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IPS-107 TEST REPORT
ON
ELECTRICAL TERMINATIONS
SUBJECTED TO
DESIGN BASIS ACCIDENT ENVIRONMENT
NORTH ANNA POWER STATIONS UNIT I AND II

VIRGINIA ELECTRIC AND POWER COMPANY
RICHMOND, VIRGINIA

STONE AND WEBSTER ENGINEERING CORP. - AGENT

CONAX CORPORATION
Subsidiary of Esterline Corporation
2300 Walden Avenue
Buffalo, New York 14225

NO.	
REV.	DATE

TEST REPORT
ON
ELECTRICAL TERMINATIONS
SUBJECTED TO
DESIGN BASIS ACCIDENT ENVIRONMENT

NORTH ANNA POWER STATIONS 1 AND 11
VIRGINIA ELECTRIC AND POWER COMPANY
RICHMOND, VIRGINIA
STONE AND WEBSTER ENGINEERING CORP. - AGENT

PREPARED BY ______________________ DATE __________
William Bernbeck, Test Engineer

APPROVED BY ______________________ DATE __________
G. L. Meiler, Engineering Manager

______________________ DATE __________
W. S. Rautio, Nuclear Products Manager

______________________ DATE __________

ABSTRACT

Electrical Terminations for inside containment application were tested under Design Basis Accident conditions for North Anna 1 and 2 Nuclear Power Plants. Test items consisted of terminal block connections and splices contained in enclosures, and splices which were exposed directly to the environment. Test items utilized conductor sizes from #16 AWG to 250 MCM. Approximately fifty-percent (50%) of the test items were irradiated to an integrated dosage level of 2.5×10^7 rads minimum prior to DBA Testing. In addition, one enclosure containing test items was also thermally aged prior to DBA Testing.

Test results show equivalent performance of enclosed terminal block connections and/or enclosed splices and indicate acceptability of either method for inside containment application.

Section I of the following report presents the test procedure utilized to conduct the test program. Section II presents details of test item construction, test details and conclusions.

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SECTION I

TEST PROCEDURE

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No. IPS - 107

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TEST PROCEDURE AND REPORT ON ELECTRICAL TERMINATIONS SUBJECTED TO DESIGN BASIS ACCIDENT ENVIRONMENT

PREPARED BY ______________________ DATE __________
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SECTION II

TEST REPORT

1.0 SCOPE This document covers the test procedure and results for determining the integrity and suitability of the following electrical penetration conductor terminations for use inside containment of the North Anna Power Station, Units 1 and 11 of the Virginia Electric and Power Company. The following types of conductor terminations were tested:

Item A. Terminal Blocks; Mounted in enclosures (terminal boxes), terminating penetration conductors and incoming cables.

Item B. Enclosed Field Splices; Penetration conductors terminated to incoming cables by field splices inside enclosures.

Item C. Factory Splices, Not Enclosed, Penetration conductors terminated to factory assembled pigtails outside enclosures.

Item D. Field Splices, Not Enclosed; Penetration conductors terminated to incoming cables by field splices outside enclosures.

Refer to Table 1 for an outline of penetration types and conductor sizes to be tested per the above itemizations.

2.0 REFERENCE SPECIFICATIONS & DRAWINGS NAS-21 Revised May 5, 1972 "Specification for Reactor Containment Electrical Penetrations for North Anna Power Station, 1975 Extension - North Anna Power Station, Virginia Electric and Power Company, Richmond, Virginia".

IPS-82	Test procedures for Spliced Conductor Connections and for Terminal Blocks for Inside Containment Application.
IPS-91*	Connecting Penetration Assemblies to Field Cables.
Drawing 7057-09000	Electrical Penetrations for North Anna Power Station Units 1 and 2.
Drawing 7057-10000	Outline drawing Instrumentation, Control, and Low Voltage Power Penetration.
Drawing 2SK-818	Enclosure, Sub-Assembly
Drawing 7079-24000	Enclosure, Sub-Assembly

* Developed for Surry Power Station; for information only.

FORM NO. 0858

3.0 ASSEMBLIES TO BE QUALIFIED

3.1 Tests of items shown in Table 1 shall qualify these items for their intended use inside the containment during design basic accident conditions.

3.2 Tests of Item A will, in addition to the above, be used to qualify penetration types 11 A, 11 B, 11 E, and 1V. These particular types will not be tested due to their lack of criticality and to their similarity to the tested types.

TABLE 1

PENETRATION CONDUCTORS TO BE TESTED

ITEM A (TERMINAL BLOCKS)		ITEM B (FIELD SPLICES, ENCL.)		ITEM C (FACTORY SPLICES, NOT ENCL.)		ITEM D (FIELD SPLICES, NOT ENCL.)	
Penetration Type	Conductor Size	Penetration Type	Conductor Size	Penetration Type	Conductor Size	Penetration Type	Conductor Size
1A	#16 AWG	1A	#16 AWG	11C ③	#2/0 AWG	11D	250 MCM
1B	#14 AWG	1B	#14 AWG				
1C	#10 AWG ①	1C	#10 AWG ①				
		11C	#2/0 AWG			11C ②	#2/0 AWG
						1A ②	#16 AWG
						1C ②	#10 AWG ①

① The #10 AWG test conductors will be connected to #12 AWG Field Conductors from incoming cables.

② Items to be tested for supplemental information only.

③ The test assembly will consist of two #2/0 solid copper conductors connected by a single #2/0 stranded copper jumper inside the test chamber.

3.3 The following specifies the rated current to be applied to each conductor under test:

Item No.	Conductor Size (AWG or MCM)	Rated Current (AC amps ± 10%)
I	#16 AWG	1.0
II	#14 AWG	1.0
III	#10 AWG	15
IV	#2/0 AWG	150
V	250 MCM	230

FORM NO. 0036

4.0 TEST ITEM CONSTRUCTION

4.1 Terminal Blocks.

4.1.1 The terminal blocks tested were all Connectron, Inc., Catalog No. NSS3, with thermoplastic parts molded of polysulfone.

4.1.2 A total of 24 terminals on eight (8) terminal blocks were tested with terminating conductors of #16, #14, #12, and #10 AWG. The #16 and #14 AWG conductors were connected to the terminal blocks with uninsulated Burndy ring tongue connectors (Hylug YAV T1). The #12 and #10 AWG conductors were connected to the terminal blocks with uninsulated Amp ring tongue connectors (Amp Inc., Solistrand, P/N 32994).

4.1.3 The conductors of 4.1.2 were further divided into one of two types as follows;

4.1.3.1 Penetration Conductors - Solid copper conductors with polyimide (kapton) insulation identical to those conductors used in Conax electrical penetration assemblies. Conductor sizes tested of this type were #16, #14, and #10 AWG.

4.1.3.2 Field Conductors - Stranded copper conductors with "XLP" insulation in neoprene jacketed cable supplied by Stone and Webster. The cable samples tested were as follows:

a) Boston Insulated Wire, 300 volt, 2/c, 16 AWG, NGA-69.
b) Rockbestos Pyrotrol 111, 600 volt, 3/c, 14 AWG, NGA-36.
c) Okonite Okoprene, 600 volt, 3/c, 12 AWG, NGB-19.

4.1.4 The penetration conductors were crimped and soldered to their respective ring tongue connectors. The field conductors were crimped only to their respective ring tongue connectors. Crimping was performed with an Amp pneumatic crimp tool, model 69010-M4.

4.2 Field Splices.

4.2.1 A total of 37 field splices were tested with terminating conductors of #16, #14, #12, #10, 2/0 AWG and 250 MCM. Field cables used in these terminations were the same as specified in 4.1.3.2 for the #10 through #16 conductors. The 2/0 AWG and 250 MCM field conductors were also supplied by Stone and Webster and are described as follows:

a) 2/0 AWG, 600 volt, silicone insulation, asbestos, jacket.
b) 250 MCM, 600 volt, silicone insulation, asbestos jacket.

4.2.2 The field splices were constructed as follows:

4.2.2.1 Fourteen each #16 AWG solid (kapton) connected to #16 AWG stranded (field) with Thomas & Betts type BB-2 in-line splice connectors.

4.2.2.2 Six each #14 AWG solid (kapton) connected to #14 AWG stranded (field) with Thomas & Betts type BB-2 in-line splice connectors.

4.2.2.3 Nine each #10 AWG solid (kapton) connected to #12 AWG stranded (field) with Thomas & Betts type CC-2 in-line splice connectors.

4.2.2.4 The connectors of 4.2.2.1, 4.2.2.2, and 4.2.2.3 were crimped and soldered onto the solid conductors and crimped only onto the stranded conductors. Crimping was performed with an Amp pneumatic crimp tool, model 69010-M4.

4.2.3 Five each 2/0 AWG solid, kapton insulated, copper conductors were connected to 2/0 stranded kapton insulated copper conductors with Conax crimp/thread connectors (P/N N-34000-01). These 2/0 stranded conductors were in turn connected to 2/0 stranded field conductors with Thomas & Betts type 54510 in-line, crimp-type splice connectors. Crimping was performed with a Thomas & Betts 13642 hydraulic crimp tool equipped with a T & B No. 45 hex die.

4.2.4 Three each 250 MCM solid, kapton insulated, copper conductors were connected to 250 MCM stranded field cable with Conax crimp/thread connectors (P/N N-34004). Crimping was performed with a Thomas & Betts 13642 hydraulic crimp tool equipped with a Thomas & Betts No. 62 hex die.

4.2.5 Splice insulation - the field splices were insulated as follows:

4.2.5.1 Each splice had 3 windings of 1.5 -mil kapton tape applied directly over the splice connector. Each winding was started at least one inch from the end of the connector on the conductor insulation and was wound to at least one inch from the end of the connector onto the other conductor insulation. Each turn of the tape utilized at least half the tape width in overlap on the previous turn. The #10 through #16 AWG terminations had 1/2 inch wide tape applied, while the #2/0 AWG and 250 MCM utilized 1 inch wide tape.

4.2.5.2 Each kapton-wrapped splice then had a piece of polyolefin heat shrink tube shrunk over the splice. The tube extended one inch minimum beyond the area covered by the kapton tape.

4.2.6 In order to provide an "intimate ground" to the field splices, each splice had a length of #16 AWG bare copper wrapped around the polyolefin tube in the vicinity of the connector. This "intimate ground" wire would then be grounded during the actual testing.

4.3 Factory Splices.

4.3.1 Two factory splices were constructed consisting of a #2/0 AWG solid copper, kapton insulated, conductor connected to a #2/0 AWG stranded copper, kapton insulated conductor. The solid conductors were connected to one end of a common stranded conductor which acted as a jumper between the two splices.

4.3.2 The factory splices were made with Conax crimp/thread connectors (P/N N-34000-01) in the manner described in 4.2.3 for connecting 2/0 solid, kapton insulated, 2/0 stranded, kapton insulated.

4.3.3 The factory splices were insulated in the manner described in 4.2.5.

4.4 Enclosures

4.4.1 Two enclosure boxes were built per Conax drawing No. 25K-313. All surfaces of the enclosures were painted with carbozinc No. 11.

4.4.2 Enclosure 1 was equipped with Crouse-Hinds CGB series cable fittings. Enclosure 2 was equipped with Thomas & Betts type 2535 series cable fittings. The cable fittings were mounted to the removable enclosure side plates.

4.4.3 The enclosure side plates and top cover were gasketed to the enclosure assembly with R-10470 silicone spong rubber tape (Connecticut Hard Rubber Company).

4.4.4 Each enclosure was equipped with a 1/2 inch drain pipe on the bottom side. Refer to Figure 15 of the photographic appendix.

4.4.5 Each enclosure had one Connectron NP 12-1/2 terminal block mounting mil rack welded inside it.

4.4.6 Each enclosure had the following numbers and types of test terminations assembled inside it:

Terminations Type	Number	Conductor Size (AWG)
Terminal Blocks	6	16
	3	14
	3	10/12

Terminations Type	Number	Conductor Size(AWG)
Field Splices	6	16
	3	14
	3	10/12
	1	2/0

In addition, each enclosure had one 3/c #14 AWG field cable and one group of eight (8) #14 AWG penetration conductors enter and exit it free of splices or terminations internal to the enclosures or test chamber.

4.4.7 Each group of penetration conductors entering the enclosures was jacketed with neoprene heat shrink tubing, positioned to allow the cable fitting sealant to seal onto it. This jacketing was brought into the enclosures a minimum of 4 inches and extended at least 1 foot outside the enclosures.

4.4.8 The conductors entering and exiting the enclosures were arranged to allow the penetration conductors to enter the enclosures from the left side (as viewed from the enclosure top cover), and the field cables to enter from the right.

4.5 Refer to Figure 1 of Appendix A for an outline of nomenclature used to describe test items. Table 1 of Appendix A outlines the pertinent information on the test items.

5.0 TEST ENVIRONMENT FACILITY

5.1 Refer to Figure 2 of Appendix A for a diagram of the Conax Design Basis Accident test facility.

5.2 The test items were assembled into a test chamber to which the following operational/environmental systems could be applied:

5.2.1 Electrical operation - enabled the test conductors and terminations to be energized to rated current or voltage as applicable. Also provided access to the test items for operational measurements during environment.

5.2.2 Loss of Coolant Accident (LOCA) - introduction of incident steam to test chamber atmosphere to cause a pressure and temperature rise from specified ambient conditions; the pressure/temperature rise characteristics to simulate those conditions inherent to a loss of coolant accident condition from a pressurized water reactor (PWR). Radiation exposure of test items preceded LOCA Incident.

5.2.3 Emergency Coolant System - introduction of a water chemical spray onto the test items both during and after LOCA incident conditions. The spray system simulates that brought about in response to a LOCA condition inside a PWR containment.

5.3 Assembly of test items into test facility.

5.3.1 Radiation Exposure - Prior to assembly into enclosures or test facility, a selection of test items was subjected to gamma irradiation. An integrated dosage of 2.5×10^7 rads minimum was imposted on the test items that composed Radiation Bundle 1 (RB1) and Radiation Bundle 2 (RB2). Refer to Table 1 of Appendix A for a breakout of those items contained in RB1 and RB2. RB1 items were irradiated on the weekend of 3/30/73, RB2 was irradiated on weekend of 4/21/73. Pre- and post-radiation photographs of the test items are contained on pages to of the Photographic Appendix. Irradiated test items comprised 41% of the total number of test items.

5.3.2 The test items, along with test control samples, were assembled into the environmental test facility as follows:

5.3.2.1 Enclosure 2, along with its built-in test items, was first placed inside the test chamber. It was positioned such that the bottom of the enclosure was about 12 inches from the bottom of the test chamber. The back side was placed against the steam inlet standoff bracket (about 1-1/2 inches from the rear chamber wall). The conductors from this enclosure were directed out the front opening of the test chamber.

5.3.2.2 Enclosure 1, along with its built-in test items, was then placed inside the test chamber immediately in front of enclosure 2 and at the same height from the chamber bottom. The conductors from this enclosure were directed out the front opening of the test chamber.

5.3.2.3 The items to be tested as non-enclosed field splices and non-enclosed factory splices were mounted directly to the front header flange of the test chamber.

5.3.2.4 The test conductors from both enclosures were directed through ports in the header flange and sealed with Conax PG packing glands or Conax MHC packing glands. The flange was then fitted and sealed to the test chamber.

5.3.2.5 The test conductors routed through the sealed header flange were terminated to the control switchboard. Wiring diagrams of the switchboard and control bench circuitry are contained in Figures 3A, 3B, 3C, 3D, and 3E of Appendix A.

6.0 TEST OPERATIONS

6.1 Insulation Resistance - The test items were subjected to insulation resistance measurements at 500 volts DC in accordance with the following schedule:

IR Test No.	Description
1	Initial readings; Terminations have been built but otherwise have not been installed into test setup.
2	Post-Radiation readings; Data on those terminations exposed to gamma irradiation.
3	Installation readings; Data on those terminations installed into test enclosures.
4	Post-age readings; Data on enclosure 1 test items after thermal aging.
5	Pre-Incident readings; Data on all terminations after installation into test chamber.
6 thru 16	Daily readings during Phases I and II of LOCA environment.
17	Post-DBA readings; Test items were still scaled into test chamber.
18	Post-DBA readings; Test items removed from test chamber.

6.2 Dielectric Strength (Hypot) - The test items were subjected to Hypot tests immediately after IR Test Nos. 3, 5, 6A, and 17. All 300 volt rated test items were tested at 1600 volts RMS, all 600 volt rated test items were tested at 2700 volts RMS.

6.3 Continuity - The test items were tested for continuity with an audible continuity checker immediately after IR test No. 2.

6.4 The data collected from 6.1, 6.2, and 6.3 are contained on the data sheets presented in Appendix B.

6.5 Thermal Aging - Enclosure 1 was subjected to a 22 year simulated life after installation of test terminations and conductors but prior to assembly into test chamber. Details of thermal aging are contained in Appendix C.

6.5.1 The field cable assembled into Enclosure 1 exhibited signs of damage of sufficient magnitude to warrant their replacement with fresh, unaged cable samples. These replacement cables were brought inside each enclosure and connected to the original field conductors about 6 to 8 inches from the original splice. Thus, the original splices were kept intact. The new splices were insulated as described in 4.2.5. In addition, the entire group of new splices from a new cable was jacketed with a piece of neoprene heat shrink tubing extending from the cable jacket to about 2 inches beyond the splices.

6.6 LOCA Environment Test Operation.

6.6.1 The test items had the following electrical conditioning applied to them five hours prior to start of Phase 1 LOCA:

a) All 250 MCM test items - 230 amperes RMS, 1.1 volts RMS.

b) All 2/0 AWG test items - 150 amperes RMS, 2.1 volts RMS.

c) All #10/#12 AWG test items - 15 amperes RMS, 7.7 volts RMS.

d) All #14 AWG test items - 1 amperes RMS, 600 volts RMS.

e) All #16 AWG test items - 1 amperes RMS, 300 volts RMS.

These conditions were maintained on the test items for the first ten minutes of Phase 1 LOCA environment.

6.6.2 Phase 1 LOCA environment began with the introduction of steam into the test chamber. Test chamber pressure and temperature characteristics obtained from time to (start of steam) to To + 30 minutes is as follows:

Time	Chamber Pressure (Psig)	Chamber Temperature (°F)
To	0	109
To + 30 sec.	24	253
To + 60 sec.	45	282
To + 90 sec.	48	285
To + 120 sec.	57.5	290
To + 180 sec.	48	282
To + 4 min.	48	283
To + 5 min.	49	289
To + 10 min.	56	300
To + 15 min.	47	293

Time	Chamber Pressure (Psig)	Chamber Temperature (°F)
To + 20 min.	47	295
To + 25 min.	48	299
To + 29 min.	47	297
To + 30 min.	45	294

6.6.3 At To + 60 seconds, a decontaminant spray was introducted into the test chamber onto the test items. This decontaminant solution consisted of a water spray with the following characteristics:

a) Boron Content - 0.23 molar (approx. 1900 ppm).

b) NaOH Content - 10^{-4} to 4×10^{-2} molal.

c) pH - 7.7

d) Temperature: +190° F

e) Spray Rate: 10 gallons per minute.

f) Amount Available: 310 gallons. At the given spray rate of 10 gallons/per/minute, the test items had this initial solution sprayed onto them for the first 30 minutes of the test.

6.6.4 At To + 10 minutes, the test items were electrically de-energized, and IR Test No. 6 was performed.

6.6.5 Phase 1 LOCA conditions were held on the test items for a total of 30 minutes.

6.6.6 Phase 11 LOCA environment began at To + 30 minutes. At that time, the steam input to the test chamber was shut off, and a fresh decontaminant solution from Tank B was sprayed onto the test items. This new solution had characteristics identical to those described in 6.6.3 except as follows:

a) pH - 7.8

b) Temperature - 114° F

6.6.7 Steam was diverted into the Bank B solution as required to raise the solution temperature. The test chamber temperature was, in turn, governed by the decontaminant solution temperature. The test chamber pressure and temperature for the first 30 minutes of Phase 11 LOCA (To + 30 min. to To + 60 min.) were as follows:

Time	Chamber Pressure (Psig)	Chamber Temperature (°F)
To + 30 min.	45	294
To + 30 min., 35 sec.	0	224
To + 31 min.	0	209
To + 32 min.	0	177
To + 33 min.	0	158
To + 34 min.	0	151
To + 35 min.	0	153
To + 40 min.	0	150
To + 45 min.	0	146
To + 50 min.	0	145
To + 55 min.	0	145
To + 60 min.	0	144

6.6.8 The test chamber pressure and temperature were held to 0 psig and 140° to 150° F respectively for the next 240 hours. During this time, the decontaminant solution was continuously sprayed into the test chamber, collected and recirculated back into the spray system. Samples of the decontaminant solution were taken daily and analyzed for pH and boron content.

6.6.9 During the course of Phase II LOCA environment, the use of steam to heat the decontaminant solution required periodic draining of Tank B to keep the level down. A new solution was prepared in Tank A with the starting chemistry described in 6.6.3 and used to replace the Tank B solution in water spray system. Changeover was performed to To + 108 hours. This Tank A solution was used for the remainder of Phase II LOCA.

6.6.10 Details of boron analysis on the decontaminant solution used in the water spray system are contained in Appendix D. The pH determinations for the solution used are also contained in that Appendix.

6.6.11 The test items were electrically energized at rated current or voltage as applicable per 6.6.1 for at least five hours of every 24 hour interval during Phase II LOCA.

6.6.12 Insulation resistance measurements were taken on each test item after the energization period and the reading recorded. Data accumulated from these readings are contained in IR Test Nos. 6 thru 16 of Appendix B.

6.6.13 Hi-Pot tests were scheduled to be performed after each IR Test of 6.6.12. However, these tests were discontinued after IR Test No. 6 because of frequent leakage and breakdown conditions imminent from the test items under environment. To preclude any possible cable damage due to repeated Hi-Pot Testing, it was decided, with Stone and Webster concurrence, to procure one final set of data after completion of Phase II LOCA environment. Hi-Pot data are contained in the Data Sheets of Appendix B.

6.6.14 Flashover Test - At time To + 164 hours, the circuit of Figure 4 of Appendix A was implemented onto test items TE 1-01 through TE 1-06 inclusive and TE2-01 through TE2-06 inclusive. This circuit allowed those terminal block test terminations to have a voltage potential applied between adjacent terminals. Intermittent flashover would be indicated by a heavy loading on the voltage source. Flashover testing was applied to the above mentioned test items at all times outside of IR measurements or rated power energization. This amounted to approximately 64 hours of flashover testing on the above mentioned test items.

7.0 TEST RESULTS

7.1 Appendix E contains the analyses (according to test termination and conductor size) of the data of Appendix B. These graphs depict a plot of minimum value data points observed from the test population (total number of test points involved).

7.2 The data of IR Test Nos. 6, 6A, 7, and 8 were determined invalid for analysis due to instrumentation difficulties. It was found that the megohmmeter secondary was intermittently being coupled to earth ground through the operational test chamber spray system. Meter isolation eliminated the errant readings produced by this condition.

7.3 Continuity to the following test items was lost from the initial assembly of the test chamber hardware and consequently, there is no data available in them throughout LOCA testing.

Test Termination	Description
TE2-07	#14 AWG terminal block
TE2-08	#14 AWG terminal block
TE2-09	#14 AWG terminal block
SPE2-07	#14 AWG enclosed field splices
SPE2-08	#14 AWG enclosed field splices
SPE2-09	#14 AWG enclosed field splices
CE1-01	#14 AWG test control sample
CE1-02	#14 AWG test control sample
CE1-03	#14 AWG test control sample
CE1-04	#14 AWG test control sample
CE1-05	#14 AWG test control sample
CE1-06	#14 AWG test control sample
CE1-07	#14 AWG test control sample
CE1-08	#14 AWG test control sample

Later investigation revealed that improper assembly of two packing glands onto the test chamber header flange caused these conductors to be broken at the packing gland.

7.4 Visual inspection of the test items showed that the common cause of low IR readings on particular field splices during LOCA conditions was due to the polyolefin sleeving over the splices splitting and opening from the LOCA high temperature conditions. This was especially prevalent with the large size, (2/0 AWG and 250 MCM) non-enclosed, field splices. Splitting of the polyolefin sleeve could have been agitated at the final assembly of the header flange to the test chamber. These items did recover to higher IR readings after LOCA environment. Low IR readings from #14 terminal block test items were caused from nicks in the kapton insulation of the penetration conductors at the test chamber header flange. However, there was no discernable cause for the low IR readings from the #10/#12 AWG terminations as such.

7.5 During Phase I LOCA conditions, the stranded field cables brought outside the test chamber had condensed steam trickling out from between the jacketing and stranding. However, this did not cause any difficulties in circuit operation.

7.6 Examination of Enclosure I immediately after removal from the test chamber showed that 2 of the 4 terminal blocks contained inside had come loose from the mounting rail.

8.0 CONCLUSIONS

8.1 Gamma irradiations had no noticeable effect on test item performance throughout the entire test effort.

8.2 Compared on a common basis, Enclosure 1 test items showed consistently lower IR characteristics than Enclosure 2 test items. The difference was all within the same order of magnitude, but cause cannot be accurately isolated as to cable fitting manufacturer or thermal aging.

8.3 Enclosed field splice terminations tended to perform nearly equal to terminal block terminations.

8.4 There was no evidence of flashover conditions from the testing of 6.6.14.

8.5 The low IR readings indicated on the graphs of Appendix E were very much common to the #10/#12 AWG conductor terminations. Visual inspection revealed no apparent damage to penetration conductors of this group.

8.6 The loosened terminal blocks mentioned in 7.6 appear to have been caused at the installation of Enclosure 1 into the test chamber. The room available to install this enclosure into the test chamber made it necessary to exert considerable force on the enclosure to install it, and the terminal blocks loosened as a result of this.

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APPENDIX A

Test Conductor Information

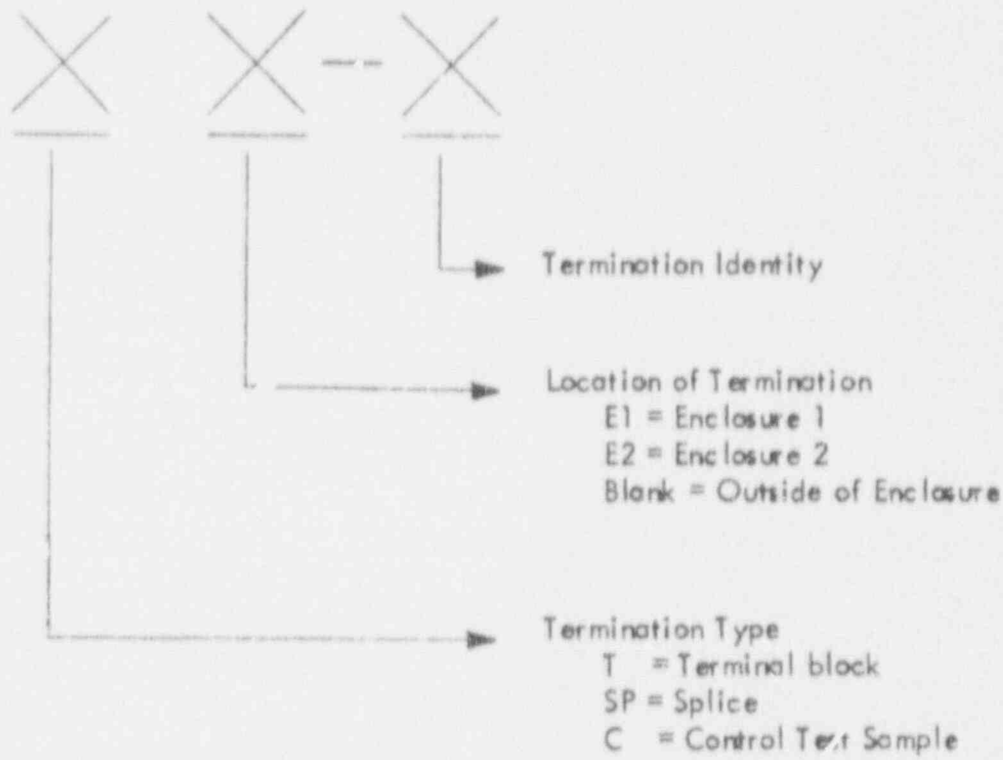
Test Item Nomenclature

Test Facility Schematic

Test Circuit Diagrams

FIGURE 1

TEST ITEM NOMENCLATURE



Examples: TE1-01 refers to Terminal #1 of Enclosure 1 terminal blocks.

SPE2-02 refers to enclosed field splice #2 of Enclosure 2.

SP-04 refers to field splice, not-enclosed, item number 4.

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Sheet 1 of 2

FIGURE 3.2

TEST CIRCUIT SCHEMATIC

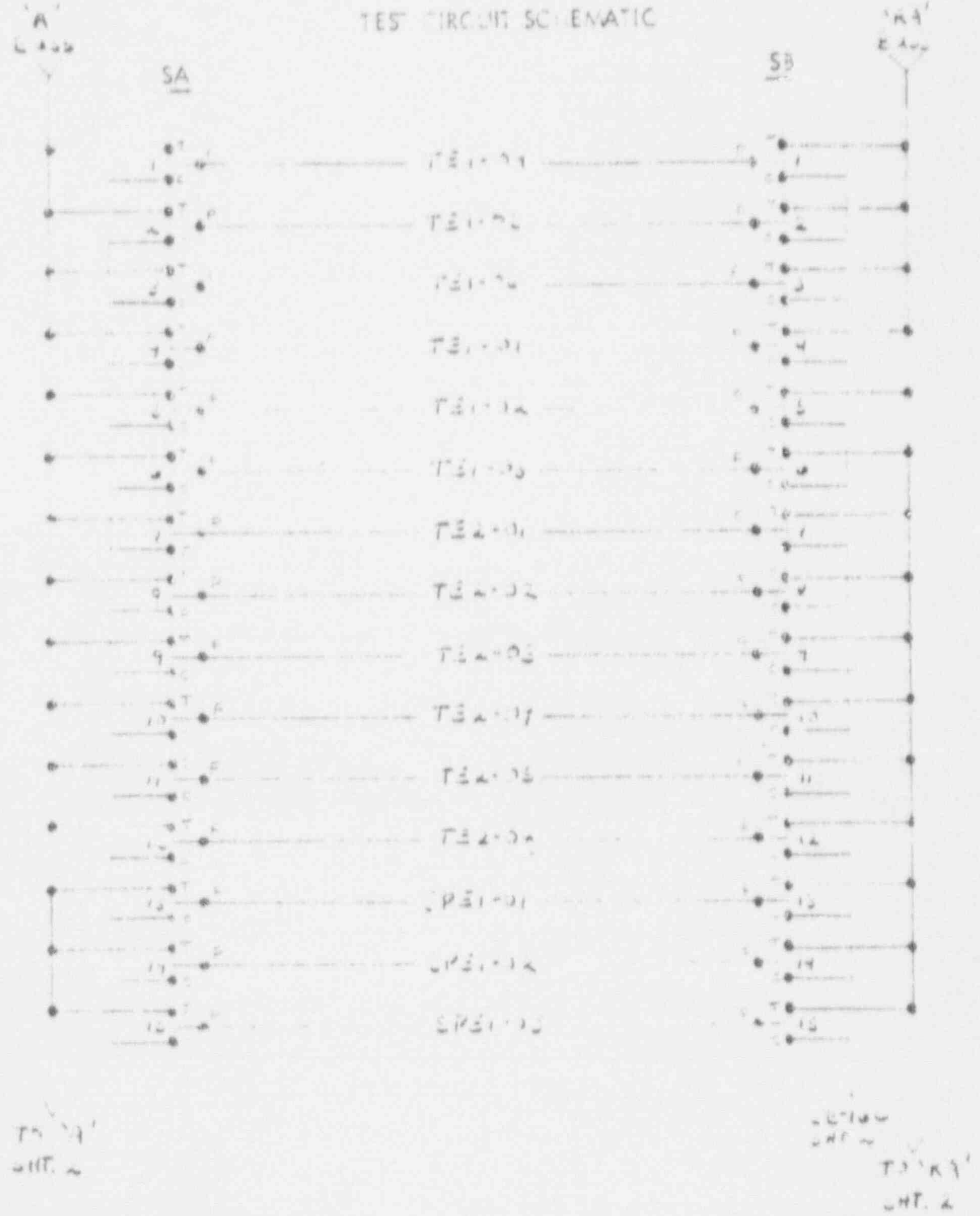

FIGURE 2

SCHEMATIC OF DESIGN BASIS ACCIDENT TEST FACILITY

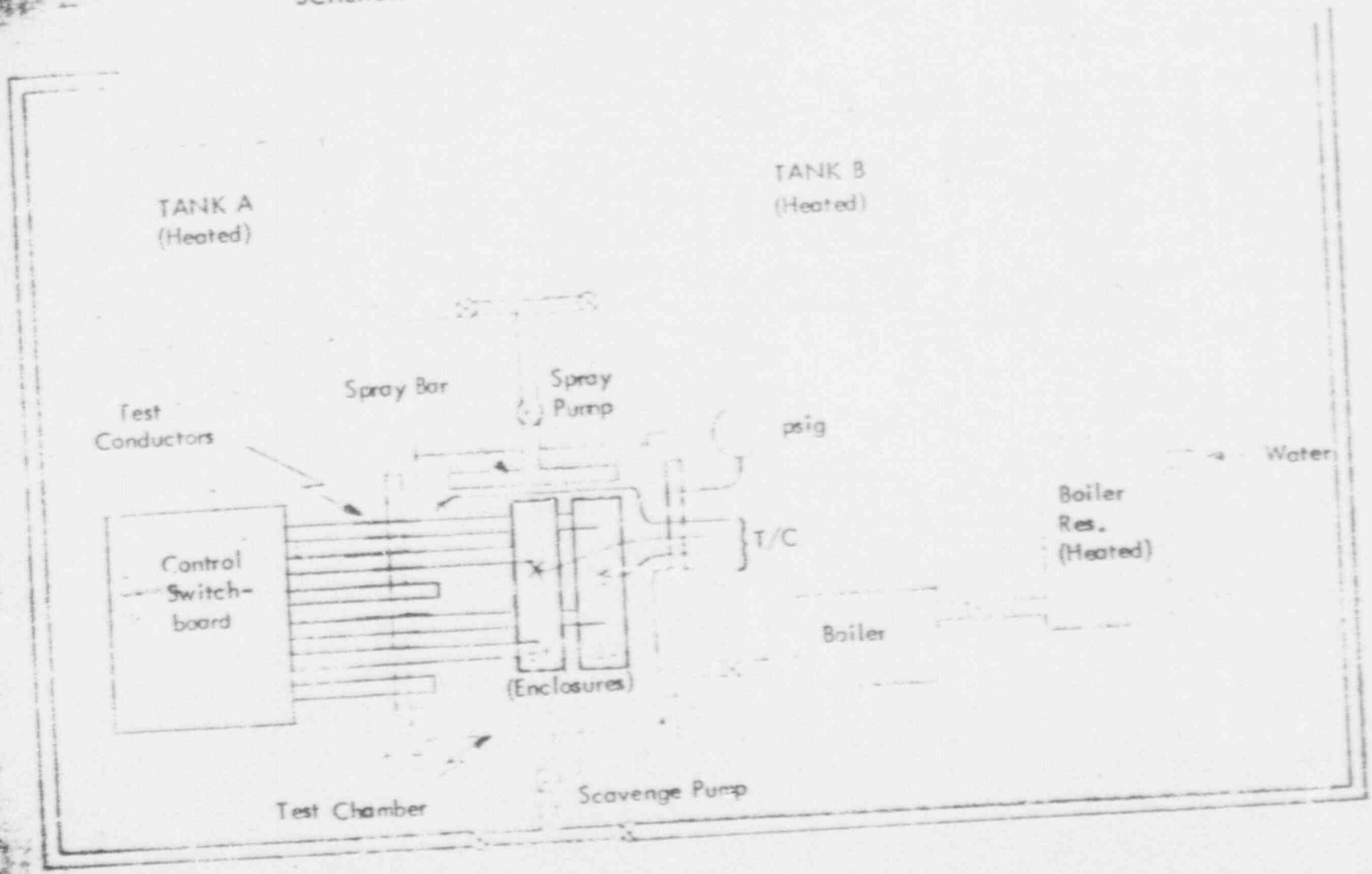

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FIGURE 3A

DIAGRAM OF TEST CIRCUIT

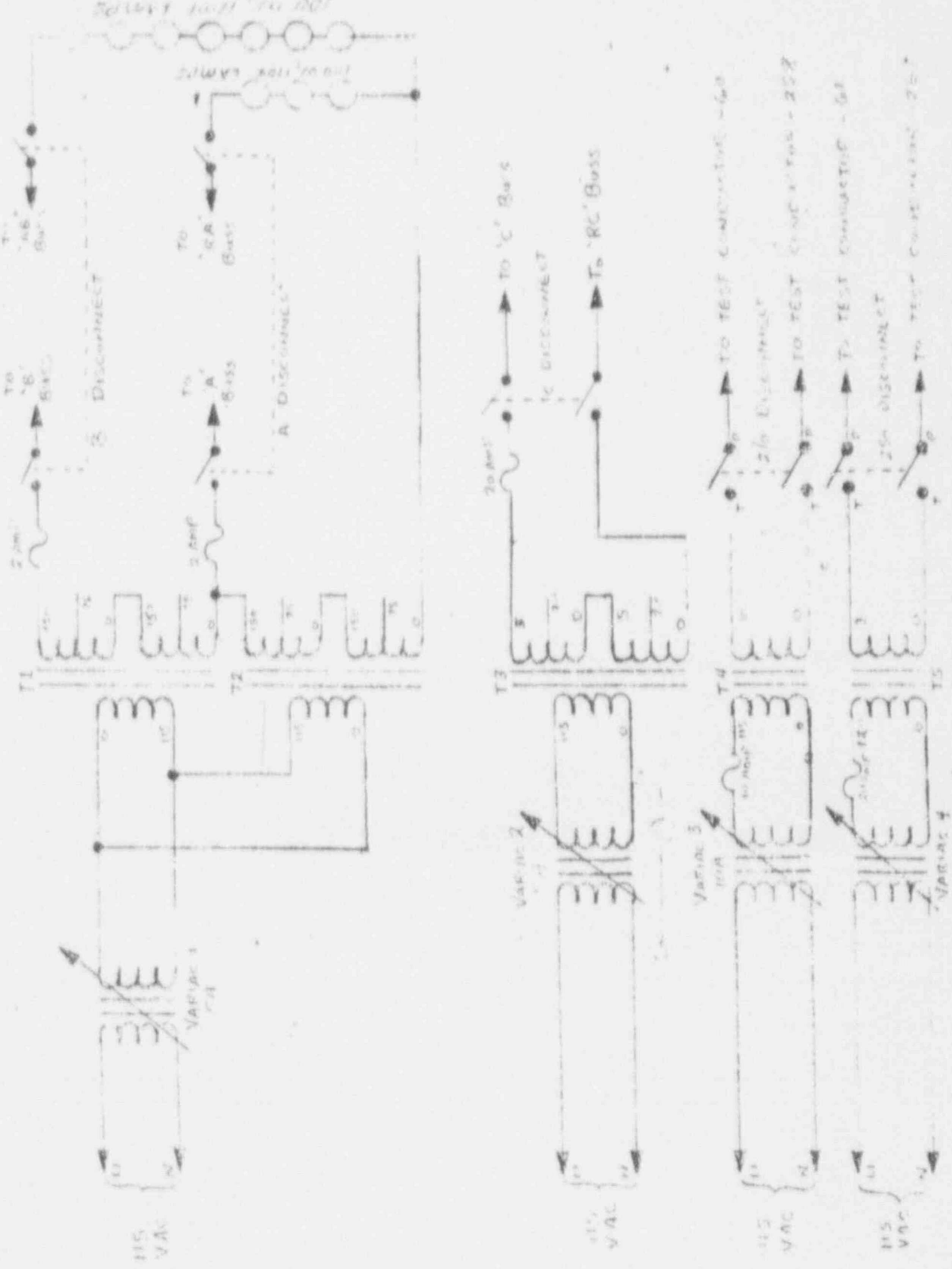

FIGURE 4

FLASHOVER TEST CIRCUIT

N.B. A similar test circuit was simultaneously imposed on test items TE2-01 through TE2-06.

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APPENDIX B

Test Data Sheets

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REPORT DATA

DATE 7/7/73	Page 1 of 7
NO. 5	
BY Rautio	
ORDER NO 7-08150	
FILE NO IPS-82	

TITLE:

INSULATION RESISTANCE TESTS DATA SHEET B #5

AMBIENT CHAMBER TEMP. 76 °F

PRE [illegible] TESTS
[illegible] INT TEST CHAMBER

TIME TEST STARTED: 0915 TIME TEST FINISHED: 1010

CONDUCTOR SIZE	TEST COND. NO.	RATED VOLTS (VDC)	TEST VOLTS (VDC)	IR (OHMS)	REMARKS
16 AWG	TE1-01	[illegible]	[illegible]	2×10^{11}	R
	TE1-02			2×10^{11}	R
	TE1-03			2×10^{11}	R
	TE1-04			1×10^{11}	R
	TE1-05			2×10^{11}	R
	TE1-06			5×10^{11}	R
14 AWG	TE1-07	600		5×10^{11}	
	TE1-08			3.6×10^{11}	
	TE1-09			4×10^{11}	
[illegible]	TE1-10			1×10^{11}	
	TE1-11			2×10^{11}	
	TE1-12			2×10^{11}	

NOTE: HP 4329A MEGOHMMETER USED FOR [illegible]

OPM-836

CONAX CORPORATION
BUFFALO, NEW YORK 1422[illegible]

REPORT DATA

TITLE: INSULATION RESISTANCE TESTS DATA SHEET D #6

FILE NO. IPS-82

AMBIENT CHAMBER TEMP. 300 °F INCIDENT TESTS

TIME TEST STARTED: 1522

TIME TEST FINISHED: 1538

CONDUCTOR SIZE	TEST COND. NO.	RATED VOLTS (VDC)	TEST VOLTS (VDC)	IR (OHMS)	REMARKS
16 AWG	TE1-01	600/300	500	0.8×10^10	
↓	TE1-02	↓	↓	4×10^10	R
	TE1-03			3×10^10	R
	TE1-04			0.6×10^10	R
	TE1-05			0.5×10^10	R
	TE1-06			0.8×10^10	R
14 AWG	TE1-07	600		>20×10^10	
↓	TE1-08	↓		>20×10^10	
	TE1-09			>20×10^10	
10 AWG/12 AWG	TE1-10			>20×10^10	
↓	TE1-11			>20×10^10	
	TE1-12			>20×10^10	

HP 4329A MEGOHMMETER

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BUFFALO, NEW YORK 14225

REPORT DATA

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NO.

BY Rautio / Basinksi

ORDER NO

TITLE:

INSULATION RESISTANCE TESTS DATA SHEET F 6A

FILE NO IPS-82

AMBIENT CHAMBER TEMP. 150 °F COOLDOWN TEST

TIME TEST STARTED: 1554

TIME TEST FINISHED : 1620

CONDUCTOR SIZE	TEST COND. NO.	RATED VOLTS (VDC)	TEST VOLTS (VDC)	IR (OHMS)	REMARKS
16 AWG	TE1-01	600	500	5×10^12	R
	TE1-02			5×10^12	R
	TE1-03			2×10^11	
	TE1-04			5×10^11	R
	TE1-05			0.7×10^11	R
	TE1-06			1×10^11	R
14 AWG	TE1-07	600		>20×10^11	
	TE1-08			>20×10^11	
	TE1-09			>20×10^11	
10 AWG / 12 AWG	TE1-10			>20×10^11	
	TE1-11			>20×10^11	
	TE1-12			>20×10^11	

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BUFFALO, NEW YORK 14225

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FILE NO. IPS-82	

TITLE:

INSULATION RESISTANCE TESTS DATA SHEET F

AMBIENT CHAMBER TEMP. 146 °F DBA PHASE II TEST DATA

TIME TEST STARTED: 0545 TIME TEST FINISHED: 0640

CONDUCTOR SIZE	TEST COND. NO.	RATED VOLTS (VDC)	TEST VOLTS (VDC)	IR (OHMS)	REMARKS
16 AWG	TE1-01	600/300	500	9×10^{11}	
↓	TE1-02	↓	↓	5×10^{12}	
	TE1-03			1×10^{12}	
	TE1-04			4×10^{11}	
	TE1-05			4×10^{11}	
	TE1-06			1×10^{12}	
14 AWG	TE1-07	600		3×10^{12}	
↓	TE1-08	↓		6×10^{10}	
	TE1-09			3×10^{11}	
10 AWG/ 12 AWG	TE1-10			$>10^{15}$	
↓	TE1-11			3×10^{14}	
	TE1-12			$>10^{15}$	

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CONAX CORPORATION
BUFFALO, NEW YORK 14225

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ORDER NO 7-08100	
FILE NO IPS-82	

TITLE:

INSULATION RESISTANCE TESTS DATA SHEET F

AMBIENT CHAMBER TEMP. 143 °F DBA PHASE II TEST DATA

TIME TEST STARTED: 0530 TIME TEST FINISHED: 0620

CONDUCTOR SIZE	TEST COND. NO.	RATED VOLTS (VDC)	TEST VOLTS (VDC)	IR (OHMS)	REMARKS
16 AWG	TE1-01	600/300	500	6×10^{11}	
	TE1-02			3×10^{12}	
	TE1-03			7×10^{11}	
	TE1-04			5×10^{10}	
	TE1-05			8×10^{10}	
	TE1-06			1×10^{12}	
14 AWG	TE1-07	600		4×10^{13}	
	TE1-08			∞	
	TE1-09			5×10^{14}	
10 AWG/12 AWG	TE1-10			5×10^{13}	
	TE1-11			1×10^{13}	
	TE1-12			4×10^{12}	

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DATE 7/10/77	PAGE 47
NO. 4	
BY Bombeck/Sweegard	
ORDER NO 7-DE106	
FILE NO. IPS-82	

TITLE: INSULATION RESISTANCE TESTS DATA SHEET F

AMBIENT CHAMBER TEMP. 145 °F DBA Phase II Test Data

TIME TEST STARTED: 0650 TIME TEST FINISHED: 0730

CONDUCTOR SIZE	TEST COND. NO.	RATED VOLTS (VDC)	TEST VOLTS (VDC)	IR (OHMS)	REMARKS
16 AWG	TE1 01	600/[illegible]	[illegible]	0.5×10^8	R
↓	TE1 [illegible]		↓	0.85×10^8	R
↓	TE1 [illegible]	↓	↓	1.6×10^8	R
↓	TE1 [illegible]	↓	↓	1.5×10^8	R
↓	TE1 05	↓	↓	0.5×10^8	R
↓	TE1 [illegible]	↓	↓	1.5×10^8	R
14 AWG	TE1 07	600	↓	10×10^8	
↓	TE1 [illegible]	↓	↓	10×10^8	
↓	TE1 [illegible]	↓	↓	10×10^8	
10 AWG/12 AWG	TE1 [illegible]	↓	↓	10×10^8	
↓	TE1 11	↓	↓	9×10^8	
↓	T[illegible]	↓	↓	0.6×10^8	

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FILE NO IPS-32	

TITLE

INSULATION RESISTANCE TESTS DATA SHEET F

AMBIENT CHAMBER TEMP. 145 °F DBA PHASE II TEST DATA

TIME TEST STARTED: [illegible] TIME TEST FINISHED : 0610

CONDUCTOR SIZE	TEST COND. NO.	RATED VOLTS (VDC)	TEST VOLTS (VDC)	IR (OHMS)	REMARKS
16 AWG	TE1-01	600/300	500	4×10^7	R
	TE1-02			0.72×10^8	R
	TE1-03			0.74×10^8	R
	TE1-04			0.8×10^8	R
	TE1-05			0.62×10^8	R
	TE1-06			1.0×10^8	R
14 AWG	TE1-07	600		1.2×10^7	
	TE1-08			2.5×10^7	
	TE1-09			3×10^6	
10 AWG/12 AWG	TE1-10			1.1×10^7	
	TE1-11			0.9×10^7	
	TE1-12			1×10^7	

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FILE NO IPS-32	

TITLE:
INSULATION RESISTANCE TESTS DATA SHEET F

AMBIENT CHAMBER TEMP. 147 °F DBA PHASE II TEST DATA

TIME TEST STARTED: 0630 TIME TEST FINISHED: 0720

CONDUCTOR SIZE	TEST COND. NO.	RATED VOLTS (VDC)	TEST VOLTS (VDC)	IR (OHMS)	REMARKS
16 AWG	TE1-01	600/300	500	5×10^7	R
↓	TE1-02	↓	↓	0.5×10^8	R
	TE1-03			$1 \times 10^{[illegible]}$	R
	TE1-04			0.7×10^8	R
	TE1-05			5×10^7	R
↓	TE1-06	↓		0.8×10^7	R
14 AWG	TE1-07	600		0.58×10^9	
↓	TE1-08	↓		0.5×10^9	
↓	TE1-09			5×10^8	
10 AWG/12 AWG	TE1-10			$0.54 \times 10^{[illegible]}$	
↓	TE1-11			4.8×10^8	
↓	TE1-12	↓	↓	1×10^7	

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TITLE:

INSULATION RESISTANCE TESTS DATA SHEET F

AMBIENT CHAMBER TEMP. 144 °F DBA PHASE II TEST DATA

TIME TEST STARTED: 053

TIME TEST FINISHED: 615

CONDUCTOR SIZE	TEST COND. NO.	RATED VOLTS (VDC)	TEST VOLTS (VDC)	IR (OHMS)	REMARKS
16 AWG	TE1-01	600/300	500	4×10^7	R
↓	TE1-02	↓	↓	5×10^7	R
↓	TE1-03	↓	↓	0.5×10^8	R
↓	TE1-04	↓	↓	0.7×10^8	R
↓	TE1-05	↓	↓	3.5×10^7	R
↓	TE1-06	↓	↓	0.3×10^8	R
14 AWG	TE1-07	600	↓	4.5×10^8	
↓	TE1-08	↓	↓	4×10^8	
↓	TE1-09	↓	↓	3.5×10^8	
10 AWG/12 AWG	TE1-10	↓	↓	3.7×10^8	
↓	TE1-11	↓	↓	3.3 × [illegible]	
↓	TE1-12	↓	↓	1.4×10^7	

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TITLE: INSULATION RESISTANCE TESTS DATA SHEET F

AMBIENT CHAMBER TEMP. 143 °F DBA PHASE II TEST DATA

TIME TEST STARTED: 0530 TIME TEST FINISHED: 0615

CONDUCTOR SIZE	TEST COND. NO.	RATED VOLTS (VDC)	TEST VOLTS (VDC)	IR (OHMS)	REMARKS
16 AWG	TE1-01	600/300	500	3.6×10^7	R
↓	TE1-02	↓	↓	$4. \times 10^7$	R
↓	TE1-03	↓	↓	0.8×10^8	R
↓	TE1-04	↓	↓	0.64×10^8	R
↓	TE1-05	↓	↓	3.2×10^7	R
↓	TE1-06	↓	↓	0.64×10^8	R
14 AWG	TE1-07	600	↓	1.7×10^8	
↓	TE1-08	↓	↓	1.6×10^8	
↓	TE1-09	↓	↓	1.6×10^8	
10 AWG/12 AWG	TE1-10	↓	↓	1.6×10^8	
↓	TE1-11	↓	↓	1.5×10^8	
↓	TE1-12	↓	↓	0.98×10^7	

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FILE NO 1PS-S2	

TITLE:

INSULATION RESISTANCE TESTS DATA SHEET F

AMBIENT CHAMBER TEMP. 145 °F DBA PHASE II TEST DATA

TIME TEST STARTED: 0530 TIME TEST FINISHED: 0610

CONDUCTOR SIZE	TEST COND. NO.	RATED VOLTS (VDC)	TEST VOLTS (VDC)	IR (OHMS)	REMARKS
16 AWG	TE1-01	600/300	500	4×10^7	R
	TE1-02			0.72×10^8	R
	TE1-03			0.74×10^8	R
	TE1-04			0.8×10^8	R
	TE1-05			0.62×10^8	R
	TE1-06			1.5×10^8	R
14 AWG	TE1-07	600		1.3×10^7	
	TE1-08			2.5×10^9	
	TE1-09			3×10^9	
10 AWG/12 AWG	TE1-10			1.1×10^9	
	TE1-11			0.9×10^9	
	TE1-12			1×10^7	

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FILE NO IPS-32	

TITLE:

INSULATION RESISTANCE TESTS DATA SHEET F

AMBIENT CHAMBER TEMP. [illegible] °F DBA PHASE II TEST DATA

TIME TEST STARTED: [illegible] TIME TEST FINISHED: [illegible]

CONDUCTOR SIZE	TEST COND. NO.	RATED VOLTS (VDC)	TEST VOLTS (VDC)	IR (OHMS)	REMARKS
16 AWG	TE1-01	600/300	500	$3.5 \times 10^{?}$	R
↓	TE1-02	↓	↓	$5 \times 10^{?}$	R
↓	TE1-03	↓	↓	0.72×10^{8}	R
↓	TE1-04	↓	↓	0.52×10^{8}	R
↓	TE1-05	↓	↓	3.5×10^{7}	R
↓	TE1-06	↓	↓	0.85×10^{8}	R
14 AWG	TE1-07	600	↓	0.55×10^{9}	
↓	TE1-08	↓	↓	5×10^{8}	
↓	TE1-09	↓	↓	4.2×10^{8}	
10 AWG/12 AWG	TE1-10	↓	↓	$1.8 \times 10^{?}$	
↓	TE1-11	↓	↓	$4.1 \times 10^{?}$	
↓	TE1-12	↓	↓	0.91×10^{7}	

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FILE NO.	IPS-32

TITLE:

INSULATION RESISTANCE TESTS DATA SHEET F

DBA PHASE II TEST DATA

AMBIENT CHAMBER TEMP. 149 °F

TIME TEST STARTED: 053

TIME TEST FINISHED: 0610

CONDUCTOR SIZE	TEST COND. NO.	RATED VOLTS (VDC)	TEST VOLTS (VDC)	IR (OHMS)	REMARKS
16 AWG	TE1-01	600/300	500	3.8×10^7	R
↓	TE1-02	↓	↓	0.52×10^8	R
↓	TE1-03	↓	↓	0.82×10^8	R
↓	TE1-04	↓	↓	[illegible]	R
↓	TE1-05	↓	↓	3×10^7	R
↓	TE1-06	↓	↓	3×10^7	R
14 AWG	TE1-07	600	↓	0.6×10^9	
↓	TE1-08	↓	↓	0.56×10^9	
↓	TE1-09	↓	↓	4.7×10^8	
10 AWG/12 AWG	TE1-10	↓	↓	0.54×10^9	
↓	TE1-11	↓	↓	4.7×10^8	
↓	TE1-12	↓	↓	1.3×10^7	

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BERNBECK/SWEIGARD

7-0810

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0915 0950

16 AWG	TE1-01	600/300	500	4.5×10^8		R
	TE1-02			1×10^9		R
	TE1-03			2×10^9		R
	TE1-04			9×10^8		R
	TE1-05			6×10^8		R
	TE1-06			2×10^9		R
14 AWG	TE1-07	600		1.5×10^9		
	TE1-08			5×10^9		
	TE1-09			3.5×10^9		
10 AWG/12 AWG	TE1-10			9×10^9		
	TE1-11			2.5×10^9		
	TE1-12			1.3×10^8		

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BERNBECK/LANGE

7-08106

INSULATION RESISTANCE TEST DATA SHEET II

AMBIENT CHAMBER TEMP. 78 °F

POST- 3 ... DATA

ITEMS REMOVED FROM TEST CHAMBER

TIME TEST STARTED: N/A

TIME TEST FINISHED: N/A

CONDUCTOR SIZE	TED COND. NO.	RATED VOLTS (VDC)	VOLTS (VDC)	IR (OHMS)	REMARKS
16 AWG	TE1-01	600/300	500	4.6×10^{9}	R
↓	TE1-02	↓	↓	4.5×10^{9}	R
↓	TE1-03	↓	↓	4.5×10^{9}	R
↓	TE1-04	↓	↓	5×10^{9}	R
↓	TE1-05	↓	↓	4.5×10^{9}	R
↓	TE1-06	↓	↓	4.8×10^{9}	R
14 AWG	TE1-07	600	↓	4.6×10^{9}	
↓	TE1-08	↓	↓	4.4×10^{10}	
↓	TE1-09	↓	↓	1.5×10^{10}	
10 AWG/12 AWG	TE1-10	↓	↓	5×10^{9}	
↓	TE1-11	↓	↓	5×10^{9}	
↓	TE1-12	↓	↓	6×10^{9}	

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APPENDIX E

Compilation of IR Test Data

CONAX CORPORATION
BUFFALO, NEW YORK 14225

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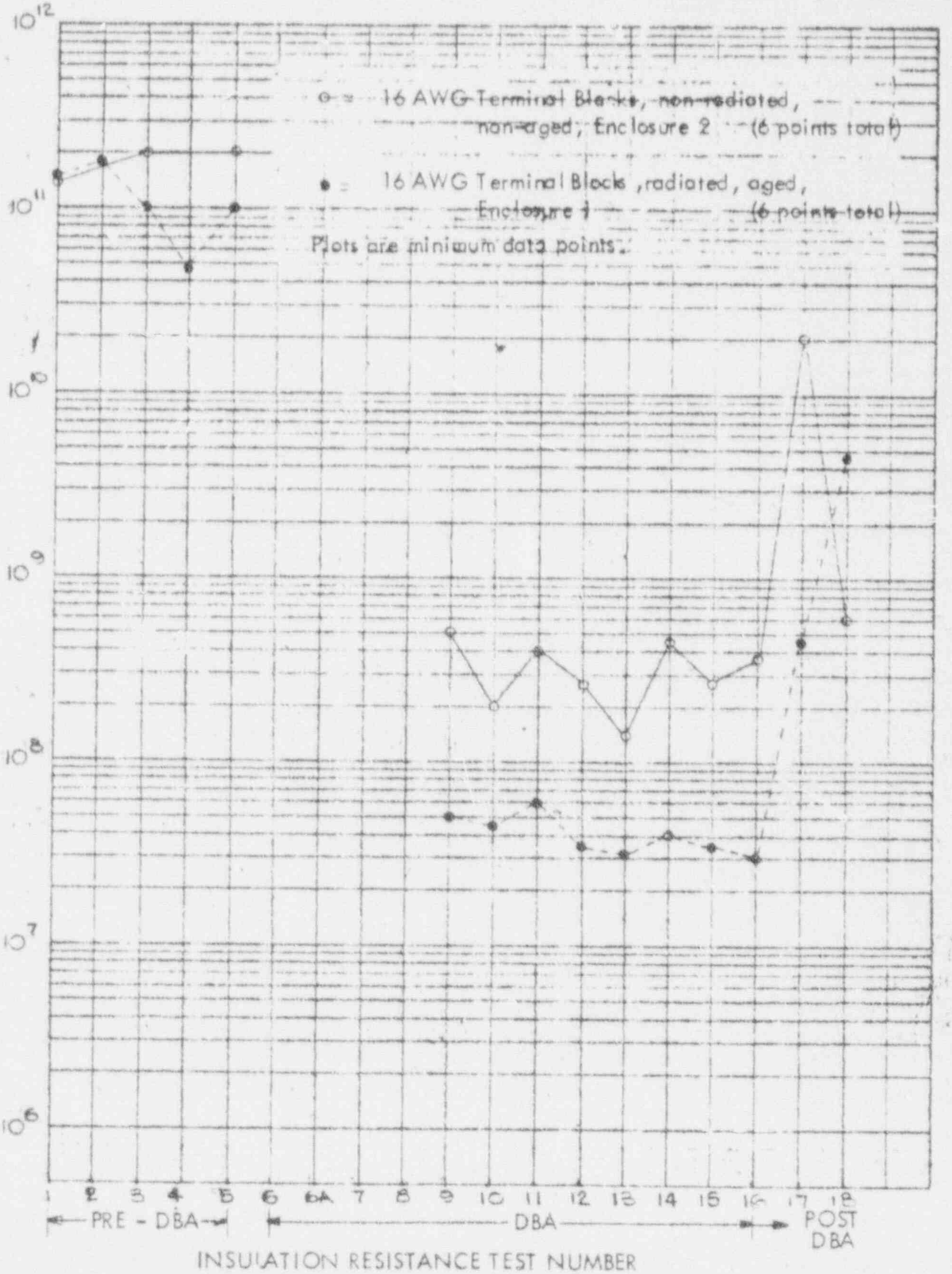
NO. 1	
BY W. G. Bernbeck	
ORDER NO 7-08100	
FILE NO IPS-107	

REPORT DATA

TITLE: 16 AWG TERMINAL BLOCKS



FORM #86

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BUFFALO NEW YORK 14...

APPENDIX F

Photographic Data Appendix

FIGURE 1

PRE-IRRADIATION CONDITION OF 16 AWG TERMINAL BLOCK

TERMINATIONS OF ENCLOSURE 1.

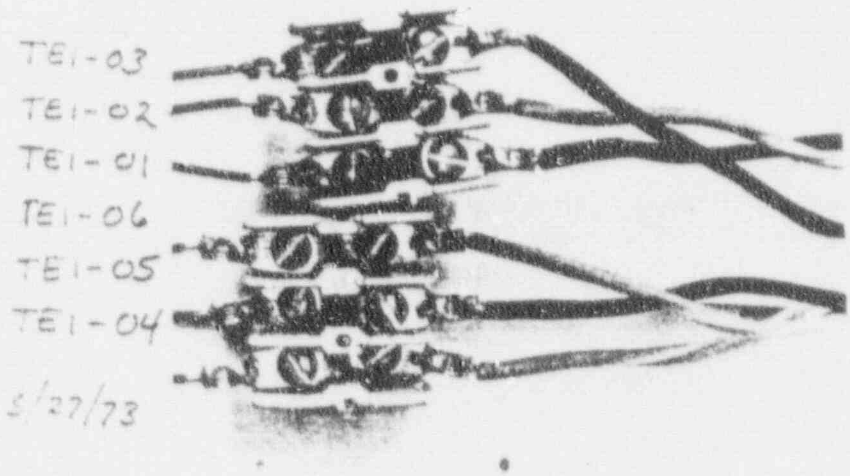
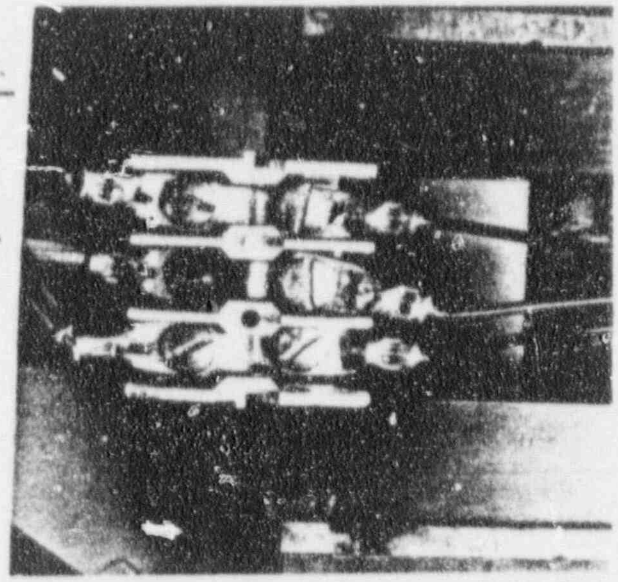


FIGURE 2

POST-IRRADIATION CONDITION OF 16 AWG TERMINAL BLOCK TERMINATIONS OF ENCLOSURE 1.

5/17/73
POST-RAD.

TE1-01
TE1-02
TE1-03



5/17/73
POST-RAD.

TE1-04
TE1-05
TE1-06

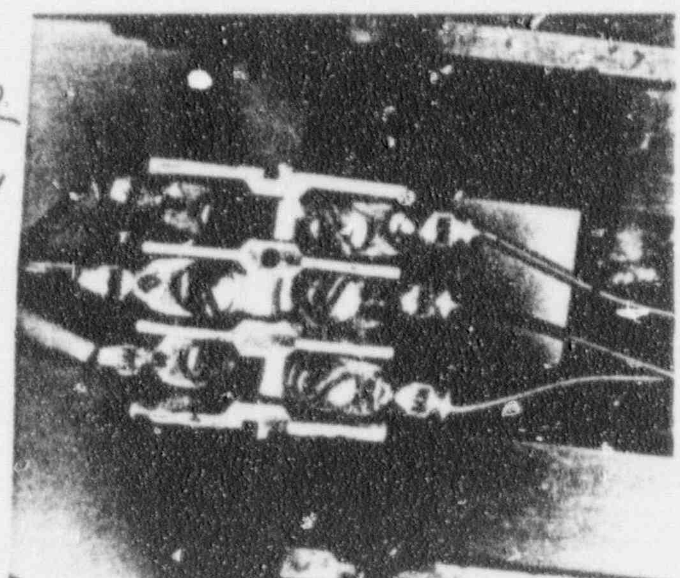
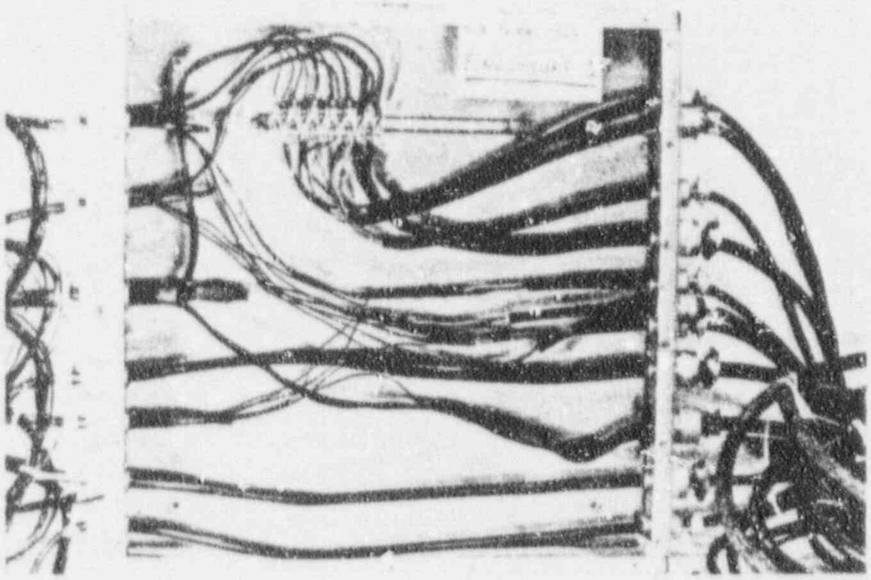
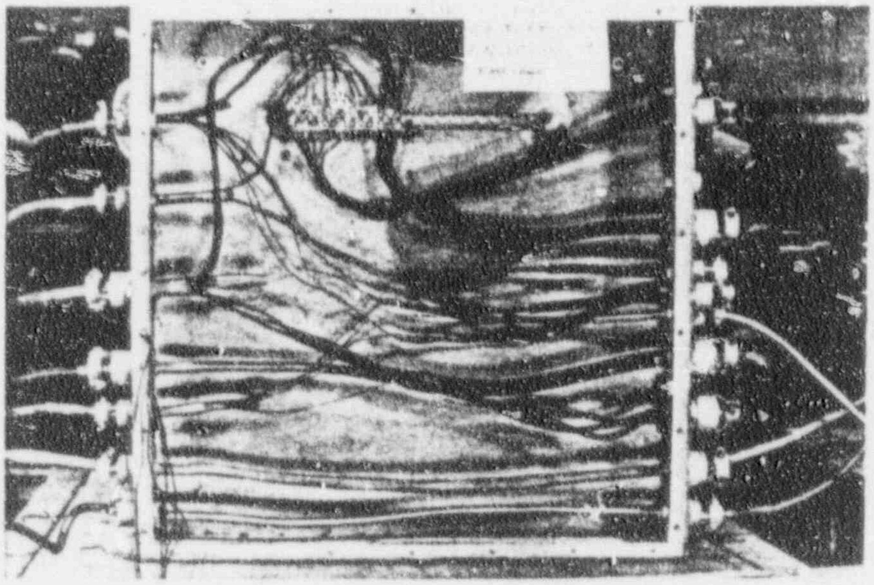


FIGURE 13

PRE - AND POST - AGE CONDITIONS OF ENCLOSURE 1.

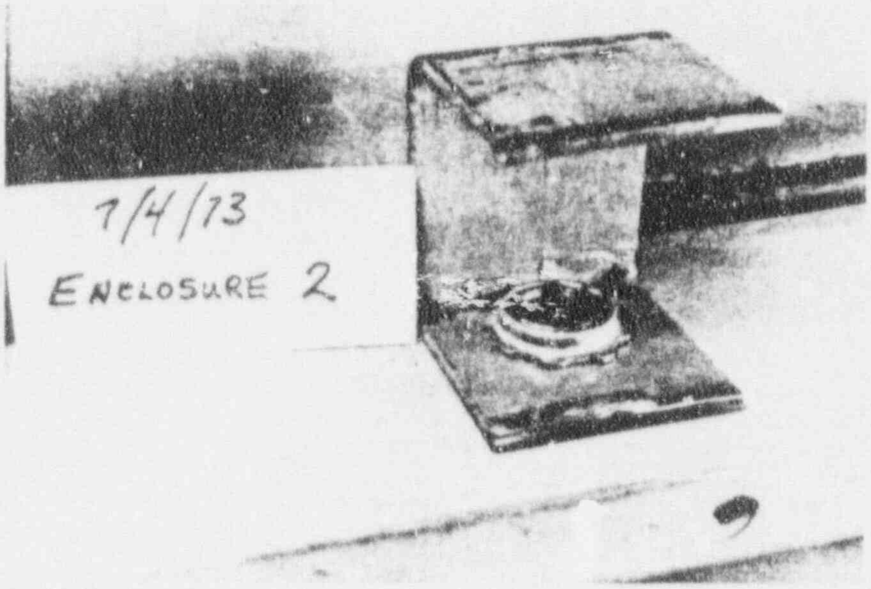




POST-AGE

FIGURE 15

DRAIN FACILITY BUILT INTO THE TEST ENCLOSURES.



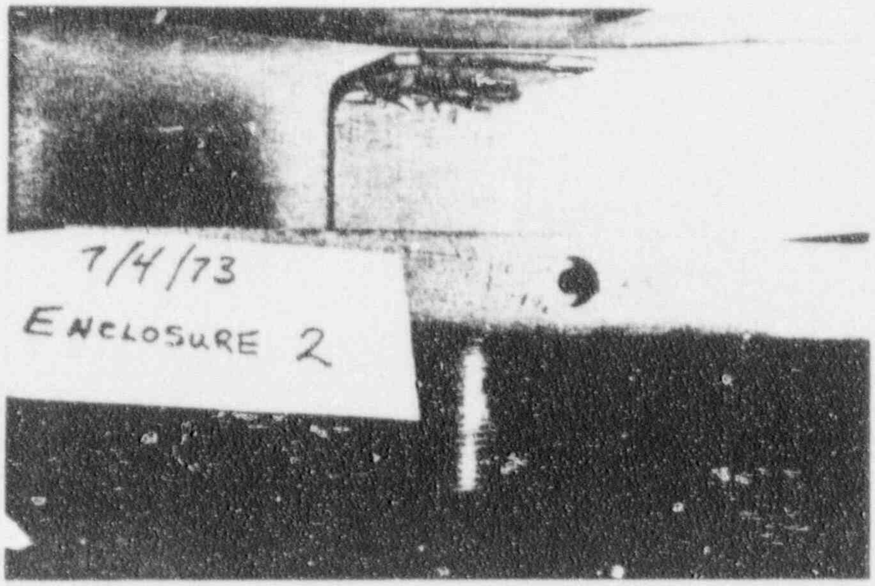


FIGURE 16 A

INSTALLATION OF ENCLOSURE 1 INTO TEST CHAMBER

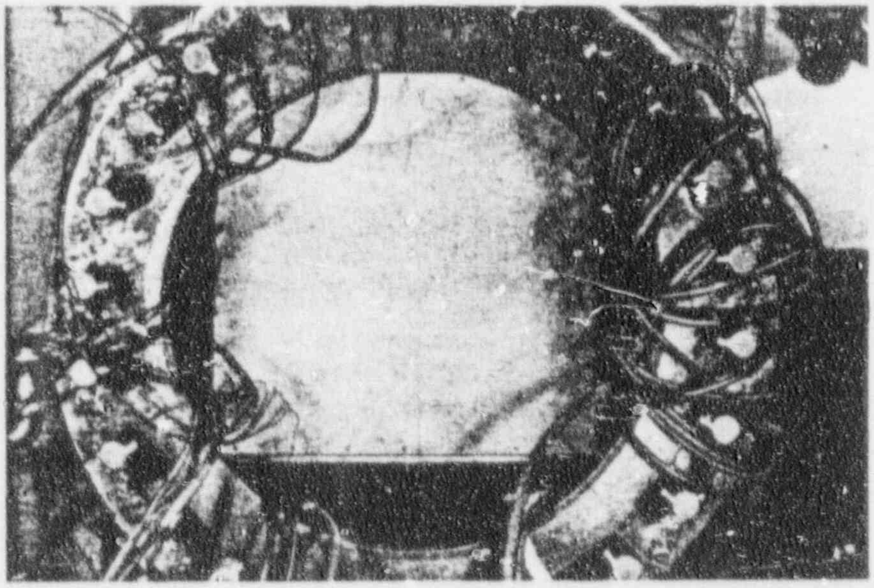


FIGURE 18

FINAL ASSEMBLY OF TEST ITEMS INTO TEST CHAMBER

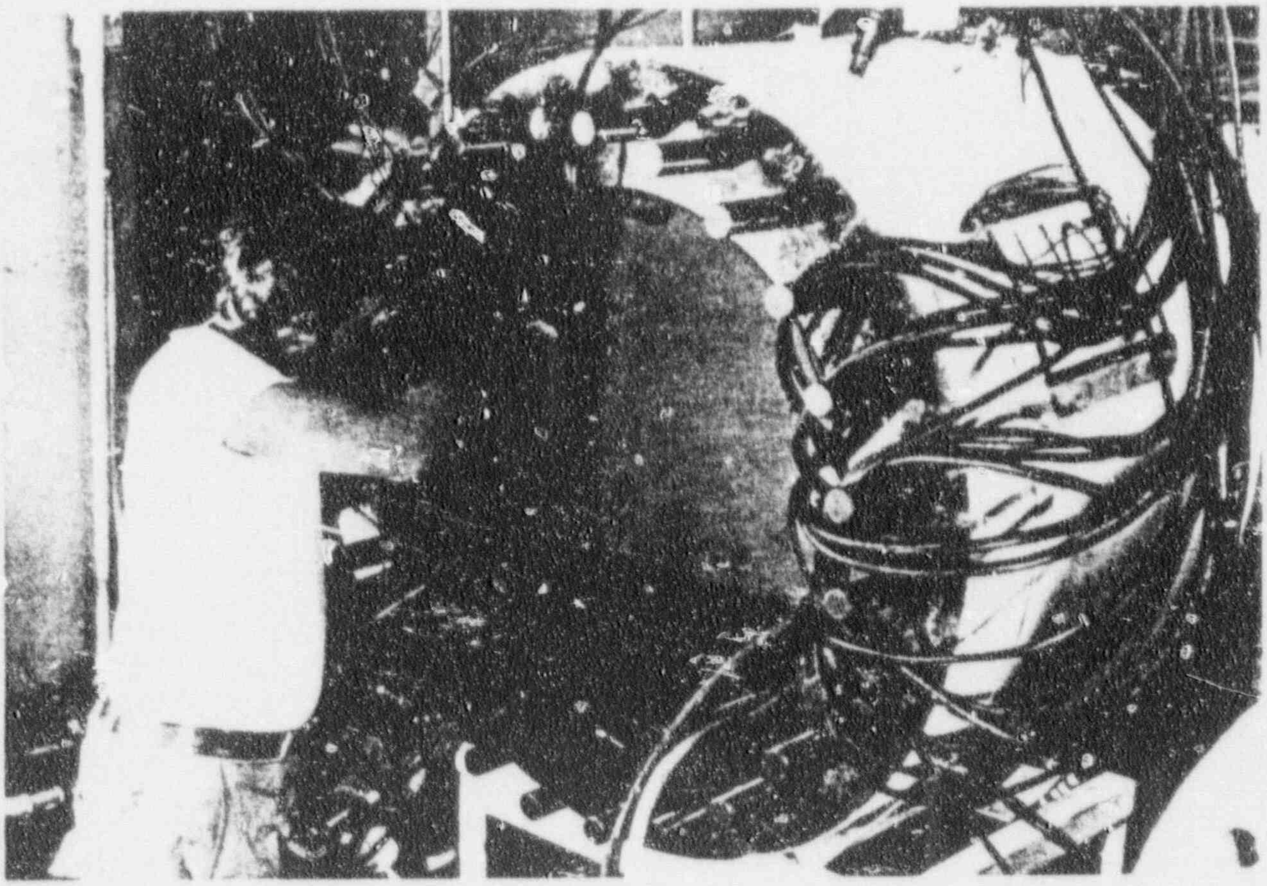


FIGURE 19

FINAL ASSEMBLY OF HEADER FLANGE ONTO TEST CHAMBER

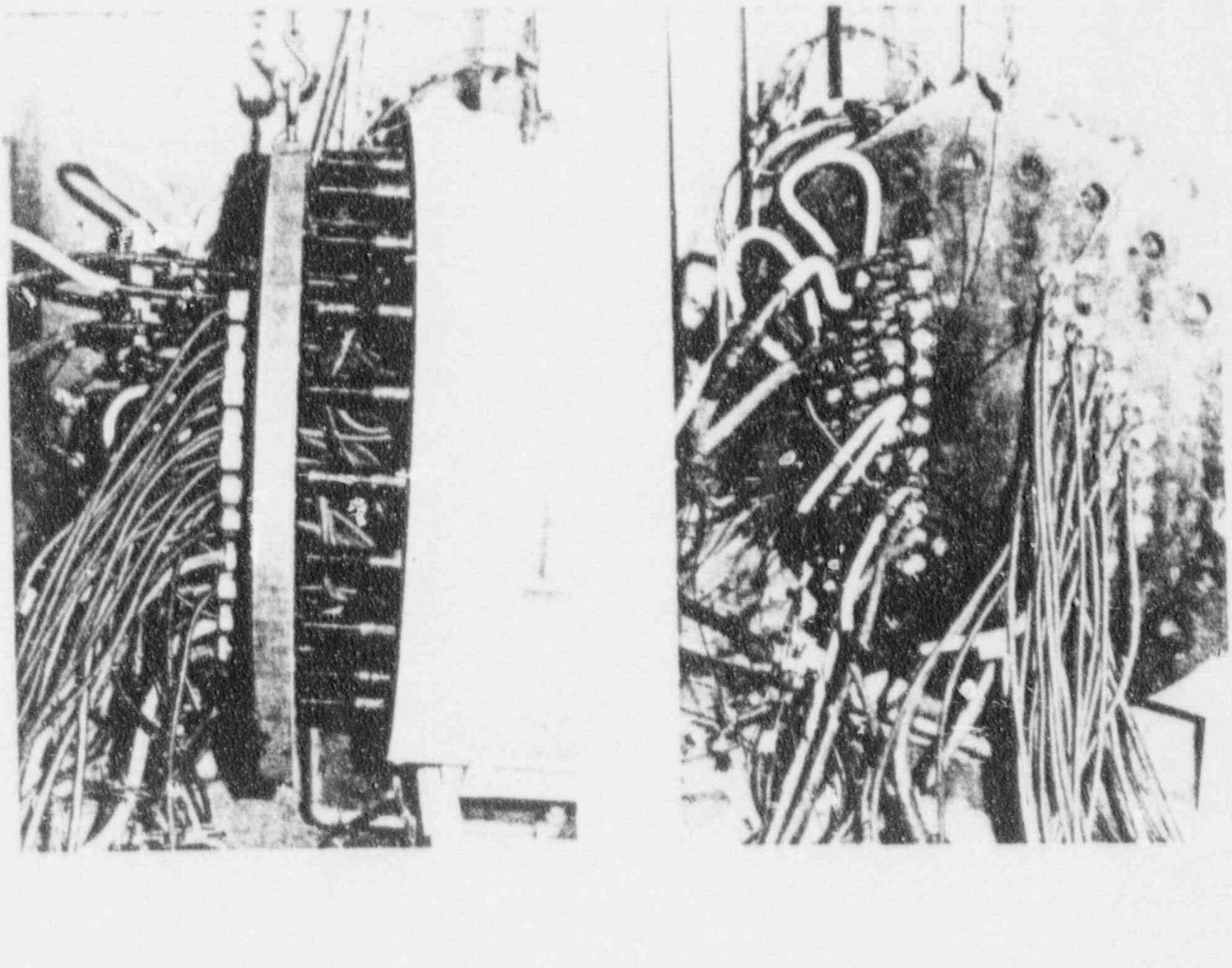


FIGURE 20

ASSEMBLY OF TEST CONDUCTORS TO CONTROL SWITCHBOARD

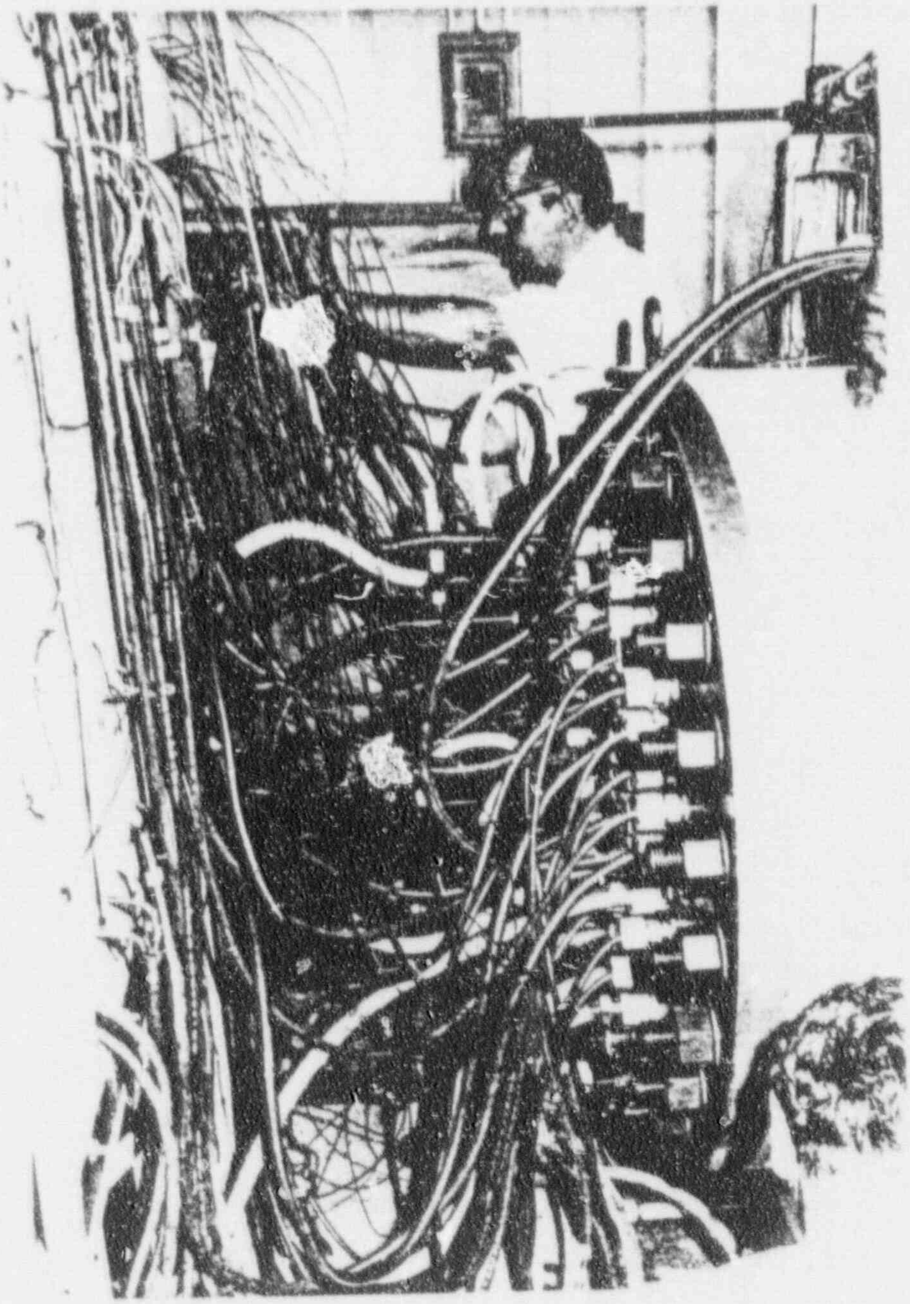


FIGURE 21

BEGINNING DBA TEST; PHASE I LOCA CONDITIONS

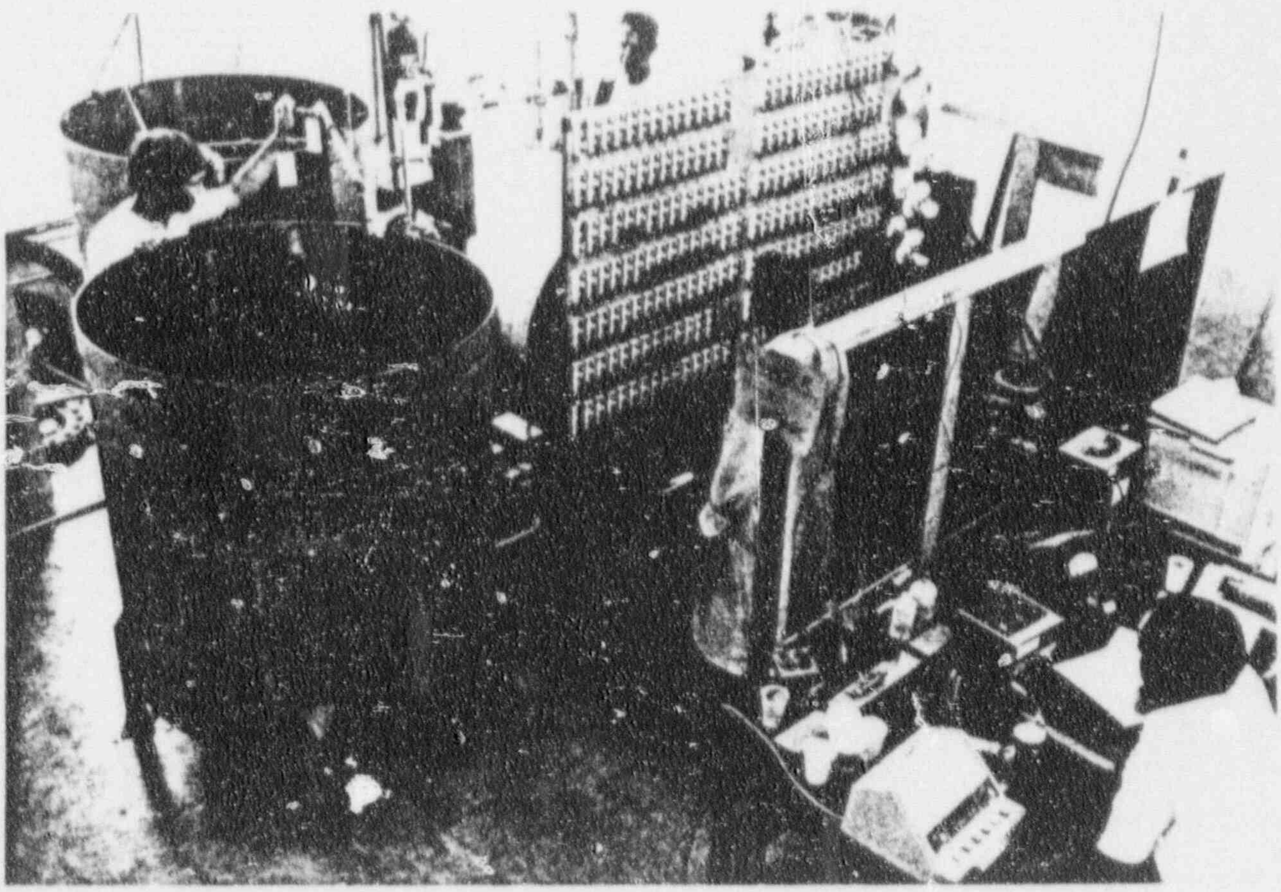
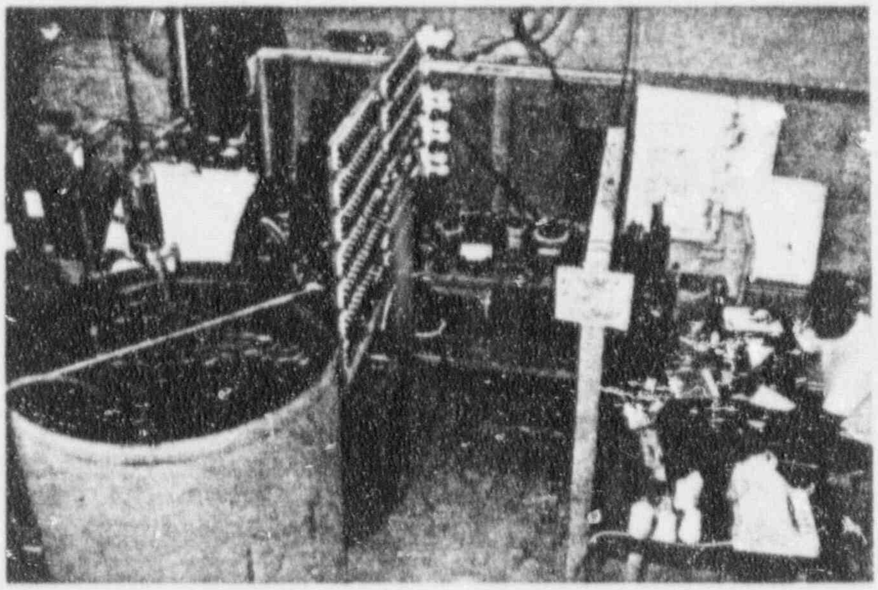
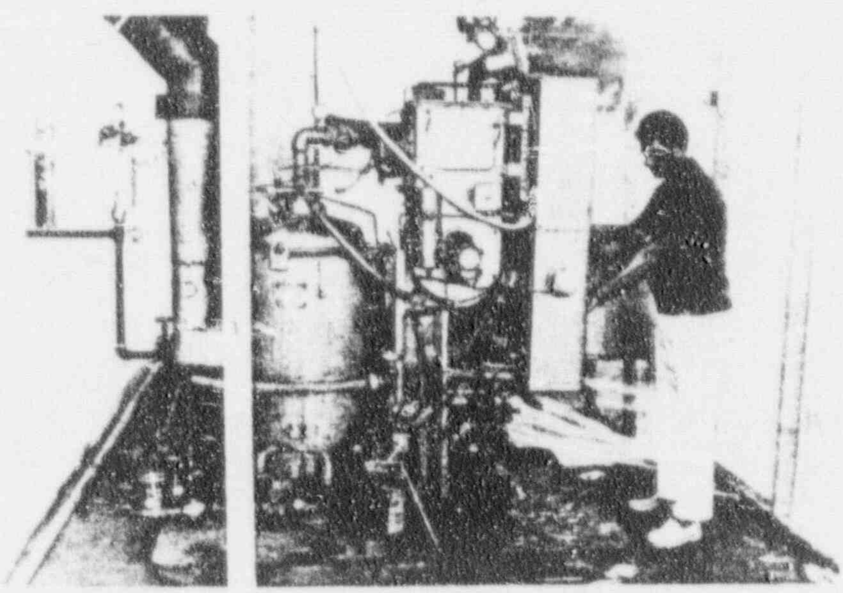


FIGURE 22



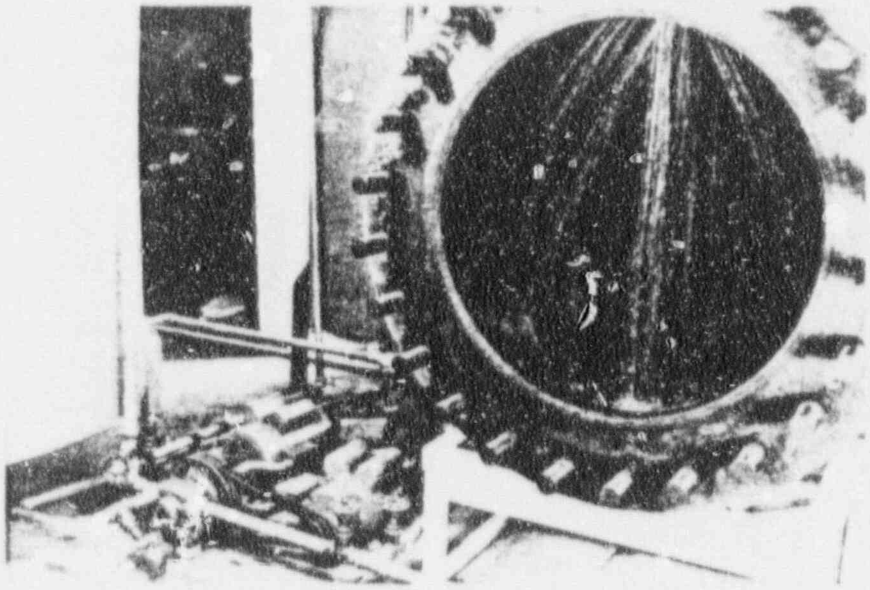
TEST FACILITY DURING PHASE II LOCA



40 BHP STEAM GENERATOR

FIGURE 23

VIEWS OF TEST FACILITY WATER SPRAY SYSTEM



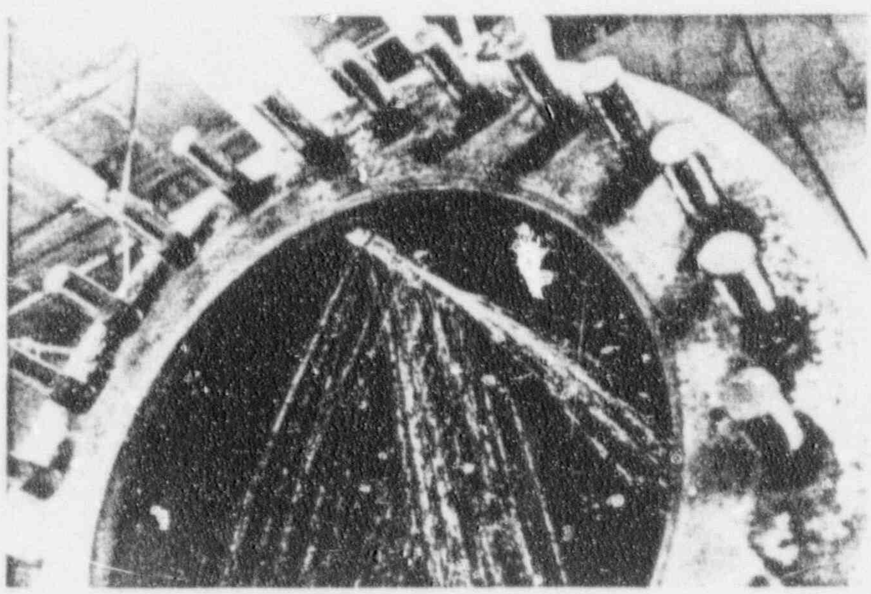
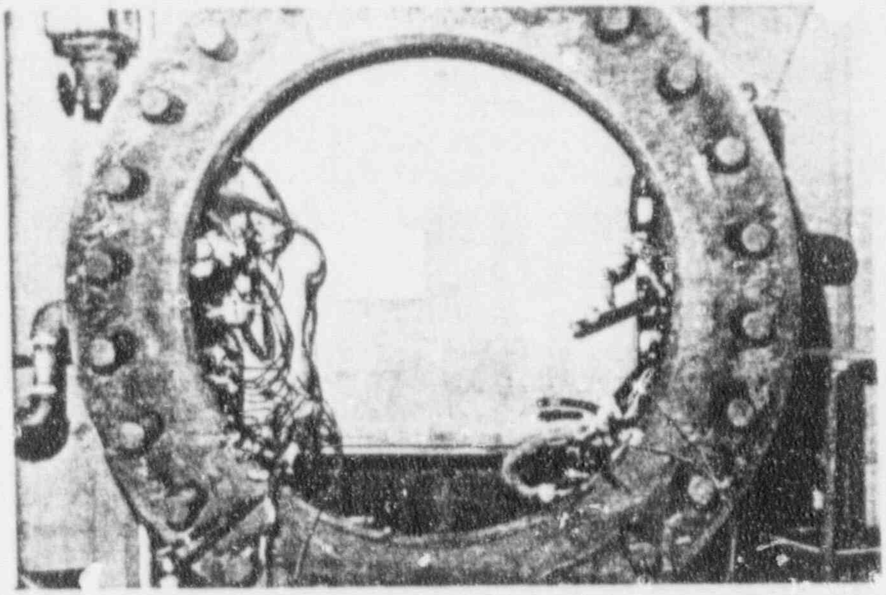
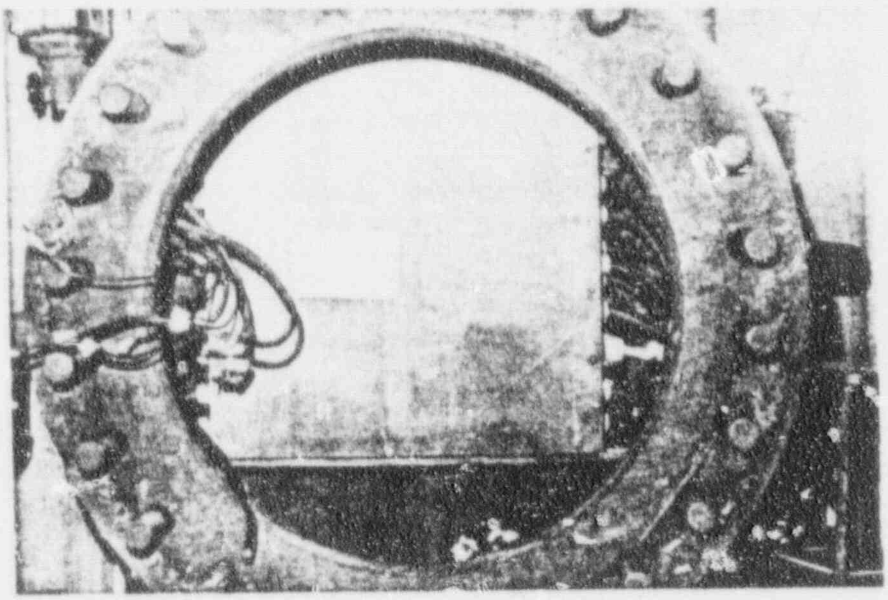


FIGURE 24

ENCLOSURES VIEWED IMMEDIATELY AFTER REMOVAL OF HEADER FLANGE FROM TEST CHAMBER AT COMPLETION OF TEST



ENCLOSURE 1



ENCLOSURE 2

FIGURE 26

VIEWS OF ENCLOSURE 1 IMMEDIATELY AFTER REMOVAL FROM TEST CHAMBER