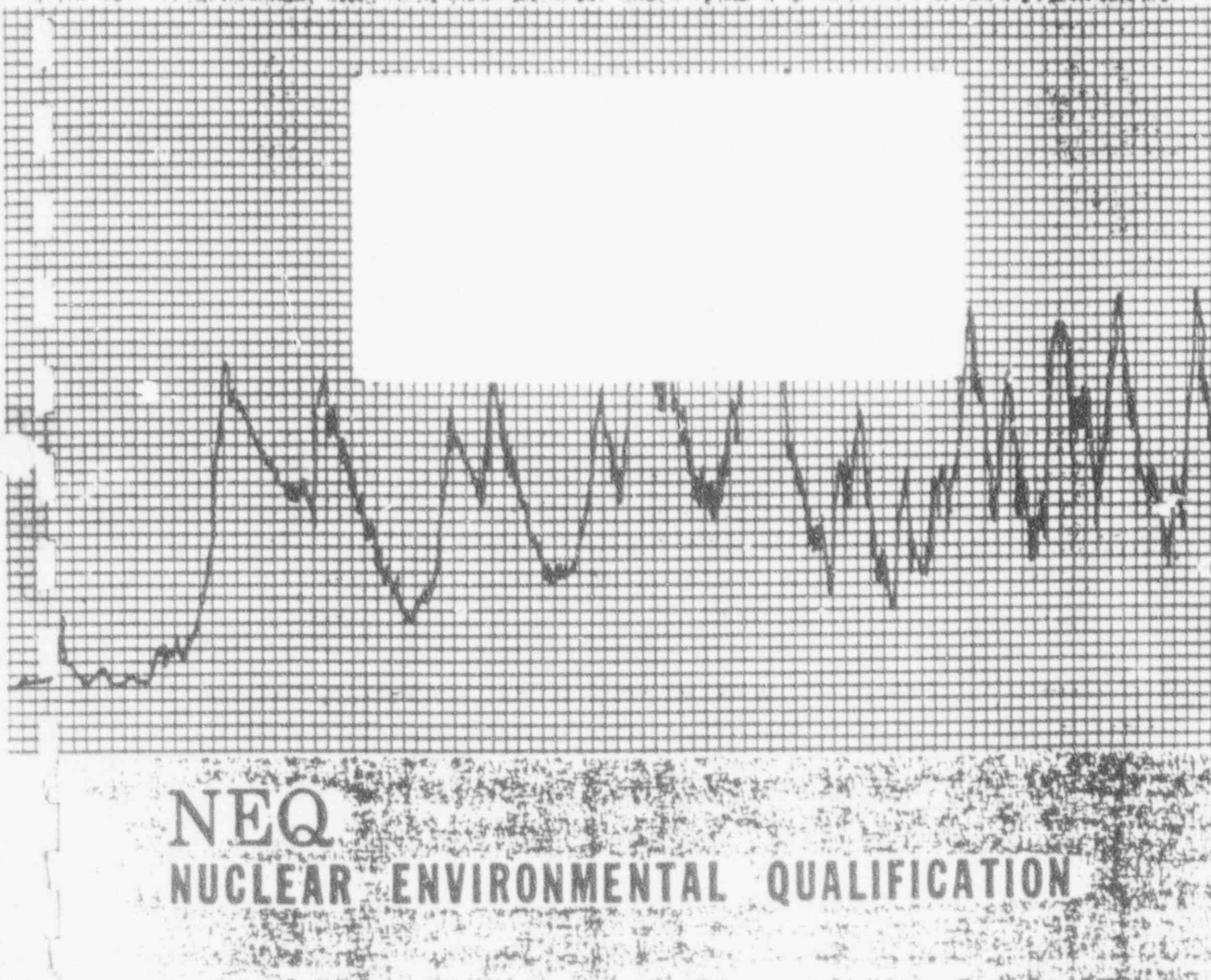
S-25 50-348/364-CIVP 2/12/92

WYLE
LABORATORIES - SCIENTIFIC SERVICES & SYSTEMS GROUP



NEQ
NUCLEAR ENVIRONMENTAL QUALIFICATION

test REPORT

NUCLEAR REGULATORY COMMISSION

Docket No. ________ Official Exh. No. 25

In the matter of ALABAMA POWER CO.

Staff ✓ IDENTIFIED 2/12/92

Applicant ________ RECEIVED 2/12/92

Intervenor ________ REJECTED ________

Cont'g Off'r ________

Contractor ________ DATE 10-87

Other ________ Witness ________

Reporter L. Estep

35T

QUALIFICATION TEST PROGRAM
ON SPLICES
FABRICATED WITH 3M SCOTCH SUPER 33+
VINYL PLASTIC ELECTRICAL TAPE AND
OKONITE SPLICING TAPES NO. 35 AND T-95
FOR THE
ALABAMA POWER COMPANY
FOR USE IN THE
FARLEY NUCLEAR GENERATING STATION

For

Alabama Power Company
P. O. Box 2641
Birmingham, AL 35291

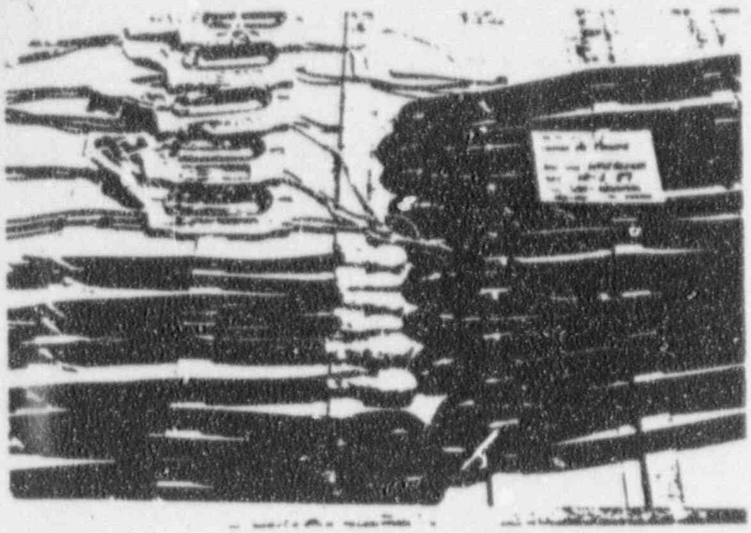
October 1987

PROPRIETARY

NEQ

Nuclear Environmental Qualification

Test Report



REPORT NO. 17947-01

WYLE JOB NO. 17947

CUSTOMER P. O. NO. QP-1859

PAGE 1 OF 258 PAGE REPORT

DATE October 8, 1987

SPECIFICATION (S)

See Test Procedure in Section VIII

1.0 CUSTOMER Alabama Power Company

ADDRESS P. O. Box 2641, Birmingham, AL 35291

2.0 TEST SPECIMEN Okonite and Scotch No. 33+ Tape Splices

3.0 MANUFACTURER Okonite and 3M Companies

4.0 SUMMARY

Various cable splice assemblies, as described in Paragraph 6.0, were subject to the environmental qualification program described herein. These specimens are as installed in Alabama Power Company's Farley Nuclear Generating Station.

This Qualification Test Program was performed to satisfy the intent of IEEE Standard 323-1983, "IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations".

(jmk)

STATE OF ALABAMA } ss.
COUNTY OF MADISON }

Alabama Professional Eng. Reg. No. 8256

Flavous R. Johnson, being duly sworn, deposes and says: The information contained in this report is the result of complete and carefully conducted tests and is to the best of his knowledge true and correct in all respects.

SEAL

SUBSCRIBED and sworn to before me this ___ day of ___, 19 87

Notary Public in and for the State of Alabama at large.

My Commission expires June 12, 19 91

Wyle shall have no liability for damages of any kind to person or property, including special or consequential damages, resulting from Wyle's providing the services covered by this report.

PREPARED BY J. Hazeltine 10/7/87

APPROVED BY F. R. Johnson 10/8/87

WYLE Q. A. G. Wayne Hight 10/8/87

WYLE LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP
HUNTSVILLE, ALABAMA

5.0 REPORT FORMAT

The Test Program was performed as specified in Reference 8.1 and as detailed in this test report. The individual test results and test procedure are presented in the following sections:

- Section I — Baseline Functional Tests
- Section II — Radiation Exposure
- Section III — Post-Radiation Exposure Functional Tests
- Section IV — Thermal Aging
- Section V — Post-Thermal Aging Functional Tests
- Section VI — Loss of Coolant (LOCA) Test
- Section VII — Post-LOCA Functional Test
- Section VIII — Wyle Laboratories Qualification Plan No. 17942-01, Revision A.

This report covers testing on the 15-year test specimens only (Specimens 1.1 through 14.3). Also included in the Qualification Plan of Section VIII is testing on 40-year specimens (Specimens 15.1A through 15.3) and 4000 volt specimens (Specimens 16.1 through 17.3). These tests were not completed in time to be discussed in this test report and shall be documented in addenda to this document.

6.0 TEST SPECIMEN DESCRIPTION

The test specimens consisted of 14 different splice constructions as listed below. Three of each specimen were built (4 for Specimen 10) with the XX.1 specimens undergoing the full test sequence. The XX.2 and XX.3 specimens were spares which were aged and irradiated but were not subjected to the LOCA test. The test specimens were constructed by Wyle Laboratories' technicians using materials provided by the Farley Nuclear Generating Station and under the supervision of Alabama Power Company technical representatives.

Specimen No.	Cable Size(s)	Configuration*	Splice** Overlap	Test Voltage	Test Current
1.1, 1.2, 1.3	1/0 to 1/0 AWG	NTO2	1/2"	633 VAC	27A
2.1, 2.2, 2.3	1/0 to 2/0 AWG	NTO3	3/4"	633 VAC	27A
3.1, 3.2, 3.3	1/0 to 8 AWG	NTO6	1"	633 VAC	27A
4.1, 4.2, 4.3	2/0 to 2/0 AWG	VTO2	1/2"	633 VAC	130A
5.1, 5.2, 5.3	2/0 to 2/0 AWG	VTO3	3/4"	633 VAC	130A
6.1, 6.2, 6.3	2/0 to 1/0 AWG	VTO6	1"	633 VAC	130A
7.1, 7.2, 7.3	1/0 to 12 AWG	TO2	1/2"	633 VAC	20A
8.1, 8.2, 8.3	8 to 8 AWG	TO3	3/4"	633 VAC	20A
9.1, 9.2, 9.3	8 to 12 AWG	TO6	1"	633 VAC	20A

6.0 TEST SPECIMEN DESCRIPTION (Continued)

Specimen No.	Cable Size(s)	Configuration	Splice** Overlap	Test Voltage	Test Current
10.1A & 10.1B 10.2, 10.3	12 AWG to ASCO Lead	NTO1	1/4"	137.5 VDC	200mA***
11.1, 11.2, 11.3	12 AWG to ASCO Lead	VTO1	1/4"	137.5 VDC	200mA***
12.1, 12.2, 12.3	12 AWG to ASCO Lead	TO1	1/4"	137.5 VDC	200mA***
13.1, 13.2, 13.3	12 AWG to ASCO Lead	NO3	3/4"	137.5 VDC	200mA***
14.1, 14.2, 14.3	12 AWG to ASCO Lead	NO6	1"	137.5 VDC	200mA***

NOTES:

* T = OKONITE T-95 Insulating Tape. Applied in 2 half-lapped layers.

N = OKONITE No. 35 Jacketing Tape. Applied in 2 half-lapped layers over T-95 tape.

V = 3M Scotch Super No. 33+ Vinyl Jacketing Tape. Applied in 2 half-lapped layers over T-95 tape.

** Overlap refers to distance from end of lug to end of T-95 tape (Specimens 1-12) or No. 35 tape (Specimens 13 and 14). When jacketing tape was used, it was applied 1/2" beyond the end of the T-95 tape.

*** Circuit load was an ASCO 125 VDC Solenoid Model No. HV202301 — 23 Watt provided to Wyle from Farley Nuclear Generating Station.

7.0 TEST PROGRAM RESULTS

It was demonstrated by testing that the test specimens are qualified to the below listed environmental conditions in accordance with IEEE Standard 323-1983, "IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations".

Radiation Dose:	22 Megarads Gamma
Service Temperature:	120°F (Containment), 104°F (Main Steam Room)
Qualified Life:	15 Years
Design Basis Event (DBE):	See Test Profile in figures of Section VI.

7.0 TEST PROGRAM RESULTS (Continued)

Two anomalies occurred during this test program. These anomalies are discussed briefl below and in more detail in Sections II and VI.

Notice of Anomaly No.	Date	Description
1	9/23-25/87	Documents the usage of a high-speed line printer that was outside of its calibration interval during the LOCA test. The printer was checked after the test and found to be within the manufacturer's tolerances. The LOCA test data in this report came from another source of hard copy information. This anomaly is judged to have no impact on the qualification of the test specimens.
2	9/30/87	Documents radiation level overexposure on Specimens 10.1A through 14.3 during the radiation exposure at the Georgia Institute of Technology. These specimens were irradiated to 22 megarads versus a requirement of 2.2 megarads. This error occurred because of a mistake in specifying the requirements to GA Tech. The anomaly resulted in an overtest to the Main Steam Room specimens but did not impact their performance during the LOCA test.

8.0 REFERENCES

8.1 Wyle Laboratories Qualification Plan Numbe 17942-01, Revision A "Qualification Plan for Splices Fabricated with 3M Scotch 33+ Vinyl Plasti Electrical Tape and Okonite Splicing Tapes No. 35 and T-95 for Alabama Powe Company for use in Farley Nuclear Plant" (see Section VIII).

8.2 IEEE 323-1983, "IEEE Standard for Qualifying Class 1E Equipment for Nuclea Power Generating Stations".

8.3 IEEE 383-1974, "IEEE Standard for Type Testing of Class 1E Cables, Fiel Splices, and Connections for Nuclear Power Generating Stations".

8.4 Regulatory Guide 1.89, "Qualification of Class 1E Equipment for Nuclear Powe Plants", dated November 1974.

8.5 10 CFR 50.49, "Environmental Qualification of Electrical Equipment Importan to Safety for Nuclear Power Plants, U. S. Nuclear Regulatory Commission" dated January 21, 1983.

8.6 Code of Federal Regulations 10 CFR 21.

8.7 Code of Federal Regulations 10 CFR 50, Appendix B.

9.0 QUALITY ASSURANCE

All work performed on this test program was done in accordance with Wyle Laboratories' Quality Assurance Program, which complies with the applicable requirements of 10 CFR 50, Appendix B, ANSI N45.2, and the "daughter" standards. Defects are reported in accordance with the requirements of 10 CFR Part 21.

10.0 TEST EQUIPMENT AND INSTRUMENTATION

All instrumentation, measuring, and test equipment used in the performance of this test program were calibrated in accordance with Wyle Laboratories' Quality Assurance Program, which complies with the requirements of Military Specification MIL-STD-45662. Standards used in performing all calibrations are traceable to the National Bureau of Standards by report number and date. When no national standards exist, the standards are traceable to international standards or the basis for calibration is otherwise documented.

SECTION I

BASELINE FUNCTIONAL TESTS

1.0 REQUIREMENTS

1.1 Test Specimen Preparation

The test specimens shall be prepared in accordance with Table IV and Figures 5-22 of Section VIII.

1.2 Acceptance Criteria

1.2.1 Continuity Test

Continuity shall be 1 ohm or less when measured with a digital ohmmeter.

1.2.2 Insulation Resistance

Insulation Resistance shall be measured at 500 VDC for 1 minute for information only.

2.0 PROCEDURES

2.1 Visual Inspection

A visual inspection was performed on the test specimen assembly components upon their receipt at Wyle Laboratories. There was no visual evidence of damage to any length of cable or assembly component found during this inspection. The assembled test specimens were photographed and tagged with Quality Assurance "Test Specimen" tags to facilitate their identification during the test program.

2.2 Test Specimen Preparation

All of the materials required to prepare the test specimens were provided to Wyle Laboratories from the Farley Nuclear Generating Station (FNGS) stock. Wyle technicians assembled the test specimens under the supervision and guidance of on-site Alabama Power Company technical representatives. The completed assemblies were approved by Alabama Power Company representatives prior to commencing testing. The following procedures were followed in the assembly of the test specimens:

1. 18-inch pieces of the following cable sizes were cut from the cable provided to Wyle Laboratories. For the Main Steam Room specimens (Specimens 10.1A to 14.3) the ASCO leads were approximately 9-12 inches and were cut off ASCO solenoid coils provided from FNGS.

2.0 PROCEDURES (Continued)

2.2 Test Specimen Preparation (Continued)

Specimen* Numbers	Lead 1**	Lead 2**
1.1, 1.2 & 1.3	1/C 1/0 AWG	1/C 1/0 AWG
2.1, 2.2 & 2.3	1/C 1/0 AWG	1/C 2/0 AWG
3.1, 3.2 & 3.3	1/C 1/0 AWG	1/C 8 AWG
4.1, 4.2 & 4.3	1/C 2/0 AWG	1/C 2/0 AWG
5.1, 5.2 & 5.3	1/C 2/0 AWG	1/C 2/0 AWG
6.1, 6.2 & 6.3	1/C 2/0 AWG	1/C 1/0 AWG
7.1, 7.2 & 7.3	1/C 1/0 AWG	1/C 12 AWG
8.1, 8.2 & 8.3	1/C 8 AWG	1/C 8 AWG
9.1, 9.2 & 9.3	1/C 8 AWG	1/C 12 AWG
10.1A, 10.1B, 10.2 & 10.3	1/C 12 AWG	1/C 18 AWG ASCO Lead***
11.1, 11.2 & 11.3	1/C 12 AWG	1/C 18 AWG ASCO Lead***
12.1, 12.2 & 12.3	1/C 12 AWG	1/C 18 AWG ASCO Lead***
13.1, 13.2 & 13.3	1/C 12 AWG	1/C 18 AWG ASCO Lead***
14.1, 14.2 & 14.3	1/C 12 AWG	1/C 18 AWG ASCO Lead***

* Three identical specimens of each type (4 for Specimen 10) were assembled. The intent was to test the XX.1 specimen with the XX.2 and XX.3 as spares.

** Cable supplied to Wyle was 1/C 1000 VAC, Okonite (EP)-CSPE Cu cable. The FNGS cable codes were 1/C 12 AWG-JA2, 1/C 8 AWG-JO4, 1/C 1/0 AWG-JO8, and 1/C 2/0 AWG-JO9.

*** The glass braid on these leads was pushed back or cut back as the splice was prepared.

2. An appropriate size compression lug was attached to each end of the above wires. The Burndy lugs were supplied from FNGS and crimped with a Wyle Burndy crimping tool.

3. The lugs were joined using copper or stainless steel hardware.

2.0 PROCEDURES (Continued)

2.2 Test Specimen Preparation (Continued)

Specimen Numbers	Type of Jacketing Tape	Overlap
1	Okonite No. 35	1/2"
2	Okonite No. 35	1/2"
3	Okonite No. 35	1/2"
4	3M Scotch Super 33+	1/2"
5	3M Scotch Super 33+	1/2"
6	3M Scotch Super 33+	1/2"
7	None	N/A
8	None	N/A
9	None	N/A
10	Okonite No. 35	1/2"
11	3M Scotch Super 33+	1/2"
12	None	N/A
13	None	N/A
14	None	N/A

7. Specimens 1.1, 2.1, 3.1, 4.1, 5.1, and 6.1 were installed inside a 24" x 24" x 6" NEMA 1 enclosure. This enclosure contained four 2 in. holes with Myers hubs and the test specimen leads were routed through these holes. The paint was scrapped on the subpanel and the splice mounted flush with this surface.

8. Specimens 10.1A & 10.1B, 10.2 & 10.3, 11.1 & 12.1, 11.2 & 12.2, 11.3 & 12.3, 13.1 & 14.1, 13.2 & 14.2, and 13.3 & 14.3 were mounted inside 3/4-inch Type C condulet fittings. The leads were routed such that the 18 AWG ASCO wires penetrated one end of the condulet and the 1/C 12 AWG wires penetrated the other end. The 8 condulets were tie-wrapped to a 36" L x 30" W x 4" H ladder rung cable tray for handling during the radiation exposure.

9. Specimens 7.1, 8.1 and 9.1 were mounted in a 12" W x 36" L x 6" H cable tray for Baseline Functional Tests and radiation exposure only. For thermal aging and the LOCA Test, they were inside the housing of a Limitorque actuator (see Section IV).

2.0 PROCEDURES (Continued)

2.2 Test Specimen Preparation (Continued)

4. The Okonite T-95 insulating tape was applied over the bolt and lug area to a thickness where no sharp edges could be felt. The T-95 tape was tensioned to approximately 75% of its initial width as it was applied.

5. Okonite T-95 insulating tape (Specimens 1-12) or Okonite No. 35 tape (Specimens 13 and 14) was applied to the cable insulation in two half-lapped layers to the overlaps listed below. These overlaps were mounted from the end of the cable insulation and not the end of the lug. It should be noted that no attempt was made to clean the cable surfaces during assembly. This was felt to be the most conservative approach with respect to adhesion of the tape. The T-95 or No. 35 tape was tensioned to 75% of its initial width as it was applied.

Specimen Numbers	Overlap Distance
1	1/2"
2	3/4"
3	1"
4	1/2"
5	3/4"
6	1"
7	1/2"
8	3/4"
9	1"
10	1/4"
11	1/4"
12	1/4"
13	3/4"
14	1"

6. Okonite No. 35 or 3M Scotch 33+ jacketing tapes were applied over the Okonite T-95 tape to the following listed overlap distances. These tapes were also tensioned to 75% of their initial width prior to application.

2.0 PROCEDURES (Continued)

2.2 Test Specimen Preparation (Continued)

10. The remaining specimens were tie-wrapped to the rungs of the 36" L x 30" W x 4" H cable tray such that the splice was in-contact with one of the rungs.

11. Photographs were taken of the complete assembly and during the preparation of each specimen type.

2.3 Baseline Functional Tests

2.3.1 Insulation Resistance Test

Using a megohmmeter, a potential of 500 VDC was applied between one end of the specimen cable and the tray, condulet or enclosure to which the specimen was mounted. The Insulation Resistance was recorded after 60 seconds and the specimen de-energized.

2.3.2 Continuity Test

The resistance between the two ends of the specimen cable was measured using a digital ohmmeter which utilized Kelvin Bridge circuitry. These values were recorded as soon as a stable reading was obtained.

3.0 RESULTS

The test specimens were subjected to the inspections, preparation and testing of Paragraph 2.0 which met the requirements of Paragraph 1.0.

The data recorded from this phase of testing is presented in Appendices I through III as noted below:

- Appendix I contains Photographs I-1 through I-19 which show the specimens during assembly and mounted in their trays, condulets or enclosure.
- Appendix II contains the Baseline Functional Test Data Sheets.
- Appendix III contains the Instrumentation Equipment Sheet which lists the equipment used to take data.

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APPENDIX I

PHOTOGRAPHS

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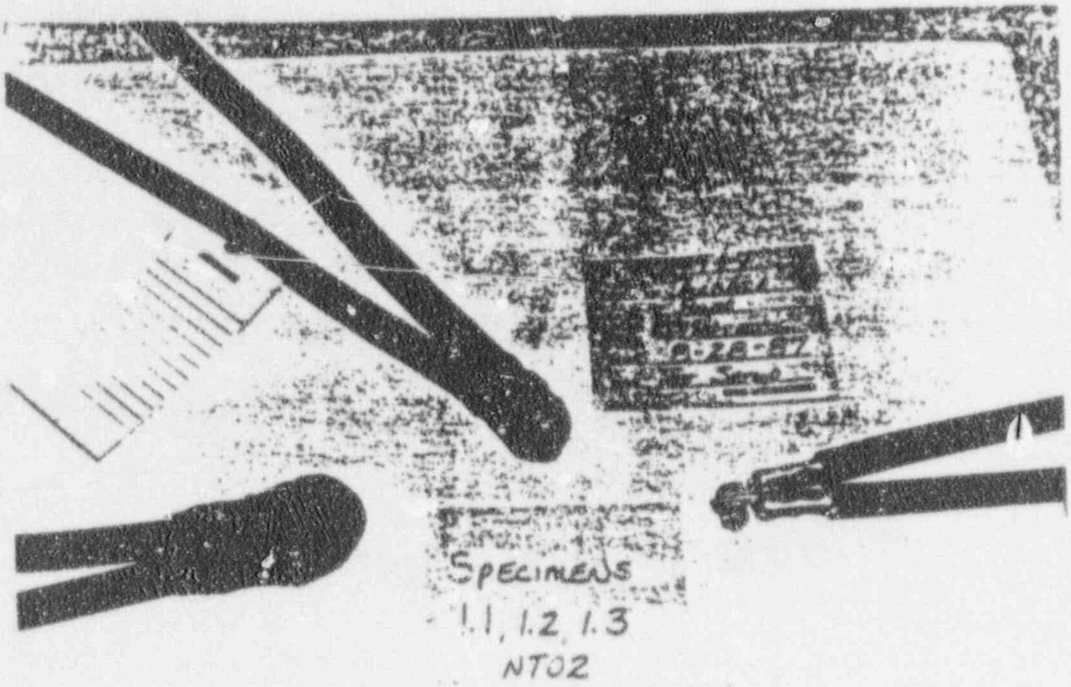
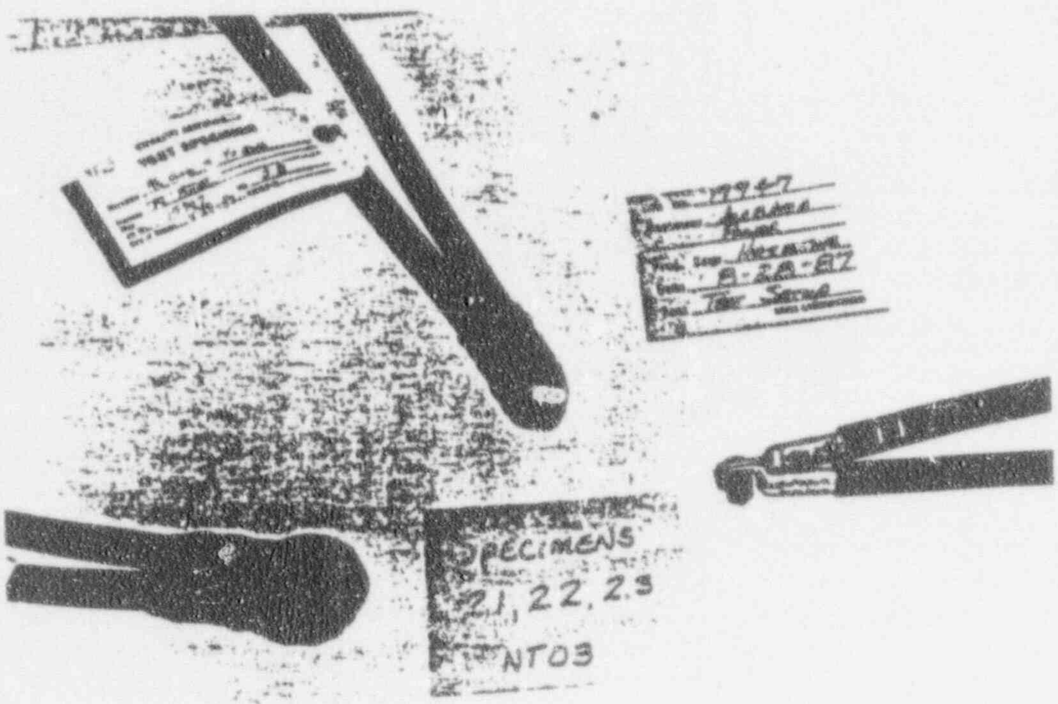


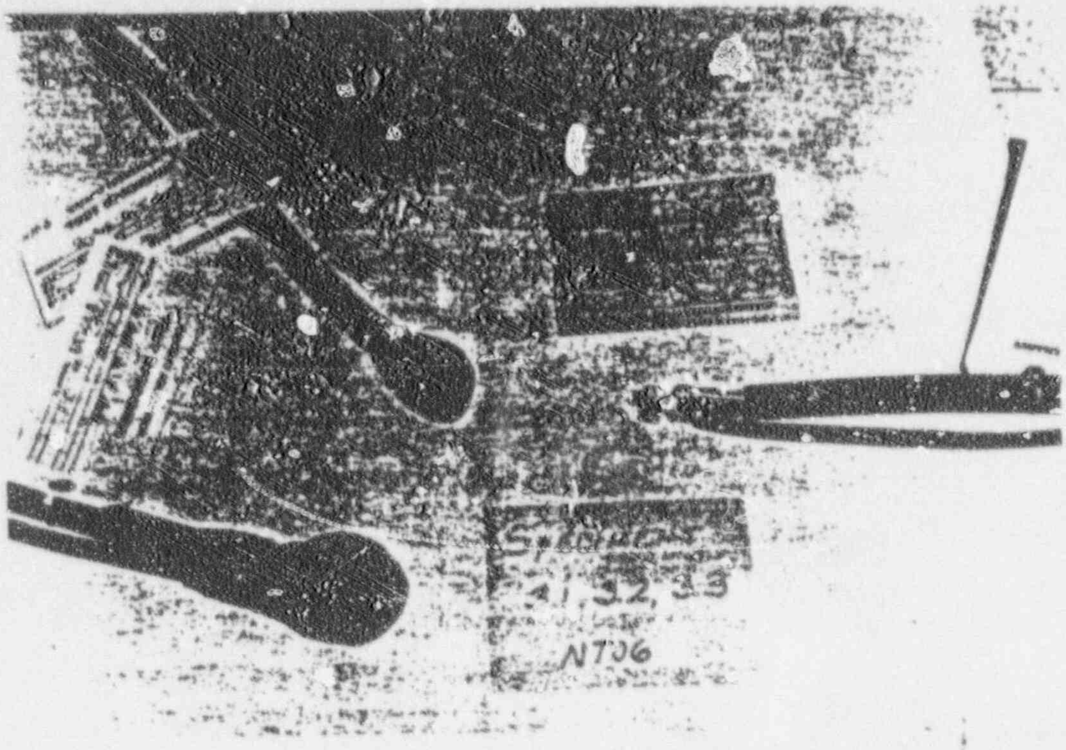
PHOTOGRAPH NO. I-1

TEST ASSEMBLY VIEW OF
SPECIMENS 1.1, 1.2, AND 1.3



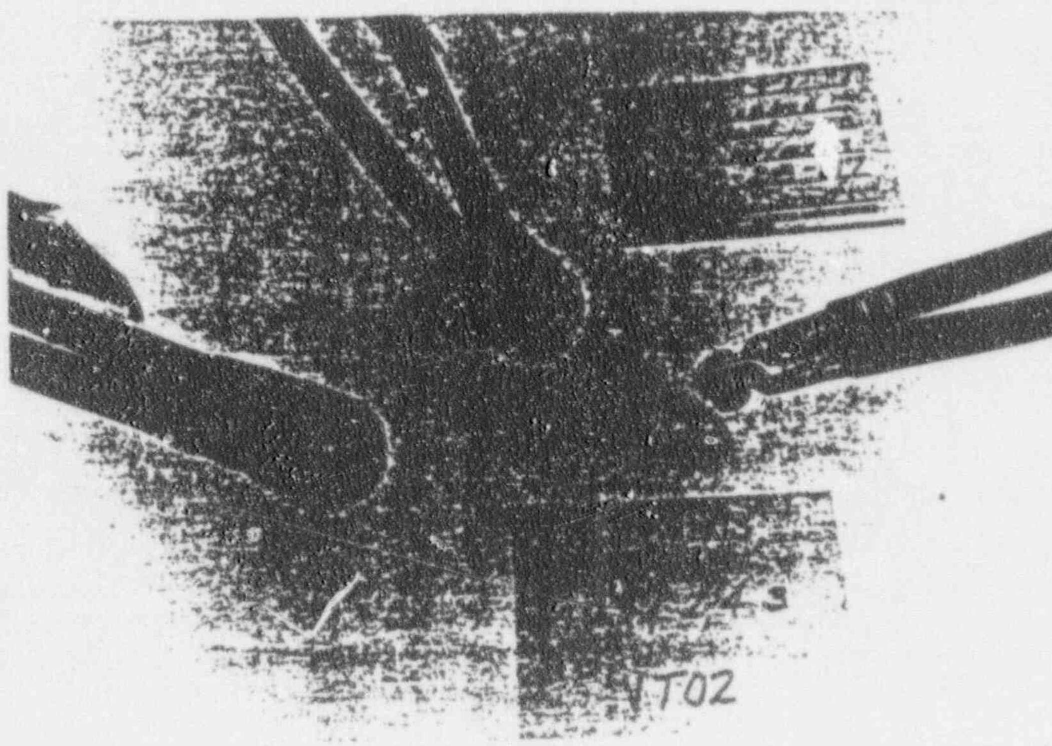
PHOTOGRAPH NO. I-2

TEST ASSEMBLY VIEW OF
SPECIMENS 2.1, 2.2, AND 2.3



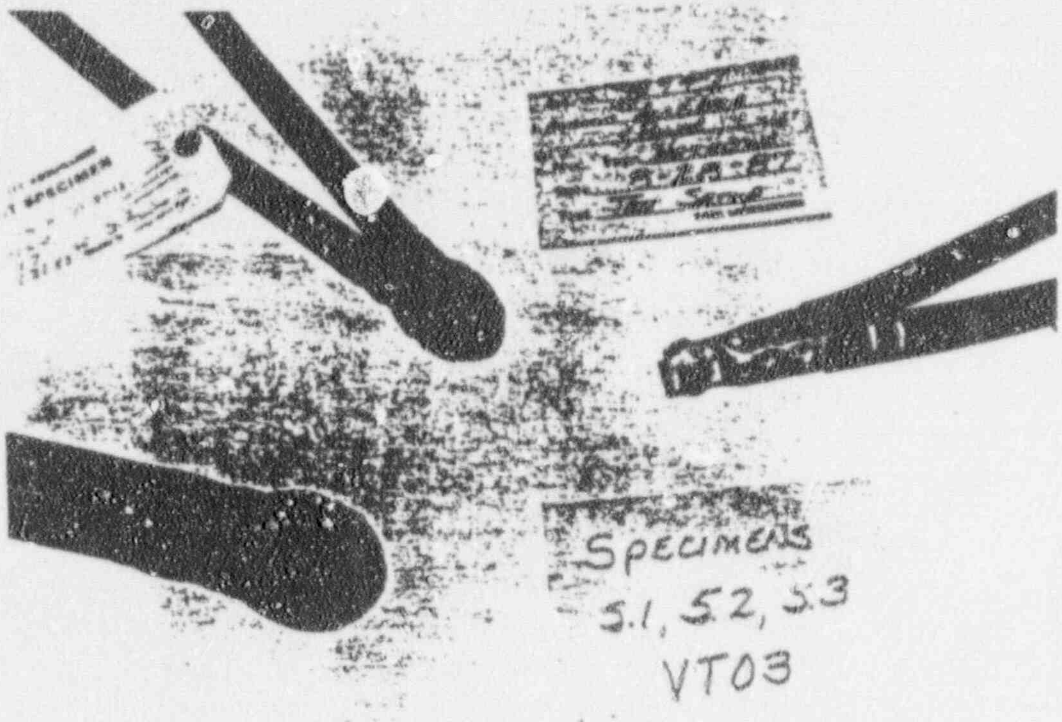
PHOTOGRAPH NO. 1-3

TEST ASSEMBLY VIEW OF
SPECIMENS 3.1, 3.2, AND 3.3



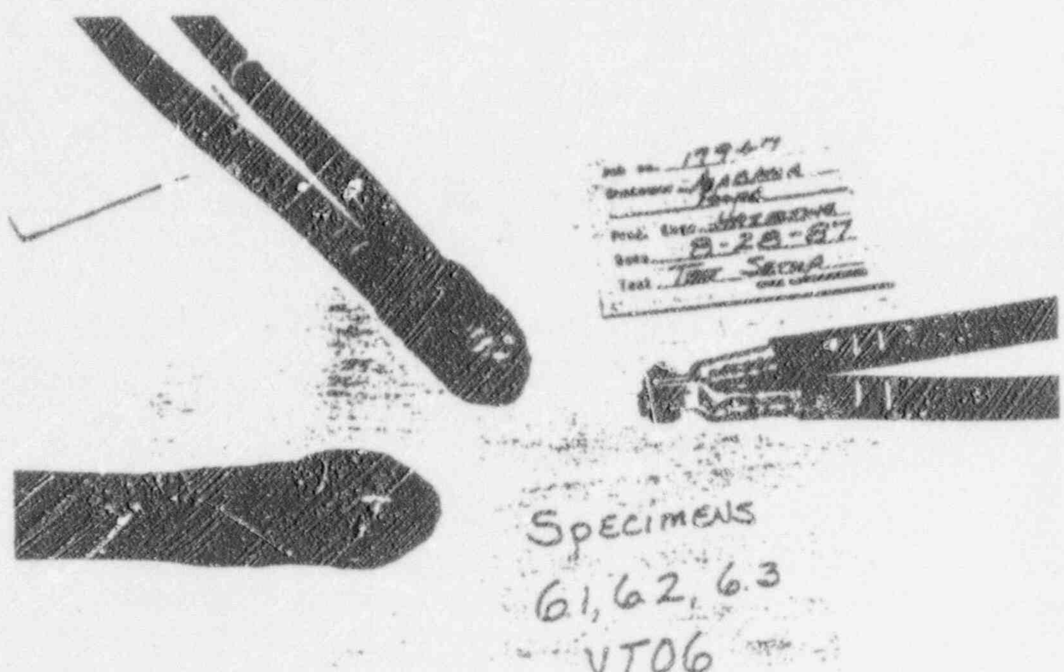
PHOTOGRAPH NO. 1-4

TEST ASSEMBLY VIEW OF
SPECIMENS 4.1, 4.2, AND 4.3



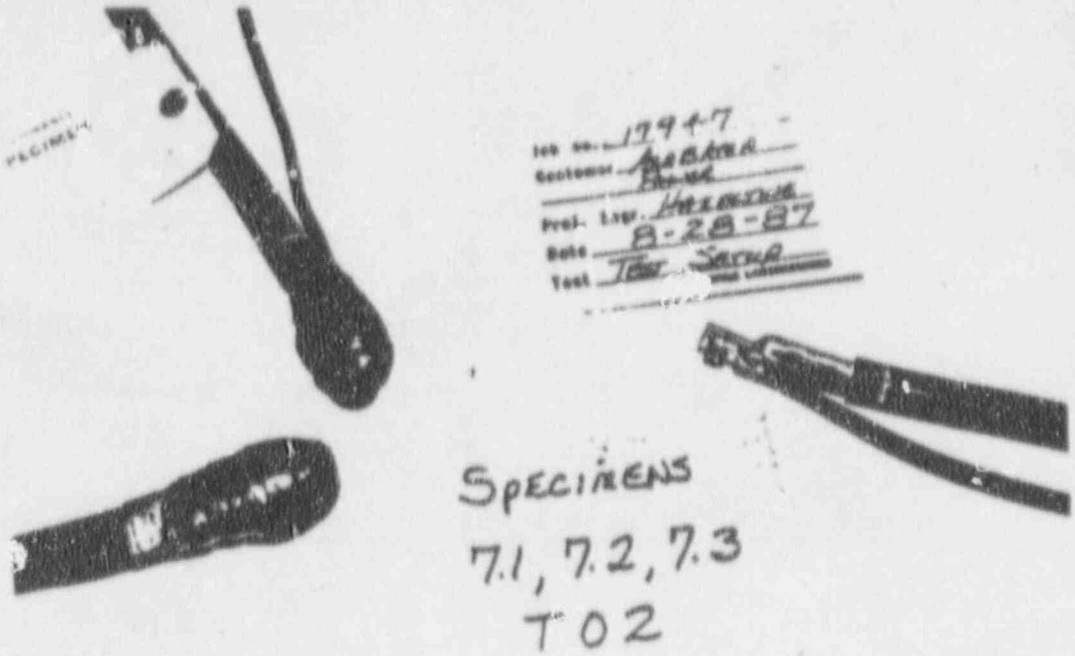
PHOTOGRAPH NO. I-5

**TEST ASSEMBLY VIEW OF
SPECIMENS 5.1, 5.2, AND 5.3**



PHOTOGRAPH NO. I-6

**TEST ASSEMBLY VIEW OF
SPECIMENS 6.1, 6.2, AND 6.3**

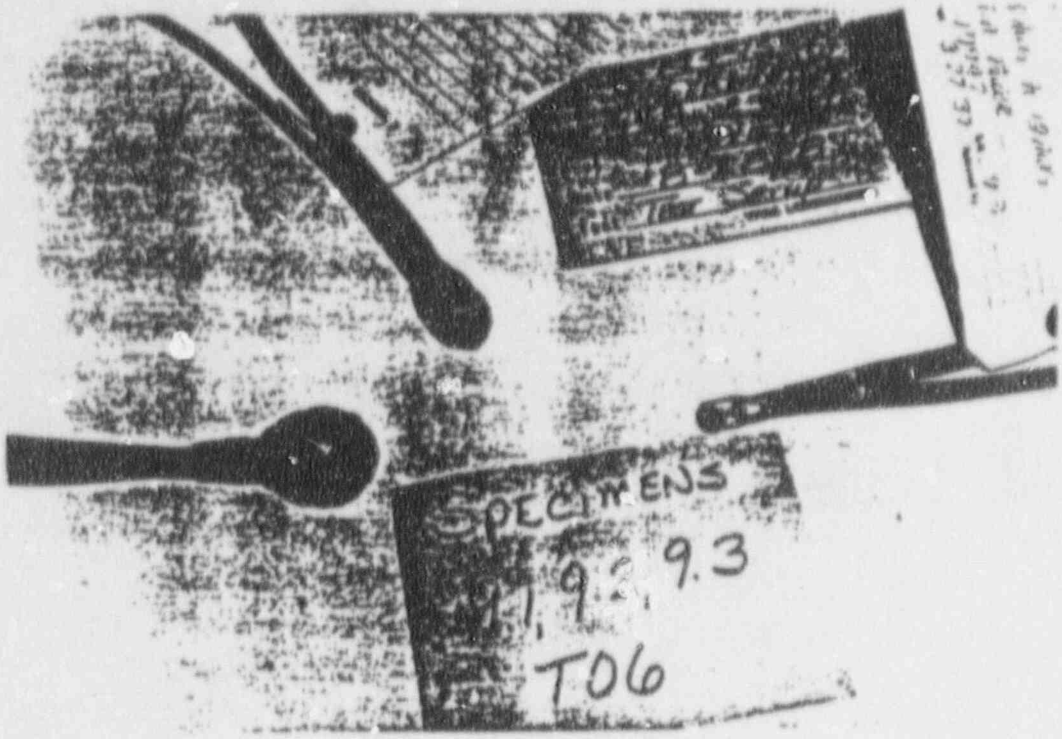


PHOTOGRAPH NO. 1-7

TEST ASSEMBLY VIEW OF SPECIMENS 7.1, 7.2, AND 7.3

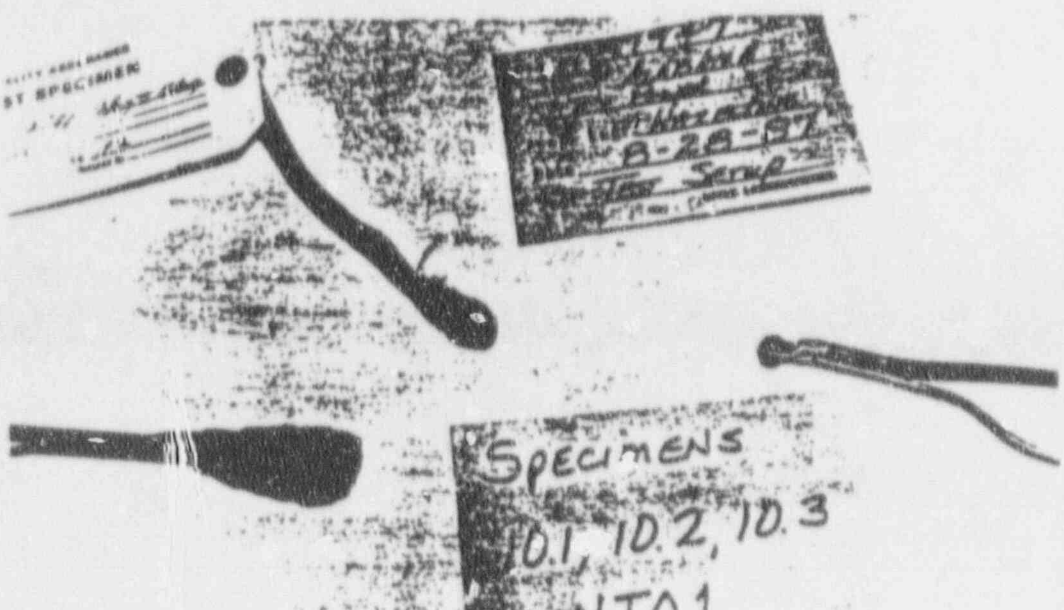
PHOTOGRAPH NO. 1-8

TEST ASSEMBLY VIEW OF SPECIMENS 8.1, 8.2, AND 8.3



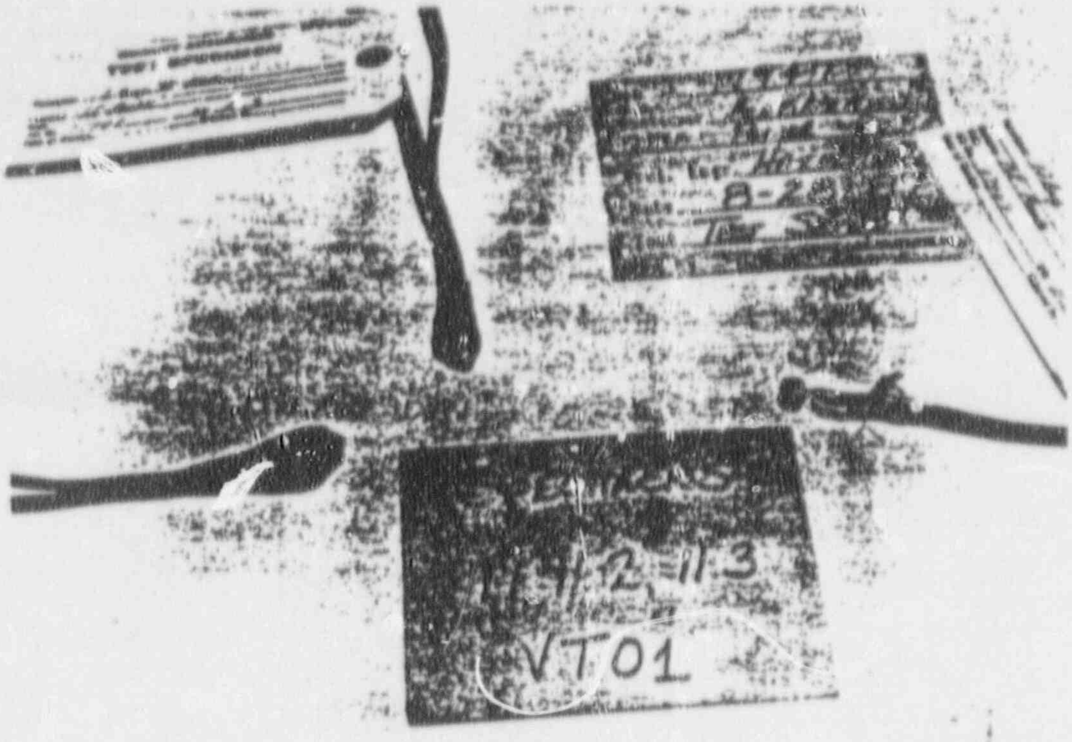
PHOTOGRAPH NO. I-9

**TEST ASSEMBLY VIEW OF
SPECIMENS 9.1, 9.2, AND 9.3**



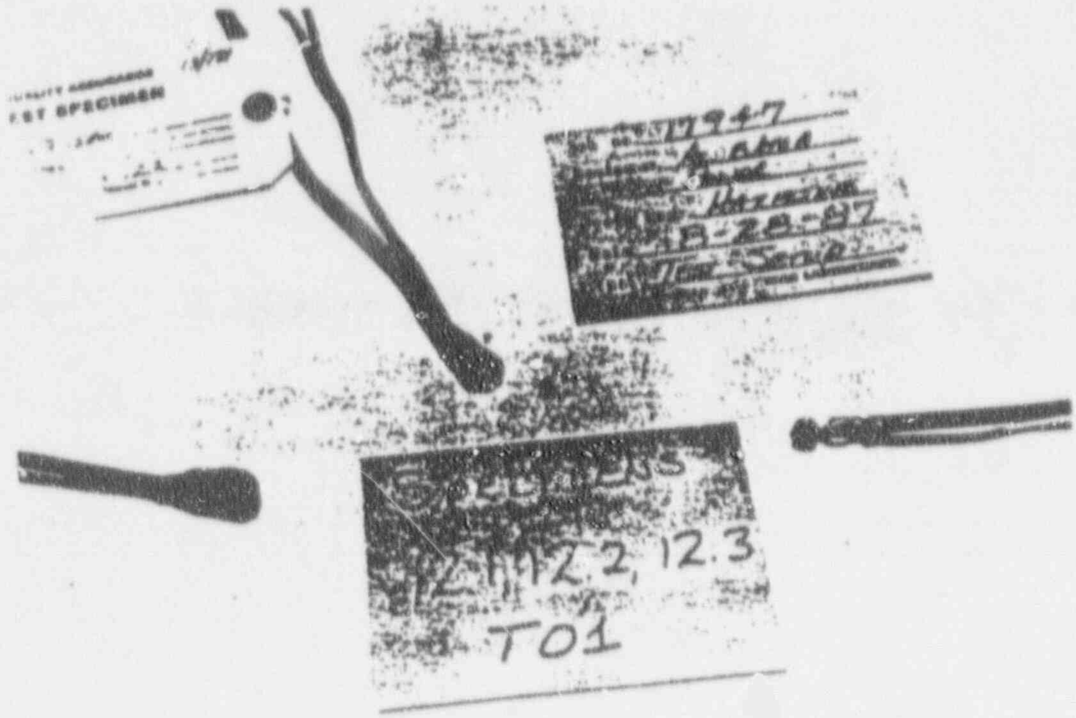
PHOTOGRAPH NO. I-10

**TEST ASSEMBLY VIEW OF
SPECIMENS 10.1, 10.2, AND 10.3**
(Specimen 10.1B was assembled after this photograph was taken.)



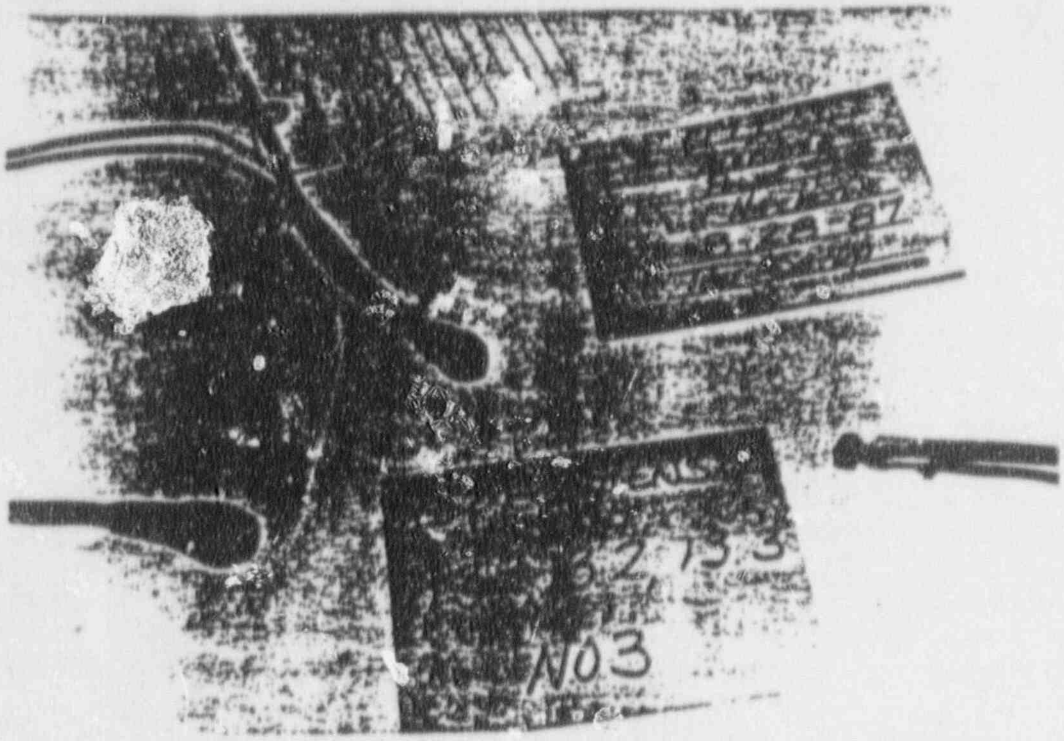
PHOTOGRAPH NO. I-11

TEST ASSEMBLY VIEW OF SPECIMENS 11.1, 11.2, AND 11.3



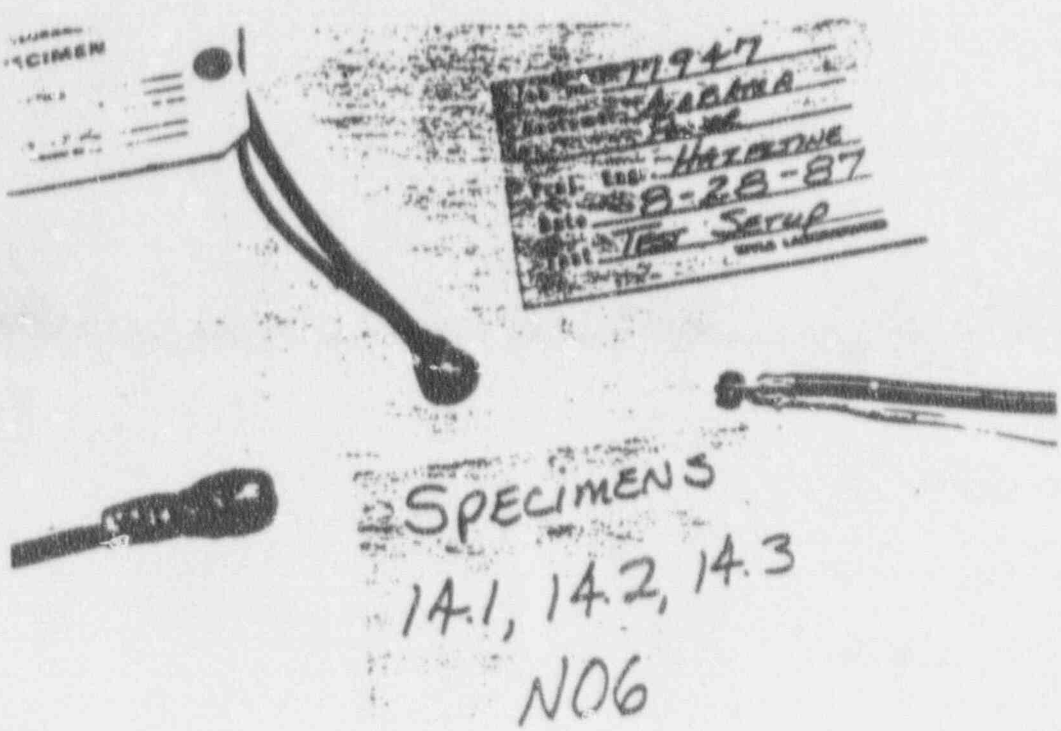
PHOTOGRAPH NO. I-12

TEST ASSEMBLY VIEW OF SPECIMENS 12.1, 12.2, AND 12.3



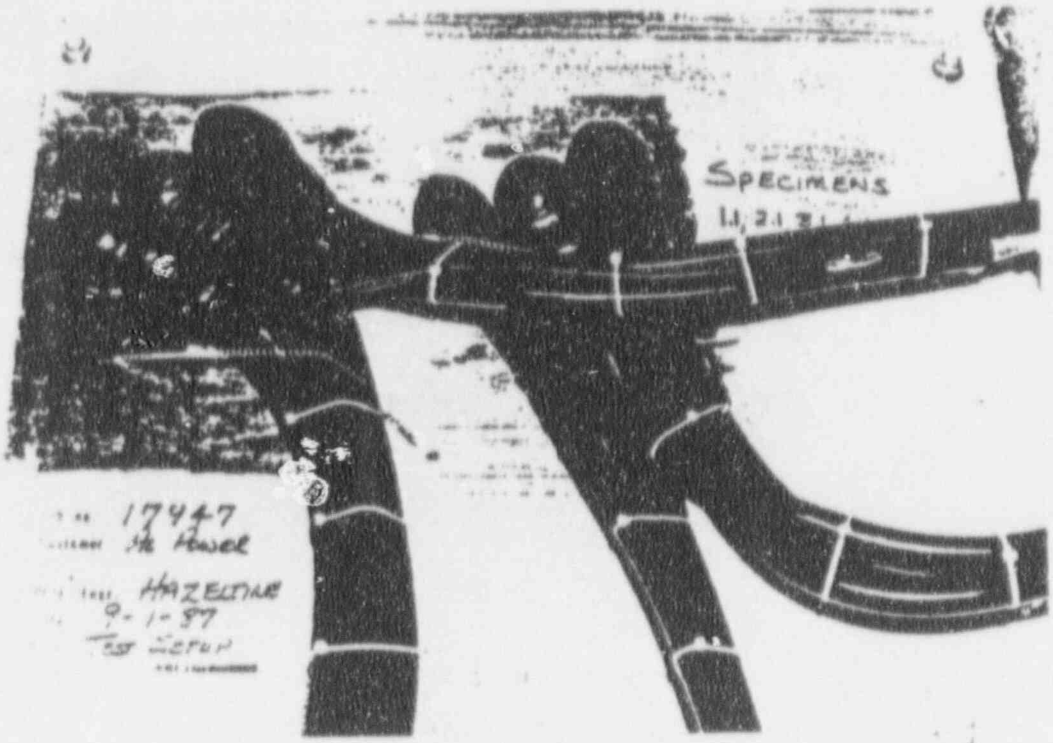
PHOTOGRAPH NO. I-13

TEST ASSEMBLY VIEW OF SPECIMENS 13.1, 13.2, AND 13.3



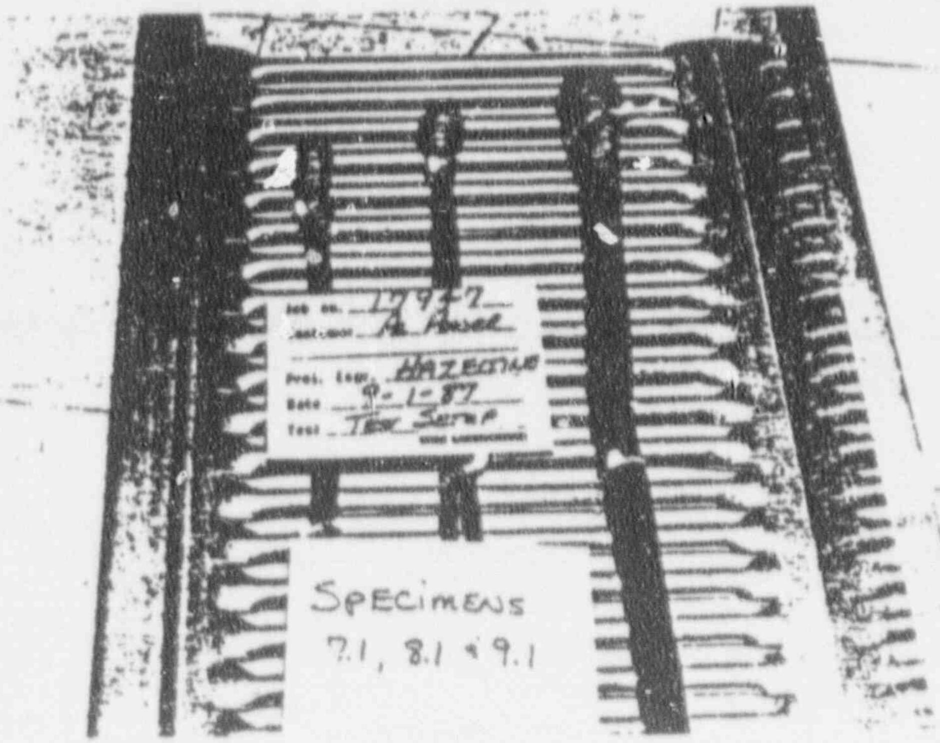
PHOTOGRAPH NO. I-14

TEST ASSEMBLY VIEW OF SPECIMENS 14.1, 14.2, AND 14.3



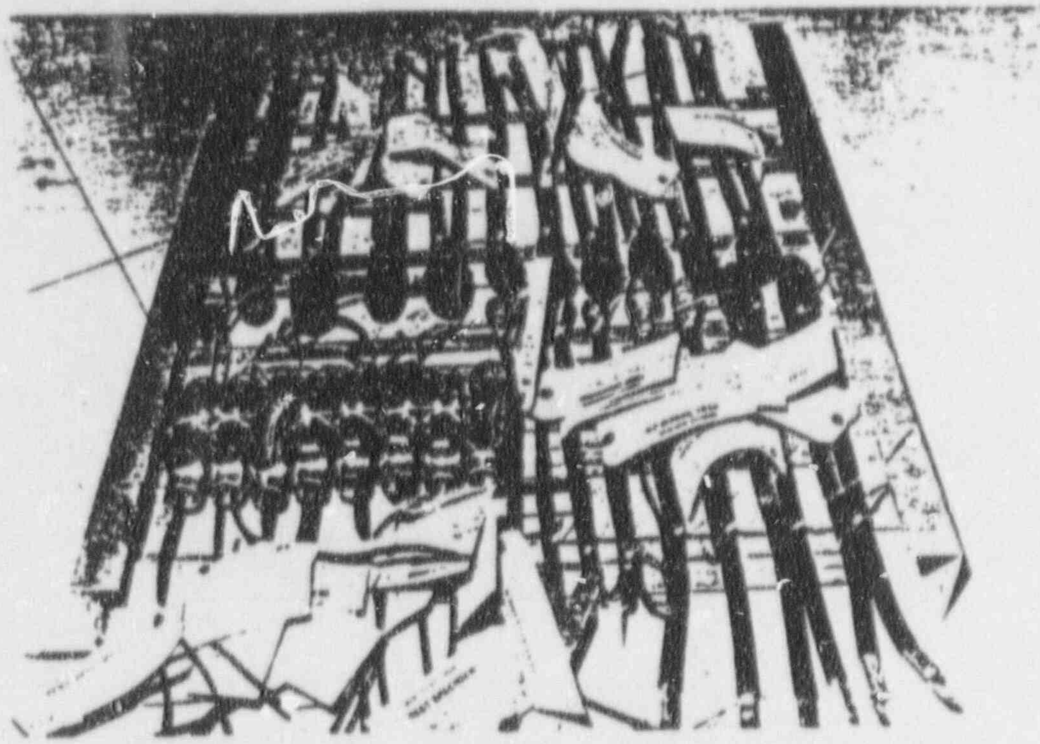
PHOTOGRAPH NO. I-15

SPECIMENS 1.1, 2.1, 3.1, 4.1, 5.1, AND 6.1 MOUNTED IN A NEMA 1 ENCLOSURE WITH PAINT REMOVED FROM THE SUBPANEL AFTER FULLY ASSEMBLED



PHOTOGRAPH NO. I-16

SPECIMENS 7.1, 8.1, AND 9.1 INSIDE THE CABLE TRAY USED FOR IRRADIATION AND BASELINE TESTS

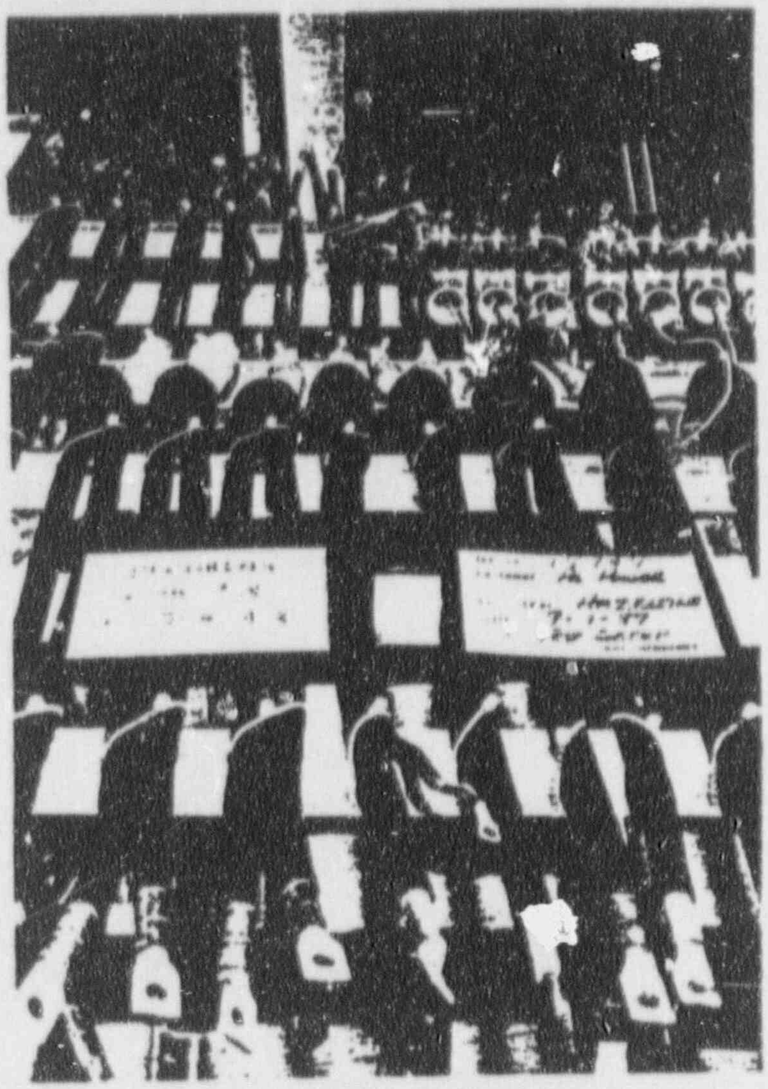


PHOTOGRAPH NO. I-17

36" x 30" x 4" CABLE TRAY CONTAINING ALL XX.2 AND XX.3 SPECIMENS. ALSO CONTAINS 8 CONDULETS.

PHOTOGRAPH NO. I-18

CLOSEUP VIEW SHOWING
INTERNAL VIEW OF TWO CONDULETS



PHOTOGRAPH NO. I-19

ANOTHER VIEW OF COMPLETED TEST SPECIMEN ASSEMBLIES IN THE 36" x 36" x 4" CABLE TRAY

BASELINE FUNCTIONAL TESTS

APPENDIX II

DATA SHEETS

Test Report No. 17947-01

DATA SHEET

Customer Alabama Power

WYLE LABORATORIES

Specimen Okonite Tape Splices

Part No. T-95, No. 35 and Scotch 33+

Amb. Temp. 75°F

Job No. 17947

Spec. WLQP 17492-01

Photo YES

Report No. 17947-01

Para. 3.3

Test Med. Air

Start Date 9-1-9[illegible]

S/N No

Specimen Temp. Ambient

GSI No

Test Title BASELINE Functional Test

Acceptance Criteria: Insulation Resistances (at 500 VDC for 1 minute) and Contact Resistances (via Kelvin Bridge Method) shall be measured for information only.

Specimen No.	Insulation Resistance	Contact Resistance
1.1	$2.2 \times 10^{12}\ \Omega$	0.35 [illegible]
1.2	$2.0 \times 10^{12}\ \Omega$	0.36 m[illegible]
1.3	$3.0 \times 10^{12}\ \Omega$	0.3[illegible]
2.1	$2.8 \times 10^{12}\ \Omega$	0.31 m
2.2	$1.7 \times 10^{12}\ \Omega$	0.32 [illegible]
2.3	$1.9 \times 10^{12}\ \Omega$	0.39 [illegible]
3.1	$4.5 \times 10^{12}\ \Omega$	1.06 [illegible]
3.2	$1.5 \times 10^{12}\ \Omega$	1.10 [illegible]
3.3	$2.5 \times 10^{12}\ \Omega$	1.11 m
4.1	$1.0 \times 10^{12}\ \Omega$	0.27 [illegible]
4.2	$1.3 \times 10^{12}\ \Omega$	0.28 m
4.3	$1.0 \times 10^{12}\ \Omega$	0.28 [illegible]
5.1	$1.1 \times 10^{12}\ \Omega$	0.28 [illegible]
5.2	$6.8 \times 10^{10}\ \Omega$	0.28 [illegible]
5.3	$9.6 \times 10^{10}\ \Omega$	0.28 [illegible]

Tested By [illegible signature] Date [illegible]

Witness none Date:

Sheet No. 1 of [illegible]

Approved [illegible signature] 9/1/[illegible]

Notice of Anomaly None

Wyle Form WH 614A, Rev. APR '84

INSTRUMENTATION EQUIPMENT SHEET

PAGE 1

DATE: 09/01/87
TECHNICIAN: C. ARBUCKLE

JOB NUMBER: 17947-00
CUSTOMER: ALA. POWER

TEST AREA: ELEC. LAB
TYPE TEST: I.R.

NO.	INSTRUMENT	MANUFACTURER	MODEL#	SERIAL #	WYLE #	RANGE 1	ACCURACY 1	CALDATE	CALDUE
1	MEG MTR	GR	1864	657113180	011898	50K-50TOHM	2-5%RANGE	04/06/87	10/06/87
2	MEG MTR	GENERAL RADIO	1862-C	257	102992	.5-2E6 MOHM	+-3%	05/18/87	11/18/87
3	DIG MTR	VALHALLA	4150	02123	101040	.02-2KOHM	.02%RDG	03/10/87	09/10/87

THIS IS TO CERTIFY THAT THE ABOVE INSTRUMENTS WERE CALIBRATED USING STATE-OF-THE-ART TECHNIQUES WITH STANDARDS WHOSE CALIBRATION IS TRACEABLE TO THE NATIONAL BUREAU OF STANDARDS.

INSTRUMENTATION Denman Compton 9/1/87

CHECKED & RECEIVED BY J. Hazett 9/1/87

Q.A. R.S. Bailes 09-02-87 (Wyle 2 A)

APPENDIX III

INSTRUMENTATION EQUIPMENT SHEET

DATA SHEET

Customer: Alabama Power
Specimen: Okonite Tape Splices
Part No.: T-95, No. 35 and Scotch 33+
Spec.: WLQP 17492-01
Para.: 3.3
S/N: No
GSI: No

Amb. Temp.: 75°F
Photo: YES
Test Med.: Air
Specimen Temp.: Ambient

WYLE LABORATORIES
Job No.: 17947
Report No.: 17947-0
Start Date: 9-1-8

Test Title: BASELINE Functional Test

(Continued)

Specimen No.	Insulation Resistance	Contact Resistan
12.1	1.1 X 10^13 Ω	9.9
12.2	6.8 X 10^12 Ω	9.71
12.3	6.7 X 10^12 Ω	10.15
13.1	3.0 X 10^12 Ω	9.5
13.2	2.4 X 10^12 Ω	10.16
13.3	4.0 X 10^12 Ω	10.37
14.1	5.0 X 10^12 Ω	9.12
14.2	1.5 X 10^12 Ω	6.51
14.3	7.6 X 10^12 Ω	20.80
15.1A	3.5 X 10^11 Ω	3.12
15.1B	1.2 X 10^12 Ω	3.18
15.1C	2.0 X 10^12 Ω	3.98
15.2A	3.2 X 10^12 Ω	3.04
15.2B	2.2 X 10^12 Ω	3.10
15.3	2.4 X 10^12 Ω	3.12

Tested By: [signature] Date: 9/1
Witness: None Date:
Sheet No. 3 of 3
Approved: [signature] 9/1/8

Notice of Anomaly: None

Wyle Form WH 614A Rev APR '84

DATA SHEET

Customer: Alabama Power
Specimen: Okonite Tape Splices
Part No.: T-95, No. 35 and Scotch 33+
Spec.: WLQP 17492-01
Para.: 3.3
S/N: No
GSI: No

Amb. Temp.: 75°F
Photo: Yes
Test Med.: Air
Specimen Temp.: Ambient

WYLE LABORATORIES

Job No.: 17947
Report No.: 17947-01
Start Date: 9-1-87

Test Title: BASELINE Functional Test

(Continued)

Specimen No.	Insulation Resistance	Contact Resistance
6.1	1.1×10^{12} Ω	0.31 mΩ
6.2	1.4×10^{12} Ω	0.31 mΩ
6.3	1.1×10^{12} Ω	0.33 mΩ
7.1	2.5×10^{12} Ω	2.35 mΩ
7.2	1.1×10^{13} Ω	2.28 mΩ
7.3	6.8×10^{12} Ω	2.30 mΩ
8.1	1.5×10^{12} Ω	1.81 mΩ
8.2	2.8×10^{12} Ω	1.82 mΩ
8.3	2.5×10^{12} Ω	1.91 mΩ
9.1	2.0×10^{12} Ω	2.98 mΩ
9.2	8.8×10^{12} Ω	3.05 mΩ
9.3	1.2×10^{12} Ω	3.12 mΩ
10.1A	2.5×10^{12} Ω	33.70 mΩ
10.1B	2.8×10^{12} Ω	8.20 mΩ
10.2	6.2×10^{12} Ω	6.05 mΩ
10.3	5.0×10^{12} Ω	9.15 mΩ
11.1	4.0×10^{12} Ω	10.49 mΩ
11.2	3.5×10^{12} Ω	5.37 mΩ
11.3	2.7×10^{12} Ω	10.55 mΩ

Tested By: [signature] Date: 9/1/87
Witness: N/A Date:
Sheet No. 2 of 2
Approved: [signature] 9/1/87

Notice of Anomaly: N/A

Wyle Form WH 614A Rev. APR 84

RADIATION EXPOSURE

SECTION II

RADIATION EXPOSURE

1.0 REQUIREMENTS

The test specimens shall be irradiated to a radiation exposure of 22 megarads for Containment Specimens 1.1 to 9.3, and 2.2 megarads for Main Steam Room Specimens 10.1A to 14.3 using a Cobalt 60 source.

2.0 PROCEDURES

The test specimens, mounted in their respective trays, condulets or enclosures were placed in the hot cell at the Neely Nuclear Research Center of the Georgia Institute of Technology and radiated as follows:

Specimens	Dose Rate	Time	Total Dose
1.1, 2.1, 3.1, 4.1, 5.1 & 6.1	4.73E5 Rads/Hr	46.55 Hr	2.20E7 Rads
10.1A to 14.3	4.67E5 Rads/Hr	47.13 Hr	2.20E7 Rads
Remaining Items	4.68E5 Rads/Hr	47.01 Hr	2.20E7 Rads

The test specimens were not powered during the exposure period.

3.0 RESULTS

The test specimens possessed sufficient integrity to withstand the radiation exposures of Paragraph 2.0 without compromise of function. No physical change was noted on the specimens after the irradiation period.

One anomaly occurred during the radiation exposure and was not detected until the test had been completed. This anomaly, Notice of Anomaly Number 2 in Appendix I, documents the overexposure of the Main Steam Room Specimens 10.1A to 14.3. These specimens were to receive 2.2 megarads but were exposed to 22 megarads. This error occurred because the wrong dose level was specified by Wyle Laboratories to Georgia Tech. These specimens did, however, complete the test satisfactorily and thus their qualification exceeds their radiation requirement.

The data from this phase of testing is presented in Appendices I and II. These appendices contain:

- Appendix I contains Notice of Anomaly Number 1.
- Appendix II contains the letter of certification on the radiation exposure from Georgia Tech.

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APPENDIX I

NOTICE OF ANOMALY

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WYLE LABORATORIES (Eastern Operations)

NOTICE OF ANOMALY

DATE: October 5, 1987

NOTICE NO: 2 P.O. NUMBER: QP-1859 CONTRACT NO: N/A

CUSTOMER: Alabama Power Company WYLE JOB NO: 17947

NOTIFICATION MADE TO: Rick Woodfin NOTIFICATION DATE: Sept. 30, 1987

NOTIFICATION MADE BY: Joe Hazeltine VIA: On-site

CATEGORY: ☐ SPECIMEN ☒ PROCEDURE ☐ TEST EQUIPMENT DATE OF ANOMALY: Sept 2-4, 1987

PART NAME: N/A PART NO. N/A

TEST: Radiation Exposure I.D. NO. N/A

SPECIFICATION: WLQP 17942-01, Revision A PARA. NO. Table IV

REQUIREMENTS:

The specimens shall be irradiated as specified in Table IV. Table IV specifies 2.2E7 Rads for Specimens 1.1 to 9.3 and 2.2E6 Rads for Specimens 10.1A to 14.3.

DESCRIPTION OF ANOMALY:

Specimens 10.1A to 14.3 were irradiated to a total dose of 2.2E7 Rads.

DISPOSITION - COMMENTS - RECOMMENDATIONS:

The mistake in the above radiation exposure was not detected until the test program had been complete. This error occurred because the wrong dose level was specified by Wyle Laboratories to the Georgia Institute of Technology Neely Nuclear Research Center. These specimens did, however, successfully complete the LOCA Test.

This anomaly resulted in an overtest to the main steam room specimens, but apparently did not impact their performance during the LOCA Test.

NOTE: IT IS THE CUSTOMER'S RESPONSIBILITY TO ANALYZE ANOMALIES AND COMPLY WITH 10 CFR PART 21.

VERIFICATION:

TEST WITNESS: Rick Woodfin PROJECT ENGINEER: [signature] 10/5/87

REPRESENTING: Alabama Power Company PROJECT MANAGER: [signature] 10/6/87

QUALITY ASSURANCE: [signature] 10/6/87 INTERDEPARTMENTAL COORDINATION: [signature] 10/6/87 [signature]

Wyle Form WH 1066, Rev. JAN '86

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APPENDIX II

RADIATION FACILITY CERTIFICATION LETTER

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Georgia Institute of Technology

NEELY NUCLEAR RESEARCH CENTER
900 ATLANTIC DRIVE
ATLANTA, GEORGIA 30332-0425

(404) 894-3600

October 5, 1987

Wyle Laboratories
7800 Governors Drive
Huntsville, Alabama 35807-5101

Attention: Mr. Joe Hazeltine

Reference: 4-7103-S
720992

Gentlemen:

The items covered by the above number have been irradiated in accordance with quality assurance requirements using Cobalt 60 (Gamma energies 1.173 Mev, 1.332 Mev) to the total dose requested.

We certify the specifics of the irradiation as follows:

Irradiation Period: Interval between September 2, 1987 through September 4, 1987 as shown on the enclosed Gamma Irradiation Log Sheets.

Dose Rate: (NTE) 1.00 E6 Rads/hr (Air Equivalent)

Total Dose: 2.20 E7 Rads (Air Equivalent)

Dosimetry: Victoreen Model 500B-1 Integrating/Rate Electrometer System with ionization chamber probe. Calibration by Victoreen traceable to NBS Cobalt-60.

Calculations, a sketch, or photographs of the arrangement are enclosed. Please let us know if any additional information is needed.

Yours truly,

R.A. Karam

Dr. R.A. Karam
Director

RAK:jlr

Enclosures

GEORGIA INSTITUTE OF TECHNOLOGY
Nuclear Research Center
900 Atlantic Drive, N.W.
Atlanta, Georgia 30332
(404) 894-3608

GAMMA IRRADIATION LOG

Client: Wyle Laboratories NRC Reference: 720992

Reference: 4-7103-S Total Dose: 2.2 E7

Item: Cable Tray/3 ea. Splices Dose Rate: (NTE) 1.0 E6

Start	Stop	Lapsed Hours	Dose Rate Rads/hour	Total Dose Rads	Cumulative Dose - Rads
9/2/87	9/4/87				
1037	0910	46.55	4.73 E5	2.20 E7	2.20 E7

		Date
Performed	[signature]	10-5-87
Reviewed	[signature]	

DOSE RATE DETERMINATION

E x P x D x T x M x H x R = Dose Rate, Rads/hr (Air Eqiuivalent)

E = Electrometer High Level Conversion
P = Probe Efficiency
D = Dose Conversion, Roentgen to Rad
T = Temperature Correction to 0 Degree Celsius
M = Pressure Correction to 760 Millimeters Mercury
H = Time Conversion, Minutes to Hours
R = Electrometer Reading

E	P	D	T	M	H	R	Dose Rate, Rads/hr
100	0.939	0.869	1.050	1.025	60	88.95	4.68 E5
100	0.939	0.868	1.050	1.025	60	88.66	4.67 E5
100	0.939	0.868	1.050	1.025	60	89.80	4.73 E5

WYLE LABORATORIES: 4-7103-S
GEORGIA TECH NUMBER: 720992

GEORGIA INSTITUTE OF TECHNOLOGY
Nuclear Research Center
900 Atlantic Drive, N.W
Atlanta, Georgia 30332
(404) 894-3608

GAMMA IRRADIATION LOG

Client: Wyle Laboratories NRC Reference: 720992

Reference: 4-7103-S Total Dose: 2.20 E7

Item: Cable Tray/18 ea. Splices Dose Rate: (NTE) 1.0 E6

Start	Stop	Lapsed Hours	Dose Rate Rads/hour	Total Dose Rads	Cumulative Dose - Rads
9/2/87	9/4/87				
1039	0940	47.01	4.68 E5	2.20 E7	2.20 E7
					Date
Performed	[signature]				10-5-87
Reviewed	[signature]				

Test Report No. 17947-01

GEORGIA INSTITUTE OF TECHNOLOGY

Nuclear Research Center
900 Atlantic Drive, N.W.
Atlanta, Georgia 30332
(404) 894-3608

GAMMA IRRADIATION LOG

Client: Wyle Laboratories | NRC Reference: 720992

Reference: 4-7103-S | Total Dose: 2.2 E7

Item: Nema Enclosure/6 Splices | Dose Rate: (NTE) 1.0 E6

Start	Stop	Lapsed Hours	Dose Rate Rads/hour	Total Dose Rads	Cumulative Dose · Rads
9/2/87	9/4/87				
1037	0910	46.55	4.73 E5	2.20 E7	2.20 E7
					Date
Performed	[signature]				10-5-87
Reviewed	[signature]				

Page No. II-14
Test Report No. 17947-01

GEORGIA INS UTE OF TECHNOLOGY
Nuclear Research Center
900 Atlantic Drive, N.W.
Atlanta, Georgia 30332
(404) 894-3608

GAMMA IRRADIATION LOG

Client: Wyle Laboratories NRC Reference: 720992

Reference: 4-7103-S Total Dose: 2.2 E7

Item: Eight (8) Condulet Fittings Dose Rate: (NTE) 1.0 E6

Start	Stop	Lapsed Hours	Dose Rate Rads/hour	Total Dose Rads	Cumulative Dose - Rads
9/3/87	9/4/87				
1040	0948	47.13	E.	2.20 E7	2.20 E7

		Date
Performed	[signature]	10-5-87
Reviewed	[signature]	

TRACEABILITY DATA

Victoreen Electrometer
Model Number 500B-1
Serial Number 340

Calibrated: November 17, 1986
By: Neely Nuclear Research Center
Georgia Institute of Technology
900 Atlantic Drive, N.W.
Atlanta, Georgia 30332
Next Calibration Due: November 17, 1987

Instruments Used

Keithley Picoampere Source
Model Number 261
Serial Number 71987

Calibration: October 9, 1986
By: General Electric Company
Integrated Communication Services Operation
2825 Pacific Drive, Suite A
Norcross, Georgia 30071
Next Calibration Due: October 9, 1987

General Electric Traceability
SLN-7081 Number 000480 (Dated July 17, 1986 and due January 17, 1987)
KEI-515 Number 23666 (Dated December 6, 1985 and due December 6, 1986

Hewlett Packard Digital Voltmeter
Model Number 3460B
Serial Number 709-00133

Calibration: September 10, 1986
By: Hewlett Packard
Product Support Division
2000 South Park Place
Atlanta, Georgia 30339
Next Calibration Due: March 10, 1987

Hewlett Packard Traceability
N.B.S. Number 234494 (Dated April 30, 1986 and due October 30, 1986)

Traceability Data Continued

<u>Victoreen</u> <u>Probe</u>
Model Number 550-6A
Serial Number 502

Calibration: June 30, 1987
By: Victoreen, Inc.
10101 Woodland Avenue
Cleveland, Ohio 44104
Next Calibration Due: June 30, 1988

Victoreen Traceability
Test Number DG8118/83
Calibration: September 29, 1983
PTW Chamber Model 30-343
Serial Number N23361-142

POST-RADIATION EXPOSURE FUNCTIONAL TESTS

SECTION III

POST-RADIATION EXPOSURE FUNCTIONAL TESTS

1.0 REQUIREMENTS

Insulation resistance values were taken for informational purposes only. Contact resistance shall be 1 ohm or less when measured with a digital ohmmeter.

2.0 PROCEDURES

The test specimens were subjected to the testing per Paragraph 2.3 of Section I.

3.0 RESULTS

The test specimens were subjected to the tests of Paragraph 2.0 which met the requirements of Paragraph 1.0. The data collected during these tests is presented in Appendices I through III as noted below.

- Appendix I contains Photographs III-1 through III-3 which show the specimens mounted in their respective trays, condulets or enclosure.
- Appendix II contains the Insulation Resistance Test Data Sheets.
- Appendix III contains the Instrumentation Equipment Sheet which lists the equipment used to collect data.

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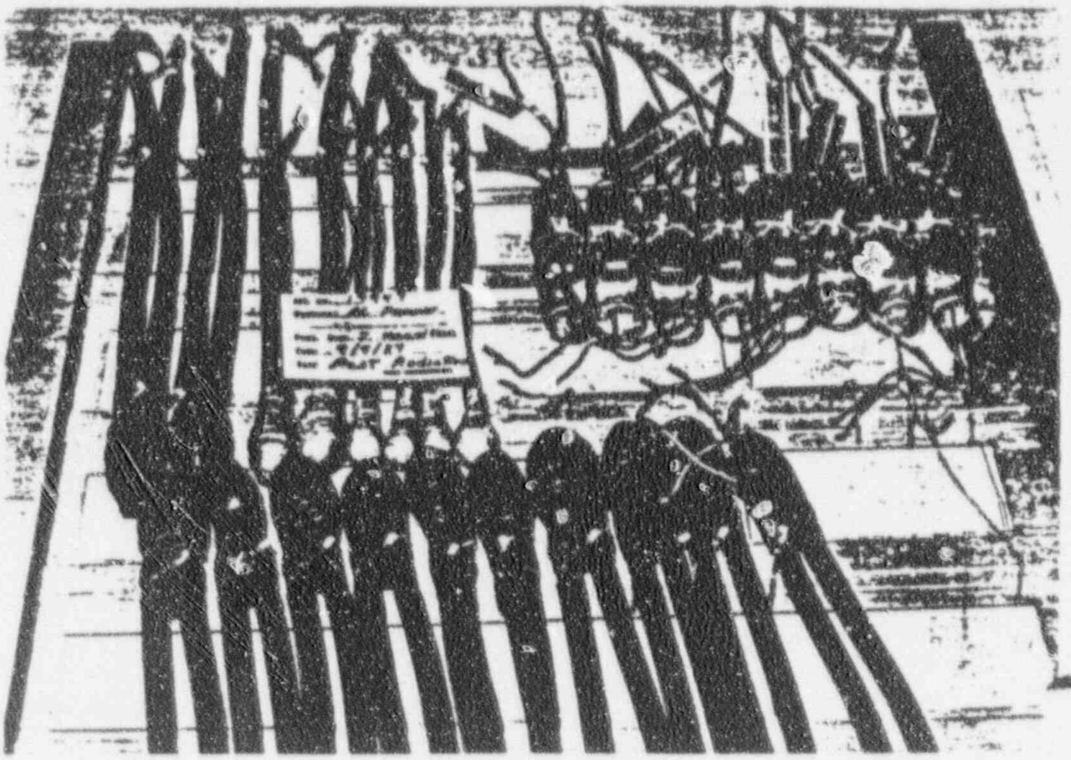
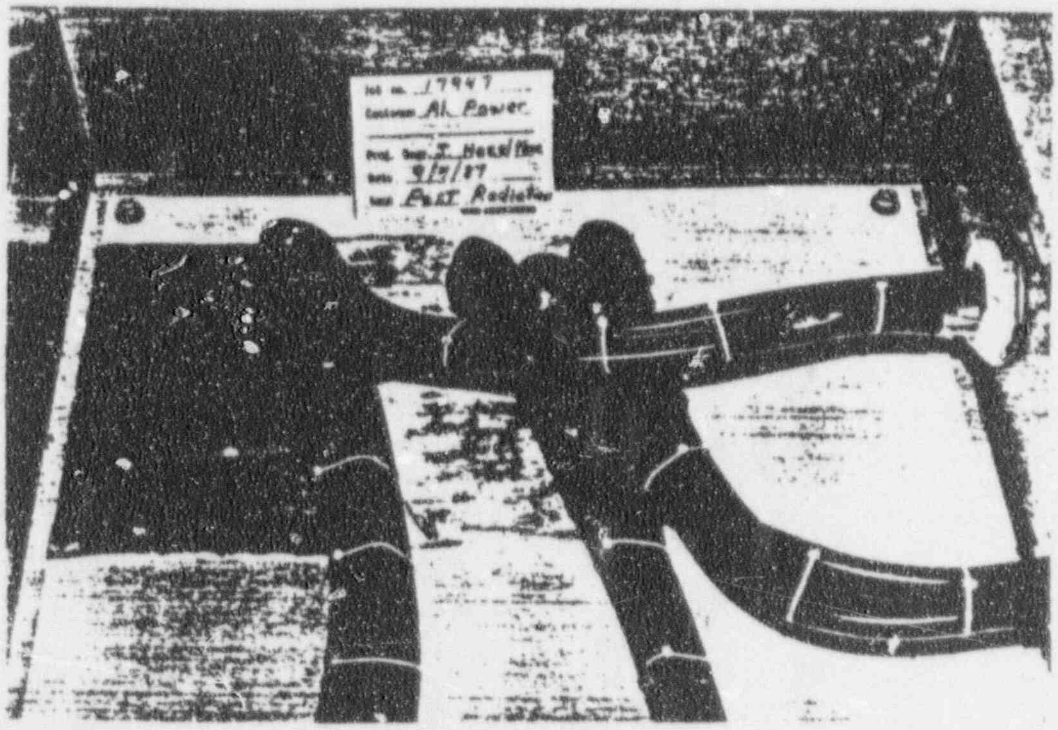


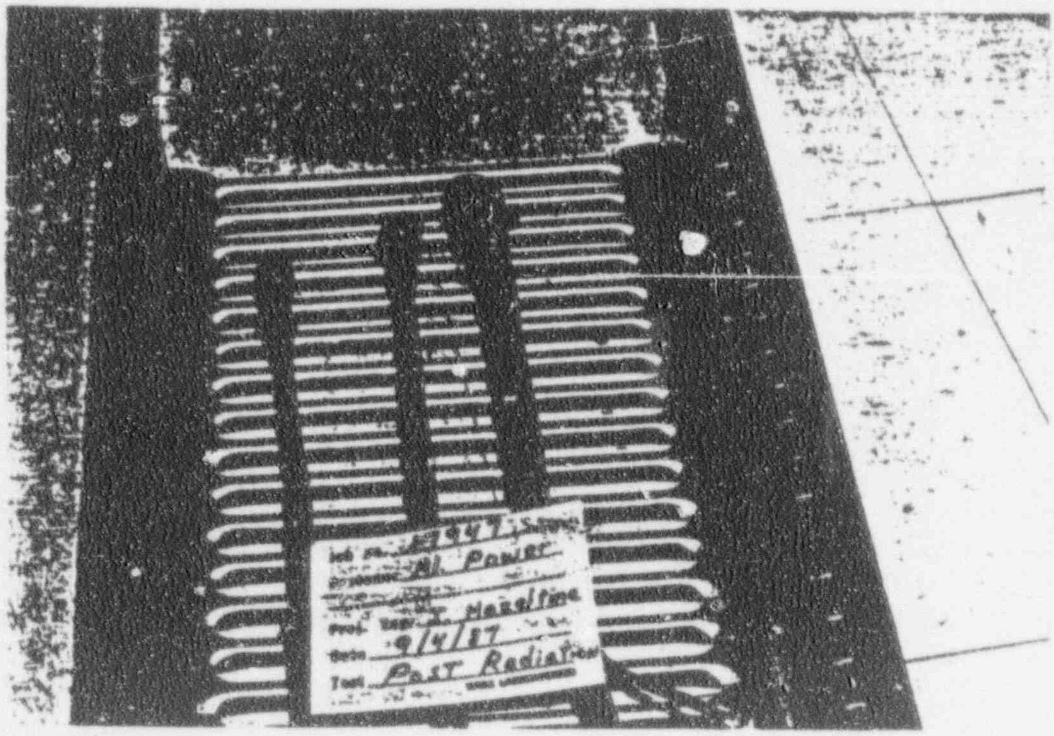
PHOTOGRAPH NO. III-3

POST-RADIATION EXPOSURE VIEW OF
ALL REMAINING SPECIMENS



PHOTOGRAPH NO. III-1

POST-RADIATION EXPOSURE VIEW OF SPECIMENS 1.1, 2.1, 3.1, 4.1, 5.1, AND 6.1



PHOTOGRAPH NO. III-2

POST-RADIATION EXPOSURE VIEW OF SPECIMENS 7.1, 8.1, AND 9.1

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APPENDIX I

PHOTOGRAPHS

APPENDIX II

DATA SHEETS

DATA SHEET

Customer: Alabama Power
Specimen: Okonite Tape Splices
Part No. T-95, No. 35 and Scotch 33+
Spec. WLQP 17492-01
Para. 3.3
S/N No
GSI No

Amb. Temp. 72°F
Photo yes
Test Med. Air
Specimen Temp. Ambient

WYLE LABORATORIES

Job No. 17947
Report No. 17947-01
Start Date 9-4-87

Test Title: Post Radiation Functional Test

Acceptance Criteria: Insulation Resistances (at 500 VDC for 1 minute) and Contact Resistances (via Kelvin Bridge Method) shall be measured for information only.

Specimen No.	~~Insulation~~ Contact Resistance	~~Contact~~ Insulation Resistance
1.1	$35 \times 10^{-4}\ \Omega$	$6.4 \times 10^{11}\ \Omega$
1.2	$3.6 \times 10^{-4}\ \Omega$	$1.7 \times 10^{12}\ \Omega$
1.3	$3.6 \times 10^{-4}\ \Omega$	$2.2 \times 10^{12}\ \Omega$
2.1	$32 \times 10^{-4}\ \Omega$	$8.0 \times 10^{11}\ \Omega$
2.2	$3.2 \times 10^{-4}\ \Omega$	$1.4 \times 10^{12}\ \Omega$
2.3	$33 \times 10^{-4}\ \Omega$	$1.4 \times 10^{12}\ \Omega$
3.1	$1.1 \times 10^{-3}\ \Omega$	$9.4 \times 10^{11}\ \Omega$
3.2	$1.1 \times 10^{-3}\ \Omega$	$1.2 \times 10^{12}\ \Omega$
3.3	$1.1 \times 10^{-3}\ \Omega$	$8.5 \times 10^{11}\ \Omega$
4.1	~~[illegible] $\times 10^{-3}\ \Omega$~~ $2.3 \times 10^{-4}\ \Omega$	$1.0 \times 10^{12}\ \Omega$
4.2	$2.9 \times 10^{-4}\ \Omega$	$1.3 \times 10^{12}\ \Omega$
4.3	$2.8 \times 10^{-4}\ \Omega$	$1.1 \times 10^{12}\ \Omega$
5.1	$3.0 \times 10^{-4}\ \Omega$	$1.3 \times 10^{12}\ \Omega$
5.2	$28 \times 10^{-4}\ \Omega$	$7.0 \times 10^{11}\ \Omega$
5.3	$2.8 \times 10^{-4}\ \Omega$	$9.0 \times 10^{11}\ \Omega$

Tested By: [signature] Date: 9-4-87
Witness: N/A Date: N/A
Sheet No. 1 of 3
Approved: Holly Carr 9-4-87

Notice of Anomaly: None

DATA SHEET

WYLE LABORATORIES

Customer: Alabama Power
Specimen: Okonite Tape Splices
Part No.: T-95, No. 35 and Scotch 33+
Spec.: WLQP 17492-01
Para.: 3.3
S/N: No
GSI: No

Amb. Temp.: 72°F
Photo: Yes
Test Med.: Air
Specimen Temp.: Ambient

Job No.: 17947
Report No.: 17947-01
Start Date: 9-4-87

Test Title: Post Radiation Functional Test

(Continued)

Specimen No.	~~Insulation~~ Contact Resistance	~~Contact~~ Insulation Resistance
6.1	$3.1 \times 10^{-4}\ \Omega$	$1.5 \times 10^{12}\ \Omega$
6.2	$3.2 \times 10^{-4}\ \Omega$	$1.3 \times 10^{12}\ \Omega$
6.3	$3.3 \times 10^{-4}\ \Omega$	$1.7 \times 10^{12}\ \Omega$
7.1	$2.3 \times 10^{-3}\ \Omega$	4.0×10^{11}
7.2	$2.3 \times 10^{-3}\ \Omega$	$3.6 \times 10^{12}\ \Omega$
7.3	$2.3 \times 10^{-3}\ \Omega$	$3.0 \times 10^{12}\ \Omega$
8.1	$1.8 \times 10^{-3}\ \Omega$	$3.0 \times 10^{11}\ \Omega$
8.2	$1.8 \times 10^{-3}\ \Omega$	$2.3 \times 10^{12}\ \Omega$
8.3	$1.7 \times 10^{-3}\ \Omega$	$2.0 \times 10^{12}\ \Omega$
9.1	$3.0 \times 10^{-3}\ \Omega$	$2.2 \times 10^{11}\ \Omega$
9.2	$3.0 \times 10^{-4}\ \Omega$	$2.3 \times 10^{12}\ \Omega$
9.3	$3.1 \times 10^{-3}\ \Omega$	$2.1 \times 10^{12}\ \Omega$
10.1A	$3.3 \times 10^{-2}\ \Omega$	$1.7 \times 10^{12}\ \Omega$
10.1B	$8.2 \times 10^{-4}\ \Omega$	$1.7 \times 10^{12}\ \Omega$
10.2	$6.1 \times 10^{-4}\ \Omega$	$1.6 \times 10^{12}\ \Omega$
10.3	$9.2 \times 10^{-3}\ \Omega$	$1.2 \times 10^{12}\ \Omega$
11.1	$1.0 \times 10^{-4}\ \Omega$	$1.0 \times 10^{12}\ \Omega$
11.2	$5.4 \times 10^{-4}\ \Omega$	$2.0 \times 10^{12}\ \Omega$
11.3	$1.0 \times 10^{-4}\ \Omega$	$1.3 \times 10^{12}\ \Omega$

Tested By: [illegible] Date: 9-4-87
Witness: N/A Date: N/A
Sheet No. 2 of 3
Approved: Holly Cass 9-4-87

Notice of Anomaly: None

DATA SHEET

WYLE LABORATORIES

Customer: Alabama Power
Specimen: Okonite Tape Splices
Part No.: T-95, No. 35 and Scotch 33+
Spec.: WLQP 17492-01
Para.: 3.3
S/N: No
GSI: No

Amb. Temp.: 72°F
Photo: yes
Test Med.: Air
Specimen Temp.: Ambient

Job No.: 17947
Report No.: 17947-01
Start Date: 9-4-87

Test Title: Post Radiation Functional Test

(Continued)	Contact ~~Insulation~~ Resistance	Insulation ~~Contact~~ Resistance
Specimen No.		
12.1	1.0 x 10⁻² Ω	1.5 x 10¹² Ω
12.2	9.8 x 10⁻³ Ω	1.7 x 10¹² Ω
12.3	1.0 x 10⁻² Ω	1.9 x 10¹² Ω
13.1	9.6 x 10⁻³ Ω	1.5 x 10¹² Ω
13.2	1.0 x 10⁻² Ω	1.7 x 10¹² Ω
13.3	1.0 x 10⁻² Ω	1.6 x 10¹² Ω
14.1	9.5 x 10⁻³ Ω	1.9 x 10¹² Ω
14.2	6.6 x 10⁻³ Ω	2.2 x 10¹² Ω
14.3	2.3 x 10⁻² Ω	2.1 x 10¹² Ω
15.1A	N/A	
15.1B	STILL AT RADIATION	
15.1C		
15.2A		
15.2B		
15.3		

Tested By: [signature] Date: 9-4-87
Witness: N/A Date: N/A
Sheet No. 3 of 3
Approved: Holly Cass 9-4-87

Notice of Anomaly: None

APPENDIX III

INSTRUMENTATION EQUIPMENT SHEET

INSTRUMENTATION EQUIPMENT SHEET

DATE: 09/04/87
TECHNICIAN: C. ARBUCKLE

JOB NUMBER: 17947-00
CUSTOMER: ALA.POWER

TEST AREA: LOCA
TYPE TEST: FUNCTIONAL

NO.	INSTRUMENT	MANUFACTURER	MODEL#	SERIAL #	WYLE #	RANGE 1	ACCURACY 1	CALDATE	CALDUE
1	DIG MTR	VALHALLA	4150	82123	101040	.02-2KOHM	.02%RDG	03/10/87	09/10/87
2	MEG MTR	GR	1864	657113180	011898	50K-50TOHM	2-5%RANGE	04/06/87	10/06/87
3	MEG MTR	GENERAL RADIO	1862-C	257	102992	.5-2E6 MOHM	+-3%	05/18/87	11/18/87

THIS IS TO CERTIFY THAT THE ABOVE INSTRUMENTS WERE CALIBRATED USING STATE-OF-THE-ART TECHNIQUES WITH STANDARDS WHOSE CALIBRATION IS TRACEABLE TO THE NATIONAL BUREAU OF STANDARDS.

INSTRUMENTATION [signature] 9-4-87

CHECKED & RECEIVED BY [signature] 09-0

Q.A. [signature] 09.09.87 (stamp: 2 Wyle A)

THERMAL AGING

SECTION IV

3.0 RESULTS

The test specimens possessed sufficient integrity to complete the thermal aging prog without evidence of excessive degradation. The Okonite leads for Specimens 13.1 to were less flexible and the outer layer of the Okonite and 3M tapes became slightly bri There was no evidence of cracking in any of the splices or cable insulations.

Appendices I through III contain the following data from thermal aging:

- Appendix I contains Photographs IV-1 through IV-4 which show the the aging chambers and setup for Specimens 7.1, 8.1, and 9.1.
- Appendix II contains typical thermal aging circular charts from 110°C 150°C aging chambers.
- Appendix III contains the Instrumentation Equipment Sheet which list: thermal aging chamber instrumentation.

SECTION IV

THERMAL AGING

1.0 REQUIREMENTS

The test specimens shall be thermally aged as follows:

Specimen No.	Aging* Temperature	Time* (Hours)	Equivalent Life Years
1.1 to 10.3	110°C	112	15
11.1 to 12.3	110°C	100	15
13.1 to 14.3	150°C	250	15

* Tolerances: (-0°C, +5°C), (-0 Hours, +3 Hours)

2.0 PROCEDURES

The test specimens, mounted in their respective tray, condulet or enclosure, were placed inside two medium sized test chambers and aged as described below. Specimens 7.1, 8.1, and 9.1 were removed from the cable tray and mounted to a Limitorque actuator fixture as shown in Photographs IV-2 and IV-3.

Specimen No.	Aging Temperature	Time (Hours)
1.1 to 6.3 7.2, 7.3, 8.2, 8.3 9.2 and 9.3	110°C	112
7.1, 8.1 and 9.1	110°C	114
10.1A to 10.3	110°C	112
11.1 to 12.3	110°C	110
13.1 to 14.3	150°C	253

APPENDIX I

PHOTOGRAPHS

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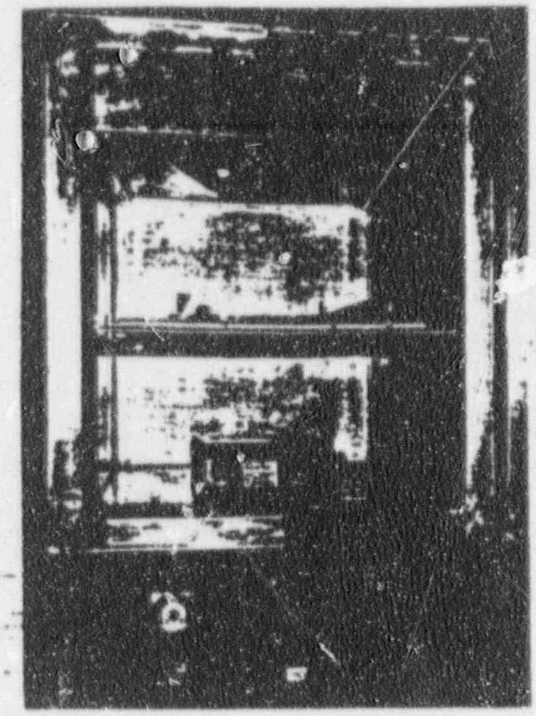
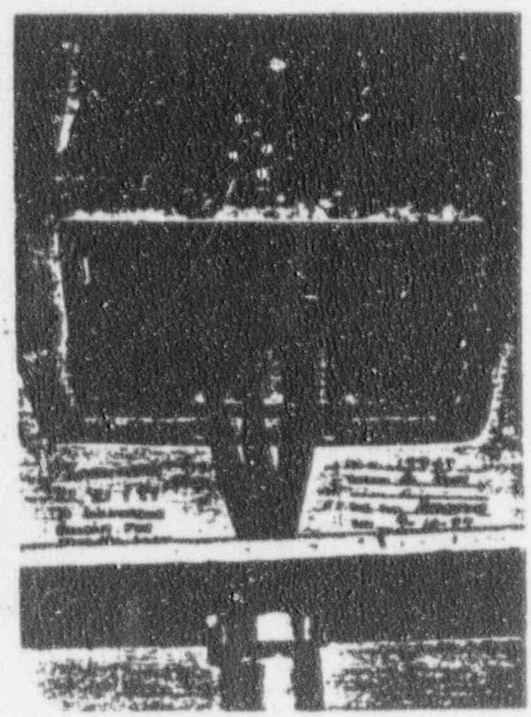


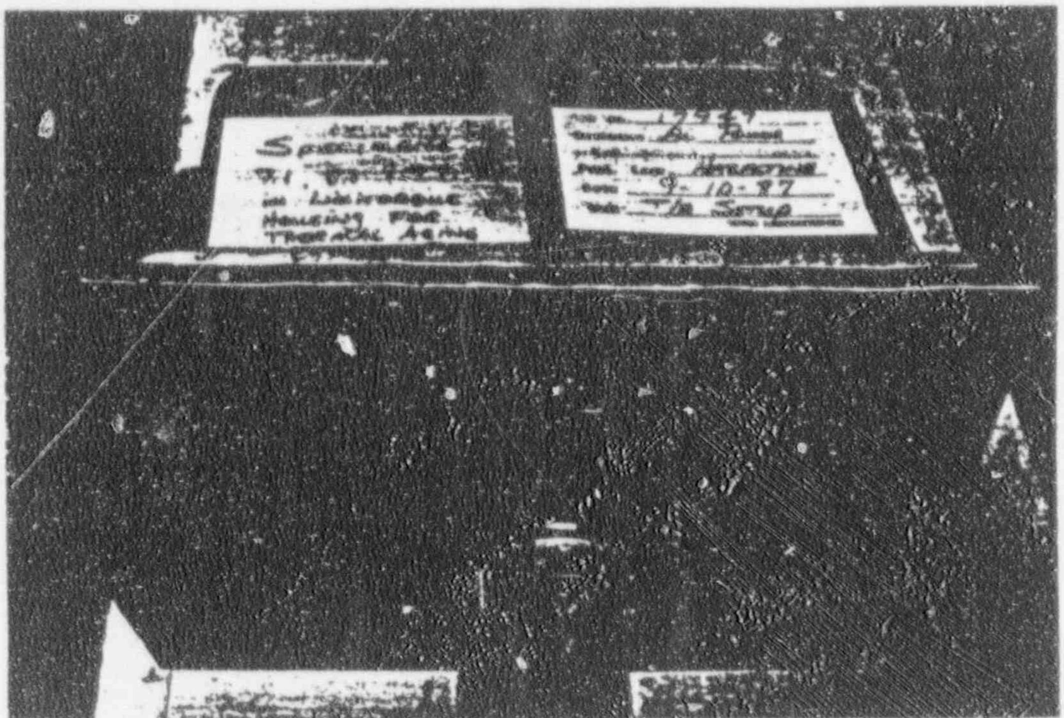
PHOTOGRAPH NO. IV-1

THERMAL AGING CHAMBER USED FOR SPECIMENS 1.1 - 12.3 (110°C)



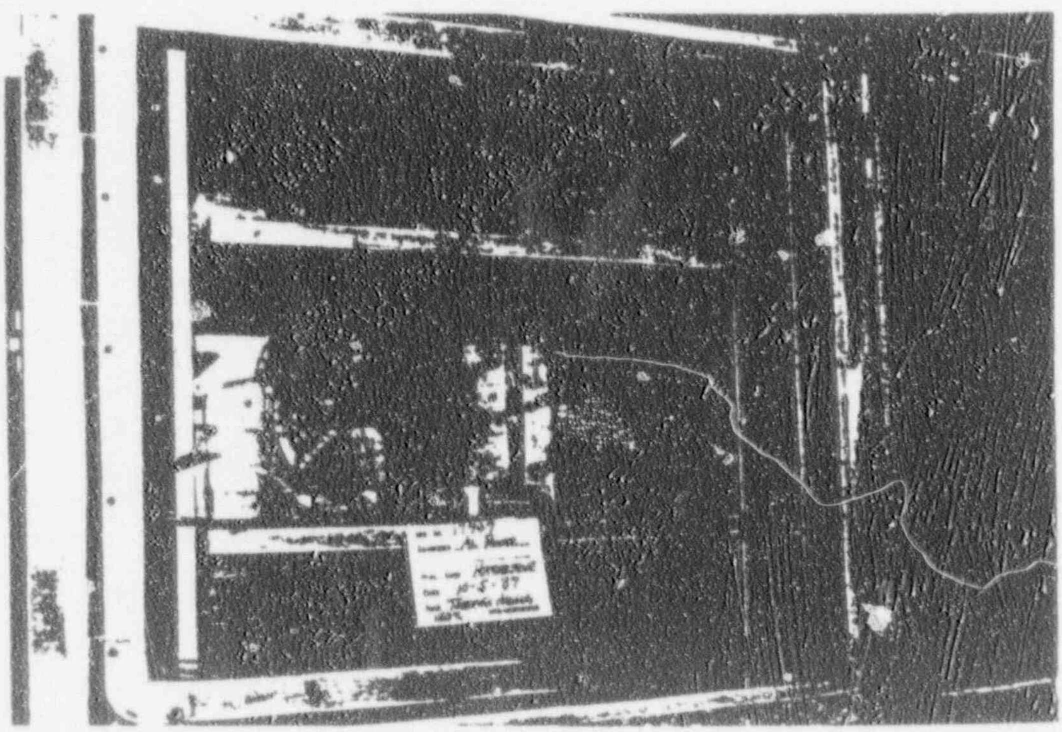
PHOTOGRAPH NO. IV-2

SPECIMENS 7.1, 8.1, AND 9.1 MOUNTED ON LIMITORQUE ACTUATOR COVER PRIOR TO THERMAL AGING



PHOTOGRAPH NO. IV-3

COMPLETE LIMITORQUE ACTUATOR ASSEMBLY CONTAINING SPECIMENS 7.1, 8.1, AND 9.1



PHOTOGRAPH NO. IV-3

THERMAL AGING CHAMBER USED FOR SPECIMENS 13.1 to 14.3 (150°C)

APPENDIX II

TYPICAL THERMAL AGING
CIRCULAR CHARTS

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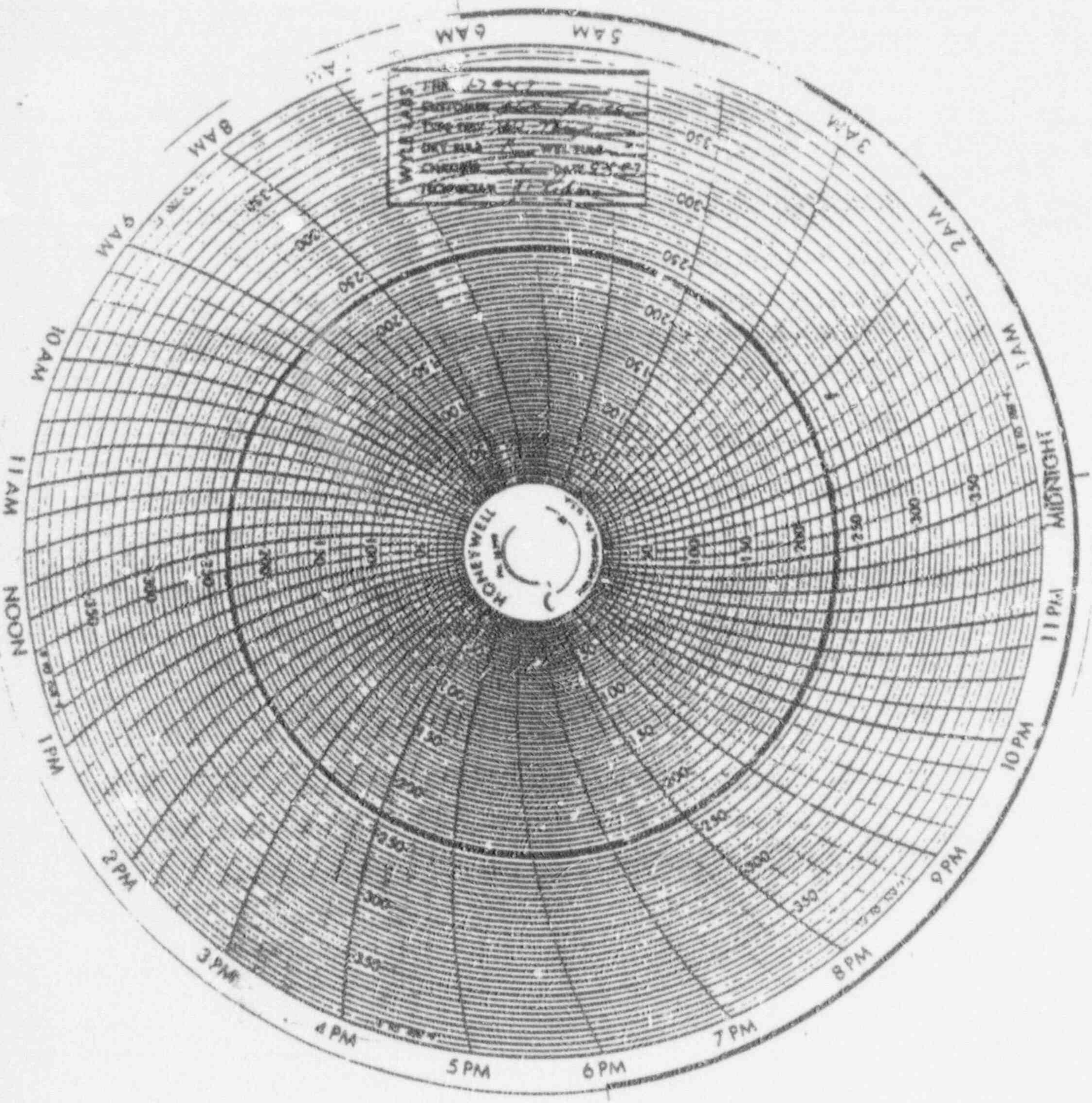
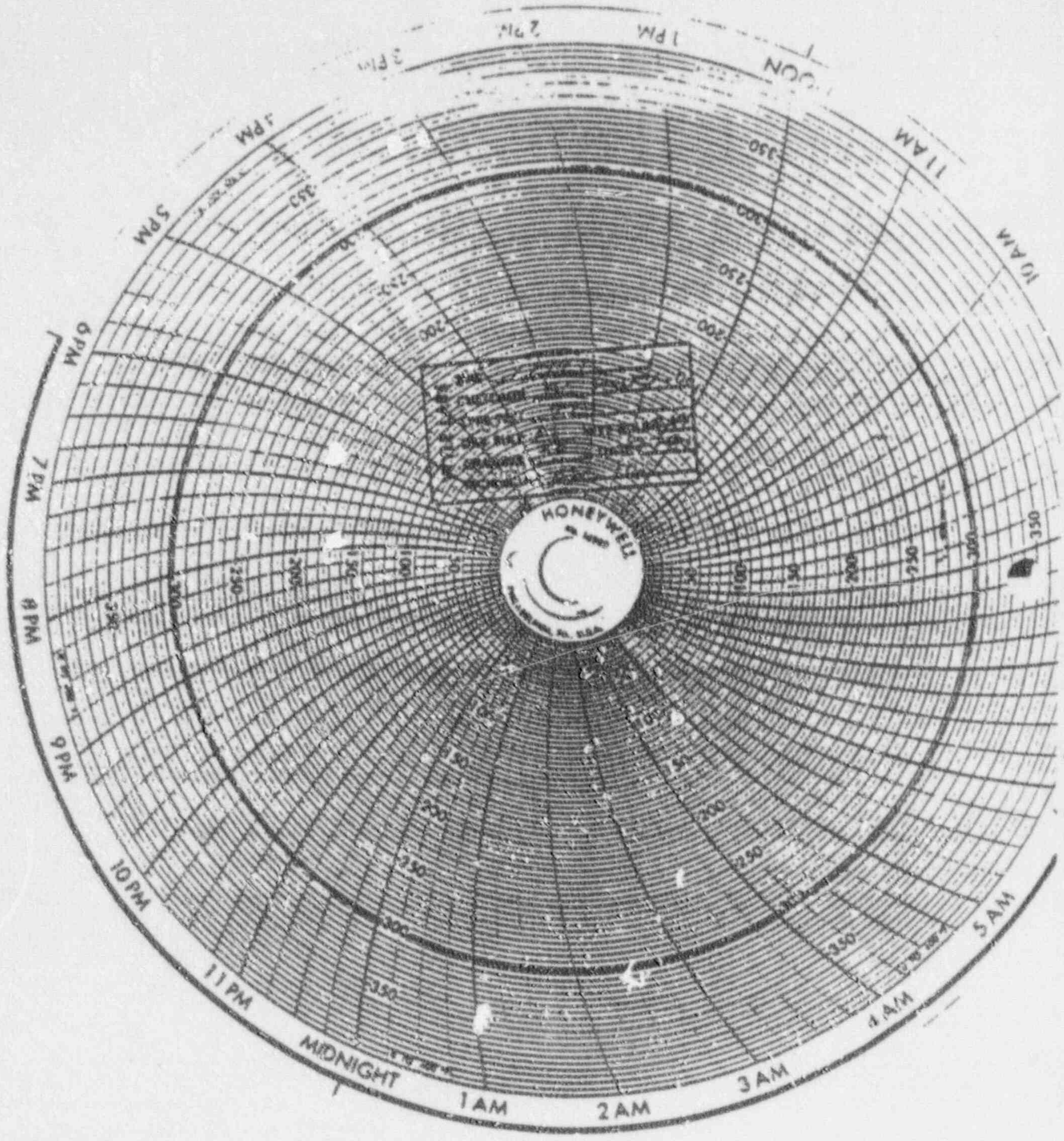


TYPICAL THERMAL AGING CIRCULAR CHART
FOR THE 118°C (230-239°F) CHAMBER



TYPICAL THERMAL AGING CIRCULAR CHART
FOR THE 150°C (302-311°F) CHAMBER

APPENDIX III

INSTRUMENTATION EQUIPMENT SHEET

INSTRUMENTATION EQUIPMENT SHEET

DATE: 09/04/87
TECHNICIAN: M. LUTTRELL

JOB NUMBER: 17947-00
CUSTOMER: ALA.POWER

TEST AREA: EV#52-39
TYPE TEST: T/A

NO.	INSTRUMENT	MANUFACTURER	MODEL#	SERIAL #	WYLE #	RANGE 1	ACCURACY 1	CALDATE	C
1	RECORD TEMP	HONEYWELL	45	8049310384004	094776	0+400#F T	.5%	06/18/87	0
2	CONTR TEMP	HONEYWELL	N/A	N/A	100787	0+200#C J	.5%	03/20/87	C
3	TEMP ALARM	RESEARCH	61034	140139	000718	0+1000#F K	.5%	03/20/87	0
4	RECORD TEMP	HONEYWELL	45	8050310383002	094782	0+400#F T	.5%	06/22/87	0
5	CONTR TEMP	RESEARCH	61011	25-061	000739	0+1000#F K	.5%	04/21/87	1
6	TEMP ALARM	RESEARCH	61034	240165	000724	-175+375#F T	.5%	08/14/87	0

THIS IS TO CERTIFY THAT THE ABOVE INSTRUMENTS WERE CALIBRATED USING STATE-OF-THE-ART TECHNIQUES WITH STANDARDS WHOSE CALIBRAT
TRACEABLE TO THE NATIONAL BUREAU OF STANDARDS.

INSTRUMENTATION [signature] 9-4-87

CHECKED & RECEIVED BY [signature]

Q.A. [signature] 9-9-87

POST-THERMAL AGING FUNCTIONAL TESTS

SECTION V

SECTION V

POST-THERMAL AGING FUNCTIONAL TESTS

1.0 REQUIREMENTS

Insulation resistance values were taken for informational purposes only. Continuity shall be 1 ohm or less when measured with a digital ohmmeter.

2.0 PROCEDURES

The test specimens were subjected to the testing per Paragraph 2.3 of Section I.

3.0 RESULTS

The test specimens were subjected to the tests of Paragraph 2.0 which met the requirements of Paragraph 1.0. The data collected during these tests is presented in Appendices I through III as noted below.

- Appendix I contains Photographs V-1 through V-4 which show the specimens mounted in their respective trays, condulets or enclosures.
- Appendix II contains the Functional Test Data Sheets.
- Appendix III contains the Instrumentation Equipment Sheet which lists the equipment used to collect data.

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APPENDIX I

PHOTOGRAPHS

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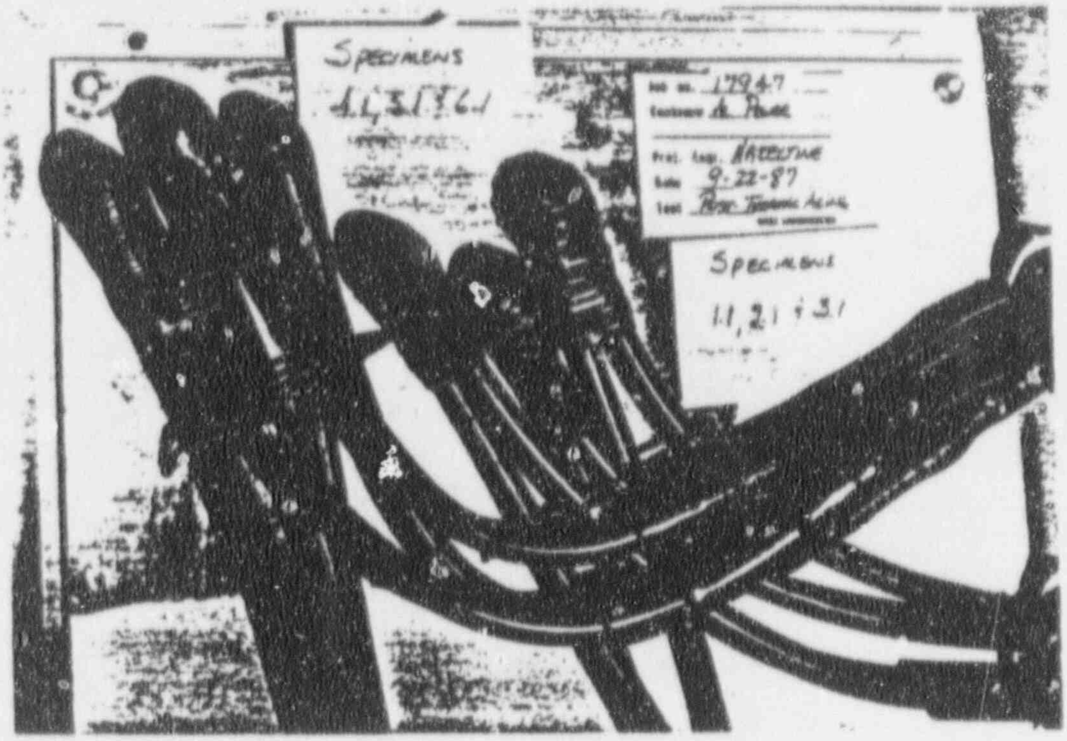
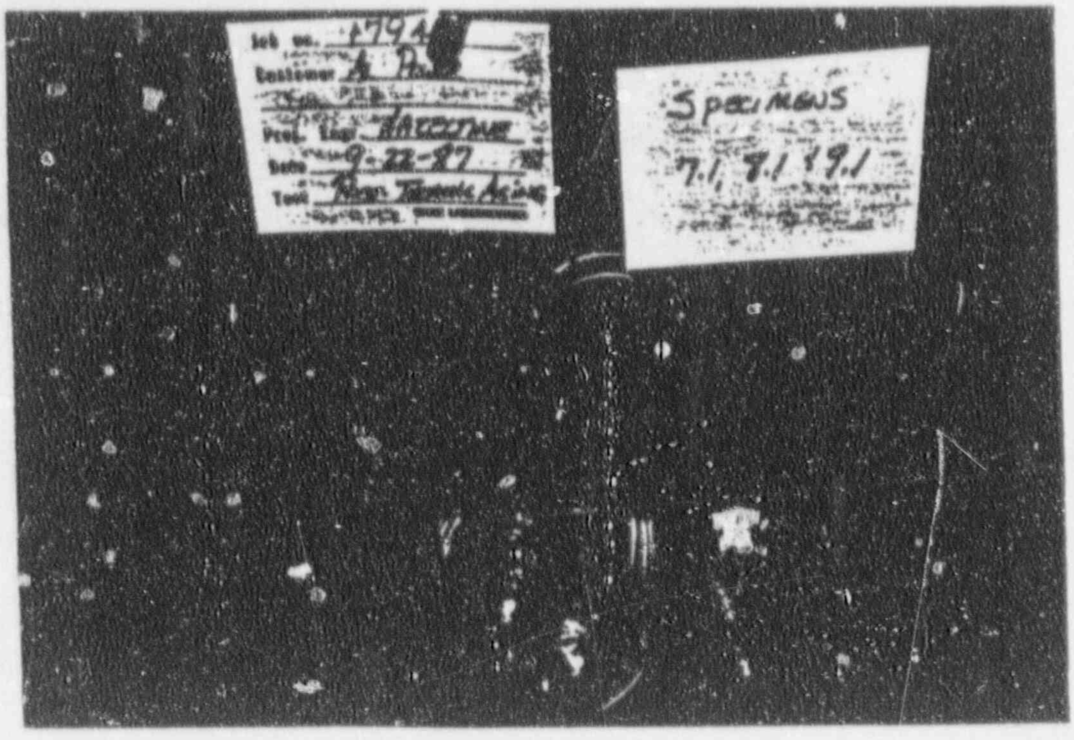


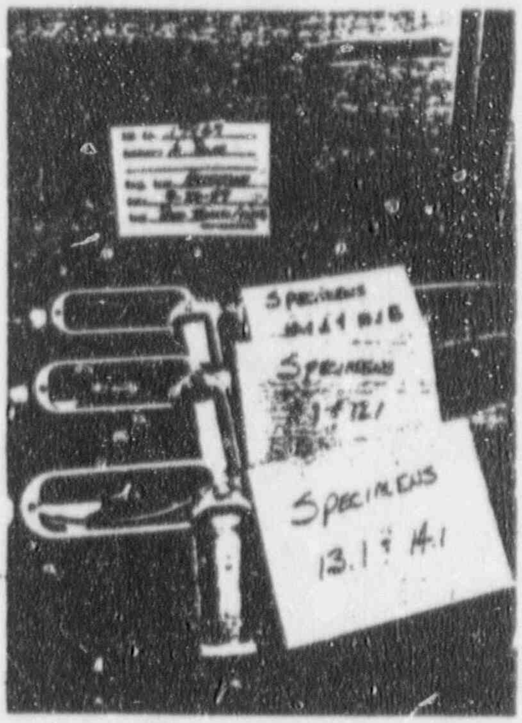
PHOTOGRAPH NO. V-1

**SPECIMENS 1.1, 2.1, 3.1, 4.1, 5.1, AND 6.1
MOUNTED INSIDE 24" x 24" x 6" ENCLOSURE
AFTER THERMAL AGING**



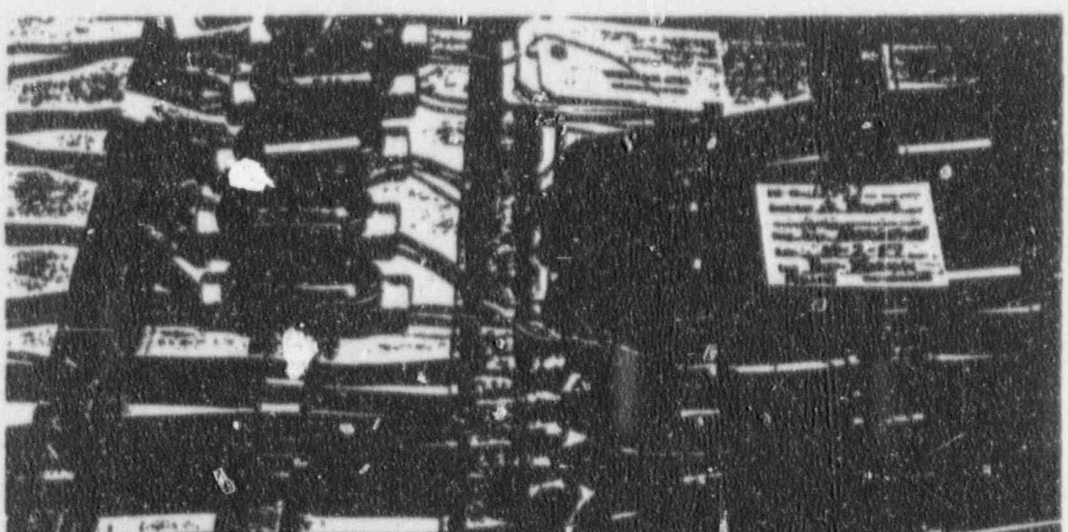
PHOTOGRAPH NO. V-2

**SPECIMENS 7.1, 8.1, AND 9.1 MOUNTED TO
LIMITORQUE ACTUATOR FIXTURE
AFTER THERMAL AGING**



PHOTOGRAPH NO. V-3

SPECIMENS 10.1A & 10.1B, 11.1 & 12.1, AND 13.1 & 14.1 MOUNTED INSIDE THEIR CONDULETS AFTER THERMAL AGING



PHOTOGRAPH NO. V-4

ALL REMAINING SPECIMENS MOUNTED IN THE 36" x 30" x 4" CABLE TRAY AFTER THERMAL AGING

Test Report No. 17947-01

DATA SHEET

Customer: Alabama Power

WYLE LABORATORIES

Specimen: Okonite Tape Splices

Part No.	T-95, No. 35 and Scotch 33+	Amb. Temp.	72°F	Job No.	17947
Spec.	WLQP 17492-01	Photo.	Yes	Report No.	17947-01
Para.	3.3	Test Med.	Air	Start Date	9/10/87
S/N	No	Specimen Temp.	Ambient		
GSI	No				

Test Title: Post-Thermal Aging Functional Test

Acceptance Criteria: Insulation Resistances (at 500 VDC for 1 minute) and Contact Resistances (via Kelvin Bridge Method) shall be measured for information only.

Specimen No.	Insulation Resistance	Contact Resistance
1.1	$1.9 \times 10^{12}\ \Omega$	$0.37 \times 10^{-3}\ \Omega$
1.2	$1.2 \times 10^{12}\ \Omega$	$0.37 \times 10^{-3}\ \Omega$
1.3	$1.8 \times 10^{12}\ \Omega$	$0.37 \times 10^{-3}\ \Omega$
2.1	$7.1 \times 10^{11}\ \Omega$	$0.33 \times 10^{-3}\ \Omega$
2.2	$1.1 \times 10^{12}\ \Omega$	$0.34 \times 10^{-3}\ \Omega$
2.3	$1.3 \times 10^{12}\ \Omega$	$0.33 \times 10^{-3}\ \Omega$
3.1	$6.2 \times 10^{11}\ \Omega$	$1.10 \times 10^{-3}\ \Omega$
3.2	$1.2 \times 10^{12}\ \Omega$	$1.13 \times 10^{-3}\ \Omega$
3.3	$1.2 \times 10^{12}\ \Omega$	$1.14 \times 10^{-3}\ \Omega$
4.1	~~1.2~~ $7.4 \times 10^{11}\ \Omega$	$0.29 \times 10^{-3}\ \Omega$
4.2	$1.1 \times 10^{12}\ \Omega$	$0.29 \times 10^{-3}\ \Omega$
4.3	$9.8 \times 10^{11}\ \Omega$	$0.30 \times 10^{-3}\ \Omega$
5.1	$5.8 \times 10^{11}\ \Omega$	$0.30 \times 10^{-3}\ \Omega$
5.2	$5.9 \times 10^{11}\ \Omega$	$0.29 \times 10^{-3}\ \Omega$
5.3	$4.0 \times 10^{11}\ \Omega$	$0.30 \times 10^{-3}\ \Omega$

Tested By: Robert Hardy Date: 9/18/87

Witness: None Date:

Sheet No. 2 of 3

Approved: J. Hazlett 9/18/87

Notice of Anomaly: None

Wyle Form WH 6 ..A Rev. APR '84

APPENDIX II

DATA SHEET

DATA SHEET

Customer: Alabama Power
Specimen: Okonite Tape Splices
Part No.: T-95, No. 35 and Scotch 33+
Spec.: WLQP 17492-01
Para.: 3.3
S/N: No
GSI: No

Amb. Temp.: 72° F
Photo: YES
Test Med.: Air
Specimen Temp.: Ambient

WYLE LABORATORIES
Job No.: 17947
Report No.: 17947-01
Start Date: 9/10/87

Test Title: Post-Thermal Aging Functional Test

(Continued)

Specimen No.	Insulation Resistance	Contact Resistance
6.1	3.8x10¹¹ Ω	0.33x10⁻³ Ω
6.2	5.6x10¹¹ Ω	0.34x10⁻³ Ω
6.3	6.4x10¹¹ Ω	0.33x10⁻³ Ω
7.1	~~3.2x10¹⁰ Ω~~ 2.0x10¹¹ Ω	2.30 x 10⁻³ Ω
7.2	7.0x10¹¹ Ω	2.31x10⁻³ Ω
7.3	6.4x10¹¹ Ω	2.31x10⁻³ Ω
8.1	~~3.1x10¹⁰ Ω~~ 1.8x10¹¹ Ω	2.05x10⁻³ Ω
8.2	7.4x10¹¹ Ω	1.87 x10⁻³ Ω
8.3	8.2x10¹¹ Ω	1.94 x10⁻³ Ω
9.1	~~2.6x10¹⁰ Ω~~ 1.9x10¹¹ Ω	3.21x10⁻³ Ω
9.2	7.5x10¹¹ Ω	3.09x10⁻³ Ω
9.3	3.3x10¹¹ Ω	3.16x10⁻³ Ω
10.1A	5.1x10⁸ Ω	48.76x10⁻⁶ Ω
10.1B	3.3x10⁸ Ω	8.25x10⁻³ Ω
10.2	2.8x10¹¹ Ω	6.10x10⁻³ Ω
10.3	3.5x10⁸ Ω	9.24x10⁻³ Ω
11.1	3.7x10⁸ Ω	10.50x10⁻³ Ω
11.2	3.9x10⁸ Ω	5.39x10⁻³ Ω
11.3	1.2x10¹² Ω	10.57x10⁻³ Ω

Notice of Anomaly: None

Tested By: Robert Hardy Date: 9-18-87
Witness: None Date:
Sheet No. 2 of 3
Approved: [signature] 9-18-87

DATA SHEET

Customer: Alabama Power
Specimen: Okonite Tape Splices
Part No.: T-95, No. 35 and Scotch 33+
Spec.: WLQP 17492-01
Para.: 3.3
S/N: No
GSI: No

Amb. Temp.: 72°F
Photo: YES
Test Med.: Air
Specimen Temp.: Ambient

WYLE LABORATORIES
Job No.: 17947
Report No.: 17947-01
Start Date: 9/10/87

Test Title: Post-Thermal Aging Functional Test

(Continued)

Specimen No.	Insulation Resistance	Contact Resistance
12.1	3.8 x 10¹¹ Ω	9.96 x 10⁻³ Ω
12.2	4.5 x 10¹¹ Ω	9.69 x 10⁻³ Ω
12.3	8.5 x 10¹¹ Ω	10.25 x 10⁻³ Ω
13.1	1.6 x 10¹¹ Ω	9.59 x 10⁻³ Ω
13.2	1.5 x 10¹¹ Ω	1.02 x 10⁻² Ω
13.3	1.5 x 10¹¹ Ω	1.03 x 10⁻² Ω
14.1	1.4 x 10¹¹ Ω	9.21 x 10⁻³ Ω
14.2	1.5 x 10¹¹ Ω	6.62 x 10⁻³ Ω
14.3	1.6 x 10¹¹ Ω	1.52 x 10⁻² Ω
15.1A	N/A	
15.1B		
15.1C		
15.2A	STILL AT RADIATION	
15.2B	FACILITY	
15.3		

Tested By: Robert Herig Date: 9-18-87
Witness: None Date:
Sheet No. 3 of 3
Approved: [signature] 9-18-87

Notice of Anomaly: None

Wyle Form 614A, Rev. APR '84

INSTRUMENTATION EQUIPMENT SHEET

DATE: 09/18/87
TECHNICIAN: R. HARDY

JOB NUMBER: 17947-00
CUSTOMER: ALABAMA POWER

TEST AREA: ELEC. LAB
TYPE TEST: POST RAD. FUNCTIONAL

NO.	INSTRUMENT	MANUFACTURER	MODEL#	SERIAL #	WYLE #	RANGE 1	ACCURACY 1	CALDATE	CALDUE
1	MEG MTR	GR	1864	657113180	011898	50K-50TOHM	2-5%RANGE	04/06/87	10/06/87
2	DIG MTR	VALHALLA	4150	82123	101040	.02-2KOHM	.02%RDG	03/11/87	03/11/88

THIS IS TO CERTIFY THAT THE ABOVE INSTRUMENTS WERE CALIBRATED USING STATE-OF-THE-ART TECHNIQUES WITH STANDARDS WHOSE CALIBRATION IS TRACEABLE TO THE NATIONAL BUREAU OF STANDARDS.

INSTRUMENTATION [signature] 9/18/87

CHECKED & RECEIVED BY [signature] 9/18/87

Q.A. [signature] 09-21-87

INSTRUMENTATION EQUIPMENT SHEET

DATE: 09/10/87
TECHNICIAN: R. HARDY

JOB NUMBER: 17947-00
CUSTOMER: ALABAMA POWER

TEST AREA: LOCA
TYPE TEST: POST T/A FUNCTIONAL

NO.	INSTRUMENT	MANUFACTURER	MODEL#	SERIAL #	WYLE #	RANGE 1	ACCURACY 1	CALDATE	CALDUE
1	DIG MTR	VALHALLA	4150	82123	101040	.02-2KOHM	.02%RDG	03/10/87	09/10/87
2	MEG MTR	GR	1864	657113180	011698	50K-50TOHM	2-5%RANGE	04/06/87	10/06/87

THIS IS TO CERTIFY THAT THE ABOVE INSTRUMENTS WERE CALIBRATED USING STATE-OF-THE-ART TECHNIQUES WITH STANDARDS WHOSE CALIBRATION IS TRACEABLE TO THE NATIONAL BUREAU OF STANDARDS.

INSTRUMENTATION R.E. Archer 9-10-87

CHECKED & RECEIVED BY F. Hazelton 9/10/87

Q.A. [signature] 09/11/87 (2 Wyle A)

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APPENDIX III

INSTRUMENTATION EQUIPMENT SHEETS

LOSS OF COOLANT (LOCA) TEST

SECTION VI

LOSS OF COOLANT ACCIDENT TEST

1.0 REQUIREMENTS

1.1 Acceptance Criteria

The splices shall maintain voltage and circuit continuity within ±25 percent of applied electrical supply. The splices shall not cause their associated fuses to blow.

1.2 Leakage Currents

Leakage currents to ground on Specimens 10.1A & 10.1B, 11.1 & 12.1, and 13.1 & 14.1 shall be measured for information purposes only during the LOCA Test.

2.0 PROCEDURES

2.1 Test Specimen Preparation

The test specimens scheduled for the LOCA Test (Specimens 1.1, 2.1, 3.1, 4.1, 5.1, 6.1, 7.1, 8.1, 9.1, 10.1A, 10.1B, 11.1, 12.1, 13.1, and 14.1) were removed from the enclosures used to age the specimens and train the wiring. The specimen leads were connected to Wyle-supplied 1/C Teflon-insulated leads through splices insulated with Raychem nuclear insulating sleeves as indicated below:

Specimen No.	Specimen Lead Size(s)	Wyle Test* Lead Size	Raychem WCSF-N Sleeves Used **
1.1	1/0 AWG	10 AWG	115/300 w/500
	1/0 AWG	10 AWG	115/300 w/500
2.1	1/0 AWG	10 AWG	115/300 w/500
	2/0 AWG	10 AWG	115/300 w/500
3.1	1/0 AWG	10 AWG	115/300 w/500
	8 AWG	10 AWG	115/300 w/200
4.1	2/0 AWG	2 AWG	300 tape*** w/650
	2/0 AWG	2 AWG	300 tape w/650
5.1	2/0 AWG	2 AWG	200 tape w/500
	2/0 AWG	2 AWG	200 tape w/500
6.1	2/0 AWG	2 AWG	200 tape w/500
	1/0 AWG	2 AWG	200 tape w/500

2.0 PROCEDURES (Continued)

2.1 Test Specimen Preparation (Continued)

Specimen No.	Specimen Lead Size(s)	Wyle Test* Lead Size	Raychem WCSF-N Sleeves Used **
7.1	1/0 AWG 12 AWG	10 AWG 10 AWG	115/300 w/500 070 w/200
8.1	8 AWG 8 AWG	10 AWG 10 AWG	115 w/200 115 w/200
9.1	8 AWG 12 AWG	10 AWG 10 AWG	115 w/200 070 w/200
10 - 14	ASCO 12 AWG	14 AWG 14 AWG	050 w/115 070

* Wyle leads were 1/C 1000 Volts, 200°C, Teflon leads (10 AWG and 2 AWG) and 1/C 600 Volts, 200°C, Teflon (14 AWG).

** Indicates shim sizes applied to smaller cable and overall sleeve size. For example, "115/300 w/500" on Specimen 1.1 indicates WCSF-N-115 and 300 sleeves over the Wyle 10 AWG and an overall sleeve of WCSF-N-500 applied over the shims and the 1/0 AWG test specimen lead.

*** Indicates that Okonite T-95 tape was applied over the sharp edges of the bolted connection. All other connections used uninsulated butt splices.

After splicing to the Wyle test leads, the specimens were re-installed in their enclosures as noted below:

Specimen No.	Enclosure Type
1.1, 2.1, 3.1, 4.1, 5.1 & 6.1	24" x 24" x 6" NEMA 1 enclosure with paint scrapped off subpanel. Enclosure contained four 3 in. Myers hubs and 12-inch long 3 in. OD conduit nipples exiting from the side and bottom. A 1/4 in. weep hole was drilled in the lower right hand corner of the enclosure.
7.1, 8.1 & 9.1	15¼" x 10¾" x 8¼" Limitorque cover bolted to a 1/2-inch thick steel plate. The Limitorque gasket was installed and there was no drain in the cover. The specimens were routed through a 1½-in. Myers hub and 90° elbow pointed downward. The splice rested on the cover approximately 3/4 in. below the bottom of the conduit entry.

2.0 PROCEDURES (Continued)

2.1 Test Specimen Preparation (Continued)

Specimen No.	Enclosure Type
10.1A & 10.1B, 11.1 & 12.1, and 13.1 & 14.1	3/4 in. Type C condulet fitting with cover and gasket. One end of the condulet was attached to FNGS-supplied 3/4 in. flexible conduit (Anaconda Type EF) and the other end was attached to an LB fitting through a 6-in. nipple. The LB fitting contained another 6-in. nipple pointed downward.

2.2 Chamber Preparation

The test specimens, mounted on their respective test fixtures, were attached to carbon steel frames and installed inside a 60-inch diameter, 60-inch long (flange to flange) LOCA test chamber. The fixtures were tack welded to the chamber to ensure a solid connection to ground existed for the leakage current circuits. The Wyle-supplied Teflon wiring was carefully routed out multiple chamber penetration assemblies in the rear of the chamber. The 125 VDC wiring was segregated from the 632 VAC wiring and exited in a separate penetration assembly. The chamber penetrations were sealed with a Scotchcast No. 9 potting compound per Wyle Laboratories standard practice.

The chamber water level control system was adjusted to ensure that the specimens did not become submerged during the chemical spray period in the test. In addition, the chemical spray flowrate was adjusted to deliver 3.75 gallons per minute (0.15 gpm per square foot over a 25 foot square area). Chemicals were prepared as described in Appendix IV.

2.3 Instrumentation Setup

The instrumentation setup for this test consisted of 30 electrical and environmental channels. These signals were fed into a Daytronics System 10 Data Acquisition System (DAS) which displayed requested information on a color monitor, fed a high-speed line printer and fed a Hewlett Packard (HP) Model 1000 minicomputer. The HP-1000 system acquired data on a hard disk and generated plots of requested channels. The data acquisition system was operated at its maximum rate during the temperature/pressure ramps and for the entire Main Steam Room test, slowed to one-minute intervals after approximately 69 minutes, and then slowed to 10-minute intervals from the 5 hour 38 minute point to the end of the test.

A 24-hour circular chart was utilized to record and monitor chamber temperature. This system was used for control purposes once the saturated steam environment was achieved in the chamber (1 hour into the Containment Test). This system utilized two Type "T" thermocouples mounted in the same location as Channels 1 and 2.

2.0 PROCEDURES (Continued)

2.3 Instrumentation Setup (Continued)

The channel number, specimen number, signal units, and signal monitored were as follow

Channel No.	Specimen No.	Units	Signal Monitored
1	All	°F	Chamber Control Type K" the couple mounted to the top c of the NEMA 1 enclosure.
2	All	°F	Chamber Control Type K" the couple mounted to the cor cover for Specimens 11.1 and
3	All	°F	Chamber Control Type K" the couple mounted to the cent the Limitorque actuator plate.
4	All	°F	Average Temperature of Cha 1, 2, and 3.
5	All	PSIG	Chamber Pressure Transducer
6	All	GPM	Chamber Spray Flowrate
7	1-3, 7-9	VAC	Input Voltage, A-B
8	1-3, 7-9	VAC	Input Voltage, A-C
9	1-3, 7-9	VAC	Input Voltage, B-C
10	1-3	Amps	Current, Phase A
11	1-3	Amps	Current, Phase B
12	1-3	Amps	Current, Phase C
13	7-9	Amps	Current, Phase A
14	7-9	Amps	Current, Phase B
15	7-9	Amps	Current, Phase C
16	4-6	VAC	Input Voltage, A-B

2.0 PROCEDURES (Continued)

2.3 Instrumentation Setup (Continued)

Channel No.	Specimen No.	Units	Signal Monitored
17	4-6	VAC	Input Voltage, A-C
18	4-6	VAC	Input Voltage, B-C
19	4-6	Amps	Current, Phase A
20	4-6	Amps	Current, Phase B
21	4-6	Amps	Current, Phase C
22	10	VDC	Input Voltage
23	10	Milliamps (mA)	Load Current
24 10.1A B	10 VI-22	mA	Leakage Current to Ground *
25	11 & 12	VDC	Input Voltage
26	11 & 12	mA	Load Current
27 2.1	11 & 12 VI-25	mA	Leakage Current to Ground *
28	13 & 14	VDC	Input Voltage
29	13 & 14	mA	Load Current
30	13 & 14 VI-28	mA	Leakage Current to Ground *

* Leakage currents to ground were calibrated to a 10 microampere resolution.

2.0 PROCEDURES (Continued)

2.4 Specimen Operability

The test specimens were electrically connected to the circuitry in Appendix III. The circ were energized continuously through the Main Steam Room test profile. For Containment test profile, the specimens were powered as listed below:

Specimen No.	Voltage	Current	Operations
1.1, 2.1, 3.1	632 VAC	27A	None. Continuousl Energized.
4.1, 5.1, 6.1	632 VAC	130A	None. Continuousl Energized.
7.1, 8.1, 9.1	632 VAC	20.2A	Powered for the firs 65 Minutes. De-ener until the 46-hour poi then re-energized fo 2 minutes.
10.1A & 10.1B	137.5 VDC	200mA*	None. Continuousl Energized.
11.1 & 12.1, 13.1 & 14.1	137.5 VDC	200mA*	Powered for the first 60 minutes. De-ener for remainder of tes

* Loading provided by an ASCO Model HV2023013U Solenoid Valve (23 Watt, 125 VDC) provided from the FNGS.

2.5 Accident Simulation

The test specimens were subjected to two temperature/pressure profiles. The first pro (Main Steam Room test) was performed as shown in Figure VI-4 of Appendix V. temperature requirement of 323°F was met in 15 seconds and the pressure requirement 6.4 PSIG was met in 2 seconds during this test.

The second profile (Containment test) was performed as shown in Figures VI-29 to VI-31 Appendix VII. The temperature requirement of 393°F was met in 109 seconds and the p pressure requirement of 53.3 PSIG was met in 217 seconds. Temperature was held ab 393°F for 304 seconds prior to the temperature decay. Chemical spray was initiated at 61-minute point and continued to the 25 hour 8 minute point in the test. The two t profiles were performed one after the other.

3.0 RESULTS

All of the test specimens demonstrated the ability to conduct the specified currents, at the specified voltages, throughout the LOCA tests.

One anomaly occurred during this test and is documented as Notice of Anomaly Number 1. This anomaly documents the usage of the high-speed printer that was outside of its calibration interval during the LOCA test. This error was discovered at the 24-hour point in the test and no other printers of the required speed were available. The post-test calibration check found the printer to be inside the manufacturer's tolerances. It should be noted that this printer provides hard copy backup data and all of the plots in Appendices V through VIII were made from data off the hard disk on the HP-1000 minicomputer.

The recorded leakage currents to ground were:

Specimen No.	Leakage Current to Ground (mA)	Notes
10.1A & 10.1B	0.00	
11.1 & 12.1	1.20	(1)
13.1 & 14.1	0.00	

NOTES: (1) This signal existed for approximately 15 minutes during the Main Steam Room test (see Figure VI-25). However, the signal was not erratic, as most leakage current signals tend to be. Troubleshooting commenced at the 15-minute point found the 125 VDC leads tied to a short length of a 3ϕ, 208 VAC power cord for the circuit on Specimens 4.1, 5.1 and 6.1. When these ties were cut, the signal immediately dropped to zero. It is therefore concluded that this signal was most likely induced and not specimen related.

The data from this phase of testing is presented in Appendices I through IX. Those appendices contain:

- Appendix I contains Notice of Anomaly Number 1 and the Post-Test Calibration record.
- Appendix II contains Photographs VI-1 through VI-14 which show the specimen, chamber, electrical and instrumentation setups.
- Appendix III contains Figures VI-1 through VI-3 which show the electrical circuitry used to energize the specimens.

3.0 RESULTS (Continued)

- Appendix IV contains the calculations for the chemical spray solution and flowrate.
- Appendix V contains Figure VI-4 which plots the chamber thermocouples and pressure for the Main Steam Room test .
- Appendix VI contains Figures VI-5 through VI-28 which plot the electrical data recorded during the Main Steam Room test.
- Appendix VII contains Figures VI-29 through VI-31 which plot temperature, pressure and chemical spray flow during the Containment test.
- Appendix VIII contains Figures VI-32 through VI-55 which plot the electrical data during the Containment test.

Appendix IX contains the Instrumentation Equipment Sheets which list equipment used to take data. The high-speed line printer was inadvertently left off and was added after the test had completed.

APPENDIX I

NOTICE OF ANOMALY

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WYLE LABORATORIES (Eastern Operations)

NOTICE OF ANOMALY

DATE: September 30, 1987

NOTICE NO: 1 P.O. NUMBER: QP-1859 CONTRACT NO: N/A

CUSTOMER: Alabama Power Company WYLE JOB NO: 17947

NOTIFICATION MADE TO: Rick Woodfin NOTIFICATION DATE: 9-28-87

NOTIFICATION MADE BY: Joe Hazeltine VIA: On site

CATEGORY: ☐ SPECIMEN ☒ PROCEDURE ☒ TEST EQUIPMENT DATE OF ANOMALY: Sept. 2[illegible]-25, 1987

PART NAME: High Speed Line Printer PART NO. TI-R08[illegible]0

TEST: LOCA Test I.D. NO. N/A

SPECIFICATION: WLQP 17942-01 PARA. NO 3.9.2

REQUIREMENTS:

The Data Acquisition System shall be operated at its peak rate during the ramp and at 1 minute intervals thereafter.

DESCRIPTION OF ANOMALY:

The Texas Instruments R0810 High Speed Line Printer, used to record hard copy data, was found to be outside its calibration interval. This error was discovered after the test had been running for approximately 24 hours and no spare printers, of the required speed, were available.

DISPOSITION · COMMENTS · RECOMMENDATIONS:

The LOCA test was completed using the out of calibration high speed printer. The printer was calibrated as soon as possible after the test and found to be inside the manufacturer's tolerances.

The line printer does not transform the data fed to it from the Daytronics Data Acquisition System. A malfunction would cause the printer to record either unintelligible data or no data at all. The calibration of printer involves checking the printer ribbon intensity and alignment, rocker switch positions (set the baud rate) and the power supply voltages.

It should be noted that the plotted data comes from the Hewlett Packard Model 1000 minicomputer. This data is also fed from the DAS and thus the hard copy data is used for backup purposes only.

NOTE: IT IS THE CUSTOMER'S RESPONSIBILITY TO ANALYZE ANOMALIES AND COMPLY WITH 10 CFR PART 21.

VERIFICATION:

TEST WITNESS: George Langford/Rick Woodfin

REPRESENTING: Bechtel/Alabama Power Co.

QUALITY ASSURANCE: [signature] 10/5/87

PROJECT ENGINEER: [signature] 9/3[illegible]/87

PROJECT MANAGER: [signature] 10/1/87

INTERDEPARTMENTAL COORDINATION: [signature] 10/[illegible]/87

[signature]

Wyle Form WH 1066, Rev. JAN '85

REQUEST FOR CALIBRATION EXTENSION

DATE 9-25-87

TO (IN TURN): POST CAL ONLY CONTROL NO.: 87-020

1. QA DEPARTMENT
2. CALIBRATION LABORATORY
3. ORIGINATOR S. Lewis DEPARTMENT 543

ORIGINATOR:

MANUFACTURER: Texas Inst WYLE NO.: 11771

MODEL NO.: 810 SERIAL NO.: 4711-1385

INSTRUMENT: RO Terminal ACCURACY: PM

CALIBRATION DUE DATE: PRESENT: 9-19-87 EXTEND TO:

CUSTOMER: APCO JOB NO.: 17947 GSI (OCAS) - YES/NO

SIGNATURES/DATE: ______ TECHNICIAN ______ PROJECT ENGINEER

CALIBRATION LABORATORY: POST CAL ONLY

CALIBRATION DUE DATE EXTENDED TO: ______ RECORDS POSTED: ______

STICKER APPLIED: ______

The test data will not be released until the instrumentation accuracy has been verified by Post Calibration. This instrument shall be returned to the Calibration Laboratory, with a Maintenance Work Order (WH 1107), on or before.

______ (DATE)

SIGNATURE/DATE ______ SUPERVISOR, CALIBRATION LABORATORY

POST CALIBRATION RESULTS:

WITHIN MANUFACTURER'S TOLERANCE - YES / NO (YES circled)

REMARKS:

SIGNATURES/DATES [signature] 9-28-87 QUALITY ASSURANCE [signature] SUPERVISOR, CALIBRATION LABORATORY

APPENDIX II

PHOTOGRAPHS

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AL POWER COMPANY — 17947

CHEMICAL SPRAY CALCULATIONS

1. Boric Acid (H_3BO_3)

   Desire 2500 ppm Boron

   - Weight Water = 120 gal x 8.325 Lb/gal = 999 Lb

   - 61.81 Lb H_3BO_3 has $\frac{10.81 \text{ B}}{61.81\ H_3BO_3}$ = 10.81 Lb Boron

   - $\frac{2500 \text{ ppm}}{1{,}000{,}000}$ x 999 Lb = 2.49 Lb Boron = $\frac{999}{1{,}000{,}000}$ x 2500 = 2.4975

   Must add 2.49 Lb x $\frac{61.81}{10.81}$ = 14.3 Lb H_3BO_3

2. Sodium Hydroxide (NAOH)

   - Add to get 10.7 pH

   - Maintain 10.5-11.0 pH during spray

3. Flow Rate (0.15 gpm/ft^2)

   - 0.15 gpm/ft^2 x (5' x 5') = 3.75 gpm

   - Maintain 3.75 to 4.25 gpm.

APPENDIX IV

CHEMICAL SPRAY CALCULATIONS

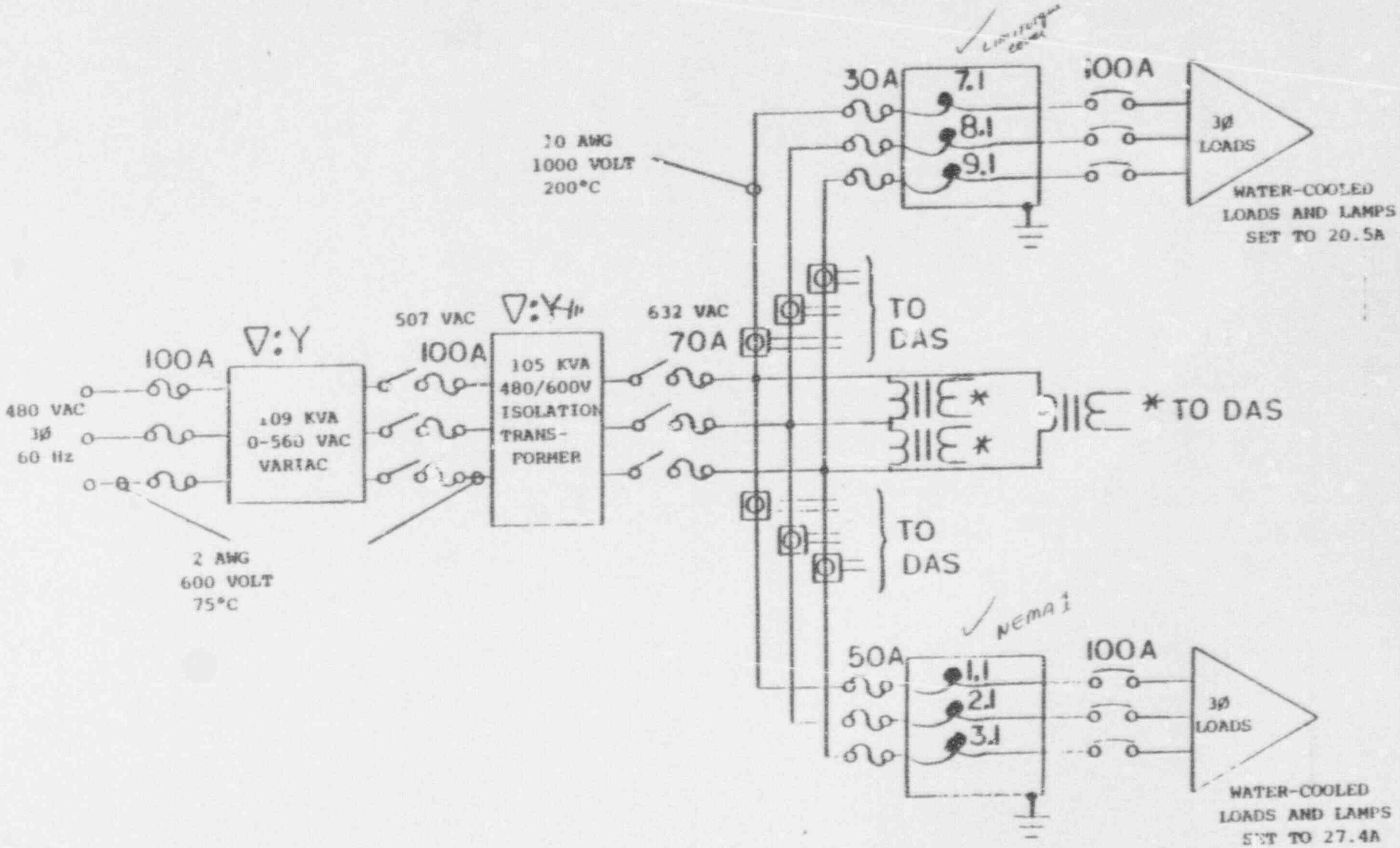


FIGURE VI-1. ELECTRICAL SETUP FOR SPECIMENS 1, 2, 3, 7, 8 AND 9

APPENDIX III

ELECTRICAL SETUP FIGURES

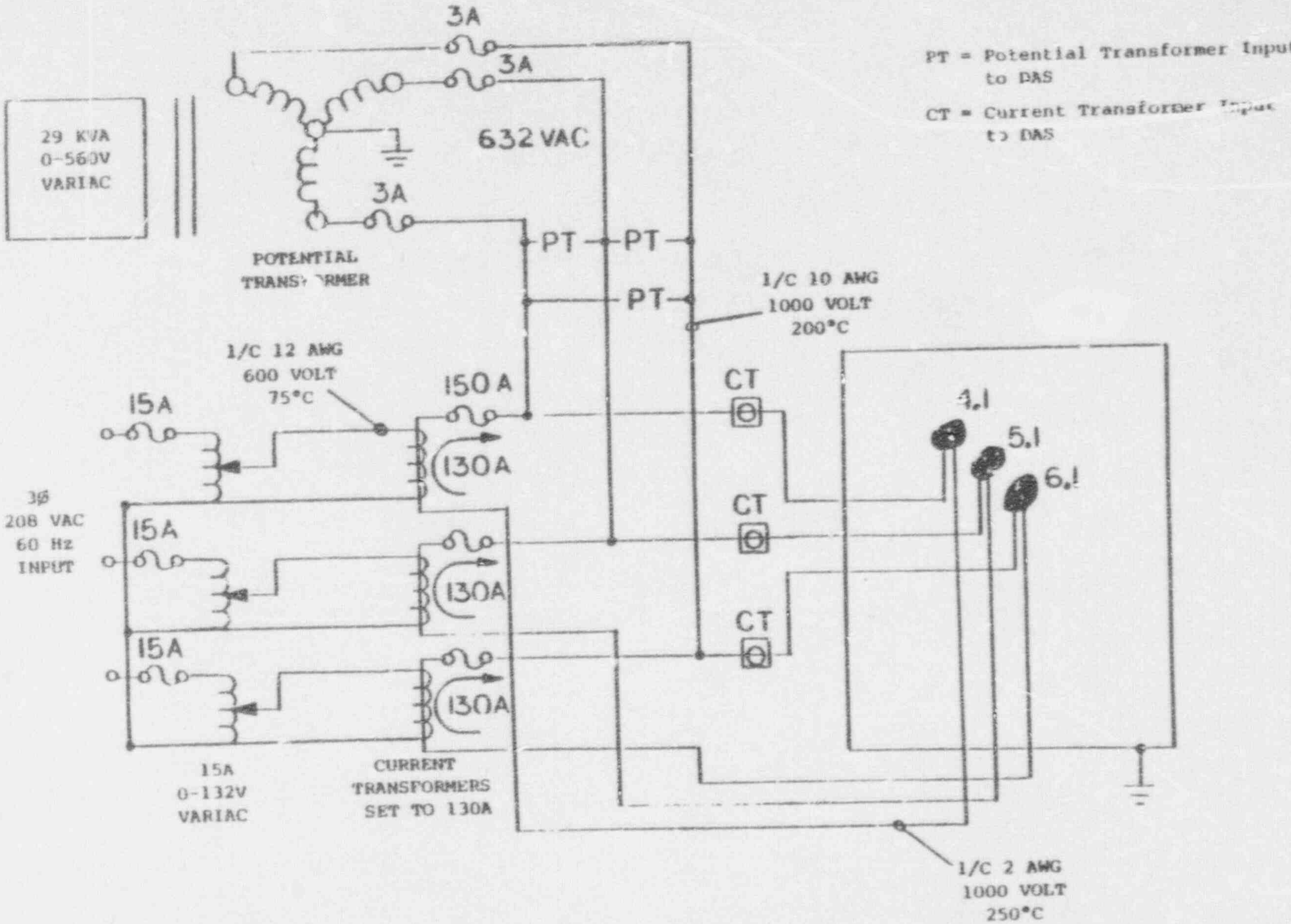


FIGURE VI-2. ELECTRICAL SETUP FOR SPECIMENS 4.1, 5.1 and 6.1

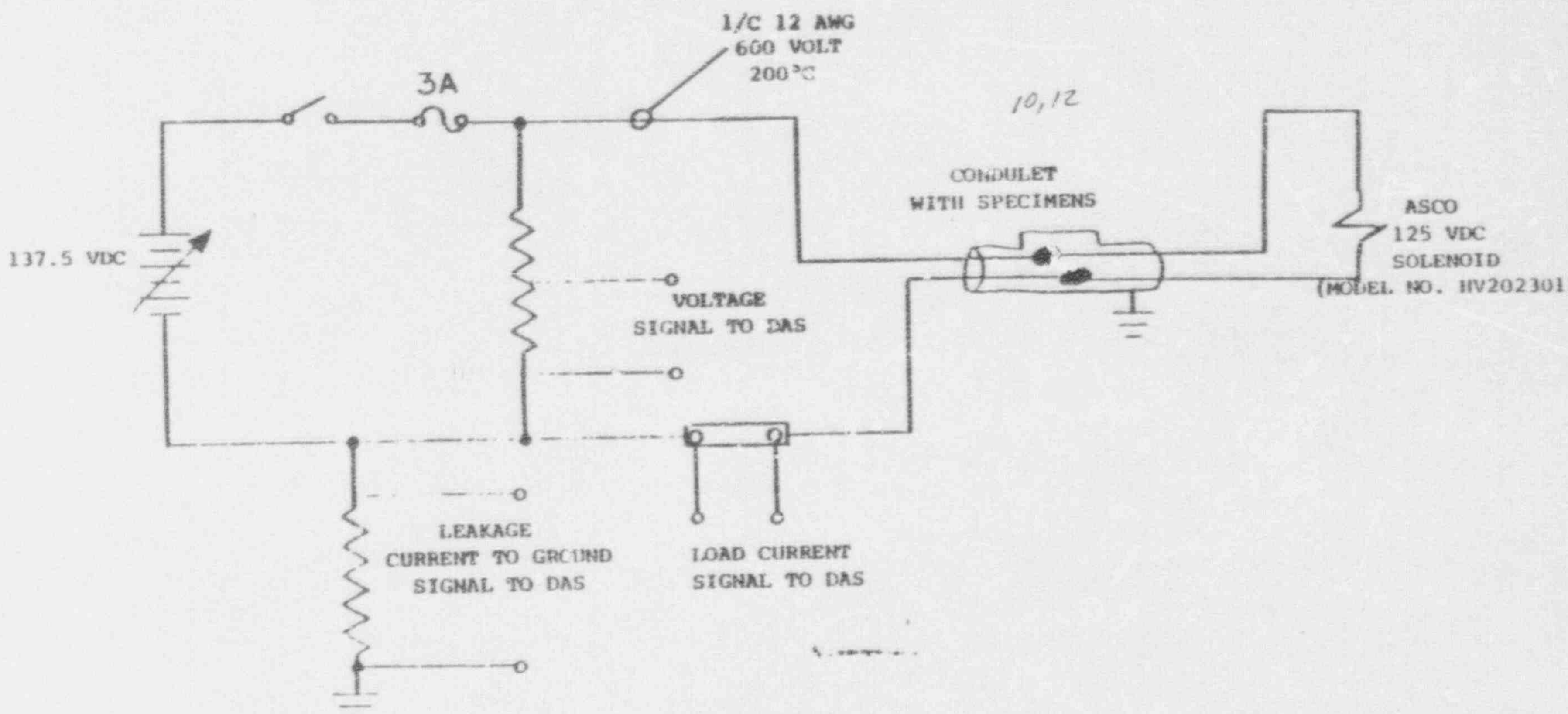
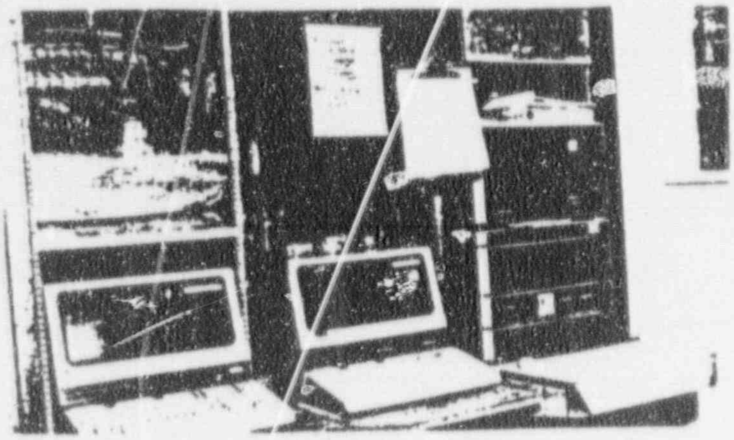
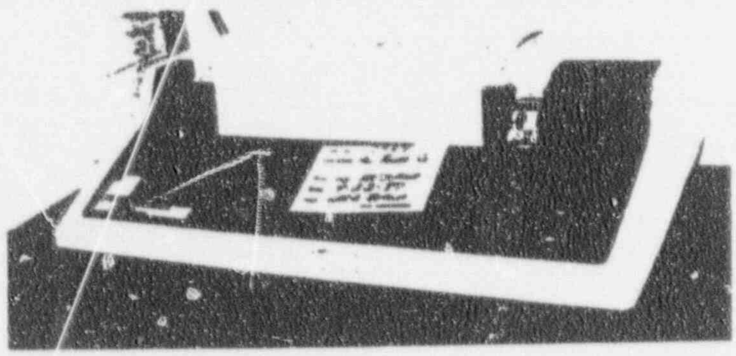


FIGURE VI-3. TYPICAL ELECTRICAL SETUP FOR SPECIMENS



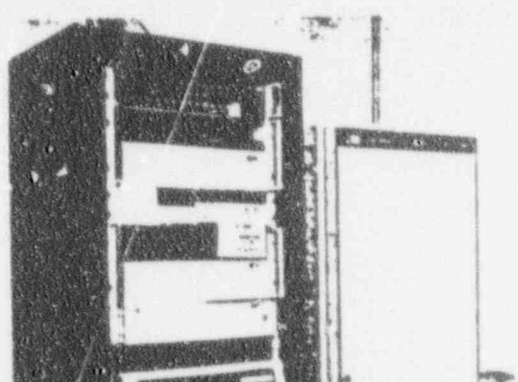
PHOTOGRAPH NO. VI-9

INSTRUMENTATION SETUP SHOWING DAYTRONICS SYSTEM 10 DATA ACQUISITION SYSTEM (DAS) AND H-P 1000 TERMINALS



PHOTOGRAPH NO. VI-10

TEXAS INSTRUMENTS 810RO HIGH-SPEED LINE PRINTER USED TO RECORD HARD COPY DATA FROM DAS



PHOTOGRAPH NO. VI-11

HEWLETT-PACKARD MODEL 1000 MINICOMPUTER USED TO RECORD DATA ON HARD DISK AND TO GENERATE PLOTS OF REQUESTED INFORMATION

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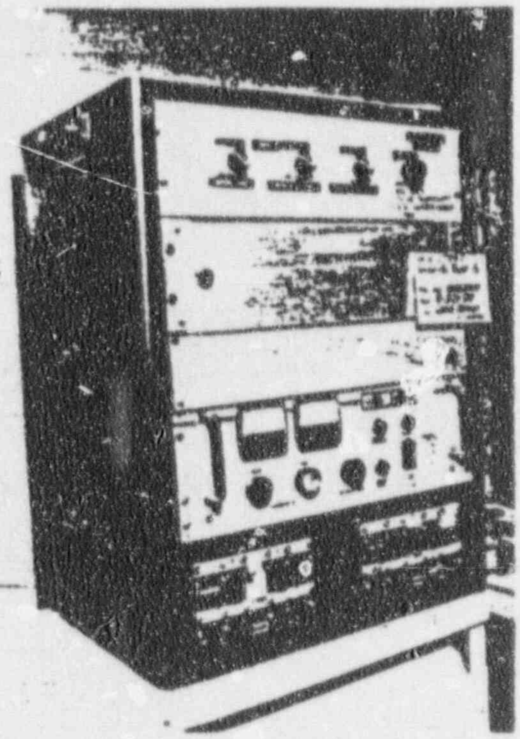
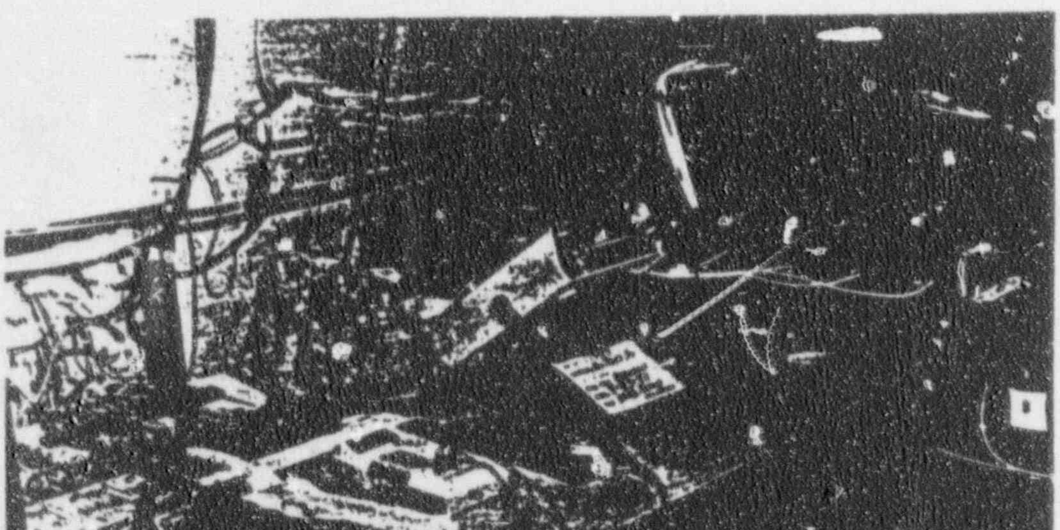


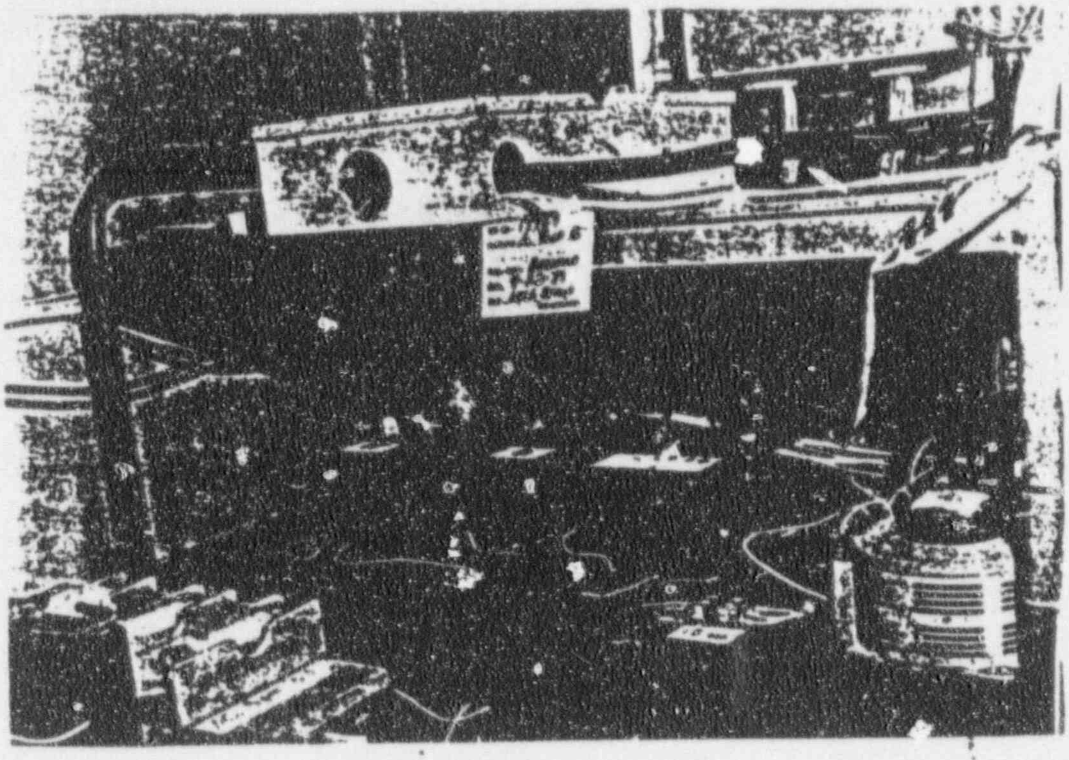
PHOTOGRAPH NO. VI-5

DC SUPPLIES AND SWITCHES FOR
SPECIMENS 10, 11/12, AND 13/14



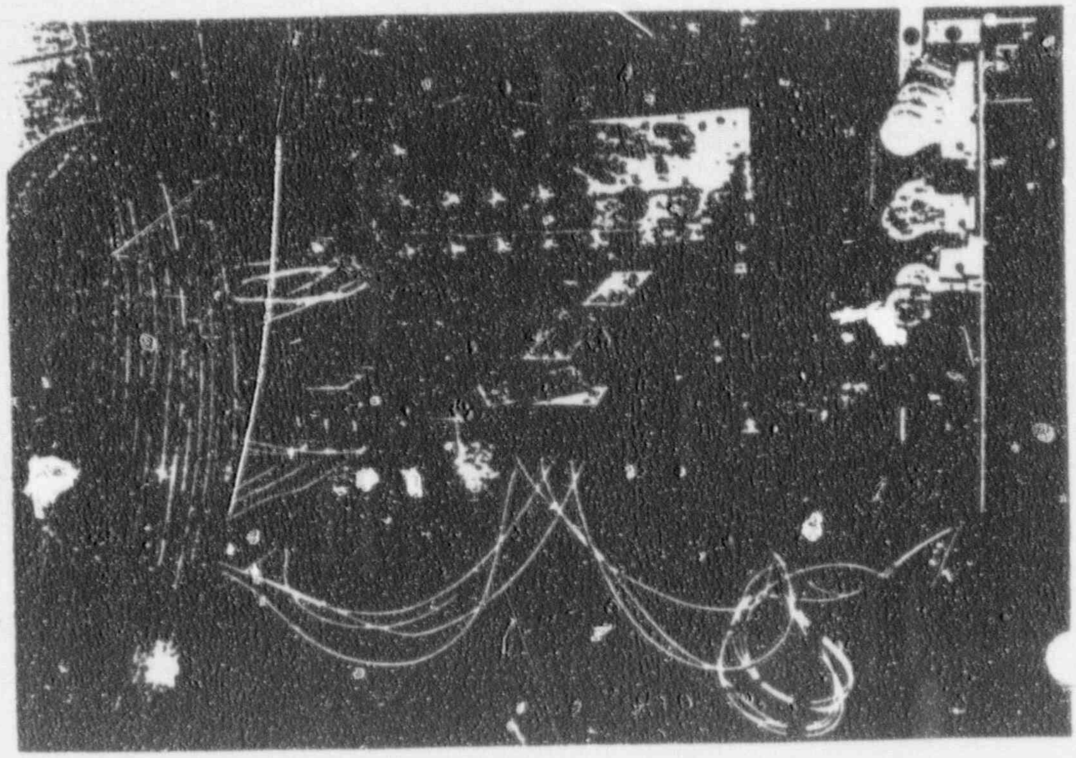
PHOTOGRAPH NO. VI-6

VIEW OF CIRCUITRY FOR SPECIMENS 10, 11/12, AND 13/14.
NOTE THE SOLENOID VALUES SUPPLIED BY ALABAMA POWER CO.



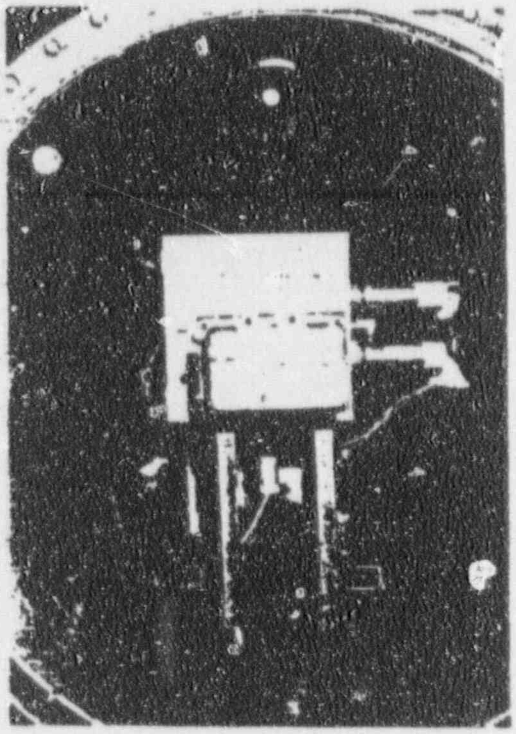
PHOTOGRAPH NO. VI-7

VIEW OF CIRCUITRY USED
FOR SPECIMENS 1-9



PHOTOGRAPH NO. VI-8

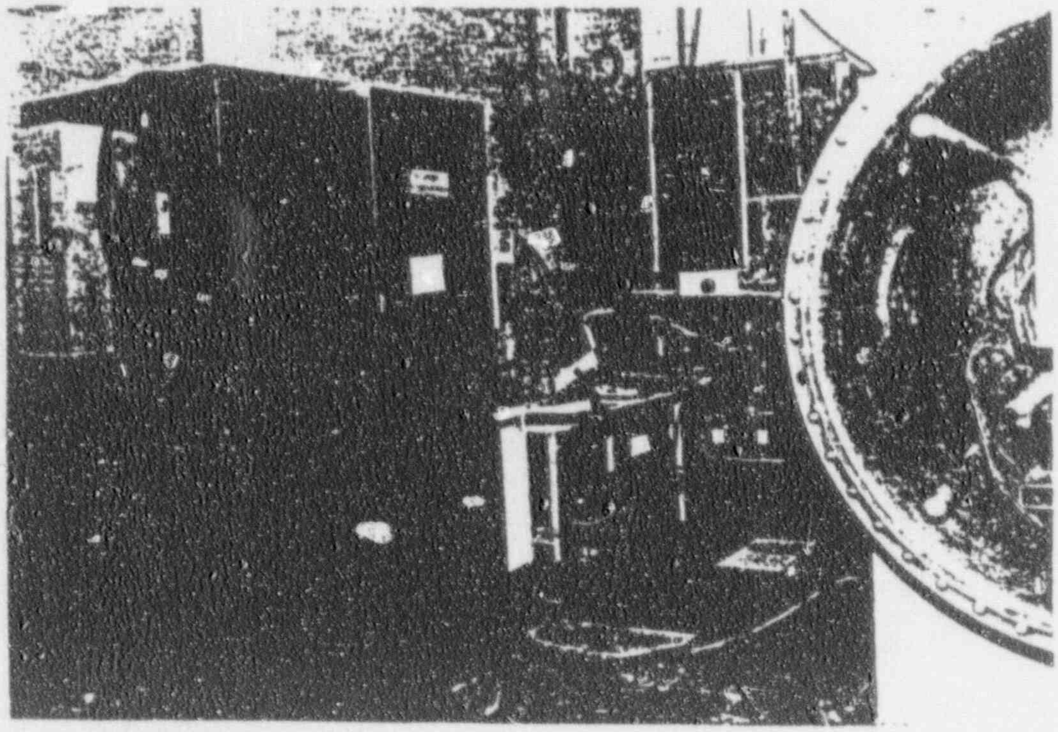
3ϕ, 600 VOLT, 100 kW, WATER-COOLED LOADS AND
120 VOLT, 75 WATT LIGHT BULBS USED
TO LOAD SPECIMENS 1-3 AND 7-9



See photo IV-4

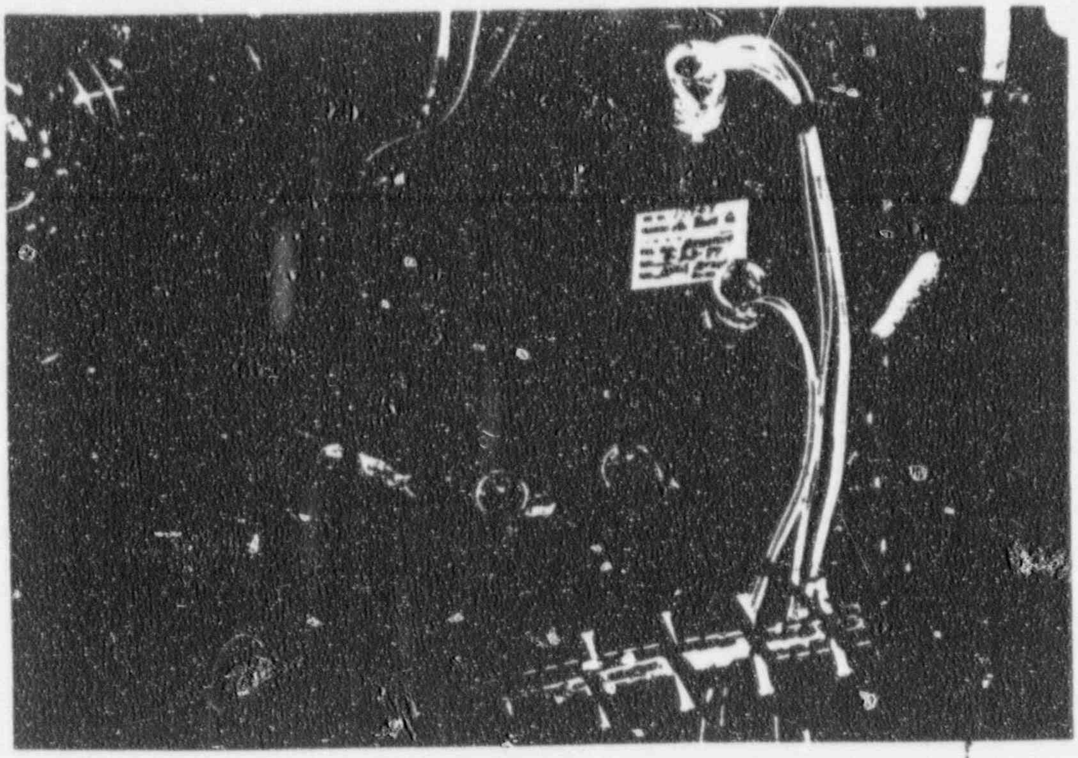
PHOTOGRAPH NO. VI-1

OVERALL VIEW OF TEST SPECIMEN ENCLOSURES INSIDE A 60" DIAMETER LOCA CHAMBER



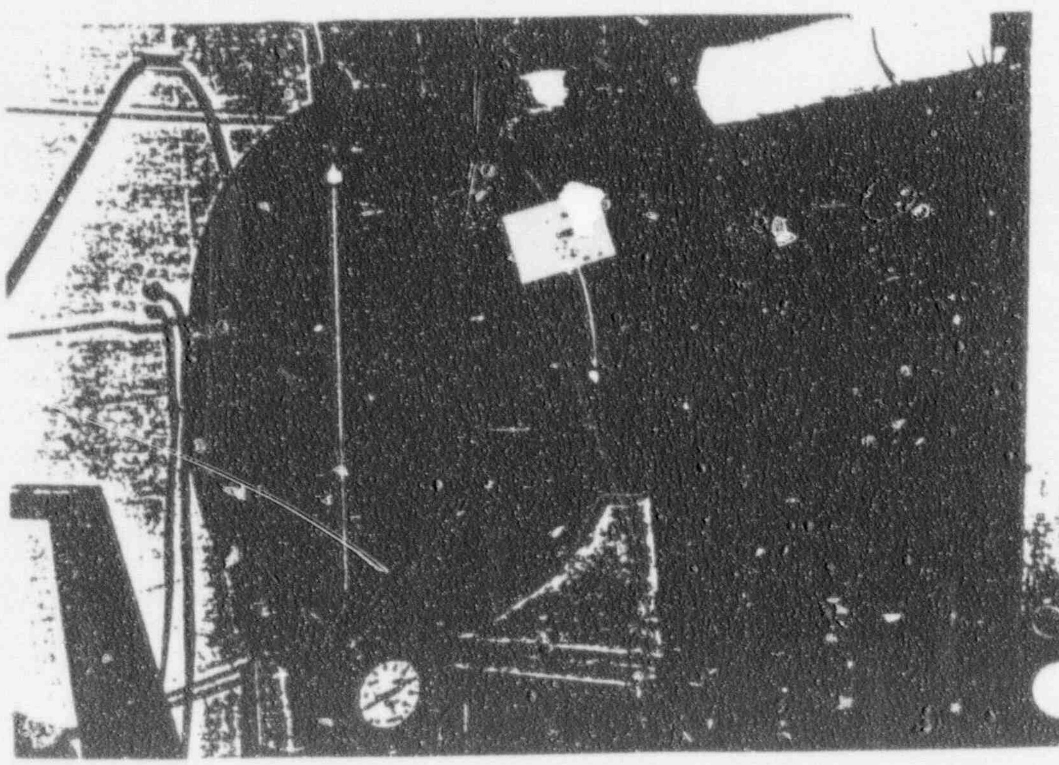
PHOTOGRAPH NO. VI-2

OVERALL VIEW OF ELECTRICAL SETUP



PHOTOGRAPH NO. VI-3

REAR VIEW OF LOCA CHAMBER SHOWING
CHAMBER PENETRATION ASSEMBLIES



PHOTOGRAPH NO. VI-4

CHEMICAL SPRAY RESERVOIR
AND PIPING SYSTEM

APPENDIX V

MAIN STEAM ROOM

TEST PROFILE

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APPENDIX VI

MAIN STEAM ROOM LOCA TEST

ELECTRICAL DATA

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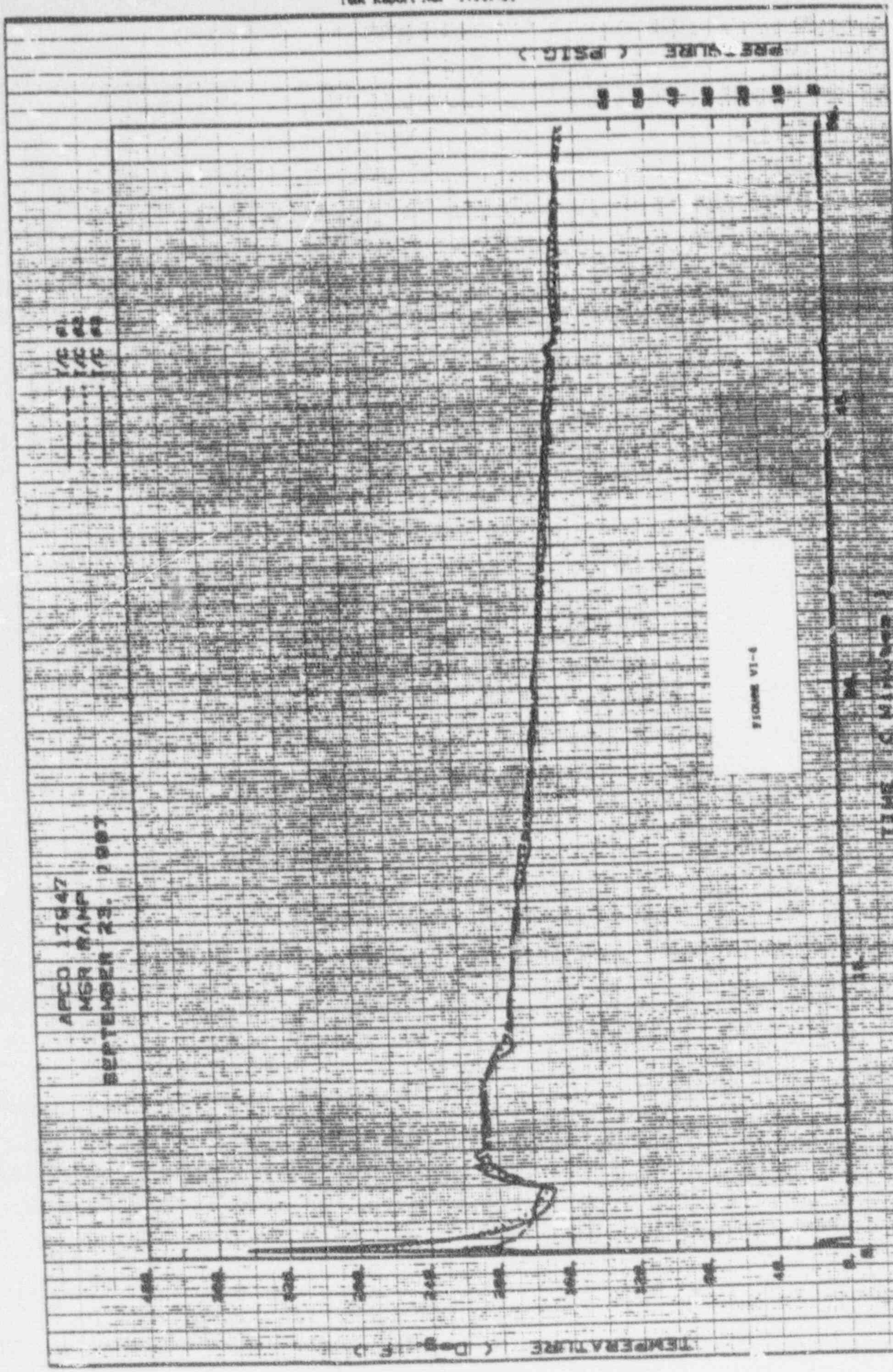
APCO 17947
MSR RAMP
SEPTEMBER 23, 1987
T/C #1
T/C #2
T/C #3
TEMPERATURE (Deg. F)
PRESSURE (PSIG)
TIME (MINUTES)

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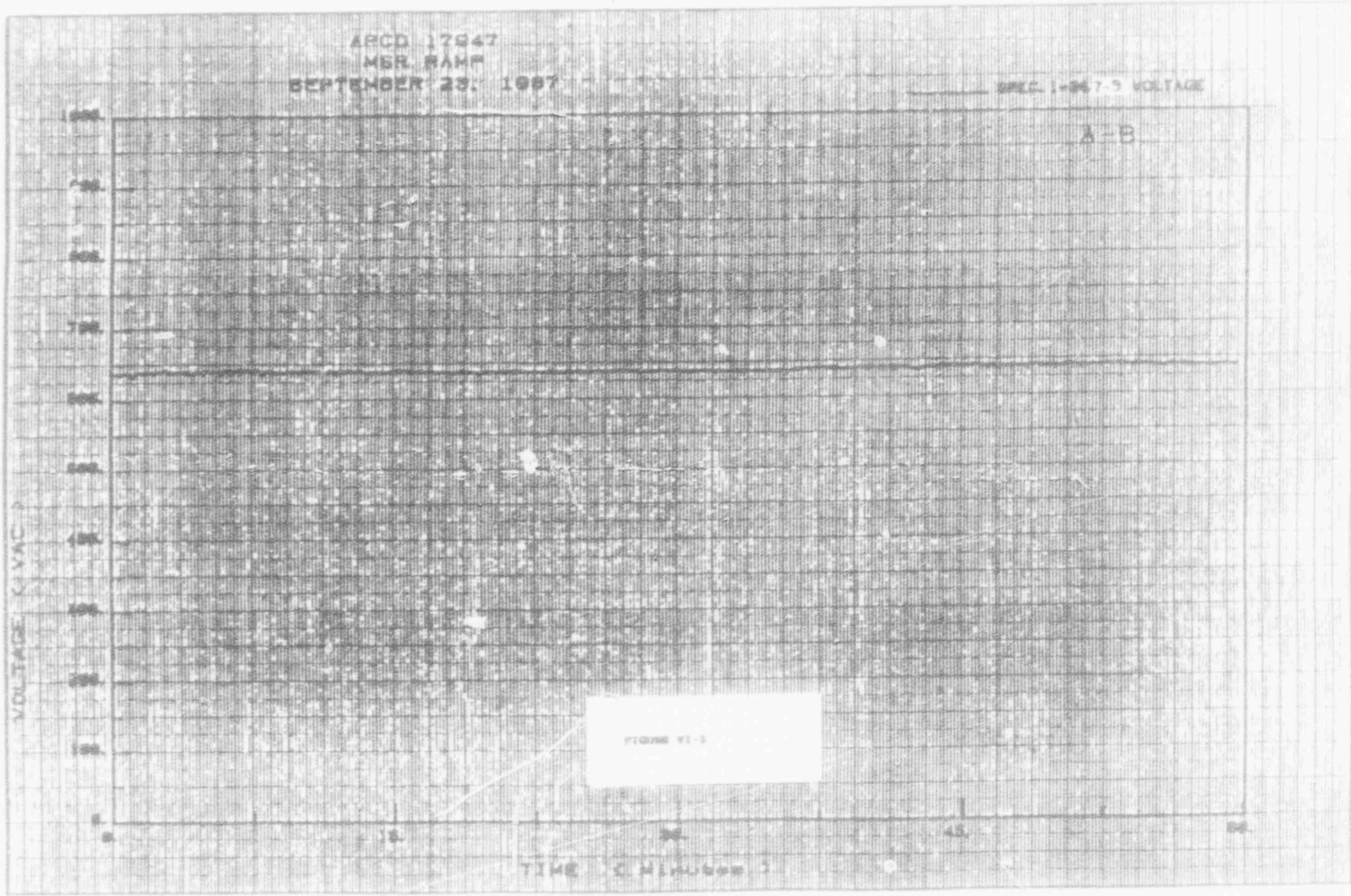

ABCD 17947
MBR RAMP
SEPTEMBER 23, 1987
A-B
VOLTAGE (VAC)
TIME (Minutes)
0.
15.
30.
45.
60.
100.
200.
300.
400.
500.
600.
700.
800.
900.
1000.

FIGURE VI-3

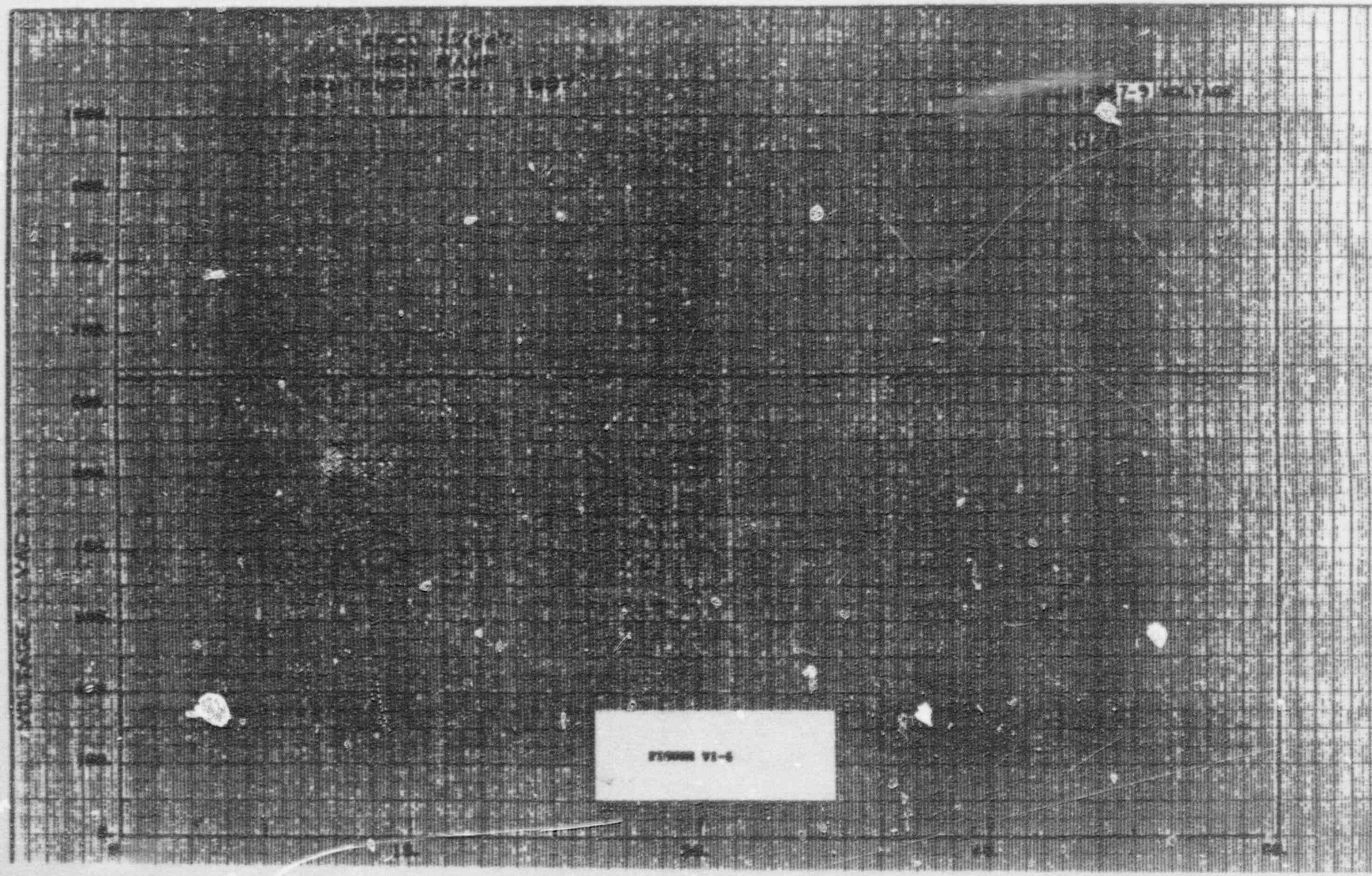


FIGURE VI-6

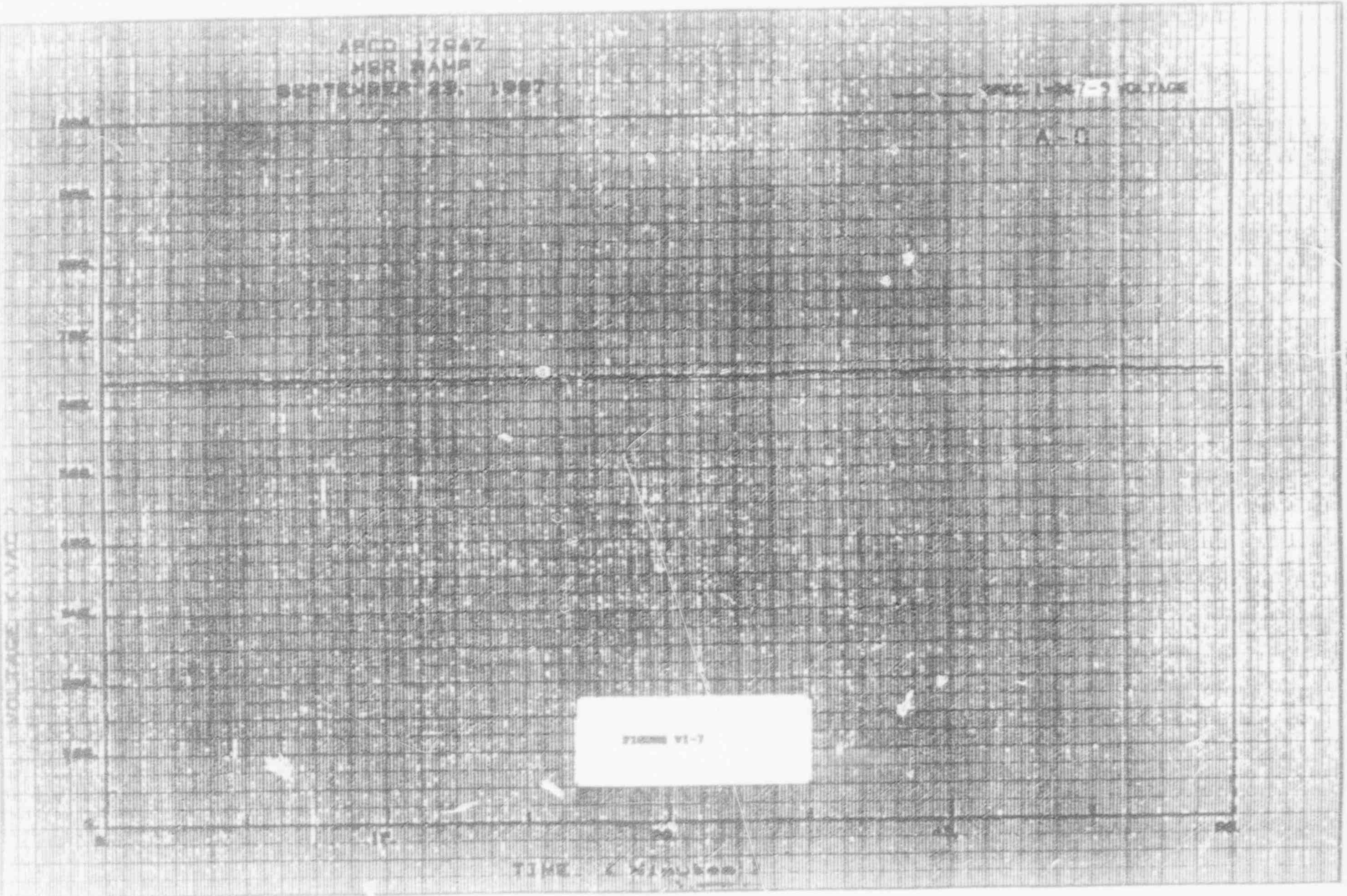
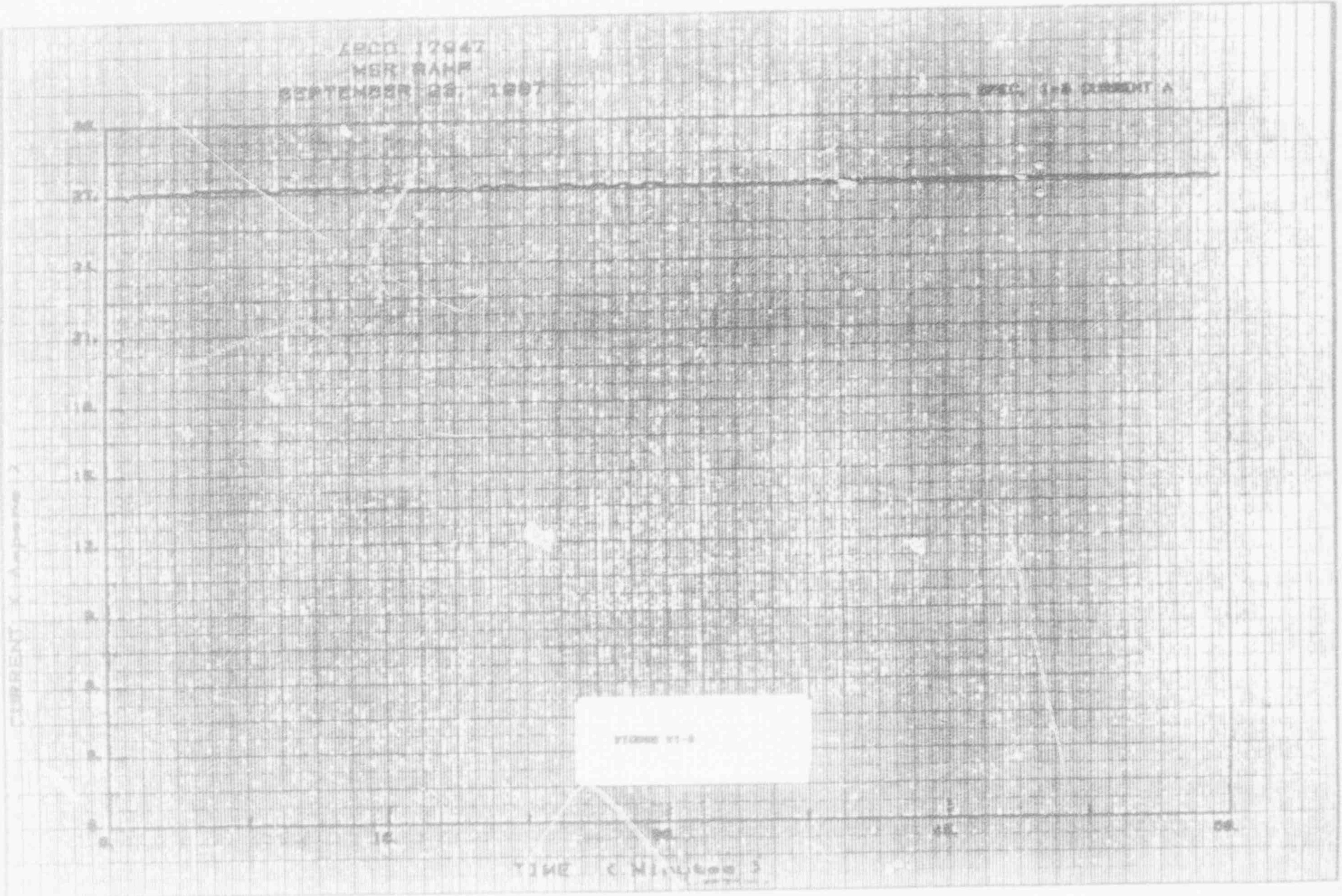


FIGURE VI-7


MSR RAMP
CURRENT (Amperes)
TIME (Minutes)
30.
27.
24.
21.
18.
15.
12.
9.
6.
3.
0.
15.
30.
45.
60.

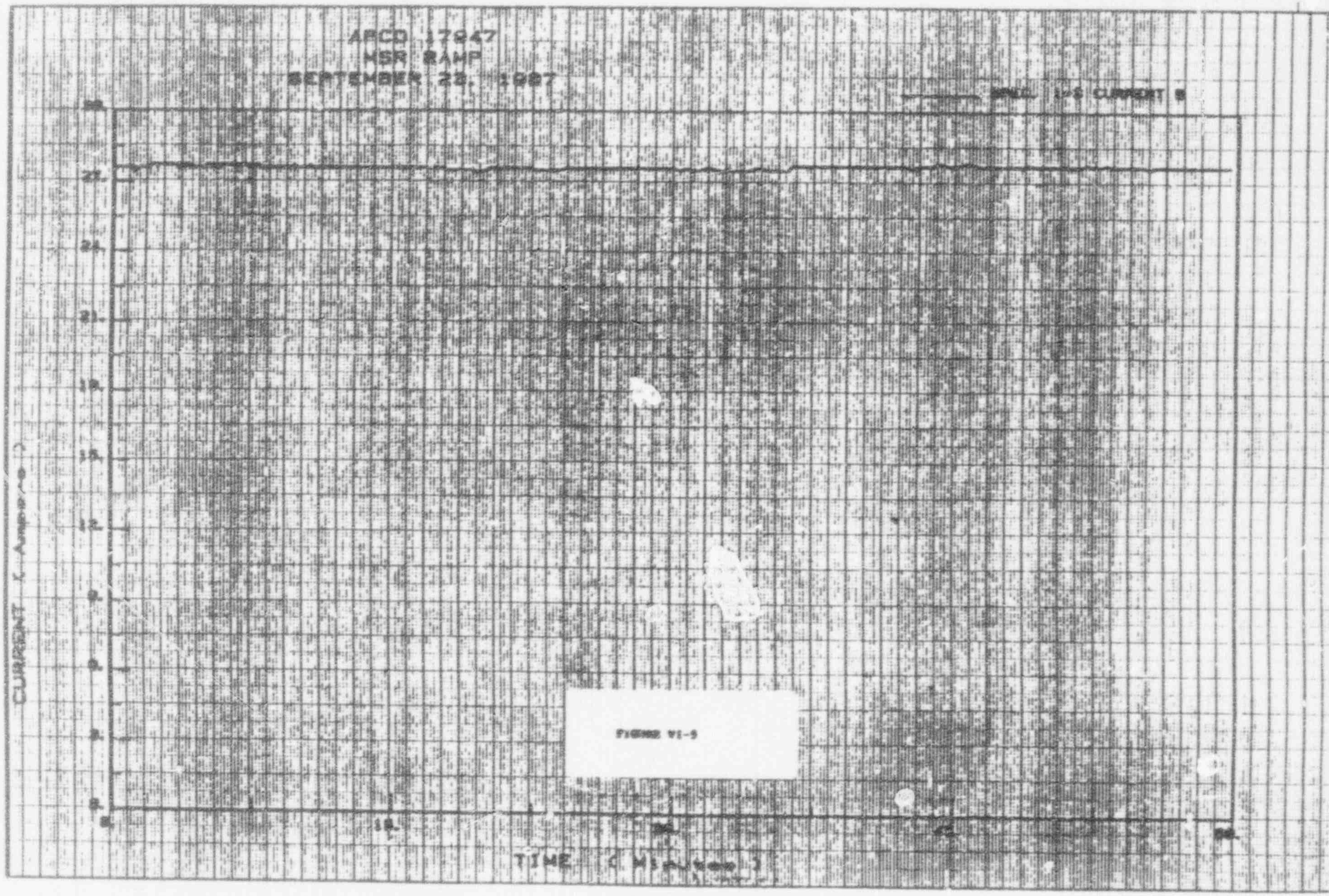


FIGURE VI-5

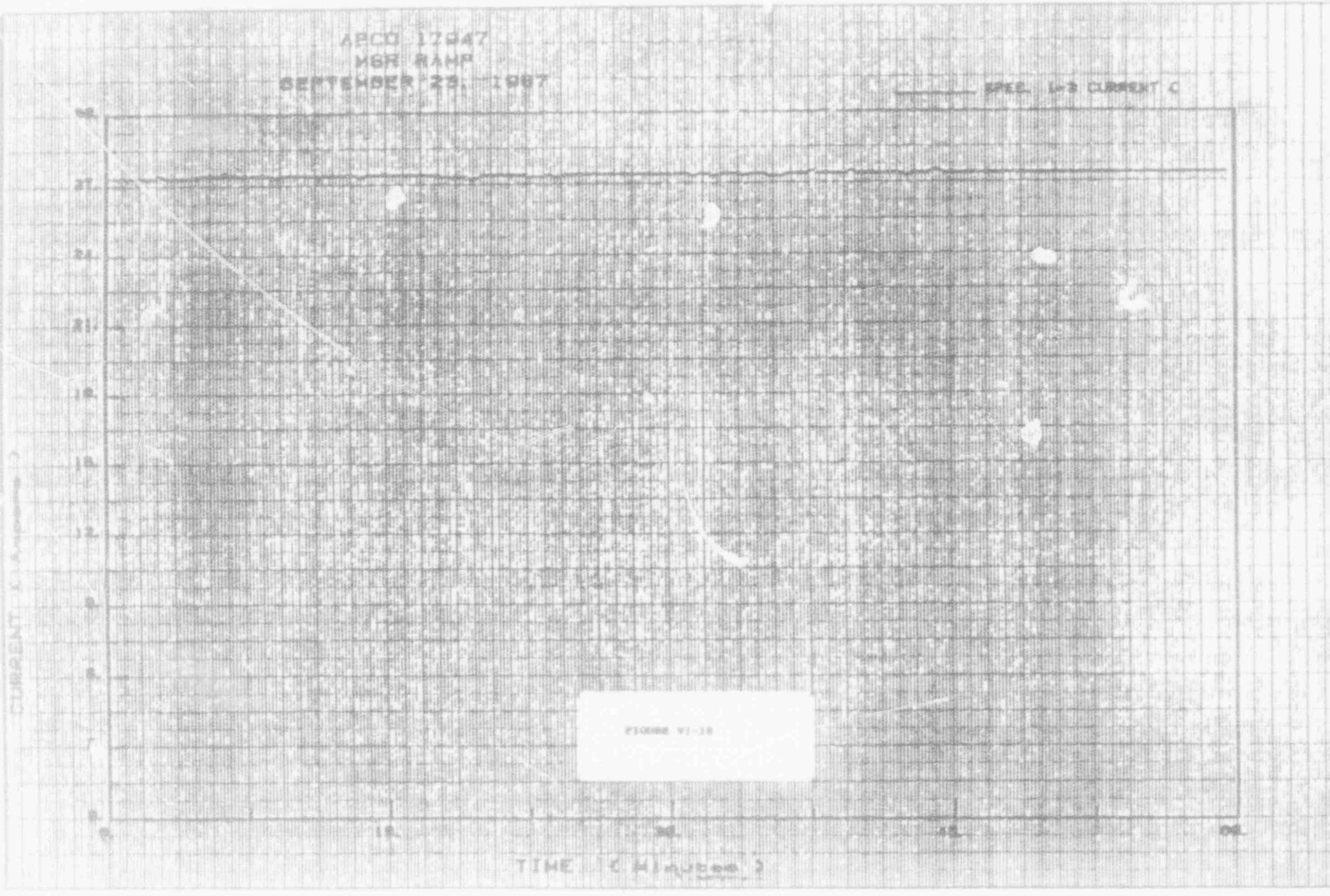

MSR RAMP
SPEC. L-3 CURRENT C
CURRENT (Amperes)
TIME (Minutes)
0
15
30
45
60
3
6
9
12
15
18
21
24
27
30

FIGURE VI-18

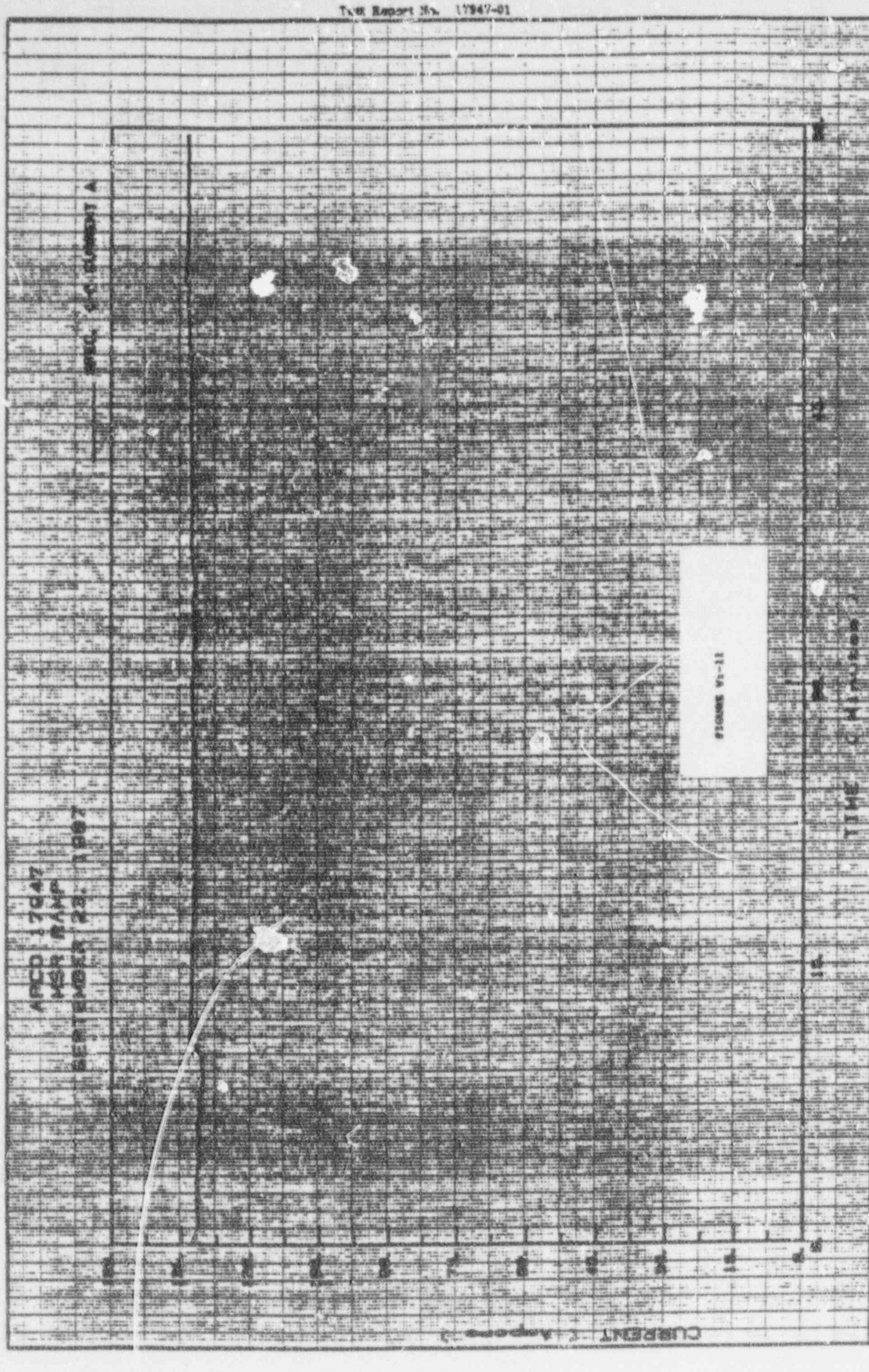

APCD 17947
MSR RAMP
SEPTEMBER 23, 1987
TIME (Minutes)
CURRENT (Amps)

FIGURE VI-11

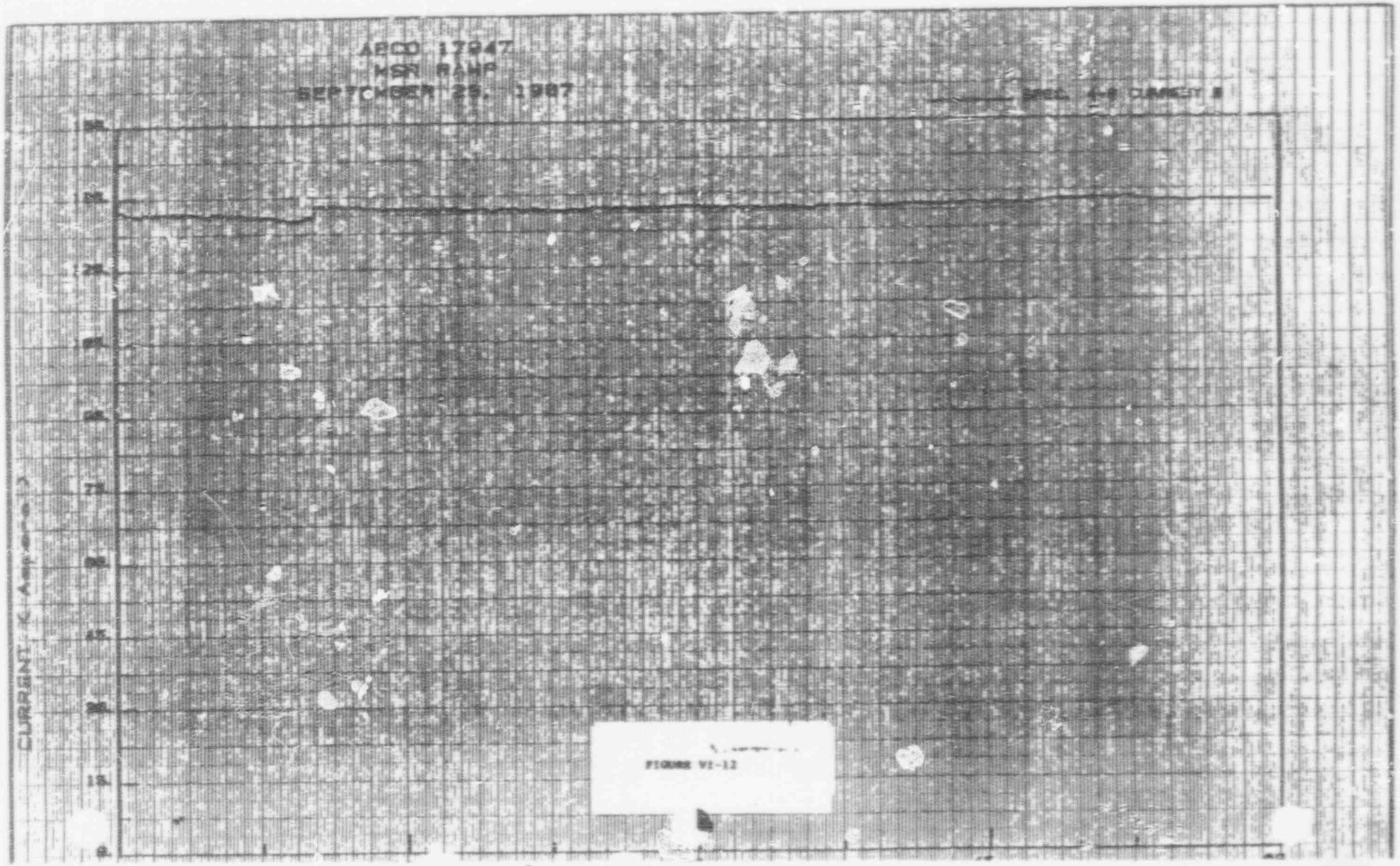


FIGURE VI-12

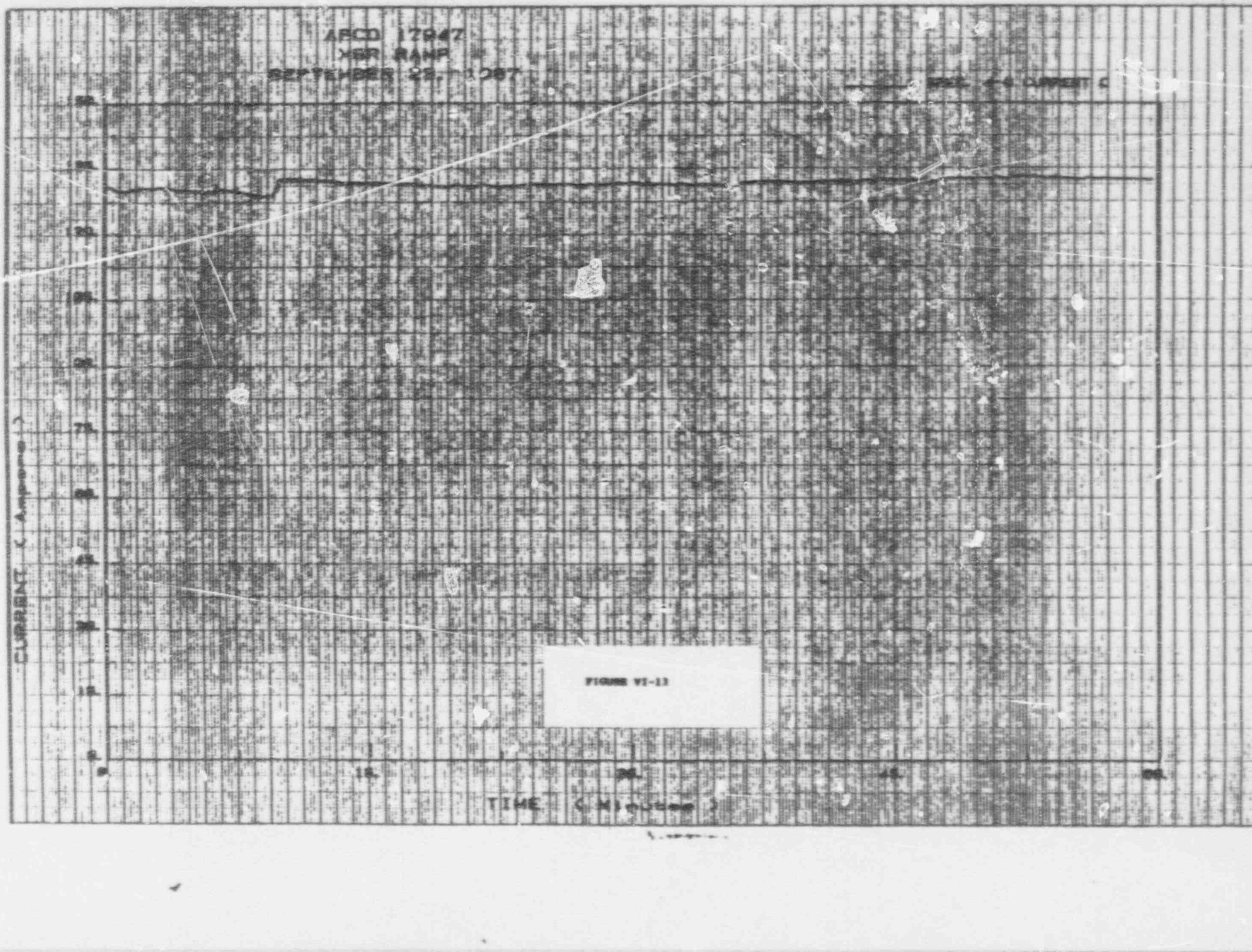
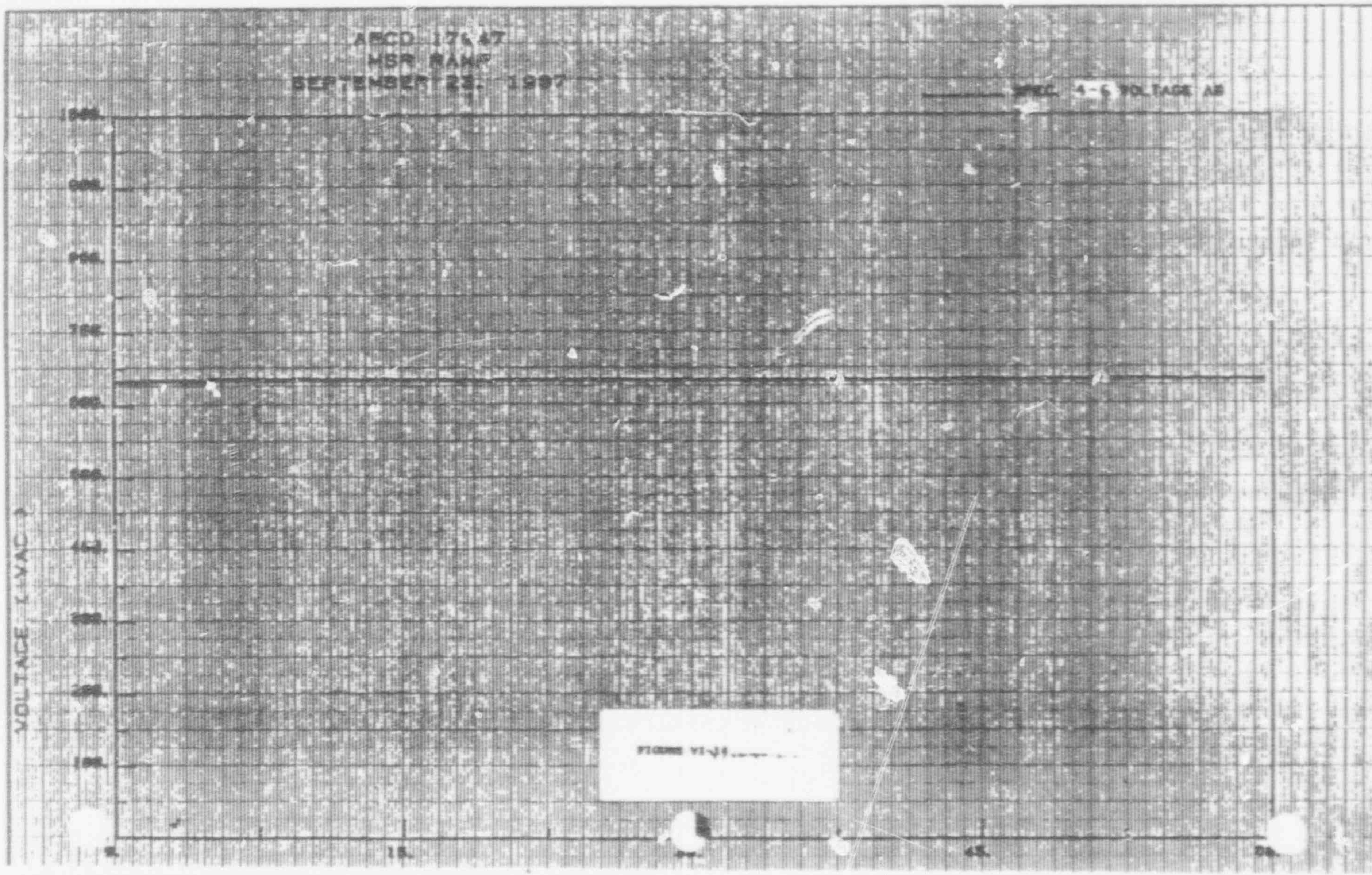

ARCD 17947
XBR RAMP
SEPTEMBER 28, 1987
SPEC. 4-6 CURRENT C
CURRENT (Amperes)
0.
15.
30.
45.
60.
75.
90.
105.
120.
135.
150.
0.
15.
30.
45.
60.
TIME (Minutes)

FIGURE VI-13



APCD 17647
MSR RAMP
SEPTEMBER 23, 1997
SPEC. 4-6 VOLTAGE AB
VOLTAGE (VAC)
15.
30.
45.
60.

FIGURE VI-14

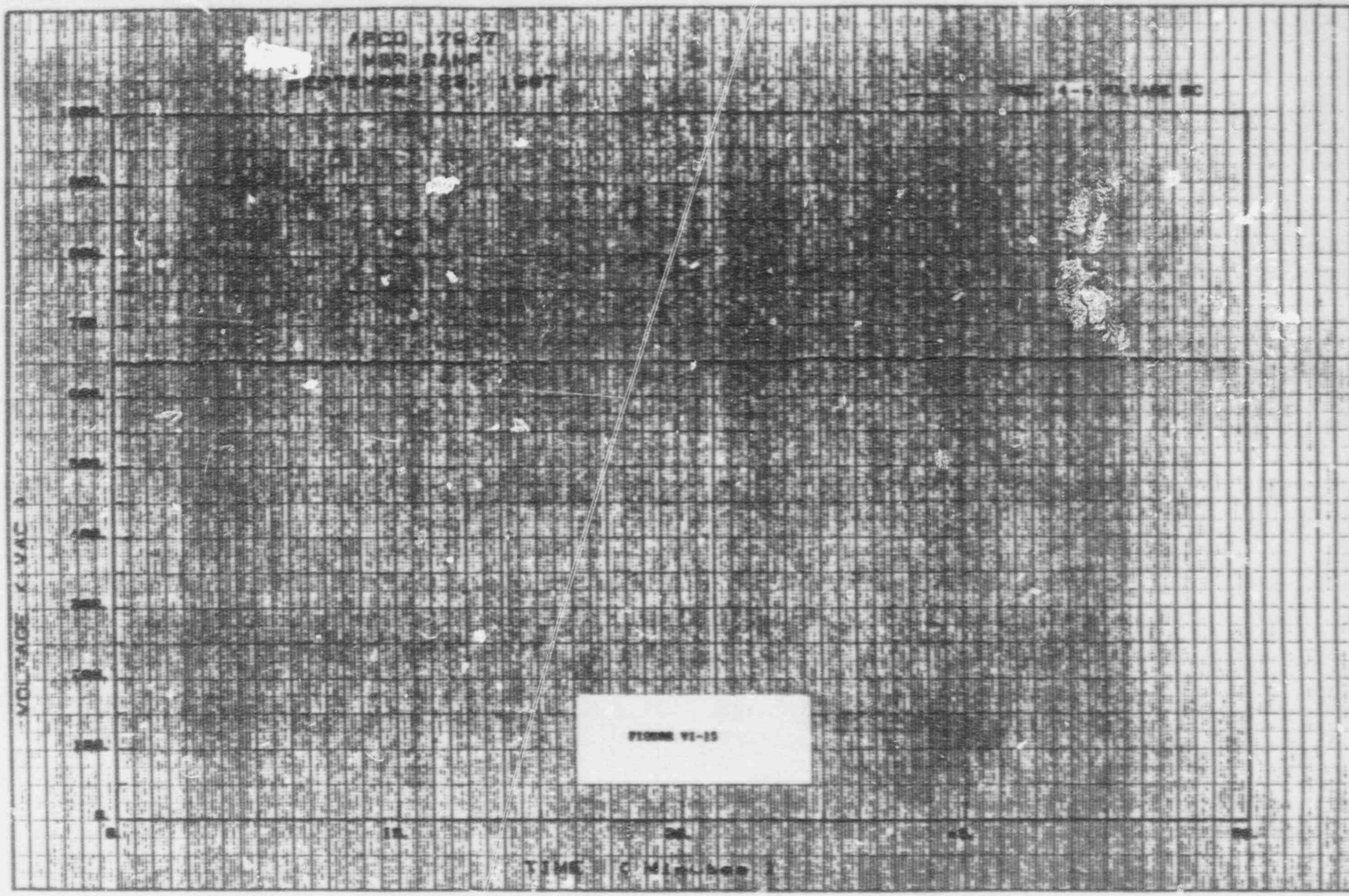


FIGURE VI-15

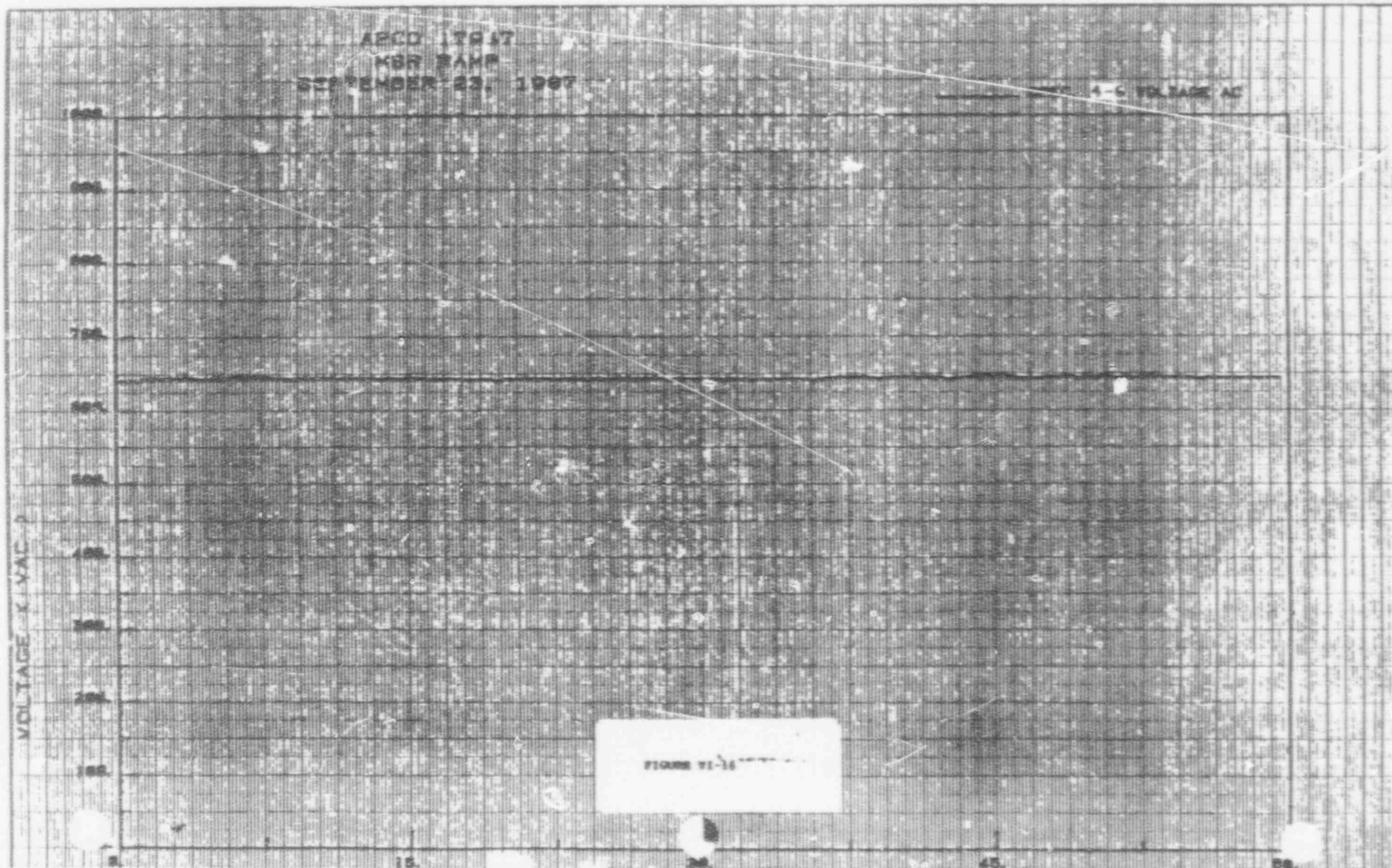
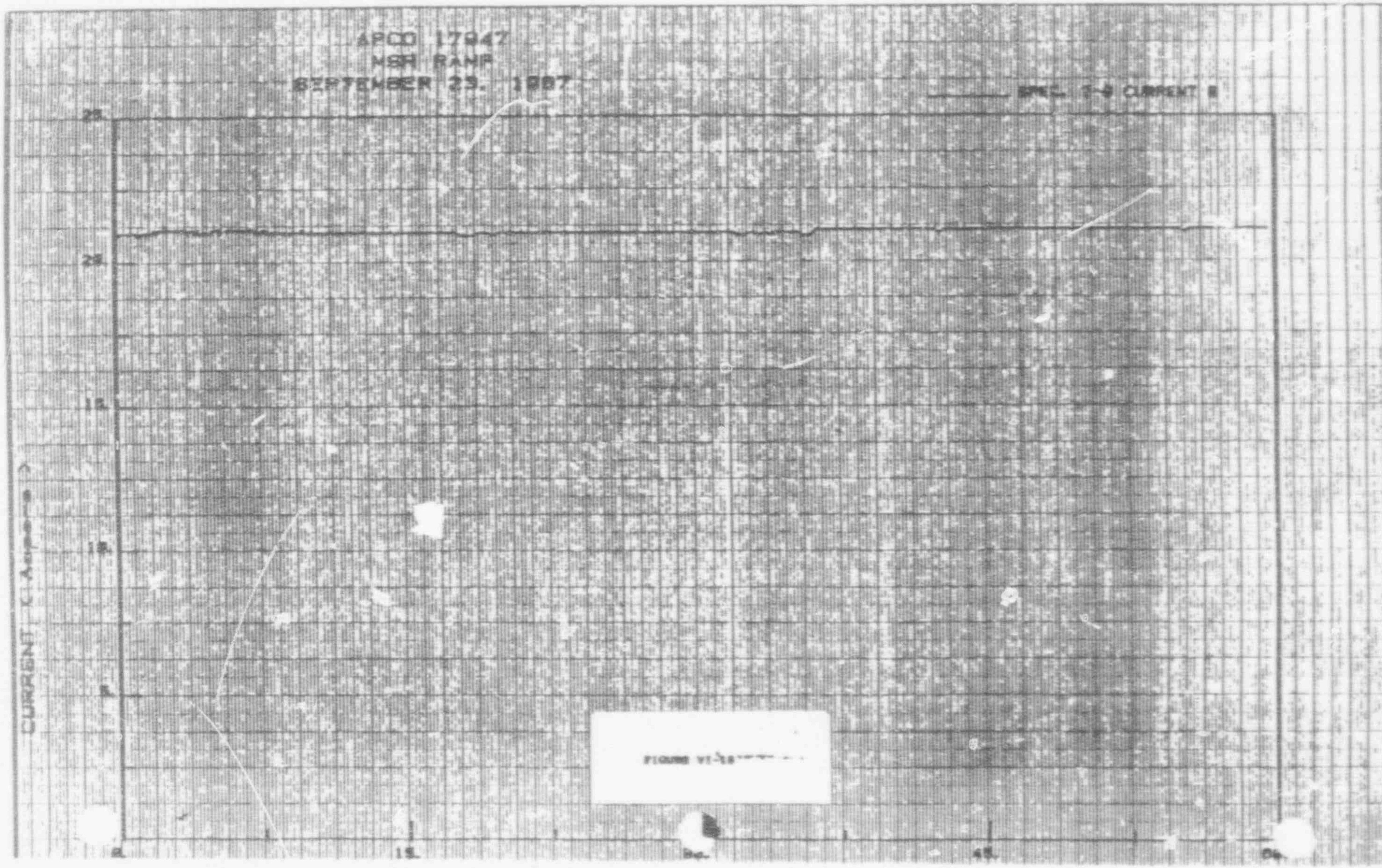


FIGURE VI-16


APCO 17947
MSR RAMP
SEPTEMBER 25, 1987
SPEC. 1-8 CURRENT B
CURRENT (Amperes)
25
20
15
10
5
0
15
30
45
60

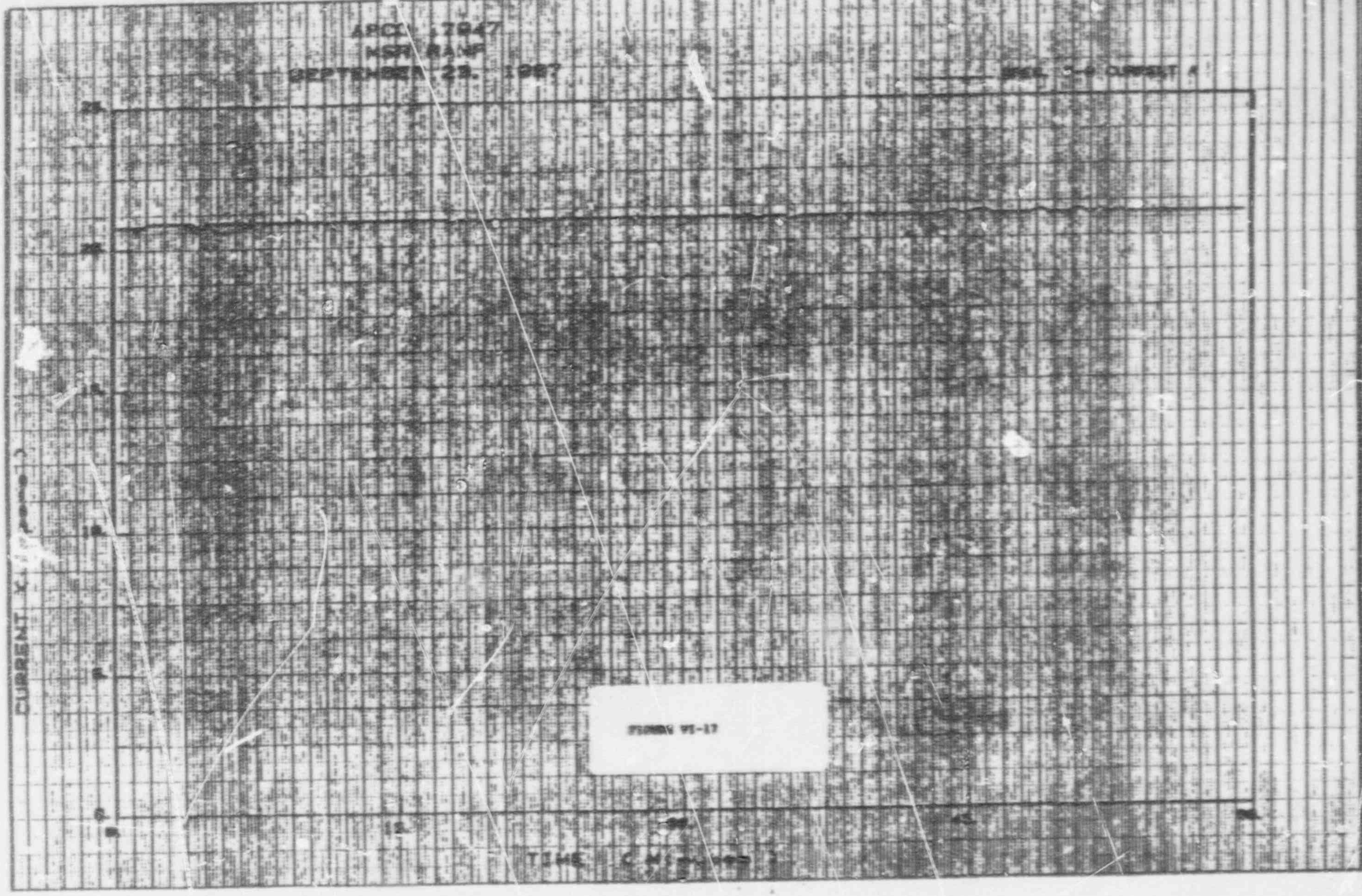


FIGURE VI-17

DEG EQUIV FOR WYLE TEST REPORT REPORT ON OKONITE FOR V-TYPE SPLICES

Activation Energy: .65 eV
Reference Temperature: 329.0556 degrees K
t 1 : 0 seconds
T 1 : 491.3334 degrees K
t 2 : 160560 seconds
T 2 : 390.7778 degrees K

Equivalent Time = 5999476 seconds
= 99991.26 minutes
= 1666.521 hours
= 69.43838 days
= .1902421 years

DEG EQUIV FOR WYLE TEST REPORT REPORT ON OKONITE FOR V-TYPE SPLICES

Activation Energy: .65 eV
Reference Temperature: 132.9 F

Plant Profile

Time (days)	Temperture (F)
1.166667E-04	338
1.166667E-04	385
1.166667E-04	406
2.333333E-04	414
5.833333E-05	399
5.833333E-05	386
1.166667E-04	370
2.333333E-04	340
3.458334E-04	277
1.018333E-02	269
3.009167E-02	259
3.240417E-02	255
.050925	250
.1111083	245
.2291667	230
.25	216
.2847209	200
10	192
109	120

Equivalent Time = 169.9495 days

Test Profile

Time (days)	Temperature (F)
0	425
1.858333	244

Equivalent Time = 69.43838

APPENDIX VII

CONTAINMENT LOCA TEST TEMPERATURE/PRESSURE PROFILE AND CHEMICAL SPRAY FLOWRATE

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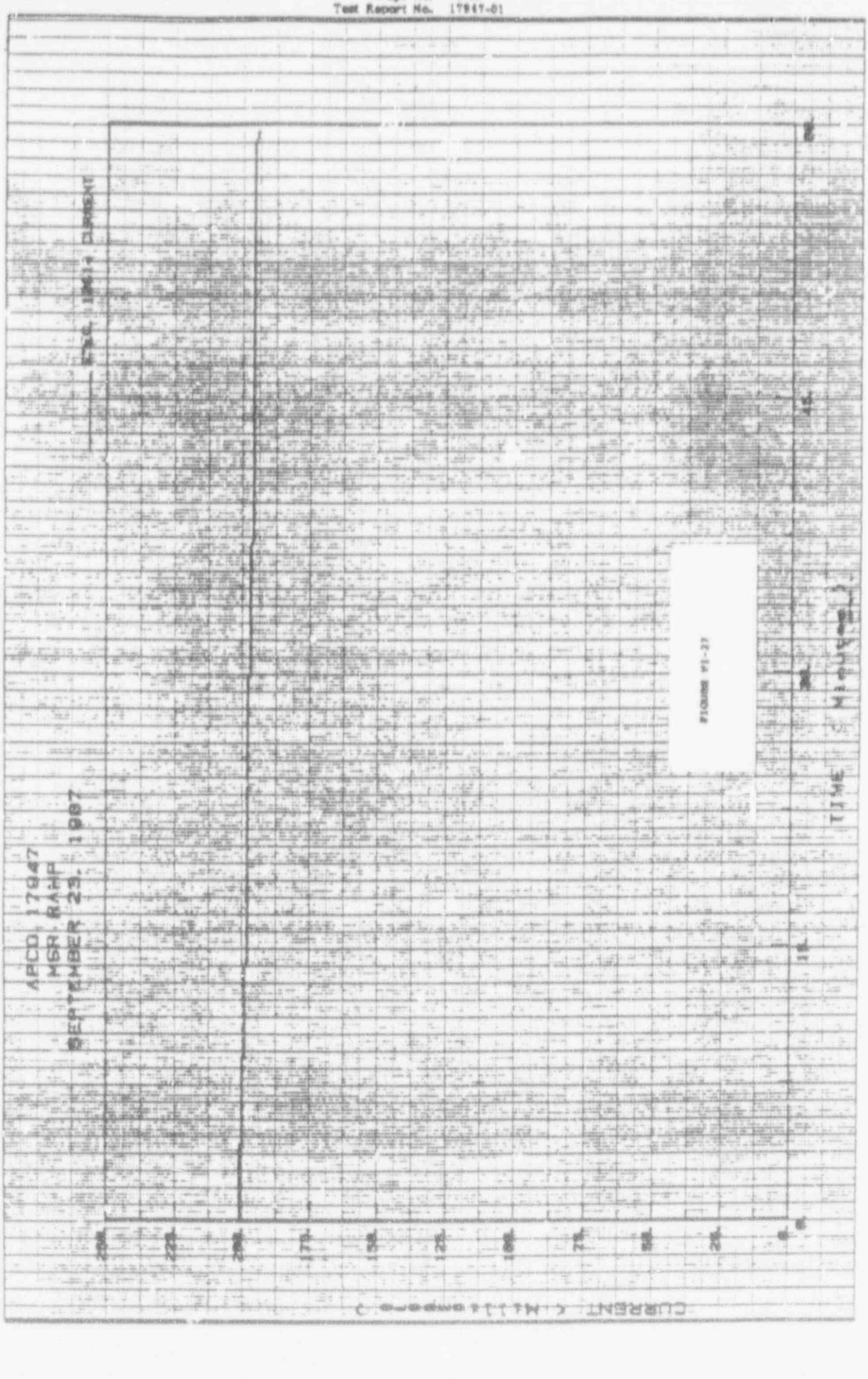
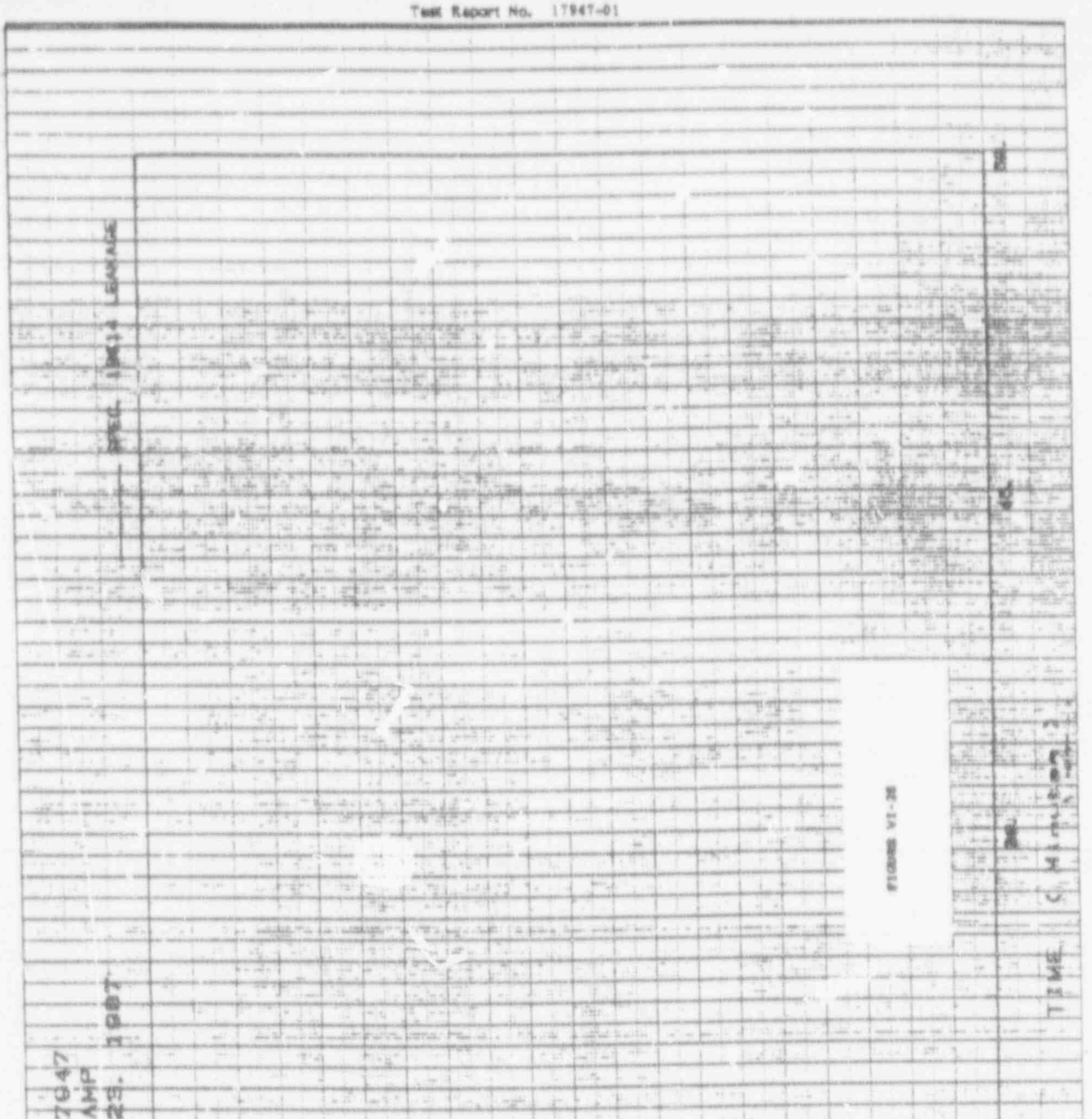
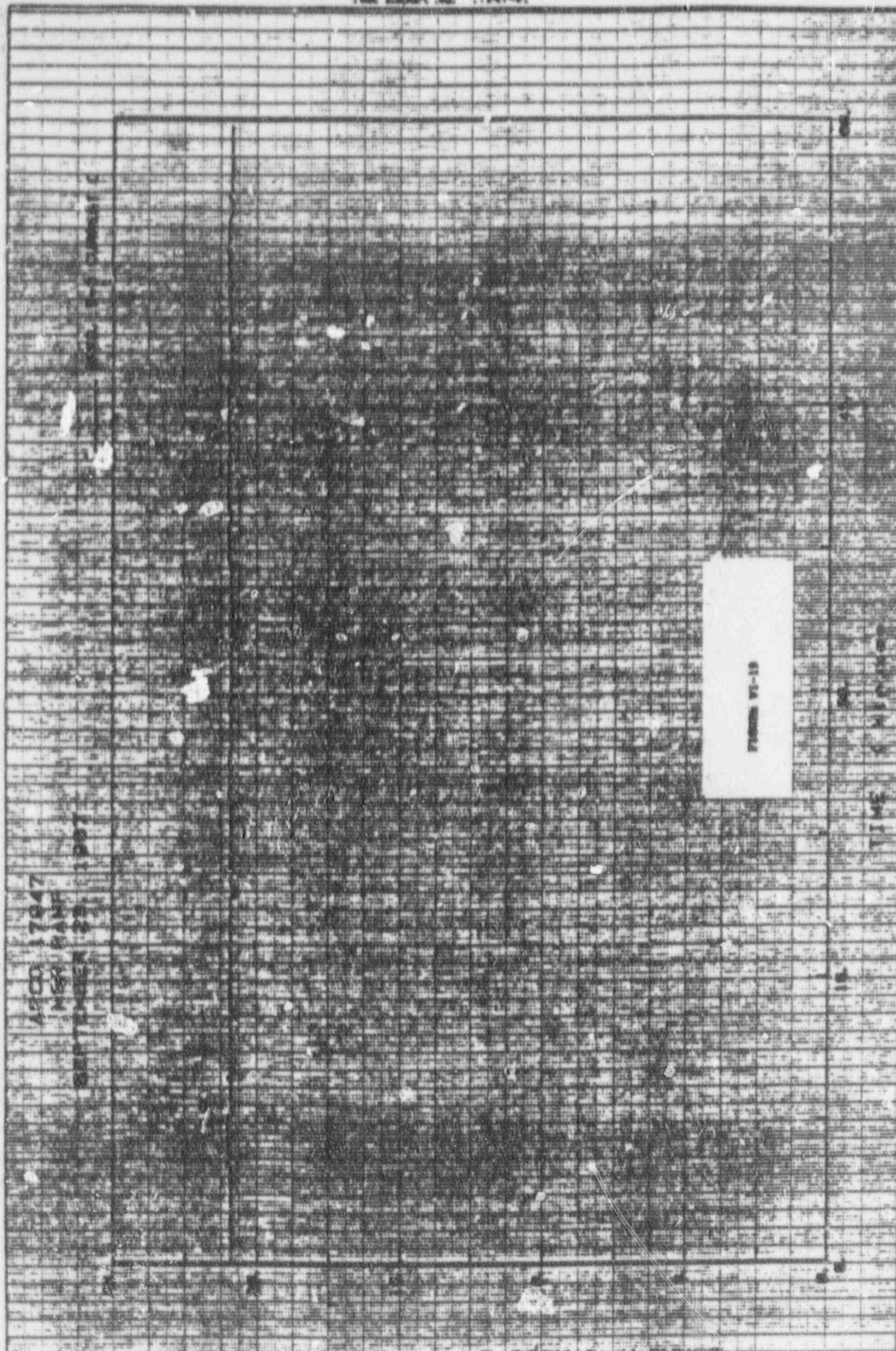

APCD 17947
MSR RAMP
SEPTEMBER 23, 1987
CURRENT (Milliampere)
TIME (Minutes)
200.
225.
200.
175.
150.
125.
100.
75.
50.
25.
0.
0.
15.
30.
45.
60.


ARCD 17947
MSR RAMP
SEPTEMBER 23, 1987
TIME (Minutes)
LEAKAGE



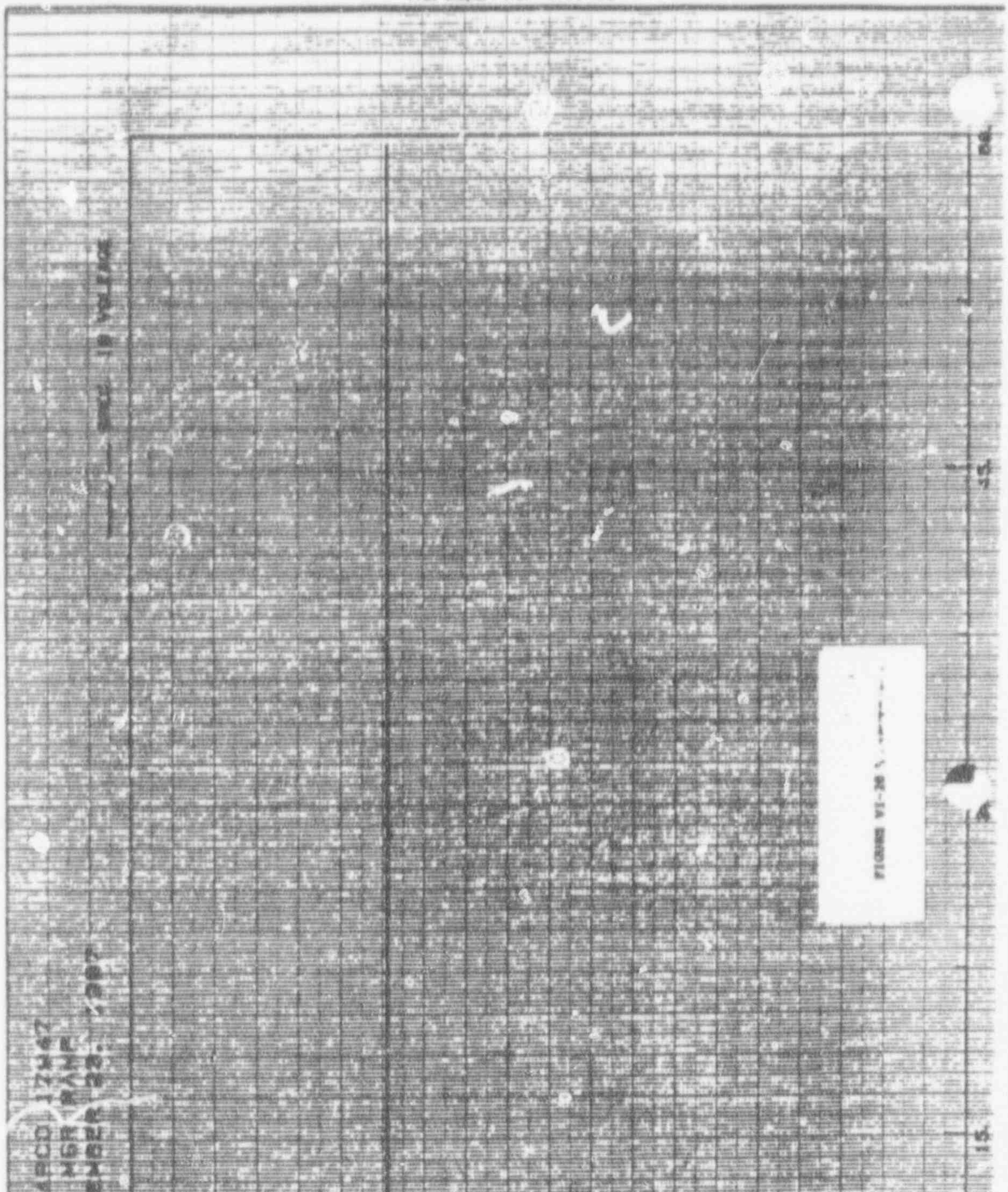


FIGURE VI-20

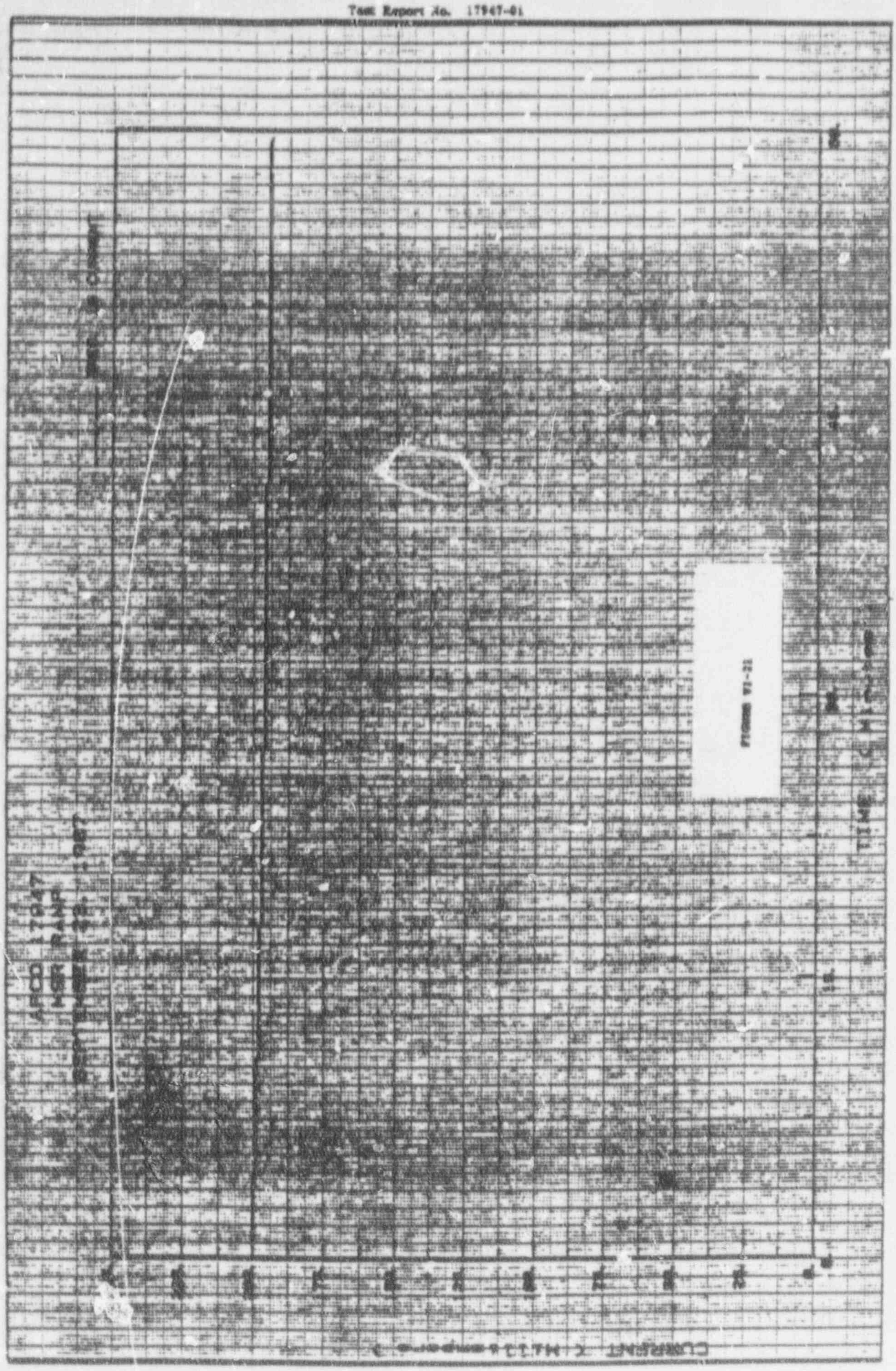


FIGURE VI-21

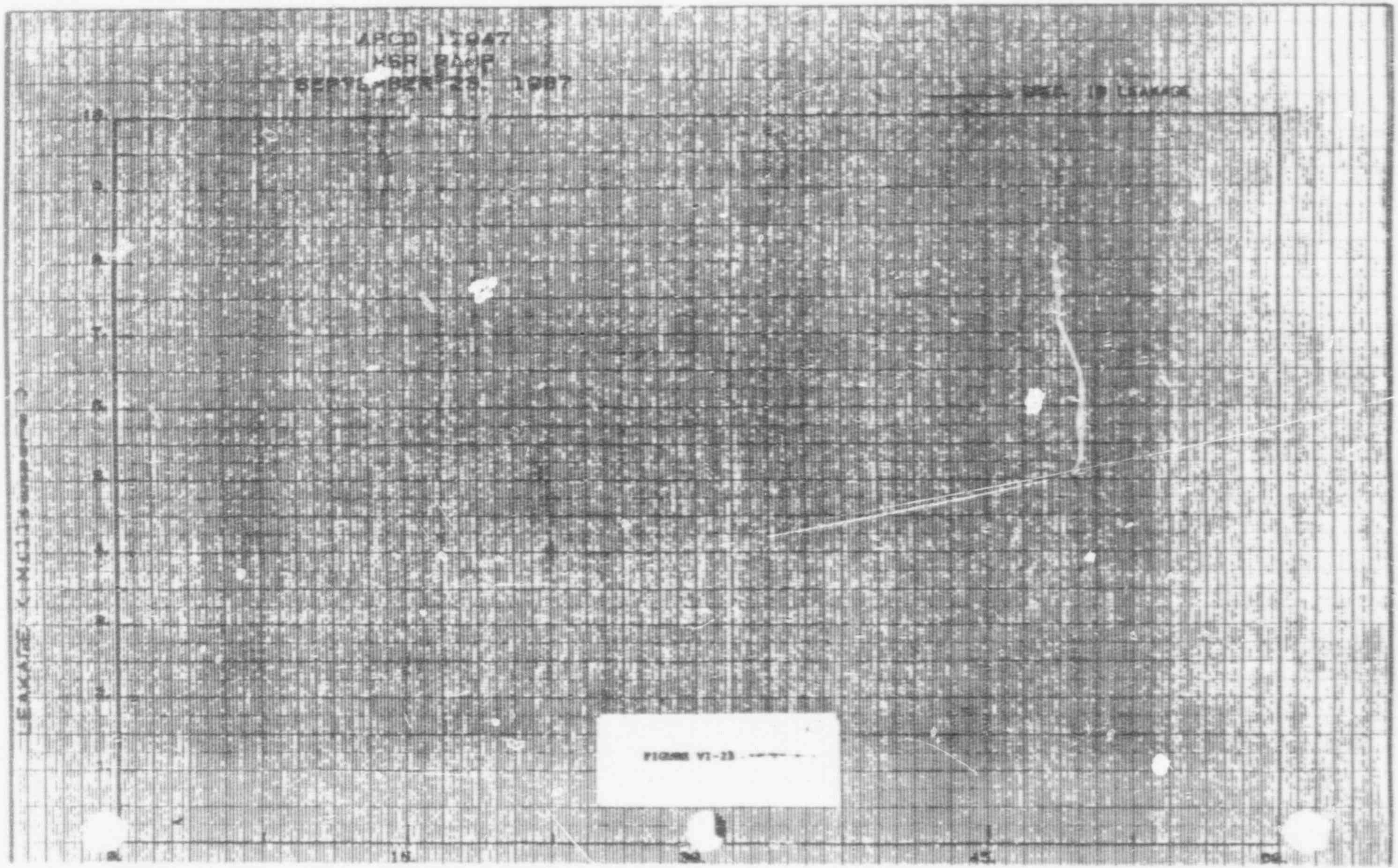

ARCO 17947
MSR RAMP
SEPTEMBER 25, 1987
SPEC. IB LEAKAGE
LEAKAGE
10
15
30
45
60

FIGURE VI-23

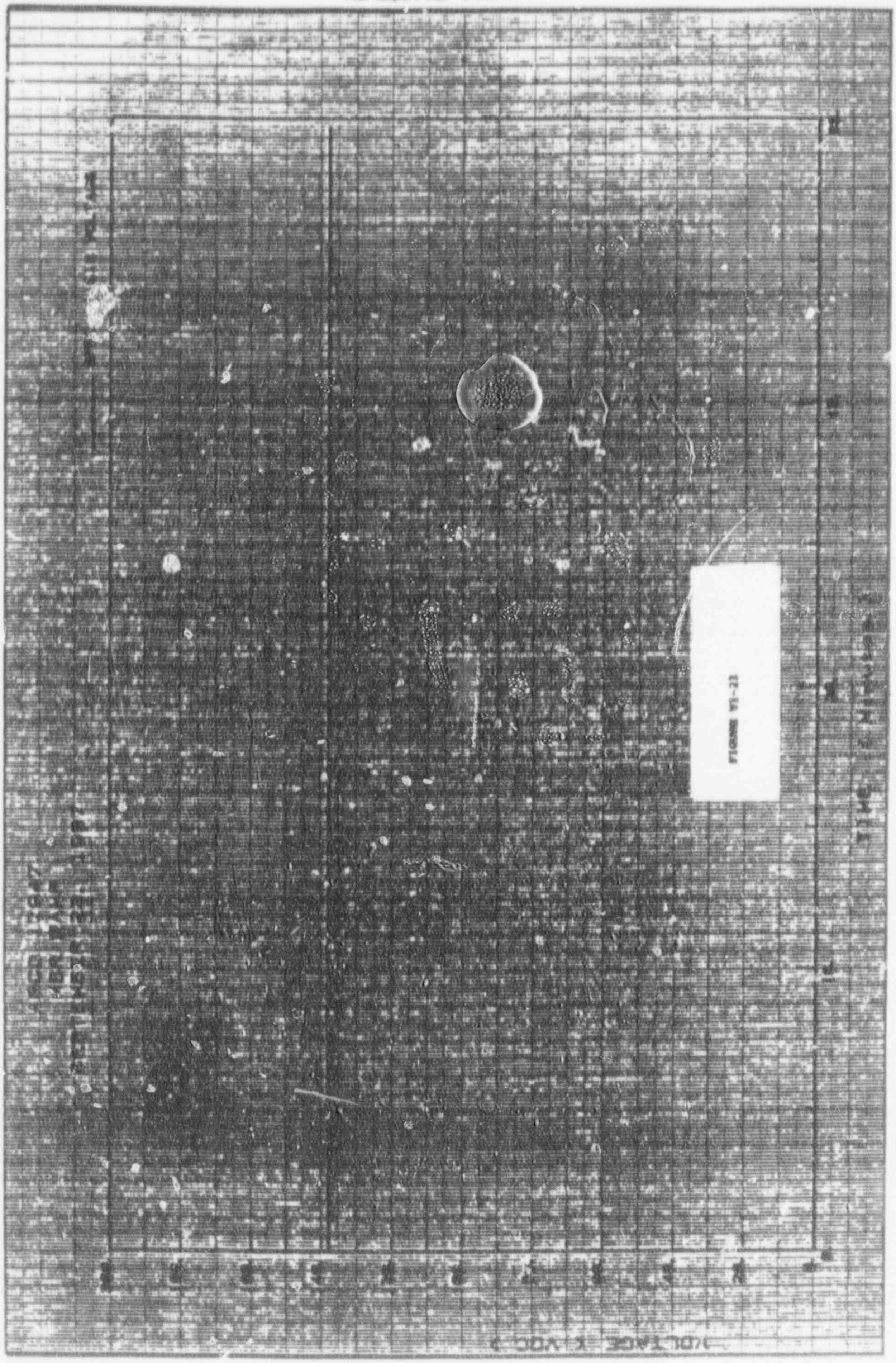
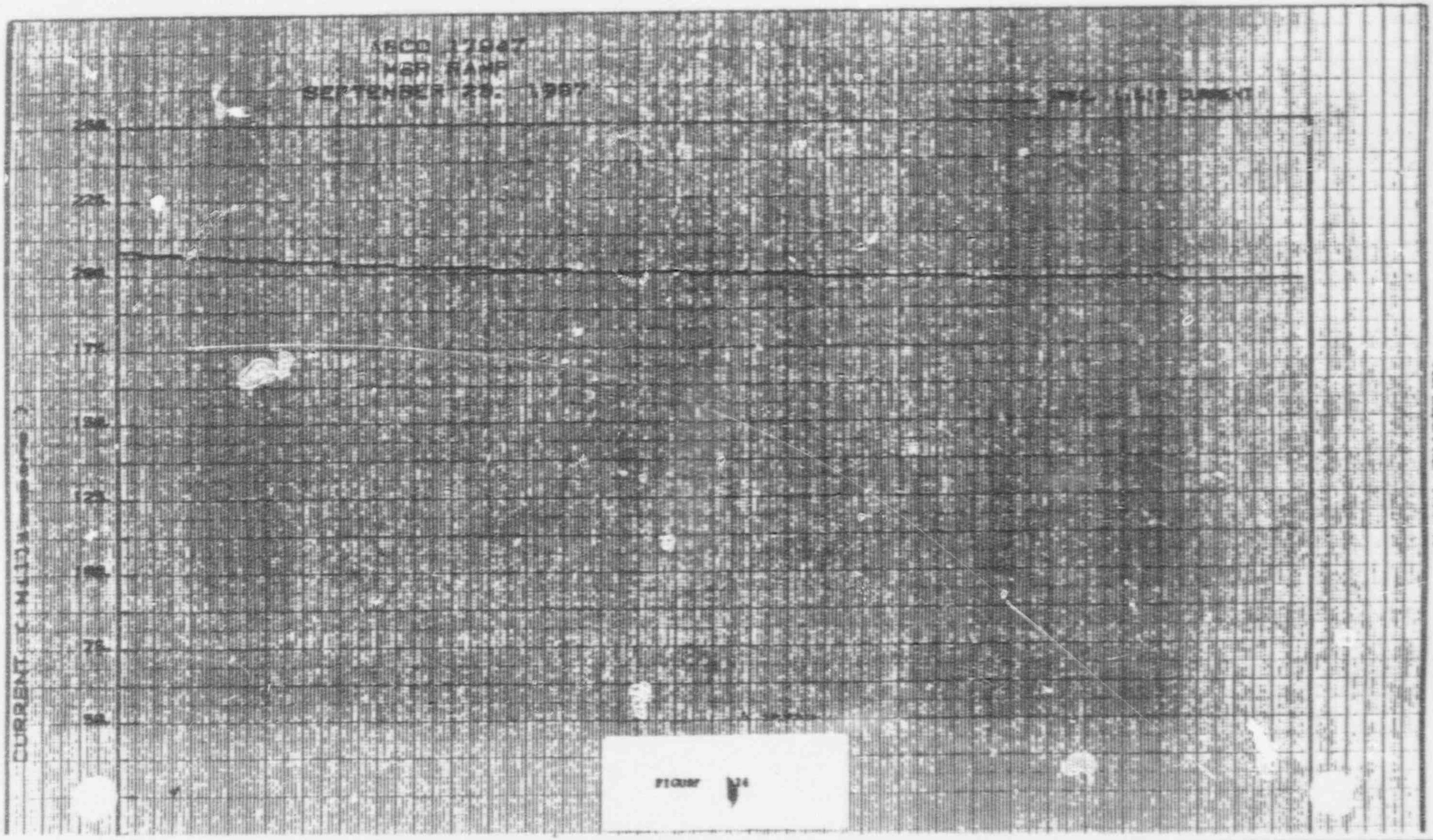


FIGURE VI-23


ABCD 17047
MSR RAMP
SEPTEMBER 23, 1987
250
225
200
175
150
125
100
75
50
CURRENT

FIGURE

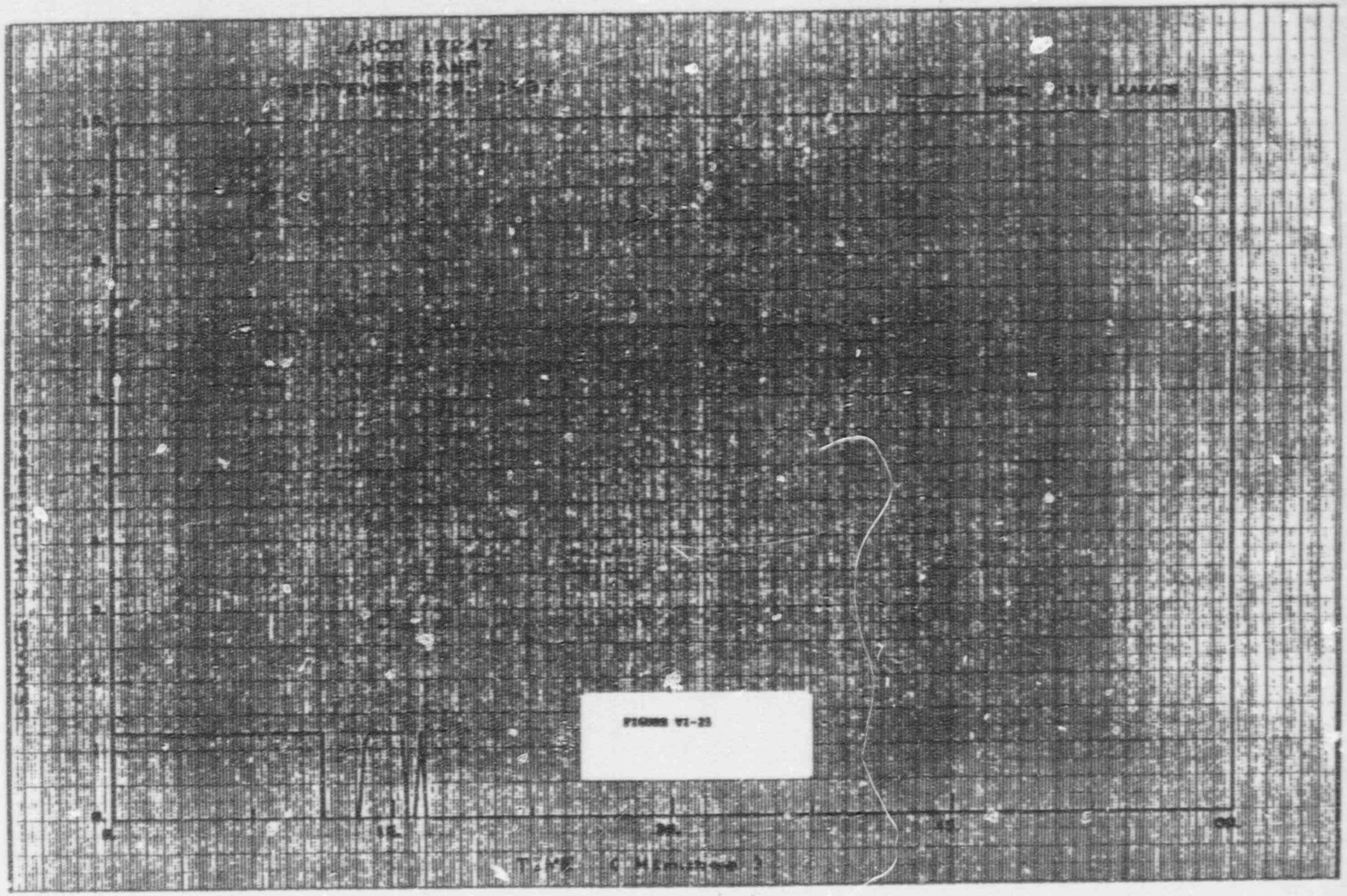
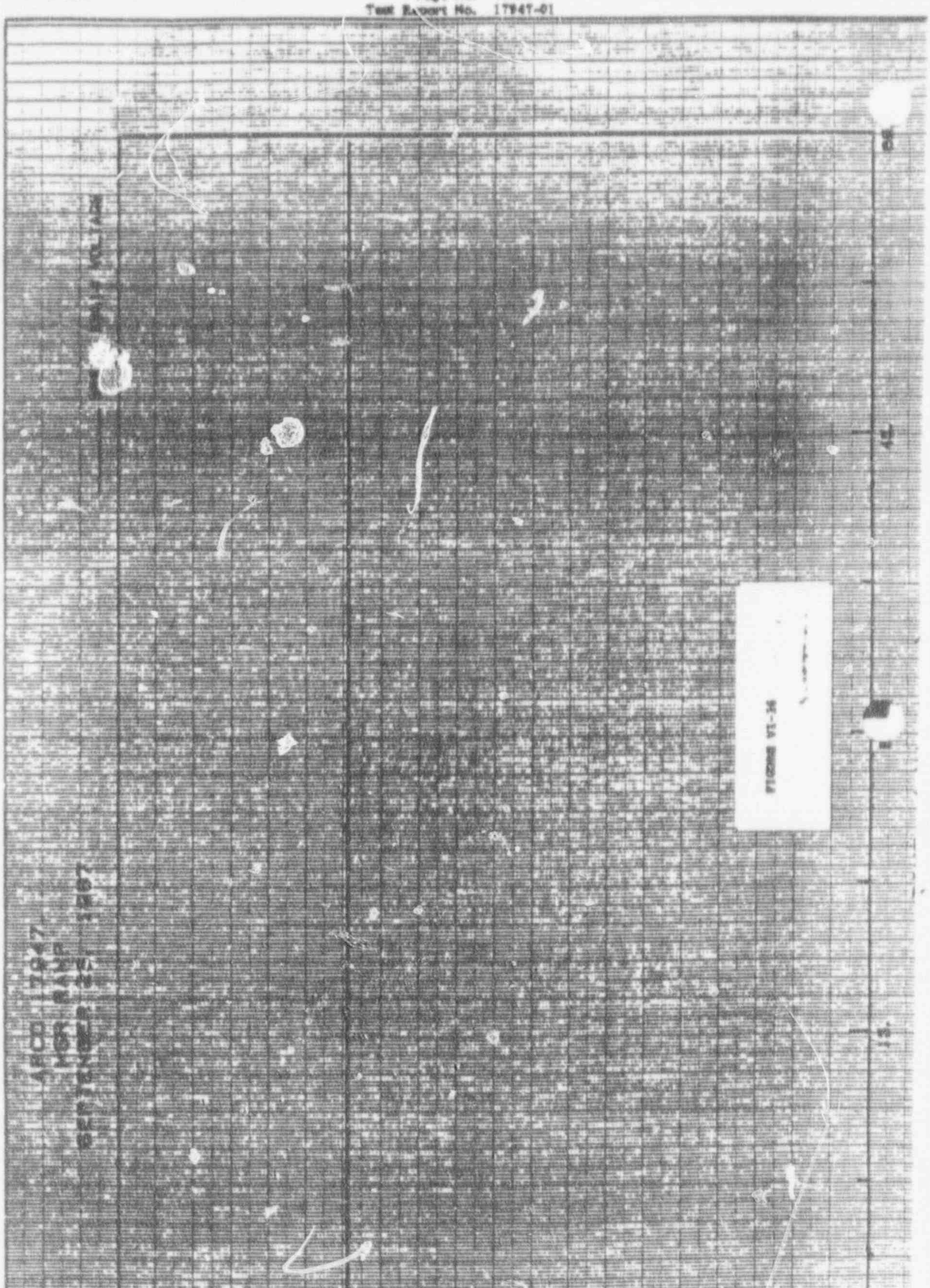


FIGURE VI-23


ARCO 17947
HCR RAMP
SEPTEMBER 25, 1987
VOLTAGE (VDC)

APPENDIX VIII

CONTAINMENT LOCA TEST ELECTRICAL DATA

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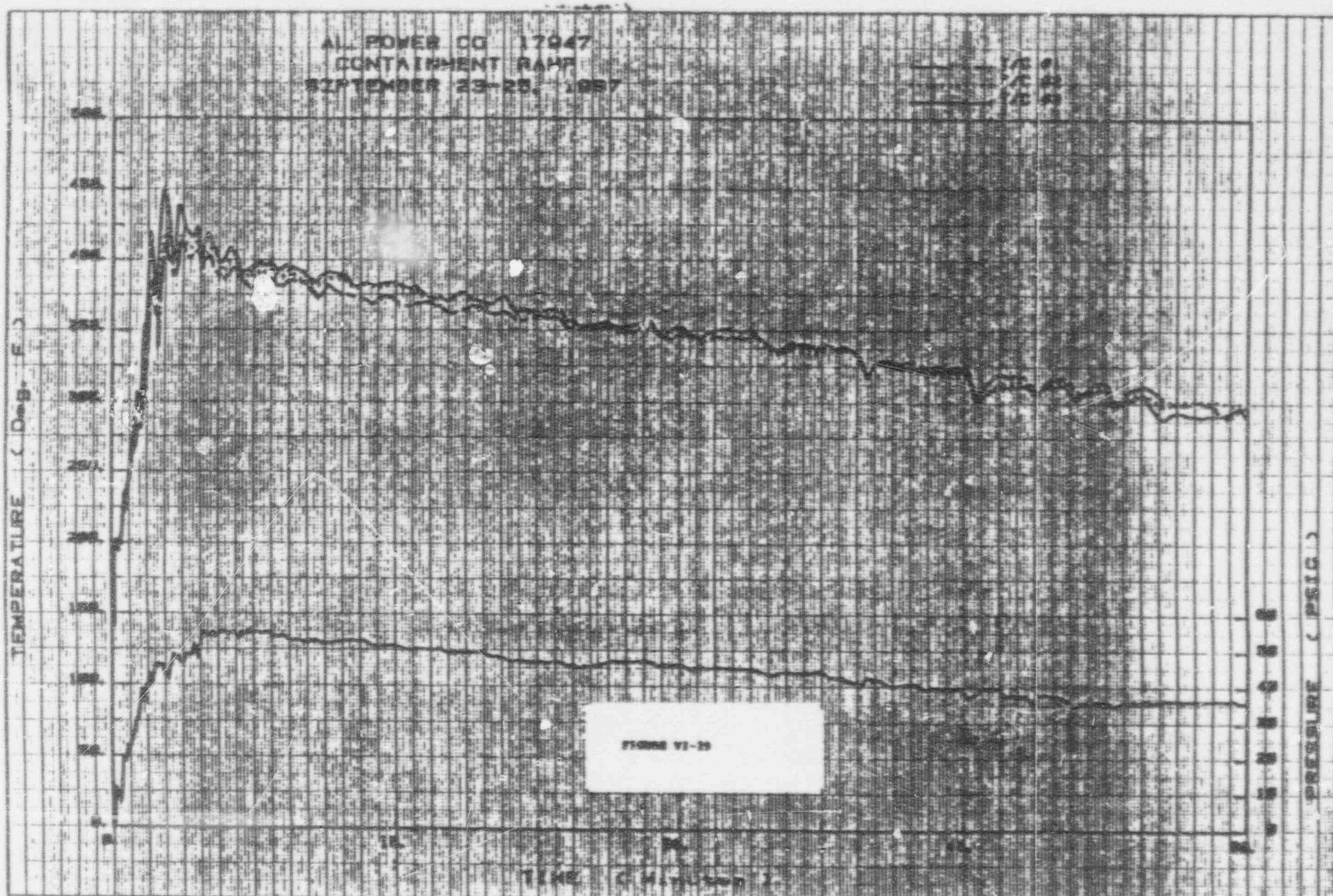
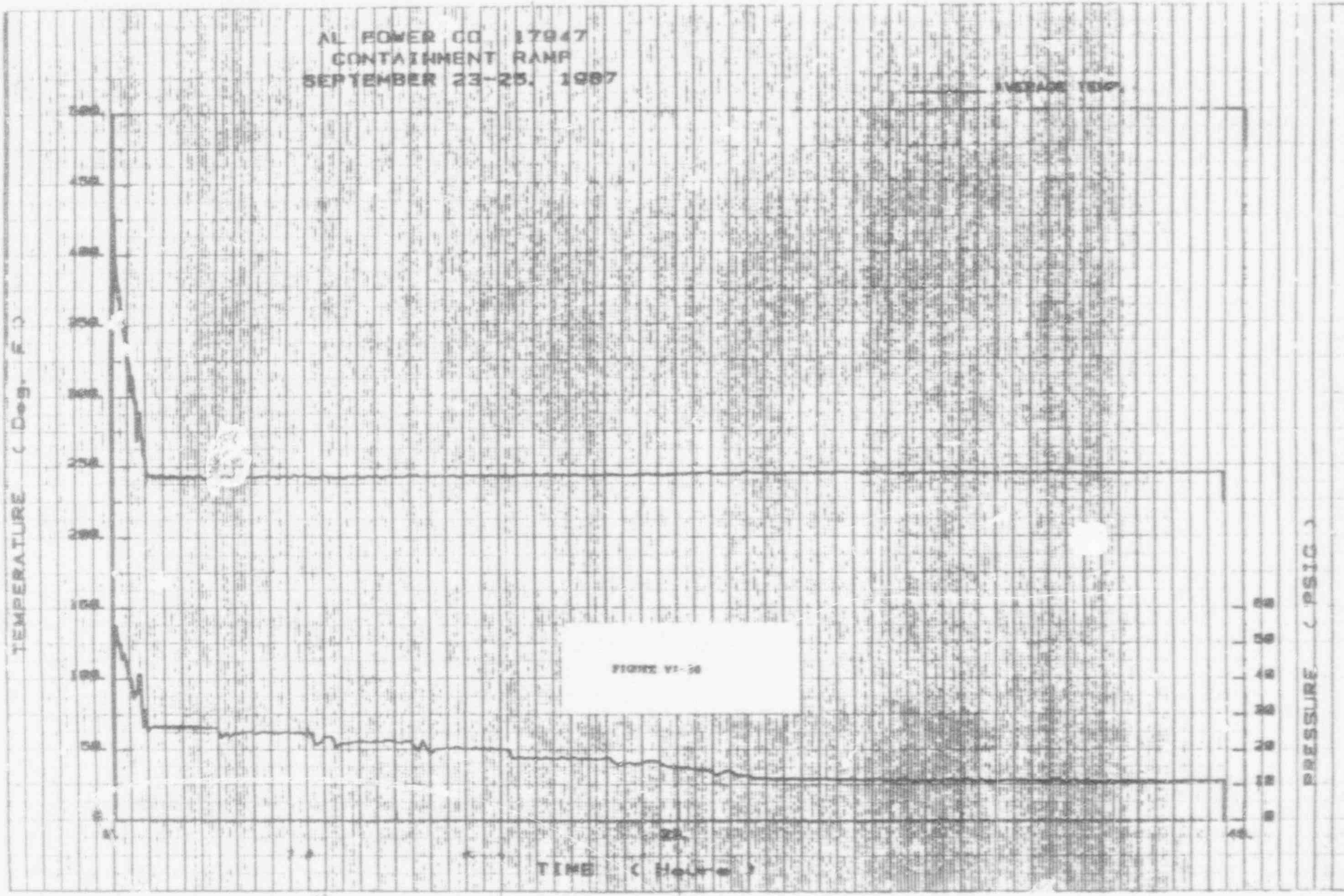

AL POWER CO 17947
CONTAINMENT RAMP
SEPTEMBER 23-25, 1987
TEMPERATURE (Deg. F)
PRESSURE (PSIG)
TIME (Minutes)

FIGURE VI-29


AL POWER CO 17947
CONTAINMENT RAMP
SEPTEMBER 23-25, 1987
AVERAGE TEMP.
TEMPERATURE (Deg. F)
500.
450.
400.
350.
300.
250.
200.
150.
100.
50.
0.
PRESSURE (PSIG)
60
50
40
30
20
10
0
TIME (Hours)
24.
48.

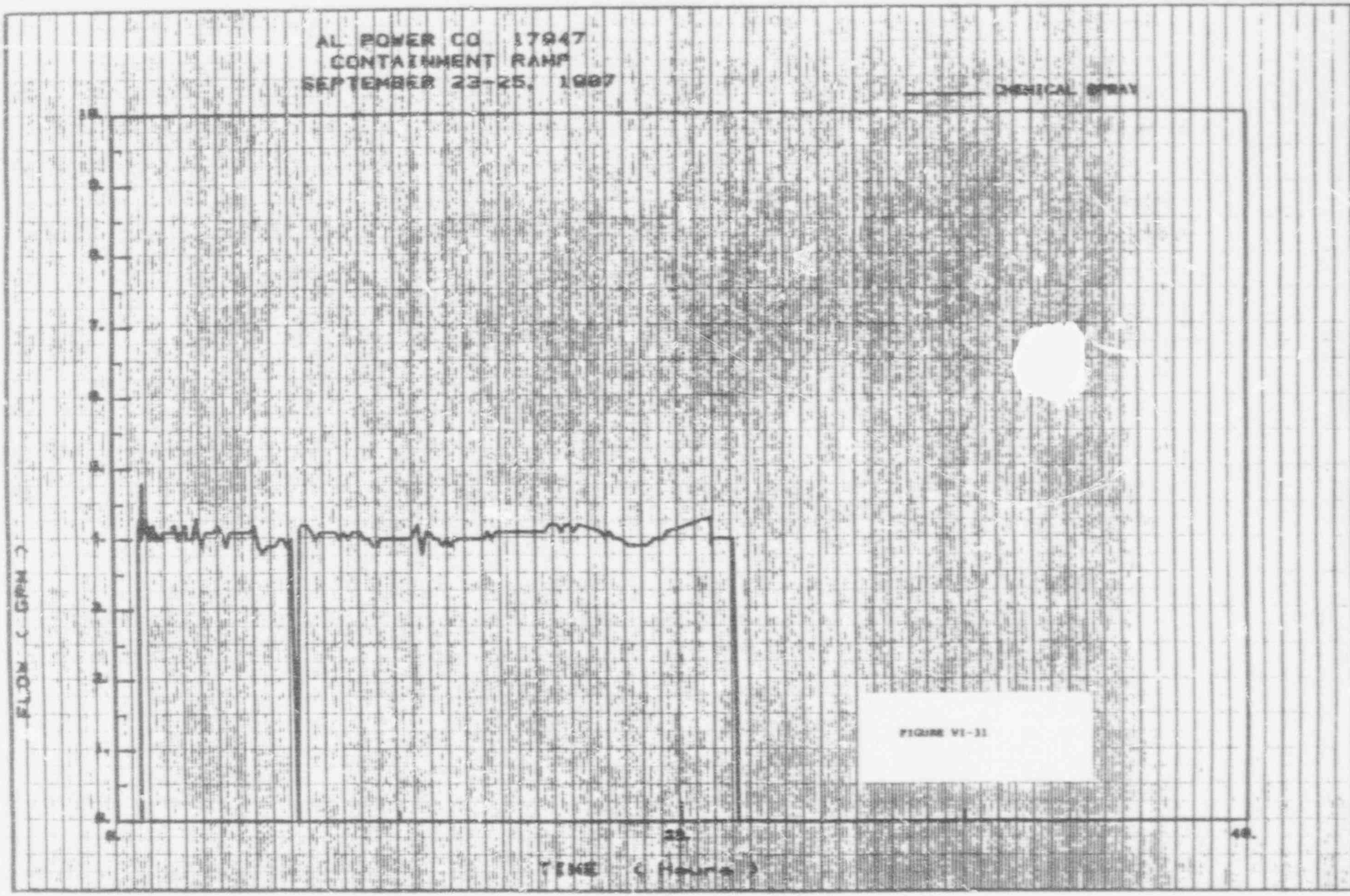

AL POWER CO 17947
CONTAINMENT RAMP
SEPTEMBER 23-25, 1987
CHEMICAL SPRAY
FLOW (GPM)
TIME (Hours)

FIGURE VI-31

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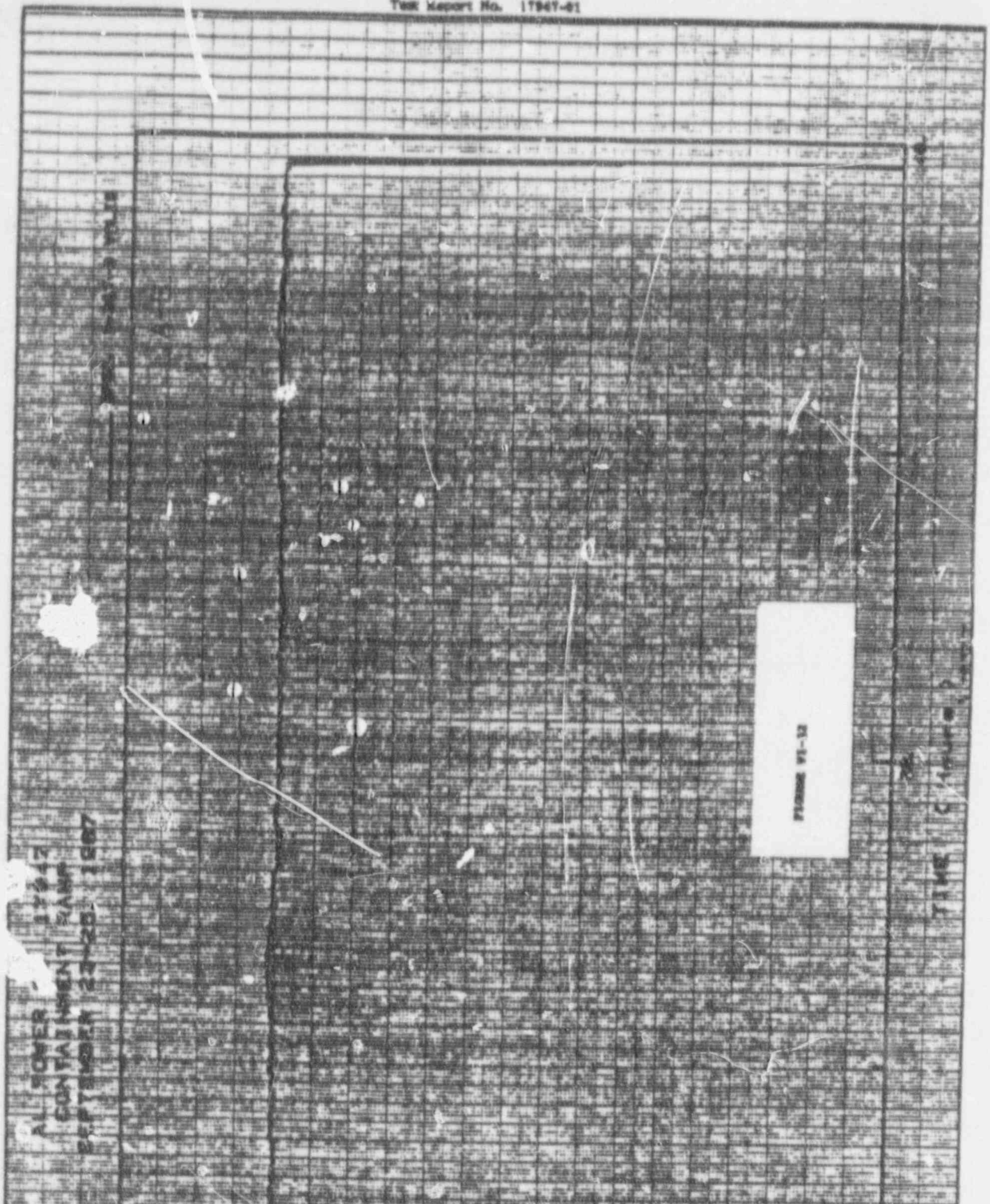
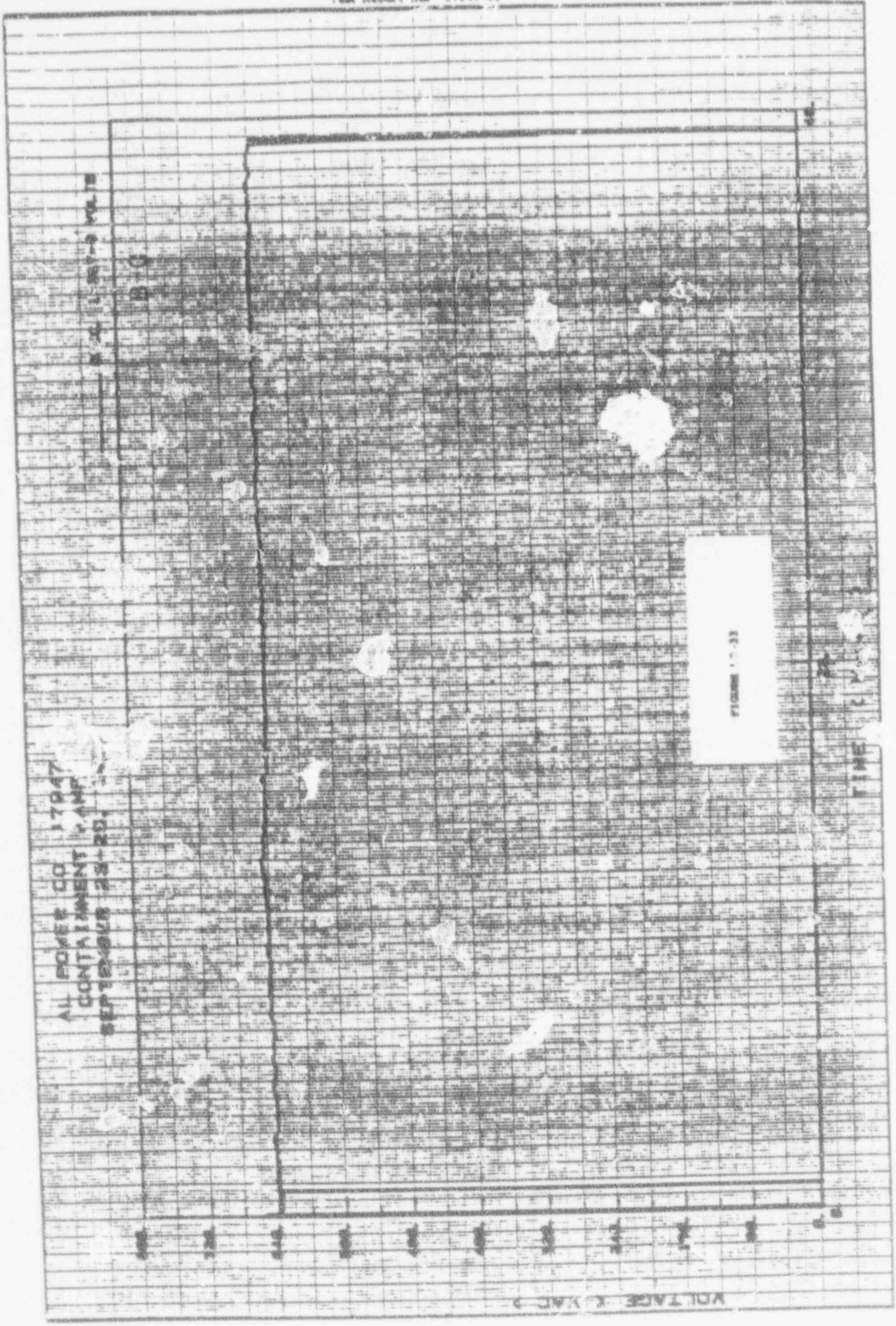
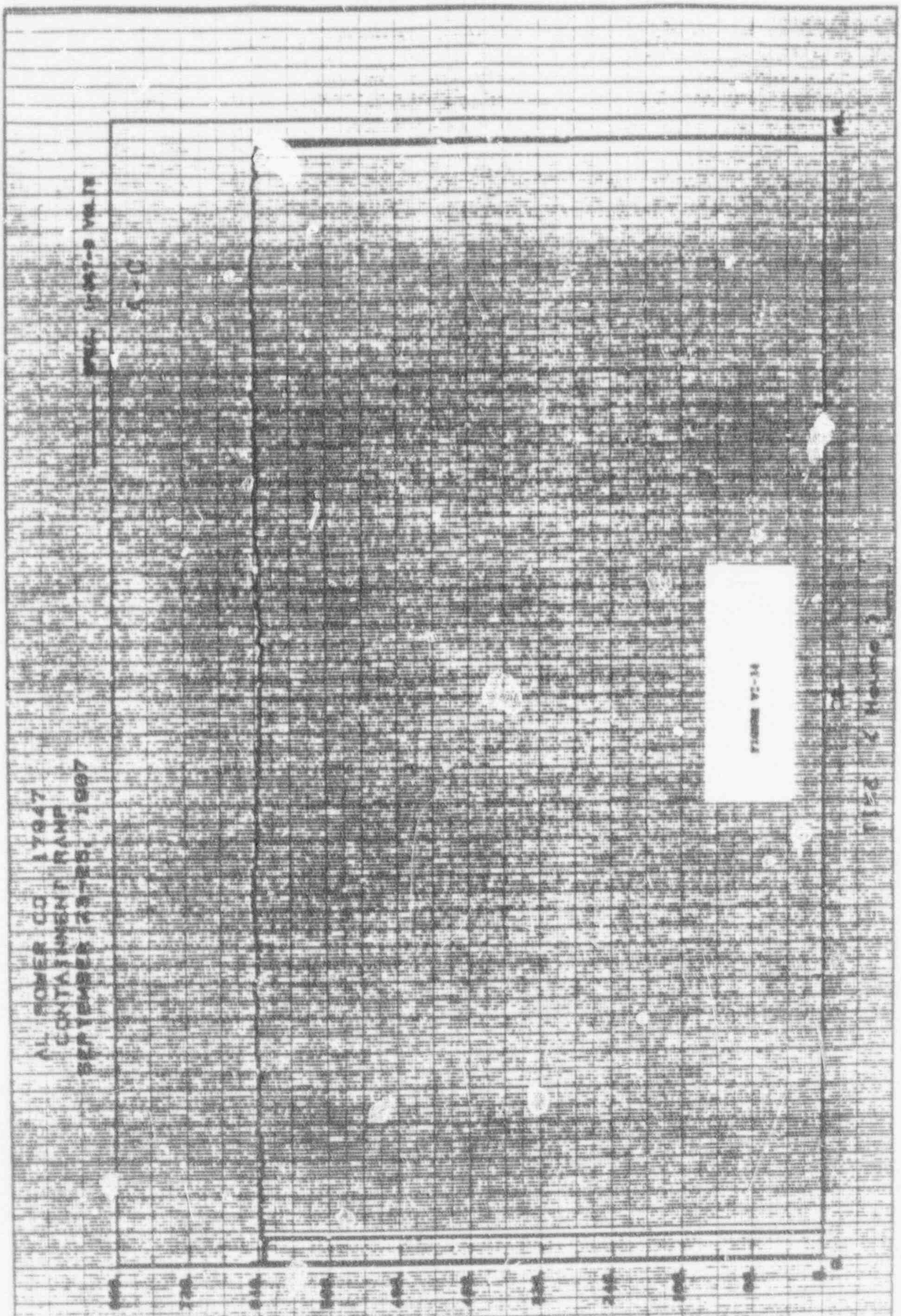
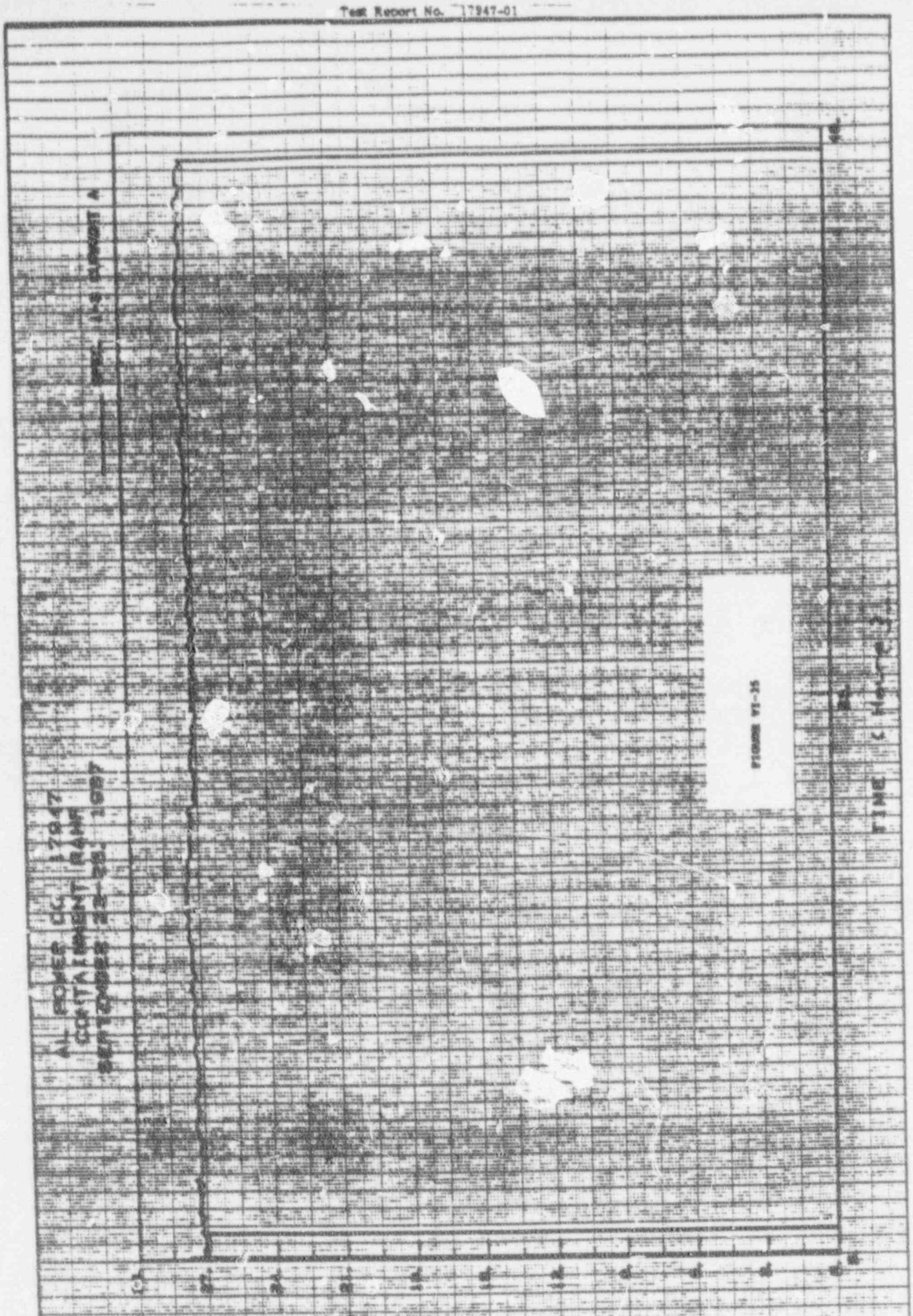
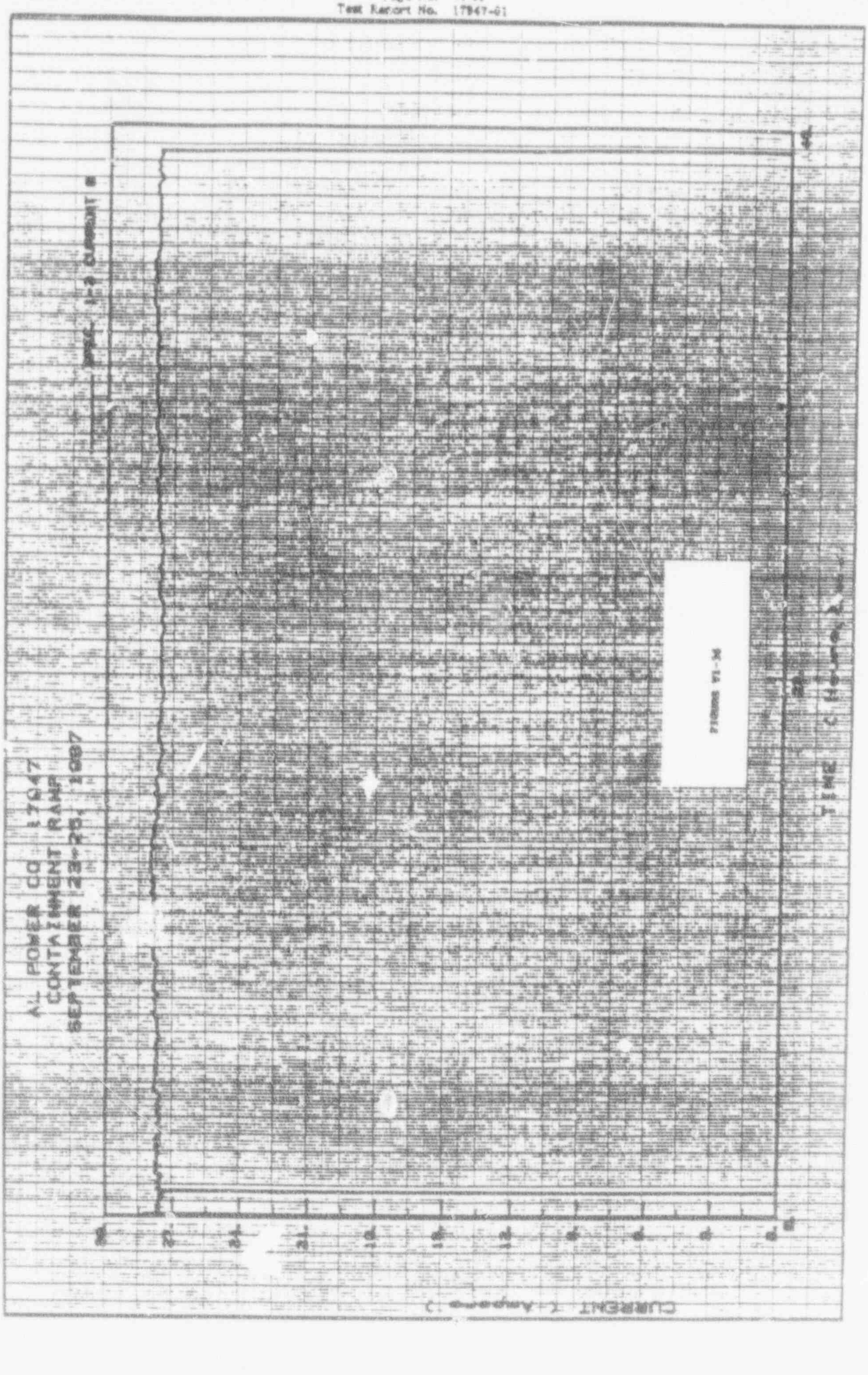

A. POWER 17947
CONTAINMENT RAMP
SEPTEMBER 23-28, 1987
TIME (Hours)
VOLTAGE (VAC)

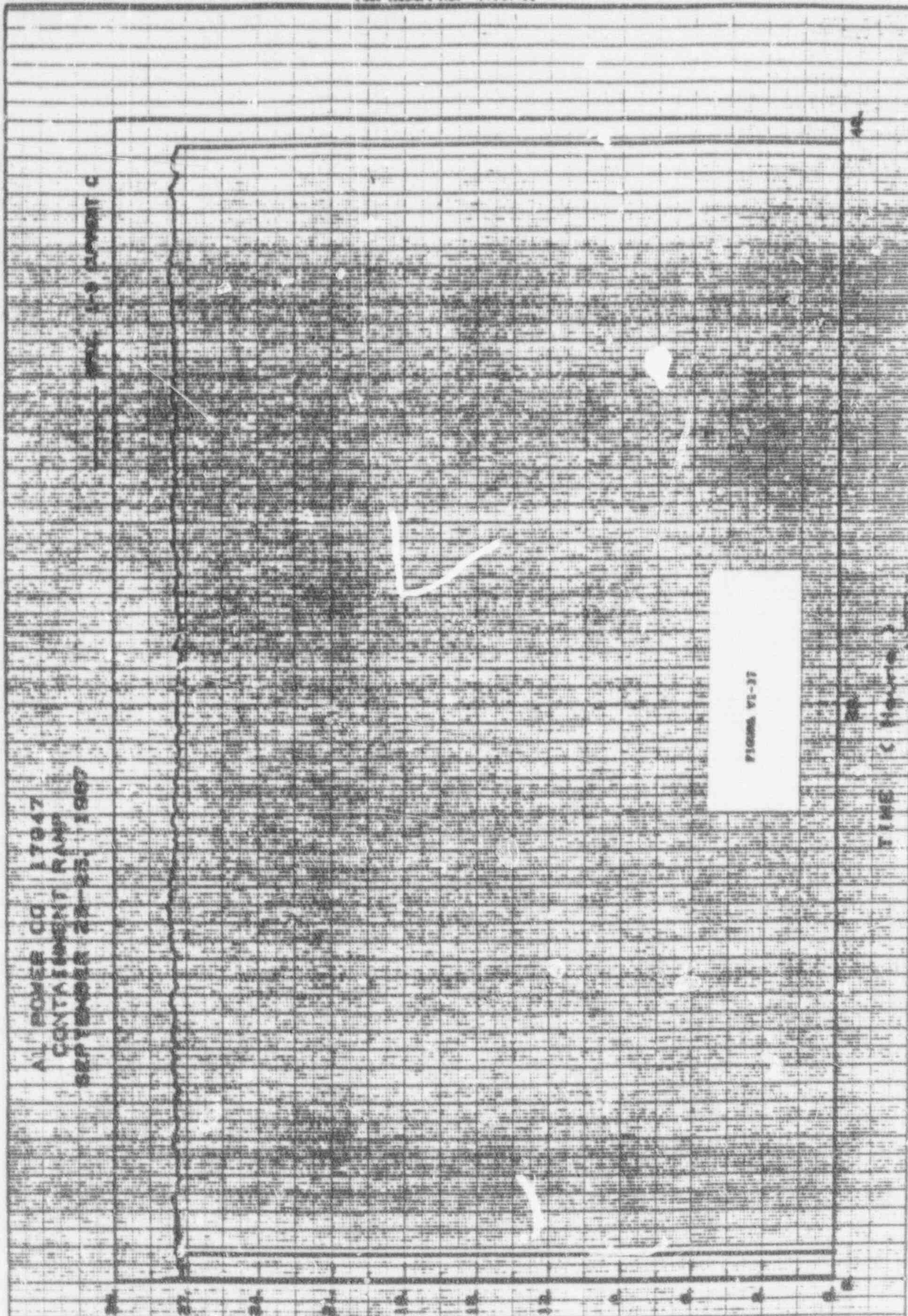
FIGURE VI-12

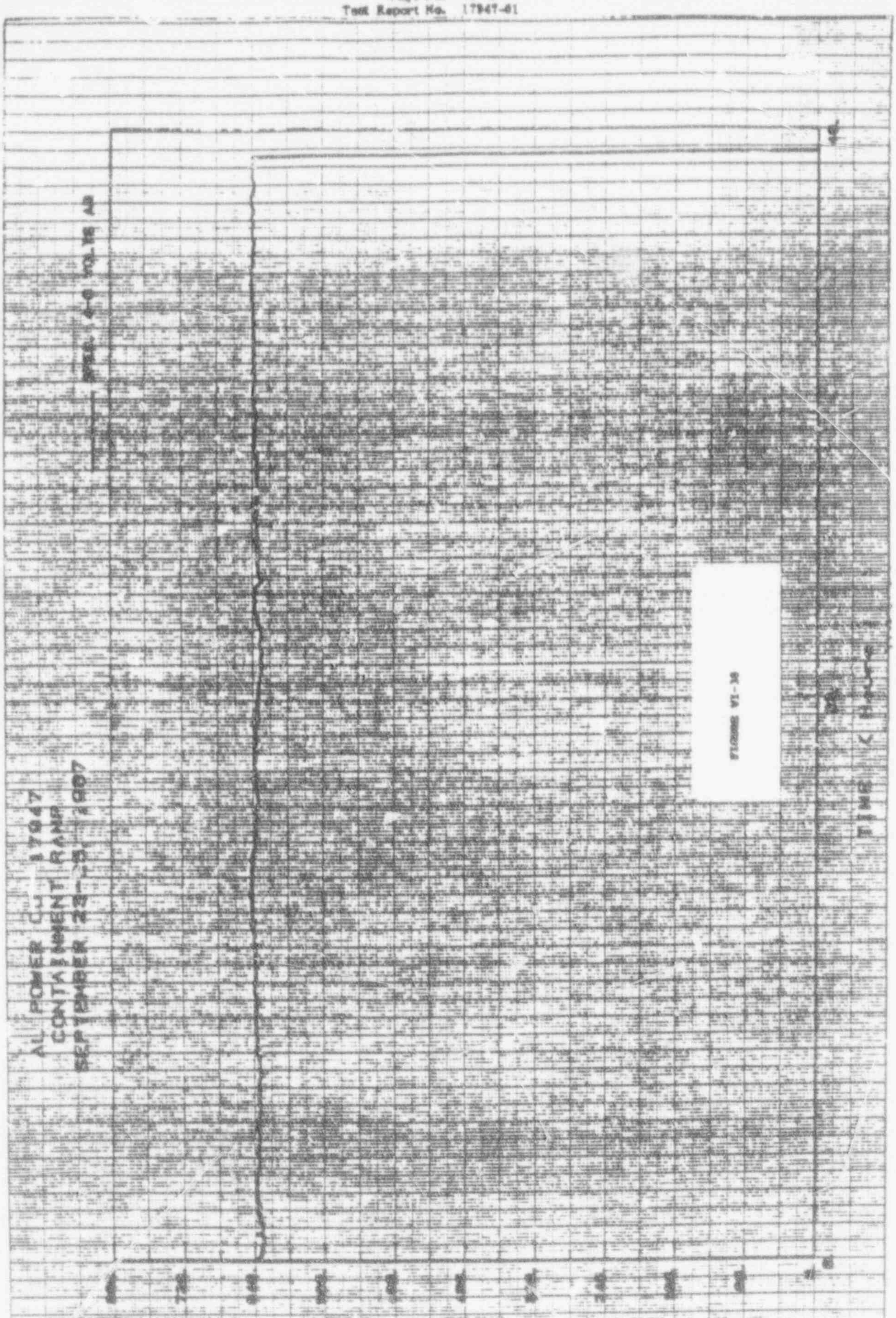

AL POWER CO 17947
CONTAINMENT
SEPTEMBER 23-20,
TIME
VOLTAGE (VAC)


AL POWER CO 17947
CONTAINMENT RAMP
SEPTEMBER 23-25, 1987
A-C
VOLTAGE (VAC)
TIME (Hours)


AL POWER CO. 17947
CONTAINMENT RAMP
SEPTEMBER 22-25, 1987
FIGURE VI-25
TIME (Hours)
CURRENT (Amperes)
0
3
6
9
12
15
18
21
24
27
30
24
48


AL POWER CO 17047
CONTAINMENT RAMP
SEPTEMBER 23-25, 1987
CURRENT (Amps)
TIME (Hours)


AT POWER CO 17947
CONTAINMENT RAMP
SEPTEMBER 23-25, 1987
TIME (Hours)
CURRENT (Amps)


CONTAINMENT RAMP
TIME (Hours)
VOLTAGE (VAC)

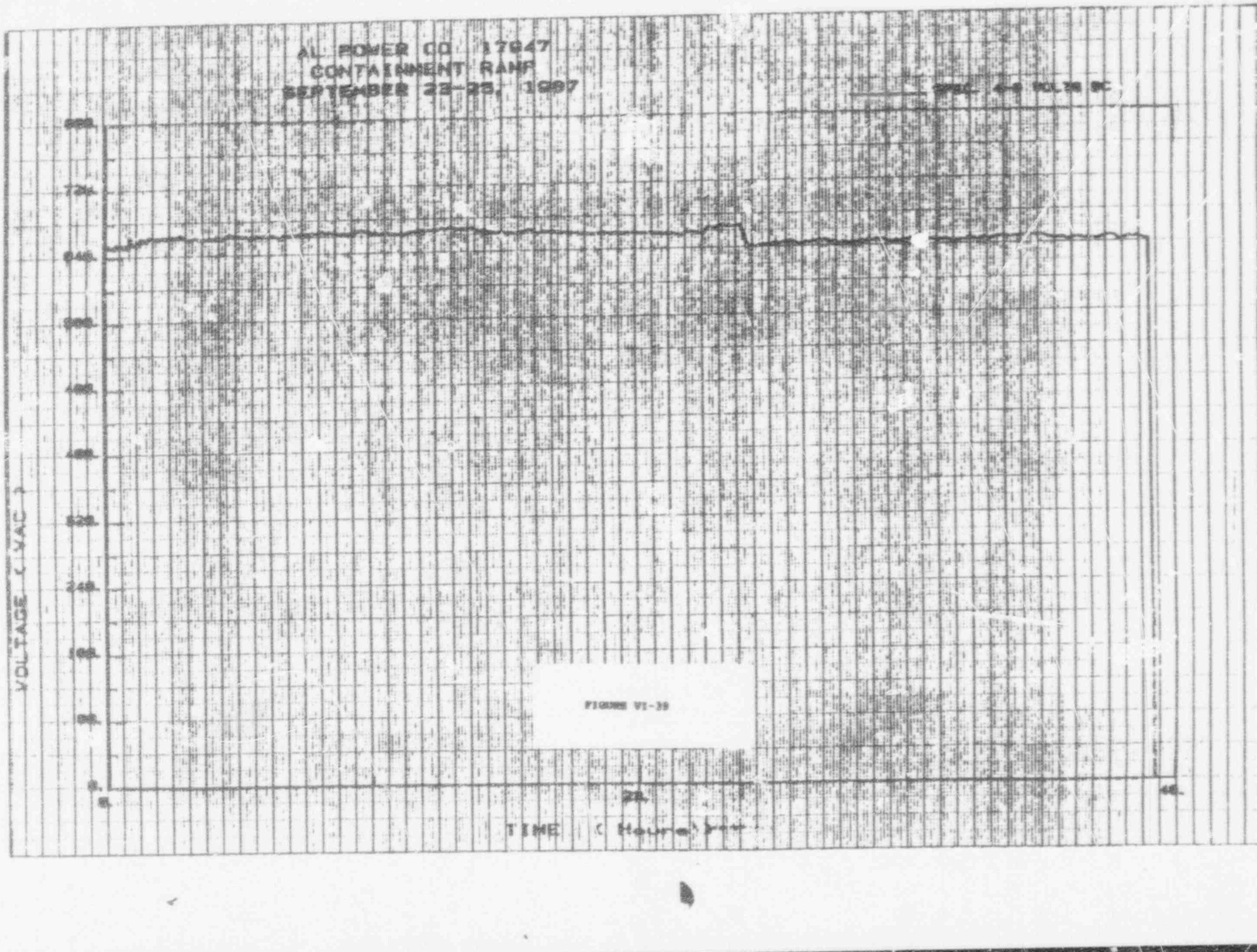
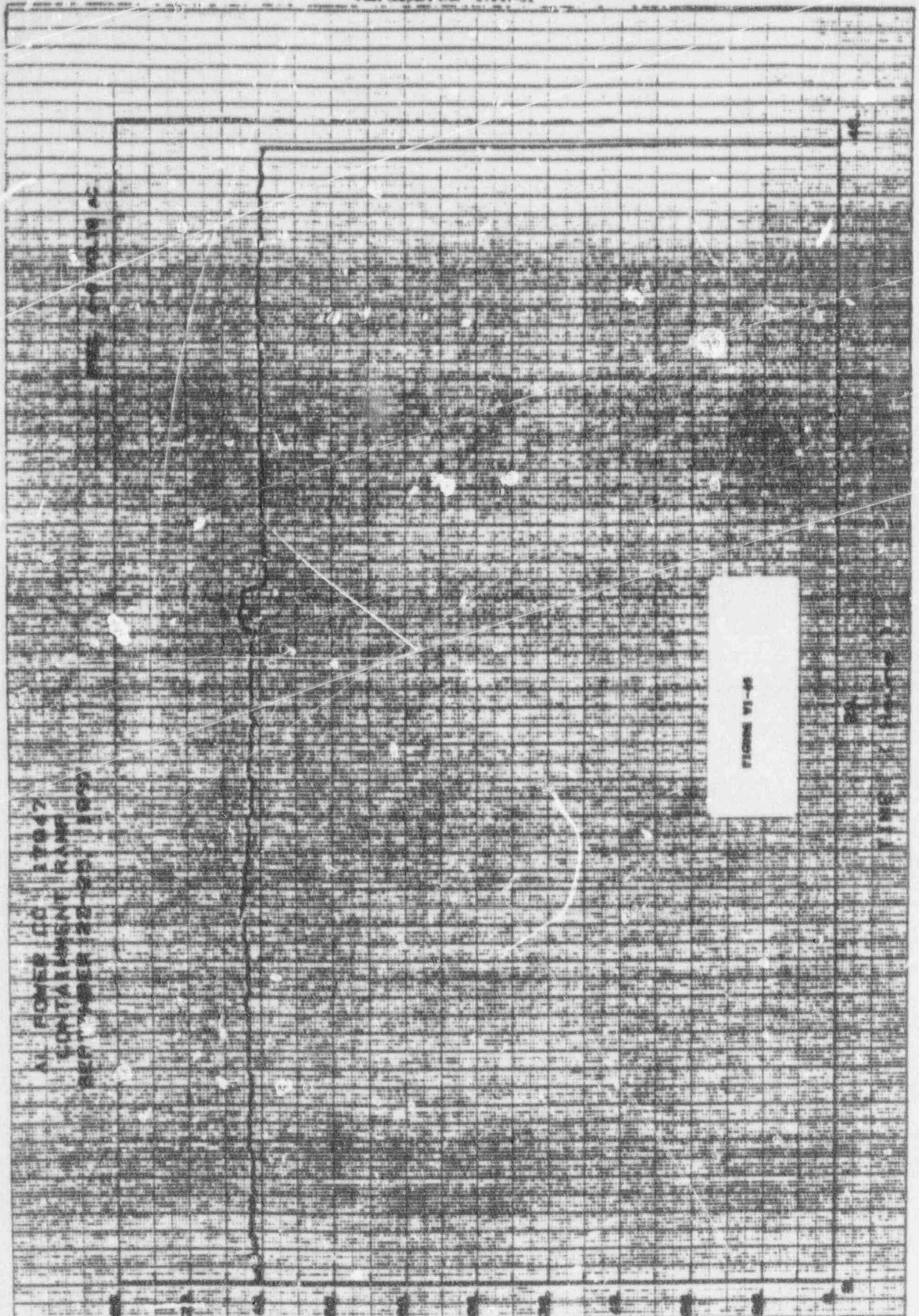

AL POWER CO 17947
CONTAINMENT RAMP
SEPTEMBER 22-25, 1987
SPEC 4-6 VOLTS DC
800.
720.
640.
560.
480.
400.
320.
240.
160.
80.
0.
VOLTAGE (VAC)
0.
20.
40.
TIME (Hours)

FIGURE VI-39



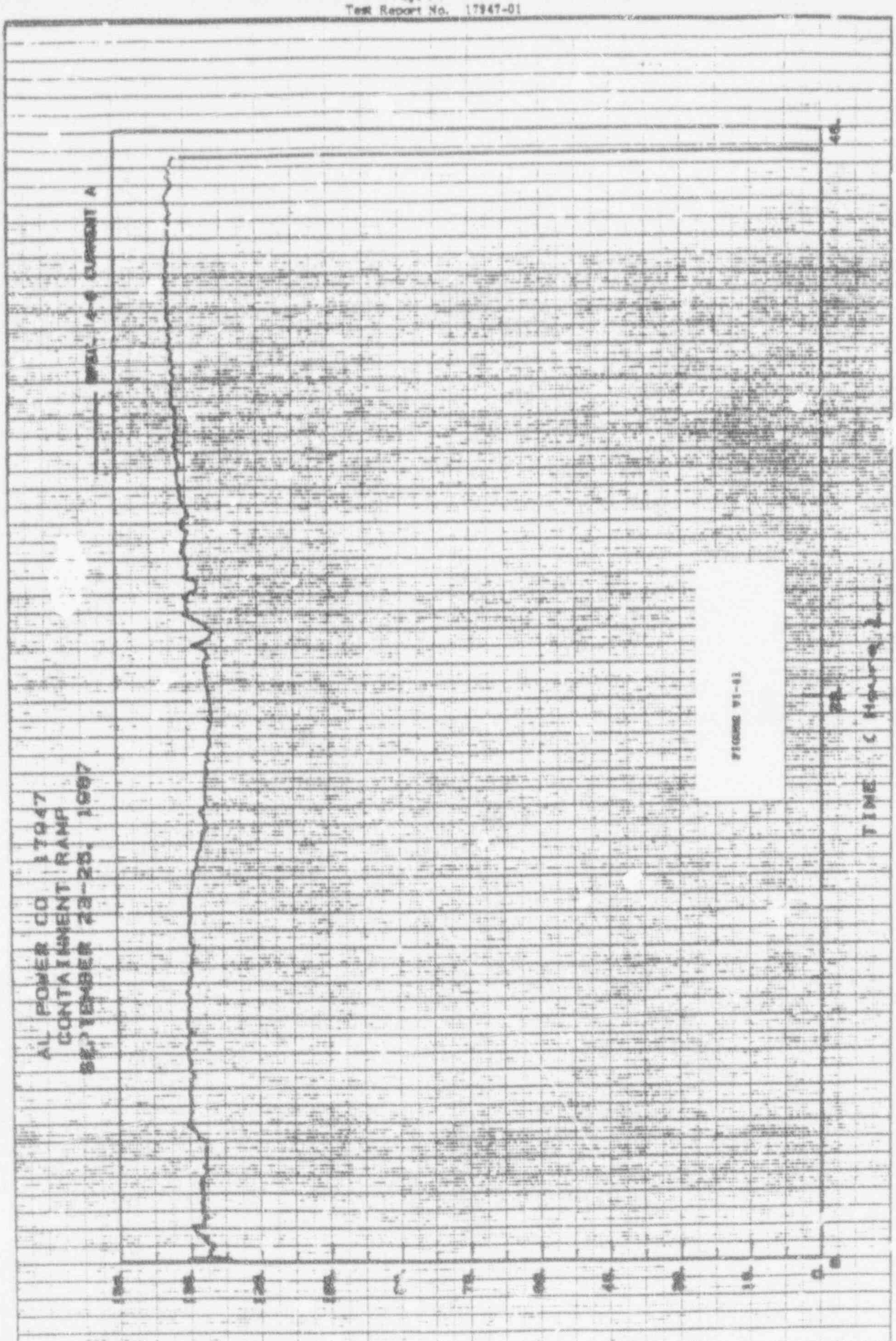
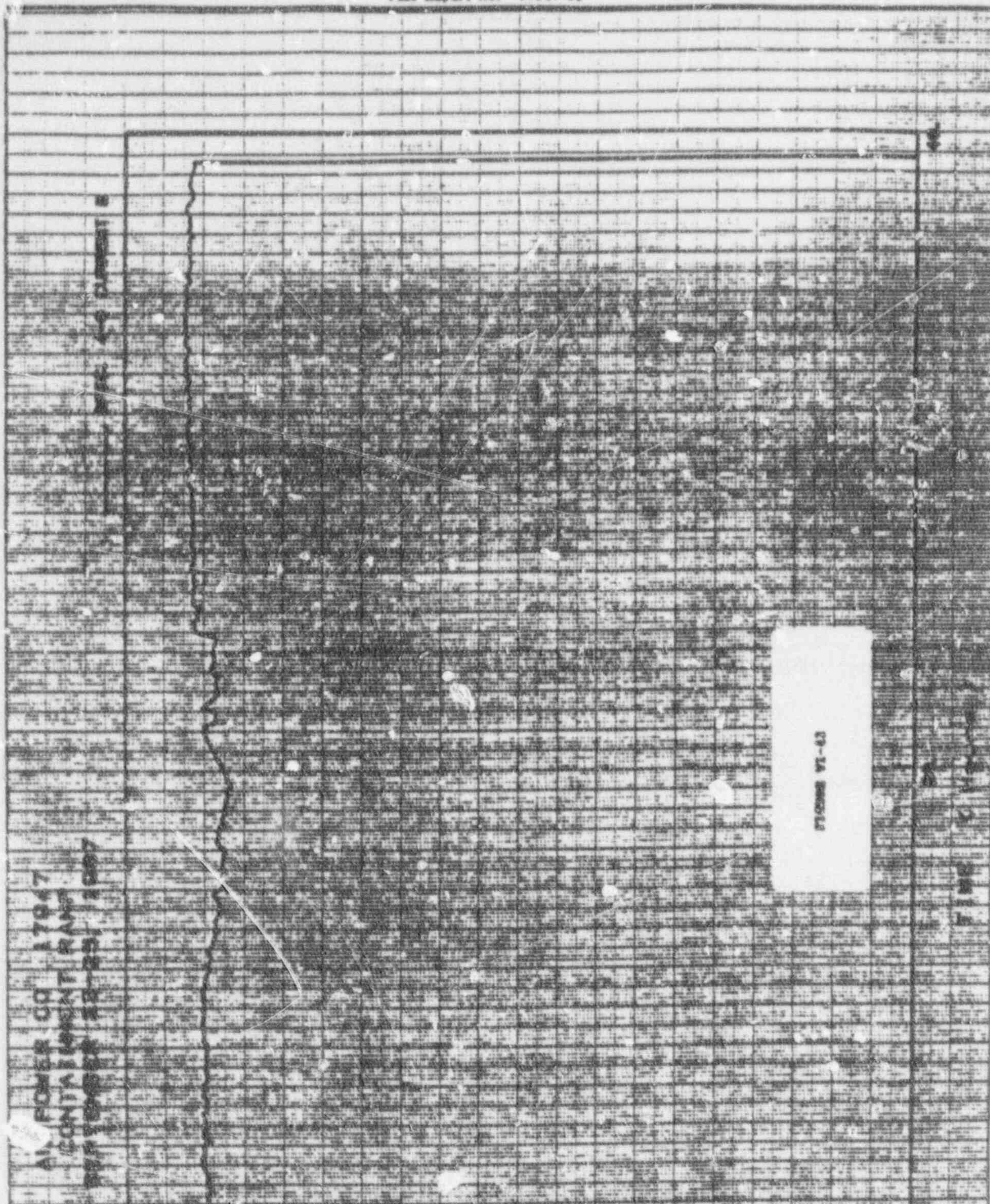

AL POWER CO 17947
CONTAINMENT RAMP
SEPTEMBER 23-25, 1987
4-6 CURRENT A
CURRENT (Amperes)
TIME (Hours)
0
20.
40.

FIGURE VI-41



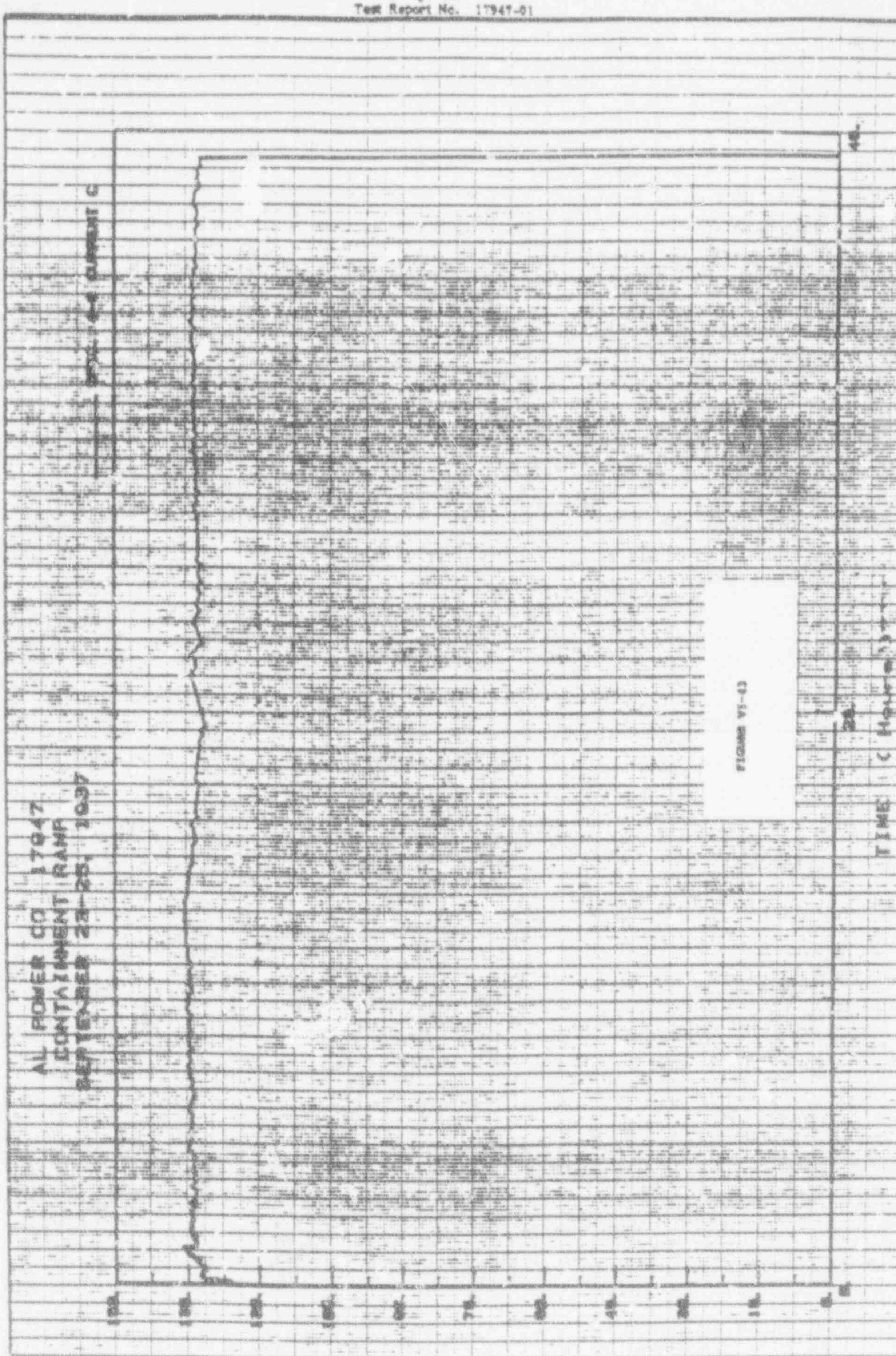
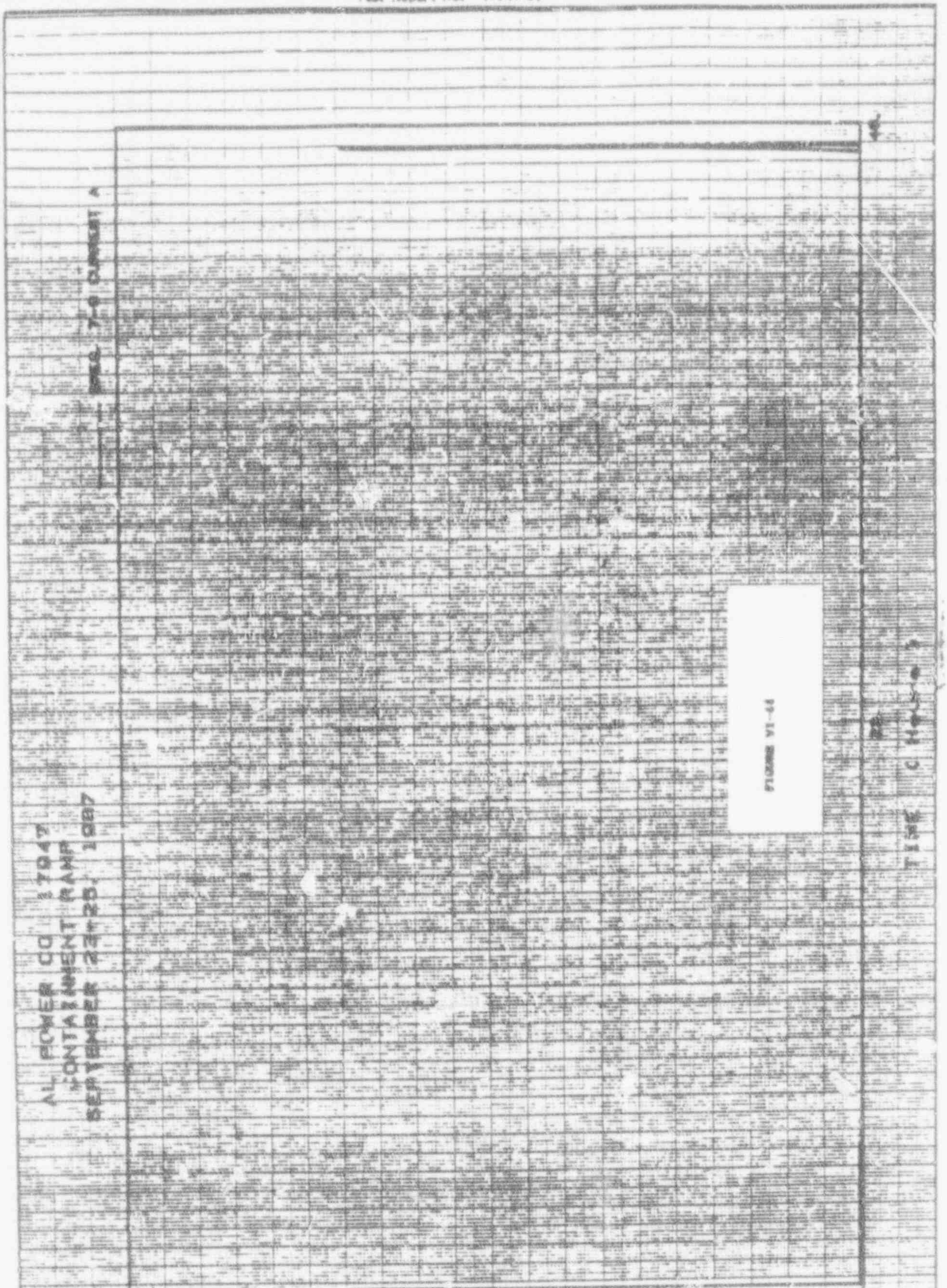
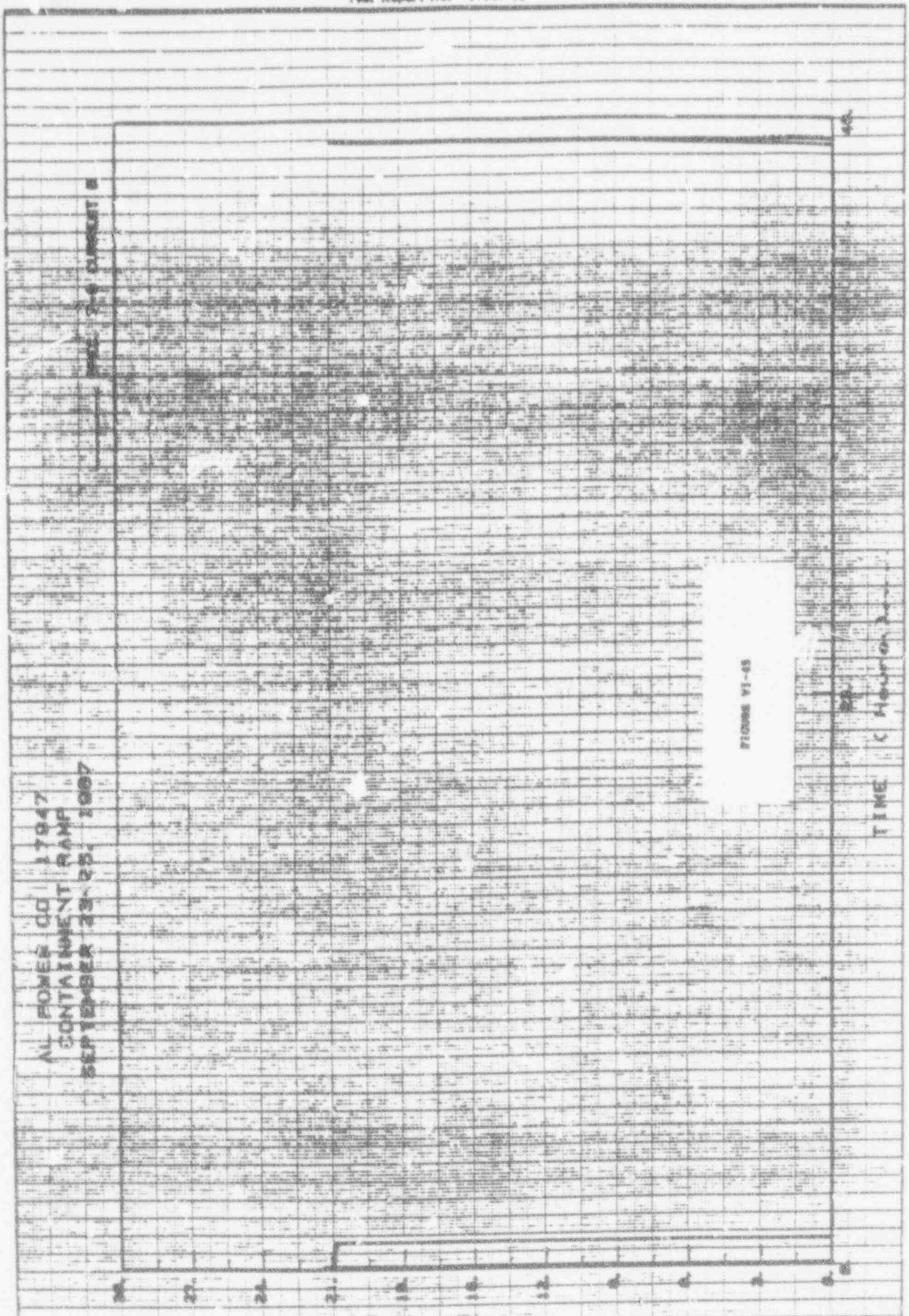

AL POWER CO 17947
CONTAINMENT RAMP
SEPTEMBER 23-25, 1987
SPEC. 4-4 CURRENT C
150
135
120
105
90
75
60
45
30
15
0
24
48
CURRENT (Amperes)
TIME (Hours)

FIGURE VI-43



AL POWER CO 17947
CONTAINMENT RAMP
SEPTEMBER 23-25, 1987
SPEC. 7-8 CURRENT A
FIGURE VI-44
TIME (Hours)
CURRENT (Amperes)


AL POWER CO 17947
CONTAINMENT RAMP
SEPTEMBER 23-25, 1987
FIGURE VI-45
TIME (Hours)
CURRENT (Amperes)
0.
3.
6.
9.
12.
15.
18.
21.
24.
27.
30.
48.

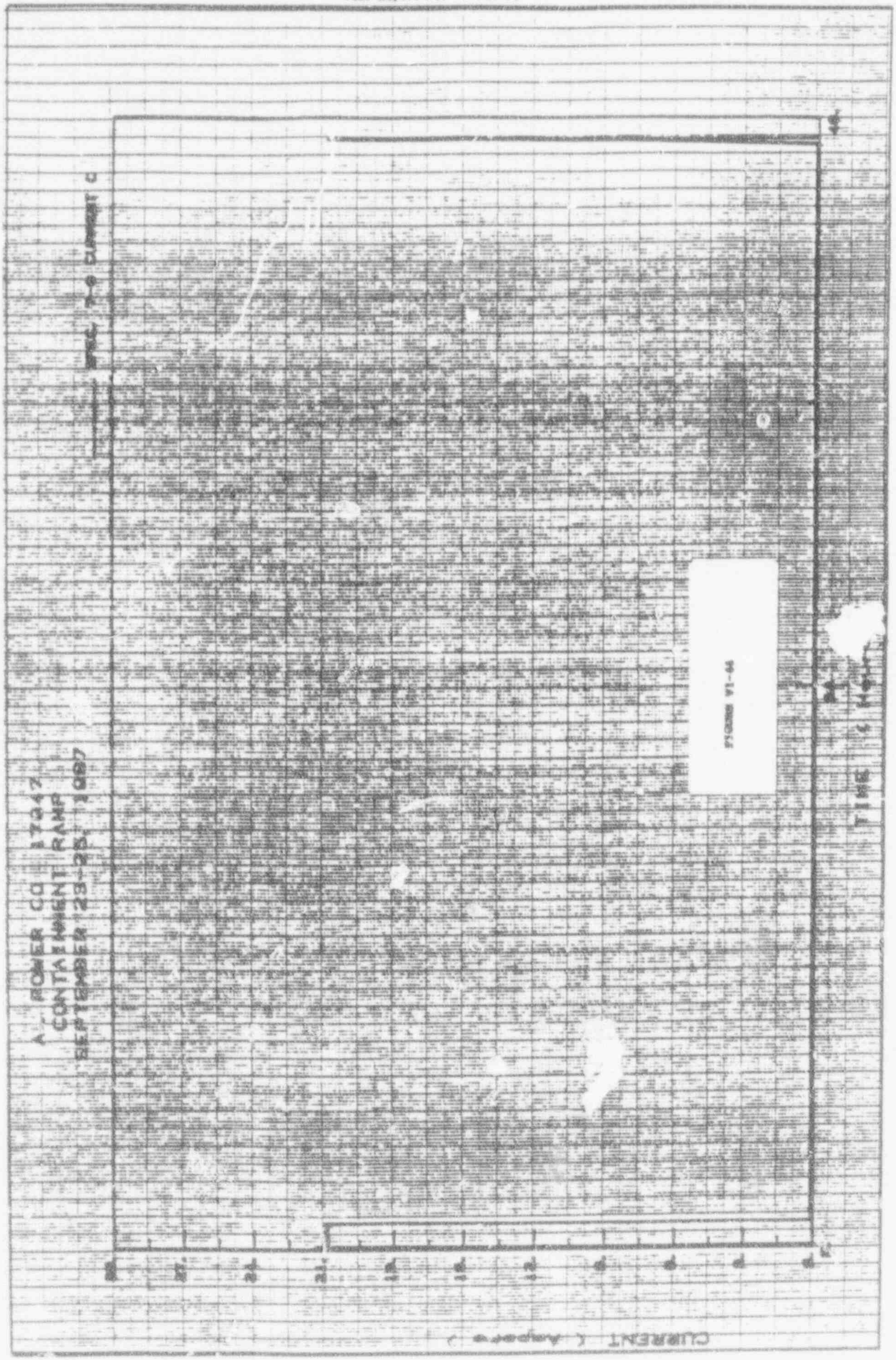

A POWER CO 17347
CONTAINMENT RAMP
SEPTEMBER 23-25 1987
CURRENT (Amperes)
TIME (Hours)

FIGURE VI-44

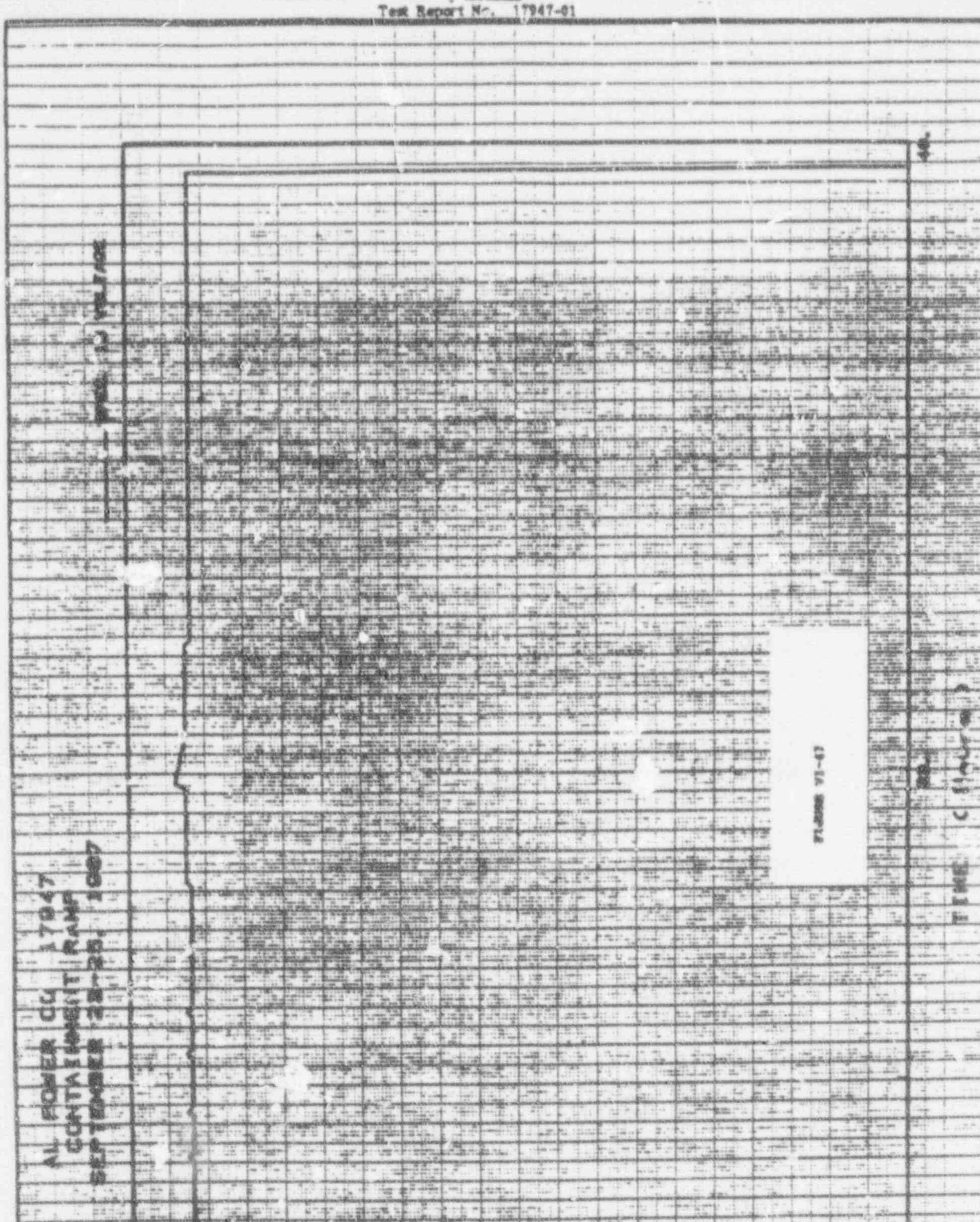
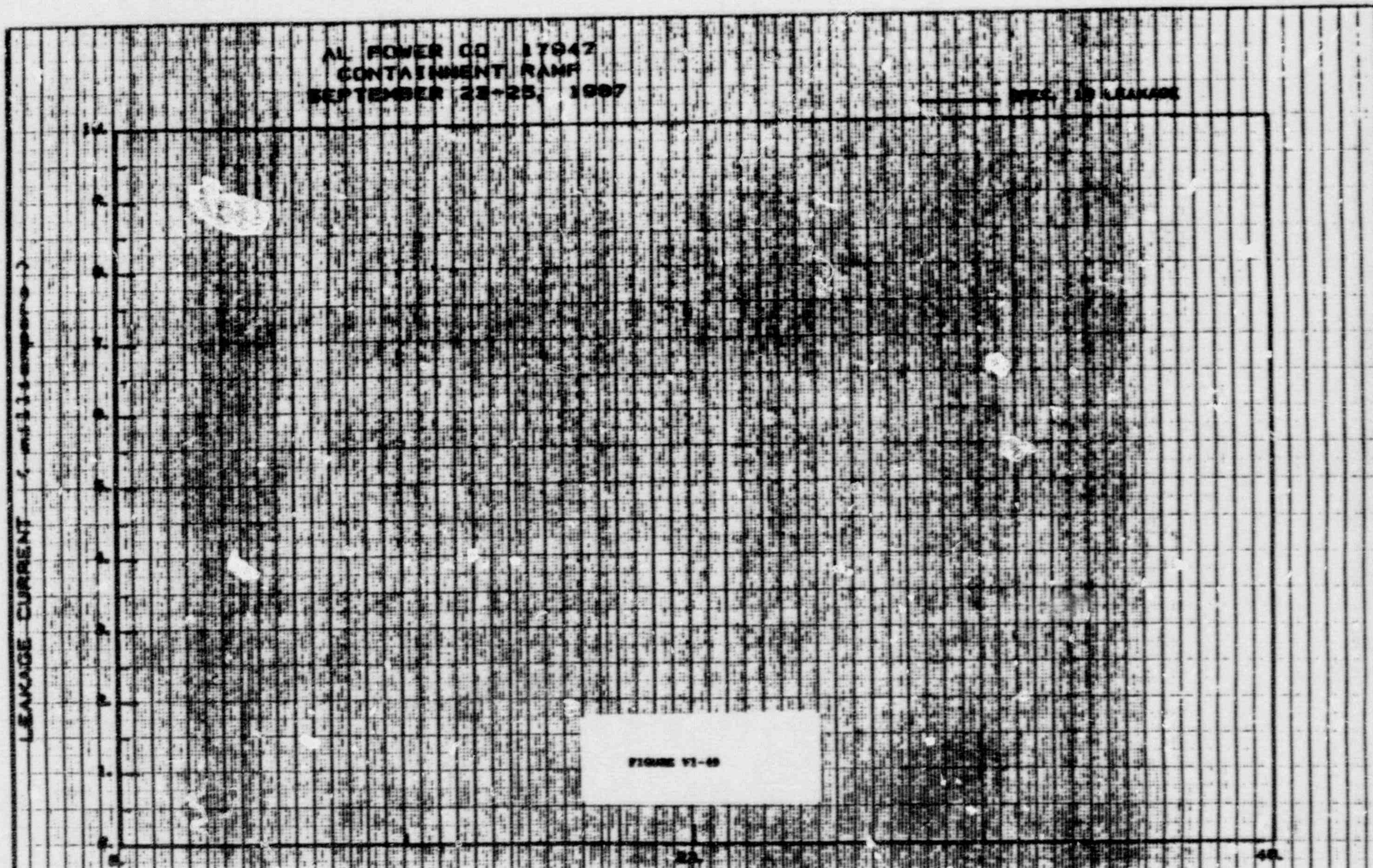
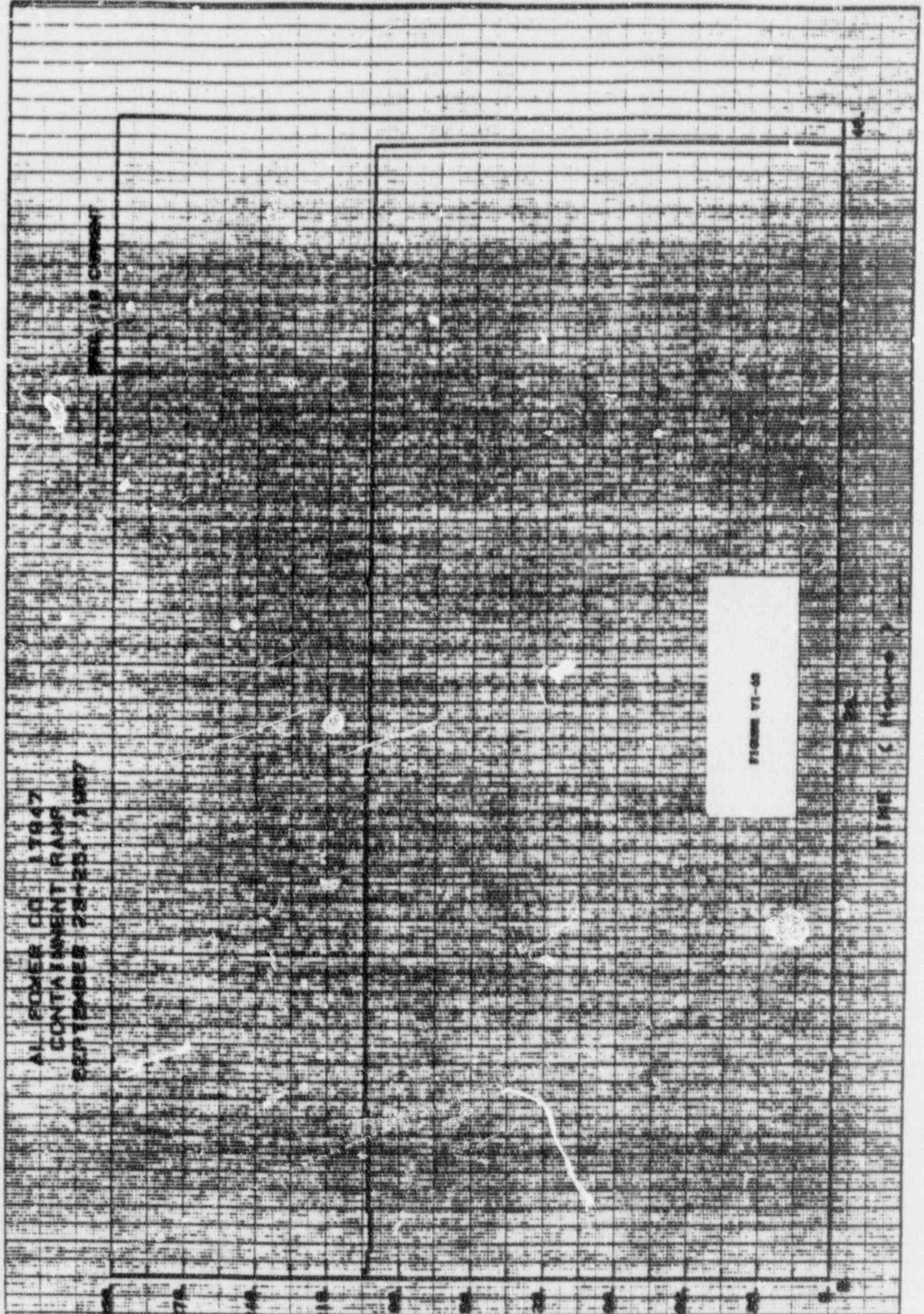
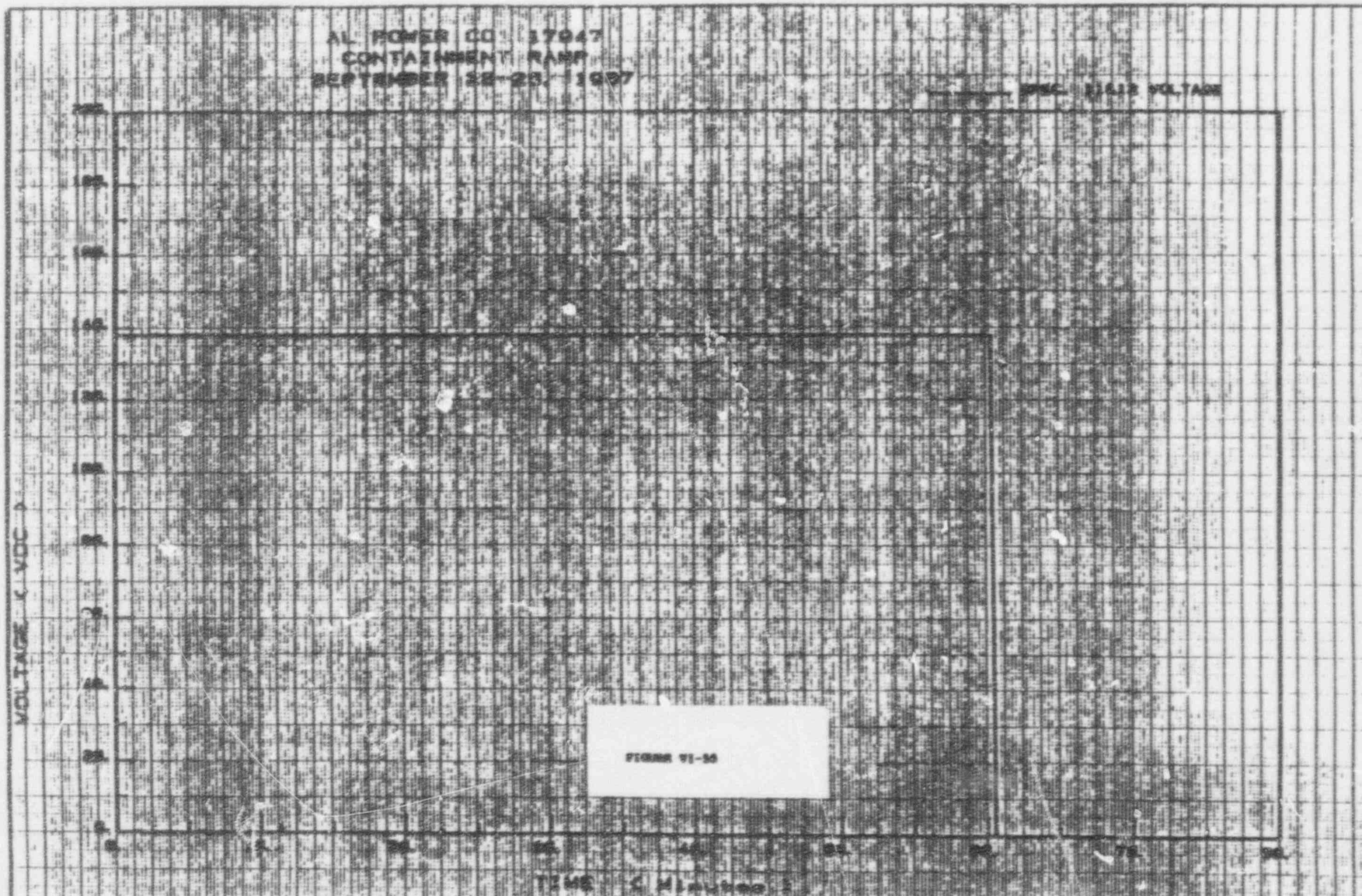

AL POWER CO 17947
CONTAINMENT RAMP
SEPTEMBER 23-25, 1987
VOLTAGE (VDC)
TIME (Hours)
0.
20.
40.

FIGURE VI-47


AL POWER CO 17947
CONTAINMENT RAMP
SEPTEMBER 23-25, 1987
LEAKAGE CURRENT (milliampere)
TIME (Hours)
0
24
48


AL POWER CO 17947
CONTAINMENT RAMP
SEPTEMBER 23-25, 1987
TIME (Hours)
CURRENT (Milliamps)


AL POWER CO 17947
CONTAINMENT RAMP
SEPTEMBER 22-23, 1997
VOLTAGE (VDC)
TIME (Minutes)

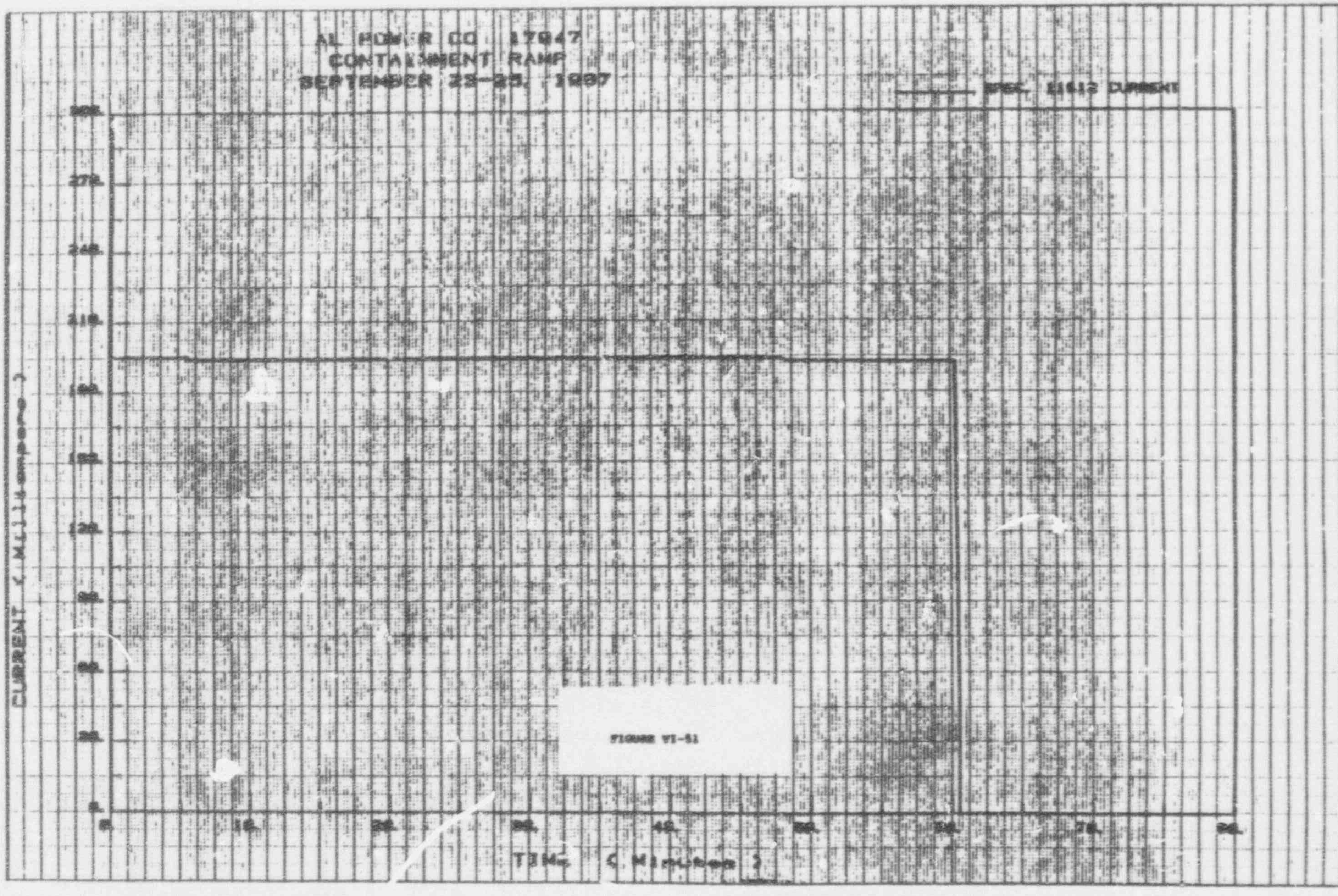
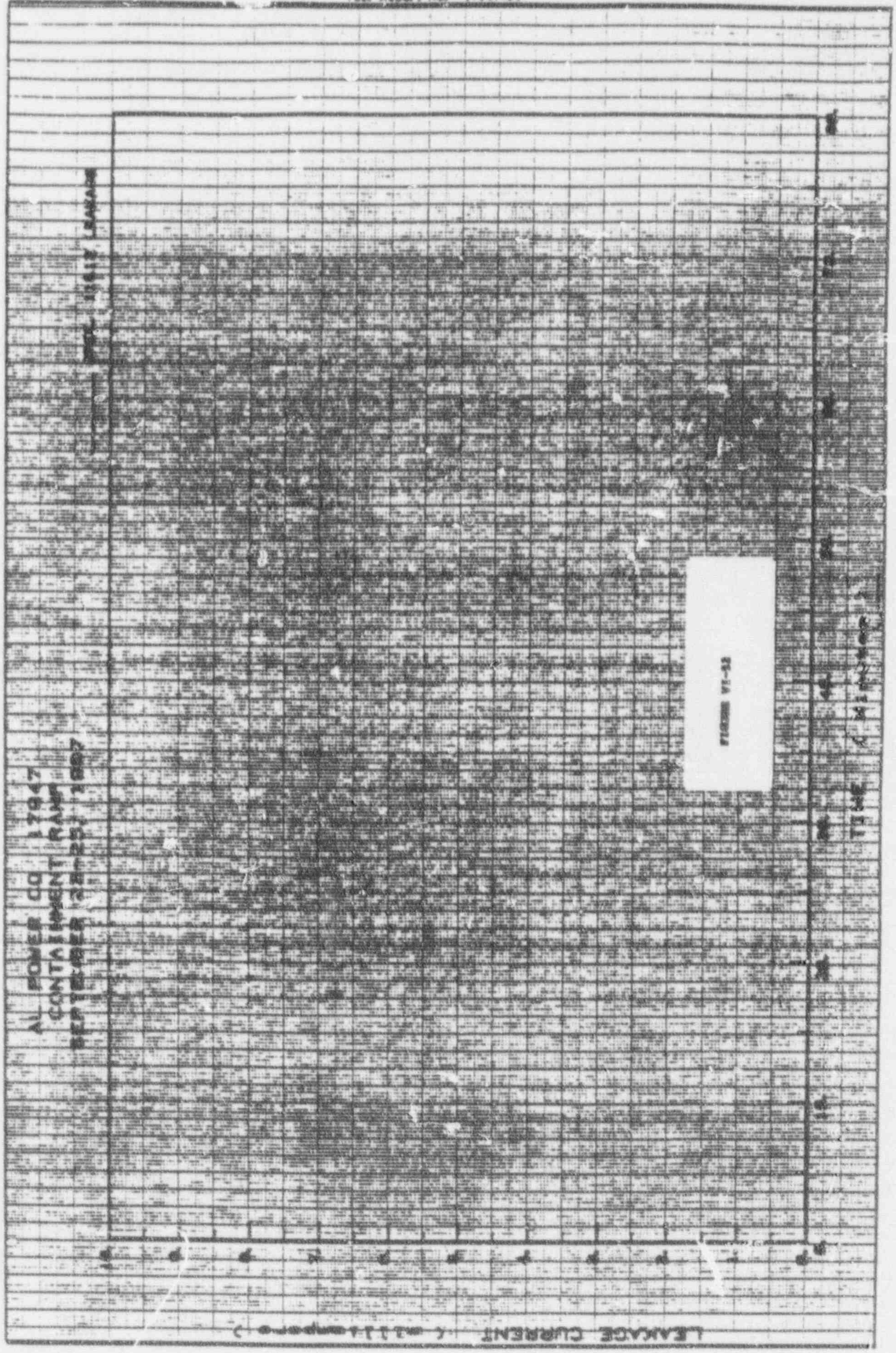

AL POWER CO 17947
CONTAINMENT RAMP
SEPTEMBER 23-25, 1987
CURRENT (Milliampere)
300.
270.
240.
210.
180.
150.
120.
90.
60.
30.
0.
0.
10.
20.
30.
40.
50.
60.
70.
80.
TIME (Minutes)

FIGURE VI-51


AL POWER CO 17947
CONTAINMENT RAMP
SEPTEMBER 23-25, 1987
LEAKAGE CURRENT (milliampere)
TIME (Minutes)

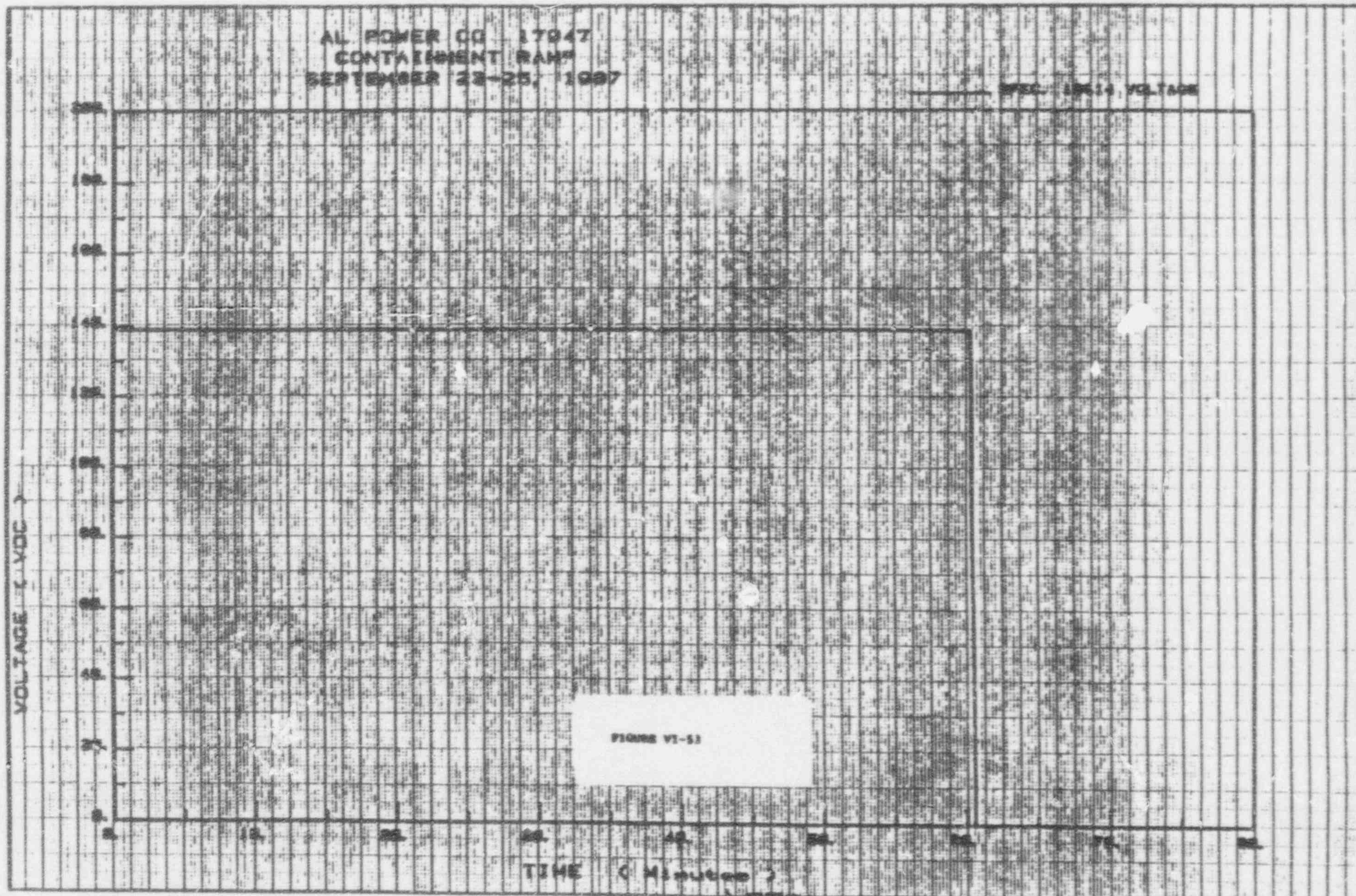

AL POWER CO 17947
CONTAINMENT RAMP
SEPTEMBER 22-25, 1987
VOLTAGE
VOLTAGE (VDC)
200.
180.
160.
140.
120.
100.
80.
60.
40.
20.
0.
0.
10.
20.
30.
40.
50.
60.
70.
80.
TIME (Minutes)

FIGURE VI-53

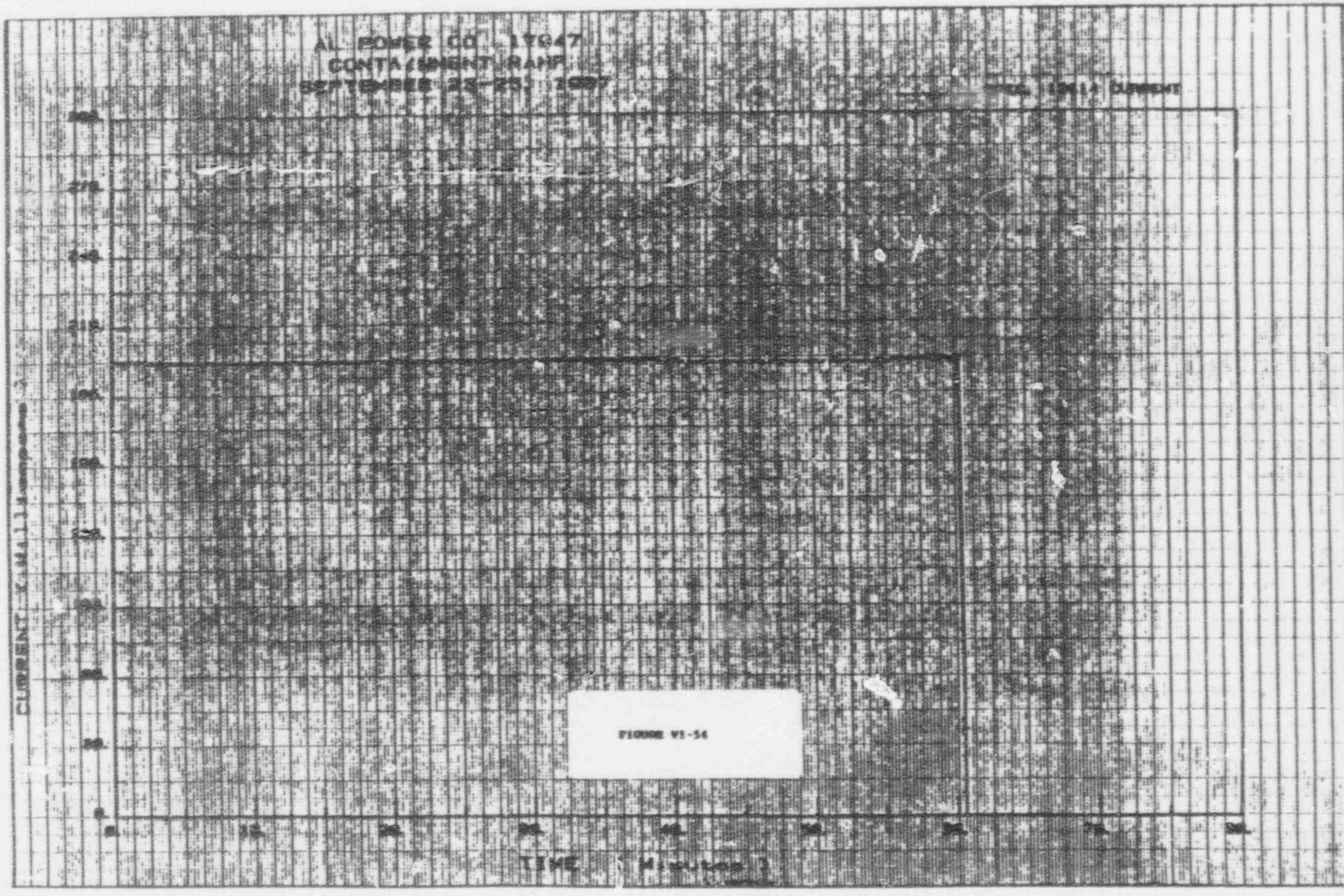

AL POWER CO. 17947
CONTAINMENT RAMP
SEPTEMBER 23-25, 1987
CURRENT
TIME (Minutes)

FIGURE VI-56

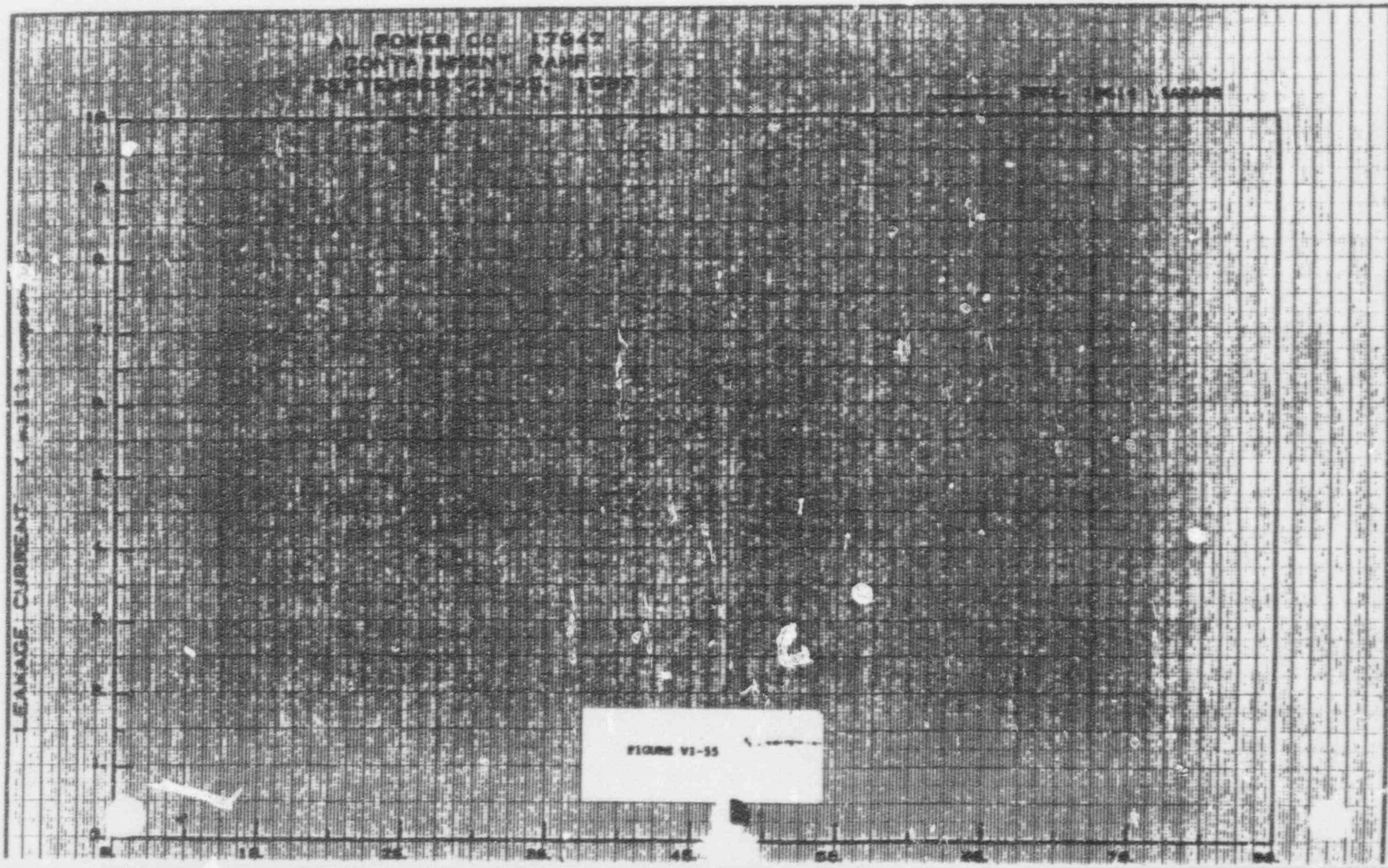


FIGURE VI-55

APPENDIX IX

INSTRUMENTATION EQUIPMENT SHEETS

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INSTRUMENTATION EQUIPMENT SHEET

DATE: 09/22/87
TECHNICIAN: N. JUNKINS

JOB NUMBER: 17947-00
CUSTOMER: AL. POWER

TEST AREA: LOCA
TYPE TEST: LOCA

NO.	INSTRUMENT	MANUFACTURER	MODEL#	SERIAL #	WYLE #	RANGE :	ACCURACY :	CALDATE	CALDUE
1	PWR SUPPLY	SORENSON	15010A	1026	095173	150VDC	.1%REG	06/11/87	12/11/87
2	PWR SUPPLY	LAMBDA	LMD120	013440	011394	120VDC	.1%REG	09/11/87	03/11/88
3	PWR SUPPLY	LAMBDA	LMD120	C14908	011395	120VDC	+-0.1%REG	07/17/87	01/17/88
4	DIG MTR	FLUKE	77	41160804	103293	DC	.7%	03/05/87	03/05/88
5	DIG MTR	KEITHLEY	179T	20331	092338	DC	.04%	10/21/86	10/21/87
6	XFORMER	METER MASTER	9FT-101	N/A	102396	RATIO 100:5	2%	08/17/87	02/17/88
7	XFORMER	METERMASTER	79FT101	N/A	103440	RATIO 100:5	2%	08/11/87	02/11/88
8	XFORMER	METER MASTER	9FT-101	N/A	102400	RATIO 100:5	2%	08/17/87	02/17/88
9	XFORMER	METERMASTER	79FT101	N/A	103450	RATIO 100:5	2%	08/17/87	02/17/88
10	XFORMER	METERMASTER	79FT101	N/A	103443	RATIO 100:5	2%	08/17/87	02/17/88
11	XFORMER	METERMASTER	79FT101	N/A	103441	RATIO 100:5	2%	08/17/87	02/17/88
12	XFORMER	METER MASTER	9FT-251	N/A	102391	RATIO 250:5	1%	09/11/87	03/11/88
13	XFORMER	METER MASTER	9FT-251	N/A	102392	RATIO 250:5	1%	07/01/87	01/01/88
14	XFORMER	METER MASTER	9FT-251	N/A	102393	RATIO 250:5	1%	07/01/87	01/01/88
15	AC CURR. PROBE	FLUKE	80I-600	N/A	104040	1-600A	2%	08/04/87	02/04/88
16	DIG MTR	FLUKE	77	24865343	101824	DC	.3%	06/30/87	06/30/88
17	DIGITAL MTR	FLUKE	77	42031532	104035	VDC	.3%	07/23/87	07/23/88
18	DIGITAL TEMP	FLUKE	2190A	208	094906	MULT	.03%	08/07/87	11/07/87
19	CALIBR VOLT	FLUKE	Y2003	N/A	094907	10-100MV	.03%	08/07/87	11/07/87

THIS IS TO CERTIFY THAT THE ABOVE INSTRUMENTS WERE CALIBRATED USING STATE-OF-THE-ART TECHNIQUES WITH STANDARDS WHOSE CALIBRATION IS TRACEABLE TO THE NATIONAL BUREAU OF STANDARDS.

INSTRUMENTATION R.E. Archer 9-22-87

CHECKED & RECEIVED BY J Hzeti 9/22/87

Q.A. RSBolieo 09-23-87

(2 Wyle)

Test Report No. 17947-01

INSTRUMENTATION EQUIPMENT SHEET

DATE: 09/23/87
TECHNICIAN: S. LEWERS

JOB NUMBER: 17947-00
CUSTOMER: AL. POWER COMPANY

TEST AREA: LOCA "A"
TYPE TEST: LOCA

NO.	INSTRUMENT	MANUFACTURER	MODEL#	SERIAL #	WYLE #	RANGE 1	ACCURACY 1	CALDATE	CAL
1	DATA SYS	DAYTRONICS	CX12	N/A	101936	MULT	*FG	07/08/87	07
2	TERMINAL	HP	2648A		100615	SYSTEM	PM	09/21/87	03.
3	COND STRAIN	VISHAY	2120	33023	094573	DC-5KHZ	5%F	09/14/87	12.
4	CONTR TEMP	AGM	EA4002	70-509	000680	0+1000*F K	1%	08/04/87	02.
5	AMPL TEMP MV	AGM ELECTRONICS	EA4002	70-510	000681	0+1000*F K	1%	08/04/87	02.
6	AMPL TEMP MV	AGM ELECTRONICS	EA4002	70-512	000683	0+1000*F K	1%	08/04/87	02.
7	GEN SIG	EXACT	340	1863911268-69	011251	1MSEC-99.900	.01%	08/11/87	02.
8	TEMP IND	DORIC	402A	106717	011831	-50+2552*F K	2.5*f	08/14/87	02.
9	PWR SUPPLY	VISHAY	2110	15892	096229	15VDC	1%REG	09/14/87	12.
10	FLOW MTR	POTTER	5440	N/A	100970	0-10 GPM	SEE CERT	11/04/86	11.
11	DIGITAL TEMP	FLUKE	2190A	208	094906	MULT	.03%	08/07/87	11.
12	CALIBR VOLT	FLUKE	Y2003	N/A	094907	10-100MV	.03%	08/07/87	11.
13	PRESS GAUGE	USG	N/A	N/A	102100	100PSI	1%	07/29/87	10.
14	CONTR TEMP	RESEARCH	61011	06015546-120	094517	-175+375*F T	.5%	09/22/87	03.
15	TEMP ALARM	RESEARCH	61034	140168	000722	-175+375*F T	.5%	09/22/87	03.
16	RECORD TEMP	HONEYWELL	45	8049 310384001	094779	0 TO 400DEG F T	.5%	09/22/87	12.
17	DIG MTR	FLUKE	77	41160804	103293	DC	.7%	03/05/87	03.
18	PRESS XDUCER	CEC	9348	00089	102580	0-100PSI	1%	09/22/[illegible]	03.
19	XDUCER	CEC	22006	L253289	103498	0-60PSIG	.25%	07/09/	01.
20	High Speed Line Printer	TI	R0810	4711-1335	11777	N/A	PM	03/19/87	09,

* See Notice of Anomaly No. 1

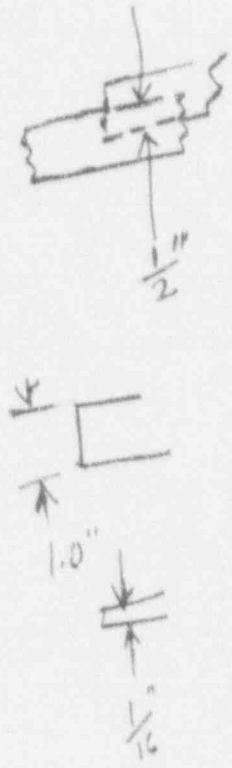
THIS IS TO CERTIFY THAT THE ABOVE INSTRUMENTS WERE CALIBRATED USING STATE-OF-THE-ART TECHNIQUES WITH STANDARDS WHOSE CALIBRATI[ON IS] TRACEABLE TO THE NATIONAL BUREAU OF STANDARDS.

INSTRUMENTATION [signature] 9/23/87

CHECKED & RECEIVED BY [signature] 9/

Q.A. [signature] 9/23/87

POST-LOCA
FUNCTIONAL TEST



1/2"
1.0"
1/16"

SECTION VII

POST-LOCA FUNCTIONAL TESTS

1.0 REQUIREMENTS

Insulation resistance values were taken for informational purposes only. Continuity shall be 1 ohm or less when measured with a digital ohmmeter.

2.0 PROCEDURES

The test specimens were subjected to the testing per Paragraph 2.3 of Section I.

3.0 RESULTS

The test specimens were subjected to the tests of Paragraph 2.0 which met the requirements of Paragraph 1.0. The data collected during these tests is presented in Appendices I through III as noted below:

- Appendix I contains Photographs VII-1 through VII-5 which show the specimens mounted in their respective fixtures.
- Appendix II contains the Functional Test Data Sheets.
- Appendix III contains the Instrumentation Equipment Sheet which lists the equipment used to collect data.

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APPENDIX I

PHOTOGRAPHS

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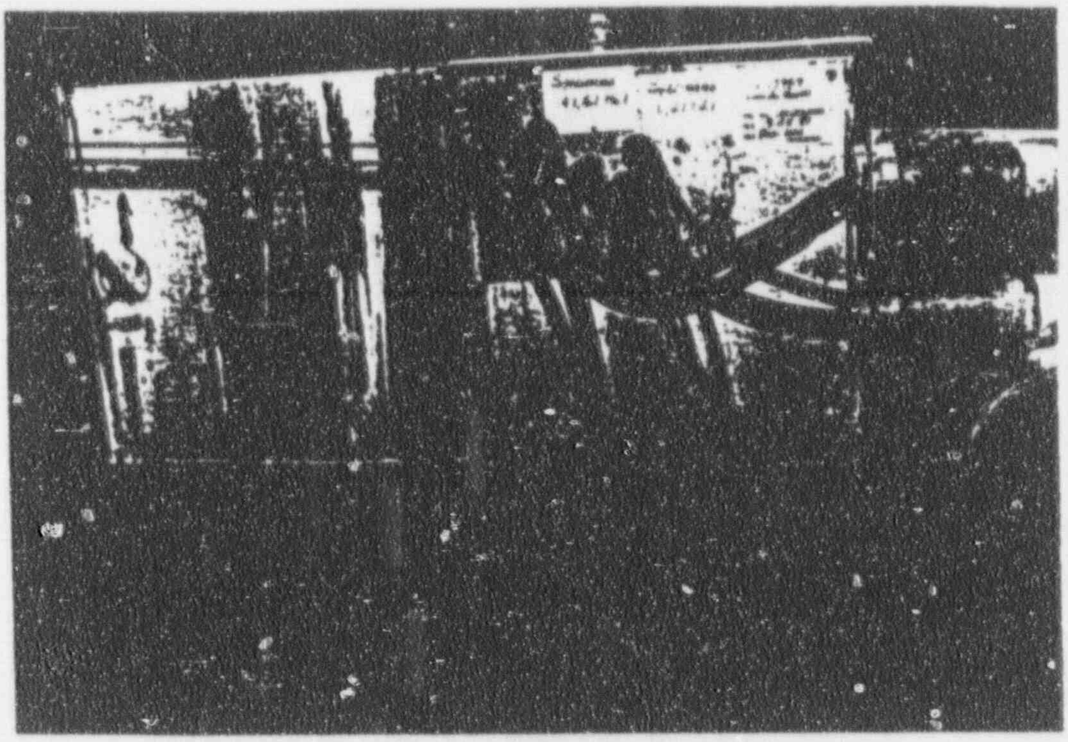
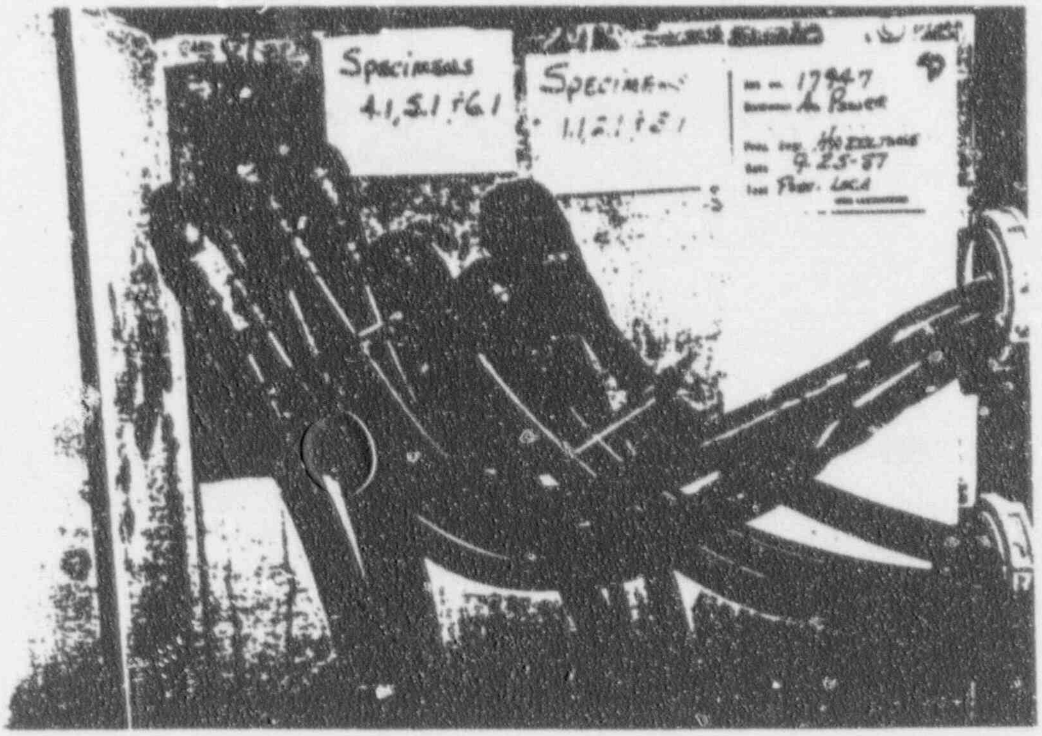


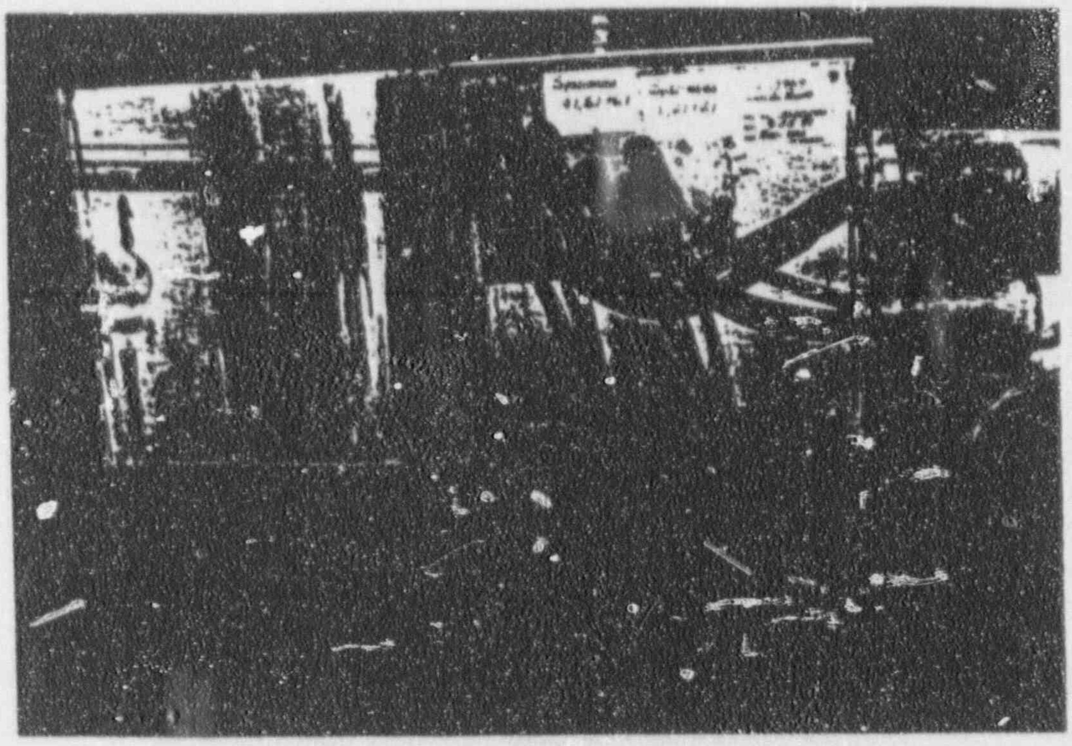
PHOTOGRAPH NO. VII-1

POST-LOCA VIEW OF SPECIMENS 1.1-6.1.
NOTE THE CORROSION INSIDE THE ENCLOSURE
AND ON THE INSIDE OF THE DOOR.



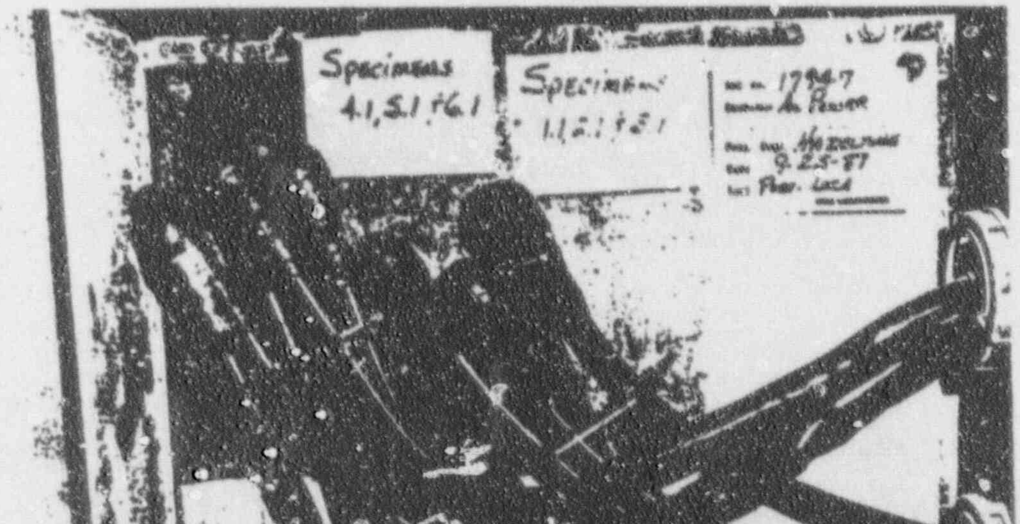
PHOTOGRAPH NO. VII-2

CLOSEUP VIEW OF SPECIMENS 1.1-6.1. NO EVIDENCE OF
ARCHING OR INSULATION BREAKDOWN WAS VISIBLE ON
ANY OF THE SPLICES. THE OUTER LAYER OF TAPE
WAS BRITTLE BUT INTACT.



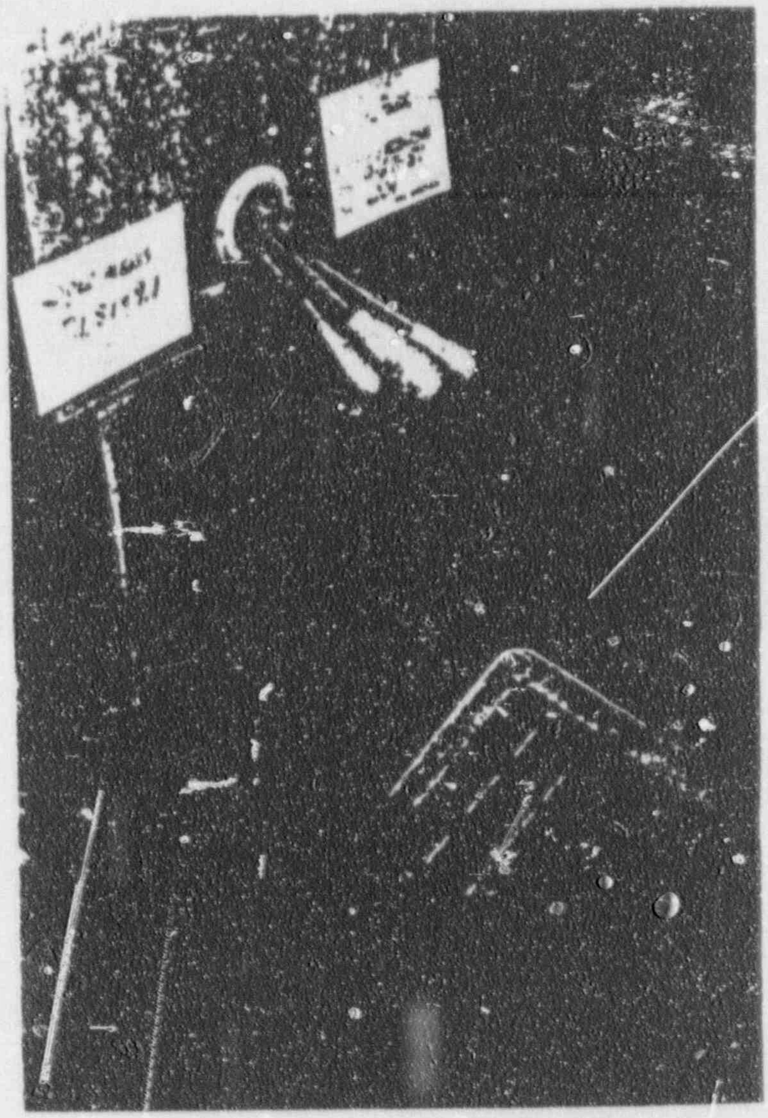
PHOTOGRAPH NO. VII-1

POST-LOCA VIEW OF SPECIMENS 1.1-6.1.
NOTE THE CORROSION INSIDE THE ENCLOSURE
AND ON THE INSIDE OF THE DOOR.



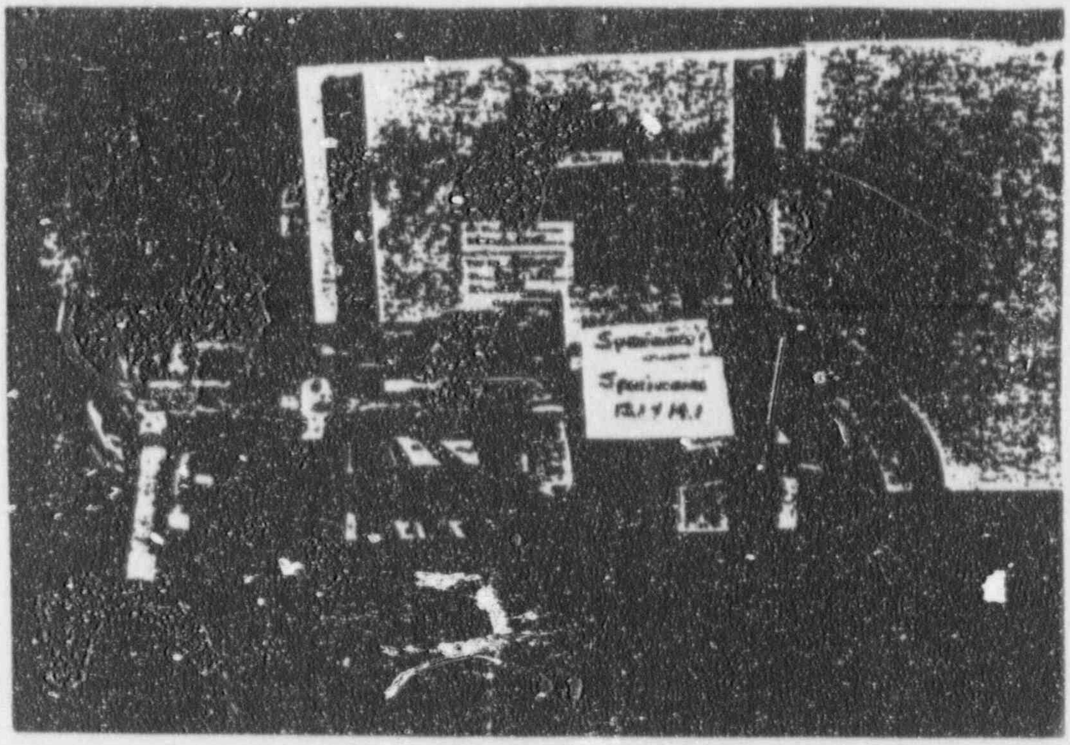
PHOTOGRAPH NO. VII-2

CLOSEUP VIEW OF SPECIMENS 1.1-6.1. NO EVIDENCE OF
ARCHING OR INSULATION BREAKDOWN WAS VISIBLE ON
ANY OF THE SPLICES. THE OUTER LAYER OF TAPE
WAS BRITTLE BUT INTACT.



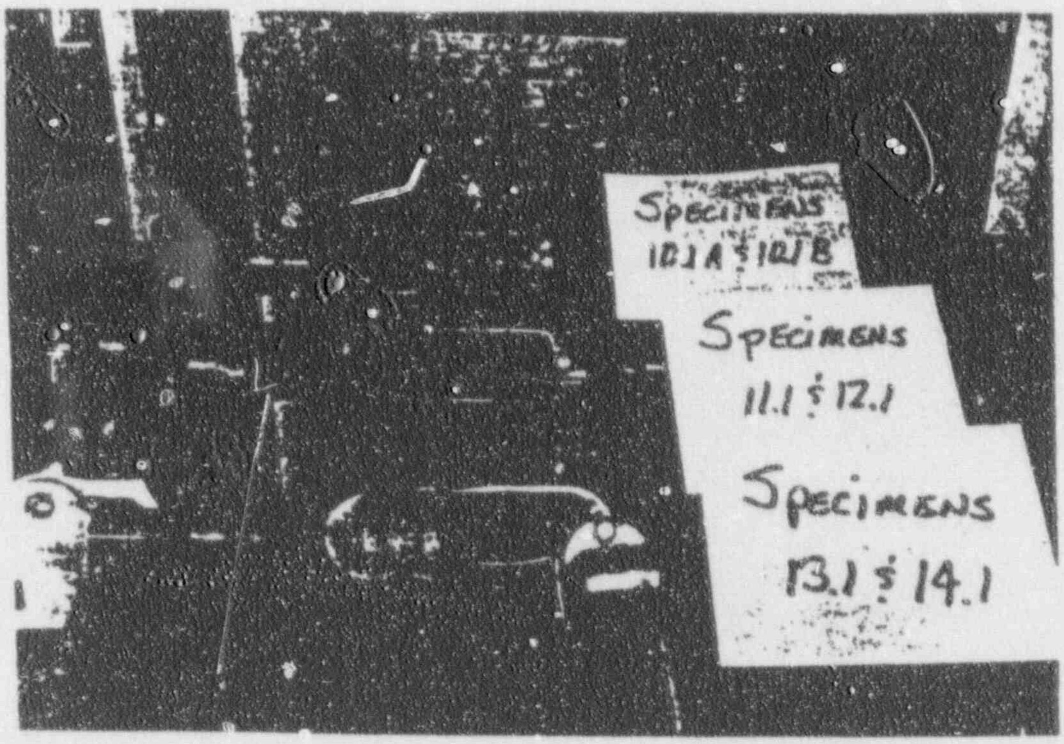
PHOTOGRAPH NO. VII-3

POST-LOCA VIEW OF SPECIMENS 7.1-9.1.
THERE WAS ABOUT 1/2" OF WATER INSIDE THE LIMITORQUE COVER AND ALL THREE SPLICES WERE WET UNDERNEATH. NOTE THE CHEMICAL SPRAY DEPOSIT AND CORROSION JUST BELOW THE MYERS HUB. THERE WAS NO EVIDENCE OF INSULATION BREAKDOWN OR ARCING ON ANY OF THE SPLICES.



PHOTOGRAPH NO. VII-4

POST-LOCA OVERALL VIEW OF
SPECIMENS 10.1 TO 14.1



PHOTOGRAPH NO. VII-5

POST-LOCA CLOSEUP VIEW OF SPLICES INSIDE CONDULETS.
ALL CONDULETS CONTAINED RUST INSIDE. THERE WAS
NO EVIDENCE OF ARCINC OR INSULATION BREAKDOWN
ON ANY SPLICE.

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APPENDIX II

DATA SH[illegible]

Test Report No. 17947-01

DATA SHEET

Customer: Alabama Power
Specimen: Okonite Tape Splices
Part No.: T-95, No.35 and Scotch 33+
Spec.: WLQP 17492-01
Para.: 3.8
S/N: No
GSI: No

Amb. Temp.: 75°F
Photo: Yes
Test Med.: Air
Specimen Temp.: Ambient

WYLE LABORATORIES

Job No.: 17947
Report No.: 17947-01
Start Date: 9-25-87

Test Title: Post-LOCA Functional Test

Acceptance Criteria: Insulation Resistances (at 500 VDC for 1 minute) and Contact Resistances (via Kelvin Bridge Method) shall be measured for information only.

Specimen No.	Insulation Resistance	Contact Resistance
1.1	1.5x10[?] Ω	3.6x10⁻³ Ω
1.2	N/A	N/A
1.3		
2.1	1.5x10[?] Ω	3.7x10⁻³ Ω
2.2	N/A	N/A
2.3		
3.1	1.6x10[?] Ω	4.8x10⁻³ Ω
3.2	N/A	N/A
3.3		
4.1	1.6x10[?] Ω	1.4x10⁻³ Ω
4.2	N/A	N/A
4.3		
5.1	1.6x10 Ω	1.2x10⁻³ Ω
5.2	N/A	N/A
5.3		

Notice of Anomaly: None

Tested By: [illegible] Date: 9-25-87
Witness: None Date:
Sheet No. 1 of 3
Approved: [illegible] 9-25-87

Wyle Form WH 614A Rev APR 84

Test Report No. 17947-01

DATA SHEET

WYLE LABORATORIES

Customer: Alabama Power
Specimen: Okonite Tape Splices
Part No.: T-95, No. 35 and Scotch 33+
Spec.: WLQP 17492-01
Para.: 3.8
S/N: No
GSI: No

Amb. Temp.: 75°F
Photo: Yes
Test Med.: Air
Specimen Temp.: Ambient

Job No.: 17947
Report No.: 17947-01
Start Date: 9-25-87

Test Title: Post-LOCA Functional Test

(Continued)

Specimen No.	Insulation Resistance	Contact Resistance
12.1	$1.9 \times 10^{9} \Omega$	$2.1 \times 10^{-2} \Omega$
12.2	N/A	N/A
12.3		
13.1	$1.0 \times 10^{10} \Omega$	$1.9 \times 10^{-2} \Omega$
13.2	N/A	N/A
13.3		
14.1	$3.0 \times 10^{9} \Omega$	$1.9 \times 10^{-2} \Omega$
14.2	N/A	N/A
14.3		
15.1A		
15.1B		
15.1C		
15.2A		
15.2B		
15.3		

Tested By: [signature] Date: 9-25-87
Witness: NONE Date:
Sheet No. 3 of 3
Approved: [signature] 9-25-87

Notice of Anomaly: None

Wyle Form WH 614A, Rev. APR '84

DATA SHEET

WYLE LABORATORIES

Customer: Alabama Power
Specimen: Okonite Tape Splices
Part No. T-95, No.35 and Scotch 33+
Spec. WLQP 17492-01
Para. 3.8
S/N No
GSI No

Amb. Temp. 75°F
Photo Yes
Test Med. Air
Specimen Temp. Ambient

Job No. 17947
Report No. 17947-01
Start Date 9-25-87

Test Title: Post-LOCA Functional Test

(Continued)

Specimen No.	Insulation Resistance	Contact Resistance
6.1	1.5 x 10^11 Ω	1.4 x 10^-3
6.2	N/A	N/A
6.3		
7.1	~~1.1 x 10^11 Ω~~ 1.6 x 10^11 Ω	5.5 x 10^-3
7.2	N/A	N/A
7.3		
8.1	1.8 x 10^11 Ω	6.7 x 10^-3
8.2	N/A	N/A
8.3		
9.1	1.8 x 10^11 Ω	6.2 x 10^-3
9.2	N/A	N/A
9.3		
10.1A	1.1 x 10^11 Ω	3.4 x 10^-3 Ω
10.1B	1.5 x 10^11 Ω	2.2 x 10^-3 Ω
10.2	N/A	N/A
10.3		
11.1	1.6 x 10^11 Ω	2.0 x 10^-3 Ω
11.2	N/A	N/A
11.3		

Tested By: [signature] Date: 9-25-87
Witness: None Date:
Sheet No. 2 of 3
Approved: [signature] 9-25-87

Notice of Anomaly: None

WYLE LABORATORIES
QUALIFICATION PLAN NO. 17942-01,
REVISION A

APPENDIX III

INSTRUMENTATION EQUIPMENT SHEET

INSTRUMENTATION EQUIPMENT SHEET

DATE: 09/25/87
TECHNICIAN: M. JUNKINS

JOB NUMBER: 17947-01
CUSTOMER: ALABAMA POWER

TEST AREA: LOCA
TYPE TEST: POST LOCA

NO.	INSTRUMENT	MANUFACTURER	MODEL#	SERIAL #	WYLE #	RANGE 1	ACCURACY 1	CALDATE	CALDUE
1	DIG MTR	VALHALLA	4150	82123	101040	.02-2KOHM	.02%RDG	09/11/87	03/11/88
2	MEG MTR	GENERAL RADIO	1862-C	257	102992	.5-2E6 MOHM	+-3%	05/18/87	11/18/87

THIS IS TO CERTIFY THAT THE ABOVE INSTRUMENTS WERE CALIBRATED USING STATE-OF-THE-ART TECHNIQUES WITH STANDARDS WHOSE CALIBRATION IS TRACEABLE TO THE NATIONAL BUREAU OF STANDARDS.

INSTRUMENTATION R.E. Archer 9-25-87

CHECKED & RECEIVED BY G. Hazett 9-25-87

Q.A. R.S. Bolis 09-28-87 (2 Wyle A)

WYLE LABORATORIES
SCIENTIFIC SERVICES & SYSTEMS GROUP
P. O. BOX 1008 • HUNTSVILLE, ALABAMA 35807
TWX (810) 726-2225 • TELEPHONE (205) 837-4411

QUALIFICATION PLAN

QUAL. PLAN 17942-01

DATE August 27, 1987

TOTAL PAGES 68

Revision A - 9/10/87

QUALIFICATION PLAN
FOR
SPLICES FABRICATED WITH
3M SCOTCH 33+ VINYL PLASTIC ELECTRICAL TAPE
AND
OKONITE SPLICING TAPES NOS. 35 AND T-95
FOR
ALABAMA POWER COMPANY
FOR USE IN FARLEY NUCLEAR PLANT

APPROVED BY: James W. Anderson 8/27/87
PROJECT MANAGER: J. W. Anderson

APPROVED BY: [signature] 8/27/87
FOR: ENVIRONMENTAL QUALIFICATION

APPROVED BY: G.W. Hight 8/27/87
QUALITY ASSURANCE: G. W. Hight

PREPARED BY: E. Reilly Schum 8/27/87
PROJECT ENGINEER: E. R. Schum

17942-1A.DOC

REVISIONS

FORM 1109-1/8-81

REV. NO.	DATE	PAGE OR PARAGRAPH AFFECTED	BY	APP'L	DESCRIPTION OF CHANGES
A	9/10/87	All 9/10	ERS	[signature] 9/10/87	Complete revision

1.0 SCOPE

This document has been prepared by Wyle Laboratories for Alabama Power Company, hereinafter referred to as the customer, for equipment used at Farley Nuclear Plant.

1.1 Purpose

The purpose of this document is to present the approach, methods, philosophies and procedures for qualifying the equipment identified in Section 1.3 for use in Farley Nuclear Plant.

Nuclear environmental qualification of any safety-related device to meet the requirements of IEEE 323-1974 is usually a three-step process, i.e., (1) normal radiation exposure, (2) aging, and (3) design basis event qualification (seismic, and where applicable, MSLB, HELB or LOCA). The purpose of the first two steps is to put the test specimens into a condition that represents the worst state of deterioration that the plant operator will permit prior to taking corrective action, i.e., its end-of-qualified-life condition. The next step demonstrates that the specimen still has adequate integrity to withstand the added environmental stresses of the specified design basis events and still perform its safety-related function.

1.2 Applicable Documents

- 10 CFR 50.49, "Environmental Qualification of Electric Equipment Important to Safety for Nuclear Power Plants," U.S. Nuclear Regulatory Commission, January 21, 1983.
- IEEE 323-1974, "IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Stations".
- IEEE 383-1974, "IEEE Standard for Type Test of Class IE Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations."
- NUREG-0588, Category I, Revision 1, "Interim Staff Position of Environmental Qualification of Safety Related Electrical Equipment," dated July, 1981.
- Regulatory Guide 1.89, "Qualification of Class 1E Equipment for Nuclear Power Plants", November 1974.
- Wyle Laboratories Quality Assurance Program Manual, April, 1987.
- Alabama Power Company Purchase Order Number QP-1859.

1.3 Equipment Description

The equipment to be qualified are electrical splices fabricated with the following tapes and assembled per Section 3.2 and Figures 5 through 19, 25, and 26. Refer to Table IV for splice types, specimen numbers, and figure numbers.

1.0 SCOPE (Continued)

1.3 Equipment Description (Continued)

- 3M Scotch 33+ vinyl plastic electrical tape
- Okonite jacketing tape Number 35
- Okonite insulation tape Number T-95

Note: Farley Nuclear Plant currently stocks 3M Scotch 88 vinyl plastic electrical tape which is identical to Scotch 33+ except for thickness. Since Scotch 33+ is thinner than Scotch 88, testing of Scotch 33+ is considered conservative and will qualify the Scotch 88 tape if the test is successful.

1.4 Qualification Sequence

The qualification program shall be performed in the following sequence:

- Receiving Inspection
- Specimen Preparation
- Baseline Functional Test
- Radiation Exposure
- Functional Test
- Thermal Aging
- Functional Test
- Accident Simulation
- Post-Test Inspection

2.0 QUALIFICATION REQUIREMENTS

2.1 Definition of Service Conditions

2.1.1 Margin

It is assumed that adequate margins have not been included in the specifications to account for normal variations in commercial production of equipment and variations in service conditions. Therefore, margin per Paragraph 6.3.1.5 of IEEE 323-1983 shall be added to the following conditions:

o	Temperature:	+15°F on DBE peak
o	Pressure:	+10% of gauge, but not to exceed 10 psig
o	Time:	+10% of post-DBE operation time (1 hour minimum total)
o	Radiation:	+10% of accident dose
o	Voltage:	+5 VAC for 575 VAC, +15 VDC for 125 VDC

2.1.2 Normal Conditions

		Containment	Main Steam Room
o	Radiation (includes accident dose)	2.0E7 rads (15 years) 5.0E7 rads (40 years)	2.0E6 rads (15 years)
o	Temperature	120°F	104°F
o	Pressure:	14.7 psia	14.7 psia
o	Relative Humidity	40-90%	40-90%

2.1.3 Accident Conditions

		Containment	Main Steam Room
o	Radiation (includes normal dose)	2.0E7 rads (15 years) 5.0E7 rads (40 years)	2.0E6 rads (15 years)
o	Temperature (peak)	378°F	308°F
o	Pressure (peak)	63.1 psia	20.5 psia
o	Relative Humidity (peak)	100%	100%
o	Spray	0.15 gpm/ft^2 H_3BO_3 (2500 ppm boron) NaOH (10.5 pH)	N/A

2.0 QUALIFICATION REQUIREMENTS (Continued)

2.1 Definition of Service Conditions (Continued)

2.1.3 Accident Conditions (Continued)

		Containment	Main Steam Room
o	Duration	30 days	less than 1 hour

The main steam room temperature and pressure profiles for a main steam line break are shown in Figures 1 and 2, respectively. The composite containment temperature and pressure profiles during a LOCA/HELB are shown in Figures 3 and 4, respectively.

2.1.4 Other Service Conditions

The subject splicing tapes are installed on cables which supply fan motors and motor and solenoid operators on valves. Typical electrical supply is 575 VAC $\pm$10% to the fan motors and motor operators and 125 VDC $\pm$10% to the solenoids.

2.2 Safety Related Functions

The safety classification of this equipment is Class 1E. The subject equipment provides essential services in support of emergency reactor shutdown, containment isolation, reactor core cooling and containment and reactor heat removal, or is otherwise essential in providing support to prevent significant release of radioactive material to the environment.

2.3 Acceptance Criteria

The following acceptance criteria has been established for the purposes of this qualification effort. Failure to meet these criteria shall not necessarily be considered a failure of the test specimen, but shall be investigated and analyzed by the test engineer.

- The splices shall maintain voltage and circuit continuity within $\pm$25 percent of applied electrical supply. The splices shall not cause their associated fuses to blow.

3.0 QUALIFICATION PROGRAM

3.1 Receiving Inspection

An inspection shall be performed upon receipt of the components at the test facility. This inspection shall assure that the equipment received is as described in Paragraph 1.3. Applicable series, model, part and/or serial numbers shall be verified. The results of the inspection (component identification, quantities, configurations, etc.) shall be recorded.

The subject test specimens shall be labeled, as deemed necessary by the Test Engineer, for positive identification of the specimens during all phases of the test program.

3.2 Specimen Preparation

As specified by customer, fifty-five (55) specimens in 17 different configurations shall be prepared per Figures 5 through 19, 25, and 26 and the following (Refer to Table IV for splice types, specimen numbers, and figure numbers.):

In general, strip 1/4" from the ends of 2 sections of cable to expose the conductor. Crimp an appropriately sized, uninsulated terminal lug to one end of each cable and bolt the lugs together per Figures 5 through 19, 25, and 26. Apply the specified tape in half-lapped layers and extend the tape beyond both ends of the splice as required. The Okonite Nos. 35 and T-95 tapes shall be tensioned to approximately 3/4 of original width (about 1/2 inch) as recommended by the manufacturer when it is applied over the splice. Okonite nuclear splicing cement shall be used as an adhesive only on the 40 year specimens (15.x). The 3M Scotch 33+ tape shall be tensioned to approximately 5/8 of its original width (about 1/2 inch) as recommended by the manufacturer.

Position and affix specimens 1.1, 2.1, 3.1, 4.1, 5.1, and 6.1 in a NEMA 1 enclosure (reference Figure 20). Position and affix specimens 7.1, 8.1, and 9.1 in an open cable tray (Note: these specimens shall be placed in the cover of a Limitorque [illegible] witch compartment prior to DBE testing - reference Figure 21). Position and affix specimens [illegible]a and 10.1b in a 3/4 inch condulet (reference Figure 22). Position and affix specimens 10.2 and 10.3 in another 3/4 inch condulet. Position and affix pairs of specimens 11.x and 12.x together in separate 3/4 inch condulets (e.g. 11.1 and 12.1 together). Repeat for pairs of specimens 13.x and 14x. All condulets shall be affixed to an open cable tray. Position and affix specimens 15.1a, 15.1b, 15.1c, 15.2a, 15.2b, and 15.3 in a second NEMA 1 enclosure (reference Figure 23. Note: specimens 15.2a, 15.2b, and 15.3 shall be removed from the enclosure prior to DBE testing). All remaining specimens (1.2, 1.3, 2.2, 2.3, 3.2, 3.3, 4.2, 4.3, 5.2, 5.3, 6.2, 6.3, 7.2, 7.3, 8.2, 8.3, 9.2, and 9.3) shall be positioned and affixed in an open cable tray. All of the specimens shall be positioned such that the spliced section touches metal.

3.0 QUALIFICATION PROGRAM (Continued)

3.4 Determination of Potential Aging Mechanisms (Continued)

3.4.1 Temperature (Continued)

3.4.1.1 Aging Matrix (Table I)

A literature search of Wyle's Aging Library has been utilized to obtain auditable aging data. For components with time/temperature-related aging mechanisms, the aging analysis was based upon available auditable aging data, as noted in Table I. The Arrhenius equations which are most appropriate to the materials and their application have been utilized when more than one equation is known. The calculated expected lives of the nonmetallic materials, as well as the radiation threshold for each material, are tabulated in the Aging Matrix, Table I.

As noted in the Aging Matrix, Table I, some of the materials which are required for the specimens to perform their safety-related function are age sensitive at the baseline temperatures under consideration. Therefore, thermal aging of the specimens is required.

3.4.1.2 Reference List (Table II)

The library references which form the basis of the analysis and/or conclusions of this report, as well as those utilized in the preparation of the Aging Matrix (Table I) are tabulated in the Reference List (Table II).

3.4.1.3 Normal Service Conditions (Table III)

The normal service conditions which are used as the basis for the calculations in the Aging Matrix (Table I) are documented in Table III.

3.4.2 Relative Humidity

For insulation systems, the effect of a humid environment is not considered an aging mechanism. As noted in Library Code 0255-80:

> "In most cases, moisture plays only a secondary role in the failure. It does not produce damage to the insulation, the insulation wears away or cracks for other reasons. Moisture merely provides a direct electrical pathway between these mature devices and ground."

3.0 QUALIFICATION PROGRAM (Continued)

3.3 Baseline Functional Test

Continuity of the assembled specimens shall be verified. Continuity is defined as a reading of 1 ohm or less when measured with a digital ohmmeter.

Insulation resistance shall be measured for information only after placing each specimen on a grounded surface and applying 500 VDC between the conductor of the spliced cable and ground for one minute. If a reading cannot be obtained at 500 VDC, the voltage shall be reduced until the insulation resistance is measurable. All results shall be recorded.

3.4 Determination of Potential Aging Mechanisms

Each component in the subject equipment has been reviewed in order to ascertain the safety related materials of construction. Then a determination of the aging mechanisms which may affect the subject materials is accomplished by reviewing the service conditions to which the equipment will be qualified. The service conditions to be addressed are:

- o Temperature
- o Relative Humidity
- o Pressure
- o Radiation

3.4.1 Temperature

Normal temperature conditions coupled with time create an aging mechanism known as time/temperature effects. As noted in Library Code 0256-80:

> "The exposure of polymers to the influence of environmental factors over a period of time generally leads to deterioration in physical properties."

Appendix A provides a detailed explanation of the methodology used to determine thermal age sensitivity and aging parameters.

The desired qualified lives of the subject equipment are 15 years for specimens 1.x through 14.x, and 40 years for specimens 15.x. The equipment shall be assigned a maximum maintenance/replacement interval no greater than its qualified life.

Each component in the subject equipment has been reviewed for function and age-related failure mechanisms which could affect its function. An Aging Matrix (Table I) has been prepared which defines the components, non-metallic materials, temperature ratings, service conditions, applications and thermal age sensitivity for each material. The materials identification tabulated in Table I is based on data obtained from the manufacturers. (See Attachment 1).

3.0 QUALIFICATION PROGRAM (Continued)

3.4 Determination of Potential Aging Mechanisms (Continued)

3.4.2 Relative Humidity (Continued)

IEEE 117-1974, Paragraph 3.3.3 states:

> "Moisture is used to make dielectric tests more discerning of physical and thermal damage to electrical insulation systems."

As further noted in Library Code 0010-78, in a discussion of moisture conditioning of thermally aged test specimens:

> "Moisture conditioning is included in the (test) procedure (of IEEE 117-1974) as a probe for determining insulation failures at the time they occur, and is not in itself intended to be an aging factor (emphasis added). Most electrical insulation, as it thermally ages, increases in ability to absorb moisture, which in turn is reflected in a lower insulation resistance and corresponding electrical strength."

The Nuclear Regulatory Commission, in a discussion of comments on 10 CFR Part 50 states:

> "It has not been demonstrated that the time-dependent variation in humidity will produce any differences in degradation of electric equipment."

It is therefore concluded that relative humidity is not an aging mechanism.

3.4.3 Pressure

The atmospheric pressure is equal to 406.912 inches of H_2O. Typically, from Library Code 0269-80, the mean changes by 8.4 inches of H_2O across the United States. Within the same location, the mean changes from 2 to 4 inches of H_2O each year. Qualification requirements for atmospheric pressure changes within the limits of 8.4 inches of H_2O are judged to be of no consequence since neither Library code 0021-78A nor 0256-80 noted an effect due to normal atmospheric changes.

3.4.4 Radiation

Evaluation has been made of the function of the component materials. This information has been compared to auditable data to determine the susceptibility of the material, in its application, to the radiation exposure level specified.

3.0 QUALIFICATION PROGRAM (Continued)

3.4 Determination of Potential Aging Mechanisms (Continued)

3.4.4 Radiation (Continued)

A literature search of Wyle's Aging Library has been utilized to obtain the radiation threshold values tabulated in Table I. Library Code 0506-81A defines the radiation threshold as:

> "The lowest radiation dose which induces permanent change in a measured property of a material,"

and also as:

> "The first detectable change in a property of a material due to the effect of radiation."

For conservatism, the lowest radiation threshold of a material, consistent with its application, is used in this procedure.

Per Table I, all of the subject equipment have radiation thresholds less than the requirements. Therefore, radiation exposure is required to confirm the capability of these specimens to perform their safety-related function in the specified environment.

3.5 Radiation Exposure

3.5.1 Radiation Exposure Before Thermal Aging

Testing sponsored by the Nuclear Regulatory Commission (NRC) and reported by Sandia Laboratories (WAL 0271-80) has shown radiation prior to thermal aging causes some polymers to degrade to a greater extent than when irradiated following thermal aging. The report states: "The mechanistic postulate is that radiation-cleaved bonds, in the form of radicals, react with oxygen to give degradation products, including peroxides. The peroxides are chemically weak links which are susceptible to thermal cleavage. This thermal peroxide cleavage gives more radicals which, in the presence of oxygen, lead to more degradation and more peroxides. Thermal aging prior to irradiation does not substantially disrupt the polymer's original molecular structure over the normal elevated temperature ranges which, in turn, results in a lesser degree of degradation than may be expected in actual plant applications. Thus, the amplification of the degradation process caused by the thermal peroxide cleavage must be accounted for by performing radiation exposure prior to thermal aging."

Subsequent testing sponsored by Sandia Laboratories, as reported in SAND-80-2149C (WAL 0474-81), establishes performing thermal aging after irradiation as the only method in which to account for the strong synergism due to radiation and high temperature found in some polymers. "The joint effect of gamma radiation and elevated temperature was also found to occur when the two environments were applied in sequential fashion but only when the experiments were performed in that order: radiation at room temperature followed by elevated temperature."

3.0 QUALIFICATION PROGRAM (Continued)

3.5 Radiation Exposure (Continued)

3.5.1 Radiation Exposure Before Thermal Aging (Continued)

Therefore, the application of the entire radiation dose prior to thermal aging is conservative.

Other NRC sponsored testing by Sandia Laboratories (WAL 0474-81A) indicates that the mechanical damage resulting from a given total dose is dependent on dose rate for some polymers. Testing was performed at 1E3 and 1E6 rads/hour. For the polymers tested, more degradation occurred at the lower dose rate. The report states, "Sufficient data has now been accumulated from the low dose rate experiments to indicate that dose rate effects are present for every material which we have studied and must, therefore be considered before extrapolating high dose rate accelerated simulations to low dose rate ambient conditions." The equipment under consideration contains several polymers.

3.5.2 Radiation Exposure Test

The specimens shall be irradiated as specified in Table IV. Radiation exposure shall be performed at a dose rate less than 1.0E6 rads/hour.

The test specimens shall be unpowered during the radiation exposure. Electrical monitoring of the test specimens is not required during the radiation exposure.

3.6 Functional Test

The functional test of Paragraph 3.3 shall be repeated after radiation exposure.

3.7 Thermal Aging

Thermal aging of the specimens shall be performed in an air -circulating oven as specified in Table IV. The thermal aging program is based on the lowest activation energy for the materials of the tape acting as the primary insulation. The Arrhenius calculations which document the accelerated aging times are included as Attachment 2.

The test specimens shall be unpowered during thermal aging. Electrical monitoring of the test specimens is not required during this phase of testing.

3.8 Functional Test

The functional test of Paragraph 3.3 shall be repeated after thermal aging.

3.0 QUALIFICATION PROGRAM (Continued)

3.9 Accident Simulation

3.9.1 Test Specimen Preparation

Prior to accident simulation testing, the following irradiated and aged test specimens shall be prepared as follows:

1. The NEMA 1 enclosure containing specimens 1.1, 2.1, 3.1, 4.1, 5.1, and 6.1 shall be mounted and affixed to a Wyle-supplied test fixture in the test chamber in an upright orientation. Specimens 7.1, 8.1, and 9.1 shall be mounted in the bottom of a Limitorque limit switch compartment cover such that the splices touch metal (reference Figure 21). A Wyle-fabricated cover plate shall be used to enclose the compartment. A 1-1/2 inch hole centered at the bottom of the plate shall be fitted with a Myers hub and a 90° elbow oriented downward to accommodate wire feed-through. The enclosed compartment shall be mounted on a Wyle-supplied test fixture in the test chamber with the elbow opening oriented downward. The 3 condulets containing specimens 10.1a and 10.1b, 11.1 and 12.1, and 13.1 and 14.1, respectively, shall be mounted in an open cable tray and positioned in the test chamber. The NEMA 1 enclosure containing specimens 15.1a, 15.1b, and 15.1c shall be mounted on a Wyle-supplied test fixture in the test chamber in an upright orientation.

   Note: Specimens 1.2, 1.3, 2.2, 2.3, 3.2, 3.3, 4.2, 4.3, 5.2, 5.3, 6.2, 6.3, 7.2, 7.3, 8.2, 8.3, 9.2, 9.3, 10.2, 10.3, 11.2, 11.3, 12.2, 12.3, 13.2, 13.3, 14.2, 14.3, 15.2a, 15.2b, and 15.3 are spares to be stored for future tests.

2. Wyle-supplied teflon-insulated cables shall be utilized for electrical connections which shall penetrate the test chamber. Each cable shall be approximately 20 feet in length. Exact length requirements shall be determined during test preparation. Each end of each teflon-insulated cable shall be stripped and spliced to the specimen leads per Wyle Laboratories standard practices.

3. All cables shall be routed through chamber penetrations, which shall be potted per Wyle Laboratories standard practices.

4. Each cable shall be labeled for identification.

5. Photographs shall be taken of the test specimens and the test setup.

6. Close and secure the chamber access door.

3.0 QUALIFICATION PROGRAM (Continued)

3.9 Accident Simulation (Continued)

3.9.2 Chamber Instrumentation

Three thermocouples shall be located in the environmental chamber within two inches of the surface of the test fixtures and shall be utilized to monitor the chamber temperature. The individual readings shall be recorded and averaged, and the average recorded. The thermocouple registering the highest temperature shall be used to control the chamber temperature during the initial and secondary ramp. The average of the values from the three thermocouples shall be used for control thereafter.

Chamber pressure shall be monitored with an appropriate pressure sensing device (i.e., transducer). Results shall be recorded.

Flow rate of the chemical spray shall be monitored by a flow meter. Results shall be recorded.

The Daytronics System 10 Data Acquisition System (DAS) shall be operated at its peak rate from initiation of each ramp until 10 minutes, and at 1-minute intervals thereafter until test completion. A pen-chart recorder shall be provided also to continuously monitor the chamber temperature.

3.9.3 Specimen Instrumentation

Channels of the DAS shall be provided to monitor voltage and current of all test specimens. Channels of the DAS shall also be provided to monitor phase-to-ground leakage current of specimens 10.1a, 10.1b, 11.1, 12.1, 13.1, and 14.1.

3.9.4 Pre-Accident Operability

All the specimens installed in the chamber shall be checked for operability by applying voltage and current as described below before the start of the accident test. Results of these tests shall establish a performance criteria for each specimen which shall be compared to the measurements taken during the accident test.

Specimen	Voltage	Current
1.1, 2.1, 3.1	633 VAC	27 Amperes
4.1, 5.1, 6.1	633 VAC	130 Amperes
7.1, 8.1, 9.1	633 VAC	20 Amperes
10.1a, 10.1b	137.5 VDC	as required by ASCO solenoid valve end device
11.1, 12.1	137.5 VDC	as required by ASCO solenoid valve end device
13.1, 14.1	137.5 VDC	as required by ASCO solenoid valve end device
15.1a, 15.1b, 15.1c	633 VAC	27 Amperes

3.0 QUALIFICATION PROGRAM (Continued)

3.9 Accident Simulation (Continued)

3.9.5 Accident Simulation Test

Prior to the initiation of the accident simulation, the test chamber shall be stabilized at 120°F and held for at least 30 minutes.

Beginning with the initial conditions, the test specimens shall be subjected to an accident simulation test that shall envelop the profile shown in Figure 24 which includes the appropriate margins. The temperature and pressure conditions shall be generated by injection of superheated steam to maintain the chamber temperature and pressure. The ramps shall be attained on a best-effort basis.

The chemical spray shall be initiated after the second ramp when conditions become saturated (280°F at 35 psig) which occurs at approximately 93 minutes into the test and shall continue for 24 hours. The spray rate shall be 0.15 gpm/ft^2. One channel of the DAS shall be used to record flow rate.

The post-DBE temperature requirement from the 240°F point at 5.0E3 seconds (84 minutes) into the second transient can be accelerated by elevating the temperature. The post-DBE accelerated aging time including margin is 43 hours and 17 minutes (+2 hours,-0 hours) at 240°F. The time is based on an Arrhenius calculation that uses an activation energy of 1.23 eV which is the lowest activation energy for the materials of the tape acting as the primary insulation for the splices that are required to operate during the second transient. Calculation of the post-DBE aging time is documented in Attachment 3.

3.9.6 Accident Operability

The specimens shall be checked for operability by applying voltage and current as described below. Performance of the test specimens shall be monitored on the DAS.

Specimens	Voltage	Current	Initiation time	Duration
1.1, 2.1, 3.1	633 VAC	27 Amperes	start of test	until end of test
4.1, 5.1, 6.1	633 VAC	130 Amperes	start of test	until end of test
7.1, 8.1, 9.1	633 VAC	20.2 Amperes	65th minute	1 hour
			45th hour	2 minutes
10.1a [illegible]	137.5 VDC	ASCO	start of test	until end of test
11.1, [illegible]	137.5 VDC	ASCO	start of test	1 hour
13.1, 14.1	137.5 VDC	ASCO	start of test	1 hour
15.1a, 15.1b, 15.1c	633 VAC	27 Amperes	start of test	until end of test

3.0 QUALIFICATION PROGRAM (Continued)

3.9 Accident Simulation (Continued)

3.9.6 Accident Operability (Continued)

If a fuse for a test specimen blows during the test, the specimen shall be identified, together with the time and the circumstances. The specimen shall not be deemed to have failed until the post-test inspection required by Section 3.10 establishes the root cause of the failure.

Specimens 7.1, 8.1, and 9.1 are only required to function for 2 minutes following accident initiation. Although not a qualification requirement, they are being tested during the last hour of the test for fragility purposes. Failure of the specimens after the first hour does not disqualify them.

3.10 Post-Test Inspection

The equipment shall be visually inspected. The equipment shall be disassembled to the extent necessary to perform the inspection. The condition of the equipment shall be recorded.

3.11 In-Process Inspection

All test specimens shall be examined for possible damage following all severe tests. All important results shall be logged.

Photographs shall be taken of any noticeable physical damage which may occur.

4.0 QUALITY ASSURANCE

All work performed on this program will be conducted in accordance with Wyle Laboratories' Quality Assurance Policies and Procedures Manual, which conforms to the applicable portions of ANSI N45.2, 10 CFR 50 Appendix B, and Military Specification MIL-STD-45662. Standards utilized in the performance of all calibrations are traceable to the National Bureau of Standards.

5.0 REPORT

A report shall be issued which shall describe the test requirements, procedures, and results. The report shall also include rationale and justification required for the test and shall describe those test items which passed the tests. The customer shall receive three bound copies plus one reproducible copy of the report. Raw test data will be made available one year after program completion.

TABLE I AGING MATRIX 08/19/87

DATA FILES: N=AB081987
B=FAR180 (TABLE III)

ITEM NO	ITEM / MANUFACTURER MATERIAL	CRITERIA AGE BEND	RATED TEMP HEAT RISE	ACT ENG Ea REF	RAD THOLD RAD REF	APPLICATION	EXP LIFE SEE NOTE
1.0	VINYL ELECTRICIAN'S TAPE (ASSUME 3M SCOTCH 33) AS FOLLOWS:					ASSEMBLY	
1.1	TAPE, BLACK VINYL PLASTIC ELECTRICAL POLYVINYL CHLORIDE	10000 YES	105	1.15 049981	5.0E5 050681A	ELECTRICAL	4.77 E 3
1.2	ADHESIVE SYSTEM RUBBER RESIN (NATURAL/SYNTHETIC RUBBER)	10000 YES	105	0.99 049981	8.0E5 042881	MECHANICAL	2.26 E 2
2.0	OKONITE NO. T-95 INSULATION TAPE ETHYLENE PROPYLENE	10000 YES	090	1.23 031386A	5.0E6 082579B	ELECTRICAL	1.97 E 3
3.0	OKONITE NO. 35 JACKETING TAPE NEOPRENE	10000 YES	090	0.65 031180A	8.0E5 043081	ELECTRICAL	7.76 E -1

TABLE II-REFERENCE LIST 09/22/87

CODE	TITLE
001076	"HUMIDIFICATION IN THE THERMAL LIFE DETERMINATION OF MOTORETTE INSULATION SYSTEMS, L.M. JOHNSON, NRL REPORT NO. 7469, SEPTEMBER 7, 1972.
002175A	"DEGRADATION OF POLYMERS," C.H. BAMFORD AND E.F.H. TIPPER, 'COMPREHENSIVE CHEMICAL KINETICS,' VOL. 14, EXCERPTS PERTAINING TO AGING) ELSEVIER SCIENTIFIC PUBLISHING COMPANY.
022679B	"INSULATIONS AND JACKETS FOR CONTROL AND POWER CABLES IN THERMAL REACTOR NUCLEAR GENERATING STATIONS," ROBERT B. BLODGETT AND ROBERT G. FISHER, 'IEEE TRANSACTIONS ON POWER APPARATUS AND SYSTEMS,' VOL. PAS-88, NO. 5, MAY, 1969.
025580	'INDUSTRIAL MOTOR USERS' HANDBOOK OF INSULATION FOR REWINDS,' L. J. REJDA AND KRIS NEVILLE, ELSEVIER, 1977.
025680	'ELEMENTS OF POLYMER DEGRADATION,' LEO REICH, ET AL., MCGRAW-HILL BOOK COMPANY, NEW YORK, 1971.
026980	'CLIMATIC ATLAS OF THE UNITED STATES,' U.S. DEPARTMENT OF COMMERCE, REPRINTED BY THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION, 1974.
027180	"A STUDY OF STRONG SYNERGISM IN POLYMER DEGRADATION," R.L. CLOUGH, K.T. GILLEN, AND E.A. SALAZAR, SANDIA LABORATORIES, NO. SAND-79-092-CK, AUGUST 8, 1979.
031180A	"DEMONSTRATION OF 40 YEAR LIFE FOR MATERIALS," THE OKONITE COMPANY.
031380A	"QUALIFICATION OF OKOGUARD ETHYLENE-PROPYLENE RUBBER INSULATION FOR NUCLEAR PLANT SERVICE (MEDIUM-VOLTAGE CABLE AND FIELD SPLICE)," OKONITE COMPANY, FORM G-3, FEBRUARY 16, 1979.
043881	"THE USE OF PLASTICS AND ELASTOMERS IN NUCLEAR RADIATION," W.W. PARKINSON AND O. SISMAN.

TABLE II-REFERENCE LIST 09/22/87

CODE	TITLE
047481	"RADIATION-THERMAL DEGRADATION OF PE AND PVC: MECHANISM OF SYNERGISM AND DOSE RATE EFFECTS," R.L. CLOUGH AND K.T. GILLEN. SANDIA NATIONAL LABORATORIES, SAND 80-2149C.
049981	QUALIFICATION REPORT, WESTINGHOUSE ELECTRIC CORPORATION, TYPE AB CIRCUIT BREAKER, REV. 2, DATED 11/30/79.
050681A	"RADIATION EFFECTS ON ORGANIC MATERIALS IN NUCLEAR PLANTS," M.B. BRUCE AND M.V. DAVIS, EPRI REPORT NO. NP-2129.

TABLE III

```
A * M * P * S   NORMAL SERVICE CONDITIONS
     BASELINE NAME:  FAR120
   TEMP SCALE (F/C)   F                      TIME SCALE (H/%)  H
        TOTAL TIME   131400    HOURS     EXEMPTION CRITERIA  10000  YEARS
   NUMBER BASELINES:  1
                     TEMP (F)    TIME (H)    ADD AR ?
                     120         131400
```

Table IV Qualification Plan Summary

Specimen	Figure/ Detail*	Cable	Radiation	Thermal Aging**	Accident
1.1, 1.2, 1.3	6/NT02	1/0 AWG Okoguard/ 1/0 AWG Okoguard	2.2E7	112 hours @ 110°C	CNMT
2.1, 2.2, 2.3	7/NT03	1/0 AWG Okoguard/ 2/0 AWG Okoguard	2.2E7	112 hours @ 110°C	CNMT
3.1, 3.2, 3.3	8/NT06	1/0 AWG Okoguard/ 8 AWG Okoguard	2.2E7	112 hours @ 110°C	CNMT
4.1, 4.2, 4.3	10/VT02	2/0 AWG Okoguard/ 2/0 AWG Okoguard	2.2E7	112 hours @ 110°C	CNMT
5.1, 5.2, 5.3	11/VT03	2/0 AWG Okoguard/ 2/0 AWG Okoguard	2.2E7	112 hours @ 110°C	CNMT
6.1, 6.2, 6.3	12/VT06	2/0 AWG Okoguard/ 1/0 AWG Okoguard	2.2E7	112 hours @ 110°C	CNMT
7.1, 7.2, 7.3	14/T02	1/0 AWG Okoguard/ 12 AWG Okoguard	2.2E7	112 hours @ 110°C	CNMT
8.1, 8.2, 8.3	15/T03	8 AWG Okoguard/ 8 AWG Okoguard	2.2E7	112 hours @ 110°C	CNMT
9.1, 9.2, 9.3	16/T06	8 AWG Okoguard/ 12 AWG Okoguard	2.2E7	112 hours @ 110°C	CNMT
10.1a, 10.1b, 10.2, 10.3	5/NT01	12 AWG Okoguard/ 18 AWG ASCO lead wire	2.2E7	112 hours @ 110°C	CNMT
11.1, 11.2, 11.3	9/VT01	12 AWG Okoguard/ 18 AWG ASCO lead wire	2.2E6	100 hours @ 110°C	MSR
12.1, 12.2, 12.3	13/T01	12 AWG Okoguard/ 18 AWG ASCO lead wire	2.2E6	100 hours @ 110°C	MSR
13.1, 13.2, 13.3	17/N03	12 AWG Okoguard/ 18 AWG ASCO lead wire	2.2E6	250 hours @ 150°C	MSR
14.1, 14.2, 14.3	18/N06	12 AWG Okoguard/ 18 AWG ASCO lead wire	2.2E6	250 hours @ 150°C	MSR
15.1a, 15.1b 15.1c, 15.2a, 15.2b, 15.3	19/T08	8 AWG Okoguard/ 12 AWG Okoguard	5.0E7	297 hours @ 110°C	CNMT
16.1, 16.2, 16.3	25/NT07	4/0 AWG Okoguard/ 4/0 AWG Okoguard	1.1E7	1325 hours @ 150°C	N.A.
17.1, 17.2, 17.3	26/NT08	4/0 AWG Okoguard/ 4/0 AWG Okoguard	1.1E7	1325 hours @ 150°C	N.A.

* The detail number is an alpha-numeric number which describes the type of tape used in the splice construction starting from the outermost tape to the innermost tape. The numeric portion of the detail number indicates the approximate length of extension of the insulating tape over the end of the splice. See the Figures for the details.

T — Okonite No. T-95 tape
N — Okonite No. 35 tape
V — 3M Scotch 33+ tape

** Tolerance (-0°C, +5°C), (-0 hours, +3 hours)

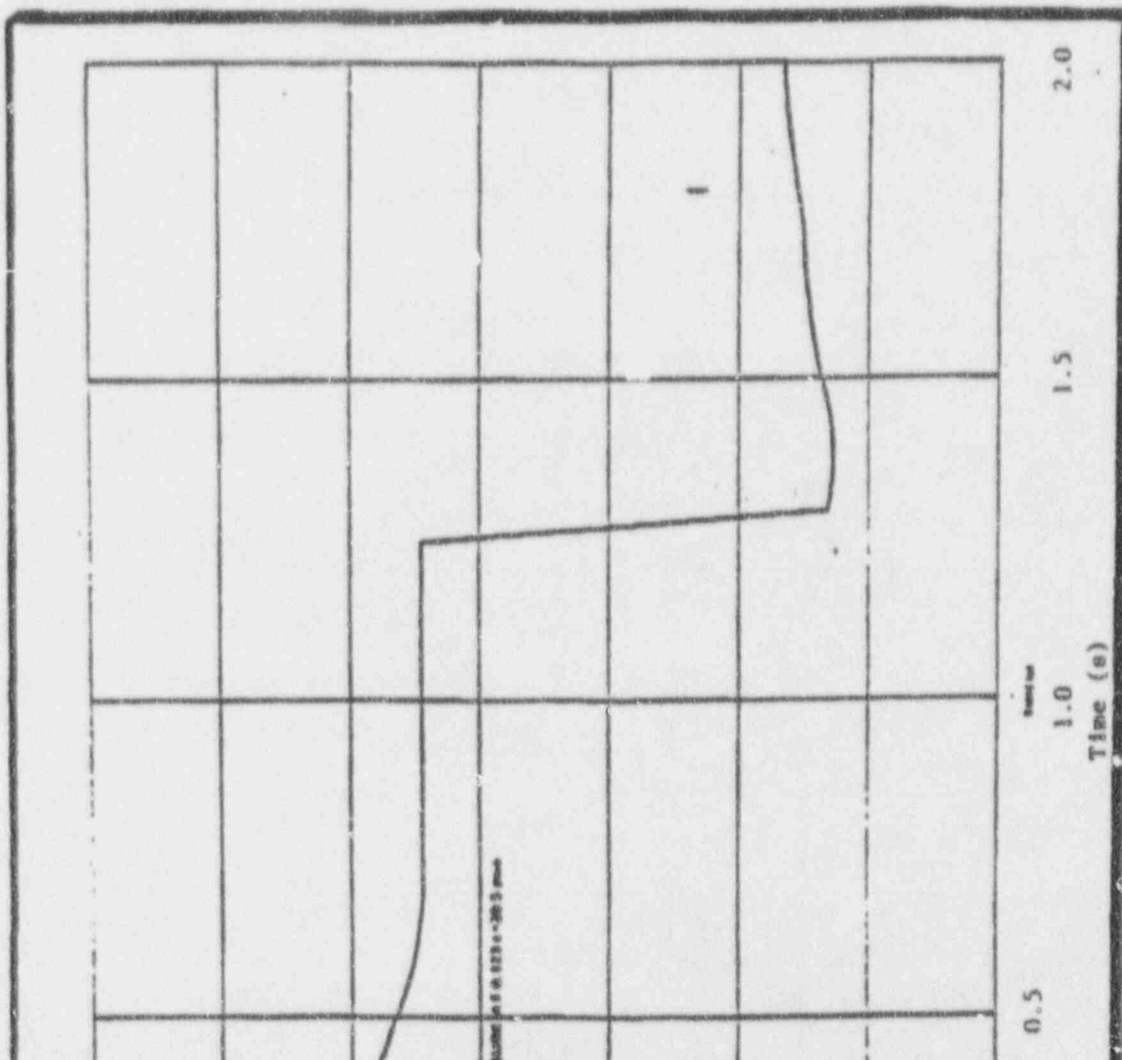


Figure I   Main Steam Room Pressure vs. Time for Main Steam Line Break

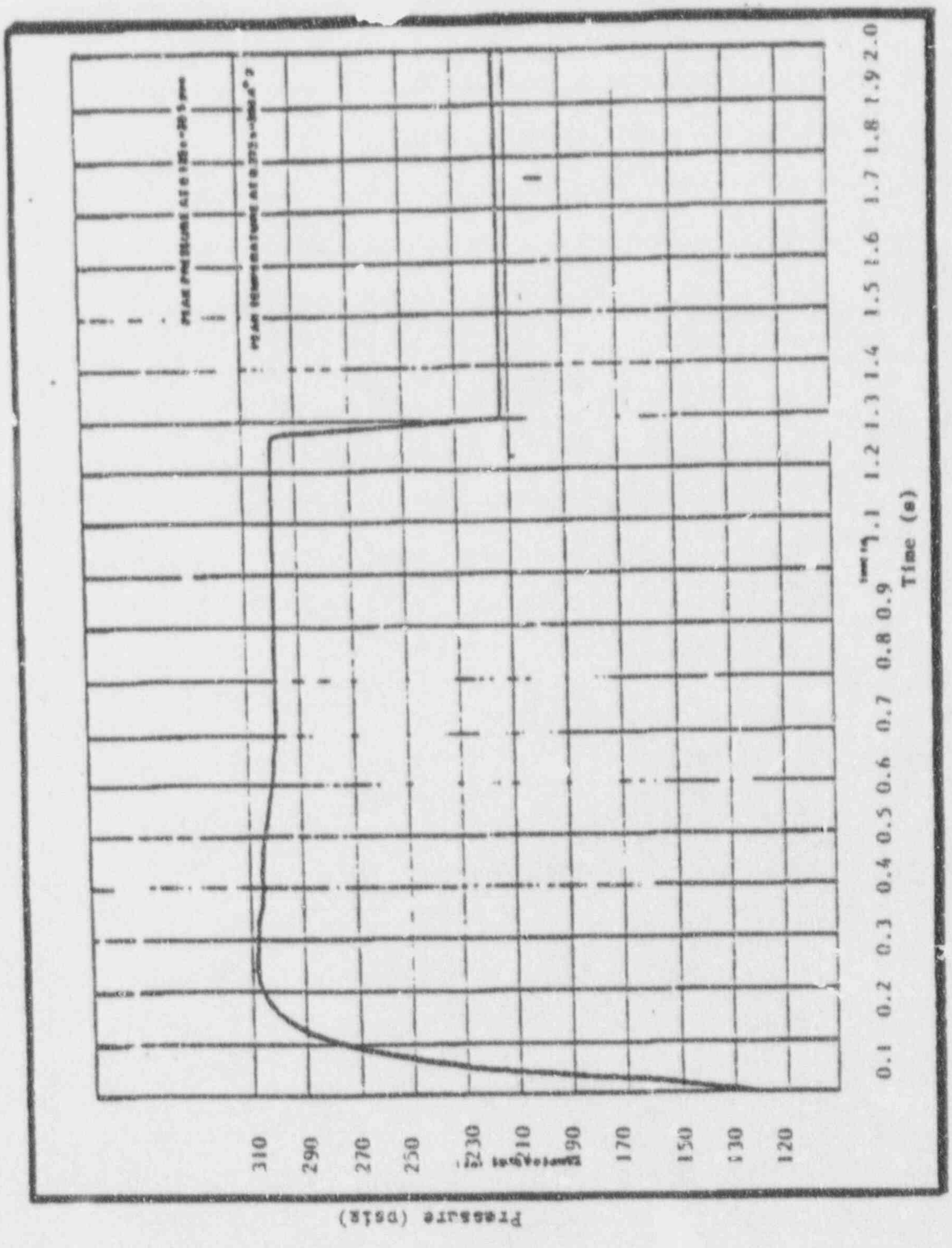


Figure 2 Main Steam Room Temperature vs. Time for Main Steam Line Break

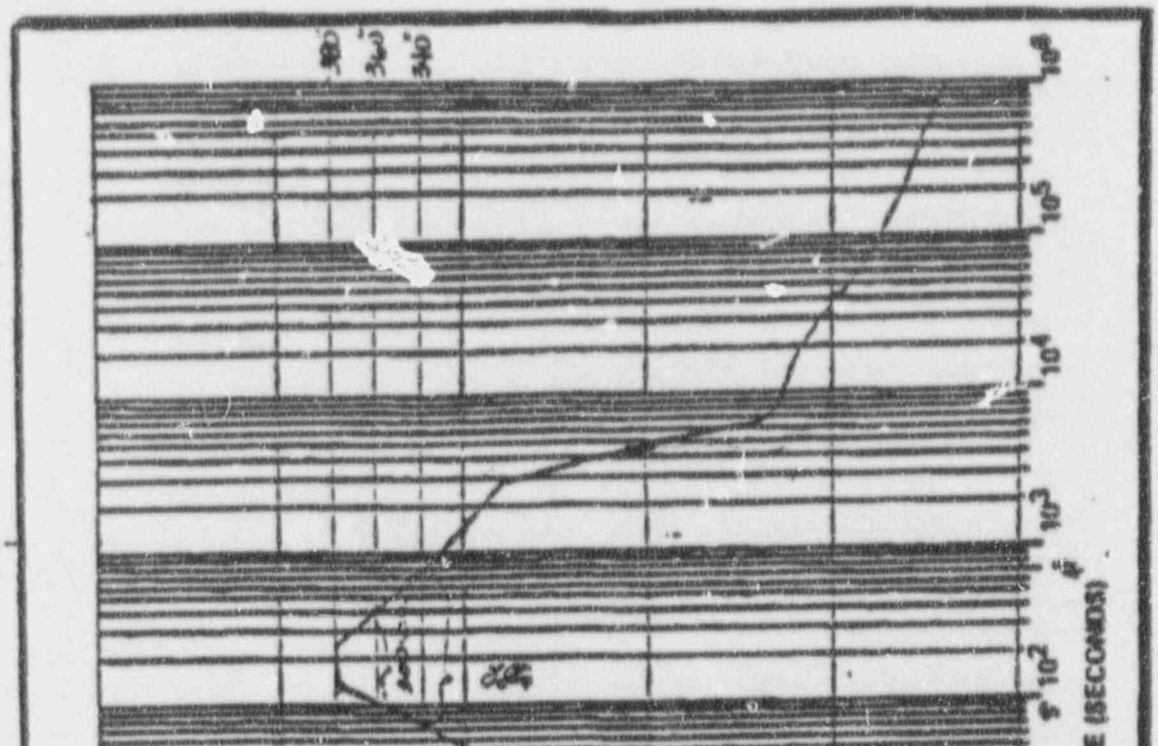


Figure 4 Containment Vapor Temperature Envelope for Farley Nuclear lant

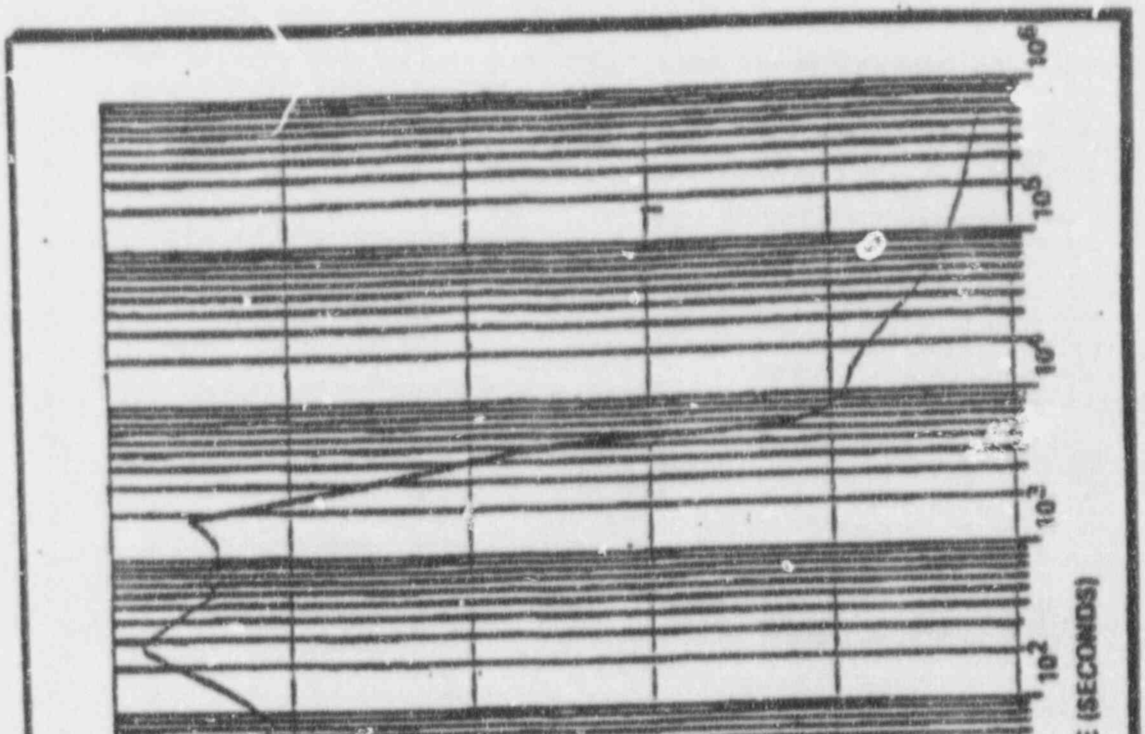
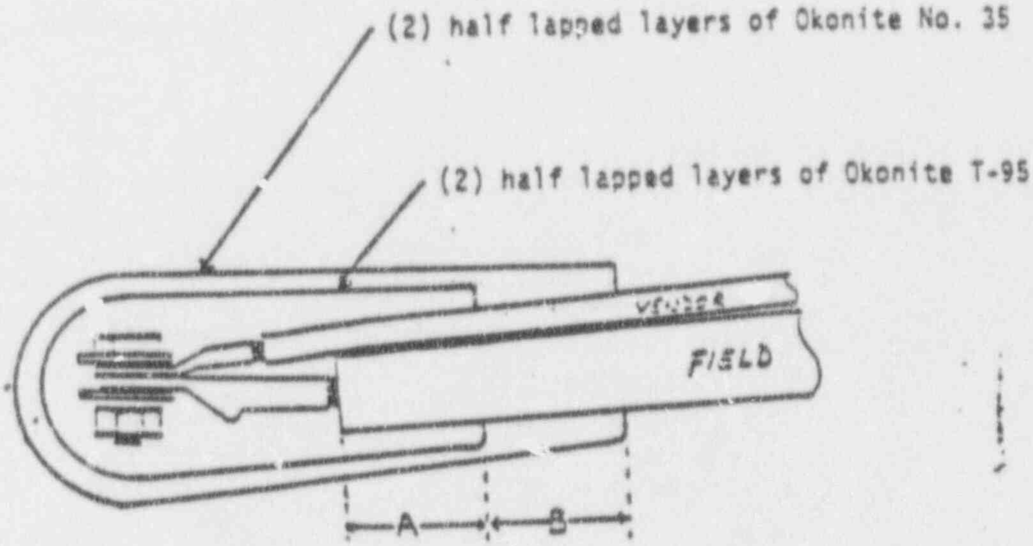


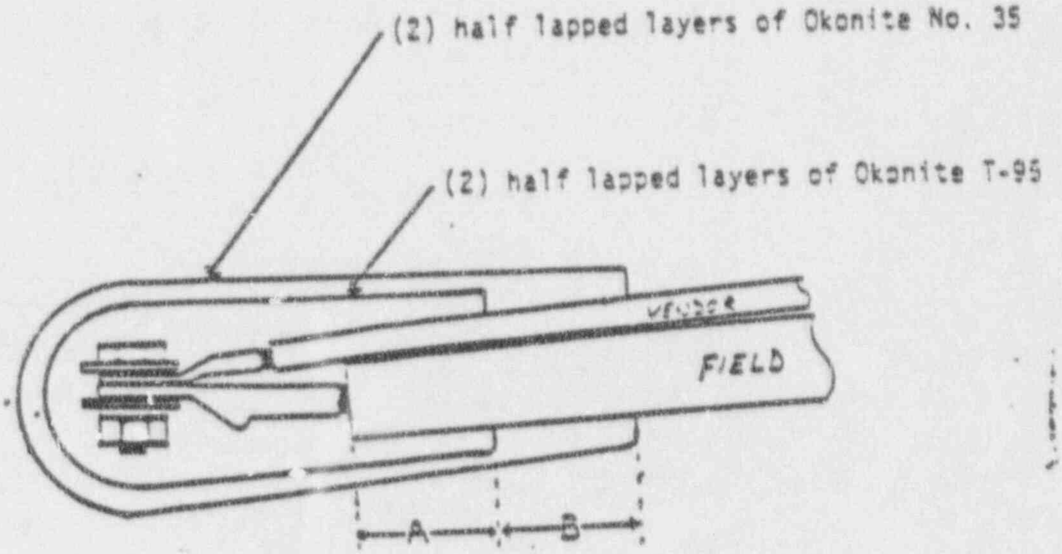
Figure 3 Containment Pressure Envelope for Farley Nuclear Plant



DETAIL NT01

A	B
0.25"	0.50"

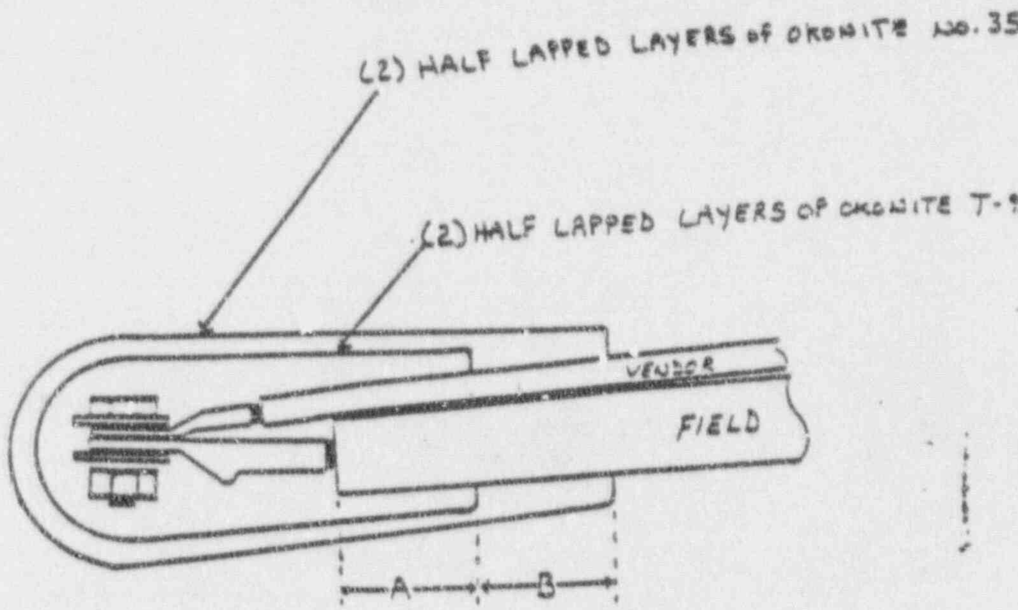
FIGURE 5



DETAIL NT02

A	B
0.50"	0.50"

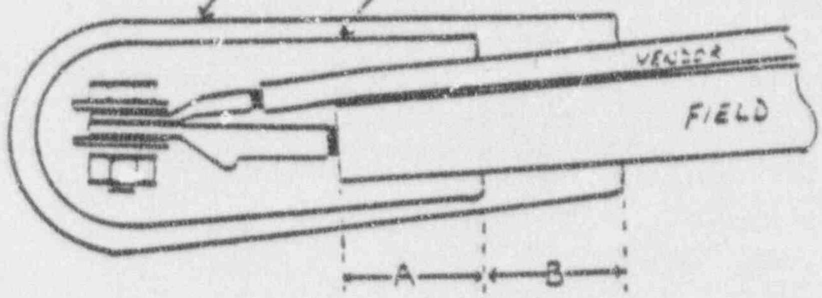
FIGURE 6



DETAIL NT03

A	B
0.75"	0.50"

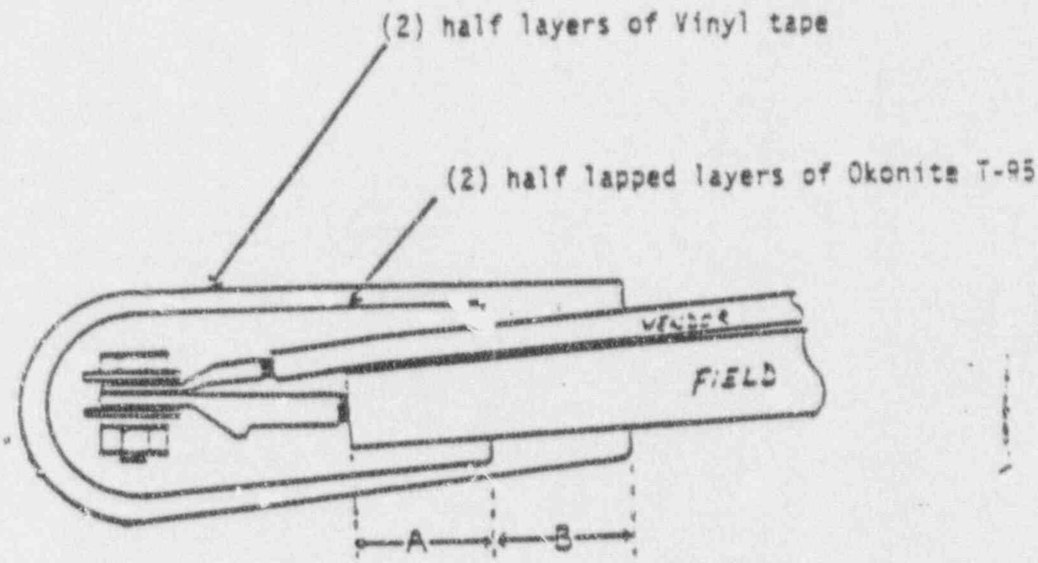
FIGURE 7



DETAIL NT06

A	B
1.00"	0.50"

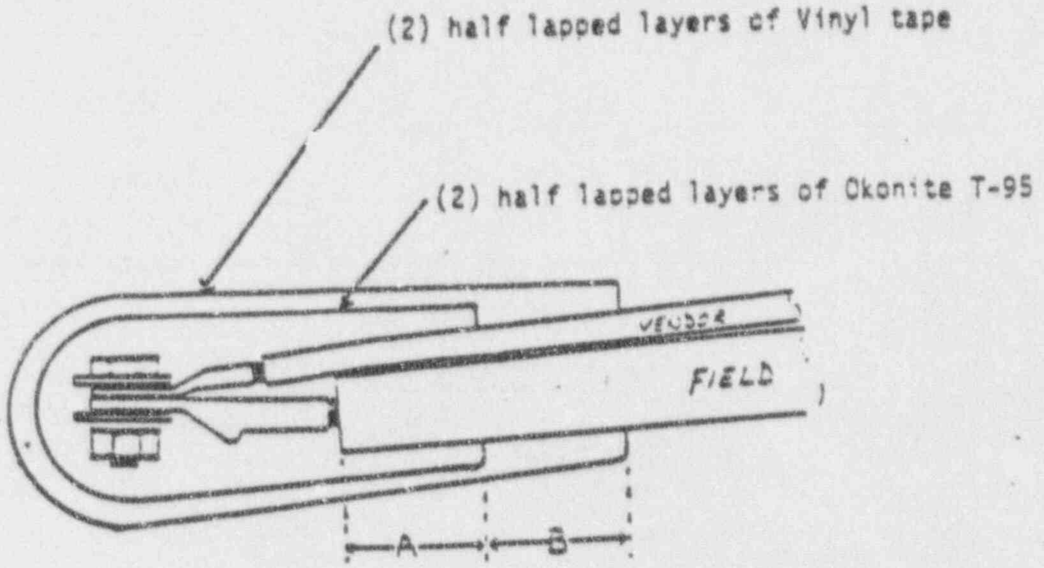
FIGURE 8



DETAIL VT01

A	B
0.25"	0.50"

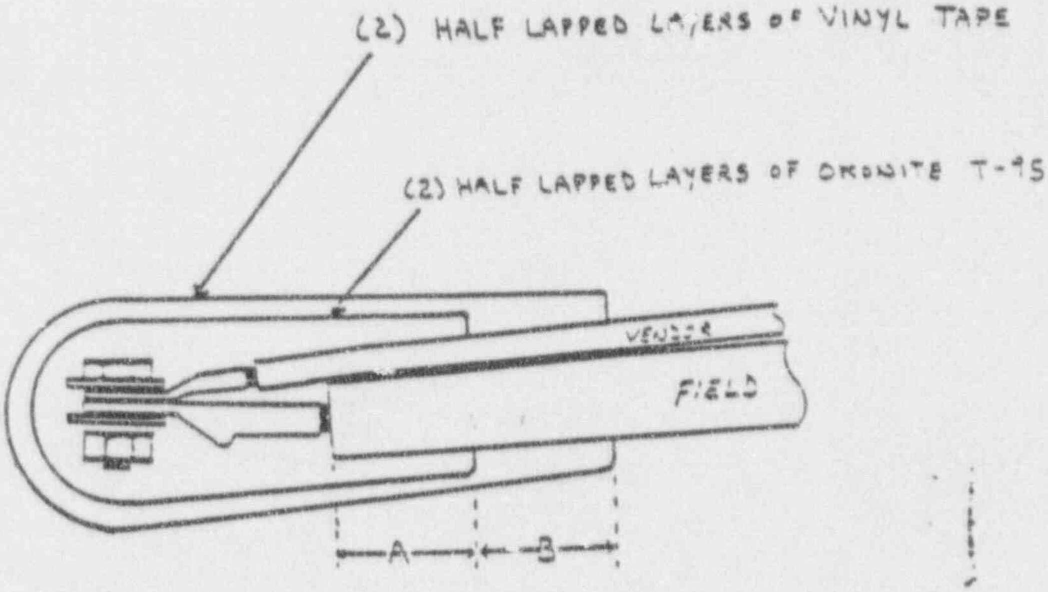
FIGURE 9



DETAIL VT02

A	B
0.50"	0.50"

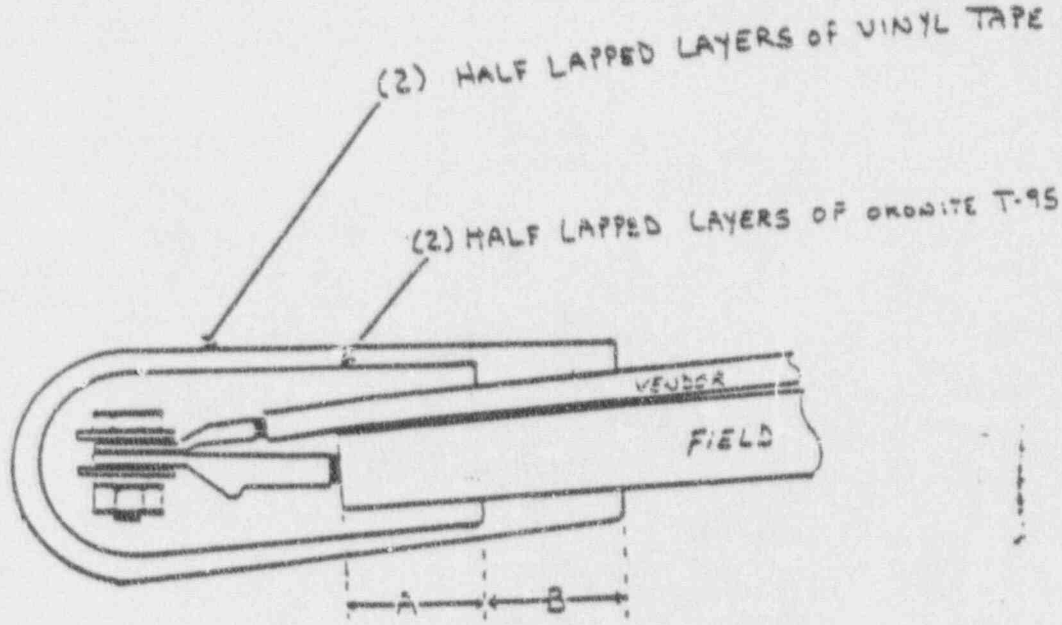
FIGURE 10



DETAIL VT03

A	B
0.75"	0.50"

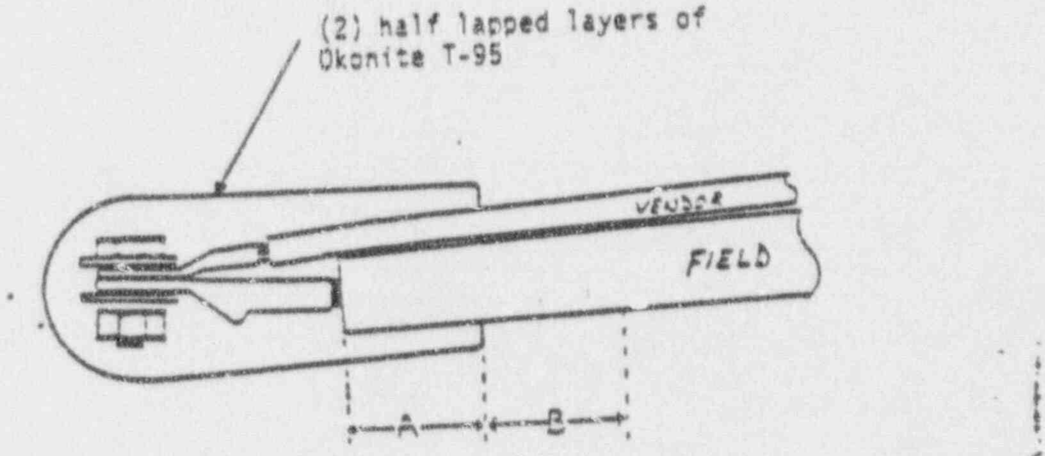
FIGURE 11



DETAIL UTC6

A	B
1.00"	0.50"

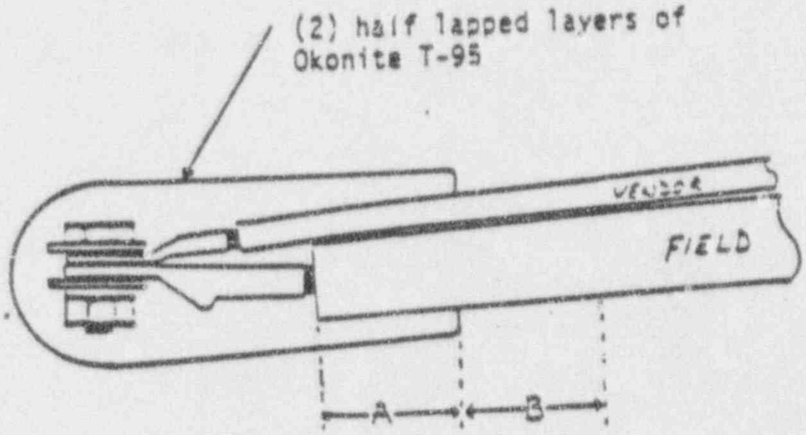
FIGURE 12



DETAIL T01

A	B
0.25"	N/A

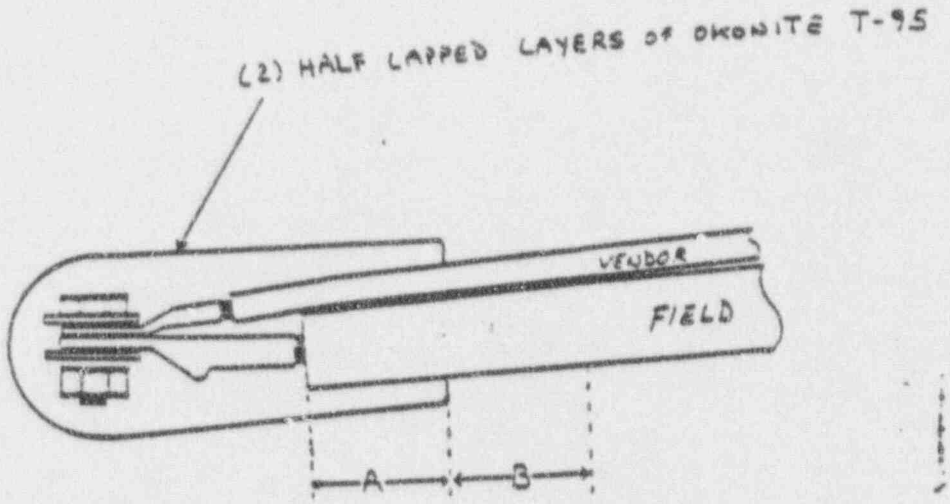
FIGURE 13



DETAIL T02

A	B
0.50"	N/A

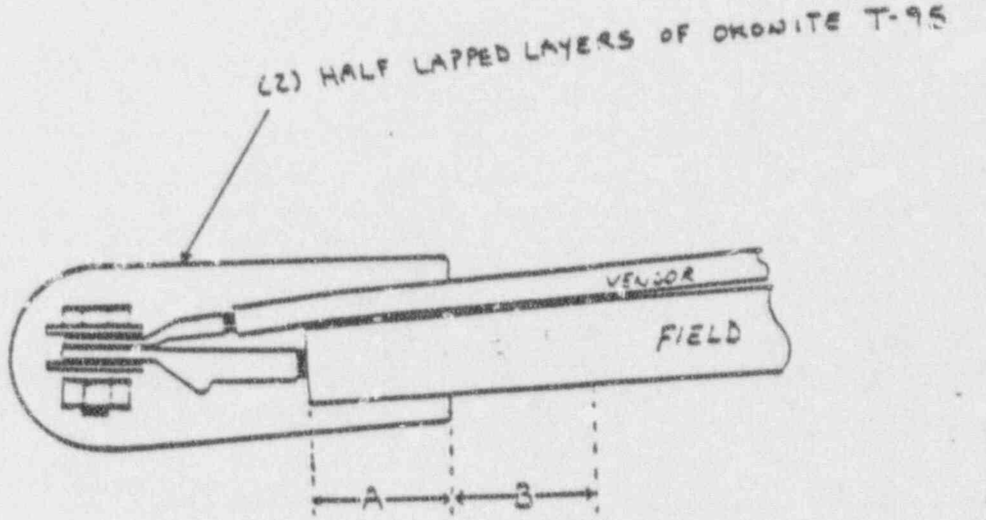
FIGURE 14



DETAIL T03

A	B
0.75"	N/A

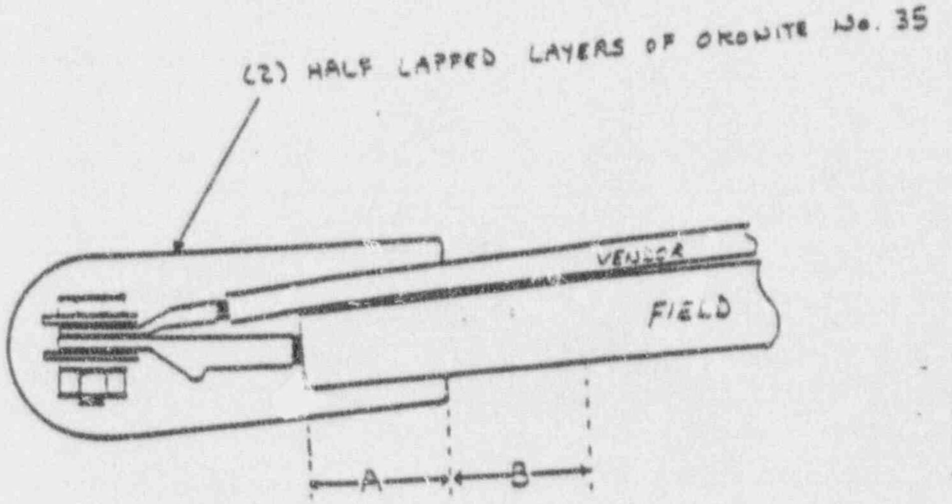
FIGURE 15



DETAIL T06

A	B
1.00"	N/A

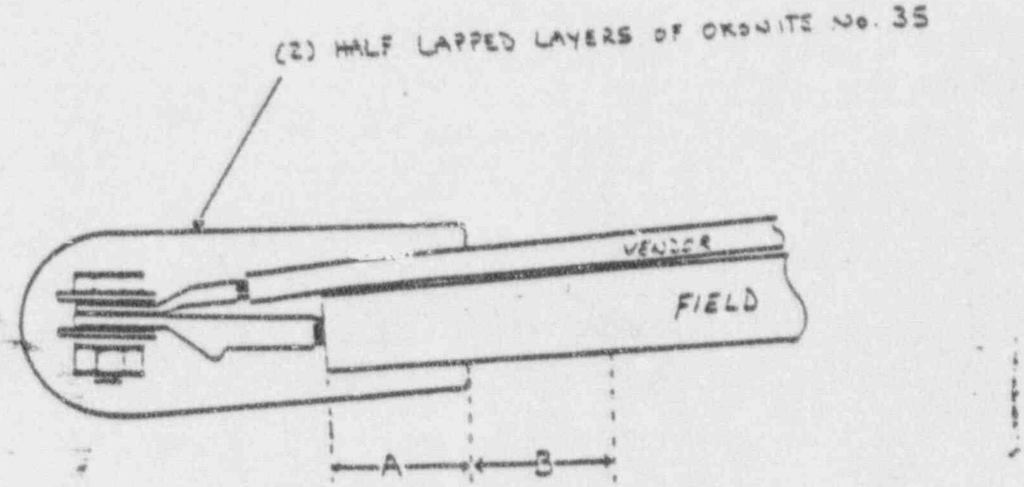
FIGURE 16



DETAIL NO3

A	B
0.75"	N/A

FIGURE 17



DETAIL NO 6

A	B
1.00"	N/A

FIGURE 18

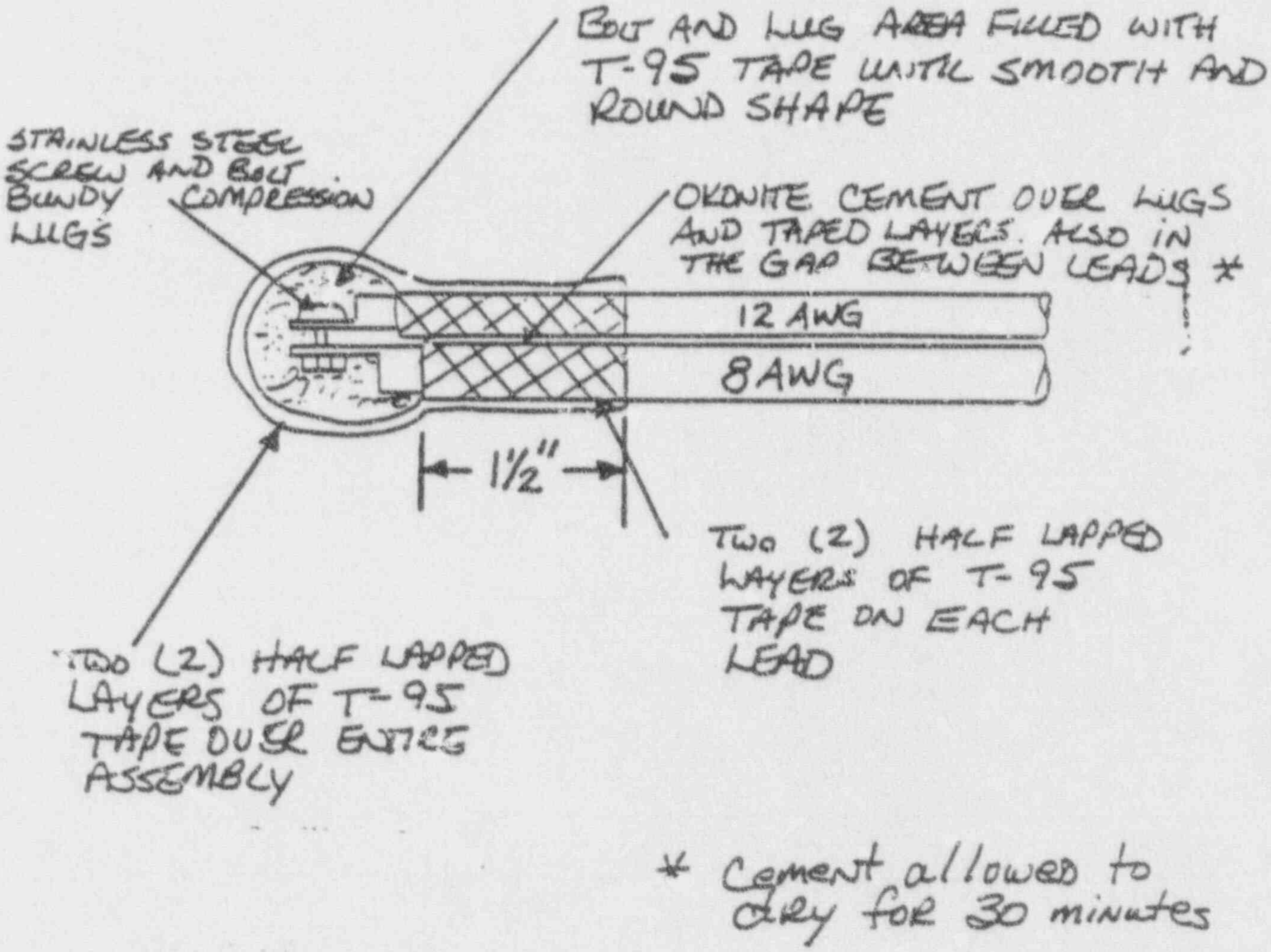
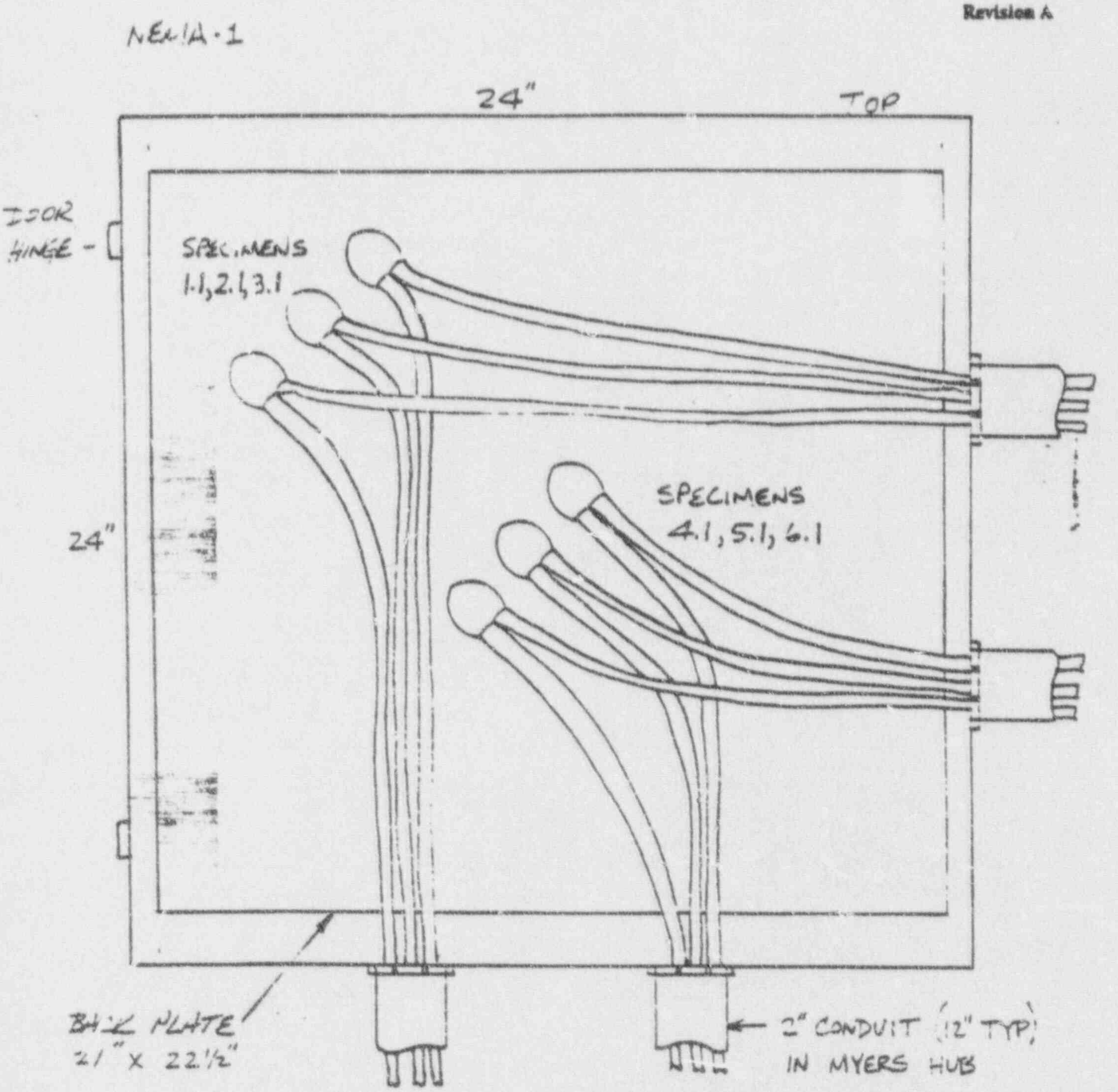
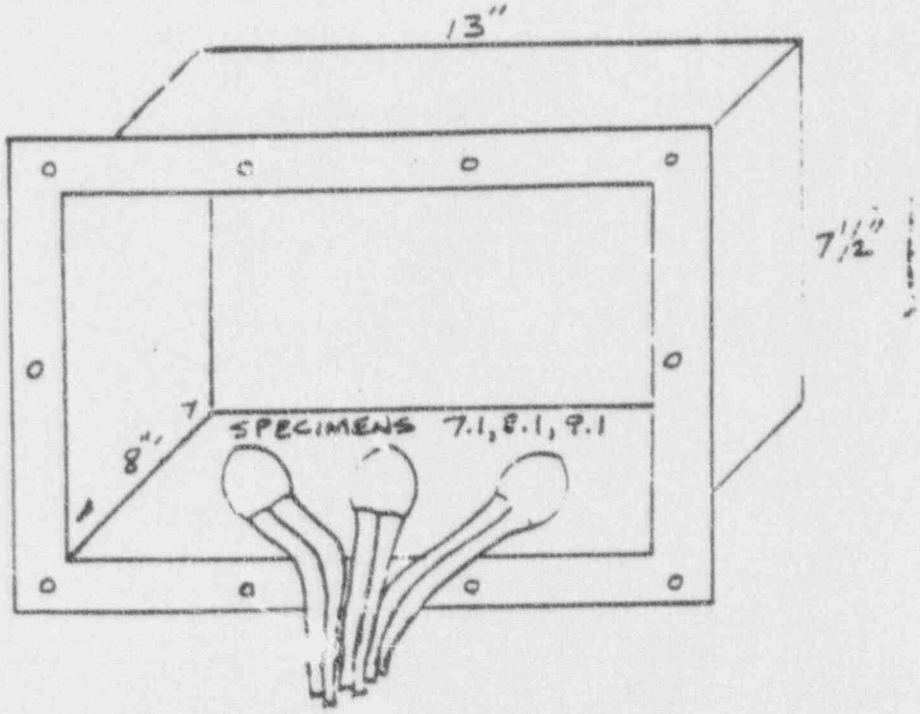

BOLT AND LUG AREA FILLED WITH T-95 TAPE UNTIL SMOOTH AND ROUND SHAPE
STAINLESS STEEL SCREW AND BOLT
BUNDY COMPRESSION LUGS
OKONITE CEMENT OVER LUGS AND TAPED LAYERS. ALSO IN THE GAP BETWEEN LEADS *
12 AWG
8 AWG
1½"
TWO (2) HALF LAPPED LAYERS OF T-95 TAPE ON EACH LEAD
TWO (2) HALF LAPPED LAYERS OF T-95 TAPE OVER ENTIRE ASSEMBLY
* Cement allowed to dry for 30 minutes

FIGURE 19



NOTES:
1) MOUNT ENCLOSURE VERTICALLY UPRIGHT.
2) REMOVE PAINT FROM SPLICE MOUNTING AREA OF BACK PLATE.
3) AFFIX SPECIMENS TO BACK PLATE WITH TIE WRAPS.

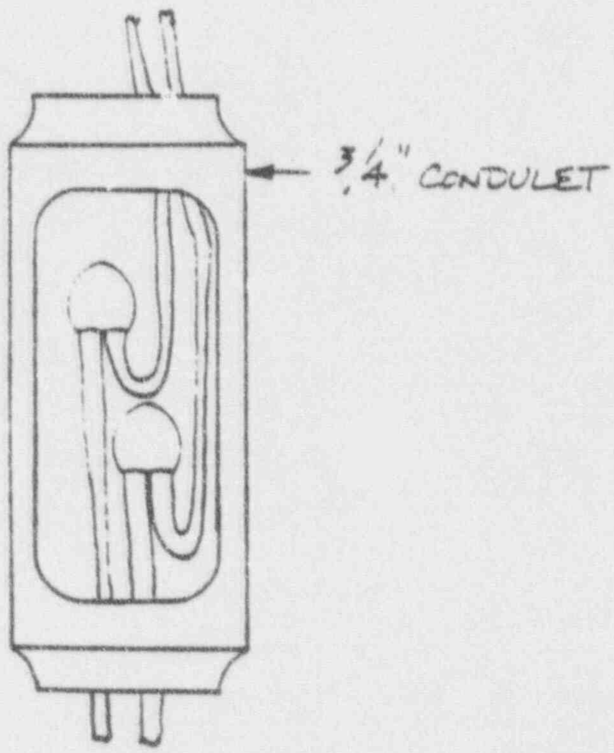
FIGURE 20



LIMITORQUE LIMIT SWITCH COMPARTMENT COVER

NOTES: 1) FABRICATE COVER PLATE (15½" X 10.2") WITH MOUNTING HOLES AND 1½" HOLE FOR MYERS HUB AND CONDUIT FOR WIRE FEED-THRU.

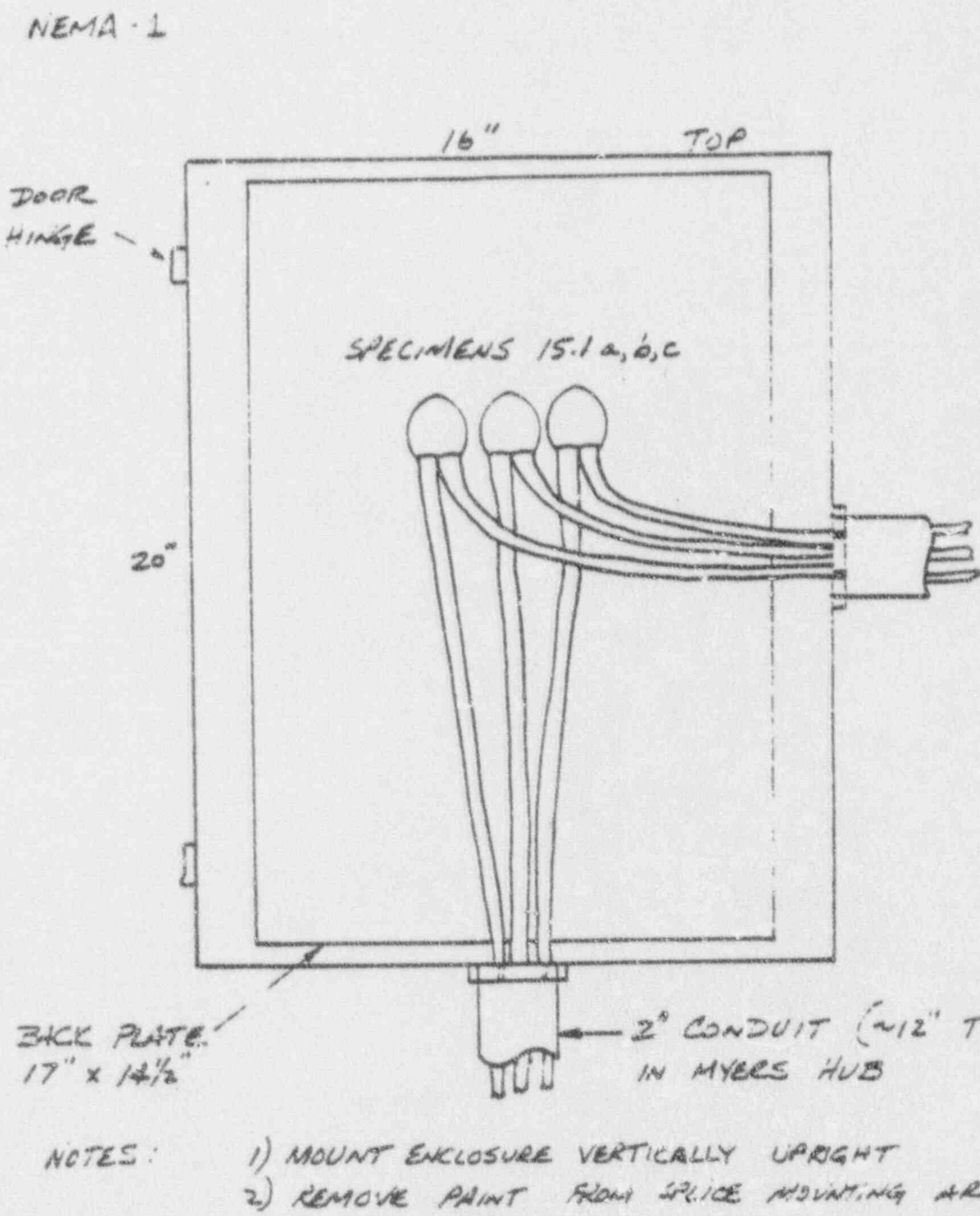
FIGURE 21



TYPICAL OF 3 CONDULETS
FOR SPECIMENS 10.1 a & b
11.1 & 12.1
13.1 & 14.1

FIGURE 22

Revision A



NOTES:

1) MOUNT ENCLOSURE VERTICALLY UPRIGHT
2) REMOVE PAINT FROM SPLICE MOUNTING AREA OF BACK PLATE
3) AFFIX SPECIMENS TO BACK PLATE WITH TIE WRAPS

FIGURE 23

Figure 24, Required Test Profile

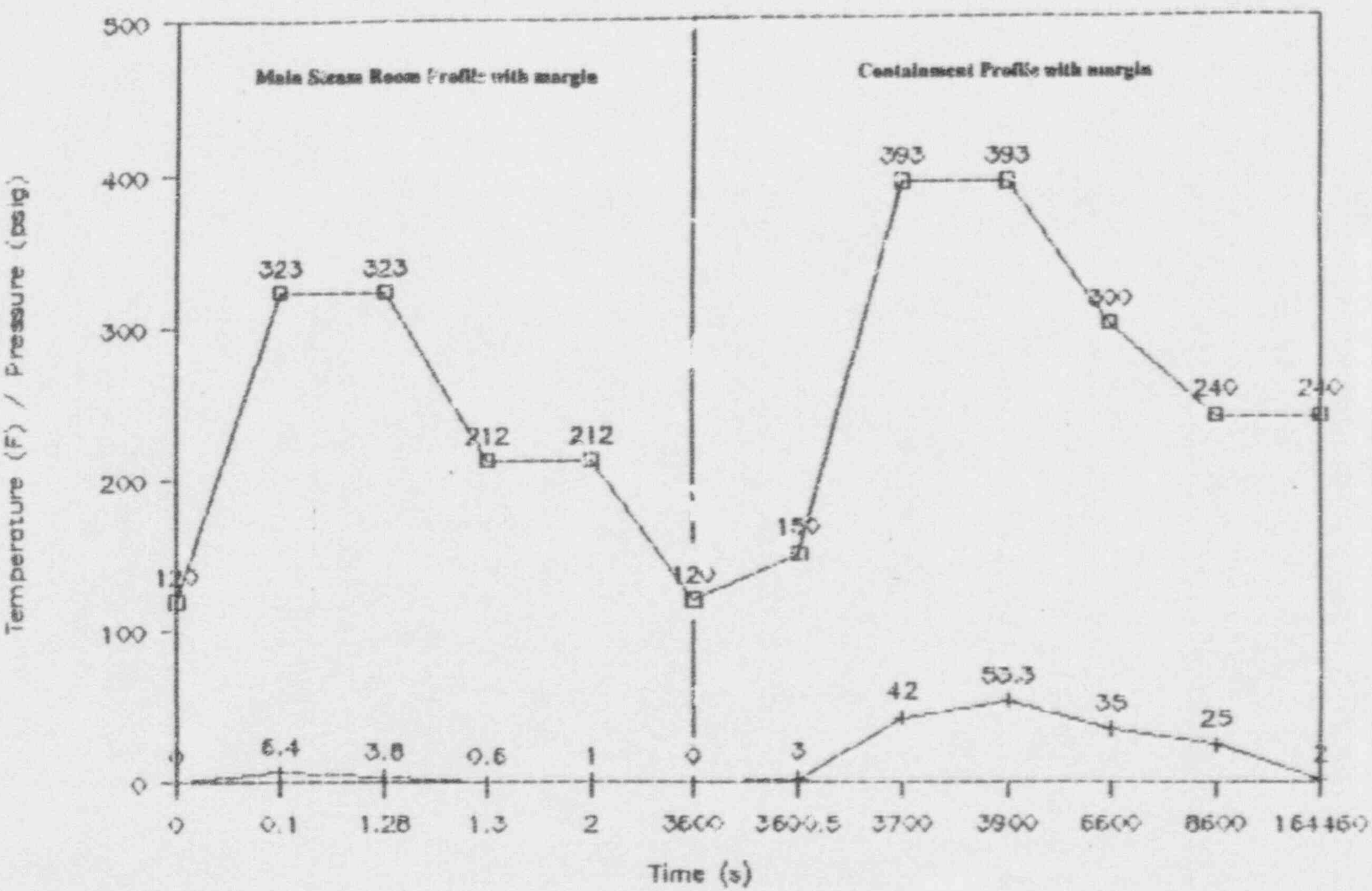
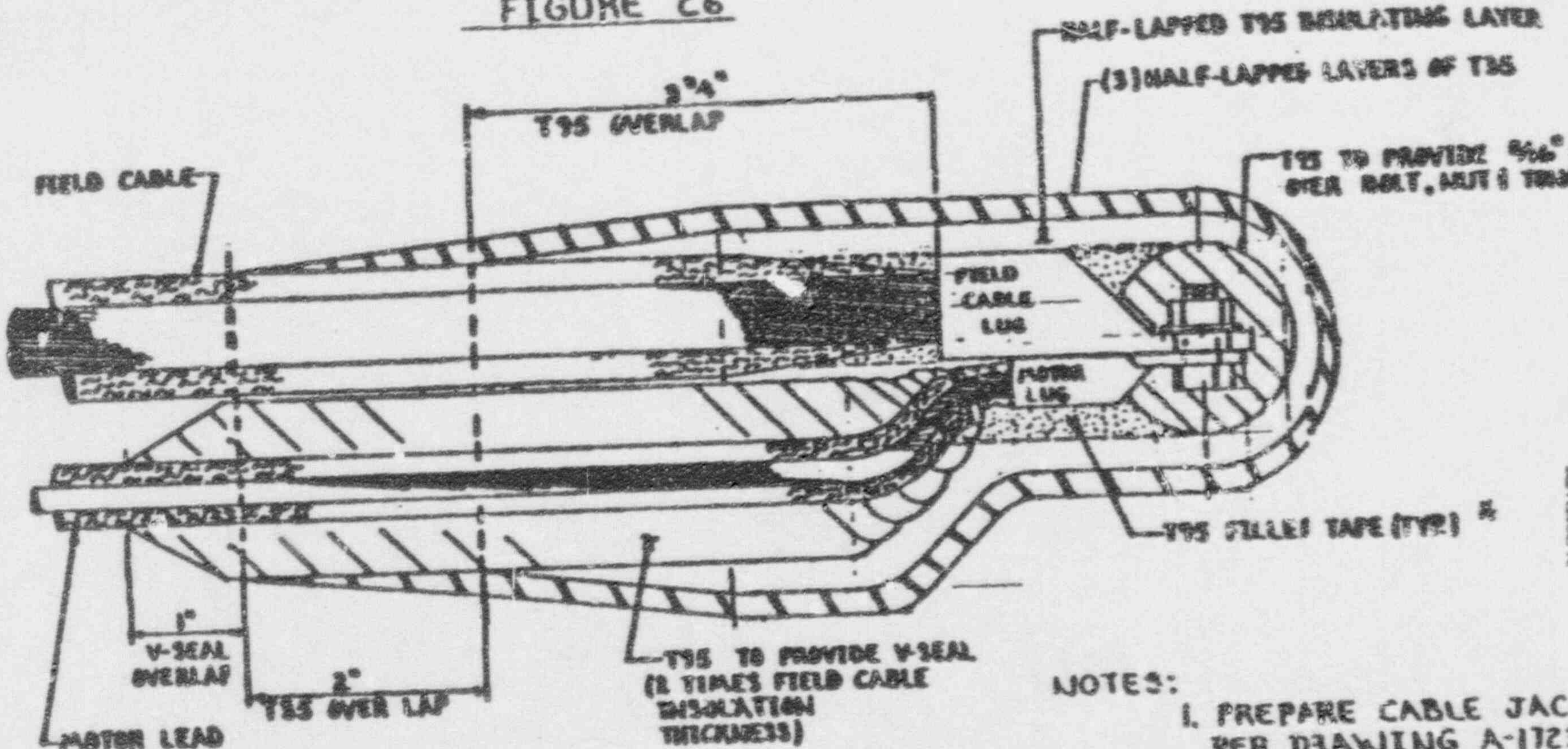


FIGURE 26



Qualification Plan No. 17940-01
Page 44
Revision A

NOTES:

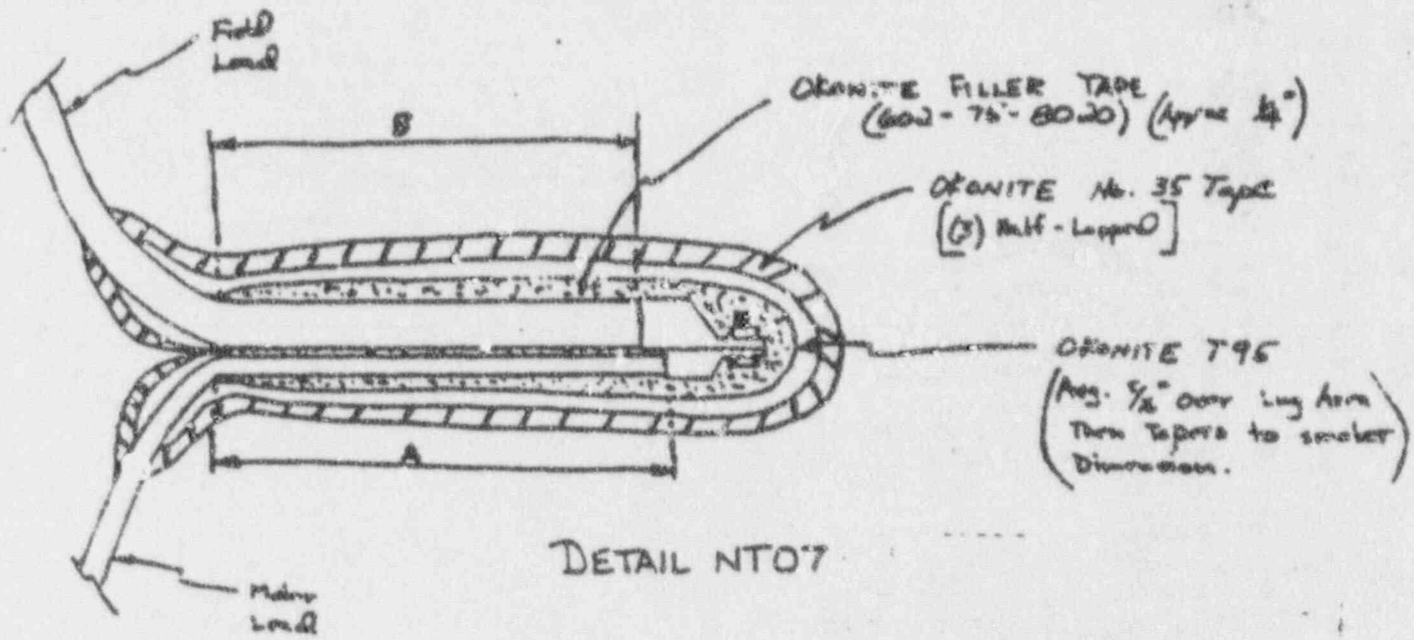
1. PREPARE CABLE JACKET PER DRAWING A-172396. (INSTALL LUG IF APPLICABL
2. COVER BOLT AND LUG TONGLE AS SHOWN.
3. BUILD UP UNIFORM DIAMETER WITH T95 TAPE (FILLER) AS SHOWN.
4. APPLY T95 INSULATING LAYERS AS SHOWN.
5. APPLY T35 OUTER LAYERS AS SHOWN.
6. USE ONLY NUCLEAR GRADE OKONITE CEMENT.

DETAIL NT08
RECOMMENDED E.Q.
4 KV MOTOR TERMINATION
(V-TYPE TAPED CONNECTION)
FOR USE OUTSIDE CTMT

* B172396 sh.1 okonite filler tape # 602-75-8000
Bunall Rubber

Chf

40 YR. Thermal & Rad. Aged



DETAIL NT07

1A Chg. Motor (Typ. of All 3 Terminations)

A - Varies from 2 3/8" to 3 3/8"

B - Varies from 2 1/4" to 2 1/2"

Note: Amount of T-95 from "Y" area to point where tape ends

Field - 2" - 2 1/4"

Motor - 1 3/4" - 2"

Amount of 35 from "Y" area to point where tape ends

Field & Motor - 1/8" to 1/2" beyond the T-95 tape.

FIGURE 25

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Section A

Electric Arc Proofing Tape

Scotch® 33+
Vinyl Plastic Electrical Tape

One tape for all jobs. 33+ is a premium-grade, 7-mil tape that applies well at −18°C/0°F and has an operating range up to 105°C/220°F.

Flame-retardant, hot-and cold-weather resistant. 33+ matches ratings of most wire and cable insulations. It resists ultraviolet rays, abrasion, moisture, alkalies, acids and corrosion. Use 33+ Tape as a primary insulation for wire cable splices up to 600 volts — and for fixture and wire splices up to 1000 volts. Use it also to maintain the electrical and high-temperature integrity of your electrical systems. 33+ provides an excellent abrasive-resistant jacket for high-voltage cable splices and terminations.

Meets requirements of ASTM D-3005-72, Type 1, UL 510 and HHI-595C, CSA Bulletin No. 561A (105°C).

Roll Size	Packing		
	Roll	Carton	Case
3/4 in x 66 ft*	1/Can	10	100
3/4 in x 44 ft			
3/4 in x 20 ft	10/Ctn.		

*Also available in a dispenser. Product is 33+D.
Other widths and lengths available upon request.

FOR PRICES, SEE PRICE PAGE SECTION A.

Scotch® 33
Vinyl Plastic Electrical Tape

33 is a 7-mil, strong, stretchy, general-purpose tape.

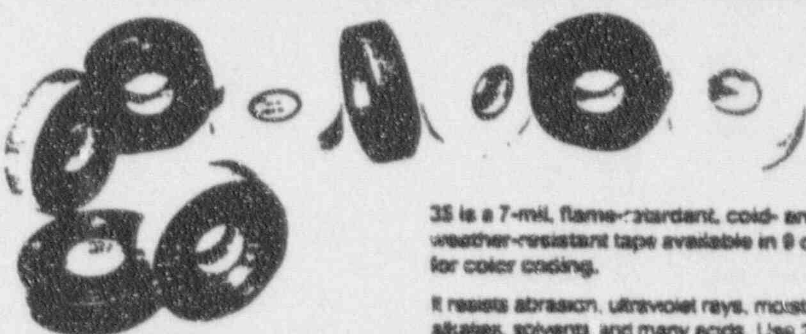
A sound balance of physical and electrical properties provides 33 Tape with the right "feel" for jobs which require holding, protecting and insulating. Tough vinyl backing shrugs off moisture, sunlight, heat and cold. Its adhesive grabs instantly and hugs tightly without creeping or end-lifting. 33 is well suited to make envelopes for resin-pressure splicing.

Meets requirements of UL 510, MIL-I-7798A and CSA.

Roll Size	Packing		
	Roll	Carton	Case
1½ in x 44 ft	1/Box	10	100
[illegible] in x 36 yds		12	48

Other widths and lengths available upon request.

FOR PRICES, SEE PRICE PAGE SECTION A.
NOTE: MIL-I-7798A is a cancelled spec.



Scotch® 35
Vinyl Plastic Electrical Tape
for Color Coding

35 is a 7-mil, flame-retardant, cold- and weather-resistant tape available in 9 colors for color coding.

It resists abrasion, ultraviolet rays, moisture, alkalies, solvents and many acids. Use 35 Tape indoors and in weather-protected outdoor applications such as phase identification, identifying motor leads, piping systems, marking safety areas, insulating splices and terminations and harnessing. 35 is recommended for PVC and polyethylene-jacketed cables.* Colors are red, yellow, blue, brown, gray, white, green, orange and violet.**

Meets requirements of UL 510 and CSA.

*Do not use on neoprene jacketed cable
**3/4-inch x 66 foot rolls only.

Roll Size	Packing		
	Roll	Carton	Case
3/4 in x 66 ft	1/Can	10	100
3/4 in x 20 ft	1/Cello Pack	10	100

Other widths and lengths available upon request.

FOR PRICES, SEE PRICE PAGE SECTION A.

Scotch® 88
Vinyl Plastic Electrical Tape

88 is a heavy-duty, 8.5-mil, flame-retardant, cold- and weather-resistant tape with superior cold-weather handling features.

Extra thickness provides added electrical properties, quicker insulation buildup and abrasion resistance. 88 Tape remains workable on cold days — even at −18°C/0°F — and doesn't get gooey on hot days. It is remarkably conformable for wrapping irregular surfaces — inside or outside. 88 resists ultraviolet rays, moisture, alkalies, acids and corrosion.

Meets requirements of ASTM D-3005-72, Type II, UL 510, MIL-I-24391 and CSA.

Roll Size	Packing		
	Roll	Carton	Case
3/4 in x 66 ft	1/Can	10	100
3/4 in x 44 ft			
1½ in x 44 ft	1/Box		
3/4 in x 36 yds	1/Box	12	48

Other widths and lengths available upon request.

FOR PRICES, SEE PRICE PAGE SECTION A.

Thermosetting Adhesives
Thermosetting adhesives have all the properties of a non-thermosetting adhesive; i.e., good initial adhesion, electrical purity, etc. When subjected to the recommended thermosetting cycle, this adhesive system will crosslink providing greater adhesion, bonding, higher solvent resistance and generally better heat resistance.

RT — **Natural or Synthetic Rubber.** This system requires the addition of a tackifier and fillers are also used to add internal strength and yield specific properties. The rubber-resin thermosetting system is very reactive at curing temperatures, so it yields a substantial increase in solvent resistance in a short heat cycle. Cure cycle recommended is 3 hours at 120°C (250°F), 2 hours at 135°C (275°F), or 1 hour at 177°C (300°F).

ST — **Silicones.** Silicone adhesive systems are compounded in a manner similar to the rubber-resin systems. However, the thermosetting reaction requires considerably higher temperature. Proper compounding of the silicone adhesive is very important to provide a system with a good balance of internal strength and adhesion. The advantages of a silicone adhesive system are many. It has exceptional heat resistance. It is inorganic and, if burned, it leaves a non-conductive residue. It may be applied at very low temperatures.

OT — **Acrylic Oil Compatible Adhesives.** Thermosetting acrylic adhesive systems are based on acrylic polymers. During manufacture these systems are controlled to a point where they are pressure sensitive but are still capable of a later thermosetting reaction providing an increase in adhesion, bonding, solvent and oil resistance. This special adhesive system will outperform other acrylic adhesives in resistance to hydrocarbon oils. A thermosetting cycle is required to obtain oil resistance. This adhesive system also offers good resistance to most common cleaning solvents used in the electronics industry without thermosetting. The normal cure cycle for this adhesive system is 3 hours at 120° C. (250°F), 2 hours at 135° C. (275° F) or 1 hour at 177° C. (300° F).

Non-Thermosetting Adhesives
A non-thermosetting adhesive is usually applicable for holding coil covers and insulation in economical, unvarnished components. Tapes using this adhesive system are also used extensively as a "third hand" during the production of a unit. Within the functional limits of the tape's backing, this type of adhesive will remain stable.

(RN)— **Natural or Synthetic Rubber.** Natural rubber by itself will not provide a pressure-sensitive adhesive system. Therefore a tackifier is added to make it pressure sensitive and inorganic fillers are added to give internal strength.

AN — **Acrylics.** Acrylic adhesives are synthetic polymers. The basic raw materials are synthesized in such a way that they usually do not require the addition of a tackifier or filler. This system provides greatly improved heat resistance, good transparency, very good shelf life, and a high degree of purity.

Adhesive System Codes

(R)— Rubber Resin
A — Acrylic
S — Silicone
O — Acrylic Oil Compatible
T — Thermosetting
(N)— Non-Thermosetting

Thermosetting Times and Temperatures

Rubber Resin and Acrylic Adhesives:	Silicone Adhesive
• 3 hours at 120° C. (250° F)	• 3 hours at 260° C. (500° F)
• 3 hours at 135° C. (275° F)	• For maximum solvent resistance cure for 24 hours at 260° C. (500° F)
• 1 hour at 177° C. (300° F)	

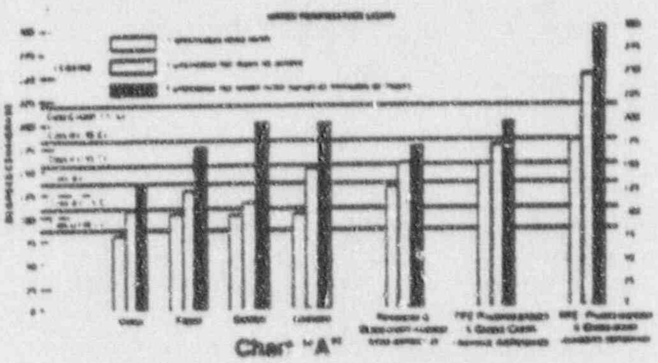


Chart "A"

Standard Slitting Tolerances:
Slitting tolerances are dependent on the type of backing. Except for vinyl, cotton, acetate and glass cloth backed tapes, tapes have a width tolerance of ± 1/32". For cotton, acetate and glass cloth backed tapes tolerance is ± 1/32". For vinyl tapes, tolerance is ± 1/32" per inch of width.

Precision Slitting Now Available On "SCOTCH" Brand Electrical Tapes
The following tapes can be slit to a tolerance of ±.005":

Paper Tapes	No. 3, 4
Acetate Film Tapes	No. 6, 7
Composite Tapes	No. 42, 55, 1174
Polyester Film Tapes	No. 5, 54, 56, 57, 58, 74, 1169, 1286, 1291
PTFE Fluorocarbon	No. 60, 61, 62, 63 (No sizes available under .250")
Polyimide Film	No. 92, 1205

We will provide this special tolerance on a minimum width of .125" and a maximum width of 2.000". Contact our nearest branch for prices on precision slit tapes.

ATTACHMENT 1

Qualification Plan No. 17942-01
Page No. 47

Revision A

	No.	Description	Adhesive System	Thickness (Mils)	Thickness (mm)	Tensile Strength (lbs/in)	Tensile Strength (N/10mm)	Elongation % at Break	Typical Adhesion (Oz/in)	Typical Adhesion (N/10mm)
Paper	2	Crepe (Black)	RT	10	.254	25	43.75	10	35	3.81
	3	Flatback (Yellow)	RT	5	.127	45	78.75	3	50	5.45
	4	Flatback (Black)	RT	5	.127	45	78.75	3	60	6.54
	9	Resin/Fibre Crepe (Tan)	RT	18	.457	50	87.5	15	30	3.27
	38	Crepe (Yellow)	RT	10	.254	25	43.75	10	35	3.81
	1239	Resin/Fibre (Tan)	RT	9	.224	35	61.25	15	35	3.81
Glass Cloth	27	Glass (White)	RT	7	.178	150	262.5	5	50	5.45
	69	Glass (White)	ST	7.5	.190	150	262.5	5	40	4.36
	79	Glass (White)	OT	7.5	.190	175	306.25	5	25	2.72
Acetate Cloth	11	Acetate (Black)	RT	8.5	.216	50	87.5	15	40	4.36
	28	Acetate (White)	RT	8	.203	50	87.5	15	60	6.54
Cotton Cloth	29	Cotton (White)	RT	9.5	.241	55	96.25	10	60	6.54
Acetate Film	6	Film (Blue)	RT	3.5	.088	20	35	40	60	6.54
	7	Film (Transparent)	RT	3.5	.088	20	35	40	60	6.54
Polyester Film	5	Film (Transparent)	OT	2.2	.056	25	43.75	100	45	4.90
	54	Film (Transparent)	RT	2.2	.056	25	43.75	100	45	4.90
	56	Film (Yellow)	RT	2.2	.056	25	43.75	100	50	5.45
	57	Film (Yellow)	RT	3.2	.081	50	87.5	125	60	6.54
	58	Film (Transparent)	RT	3.2	.081	50	87.5	125	55	6.00
	74	Film (Yellow)	RT	.8	.020	12	21	85	20	2.18
	75	Film (Yellow Double-coated)	RT	3.5	.088	20	35	50	40	4.36
	1189	Film (Black)	RT	2.2	.056	25	43.75	100	45	4.90
	1288	Film (Yellow)	OT	2.2	.056	25	43.75	100	35	3.81
	1291	Film (Yellow)	OT	3.2	.081	50	87.5	100	35	3.81
Polyester Web	1277	Resin Saturated (Red)	RT	9	.229	20	35	25	35	3.81
Vinyl	22	Black	RN	10	.254	30	52.5	200	35	3.81
	→ 33	Black	RN	7	.178	18	31.5	175	30	3.27
	35	Various Colors	RN	7	.178	15	26.25	200	25	2.72
	85	Black	AN	11	.279	35	61.25	300	20	2.18
Transfer Adhesive	1146	Transfer Adhesive Film	RT	2	.051	—	—	—	35	3.81
Composites	26	Acetate Film/Cloth	RT	6.3	[illegible]	55	96.25	10	80	8.72
	42	Acetate Film/Fibre (Transparent)	RN	4	.102	25	43.75	4	40	4.36
	55	Polyester Film/Mat (W[illegible]ite)	RT	7.5	.190	40	70	30	80	8.72
	1174	Polyester Film/Mat ([illegible]hite)	RT	10	.254	50	87.5	35	95	10.35
	1300	Polyester Film/Paper (Tan)	RT	6.0	.152	45	78.75	5	45	4.90
Reinforced Epoxy Film	10	Reinforced Film (Cream)	RT	5.5	.140	40	70	30	45	4.90
Filament Reinforced	48	Polyester Film/Glass Filament (White)	RT	6.5	.165	225	393.75	5	65	7.08
	1279	Paper/Glass Filament (White)	OT	8.5	.216	275	481.25	2	60	6.54
	1312	Polyester Film/Synthetic Filament (Transparent)	RN	8	.203	275	481.25	18	45	4.90
Foil	49	Aluminum (Non-Conductive Adhesive)	AN	4.8	.122	30	52.5	—	50	5.45
	1170	Aluminum (Conductive Adhesive)	AN	4.0	.102	15	26.25	—	35	3.81
	1181	Copper (Conductive Adhesive)	AN	3.5	.088	25	43.75	—	35	3.81
	1194	Copper (Non-Conductive Adhesive)	AN	3	.076	20	35	—	50	5.45
	1245	Embossed Copper (Non-Conductive Adhesive)	AN	4.0	.108	20	35	—	40	4.36

All property values on this chart are based on several determinations, and are not intended for specification purposes. Proposed specifications with minimum and maximum values are available upon request.

Qualification Plan No. 17942-01
Page No. 48

ATTACHMENT 1

Revision A

Electrical Properties: Dielectric Strength (volts)	Insulation Resistance Megohms @ ...% RH*	Electrolytic Corrosion Factor	Thermal Properties (Refer to Chart ...): Continuous Long Term °C	Functional Days ... °C	Functional Min-hours °C	Military Specifications	UL Recognized	CSA Certified	Approx. Cost per Max. Dist. Dimension**
1,800	10	.8	105°	130°	175°	MIL-I-15126F (Type PCT)	—	—	.00133
1,500	5	.8	105°	130°	175°	—	—	—	.00116
1,500	5	.8	105°	130°	175°	—	—	—	.00124
3,700	20	.8	105°	130°	175°	—	—	—	.00211
1,800	10	.8	105°	130°	175°	MIL-I-15126F (Type PCT)	—	—	.00124
2,000	14	.8	105°	130°	175°	—	—	—	.00133
3,000	250	.97	130°	160°	170°	MIL-I-15126F (Type GFT)	[illegible] OANZ2, File E17385A	Guide 1819-N-90, File LR12610	.00346
3,500	250	1.0	180°	250°	300°	MIL-I-19166C	Guide OANZ2, File E17385A	—	.00581
3,000	175	1.0	155°	175°	200°	—	Guide OANZ2, File E17385B	—	.003[illegible]
3,000	$.2x10^6$	1.0	105°	150°	200°	MIL-I-15126F (Type ACT)	—	—	.00234
3,000	$.3x10^6$	1.0	105°	150°	200°	MIL-I-15126F (Type ACT)	—	—	.00220
2,000	30	.85	105°	120°	200°	MIL-I-15126F (Type CF[illegible])	—	—	.00233
6,000	$> 1.0x10^6$	1.0	105°	150°	200°	—	—	—	.00131
6,000	$> 1.0x10^6$	1.0	105°	150°	200°	—	—	—	.00134
5,000	$> 1.0x10^6$	1.0	130°	155°	175°	MIL-I-15126F (Type MFT2.5)	—	—	.00145
5,000	$> 1.0x10^6$	1.0	130°	155°	175°	MIL-I-15126F (Type MFT2.5)	—	—	.00145
5,000	$> 1.0x10^6$	1.0	130°	155°	175°	MIL-I-15126F (Type MFT2.5)	—	—	.00185
6,500	$> 1.0x10^6$	1.0	130°	155°	175°	MIL-I-15126F (Type MFT3.5)	—	—	.00243
6,500	$> 1.0x10^6$	1.0	130°	155°	175°	MIL-I-15126F (Type MFT3.5)	—	—	.00243
3,500	$> 1.0x10^6$	1.0	130°	155°	175°	—	—	—	.00193
6,000	$> 1.0x10^6$	1.0	130°	155°	[illegible]5°	—	—	—	.00407
5,000	$> 1.0x10^6$	1.0	130°	155°	175°	—	—	—	.00211
5,000	$> 1.0x10^6$	1.0	130°	155°	175°	MIL-I-15126F (Type MFT2.5)	—	—	.00145
5,000	$> 1.0x10^6$	1.0	130°	155°	175°	MIL-I-15126F (Type MFT3.5)	—	—	.00244
7,000	$> 1.0x10^6$	1.0	155°	175°	200°	—	—	—	.00323
12,000	$> 1.0x10^6$	1.0	80°	105°	135°	—	Guide [illegible]ANZ, File E1738[illegible]	—	.00231
10,000	$> 1.0x10^6$	1.0	80°	105°	135°	—	Guide OANZ, File E17385	—	.00206
8,500	$> 1.0x10^6$	1.0	80°	105°	135°	—	Guide OANZ, File E17385	—	.00206
13,000	$> 1.0x10^6$	1.0	105°	150°	200°	—	Guide OANZ2, File E17385A	Guide 1819-N-90, File LR9176	.00317
—	$> 1.0x10^6$	1.0	130°	155°	200°	—	—	—	.00199
6,000	$5.0x10^6$	1.0	105°	150°	200°	—	—	—	.00404
4,500	60	.95	105°	150°	200°	—	—	—	.00157
5,000	$> 1.0x10^6$	1.0	130°	155°	175°	—	—	—	.00233
6,500	$> 1.0x10^6$	1.0	130°	155°	175°	—	—	—	.00309
6,000	70	.8	105°	130°	175°	—	—	—	.00127
6,500	$1.0x10^6$	1.0	130°	155°	175°	—	Guide OANZ2, File E17385A	—	.00480
5,000	10,000	1.0	130°	155°	175°	—	—	—	.00191
3,000	350	1.0	105°	130°	175°	—	—	—	.00176
5,800	3,500	.98	105°	—	—	—	—	—	.00164
—	—	—	155°	175°	200°	—	Guide OANZ2, File E17385A	—	.00252
—	—	—	155°	175°	200°	—	—	—	.[illegible]2279
—	—	—	155°	175°	200°	—	—	—	.02293
—	—	—	155°	175°	200°	—	Guide OANZ2, File E17385A	—	.00878
—	—	—	155°	175°	200°	—	Guide OANZ2, File E17385A	—	.01986

*Insulation resistance is measured in accordance with the resistance method for indirect measurement of electrolytic corrosion per ASTM-D1000.
**Approximate costs for comparison purposes only and do not reflect possible price changes. Please contact nearest 3M sales branch for current prices.

VENDOR CONTACT REPORT

Contact Report Of: RON WAYDEN   Telephone ☑   Visit ☐

Date of Contact: JULY 31, 1981   Follow Up Date: ____
S.E.W. 17464

Agency or Company and Address	OKONITE BIRMINGHAM, AL
Phone	(205) 592-8968
Person(s) Contacted and Title	MALCOLM HARTLEY TECH./SALES REP.
Item(s) and Part Number(s)	T-95 SPLICE TAPE No. 35 JACKET TAPE
Information needed	☐ Temperature Limits ☐ Time/Temperature Data ☐ Catalogue ☐ Life Cycles ☐ Reliability Data (Mil Spec) ☐ Radiation ☑ Material ☐ Other ____
Discussion	T-95 IS COMPOSED OF AN ETHYLENE PROPYLENE BASE THERMOSETTING COMPOUND. No. 35 IS A NEOPRENE BASE JACKET TAPE. MR. HARTLEY ADDED THAT THE T-95 TAPE & OKOGUARD INSULATION (EP) SHOULD DISPLAY SIMILAR AGING CHARACTERISTICS. THE No. 35 TAPE AND OKOPRENE JACKETS SHOULD ALSO PERFORM SIMILARLY IN AN AGING PROGRAM.
Action	N/A
Copies To	J. BOWMAN, R. BENNETT, J. HENLEY, M. BRUCE, F. LOUNSBERRY, VCR FILE

WH 1180

WYLE LABORATORIES
NUCLEAR ENGINEERING SERVICES
ACCELERATED AGING 08/26/87

KEY NUMBER: 01390
GENERIC NAME: ETHYLENE PROPYLENE DIENYL
ACTIVATION ENERGY: 1.23 OKONITE T-95 MAX TEMPERATURE (C): 090

ACTIVATION ENERGY 1.23 AGING TEMPERATURE (C) 110

TEMPERATURE [F]	TIME [H]
120	350400

TOTAL TIME= 350400.00 HOURS

ACCELERATED AGING TIME AT 110 C=
296.252 HOURS
12.34 DAYS

WYLE LABORATORIES
NUCLEAR ENGINEERING SERVICES
ACCELERATED AGING 08/24/87

KEY NUMBER: 00840
GENERIC NAME: CHLOROPRENE RUBBER
ACTIVATION ENERGY: 0.65 OKONITE No.35 MAX TEMPERATURE (C): 050

ACTIVATION ENERGY 0.65 AGING TEMPERATURE (C) 150

TEMPERATURE [F]	TIME [H]
104	131400

TOTAL TIME= 131400.00 HOURS

ACCELERATED AGING TIME AT 150 C=
249.365 HOURS
10.39 DAYS

WYLE LABORATORIES
NUCLEAR ENGINEERING SERVICES
ACCELERATED AGING 08/26/87

KEY NUMBER: 01390
GENERIC NAME: ETHYLENE PROPYLENE DIENYL
ACTIVATION ENERGY: 1.23 OKONITE T-95 MAX TEMPERATURE (C): 090

ACTIVATION ENERGY 1.23 AGING TEMPERATURE (C) 110

TEMPERATURE [F]	TIME [H]
104	131400

TOTAL TIME= 131400.00 HOURS

ACCELERATED AGING TIME AT 110 C=
31.532 HOURS
1.31 DAYS

[illegible]

WYLE LABORATORIES
NUCLEAR ENGINEERING SERVICES
ACCELERATED AGING 08/26/87

KEY NUMBER: 01390
GENERIC NAME: ETHYLENE PROPYLENE DIENYL
ACTIVATION ENERGY: 1.23 OKONITE T-95 MAX TEMPERATURE (C): 090

ACTIVATION ENERGY 1.23 AGING TEMPERATURE (C) 110

TEMPERATURE [F]	TIME [H]
120	131400

TOTAL TIME= 131400.00 HOURS

ACCELERATED AGING TIME AT 110 C=
111.034 HOURS
4.62 DAYS

[illegible]

WYLE LABORATORIES
NUCLEAR ENGINEERING SERVICES
ACCELERATED AGING 03/22/87

KEY NUMBER: 01390
GENERIC NAME: ETHYLENE PROPYLENE DIENYL
ACTIVATION ENERGY: 1.23 OKONITE T-95 MAX TEMPERATURE (C): 090

ACTIVATION ENERGY 1.23 AGING TEMPERATURE (C) 150

TEMPERATURE [C]	TIME [H]
90	350400

TOTAL TIME= 350400.00 HOURS

ACCELERATED AGING TIME AT 150 C=
1324.962 HOURS
55.20 DAYS

1325 HOURS

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WYLE LABORATORIES
NUCLEAR ENGINEERING SERVICES
LINEAR SLOPE EQUIVALENT 09/02/87

REF TEMP & SCALE 240.00 F   ACTIVATION ENERGY 1.23 eV
NUMBER OF SLOPES 2   TEMPERATURE SCALE F

INITIAL TEMP	FINAL TEMP	HOURS	EQUIVALENT HOURS
240.00	120.00	276.3900	43.02
120.00	120.00	514.2200	0.26
	TOTALS:	790.6100	43.28

PRESS ANY KEY TO CONTINUE

43 HOURS, 17 MINUTES
@ 240°F FROM 84 MINUTE
POINT, POST-DBE, CONTAINMENT

APPENDIX A

Methodology Used in the Determination of Thermal Age Sensitivity and Aging Parameters (Materials)

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Methodology Used in the Determination of Thermal Age Sensitivity and Aging Parameters (Materials)

For many nonmetallic materials it is known that the degradation process can be defined by a single temperature-dependant reaction that follows the Arrhenius equation *(IEEE Std. 101-1972, "IEEE Guide for the Statistical Analysis of Thermal Life Test Data")*.

$$k = A_{exp}(-(E_a/k_B T)) \tag{1}$$

where:

k = reaction rate

A = frequency factor

exp = exponent to base e

E_a = activation energy

k_B = Boltzmann's Constant

T = absolute temperature (Kelvin)

Life is assumed to be inversely proportional to the chemical reaction rate. In terms of life, and after converting to Napierian base logarithms, Equation (1) becomes:

$$\ln(\text{life}) = (E_a/k_B)(1/T) + \text{Constant} \tag{2}$$

Equation (2) has the algebraic form:

$$y = mx + b \tag{3}$$

where:

$y = \ln(\text{life})$

$x = 1/T$

$m = E_a/k_B$, constant for single dominant reactions

b = constant

The constants m and b can be estimated by fitting the experimental data in the form of ln (life) versus 1/T to the above simple linear relationship.

Available material aging data is used as the basis to determine components with time-temperature related aging mechanisms. Actual operating experience and previous test data for the same or similar materials are also considered. Where this data is unavailable, careful extrapolation and/or selective engineering judgment is employed and identified in the Aging Analysis section applicable to the specific equipment being qualified.

Metals are judged to be age insensitive for time-temperature effects. For nonmetallic materials, a determination was made as to whether the material can be qualified for a 40-year life. This was done by using the normal service temperature(s) for the baseline temperature. Where appropriate, allowance was made for self-induced or cabinet heat rise.

The basis for evaluating the thermal sensitivity of each nonmetallic material is to determine the expected life in its service environment. If the calculated expected life is greater than 120 years for a mild environment, 1,000 years for materials located in a harsh environment outside containment, and 10,000 years for materials located in containment, the material is considered age insensitive for the application. The results of this evaluation are shown in Table I under the column headed "AGE SENS" (Age Sensitivity).

For an aging analysis in a mild environment, the conservative approach is to define the qualified life as one-third of the calculated expected life.

The calculated expected lives of the nonmetallic materials considered in this report are shown in the Aging Matrix, Table I.

EXAMPLE 1: Assume that an expected life calculation is to be performed. It is assumed that the material is at a service temperature of 30°C for 80 percent of the time.

The Arrhenius equation, Equation (2), is repeated:

$$\ln(\text{life}) = (E_a/k_B)(1/T) + \text{Constant} \quad (4)$$

A substitution is made for the material's slope and constant and the Arrhenius equation evaluated for a given type and level of degradation, e.g., for Nylon (Zytel 101), for 50% loss of tensile strength, the Arrhenius equation is:

$$\ln(\text{life}) = 9927.367364\,(1/T) - 17.84346349 \quad (5)$$

For a baseline temperature of 30°C:

$$T = 30^{\circ}C + 273 = 303^{\circ}K \quad (6)$$

$$\ln(\text{life}) = 9927.367364\,(1/303) - 17.84346349 \quad (7)$$

$$\ln(\text{life}) = 14.92 \quad (8)$$

Life = 3,018,061 hours = 344.5 years

END OF EXAMPLE 1

In some instances it is necessary to account for a range of normal service temperatures due to changes in plant operating conditions, seasonal factors, differing electrical loads, etc. The expected life of a nonmetallic material can be calculated for any number of baseline temperatures as shown in the following example.

EXAMPLE 2: Assume that an expected life calculation is to be performed. It is assumed that the material is at a service temperature of 30°C for 80 percent of the time and at a service temperature of 40°C for the remaining 20 percent of the time.

The calculated expected life can be determined using the Arrhenius equation:

$$life = (_{exp} (E_a/k_B) (1/T_R) + constant) / (dt_1 \exp (E_a/k_B) (1/T_R - 1/T_1)) + (dt_{2\ exp} (E_a/k_B) (1/T_R - 1/T_2)) \quad (9)$$

Where:

E_a = activation energy (eV)

k_B = Boltzmann's constant (8.617×10^{-5} eV/oK)

T_R = any convenient reference temperature

dt_1 = the decimal equivalent of the time spent at temperature T_1 (0.80)

dt_2 = the decimal equivalent of the time spent at temperature T_2 (0.20)

T_1 = service temperature (30°C = 303°K)

T_2 = service temperature (40°C = 313°K)

Utilizing the slope and constant of Equation (5) and a reference temperature of 25°C (298°K) yields:

$$life = (5229618.74)/(0.80\ (1.732775818) + (0.20\ (4.935851414))) \quad (10)$$

$$= 2203432.56 \text{ hours} = 251.5 \text{ years.}$$

END OF EXAMPLE 2

It is further noted that, for many reactions, the activation energy can be considered to be constant over the applicable temperature range. Equation (1) can be transformed into a form which yields an acceleration factor.

The acceleration factor is defined as t_2/t_1.

The equation is:

$$t_2/t_1 = (\exp(-(E_a/k_B)(1/T_1 - 1/T_2)) \qquad (11)$$

where:

t_1 = accelerated aging time at temperature T_1

t_2 = normal service time at temperature T_2

exp = exponent to base e

E_a = activation energy (eV)

k_B = Boltzmann's Constant (8.617×10^{-5} eV/°K)

T_1 = accelerated aging temperature (K)

T_2 = normal service temperature (K)

The transformation of the reaction rate form of the Arrhenius equation to an acceleration form is accomplished as follows:

The derivation of an acceleration factor is accomplished by taking the difference between any two points of the linear relationship. Thus, if we substitute t for life into Equation (2), we obtain:

$$\ln t = (E_a/k_B)(1/T) + \text{Constant} \qquad (12)$$

For the set of points (t_1, T_1), Equation (12) becomes:

$$\ln t_1 = (E_a/k_B)(1/T_1) + \text{Constant} \qquad (13)$$

For the set of points (t_2, T_2), Equation (12) becomes:

$$\ln t_2 = (E_a/k_B)(1/T_2) + \text{Constant} \qquad (14)$$

Subtracting Equation (13) from Equation (14) yields:

$$\ln t_2 - \ln t_1 = (E_a/k_B)(1/T_2) + \text{Constant} - (E_a/k_B)(1/T_1) - \text{Constant} \qquad (15)$$

Simplifying and rearranging Equation (15) yields:

$$\ln(t_2/t_1) = -(E_a/k_B)(1/T_1 - 1/T_2) \quad (16)$$

Taking antilogarithms yields:

$$t_2/t_1 = \exp(-(E_a/k_B)(1/T_1 - 1/T_2)) \quad (17)$$

Equation (17) is the same as Equation (11).

The acceleration factor (t_2/t_1) is the reciprocal of the time compression factor (t_1/t_2). Taking the reciprocal of Equation (17) yields:

$$t_1/t_2 = \exp((E_a/k_B)(1/T_1 - 1/T_2)) \quad (18)$$

Solving Equation (16) for t_1 yields:

$$t1 = t2 \exp((Ea/kB)(1/T1 - 1/T2)) \quad (19)$$

E[illegible]tion (19) can be used to derive the accelerated aging times for materials with known activation e[illegible] In many cases, it is not practical to independently accelerate the time-temperature effects of each nonmetallic material. In this case, a determination is made as to which material has the lowest activation energy. The time-temperature effects are accelerated based upon the lowest activation energy for conservatism. This ensures that the degradation of each age-sensitive material is accelerated to at least the equivalent degradation as that to be encountered during the qualified life.

The conservatism of basing accelerated aging on the lowest activation energy is demonstrated as follows:

The acceleration factor (t_2/t_1) of Equation (17) is greater than 1, for a constant activation energy, when the accelerated aging temperature T_1 is greater than the normal service temperature T_2.

With T_1 greater than T_2, the term $(1/T_1 - 1/T_2)$ is negative. This negative multiplied by the negative in the exponent results in a positive exponent. A positive exponent, in turn, results in an acceleration factor greater than 1.

The acceleration factor versus (1/T) for various activation energies can be plotted as shown in Figure A-1. Since the slope of each plot is proportional to the activation energy, per Equation (3), it is shown that a lower activation energy causes a lower slope and therefore a lower acceleration factor. Thus, for a given accelerated aging temperature, different activation energies cause different acceleration factors, assuming that the normal service temperature is the same. This is demonstrated in the following example.

EXAMPLE 3: Assume that a system consists of four materials which have activation energies of 0.80, 1.00, 1.20 and 1.40 eV. It is assumed that each material is normally at a service temperature of 30°C for a qualified life of 350,400 hours (40 years). It is further assumed that accelerated thermal aging shall be performed at 90°C.

If the accelerated aging is based upon the material with an activation energy of 1.0eV, the following results:

The relationship of the curves of Figure A-1 is generated from Equation (19) and is defined as:

$$t_2/t_1 = \exp(-(E_a/k_B)(1/T_1 - 1/T_2)) \qquad (20)$$

Substituting Ea = 1.0 eV, T1 = 363°K and T2 = 303°K into Equation (19) yields an acceleration factor of approximately:

$$t2/t1 = 562 \qquad (21)$$

Thus, for a normal service time of 40 years (t_2 = 350400 hours), the accelerated aging time from Equation (19) is:

$$t_1 = 350{,}400/562 = 624 \text{ hours} \qquad (22)$$

Therefore, using the accelerated thermal aging program of 90°C for 624 hours, the equivalent demonstrated normal service time at 30°C for the other materials with activation energies of 0.80, 1.20 and 1.40 eV can be calculated using Equation (20).

Thus for E_a = 0.80 eV:

$$t_2 = 624 \exp(-(0.80/8.617 \times 10^{-5})(1/363 - 1/303))(23)$$

$$t_2 = 98{,}779 \text{ hours (11.3 years)} \qquad (23)$$

For E_a = 1.20 eV:

$$t_2 = 624 \exp(-(1.20/8.617 \times 10^{-5})(1/363 - 1/303))$$

$$t_2 = 1{,}242{,}814 \text{ hours (141.9 years)} \qquad (24)$$

For E_a = 1.40 eV:

$$t_2 = 624 \exp((-(1.40/8.617 \times 10^{-5})(1/363 - 1/303))(27)$$

$$t_2 = 4{,}406{,}352 \text{ hours (503.2 years)} \quad (25)$$

Thus, it is seen that materials with activation energies less than the 1.0 eV, on which the aging program was based, are underaged by the accelerated aging at 90°C for 624 hours.

In order to ensure the demonstration of a 40-year service life for all materials, the lowest activation energy should be chosen. Basing the accelerated aging program on the lowest activation energy of 0.80 eV results in the following:

Substituting Ea = 0.80 eV, T1 = 363°K and T2 = 303°K into Equation (20) yields an acceleration factor of approximately:

$$t_2/t_1 = 158 \quad (26)$$

Thus, the aging time is:

$$t_1 = 350{,}400/158 = 2214 \text{ hours} \quad (27)$$

Rechecking the other materials for adequate aging results in the following for an accelerated aging program of t_1 = 2214 hours, T_1 = 363°K and T_2 = 303°K.

For E_a = 1.00 eV:

$$t_2 = 1{,}243{,}165 \text{ hours (142 years)} \quad (28)$$

For E_a = 1.20 eV:

$$t_2 = 4{,}409{,}598 \text{ hours (503.4 years)} \quad (29)$$

For E_a = 1.40 eV:

$$t_2 = 15{,}641{,}171 \text{ hours (1786 years)} \quad (30)$$

Thus, it has been demonstrated that basing an accelerated thermal aging program on the lowest activation energy, when the baseline temperatures are common, provides the conservatism desired.

END OF EXAMPLE 3

In some instances it is necessary to account for a range of normal service temperatures due to changes in plant operating conditions, seasonal factors, differing electrical loads, etc. These variations are accounted for as shown in the following example:

EXAMPLE 4: Assume that a thermal aging program is to be performed on a system wherein the lowest activation energy is 0.80 eV. It is assumed that the system is at a service temperature of 30°C for 80% of the time, and a service temperature of 40°C for the remaining 20% of the time during its desired 40-year life. It is further assumed that the accelerated aging shall be performed at 90°C.

The thermal aging time required to simulate these parameters is calculated using the Arrhenius equation:

$$t_1 = t_2 \exp((E_a/k_B)(1/T_1 - 1/T_2))$$
$$+ t_3 \exp((E_a/k_B)(1/T_1 - 1/T_3)) \qquad (31)$$

where:

t_1 = accelerated aging time at temperature T_1

t_2 = normal service time at temperature T_2

t_3 = normal service time at temperature T_3

exp = exponent to base e

E_a = activation energy (eV)

k_B = Boltzmann's Constant (8.617×10^{-5} eV/°K)

T_1 = accelerated aging temperature (K)

T_2 = normal service temperature (K)

T_3 = normal service temperature (K)

Therefore the thermal aging time at temperature t_1 is

$$t_1 = 1771 \text{ hours} + 1179 \text{ hours} = 2950 \text{ hours} \qquad (32)$$

The thermal aging time required to simulate any number of baseline temperatures can be calculated using this technique.

END OF EXAMPLE 4

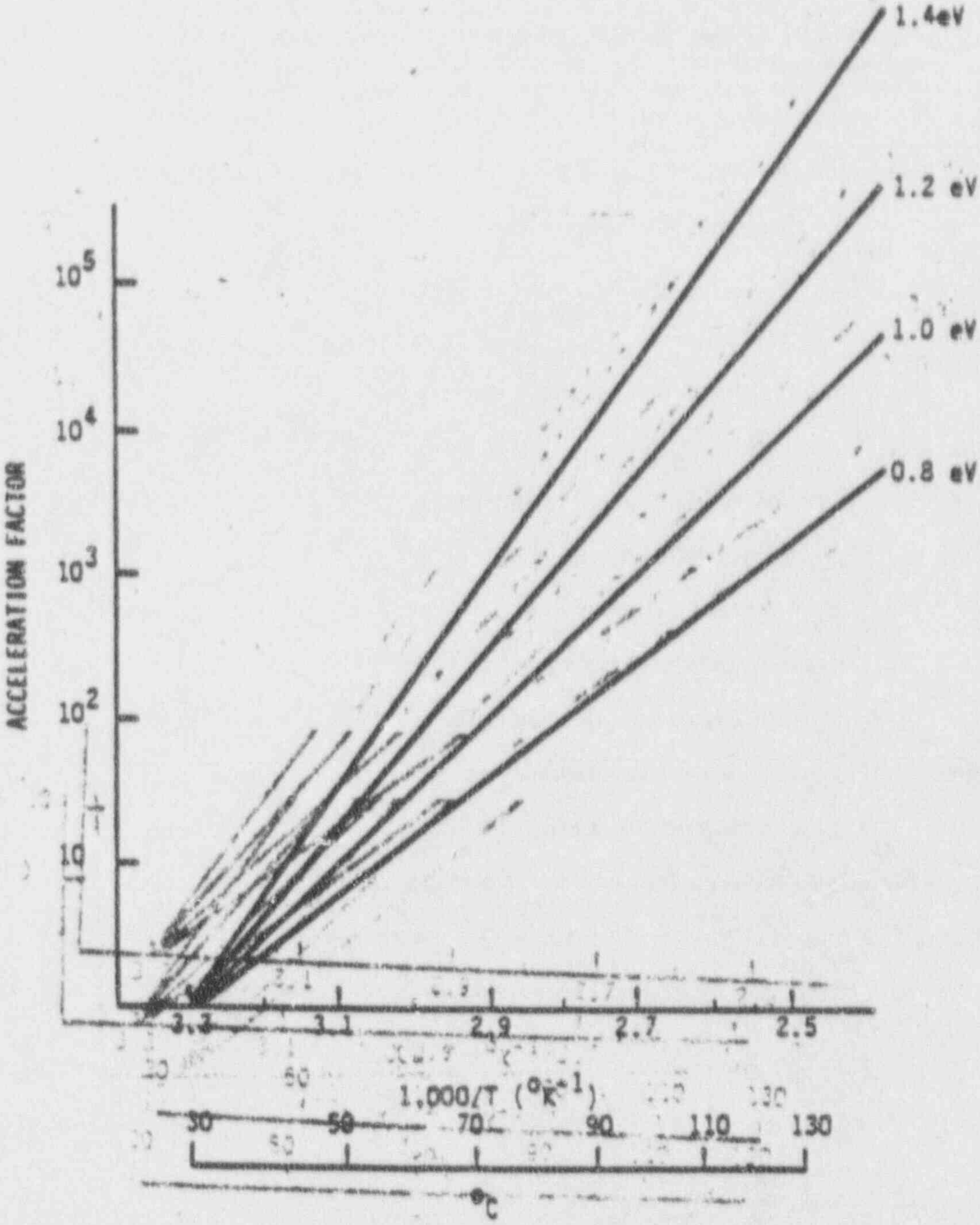

Figure A-1 Acceleration Factors Versus 1/T for Activation Energies of 0.8, 1.0, 1.2 and 1.4 eV