} = ____ T_{13}= ____

$\bar{T}_1$= ____ Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{\bar{T}_0 - T}$ = ____

Specimen Ident ____

Thickness: T_{11}= ____ T_{12}= ____ T_{13}= ____

$\bar{T}_1$= ____ Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{\bar{T}_0 - T}$ = ____

Specimen Ident ____ Radiation Dose ____

Thickness: T_{11}= ____ T_{12}= ____ T_{13}= ____

$\bar{T}_1$= ____ Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{\bar{T}_0 - T}$ = ____

Specimen Ident ____

Thickness: T_{11}= ____ T_{12}= ____ T_{13}= ____

$\bar{T}_1$= ____ Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{\bar{T}_0 - T}$ = ____

Signature of Test Supervisor [signature] Date 9/24/75

AFTER IRRADIATION
AFTER STEAM

Radiation Type GAMA

Radiation Dose 3x10^7 ____ ____

Specimen Ident N O ____ ____ ____ ____

Durometer-Shore A: 81 82 ____ ____ ____ ____

Tensile Strgth-PSI - - ____ ____ ____ ____

Specimen Ident 3or111 Radiation Dose 3x10^7
Thickness: T_{11}= .1150 T_{12}= .1152 T_{13}= .1150
$\overline{T}_1$= .115 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = 74.9%

Specimen Ident +
Thickness: T_{11}= .1148 T_{12}= .1148 T_{13}= .1153
$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = 75.2%

Specimen Ident ____ Radiation Dose ____
Thickness: T_{11}= ____ T_{12} = ____ T_{13}= ____
$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Specimen Ident ____
Thickness: T_{11}= ____ T_{12}= ____ T_{13}= ____
$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Specimen Ident ____ Radiation Dose ____
Thickness: T_{11}= ____ T_{12}= ____ T_{13}= ____
$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Specimen Ident ____
Thickness: T_{11}= ____ T_{12}= ____ T_{13}= ____
$\overline{T}_1$= ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Signature of Test Supervisor [illegible] Date 9/24/75

ISOMEDIX

August 19, 1975

Mr. Dan Feingold
ITT-Grinnell Corporation
260 W. Exchange Street
Providence, Rhode Island 02091

Dear Mr. Feingold:

This will summarize parameters pertinent to the irradiation of cylinder and capsule samples recently completed.

Samples were placed in a Cobalt-60 gamma field per the attached "Test Report Form", to accumulate doses as shown.

The samples were rotated and turned during exposure to obtain the dose distribution described. Irradiation was conducted in air at ambient temperature and pressure. Radiant heat from the source heated the samples somewhat, but the temperature did not exceed 110°F, as indicated by previous measurements on an oil solution in the same relative position.

Dosimetry was performed using a Victoreen Model 555 Integrating Dose Rate Meter and Probe. The unit was calibrated on January 15, 1974 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. Backup dosimetry using a Red Perspex system confirmed the Victoreen readings.

Irradiation was completed on July 25, 1975.

Very truly yours,

George R. Dietz
Manager, Radiation Services

GRD:km

Attachment

Isomedix Inc. • 25 Eastmans Road, Parsippany, New Jersey (201) 887-4700
Mailing Address: Post Office Box 177, Parsippany, New Jersey 07054

CHICAGO DIVISION • 7828 Nagle Ave., Morton Grove, Illinois 60053 (312) 966-1160

TEST REPORT FORM

SEAL MATERIAL IRRADATION

Fixture Ident. No.	Dosimeter Reading (per hour)	Calculated Dose	Comments
CODE A			
1 cylinder marked $1x10^7$	.725	10.0 Mrad	14 hr. exposure
1 capsule marked $1x10^7$	.715		
	.712		
	.716		
Ave.	.715		
CODE B			
1 cylinder marked $3x10^7$	.720	30.0 Mrad	42 hr. exposure
1 capsule marked $3x10^7$	.710		
	.714		
	.715		
Ave.	.715		
CODE C			
1 cylinder marked $5x10^7$	.718	45.4 Mrad	63.5 hr. exposure
1 capsule marked $5x10^7$	.716		
1 cylinder marked $1x10^8$	.712		
1 capsule marked $2x10^8$	.714		
Ave.	.715		

Please indicate here or by separate report the method by which calculated dose is determined.

Using Red Perspex Dosimetry, a total dose for a period of time is determined. Divided by time, this yields a dose rate. Total dose is a function of dose rate times time. Dosimeters are placed on or in test items, and readings averaged when two or more dosimeters are in the same relative positions.

HYDRAULIC FLUID IRRADIATION

PRE-IRRADIATION TEST DATA SHEET

HYDRAULIC FLUID Manufacturer G.E. Silicone Products Dep't.

Designation SF 1154 75 centistokes @ 77F Lot No. EC 282-1

DYE Manufacturer American Cyanamid Co.

Designation CALCO Oil Blue V Lot No. ML 1462

FORMULA 4 fl. oz. (powder) dye

mixed with 55 gal (440 lb) fluid

SPECIMEN CONTAINERS

Ident ORIGINAL

Contents Fresh fluid from sample

Ident 1

Contents Fluid only - no seals (container made of glass)

Ident 2

Contents Fluid, seals, steel fixtures (container made of polysulfone)

HYDRAULIC FLUID IRRADIATION

POST-IRRADIATION TEST DATA SHEET

Radiation Type *gamma*

Radiation Dose	0	3×10^7 R	3×10^7 R
Specimen Ident	ORIGINAL	1	2
Temperature		**Viscosity**	
-30°F	8102	12236	10831
77°F	164	191	181
300°F	12.9	14.5	13.9

APPENDIX A

PHD-7569-1

Radiation and Environmental Test
Of Seal Materials for Snubbers

ITT GRINNELL CORP.
HANGER DIVISION
RD & E, SNUBBER SECTION

Radiation and Environmental Test of Seal Materials for Snubbers

Revision 1 Approval ______ Date 7-23-77
Dept. Mgr.

Report No. PHD-7569-1 Rev. 1

Prepared by ______ Date 3-31-77
Sr. Engr.

Approved by ______ Date 4/14/77
Sect. Mgr.

Approved by ______ Date 4-15-77
Dept. Mgr.

This report complements Report No. PHD-5347-2R, "Radiation and Environmental Test of Seal and Fluid Materials for Snubbers" dated 10/3/75. This report contains data on seal material subjected to an integrated radiation dose of 3×10^7 rads plus a 72 hour elevated temperature, 100% steam environmental test. The seal materials of this report were not qualified in the above referenced report.

Purpose

The purpose of these tests is to demonstrate the ability of the tested seal materials to meet the requirements for usage in ITT Grinnell snubbers used in nuclear power plant applications.

Results

Table 1 below summarizes the results obtained on seal materials exposed to a total integrated radiation dose of 3×10^7 rads while immersed in GE SF 1154 hydraulic fluid. The table shows percent change in durometer, tensile strength and compression set. Compression set samples were compressed to 75% of their initial thickness. The average compression set is the percentage of initial compression that remains after relief of compressive force. Data sheets for the individual seals are at the end of this report.

TABLE I

Compound	Durometer Average % Change	Tensile Strength Average % Change	Average Compression Set - % of Initial Compression
Minnesota 559GT	0	0	58.
Minnesota 560ND	+ 11.2	- 7.7*	33.
Polyseal HK-471	+ 9.9	-26.3	31.
Polyseal E2050-90	+ 4.4	-38.8	41.5

* Only one tensile value was used in this average; the second reading appeared to be in error

The compression samples were again compressed to 75% of initial pre-radiation thickness and they, along with uncompressed samples, were subjected to an additional environment of 250°F, all steam for 72 hours. Table II below shows the tabulated results as change of durometer, change of tensile strength and compression set. Changes are measured from initial quantities.

TABLE II

Compound	Durometer Average % Change	Tensile Strength Average % Change	Average Compression Set - % of Initial Compression
Minnesota 559GT	+ 2.24	0	56.7
Minnesota 560ND	+ 14	- 14.5	36.8
Polyseal HK471	+ 3.5	- 33.2	30.9
Polyseal E2050-90	+ 15.8	- 37.6	40.5

Data sheets showing individual seal properties can be found at the end of this report.

Conclusions

Durometer - The change in durometer for all compounds is negligible and should not be a factor in seal operability or life.

Tensile Strength - The change in tensile strength of the Polyseal compounds (HK471 and E2050-90) is significant; however, tensile strength change should not effect seal operability or life.

Compression Set - Compression set is a measure of the recoverability of compounds from compression and thence a measure of the continued contact between seal and container. Of the quantities measured, compression set should give the greatest indication of operability after conditioning. While the compression sets measured are significant, it should be noted that all but one of the compounds recovers 60% of the initial compression and that compound Minnesota 559GT recovers 40%.

Comparison of compression sets of this testing with those of PHD-5347-2R shows that the new seal materials are at the low end of compression set, and hence should be acceptable for usage in ITT Grinnell snubbers.

Procedure - Seal Irradiation

Test specimens for all seals were O-rings in ARP568-212 size. Specimens were tested for compression set, change in tensile strength, and change in durometer.

Compression set indicates the extent to which squeeze initially applied by the gland to the seal is lost as the seal ages. It is measured by compressing a specimen by a given

Procedure - Seal Irradiation (cont'd)

amount (to 75% of its initial thickness for this test); ageing the seal in this compressed state; and then measuring the free thickness of the seal after ageing. The difference between initial and final thickness is expressed as a percent of initial squeeze.

To test for compression set, a test fixture was made for each specimen. The fixture consisted of a series of steel plates ground flat separated by a spacer ground to a predetermined dimension to assure 25% compression. The complete assembly was held together by a bolt running through the center (see Figure 1). The initial thickness of each compression set test specimen was measured at three locations around the O-ring. The spacer for the test fixture was then ground to give exactly 25% squeeze for the specimen. Specimens were compressed and placed in GE SF-1154 hydraulic fluid immediately prior to irradiation and were removed from the fluid and the compression relieved approximately 75 hours after irradiation was completed. Specimens were exposed to gamma radiation at a rate of .75 Megarads per hour for a period of 40 hours.

Durometer and tensile strength were measured with a separate set of specimens which were not compressed. First the durometer and specimen diameter were measured, then the O-ring was cut and mounted in a tensile tester.

Two specimens were used to determine initial tensile strength; another two specimens were used to measure durometer and tensile strength after irradiation; a third pair of specimens were used to measure durometer and tensile strength after irradiation and steam; and a final pair were used to measure compression set.

Procedure - Seal Irradiation (cont'd)

Tensile strength measurements were made using a 0 - 250 lb. range Scott tensile tester. Durometer measurements were made with a Shore Instrument and Mfg. Co. Type A2 durometer.

Procedure - Seal Temperature/Steam Exposure

After measurements were taken, the specimens used to measure compression set were remounted in the fixture of Fig. 1, along with the two remaining uncompressed O-rings. The complete assembly was installed in a test chamber as shown in Figure 2. Approximately three inches of water was put into the test chamber and then the complete chamber was placed in a power-o-matic mechanical convection oven. Temperature was determined and monitored using a Copper-Contanten Thermocouple and Leeds-Northrup Potentiometer Model No. 8693-2. Timing began when the temperature reached 250° F. The test was completed after 72 hours at this condition. After completion of test, specimens were again measured for durometer and compression set as described in previous procedure.

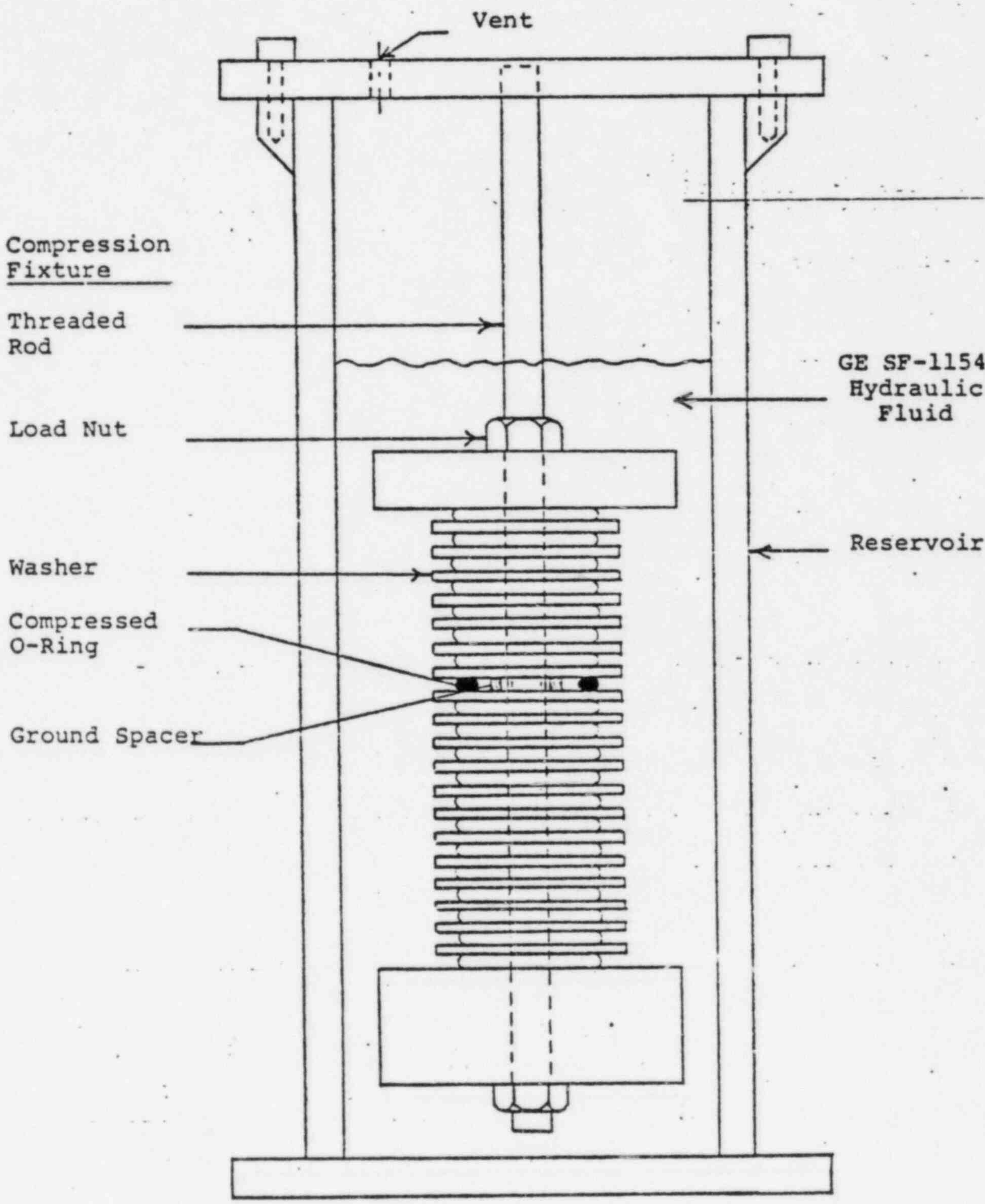

Vent
Compression Fixture
Threaded Rod
Load Nut
Washer
Compressed O-Ring
Ground Spacer
GE SF-1154 Hydraulic Fluid
Reservoir

Figure 1

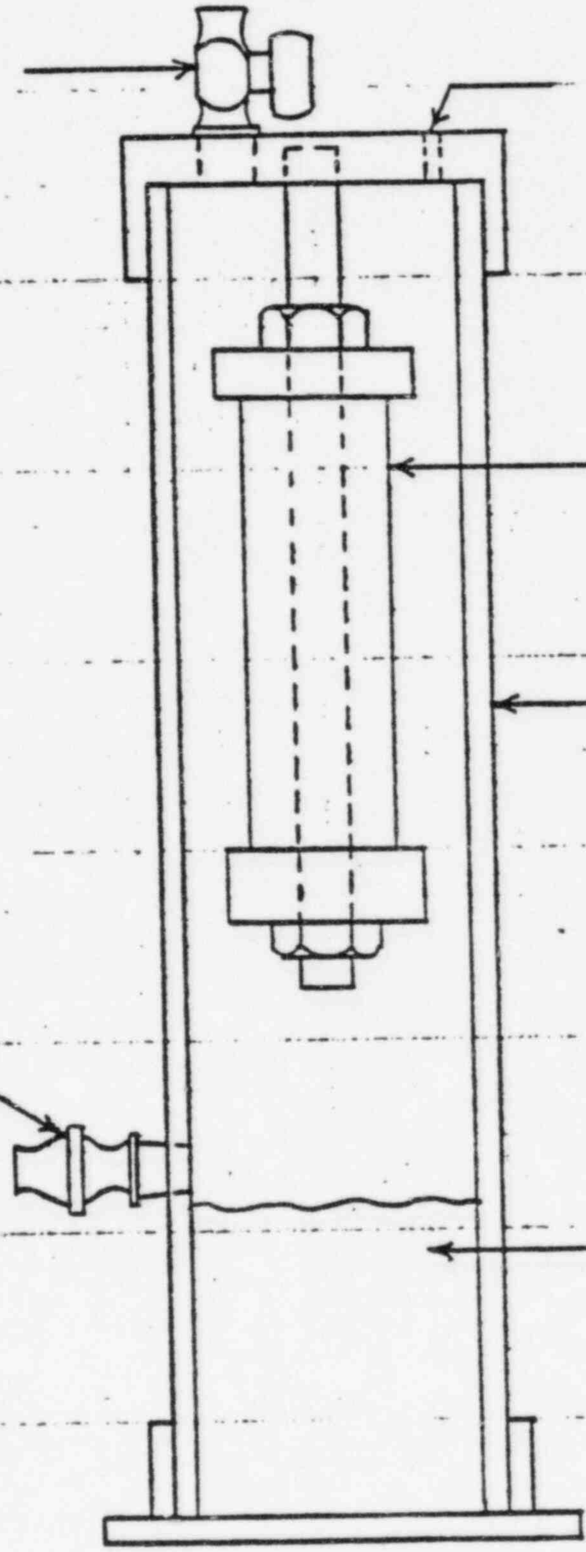

Petcock
Thermocouple Port
(sealed during test)
Compression Fixture
(See Fig. 1 for details
Steam Chamber
Petcock
Water

Figure 2

ISOMEDIX

March 29, 1977

RECEIVED
PIPE HANGER DIVISION
APR 1 1977
RESEARCH, DEVELOPMENT AND ENGINEERING

Mr. Daniel W. Mills
Senior Engineer
ITT Grinell Corp.
260 West Exchange Street
Providence, RI 02901

Dear Mr. Mills:

This will summarize parameters pertinent to the irradiation of seal material per your letter of February 17, 1977.

The fixture, with seals, was placed in a Cobalt-60 gamma field such that the dose rate over the exposure period was 0.75 Mrad per hour. The sample was irradiated for 40 hours, yielding a dose of 30 Mrad.

Irradiation was conducted in air at ambient temperature and pressure. Radiant heat from the source heated the samples somewhat, but the temperature did not exceed 90°F, as indicated by previous measurements on an oil solution in the same relative position.

Dosimetry was performed using a Victoreen Model 555 Integrating Dose Rate Meter and Probe. The unit was calibrated on October 16, 1975, 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. Backup dosimetry using a Red Perspex system confirmed the Victoreen readings.

Irradiation was completed on March 7, 1977, at which time your representative picked up the sample.

Very truly yours,

George R. Dietz
George R. Dietz
Manager, Radiation Services

GRD:of

Isomedix Inc. • 25 Eastmans Road, Parsippany, New Jersey (201) 887-4700
Mailing Address: Post Office Box 177, Parsippany, New Jersey 07054

CHICAGO DIVISION • 7828 Nagle Ave., Morton Grove, Illinois 60053 (312) 966-1160

TEST REPORT FORM - SEAL MATERIAL IRRADIATION

Initial Data

Specimen Type and Size: O RING .8212

Molder: Minnesota Rubber Co. Compound No. 559 GT

Batch No. ________ Cure Date 1Q77

Certificate of Compliance Minnesota Rubber Co FOM#3949

Durometer-Shore A: 90 90 93 89 91 90 89 90

Tensile Strgth-PSI 1397 1331

Irrad. Test Ident 1 2 3 4 5 6

Specimen Ident 2

Thickness: T_{01} = .138 T_{02} = .138 T_{03} = .138

$\bar{T}_0$ = .138 .75 $\bar{T}_0$ = .1035

Fixture Dimension: T = .1035

Specimen Ident 4

Thickness: T_{01} = .137 T_{02} = .139 T_{03} = .139

$\bar{T}_0$ = .138 .75 $\bar{T}_0$ = .1035

Fixture Dimension: T = .1035

Specimen Ident ____

Thickness: T_{01} = ____ T_{02} = ____ T_{03} = ____

$\bar{T}_0$ = ____ .75 $\bar{T}_0$ = ____

Fixture Dimension: T = ____

Specimen Ident ____

Thickness: T_{01} = ____ T_{02} = ____ T_{03} = ____

$\bar{T}_0$ = ____ .75 $\bar{T}_0$ = ____

Fixture Dimension: T = ____

Specimen Ident ____

Thickness: T_{01} = ____ T_{02} = ____ T_{03} = ____

$\bar{T}_0$ = ____ .75 $\bar{T}_0$ = ____

Fixture Dimension: T = ____

Specimen Ident ____

Thickness: T_{01} = ____ T_{02} = ____ T_{03} = ____

$\bar{T}_0$ = ____ .75 $\bar{T}_0$ = ____

Fixture Dimension: T = ____

Signature of Test Supervisor Daniel W. Mibb[?] Date 3/9/77

3X10^7 RAD

559GT

Radiation Type GAMA

Radiation Dose 3X10^7 RAD ____ ____

Specimen Ident	1	3				
Durometer-Shore A:	93	91				
Tensile Strgth-PSI	1324	1404				

Specimen Ident 2 Radiation Dose 3X10^7 RAD
Thickness: T_{11} = .118 T_{12} = .118 T_{13} = .118

$\overline{T}_1$ = .118 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = .58

Specimen Ident 4 3X10^7 RAD.
Thickness: T_{11} = .118 T_{12} = .118 T_{13} = .118

$\overline{T}_1$ = .118 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = .58

Specimen Ident ____ Radiation Dose ____
Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Specimen Ident ____
Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Specimen Ident ____ Radiation Dose ____
Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Specimen Ident ____
Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Signature of Test Supervisor David W. Miller Date 3/9/77

3X10[7] RADS + 72 hrs Steam 559GT

Radiation Type Gama

Radiation Dose 3X10[7] Rad ____ ____

Specimen Ident 5 6 ____ ____ ____ ____

Durometer-Shore A: 92 91 ____ ____ ____ ____

Tensile Strgth-PSI 1137 1137 ____ ____ ____ ____

Specimen Ident 2 Radiation Dose 3X10[7] RAD
Thickness: T_{11} = .119 T_{12} = .119 T_{13} = .118

$\bar{T}_1$ = .1187 Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{T_0 - T}$ = .559

Specimen Ident 4
Thickness: T_{11} = .119 T_{12} = .118 T_{13} = .118

$\bar{T}_1$ = .1183 Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{T_0 - T}$ = .575

Specimen Ident ____ Radiation Dose ____
Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\bar{T}_1$ = ____ Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{T_0 - T}$ = ____

Specimen Ident ____
Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\bar{T}_1$ = ____ Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{T_0 - T}$ = ____

Specimen Ident ____ Radiation Dose ____
Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\bar{T}_1$ = ____ Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{T_0 - T}$ = ____

Specimen Ident ____
Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\bar{T}_1$ = ____ Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{T_0 - T}$ = ____

Signature of Test Supervisor David W. Miller Date 3/14/77

TEST REPORT FORM - SEAL MATERIAL IRRADIATION

Initial Data

Specimen Type and Size: O Ring 8212
Molder: Minnesota Rubber Co. Compound No. 560 NJD
Batch No. ______ Cure Date 4Q76
Certificate of Compliance Minnesota Rubber Co., FOM#3949

Durometer-Shore A:	69	72	70	69	70	71	67	69
Tensile Strgth-PSI	1276	1075						
Irrad. Test Ident			1	2	3	4	5	6

Specimen Ident 2
Thickness: T_{01} = .138 T_{02} = .138 T_{03} = .137

$\bar{T}_0$ = .1377 .75 $\bar{T}_0$ = .1032
Fixture Dimension: T = .103

Specimen Ident 4
Thickness: T_{01} = .138 T_{02} = .138 T_{03} = .138

$\bar{T}_0$ = .138 .75 $\bar{T}_0$ = .1035
Fixture Dimension: T = .104

Specimen Ident ______
Thickness: T_{01} = ______ T_{02} = ______ T_{03} = ______
$\bar{T}_0$ = ______ .75 $\bar{T}_0$ = ______
Fixture Dimension: T = ______

Specimen Ident ______
Thickness: T_{01} = ______ T_{02} = ______ T_{03} = ______
$\bar{T}_0$ = ______ .75 $\bar{T}_0$ = ______
Fixture Dimension: T = ______

Specimen Ident ______
Thickness: T_{01} = ______ T_{02} = ______ T_{03} = ______
$\bar{T}_0$ = ______ .75 $\bar{T}_0$ = ______
Fixture Dimension: T = ______

Specimen Ident ______
Thickness: T_{01} = ______ T_{02} = ______ T_{03} = ______
$\bar{T}_0$ = ______ .75 $\bar{T}_0$ = ______
Fixture Dimension: T = ______

Signature of Test Supervisor Daniel W. Mildoff Date 3/9/77

3X10^7 RAD

560ND

Radiation Type GAMA

Radiation Dose 3X10^7 RAD ____ ____

Specimen Ident 1 3 ____ ____ ____ ____

Durometer-Shore A: 79 77 ____ ____ ____ ____

Tensile Strgth-PSI 1085 535 ____ ____ ____ ____

Specimen Ident 2 Radiation Dose 3X10^7 RAD

Thickness: T_{11} = .126 T_{12} = .126 T_{13} = .126

$\bar{T}_1$ = .126 Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{T_0 - T}$ = .337

Specimen Ident 4 3X10^7 RAD

Thickness: T_{11} = .127 T_{12} = .127 T_{13} = .127

$\bar{T}_1$ = .127 Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{T_0 - T}$ = .324

Specimen Ident ____ Radiation Dose ____

Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\bar{T}_1$ = ____ Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{T_0 - T}$ = ____

Specimen Ident ____

Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\bar{T}_1$ = ____ Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{T_0 - T}$ = ____

Specimen Ident ____ Radiation Dose ____

Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\bar{T}_1$ = ____ Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{T_0 - T}$ = ____

Specimen Ident ____

Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\bar{T}_1$ = ____ Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{T_0 - T}$ = ____

Signature of Test Supervisor Daniel W. Mettf Date 3/9/77

560ND

3X10^7 RAD + 72 hr Steam.

Radiation Type GAMA

Radiation Dose 3X10^7 ____ ____ ____

Specimen Ident 5 6 ____ ____ ____ ____

Durometer-Shore A: 77 78 ____ ____ ____ ____

Tensile Strgth-PSI 1142 869 ____ ____ ____ ____

Specimen Ident 2 Radiation Dose 3X10^7 RAD
Thickness: T_{11} = .124 T_{12} = .125 T_{13} = .125

$\overline{T}_1$ = .1247 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = .374

Specimen Ident 4
Thickness: T_{11} = .126 T_{12} = .125 T_{13} = .126

$\overline{T}_1$ = .1257 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = .362

Specimen Ident ____ Radiation Dose ____
Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Specimen Ident ____
Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Specimen Ident ____ Radiation Dose ____
Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Specimen Ident ____
Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Signature of Test Supervisor David W. Mills Jr. Date 3/14/77

TEST REPORT FORM - SEAL MATERIAL IRRADIATION

Initial Data

Specimen Type and Size: O Ring 212 Size

Molder: Polyseal (Buckeye Rubber) Compound No. HK471

Batch No. ________ Cure Date 10?77

Certificate of Compliance Polyseal/Buckeye Rubber

Durometer-Shore A:	73	74	69	69	72	66	69	65
Tensile Strgth-PSI	2017	2078						
Irrad. Test Ident			1	2	3	4	5	6

Specimen Ident 2

Thickness: T_{01} = .140 T_{02} = .141 T_{03} = .140

$\overline{T}_0$ = .1403 .75 $\overline{T}_0$ = .1052

Fixture Dimension: T = .105

Specimen Ident 4

Thickness: T_{01} = .140 T_{02} = .140 T_{03} = .139

$\overline{T}_0$ = .1397 .75 $\overline{T}_0$ = .1047

Fixture Dimension: T = .105

Specimen Ident ____

Thickness: T_{01} = ____ T_{02} = ____ T_{03} = ____

$\overline{T}_0$ = ____ .75 $\overline{T}_0$ = ____

Fixture Dimension: T = ____

Specimen Ident ____

Thickness: T_{01} = ____ T_{02} = ____ T_{03} = ____

$\overline{T}_0$ = ____ .75 $\overline{T}_0$ = ____

Fixture Dimension: T = ____

Specimen Ident ____

Thickness: T_{01} = ____ T_{02} = ____ T_{03} = ____

$\overline{T}_0$ = ____ .75 $\overline{T}_0$ = ____

Fixture Dimension: T = ____

Specimen Ident ____

Thickness: T_{01} = ____ T_{02} = ____ T_{03} = ____

$\overline{T}_0$ = ____ .75 $\overline{T}_0$ = ____

Fixture Dimension: T = ____

Signature of Test Supervisor David W. Millek Date 3/9/77

3X10^7 RAD

Radiation Type GAMA

Radiation Dose 3X10^7 RAD ____ ____

Specimen Ident 1 3 ____ ____ ____ ____

Durometer-Shore A: 78 77 ____ ____ ____ ____

Tensile Strgth-PSI 1665 1351 ____ ____ ____ ____

Specimen Ident 2 Radiation Dose 3X10^7 RAD

Thickness: T_{11} = .130 T_{12} = .129 T_{13} = .129

$\bar{T}_1$ = .1293 Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{\bar{T}_0 - T}$ = .312

Specimen Ident 4 3X10^7 RAD

Thickness: T_{11} = .129 T_{12} = .129 T_{13} = .128

$\bar{T}_1$ = .1287 Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{\bar{T}_0 - T}$ = .317

Specimen Ident ____ Radiation Dose ____

Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\bar{T}_1$ = ____ Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{\bar{T}_0 - T}$ = ____

Specimen Ident ____

Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\bar{T}_1$ = ____ Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{\bar{T}_0 - T}$ = ____

Specimen Ident ____ Radiation Dose ____

Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\bar{T}_1$ = ____ Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{\bar{T}_0 - T}$ = ____

Specimen Ident ____

Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\bar{T}_1$ = ____ Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{\bar{T}_0 - T}$ = ____

Signature of Test Supervisor David W. Mebb [signature] Date 3/9/77

3X10^7 RAD + 72hr Steam

Radiation Type GAMA

Radiation Dose 3X10^7 RAD

Specimen Ident 5 6

Durometer-Shore A: 78 77

Tensile Strgth-PSI 1332 1402

Specimen Ident 2 Radiation Dose 3X10^7 RAD

Thickness: T_{11} = .130 T_{12} = .130 T_{13} = .129

$\overline{T}_1$ = .1297 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = .300

Specimen Ident 4

Thickness: T_{11} = .128 T_{12} = .129 T_{13} = .129

$\overline{T}_1$ = .1287 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = .317

Specimen Ident ____ Radiation Dose ____

Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Specimen Ident ____

Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Specimen Ident ____ Radiation Dose ____

Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Specimen Ident ____

Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Signature of Test Supervisor Daniel W. Miller Date 3/14/77

TEST REPORT FORM - SEAL MATERIAL IRRADIATION

Initial Data

Specimen Type and Size: O Ring 212 size

Molder: Polyseal (Buckeye Rubber) Compound No. E2050-90

Batch No. ______ Cure Date 1Q77

Certificate of Compliance Polyseal / BUCKEYE RUBBER

Durometer-Shore A: 85 86 85 84 85 84 85 85

Tensile Strgth-PSI 1737 1606

Irrad. Test Ident 1 2 3 4 5 6

Specimen Ident 4

Thickness: T_{01} = .140 T_{02} = .140 T_{03} = .140

$\bar{T}_0$ = .140 .75 $\bar{T}_0$ = .105

Fixture Dimension: T = .105

Specimen Ident 6

Thickness: T_{01} = .140 T_{02} = .140 T_{03} = .140

$\bar{T}_0$ = .140 .75 $\bar{T}_0$ = .105

Fixture Dimension: T = .105

Specimen Ident ______

Thickness: T_{01} = ______ T_{02} = ______ T_{03} = ______

$\bar{T}_0$ = ______ .75 $\bar{T}_0$ = ______

Fixture Dimension: T = ______

Specimen Ident ______

Thickness: T_{01} = ______ T_{02} = ______ T_{03} = ______

$\bar{T}_0$ = ______ .75 $\bar{T}_0$ = ______

Fixture Dimension: T = ______

Specimen Ident ______

Thickness: T_{01} = ______ T_{02} = ______ T_{03} = ______

$\bar{T}_0$ = ______ .75 $\bar{T}_0$ = ______

Fixture Dimension: T = ______

Specimen Ident ______

Thickness: T_{01} = ______ T_{02} = ______ T_{03} = ______

$\bar{T}_0$ = ______ .75 $\bar{T}_0$ = ______

Fixture Dimension: T = ______

Signature of Test Supervisor David W. Mills [signature] Date 3/9/77

3 X 10^7 RAD

Radiation Type GAMA

Radiation Dose 3X10^7 RAD ____ ____

Specimen Ident	1	2				
Durometer-Shore A:	88	88				
Tensile Strgth-PSI	1120	927				

Specimen Ident 4 Radiation Dose 3X10^7 RAD

Thickness: T_{11} = .126 T_{12} = .126 T_{13} = .126

$\bar{T}_1$ = .126 Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{\bar{T}_0 - T}$ = .40

Specimen Ident 6 3 X10^7 RAD

Thickness: T_{11} = .125 T_{12} = .125 T_{13} = .126

$\bar{T}_1$ = .1253 Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{\bar{T}_0 - T}$ = .42

Specimen Ident ____ Radiation Dose ____

Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\bar{T}_1$ = ____ Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{\bar{T}_0 - T}$ = ____

Specimen Ident ____

Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\bar{T}_1$ = ____ Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{\bar{T}_0 - T}$ = ____

Specimen Ident ____ Radiation Dose ____

Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\bar{T}_1$ = ____ Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{\bar{T}_0 - T}$ = ____

Specimen Ident ____

Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\bar{T}_1$ = ____ Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{\bar{T}_0 - T}$ = ____

Signature of Test Supervisor Daniel W. Mill[illegible] Date 3/9/77

3X10⁷ RAD + 72 hr. Steam

Radiation Type GAMA

Radiation Dose 3X10⁷ RAD ____ ____

Specimen Ident 3 5 ____ ____ ____ ____

Durometer-Shore A: 88 88 ____ ____ ____ ____

Tensile Strgth-PSI 1180 905 ____ ____ ____ ____

Specimen Ident 4 Radiation Dose ____
Thickness: T_{11} = .126 T_{12} = .126 T_{13} = .126

$\overline{T}_1$ = .126 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = .4

Specimen Ident 6
Thickness: T_{11} = .125 T_{12} = .126 T_{13} = .126

$\overline{T}_1$ = .1257 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = .409

Specimen Ident ____ Radiation Dose ____
Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Specimen Ident ____
Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Specimen Ident ____ Radiation Dose ____
Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Specimen Ident ____
Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{\overline{T}_0 - T}$ = ____

Signature of Test Supervisor Daniel W. Mitchell Date 3/14/77

ITT GRINNELL CORP.
HANGER DIVISION
RD & E, SNUBBER SECTION

Radiation and Environmental Test of Seal Materials for Snubbers

Revision 1 Approval ______ Date 7-23-77
Dept. Mgr.

Report No. PHD-7569-1 Rev. 1

Prepared by ______ Date 3-31-77
Sr. Engr.

Approved by ______ Date 4/14/77
Sect. Mgr.

Approved by ______ Date 4-15-77
Dept. Mgr.

This report complements Report No. PHD-5347-2R, "Radiation and Environmental Test of Seal and Fluid Materials for Snubbers" dated 10/3/75. This report contains data on seal material subjected to an integrated radiation dose of 3×10^7 rads plus a 72 hour elevated temperature, 100% steam environmental test. The seal materials of this report were not qualified in the above referenced report.

Purpose

The purpose of these tests is to demonstrate the ability of the tested seal materials to meet the requirements for usage in ITT Grinnell snubbers used in nuclear power plant applications.

Results

Table 1 below summarizes the results obtained on seal materials exposed to a total integrated radiation dose of 3×10^7 rads while immersed in GE SF 1154 hydraulic fluid. The table shows percent change in durometer, tensile strength and compression set. Compression set samples were compressed to 75% of their initial thickness. The average compression set is the percentage of initial compression that remains after relief of compressive force. Data sheets for the individual seals are at the end of this report.

TABLE I

Compound	Durometer Average % Change	Tensile Strength Average % Change	Average Compression Set - % of Initial Compression
Minnesota 559GT	0	0	58.
Minnesota 560ND	+ 11.2	- 7.7*	33.
Polyseal HK-471	+ 9.9	-26.3	31.
Polyseal E2050-90	+ 4.4	-38.8	41.5

* Only one tensile value was used in this average; the second reading appeared to be in error

The compression samples were again compressed to 75% of initial pre-radiation thickness and they, along with uncompressed samples, were subjected to an additional environment of 250°F, all steam for 72 hours. Table II below shows the tabulated results as change of durometer, change of tensile strength and compression set. Changes are measured from initial quantities.

TABLE II

Compound	Durometer Average % Change	Tensile Strength Average % Change	Average Compression Set - % of Initial Compression
Minnesota 559GT	+ 2.24	0	56.7
Minnesota 560ND	+ 14	- 14.5	36.8
Polyseal HK471	+ 3.5	- 33.2	30.9
Polyseal E2050-90	+ 15.8	- 37.6	40.5

Data sheets showing individual seal properties can be found at the end of this report.

Conclusions

Durometer - The change in durometer for all compounds is negligible and should not be a factor in seal operability or life.

Tensile Strength - The change in tensile strength of the Polyseal compounds (HK471 and E2050-90) is significant; however, tensile strength change should not effect seal operability or life.

Compression Set - Compression set is a measure of the recoverability of compounds from compression and thence a measure of the continued contact between seal and container. Of the quantities measured, compression set should give the greatest indication of operability after conditioning. While the compression sets measured are significant, it should be noted that all but one of the compounds recovers 60% of the initial compression and that compound Minnesota 559GT recovers 40%.

Comparison of compression sets of this testing with those of PHD-5347-2R shows that the new seal materials are at the low end of compression set, and hence should be acceptable for usage in ITT Grinnell snubbers.

Procedure - Seal Irradiation

Test specimens for all seals were O-rings in ARP568-212 size. Specimens were tested for compression set, change in tensile strength, and change in durometer.

Compression set indicates the extent to which squeeze initially applied by the gland to the seal is lost as the seal ages. It is measured by compressing a specimen by a given amount (to 75% of its initial thickness for this test); ageing the seal in this compressed state; and then measuring the free thickness of the seal after ageing. The difference between initial and final thickness is expressed as a percent of initial squeeze.

To test for compression set, a test fixture was made for each specimen. The fixture consisted of a series of steel plates ground flat separated by a spacer ground to a predetermined dimension to assure 25% compression. The complete assembly was held together by a bolt running through the center (see Figure 1). The initial thickness of each compression set test specimen was measured at three locations around the O-ring. The spacer for the test fixture was then ground to give exactly 25% squeeze for the specimen. Specimens were compressed and placed in GE SF-1154 hydraulic fluid immediately prior to irradiation and were removed from the fluid and the compression relieved approximately 75 hours after irradiation was completed. Specimens were exposed to gamma radiation at a rate of .75 Megarads per hour for a period of 40 hours.

Durometer and tensile strength were measured with a separate set of specimens which were not compressed. First the durometer and specimen diameter were measured, then the O-ring was cut and mounted in a tensile tester.

Two specimens were used to determine initial tensile strength; another two specimens were used to measure durometer and tensile strength after irradiation; a third pair of specimens were used to measure durometer and tensile strength after irradiation and steam; and a final pair were used to measure compression set.

Procedure - Seal Irradiation (cont'd)

Tensile strength measurements were made using a 0 - 250 lb. range Scott tensile tester. Durometer measurements were made with a Shore Instrument and Mfg. Co. Type A2 durometer.

Procedure - Seal Temperature/Steam Exposure

After measurements were taken, the specimens used to measure compression set were remounted in the fixture of Fig. 1, along with the two remaining uncompressed O-rings. The complete assembly was installed in a test chamber as shown in Figure 2. Approximately three inches of water was put into the test chamber and then the complete chamber was placed in a power-o-matic mechanical convection oven. Temperature was determined and monitored using a Copper-Contanten Thermocouple and Leeds-Northrup Potentiometer Model No. 8693-2. Timing began when the temperature reached 250° F. The test was completed after 72 hours at this condition. After completion of test, specimens were again measured for durometer and compression set as described in previous procedure.

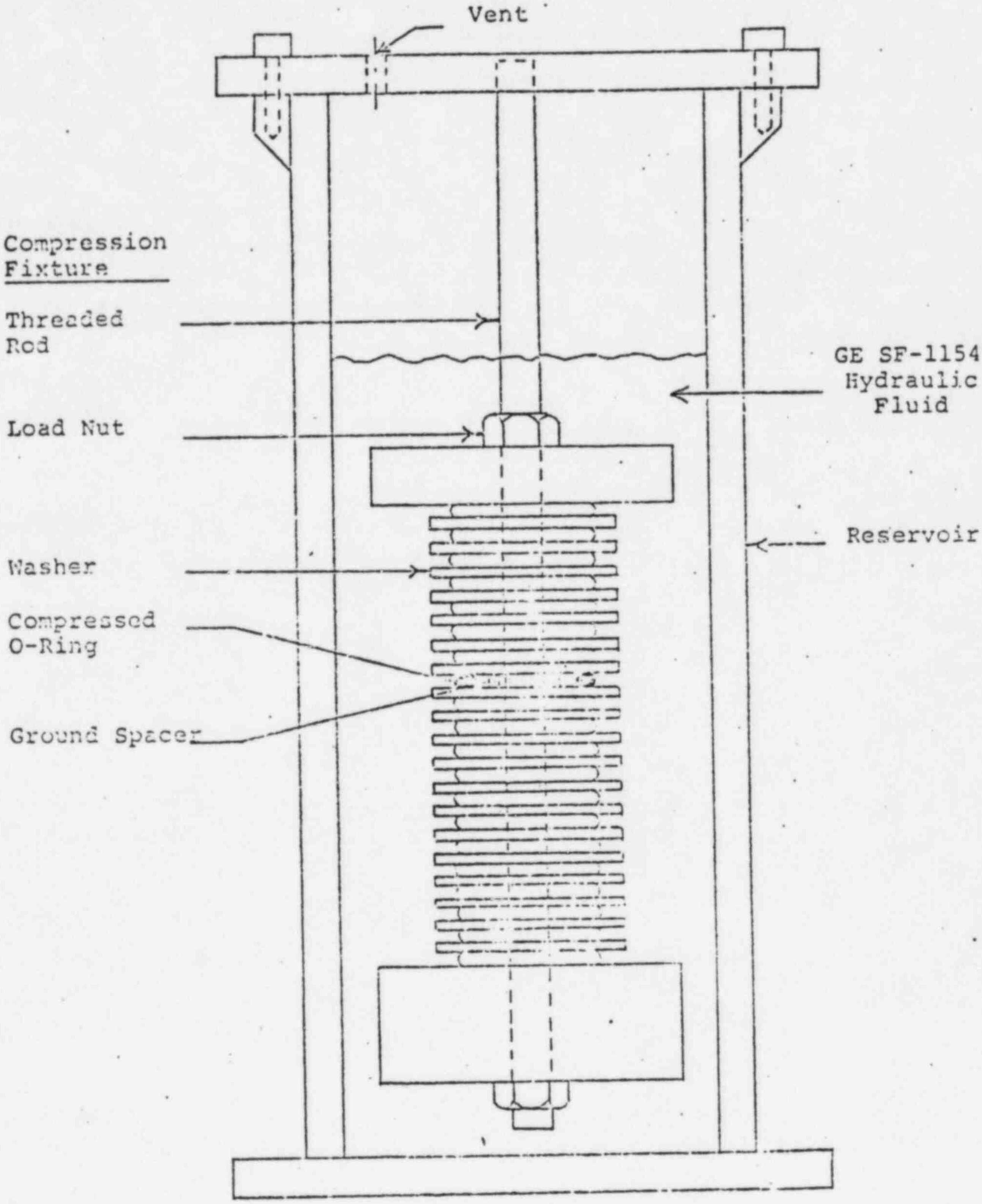

Vent
Compression Fixture
Threaded Rod
GE SF-1154 Hydraulic Fluid
Load Nut
Reservoir
Washer
Compressed O-Ring
Ground Spacer

Figure 1

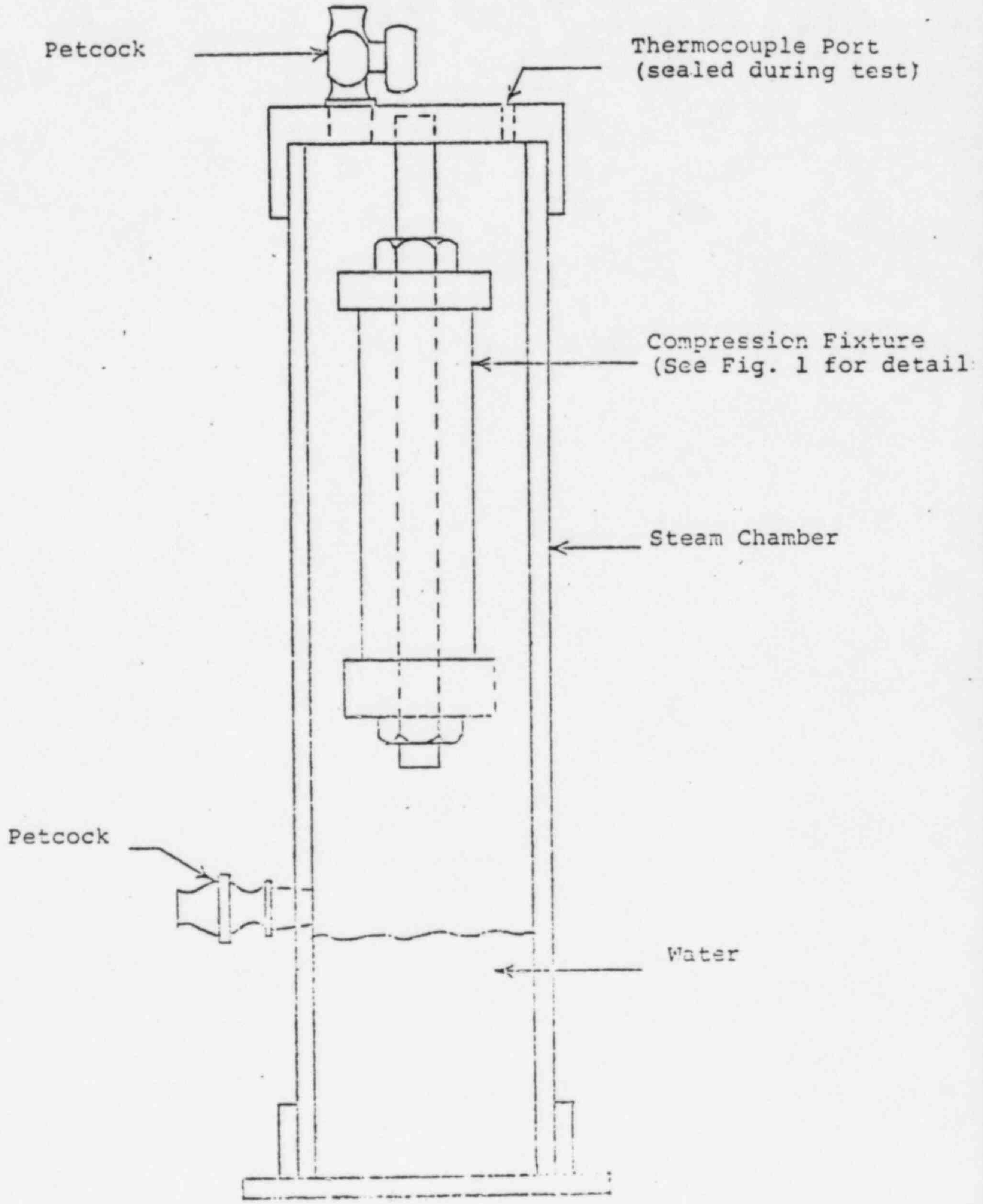

Petcock
Thermocouple Port
(sealed during test)
Compression Fixture
(See Fig. 1 for detail
Steam Chamber
Petcock
Water

Figure 7

ISOMEDIX

March 29, 1977

Mr. Daniel W. Mills
Senior Engineer
ITT Grinell Corp.
260 West Exchange Street
Providence, RI 02901

Dear Mr. Mills:

This will summarize parameters pertinent to the irradiation of seal material per your letter of February 17, 1977.

The fixture, with seals, was placed in a Cobalt-60 gamma field such that the dose rate over the exposure period was 0.75 Mrad per hour. The sample was irradiated for 40 hours, yielding a dose of 30 Mrad.

Irradiation was conducted in air at ambient temperature and pressure. Radiant heat from the source heated the samples somewhat, but the temperature did not exceed 90°F, as indicated by previous measurements on an oil solution in the same relative position.

Dosimetry was performed using a Victoreen Model 555 Integrating Dose Rate Meter and Probe. The unit was calibrated on October 16, 1975, 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. Backup dosimetry using a Red Perspex system confirmed the Victoreen readings.

Irradiation was completed on March 7, 1977, at which time your representative picked up the sample.

Very truly yours,

George R. Dietz
Manager, Radiation Services

GRD:of

Isomedix Inc. • 25 Eastmans Road, Parsippany, New Jersey (201) 887-4700
Mailing Address: [illegible]

CHICAGO DIVISION • [illegible]

TEST REPORT FORM - SEAL MATERIAL IRRADIATION

Initial Data

Specimen Type and Size: O RING .8212

Molder: MINNESOTA RUBBER CO. Compound No. 559 GT

Batch No. ______ Cure Date 1Q77

Certificate of Compliance Minnesota Rubber Co FORM #3949

Durometer-Shore A:	90	90	93	89	91	90	89	90
Tensile Strgth-PSI	1397	1331						
Irrad. Test Ident			1	2	3	4	5	6

Specimen Ident 2

Thickness: T_{01} = .138 T_{02} = .138 T_{03} = .138

$\overline{T}_0$ = .138 .75 $\overline{T}_0$ = .1035

Fixture Dimension: T = .1035

Specimen Ident 4

Thickness: T_{01} = .137 T_{02} = .139 T_{03} = .139

$\overline{T}_0$ = .138 .75 $\overline{T}_0$ = .1035

Fixture Dimension: T = .1035

Specimen Ident ______

Thickness: T_{01} = ______ T_{02} = ______ T_{03} = ______

$\overline{T}_0$ = ______ .75 $\overline{T}_0$ = ______

Fixture Dimension: T = ______

Specimen Ident ______

Thickness: T_{01} = ______ T_{02} = ______ T_{03} = ______

$\overline{T}_0$ = ______ .75 $\overline{T}_0$ = ______

Fixture Dimension: T = ______

Specimen Ident ______

Thickness: T_{01} = ______ T_{02} = ______ T_{03} = ______

$\overline{T}_0$ = ______ .75 $\overline{T}_0$ = ______

Fixture Dimension: T = ______

Specimen Ident ______

Thickness: T_{01} = ______ T_{02} = ______ T_{03} = ______

$\overline{T}_0$ = ______ .75 $\overline{T}_0$ = ______

Fixture Dimension: T = ______

Signature of Test Supervisor [signature] Date 3/7/77

3X10 RAD

559GT

Radiation Type GAMA

Radiation Dose 3X10^7 RAD

Specimen Ident	1	3				
Durometer-Shore A:	93	91				
Tensile Strgth-PSI	1324	1404				

Specimen Ident 2 Radiation Dose 3X10^7 RAD
Thickness: T_{11} = .118 T_{12} = .118 T_{13} = .118

$\overline{T}_1$ = .118 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = .58

Specimen Ident 4 3X10^7 RAD.
Thickness: T_{11} = .118 T_{12} = .118 T_{13} = .118

$\overline{T}_1$ = .118 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = .58

Specimen Ident ____ Radiation Dose ____
Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Specimen Ident ____
Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Specimen Ident ____ Radiation Dose ____
Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Specimen Ident ____
Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Signature of Test Supervisor [illegible] Date 3/?/77

3X10⁷ RADS + 72 hrs Steam 559GT

Radiation Type Gama

Radiation Dose 3X10⁷ Rad ____ ____

Specimen Ident 5 6 ____ ____ ____ ____

Durometer-Shore A: 92 91 ____ ____ ____ ____

Tensile Strgth-PSI 1137 1137 ____ ____ ____ ____

Specimen Ident 2 Radiation Dose 3X10⁷ RAD

Thickness: T_{11} = .119 T_{12} = .119 T_{13} = .118

$\bar{T}_1$ = .1187 Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{T_0 - T}$ = .559

Specimen Ident 4

Thickness: T_{11} = .119 T_{12} = .118 T_{13} = .118

$\bar{T}_1$ = .1183 Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{T_0 - T}$ = .575

Specimen Ident ____ Radiation Dose ____

Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\bar{T}_1$ = ____ Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{T_0 - T}$ = ____

Specimen Ident ____

Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\bar{T}_1$ = ____ Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{T_0 - T}$ = ____

Specimen Ident ____ Radiation Dose ____

Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\bar{T}_1$ = ____ Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{T_0 - T}$ = ____

Specimen Ident ____

Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\bar{T}_1$ = ____ Compression Set: $\frac{\bar{T}_0 - \bar{T}_1}{T_0 - T}$ = ____

Signature of Test Supervisor [signature] Date 3/4/77

TEST REPORT FORM - SEAL MATERIAL IRRADIATION

Initial Data

Specimen Type and Size: O RING 8212
Molder: MINNESOTA RUBBER CO. Compound No. 560 ND
Batch No. ______ Cure Date 4 Q 76
Certificate of Compliance MINNESOTA RUBBER CO., FOM#3949

Durometer-Shore A:	69	72	70	69	70	71	67	69
Tensile Strgth-PSI	1276	1075						
Irrad. Test Ident			1	2	3	4	5	6

Specimen Ident 2
Thickness: T_{01} = .138 T_{02} = .138 T_{03} = .137

$\overline{T}_0$ = .1377 .75 $\overline{T}_0$ = .1032
Fixture Dimension: T = .103

Specimen Ident 4
Thickness: T_{01} = .138 T_{02} = .138 T_{03} = .138

$\overline{T}_0$ = .138 .75 $\overline{T}_0$ = .1035
Fixture Dimension: T = .104

Specimen Ident ______
Thickness: T_{01} = ______ T_{02} = ______ T_{03} = ______
$\overline{T}_0$ = ______ .75 $\overline{T}_0$ = ______
Fixture Dimension: T = ______

Specimen Ident ______
Thickness: T_{01} = ______ T_{02} = ______ T_{03} = ______
$\overline{T}_0$ = ______ .75 $\overline{T}_0$ = ______
Fixture Dimension: T = ______

Specimen Ident ______
Thickness: T_{01} = ______ T_{02} = ______ T_{03} = ______
$\overline{T}_0$ = ______ .75 $\overline{T}_0$ = ______
Fixture Dimension: T = ______

Specimen Ident ______
Thickness: T_{01} = ______ T_{02} = ______ T_{03} = ______
$\overline{T}_0$ = ______ .75 $\overline{T}_0$ = ______
Fixture Dimension: T = ______

Signature of Test Supervisor [signature] Date 3/6/77

3X10[7] RAD

560ND

Radiation Type GAMA

Radiation Dose 3X10[7]RAD ____ ____

Specimen Ident	1	3	____	____	____	____
Durometer-Shore A:	79	77	____	____	____	____
Tensile Strgth-PSI	1085	535	____	____	____	____

Specimen Ident 2 Radiation Dose 3X10[7]RAD

Thickness: T_{11} = .126 T_{12} = .126 T_{13} = .126

$\overline{T}_1$ = .126 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = .337

Specimen Ident 4 3X10[7] RAD

Thickness: T_{11} = .127 T_{12} = .127 T_{13} = .127

$\overline{T}_1$ = .127 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = .324

Specimen Ident ____ Radiation Dose ____

Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Specimen Ident ____

Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Specimen Ident ____ Radiation Dose ____

Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Specimen Ident ____

Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Signature of Test Supervisor [signature] Date 3/9/77

Radiation Type Gama

Radiation Dose 3X10^7 ____ ____

Specimen Ident	5	6				
Durometer-Shore A:	77	78				
Tensile Strgth-PSI	1142	869				

Specimen Ident 2 Radiation Dose 3X10^7 RAD
Thickness: T_{11} = .124 T_{12} = .125 T_{13} = .125

$\overline{T}_1$ = .1247 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = .374

Specimen Ident 4
Thickness: T_{11} = .126 T_{12} = .125 T_{13} = .126

$\overline{T}_1$ = .1257 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = [illegible] .362

Specimen Ident ____ Radiation Dose ____
Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Specimen Ident ____
Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Specimen Ident ____ Radiation Dose ____
Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Specimen Ident ____
Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Signature of Test Supervisor [illegible] Date [illegible]

TEST REPORT FORM - SEAL MATERIAL IRRADIATION

Initial Data

Specimen Type and Size: O Ring 212 Size
Molder: Polyseal (Buckeye Rubber) Compound No. HK471
Batch No. ________ Cure Date 10-77
Certificate of Compliance Polyseal/Buckeye Rubber

Durometer-Shore A:	73	74	69	69	72	66	69	65
Tensile Strgth-PSI	2017	2078						
Irrad. Test Ident			1	2	3	4	5	6

Specimen Ident 2
Thickness: T_{01} = .140 T_{02} = .141 T_{03} = .140
$\overline{T}_0$ = .1403 .75 $\overline{T}_0$ = .1052
Fixture Dimension: T = .105

Specimen Ident 4
Thickness: T_{01} = .140 T_{02} = .140 T_{03} = .139
$\overline{T}_0$ = .1397 .75 $\overline{T}_0$ = .1047
Fixture Dimension: T = .105

Specimen Ident ____
Thickness: T_{01} = ____ T_{02} = ____ T_{03} = ____
$\overline{T}_0$ = ____ .75 $\overline{T}_0$ = ____
Fixture Dimension: T = ____

Specimen Ident ____
Thickness: T_{01} = ____ T_{02} = ____ T_{03} = ____
$\overline{T}_0$ = ____ .75 $\overline{T}_0$ = ____
Fixture Dimension: T = ____

Specimen Ident ____
Thickness: T_{01} = ____ T_{02} = ____ T_{03} = ____
$\overline{T}_0$ = ____ .75 $\overline{T}_0$ = ____
Fixture Dimension: T = ____

Specimen Ident ____
Thickness: T_{01} = ____ T_{02} = ____ T_{03} = ____
$\overline{T}_0$ = ____ .75 $\overline{T}_0$ = ____
Fixture Dimension: T = ____

Signature of Test Supervisor [illegible signature] Date 3/5/77

3X10 RAD

Radiation Type GAMA

Radiation Dose $3X10^7$ RAD ____ ____

Specimen Ident 1 3 ____ ____ ____ ____

Durometer-Shore A: 78 77 ____ ____ ____ ____

Tensile Strgth-PSI 1665 1351 ____ ____ ____ ____

Specimen Ident 2 Radiation Dose $3X10^7$ RAD

Thickness: T_{11} = .130 T_{12} = .129 T_{13} = .129

$\overline{T}_1$ = .1293 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = .312

Specimen Ident 4 $3X10^7$ RAD

Thickness: T_{11} = .129 T_{12} = .129 T_{13} = .128

$\overline{T}_1$ = .1287 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = .317

Specimen Ident ____ Radiation Dose ____

Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Specimen Ident ____

Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Specimen Ident ____ Radiation Dose ____

Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Specimen Ident ____

Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Signature of Test Supervisor [illegible] Date 3/9/77

3X10⁷ RAD + 72hr Steam

Radiation Type GAMA

Radiation Dose 3X10⁷RAD ____ ____

Specimen Ident	5	6				
Durometer-Shore A:	78	77				
Tensile Strgth-PSI	1332	1402				

Specimen Ident 2 Radiation Dose 3X10⁷RAD
Thickness: T_{11} = .130 T_{12} = .130 T_{13} = .129

$\overline{T}_1$ = .1297 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = .300

Specimen Ident 4
Thickness: T_{11} = .128 T_{12} = .129 T_{13} = .129

$\overline{T}_1$ = .1287 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = .317

Specimen Ident ____ Radiation Dose ____
Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Specimen Ident ____
Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Specimen Ident ____ Radiation Dose ____
Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Specimen Ident ____
Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Signature of Test Supervisor [illegible] Date 3/ /77

TEST REPORT FORM - SEAL MATERIAL IRRADIATION

Initial Data

Specimen Type and Size: O Ring 217 Size
Molder: Polyseal (Buckeye Rubber) Compound No. E2050-90
Batch No. ______ Cure Date 1Q77
Certificate of Compliance Polyseal / BUCKEYE RUBBER

Durometer-Shore A:	85	86	85	84	85	84	85	85
Tensile Strgth-PSI	1737	1606						
Irrad. Test Ident			1	2	3	4	5	6

Specimen Ident 4
Thickness: T_{01} = .140 T_{02} = .140 T_{03} = .140

$\overline{T}_0$ = .140 .75 $\overline{T}_0$ = .105
Fixture Dimension: T = .105

Specimen Ident 6
Thickness: T_{01} = .140 T_{02} = .140 T_{03} = .140

$\overline{T}_0$ = .140 .75 $\overline{T}_0$ = .105
Fixture Dimension: T = .105

Specimen Ident ______
Thickness: T_{01} = ______ T_{02} = ______ T_{03} = ______
$\overline{T}_0$ = ______ .75 $\overline{T}_0$ = ______
Fixture Dimension: T = ______

Specimen Ident ______
Thickness: T_{01} = ______ T_{02} = ______ T_{03} = ______
$\overline{T}_0$ = ______ .75 $\overline{T}_0$ = ______
Fixture Dimension: T = ______

Specimen Ident ______
Thickness: T_{01} = ______ T_{02} = ______ T_{03} = ______
$\overline{T}_0$ = ______ .75 $\overline{T}_0$ = ______
Fixture Dimension: T = ______

Specimen Ident ______
Thickness: T_{01} = ______ T_{02} = ______ T_{03} = ______
$\overline{T}_0$ = ______ .75 $\overline{T}_0$ = ______
Fixture Dimension: T = ______

Signature of Test Supervisor [illegible signature] Date 3/6/77

3X10⁷ RAD

Radiation Type GAMA

Radiation Dose 3X10⁷RAD ____ ____

Specimen Ident 1 2 ____ ____ ____ ____

Durometer-Shore A: 88 88 ____ ____ ____ ____

Tensile Strgth-PSI 1120 927 ____ ____ ____ ____

Specimen Ident 4 Radiation Dose 3X10⁷RAD
Thickness: T_{11} = .126 T_{12} = .126 T_{13} = .126

$\overline{T}_1$ = .126 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = .40

Specimen Ident 6 3X10⁷RAD
Thickness: T_{11} = .125 T_{12} = .125 T_{13} = .126

$\overline{T}_1$ = .1253 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = .42

Specimen Ident ____ Radiation Dose ____
Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Specimen Ident ____
Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Specimen Ident ____ Radiation Dose ____
Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Specimen Ident ____
Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Signature of Test Supervisor [illegible signature] Date 3/9/77

3X10⁷ RAD + 72 hr. Steam

Radiation Type GAMA

Radiation Dose 3X10⁷ RAD ____ ____

Specimen Ident	3	5	____	____	____	____
Durometer-Shore A:	88	88	____	____	____	____
Tensile Strgth-PSI	1180	905	____	____	____	____

Specimen Ident 4 Radiation Dose ____
Thickness: T_{11} = .126 T_{12} = .126 T_{13} = .126

$\overline{T}_1$ = .126 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = .4

Specimen Ident 6
Thickness: T_{11} = .125 T_{12} = .126 T_{13} = .126

$\overline{T}_1$ = .1257 Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = .409

Specimen Ident ____ Radiation Dose ____
Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Specimen Ident ____
Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Specimen Ident ____ Radiation Dose ____
Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Specimen Ident ____
Thickness: T_{11} = ____ T_{12} = ____ T_{13} = ____

$\overline{T}_1$ = ____ Compression Set: $\frac{\overline{T}_0 - \overline{T}_1}{T_0 - T}$ = ____

Signature of Test Supervisor [signature] Date 3/18/77

ENGINEERING PARTS LIST

Type Support Large Bore Snubber	Size 18 Dia. Bore	EPL No. MB-5222-31	
Ass'y No. E-PHD-5222-5-A1	Cap. 1500 kips	Page 1 of 6	

Rev.	By - Date	Chkd - Date	S.R. Chng Date	Appr - Date	Comments
1	[illegible] 1/11/79	[illegible] 1/12/79	N/A	[illegible] 1/12/79	
2	IH 2/12/81	DSS 2-13-81	N/A	[illegible] 2/13/81	
3	DL 10/28/81	[illegible] 10/29/81	N/A	DT 10/29/81	
4	DL 10/12/82		N/A		

MODEL 52

FOR REFERENCE ONLY

ENGINEERING PARTS LIST | EPL No. MB-5222-31 | Page 2 of 6 | Rev. 4 | Date 10/12/8

	Qty Per	Drawing No.		Description	Material	Rev.	Rev. Dat
1	1	E PHD-5222-5		Large Bore Snubber Ass'y		G	11/10/81
2	1	CPHD-5222-184		Rear Bracket Ass'y	ASTM 487-74d GR. 10Q *	H	6/23/80
3	1	BPHD-5222-100		Rear Bracket Casting	ASTM 487-74d GR. 10Q *	G	6/23/80
4	2	APHD-5222-12		Lifting Lug	ASTM 487-74d GR. 10Q *	D	6/23/80
5	1	CPHD-5222-166		Pivot Lug Ass'y	ASTM 487-74d GR. 10Q *	D	6/23/80
6	1	BPHD-5222-157		Pivot Lug Casting	ASTM 487-74d GR. 10Q *	E	1/2/80
7	2 #	SKF GEZ-600 ESB		Spherical Bearing	Steel **		
8	1	D5689H-13		Cylinder Hyd MFP Model 52		14	5/21/80
9	1	D5689H-13	-1	Piston-Piston Rod	ASTM A668-72 GR.M Forging *		
10	2	D5689H-13	-2	Piston Seal	Ethylene Propylene See Appr Comp. List, Pg. 6 **		
11	1	D5689H-13	-3	Head	ASTM A516-73 GR. 70 Plate *		
12	1	D5689H-13	-4	External Bearing	ASTM A516-73 GR. 70 Plate *		
13	1	D5689H-13	-5	Tubing	ASTM A148-73 GR. 150-125 Casting *		
14	1	D5689H-13	-6	Rod Seal	Ethylene Propylene See Appr Comp. List Pg. 6 **		
15	1	D5689H-13	-7	Retainer	ASTM A516-73 GR. 70 Plate *		
16	1	D5689H-13	-8	Rod Bushing	ASTM A546 GR. 80-55-06 or 80-60-03 Bronze Plate CDA 524**		
17		D5689H-13	-9	Tie Rod Nuts	ASTM-A194-71 GR. 7 or 7B *		
18	1	D5689H-13	-10	Threaded Cap	ASTM-A516-73 GR. 70 Plate *		
19		D5689H-13	-11	Tie Rods	ASTM-A-193-73 GR. B7 *		
20	1	D5689H-13	-12	Rod Pressure Ring	SAE 660 Bronze **		
	1	D5689H-13	-13	Rod Seal Cage	AISI 1018 or 1020 **		

ENGINEERING PARTS LIST	EPL No. MB-5222-31	Page 3 of 6	Rev. 4 Date 10/12/82

	Qty Per	Drawing No.		Description	Material	Rev.	Rev. Date
1	2	D5689H-13	-14	Cylinder End Seal	Ethylene Propylene See Appr. Comp. List, Pg. 6 **	✓	
2	1	D5689H-13	-15	Rod Wiper	Ethylene Propylene See Appr. Comp. List, Pg. 6 **	✓	
3	1	D5689H-13	-16	Rod Wave Spring	AISI 1070-1090 Spr. Stl. R_C 44-54 **		
4	2	D5689H-13	-17	Piston-Anti Roll Ring	AISI 1010-1018 R_B 40 Max. **		
5	2	D5689H-13	-18	Piston Retaining Ring	AISI 1070-1090 Spr. Stl. R_C 44-54 **		
6	1	D5689H-13	-19	Piston Wear Ring	Bronze Leaded ASTM B584-73 Alloy 937 **		
7	2	D5689H-13	-20	Piston Seal Backup Ring	Bronze Leaded ASTM B584-73 Alloy 937 **		
8	16	D5689H-13	-21	Retainer Scr. 5/16-24 x 1 1/2 Lg.	ASTM A354-66 GR. BB, BC or BD*		
9	1	D5689H-13	-22	Retaining Ring	AISI 1075-1095 Spr. Stl. R_C 47-51 **		
10	1	D5689H-13	-23	External Brg. Seal	Ethylene Propylene See Appr. Comp. List Pg. 6 **	✓	
11	12	D5689H-13	-24	Retainer Screws 1/2 - 20 x 5" Lg.	ASTM A354-66 GR. BB, BC or BD *		
12	16	D5689H-13	-25	5/16 Flat Washer	Steel **		
13	1	CPHD-5222-198		Clevis Ass'y	ASTM 487-74d GR. 10Q *	C	6/23/80
14	1	BPHD-5222- 176		Clevis End Casting	ASTM 487-74d GR. 10Q *	E	6/23/80
15	1	BPHD-5222-56-1		Pivot Pin R.B.	A 564-74 GR. XM-13 *	D	6/23/80
16	4	5100-600		Retaining Ring	AISI 1075-1095 Spr. Stl. R_C 47-51 **		
17	1	BPHD-5222- 56		Pivot Pin Clevis	A564-74 GR. XM-13 *	D	6/23/80
18	2	BPHD-5222-20		Snubber Valve Ass'y		D	1/28/80
19	2	BPHD-5222-21		Valve Body	AISI 10L18 ASTM A108 GR.1013 CW 60 ksi Min UTS. 40 ksi Y.S. 215 BHN Max.*	H	6/19/81
20	2	APHD-5222-22		Valve Poppet	AISI 10L18 ASTM A108 GR.1018 CW 60 ksi Min UTS. 40 ksi Y.S. 215 BHN Max.*	D	1/14/81
21	2	APHD-5222-23		Valve Seat Disc	ASTM A515-72 GR.65 or GR.70	E	8/25/80

ENGINEERING PARTS LIST	EPL No. MB-5222- 31	Page 4 of 6	Rev. 4	Date 10/12/82

	Qty Per	Drawing No.	Description	Material	Rev.	Rev. Date
1	1 1	LC-049H-5 LC-055H-5	Tension Spr.-Lee Spr. Co. Comp. Spr.-Lee Spr. Co.	Mil-QQ-W-423, FS-302 AMS-5688 **		
2	2	APHD-5222-24	Spring Plunger	AISI 10L18, ASTM A-108 GR.1018 CW 60 ksi Min. UTS 40 ksi Y.S. 215 BHN Max.* **	C	1/22/80
3	2	APHD-5222-25	Adjustment Screw	Holo-Krome Alloy Stl. **	B	1/22/80
4	4	649027-1/4	Thread Seal	Seal EP Retainer Comm. Stl. Cad. Pltd. Appr. Comp. List Pg. 6 **		
5	4	C4-4.1	1/4 Plain Washer	L.C. Steel **		
6	4	C2-3.2	1/4-28 NF Hex Jam Nut	ASTM A307-74 GR.A or SA307 GR.B		
7	2	APHD-5222-26	Orifice Valve Stem	SA-36 or ASTM A-108-73 GR. 1018 CW	C	12/11/80
8	2	APHD-5222-27	Retainer Plate	SA-36 or ASTM A-108-73 GR. 1018 CW **	D	5/6/81
9	4	C2-2.6	Retainer Plate Screw #10-32 x 1/2 Lg. Soc. Hd. Cap Scr.	Holo-Krome Alloy Stl. **		
10	4	-125	O-Ring	Ethylene Propylene See Appr. Comp. List Pg. 6 **	✓	
11	2	-916	O-Ring	Ethylene Propylene See Appr. Comp. List Pg. 6 **	✓	
12	8		Mntg. Bolt 3/8-16 UNC x 4.375 Lg.	SA-320 GR. L7 or SA-193 GR. B7		
13	65 Ft		Tubing 1" OD x .065 Wall	A179 Soft Annealed Qual. to SA-106 GR. A **		
14	1	AH-1441	Nameplate	.015 Thk. St. St. **	B	9/19/75
15	4		#4 Parker Kalon Dr. Sc.	Hardened Stl. **		
16	1	CPHD-5222- 54	Extension Piece Ass'y	SA-181 CL-2 & SA-36	G	6/20/80
17	1	BPHD-5222-51-1	Extension Piece	SA-181 CL-2	D	3/5/82
18	2	BPHD-5222- 52	Extension Base Plate	SA-36 or SA 515 GR. 70	C	6/20/80
19	8	APHD-5222- 58	Lifting Lug	SA-515 GR. 65	E	6/20/80
20	28		Soc. Hd. Cap Scr. 1 1/4-12 UNF-2A x 7.5 Lg.	A-354 GR.BC or A-193 GR. B7		
	56		Washer 1 1/4 I.D. x 1.903/1.938 O.D. .136/.192 Thk.	SAE Hardened Steel **		

	Qty Per	Drawing No.	Description	Material	Rev.	Rev. Date
1	2	721-FSO-1/2	Fill Port Plug, Hi Seal	Stl. w/908 EP O-Ring **		
2	2	APHD-5222-28	Tamper-Proof Valve Cover	Steel **	A	1/22/80
3	4	C2-2.6	Soc. Hd. Cap Scr. 10-32 UNC-3A x .38 Lg.	Steel **		
4	1		Safety Wire	St.St. w/Lead Press Seal **		
5	1	B-1610-P or S-1610-P or SS-1610-P Equiv.	Plug - Swagelok 1"	Brass ** Steel ** Stainless Steel **		
6	1	S810-R-16 or SS-810-R-16 Equiv.	Reducer - Swagelok 1"x1/2"	Steel ** Stainless Steel **		
7	2	S-1610-3 or SS-1610-3 Equiv.	Union Tee - Swagelok 1"	Steel ** Stainless Steel **		
8	2	S-1610-1-16 ST or SS-1610-1-16 ST Equiv.	Male Connector - Swagelok 1"	Steel ** Stainless Steel **		
9	2		Tubing 1" O.D.x.065 WL	A179 Soft Annealed Qual. to SA106 GR. A **		
10	1	YB-2342	Reservoir & Mntg. Brkt.	Oil-Rite (3 Gal) St. St. **		
11	2	D5689H-13 -26	Wiper Retainer Plate	ASTM A620 **		
12	20	D5689H-13 -27	Flat Washer 1/2	Steel **		
13	8	D5689H-13 -28	Push Nut - Truarc	SAE 1075 Spring Steel **		
14	1	9200B Series - 4PP	Circle Seal Plug Valve	Bronze **		
15	1	-113	O'Ring	Ethylene Propylene, See Appr. Comp. List Pg. 6 **	✓	
16	2	-211	O'Ring	Ethylene Propylene, See Appr. Comp. List Pg. 6 **	✓	
17	1	SS-810-1-8, S-810-1-8	Male Connector-Swagelok	Stainless Steel, Steel **		
18	1	SS-8-TA-1-8, S-8-TA-1-8	Tube Adapter- Cajon	Stainless Steel, Steel **		
19	1	SS-810-P, S-810-P	Plug-Swagelok	Stainless Steel, Steel **		
20	1	BPHD-5222-278	Filter Screen	AISI Type 302 or 304 S.S.**	A	1/13/81
21	1	5005-50	Retaining Ring Truarc	Steel**		

ENGINEERING PARTS LIST		EPL No. MB-5222- 31	Page 6 of 6	Rev. 4	Date 10/12/82
Qty Per	Drawing No.	Description	Material	Rev.	Rev. Date
10.38	Gallons	Hydraulic Fluid	GE SF1154 Silicone Fluid **		

#Denotes: (1) bearing, with mftg. identification mark, is supplied loose for snubber RCP attachment lug.

		* Code Case 1644	**Code Exempt Per NF 2121		

Approved Ethylene Propylene Compounds per PHD-7559-1

Acusnnet #E-17018	Minnesota Rubber #560 ND
Parker #E-740-75	National Seal, Federal Mogul #E-50
Parker #E-692-75	Mantaline, 70 Dur EPDM
Parker #E-515-80	W.H. Salisbury, #80154
Minnesota Rubber #559 EQ	Polyseal HK 471
Minnesota Rubber #559 GT	Polyseal E2050-90

ENGINEERING PARTS LIST

Type Support Large Bore Snubber	Size 14 Dia. Bore	EPL No. MB-5222-45
Ass'y No. D-PHD-5222-6-D1	Cap. 1000 kips	Page 1 of 6

Rev.	By - Date	Chkd - Date	S.R. Chng Date	Appr - Date	Comments
1	[illegible] 1/11/79	[illegible] 1/12/79	N/A	[illegible] 1/12/79	
2	TR 2/12/81	DSS 2-13-81	N/A	[illegible] 2/13/81	
3	DL 10/28/81	[illegible] 10-29-81	N/A	DT 10/29/81	
4	DL 10/12/8[illegible]				

MODEL 90

FOR REFERENCE ONLY

ENGINEERING PARTS LIST | EPL No. MB-5222- 45 | Page 2 of 6 | Rev. 4 Date 10/12/82

	Qty Per	Drawing No.		Description	Material	Rev.	Rev. Date
						J	12/6/82
1	1	EPHD-5222- 6		Large Bore Snubber Ass'y			
2	*** 1	CPHD-5222- 187		Rear Brkt Ass'y	ASTM 487-74d GR. 10Q *	D	6/23/80
3	1	BPHD-5222- 106		Rear Brkt Casting	ASTM 487-74d GR. 10Q *	D	6/23/80
4	2	APHD-5222- 12		Lifting Lug	ASTM 487-74d GR. 10Q *	D	6/23/80
5	1	D5689H- 2		Cylinder, Hyd MFP Model 90		17	5/21/80
6	1	D5689H- 2	-1	Piston, Piston Rod	ASTM A668-72 CL M Forging *		
7	2	D5689H- 2	-2	Piston Seal	Ethylene Propylene See Appr. Comp. List Pg. 6 **		
8	1	D5689H- 2	-3	Head	ASTM A516-73 GR. 70 Plate *		
9	1	D5689H- 2	-4	Pivot Lug/Cap Ass'y	ASTM 487-74d GR. 10Q *		
10	1	CPHD-5222- 168		Pivot Lug Ass'y	ASTM 487-74d GR. 10Q *	F	6/23/80
11	1	BPHD-5222-160		Pivot Lug Casting	ASTM 487-74d GR. 10Q *	E	6/23/80
12	1	D5689H-2	-5	Tubing	ASTM A148-73 GR. 150-125 Casting *		
13	1	D5689H-2	-6	Rod Seal	Ethylene Propylene See Appr. Comp. List Pg. 6 **		
14	1	D5689H-2	-7	Retainer	ASTM A516-73 GR. 70 Plate *		
15	1	D5689H-2	-8	Rod Bushing	ASTM A546 GR. 80-55-06 or 80-60-03 Bronze Plate CDA 524 **		
16	28	D5689H-2	-9	Tie Rod Nuts	ASTM-A194-71 GR. 7 or 7B *		
17	2	D5689H-2	-10	Piston Seal Backup Ring	Bronze-Leaded ASTM B584-73 Alloy 937 **		
18	28	D5689H-2	-11	Tie Rod	ASTM A193-73 GR. B7 *		
19	1	D5689H-2	-12	Rod Pressure Ring	SAE 660 Bronze **		
20	1	D5689H-2	-13	Rod Seal Cage	AISI 1018 or 1020 **		

ENGINEERING PARTS LIST		EPL No. MB-5222- 45	Page 3 of 6	Rev. 4 Date 10/12/82	

	Qty Per	Drawing No.	Description	Material	Rev.	Rev. Date
1	2	D5689H- 2 -14	Cylinder End Seal	Ethylene Propylene ** See Appr. Comp. List Pg. 6	✓	
2	1	D5689H- 2 -15	Rod Wiper	Ethylene Propylene ** See Appr. Comp. List Pg. 6	✓	
3	1	D5689H- 2 -16	Rod Wave Spring	AISI 1070-1090 Spr. Stl. R_C 44-54 **		
4	2	D5689H- 2 -17	Piston Anti Roll Ring	AISI 1010 or 1018 R_B 40 Max. **		
5	2	D5689H- 2 -18	Piston Retaining Ring	AISI 1070 or 1090 Apr. Stl. R_C 44-54 **		
6	1	D5689H- 2 -19	Piston Wear Ring	Bronze-Leaded ** ASTM B584-73 Alloy 937		
7	2	D5689H- 2 -20	SKF GEZ 408 ESB Spherical Bearing	Steel **		
8		D5689H- 2 -21	Retainer Scr. 5/16 - 24 x 1 1/2 Lg.	ASTM A354-66 GR. BB, BC, BD *		
9		D5689H- 2 -22	Retaining Ring	AISI 1075-1095 Spr. Stl. R_C 47-51 **		
10	1	CPHD-5222- 180-3	Clevis Ass'y	ASTM 487-74d GR. 10Q *	E	6/23/80
11	1	BPHD-5222- 178	Clevis End Casting	ASTM 487-74d GR. 10Q *	F	6/23/80
12	1	BPHD-5222- 131-1	Pivot Pin - R.B.	A564-74 GR. XM-13 *	D	6/20/80
13	4	5100- 450	Retaining Ring (TRUARC)	AISI 1075-1095 Spr. Stl. R_C 47-51 **		
14	1	BPHD-5222- 131-2	Pivot Pin, Clevis	A564-74d GR. 10Q *	D	6/20/80
15	2	BPHD-5222-20	Snubber Valve Ass'y		D	1/28/80
16	2	BPHD-5222-21	Valve Body	AISI 10L18 ASTM A108 GR. 1018 CW 60 ksi Min. UTS. 40 ksi Y.S. 215 BHN Max.*	H	6/19/81
17	2	APHD-5222-22	Valve Poppet	AISI 10L18 Min. UTS. 40 ksi Y.S. 215 BHN Max. *	D	1/14/81
18	2	APHD-5222-23	Valve Seat Disc	ASTM A515-72 GR. 65 or 70	E	3/25/80
19	1 1	LC-045H-5 LC-049H-5	Tension Spr. - Lee Spr. Co. Comp. Spr. - Lee Spr. Co.	Mil-QQ-W-423, FS-302 AMS-5688 **		
20	2	APHD-5222-24	Spring Plunger	AISI 10L18 ASTM A108 GR. 1018 CW 60 ksi Min. UTS. 40 ksi Y.S. 215 BHN Max.**	C	1/22/80
	[illegible]	APHD-5222-25	Adjustment Screw	Holo Krome Alloy Steel **	B	1/22/80

ENGINEERING PARTS LIST			EPL No. MB-5222-45	Page 4 of 6	Rev. 4	Date 10/12/82
	Qty Per	Drawing No.	Description	Material	Rev.	Rev. Date
1	4	649027-1/4	Thread Seal	Seal-E.P. Retainer Comm. Stl. Cap. Pltd. Appr.Comp.List ** Pg.6	✓	
2	4	C4-4.1	1/4 Plain Washer	L.C. Steel **		
3	4	C2-3.2	1/4-28 NF Hex Jam Nut	ASTM A307-74 GR.A or SA307 GR.B		
4	2	APHD-5222-26	Orifice Valve Stem	SA 36 or ASTM A108-73 GR. 1018 CW	C	12/11/8
5	2	APHD-5222-27	Retainer Plate	SA 36 or ASTM A108-73 GR 1018 CW **	D	5/8/81
6	4	C2-2.6	Retainer Plate Screw 10-32 UNF x 1/2 Lg. Soc.Hd.Cap Scr.	Holo Krome Alloy Steel **		
7	4	-125	O-Ring	Ethylene Propylene See Appr. Comp. List Pg.6 **	✓	
8	2	-916	O-Ring	Ethylene Propylene See Appr. Comp. List Pg.6 **	✓	
9	65 Feet		Tubing 1" OD x .065 wall	A179 Soft Annealed Qual. to SA106 GR. A **		
10	1	AH-1441	Nameplate	.015 Thk. St. St. **	B	9/19/75
11	4		#4 Parker Kalon Drive Scr.	Hardened Steel **		
12	2	721-FSO-1/2	Fill Port Plug, Hi Seal	Stl. w/908 EP O-ring **	✓	
13	2	APHD-5222-28	Tamper-Proof Valve Cover	Steel **	A	1/22/80
14	4	C2-2.6	Soc. Hd. Cap Screw #10-32 UNC -3A x .38 Lg.	Steel **		
15	1		Safety Wire	St. St. w/Lead Press Seal**		
16	1	B-1610-P or S-1610-P SS-1610-P Equiv.	Plug - Swagelok 1"	Brass ** Steel ** Stainless Steel **		
17	1	S-810-R-16 or SS-810-R-16 Equiv.	Reducer - Swagelok 1"x1/2"	Steel ** Stainless Steel **		
18	2	S-1610-3 or SS-1610-3 Equiv.	Union Tee - Swagelok 1"	Steel ** Stainless Steel **		
19	2	S-1610-1-16ST or SS-1610-1-16ST Equiv.	Male Connector - Swagelok 1"	Steel ** Stainless Steel **		
20	2		Tubing 1" O.D.x.065 Wall	A179 Soft Annealed Qual. to SA106 GR. A **		

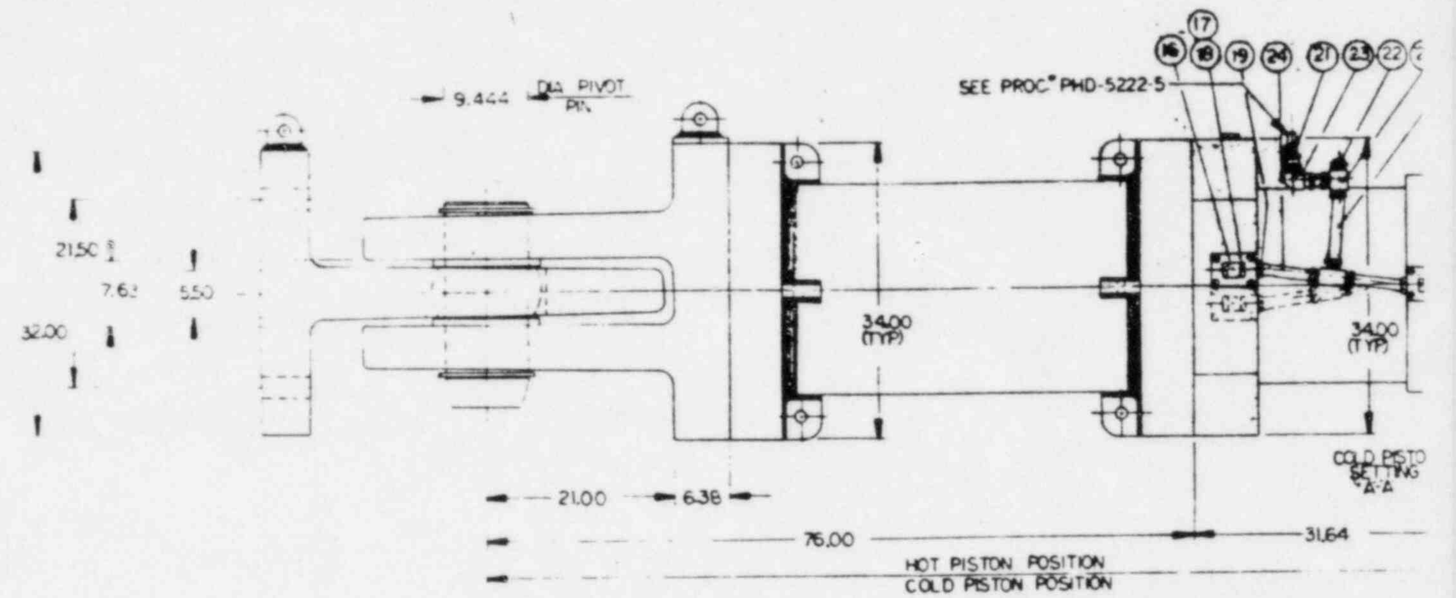
ENGINEERING PARTS LIST			EPL No. MB-5222-45	Page 5 of 6	Rev. 4 Date 10/12/82	
	Qty Per	Drawing No.	Description	Material	Rev.	Rev. Date
1	*** 1	YB-2342	Reservoir & Mntg. Brkt.	Oil-Rite (3 Gal) St. St.**		
2	2	D5689H-2 -24	Wiper Retainer Plate	ASTM A620 **		
3	*8	D5689H-2 -25	Flat Washer 1/2	Steel **		
4	*8	D5689H-2 -26	Push Nut- Truarc	SAE 1075 Spring Steel**		
5	1	9200B Series - 4PP	Circle Seal Plug Valve	Bronze **		
6	1	-113	O'ring	Ethylene Propylene, See Appr. Comp. List, Pg. 6 **		
7	2	-211	O'ring	Ethylene Propylene, See Appr. Comp. List, Pg. 6 **		
8	1	SS-810-1-8, S-810-1-8	Male Connector- Swagelok	Stainless Steel, Steel**		
9	1	SS-8-TA-1-8, S-8-TA-1-8	Tube Adapter- Swagelok	Stainless Steel, Steel**		
10	1	SS-810-P, S-810-P	Plug- Swagelok	Stainless Steel, Steel**		
11	16	D5689H-2 -23	5/16 Flat Washer	Steel **		
12	1	BPHD-5222-278	Filter Screen	AISI Type 302 or 304 S.S.**	A	1/13/81
13	1	5005-50	Retaining Ring Truarc	Steel **		
14	7.21	Gallons	Hydraulic Fluid	GE SF1154 Silicone Fluid**		
15						
16						
17						
18						
19						
20						

ENGINEERING PARTS LIST | EPL No. MB-5222-45 | Page 6 of 6 | Rev. 4 Date 10/12/82

	Qty Per	Drawing No.	Description	Material	Rev.	Rev. Date
1						
2						
3			#Denotes: (1) bearing, with mftg. identification mark, is supplied loose for snubber RCP attachment lug.			
4						
5						
6			*Code Case 1644	**Code Exempt Per NF 2121		
7			*** A Quantity of One (1) of These Items Will			
8			Accomodate Two (2) D-1 Snubber Assemblies			
9						
10						
11			Approved Ethylene - Propylene Compounds per PHD-7559-1			
12						
13		Acushnet #E-17018		Minnesota Rubber #560 ND		
14		Parker #D-740-75		National Seal, Federal Mogul #E-50		
15		Parker #E-692-75		Mantaline, 70 Dur EPDM		
16		Parker #E-515-80		W. H. Salisbury, #80154		
17		Minnesota Rubber #559 EQ		Polyseal HK 471		
18		Minnesota Rubber #559 GT		Polyseal E2050-90		
19						
20						

Reference 14

EPRI, "Radiation Effects on Organic Materials in Nuclear Plants", Report EPRI NP-2129, November 1981.



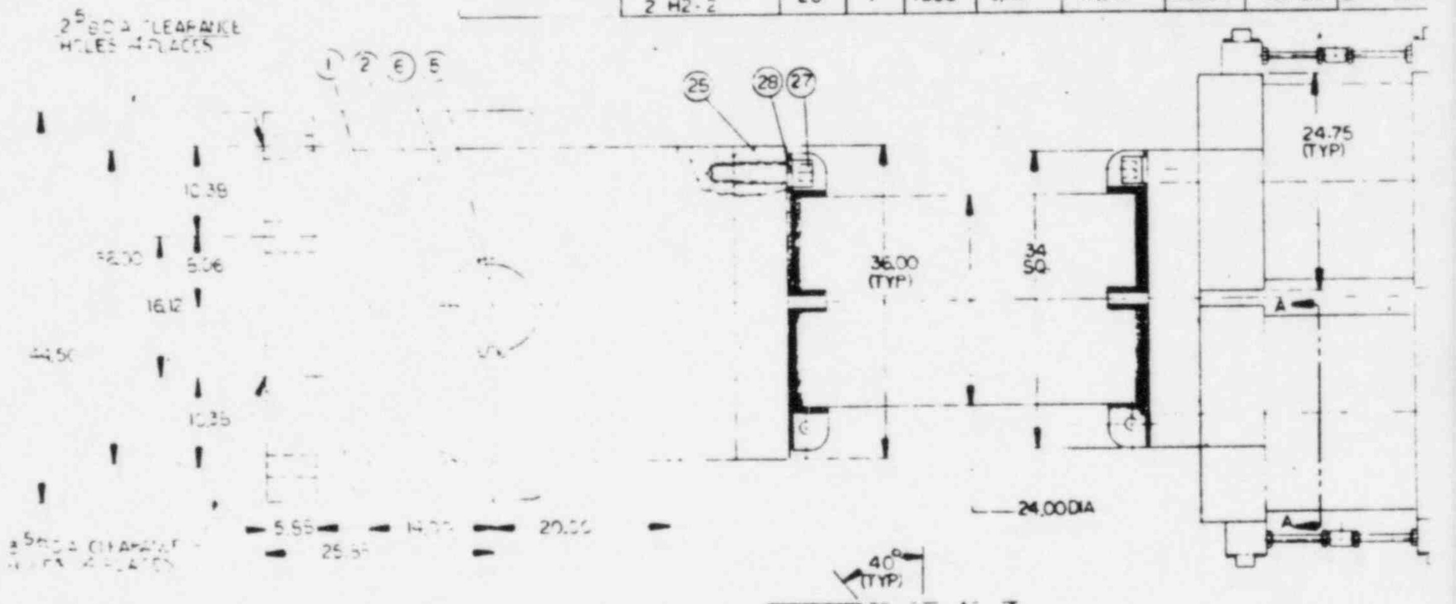
TORQUE VALUES	
TYPE	TORQUE FT LBS
EXT. PC STUDS	4[illegible]
TIE RODS	10[illegible]
CLEVIS END	6000
VALVE MTG BOLTS	[illegible]
FILL PORT PLUG	[illegible]

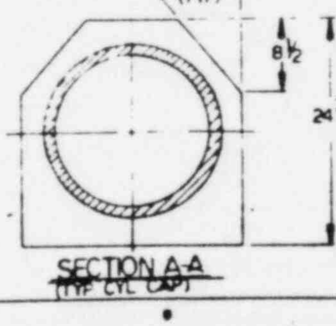
DESIGN SPECIFICATIONS

SNUBBER INSTALLATION DRAWING	SNUBBER ASSEMBLY NO	CYL SIZE	QTY	LOAD/SNBR KIPS	SPRING RATE KIP-INCH		PISTON POSITION		PISTON SE[TTING] 'A'-'A'
					COMP.	TENSION	HOT	COLD	
B PHD 5222-83	PHD-5222-S-H2	20	2	1500	11,002	11,240	128.64	129.54	8.39

AS-BUILT SPECIFICATIONS

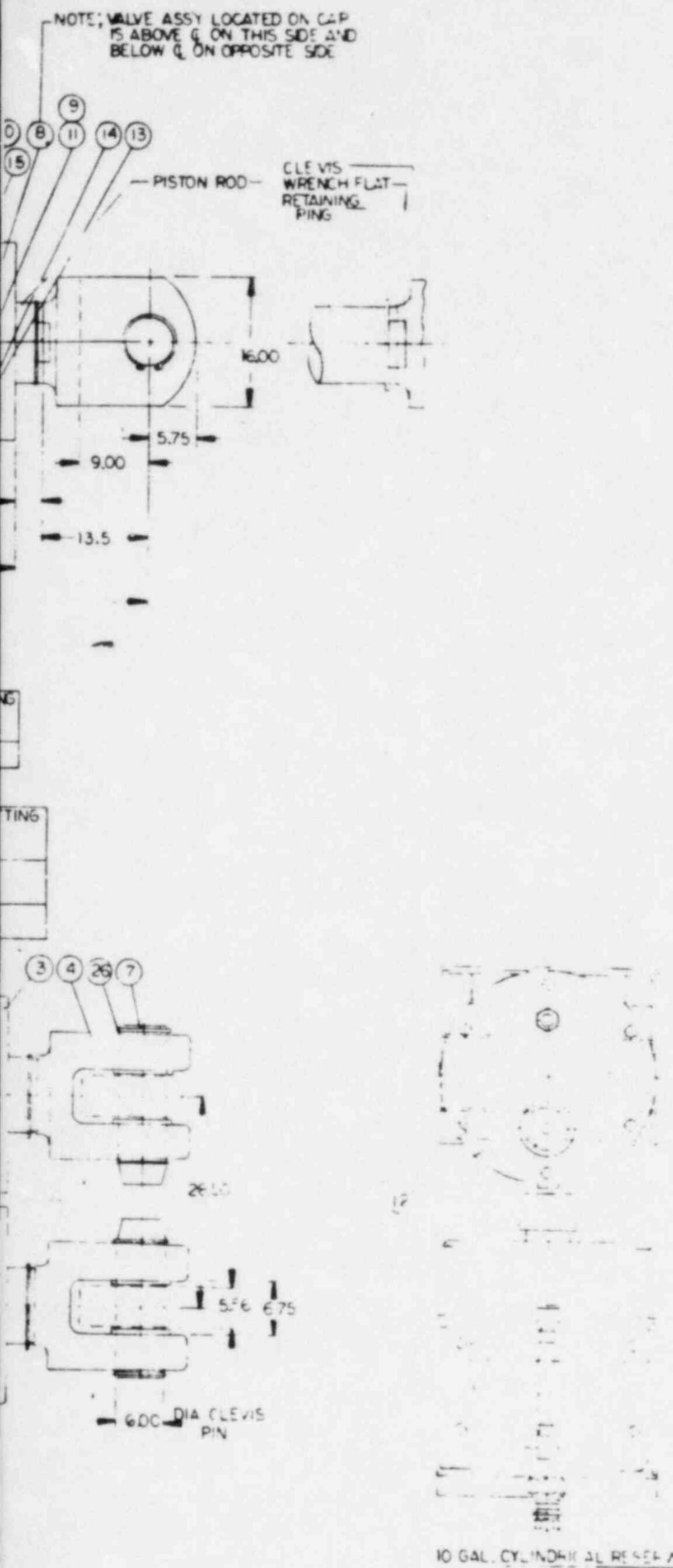
SNUBBER INSTALLATION DRAWING	SNUBBER IDENTIFICATION	CYL SIZE	QTY	LOAD SNBR KIPS	SPRING RATE KIP INCH		PISTON POSITION		PISTON 'A'-
					COMP.	TENSION	HOT	COLD	
B PHD 5222-83	1-H2-1 1-H2-2	20	1	1500	9,412	10,858	128.450 128.542	129.340 129.432	① 8.33
	2-H2-1 2-H2-2	20	1	1500	9,484	11,310	128.516	129.406	② 8.26





SECTION A-A
(TYP CYL CAP)

[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
[illegible]	[illegible] ADDED [illegible] PISTON SETTING REV'D [illegible] REV'D TITLE BLOCK ADDED [illegible] PRE LOAD [illegible]	[illegible]	[illegible]		[illegible]
C	[illegible] VALUE WAS 984 [illegible] LBS	[illegible]	[illegible]		[illegible]
D	[illegible] CHGD ALSO TUBING CONFIG. ITEM 32 ADDED. NOTE ADDED. [illegible]	[illegible]	[illegible]		[illegible]
E	REVISED AND REDRAWN INCLUDING PARTS LIST	DL	[illegible]		[illegible]
F	[illegible] CHANGED TO CONFORM TO C-[illegible] REV. E 1-H2 WAS 129.473 2-H2 WAS 129.488	[illegible]	[illegible] 12/6/[illegible]		[illegible]



NOTES

1. THIS EQUIPMENT IS IN COMPLETE ACCORD WITH SUB-SECTION NF SECTION III ASME B & P.V.
2. ITEM [illegible] VALVE BLOCK - REPLACE RETAINER PLATE DWG # PHD-[illegible]-20 ITEM [illegible] WITH ALTERNATE RETAINER PLATE [illegible] FOR ALIGNMENT OF VALVE CONNECTION [illegible]
3. [illegible] SHIPPED AS SHOWN SNUBBER SHIPPED AS FOLLOWS [illegible] ITEM REAR BRACKET [illegible] ITEM EXT. [illegible] ASSY [illegible] ITEM REMAINDER OF SNUBBER ASSY

TOTAL ASSY WT. [illegible]

FOR REFERENCE ONLY

MIDLAND PLANT UNIT 1 & 2
CONSUMERS POWER CO.

SCALE NONE EPL NE [illegible]	LIST OF PARTS PHD-5[illegible]-24	ITT Grinnell Corporation PIPE HANGER DIVISION RESEARCH DEVELOPMENT & ENGINEERING PROVIDENCE R.I.
MAT'L SPEC	SUPERSEDES	
FAB SPEC		
WELD SPEC	TOLERANCE EXCEPT AS NOTED / DATE 1-4-78	D PHD-52[illegible]-9
NDE PROCEDURE		
FINISH EXCEPT AS NOTED	FRAC. DEC. ANG. / DRAWN CHK'D APP'D	LARGE BORE SNUBBER ASSY / REV F
Q.A. REVIEW		BECHTEL [illegible] 7220-[illegible]-AC

Title of Calculation: REPLACEMENT INTERVAL CALCULATION FOR THE ITT GRINNELL HYDRAULIC SNUBBER SEALS AND HYDRAULIC FLUID

Project: MIDLAND PLANT UNITS 1 & 2

Client: CONSUMERS POWER COMPANY File Number: CPC-09-E.041

Check as Applicable /✓/ Manual Calculation /__/ Computer Calculation

Method: THE REPLACEMENT INTERVALS FOR ORGANIC MATERIALS HAS BEEN QUANTIFIED UTILIZING THE ARRHENIUS METHODOLOGY AS RECOMMENDED IN NUREG-0588.

Assumptions: (SEE PAGE 3 OF 6)

References: (SEE PAGE 4 OF 6)

Computer Run Information: (future revision changes shall be shown in the body of the calculation)

Computer Run Document Number: ______ Date: ______
Computer Program: ______ Version: ______
QA Category (QEP 3-5): ______ Verified: /_/YES /_/No
Operating System: ______ Version: ______
Tape Number: ______ Date: ______

Calculation Revision	Description of Change	Approval Signature	Date
0	N/A	[signature] Kelly	1/20/83
		[signature]	1/20/83

NUTECH CALCULATION VERIFICATION SHEET

TITLE: REPLACEMENT INTERVAL CALCULATION FOR THE ITT GRINNELL HYDRAULIC SNUBBER SEALS AND HYDRAULIC FLUID

PROJECT: MIDLAND PLANT, UNITS 1 & 2

CLIENT: CONSUMERS POWER COMPANY FILE NUMBER: CPC-09-E.041

Method of Verification (Check as applicable)

/✓/ Criteria Check* /__/ Alternate Calculation (attached)

/__/ Design Review /__/ Qualification Testing

/__/ Other: MARKED UP CALCULATION IN ACCORDANCE WITH 3-2 IF APPLICABLE

Note: An accuracy check must be performed of all work.

*The signature below signifies that this calculation has received design verification by a criteria check. No other signature will be shown on the individual sheets to document this verification.

Revision	Signature	Revision	Signature
0	W. R. Kelley		

Personnel Identification

All personnel participating in preparing, checking and approving this calculation most enter the below information.

Name (Printed)	Signature	Initials	Employee No.
M. ROSA LEE	M. Rosa Lee	MFL	0838
W. R. KELLEY	W. R. Kelley	WRK	0803
P. A. DiBENEDETTO	P. A. DiBenedetto	PDB	0593

nutech
Bethesda, Maryland

PROJECT Midland Units 1 & 2 FILE NO. CPC-09-E.041
OWNER Consumers Power Co.
CLIENT Consumers Power Co.

Purpose

This calculation justifies the replacement interval of non-metallic parts in the ITT Grinnell Hydraulic Snubber due to thermal degradation.

Results

Fluid & seal replacement due to thermal degradation should be accomplished on a 5 year interval. Calculation are shown on page 4.

Assumptions

1. The Hydraulic Snubber is subjected to a constant 120°F temperature.
2. The activation energy for Ethylene Propylene is 0.95 eV. for Hydraulic Fluid (silicon base) is 1.1 eV (Reference 2)
3. The material degradation is a function of temperature only, ie Arrhenius methodology is applicable to determine the thermal degradation.

REVISION	0					PAGE 3
PREPARED BY / DATE	MRE 1/6/83					OF 6
CHECKED BY / DATE	WRK 1/20/83					

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Bethesda, Maryland

PROJECT Midland Units 1 & 2 FILE NO. CPC-09-E.041
OWNER Consumers Power Co.
CLIENT Consumers Power Co.

Reference

1. ITT Grinnell Corp. "Radiation and Environmental Test of Seal and Fluid materials for snubbers", Report No. PHD-5439-2R Rev. 1, July 23, 1977

2. EPRI, "A Review of Equipment Aging Theory and Technology" EPRI Report EPRI NP-1558, September 1980

Calculations

The qualified life of the seals made of EPDM (listed on page 5) based on thermal degradation can be established by using the Arrhenius relationship and test data from Reference 1. During testing the seals were subjected to a temperature of 268°F for a period of 72 hours. (Ref 1)

The Arrhenius relationship can be written as:

$$\ln\left(\frac{t_1}{t_2}\right) = \frac{\phi}{K}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

where: t_1 = qualified service life

t_2 = time at test temperature = 72 hours

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CHECKED BY / DATE	[illegible] 1/24/83					

PROJECT Midland Units 1 & 2 FILE NO. CPC-09-E.041

OWNER Consumers power Co.

CLIENT Consumers power Co.

ϕ = activation energy for Ethylene propylene = 0.95 eV.

K = Boltzmann's Constant = 0.8617×10^{-4} eV/°K

T_1 = service temperature = 120°F = 321.9 °K

T_2 = test temperature = 268°F = 404.1 °K

$$\ln\left(\frac{t_1}{72}\right) = \frac{0.95}{0.8617 \times 10^{-4}}\left(\frac{1}{321.9} - \frac{1}{404.1}\right)$$

$$= 6.96792$$

$$t_1 = 72 \times e^{6.96792}$$

$$= 7.6465 \times 10^4 \text{ hr}$$

$$= 8.73 \text{ yrs}$$

The acitivation energy of hydraulic fluid is higher than that of seals. Therefore the service life of hydraulic fluid is longer than 8.73 yrs. For conservatism, a 5-year replacement interval is recommended for both seals and hydraulic fluid.

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MIDLAND SNUBBER SEALS

ITEM	SEAL TITLE	LOCATION	FUNCTION-TYPE	SIZE	MANUFACTURER	COMPOUND	CURE METHOD
1	O'RING - OUTLET ADAPTER	RESERVOIR	STATIC - 'O' RING	1.737 I.D. x .103W	FEDERAL-MOGUL	E 50	EPDM-PEROXIDE
2	O'RING - DRAIN ADAPTER	RESERVOIR	STATIC - 'O' RING	.987 I.D. x .103W	FEDERAL-MOGUL	E 50	EPDM-PEROXIDE
3	O'RING - FILTER ADAPTER	RESERVOIR	STATIC - 'O' RING	.987 I.D. x .103W	FEDERAL-MOGUL	E 50	EPDM-PEROXIDE
4	O'RING - MTG. STUDS	SIGHT GLASS-RES.	STATIC - 'O' RING	.487 I.D. x .103W	FEDERAL-MOGUL	E 50	EPDM-PEROXIDE
5	O'RING - GLASS GAUGE	SIGHT GLASS-RES.	STATIC - 'O' RING	.299 I.D. x .103W	FEDERAL-MOGUL	E 50	EPDM-PEROXIDE
6	O'RING - CAP	SIGHT GLASS-RES.	STATIC - 'O' RING	.551 I.D. x .070W	FEDERAL-MOGUL	E 50	EPDM-PEROXIDE
7	O'RING - C.R. SEAL VALVE	TUBING RUN	STATIC - 'O' RING	.796 I.D. x .139W	FEDERAL-MOGUL	E 50	EPDM-PEROXIDE
8	O'RING - C.R. SEAL VALVE	TUBING RUN	STATIC - 'O' RING	.549 I.D. x .103W	FEDERAL-MOGUL	E 50	EPDM-PEROXIDE
9	EXTERNAL BEARING SEAL	MODEL 52 ONLY	STATIC - 'O' RING	VARIOUS	ACUSHNET	E 17018	EPDM-PEROXIDE
10	ROD SEAL	CYLINDER	DYNAMIC - LIP	VARIOUS	MINNESOTA RUBBER	559-EQ	EPDM-PEROXIDE
11	O'RING - END SEAL	CYLINDER	STATIC - 'O' RING	VARIOUS	ACUSHNET	E 17018	EPDM-PEROXIDE
12	ROD WIPER	CYLINDER	DYNAMIC - LIP	VARIOUS	MINNESOTA RUBBER	559-EQ	EPDM-PEROXIDE
13	PISTON SEAL	CYLINDER	DYNAMIC - U-CUP	VARIOUS	W.H. SALISBURY	80154	EPDM-SULFUR
14	O'RING - VALVE	TUBE CONN.	STATIC - 'O' RING	1.171 I.D. x .116W	FEDERAL-MOGUL	E 50	EPDM-PEROXIDE
15	O'RING - VALVE	RETAINER PL.	STATIC - 'O' RING	1.299 I.D. x .103W	FEDERAL-MOGUL	E 50	EPDM-PEROXIDE
16	THREAD SEAL	VALVE	STATIC - THREAD	.644 I.D. x .087W	FEDERAL-MOGUL	E 50	EPDM-PEROXIDE
17	THREAD SEAL	VALVE	STATIC - THREAD	1.299 I.D. x .103W	FEDERAL-MOGUL	E 50	EPDM-PEROXIDE
18	FILL PORT PLUG	CYLINDER	STATIC - 'O' RING	.644 I.D. x .087W	FEDERAL-MOGUL	E 50	EPDM-PEROXIDE
19	FILL PORT PLUG	CYLINDER	STATIC - 'O' RING	.755 I.D. x .097W	FEDERAL-MOGUL	E 50	EPDM-PEROXIDE

CYLINDER MODEL	QUANTITY OF SEALS
52	30
90	29

TABLE: 4

CPC-09-E.041
page 6 of 6
Rev. 1 1/6/83

NUTECH CALCULATION COVER SHEET

Title of Calculation: SURFACE TEMPERATURE ANALYSIS FOR THE ITT GRINNELL HYDRAULIC SNUBBERS

Project: MIDLAND PLANT, UNITS 1 & 2

Client: CONSUMERS POWER COMPANY File Number: CPC-09-E.040

Check as Applicable /✓/ Manual Calculation /__/ Computer Calculation

Method: THIS CALCULATION UTILIZES CONVECTIVE AND CONDENSING HEAT TRANSFER EVALUATIONS FOR SURFACE TEMPERATURE ANALYSES OF THE SUBJECT EQUIPMENT UNDER POSTULATED MSLB CONDITIONS FOR THE MIDLAND PLANT.

Assumptions: SEE PAGE 4 OF 20

References: SEE PAGE 5 of 20

Computer Run Information: (future revision changes shall be shown in the body of the calculation)

Computer Run Document Number: ______ Date: ______

Computer Program: ______ Version: ______

QA Category (QEP 3-5): ______ Verified: /_/YES /_/No

Operating System: ______ Version: ______

Tape Number: ______ Date: ______

Calculation Revision	Description of Change	Approval Signature	Date
0	N/A	[signature] [signature]	1/20/83 1/24/83

NUTECH CALCULATION VERIFICATION SHEET

TITLE: SURFACE TEMPERATURE ANALYSIS FOR THE ITT GRINNELL HYDRAULIC SNUBBERS

PROJECT: MIDLAND PLANT, UNITS 1 & 2

CLIENT: CONSUMERS POWER COMPANY FILE NUMBER: CPC-09-E.040

Method of Verification (Check as applicable)

/✓/ Criteria Check*

/__/ Alternate Calculation (attached)

/__/ Design Review

/__/ Qualification Testing

/__/ Other: MARKED UP CALCULATION IN ACCORDANCE WITH 3-2 IF APPLICABLE

Note: An accuracy check must be performed of all work.

*The signature below signifies that this calculation has received design verification by a criteria check. No other signature will be shown on the individual sheets to document this verification.

Revision	Signature	Revision	Signature
0	Walter R Kelley		

Personnel Identification

All personnel participating in preparing, checking and approving this calculation most enter the below information.

Name (Printed)	Signature	Initials	Employee No.
M. ROSA LEE	M Rosa Lee	MRL	0838
W. R. KELLEY	Walter R Kelley	WRK	0803
P. A. DiBENEDETTO	P.A. DiBenedetto	PDB	0593

nutech
Bethesda, Maryland

PROJECT Midland Units 1 & 2 FILE NO. CPC-09-E.040
OWNER Consumers Power Co.
CLIENT Consumers Power Co.

Purpose

The purpose of this calculation is to determine the surface temperature of the hydraulic snubber seals during an MSLB environment (which envelops LOCA temperature profile). The NRC CSB-IEM method is used to determine the maximum surface temperature.

Results

The results are shown on pages 10 & 11

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Bethesda, Maryland

PROJECT: Midland Units 1 & 2 FILE NO. CPC-09-E.040
OWNER: Consumers Power Co.
CLIENT: Consumers Power Co.

Assumptions:

1. The initial temperature of the seals T_o is 120°F (was given as the maximum normal surface temperature)

2. The convective heat transfer coefficient $h = 250$ Btu/(hr-ft²-°F) has been assumed constant whenever the condensing heat flux is less than the convective heat flux. The condensing heat flux will be calculated based on the four times of the Tagami condensing heat transfer coefficient taken from figure 3 which is from figure A-1 of Reference 2.

3. The transient bulk temperature profile is shown on figure 1 which is from Midland figure F2 of Reference 2.

4. The equivalent thermal conductivity K_e is determined based on the composite wall model.

5. The equivalent $(\rho C_p)_e$ (the product of material specific heat and density) is determined based on the composite wall model.

6. The temperature rise of the object after being exposed 1 second of a sudden change of outside environmental temperature is slow enough to be overridden by the temperature rise resulted from the next sudden change of outside temperature.

7. The equivalent K_e and $(\rho C_p)_e$ are used to determine the surface temperature of the Neutron detector, e.g. the heat transferred through a composite wall with different Ks and (ρC_p)'s is equivalent to the heat transferred through a single wall with K_e and $(\rho C_p)_e$

8. The environmental steam partial pressure is equal to the containment pressure.

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PROJECT Midland Units 1 & 2 FILE NO. CPC-09-E.040
OWNER Consumers Power Co.
CLIENT Consumers Power Co.

References

1. Kreith, Frank: "Principles of Heat Transfer" International Textbook Company, Scranton, PA 1965.

2. Midland 1 & 2 - FSAR Equipment Qualification, Report on Equipment Qualification for Main Steam Line Break Conditions.

3. Holman, J.P.: "Heat Transfer" McGraw Hill, Inc, 1968

4. Crane: "Flow of Fluids Through Valves, Fittings, and Pipe" Technical paper No 410.

5. NUREG 0588, "Interim Staff Position on Environmental Qualification of Safety-Related Electrical Equipment". Rev. 1, Jul 1981.

6. Keenan, Keyes, Hill, and Moore, "Steam Table" John Wiley & Sons, Inc. 1969

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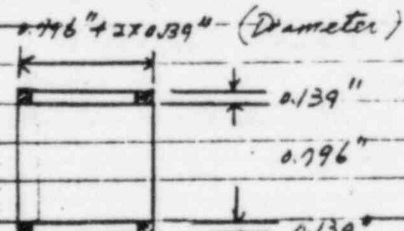
Bethesda, Maryland

PROJECT Midland Units 1 & 2 FILE NO. CPC-09-E.040
OWNER Consumers Power Co.
CLIENT Consumers Power Co.

Introduction

Non-metallic components of the ITT Grinnell Hydraulic Snubber consist of hydraulic fluid and seals at various location. The seals are listed on page 18 and their locations are shown on page 19. The seals are made of EPDM (a Ethylene propylene based material) Item 7 of the list on page 18 is the one that is direct exposed to the accident environment and has the least heat conductive material next to it. For conservatism, the surface temperature determined for No 7 seal will be compared to the temperature of 350 °F which is recognized as maximum service temperature* of EPDM by the industry. The dimension of the circle seal valve (to which No 7 seal is attached) is sketched as follow:



* for continuous use

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Material properties

(1) Ethylene - propylene

$K = 0.19$ Btu/hr - ft - °F Reference 2, page 16

$C_p = 0.65$ Btu/lb - °F Reference 2, page 16

$\rho = 81.1$ lbm/ft³ Reference 2, page 16

$(\rho C_p)_{seal} = 52.7$ Btu/ft³ - °F Reference 2, page 16

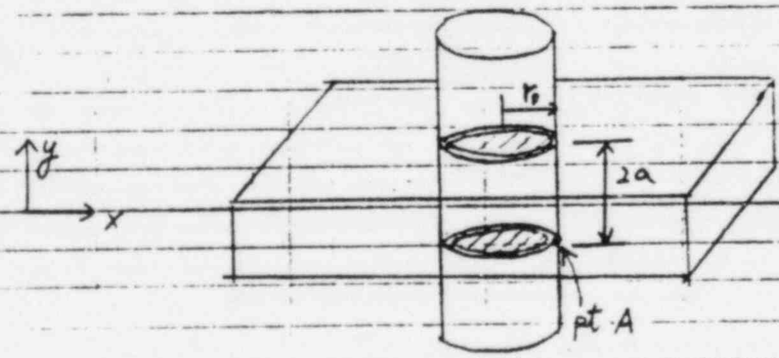
(2) Stainless Steel

$K = 10.0$ Btu/hr - ft - °F

$(\rho C_p)_{valve\ body} = 54.0$ Btu/ft³ - °F Reference 2, page 18

Calculation

This problem is treated as a finit cylinder subject to an MSLB temperature exposure.



$2a = 0.796 + 0.139 \times 2 = 1.074$

$a = 0.537$

$r_0 = \frac{0.796 + 0.139}{2}$

$= 0.537''$

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PROJECT Midland Units 1 & 2 FILE NO. CPC-09-E.040
OWNER Consumers Power Co.
CLIENT Consumers Power Co.

$$K_e = \frac{0.796 + 2\times0.139}{\frac{0.796}{10} + \frac{2\times0.139}{0.19}} = 0.6962$$

$$(\rho C_p)_e = \frac{1.074}{\frac{0.796}{54.0} + \frac{0.278}{52.7}} = 53.657$$

For X-direction

Fourier modulus F_o for $\tau = 1$ sec

$$F_o = \frac{K_e \cdot \tau}{(\rho C_p)_e \cdot r_o^2} = \frac{0.6962 \cdot 1/3600}{53.657 \cdot \left(\frac{0.537}{12}\right)^2} = 1.8\times10^{-3}$$

Biot modulus B_i for $h = 250$ Btu/hr-ft²-°F (convective heat transfer coefficient)

$$B_i = \frac{h r_o}{K_e} = \frac{250 \cdot \frac{0.537}{12}}{0.6962} = 16.069$$

$$B_i^{-1} = 6.22\times10^{-2} = 0.0622$$

For y-direction

Fourier modulus F_o for $\tau = 1$ sec

$$F_o = \frac{K_e \cdot \tau}{(\rho C_p)_e\, a^2} = 1.8\times10^{-3}$$

Biot modulus B_i for $h = 250$ Btu/hr-ft²-°F

$$B_i = \frac{h a}{K_e} = 16.069$$

$$B_i^{-1} = 0.0622$$

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PREPARED BY / DATE	HKL 1/5/83					OF 20
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PROJECT: Midland Units 1 & 2   FILE NO. CPC-09-E.040
OWNER: Consumers Power Co.
CLIENT: Consumers Power Co.

To calculate the temperature at pt. A (the surface of the seals) the relationship $T_s = \theta(T_o - T_\infty) + T_\infty$ and figures 1, 2, 3 and 4 are used. Here:

$$\theta_{cyl\ 2a\ long} = \theta_{infinite\ cyl} \cdot \theta_{2a\ plate}$$

$$\theta = \theta_x \cdot \theta_y$$

From figure 2, page 15

$\theta_x = 0.985$ from $r/r_o = 1.0$ chart

From figure 3, page 16

$\theta_y = 0.99$ from $x/L = 1.0$ chart

$\therefore \theta = 0.985 \times 0.99 = 0.975$

at $t = 0$ seal surface $= 120°F$ $T_\infty = 120°F$

$t = 1$ seal surface $= 120°F$ $T_\infty = 230°F$

$t = 2$ $\tau = 1$ $\theta = 0.975$ $T_\infty = 230$ @ $t = 1$ from figure 1

$T_s = 0.975(120 - 230) + 230 = 122.8$ °F

$t = 3$ $\tau = 1$ $\theta = 0.975$ $T_\infty = 290$ @ $t = 2$ from figure 1

$T_s = 0.975(122.8 - 290) + 290 = 126.9$ °F @ $t = 3$

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CHECKED BY / DATE	[illegible] 1/20/83	

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Bethesda, Maryland

PROJECT: Midland Units 1 & 2 FILE NO. CPC-09-E.040

OWNER: Consumers Power Co.

CLIENT: Consumers Power Co.

The surface temperature of the seal was determined by the above procedure and the total conductive heat flux is compared to the condensing heat flux which is calculated by the relationship of $Q/A = h_{cond}(T_{sat} - T_S)$ where h_{cond} = condensing heat transfer coefficient is equal to the lager of 4 times of Tagami correlation or 4 times Uchida correlation from figure 4, page 17, T_{sat} = saturation temperature corresponding to the containment pressure from figure 1, page 14. In any case of that the condensing heat flux is greater than the convective heat flux calculated by h_{conv} = 250 Btu/hr-ft^2-°F, the surface temperature will be recalculated by using the more conservative heat transfer coefficient. The table a next page summarizes the results.

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Bethesda, Maryland

PROJECT: Midland Units 1 & 2 FILE NO. CPC-09-E.040

OWNER: Consumers Power Co

CLIENT: Consumers Power Co

Table 1

	(1) t (sec)	(2) t-1 (sec)	(3) T_∞ @ t-1 (°F)	(4) T_s @ t (°F)	(5) $(Q/A)_{conv}$ (10^4 Btu/ft²)	(6) $P_{containment}$ (psig)	(7) T_{sat} (°F)	(8) h_{cond} (Btu/hr-ft²-°F)	(9) 4 × h_{cond} (Btu/hr-ft²-°F)	(10) $(Q/A)_{cond}$ (10^4 Btu/ft²)
	0	—	—	120	—	—	—	—	—	—
	1	0	120	120	2.75	7.0	232.3	24	96	1.07
	2	1	230	122.8	4.18	14.2	247.8	38	152	1.90
	3	2	290	126.9	5.20	18.5	256.2	52	208	2.69
	4	3	335	132.1	5.82	27.5	270.5	73	292	4.04
	5	4	365	138.0	6.30	33.0	278.1	88	352	4.93
	6	5	390	144.3	6.64	38.5	285.0	105	420	5.91
	7	6	410	150.9	6.98	42.0	289.1	121	484	6.69
	8	7	430	157.9	7.05	45.5	293.0	137	548	7.40
*	8	7	430	159.3	8.42	45.5	293.0	137	548	7.33
	9	8	440	167.7	8.46	48.5	296.1	151	604	7.76
	10	9	450	176.2	8.21	51.0	298.7	167	668	8.18
	11	10	450	184.4	7.97	52.0	299.7	187	748	8.62
**	11	10	450	185.5	9.26	52.0	299.7	187	748	8.54
	12	11	450	194.5	8.94	53.0	300.7	201	804	8.54
	13	12	450	203.2	8.64	54.0	301.7	215	860	8.47
	14	13	450	211.6	8.34	54.5	302.2	230	920	8.33
	15	14	450	219.7	8.06	55.5	303.2	250	1000	
***	15	14	450	219.9	8.62	55.5	303.2	250	1000	8.33
****	25	24	450	230.2	5.50	56.0	303.7	160	640	4.70
	35	34	450	240.0	5.25	58.0	305.5	100	400	2.62
	45	44	450	249.4	5.02	57.0	304.6	100	400	2.21
	55	54	425	257.2	4.20	56.0	303.7	100	400	1.86
	65	64	415	264.2	3.77	52.0	299.7	100	400	1.42
	75	74	410	270.7	3.48	50.0	297.7	100	400	1.08
	85	84	405	276.7	3.21	71.08		100	400	

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Table 1 continues

t	$t-1$	T_{od}	T_s	$(Q/A)_{conv.}$	P	T_{sat}	$h_{cond.}$	$u \times h_{cond}$	$(Q/A)_{cond}$
95	94	400	282.2	2.95					
105	104	395	287.2	2.70					
115	114	390	291.8	2.46					
125	124	385	295.9	2.23					
135	134	380	299.7	2.01					
145	144	375	303.0	1.80					
155	154	370	306.0	1.60					
165	164	365	308.7	1.40	> $(Q/A)_{cond}$ and T_s > T_{sat} ∴ no condensing will occur.				
175	174	360	310.9						
185	184	355	312.9						
195	194	350	314.6						
205	204	345	315.9						
215	214	342.5	317.1						
225	224	340	318.1						
235	234	337.5	319.0						
245	244	335	319.7						
255	254	332.5	320.2						
265	264	330	320.7						
275	274	327.5	321.0						
285	284	325	321.2	} maximum surface temperature					
295	294	322.5	321.2						
305	304	320	321.2						
315	314	317.5	321.0						
325	324	315.0	320.7						

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Explanatory note for Table 1

col:

(1) time t

(2) time $t-1$

(3) Environmental temperature T_∞ from figure 1, page

(4) $T_S @ t = \theta \cdot (T_S @ t-1 - T_\infty @ t-1) + T_\infty @ t-1$

(5) $(Q/A)_{conv.} = h \times (T_\infty - T_S) @ t$ — initially $h = 250$

(6) $P_{containment}$ from figure 1

(7) $T_{sat} = f(P_{containment})$ from steam Table

(8) condensing heat transfer coefficient from figure 4, page

(9) $4 \times$ col (8)

(10) $(Q/A)_{cond} = $ col (9) $\times$ (col (7) - col (4))

* $t = 8$ — $h = 300$ — $B_i = 19.283$ — $B_i^{-1} = 0.051$
$\theta_x = 0.98$, $\theta_y = 0.99$ $\Rightarrow \theta = 0.970$

** $t = 11$ — $h = 350$ — $B_i = 22.69$ — $B_i^{-1} = 0.044$
$\theta_x = 0.978$, $\theta_y = 0.988$ $\Rightarrow \theta = 0.966$

*** $t = 15$ — $h = 375$ — $B_i = 24.10$ — $B_i^{-1} = 0.042$
$\theta_x = 0.977$, $\theta_y = 0.988$ $\Rightarrow \theta = 0.965$

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**** $T = 10$ sec $h = 250$

$$F_o = \frac{K_c \cdot T}{(\rho C_p) \cdot r_i^2} = 1.8 \times 10^{-2}$$

$B_i = 16.069$ from page

$B_i^{-1} = 0.0622$

$\theta_x = 0.970$

$\theta_y = 0.985$

$\theta = 0.97 \cdot 0.985 = 0.9555$

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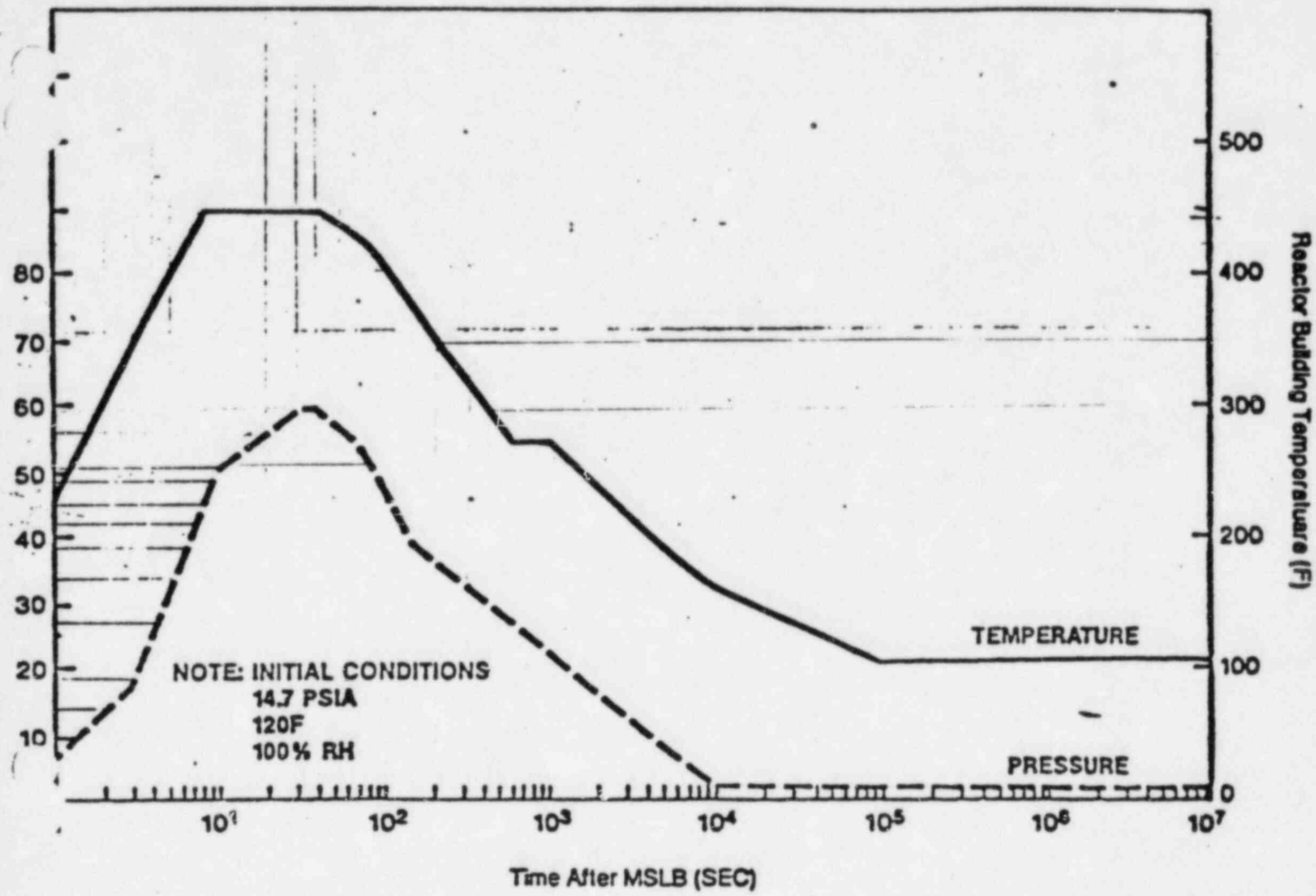

Figure 1.

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CONSUMERS POWER COMPANY MIDLAND UNITS 1 AND 2
Reactor Building Pressure and Temperature vs Time After MSLB
F2

63-G-2536-41

Program Revision 0
10/82

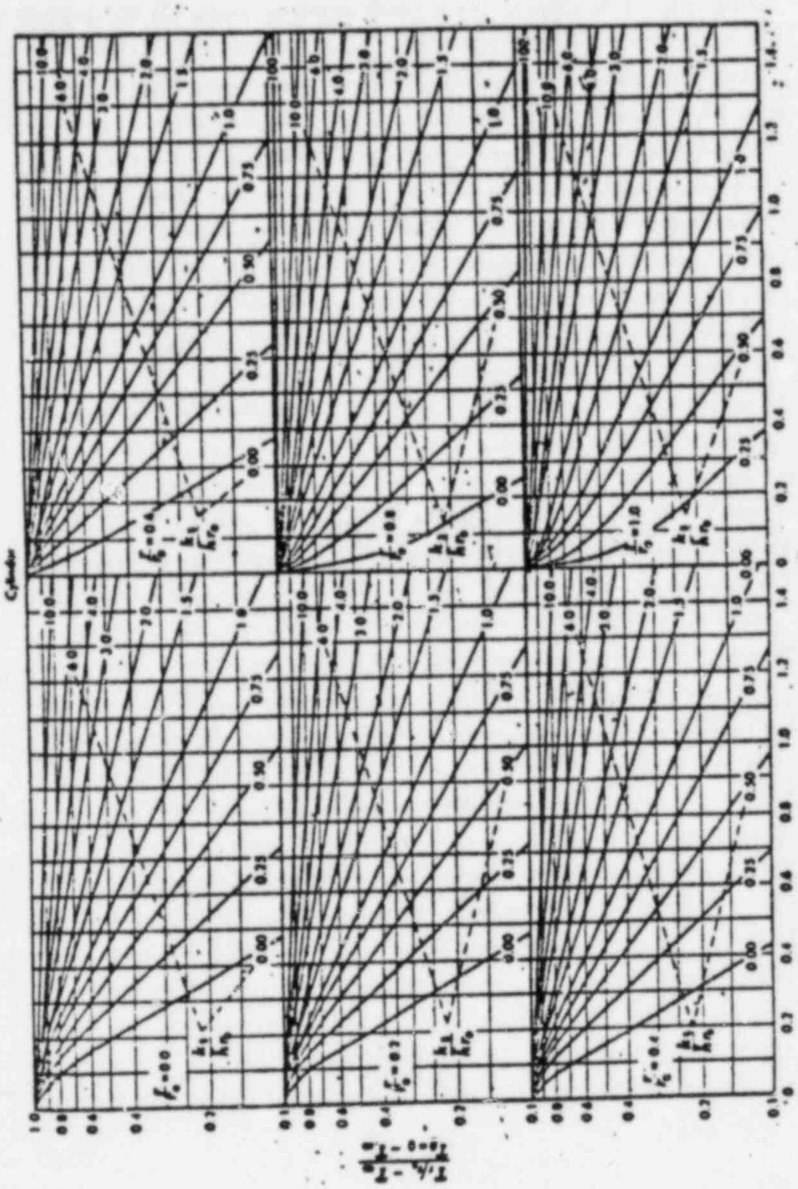

FIG. 4-10. Dimensionless temperature distribution in a long circular cylinder subjected to a sudden change in environmental temperature. (By permission from L. M. K. Boelter, V. H. Cherry, and H. A. Johnson, *Heat Transfer*, 3d ed., 1942)

Figure 2

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MFL 1/7/83
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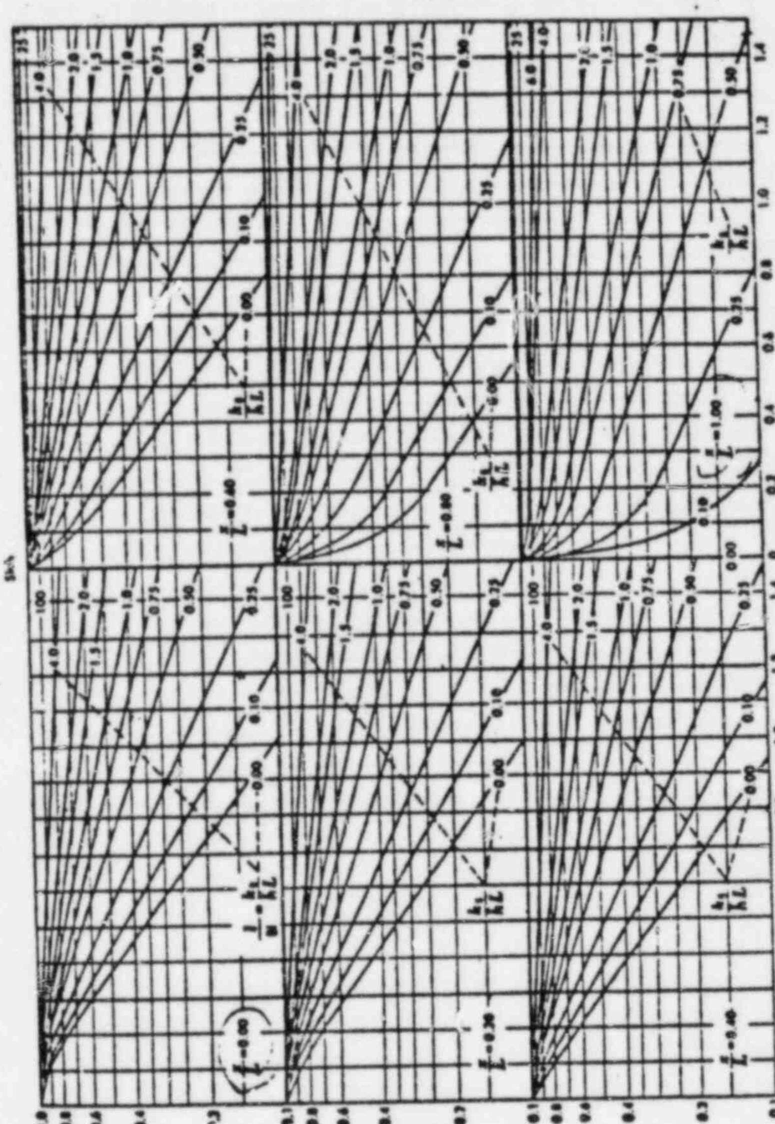

Fig. 4-8. Dimensionless temperature distribution in a wall subjected to a sudden change in environmental temperature.

Figure 3

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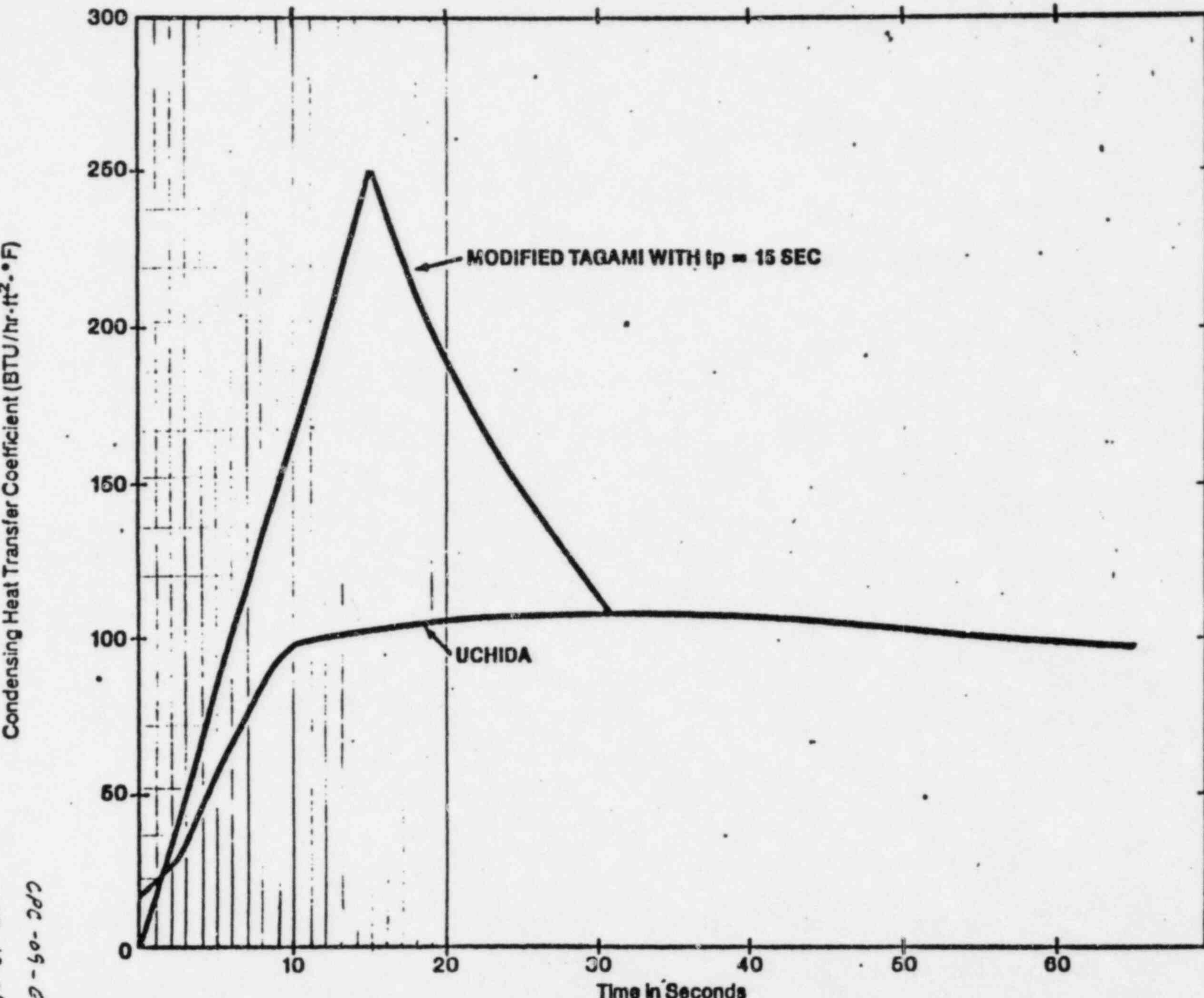

COMPARISON OF MODIFIED TAGAMI HEAT TRANSFER COEFFICIENT WITH UCHIDA HEAT TRANSFER COEFFICIENT

Figure A.1

Figure 4

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MIDLAND SNUBBER SEALS

ITEM	SEAL TITLE	LOCATION	FUNCTION-TYPE	SIZE	MANUFACTURER	COMPOUND	CURE METHO
1	'O'RING - OUTLET ADAPTER	RESERVOIR	STATIC - 'O' RING	1.737 I.D. x .103W	FEDERAL - MOGUL	E 50	EPDM - PEROXIDE
2	'O'RING - DRAIN ADAPTER	RESERVOIR	STATIC - 'O' RING	.987 I.D. x .103W	FEDERAL - MOGUL	E 50	EPDM - PEROXIDE
3	'O'RING - FILLTER ADAPTER	RESERVOIR	STATIC - 'O' RING	.987 I.D. x .103W	FEDERAL - MOGUL	E 50	EPDM - PEROXIDE
4	'O'RING - MTG. STUDS	SIGHT GLASS-RES.	STATIC - 'O' RING	.487 I.D. x .103W	FEDERAL - MOGUL	E 50	EPDM - PEROXIDE
5	'O'RING - GLASS GAUGE	SIGHT GLASS-RES.	STATIC - 'O' RING	.299 I.D. x .103W	FEDERAL - MOGUL	E 50	EPDM - PEROXIDE
6	'O'RING - CAP	SIGHT GLASS-RES.	STATIC - 'O' RING	.551 I.D. x .070W	FEDERAL - MOGUL	E 50	EPDM - PEROXIDE
7	'O'RING - CIR. SEAL VALVE	TUBING RUN	STATIC - 'O' RING	.796 I.D. x .139W	FEDERAL - MOGUL	E 50	EPDM - PEROXIDE
8	'O'RING - CIR. SEAL VALVE	TUBING RUN	STATIC - 'O' RING	.549 I.D. x .103W	FEDERAL - MOGUL	E 50	EPDM - PEROXIDE
9	EXTERNAL BEARING SEAL	MODEL 52 ONLY	STATIC - 'O' RING	VARIOUS	ACUSHNET	E 17018	EPDM - PEROXIDE
10	ROD SEAL	CYLINDER	DYNAMIC - LIP	VARIOUS	MINNESOTA RUBBER	559-EQ	EPDM - PEROXIDE
11	'O'RING - END SEAL	CYLINDER	STATIC - 'O' RING	VARIOUS	ACUSHNET	E 17018	EPDM - PEROXIDE
12	ROD WIPER	CYLINDER	DYNAMIC - LIP	VARIOUS	MINNESOTA RUBBER	559-EQ	EPDM - PEROXIDE
13	PISTON SEAL	CYLINDER	DYNAMIC - U-CUP	VARIOUS	W.H. SALISBURY	80154	EPDM - SULFUR
14	'O'RING - VALVE	TUBE CONN.	STATIC - 'O' RING	1.171 I.D. x .116W	FEDERAL - MOGUL	E 50	EPDM - PEROXIDE
15	'O'RING - VALVE	RETAINER PL.	STATIC - 'O' RING	1.299 I.D. x .103W	FEDERAL - MOGUL	E 50	EPDM - PEROXIDE
16	THREAD SEAL	VALVE	STATIC - THREAD	.644 I.D. x .087W	FEDERAL - MOGUL	E 50	EPDM - PEROXIDE
18	THREAD SEAL	VALVE	STATIC - THREAD	1.299 I.D. x .103W	FEDERAL - MOGUL	E 50	EPDM - PEROXIDE
17	FILL PORT PLUG	CYLINDER	STATIC - 'O' RING	.644 I.D. x .087W	FEDERAL - MOGUL	E 50	EPDM - PEROXIDE
19	FILL PORT PLUG	CYLINDER	STATIC - 'O' RING	.755 I.D. x .097W	FEDERAL - MOGUL	E 50	EPDM - PEROXIDE

CYLINDER MODEL	QUANTITY OF SEALS
52	30
90	29

TABLE: 4

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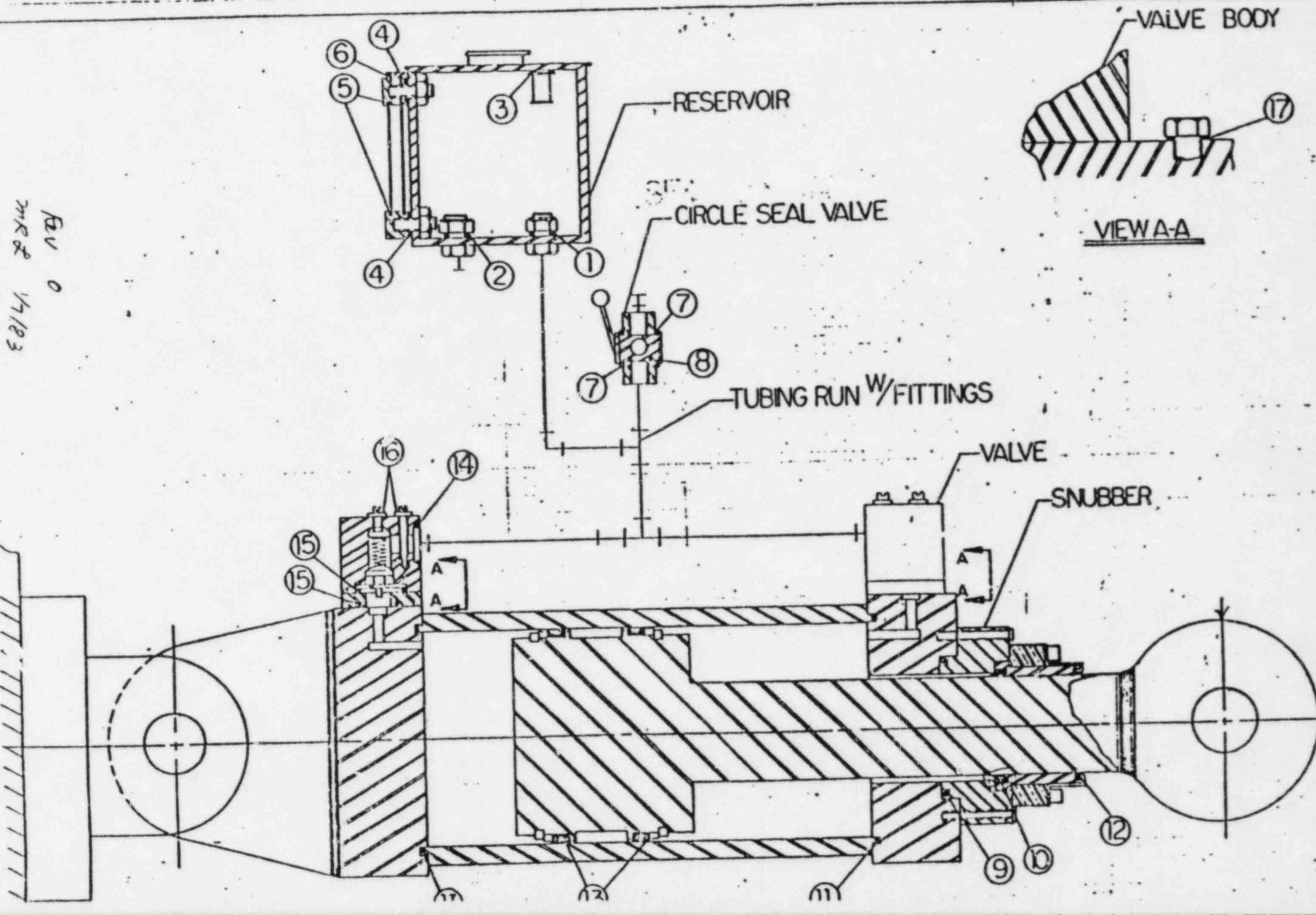

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Reference 18

Midland Plant, Units 1 & 2 Environmental Qualification Report, Vol. I, Revision 1, December 1982.