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ACCESSION NBR: 8701210149 DOC. DATE: 87/01/15 NOTARIZED: YES DOCKET #
FACIL: 50-410 Nine Mile Point Nuclear Station, Unit 2, Niagara Moha 05000410
AUTH. NAME AUTHOR AFFILIATION
MANGAN, C. V. Niagara Mohawk Power Corp.
RECIP. NAME RECIPIENT AFFILIATION
Record Services Branch (Document Control Desk)

see Rop S

SUBJECT: Forwards design change for power supply to MSIV actuator solenoids, per IEEE 279 & GDC 21 to 10CFR50, App A. Response to NRC 870109 concerns also encl. Info will be incorporated into next rev to FSAR.

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NIAGARA MOHAWK

NIAGARA MOHAWK POWER CORPORATION/301 PLAINFIELD ROAD, SYRACUSE, N.Y. 13212/TELEPHONE (315) 474-1511

January 15, 1987
(NMP2L 0973)

U.S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, D.C. 20555

Re: Nine Mile Point Unit 2
Docket No. 50-410

Gentlemen:

In the meeting of January 6, 1987, between Niagara Mohawk and members of your staff, the Nuclear Regulatory Commission expressed concerns with the current design for the power supply to the Main Steam Isolation Valve (MSIV) actuator solenoids.

Attachment 1 to this letter provides a design change to the method of supplying power to the actuator solenoids. Attachment 2 provides responses to the concerns raised by your staff about the revised design during a conference call on January 9, 1987.

Niagara Mohawk believes the revised design being implemented at Nine Mile point Unit 2 meets all requirements of IEEE 279 and General Design Criteria 21 to 10CFR50 Appendix A. It also addresses all prior concerns raised by the Nuclear Regulatory Commission. The revised design will be incorporated into the next update of the Final Safety Analysis Report.

Very truly yours,

CVMangan
C. V. Mangan
Senior Vice President

TS/pns
2440G
Attachment

xc: Regional Administrator, Region I
Ms. E. G. Adensam, Project Director
Mr. W. A. Cook, Resident Inspector
Project File (2)

B001
1/1

8701210149 870115
PDR ADOCK 05000410
P PDR

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

In the Matter of	]	
	]	
Niagara Mohawk Power Corporation	]	Docket No. 50-410
	]	
(Nine Mile Point Unit 2)	]	

AFFIDAVIT

C. V. Mangan, being duly sworn, states that he is Senior Vice President of Niagara Mohawk Power Corporation; that he is authorized on the part of said Corporation to sign and file with the Nuclear Regulatory Commission the documents attached hereto; and that all such documents are true and correct to the best of his knowledge, information and belief.

C Mangan

Subscribed and sworn to before me, a Notary Public in and for the State of New York and County of Onondaga, this 15th day of January, 1987.

Beth Menikheim
Notary Public in and for
Onondaga County, New York

My Commission expires:

BETH A. MENIKHEIM
Notary Public in the State of New York
Qualified in Onondaga County No. 4804074
My Commission Expires August 31, 19.88

ATTACHMENT 1

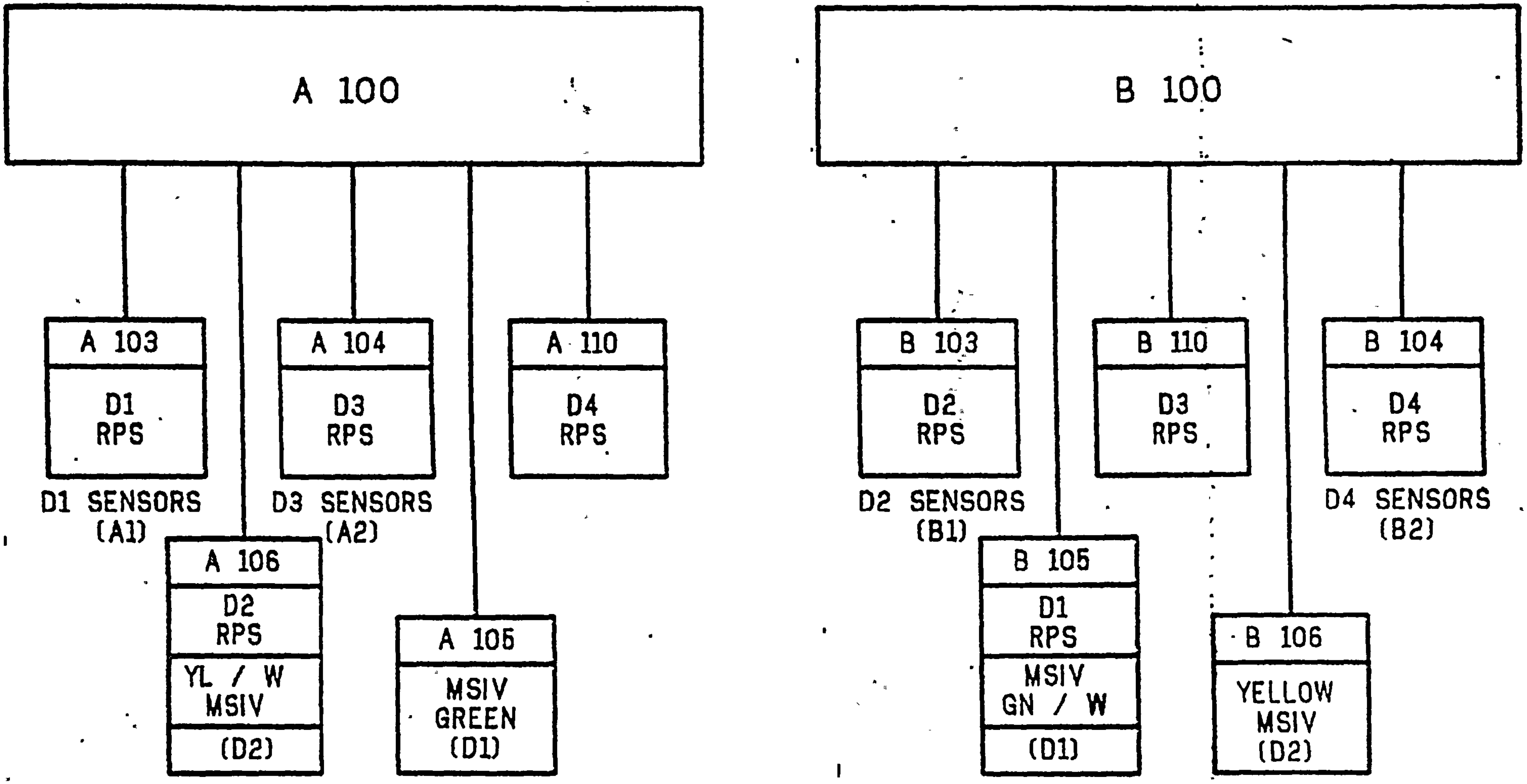
REVISED MSIV ACTUATOR CONTROL POWER SCHEME

The attached sketches show the revised method of supplying the electrical solenoids associated with the MSIVs. No transfer will exist between UPS3A and UPS3B. In addition, the transfer that formerly existed to test the solenoid (SVC) has also been removed. Therefore, if either UPS supply is lost, no transfer will occur.

On January 6, 1987, we discussed using an appropriate isolation switch for bus transfer that could be administratively closed during surveillance testing. We indicated during this meeting that prior to implementing this approach a full evaluation of the design would be performed to minimize undesirable operation scenarios. We have completed this evaluation and determined that the drawbacks associated with the required administrative controls, and the need to address the isolation of the MSIV by the spurious trip of a single sensor, are undesirable. We have, therefore, prepared the attached design to eliminate both of the above stated drawbacks.

The proposed design precludes closure of the MSIVs caused by a single actuation of a NS4 sensor. It will also allow Niagara Mohawk Power Corporation to perform their technical specification required surveillance without requiring an administratively controlled bus transfer. We believe that these new design features meet all regulatory requirements and fulfill our commitments, per Nine Mile Point Unit 2 Final Safety Analysis Report Responses to Questions 421.24, 421.25 and satisfies the Safety Evaluation Report Supplement 3 (SSER 3), Section 7.3.2.5.

RPS / MSIV POWER SUPPLY



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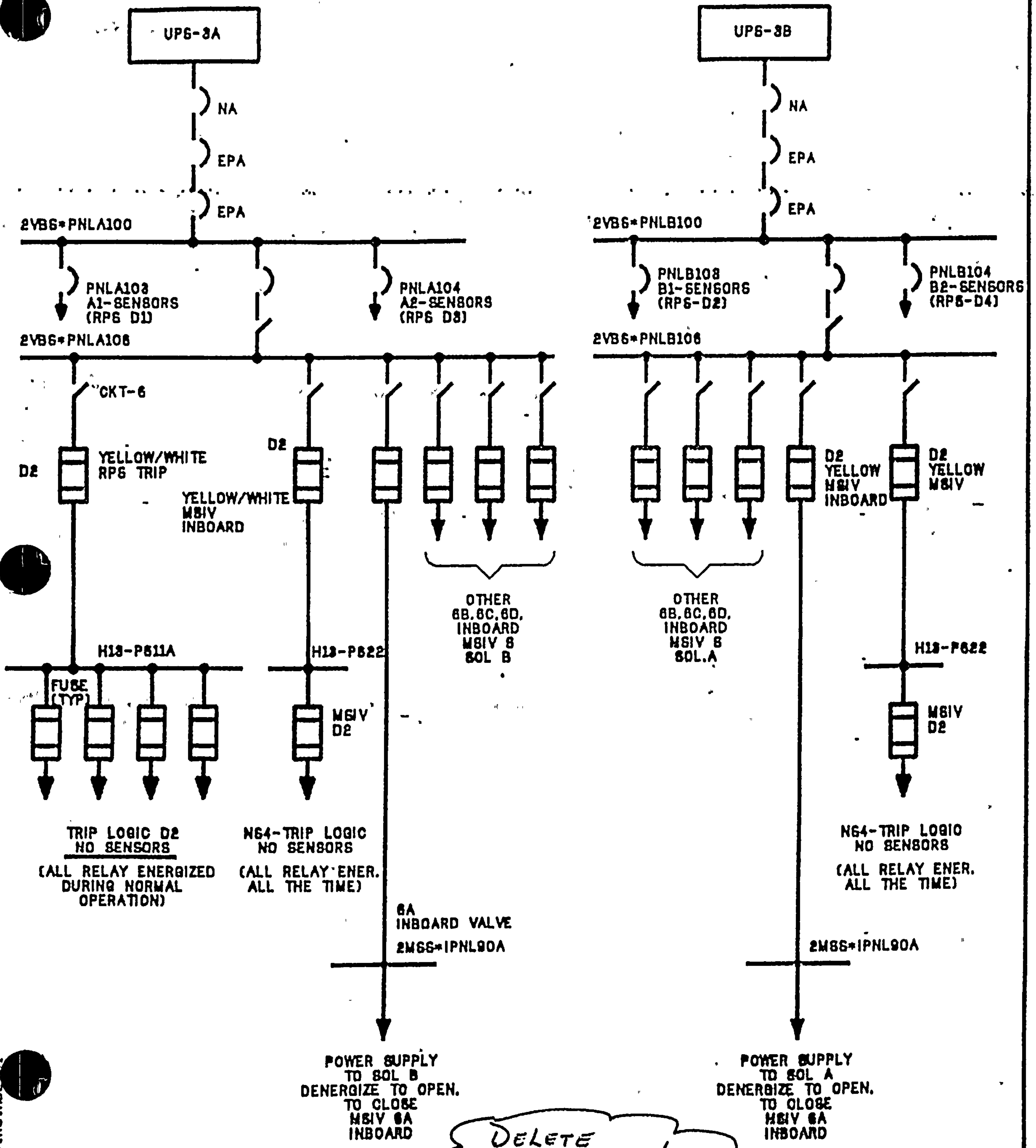
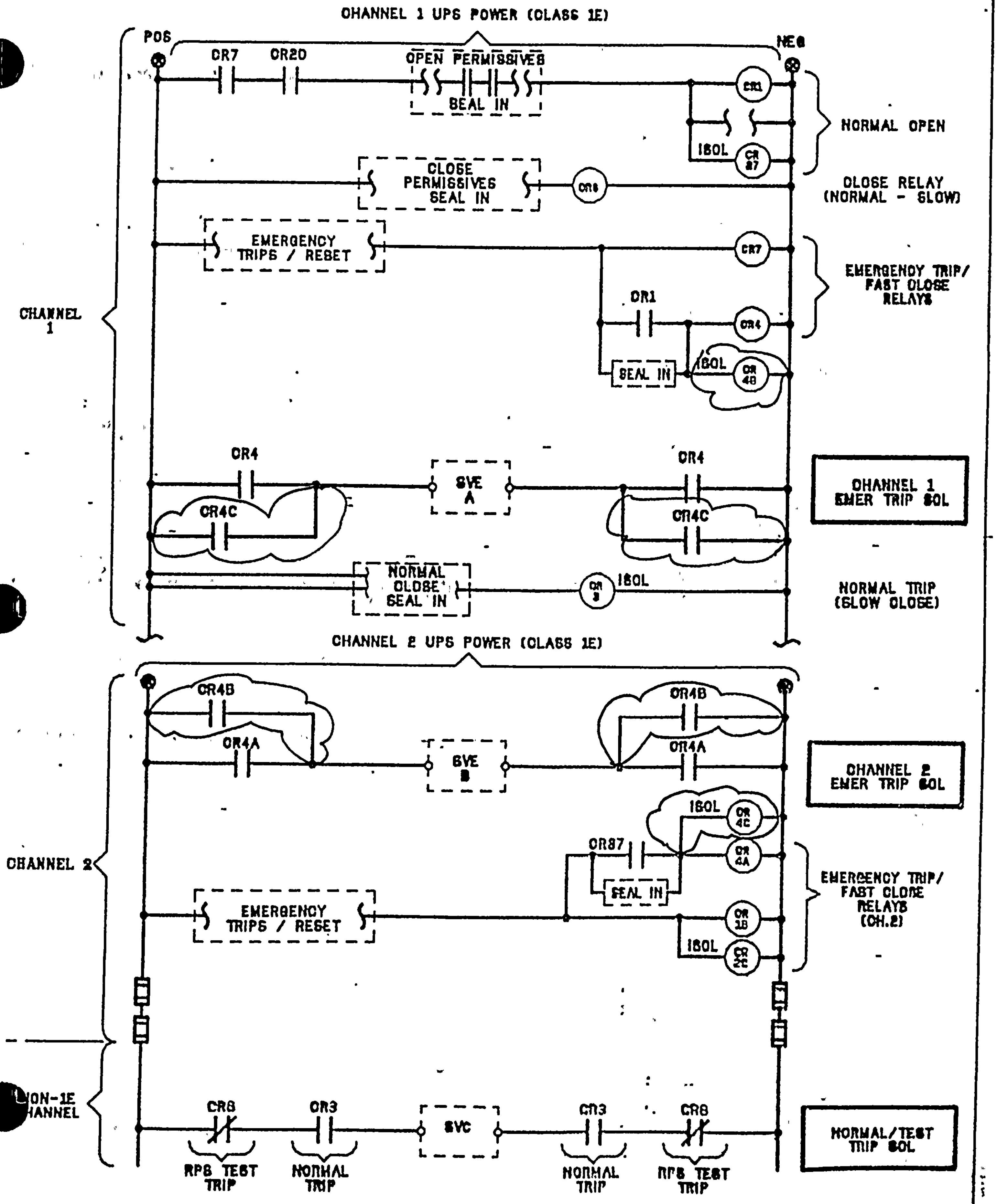
POWER Transfer

POWER SUPPLY MSIV TRIP LOGIC



DELETE
Power Transfer

MSIV REVISED CIRCUITRY



ATTACHMENT 2

During a telephone conversation with members of your staff on 1/9/87, we discussed a proposed revision to the MSIV actuator circuitry described in Attachment 1. A request for additional information and clarification was made. The following responds to these requests/clarifications.

I. ITE/TELEMECHANIQUE (GOULD) TYPE J10 RELAYS USED FOR ISOLATION

The vendor supplied design for the original MSIV mechanical latch trip actuator control logic utilized the subject relays for coil-to-contact isolation between Logic channels 1 and 2, and between the Non-1E Logic Channel and Channel 1.

The proposed logic circuits for the hydraulic actuators also utilize these relays in the same manner, although in some cases they perform different functions.

Regardless of function, the mounting configuration for the relays remains the same, with the relay coil on one side of a metal barrier and the contacts on the opposite side. Barrier penetration is made only by the mechanical operating shaft of the relay which is non-metallic. Minimum physical separation of coil and contacts is maintained.

Propagation of postulated fault currents from relay coil to contacts, or vice versa, is not possible. The enclosed information on relay qualification, provides the technical and testing justification for this application of J10 relays.

II. USE OF DOUBLE FUSES INTERRUPTING DEVICES AS ISOLATION DEVICES

The new actuator control circuit meets the Unit 2 Licensing commitment described in the Final Safety Analysis Report. A detailed comparison of the NMP2 design to the criteria contained in Regulatory Guide 1.75 "Physical Independence of Electrical Systems" and IEEE 384, "IEEE

Trial-Use Standard Criteria for Separation of Class 1E Equipment and Circuits" was provided to the NRC staff in Questions and Responses F421.47. The comparison was made both for Power Generation Control Complex and balance of plant to show that NMP2 meets the requirements of the above mentioned documents. As explained on page 1 of 17, Table 421.47-1, NMP2 is using two interrupting devices actuated by fault current to isolate non-class 1E devices and circuits from Class 1E circuits only in the case of control and instrument circuits. Fuses are used as interrupting devices. These fuses are Class 1E and both are coordinated with the upstream protective devices. This approach is documented under NMP2 compliance to Regulatory Guide 1.75, Regulatory Position C1 in FSAR Section 1.8, page 89 of 169. The use of two 1E fuses was accepted by the NRC staff as documented in Supplement 4 of SER, Section 8.4.5, page 8-3.

Additionally, the use of two Class 1E interrupting devices to isolate Class 1E circuits and components from non-class 1E circuits and components within the RPS system has been specifically addressed and accepted by the NRC staff, as documented in Supplement 5 of SER, Section 7.2.2.10, page 7-2 (Instrumentation and Controls Reactor Trip system).

III. Main Steam Isolation Valve Testing

The present commitment for testing the MSIVs involves a monthly partial stroke test and a full stroke test at each cold shutdown. The partial stroke test verifies the MSIV input to the RPS scram logic circuit and the full stroke test verifies MSIV operability under emergency trip conditions. This testing is consistent with industry practice for Y-pattern globe valves used in BWR's. The difference between testing the current design and the original mechanical latch design relates to the ability to de-energize one of the hydraulic solenoids. With the previous design, the main steam isolation valve would not close with a single solenoid de-energized. With the new design, the actuation of one solenoid causes a full closure of the valve. Therefore, the logic change shown in Attachment 1 (CR4C and CR4B) was included. This allows

testing in conformance with Regulatory Guide 1.118 and Technical Specifications. For both the NMP2 ball valve and the industry's Y-pattern globe valve, the valve full closure test occurs during cold shutdown. This verifies correct performance of the actuator solenoids and main steam isolation valves.

Results obtained from our testing is consistent with the results obtained from the current staff approved industry testing practice. Solenoid valves supplied with both Rockwell & Atwood-Morrill Y-pattern valves are not provided with valve position indication. Because of the location of these solenoids, without position indication, positive confirmation of position change is not practical. Therefore, the only positive confirmation of the functioning of these valves is during each refueling outage test. NMP2 results will be the same. The probability that the protection system will fail to operate is the same as previously provided. As a comparison, the series valve arrangement contained in the Y-pattern globe valve requires actuation of both solenoid valves to operate the MSIV.

IV. QUALITY OF SOLENOID "SVC" AND NON-1E CHANNEL

The Non-1E Channel is basically the same configuration for the hydraulic actuator as it was for the original Mechanical latch trip actuator. This portion of the control circuit is considered Non-1E since operation of solenoid "SVC" is not required for safe shutdown. However, the quality of Non-1E components and their installation approach the level of quality achieved in the Class 1E circuits.

The vendor supplied Non-1E components and wiring in the logic panels are identical to those found in the Class 1E channels. The vendor supplied solenoid, "SVC", is similar in design to the Class 1E emergency trip solenoids (although not the identical model). Field installed wiring for logic panel modifications uses Class 1E wires, connectors and installation procedures. All site supplied interconnecting cable is

purchased as Class 1E. Although not required to meet Class 1E design criteria, local terminations at solenoid "SVC" included the installation of environmental seals to protect terminations and components from degradation due to high temperatures. Field installed conduit and conduit supports are identical to Class 1E installations, maintain proper separation, and are either seismically qualified, or have had a QA Cat II over I evaluation performed.

V. RELIABILITY OF DUAL UNINTERRUPTABLE POWER SUPPLIES FEEDING MSIV LOGIC CIRCUITS

Power is provided to the MSIV actuator circuits via 2 sets of uninterruptable power supplies. UPS 3A provides power to the outboard valves (Channel 1) and the inboard valves (Channel 2 and Non-1E Channel). UPS 3B provides power to the inboard valves (Channel 1) and the outboard valves (Channel 2 and Non-1E Channel). Although the UPS's are considered and classified as Non-safety related (QA Cat II) due to the system's fail safe design, these units were specified and procured to the same specification and purchase order as other Unit 2 Class 1E UPS's.

Each UPS has three sources of power to draw from: 1. <u>Normal</u> - rectified, inverted, regulated 120 VAC output from a normal 600-volt input supply which is ultimately fed from the normal station service transformer with a reserve station transformer as the alternate; 2. <u>Battery Backup</u> - inverted, regulated 120 VAC output direct from station batteries; 3. <u>Alternate</u> - regulated 120 VAC output from a 600-volt input supply which is ultimately fed from the station service transformer with the reserve transformer as the alternate. Also, the alternate source can be configured with the stub bus as the source.

Under normal conditions, UPS output is derived from the Normal power source. Upon loss of Normal supply, UPS power is maintained through the inverter from the battery backup supply. If both Normal and Backup source are lost, the UPS logic will auto transfer to the alternate source within 1/4 cycle.

The power distribution for the MSIV logic circuits which utilized UPS 3A and 3B, each having three sources of input power, is inherently reliable due to the basic design and quality of equipment.

VI. CHANGES TO PREVIOUS SUBMITTALS

The proposed removal of the RPS uninterruptable power supply auctioneering circuit, required revisions to previously submitted correspondence.

1. Reference Letter #NMP2L 0920, dated October 21, 1986, which enclosed the final report in accordance with 10CFR50.55(e) concerning MSIV Actuator Problems. The final report, 10CFR50.55(e), MSIV Actuators, page 21, Section 4.1.4, paragraph 2, should be modified as follows:

    FROM:

    To enhance the reliability of the design, both 2" diameter SOVs will be supplied from either of the two RPS uninterruptable power supplies through appropriate auctioneering circuitry, such that a loss of either supply will not de-energize (open) either SOV. Enhanced monitoring of the hydraulic system will be added to detect and alert the control room of abnormal operation.

    TO:

    To enhance the reliability of the design, monitoring of the hydraulic system will be added to detect and alert the control room of abnormal operation.

REASON:

Deleted section will no longer apply since it is proposed to remove this enhancement from the circuit.

2. Reference Letter #NMP2L 0955, dated December 16, 1986, which provided information relative to the ongoing MSIV Preoperational Testing. Section IV and X need revisions as follows:

   A. Section IV of attachment titled "Actuator Modification" lists the following:

      "6. Addition of dual power sources for all hydraulic solenoid operated valves." This item will no longer apply since it is proposed to remove the modification from the circuit.

   B. Section X of attachment titled "Evaluation of RPS Trip Initiating During Actuator Testing." The last paragraph beginning, "A modification has been developed for ...", and ending, "... from one source to the alternate." This item will no longer apply since it is proposed to remove the modification from the circuit.

CALCULATION TITLE PAGE

*SEE INSTRUCTIONS ON REVERSE SIDE

5010 64 (FRONT)

CLIENT & PROJECT Niagara Mohawk Power Corp. 9 Mile Pt. 2	PAGE 1 OF 11 3 Pages & Attach.
CALCULATION TITLE (Indicative of the Objective): Justification for use of a Gould J10 Control Relay as an Isolation Device between 1E and non 1E circuits in the MSIV Logic Cabinets.	QA CATEGORY (✓) ☒ I - NUCLEAR SAFETY RELATED ☐ II ☐ III ☐ ______ OTHER

CALCULATION IDENTIFICATION NUMBER				
J. O. OR W.O. NO.	DIVISION & GROUP	CURRENT CALC. NO.	OPTIONAL TASK CODE	OPTIONAL WORK PACKAGE NO.
12177	EQS	12177-EQS-92	N/A	N/A

* APPROVALS - SIGNATURE & DATE						
PREPARER(S)/DATE(S)	REVIEWER(S)/DATE(S)	INDEPENDENT REVIEWER(S)/DATE(S)	REV. NO. OR NEW CALC NO.	SUPERSEDES * CALC. NO. OR REV. NO.	CONFIRMATION *REQUIRED (✓) YES	NO
Joseph Baty 1/10/87	Laszlo Rlly 1-10-87	Laszlo Rlly 1-10-87	0	N/A	✓	

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CALCULATION SHEET

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CALCULATION IDENTIFICATION NUMBER				
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OBJECTIVE

The objective of this calculation is to provide justification for using the contacts of a J10 Relay as an Isolation Device between 1E and non 1E circuits.

Conclusions

The Gould J10 Relay is Qualified for use as an Isolation Device between 1E and non 1E circuits in the MSIV Logic Cabinets because of the following reasons.

1.) Fully Qualified as a Control Relay
2) Relays are exposed to Mild Environment service conditions for normal and accident operability requirements.
3) The Relays are Qualified to function as an Isolation Device at the Maximum Credible Voltage & Current conditions specified.
4) The J10 was "Hi Pot" Tested to 2200 VAC during an EQ Qual Program.
5) An Isolation Barrier is provided when separation in accordance with Reg Guide 1.75 is required.

CALCULATION SHEET

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CALCULATION IDENTIFICATION NUMBER				
J.O. OR W.O. NO. 12177	DIVISION & GROUP EQS	CALCULATION NO. 12177-EQS-92	OPTIONAL TASK CODE N/A	PAGE 4

REFERENCES

1) Equipment Qualification Environmental Design Criteria EQEDC-1 Rev 3 dated 12/20/85.

2) E&DCR No. M10033 (Attachment 1 Page 84 only)

3) Gould J10 Qualification Report IEEE-05-360-5004B

4) Stone & Webster Calculation No. 12177-EQS-85

5) Stone & Webster Calculation No. 12177-EQS-86

6) Telecon Note between Joseph Booy of SWEC and Paul Higgins of Gould/Telemecanique dated 1/9/87. (Attachment 2)

7) SWEC Calculation 12177-EC-128 (Attachment 3 Page 130B only)

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Supplemental Analysis

The Gould J10 Control Relay is Qualified to meet the Requirements of IEEE-323-1974 for the specific Environmental Parameters listed in the purchase specification. (see References 3, 4 & 5)

The J10 Relays are located in the Main Steam Isolation Valve (MSIV) Logic Cabinets. The Logic Cabinets are located in Zones ABN24033 and ABS24036. The Normal Temperature in these 2 Rooms (Per Ref 1) during Plant Operation is 89°F, 88°F and 104°F Maximum. These Temperatures are mild, and are enveloped by the Tested Temperature of 104°F for the J10 Relay.

The Total Integrated Dose for both Gamma and Beta for 40 years life plus a 100 Day Accident plus 10% Margin is 2.78E4 Rads. The Relays are Qualified to a Tested Radiation level of 1×10^7 Rads γ. Therefore the expected Radiation exposure specified will not have an affect on its Performance.

Supplemental Analysis

Both the 89°F Normal and 104°F Max. Service Temperature And the 2.78E4 Rads TID are enveloped by the Tested levels of 104°F Continuous an 1×10^7 Rads & Per Test Report ER-81-32 (See Ref. 3).

The Environment for which the J10 Relays Are located, will not support any significant Aging Mechanism that would Result in the loss of Function of the J10 Relay.

Also, these two zones ARN24033 & ABS24036 do <u>NOT</u> Contain any Fluid Carrying Pipes that could Rupture and Provide A Means for Condensation to Form on the Relay / Contact Terminals.

Therefore for the Reasons stated Above, the Two Zones where the J10 Relay (ie MSIV Logic Cabinets) are to be Considered "Mild" environment Service Condition

ANALYSIS

This part of the calculation will show how the J10 Relays are qualified for the Maximum Credible Voltage at the MSIU Logic Cabinets and the Maximum Credible Fault Current at the MSIU Logic Cabinets;

The Maximum Credible Voltage at MSIU Logic Cabinets

The Power distribution system for the MSIU's are designed to have 108 Volts AC at the MSIU Logic Cabinets when the output from the Un-Interruptible Power Supply (UPS) is at the minimum or 121.52 Volts (-2% of 124 Volts) the output is limited by 2 Cat I, Class 1E electrical Protection Devices. The overvoltage setting of the Electric Protective Assemblies (EPA's) at the output of the UPS is set at 132VAC. If for any fault in the UPS transient overvoltage occurs, the EPA's will trip the UPS at 132VAC. This corresponds to a Voltage of about 119 Volts at the Main Steam Isolation Valve Logic Cabinets. The J10 Relay and all the Contacts are designed to operate at 120VAC continuously. So Voltages of

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Supplemental Analysis

119 VAC will have no detrimental effect on Relay. Also, due to certain power supply switching schemes, a short transient (ie less than 1 second) voltage surge of up to 2 times the working voltage (2x120V=240VAC) could happen. Per telecon with Gould this will have no impact on the operation/life of the coil because the coil insulation system is designed to withstand 600VAC across the coil in a transverse mode. The GPA will clear all other faults within the adjustable range of 1 to 4 seconds.

The Maximum Credible Current at the MSIU logic Cabinet.

The Maximum fault current available at the MSIU Logic Cabinets is about 220 amps for a fault at the Logic Cabinet level. The circuit is protected against overcurrent by (2) 15 amp class 1G fuses in the distribution panels. This 15 amp fuse will blow off in about 0.013 seconds or 0.78 cycles (see Attachment 3) with the above fault current. This instantaneous fault clearing will prevent any damage to the Relay and all contacts.

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Supplemental Analysis

As Part of the Relay Qualification that was not provided to SWEC but is maintained at Gould/Telemecanique for Review, the J10 Relays were Tested electrically.

The Qualification Report is Gould No. R-323-3 (Franklin Report No. F-C4590) A summary of that Report Appears in References 4 & 5. As Part of that EQ Test A specific sub test was performed at each point where the J10 were subjected to A functional check per Gould Test Report No. 81W028. Part of Test was A "Hi Pot" Test at twice the Rated Voltage (ie 2x600) + 1000 Volts

Therefore at various points during the EQ Test (R-323-3) the J10's were "Hi Poted" for 60 seconds continuously at 2200 Volts AC (ie 2x(600)+1000 = 2200 VAC) between the Coil and the Contacts, between Contacts to Case and between Contact to Contact.

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Supplemental Analysis

This HiPot Test was performed by Gould to Coincide with the UL 508 Test Requirements. When Testing for 1E Service, Gould decided to use the UL 508 Hi Pot Test Requirements.

Note that the Gould J10 Relay is UL Rated and meets the Requirements of UL 508. Gould/Telemecanique has stated that this HiPot Testing was performed on J10 Relays that are Identical to the ones used at Nine Mile Pt. 2. (see Reference 6)

Gould/Telemecanique will send a Letter stating the applicability of the "HiPot" Testing of R-323-3 to the 9 Mile Project. He also stated that SWEC is welcome to come and audit that Report at any time.

In Addition, since the Maximum Credible Fault Voltage at the J10 (Relay logic Cabinet) is 119 VAC. And there is No Condensing fluids in the Zone where the J10's

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CALCULATION IDENTIFICATION NUMBER				
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Supplemental Analysis

Are located. The J10 Relays Are Qualified TO FUNCTION AS AN ISOLATION Device.

They were tested to 2200 VAC And did not Break down. They would certainly be Acceptable AT VOLTAGES much lower. (i.e. 119 VAC)

Also, A METAL physical Barrier is placed between Any Safety Related Circuit And A NON Safety Related Circuit to MAINTAIN physical Separation in Accordance with Reg Guide 1.75 this physical separation is shown on Page 84 of Reference 2. (See Attachment 1)

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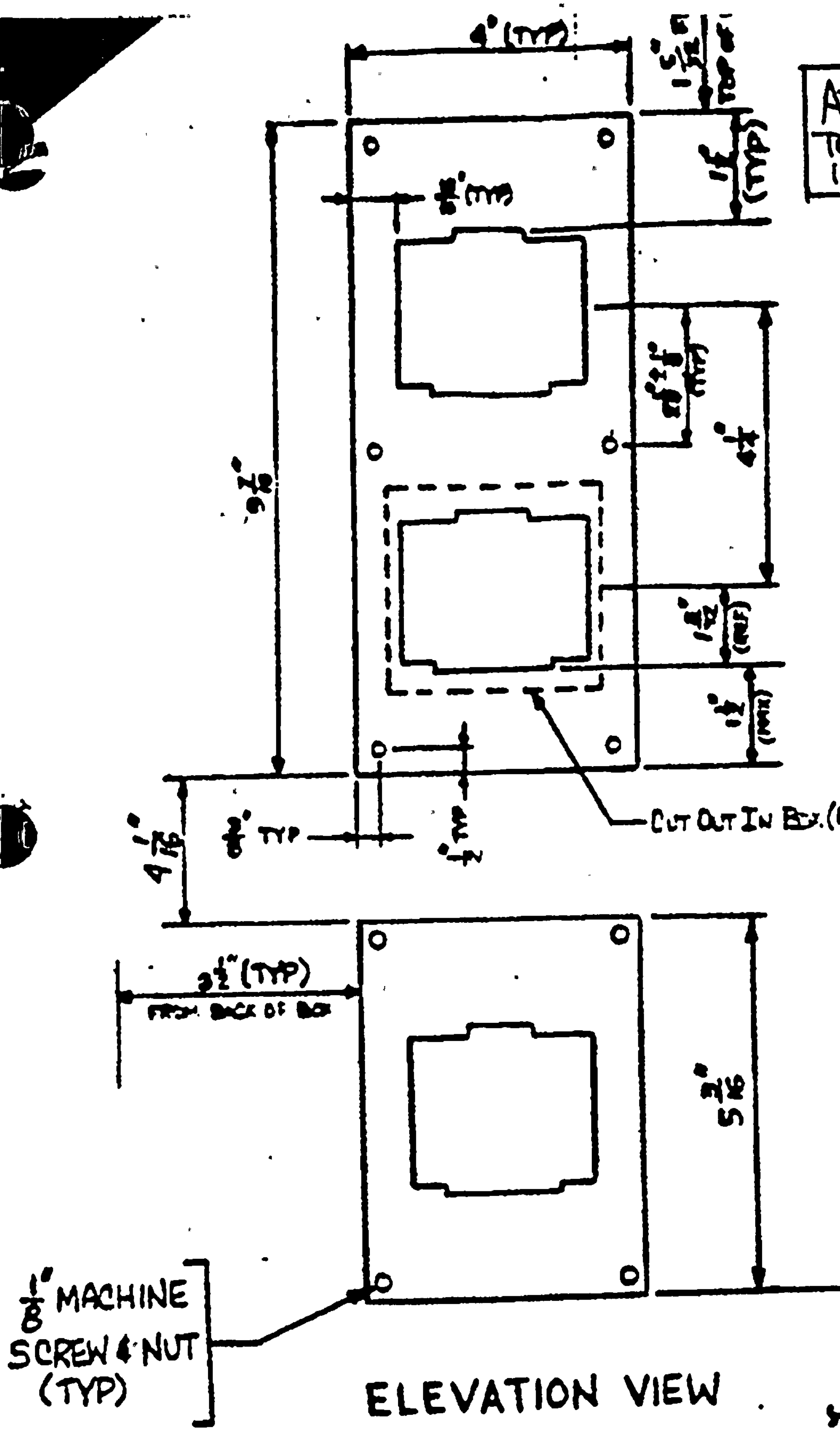
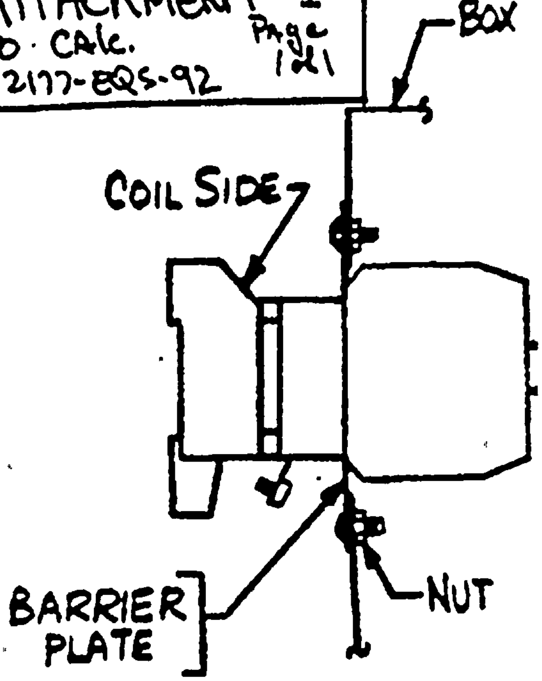
8 10/17/86

ATTAChMENT 1
TO CAlc. 12177-EQS-92
Page 121



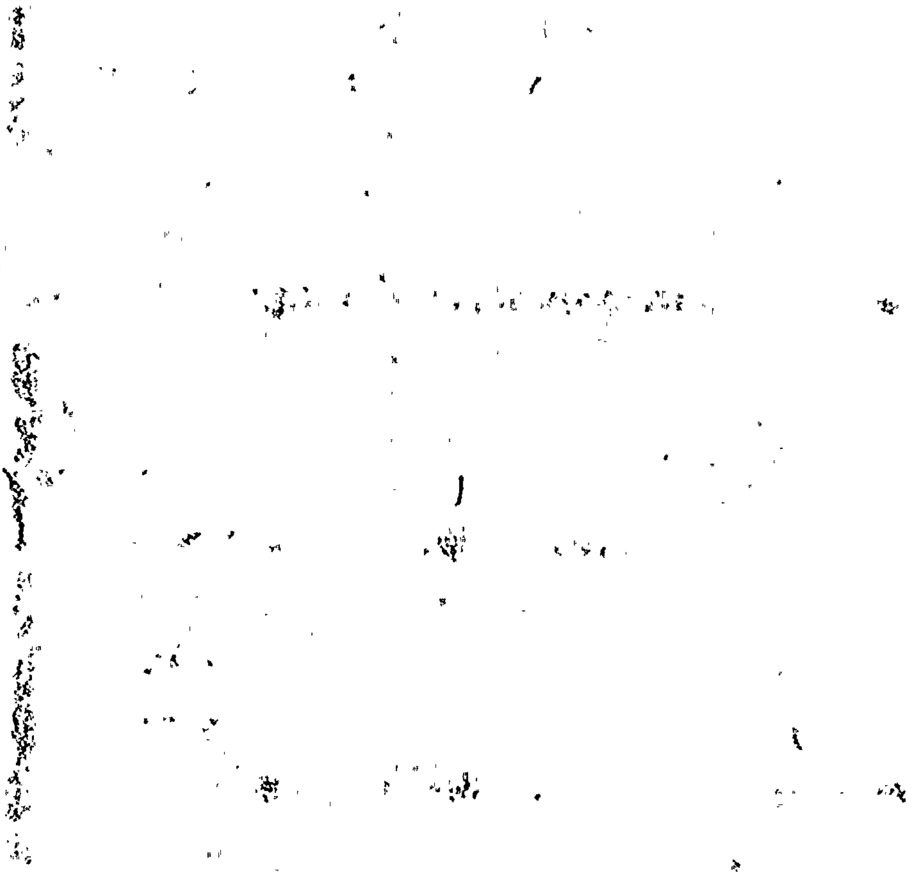
ELEVATION VIEW

BARRIER PLATE LOCATIONS
(TYP. BOTH SIDES)



DETAIL C - FOR REFERENCE ONL
SIDE VIEW

E&DCR M1003



ATTACHMENT 2
to CALC 12177-EQS-92
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J.O. No. 12177
NMPC
NMP2

TEL-CON-NOTE

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J.S. JAMS
S. TSOMBARIS
P. MATURSE
Job book

TIME	DATE
2:00	1/9/87

	Name	Company
From:	Joseph Booty	Stone & Webster Eng. Co.
To:	Paul Higgins	Telemecanique / Gould

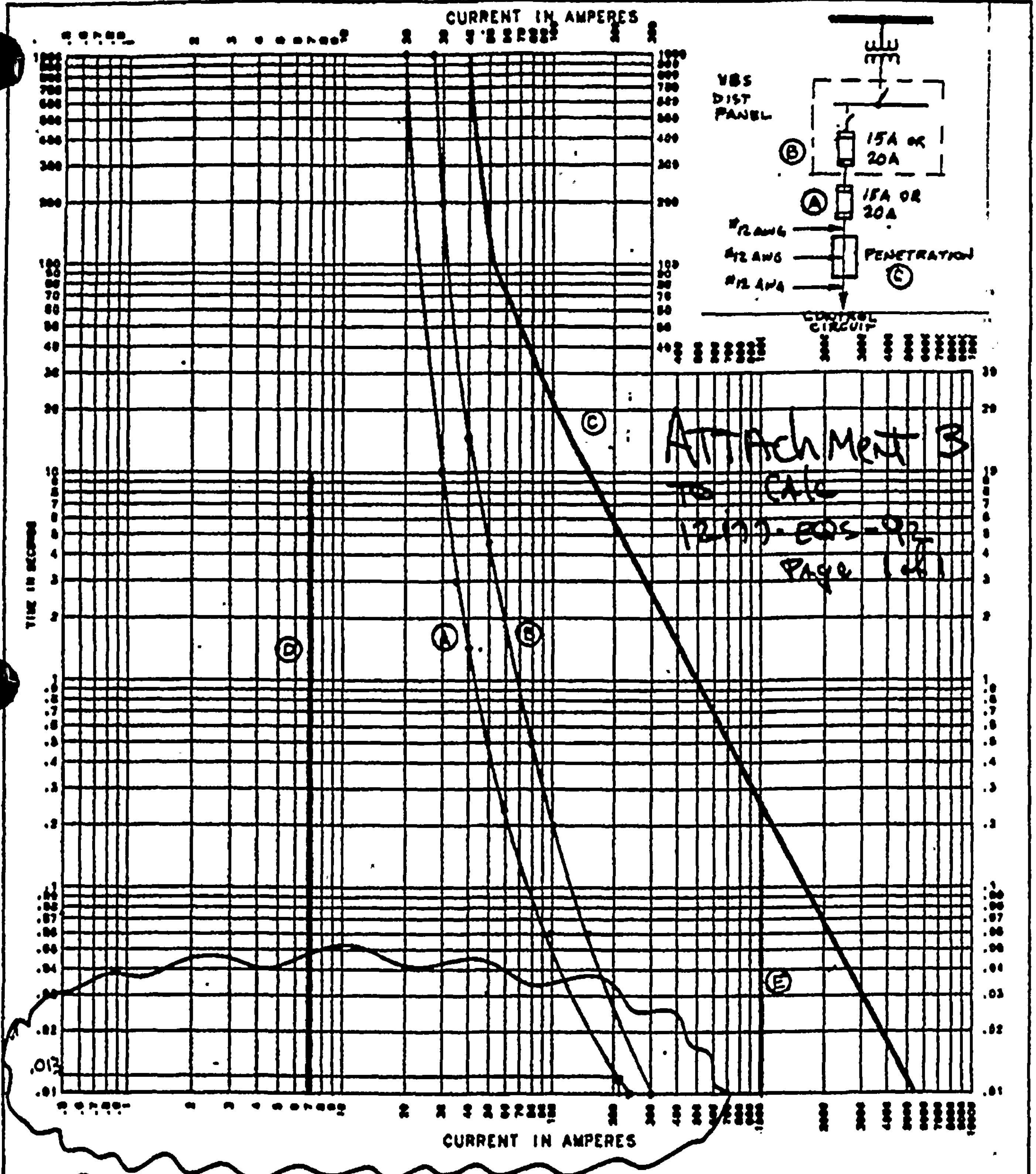
TOPIC: Di-electric Testing of J10 Relays

DISCUSSION: ACTION REQUIRED

MR Booty called MR Higgins to obtain Details of the Dielectric Testing Performed on The J10 Relays. MR. Higgins stated that the J10 Relays Are Qualified under Test Report R-323-3 (FRANKLIN Report #. F-C4590) And as a Subdivision of that Test, A specific Voltage Dielectric Test was performed (Report # 81W028) The Test Specimen was Tested as follows: "HiPot at Twice the System Rated Voltage + 1000 VAC. i.e 2 × (600) + 1000 = 2200 VAC. for 60 Seconds between Contact to Contact, Contact to Case & Contact to Coil. ... This Test duplicated what was Required for UL 508, in order to Maintain the UL Rating. MR. Higgins also stated that Voltage Transients (i.e less than 1 second) up to the System voltage of 600 VAC. will not cause any damage to the Coil

MR Higgins will send a letter confirming these Statements at his earliest convenience

CONTROL SCHEME V ⚠1 - Page 1308



ATTACHMENT B
TO CALC
12177-EQS-92
Page (d)

Ⓐ PRIMARY PROTECTION DEVICE

Ⓑ SECONDARY PROTECTION DEVICE

Ⓒ PENETRATION CAPABILITY CURVE

Ⓓ PENETRATION CONTINUOUS CURRENT

Ⓔ MAXIMUM AVAILABLE SHORT-CIRCUIT CURRENT AT THE PENETRATION.

FIGURE 8.3-8B

PENETRATION PROTECTION

NIAGARA MOHAWK POWER CORPORATION
NINE MILE POINT-UNIT 2
FINAL SAFETY ANALYSIS REPORT

12 AWG
7.0

b

QUALIFICATION PROGRAM EVALUATION

FOR

GOULD, INC. - CONTROL & SYSTEMS DIVISION

CLASS IE RELAYS

(TYPE J10)

Stone & Webster Engineering
J.O. No. 12177
Spec. No. [illegible]

RELEASED FOR:
RETURN TO SUPPLIER ☑
ENG & DESIGN ☐
FABRICATION ☐

DIRECTIONS TO SITE:
FOR CONSTRUCTION ☑
NOT FOR CONSTRUCTION ☐

☒ APP Approved, Acceptable For Use
☐ AAR - Approved As Revised
☐ UNA Unacceptable
☐ BLT As - Built
☐ FIO For Information Only

Date [illegible]
By [illegible]

2/19/85

REPORT NO: ER-81-32

JOB NO: EH-3131E

DATE: August 25, 1981

PREPARED FOR:

STONE & WEBSTER, INC.
CHERRY HILL, NEW JERSEY

Prepared by: Steven D. Slesinger
Steven D. Slesinger, Electrical Engineer

Approved by:
H. Eminger, Engineering Manager

RECEIVED
J. O. NO. 12187
FEB 25 1985
STONE & WEBSTER
ENG. CORP.
CONTROL [illegible]

FLUID SYSTEMS DIVISION
Gulf + Western Manufacturing Company
25 Graystone Street
Warwick, RI 02886

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1.0 OBJECTIVES

1.1 To review the Gould Qualification Program against the requirements of S&W Design Specification, NMP2-P303D, for equipment supplied for the Nine Mile Point Unit 2 Nuclear Power Generating Station.

1.2 To evaluate the Gould Control and System Division's claim that there are no significant aging mechanisms that affect the vibratory and seismic withstandability of Model J10 relays when exposed to the specified environmental conditions.

2.0 GOULD TEST PROGRAM EVALUATION

Gould Series J10 relays have been previously qualified to IEEE Standard 323-1974. The Gould Test Plan is contained in a document entitled:

> "Control & Systems Division's Plan for IEEE Standard 323-1974 Qualification," Report Number CC-323.74-3.6, Revision 6, dated: April 27, 1977.

The final test report is contained in a document prepared by the Franklin Research Center (FRC Project F-C4590) entitled:

> "A Study of the Effect of Aging on the Operation of Switching Devices during Vibration @ Frequencies in the Seismic Range," dated: October, 1977.

Supplemental seismic testing in accordance with IEEE 344-1975 was performed at Wyle Laboratories per Wyle Seismic Test Plans 43513-1 and 44627-1.

Gould has classified the FRC and Wyle Test Reports as proprietary information and copies of the final reports are not released. However, Gould maintains the reports at their Westminster, Maryland offices for review.

On September 30, 1980, the United States Nuclear Regulatory Commission issued IE Supplement 2 to Bulletin 79-01B, entitled: "Environmental Oualfication of Class IE Equipment." This document, in a question and answer format, presented the NRC positions and interpretations of requirements for qualification testing and documentation.

Answer A.8 of IEB 79-01B defines the NRC staff position regarding specific documentation required to be maintained at the utility central file. It is stated that, "The staff will accept summary test reports maintained at the utility's central file which reference the actual test reports and data available at a single location. . .". It is further stated that, "Test reports are not required to be submitted. Test report references must be included in the plant submittals and these reports must be available for staff review on demand."

Gould has provided FSD with summary test reports as required by the NRC. Although entitled "certifications", these documents contain a listing of FSD's specified service conditions, a brief description of the test procedure, results of testing, an evaluation of the test versus the specified service conditions, and a reference to the test reports.

For the J10 relay, Gould has provided FSD with the following two reports:

CC-323.74-62, Rev. 0; Certificate of Conformance for J10 Relays to IEEE 323-1974; dated 1/18/80.

SC 274, Rev 0; Seismic Certification of J10 Realys to IEEE 344-1975; dated 1/18/80.

FSD's review of the Gould program included a technical audit of the actual test reports maintained at Gould's Westminster, Maryland facility. FSD's review of Gould's program has determined that the testing performed exceeds the requirements of S&W Design Specification NMP2-P303D. Comparison of the test program with the specification requirements is as follows:

2.1 Environmental Service Requirements

J10 relays used in the FSD MSIV electrical system are located in the relay logic cabinets. The environmental service conditions per S&W Specification NMP2-P303D for the cabinets are:

Normal Conditions

Pressure:	-0.1 to -1.0 in water gage, static pressure
Temperature:	65°F to 104°F
Relative Humidity:	20% to 90%
Radiation:	5.0×10^4 rads (40-year integrated dose)

Accident Conditions

Pressure:	7 in. water gage, static pressure
Temperature:	65°F to 104°F
Relative Humidity:	100%
Radiation:	4.0×10^5 rads (1st hour) 2.0×10^6 rads (6-month integrated dose)

Attachment A to Gould Report CC-323.74-62 lists the environmental and operational levels simulated for the aging tests. Comparison with the above SCW specified conditions demonstrates that the SCW requirements were met or exceeded.

2.2 Definition of Class IE Relay Safety Function

The safety function for relays in the G+W-FSD MSIV system is that there be no spurious operation of the relay contacts that could prevent MSIV closure during a Design Basis Event (DBE) or unintentional re-opening of the MSIV following the DBE.

Spurious operation is defined as inadvertant opening/closure of contacts for a duration equal to or greater than 3.0 milliseconds.

2.3 Discussion of Gould Test Philosophy

Gould has followed an innovative approach to equipment qualification.

Due to the fact that each nuclear generating plant licensee supplies earthquake data historically relevant to the plant site in question plus anticipated structural response spectra (as related to those localized earth-movements), it becomes apparent that a new test program would be necessary to qualify the Gould products to IEEE 344 for use at each job site (except in the rare case where new requirements are enveloped by previous testing).

If vibratory and seismic forces were a significant aging mechanism when applied to Gould's switching devices, then a new qualification program to IEEE 323 would also be required for each different plant.

It was recognized that if a program could be conducted to demonstrate environmental aging does not significantly affect the vulnerability of switching devices to vibratory forces in the range of seismic frequencies, then future seismic qualification could be conducted with new off-the-shelf specimens.

This program (FRC Project F-C4590, referenced above) is detailed in a technical paper, F80259-2, entitled "A Study of the Effect of Aging on the Operation of Switching Devices," contained herein as Appendix A.

It was determined by FSD, during the technical audit of the proprietary test reports at Gould's plant, that test Speciman No. 3B was a J10 relay.

The conclusion (page 9) of Technical Paper F80259-2 states:

"In summary, it was observed that: . . .

> Thirteen devices (1B, 2B, 3B, 4B, 7B, 8B, 15B, 16B, 17B, 18B, 22B, 27B, and 28B) gave no evidence of aging with respect to seismic vulnerability;"

The seismic simulation of FSD's relay logic cabinet per the S&W specified response spectra will demonstrate the adequacy of Gould J10 relays as utilized in the FSD cabinets. The seismic test report in conjunction with the Gould test reports will provide all required qualification documentation.

3.0 CONCLUSIONS

3.1 Gould J10 relays have the ability to perform their safety-relayed function in the Nine Mile Point Unit 2 Nuclear Power Generating Station per the normal and accident environmental conditions of S&W Design Specification NMP2-P303D.

The qualified life for relays mounted in G+W-FSD's relay logic cabinets at the maximum specification temperature of 104°F is forty (40) years.

3.2 Environmentally aged Gould J10 relays need not be used when seismically testing the G+W-FSD relay logic cabinet. New, off-the-shelf relays may be used.

APPENDIX A

TECHNICAL PAPER F80259-2

F 80 259-2

A STUDY OF THE EFFECT OF AGING ON THE OPERATION OF SWITCHING DEVICES

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Abstract - An experimental study was conducted to determine whether equipment aging affects the vulnerability of electric switching devices to malfunction caused by vibratory stresses in the range of seismic frequencies and acceleration amplitudes. The study included a vibration test before and after a program of accelerated aging designed to simulate forty years of service in areas outside the containment of a nuclear power generating station. Gamma irradiation, thermal aging, electrical/mechanical cycling and simulation of operating basis earthquakes were included in the program of accelerated aging. Malfunction was defined as spurious opening or closing of contacts for times in excess of 1 ms during the vibration tests.

For most devices the fragility level was approximately the same before and after aging. In some cases the fragility level increased and in others it decreased, but the changes were usually not significantly different from the difference of fragility levels observed for duplicate specimens under identical test conditions. Because of the absence of a clear correlation between accelerated aging and the vulnerability to vibratory stresses, the results of the study do not support the requirement that seismic qualification be conducted with aged specimens.

INTRODUCTION

The objective of this study was to determine the effect of accelerated aging on the vulnerability of electric switching devices to vibratory motion at frequencies and amplitudes typical of seismic disturbances. The publication of IEEE Std 323-1974 [1] and its endorsement (with exceptions) by Regulatory Guide 1.89 [2] of the U.S. Nuclear Regulatory Commission emphasized the requirement of an earlier standard, IEEE Std 279-1971 [3], that the degradation of safety-system equipment during service be taken into account in qualification for use in nuclear power generating stations. However, the status of equipment aging technology and our ability to define all of the significant aging stresses that may be imposed in service are inadequate to permit the formulation of accelerated aging procedures (to simulate the natural aging that occurs in service) on a scientifically rigerous basis. Furthermore, without experimental verification, it need not necessarily be assumed that aged equipment is more likely than new equipment to malfunction when subjected to the stresses of an accident, during which the equipment is required to perform a safety function. The study reported herein was an effort to determine experimentally the effect of accelerated aging on the vulnerability of electric switching devices to malfunction as a consequence of a seismic disturbance. While the accelerated aging program was intended to be typical of programs used in the qualification of electrical switching devices, its correlation with a specific set of service conditions was not of major importance.

TEST SPECIMENS

This program was conducted on the 24 specimens listed in Table 1. Specimens 1B through 18B constitute a series of 9 pairs of duplicate specimens; specimens 27B and 28B, which are identical to specimens 7B and 8B, were added to the program after the initial series of vibration tests had been completed.

Table 1. Identification of Test Specimens

Note: All specimens consisted of duplicate pairs, except specimens 19B through 22B

Specimen No.	Description
1B	Circuit Breaker
2B	Circuit Breaker
3B	Relay
4B	Relay
5B*	Time-Delay Relay
6B*	Time-Delay Relay
7B	Time-Delay Relay
8B	Time-Delay Relay
9B	Relay
10B	Relay
11B	Contactor
12B	Contactor
13B	Starter
14B	Starter
15B	Circuit Breaker
16B	Circuit Breaker
17B	Circuit Breaker
18B	Circuit Breaker
19B	Starter
20B	Starter
21B*	Circuit Breaker
22B	Current-Limiting Fuses/ Fuse Block with Trip Indicator
27B	Time-Delay Relay
28B	Time-Delay Relay

*Failed functional test after irradiation.

F 80 259-2 A paper recommended and approved by the IEEE Power Generation Committee of the IEEE Power Engineering Society for presentation at the IEEE PES Winter Meeting, New York, NY, February 3-8, 1980. Manuscript submitted September 7, 1979; made available for printing November 16, 1979.

Four other devices were represented by one specimen each: Specimens 19B, 20B and 21B were switching devices; and specimen 22B consisted of fuses mounted on a block equipped with a trip-indicating mechanism. Specimens 5B, 6B and 21B failed as a result of gamma irradiation and were not carried through the rest of the program.

EXPERIMENTAL PROGRAM

The experimental program consisted essentially of the following elements: a fragility-type vibration test on new devices, accelerated aging of the devices and a repetition of the vibration test. These test elements are listed in Table 2 and are described in the following paragraphs.

Table 2. List of Test Elements

1. Functional Test
2. Vibration Test
3. Functional Test
4. Gamma Irradiation
5. Functional Test
6. Accelerated Thermal Aging (At High Relative Humidity)
7. Functional Test
8. Electrical/Mechanical Life Cycling
9. Functional Test
10. Accelerated Thermal Aging (Coils Only)
11. Functional Test
12. OBE Vibration
13. Repeat of Vibration Test
14. Functional Test

Functional Test. Baseline functional tests were conducted at a test bench, where arrangements were made for the proper coil power source for electrically operated specimens. Coil continuity was checked with an ohmmeter and a check was made for short circuits to ground. If a device had NC (normally closed) contacts, electrical continuity through these contacts was checked. Devices with NO (normally open) contacts were exercised to the closed position, and continuity was checked through these contacts; the devices were then returned to the open condition. Three such operating cycles were accumulated on each operating device during each functional test.

Vibration Test. This test was designed to provide a means of comparing the performance of the devices before and after aging when subjected to vibration at discrete frequencies separated by 1/3-octave intervals between 1 and 32 Hz. All specimens were mounted in their normal, upright position and subjected to single-frequency, sinusoidal vibration in the horizontal direction, perpendicular to the front face of each device (parallel to axis of contact motion), which was judged to be the direction most likely to produce spurious contact chatter. Figure 1 illustrates a typical test setup. At each frequency, the acceleration amplitude was increased gradually to the test limit (see TEST RESULTS) or to the fragility level, and vibration was then continued for 30 seconds. The fragility level at any one frequency was defined as the highest acceleration amplitude the device could withstand for 30 seconds without malfunction. This procedure provided a severe test of the vulnerability of the devices to seismic vibrations.

Malfunction was defined as spurious contact opening or closing for an interval exceeding 1 ms. The devices were also monitored for incipient failure, which was defined as an increase in contact resistance as evidenced by a reduction in contact current. The criterion for malfunction is somewhat arbitrary, because no specific application was addressed; however, it is a conservative choice compared with the typical qualification requirement that contact chatter time be less than 2 ms, i.e., twice the value used in this study. The conservatism of 1 ms is also indicated by the fact that IEEE Std 649 [4] gives the maximum permissible contact chatter time as 2 ms.

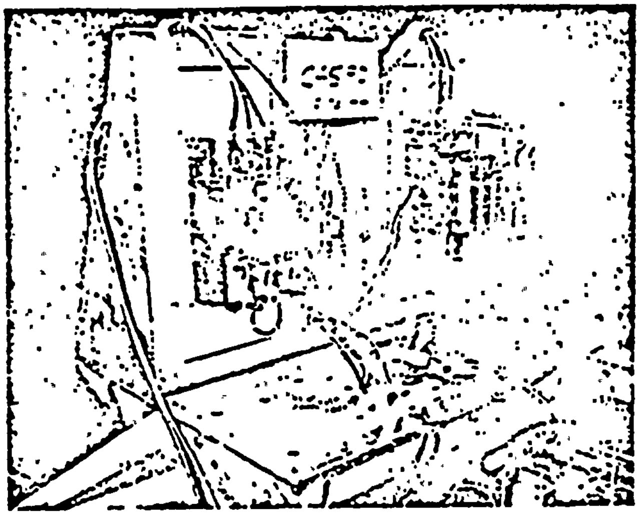

Figure 1. View of Specimens 19B and 20B Mounted on Shaker

All the 3-pole devices were checked in two modes:

Mode 1. Coil energized/breaker closed; two closed (NO) contact pairs wired in series with a current source and sensitive ammeter, one closed (NO) contact pair connected to the contact monitor to detect spurious openings.

Mode 2. Coils de-energized/breaker open: one open (NO) contact pair connected to the contact monitor to detect spurious closures.

During vibration, the aged* contacts were monitored for contact chatter, and the other contacts were energized. If malfunction occurred, the acceleration amplitude was decreased in small steps to establish the fragility level, at which vibration was maintained for 30 seconds.

Operation of the devices was checked during vibration at each of the test frequencies; in addition, for those devices that exhibited fragility (i.e., spurious contact opening or closing) at acceleration levels below the test limits, operation was checked at an acceleration amplitude 10% below the fragility level.

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* The aged contacts were those that had been subjected to electrical/mechanical life cycling. See Electrical/Mechanical Life Tests under TEST PROCEDURES.

Gamma Irradiation. Following the initial vibration test and functional check, the specimens were exposed to gamma radiation from a cobalt 60 source. In all but two cases the specimens received an air equivalent dose of 10 Mrd of gamma radiation.* Specimen 27B was irradiated to a dose of 0.5 Mrd and 28B to a dose of 1.0 Mrd. These doses considerably exceed the dose expected from 40 years of normal service plus the dose due to abnormal operating conditions in the outside-containment locations where the devices are normally used; the sum of these does not exceed approximately 10^4 rd.

Coils used to replace those damaged during the supplemental accelerated thermal aging of coils were exposed, prior to their assembly into the test specimens, to the same dose as that which had been received by the damaged coils.

Figure 2 shows some of the specimens in a typical arrangement for gamma irradiation.

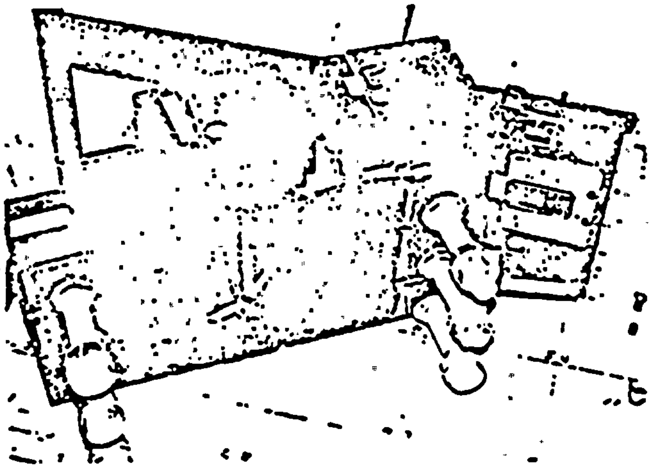

Figure 2. Photograph of Typical Setup for Gamma Irradiation (Photographed at Radiation Technology, Inc.)

Accelerated Thermal Aging. It was desired that all of the test specimens be brought to a condition equivalent to that expected after 40 years of installed life in a nuclear power plant, while de-energized, in an ambient environment having a continuous temperature of 104°F (40°C). Based on the Arrhenius model, the calculated accelerated aging time for an oven temperature of 212°F (100°C) was 107 hours. [5]

Humidity. In an effort to simulate the effects of humidity, the relative humidity in the thermal-aging oven was maintained at a value close to 100% during most of the accelerated aging period. It is not known by what factor humidity effects were accelerated, if any.

Electrical/Mechanical Life Tests. The test specimens were subjected to electrical/mechanical life tests to simulate degradation caused by operation in service. The projected number of operating cycles over a 40-year period was determined by the manufacturer on the basis of prior experience. Table 3 lists the electrical loading and the number of cycles accumulated on each device. In multi-contact devices, only one of the contacts was energized during operational aging; this aged contact was the one monitored for contact chatter during subsequent vibration tests.

Table 3. Cycles Accumulated During Electrical/Mechanical Life Tests

SPECIMEN NO.	NO. OF CYCLES	CONDITIONS
1B	6000 4000	30 amp No load
2B	6000 4000	30 amp No load
3B J-10	2.0×10^6	5 amp
4B	2.0×10^6	5 amp
5B	Removed from program after irradiation	
6B	Removed from program after irradiation	
7B	1.0×10^6	Relay load
8B	1.0×10^6	Relay load
9B	2.0×10^6	5 amp
10B	2.0×10^6	5 amp
11B	2.5×10^6	30 amp
12B	2.5×10^6	30 amp
13B*	2.5×10^6	Note 1
14B*	2.5×10^6	Note 1
15B	6000 4000	30 amp No load
16B	6000 6000	30 amp No load
17B	4000 4000	125 amp No load
18B	4000 4000	125 amp No load
19B*	1.0×10^6	Note 2
20B*	2.5×10^6	Note 1
21B	Removed from program after irradiation	
22B	No operations required	——
27B	1.0×10^6	Relay load
28B	1.0×10^6	Relay load

*These devices were cycled without electrical loading. However, the contacts were replaced with contacts removed from identical devices previously subjected to electrical load cycles as follows:

Note 1. Make 84 A @ 45% P.F., break 14 A @ 90% P.F. and 480 V. 2.5×10^6 cycles at rate of 900/h.

Note 2. Make 300 A @ 45% P.F., break 50 A @ 95% P.F. and 480 V. 1.0×10^6 cycles at rate of 450/h.

OBE Vibration. For this part of the program, the specimens were again mounted in their normal upright position in a rigid fixture. The shaker actuator was oriented at an angle of 45° with the horizontal direction, so that the specimens were subjected simultaneously to horizontal and vertical (inphase)

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* Air equivalent dose is defined as the energy that would be absorbed per unit mass of air at the geometric center of the volume occupied by the specimen if it were replaced with air and a uniform flux were incident at the boundary of the volume, directed toward the center. Irradiation was conducted at Radiation Technology, Inc., and Isomedix Inc.

vibrations. Figure 3 illustrates a typical test setup. The level of OBE vibration chosen for these tests and a typical test response spectrum are shown in Figure 4. Each device was subjected to five OBE-level vibrations of 30-second duration, with the front of the device facing each of the four cardinal directions, making a total of twenty 30-second vibrations.

For each of the switching devices, the contact that had been subjected to life cycling was monitored for contact chatter exceeding 1 ms in duration.

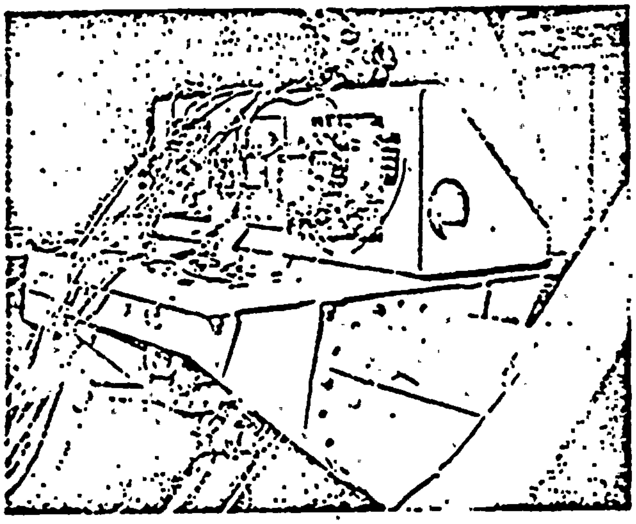


Figure 3. Typical Arrangement of Specimens for OBE Vibration Test
Actuator Orientation: 45° with Horizontal Direction
Specimen Orientation: Normal Upright Position

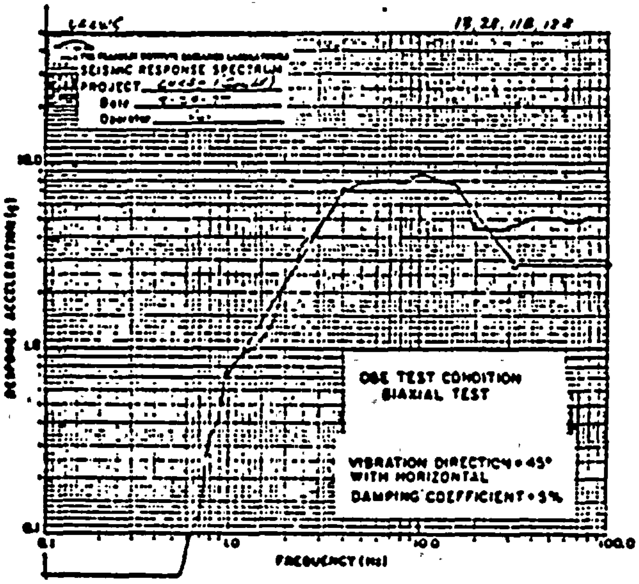


Figure 4. Typical Test Response Spectrum of the OBE Vibration

The other, closed-contact pairs were connected in series with a low-voltage current supply and energized with load currents. The OBE test was performed only with the specimens energized (coil-activated devices) or closed (handle-activated devices).

TEST RESULTS

The test results are illustrated by the diagrams in Figure 5, which show the differences between fragility levels before and after the accelerated aging program. In most cases, there was no difference between the fragility levels before and after aging; this includes the cases in which the fragility level exceeded the test limit.

The specimens passed all inspections and functional tests conducted, in accordance with the outline given in Table 2, with minor exceptions occurring after gamma irradiation. These exceptions are discussed in the following paragraphs.

The functional tests which were performed following 10 Mrd of gamma irradiation revealed discoloration of plastic materials (specimens 13B and 14B) and three inoperative devices: 5B, 6B and 21B. The celcon and delrin parts in specimens 5B, 6B and 21B fractured as a consequence of crystallization and embrittlement. A delay-time adjustment screw was broken on specimen 5B during the functional test.

Specimens 7B and 8B did not function properly when first checked at this point in the program (after irradiation), and specimens 27B and 28B were added to the program to replace them. However, when the specimens were rechecked, they functioned satisfactorily. Consequently, specimens 7B and 8B were put through the rest of the program along with the duplicate specimens 27B and 28B; and they continued to function satisfactorily throughout the program. A thorough review of all events pertaining to specimens 7B and 8B did not resolve the conflicting observations made after irradiation during the first functional test and the subsequent recheck.

When specimens 27B and 28B were added to the program to replace specimens 7B and 8B, the gamma dose had been re-evaluated; and it was decided on the basis of additional information that a much lower gamma dose was more appropriate for the out-of-containment locations where switchgear components are likely to be placed. Therefore, specimens 27B and 28B were subjected to 0.5 Mrd and 1.0 Mrd, respectively, of gamma radiation. Since the initial vibration tests had already been completed when specimens 27B and 28B were added to the program (and the vibration test facility was unavailable for a prolonged period), these specimens were subjected only to the final vibration test. However, these are solid state time-delay relays (i.e., have no moving parts) which either function satisfactorily or do not function at all; and since they passed the final vibration test, it is reasonable to assume that they would also have passed the initial vibration test.

ANALYSIS OF THE EFFECT OF AGING ON SEISMIC VULNERABILITY

Introduction. In those cases in which the devices did not exhibit spurious contact chatter either before or after the aging program, it is reasonable to assume that aging had negligible influence on their seismic vulnerability as tested in this study. In cases where contact chatter did occur (in one or both of the vibration tests), an attempt was made to determine whether aging had produced a significant change in the fragility level, which is a measure of the ability of the devices to withstand vibrations in the seismic range. Since only two specimens of each device were tested (the number being limited by

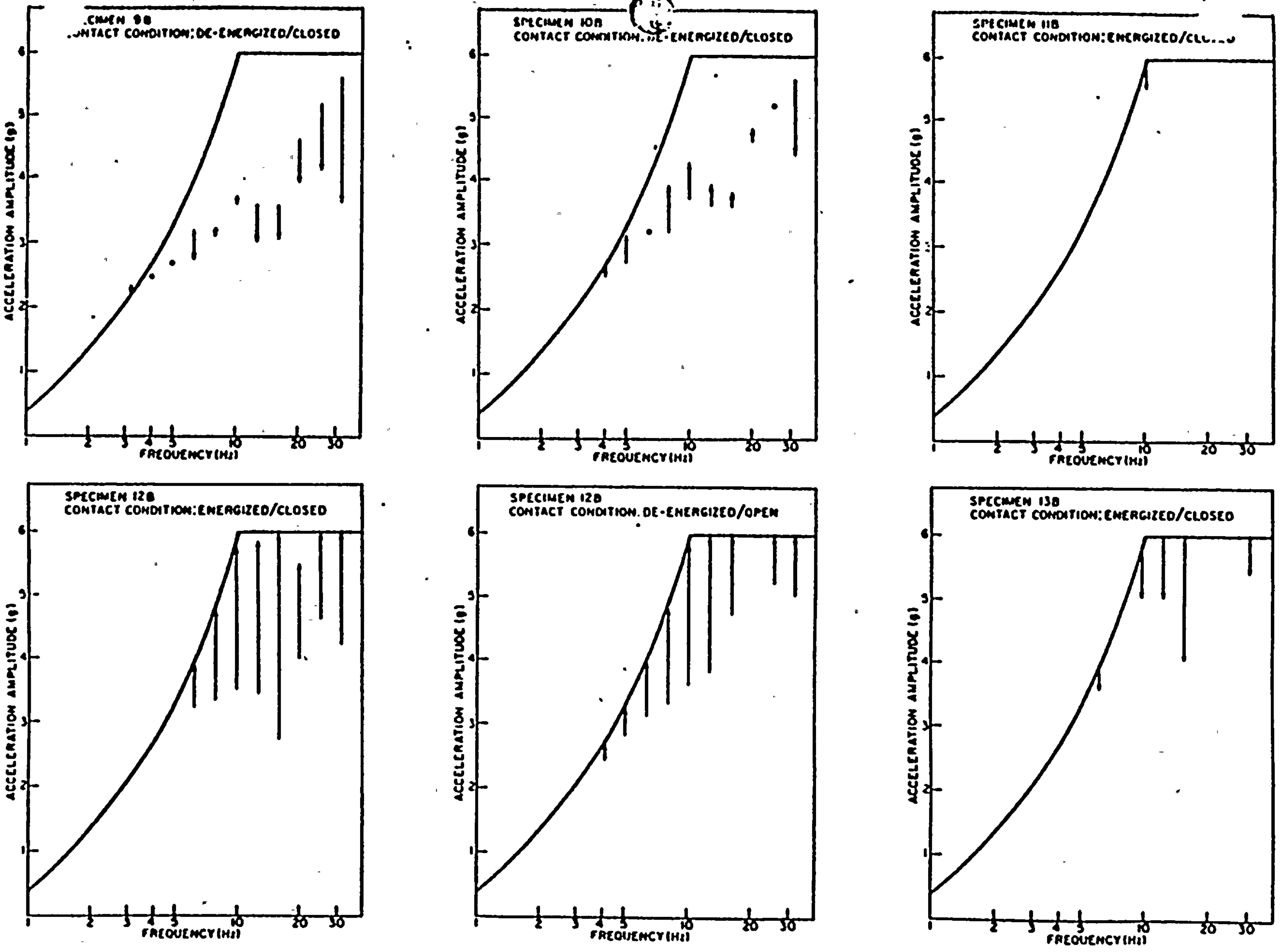


Figure 5. Changes in Fragility Level

NOTE: The heavy line in each figure represents the test limit. The arrows indicate changes in fragility level, the tail being the fragility level before aging and the head the fragility level after aging. Solid circles indicate points where there was no change in fragility level. The absence of an arrow or a solid circle indicates the fragility level exceeded the level of the heavy line.

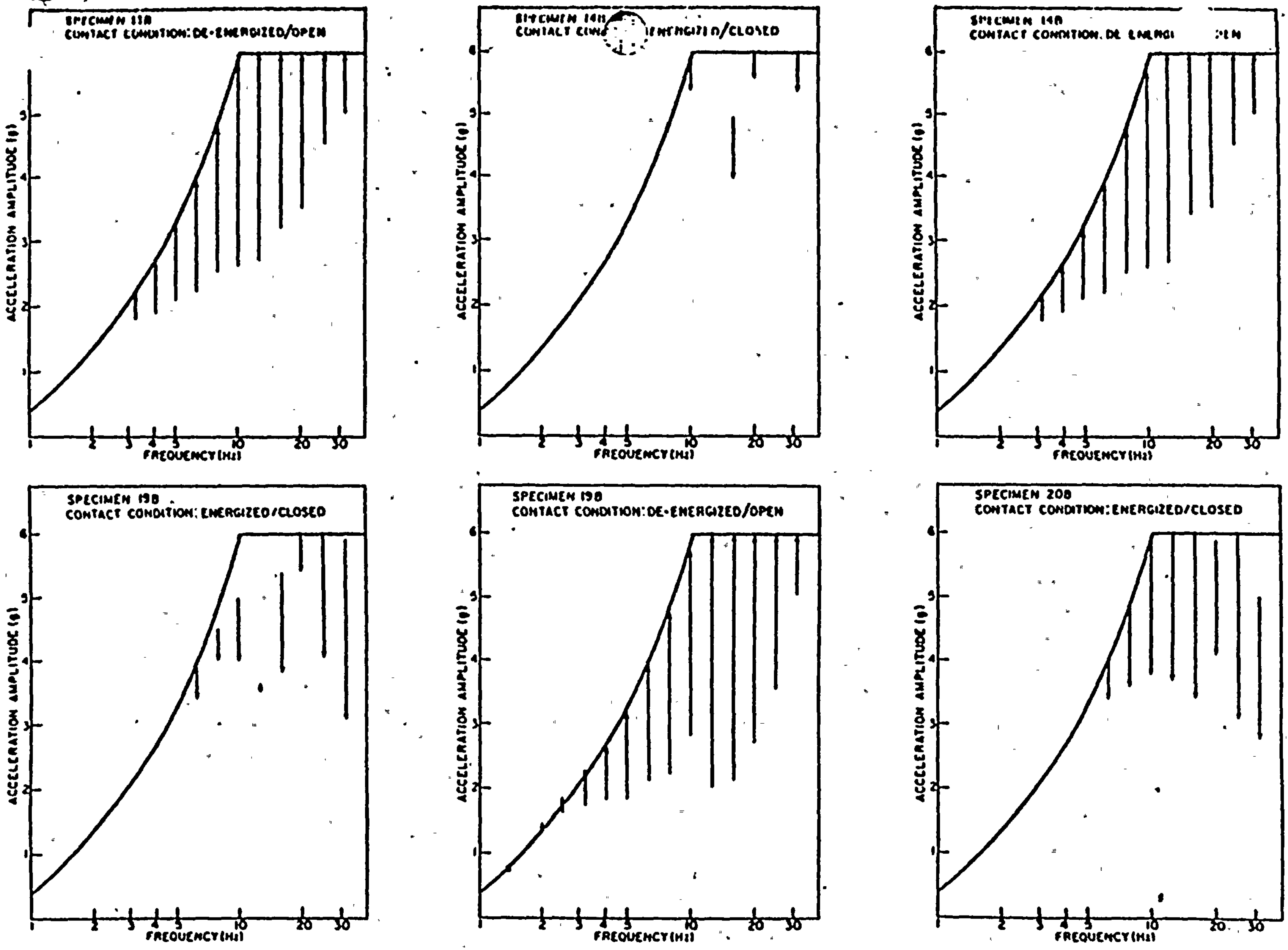


Figure 5. Changes in Fragility Level (cont.)

NOTE: The heavy line in each figure represents the test limit. The arrows indicate changes in fragility level, the tail being the fragility level before aging and the head the fragility level after aging. Solid circles indicate points where there was no change in fragility level. The absence of an arrow or a solid circle indicates the fragility level exceeded the level of the heavy line.

technical considerations), it was difficult to perform a quantitative statistical analysis; therefore, a qualitative measure was the best that could be achieved using conventional statistical procedures. Essentially, an attempt was made to ascertain whether the changes observed were sufficiently large to be unlikely to have occurred by chance.

It was assumed that the effect of aging, if any, would be a reduction in the value of the fragility level. A normal distribution of fragility levels about the mean was assumed to apply for repeated measurements. This implies that small variations of fragility level about the mean value are much more likely than large variations to occur by chance. Therefore, a large reduction in the fragility level measured after aging, compared to the fragility level before aging, was more likely to be a statistically significant effect of aging rather than a chance variation. The criterion chosen for distinguishing significant changes is illustrated in Figure 6: a limiting change in fragility level was defined such that values less than $(\bar{g} - u)$ were likely to occur by chance in only 10 percent of the measurements. If the fragility level after aging was less than $(\bar{g} - u)$, the change was regarded as being statistically significant at the 10-percent level. In the language of statistics, the hypothesis that aging has no significant effect was made and a test was applied to determine whether the hypothesis could be rejected.

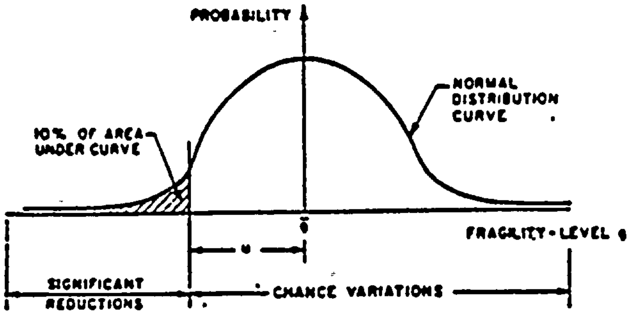


Figure 6. Definition of Significant Reductions in Fragility Level

A description of the analytical procedure and the tabulated results are given in the following section.

<u>Analysis</u>. Each frequency had to be tested separately for a significant difference in the fragility "g" level since each frequency is independent of the others.

Let g_b = mean g level before aging, from 2 samples
g_a = mean g level after aging, from 2 samples
r_b = range of values of g_b
r_a = range of values of g_a
S_b = estimated standard deviation of sample b
S_a = estimated standard deviation of sample a
n_b = number of units in sample b
n_a = number of units in sample a
d.f. = degrees of freedom = $(n_a-1) + (n_b-1)$

The standard deviation S_d of the difference may be calculated from

$$S_d^2 = \frac{(n_a - 1)S_a^2 + (n_b - 1)S_b^2}{n_a + n_b - 2}$$

For small samples, the standard deviation of the sample may be estimated by the range r of the sample, i.e., $S_a = r_a$ and $S_b = r_b$. Then for $n_a = n_b = 2$, we have

$$S_d = \left[\left(r_a^2 + r_b^2\right)/2\right]^{1/2}$$

As stated above, it was decided to regard the change (reduction) in fragility level as significant if it was large enough to have occurred by chance in only 10% of a large number of tests. Accordingly, the probability that the observed data could have occurred by chance was assigned the value 10%. From tables of "student" t for 2 degrees of freedom, for $\alpha = 10\%$ we find $t = 1.89$. The difference $(\bar{g}_a - \bar{g}_b)$ is significant at the 10% level, one-tailed, if it is greater than u, where

$$u = t_{1-\alpha}\, S_d\left[\left(n_a + n_b\right)/n_a n_b\right]^{1/2}$$

For the values given

$$u = 1.89\left[\left(r_a^2 + r_b^2\right)/2\right]^{1/2}$$

$$= 1.34\left(r_a^2 + r_b^2\right)^{1/2}$$

The analysis was applied for each of the frequencies tested separately and not for a pooling of the changes for all the frequencies.

The number of samples was insufficient and the variance among measurements too large to permit any strong statistical statements. Only very large changes in fragility level would allow the differences to be significant. Therefore, the trends observed could not be substantiated by the analysis.

In most cases, the analysis did not provide a basis for rejecting the hypothesis that there was no statistically significant aging effect. A summary of the results of calculations for a number of specimens is given in Table 4.

<u>Alternative Statistical Analyses</u>. Other statistical tests can be applied which take the changes in fragility level at the several frequencies into account together rather than separately, as was done in the foregoing section. The Wilcoxon Matched-Pairs Signed-Ranks Test (a powerful non-parametric test) is suitable for this purpose [6]. When this test was applied to specimens 9B and 10B individually, it was shown that aging decreased the fragility level of 9B with a significance level of 5%, but aging did not decrease the fragility of 10B at the 10% significance level.

DISCUSSION OF RESULTS

The evaluation of the effect of aging on the fragility level of the devices was based on the data obtained on 10 pairs of specimens (1B through 15B, plus 27B and 28B) and four individual specimens (19B through 22B).

Table 4. Summary of Observed Changes in Fragility Level

f (Hz)	Specimens 9B and 10B					Specimens 11B and 12B					Specimens 13B and 14B					Specimen 19B			Specimen 20B		
		Decrease		Increase			Decrease		Increase			Decrease		Increase							
	None	Signif.	Not Signif.	Signif.	Not Signif.	None	Signif.	Not Signif.	Signif.	Not Signif.	None	Signif.	Not Signif.	Signif.	Not Signif.	None	Decrease	Increase	None	Decrease	Increase
1.0	✓					✓					✓					✓			✓		
1.3	✓					✓					✓					✓			✓		
1.6	✓					✓					✓					✓			✓		
2.0	✓					✓					✓					✓			✓		
2.5	✓					✓					✓					✓			✓		
3.2			✓			✓					✓					✓			✓		
4.0	✓					✓					✓					✓			✓		
5.0				✓		✓					✓					✓			✓		
6.3			✓							✓			✓				✓			✓	
8.0					✓					✓	✓						✓			✓	
10.1					✓					✓		✓					✓			✓	
12.7			✓							✓			✓					✓		✓	
16.0			✓							✓		✓					✓			✓	
20.1			✓							✓			✓				✓			✓	
25.4		✓								✓	✓						✓			✓	
32.0		✓								✓		✓					✓			✓	

Of the 24 specimens included in the analysis, a pair of time-delay relays (5B and 6B) and a circuit breaker (21B) were dropped from the program because of failure to pass baseline tests after gamma irradiation. It is possible that the substitution of radiation-resistant materials for the celcon and delrin parts in these devices would correct the problem. Also, the devices might not have failed if the radiation dose had been limited to a level consistent with most out-of-containment applications.* Accordingly, it is not certain that there was significant aging of specimens 5B, 6B and 21B; but it would be advisable in any case, on the basis of the results of the test program, to avoid the use of materials, such as celcon and delrin, which do not have high resistance to gamma radiation.

Five pairs of devices and one other device did not have any fragility levels below the test levels before or after the accelerated aging tests. (These specimens were 1B/2B, 3B/4B, 7B/8B, 15B/16B, 17B/18B and 22B). Two devices (27B, 28B) which did not receive a "before" test showed no spurious response in an "after" test. Since these were solid state time-delay relays which have no moving contacts, it is reasonable to assume that they would not have exhibited any spurious response in the "before" test if it had been performed. The results obtained with this group of 13 specimens is consistent with the position that aging does not significantly affect the seismic vulnerability of the devices.

The data of the remaining specimens were subjected to a statistical analysis, the results of which (see Table 4) are summarized below:

1. For units 9B and 10B, there was a significant decrease in fragility level at two frequencies and a significant increase at one frequency. There were changes in fragility level at seven other frequencies that were not statistically significant. In addition, there was no change in fragility level at six other frequencies. Therefore, degradation due to aging was not demonstrated for these two specimens at the 10% significance level.
2. For units 11B and 12B, at all eight frequencies where there was a change in fragility level the mean change was to a higher fragility level. While this appeared to be a strong trend toward improvement with aging, none of the changes was statistically significant at the 10% level. In addition, there was no change in fragility level at eight other frequencies. Therefore, the apparent improvement in performance was not demonstrated for these two specimens at the 10% significance level.
3. For units 13B and 14B, there were decreases in fragility level at six frequencies; three of these were statistically significant at the 10% level and three were not. In addition, there was no change in fragility level at ten other frequencies. Therefore, degradation due to aging was not demonstrated for these two specimens at the 10% significance level.
4. For the two devices, 19B and 20B, where only a single specimen of each was available, a strong trend toward a decrease in fragility level was observed across frequencies between 6.3 and 32 Hz, but this was not analyzed statistically. At frequencies between 1.0 and 5.0 Hz, both units had no change in fragility level. For these two units, if the same changes in fragility level had been observed in a larger sample size, it is suspected that an aging trend could have been demonstrated statistically.

---

* See Functional Tests under TEST RESULTS.

CONCLUSION

The study was conducted to investigate the effect of aging on the vulnerability of electromechanical components to seismic-type vibration with respect to their Class 1E function. The devices tested included relays, starters, contactors and circuit breakers. Each device was subjected to a vibration test before and after an accelerated aging program intended to simulate the degradation caused by 40 years of service in a nuclear power generating station. The vibration test consisted of shaking each device in the direction that was most likely to cause spurious opening or closing of contacts, at discrete frequencies between 1.0 and 32.0 Hz at intervals of 1/3 octave, at maximum acceleration amplitudes that increased from 0.4 g at 1.0 Hz to 6 g at 12.7 Hz and remained at the 6 g level for higher frequencies.

In summary, it was observed that:

- three devices (5B, 6B and 21B) failed as a consequence of exposure to gamma radiation;
- thirteen devices (1B, 2B, 3B, 4B, 7B, 8B, 15B, 16B, 17B, 18B, 22B, 27B and 28B) gave no evidence of aging with respect to seismic vulnerability;
- statistical analysis of the test data for six devices (9B, 10B, 11B, 12B, 13B and 14B) led to the conclusion that aging could not be demonstrated at a significance level of approximately 10%;
- one device (19B) exhibited a strong aging trend, but it probably was not significant at the 10% level;
- one device (20B) exhibited a strong aging trend that probably was significant at the 10% level.

A factor that contributed to conservatism was the fact that each device was subjected to a relatively severe vibration test, viz., continuous sinusoidal vibration for 30 seconds at fragility levels (or maximum test levels), at 16 discrete frequencies, in the energized and de-energized states, before and after the accelerated aging program.

When the program is considered as a whole, the overall qualitative impression is that aging (as simulated in this program) does not have a significant effect on the seismic vulnerability of most of the types of contact devices tested.

REFERENCES

[1] IEEE Standard 323-1974, IEEE Standard for Qualifying Class IE Equipment for Nuclear Power Generating Stations, The Institute of Electrical and Electronics Engineers, Inc., New York, N.Y., 1974.

[2] Regulatory Guide 1.89, Qualification of Class IE Equipment for Nuclear Power Plants, U. S. Atomic Energy Commission, Directorate of Regulatory Standards, Washington, D.C., Nov. 1974.

[3] IEEE Std 279-1971, Criteria for Protection Systems for Nuclear Power Generating Stations, The Institute of Electrical and Electronics Engineers, Inc., New York, NY, 1971.

[4] IEEE Std 649, IEEE Standard for Qualifying Class IE Motor Control Centers for Power Generating Stations, The Institute of Electrical and Electronics Engineers, Inc., New York, N.Y., to be published.

[5] FRC Final Report F-C4590, A Study of the Effect of Aging on the Operation of Switching Devices During Vibration at Frequencies in the Seismic Range, Franklin Research Center, Phila., PA, Oct. 1977.

[6] S. Siegel, Non-Parametric Statistics for the Behavioral Sciences, McGraw Hill, 1956 (pp. 75-83).

ACKNOWLEDGMENTS

Among the many persons who contributed to this study, the authors wish particularly to thank Gerald D. Guske (FRC), who performed the experiments; Robert J. Gibson (FRC), who conducted the statistical analysis; and Paul Higgens (Gould), who monitored the entire program.

BIOGRAPHIES

Salvatore P. Carfagno (M '78) was born in Norristown, PA, on November 29, 1925. He received a B.S. in Mechanical Engineering from Drexel University, an M.S. in Physics from the University of Pennsylvania and a Ph.D. in Physics from Temple University, all in Philadelphia, in 1947, 1949 and 1963, respectively.

In 1948 he joined The Franklin Institute, Philadelphia, where he has participated in studies involving heat transfer, fluid mechanics, magnetohydrodynamics, gaseous ignition, energy conservation and qualification of safety-system equipment. He is currently Manager of Performance Qualification at Franklin Research Center, a division of The Franklin Institute. Dr. Carfagno is also an Adjunct Professor of physics at Drexel Evening College.

Dr. Carfagno is a member of IEEE, ASTM, Sigma Xi, and Tau Beta Pi. He has been a member of IEEE Subcommittee 2, Equipment Qualification, for many years and has served on a number of its Working Groups.

G. Erich Heberlein, Jr. (M'68) was born on May 16, 1940 in Pittsburgh, PA. He received a B.S. degree in Mechanical Engineering from Northrup University in Englewood, CA, in 1966.

In 1966 he joined Gould Inc., then I-T-E Circuit Breaker Company, and is now manager of Development Engineering of the Distribution and Controls Division in Westminister, MD. He is the author of several seismic technical papers, including an IEEE transaction paper.

Mr. Heberlein is a member of the Institute of Environmental Sciences, and is the Chairman of the International Electrotechnical Commission (IEC) Working Group for drafting seismic standards for electrical and communication equipment.

Gould Inc., Circuit Protection & Controls Division
[illegible]
Telephone [illegible]

GOULD

ATTACHMENT 1

CERTIFICATE OF CONFORMANCE

Equipment : J10 Relay
(J20M22, J20A20, J20A40)

Customer : Gulf & Western
EPC-FLUID
Systems Division

Specifications : ES1002
Rev. 3
IEEE 323-1974

Purchase Order No. : EPGCZ04752

Gould Reference : SO #84-68454
R-323-3
Arrhenius File I

Certification No. : CC-323.74-62, Rev. 0

1.0 PURPOSE

To certify that the subject Gould equipment of Section 2.0 will perform its required Class 1E functions after being subjected to a variety of environmental and operational aging tests designed to simulate a 40 year life, to confirm that the seismic withstandability of the equipment is not lowered by the aging phenomena, and to qualify the equipment to satisfy the requirements of referenced specifications.

2.0 CLASS 1E EQUIPMENT COVERED BY THIS DOCUMENT

Gould type J10 control relay.

CLASS 1E EQUIPMENT	I.D. NO.	QUALIFIED LIFE*
Relay	J20M22 J20A20/ J20A40	40 yrs.

*See Section 4.0 of this document for a discussion of the qualified life.

3.0 SERVICE CONDITIONS

Pressure : -.5 psig to 5 psig

Relative Humidity : 20% to 100%.

Temperature : -23.3°C to 65.6°C .

Radiation : 8.8×10^6 rads integrated dosage 40 yrs.

Contamination : Not specified

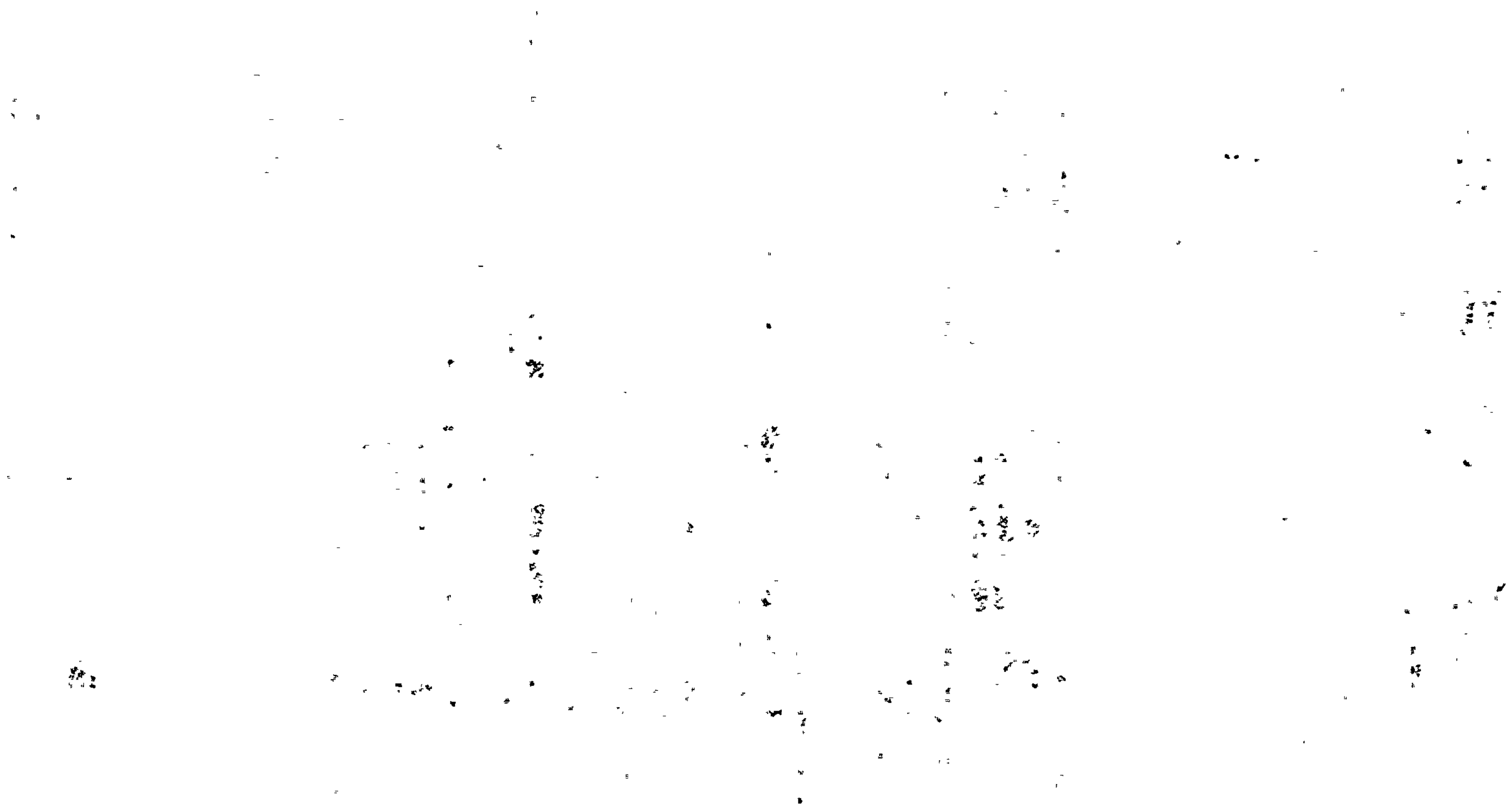
Operation : 50 to 400 per year

x 40 x 40

2000 16000

4.0 DISCUSSION

Representative samples of the equipment listed in Section 2.0 were put through an accelerated aging test.



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The aging test program was developed with the assistance and guidance of the Franklin Institute Research Laboratories, Philadelphia, Pennsylvania, and was, for the most part, carried out at that facility. Furthermore, the program was performed in accordance with the principles of IEEE Std. 323-1974.

Section 5.0 outlines the procedure and order of the accelerated aging program. Attachment A lists the levels reached for the various environmental/operational tests.

Throughout the tests, the devices progress was checked by base line functional tests in order to determine failure causes, if any. These checks consisted of a visual check for structural anomalies and electrical checks for proper contact continuity and operation of the devices. The two seismic withstandability test evaluations indicated were used as a control to compare the devices seismic withstandability before and after the aging sequence.

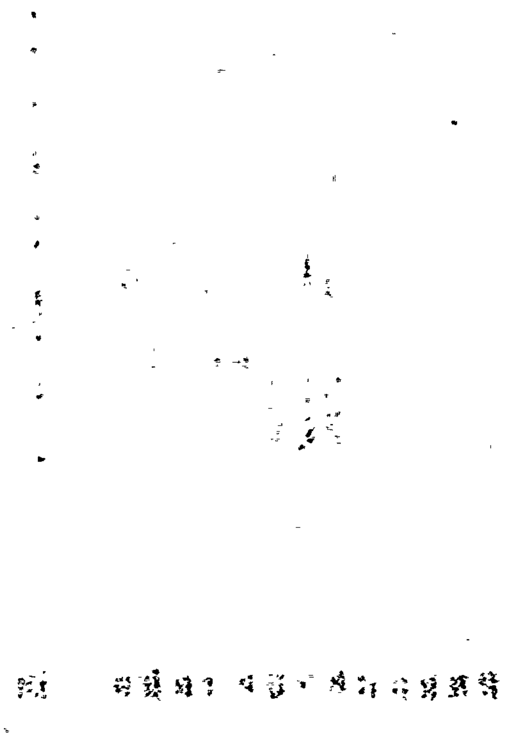
The last base line functional test was used to confirm that devices could still perform their Class 1E functions. Proper Class 1E operation was also verified in a 50°C ambient and during the seismic withstandability evaluations.

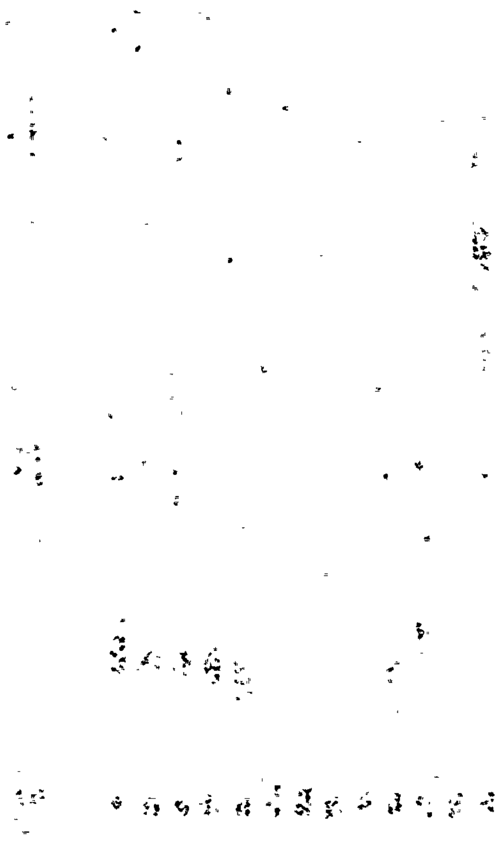
Seismic aging consisted of the application of five biaxial (front-to-back/vertical and side-to-side/vertical), in and out of phase, random motion tests. Attachment A contains a typical TRS curve.

The seismic withstandability evaluation consisted of single frequency tests at every 1/3 octave interval from 1 to 32 Hz. Tests were performed in the axis that was determined to be the most vulnerable for the equipment. Fragility levels at each of the test frequencies, for the before and after tests, were then compared and used in the evaluation of aging effects on the equipment's seismic withstandability.

The order of the accelerated aging procedure was chosen to be the most severe sequence since it was impossible to perform the various aging exposures simultaneously. Thermal aging was performed based upon the Arrhenious relationship between time and temperature for the weak link material. The weak link material choice by the Franklin Institute was based upon the thermal degradation characteristics of the various nonmetalic materials, their specific function and the state of the art of thermal aging techniques. A pan of water was placed in the oven during thermal aging. This was done in an attempt to simulate the effects of high humidity on the test specimens.

The equipment has a nominal qualified life of 40 years in a continuous 40°C ambient. This is usually quite conservative since the ambient specified for our equipment is rarely 40°C





continuously. Usually 40°C is specified as the maximum temperature (meeting NEMA ICS) with an average ambient temperature much lower than this. Since an average ambient temperature is not specified, only minimum and maximum, it is difficult to give a precise qualified life. However, extrapolating for a 65.6°C continuous ambient temperature (worse case condition), the qualified life would be 1.03 years; for 50°C continuous, the qualified life would be 11-1/2 years. Based upon the minimum and maximum temperatures specified, an average temperature of 16.65°C would result in a qualified life greatly in excess of 40 years. Therefore, if the average temperature is less than 40°C, the subject equipment would have a qualified life of 40 years or more.

5.0 ACCELERATED AGING PROGRAM OUTLINE

1. Base line function test
2. Seismic withstandability evaluation
3. Base line functional test
4. Gamma irradiation
5. Base line functional test
6. Thermal and humidity aging
7. Base line functional test
8. Mechanical and electrical operations
9. Base line functional test
10. Seismic aging
11. Base line functional test
12. Seismic withstandability evaluation
13. Base line functional test

6.0 RESULTS AND SUMMARY

The results of the aging test program demonstrated that the equipment of Section 2.0 will operate properly (i.e., perform their 1E functions) for a 40 year time period in the environment specified in Section 3.0, provided the number of operations indicated in Attachment A are not exceeded, and any specified maintenance and surveillance procedures are followed. The qualified life for the subject equipment will have to be lowered in accordance with the stipulations of Section 4 if it is determined that the average ambient temperature is greater than 40°C. Although, as shown on Attachment A, there was no maintenance performed on the specimens during the test, the devices must still be periodically inspected for any unusual condition such as a heavy accumulation of dust, dirt,

moisture or abnormal heating, the cause of which must be corrected. In addition, wire terminations should be checked for tightness.

The statistical analysis performed on the results of the two seismic withstandability evaluations confirmed that the seismic withstandability of the subject equipment was not significantly altered by the aging simulation.

7.0 CERTIFICATION

It is hereby certified that the information presented in this document is true and that all tests were performed. Test reports are considered proprietary but are available for review at Gould, Inc. offices, Westminster, Maryland.

G. Erich Heberlein, Jr.
Manager of Development Engineering

January 18, 1980

vmr

CC-323.74-62

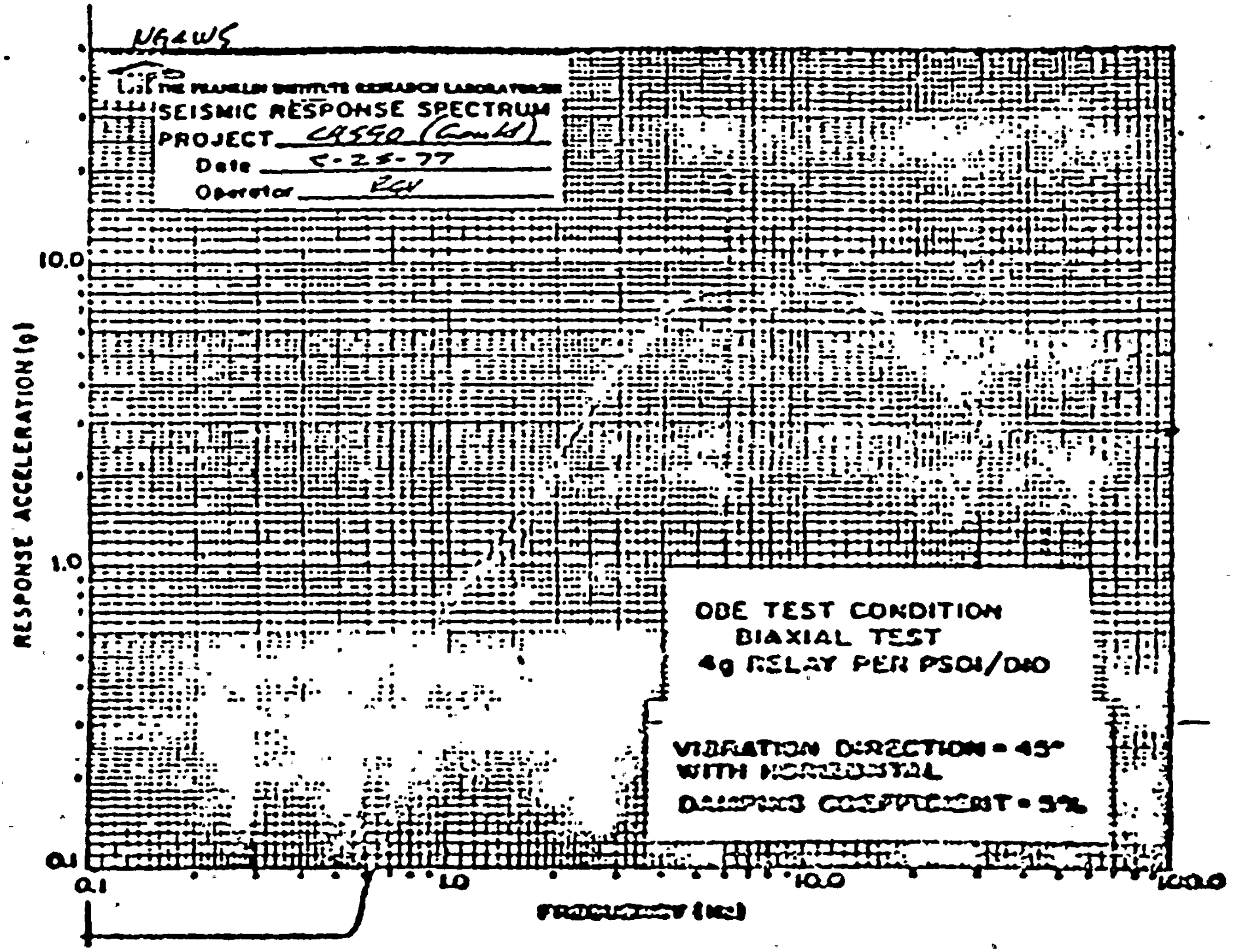


Figure 5-1. Typical Test Response Spectrum of the OBE Vibration

ATTACHMENT A

The attached table lists the various environmental and operational levels simulated for the various aging tests performed during test R-323-3.

	J10 Relay
Radiation: (Gamma)	1×10^7 rads
Thermal: (40°C for 40 yrs. simulation)	100°C for 107 hrs.
Relative Humidity: (During Thermal Aging)	95 to 100% for 80% of the time
Mechanical/Electrical Operations:	2×10^6 @ 5 amps Make and break
Seismic Aging (ZPA): (Also see TRS Curves)	4.0 g's
Contamination:	Medium accumulation of dust and dirt
Maintenance Performed:	None.
Seismic Withstandability:	No change due to aging
Anomalies:	None

Gould Inc., Circuit Protection & Controls Division
801 Baltimore Blvd., W[illegible]
Telephone [illegible]

GOULD

ATTACHMENT 2

SEISMIC CERTIFICATION

Equipment : J10 Relay
(J20M22, J20A20 /J20A40)

Customer : Gulf & Western
EPG-FLUID
Systems Division

Specifications : ES-1002 Rev. 3
IEEE 344-1975

Purchase Order : Graybar EPGCZ04752

Gould Reference : SO #84-68454
R-STS-10, 11
R-STD-2

Certification : SC 274, Rev. 0

1.0 PURPOSE

To establish acceleration levels that the subject equipment of Section 2.0 have successfully passed without contact chatter durations greater than 2 mseconds.

2.0 EQUIPMENT COVERED BY THIS DOCUMENT

Gould type J10 (J20M22, J20A20/J20A40) control relay.

3.0 DISCUSSION

Seismic tests have been performed on samples of the subject equipment in accordance with IEEE 344-1975. The equipment tested was new and random selected. The use of non-aged equipment is justified in that as a part of the IEEE 323-1974 qualifications program, tooling, and analysis it was demonstrated that with the respected subject equipment the seismic withstandability was not lowered by the aging parameters used in the program. Most of the seismic tests were performed on assembled structures with accelerometers placed next to the internal components. The TRS curves presented for these tests are generated from the time histories for the appropriate specimen mounted accelerometers. The tests discussed in this document were proof tested to a particular customer's requirement and are not necessarily the fragility limit for the subject equipment.

Random multifrequency motion consisting of frequency bandwidths spaced one-third octave apart over the frequency range of interest was used as the excitation function. The duration of each test run was 30 seconds. The random motion was applied simultaneously in the vertical and one horizontal axis at a time. The specimen was rotated 90° during the test so that two orthogonal horizontal axes would be tested. Most tests were performed with phase incoherent inputs; those that weren't, were tested with the horizontal and vertical inputs in phase and then out of phase.

Five OBE level (approximately half the SSE level) tests were run prior to the SSE level tests in both the front-to-back/vertical and side-to-side/vertical axes.

Devices were tested in the energized, de-energized and transitional states with both normally open and normally closed contacts monitored for proper operation and chatter durations greater than 1 msecond.

TRS curves for the various seismic tests performed on the subject equipment are contained in Attachment A. The curves are supplied for both horizontal axes and the vertical axis. They are applicable for all electrical states and contact configurations.

4.0 CERTIFICATION

It is hereby certified that this document represents a true accounting of seismic tests performed on seismically equivalent samples of the subject.

In order for the test data to be valid, the relay must be mounted to a vertical surface in their standard configurations.

G. E. Heberlein, Jr.
Manager of Development Engineering
Product Development

January 18, 1980

vmr

SC 274

ATTACHMENT A

Summary of
Seismic Test
Performed on J Relay

Gould Inc., Control and Systems Division
P.O. [illegible]
[illegible]

GOULD

SUMMARY OF SEISMIC TEST
PERFORMED ON THE J RELAY LINE

Seismic tests identified as R-STD-2, R-STS-10, R-STS-11, and R-STS-16 have been performed on the Gould J Relay line.

Test R-STD-2 was performed on the J Relay mounted directly to a test table fixture while tests R-STS-10, R-STS-11 and R-STS-16 were performed with J. Relays mounted in a Motor Control Center. All tests were performed in accordance with IEEE Std. 344-1975 at Wyle Laboratories, Huntsville, Alabama.

The following is a summary of the above referenced test reports:

(1) R-STD-2 (Wyle Report 43513-1) - This test used Random Motion and Sine Beat superimposed on random as the input function. Test durations were 30 seconds for both OBE and SSE levels. The test was performed biaxially, in and out of phase. The specimen was rotated 90° in order to test two orthogonal horizontal axes. The Relay was tested in the energized and de-energized condition and in the transition state. Contacts were monitored for chatter, the first mode of failure.

(2) R-STS-10 (Wyle Report 43840-1) - J relays were mounted in a Motor Control Center for this test. Random motion was used as the excitation function, the amplitude of which was controlled in 1/3 octave intervals from 1 to 40 Hz. The test was performed biaxially with phase incoherent inputs. The specimen was rotated 90° during the test in order to test two orthogonal horizontal axes. These durations were 30 seconds for both OBE and SSE levels. The J relays were tested in both the energized and de-energized mode with their contacts monitored for malfunctions (i.e., the unwanted change of state of the contacts (chattering)).

(3) R-STS-11 (Wyle Report 42946-1) - For this test, the J relays were mounted in a Motor Control Center with sine beat used as the input function. Five beats of five (5), ten (10) and twelve (12) cycles per beat with 2 second pauses between beats were used. The sine beats were applied biaxially in and out of phase with the specimen rotated 90° during the test in order to

test two orthogonal horizontal axes. Contacts were monitored for chatter throughout the test in the energized and de-energized state.

(4) R-STS-16 (Wyle Report 43472-1) - J relays were mounted in a Motor Control Center for this test. Random motion was used as the input function, the amplitude of which was controlled in 1/3 octave intervals from 1 to 50 Hz. The test was performed biaxially with phase incoherent inputs. The specimen was rotated 90° during the test in order to test two orthogonal horizontal axes. Test durations were 30 seconds for both OBE and SSE levels. The J relays were tested in the energized and de-energized conditions and in the transition state.

One additional note, the design of the J relays is such that an increase in the number of contact blocks, up to a maximum of three, has the effect of increasing the seismic withstandability of the relay in both the energized and de-energized states. Test data is available for review at Gould Control & Systems Division office, Westminster, Maryland.

Attachment A contains the highest horizontal (both front-to-back and side-to-side) and vertical RRS curves reached during the referenced tests. Note, however, that these are not fragility curves as contact chatter was not present.

Prepared by:

Paul W. Higgins

Paul W. Higgins
Associate Development Engineer

Approved by:

G. Erich Heberlein

G. Erich Heberlein, Jr.
Engineering Manager
Research and Development

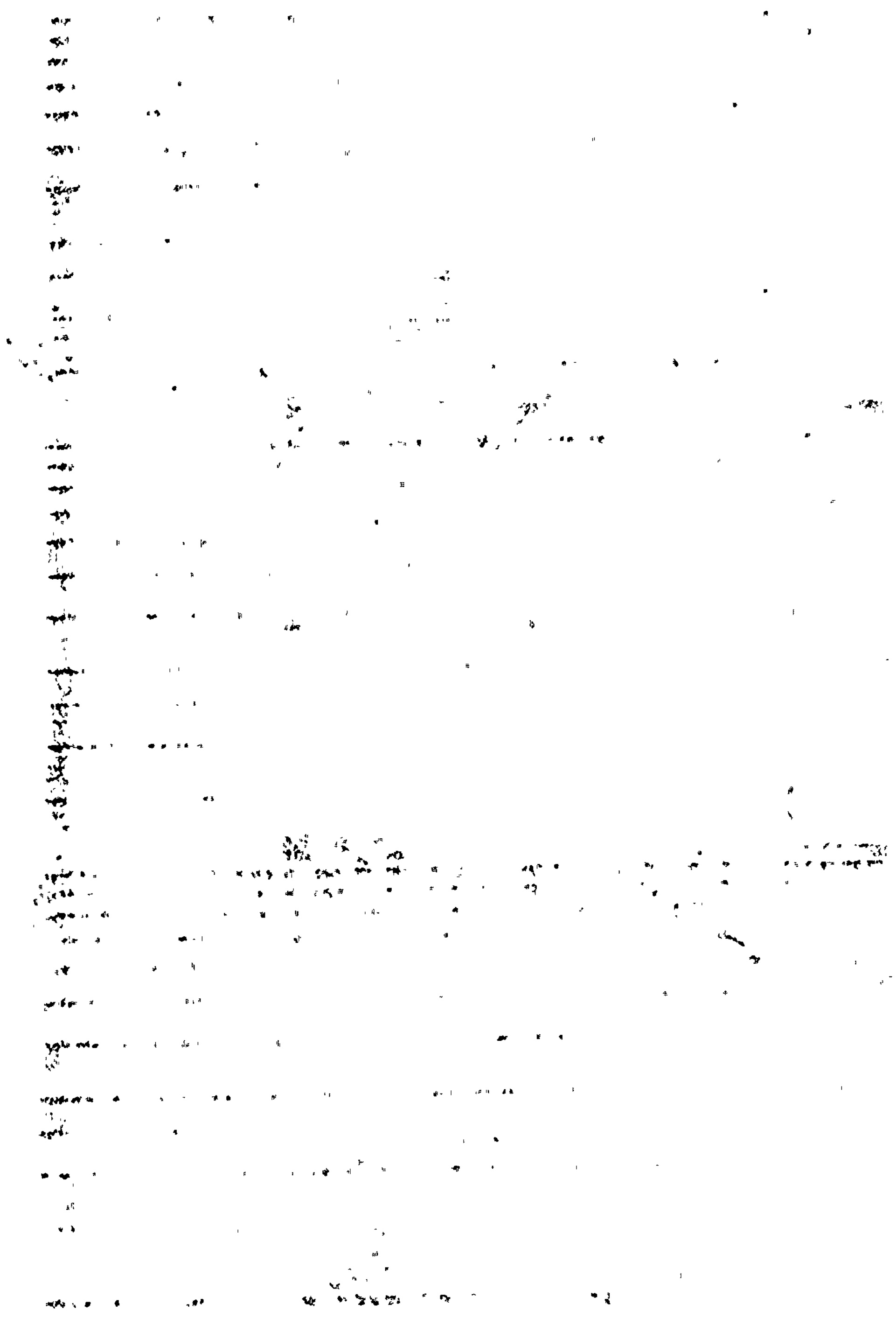
January 9, 1978

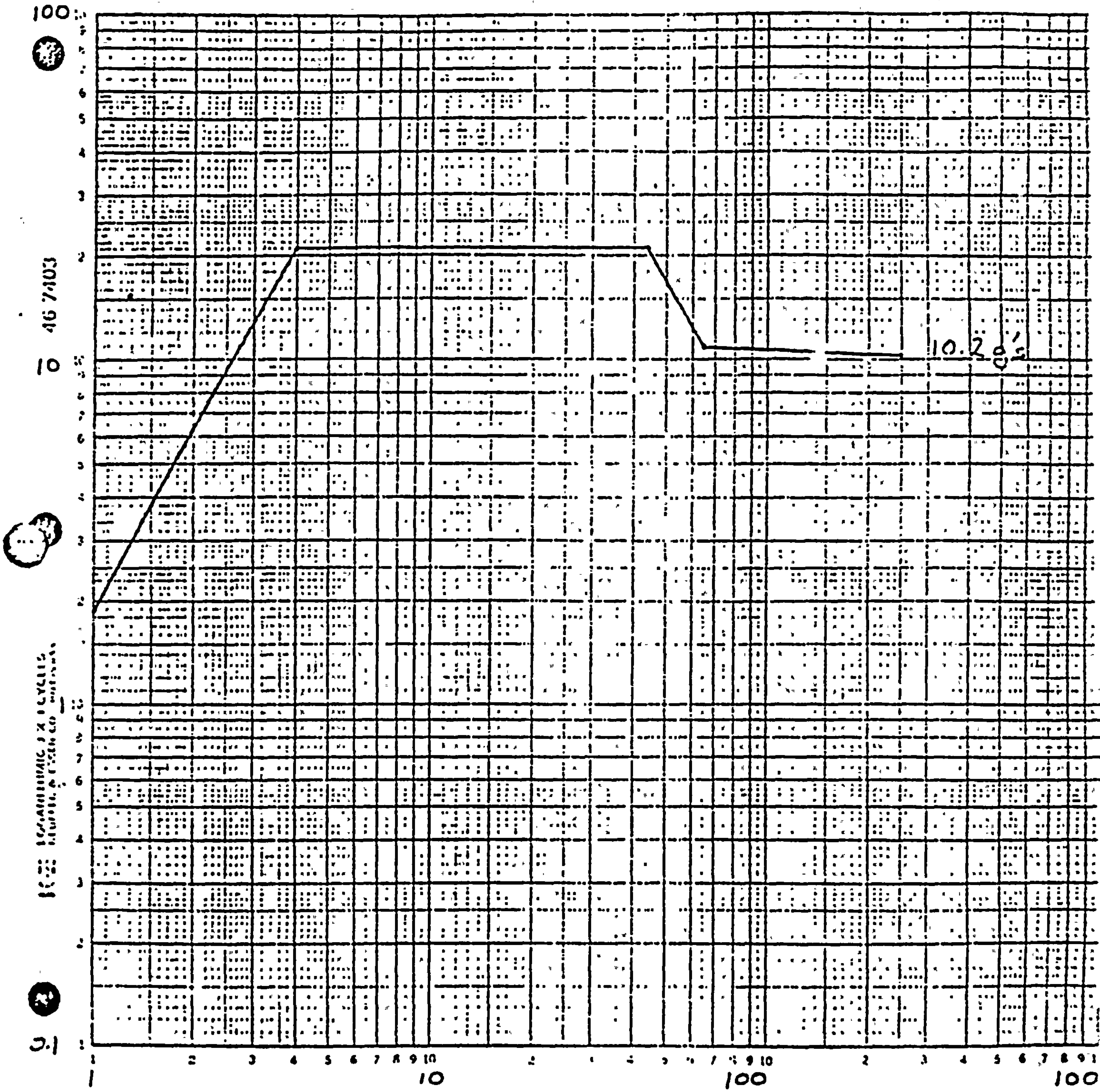
djg

SC-164

ATTACHMENT A

Horizontal and Vertical RRS
Curves for the J Relay Line



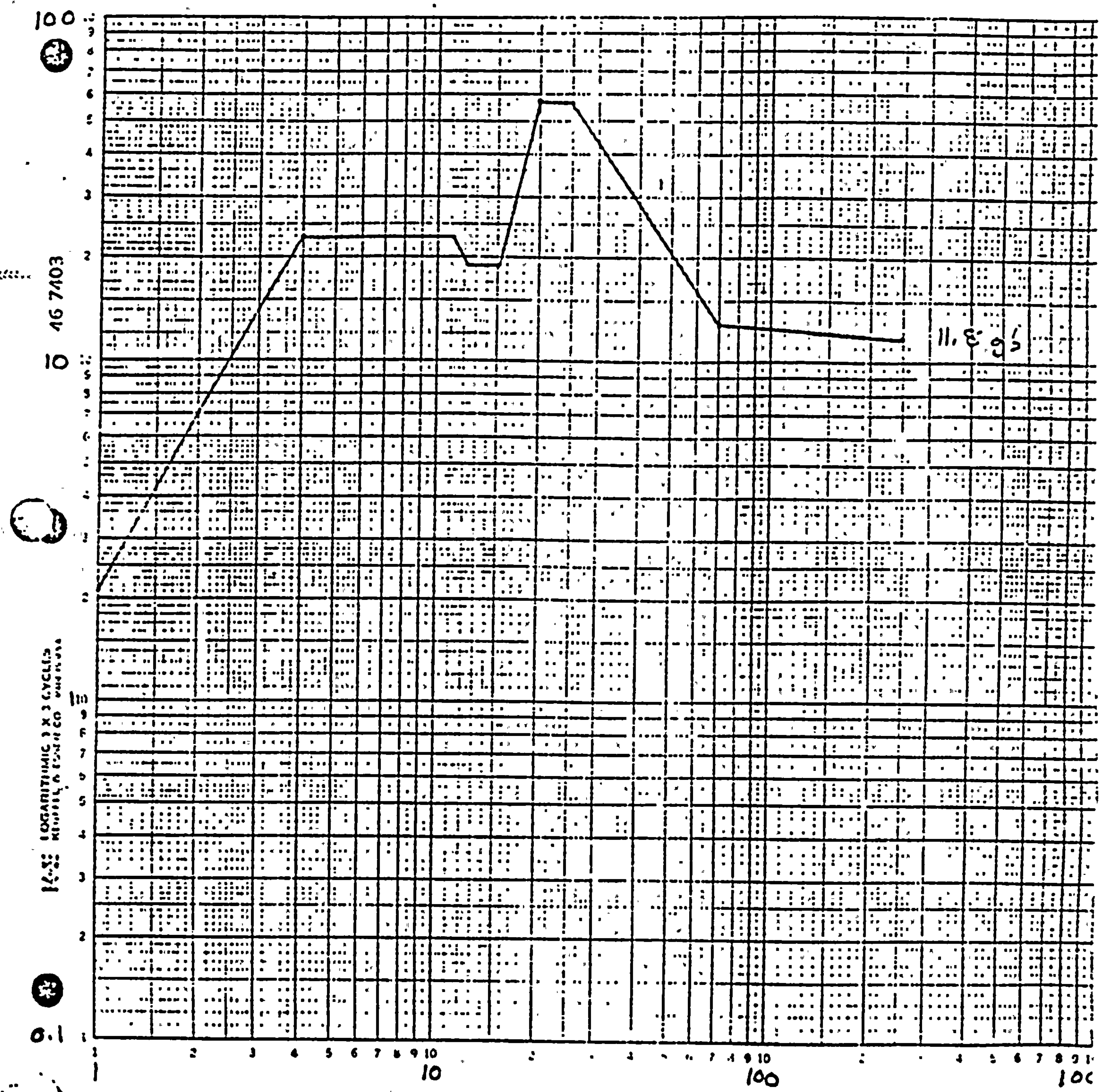


HORIZONTAL TRS (S-S)

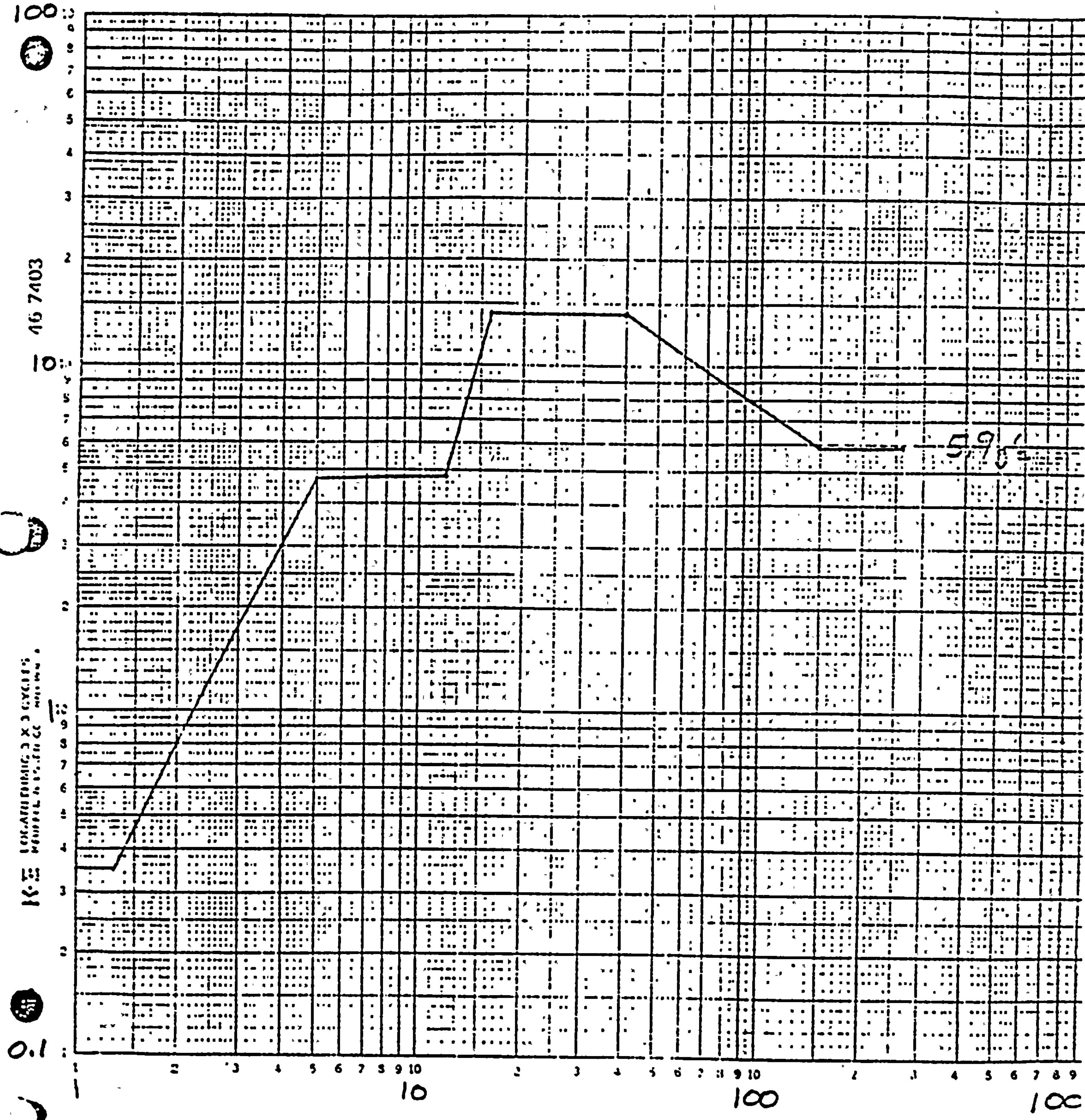
1 % DAMPING

J RELAY LINE

2-34-1[illegible]S

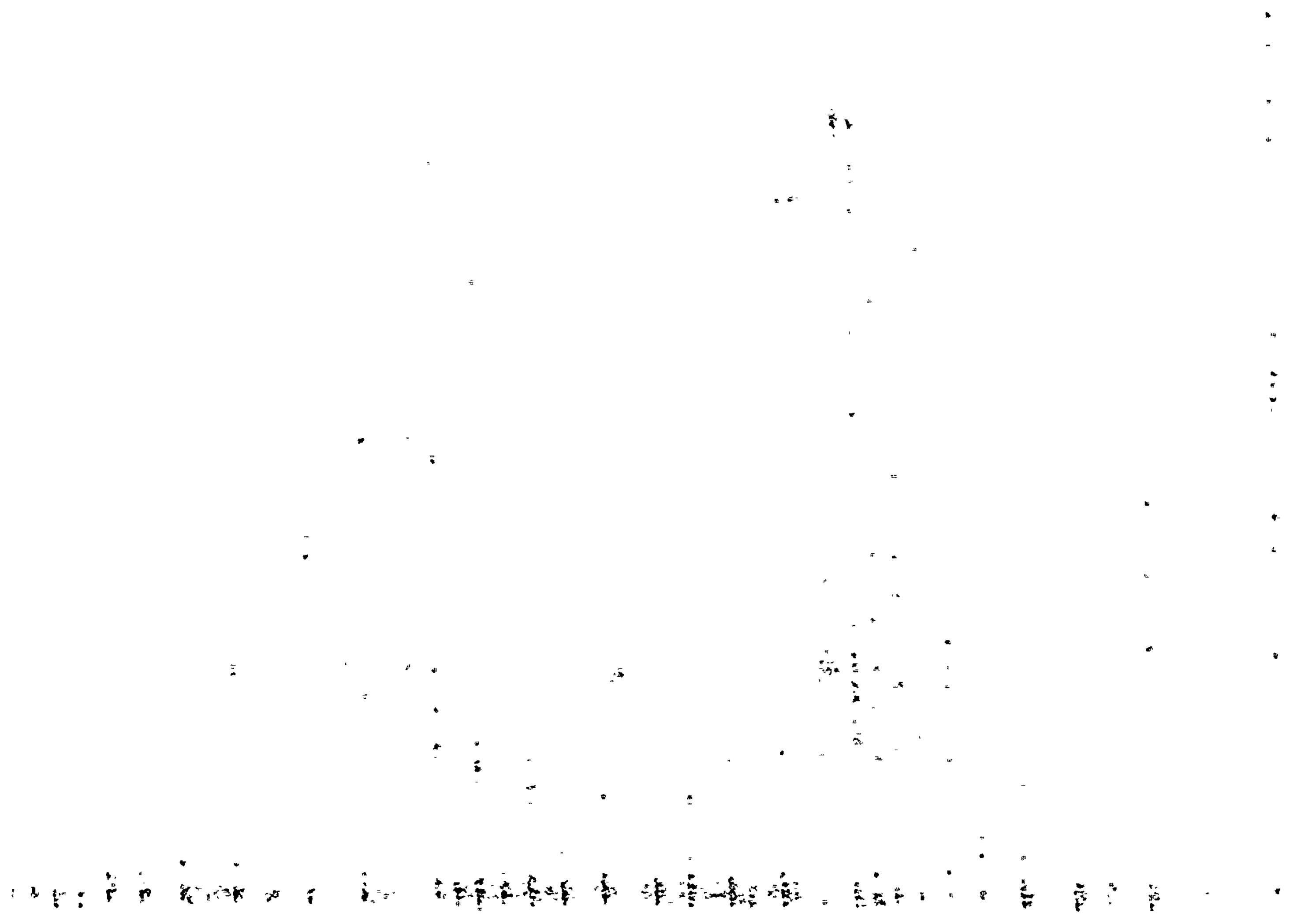


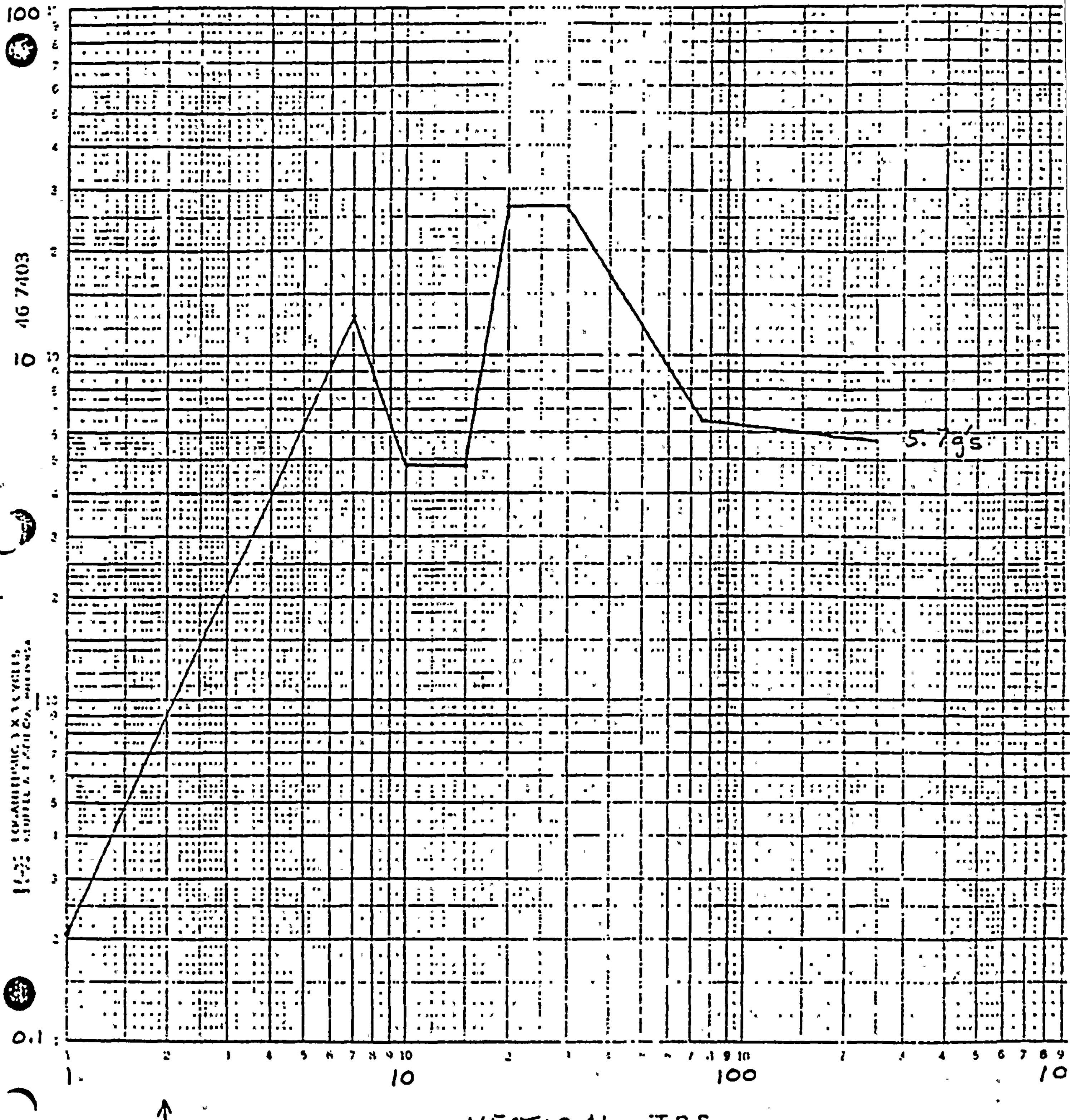
VERTICAL TRS
1% DAMPING
J RELAY LINE
2-24-2V



HORIZONTAL TRS (F-B)
1 % DAMPING
J RELAY LINE

g's
FREQ. HZ





VERTICAL TRS
1 % DAMPING
J RELAY LINE

Gould Inc., Distribution and Controls Division
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Telephone (301) 876-2214

GOULD
An Electrical/Electronics Company

August 21, 1981

ATTACHMENT 3

Mr. Steven D. Slesinger
Electrical Engineer
G + W Fluid Systems
Gulf + Western Manufacturing Company
25 Graystone Street
Warwick, Rhode Island 02886

Subject: Stone & Webster Technical Meeting - July 31, 1981

Dear Steve:

On July 31, 1981 a meeting was held between Stone & Webster's Mr. Anthony Giancatarino, Mr. William Provencher (Environmental Qualification). Mr. Paul Higgins, Project Engineer, Gould, and myself. The purpose of the meeting was to have a technical exchange with respect to Gould's qualification program. By having a direct contact, a clearer understanding of technical information is often achieved. It is Gould's contentions that we have provided sufficient information to Gulf + Western and have met the contact requirements. I note that you have also conveyed this to Gould.

In the meeting, in order to have a complete understanding, Gould agreed to provide some additional technical information. Gould provides this in the good spirit of cooperation and understanding. There were four areas of interest:

1. Requirement: Provide Hooker Chemical correspondence referenced in the Franklin Institute report.

   Gould's Response: Attached you will find not only the Hooker letter but all the supporting documentation provided by Hooker.

2. Requirement: Provide arrhenius plots for Phelps Dodge.

   Gould's Response: The arrhenius plots are attached.

3. Requirement: Provide a calculation showing the severity or stress that was occurred doing the electro-mechanical aging.

   Gould's Response: Attached you will find a paper on J Coil Life Test. This includes the stress calculations.

4. Requirement: Review the Franklin Institute report and provide clarification with respect to the seismic withstandability test in natural aged specimens.

   Gould's Response: Please note that the natural aged specimens were not subjected to the first seismic withstandability test. It was deemed unnecessary since the naturally aged specimens were already "naturally aged", i.e., a comparison before aging to after aging could not be done.

In addition, we made an inspection of the actual J coils that failed under the high temperature aging tests. There was no evidence of the epoxy material failing.

If you have any comments or questions concerning this letter, please let me know. I would appreciate your forwarding this information to your customer, Stone & Webster.

Sincerely yours,

G. Erich Heberlein, Jr.
Manager, Development Engineering

GEH/be

Enclosures

J COIL LIFE TEST

The following demonstrates the aging effect or aging stress due to the rapid operation that is occurred during the electrical life (electrical/mechanical aging test).

It is a natural phenomena with an open solenoid in an AC circuit that the current is higher than when the solenoid is in the closed position. Thus, it is what is called an inrush current and a holding current. The case in point, the J relay experiences a 1.08 ampere inrush current and a .125 holding current. This current is at 120 volts or the voltage used throughout the aging test.

During the performance of the electrical/mechanical aging test, the relay was operated at its fastest manageable rate. This rate is three operations per second, with the J relay experiencing 2 million operations (2×10^6) or 6.6×10^5 seconds which is 185 hours. By noting the formula on Figure 1 (attached) the equivalent duty cycle can be calculated. Thus, the current experienced is a continuous current of .54 amperes. This duty cycle current stresses the coil at higher temperatures than would be experienced if the coil were energized and left on the duration. The ratio being:

$$\int I^2 R \ dt$$

or assuming the same resistance and same time, the ratio is I^2t for the duty cycle to I^2 continuous, i.e., 0.25 to 0.0156. This is 16 x the heat for the same period of time. Since the duration is 185 hours, the coils were stressed substantial time and as well were stressed electrically. Therfore, it is Gould's opinion that any synergistic effect would occur from an aging phenomena of heat and electrical stress. The rapid operation of three cycles per second for a duration of 185 hours would be much higher than it would occur in actual field usage.

FIG. 1.

$$I_{EFFECTIVE} = \sqrt{\frac{(I_1)^2(t_1)+(I_2)^2(t_2)+(I_3)^2(t_3)}{t_1+t_2+t_3}}$$

I_1 = INRUSH CURRENT ∴ 1.08A @ 120V

I_2 = HOLDING CURRENT ∴ 0.125A @ 120V

I_3 = OPEN CURRENT ∴ NO CURRENT (0)

t_1 = INRUSH TIME ≈ 0.083 SEC.

t_2 = HOLDING TIME ≈ 0.083 SEC

t_3 = OFF TIME ≈ 0.166 SEC

SOLVING:

$I_{EFFECTIVE}$ = 0.5436 A

Hooker DUREZ DIVISION

NORTH TONAWANDA, NEW YORK 14120 (716) 696-6123

December 9, 1976

Mr William Denny
Franklin Institute Research Lab
20th Street and the Parkway
Philadelphia PA 19103

Dear Mr Denny:

As agreed in by phone, December 8, 1976, I have enclosed a copy of our thermal aging curves developed for Durez 791. This is a general purpose phenolic similar in formulation and performance to Durez 118.

Also attached is a reference to an article on radiation damage to plastics. Durez 118 should be similar to an organic filled phenolic.

We understand you are consulting for ITE Imperial and trust this information will be helpful.

Very truly yours,

W Andrew Dannels
Technical Manager
Molding Materials

DISTRIBUTION		
TO	INIT	DATE
SPC	[illegible]	[illegible]/13
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AREA:		

Durez 'D'
Hooker Chem & Plastics Corp
2/5/

RADIATION DAMAGE TO PLASTICS

Plastic materials are susceptible to radiation damage which causes a reorientation of their molecular structure. Since plastics are polymers, reorientation results in changes in physical properties due to breaking of polymer chains, absorption of oxygen, or reaction with the environment.

On many of the plastics, electrical properties, such as volume resistivity, dielectric strength and arc resistance, appear to be practically unchanged at dosages which cause extensive physical breakdown in the material. Included were unfilled phenolic resin, a paper-filled phenolic, and a mineral-filled polyester. Commercial plastics containing fillers perform in proportion to the stability of the filler. Stable fillers (minerals) improve compound stability whil unstable fillers (cellulose-organic fibers) decrease stability. Damage in terms of loss of physical strength are given below:

Material	Filler	Threshold Damage (Rads)	25% Damage (Rads)
Phenolic	None (all resin)	1×10^6	1×10^7
Phenolic	Mineral (asbestos)	$1 \times 10^7 - 10^8$	$1 \times 10^8 - 10^9$
Phenolic	Organic (cellulose)	1×10^5	1×10^7
Phenolic	Mineral (graphite)	1×10^5	1×10^7
Polyester	Mineral	1×10^7	1×10^9

A rad is the unit of absorbed dose and is 100 ergs per gram.

Durez phenolic, polyester and diallyl phthalate materials have not been tested but should perform within the limits listed in the Table above. Diallyl phthalate should behave like the polyesters. Resistance to radiation damage at elevated temperatures has not been determined.

The information herein was extracted from reprints APEX 167 and 261, availabl from the Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C. Other sources of data are:

1. Plastics in Nuclear Eng., James O. Turner, Un. of Calif. Reinhold Publishing, 430 Park Avenue, New York 22, N. Y.
2. Materials in Design Engineering, Vol. 52, P. 130, July, 1960.

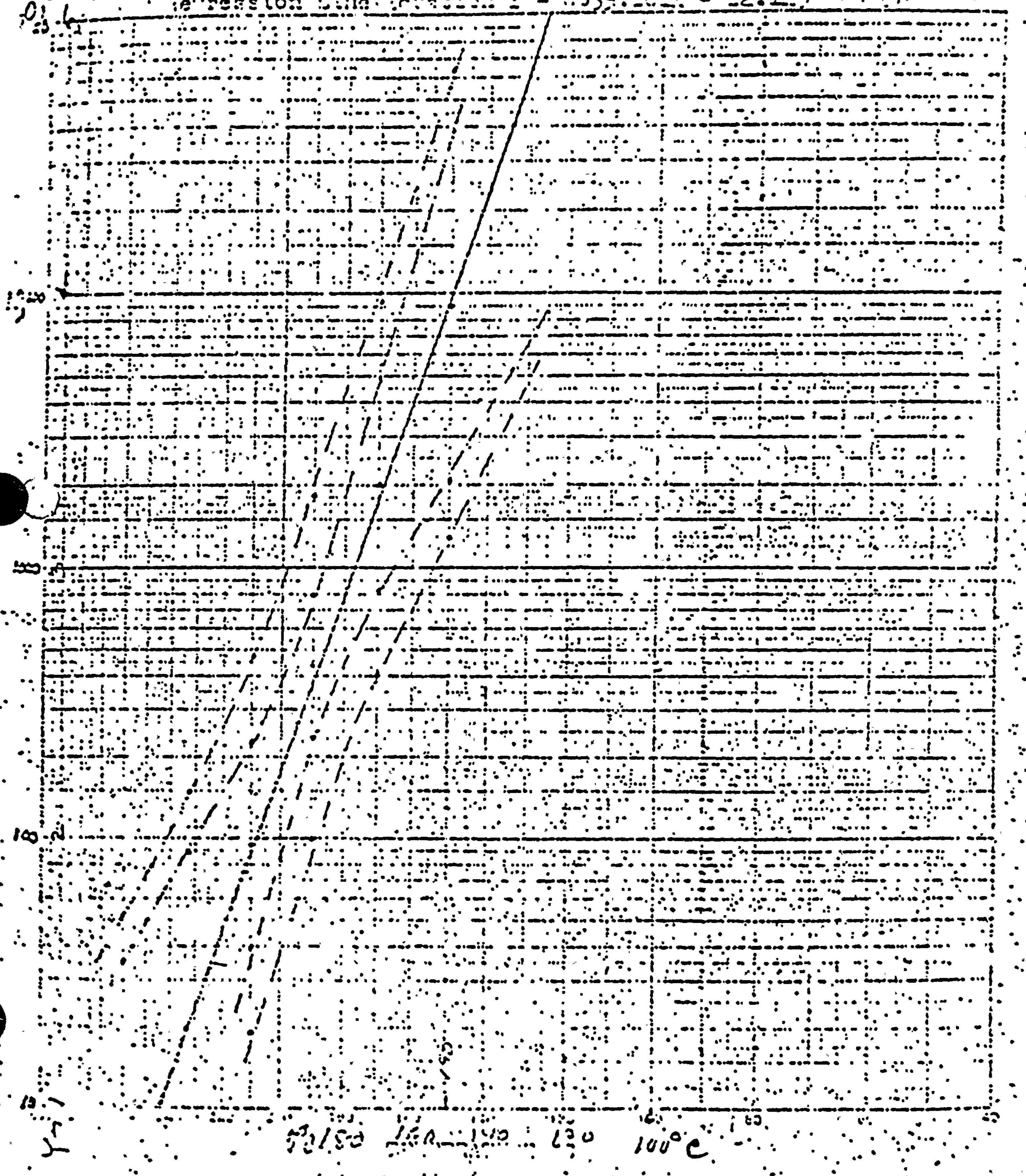
hours

50% Retention
X = 1/T
Y = log t

LIFE CURVE DATA 791.1/A[illegible]

~~[illegible]~~ IMPACT

Regression Line Equation Y = 6335.161X - 12.1[illegible]



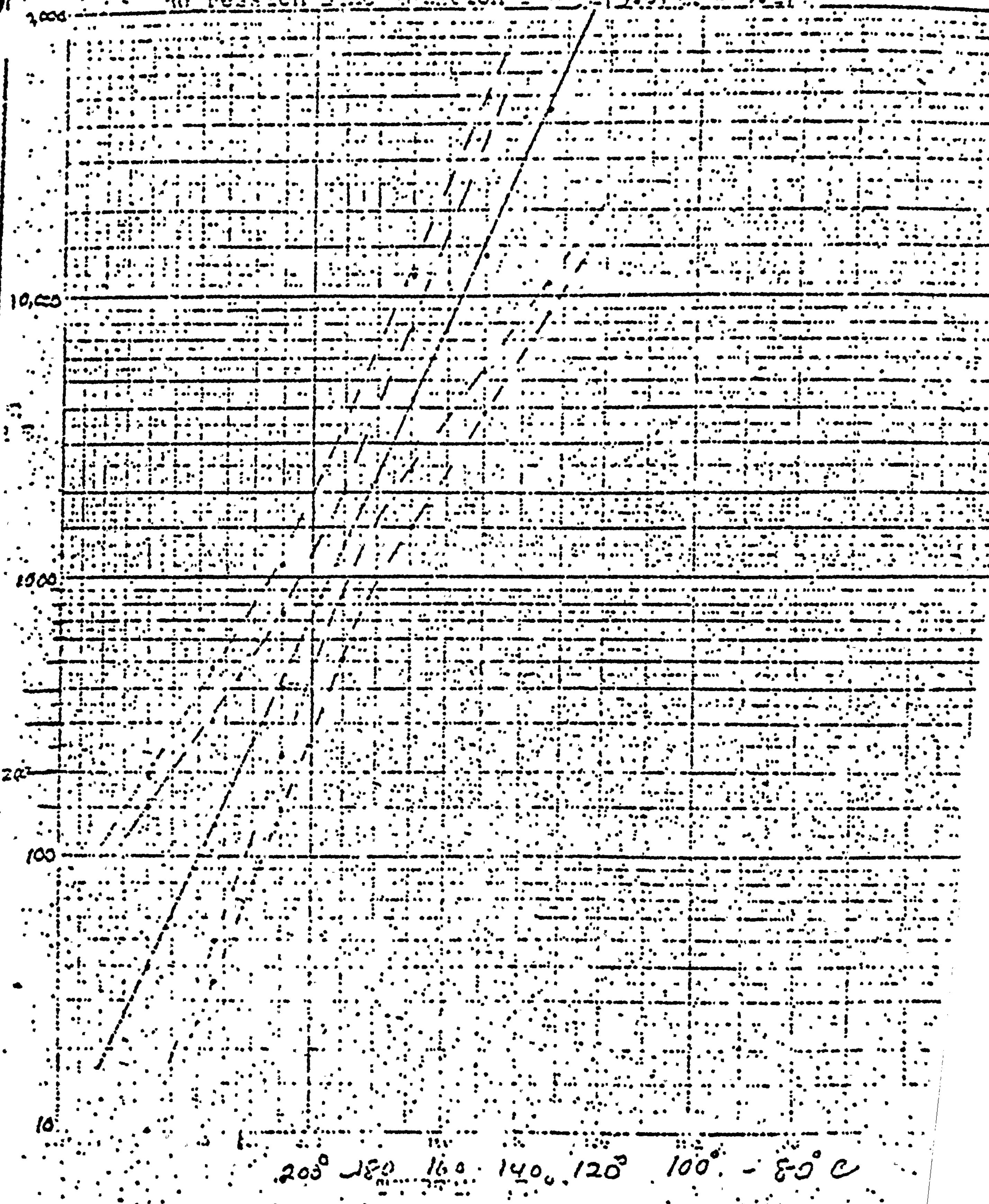
Howdy

[illegible]

FLEXURAL STRENGTH

50% Retention

Regression Line Equation Y = [illegible]273.07[illegible] - [illegible].27[illegible]



TEST RECORD NO. 6

SAMPLES:

Specimens of Grades 649, 666, 1500, and 2000 were subjected to the test procedure described below to determine the thermal aging characteristics of the materials. Grades 649 and 666 are phenolic, Grade 1500 is an alkyd, and Grade 2000 is an epoxy molding compound.

GENERAL PROCEDURE

The investigation followed the guides for evaluating insulating material as recommended by IEEE Standard Nos. 98, 99, 101. This program is based on the assumption that heat aging is the chief cause of insulation deterioration.

Each submitted plastic was subjected to a specific testing procedure and a time-temperature relationship was established. Based on the information developed, a temperature rating was assigned to each material which would give an anticipated value of approx 6722 hr. The 6722 hr value is considered to correlate the specific oven test life in this aging program with know acceptable long time field service experience of 1/16 in. thick Grade 685 at 150 C. It is a correlating factor only and should not be used when attempting to determine the expected life of the material in an end product.

LONG-TERM THERMAL AGING

General - The thermal aging and associated check tests were performed at the manufacture's facilities. The equipment testing procedures, and representative tests were witnessed by a representative of Underwriters' Laboratories, Inc.

Thermal Aging - Samples were placed in forced air-circulating ovens (Blue-M Electric Co., Models CV16A or CV16C) maintained at constant temperature. The ovens were adjusted such that the exhaust was closed and the blower intake was at maximum. Additional samples were placed in the ovens after one and two cycle delays. Periodically a sample was removed from the oven, conditioned at 23 C and 50 per cent relative humidity for at least 48 hr, and subjected to the check test.

JNT:HB

Aging was continued until check tests indicated that the property, either mechanical or electrical, had deteriorated to substantially less than one-half of the unaged test value. The time at which one-half of the unaged test value was reached was considered the end point for that material.

Tests - The following tests were performed on samples:

Test	Test Method (ASTM)	Sample Size (In.) (Length by Width or Diameter)
Flexural Strength	D790-63	5 by 1/2
Electric Strength	D149-64†	4

† - Short time, rate of voltage increase 500 v/sec., in air.

Theoretical Analysis - After accumulating the necessary data, it was necessary to evaluate the insulation in terms of operating temperature and life expectancy.

The IEEE publications Nos. 98, 99, and 101 were used as a guide. Reference should be made to these publications for a more detailed explanation of the analysis method.

For this evaluation, the life expectancy of an insulating material is considered to be a function of temperature. It has been found that the Arrhenius equation, which describes the temperature dependence of the "velocity coefficient" of chemical reactions, can be used to approximate the relationship between insulation life and temperature. This equation, as applied in this case, indicates that the natural logarithm of insulation life should be a linear function of the reciprocal of the absolute temperature. Regression analysis is used to determine the best estimate of the slope and intercept of the straight line that relates the natural logarithm of insulation life to the reciprocal operating temperature.

The form of the Arrhenius equation used is:

base 10 → log K

$$\ln K = \ln A - \frac{E}{R}\frac{1}{T}$$

where K is life in hours,
T is in degrees Kelvin,
and E, R, and A are constants.

JKT:MS

Using this form, a graph of "end-of-life" versus temperature was plotted on logarithmic - reciprocal absolute temperature paper. See ILLS. 3 through 11. See Table III for the end-of-life values used to compute the lines and the equations of the lines. Table V tabulates the values measured for each property as a function of exposure time at each temperature.

TABLE III

Grade	Property	Thickness In.	Exposure Temperature, Degrees C	Failure, Hr ÷
685 (Control)	Dielectric Strength	1/16	160	3043
			170	1376
			180	675
			190	335
649	Dielectric Strength	1/8	180	6192[a]
			190	2455[b]
			200	892
			210	696
649	Flexural Strength	1/8	180	4000
			190	2274
			200	896
			210	705
666	Dielectric Strength	1/8	170	3455
			180	3088
			190	2525
			200	504
			210	414
666	Flexural Strength	1/8	170	3933
			180	3614
			190	2724
			200	895
			210	570
1500	Dielectric Strength	1/8	160	5642
			170	2470
			180	1891[c]
			190	973
			200	354

JRT:MB

TABLE III

Grade	Property	Thickness In.	Exposure Temperature, Degrees C	Failure, Hr †
1500	Flexural Strength	1/8	170	16399^{a}
			180	5973^{c}
			190	1826^{e}
			200	1035^{f}
2000	Dielectric Strength	1/8	190	3228
			200	1286
			210	893
2000	Flexural Strength	1/8	180	4819
			190	3900
			200	2229^{c}
			210	1020

† - Failure time was estimated by calculating the best fitting polynomial equation of the degradation data for each property. The equation was computed by applying least squares analysis to the degradation data in Table V.

Notes "a" through "f" - Estimated failures, testing terminated after the following accumulated hours:

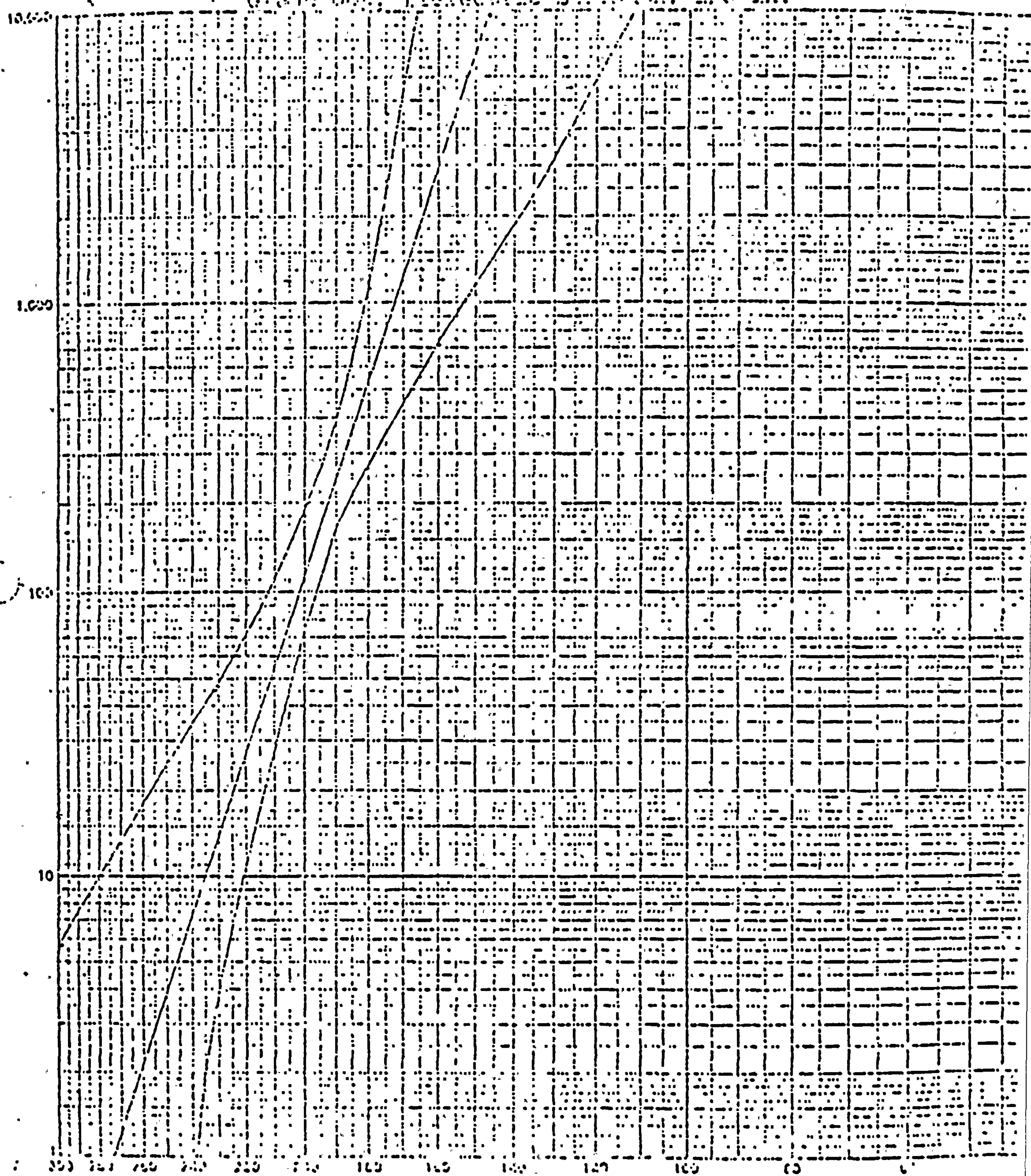
Note	Accumulated Hours
a	5112
b	2328
c	1656
d	4440
e	1242
f	816

JRT:KS

Y = 7222X - 12.1930

aliphatic

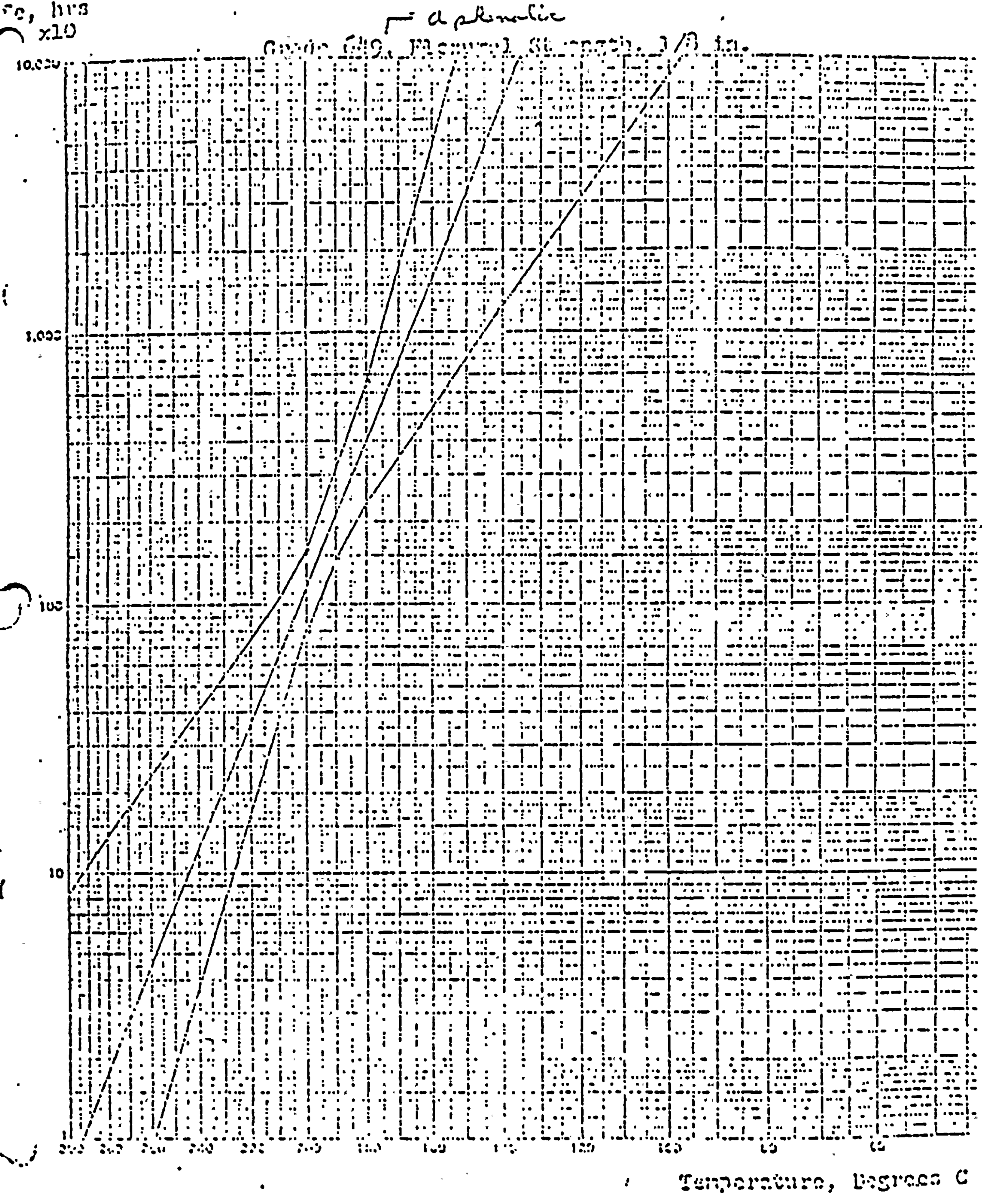
Grade 640, Dielectric Strength, 1/8 in.



Y = 5842X - 9.2963

a phenolic

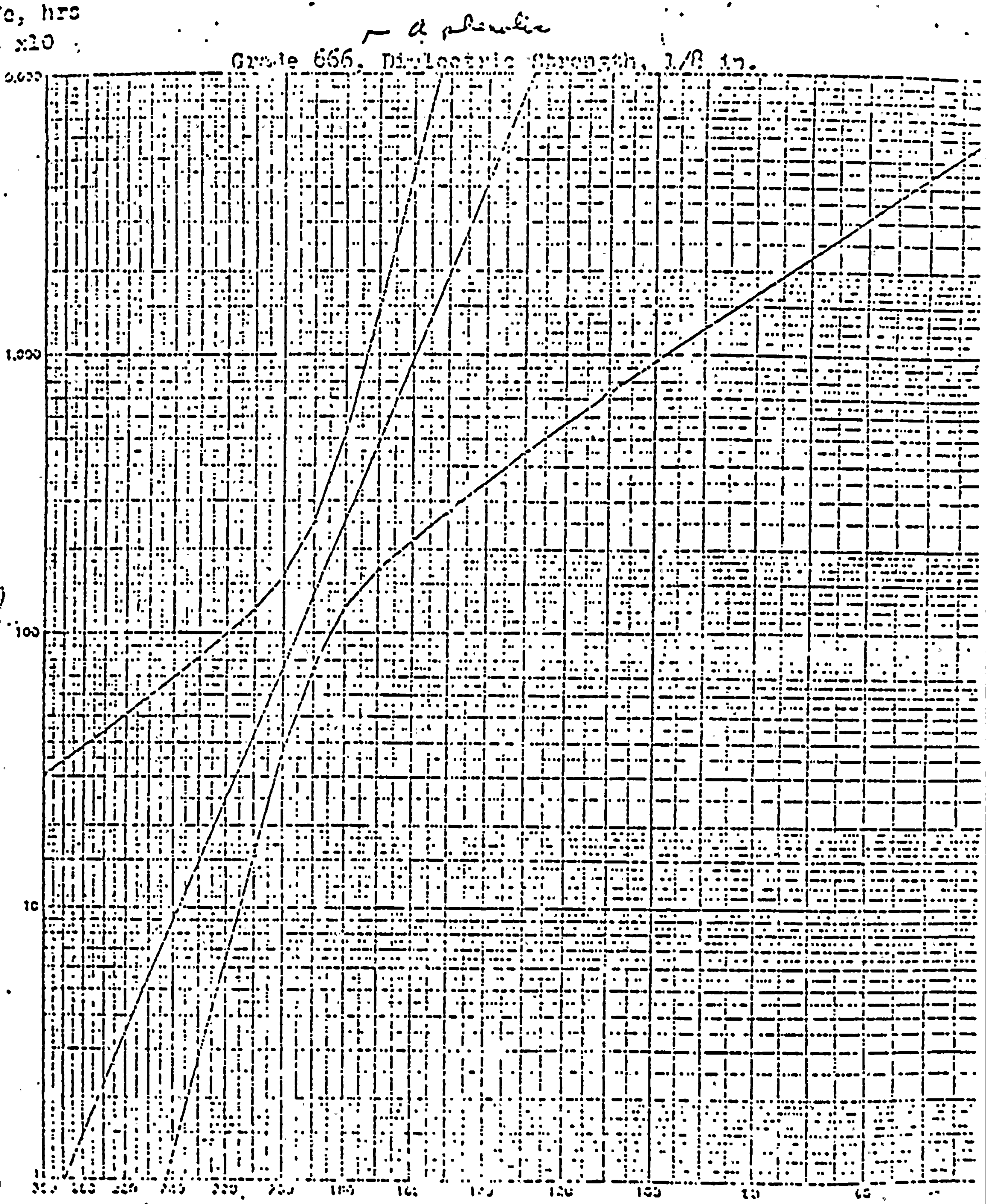
Grade 619, Flexural Strength, 1/8 in.



Y = 5596X - 8.9454

~ a phenolic

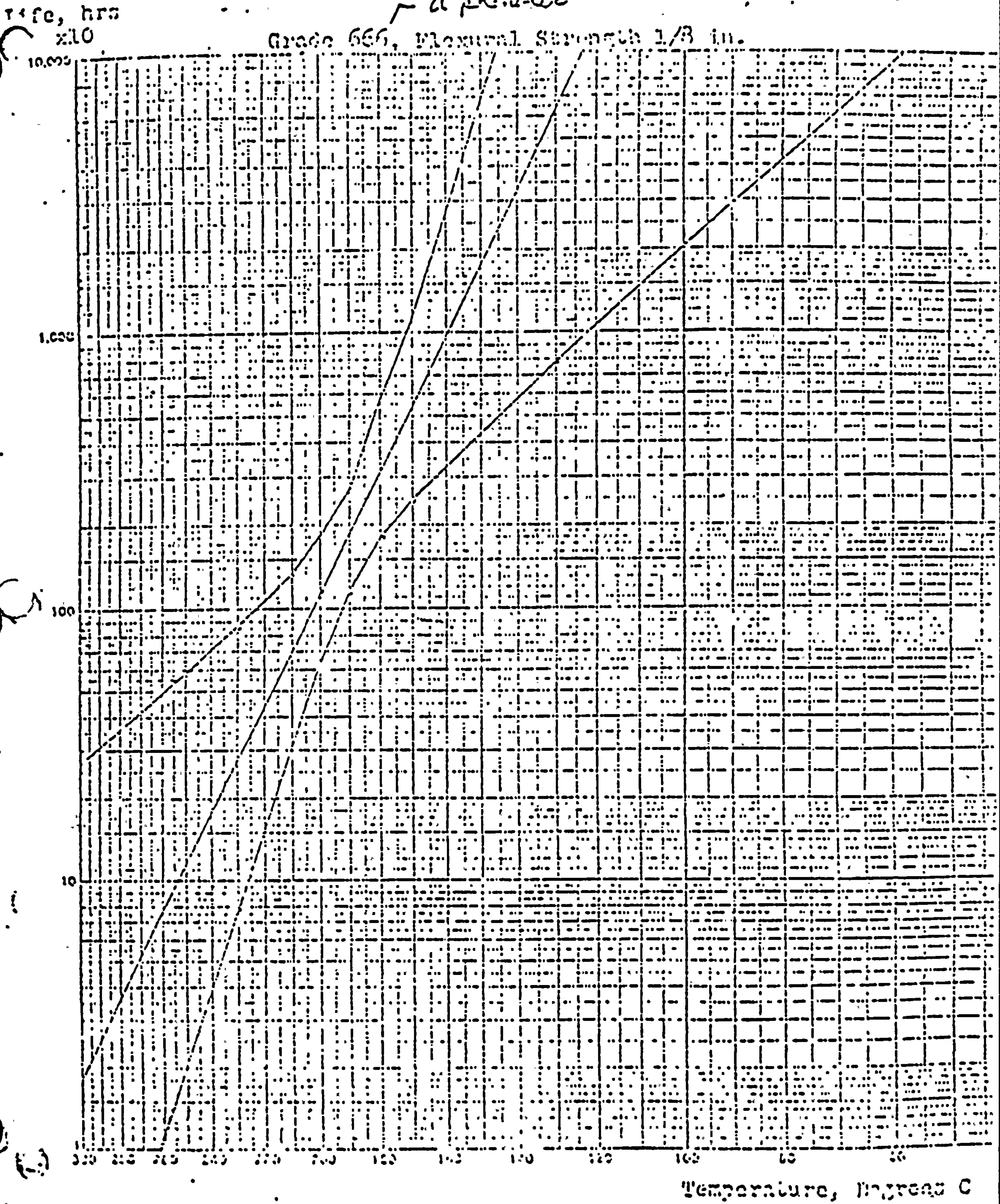
Grade 666, Dielectric Strength, 1/8 in.



$Y = 4858X - 7.2410$

A phenolic

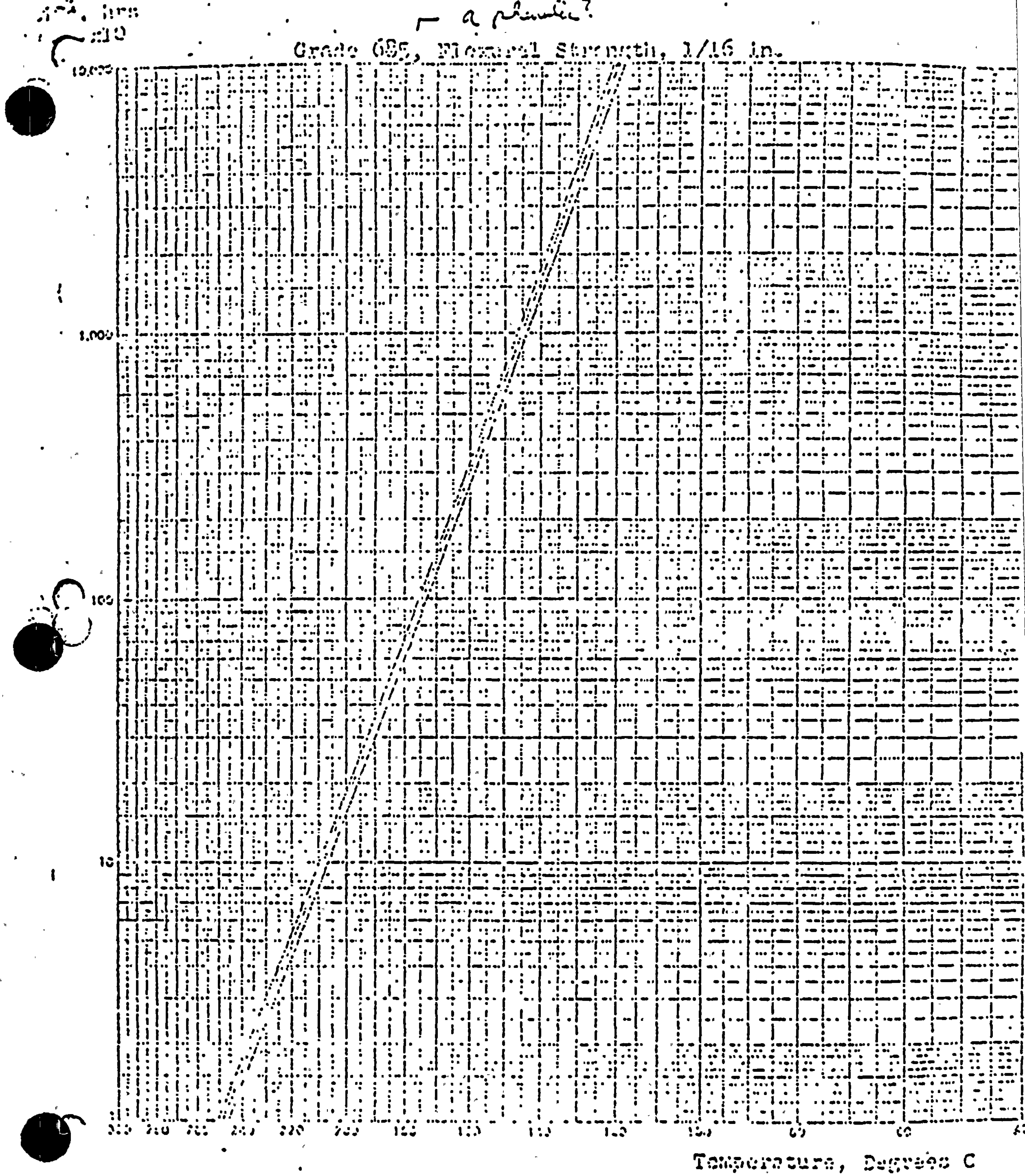
Grade 666, Flexural Strength 1/8 in.



Y = 6338X - 11.2690

— a plastic?

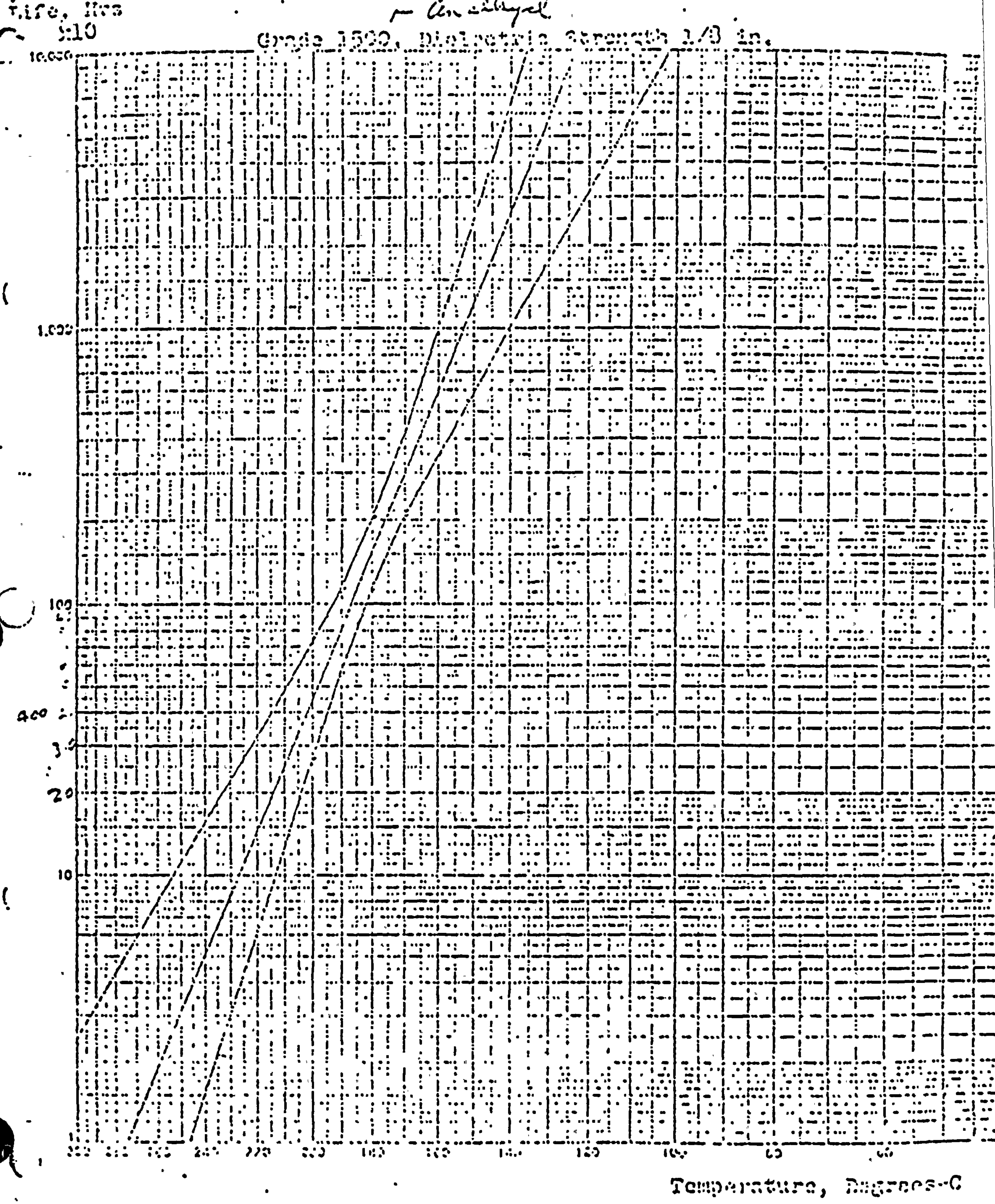
Grade 695, Flexural Strength, 1/16 in.



Y = 5740X - 9.4597

~ Anhyd

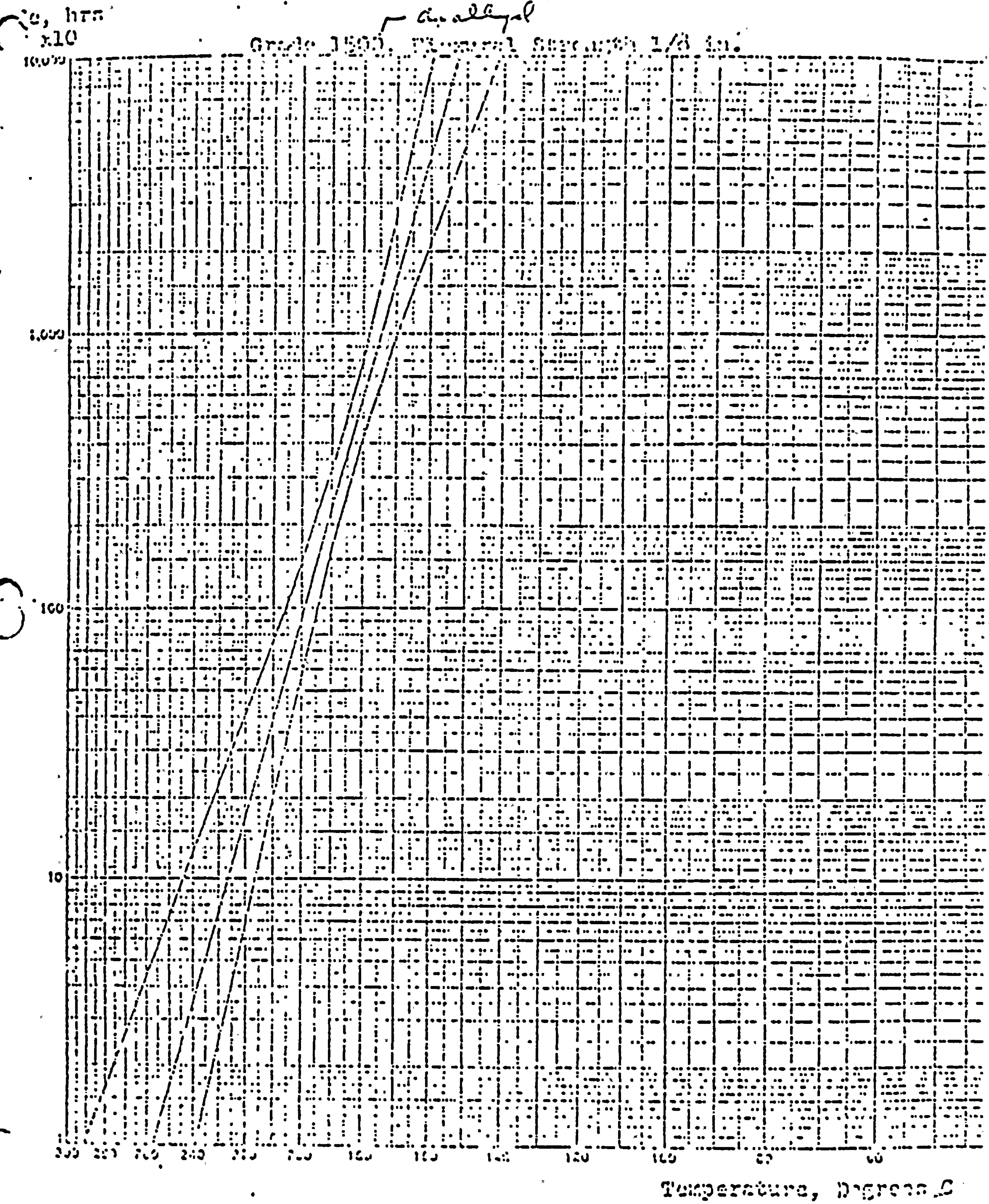
Grade 1500, Dielectric Strength 1/8 in.



Y = 8441x - 19.2084

as alleged

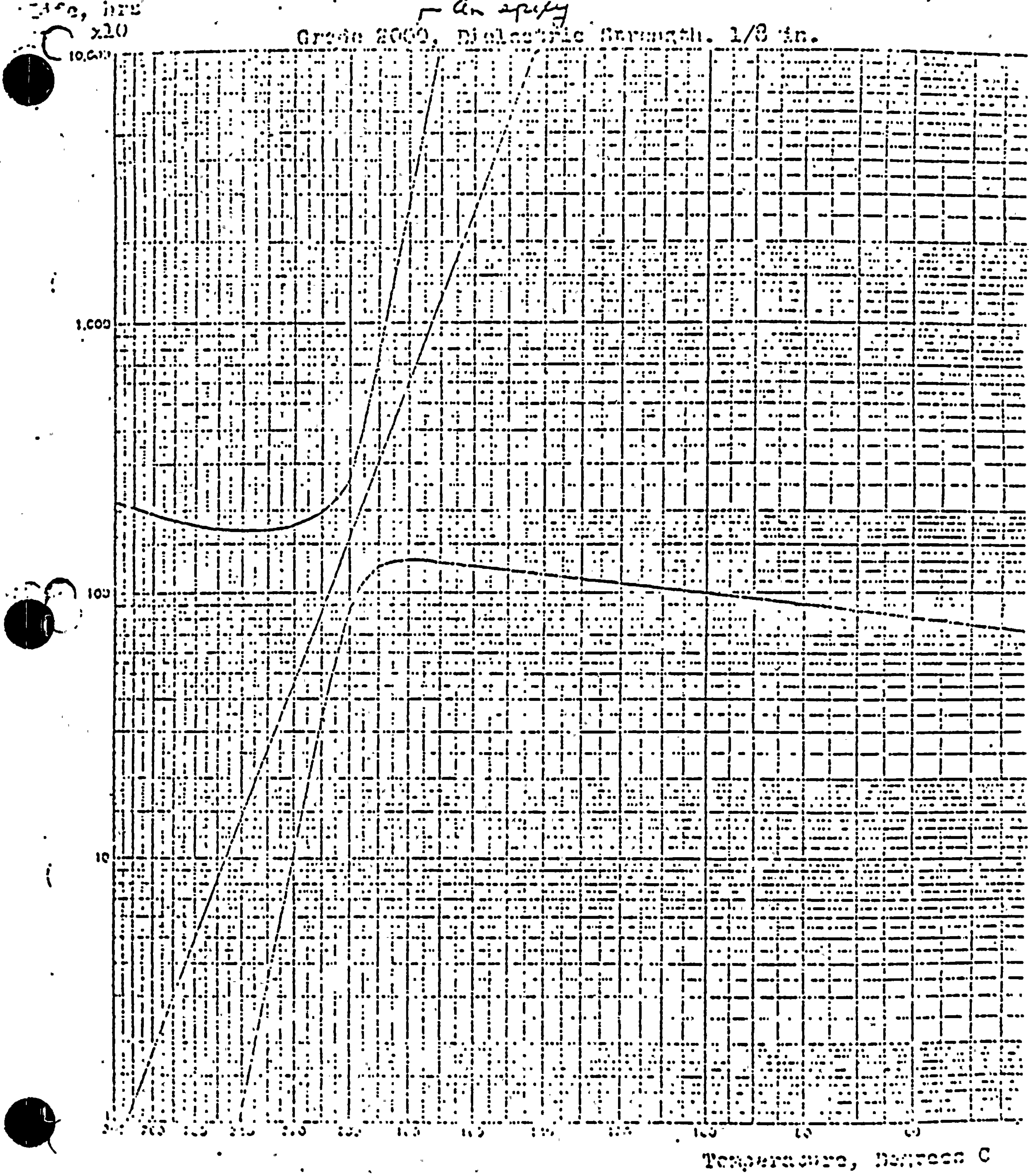
Grade 1500, Flexural Strength 1/8 in.



Y = [illegible] - 10.0494

an epoxy

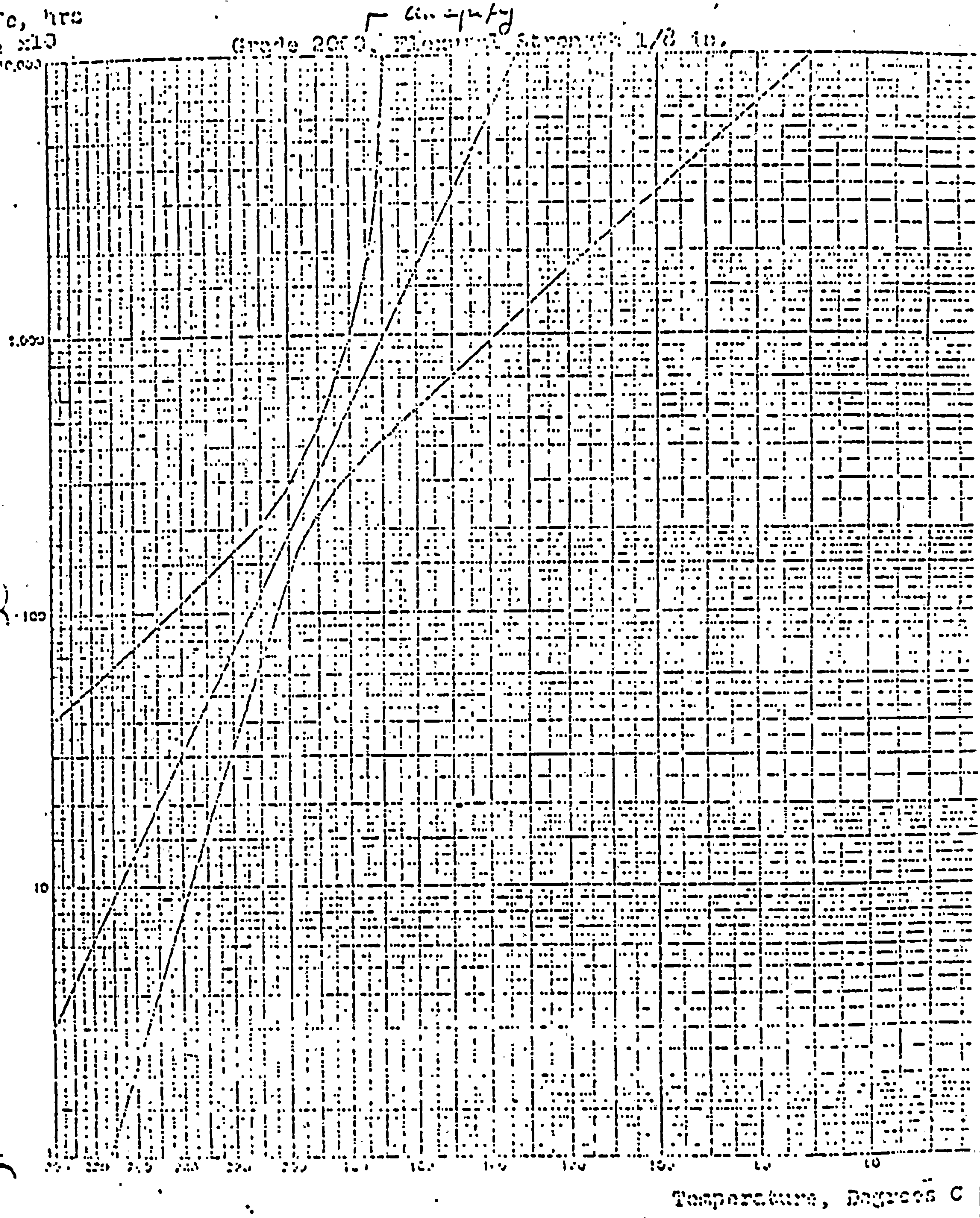
Grade 2000, Dielectric Strength. 1/8 in.



Y = 4913X - 7.0957

[illegible]

Grade 2000, Flexural Strength 1/8 in.



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File E39252
Assignment 66ME416

July 16, 1968

REPORT

on

COMPONENT-PLASTIC MATERIALS

Hooker Chemical Corp.
Durez Plastics Division
North Tonawanda, New York

B/11

I have not made a copy of This data - please treat accordingly. This is a good example of the kind of data that exists for UL listed materials.

Bernie

Bob, Sorry for quality of repro. (4TH Generation, at best, copy)

CEK

This IS THE PORTION OF THIS REPORT THAT WAS PERMITT

DESCRIPTION

PRODUCT COVERED:

Durez Phenolic Molding Compounds Nos. 791, 1308, 1328, 11864, 19089, 18975, 21426, 22262 and Alkyd Molding Compounds Nos. 24150, 24525 and 24480. Minimum thickness 1/8 in.

FACTORY LOCATION:

Hooker Chemical Corp., Durez Plastics Division,
North Tonawanda, New York.

GENERAL DESCRIPTION OF MATERIAL (NOT FOR INSPECTOR USE):

Heat Resistant Grade Phenolics

1308, 1328	mineral and wood flour filled phenolic differing in pigment
11864, 19089	mineral filled phenolic
21426, 22262	mineral filled phenolics, the latter being specially suited for transfer molded applications

Heat Resistant Grade Alkyds

24150, 24525	all are glass filled Alkyds
24480	a combination of nylon and glass fill

High Impact Grade Phenolic

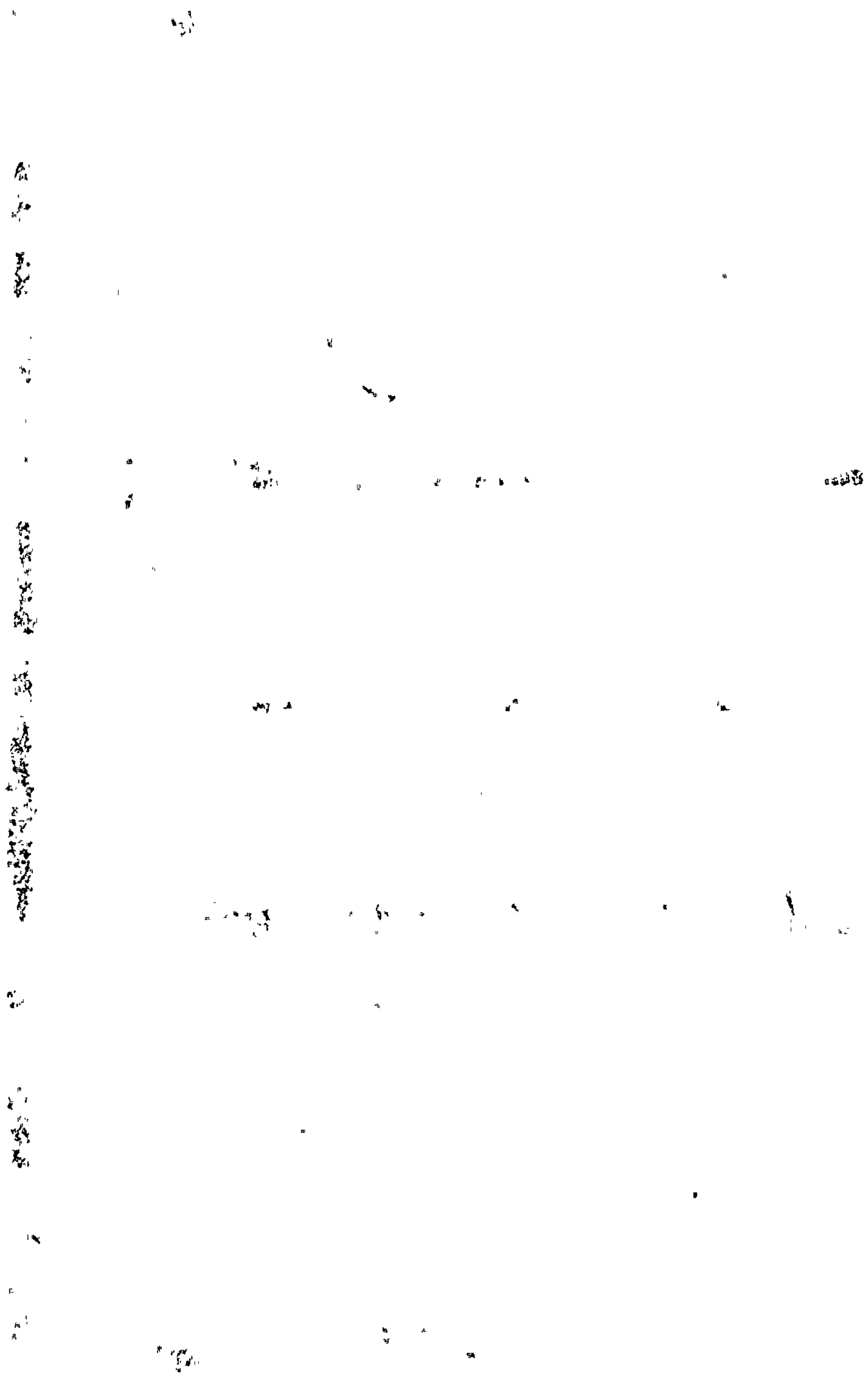
18975	mineral filled phenolic

General Purpose Grade Phenolic

791 (control)	wood flour filled phenolic

IDENTIFICATION:

The infrared spectrum illustrated in Ill. Nos. 1-4 may be used to identify the material covered by this report.



CONSTRUCTION DETAILS:

General - The material is produced and shipped as solid granular material, cut to a nominal size of 1/10 inch or finer for phenolics and 1/4 inch for the Alkyd materials.

Marking - Shipping containers are marked with the material designation and the material manufacturer's name.

GENERAL DESCRIPTION OF INVESTIGATION (NOT FOR INSPECTOR'S USE):

A. ~~Thermal Aging~~ Program - Samples of Grades 1308, 11864, 21426, 24150 and the control Grade 791 were subjected ~~to a specific set of~~ functional testing procedures before oven aging and at certain intervals during oven aging of the material. Oven aging temperatures were selected which would cause accelerated aging. Aging was continued at each temperature until a property being evaluated reached a test value of one half of the unaged test value. For that property, this was considered the end of life for the material at that oven temperature.

The end points at each aging temperature were [illegible]tted. Performance was analyzed using the least squares [illegible]hod of regression analysis as indicated in IEEE Standards [illegible]s. 98, 99 and 101. [redacted]

A control material Grade 791 was subjected to the same type of functional testing procedures and oven aging conditions to serve as a common base for establishing temperature ratings for the candidate materials. The performance of the control material was analyzed in the same manner as the candidate materials.

B. Performance Indexing Data - Various tests related to the flammability characteristics, electrical characteristics and resistance to ignition properties of Grades 1308, 1323, 11864, 19039, 18975, 21426, 22262, 24150, 24525, 24480 and the control Grade 791 were conducted on unaged specimens.

ENGINEERING CONSIDERATIONS (NOT FOR INSPECTOR'S USE):

Use - For use only in products where the acceptability of the combination is determined by Underwriters' Laboratories, Inc.

Conditions of Acceptability - The following are among the considerations to be made in judging the use of this material in an end use product.

The results of the thermal aging program are summarized in Table I.

The results of the performance indexing are summarized in Table II.

These data may be used as an aid in evaluating the materials covered by this report when used in end product applications.

Reference should be made to the end product Standards and most current guides to the use of plastics (such as Subject 746 dated March 1, 1967) with regard to other requirements which should be considered in judging the suitability of these insulating materials in end products.

Reference may also be made to Manufacturer's Technical Data (see Ill. No. 19).

TABLE I

Results of Thermal Aging Program

Material	Thickness (Inch)	Temperature Rating Degrees C	Properties Covered
791	1/8	150	M, E, F & D.S.
1308, 1328, 19089, 18975, 21426, 22262, 24480	1/8	155	M, E, F & D.S.
11864, 24525	1/8	170	M, E, F & D.S.
24150	1/8	180	M, E, F & D.S.

M - Flexural Strength
Impact Strength
E - Dielectric Strength
Arc Resistance
F - Flammability
D. S. - Dimensional Stability

Flexural Strength - Determined in accordance with ASTM D790. Degradation to 50 percent of the original values was considered to be end of life.

Impact Strength. Unnotched - To be determined in accordance with ASTM D256, Method B. Degradation to 50 percent of the original values was considered to be end of life.

Dielectric Strength - Determined in accordance with ASTM D149. No appreciable degradation occurred during aging.

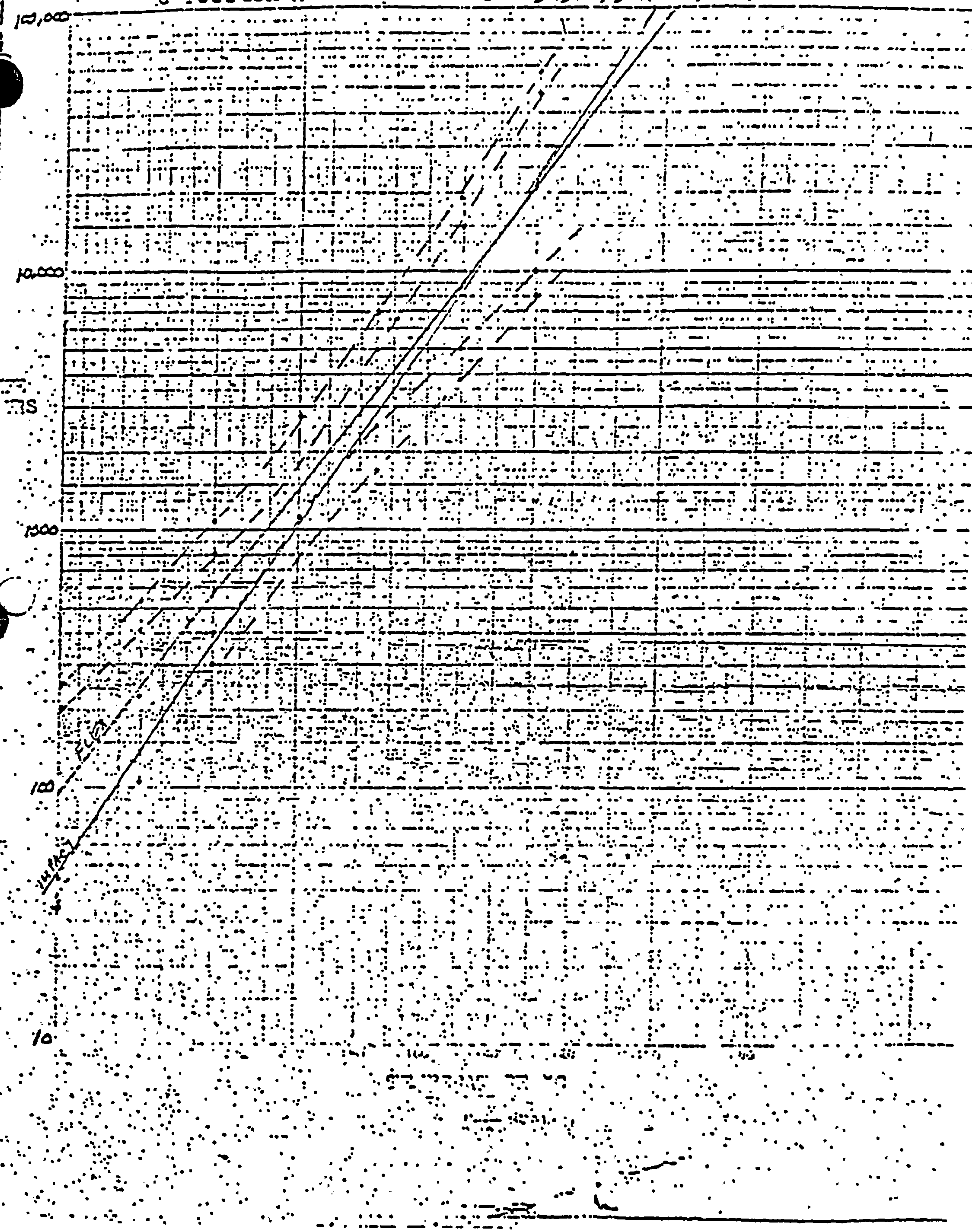
Arc Resistance - Determined in accordance with ASTM D495. No apprecialbe degradation occurred during aging.

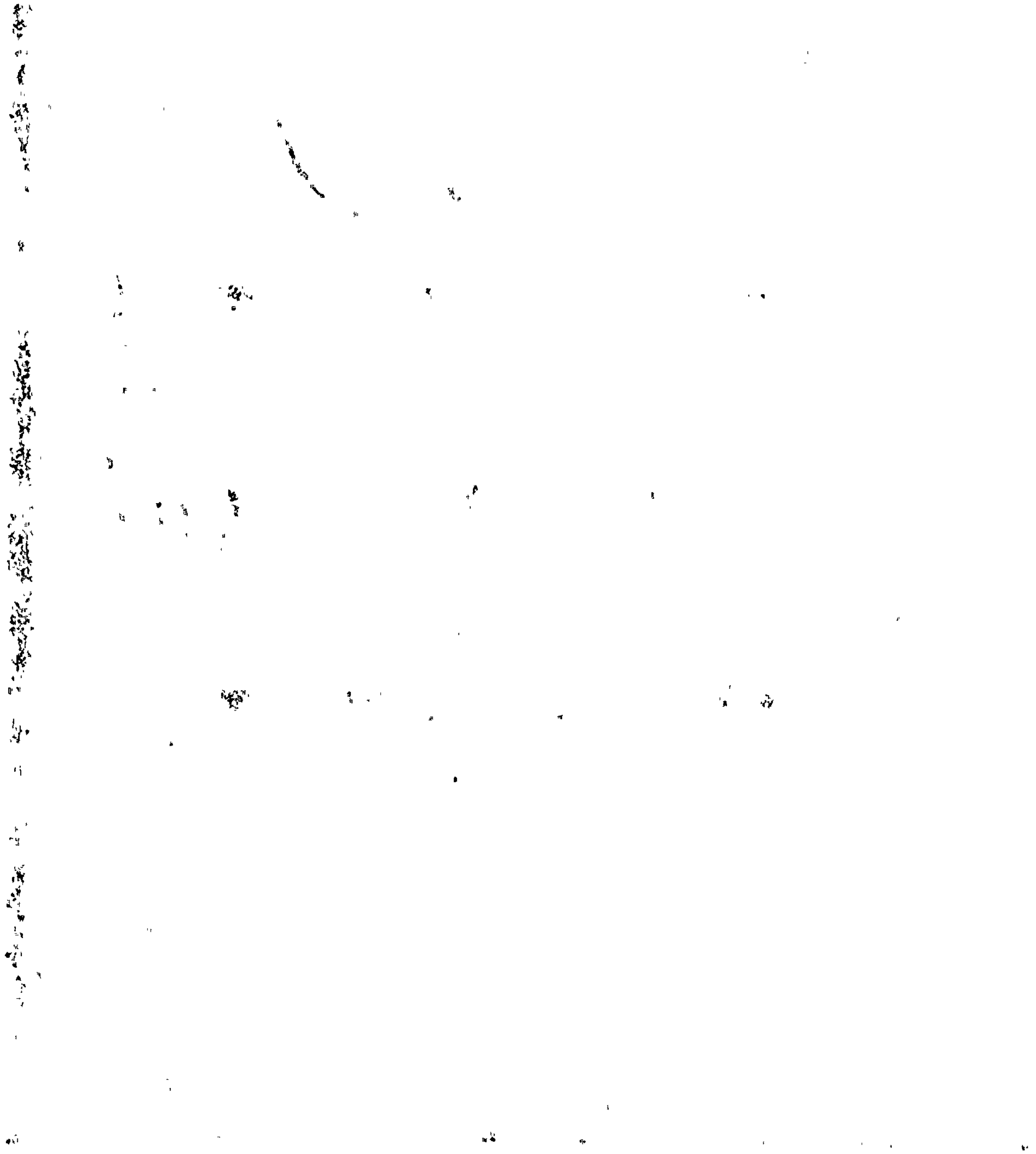
Dimensional Stability - Measured on Flexural Strength specimens. No appreciable change during aging.

Flammability - Determined in accordance with ASTM D635. No change in flammability classification during the aging period.

The above is a summary of the properties covered in the aging program. For actual failure times and property values, refer to test record.

Regression Line Equation Y = 3239.536X - [illegible]



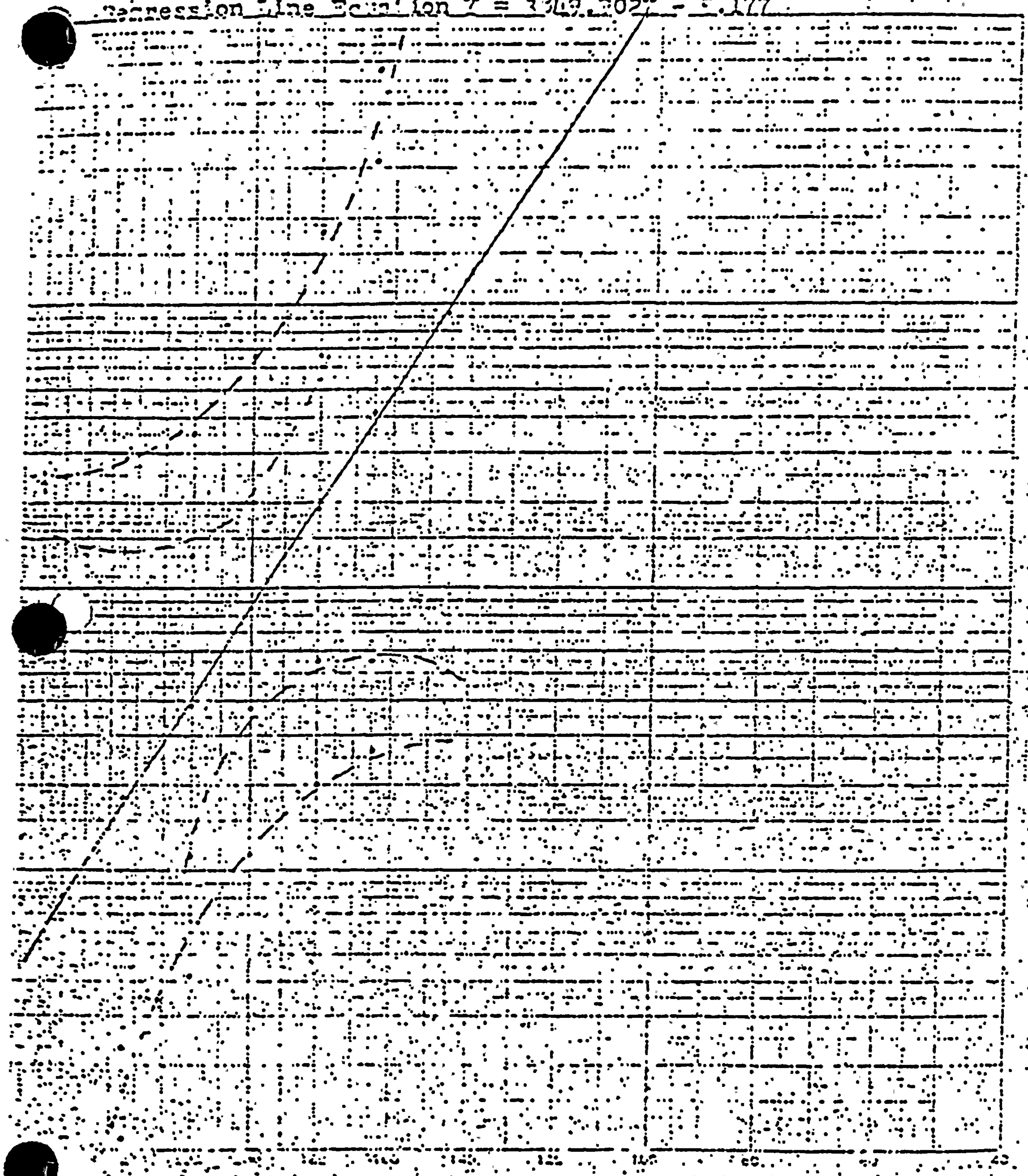


[illegible] 211.26 1¼"

IMPACT

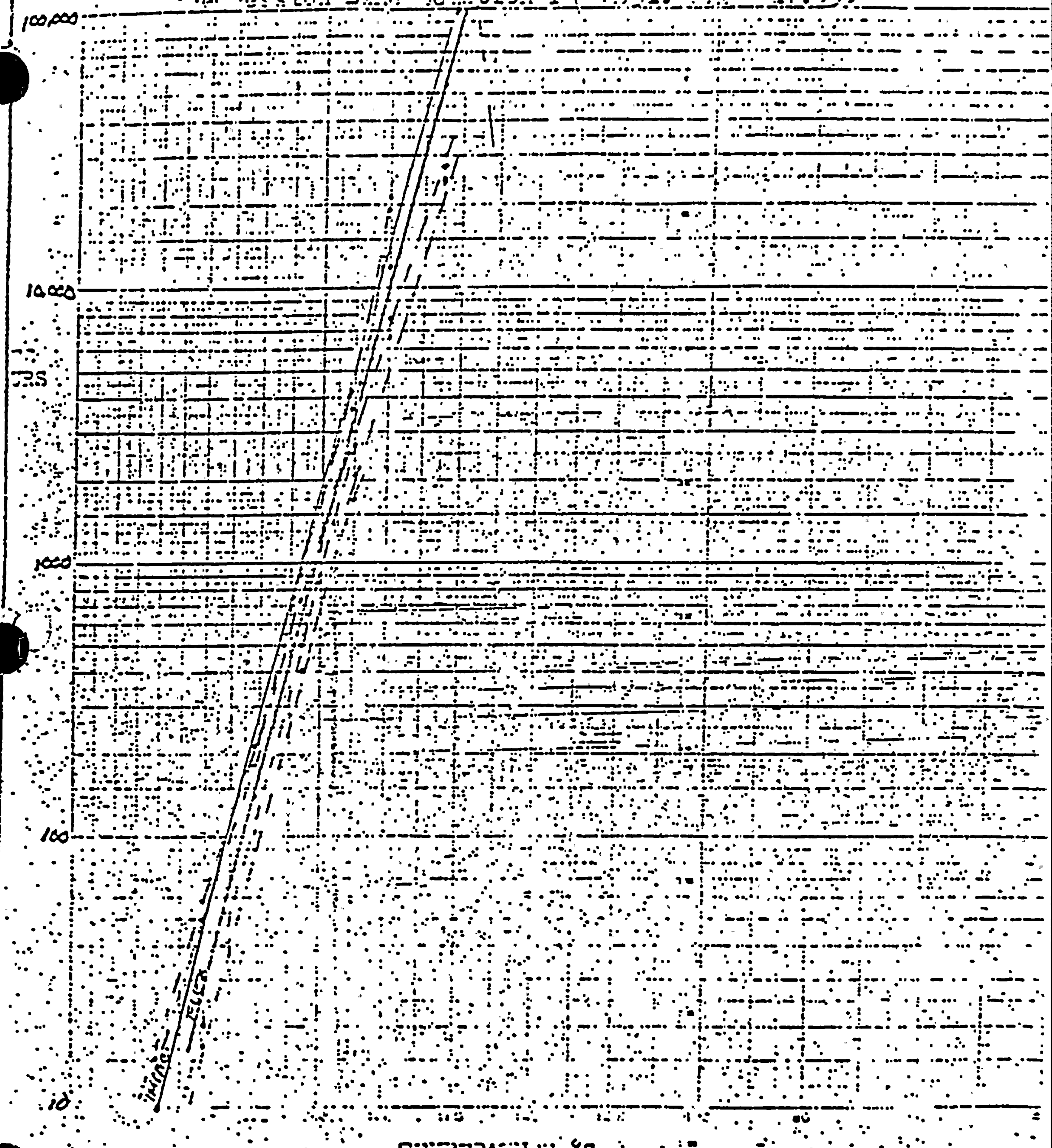
C.V.

Regression Line Equation Y = 349.202X - 5.177



FLEXURAL [illegible]

Regression Line Equation Y = 1931.479X - 17.338



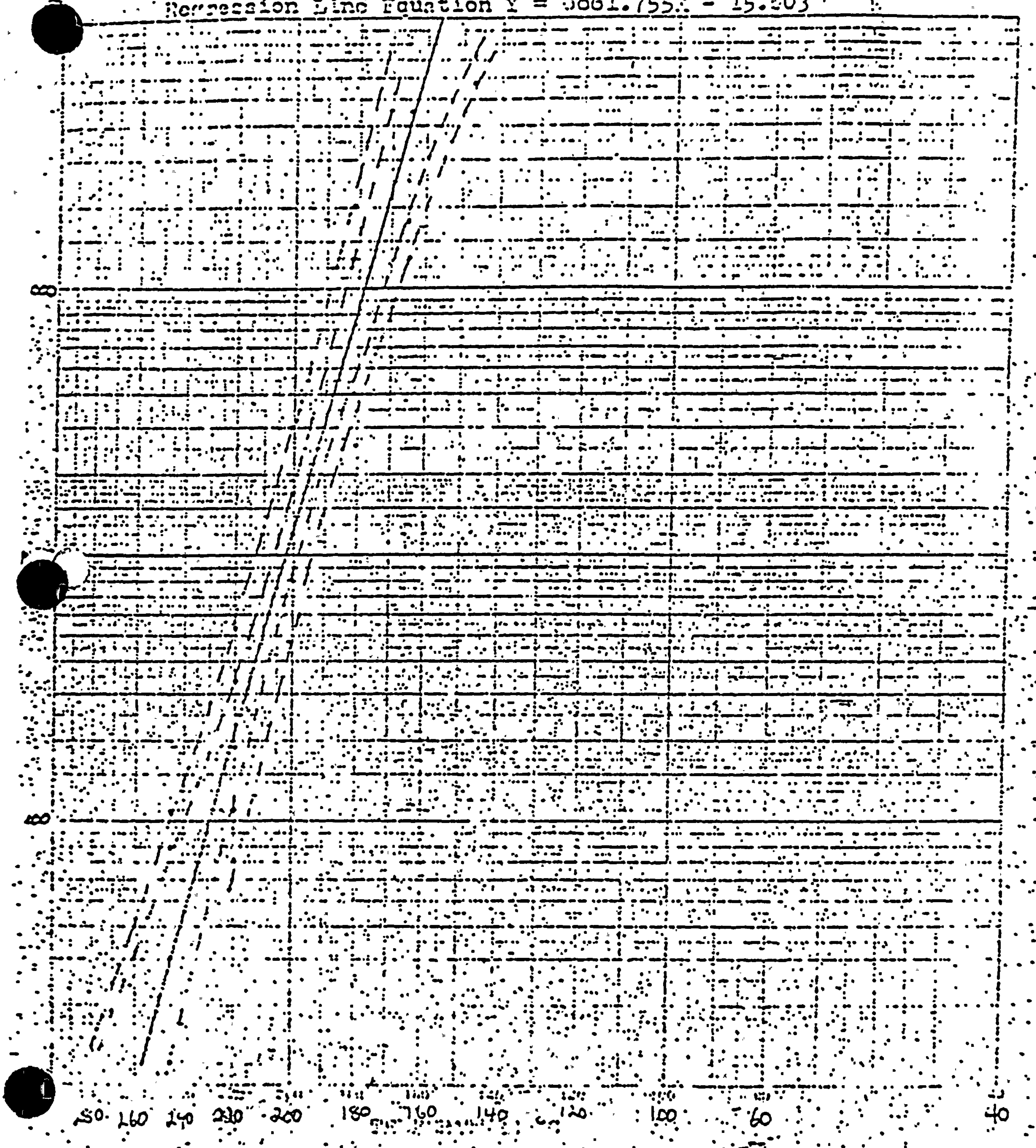
TEMPERATURE °R

LIFE CURVE (24150) 1/4"
~~IMPACT~~
IMPACT

O K

24150

Regression Line Equation Y = 3861.755X - 15.403

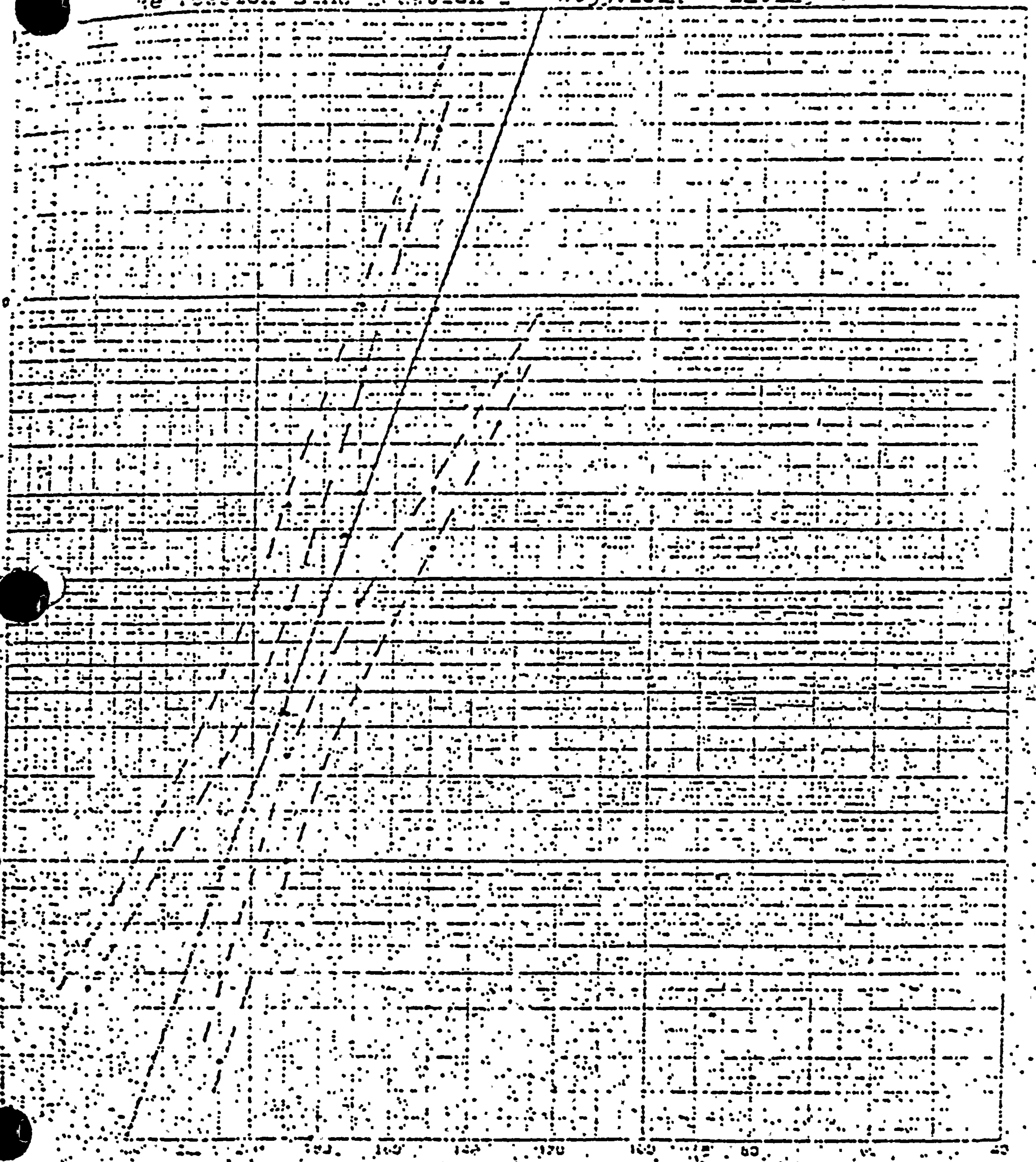


LIFE [illegible] [illegible] 79[illegible] 1/4"   C C

[illegible]

IMPACT

Regression Line Equation Y = 6335.161X - 12.1[illegible]3



Regression Line Equation Y = [illegible]

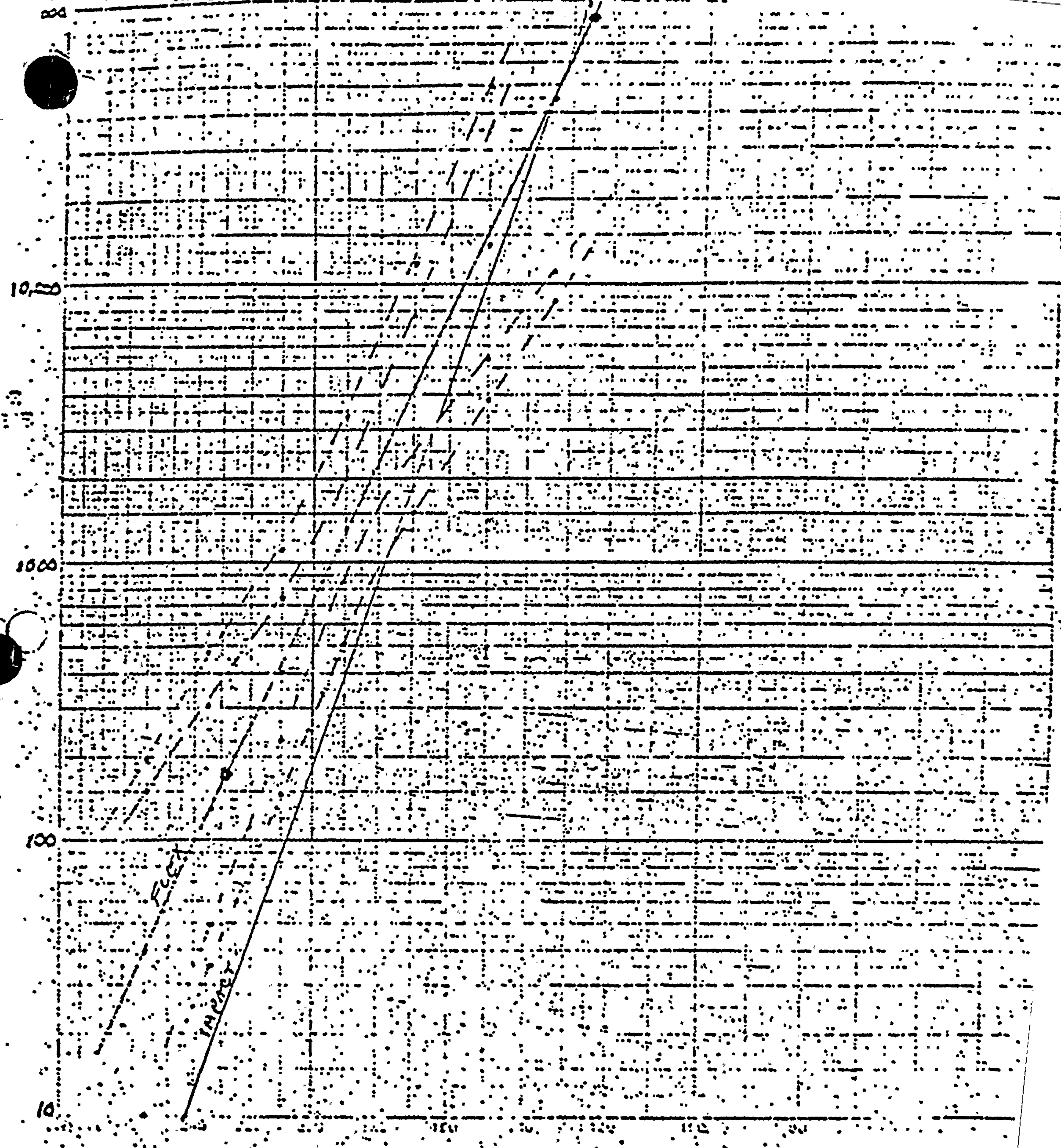


TABLE IV

OVEN TEMPERATURES DEGREES C

erials	Aging Temperatures						
	240	225	215	205	190	175	165
			x	x	x	x	x
8		x	x	x	x	x	x
64		x	x	x	x		
26	x	x	x	x	x(1)	x	x
50		x	x	x	x	x	
25			x	x			
75			x				
39			x				
30				x	x		

TABLE III

AGING TEST PER MATERIAL PER TEMPERATURE

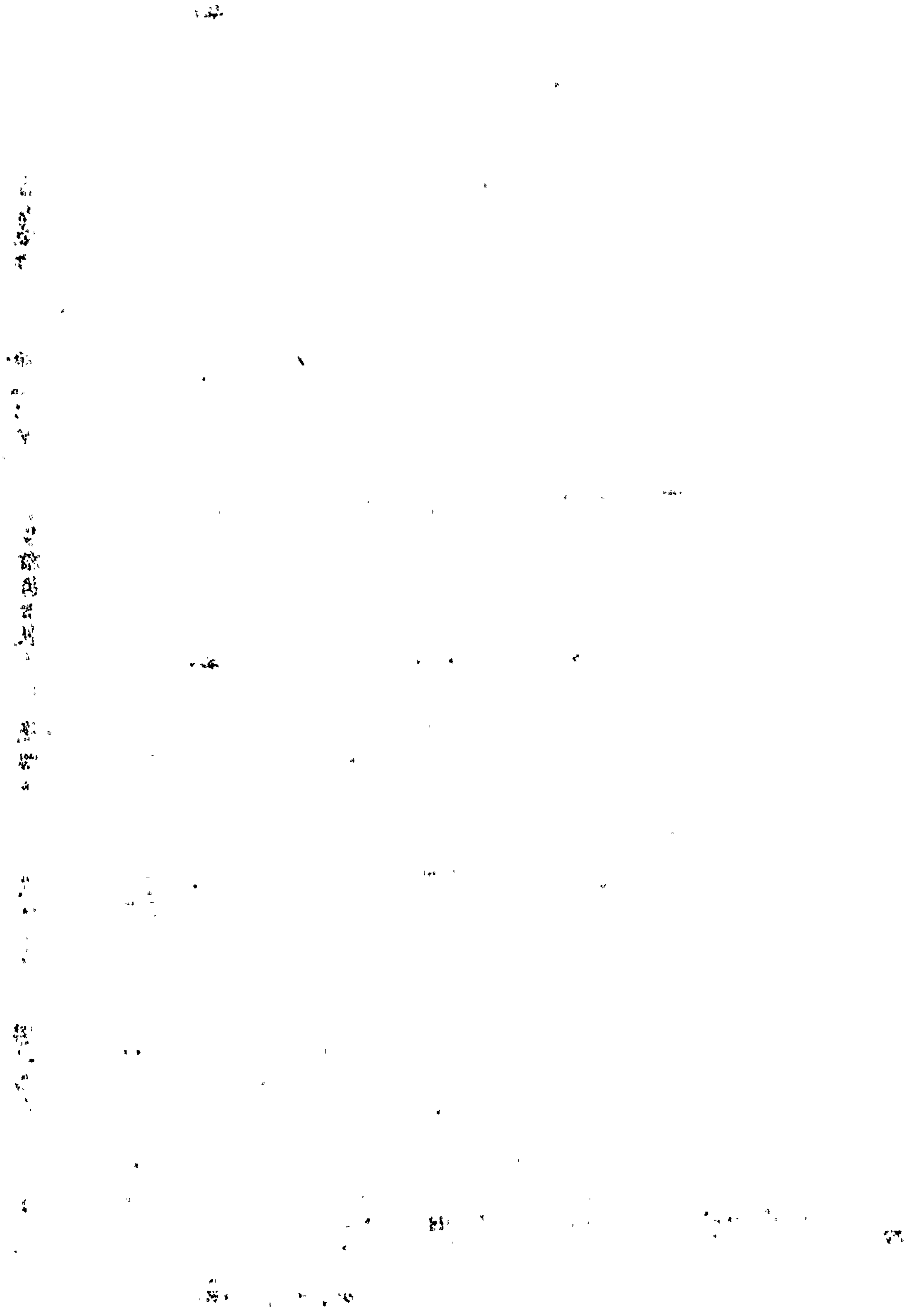
operty	ASTM Method	Specimen Size	Specimens Per Measure
exural strength	D790	5 by 1/2 by 1/8	5
exural strength	D790	5 by 1/2 by 1/4	5
pact strength unnotched	D256 Method "B"	2-1/2 by 1/2 by 1/4	5
mensional stability	(1)		
electric strength	D149 (2)	4 dia by 1/16	5
ammability A	D635 (3)	5 by 1/2 by 1/4	5
c resistance	D495	(4) (3)	

TES:

1) Measure dimensional stability on flexural specimens.
2) 500 v/sec. to dielectric breakdown (IN AIR).
3) Delayed specimens tested when other properties decrease to 50 percent of the as received value.
4) Dielectric strength specimens used.

NTROL DATA:

The control material was a phenolic molding compound
ce 791 which, based on tests and field experience,
is been shown to be suitable for continuous operation
t 150 C. Specimens of this material were aged at
levated temperatures and the degradation of tensile
ield was measured periodically to establish a time-
emperature relationship based on 50 percent degradation
or this material under the same test procedure as that
sed for phenolic molding compounds Nos. 1308, 21426,
1864 and Alkyd molding compound No. 24150.



TEST RECORD NO. 2

9

AMPLES:

Durez Phenolic Molding Compounds Nos ✓1308, 21426,✓ 1864 and Alkyd Molding Compound No. 24150 were subjected o the test procedure described below to determine the hermal aging characteristics of the material.

ENERAL:

The investigation followed the proposed test :ocedure for evaluation of insulating material as :ecommended by IEEE. This program is based on the ;sumption that heat aging is the chief cause of insulation :terioration.

Samples of the phenolic and Alkyd materials and .so the control material were subjected to a specific sting procedure, and time temperature relationships re established. Based on a comparison of the relationips developed, and also with consideration to the eld service record of 1308, 21426, 11864 and 24150 rerature ratings, as indicated in Table I of this)t, were established.

The program covers the effects of aging on the exural strength, impact strength and dielectric strength operties of each material.

OCEDURE:

Selection of Aging Temperatures - The temperatures be used to produce the accelerated aging of Durez enolic Molding Compound Nos. 1308, 21426, 11864 and :yd Molding Compound No. 24150 were selected as 215, 205,), 175 and 165 degrees C.

Sample Preparation - A sufficient number of specimens 'e compression molded in the sizes needed to perform : physical and electrical property tests at various 'iods of time at each aging temperature.

PERTIES EVALUATED:

The property measurement test data permits the phical determination of the time needed, at each temperature, to produce a 50 percent degradation .as received property value. The 50 percent ation points (at each aging temperature and for each perty) were used to establish a time-temperature ationship. Fifty percent degradation points were ablished for the properties of flexural strength and

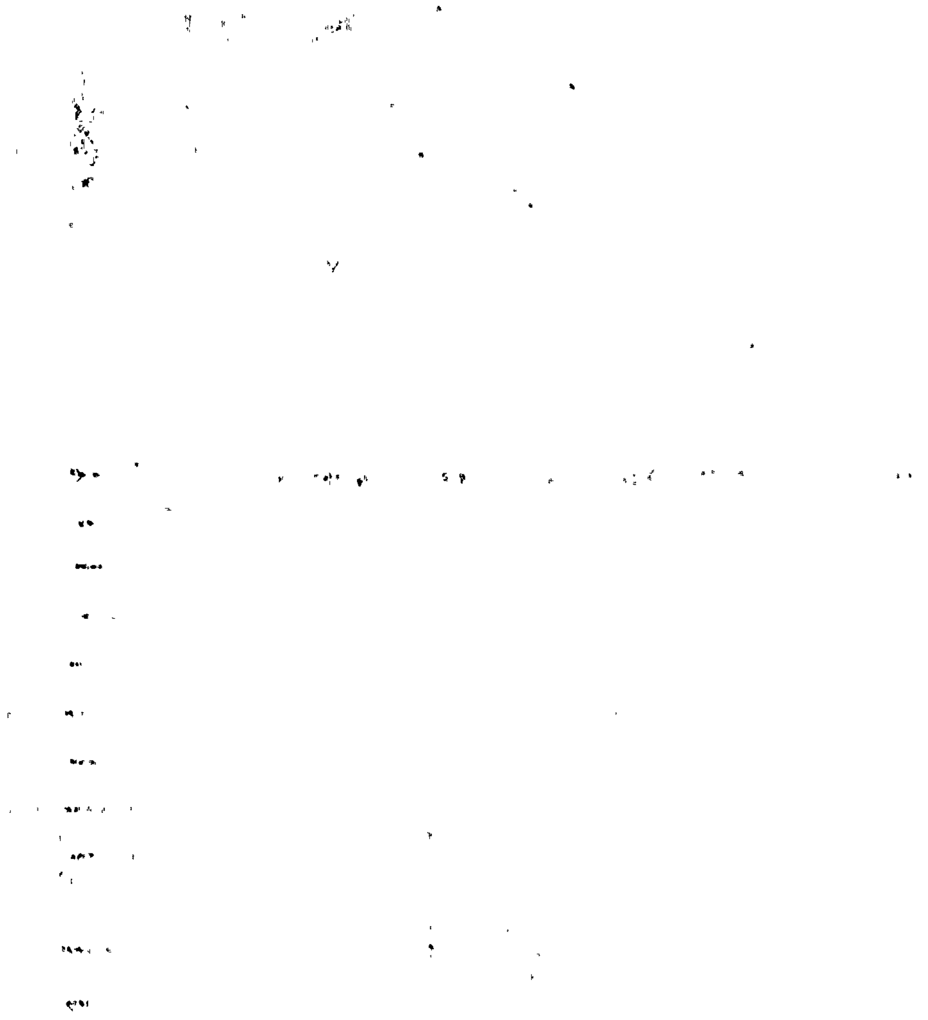
Grade 2146

Temperature Degrees C	240	225	215	205	190	175	165
Flexural Strength							
1/4 inch	497	645	954	1300	1525	2958	7392 +
1/8 inch	332	517	568	970	1505	3182	6340
Impact Strength	-	423	469	995	560	4182	-
Dielectric Strength	-	208	-	-	173	-	-

rade 791

Temperature Degrees C	215	205	190	175	165
Flexural Strength					
1/4 Inch	318	643	1259	2232	7420
1/8 Inch	314	545	1241	1603	6051
Impact Strength	104	111	365	987	4349
Dielectric Strength	Did not fail				

G.P. Phenolic



Attached are the curves you requested

Donald L. Schaedt
Sales Engineer

phelps dodge
Magnet Wire Company 4300 New Haven Avenue
Fort Wayne, Indiana 46803
(219) 743-0331

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phelps dodge
Magnet Wire Company P. O. Box 600, Fort Wayne, Indiana 46801

FORT WAYNE
IND.

DISTRIBUTION		
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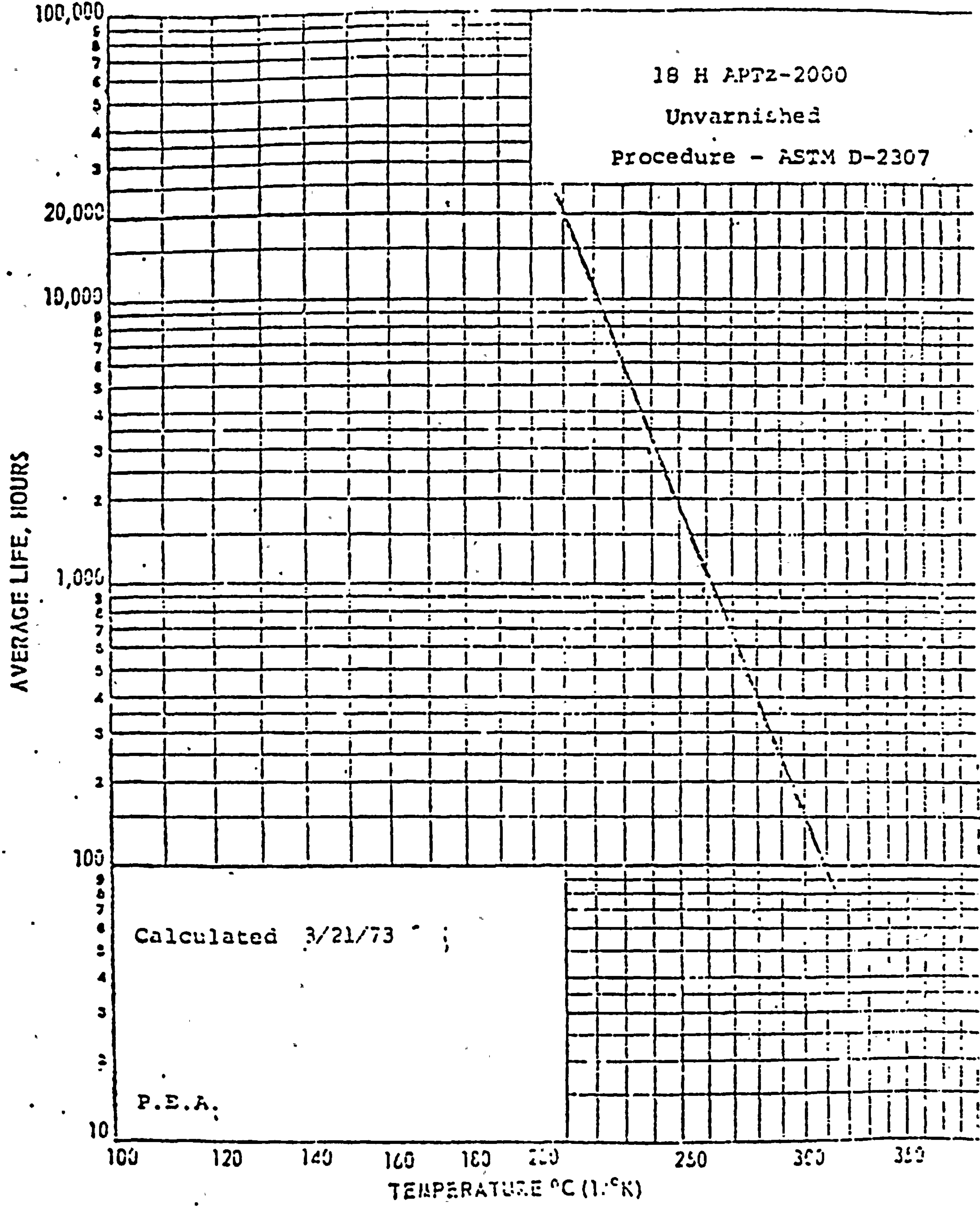
AREA:		

Mr. Jerry Gambs
Franklin Institute
Research Labs
20th & The Parkway
Philadelphia, PA 19103

PHELPS DODGE MAGNET WIRE COMPANY
FT. WAYNE, INDIANA

PRODUCT ANALYSIS LABORATORY

Curve I


18 H APTz-2000
Unvarnished
Procedure - ASTM D-2307

Calculated 3/21/73

P.E.A.

PHELPS DODGE MAGNET WIRE CORPORATION
FT. WAYNE, INDIANA

Product Analysis Laboratory