# ENVIRONMENTAL QUALIFICATION OF OKONITE TAPE SPLICE (T-95/No. 35) UNDER LOCAL SUBMERGENCE FOR POWER AND CONTROL APPLICATIONS

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# Environmental Qualification of Okonite Tape Splice (T-95/No. 35) Under Local Submergence For Power and Control Applications

## 1.0 Summary

This evaluation demonstrates the environmental qualification for Okonite tape splices (T-95/No. 35) for local submergence conditions. Okonite tape splices are used in both In-Line (straight) and "V" type splice applications. The In-Line splices are used in power (4kV, 600VAC/250VDC) and control applications (120VAC/125VDC). The "V" type splices are used in the same applications as the In-Line splices with the exception of 4kV power application. Okonite tape splices are not recommended by Commonwealth Edison for use in EQ related instrument loop applications, and therefore, are not used in instrument circuits. Under certain design basis accident conditions, Okonite tape splices could be exposed to the effects of a steam line break accident, and potentially, be locally submerged inside junction or pull boxes. The environmental qualification of the tape splices to 10CFR50.49 and NUREG-0588 Category I requirements was established by performing the following:

- Determine splice materials o construction and their water absorption/repellency characteristics
- Determine circuit applications where Okonite tape splices are used
- Evaluating splice configuration details based on their physical orientation within electrical boxes and within associated raceway configurations
- Determining the potential failure modes of the splices
- Identifying the worst case postulated environmental conditions, including local submergence, that the splices could experience

Once the as-installed configurations had been determined, these configurations were reviewed and compared to the tested configurations. The as-tested configurations were determined to be representative of the as-installed configurations which would experience postulated accident conditions in both inside and outside containment areas, typically in nuclear stations. Specific details of this evaluation are found in the following sections which support the overall basis for this acceptance.

## 2.0 Okonite Tape Splice Materials of Construction and Their Water Absorption/Repellency Characteristics

### 2.1 Okonite T-95 Insulating Tape

The T-95 high voltage insulating tape is an ethylene-propylene based thermosetting polymer. It is designed as a high voltage, high temperature splicing tape, that is recommended for insulating splices and terminations on high voltage cables that are insulated with ethylene-propylene, butyl, oil base and thermoplastic and cross-linked polyethylene compounds. The insulation tape is similar to a true cable insulation or jacketing compound, formulated and designed for use with electric cable. The insulating tape has a dielectric strength of 600V/mil. The insulating tapes' self-fusing capability (i.e., the ability to self-unite as one homogeneous, void free mass), makes the tape layers mold into a completely solid material, similar to the cables' original insulation and jacket. In this condition, physically there are no layers which can delaminate; there is no adhesive to encourage "oozing," drying-out or unwrapping of the tape. The tape is heat and moisture resistant. The tape has a nominal thickness of 20 mils. In regard to moisture exposure, the tape is essentially non-hydroscopic as evidenced by its negligible gravimetric water absorption guaranteed value of 10 MG/SG.IN. maximum after 7 days @ 70°C (ASTM D-470).

### 2.2 Okonite #35 Jacketing Tape

The Okonite #35 jacketing tape is designed to provide mechanical protection to the T-95 splices for neoprene, plastic and other synthetic rubber-like cable jacket materials for all voltage applications. When wrapped, it fuses into a homogeneous, void free wall that has resistance to weathering elements such as rain, wind, and sun normally found in nature, is resistant to the splashings of moist oils, chemicals and acids and has good electrical properties (i.e., a dielectric strength of 500V/mil.).

## 3.0 Circuit Applications Where Okonite Tape is Used

As previously summarized the tape splices are used in both In-Line and "V" type splice applications. The In-Line splices are used in power (4kV/600VAC/250VDC) and control applications (120VAC/125VDC). The "V" type splices are used in the same applications as the In-Line with the exception of 4kV power. (Accordingly no 4kV power splice connections are contained in junction or pull boxes.) In addition, no Okonite tape splices are used in EQ related instrument loop applications.

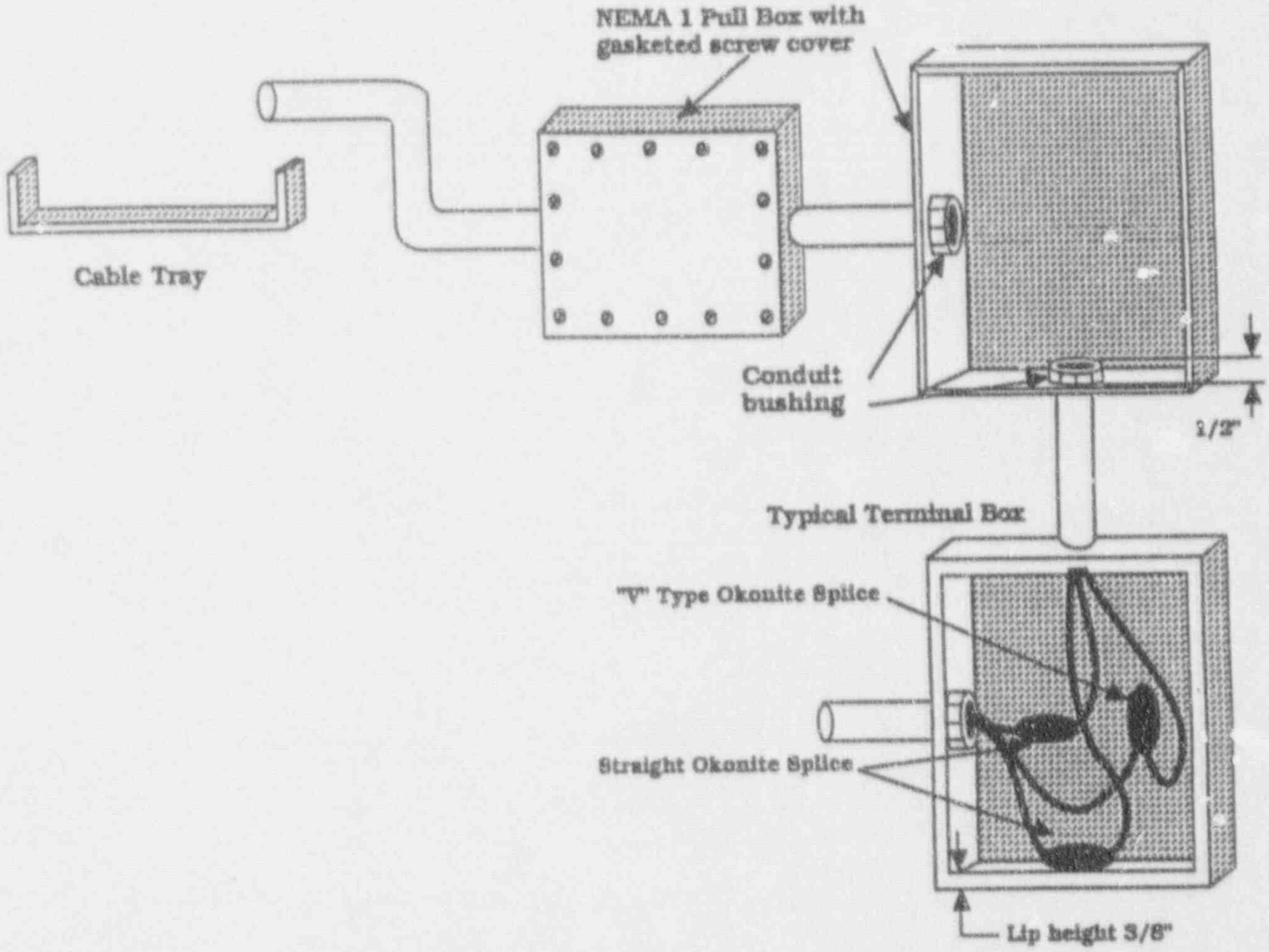



**Figure 1: Electrical Installation Configuration**

## 4.0 Okonite Tape Splice Configurations

Figure 1 depicts the typical electrical installation configurations which utilize Okonite tape splices. The different junction or pull boxes that are used for electrical installations, as shown in Figure 1, are typically gasketed and have a lip. The lip height for the box in Figure 1 is 3/8". By design, the gasket does not provide a sealing function against moisture/steam intrusion. Accordingly, the gasketed cover does not preclude the free exchange of steam/moisture between the inside and outside of the box. Moisture is expected to enter the junction or pull box and accumulate up to but no more than the 3/8" depth. The source of moisture is from condensate originating from a postulated steamline break accident. The quantity of moisture is expected to accumulate from the steam condensation that occurs inside the box and within associated conduits attached to the box, as well as from spray intrusion into the box through the gasketed cover. For boxes which do not have the capability for drainage, the total volume of condensate is limited to the lip height since any excess condensate is expected to flow out through the gasketed cover. As shown in Figure 1, the electrical installation configuration does not allow for the direct funnelling of condensate.

## 5.0 Potential Failure Modes of the Splices

The Okonite tape splices provides a dielectric insulation function between conductor to ground (the metal body of the junction or pull box) and between conductor (phase) to conductor (phase). The splices also maintain circuit continuity. The T-95 tape insulation provides the dielectric insulation and the No. 35 jacketing tape provides the mechanical protection to the T-95 tape insulation. The thickness of the T-95 tape is 20 mils. Therefore the minimum dielectric breakdown that is the minimum voltage threshold value when flashover occurs of the T-95 tape splice (i.e., 600 volts/mil x 20 mils) is at least 12,000 volts. This dielectric capability provides a 2400 percent margin over the worst case 600 volt power and control application which is actually 480 VAC. In addition, since the installation procedures require a minimum two half-lapped layers of Okonite T-95 tape, this results in an installed minimum thickness of 40 mils. Accordingly, this provides an even higher actual value for the dielectric breakdown. Figure 2 shows the worst case configuration of the low voltage (i.e., 600 volts) power and control splice application.

The dielectric leakage that may occur through the insulation is a function of temperature, applied voltage, insulation material and age of the insulation material. Until degradation occurs which would result in a dielectric failure of the insulation material (i.e., T-95 tape), this leakage current will be small (i.e., in the order of 10 mA) which would not affect circuit function since the dielectric insulating capability of the tape is high. The other possible, but unlikely, leakage current is attributed to moisture/condensate

penetrating between the cable insulation and the T-95 tape. This leakage current is attributed to moisture/condensate penetration between the cable insulation and the T-95 tape. This leakage current is possible only when the acceptable splice configuration is deviated from and/or mechanical adhesion of the splicing tape to the cable insulation occurs. This leakage current will be large since the leakage path only depends upon the conductivity of the condensate and the path length between the bare metal inside the splice and the ground plane. In fact this type of leakage will usually result in blowing a fuse which is electrically equivalent to a "short to ground." A properly installed splice would, therefore, not experience this failure.

## 6.0 Postulated Worst Case Line Break Accident

For inside containment applications, the enveloping accident profile (all possible line breaks) including demineralized/chemical spray are postulated. For outside containment applications, the enveloping accident profile for all possible line breaks excluding spray are postulated.

## 7.0 Type Test Results

Appendices A through D of this report describe environmental qualification testing that address the following:

A Environmental Qualification of Okonite (600 V) In-Line and "V" Type Splices and (5kV) for Inside BWR/PWR Containment Applications.

B Environmental Qualification of Okonite 600V Power and Control Splices for Inside BWR Containment Application While Under "Local Submergence."

C Environmental Qualification of Okonite 600V Power and Control Splices for Inside PWR Containment Application While Under "Local Submergence."

D Environmental Qualification of Okonite 600V Power and Control Splices for Outside Containment Applications for both PWR/BWR Stations While Under "Local Submergence."

### 7.1 Summary of Appendix A Test Results

The test results evaluated in Appendix A establish that the Okonite In-Line Splices (600V and 5kV) are environmentally qualified for inside BWR/PWR containment applications. The splices maintained the 80V/mil dielectric test under tap water after having been exposed to a 40-year end-of-life condition and the worst case enveloping BWR/PWR

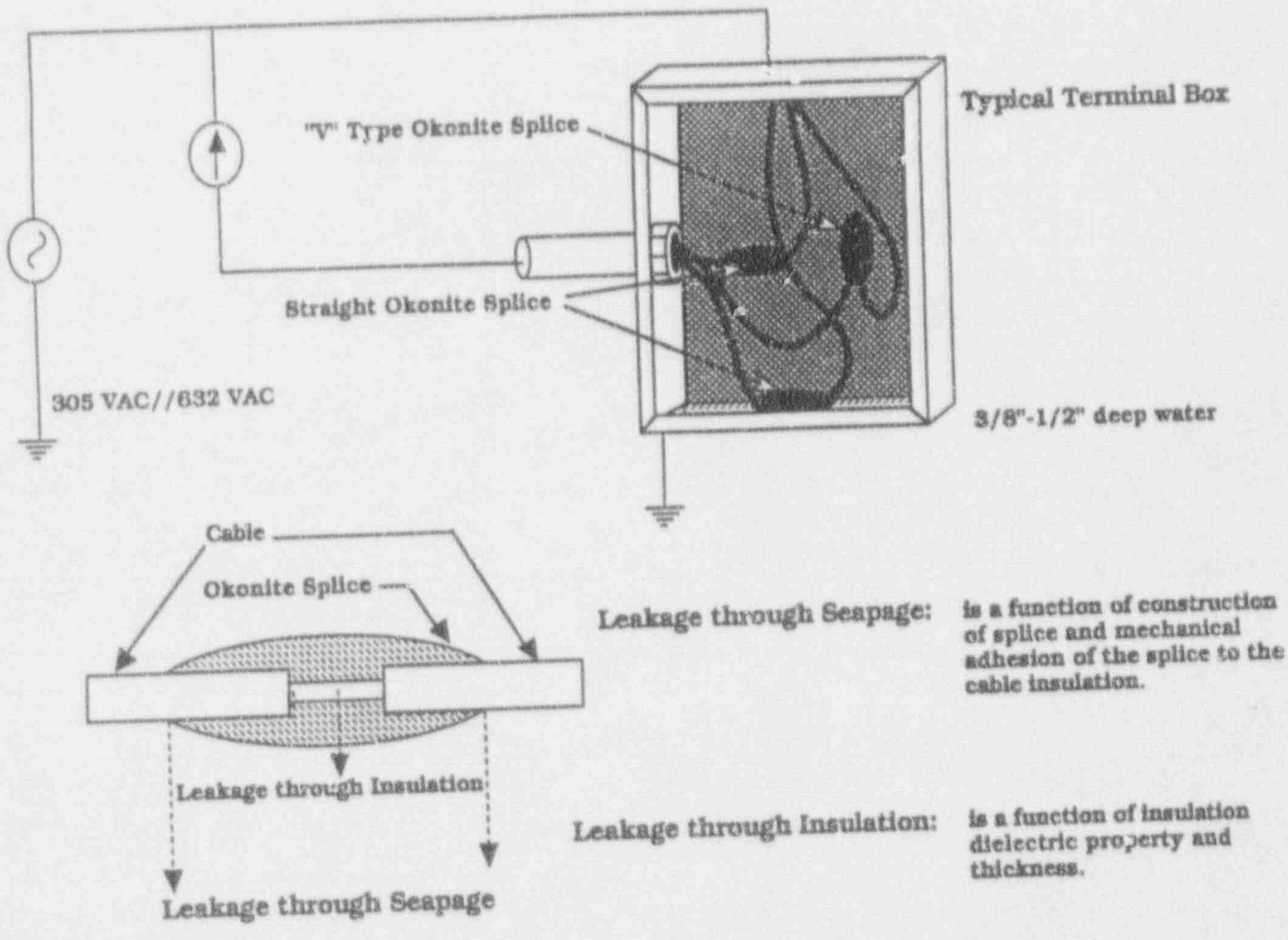



Figure 2: Leakage Path Under Submergence

inside containment accident profile. The dielectric test under tap water established that the electrical circuit integrity of the splice had been maintained. Also the insulation resistance (IR) and dielectric tests performed prior to the accident exposure demonstrates that the Okonite tapes do not degrade their electrical characteristics during the normal 40 years installed life. This test establishes that the T-95/No. 35 splice is a qualified material for the worst case environment postulated at BWR/PWR nuclear plants.

7.2 Summary of Appendix B Test Results

The test results evaluated in Appendix B establish that the Okonite 600V In-Line and "V" type splice are environmentally qualified for inside BWR containment low voltage (600V) power and control applications when the splice maybe physically attached to the bottom surface of the junction box that provides no drainage. The test results demonstrated that the In-Line and "V" type splice have the same electrical performance characteristics although their physical configurations are different (i.e., In-Line type vs "V" type splices). In addition the test configuration in the test vessel allowed direct impingement of demineralized water spray and steam to enter the junction box. During the test, approximately 1/4" of water accumulated inside the junction box resulting in splices being partially submerged. The splices continued to hold the applied voltage (532 VAC and 132 VAC) and current (6.7 amps, 15 amps) with no noticeable leakage current through out the entire DBE exposure.

7.3 Summary of Appendix C Test Results

The test results evaluated in Appendix C establish that both Okonite In-Line and "V" type splice are qualified for inside PWR containment low voltage power and control applications when the specimens maybe physically attached to the bottom of a Limitorque switch compartment that may not have drainage. The test results demonstrate that the In-Line and "V" type splice have the same electrical performance characteristics although their physical configurations are different. The test established that the Okonite T-95 tape will maintain its electrical performance characteristics even without the No. 35 jacketing tape. In addition the tested configuration allowed for the Limitorque switch compartment to be open inside the test vessel which allowed direct impingement of chemical spray and steam to enter the Limitorque switch compartment. During the test approximately 1/2" of water accumulated inside the switch compartment resulting in the splices being partially submerged. The splices continued to hold the applied voltage (632 VAC and 137.5 VDC) with minimal leakage current (i.e., 1.2 mA at 137.5 VDC) throughout the entire DBE exposure.

## 7.4 Summary of Appendix D Test Results

The test results evaluated in Appendix D establish that both the 600V Okonite In-Line and "V" type splice are qualified for BWR/PWR outside containment low voltage power and control applications when the specimens are physically attached to the bottom of the junction box. The test results also demonstrated that the In-Line and "V" type splice have the same electrical performance characteristics although their physical configurations are different. The tested configuration allowed for the conduit run to the junction box to be left open inside the test vessel which allowed direct impingement of steam to enter the junction box. During the test approximately 3/8" of water inside the junction box and the splices were partially submerged holding the applied accumulated voltage (305 VAC) with minimal leakage current (i.e., 19 mA at 305 VAC) throughout the entire DBE exposure.

## 7.5 Overall Type Test Summary

The results from tests performed on different Okonite T-95/No. 35 In-Line and "V" type splices specimens demonstrates that these splices are environmentally qualified for both inside/outside containment application which includes postulated worst case "local submergence" conditions when the splices are in the unlikely condition of being physically attached to the bottom of the junction box for low voltage (600 VAC) power and control applications. This qualification is in compliance with 10CFR50.49, NUREG-0588, Category I and IEEE 323-1974 requirements.

## 8.0 Test Margins

In a postulated steam line break accident, steam is expected to penetrate all unsealed boxes. However, the line break is isolated within minutes, thereby eliminating the constant source of steam. Similarly, the chemical/demineralized water spray is terminated after a few minutes to hours after the postulated accident inside the containment. Therefore, after the steam line break and/or spray has been terminated, the amount of condensate inside the boxes will decrease and subsequently evaporate during the post accident duration.

The tested configurations with the open conduit run inside the test vessel allows for the conservative direct intrusion of steam/spray into the box. This is typically not the case for in-plant configurations since the entire raceway system is closed, with the exception of the cable tray, but it conservatively envelopes the in-plant configurations. As described above, steam was injected continuously during the entire test duration and spray for the specified duration (46 hrs. to 72 hrs.), in compliance with the station required spray durations. Therefore, the constant steam injection to the test vessel, and

as a result, the increased inventory of water, is more conservative with respect to the postulated accident scenario. The test configuration is more conservative than actual conditions which would be experienced during a postulated accident for both inside or outside containment applications.

As previously stated, the amount of condensate inside the boxes is expected to be limited by the lip height, subsequently, any excess volume of condensate exceeding this height does not degrade the qualification of the splices submerged by the condensate. This was indeed experienced in all the tests run for boxes without adequate drainage.

All the tests described in Appendices B, C and D resulted in minimal leakage current (i.e., less than 19 mA at 305 VAC). This amount of leakage current is not sufficient to malfunction a power/control device or "blow" a fuse. The measured leakage current of 19 mA at 305 VAC (Appendix D) is electrically equivalent to 7.8 mA at 125 VDC. This leakage current is less than 10% of load current of typical control devices. Therefore, this leakage current will not be capable of malfunctioning control devices. As described earlier in Section 5.0, the leakage due to lack of mechanical bonding between the cable insulation and the T-95 tape is not expected to occur to result in a short circuit. Therefore, the leakage under "local submergence" for the Okonite low voltage splice would occur through the insulation (i.e., T-95) tape and not due to lack of mechanical bonding between the cable insulation and the T-95 tape. The splices were partially submerged due to the quantity of water trapped inside the box which was limited by the lip height. This is representative of that which would be fully submerged. The electrical circuit integrity continues to be maintained because in either case, the splices do not degrade their mechanical bonding capability. This is due to the fact that all the partially submerged specimens maintained their circuit integrity which is representative of a fully submerged condition. Considering the sample size (more than 20 test samples), if there was a mechanical bonding problem, if would have been identified. Since the tape is uniformly applied, the mechanical bonding characteristics would not behave differently irrespective of mechanical bonding occuring above or below the level of submergence.

## 9.0 Conclusion

As discussed in Section 8.0, the leakage under "local submergence" for the low voltage power and control splices is due to the dielectric insulation property of the T-95 tape and the dielectric insulation property is acceptable. As shown in Section 7.0 and 8.0, the tested accident profile is more severe than the postulated DBE profiles in the BWR/PWR nuclear plants, and is therefore, enveloping the DBE conditions. In Appendices B, C and D, environmental qualification of low voltage power and control splices under "local submergence" is demonstrated. Therefore, the low voltage power and control Okonite tape splices are environmentally qualified under "local submergence" due to a postulated

line break per 10CFR50.49, NUREG-0588, Category I, and IEEE 323-1974 requirements.

# Appendix A

## A.0 Environmental Qualification of Okonite In-Line and "V" Type Splices (600 V) and In-Line Splice (5kV) for Inside BWR/PWR Containment Application

## A.1 Purpose

The purpose of this section is to summarize the environmental qualification of Okonite EPR insulated In-line and "V" type splice assemblies consisting of Okonite T-95 insulating tape, No. 35 jacket tape and T-95 nuclear grade cement for 600 V power and control and 5kV power applications, to perform their intended safety-related functions during the normal service and DBE/Post-DBE conditions in accordance with 10 CFR 50.49, NUREG-0588 Category I, IEEE 323-1974, and IEEE 383-1974 requirements.

## A.2 References

A.2.1 Okonite Engineering Report 407, "LOCA Qualification of 600 Volt Splices," Rev. None, dated 01-21-85

A.2.2 Okonite Report NQRN-3, "Nuclear Environmental Qualification Report for Okoguard Insulated Cables and T-95 and No. 35 Splicing Tapes," Rev. 04, dated 10-24-88

A.2.3 Okonite Splicing Instructions/Drawings

A.2.4 Okonite Company Form G-3, "Qualification of Okoguard Ethylene Propylene Rubber Insulation for Nuclear Plant Service," dated 06-28-79

## A.3 Specimen Tested

A.3.1 Okonite 660 V In-Line Splices

The test specimens used in the qualification test of Okonite 600 volt In-Line splices were configured as described below (Ref. A.2.1, Para, 1.4.1.1, Page 1):

| | |
|---|---|
| Four 7 ft. samples: | 2 non-aged, 2 thermally aged (Drawing D11845, Ref. A.2.1) |
| Cable Description - | 2kV A/C #6 7X AC, insulated with extruded 0.055: Okonite (EPR) and 0.030" Okolon (CSPE), 90°C rated conductor temperature with 130°C overload rating. |

Splice - In-Line (straight) splice utilizing Okonite T-95 and No. 35 tape and T-95 cement constructed per Okonite Instruction in Appendix 1, Reference A.2.1.

This configuration used a 2kV rated cable. However, the splices made are 600V splices. Therefore, all thicknesses are based on 600 V cable (see Page 2 of Ref. A.2.1).

A.3.2 Okonite 5kV In-Line Splices

The test specimens used in the qualification test of Okonite 5kV In-Line splices were configured as described below (Ref. A.2.2, Para. 1.4.1.1, Page 3):

Two 15 ft. cable samples: one non-aged, one thermally aged

Cable Description - 5kV, #6, 7X BC, extruded semicon, 0.090" Okoguard extruded semicon, 0.005" x 1" BC shielding tape, 12 1/2% lap, no jacket.

Splice - In-Line (straight) splice using T-95 and No. 35 tapes and T-95 cement constructed as shown in Appendix 1 of Reference A.2.2, Drawing 11489 with the following exceptions:

Test Configuration Conditions:

- The specimen cable had no jacket. However, jacketing tape No. 35 was applied over the splice.
- Grounding straps and tinned copper perforated strips were not used.
- A compression connector was used in lieu of a solder connection.

## A.4 Similarity Analysis

The subject Okonite In-line splices are installed in various Class 1E low voltage power and control, and medium voltage power circuits. The splices tested in References A.2.1 and A.2.2 were single conductor In-line splices suitable for Okonite/Okoguard (EPR) insulated and Okolon jacketed cables. Per Reference A.2.3, multi-conductor splice configuration utilizes the identical Okonite T-95 insulating and No. 35 jacketing tapes and T-95 cement which were tested in References A.2.1 and A.2.2 qualification reports. It should be noted that Okonite utilizes the same tapes for both 600V power and control and 5kV power applications (see Page 2 of Reference A.2.4). Also multi-conductor splices have an additional layer of protective splicing tape applied over the entire splices which provides even greater protection the against external environment. Therefore, qualification applies to both single and multi conductor In-line splices constructed using Okonite instruction/drawings. The "V" type splices for low voltage power (600 VAC/250 VDC) and control (125 VDC, 120 VAC) use the same material except that the splice is a back-to-back bolted connection. Therefore, qualification of these splices are established by the qualification of In-line 600V splices. Qualification for the configuration of "V" type splice is established in Appendix B.

## A.5 Splice Qualified

a. Okonite Company Drawing 11485, Rev. 1, Instructions for straight splice for 600 V single conductor Okonite insulated, Okolon jacketed, non-shielded nuclear station cable.

b. Okonite Company Drawing 11492, Rev. B, Drawing for straight splice for 600 V multi-conductor Okonite insulated, Okolon jacket and overall Okolon jacket, nuclear station cable.

c. Okonite Company Drawing 11489, Rev. B, Drawing for straight splice for single conductor 5kV Okoguard insulated, Okolon jacketed, shielded nuclear station cable.

d. Okonite Company Drawing 11559, Rev. A, Instructions for straight splice for 5kV, multi-conductor Okonite insulated, Okolon jacket nuclear station cable.

## A.6 Failure Mode Analysis

| Item | Construction | Activation Energy | | | Safety Function | Failure Mode |
|---|---|---|---|---|---|---|
| | | Value (eV) | Ref. | Basis | | |
| Insulating Tape | Okonite T-95<br><br>[EPR Based Thermosetting Compound] | 1.089 | A.2.1<br>A.2.2 | Retention of Elongation | Provide Electrical Insulation and Environ-mental Seal Necessary to Protect Circuit Integrity | Insulation that Causes a Loss of Circuit Integrity |
| Jacketing Tape | Okonite No. 35<br><br>[Neoprene] | | | | * | |
| Adhesive | Okonite T-95 Cement | | | | ** | |

* Jacketing tape No. 35 is used for mechanical protection and provides fire retardant properties. This tape is not used to provide insulation and hence, no credit is given for environmental qualification.

** The cement used in the splice is also an EPR compound in adhesive form. Once the cement is dry, both tape and cement have the same chemical structure and are rated for continuous service of 90°C. Therefore, the safety function and failure mode are the same for both the cement and the T-95 insulating tape.

## A.7 Test Sequence

The subject Okonite 600 V and 5kV In-line splices were type tested in accordance with the test sequence of IEEE 323-1974 and IEEE 383-1974 (Para. 1.4.1.5, Page 3, Ref. A.2.1, and Para. 1.4.1.5, Pages 4 and 5, Ref A.2.2). Additional electrical and mechanical tests in excess of the requirements of IEEE 323-1974 and/or IEEE 383-1974 were also performed.

### Thermal Aging and Qualified Life Evaluation

Component aging is based on the organic materials used in the construction of the Okonite In-line splices. Thermal aging follows an Arrhenius relationship of the form:

$$t_{ser} = t_{age} \exp\left[\frac{\phi}{k}\left(\frac{1}{T_{ser}} - \frac{1}{T_{age}}\right)\right]$$

Where:

$t_{age}$ = Duration of aging in hours

$t_{ser}$ = Duration of service in hours (i.e., qualified life)

$T_{age}$ = Aging temperature (°K)

$T_{ser}$ = Service temperature (°K)

k = Boltzmann's Constant ($8.617 \times 10^{-5}$ eV/°K)

$\phi$ = Activation energy (eV)

The tested In-line splice configurations (600 V and 5kV) utilize Okonite T-95 tape as the primary insulation. Therefore, it is the limiting factor for splice degradation. Okonite No. 35 jacketing tape is used only for mechanical protection and is not included as the basis for qualification. The T-95 insulating tape is an EPR based material. The EPR base in T-95 tape is similar to the EPR in the other Okonite insulations which are thermoset materials (i.e., cable insulation), thereby aging characteristics are expected to be essentially the same. Based on this similarity, the activation energy of T-95 tape is 1.089eV.

Using the Arrhenius equation, the qualified life of the Okonite T-95 splicing tape is determined by utilizing the above calculated activation energy, the test specimen thermal aging data, and the maximum normal ambient temperature of any nuclear station.

Per References A.2.1 and A.2.2 (Paragraph 1.4.1.5), the test specimens were

thermally aged for 3 weeks (504 hours) at 150°C temperature.

Substituting into the Arrhenius equation yields the following qualified life:

$$t_{ser} = 504 \exp\left[\frac{1.089}{8.617 \times 10^{-5}}\left(\frac{1}{346.88} - \frac{1}{423}\right)\right]$$

$$= 354604.13\ hours\ @\ 165°F\ (346.88°K)$$

$$= 40.45\ years\ @\ 165°F\ (346.88°K)$$

At 165°F (73.88°C), the thermal aging as shown above, results in an equivalent qualified life of at least 40 years. However, the subject Okonite splices require qualification at 90°C conductor temperature which includes heat rise. Appendix 2 of References A.2.1 and A.2.2, demonstrates the qualification of Okonite EPR insulation at 90°C conductor temperature for a qualified life of 40 years.

## A.8 Radiation Aging

The test specimens (600 V and 5kV In-line splices) were irradiated in a Cobalt-60 field of gamma radiation to a minimum total integrated dost (TID) of 2.00 x $10^8$ rads at a dose rate of less than 1 x $10^6$ rads/hour (Appendix 4, Ref. A.2.1 and Appendix 3, Ref. A.2.2). This dose rate meets IEEE 383-1974, Section 2.3.3.3 requirement.

The TID requirement for CECo's PWR and BWR plants for 40 years normal and 1 year accident operation is 2 x $10^8$ rads of gamma radiation, which includes the margin as required by IEEE 323-1974.

Therefore, the radiation test parameters envelop the TID requirement for all six CECo stations.

## A.9 DBE (LOCA Exposure) Evaluation

**Test LOCA Profile (600 V In-line Splices)**

| | | | | | | |
|---|---|---|---|---|---|---|
| Temperature (°F) | : | 346 | 335 | 315 | 265 | 212 |
| Duration | : | 3 hrs. | 3 hrs. | 4 hrs. | 81 hrs. | 3,024 hrs. |
| Pressure (psig) | : | 116 | 101 | 76 | 26 | 0 |
| Rel. Humidity (%) | : | Steam | Steam | Steam | Steam/100% | Steam/100% |

The initial peak of 346°F for 3 hours provides additional margin to the postulated DBE profile. The test parameters shown above are actual test data per Appendix 3 of

Reference A.2.1. This test profile and chemical spray envelops the worst case postulated DBE for inside containment application.

**Test LOCA Profile (5kV In-Line Splices)**

| | | | | | | |
|---|---|---|---|---|---|---|
| Temperature (°F) | : | 335 | 335 | 316 | 265 | 212 |
| Duration | : | 3 hrs. | 3 hrs. | 4 hrs. | 82 hrs. | 3,021 hrs. |
| Pressure (psig) | : | 114 | 101 | 74 | 26 | 0-2 |
| Rel. Humidity (%) | : | 100 | 100 | 100 | 100 | 100 |

The initial peak of 345°F for 3 hours is used as additional margin. The test parameters shown above are actual test data per Reference A.2.2, Figure 1 of Appendix 4. This test profile and chemical spray envelops the worst case postulated DBE for all CECo stations inside containment application.

## A.10 Electrical Integrity

Per Paragraph 1.4.2.4 (Ref. A.2.1 and Ref. A.2.2), throughout the LOCA exposure the Okonite In-line splice specimens were energized with their respective rated voltage of 600 V and 5kV and loaded with 80 amps initially. As the temperature changed, the current was re-adjusted to maintain 80 amps. Insulation resistance measurements were performed periodically. All samples passed tests as described in Paragraph 1.4.3 of Reference A.2.1 and Reference A.2.2. All samples maintained the electrical load throughout the entire profile.

## A.12 Performance Test/Acceptance Criteria

The acceptance criteria for the subject Okonite In-line splices is that they must be able to maintain the rated load throughout the entire LOCA profile, and must withstand a post-LOCA voltage withstand test as outlined in Section 2.4.4 of IEEE 383-1974.

## A.13 High Voltage Withstand Test (Hi-Pot.)

At the conclusion of 30-day and 130-day post-LOCA simulation, the test specimens (i.e., cables including splicing tapes) were straightened and wound around a mandrel at 40 times of cable diameter, and immersed in water. The test specimens passed the high voltage withstand test for 5 minutes at 80 VAC/mil, while immersed in the water per IEEE 383-1974, Section 2.4.4 [Para. 1.4.1.6 (b), Ref. A.2.1 and A.2.2].

## A.14 Conclusion

Based on the test results and the evaluation presented above, it is concluded that the Okonite In-line splice tapes are environmentally qualified for power (4kV, 600 VAC, 250 VDC) and control (120 VAC, 125 VDC) and "V" type splices are qualified for power (600 VAC, 250 VDC) and control (120 VAC, 125 VDC) application for all nuclear stations.

# Appendix B

## B.0 Environmental Qualification of Okonite 600V Power and Control Splices Inside BWR Containment While Under "Local Submergence"

## B.1 Purpose

The purpose of this section is to establish environmental qualification of Okonite In-line and "V" type splice (consisting of Okonite T-95 insulating tape and No. 35 jacketing tape) under "local submergence" for inside BWR containment low voltage power (600 VAC, 250 VDC) and control (120 VAC/ 125 VDC) circuit applications.

## B.2 References

B.2.1 Cable Termination, CECo Instruction No. WI-500, Rev. 10

B.2.2 Wyle Test Report #17856-2, "Environmental Qualification of Okonite Taped 'V' Splices," dated 09-09-86

B.2.3 Wyle Test Report #17856-3, "Environmental Qualification of Okonite Taped 'V' Splices, Phases 2, " dated 09-12-86

## B.3 Splice Configurations

Each specimen consisted of two individual wires, each approximately 10"-15" long, spliced with various types of crimped ring-torque terminals bolted together back to back. The test specimens were assembled using various configurations of Okonite tapes applied over the splices:

1. Specimens 1A, 1B, 1C, 7A, 7B, and 7C (Zero overlap), Figure B.1

    a. One length each of Okonite #14 AWG and Thermofit wire were used for these splices.

    b. Okonite Nuclear Splicing Cement was applied to areas of the splices which are to be taped.

    c. Two half-lapped layers of Okonite T-95 tape were applied, starting the wrap just past the edge of the lug touching the conductor insulation, proceeding over the bolted splice and returning to the starting point of the wrap.

    d. Two half-lapped layers of Okonite No. 35 jacketing tape were applied over the T-95 tape, starting at point ½" past the end of the splicing lug over the conductor insulation, proceeding over the splices and returning to the starting point of the wrap.

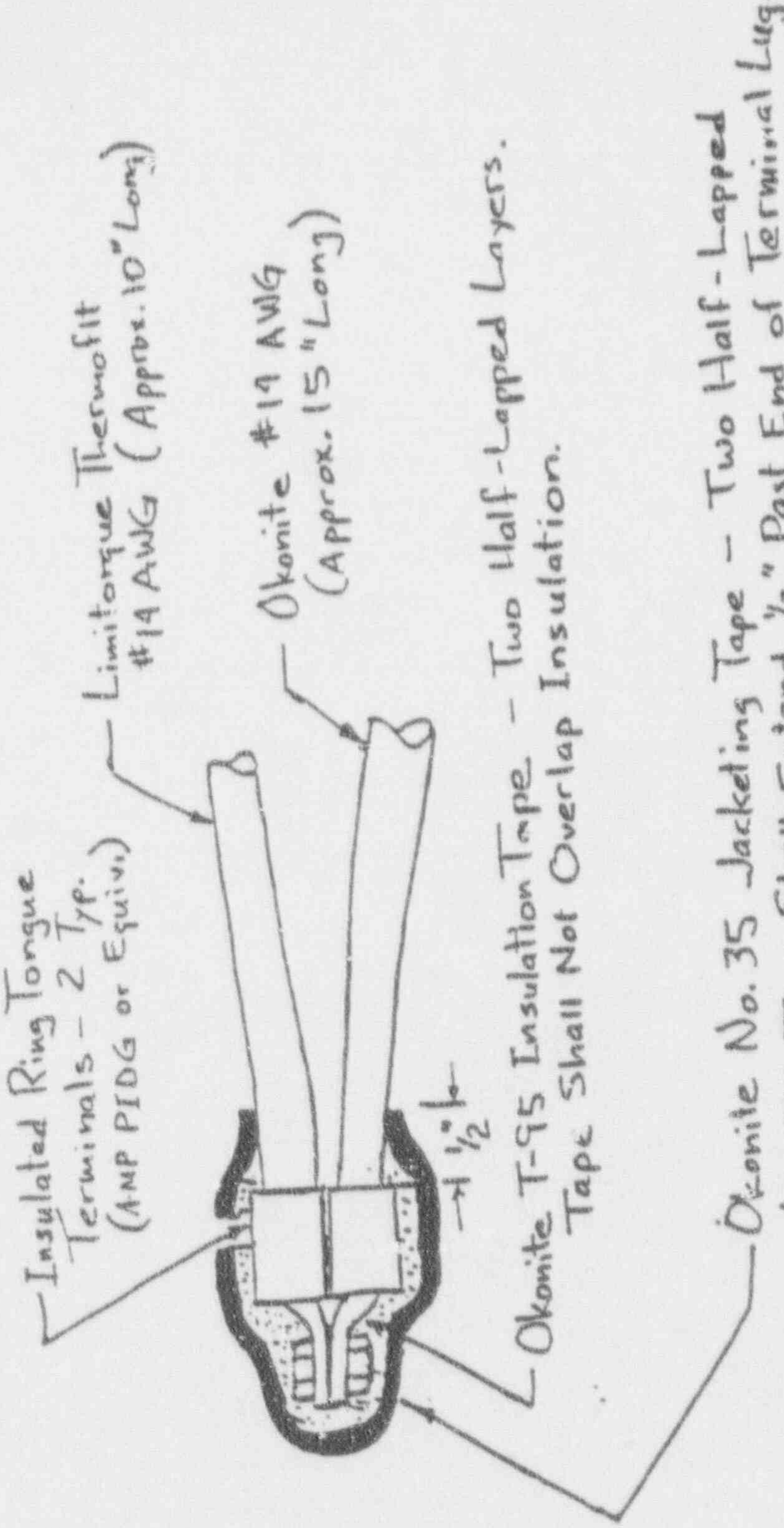



Figure B.1: Specimens 1A, 1B, 1C, 7A, 7B, 7C

e. The splices was constructed accordance with Reference B.2.1 procedure.

2. Specimens 2A, 2B, 2C, 8A, 8B, and 8C (¼" overlap), Figure B.2

a. Steps 1a. and 1b. were repeated.

b. Two half-lapped layers of Okonite T-95 tape, starting the wrap ¼" past the end of the lug, proceeding over the bolted splice and returning to the starting point of the wrap.

c. Steps 1d. and 1e. were repeated.

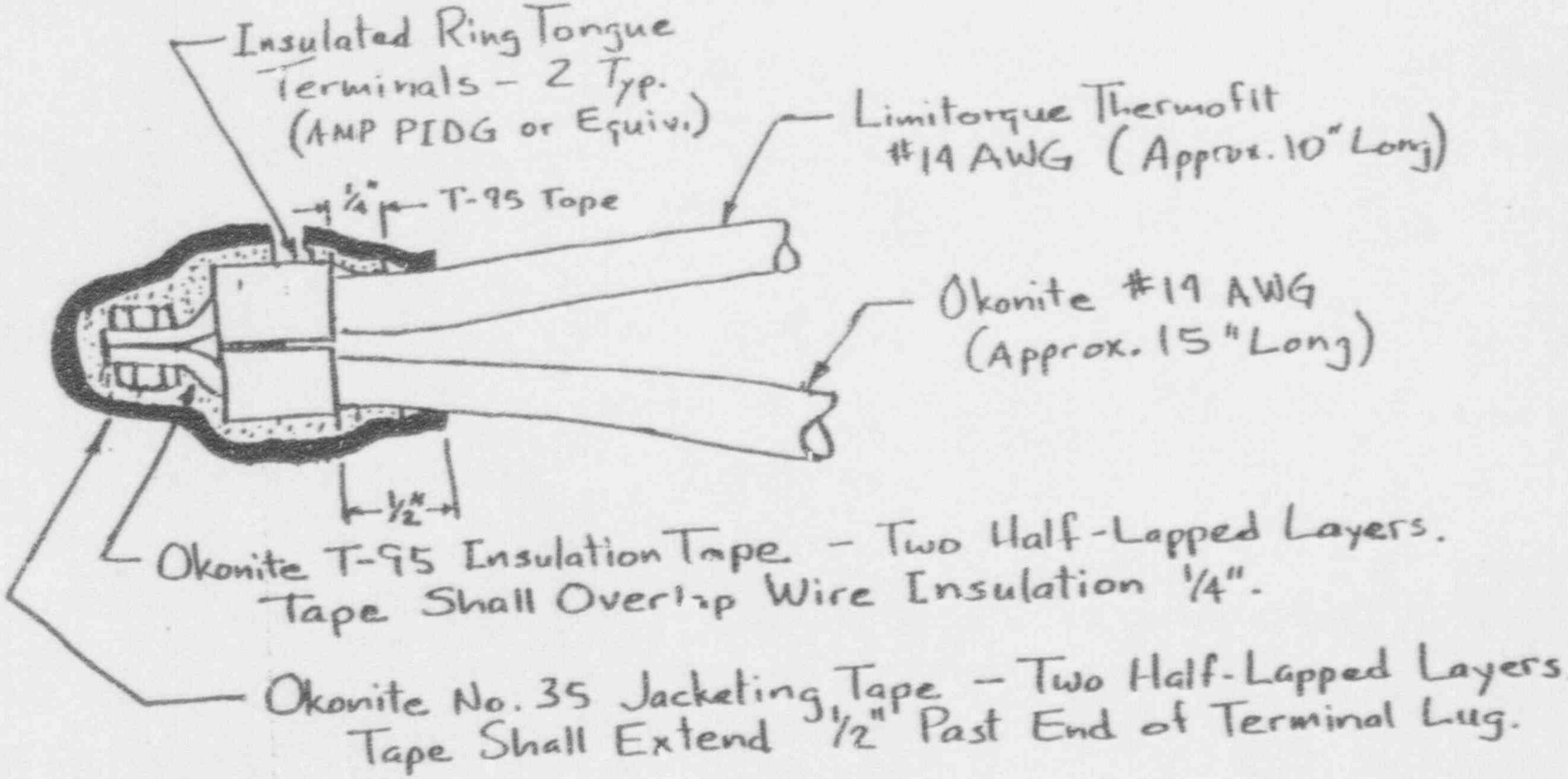



Figure B.2: Specimens 2A, 2B, 2C, 8A, 8B, 8C

3. Specimens 3A, 3B, and 3C (½" overlap), Figure B.3

   a. Two lengths of Okonite #2 AWG wire were used for these splices.

   b. Step 1b. was repeated.

   c. Single layer of Okonite T-95 tape was applied starting ½" past the lug and proceeding to the splice. Additional layers were applied over the bolt connection for softening.

   d. Steps 1d. and 1e. were repeated.

4. Specimens 4A, 4B, and 4C (3/4" overlap), Figure B.4

   a. Steps 1a. and 1b. were repeated.

   b. Step 3c was repeated, except start the wrap 3/4" past the end of the splicing lug instead of ½" past the end.

   c. Steps 1a. and 1b. were repeated.

5. Specimens 5A, 5B, and 5C (0" overlap), Figure B.5

   a. Two lengths of Okonite #14 AWG wire were used for these specimens.

   b. Step 1b. through 1e. were repeated.

6. Specimens 6A, 6B, and 6C (¼" overlap), Figure B.6

   a. Step 5a. was repeated.

   b. Step 1b. was repeated.

   c. Step 2b. was repeated.

   d. Steps 1d. and 1e. were repeated.

These specimens were prepared using the same construction as that of the "V" splices installed at LaSalle County Station (LSCS).

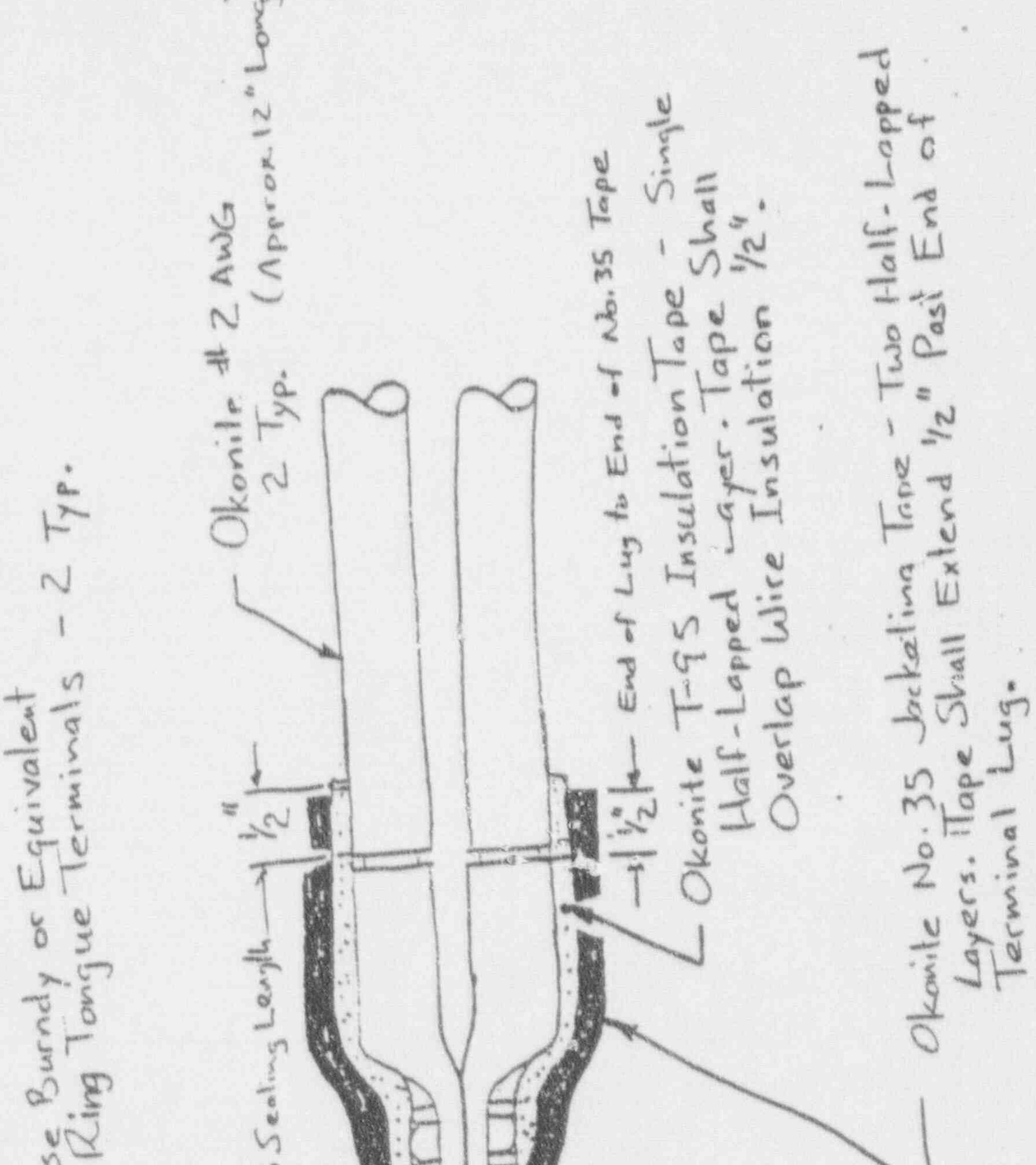



Figure B.3: Specimens 3A, 3B, 3C

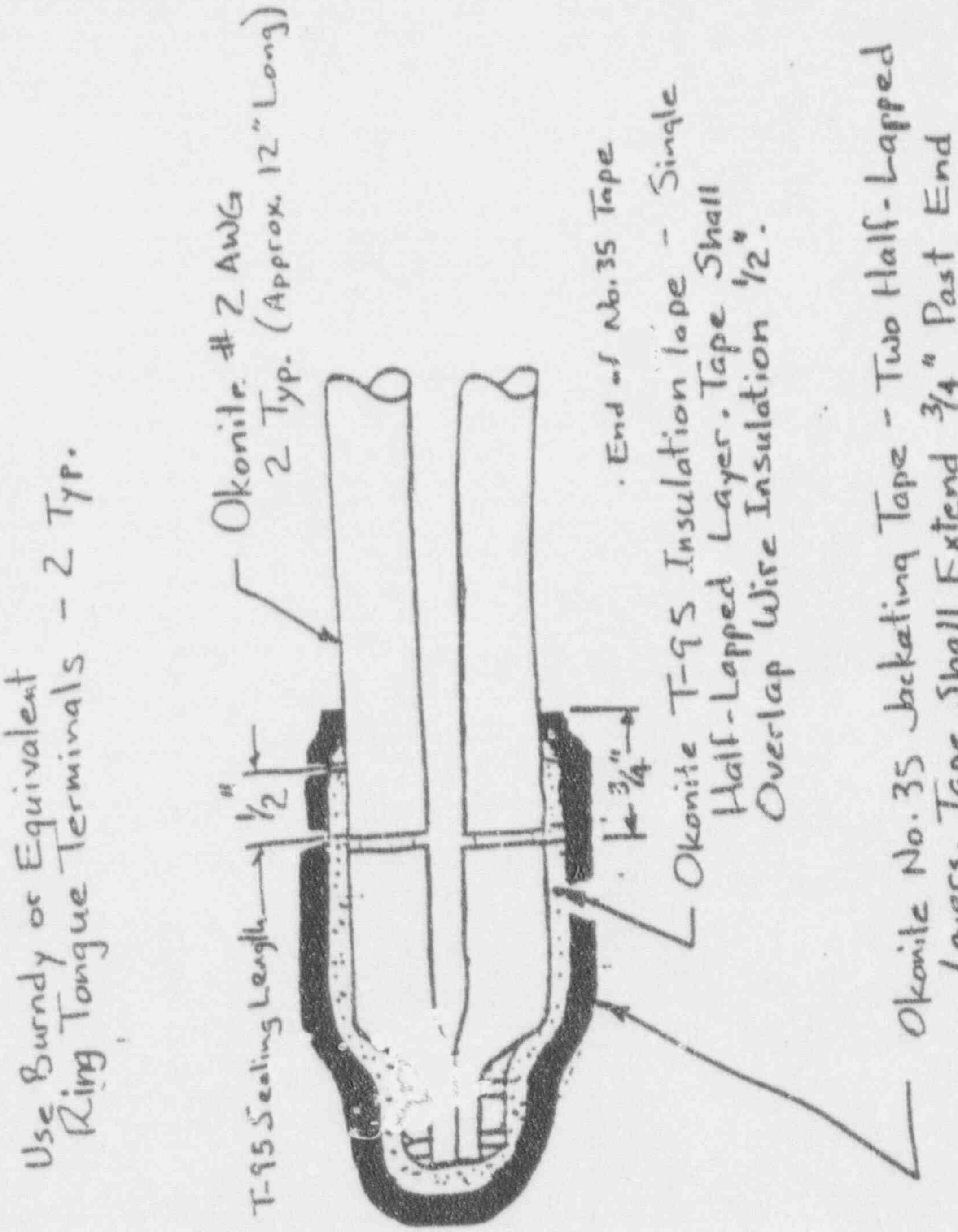



Figure B.4: Specimens 4A, 4B, 4C

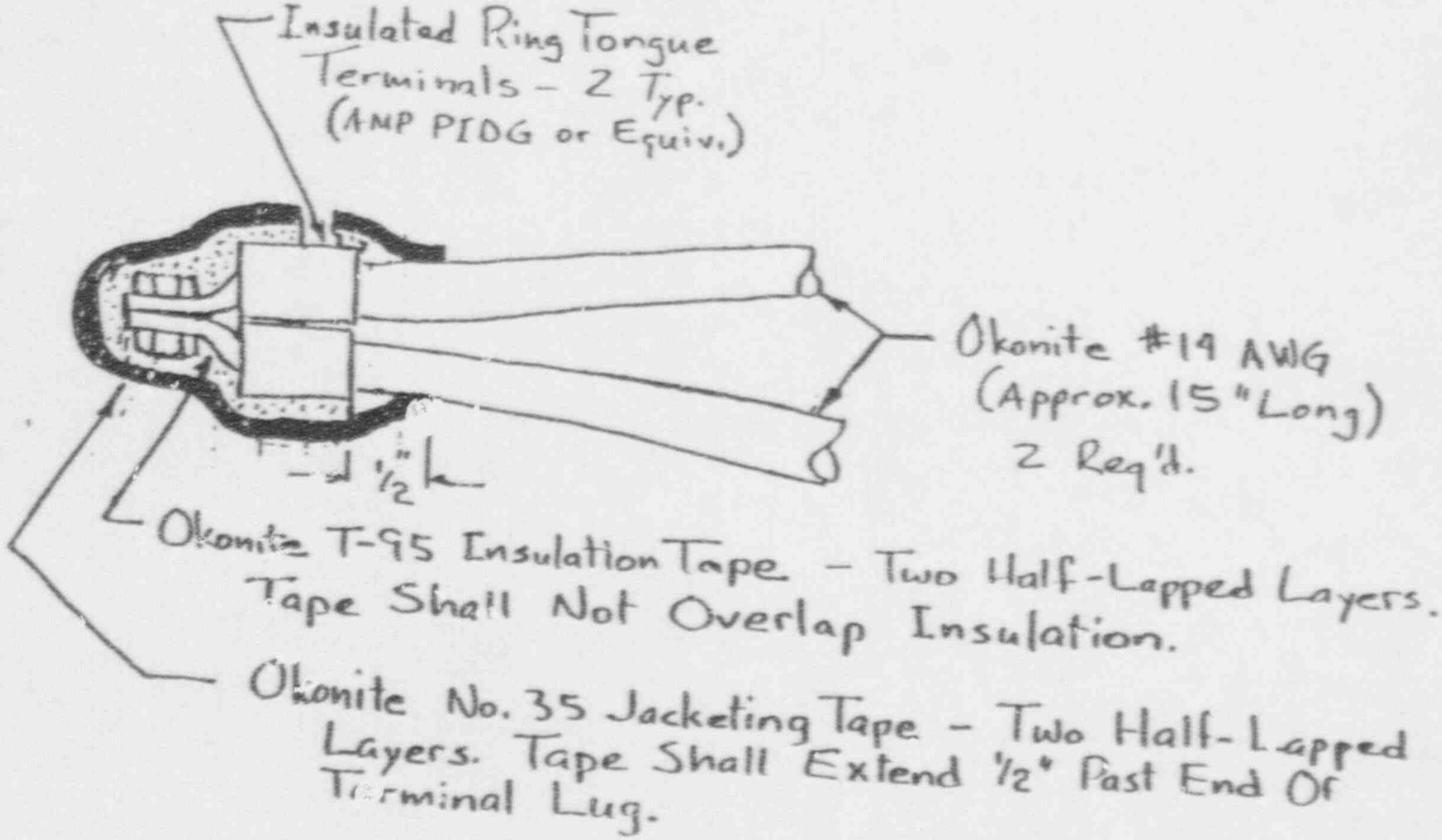



Figure B.5: Specimens 5A, 5B, 5C

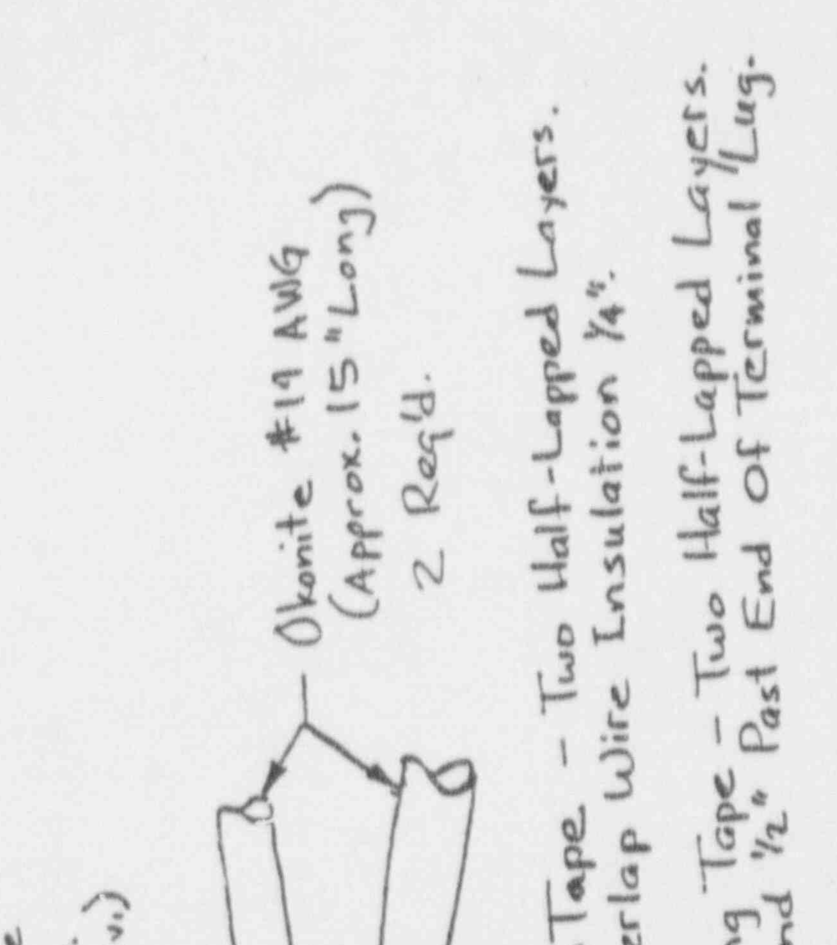



Figure B.6: Specimens 6A, 6B, 6C

## B.4 Test Sequence

The LOCA test was performed in two phases. All specimens listed above went through the first phase of testing. In addition, specimens 4A, 4B, 5C, 6A, 6B, and 6C went through the second phase of testing.

a. First Phase Sequence (Reference B.2.2)

- Inspection and specimen preparation
- Functional test
- Accident simulation (24 hours)
- Functional test
- Post-test inspection

b. Second Phase Sequence (Reference B.2.3)

- Inspection
- Functional test
- Accident simulation (72 hours)
- Functional test
- Post-test inspection

## B.5 Mounting and Orientation of Specimens

a. The specimens were mounted in two NEMA 12 enclosures. Specimens 1A, B, C through 6A, B, C were mounted in enclosure #1. Specimens 7A, B, C and 8A, B, C were mounted in enclosure #2. The difference between these two enclosures is that enclosure #2 had a ¼" weep hole in its bottom (Figure B.7). The specimens locations inside the enclosures were as follows (Photographs B.1 and B.2):

- The 'A' specimens located at bottoms of enclosures.
- The 'B' specimens located at sides of enclosures.
- The 'C' specimens suspended at random inside of enclosures.

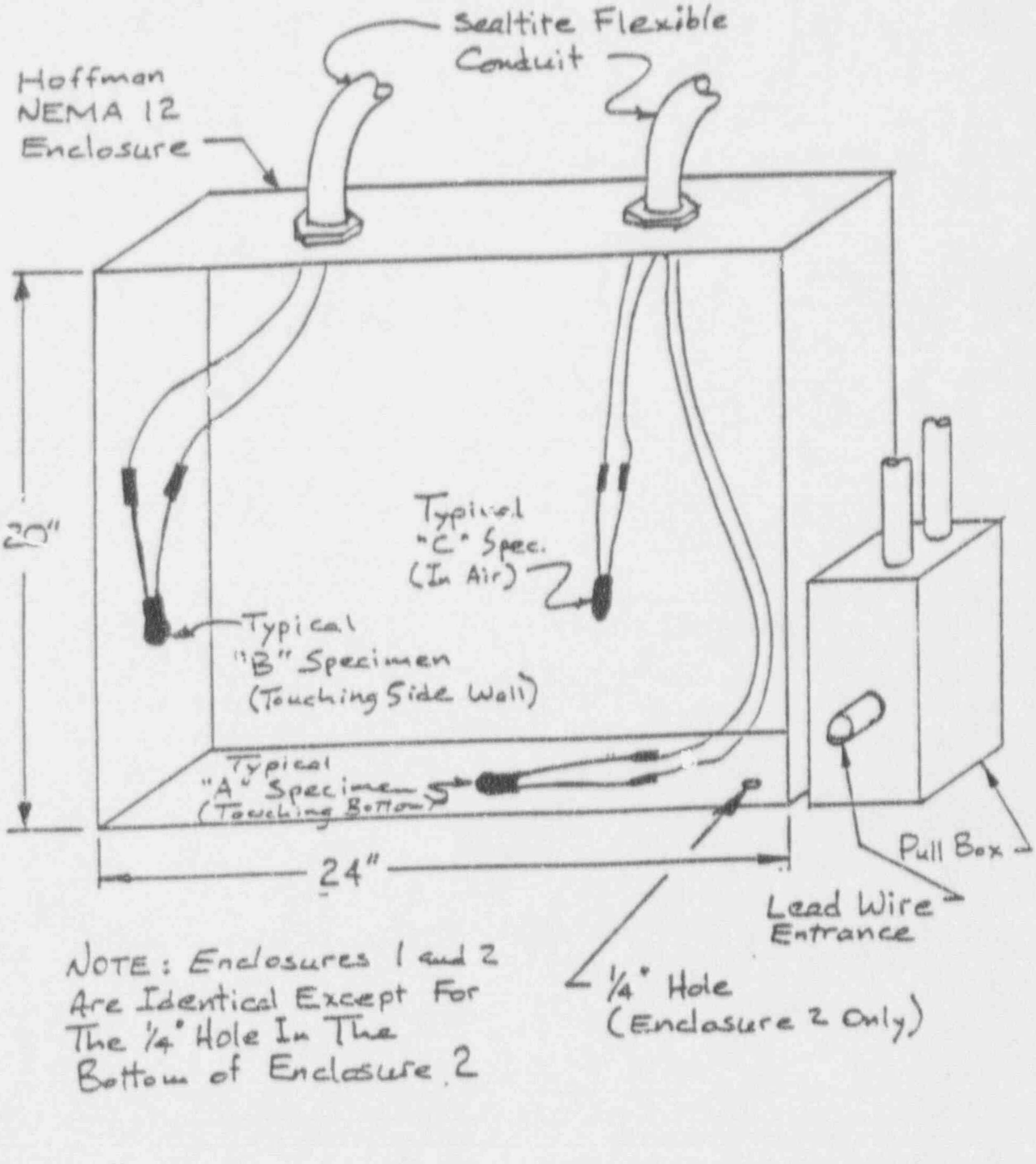
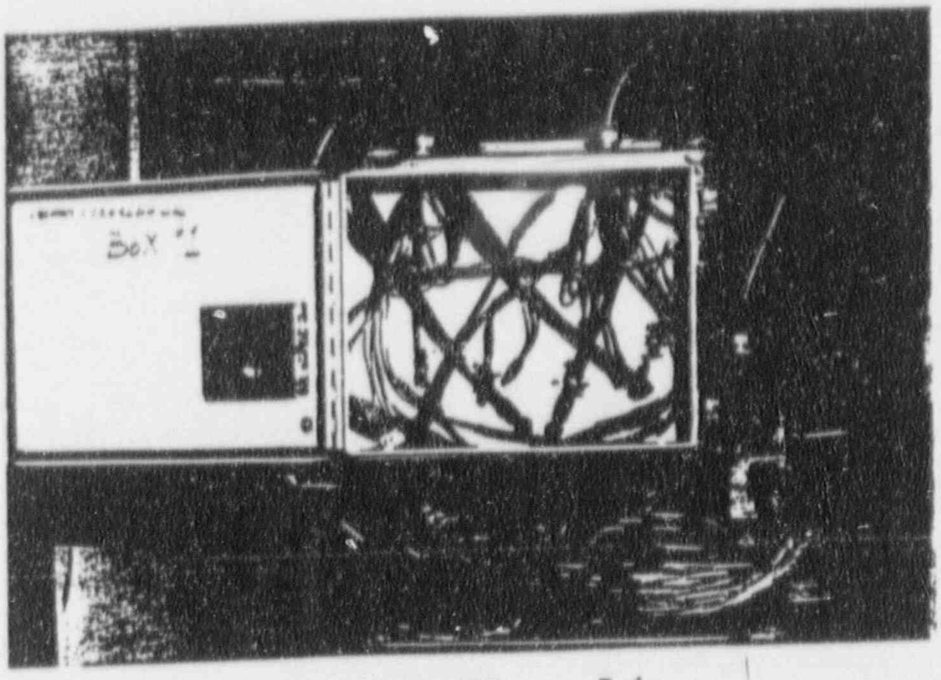
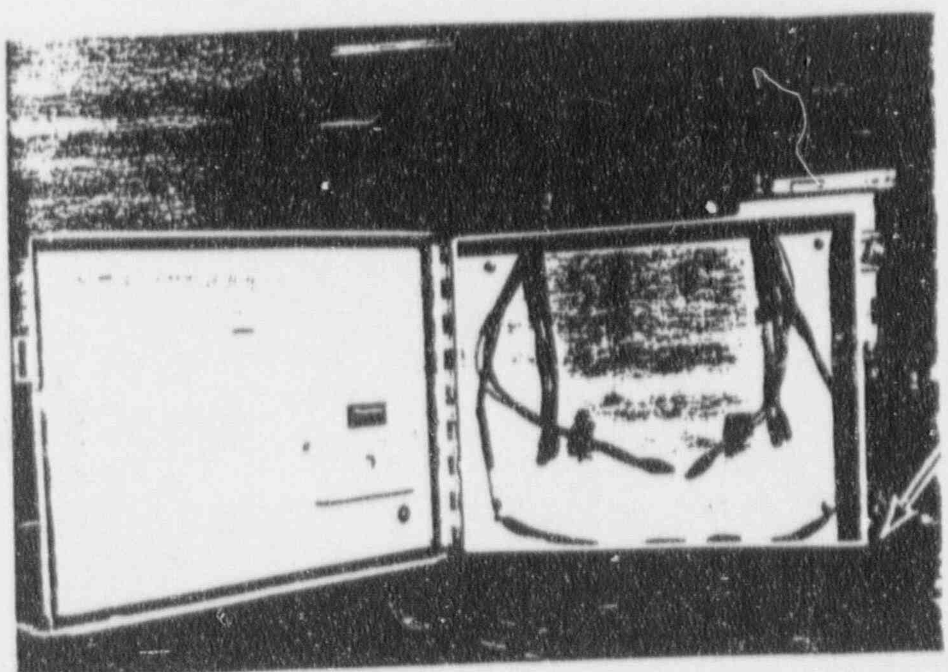



Figure B.7: Specimen Location Inside Enclosures



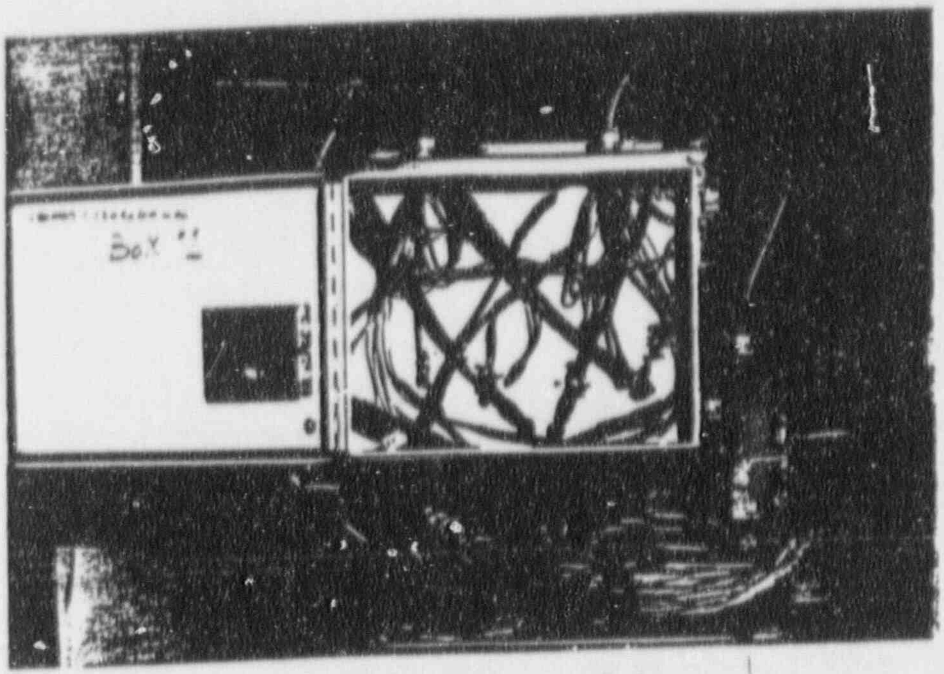
**PHOTOGRAPH B.1**

NEMA ENCLOSURE # 1
SPECIMENS 1 THROUGH 6 (A THROUGH C FOR EACH)



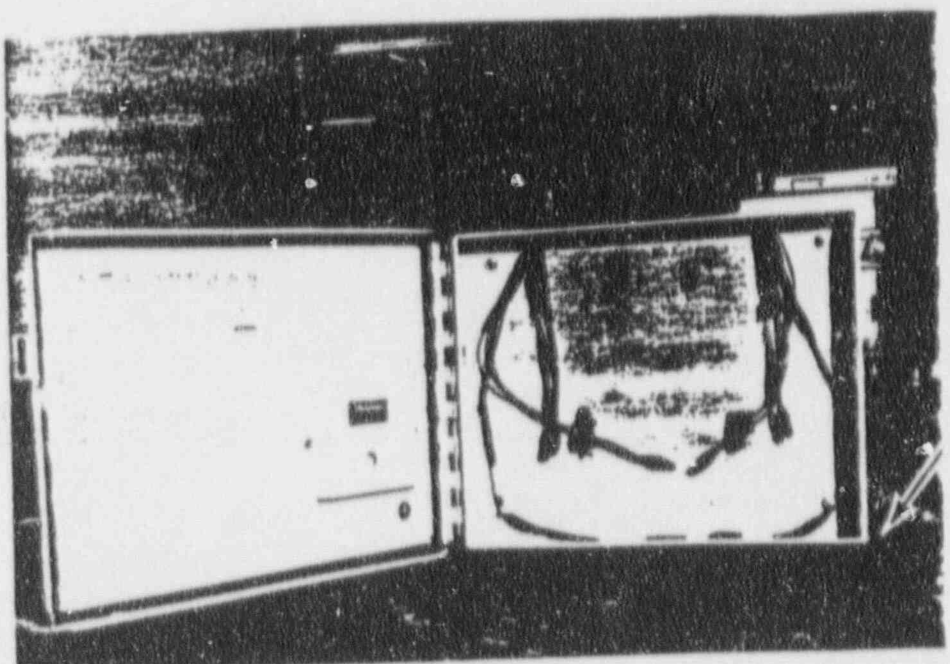
**PHOTOGRAPH B.2**

NEMA ENCLOSURE # 2
SPECIMENS 7 AND 8 (A THROUGH C FOR EACH)
ARROW DENOTES "WEEP-HOLE"




**PHOTOGRAPH B.1**

NEMA ENCLOSURE # 1
SPECIMENS 1 THROUGH 6 (A THROUGH C FOR EACH)



**PHOTOGRAPH B.2**

NEMA ENCLOSURE # 2
SPECIMENS 7 AND 8 (A THROUGH C FOR EACH)
ARROW DENOTES "WEEP-HOLE"

b. Flexible conduits were entered the top of each enclosure from pull box. Both enclosures were inserted into LOCA chamber.

## B.6 Electrical Powering and Monitoring

a. The following table illustrates the powering of these specimens (Figure B.8):

| Specimen No. | Current Amps | Voltage* VAC | Circuit No. |
|---|---|---|---|
| 1A, 1B, 1C | 6.7 | 528 | 1 |
| 2A, 2B, 2C | 6.7 | 528 | 2 |
| 3A, 3B, 3C | 15 | 528 | 3 |
| 4A, 4B, 4C | 15 | 528 | 4 |
| 5A, 5B, 5C | 6.7 | 132 | 5 |
| 6A, 6B, 6C | 6.7 | 132 | 6 |
| 7A, 7B, 7C | 6.7 | 528 | 7 |
| 8A, 8B, 8C | 6.7 | 528 | 8 |

*528 VAC (+10, -0 VAC)
132 VAC ( +5, -0 VAC)

b. All circuits input voltage and current were monitored as well as chamber pressure, temperature, and water flow.

## B.7 LOCA Test

a. Numerous testing performed on Okonite tape splices conclude:

1. The tapes went through numerous testing in both "V" and In-line configurations, having passed the tests successfully.

2. Failure of the splices may occur only in conditions of high temperature and humidity.

Based on these findings, only a LOCA accident simulation test was performed. This test was performed to verify tapes used in splice "V" configurations under extreme conditions of temperature/humidity and "local submergence," will pass the test.

b. After visual inspection, the specimens were submitted to the function test. The test consisted of measurement of insulation resistance (IR) by applying 500 VDC for a minimum of 1 minute; prior to measurement of the resistance between conductor and ground, at ambient temperature after the specimens were installed in the test chamber.

c. LOCA Test Profile

The LOCA test profile was as follows (Figures B.9 and B.10):

| | Temperature °F | Duration Hours | Humidity | Pressure psig |
|---|---|---|---|---|
| Phase 1 Pressure | 355 | 3 | Steam | 49.5 |
| | 320 | 3 | Steam | 49.5 |
| | 250 | 18 | Steam | Saturation |
| Phase 2 Pressure | 266 | 72 | Steam | Saturation |

Demineralized water spray at 15 gal/min/ft$^2$ for the last 72 hours.

NOTE: Only Specimens 5A, B, C, and 6A, B, C were monitored during Phase 2 of the test (Photographs B.3 and B.4).

d. All the test specimens maintained the voltage and current throughout the 24 hour LOCA exposure (Pages III-28 through III-37 of Reference B.2.2 and Pages III-28 through III-32 of Reference B.2.3).

e. Visual inspection was performed upon the test completion. No signs of the specimens damage or degradation were found (Photographs B.5, B.6 and B.7).

f. The test specimens complied with specified acceptance criteria, without exception, during and after the test.

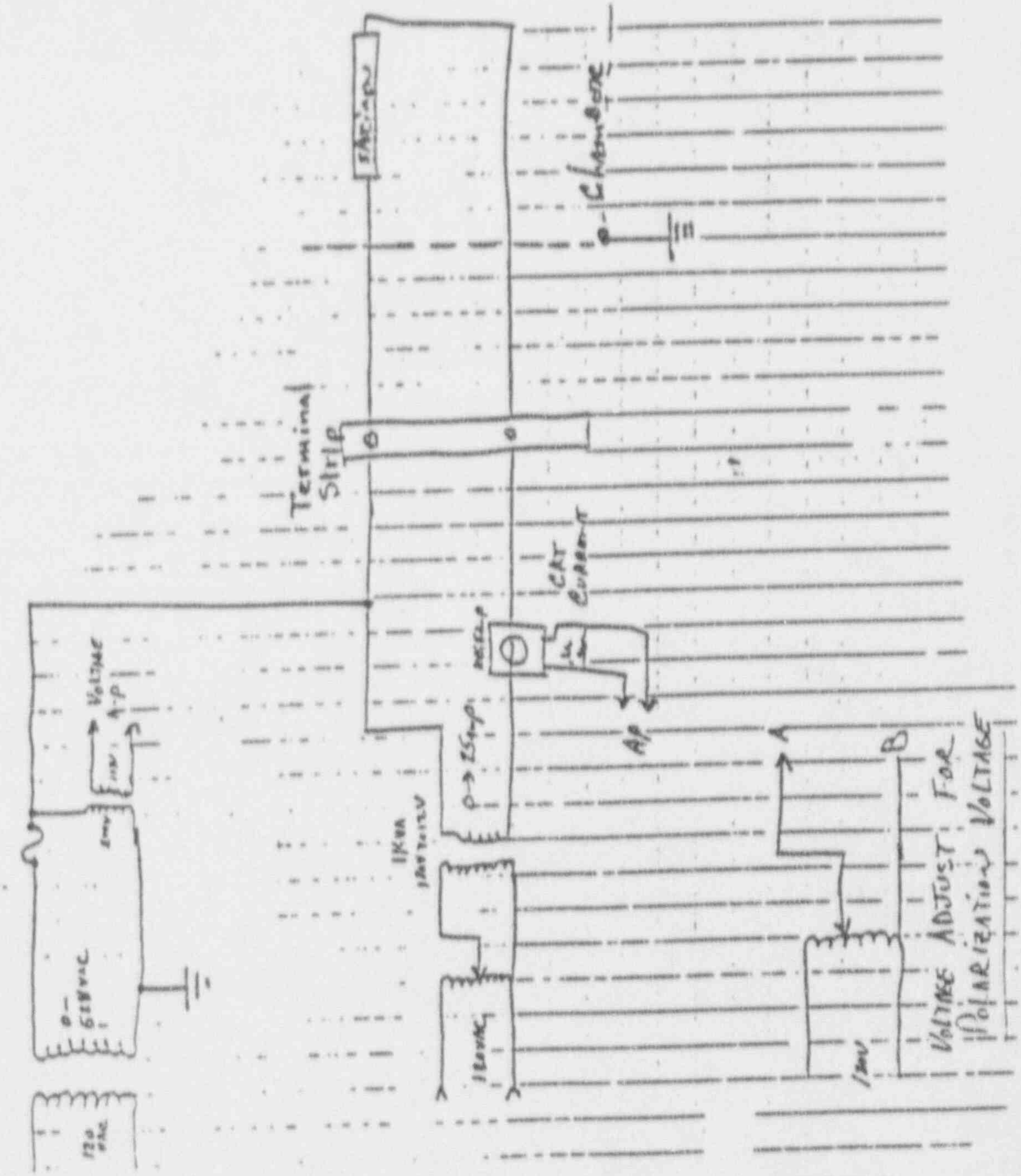



Figure B.8: Typical Powering Circuit

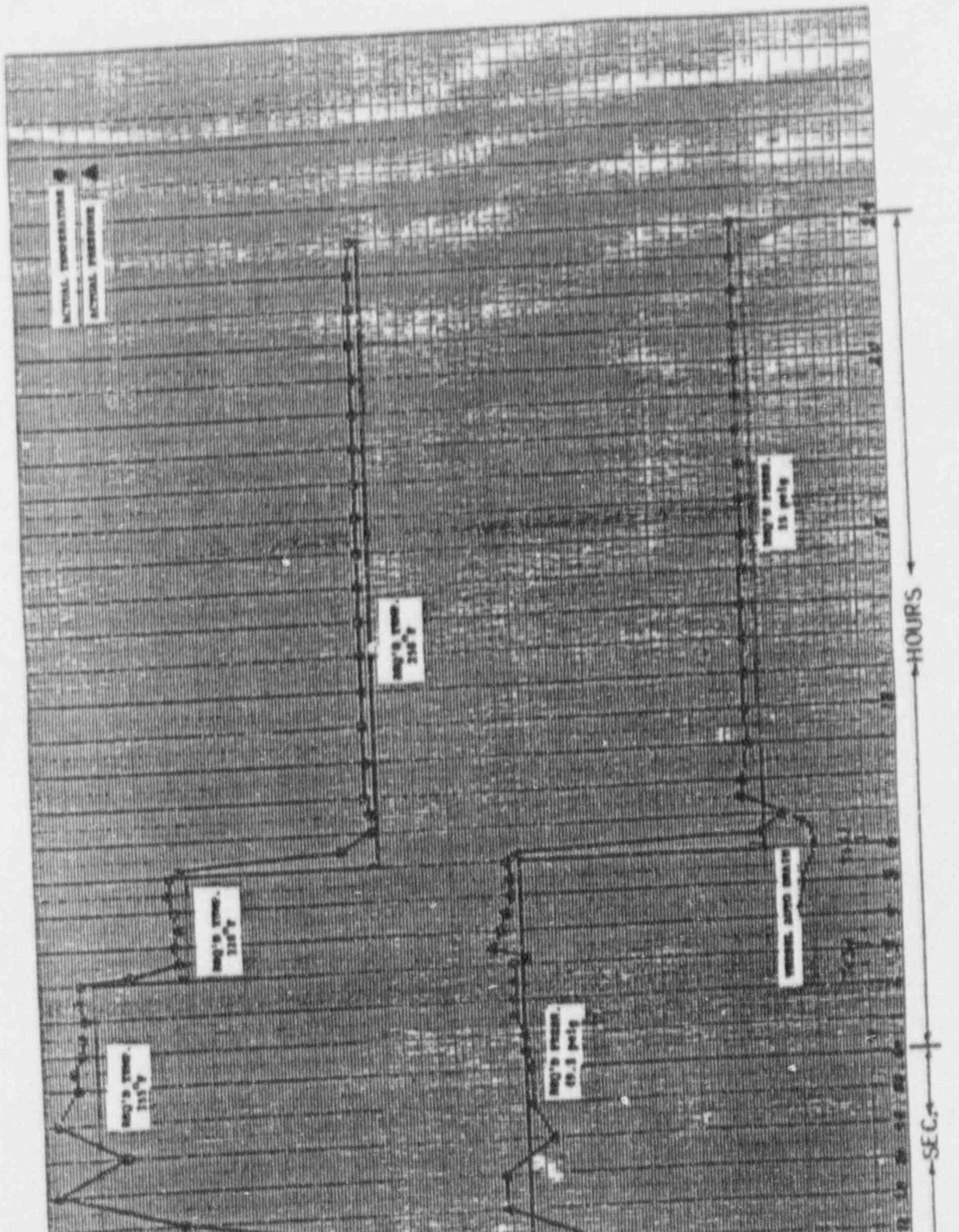



Figure B.9: Actual Test Profile

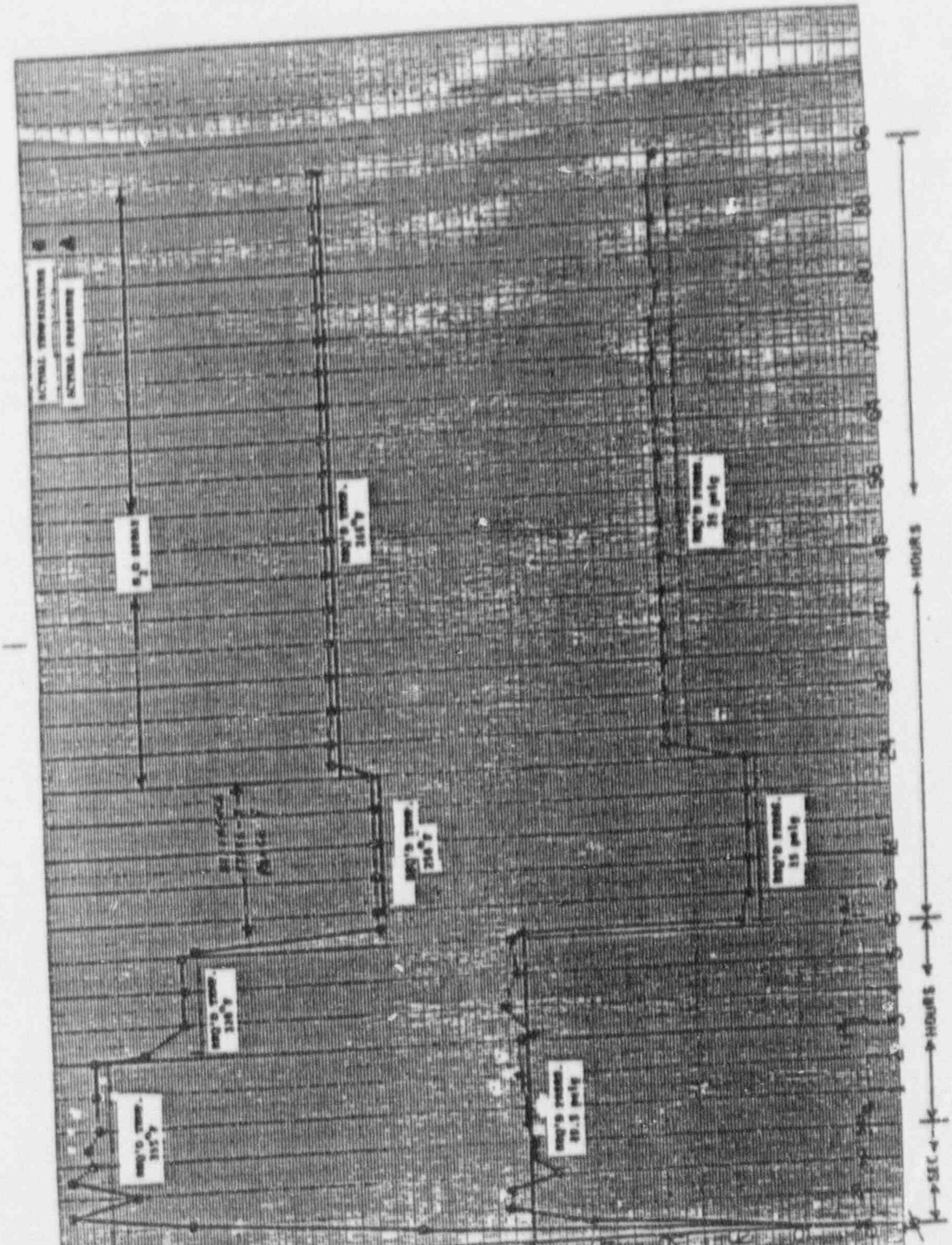
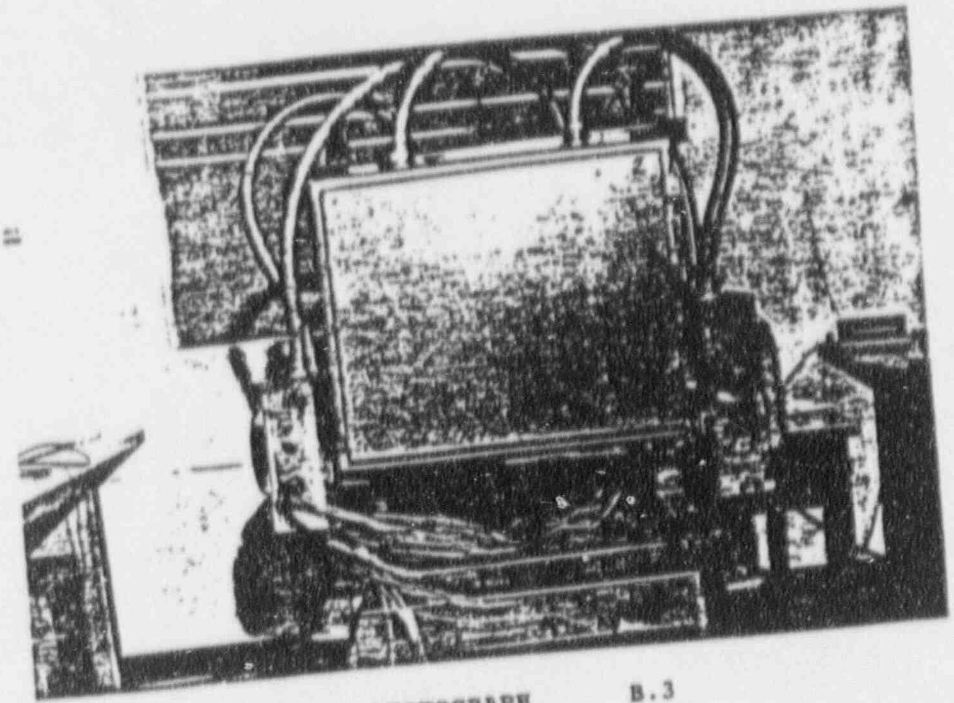
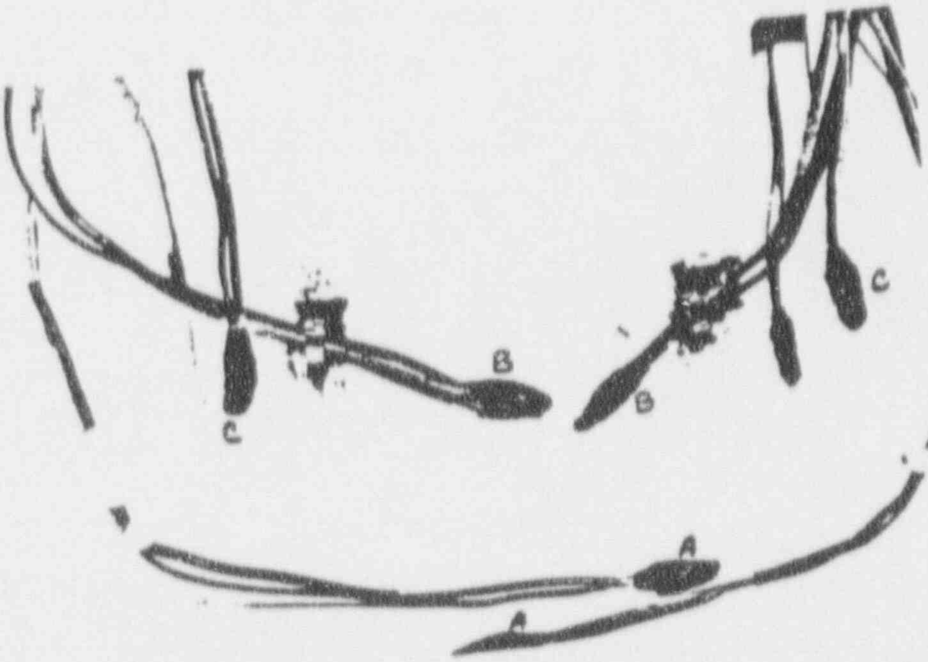


Figure B.10: Actual Test Profile



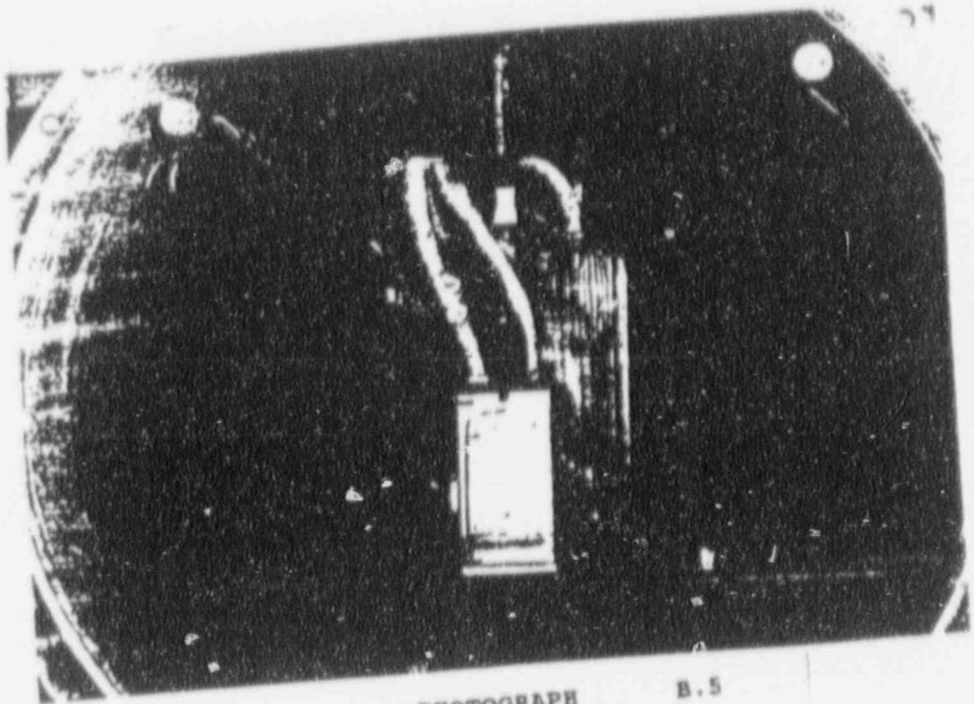
PHOTOGRAPH B.3

HOFFMAN ENCLOSURE PRIOR TO LOCA TEST



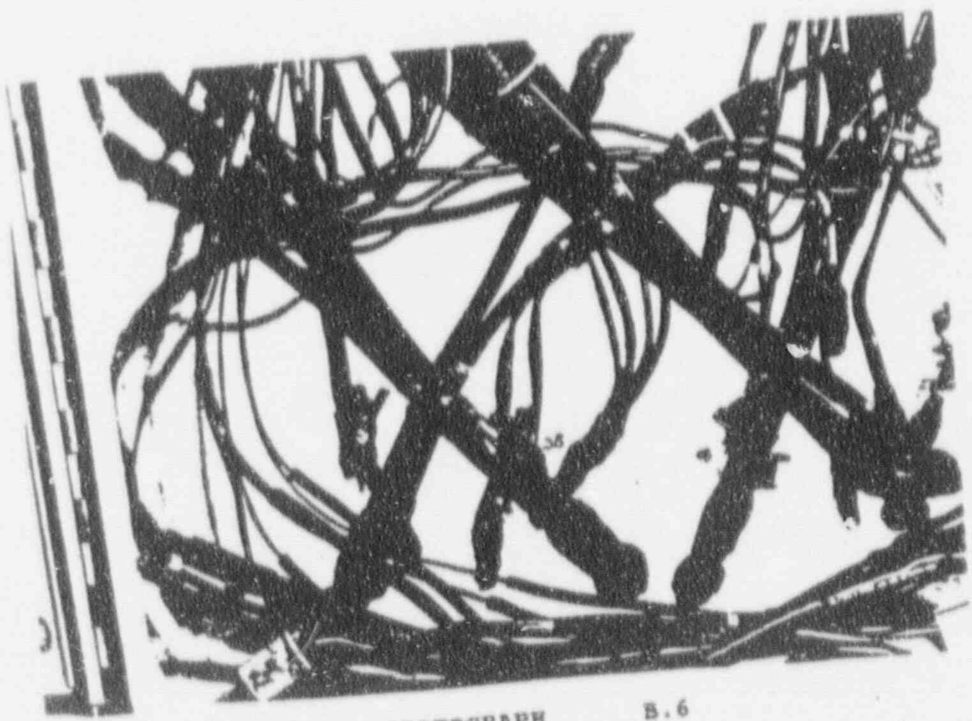

PHOTOGRAPH B.4

TYPICAL SPECIMEN ARRANGMENT PRIOR TO LOCA TEST



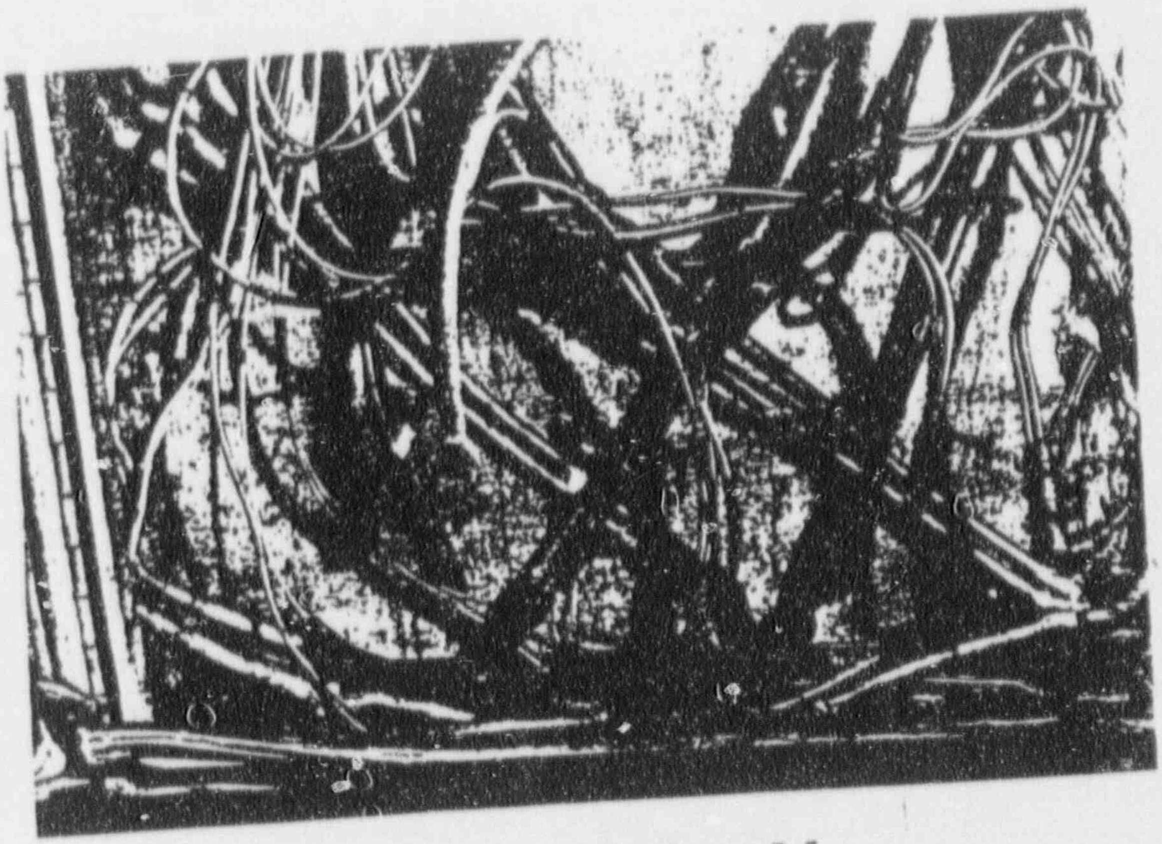
PHOTOGRAPH B.5

SPECIMENS FOLLOWING TEST



PHOTOGRAPH B.6

SPECIMENS 1A, 1B, 1C THROUGH 6A, 6B, 6C PRIOR TO TEST



PHOTOGRAPH B.7

SPECIMENS 1A, 1B, 1C THROUGH 6A, 6B, 6C AFTER TEST

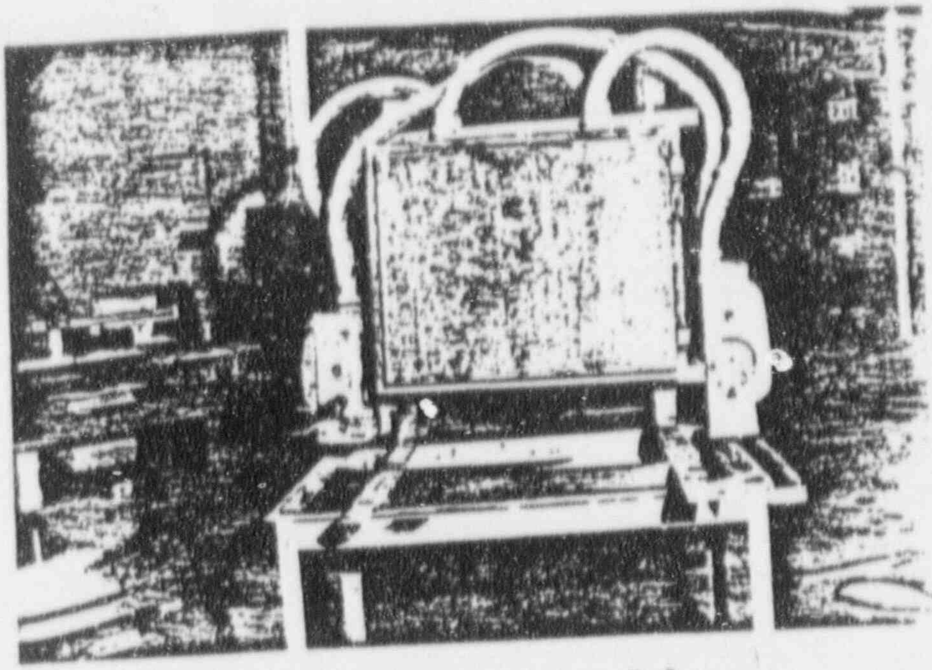
## B.8 Post-Test Inspection

Following Phase 2 of this program, the specimens were removed from the test vessel and visually inspected. There was a light coat of white and brown residue covering all surfaces of the specimens. There was approximately 1/4" of water in the NEMA-12 enclosure (there was no provision for a drain of condensate). All test specimens were damp to the touch (Photographs B.8 and B.9).

The NEMA-12 enclosure only accumulated 1/4" of water confirming that the volume of the water inside the enclosed is limited by the lip height. The "V" type splices maintained their circuit integrity under the "local submergence" inside the NEMA enclosure.

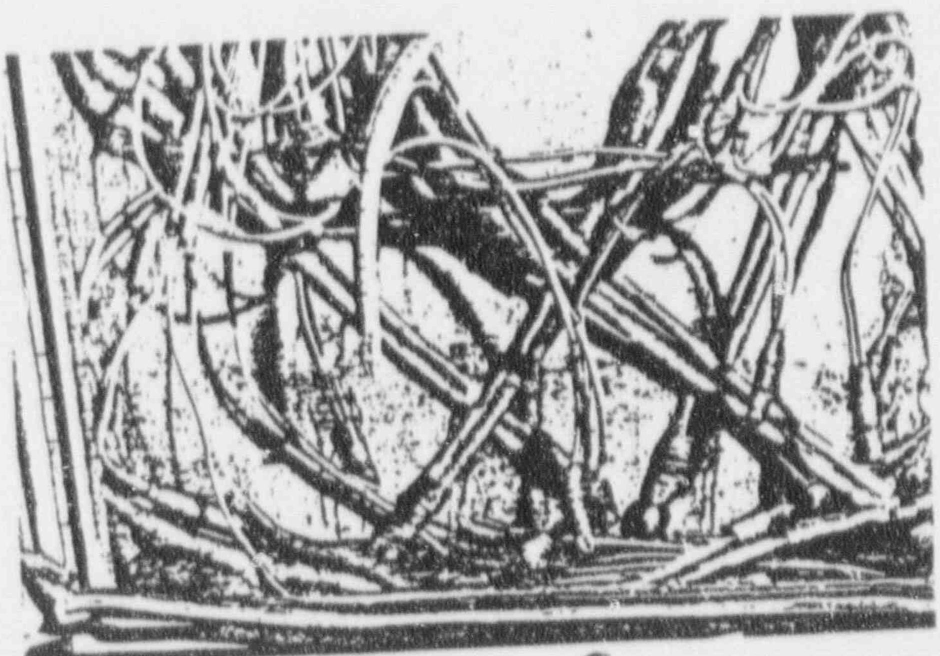
## B.9 Conclusion

The LOCA tests performed (References B.2.2 and B.2.3) establish that the Okonite splices for low voltage power and control application are environmentally qualifed and will maintain their circuit integrity even when locally submerged due to condensate from steam/demineralized water spray exposure.



PHOTOGRAPH B.8

NEMA-12 ENCLOSURE AFTER ACCIDENT TEST



PHOTOGRAPH B.9

SPECIMENS FOLLOWING ACCIDENT TEST

# Appendix C

## C.0 Environmental Qualification of Okonite 600V Power and Control Splices Inside PWR Containment While Under "Local Submergence"

## C.1 Purpose

The purpose of this section is to establish environmental qualification of 600V power and control Okonite In-line and "V" type splice (consisting of Okonite T-95 insulating tape and No. 35 splicing tape) under "local submergence" for inside PWR containment applications.

## C.2 References

C.2.1. Wyle Test Report No. 17947-01, "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 Stations," dated October 8, 1987

## C.3 Test Specimen Description

The test specimens consisted of 14 different splice constructions as listed below. Three of each specimen were built (4 of 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 |
| 10.1A, 10.1B, 10.2, 10.3 | 12 AWG to ASCO Lead | NTO1 | 1/4" | 137.5 VDC | 200mA *** |

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

Notes:

\+ Specimens 1-6 will be dropped from further discussion as they were tested inside an enclosure with adequate drainage.

* 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.

## C.4 Test Specimen Preparation (Figures C.1 through C.9)

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 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 form 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.

| Specimen* Numbers | Lead 1** | Lead 2** |
|---|---|---|
| 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.

4. The Okonite T-95 insulating tapes 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 7-12) 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 |
|---|---|
| 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.

| Specimen Numbers | Type of Jacketing Tape | Overlap |
|---|---|---|
| 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 |

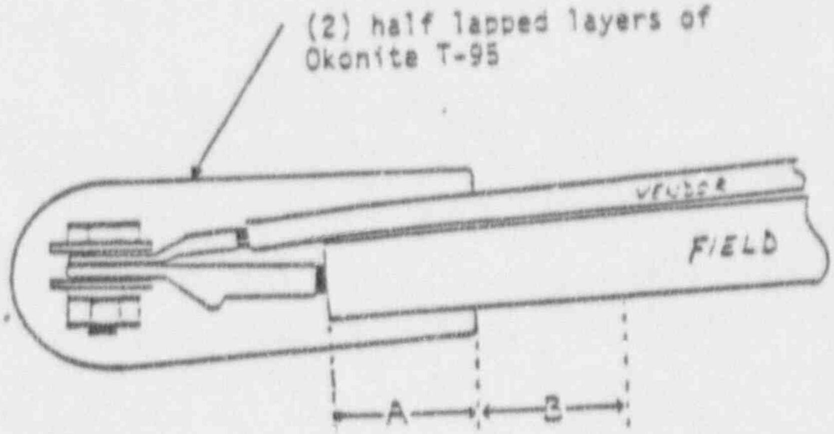
7. Specimens 10.1A and 10.1B, 10.2 and 10.3, 11.1 and 12.1, 11.2 and 12.2, 11.3 and 12.3, 13.1 and 14.1, 13.2 and 14.2, and 13.3 and 14.3 were mounted inside 3/4-inch Type C condulet fittings. The leads were routed such that the 18 AWG ASCO wires penetrated one end of the condulet and the 1/C 12 AWG wires penetrated the other end. The 8 condulets were tie-wrapped to a 33" L x 30" W x 4" H ladder rung cable tray for handling during the radiation exposure.

8. 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.

## C.5 Test Sequence

The test program consisted of the following test sequence:

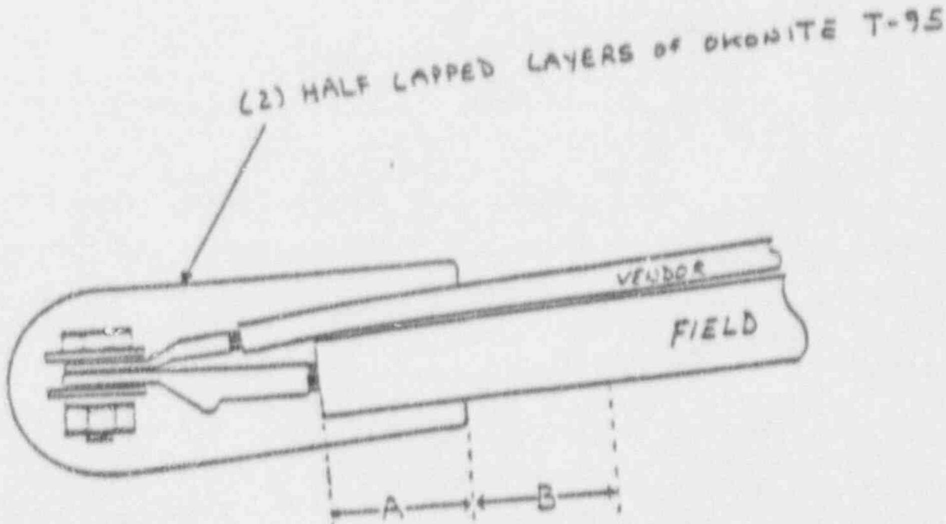
- Receiving Inspection
- Specimen Preparation
- Baseline Functional Test
- Radiation Exposure
- Functional Test
- Thermal Aging
- Functional Test
- Accident Simulation
- Post-Test Inspection




DETAIL T02

| A | B |
| --- | --- |
| 0.50" | N/A |

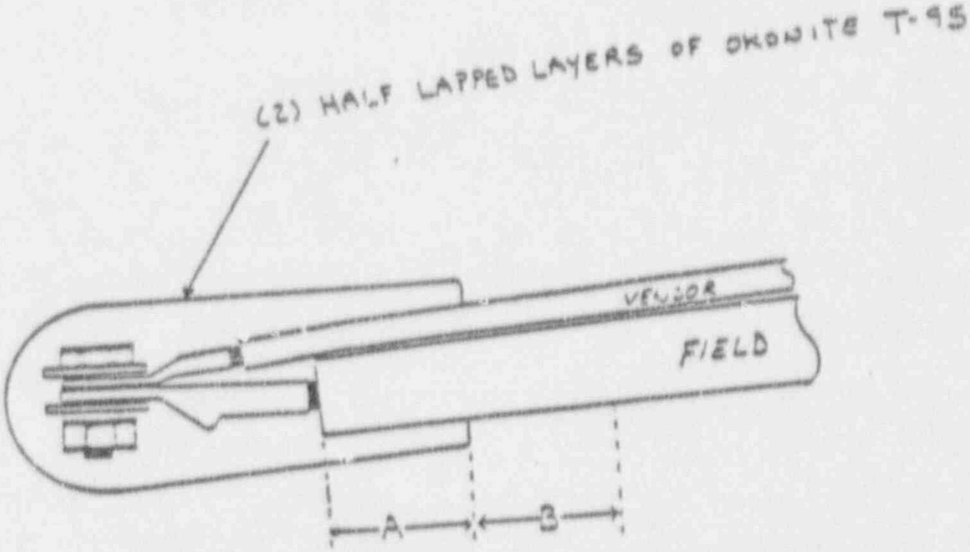
**Figure C.1: Specimens 7.1, 7.2, 7.3**




DETAIL T03

| A | B |
|---|---|
| 0.75" | N/A |

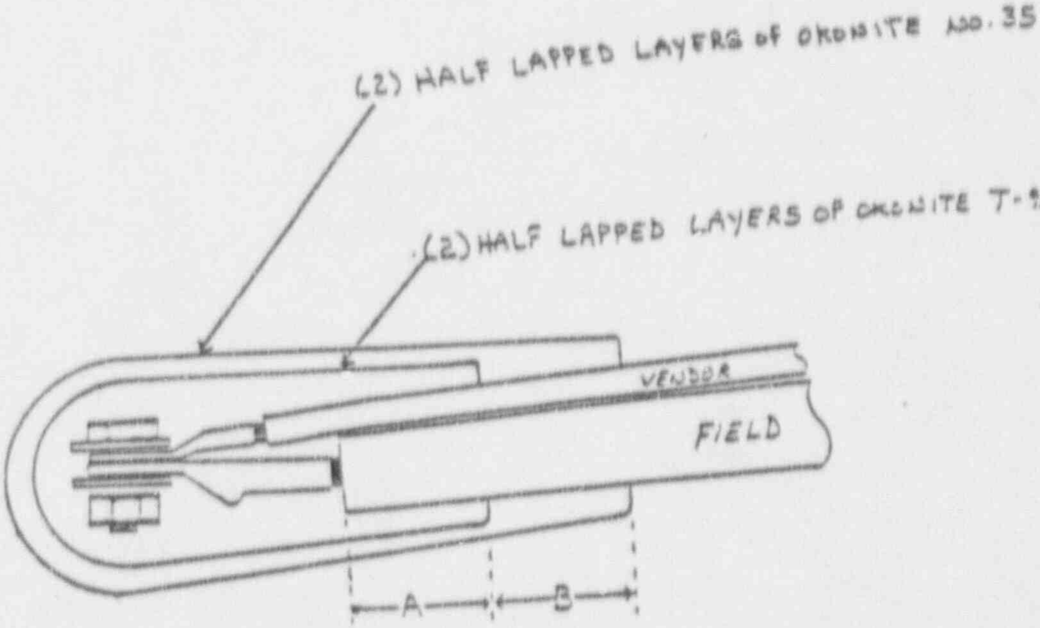
Figure C.2: Specimens 8.1, 8.2, 8.3




DETAIL T06

| A | B |
|---|---|
| 1.00" | N/A |

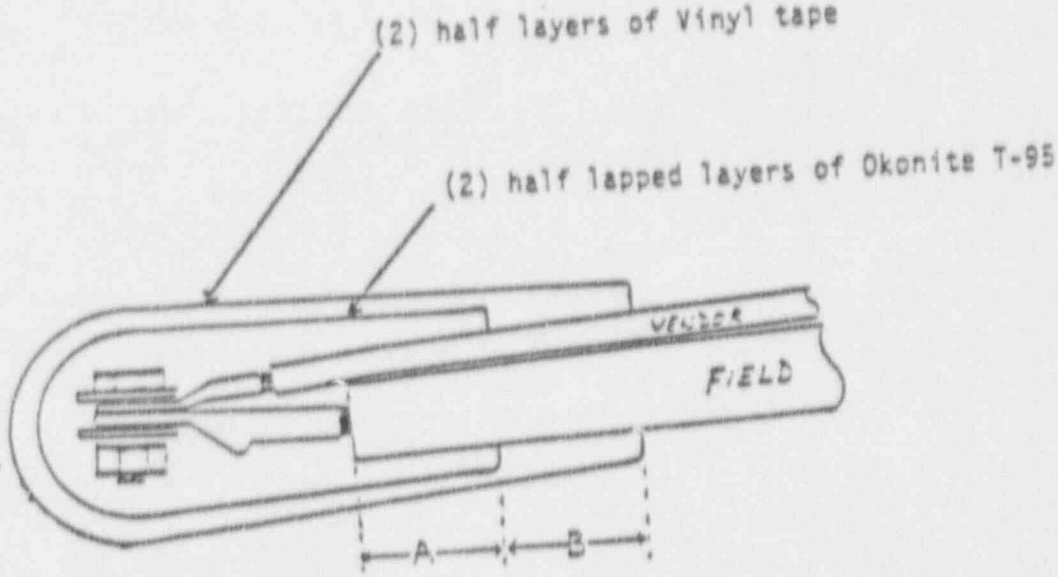
Figure C.3: Specimens 9.1, 9.2, 9.3




DETAIL NTO1

| A | B |
|---|---|
| 0.25" | 0.50" |

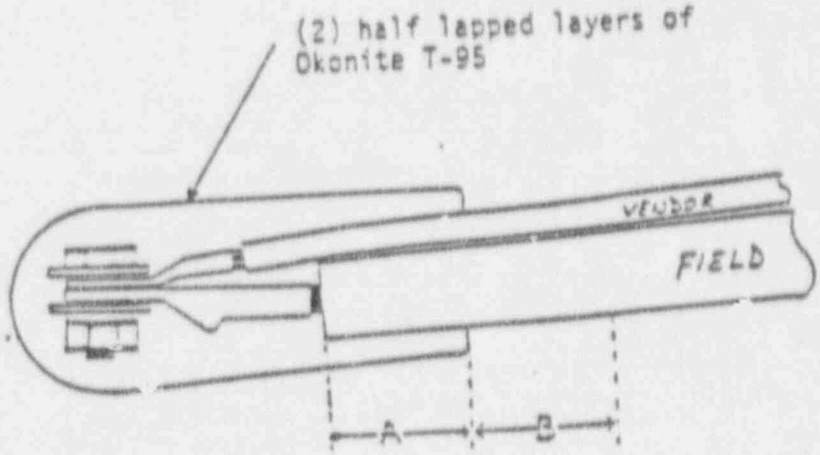
Figure C.4: Specimens 10.1A, 10.1B, 10.2, 10.3




DETAIL VT01

| A | B |
|---|---|
| 0.25" | 0.50" |

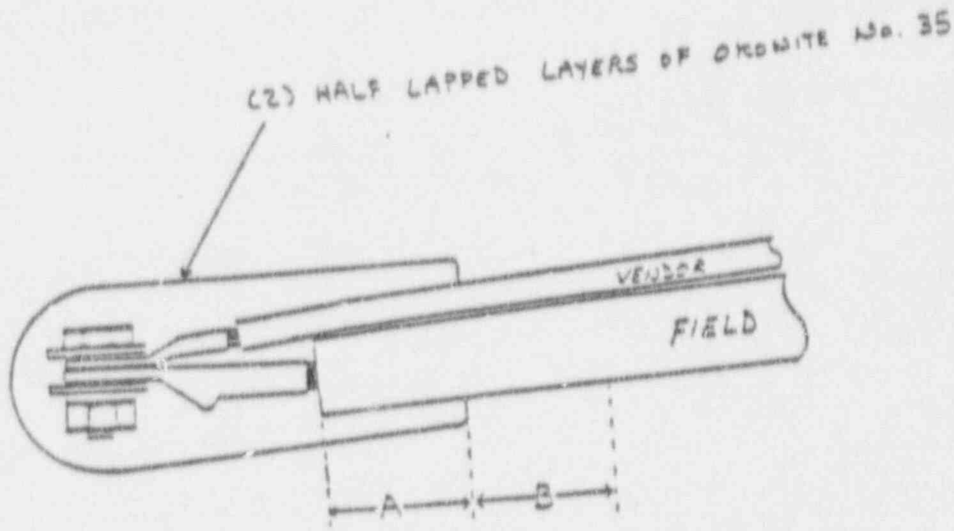
**Figure C.5: Specimens 11.1, 11.2, 11.3**




DETAIL T01

| A | B |
| --- | --- |
| 0.25" | N/A |

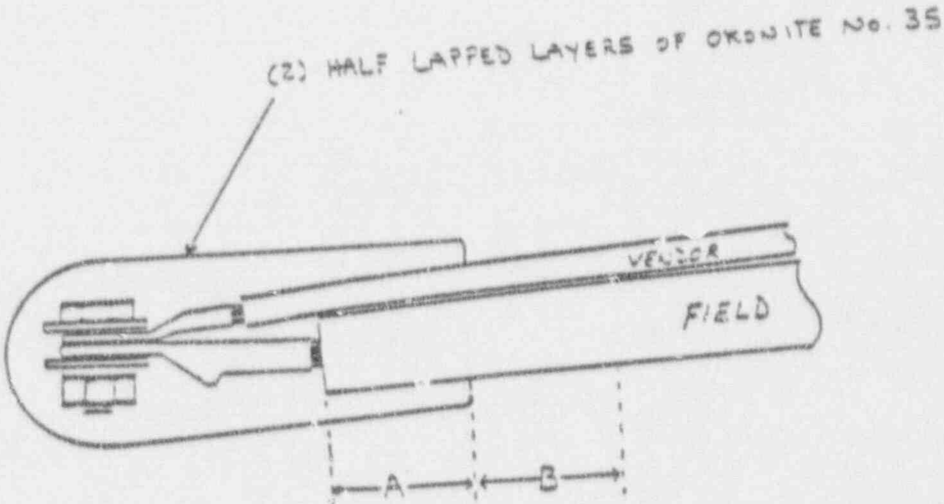
Figure C.6: Specimens 12.1, 12.2, 12.3




DETAIL NO3

| A | B |
|---|---|
| 0.75" | N/A |

Figure C.7: Specimens 13.1, 13.2, 13.3




DETAIL NO 6

| A | B |
|---|---|
| 1.00" | N/A |

Figure C.8: Specimens 14.1, 14.2. 14.3

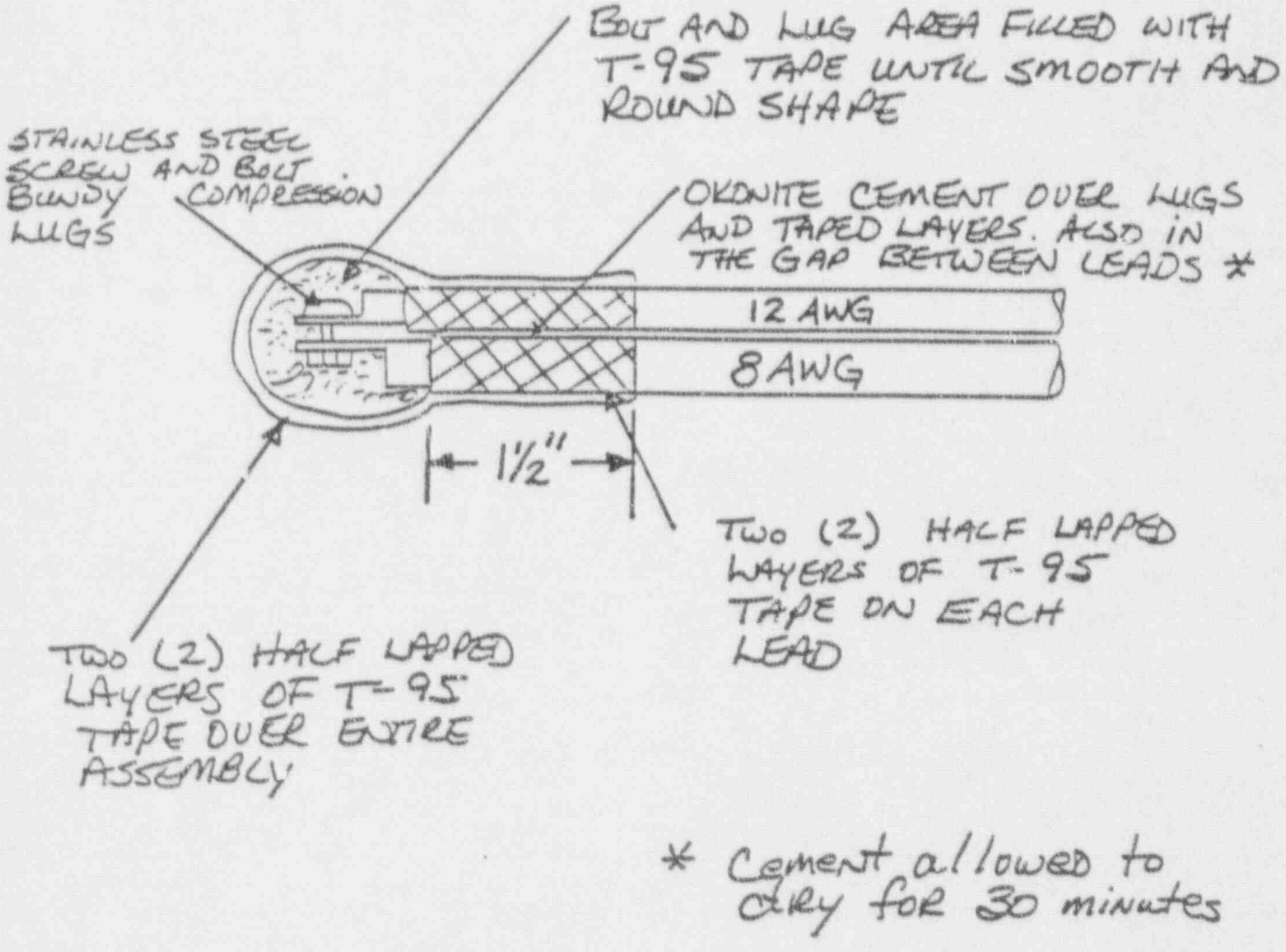



Figure C.9: Details of Test Specimens

## C.6 Thermal Aging

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.

| Specimen No. | Aging Temperature | Time (Hours) |
|---|---|---|
| 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 |

## C.7 Radiation Aging

The test specimens were indicated to a TID of 22 Megarads.

## C.8 Loss of Coolant Accident Test

### C.8.1 Test Specimen Preparation

The test specimens scheduled for the LOCA Test (Specimens 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 ** |
|---|---|---|---|
| 7.1 | 1/0 AWG | 10 AWG | 115/300 w/500 |
| | 12 AWG | 10 AWG | 070 w/200 |
| 8.1 | 8 AWG | 10 AWG | 115 w/200 |
| | 8 AWG | 10 AWG | 115 w/200 |
| 9.1 | 8 AWG | 10 AWG | 115 w/200 |
| | 12 AWG | 10 AWG | 070 w/200 |
| 10 - 14 | ASCO | 14 AWG | 050 w/115 |
| | 12 AWG | 14 AWG | 070 |

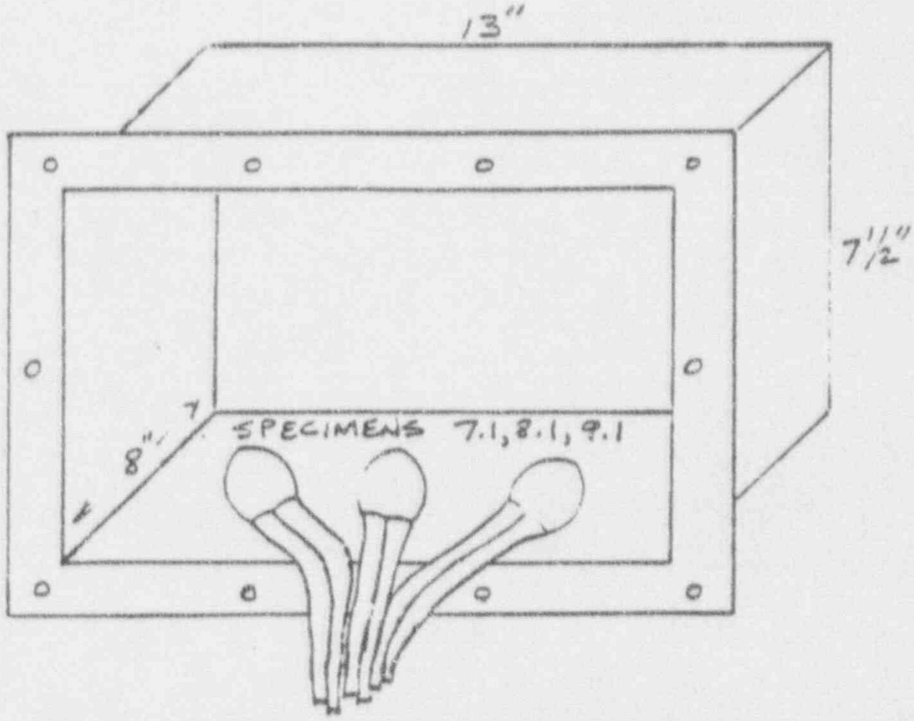
* Wyle leads were 1/C 1000 Volts, 200°C, Teflon leads (10 AWG and 2 AWG) and 1/C 600 Volts, 200°C, Teflon (14 AWG).

** Indicates shim sizes applied to smaller cable and overall sleeve size. For example, "115/300 w/500" 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:

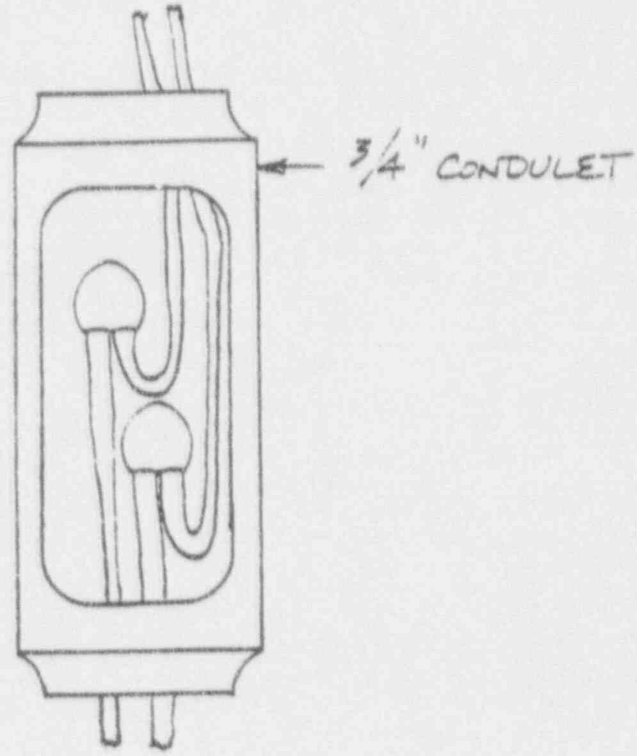
| Specimen No. | Enclosure Type |
|---|---|
| 7.1, 8.1 and 9.1 | 15⅛" x 10¼" x 8½" Limitorque cover bolted to a ½" thick steel plate. the Limitorque gasket was installed and there was no drain in the cover. The specimens were routed through a 1½-inch Myers hub and 90° elbow pointed downward. The splice rested on the cover approximately ¾ inch below the bottom of the conduit entry (Figure C.10). |
| 10.1A, 10.1B, 11.1, 12.1, 13.1 and 14.1 | ¾-inch condulet fitting with cover and gasket. One end of the condulet was attached to FNGS-supplied ¾-inch flexible conduit (Anaconda Type EF) and the other end was attached to an LB fitting through a 6-inch nipple. The LB fitting contained another 6-inch nipple pointed downward (Figure C.11). |




LIMITORQUE LIMIT SWITCH COMPARTMENT COVER

NOTES: 1) FABRICATE COVER PLATE (15½" X 10½") WITH MOUNTING HOLES AND 1½" HOLE FOR MYERS HUB AND CONDUIT FOR WIRE FEED-THRU.

Figure C.10: Specimens 7.1, 8.1, 9.1 inside a Limitorque Limit Switch Compartment Cover




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

**Figure C.11:** Typical of 3 Condulets for Specimens 10.1A, 10.1B, 11.1, 12.1, 13.1, 14.1

C.8.2 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 flow rate was adjusted to deliver 3.75 gallons per minute (0.15 gpm per square foot over a 25 foot square area).

C.8.3 Specimen Operability (Figures 6.12 and 6.13)

| Specimen No. | Voltage | Current | Operations |
|---|---|---|---|
| 7.1, 8.1, 9.1 | 632 VAC | 20.2A | Powered for the first 65 minutes. De-energized until the 46-hour point then re-energized for 2 minutes. |
| 10.1A and 10.1B | 137.5 VDC | 200mA* | None. Continuously energized. |
| 11.1 and 12.1, 13.1 and 14.1 | 137.5 VDC | 200mA* | Powered for the first 60 minutes. De-energized for remainder to test. |

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

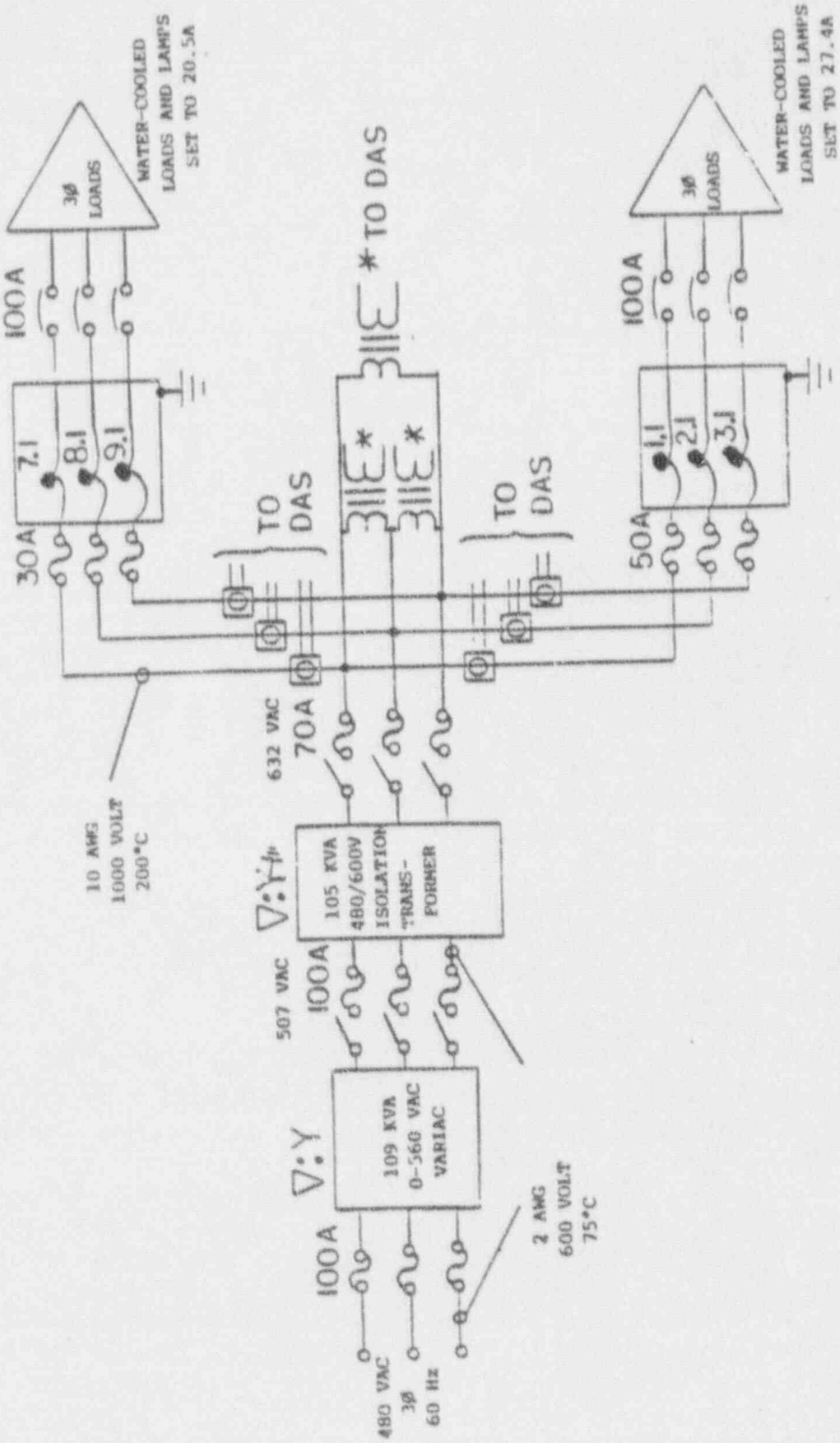



Figure C.12: Electrical Powering Circuit

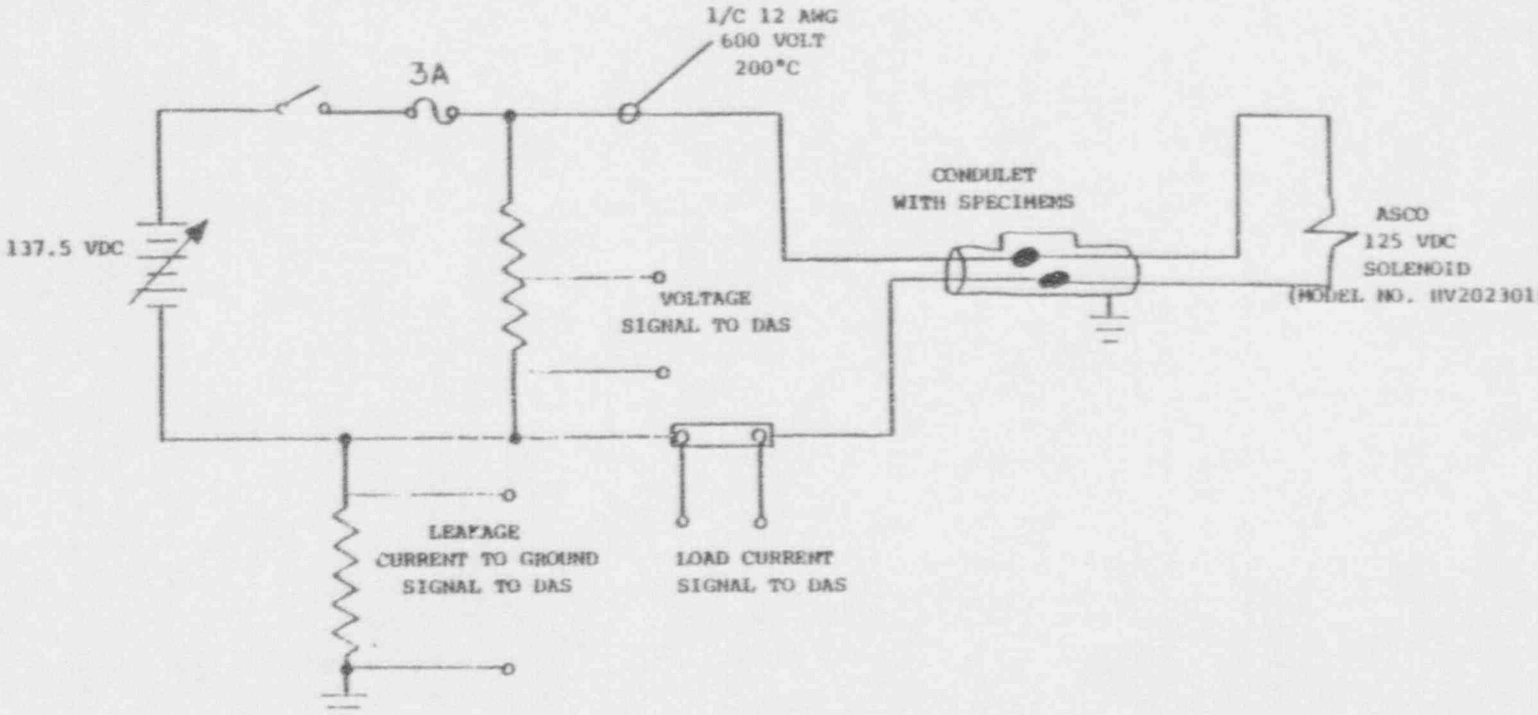



Figure C.13: Typical Electrical Setup for Specimens 10.1A, 10.1B, 11.1, 12.1, 13.1, 14.1

C.8.4 Accident Simulation

The test specimens were subjected to two temperature/pressure profiles. The first profile (Main Steam Room Test) was performed as shown in Figure C.14. The temperature requirement of 323°F was met in 15 seconds and the pressure requirement of 6.4 PSIG was met in 2 seconds during this test.

The second profile (containment) is as shown in Figures C.15, C.16 and C.17. The temperature peak of 393°F was met in 109 seconds and the peak pressure requirement of 53.3 PSIG was met in 217 seconds. Temperature was held above 393°F for 304 seconds prior to the temperature decay. Chemical spray was initiated at the 61-minute point and continued to the 25 hour 8 minute point in the test. The two test profiles were performed one after the other.

C.8.5 DBE Test Results

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

The recorded leakage currents to ground were:

| Specimen No. | Leakage Current to Ground (mA) |
|---|---|
| 10.1A and 10.1B | 0.00 |
| 11.1 and 12.1 | 1.20 |
| 13.1 and 14.1 | 0.00 |

## C.9 Conclusion

All the test specimens maintained their circuit integrity throughout the DBE exposure. The test specimens (7.1 through 9.1) were immersed with ½" of water (Photograph C.1). The test specimens (10.1 through 14.1) inside the conduits had no signs of arcing or insulation breakdown (Photographs C.2 and C.3). Therefore, it can be concluded that the Okonite low voltage tape splices (with and without O-35 jacketing tape) are enironmentally qualified and will perform its safety function (i.e., maintain circuit integrity) even when "locally submerged" due to a postulated LOCA environment for PWR Nuclear Power Plants.

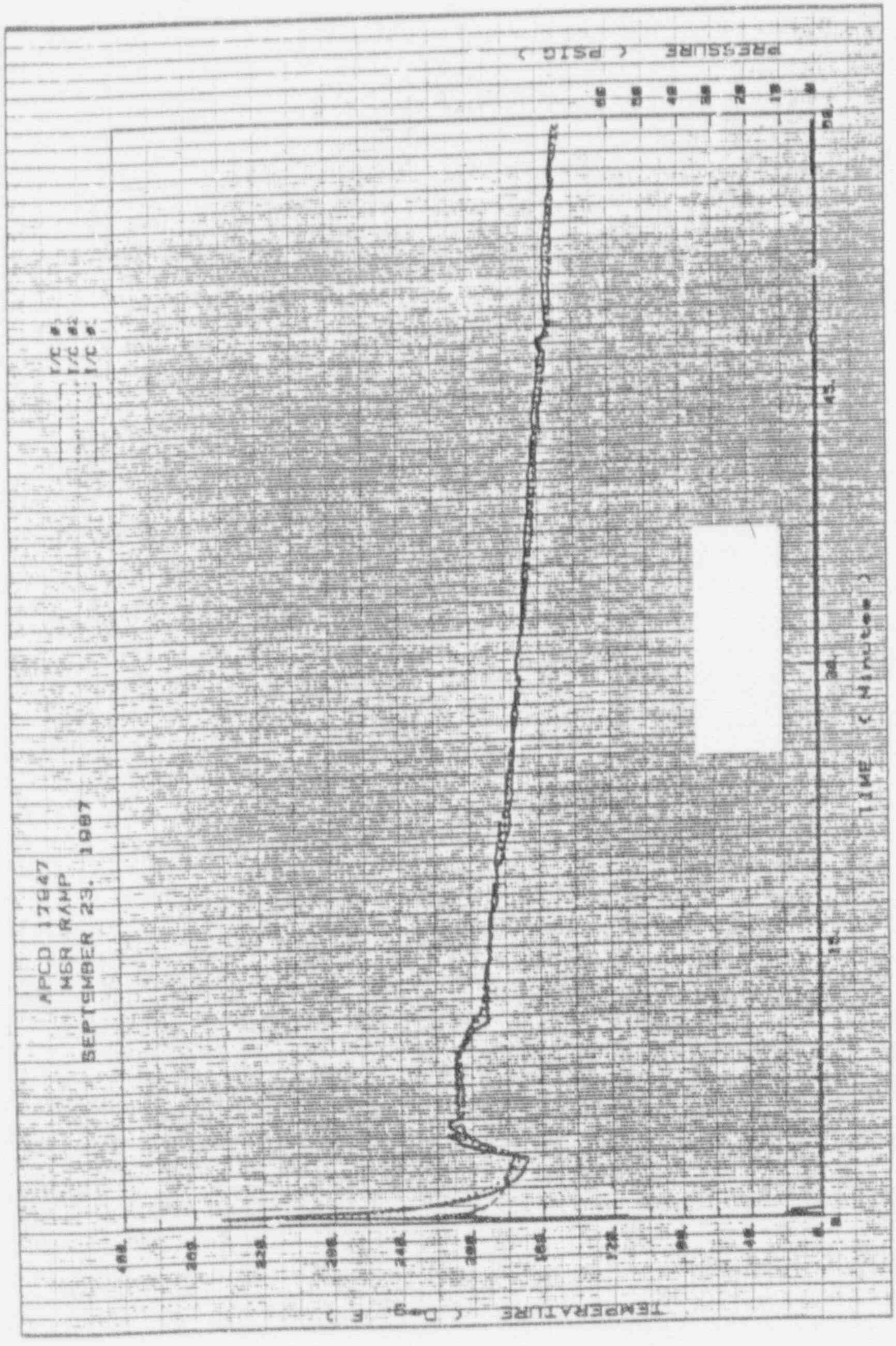



Figure C.14: Actual Main Steam Room Test Profile

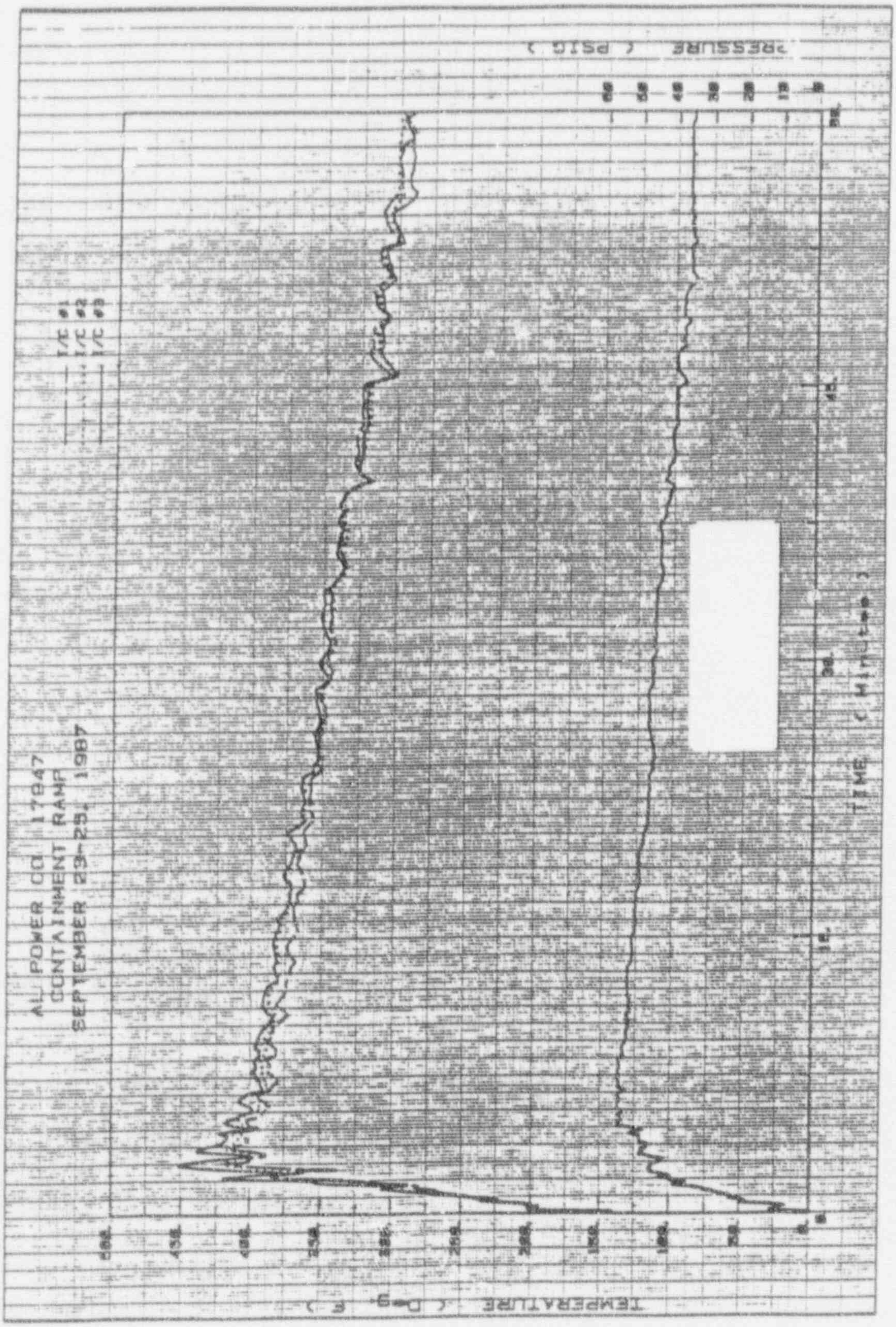



Figure C.15: Actual Containment Test Profile

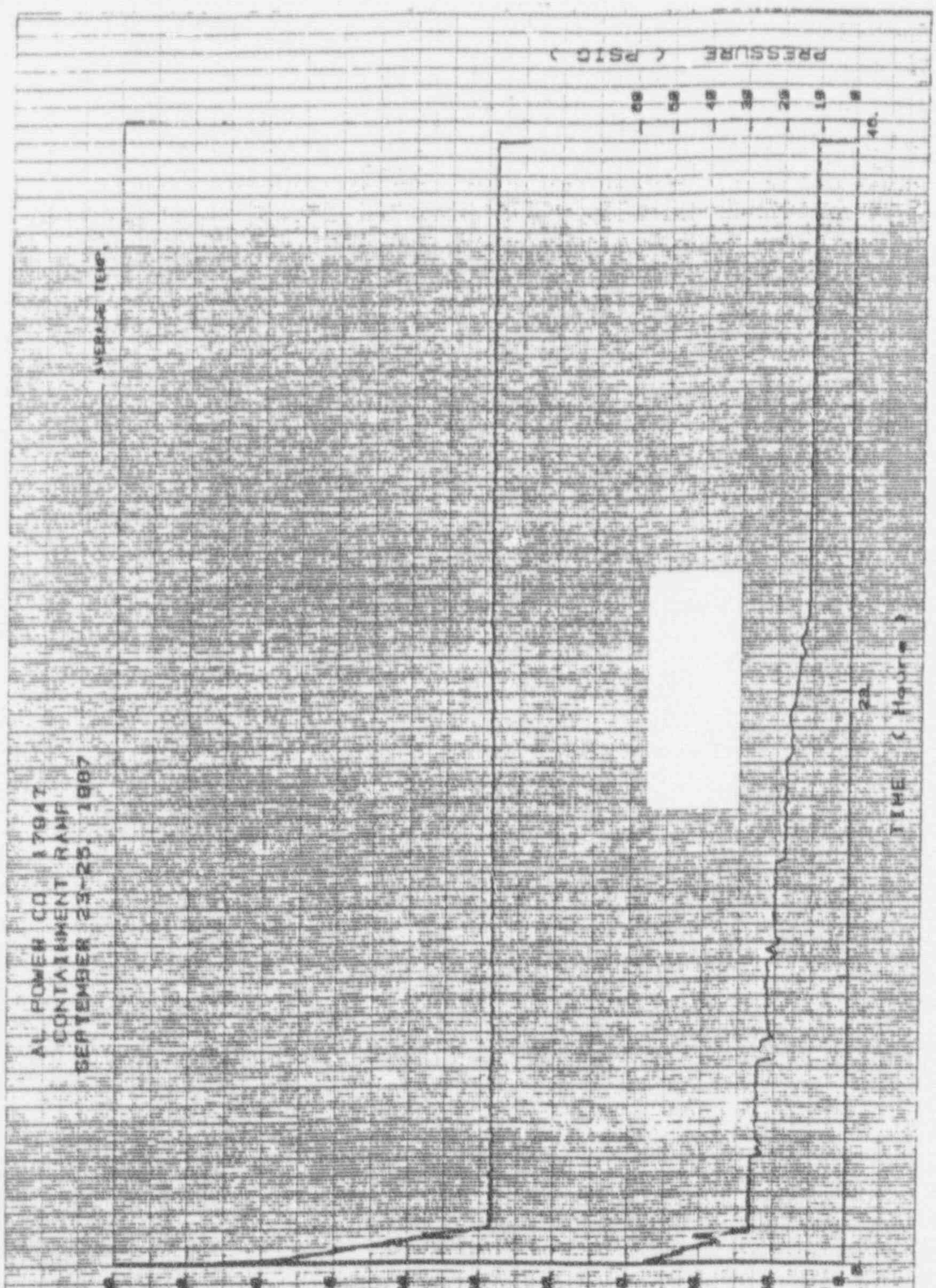



Figure C.16: Actual Containment Test Profile

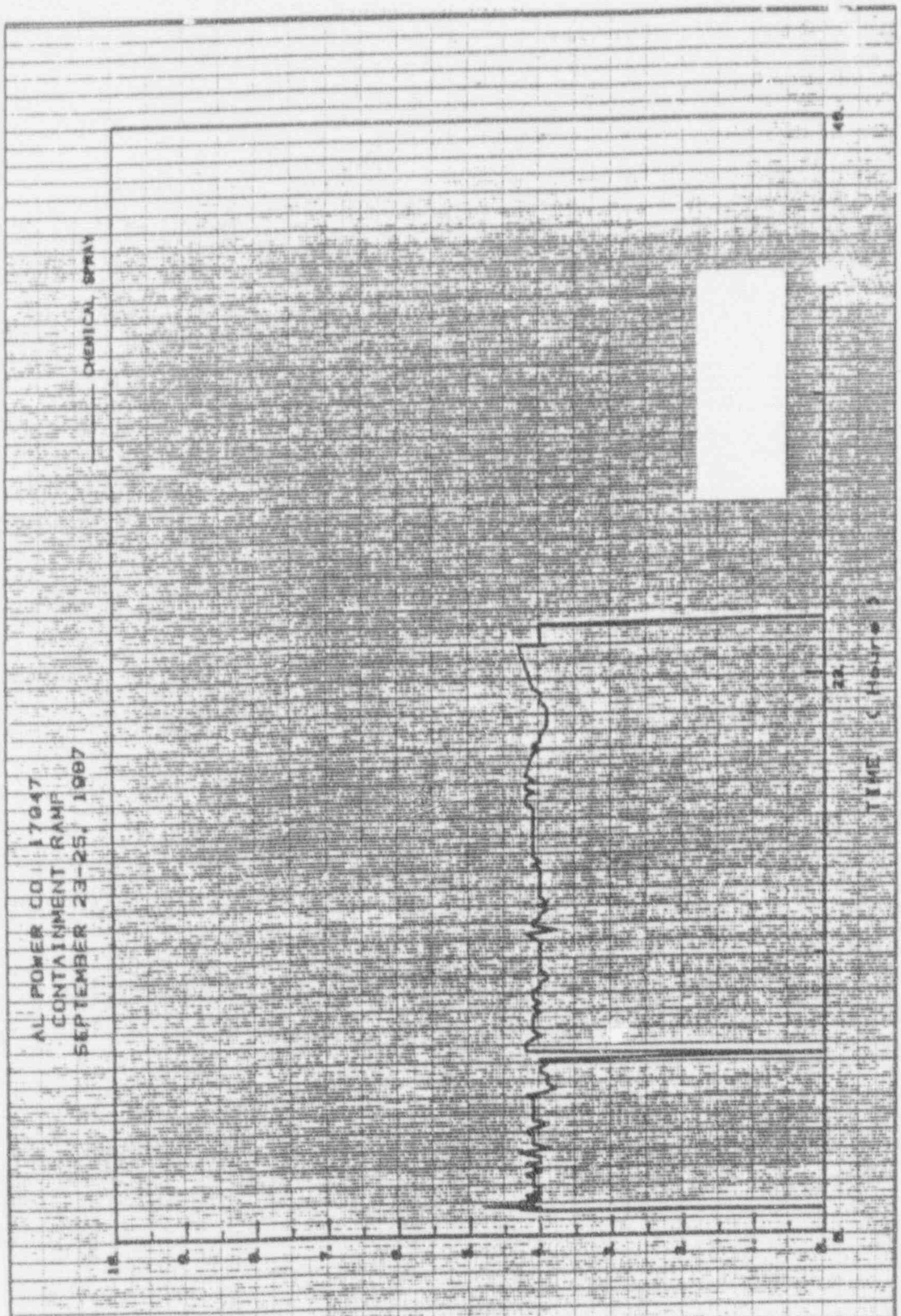
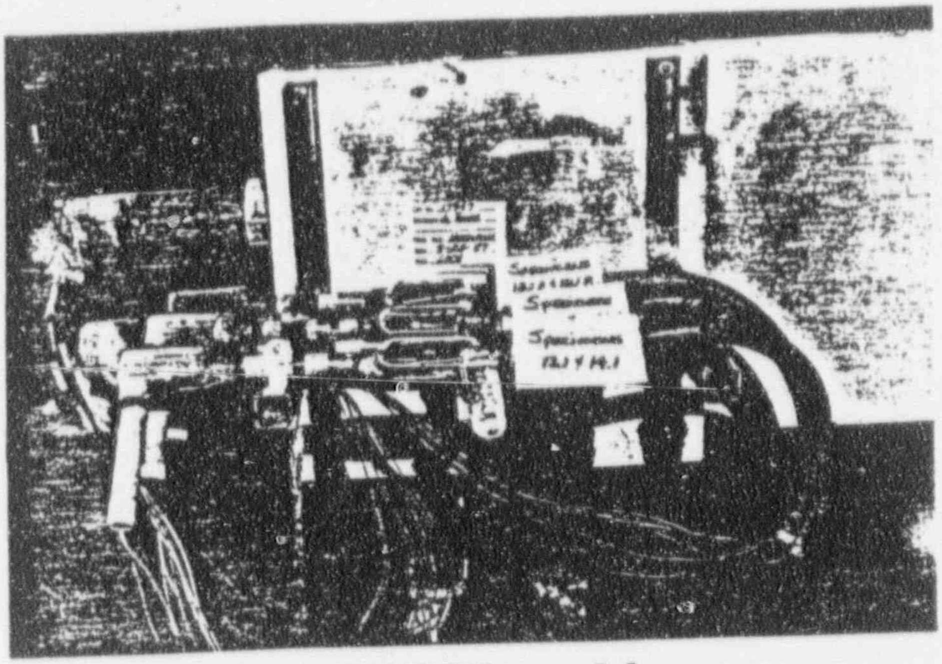



Figure C.17: Chemical Spray during Containment Test

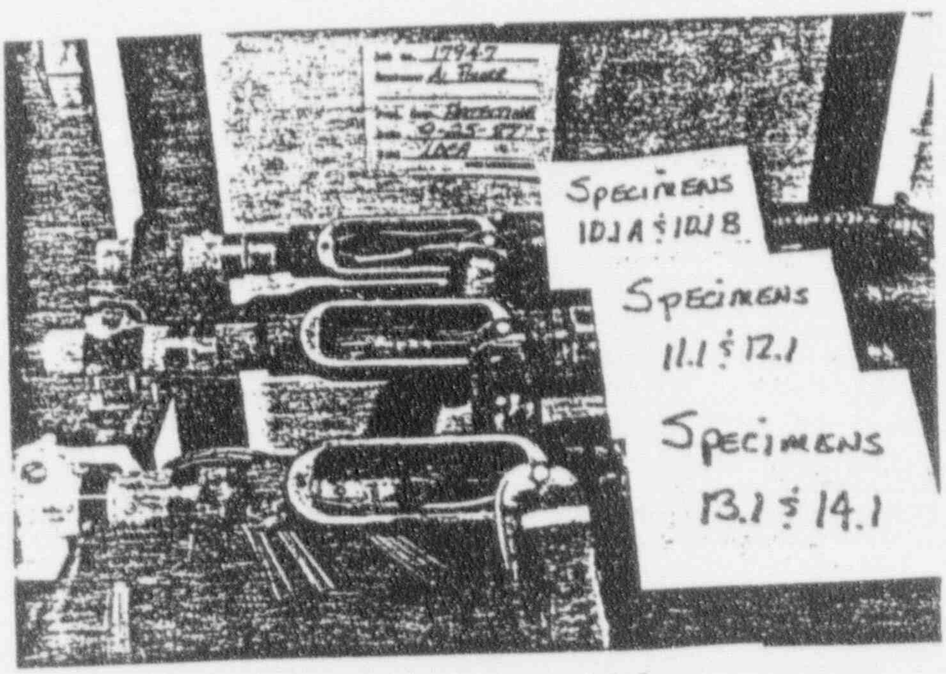
PHOTOGRAPH C.1

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 C.2

POST-LOCA OVERALL VIEW OF
SPECIMENS 10.1 TO 14.1




PHOTOGRAPH C.3

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

## D.0 Environmental Qualification of Okonite 600V Power and Control Splices Outside PWR/BWR Containment While Under "Local Submergence"

## D.1 Purpose

The purpose of this section is to establish environmental qualification of low voltage power and splice assemblies consisting of Okonite T-95 insulating tape and No. 35 splicing tape for outside containment applications under "local submergence" at PWR/BWR Nuclear Stations. The "local submergence" may result due to accumulation of condensate inside junction/pull boxes without adequate drainage for the condensate.

## D.2 References

D.2.1 Wyle Lab Test Report No. 17961-01, Revision 00, dated 06-20-88; "Qualification Test Program for Okonite Taped "V" and In-line Splices for Commonwealth Edison Company for Use in LaSalle County Nuclear Power Station"

D.2.2 Commonwealth Edison Procedure No. LEP-GM-137, Revision 03, dated 12-07-87; "Methods of Taping Terminations"

## D.3 Similarity Analysis

The tested splice assemblies (test specimens) were constructed to:

1. Reflect installed splice assemblies at LSCS which were made per CECo procedure LEP-GM-137, Revision 03 (Reference D.2.2). These are Specimen Sets 12, 13 and 14.

2. Reflect installed splice assemblies at LSCS which were found during a field walkdwon. These are Specimen Sets 1-4, 6-11, and 15-21.

3. Reflect interface with various miscellaneous cables which were manufactured by vendors other than Okonite Cable Co. This was done to prove material compatibility of the Okonite splice assembly to various cable materials. These are Specimen Sets 4, 11 and 1-21. Note: Specimen Set 15 was built per Okonite drawing No. D-11485.

   Therefore, the tested splice assemblies are identical in form, fit, function and materials of construction to those splice assemblies installed in LSCS after 2-22-83. For existing and future installation of these splice assemblies traceability to the correct T-95 insulating type and 0-35 splicing tape is established from the Wyle Lab test specimen inspection sheets: (Reference D.2.1, Page I-7)

Okonite T-95 insulating tape (tested) = Okonite P/N 602-25-5010

Okonite O-35 splicing tape (tested) = Okonite P/N 602-35-7010

## D.4 Equipment Description (Reference D.2.1, Pages I-7 and VII-4)

The equipment to be qualified consists of various Okonite tape splice configurations located in various outside containment areas at LaSalle County Nuclear Power Station. The cable and connectors used in the construction of the splice assemblies are qualified separately and are not part of the test specimens for the purposes of this analysis. The representative test specimens are 20 specimen sets, each consisting of three specimen subsets, as defined in Tables I and III, and Figures 2 through 6, Reference D.2.1, Section VII.

Each splice assembly was constructed using the following splice tapes:

Okonite T-95 insulating tape = Okonite P/N 602-25-5010

Okonite O-35 splicing (jacketing) tape = Okonite P/N 602-35-7010

## D.5 Performance Requirements/Acceptance Criteria

### D.5.1 Baseline Function Test (Reference D.2.1, Page VII-13)

Each splice assembly shall have its insulation resistance (IR) measured while in contact with a grounded metal surface by application of 500 VDC between its conductor and ground, for a minimum of one minute. The IR is then recorded for information only (i.e., no acceptance criteria is specified).

If the IR measured for any test specimen is equal to or below $5.0 \times 10^5$ ohms the megohmeter output voltage shall be reduced until the IR value is measurable (usually $1.0 \times 10^6$ ohms).

### D.5.2 Intermediate Function Tests (prior to DBE)

The same requirements outlined in Section D.5.1 of this analysis also apply for these tests (Reference D.2.1, Pages VII-14 and -15).

### D.5.3 Accident (DBE) Test/Post Accident (Post-DBE) Test

#### D.5.3.1 Function Test (Reference D.2.1, Pages VII-18 and -19)

Each test specimen (remaining in the test program) shall be IR-tested as described in Section D.5.1 of this analysis at the following times:*

a. Pre-test ambient temperature
b. Pre-test pre-heat chamber temperature
c. Peak DBE temperature
d. Accelerated Post-DBE temperature (212°F) at t = 13, 26, 39 and 54 hours
e. Ambient temperature upon completion of DBE/Post-DBE test

* Except for Specimen Sets 3, 8 and 13.

D.5.4 Acceptance Criteria (Reference D.2.1, Page VII-18 and 19)

The test specimens shall demonstrate electrical integrity during DBE and Post-DBE testing. This is accomplished by connecting all test specimens to the appropriate fused circuits (Figure 7.7). Current loads shall be applied to the test specimen sets as shown in Reference D.2.1, Table III (Pages VII-43 through 48).

During all times of the DBE/Post-DBE test (except when measuring IR) the leakage currents shall be measured and recorded for all specimen sets for information only.

## D.6 Qualification Test Sequence

The test specimens were subjected to the following type test sequence per IEEE 323-1974:

- Receiving Inspection
- Test Sample Preparation (Wyle)
- Visual Inspection
- Baseline Functional Test
- Normal Conditions Radiation Exposure (40-Year Integrated Dose)
- Functional Test
- Thermal Aging
- Functional Test
- Accident Radiation Exposure (includes 10% margin)
- Functional Test
- Additional Thermal Aging
- Functional Test
- Accident/Post-Accident Simulation
- Functional Test
- Post-Test Inspection

## D.7 Evaluation of Qualification Test Results

D.7.1 Test Specimen Receipt Inspection, Preparation and Baseline Function Testing

a. A visual inspection of the specimen equipment, parts and components was conducted. The purpose was to document manufacturer and model numbers of the equipment, components and parts to be tested and any noticeable damage. The inspection items were tagged with Quality Assurance "Test Specimen" tags to facilitate identification during the preparation activities conducted prior to testing. Photographs were taken of the cable splice specimens and a "Test Specimen Inspection" report recorded any defects noted (Reference D.2.1, Pages I-7 through 9).

b. Three specimen splices for each of 20 specimen sets were prepared in accordance with CECo LEP-GM-137 (Reference D.2.2) or splicing/taping methods were used during specimen preparation to reflect as-installed splice configurations. Metal identification tags were applied to each specimen such that 1A, 1B, 1C, 2A, 2B, 2DC, etc., were used for the remainder of the test program for identification purposes.

c. The specimen sets were either "V" or In-line splices fabricated from metallic and non-metallic parts. Okonite rubber cement and tapes were used in the fabrication of each splice. Each specimen set of three splices was assigned to a test group:

Splice Assembly Test Grouping

| Specimen Set | Type Splice | Group Assig. |
|---|---|---|
| 1 | V | Group 1 |
| 2 | V | Group 1 |
| 3 | V | Group 2 |
| 4 | V | Group 1 |
| 5 | - | |
| 6 | In-line | Group 1 |
| 7 | In-line | Group 1 |
| 8 | In-line | Group 2 |
| 9 | In-line | Group 1 |
| 10 | In-line | Group 1 |
| 11 | V | Group 1 |
| 12 | V | Group 1 |
| 13 | V | Group 2 |
| 14 | In-line | Group 1 |

| | | |
|---|---|---|
| 15 | V | Group 1 |
| 16 | In-line | Group 1 |
| 17 | V | Group 1 |
| 18 | In-line | Group 1 |
| 19 | V | Group 1 |
| 20 | In-line | Group 1 |
| 21 | V | Group 1 |

d. Of the Specimen Sets 1 through 21, Specimen Set 5 was not prepared because procurement of Rockbestos No. 14 AWG cable (Product Code E41-0114), with neoprene jacket, was not possible. Specimen Set 5 was then excluded from this and all remaining sections of the test program and all remaining specimen splices were prepared as listed below:

| Specimen Set | 1st Lead* | 2nd Lead* | In-line Splice | Connector | Bolt Size |
|---|---|---|---|---|---|
| 1 | 1 | 2 | No | 3 | 11 |
| 2 | 1 | 2 | No | 3 | 11 |
| 3 | 4 | 4 | No | 5 | 12 |
| 4 | 2 | 2 | No | 3 | 11 |
| | -- | -- | -- | -- | |
| 6 | 1 | 2 | Yes | 3 | 11 |
| 7 | 1 | 2 | Yes | 3 | 11 |
| 8 | 4 | 4 | Yes | 5 | 12 |
| 9 | 2 | 2 | Yes | 3 | 11 |
| 10 | 2 | 2 | Yes | 10 | 12 |
| 11 | 6 | 6 | No | 7 | 11 |
| 12 | 2 | 2 | No | 10 | 12 |
| 13 | 4 | 4 | No | 5 | 12 |
| 14 | 1 | 2 | No | 10 | 12 |
| 15 | 1 | 2 | Yes | 10 | 12 |
| 16 | 8 | 8 | No | 10 | 12 |
| 17 | 8 | 8 | Yes | 10 | 12 |
| 18 | 9 | 9 | No | 3 | 11 |
| 19 | 9 | 9 | Yes | 10 | 12 |
| 20 | 1 | 1 | No | 10 | 12 |
| 21 | 1 | 1 | Yes | 10 | 12 |

*See Notes below for description of specimen set leads.

Notes:

1. Reliance thermofit Spec. 4824-6CM (Nomex) No. 14 AWG.
2. Okonite EPR insulation, Okolon Jacket No. 14 AWG.
3. PIDG ring terminal, 14-16 AWG, No. 10 stud, blue stripe.

4. Okonite EPR insulation, Okolon Jacket No. 2 AWG.
5. Burndy lug terminal, N60, 2 STR CU., brown die.
6. Market flex lead (Belden silicone rubber) No. 18 AWG.
7. PIDG ring terminal, 16-22 AWG, No. 10 stud, red stripe.
8. Rockbestos firewall Specimen, No. 14 AWG.
9. Rockbestos B8483, No. 16 AWG.
10. PIDG ring terminal, 14-16 AWG, 5/16" stud, blue stripe.
11. #8-32 x 1/2" round head machine screw, #8 internal tooth loc..washer. #8-32 hexagon nut (all 18-8 stainless steel).
12. 1/4" x 3/4" round head machine screw, 1/4" flat washer(s), 1/4" internal tooth lockwasher, 1/4"-20 hexagon nut (all 18-8 stainless ...el).

e. Fabrication Methodology (Reference D.2.2, Pages VII-24 through VII-28,) (Figures D.1 through D.5):

| | |
|---|---|
| Specimens 1A, 1B, 1C - | T-95 tape - two half lapped layers - no overlap of wire insulation O-35 tape - two half lapped layers -tape extends ½" past end of lug barrel. |
| Specimens 2A, 2B, 2C - | T-95 tape - two half lapped layers - overlaps terminal lugs ¼" O-35 tape - two half lapped layers - tape extends ½" past end of lug barrel. |
| Specimens 3A, 3B, 3C - | Single half lapped over cable insulation extending 1/3" -T-95 tape - two half lapped layers over connection area on lugs - O-35 tape extends 3/4" past end of lug barrel. |
| Specimens 4A, 4B, 4C - | T-95 tape - two half lapped layers extends ¼" past end of terminal lug barrel. |
| Specimens 6A, 6B, 6C - | In-line splices - same overlap as 1A, 1B, 1C. |
| Specimens 7A, 7B, 7C - | In-line splices - same overlap as 2A, 2B, 2C. |
| Specimens 8A, 8B, 8C - | In-line splices - same overlap as 3A, 3B, 3C. |
| Specimens 9A, 9B, 9C - | In-line splices without T-95 tape overlap over wire insulation. Tape O-35 overlaps ½" past end of lug barrel. |
| Specimens 10A, 10B, 10C - | Same as 4A, 4B, 4C. |
| Specimens 11A, 11B, 11C - | Same as 4A, 4B, 4C. |

f. An insulation resistance measurement was performed to satisfy the baseline functional test requirement. 500 VDC for 1 minute was applied between a conductor of the splice and ground. Resistance was recorded for each specimen. Lowest resistance was $9 \times 10^9$ ohms for specimen 10B; highest resistance was $5.8 \times 10^{13}$ ohms for Specimen 18A (Reference D.2.1, Pages I-23 and I-24).

## D.8 Normal Radiation Exposure Test

The test specimens were irradiated in two groups which were mounted in two metallic cable trays. The total dosage was $6.0 \times 10^6$ rads (gamma) from a Cobalt 60 source (cumulative TID) at a rate of $3.78 \times 10^5$ rads/hr. The test arrangement was: (Reference D.2.1, Pages II-1 and 5)

| Specimen Sets | Cable Tray |
|---|---|
| 3, 8, 14, 15, 16, 17, 18, 19, 20, 21 | 1 |
| 1, 2, 4, 6, 7, 9, 10, 11, 12, 13 | 2 |

Visual inspection was undertaken after completion of normal radiation exposure. Inspections looked for physical damage on other visible defects (Reference D.2.1, Page II-2).

There was no evidence of degradation of the specimens sets due to radiation exposure of the other specimens. The observations noted are not significant in effecting specimen electrical integrity.

## D.9 Thermal Aging Test

The test specimens mounted in metal trays as noted in Section D.8 were placed in a thermal aging chamber at a temperature of 130°C (266°F +9° -0°) for the test periods stated herein: (unenergized state)

| Specimen Sets | Total Aging Times (hours) |
|---|---|
| 3, 8, 13 | 336.5 |
| 1, 2, 4, 6, 7, 9, 10, 11, 12, 14<br>15, 16, 17, 18, 19, 20, 21 | 196.25 |
| 11 | 170.25 |

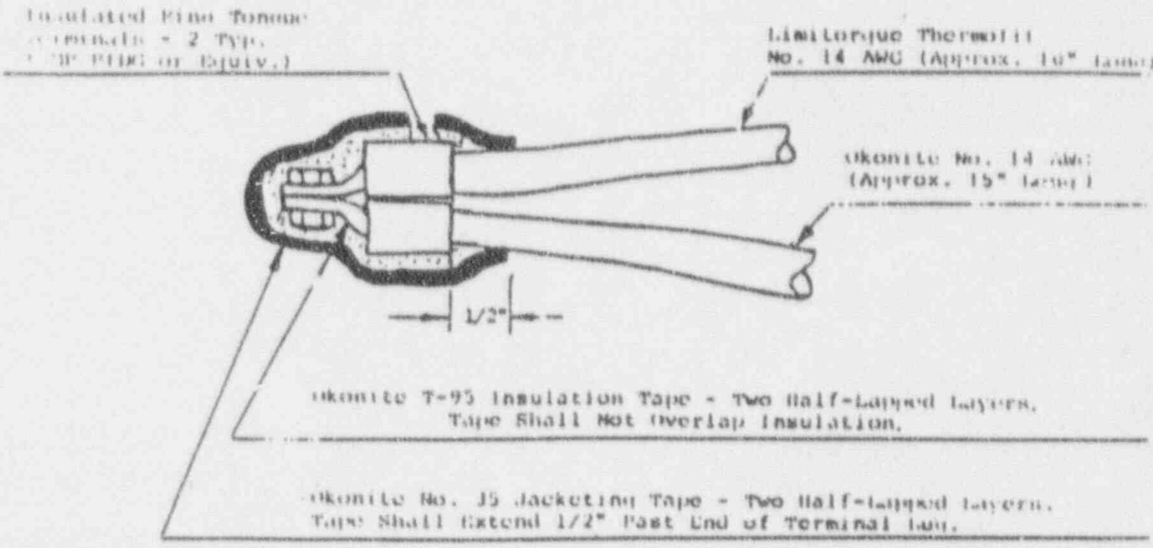



Figure D.1: Specimens 1A, 1B, 1C, 2A+, 2B+, 2C+, 6A*, 6B*, 6C*, 7A++, 7B++, 7C++, 14A**, 14B**, 14C**, 15A***, 15B***, 15C***

Notes:

1. Okonite cement to be applied prior to taping.
2. *In-line splices with the same overlap as 1A, 1B, 1C. CECo to specify connectors.
3. **Same configuration as 1A, 1B, & 1C splices: 4 half-lapped layers of T-95 tape with 1" overlap, 2 half-lapped layers of No. 35 tape with 1-1/2" overlap.
4. ***Same configuration as 6A, 6B & 6C splices: 8 half-lapped layers of T-95 tape with 1-3/8" overlap, 2 half-lapped layers of No. 35 tape with 2-3/8" overlap.
5. +Same configuration as 1A, 1B, 1C splices: T-95 tape overlap of 1/4".
6. ++In-line splices with the same overlap as 2A, 2B, 2C splices

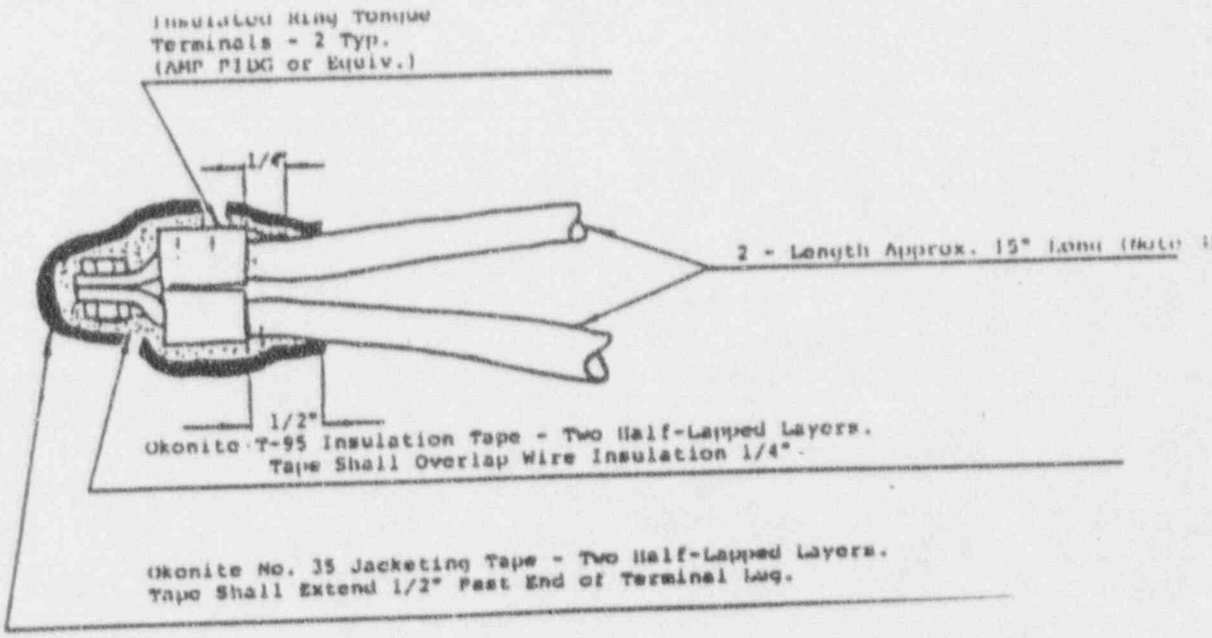



Figure D.2: Specimens 4A, 4B, 4C, 5A, 5B, 5C, 10A, 10B, 10C, 11A, 11B, 11C

Notes:

1. Okonite cement to be applied prior to taping.

2. 10A, 10B 10C are in-line splices with the same overlap as shown.
   CECo to specify connectors.

3. Two lengths of Okonite No. 14 AWG for Specimens 4A, 4B, 4C and 10A, 10B, 10C.

   Two lengths of Rockbestos No. 14 AWG Cable (Rockbestos Product Code E41-0114) with neoprene jacket, taping over jacket for Specimens 5A, 5B, 5C.

   Two lengths of Markel Flexlead CSA (SOR Pigtail) for Specimens 11A, 11B, 11C.

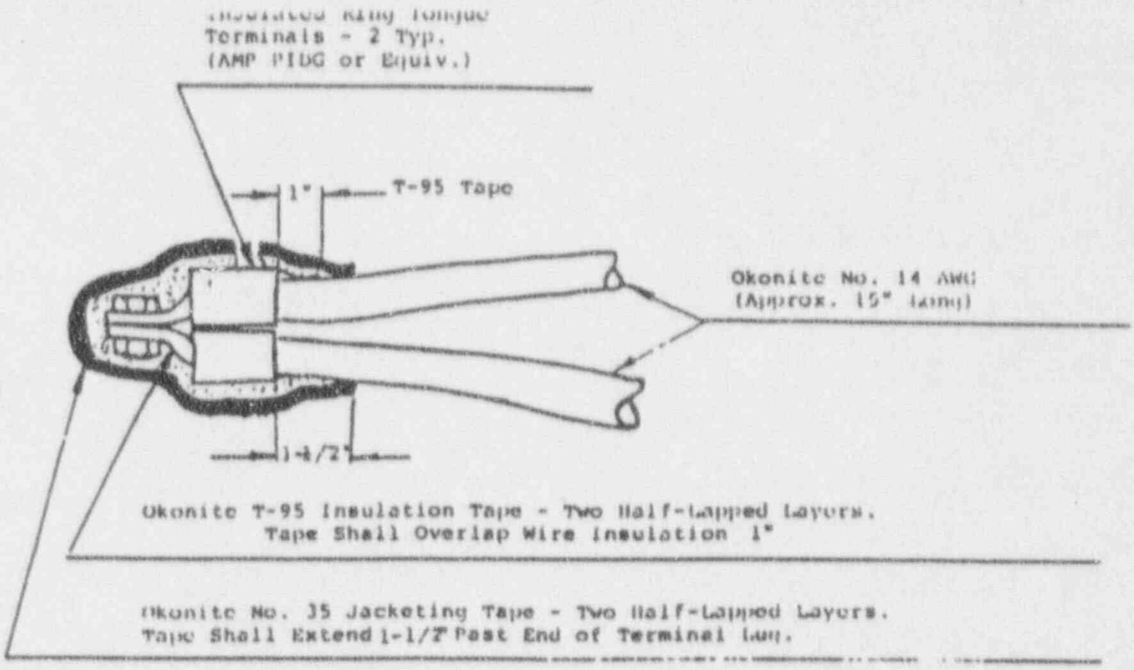



Figure D.3: Specimens 12A, 12B, 12C, 9A*, 9B*, 9C*

Notes:
1) Okonite cement to be applied prior to testing.
2) *In-line splices without T-95 tape overlap over wire insulation and with tape No. 35 overlap of 1/2" over the wire insulation past end of terminal lug.
3) CECo to specify connectors

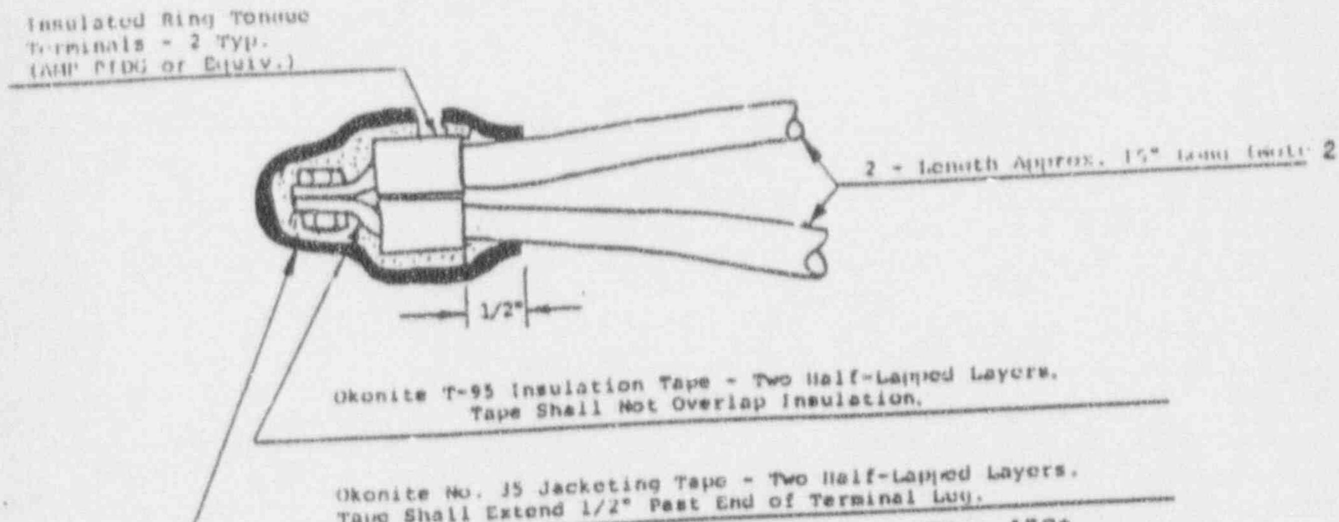



**Figure D.4: Specimens 16A, 16B, 16C, 17A*, 17B*, 17C*,
18A, 18B, 18C, 19A*, 19B*, 19C*,
20A, 20B, 20C, 21A*, 21B*, 22C***

Notes:
1) Okonite cement to be applied prior to taping.
2) Two lengths of SIS switchboard wire #14AWG for specimens 16A, 16B, 16C and 17A, 17B, 17C
   Two lengths of Rockbestos 88483 # 16 AWG for specimens 18A, 18B, 18C, and 19A, 19B 19C.
   Two lengths of Nomex #14AWG for specimens 20A, 20B, 20C, and 21A, 21B, 21C
3) *In-line splices with the same overlap and number of tape layers
4) CECo to specify connectors

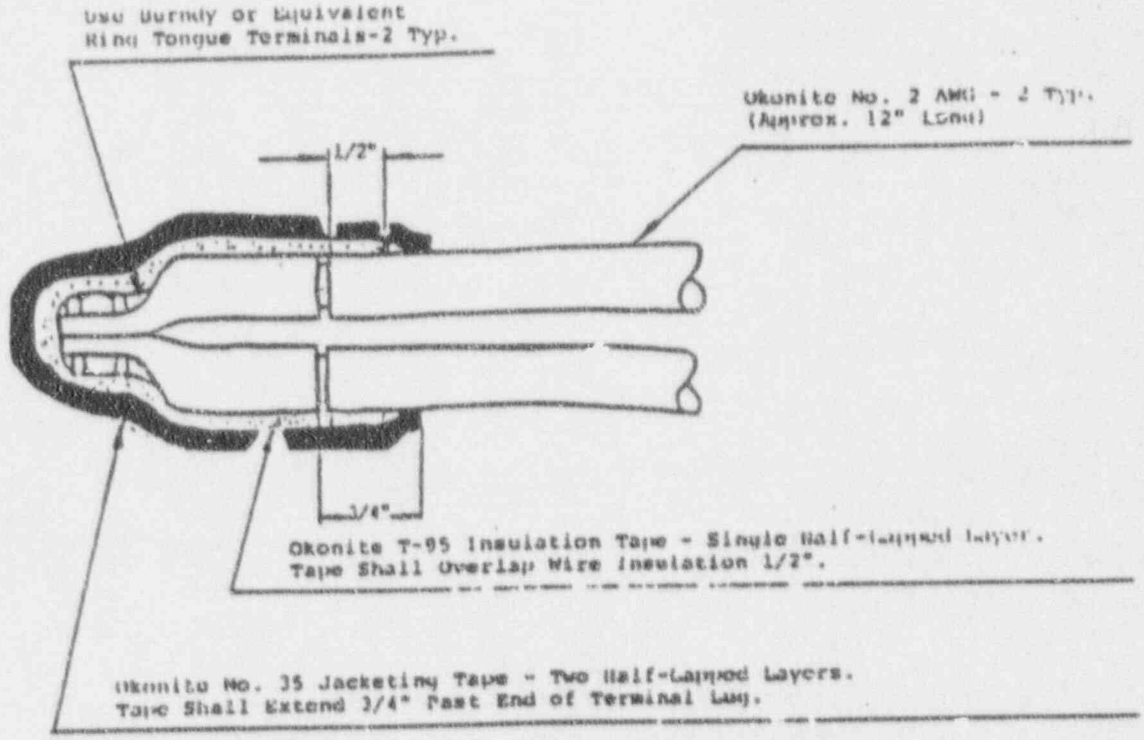



Figure D.5: Specimens 3A+, 3B+, 3C+, 8A*, 8B*, 8C*,
13A**, 13B**, 13C**

Notes:

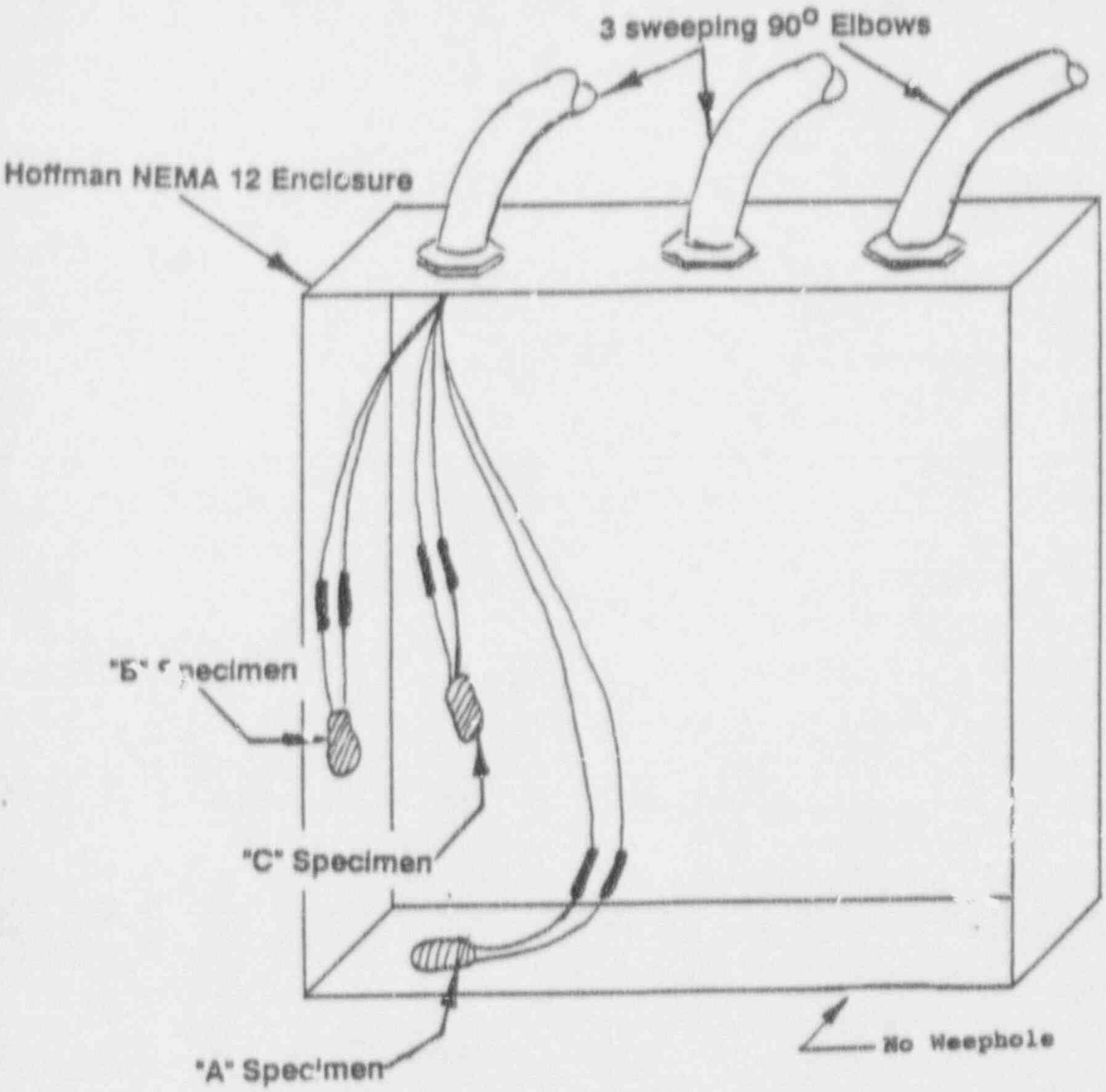
1) Okonite cement to be applied prior to taping

2) *In-line splices with the same overlap. CECo to specify connetors.

Bolt to be softened with T-95 insulation tape prior to installation of T-95 tape overlapping cable insulation.

3) **The same configuration as 3A, 3B & 3C splices: 4 half-lapped layers of T-95 tape with 1" overlap, 2 half-lapped layers of No. 35 tape with 1-1/2 overlap.

4) + Single half-lapped only over cable insulation. Two half-lapped layers over connection area.



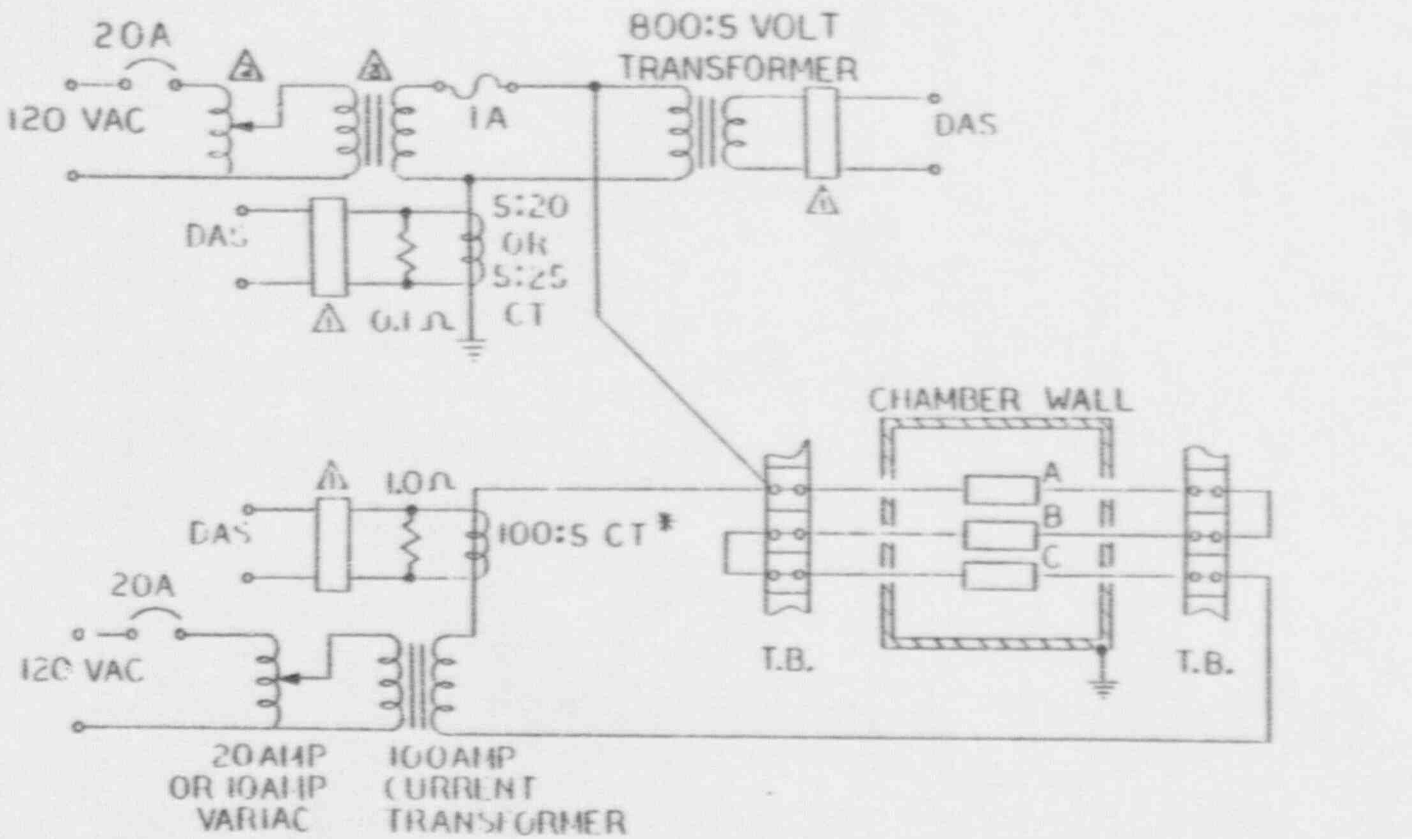

Hoffman NEMA 12 Enclosure with 3 sweeping 90° Elbows and 1/4" weep hole in bottom

"A" Specimen touching bottom

"B" Specimen touching side wall

"C" Specimen suspended in air

Figure D.6: Typical Location of Test Specimens inside the Hoffman Enclosure




* THREE LOOPS THROUGH CT RESULTING IN A 33:5 RATIO

△1 AC/DC CONVERTER

△2 CIRCUITS 1-20 ; 1 20AMP VARIAC PER 5 ISOLATION TRANSFORMERS
CIRCUIT 21; 1 15AMP VARIAC

△3 ISOLATION TRANSFORMERS – CIRCUITS 1-20; 120:600 VOLT
CIRCUIT 21; 120:480 VOLT

**Figure D.7: Electrical Power Circuit**

As each specimen sets completed their total thermal aging periods, they were removed from the test chamber and visual inspections and functional tests were conducted (Reference D.2.1, Section II, Paragraph 2.2).

**Post-Thermal Aging Functional Test**

Insulation resistance was measured at 500 VDC for 1 minute between a splice conductor and g round resistance was recorded for each specimen lowest resistance reading was $1.8 \times 10^{10}$ ohms for specimen 14B. (Reference D.2.1, Pages V-15 through V17)

## D.10 Accident Radiation Exposure Test

The test specimens were irradiated in the same manner described in Section 7.8 of this analysis. The specimens received a TID for t his test phase of $4.01 \times 10^6$ rads of Cobalt-60 (gamma) radiation at a dose rate of $2.42 \times 10^5$ rads/hour. (Reference D.2.1, Pages IV-1 and 5).

The TID for the specimens is $6.00 \times 10^6$rads + $4.01 \times 10^6$ rads = $1.01 \times 10^7$ rads. This satisfies the outside containment requirement for a TID of $1.0 \times 10^7$ rads for all zones.

Post Accident Radiation function Tests revealed a minimum IR value measured of $2.5 \times 10^{11}$ ohms (Specimen 1C) which is well within acceptable values. (Reference D.2.1, Pages IV - 14)

## D.11 Additional Thermal Aging Test

Due to insufficient thermal aging, the test specimens were additionally thermally aged at a temperature of 130°C for the following durations: (Reference D.2.1, Page V-1)

| Specimen Sets | Additional Aging Time (hours) | Total Aging Time (hours) |
|---|---|---|
| 3, 8 and 13 | 1,095.6 | 1,432 |
| 1, 2, 4, 6, 7, 9, 10, 12, 14, 15, 16, 17, 19, 20 and 21 | 70.25 | 266.5 |
| 11 | Not Required | 170.25 |

**Post Thermal Aging Function Test**

The lowest IR measured for any specimen was $1.8 \times 10^{10}$ ohms (Specimen 14B) which is well within an acceptable range of IR values. (Reference D.2.1, Pages V-15 through 17)

## D.12 Accident/Post-Accident Test

D.12.1 Test Configuration (Reference D.2.1, Pages VI-1 through 4)

Group I Specimen Sets, with each specimen set consisting of specimen splices A through C, were connected to Wyle test leads (No. 14 AWG Teflon wire) using butt splices. The specimen/lead splices were sealed using Raychem WCSF-N heat shrink tubing. the splices of each specimen set were mounted in a Nema 12 enclosure, of dimensions 36"H x 48"L x 12"W, such that splice A was in contact with the bottom of the enclosure, splice B was in contact with the side of the enclosure, and splice C was suspended free in air (Figure D.6). A weep hole for the Nema 12 enclosure was sealed in order to allow any condensation on the inside of the enclosure to accumulate in the bottom. The Wyle test leads for the specimen sets were routed out of the Nema 12 enclosure through two 2-inch Myers hubs connected to 2-inch sweeping 90° conduits. The Wyle test leads for each specimen circuit (specimen splices A, B, and C) were intentionally routed such that all leads of a given circuit entered and exited the Nema 12 enclosure through the same 2-inch penetration (Photographs D.1, D.2, D.3, D.4, D.5, D.6, D.7, D.8).

D.12.2 Electrical Powering

The Wyle test leads were routed through a Wyle chamber penetration and the penetration sealed as per Wyle Laboratories' standard practice. The Wyle test leads were connected to terminal blocks outside of the test chamber and electrical loads were applied as shown in Figure D.7 (Reference D.2.1, Section VI). With the electrical loads connected to the test specimen set circuits, the voltages were adjusted to 305 VAC with a tolerance of +10%, -0% and the currents were adjusted to 2.0 amps (Specimen Set 11) and 6.7 amps (all remaining specimen sets) with tolerances of +10%, -0% during the transient and +5%, -0% for the remainder of the accident simulation.

Group II specimens, with each specimen set consisting of Specimen Splices A through C, were connected to Wyle test leads (No. 2 AWG Teflon wire) using butt splices. The specimen/lead splices were sealed using Raychem WCSF-N heat shrink tubing. The splices of each specimen set were mounted in a Nema 12 enclosure of dimensions of 36"H x 48"L x 12"W, such that splice A was in contact with the bottom of the enclosure, splice B was in contact with the side of the enclosure, and splice C was suspended in free air (Figure D.6). A weep hole for the Nema 12 enclosure was sealed in order to allow any condensation on the inside of the enclosure to accumulate in the bottom. The Wyle test leads for the specimen sets were routed out of the enclosure through three 2-inch Myers hubs connected to 2-inch sweeping 90° conduits. the Wyle test leads for each specimen circuit (Specimen Splices A, B, and C) were intentionally routed such that all leads of a given circuit entered and exited the Nema 12 enclosure through the same 2-inch penetration (Photographs D.9, D.10, D.11, D.12).

D.12.3 Evaluation of Accident Portion of Test

Examination of the first six hours of testing for both test groups reveals that all test specimens were exposed to test temperatures in excess of the required 212°F +15°F margin (Figure D.8). (See Pages VI-71 and VI-101, Reference D.2.1).

One test anomaly occurred during the accident part of the DBE/Post-DBE test for the Group I test specimens.

D.12.4 Electrical Integrity

Electrical power to the specimen sets was applied in the manner depicted in the test report (Reference D.2.1, Appendix II of Section VI, Figure 1), voltage, load current and leakage current were monitored continuously and recorded (Reference D.2.1, Table III of Section VII):

| Test Voltage (VAC) | Test Current (A) | Specimen Sets (No.) |
|---|---|---|
| 305 (+10%, -0%) | 6.7 | 1 through 10<br>12, 14 through 21 |
| | 2.0 | 11 |
| | 64.0 | 3, 8, 13 |

The test specimens were subjected to an insulation resistance test at the start of the test program and immediately after Radiation, Thermal Aging and Accident Exposure test portions of the program.

Peak Leakage Current Data

All environmental channels were monitored during the accident simulation test phase of the program.

| Group I* Specimen No. | Heat Rise (°C) | Peak Leakage Current (mA) |
|---|---|---|
| 1 | 3.5 | 6 |
| 2 | 3.5 | 21 |
| 4 | 3.5 | 19 |
| 6 | 3.5 | 11 |
| 7 | 3.5 | 23 |
| 9 | 3.5 | 13 |
| 10 | 3.5 | 9 |
| 11 | 0.0 | 17 |
| 12 | 3.5 | 8 |
| 14 | 3.5 | 59 |
| 15 | 3.5 | 9 |
| 16 | 3.5 | 1 |
| 17 | 3.5 | 1 |
| 18 | 3.5 | 10 |
| 19 | 3.5 | 7 |
| 20 | 3.5 | 27 |
| 21 | 3.5 | 8 |

* Figures D.9 through D.25

| Group II** Specimen No. | Heat Rise (°C) | Peak Leakage Current (mA) |
|---|---|---|
| 3 | 17.3 | 1 |
| 8 | 17.3 | 6 |
| 13 | 17.3 | 3 |

** Figures D.26 through D.28

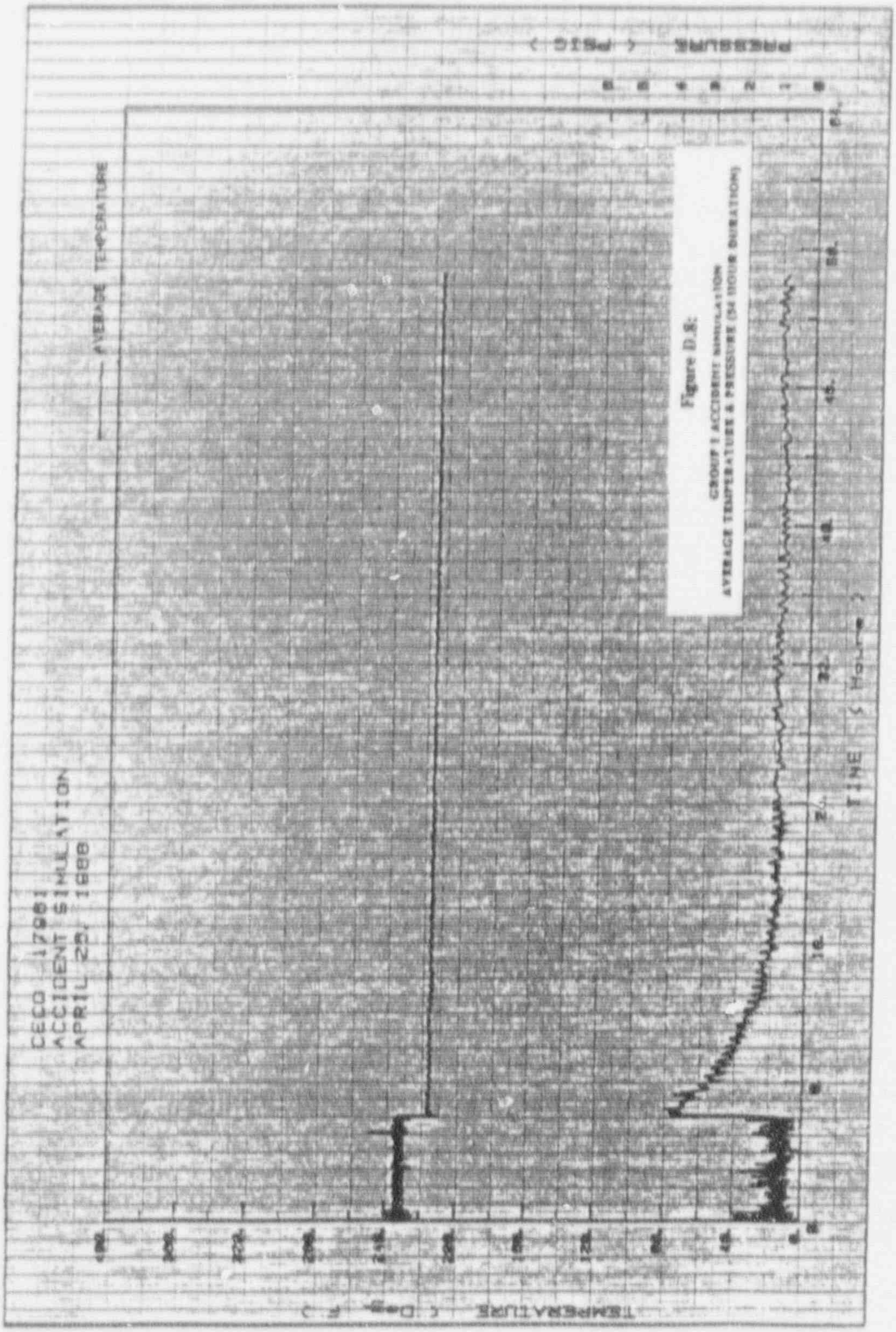
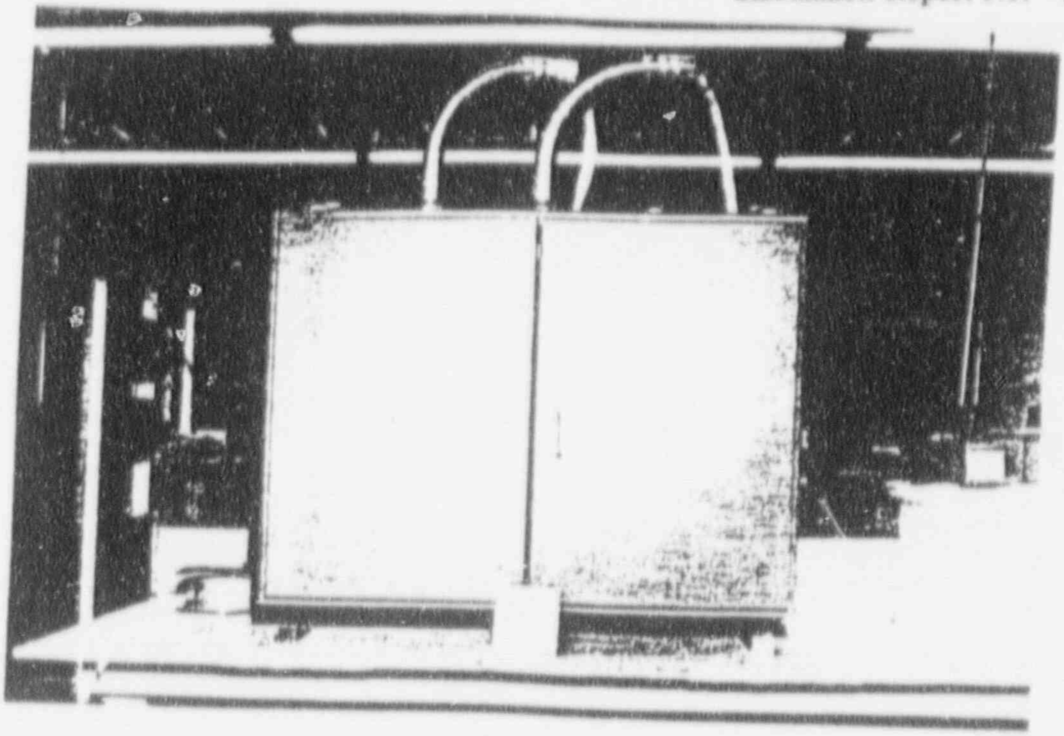
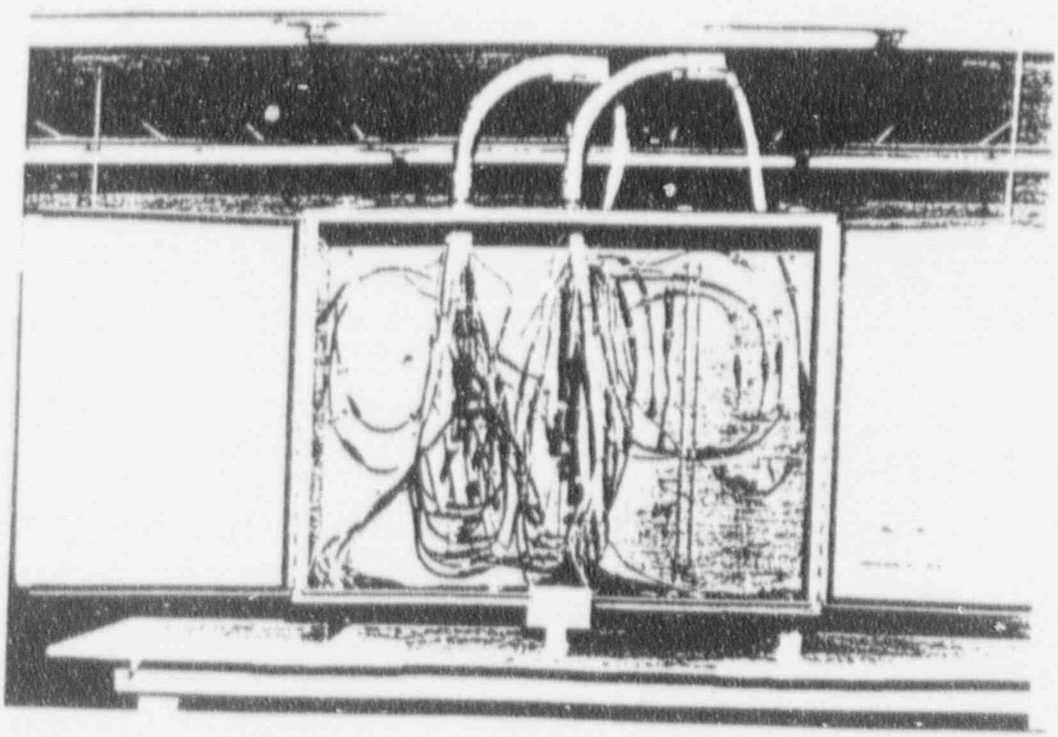



Figure D.8:
GROUP I ACCIDENT SIMULATION
AVERAGE TEMPERATURE & PRESSURE (54 HOUR DURATION)



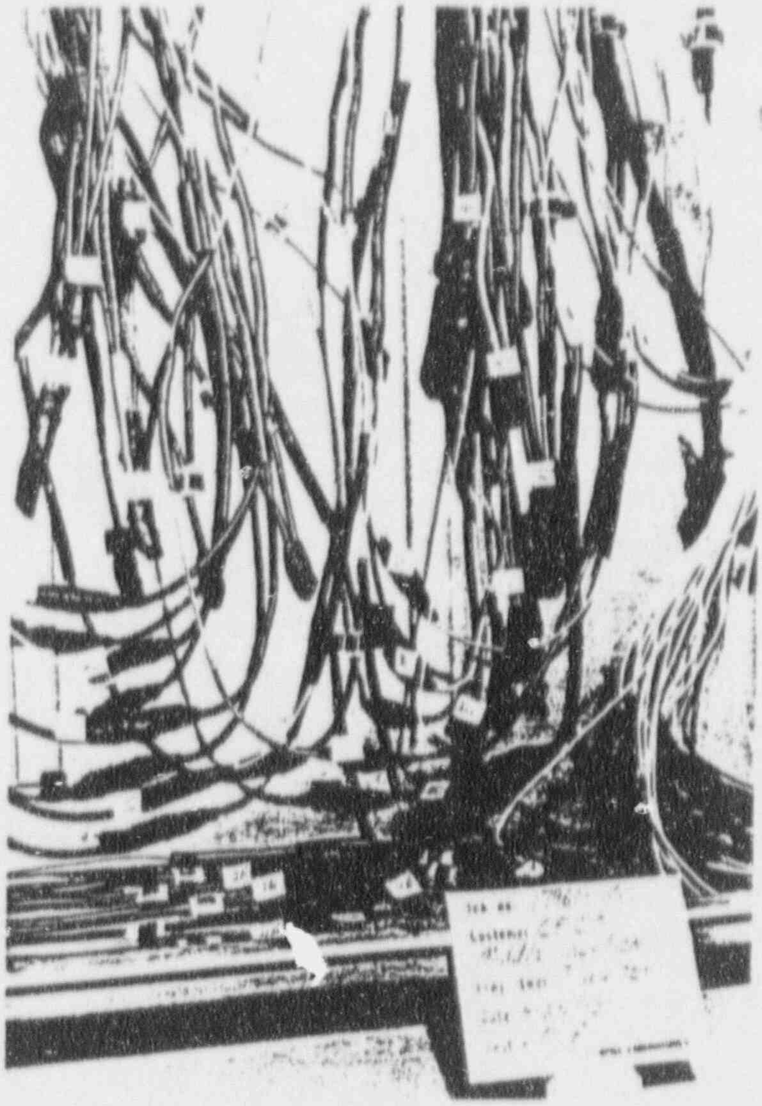
PHOTOGRAPH D.1

GROUP I ACCIDENT TEST SETUP
NEMA 12 ENCLOSURE



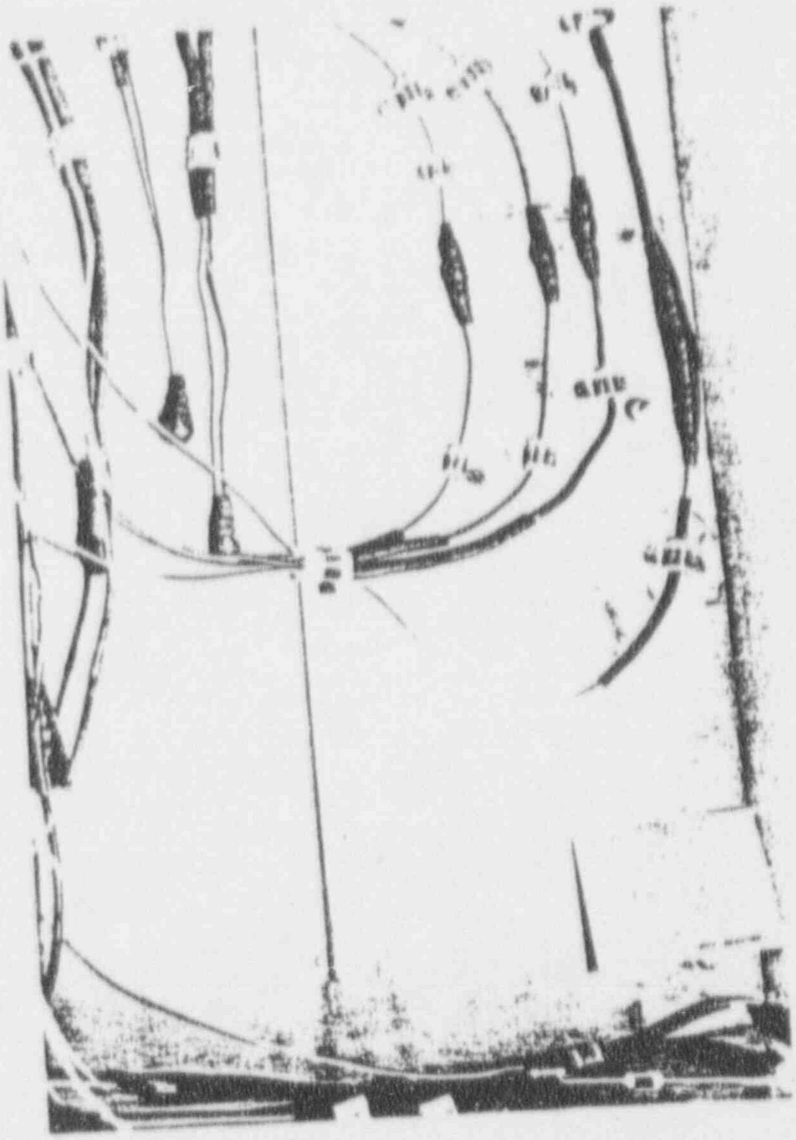
PHOTOGRAPH D.2

GROUP I ACCIDENT TEST SETUP
SPECIMEN SETS MOUNTED IN ENCLOSURE



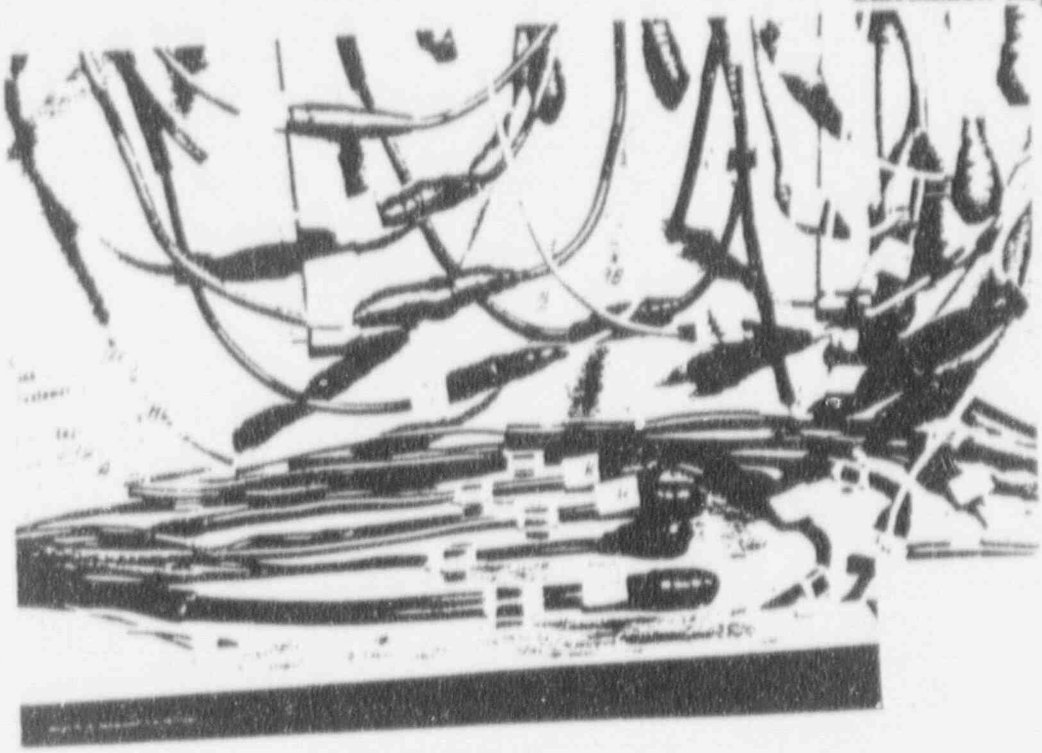
PHOTOGRAPH D.3

GROUP I ACCIDENT TEST SETUP
SPECIFIC MOUNTING OF SPLICES



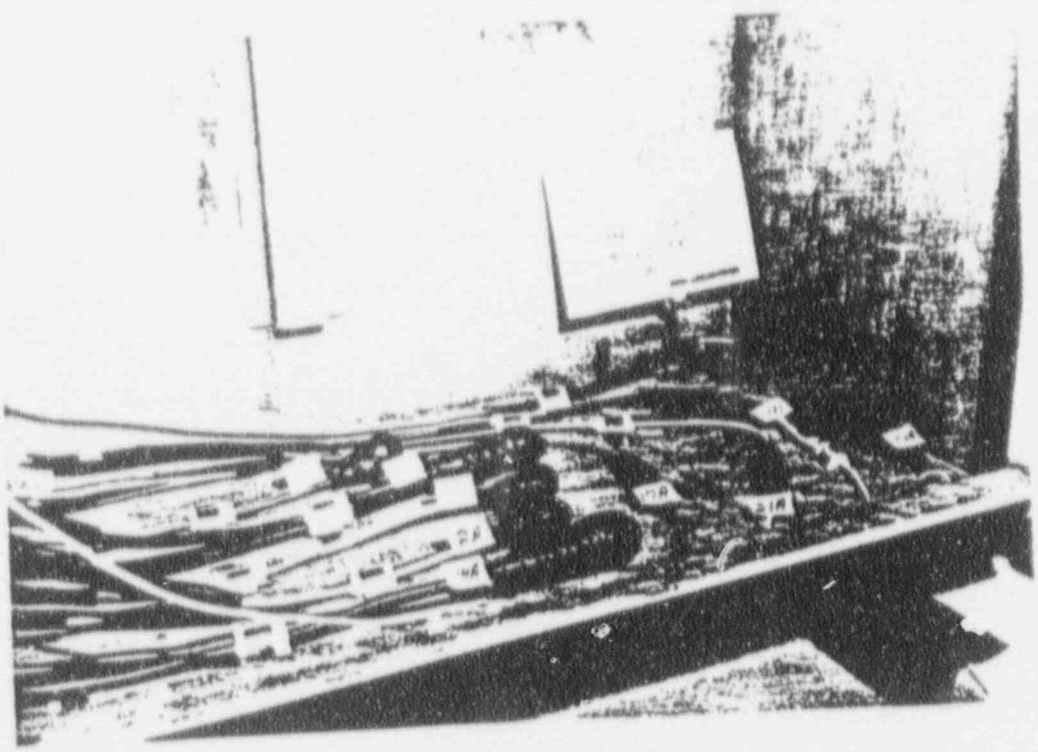
PHOTOGRAPH D.4

GROUP I ACCIDENT TEST SETUP
SPECIFIC MOUNTING OF SPLICES



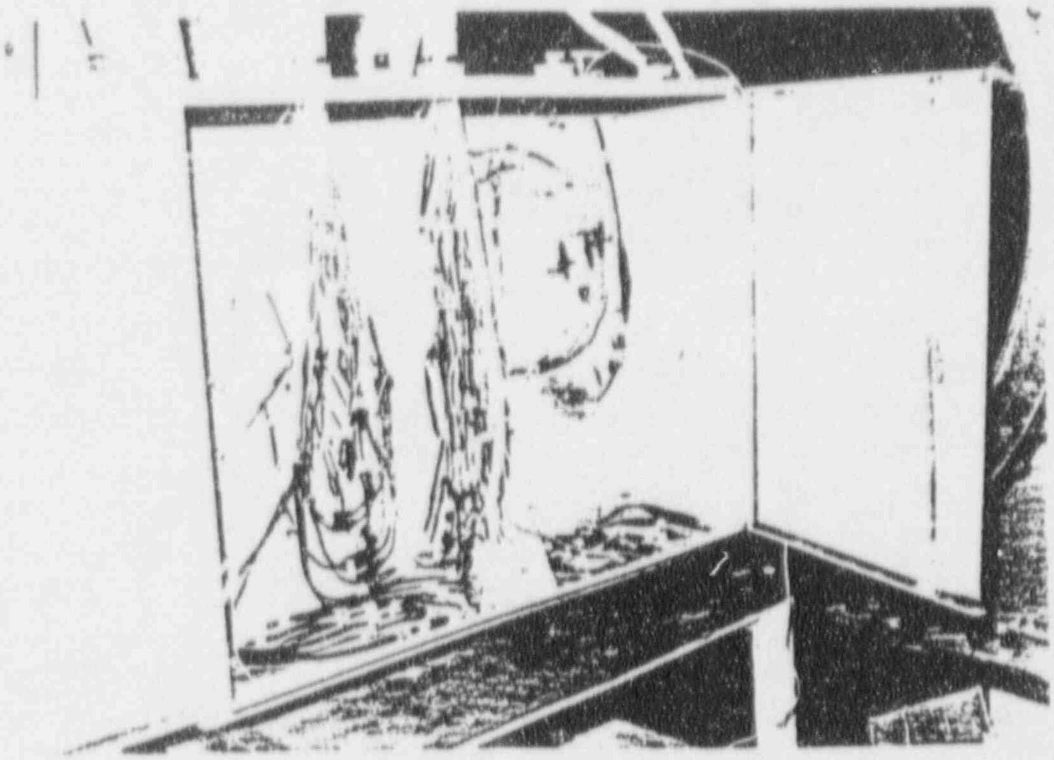
PHOTOGRAPH D.5

GROUP I ACCIDENT TEST SETUP
SPECIFIC MOUNTING OF SPLICES



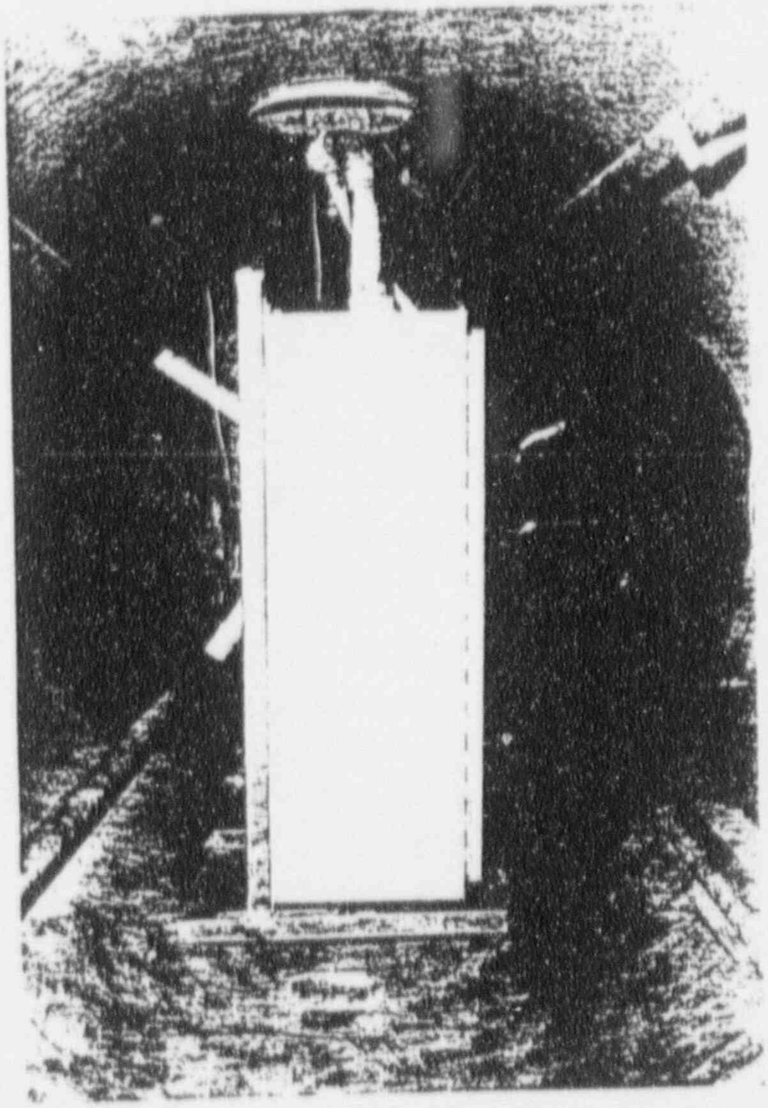
PHOTOGRAPH D.6

GROUP I ACCIDENT TEST SETUP
SPECIFIC MOUNTING OF SPLICES



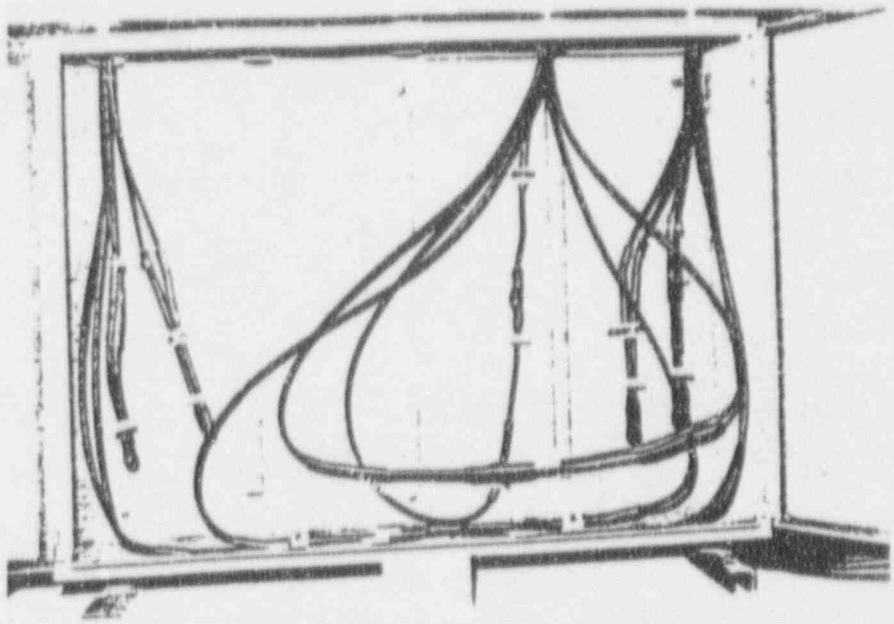
PHOTOGRAPH D.7

GROUP I ACCIDENT TEST SETUP
SPECIMEN SETS IN ENCLOSURE PRIOR TO MOUNTING IN TEST CHAMBER



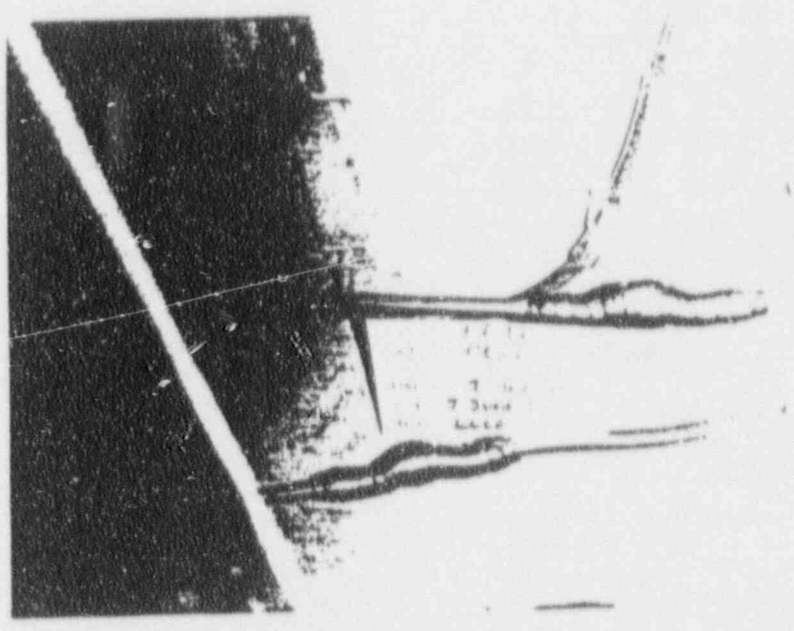
PHOTOGRAPH D.8

GROUP I ACCIDENT TEST SETUP
ENCLOSURE MOUNTED IN TEST CHAMBER



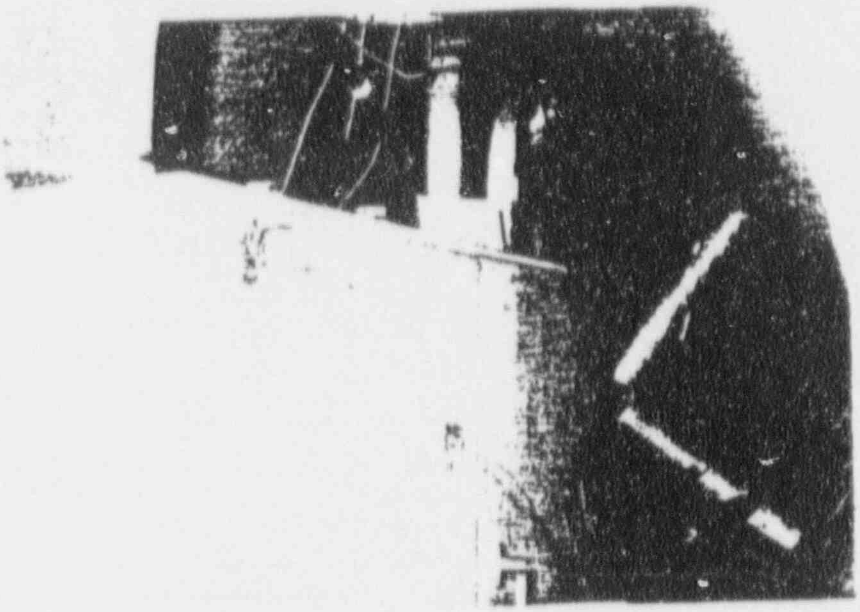
PHOTOGRAPH D.9

GROUP II ACCIDENT TEST SETUP
SPECIMEN SETS MOUNTED IN ENCLOSURE



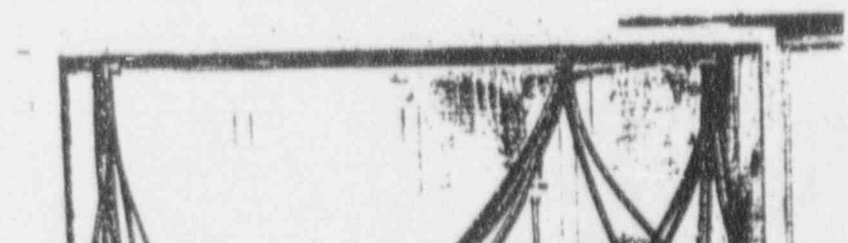
PHOTOGRAPH D.10

GROUP II ACCIDENT TEST SETUP
SPECIFIC MOUNTING OF SPLICES



PHOTOGRAPH D.11

GROUP II ACCIDENT TEST SETUP
ENCLOSURE MOUNTED IN TEST CHAMBER WITH
T/C NOS. 2 AND 3 ATTACHED



PHOTOGRAPH D.12

GROUP II POST-TEST INSPECTION
SPECIMEN SETS MOUNTED IN ENCLOSURE

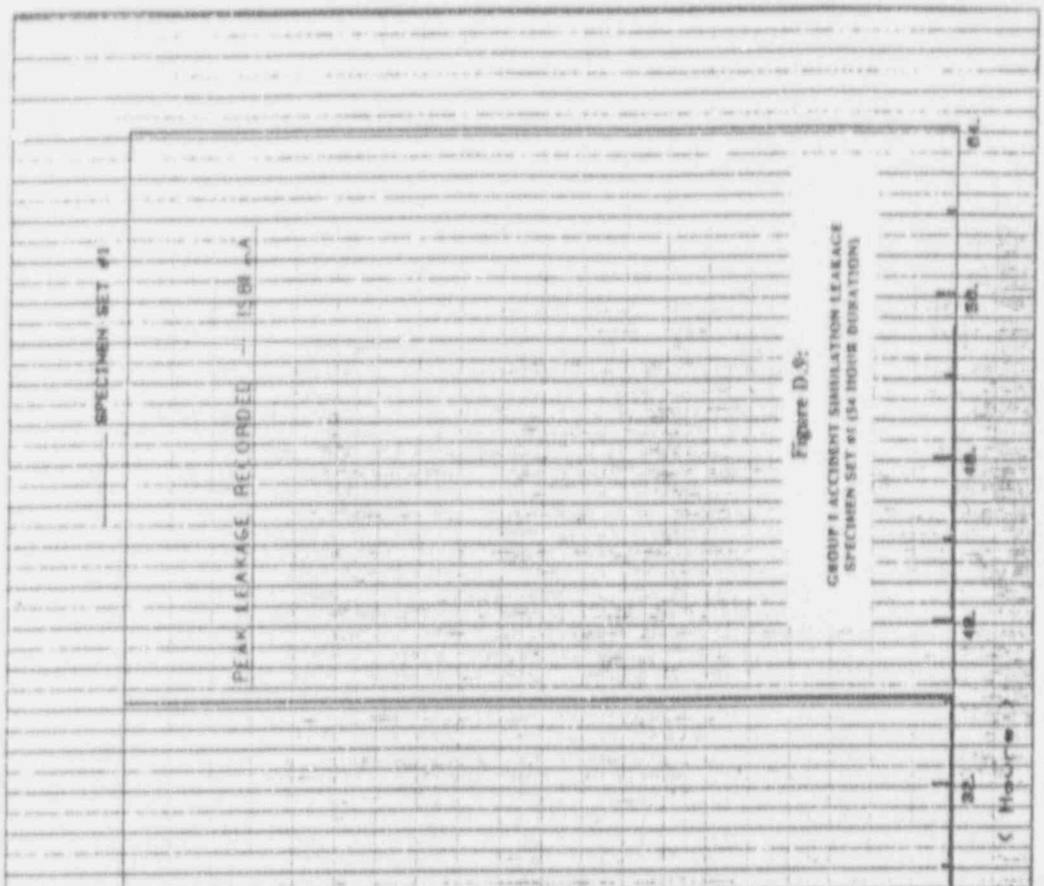



Figure D.9:

GROUP I ACCIDENT SIMULATION LEAKAGE
SPECIMEN SET #1 (54 HOUR DURATION)

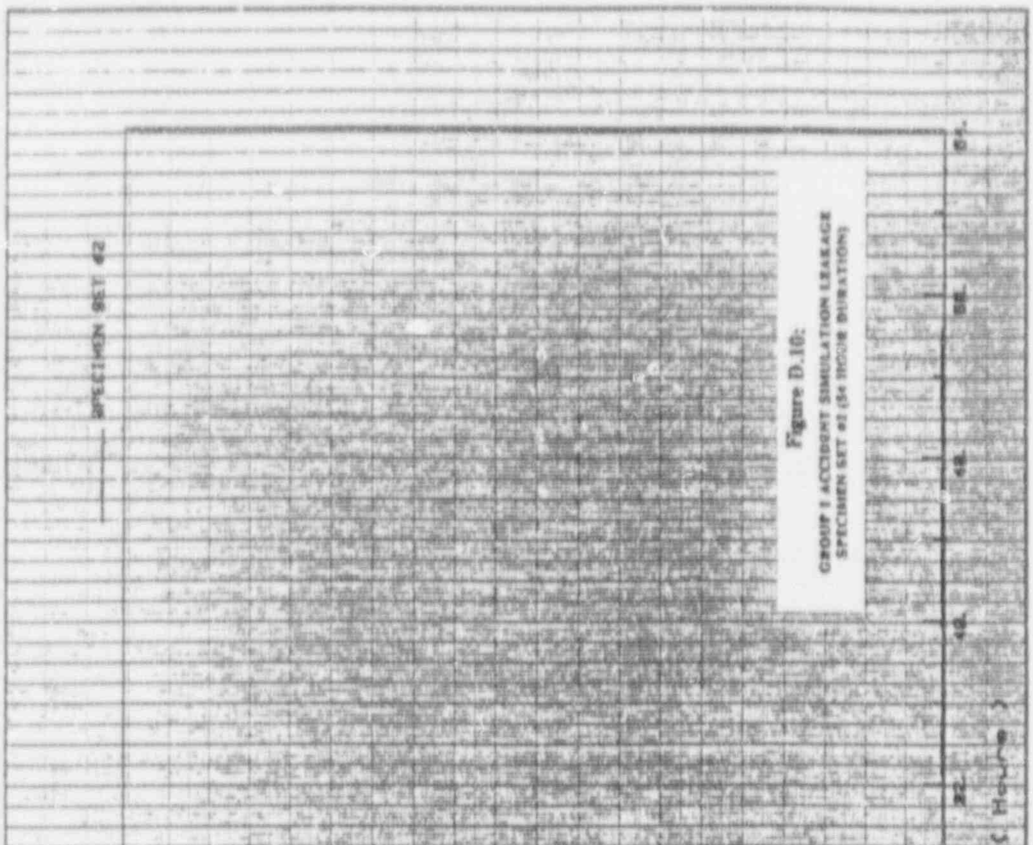



Figure D.10:
GROUP I ACCIDENT SIMULATION LEAKAGE
SPECIMEN SET #2 (54 HOUR DURATION)

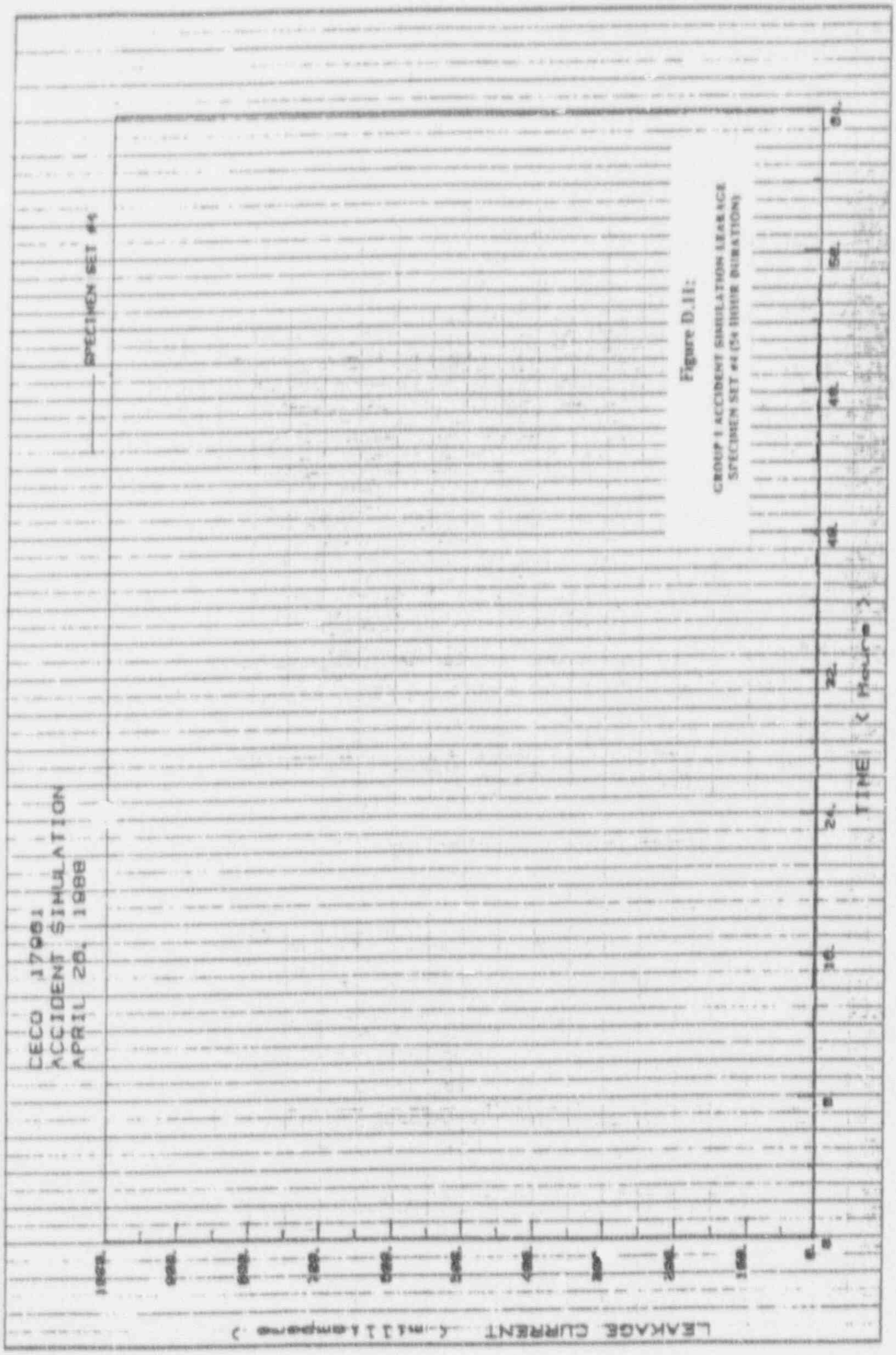



Figure D.11:
GROUP 1 ACCIDENT SIMULATION LEAKAGE
SPECIMEN SET #4 (54 HOUR DURATION)

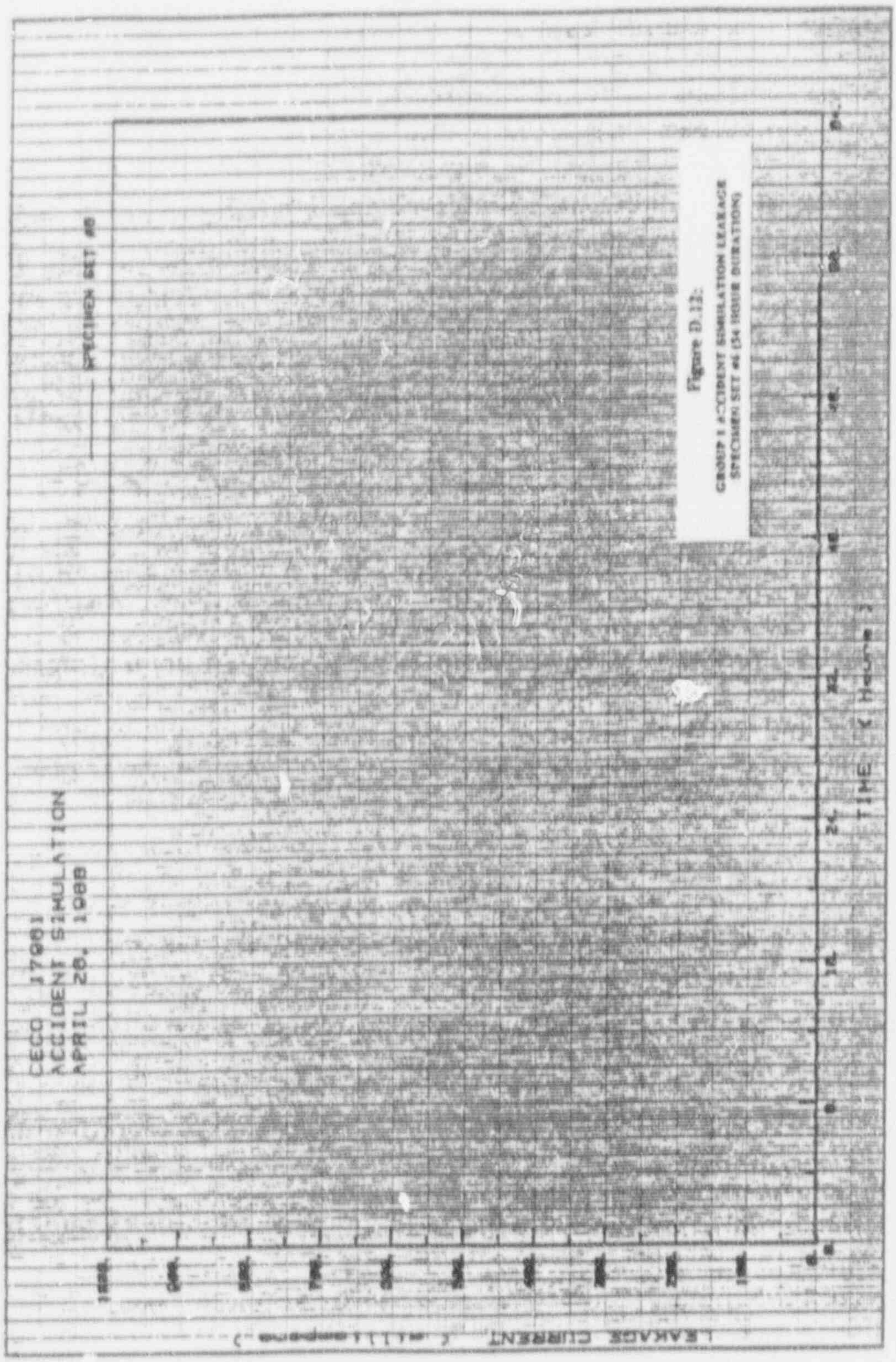



Figure D.12:
GROUP I ACCIDENT SIMULATION LEAKAGE
SPECIMEN SET #6 (34 HOUR DURATION)

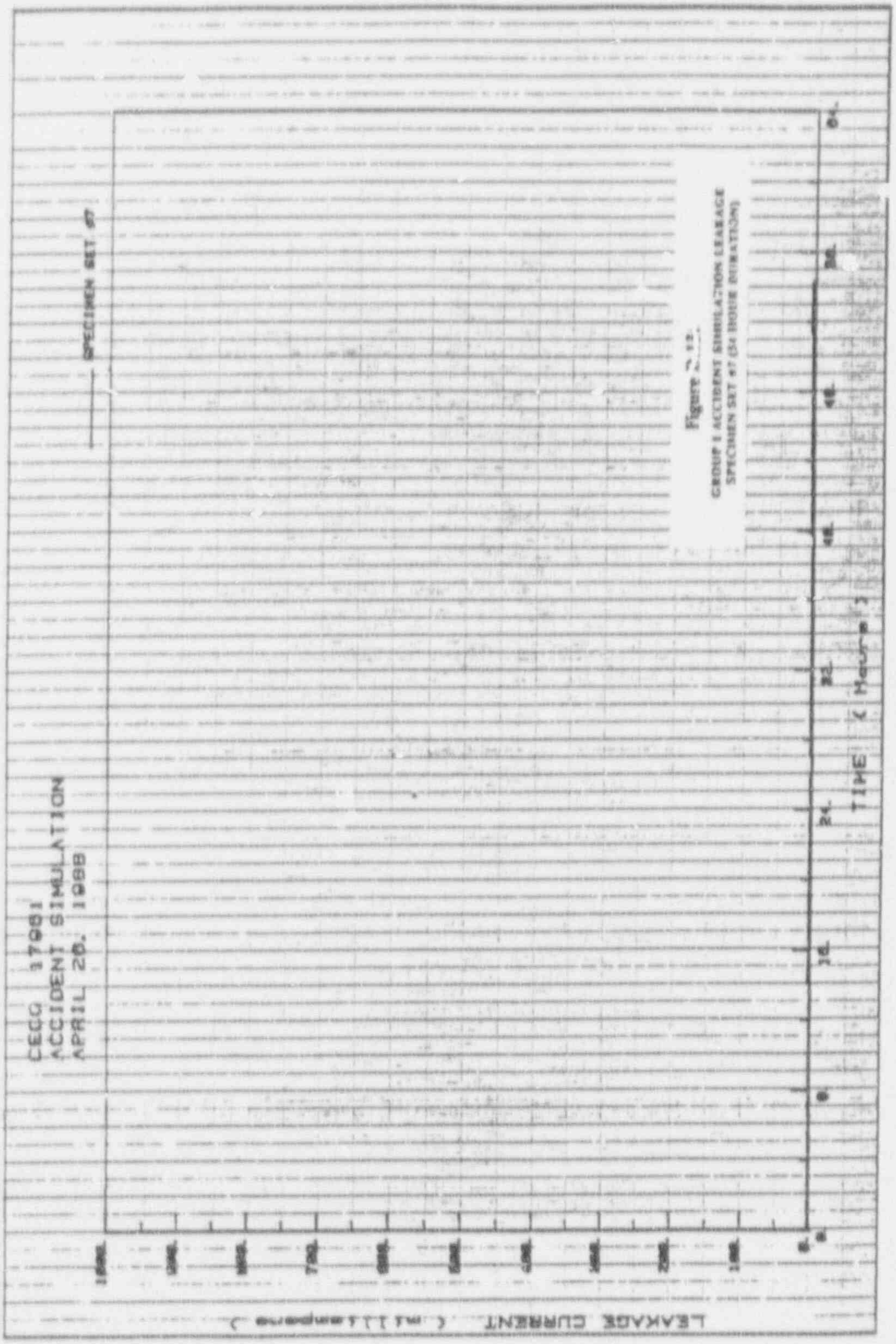



Figure 2.12
GROUP I ACCIDENT SIMULATION LEAKAGE
SPECIMEN SET #7 (54 HOUR DURATION)

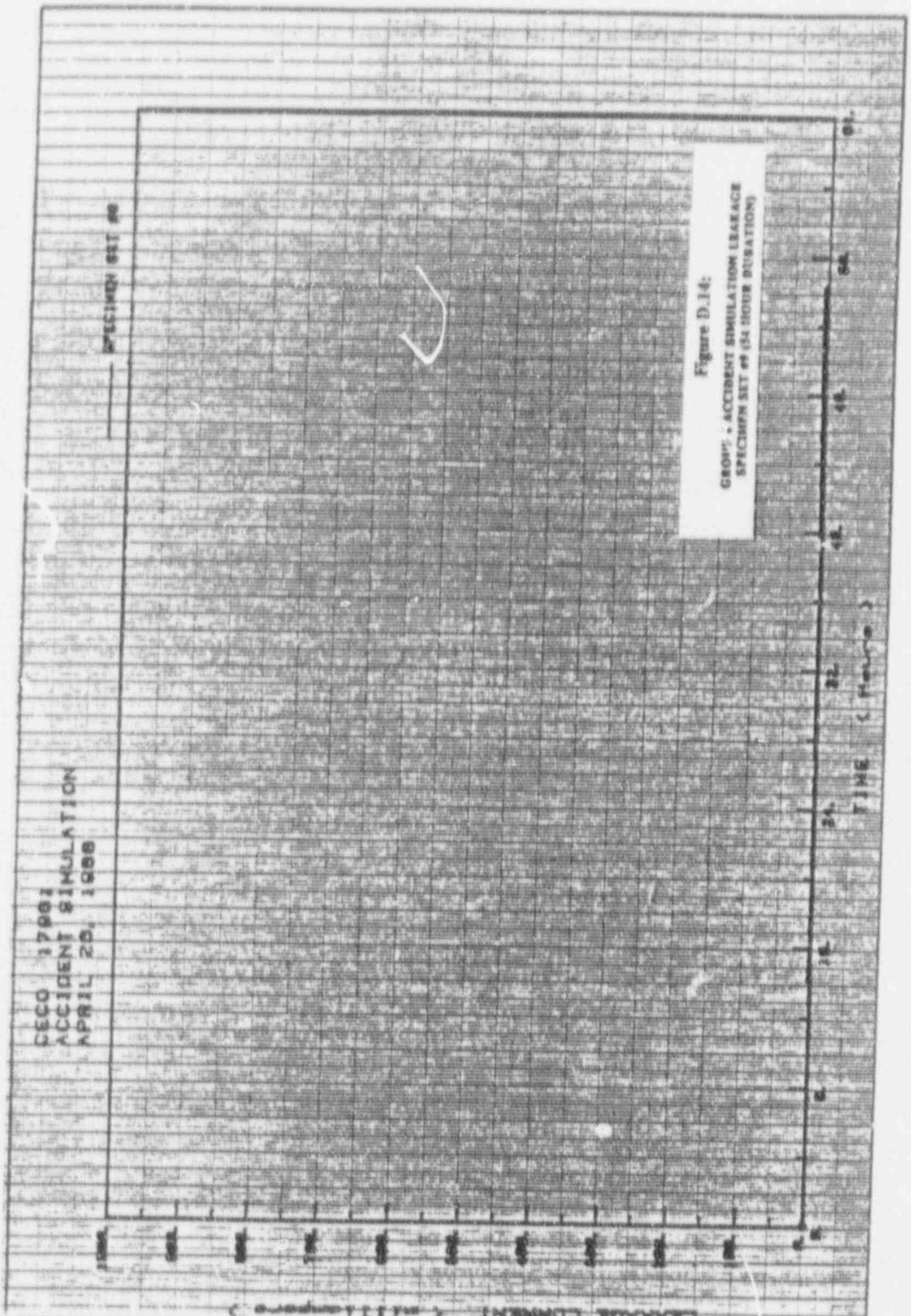



Figure D.14:
GROUP [illegible] ACCIDENT SIMULATION LEAKAGE
SPECIMEN SET #8 (54 HOUR DURATION)

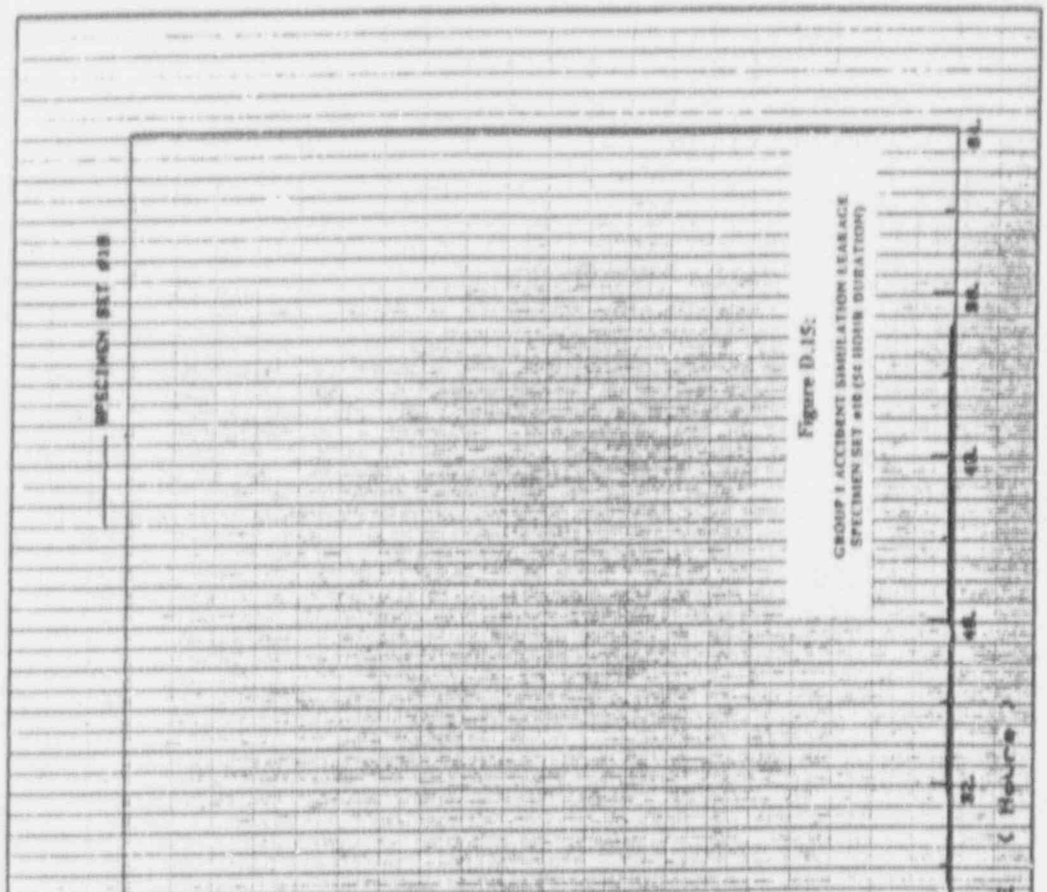



Figure D.15:
GROUP I ACCIDENT SIMULATION LEAKAGE
SPECIMEN SET #18 (54 HOUR DURATION)

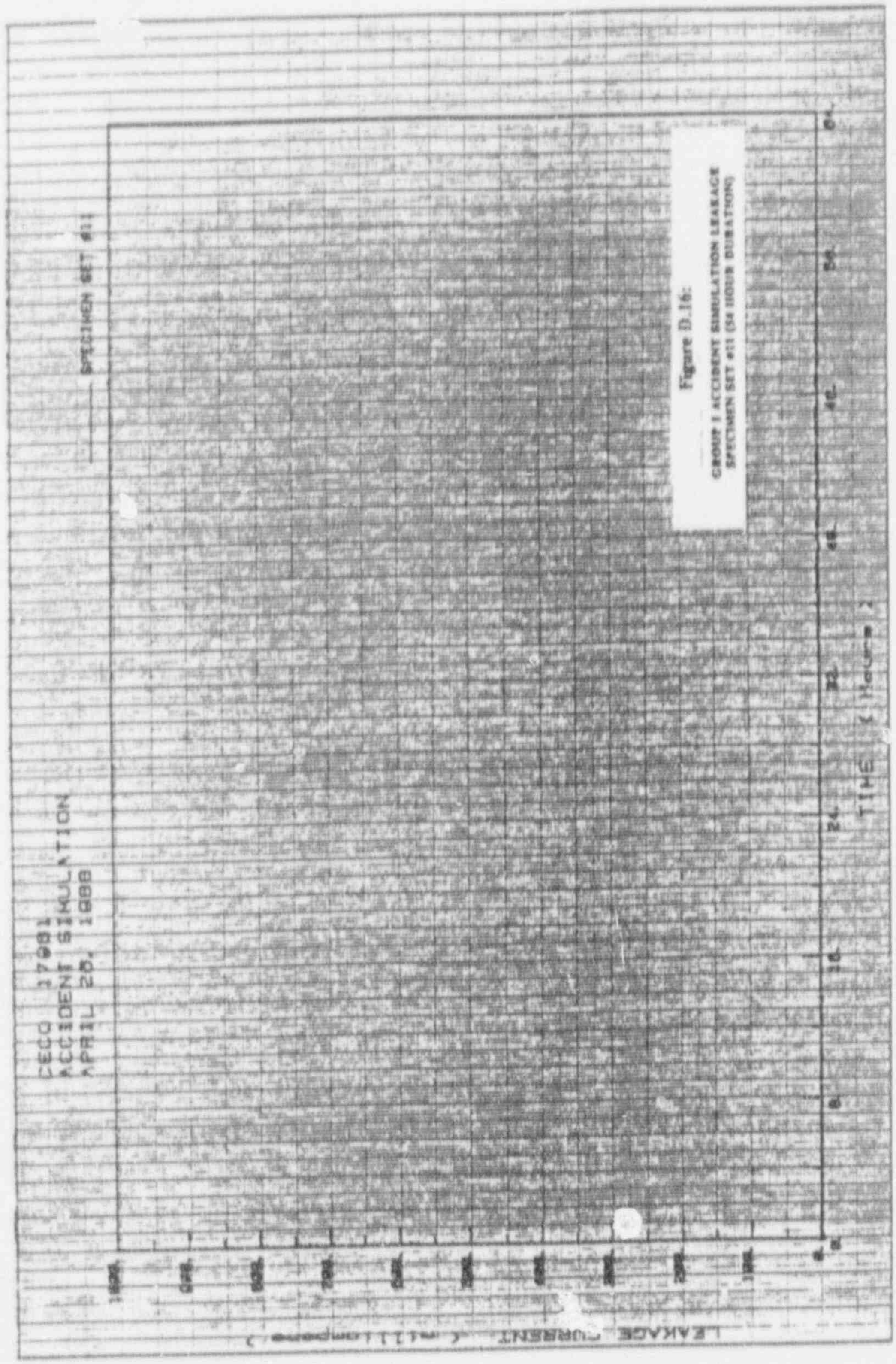



Figure D.16:

GROUP I ACCIDENT SIMULATION LEAKAGE SPECIMEN SET #11 (54 HOUR DURATION)

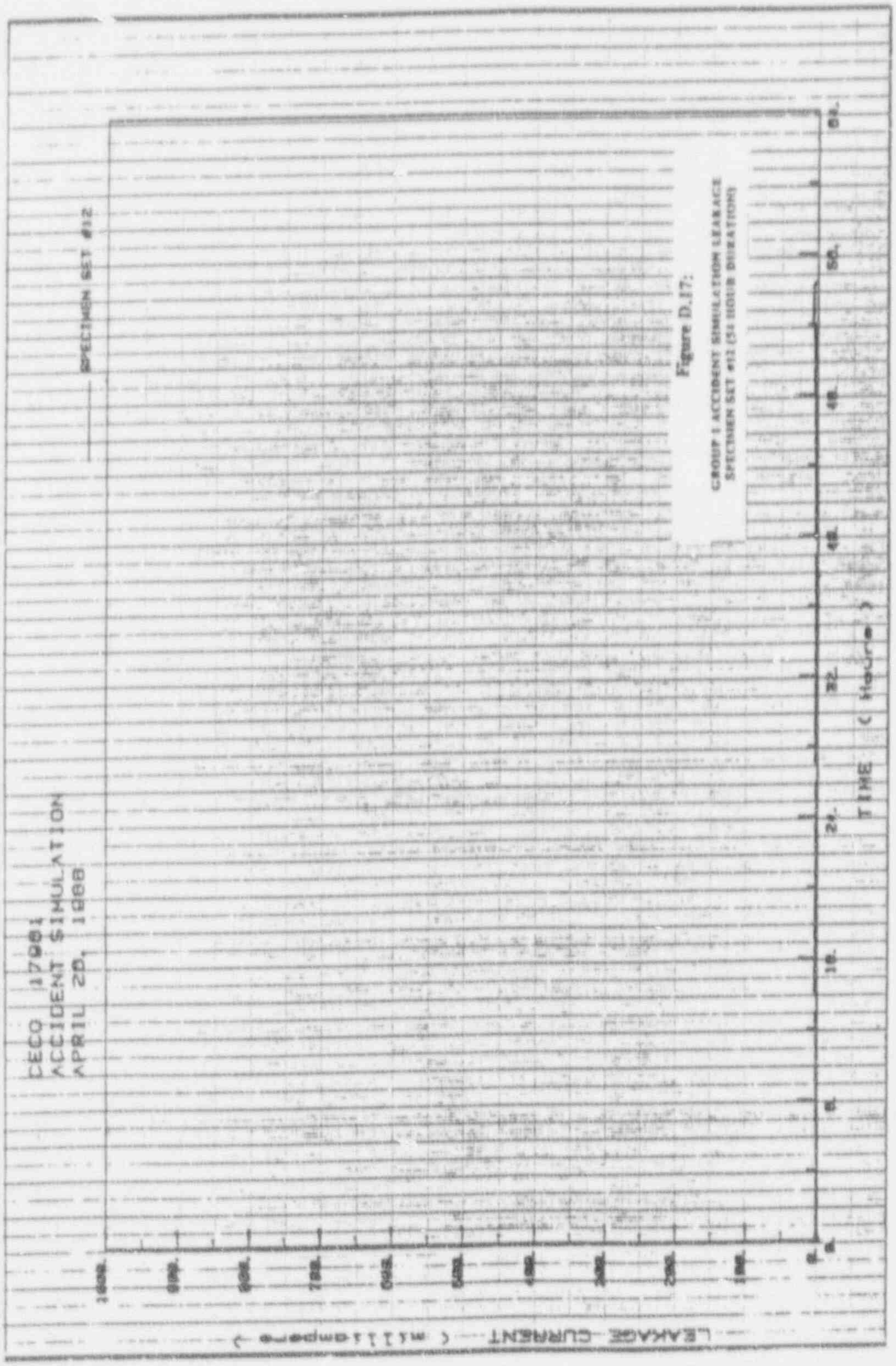



Figure D.17:
GROUP I ACCIDENT SIMULATION LEAKAGE
SPECIMEN SET #12 (51 HOUR DURATION)

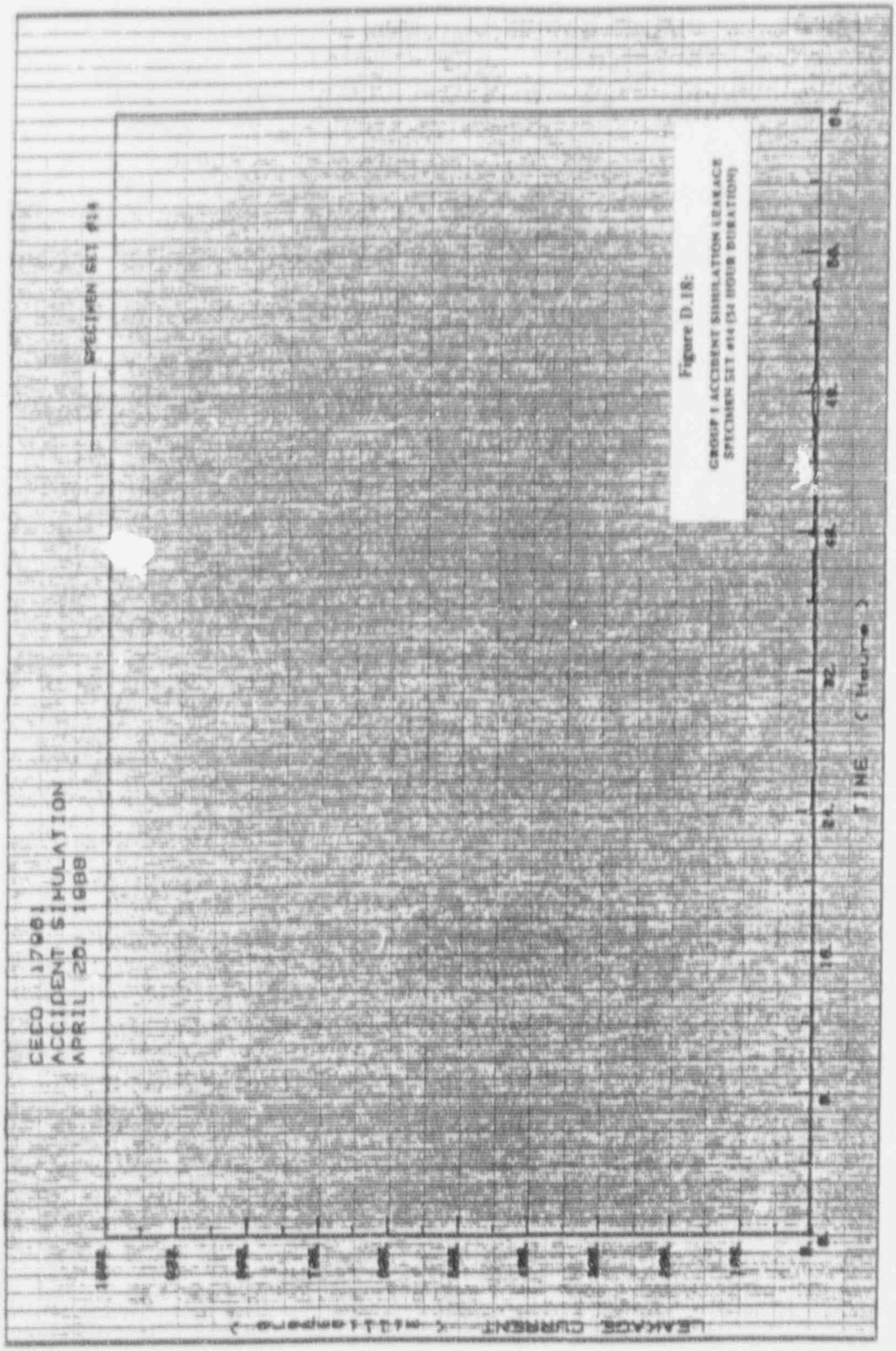



Figure D.18:
GROUP I ACCIDENT SIMULATION LEAKAGE
SPECIMEN SET #14 (54 HOUR DURATION)

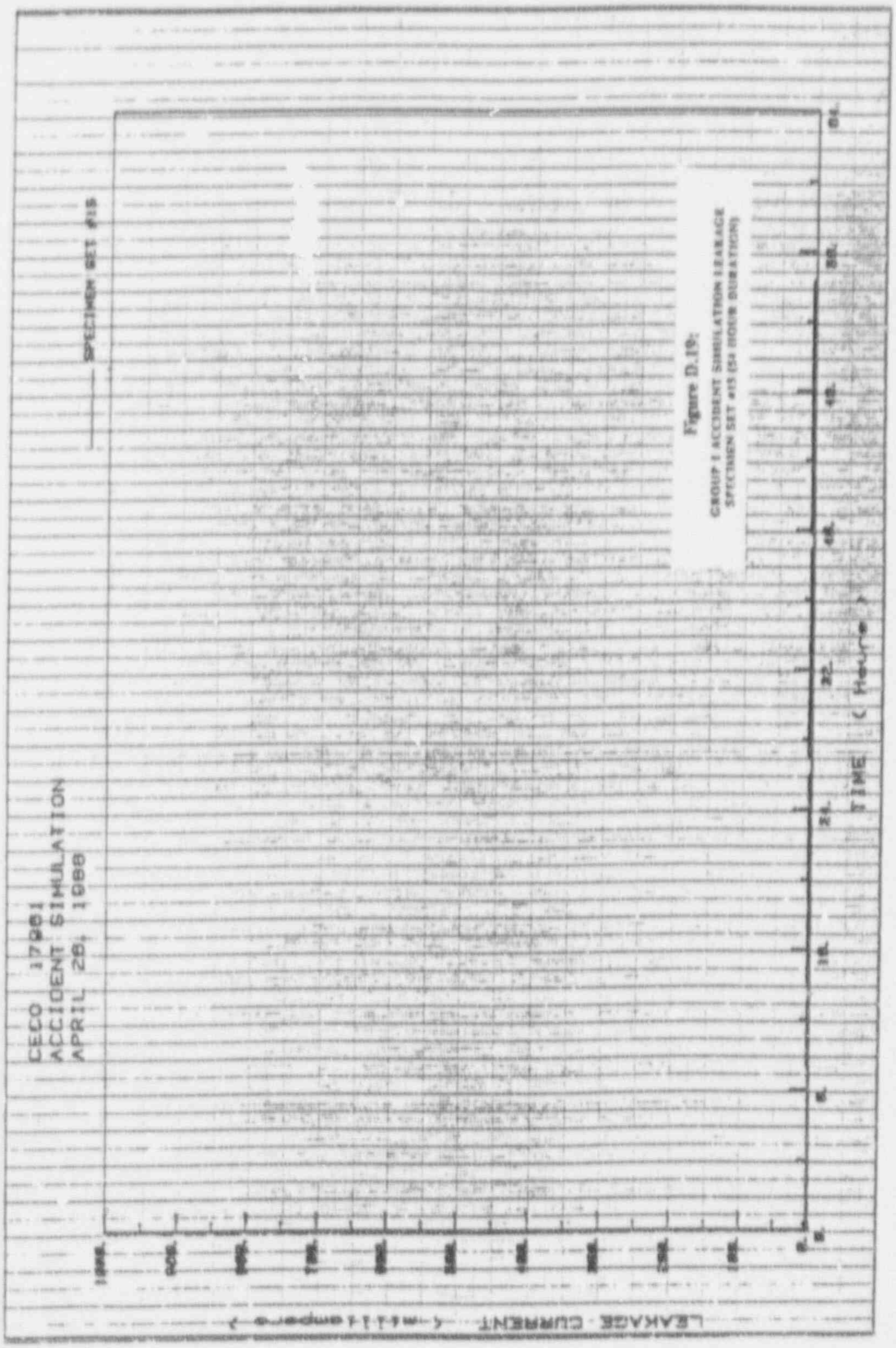



Figure D.19:
GROUP 1 ACCIDENT SIMULATION LEAKAGE
SPECIMEN SET #15 (54 HOUR DURATION)

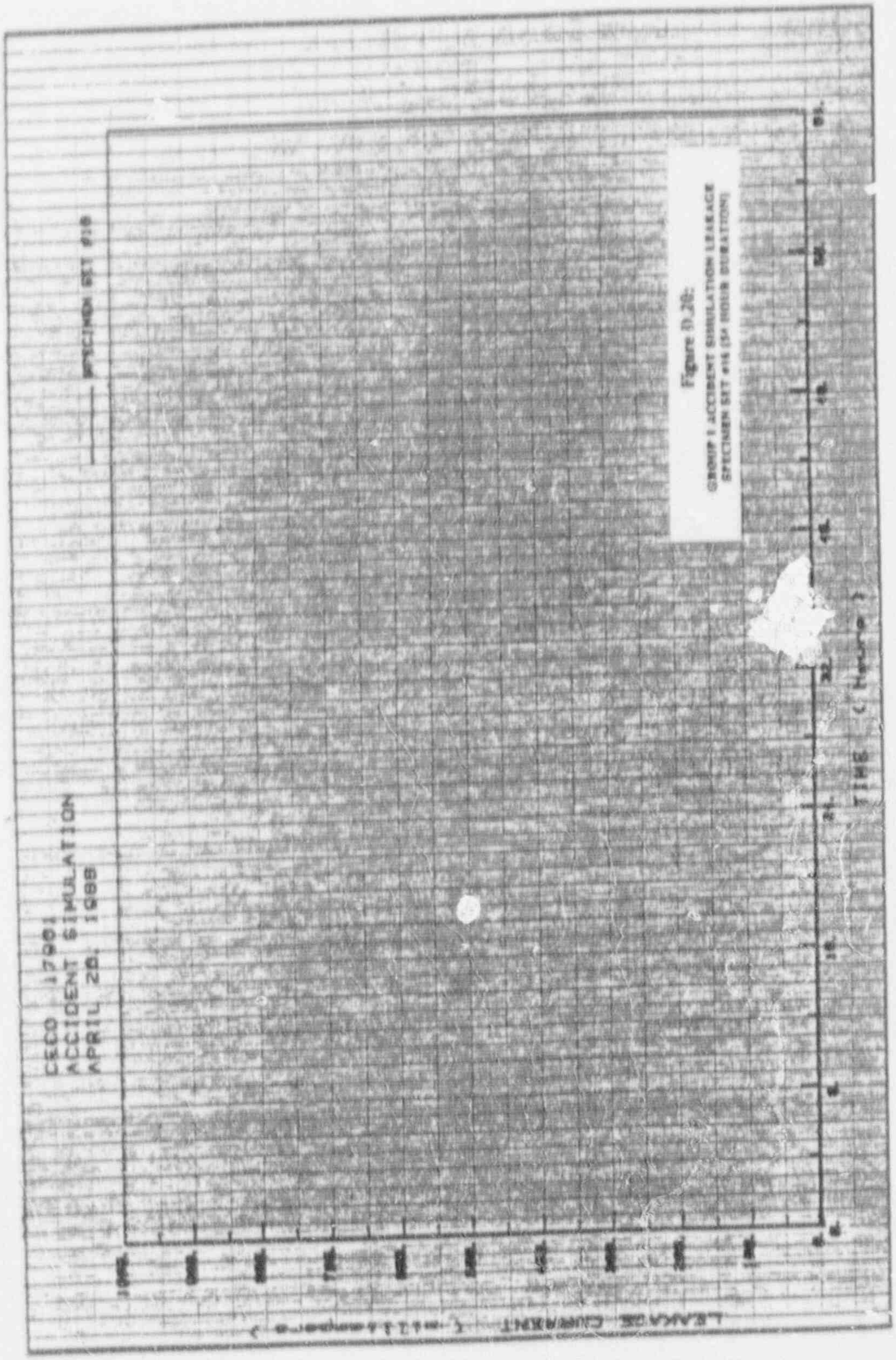



Figure D.28:
GROUP I ACCIDENT SIMULATION LEAKAGE
SPECIMEN SET #16 (24 HOUR DURATION)

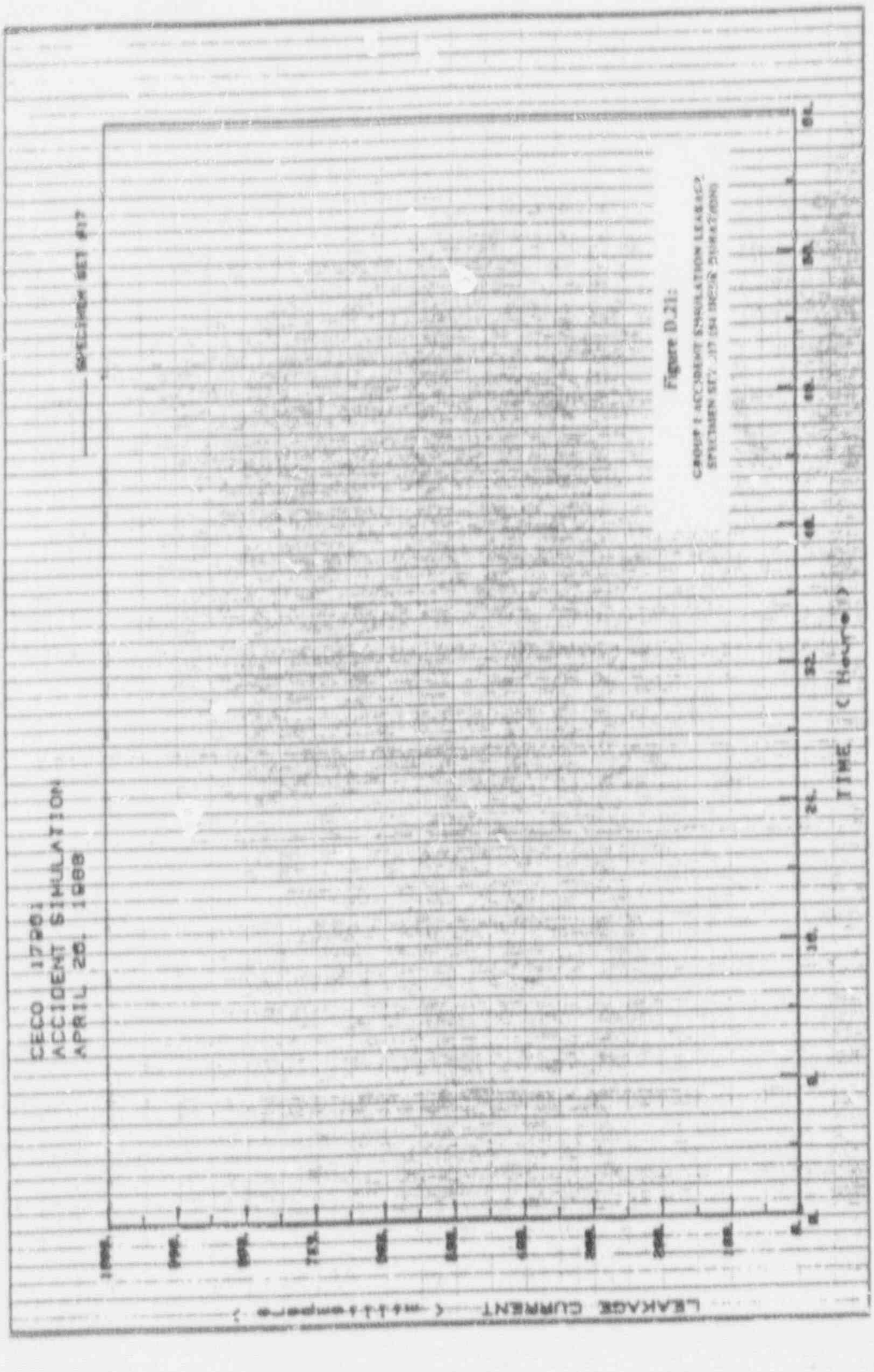



Figure D.21:
GROUP I ACCIDENT SIMULATION LEAKAGE
SPECIMEN SET #17

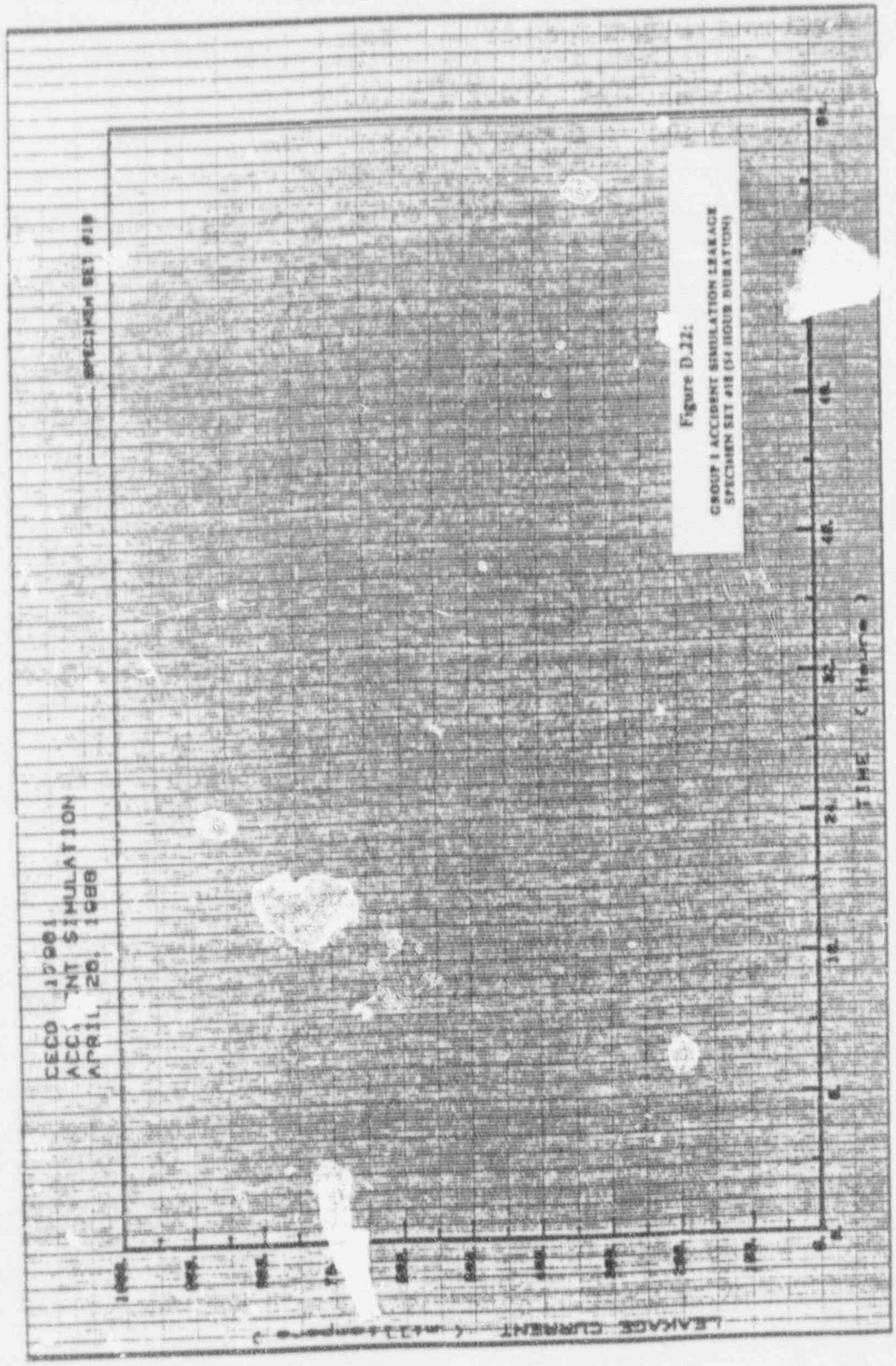



Figure D.22:
GROUP I ACCIDENT SIMULATION LEAKAGE
SPECIMEN SET #18 (54 HOUR DURATION)

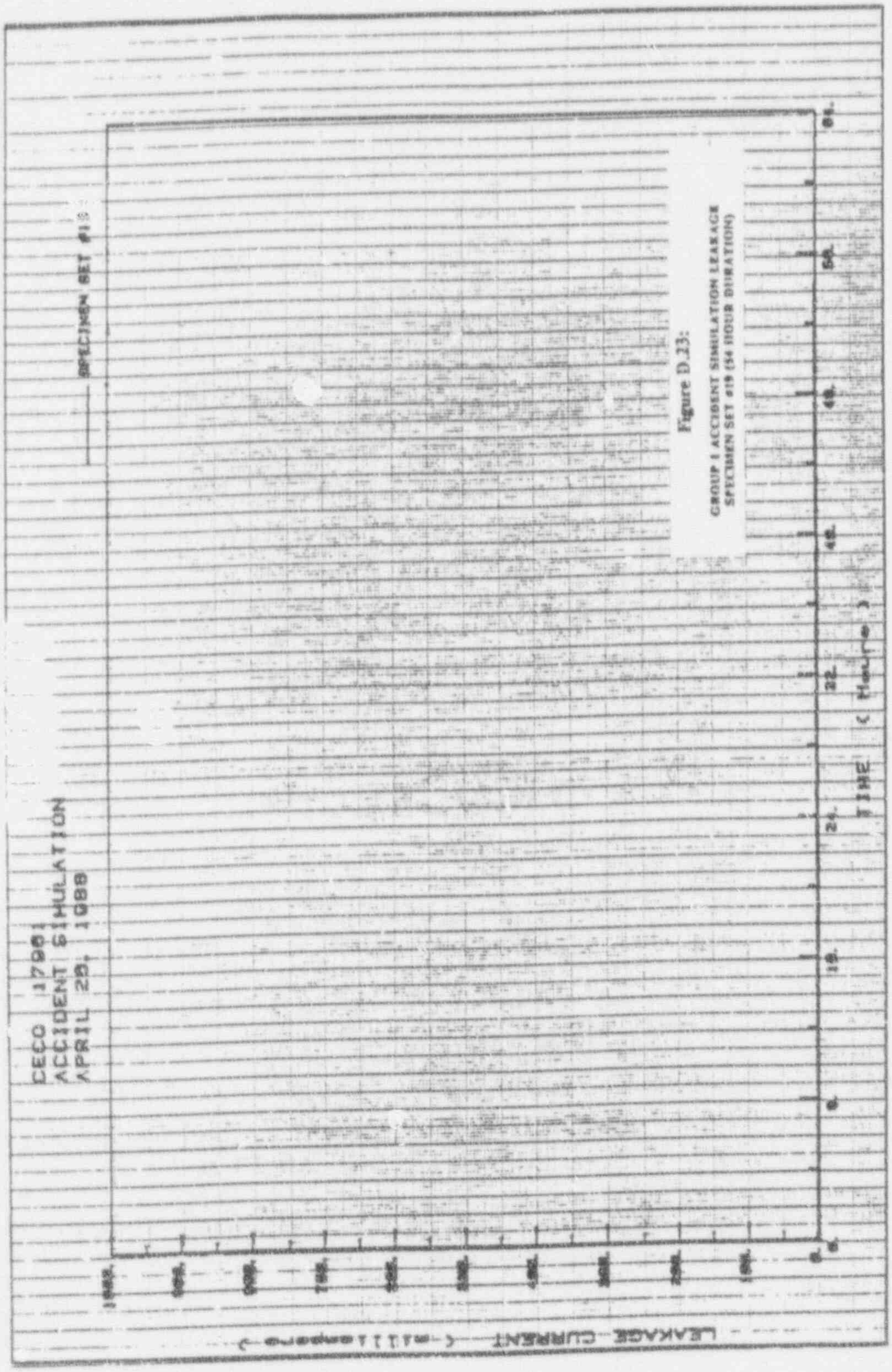



Figure D.23:

GROUP I ACCIDENT SIMULATION LEAKAGE SPECIMEN SET #19 (54 HOUR DURATION)

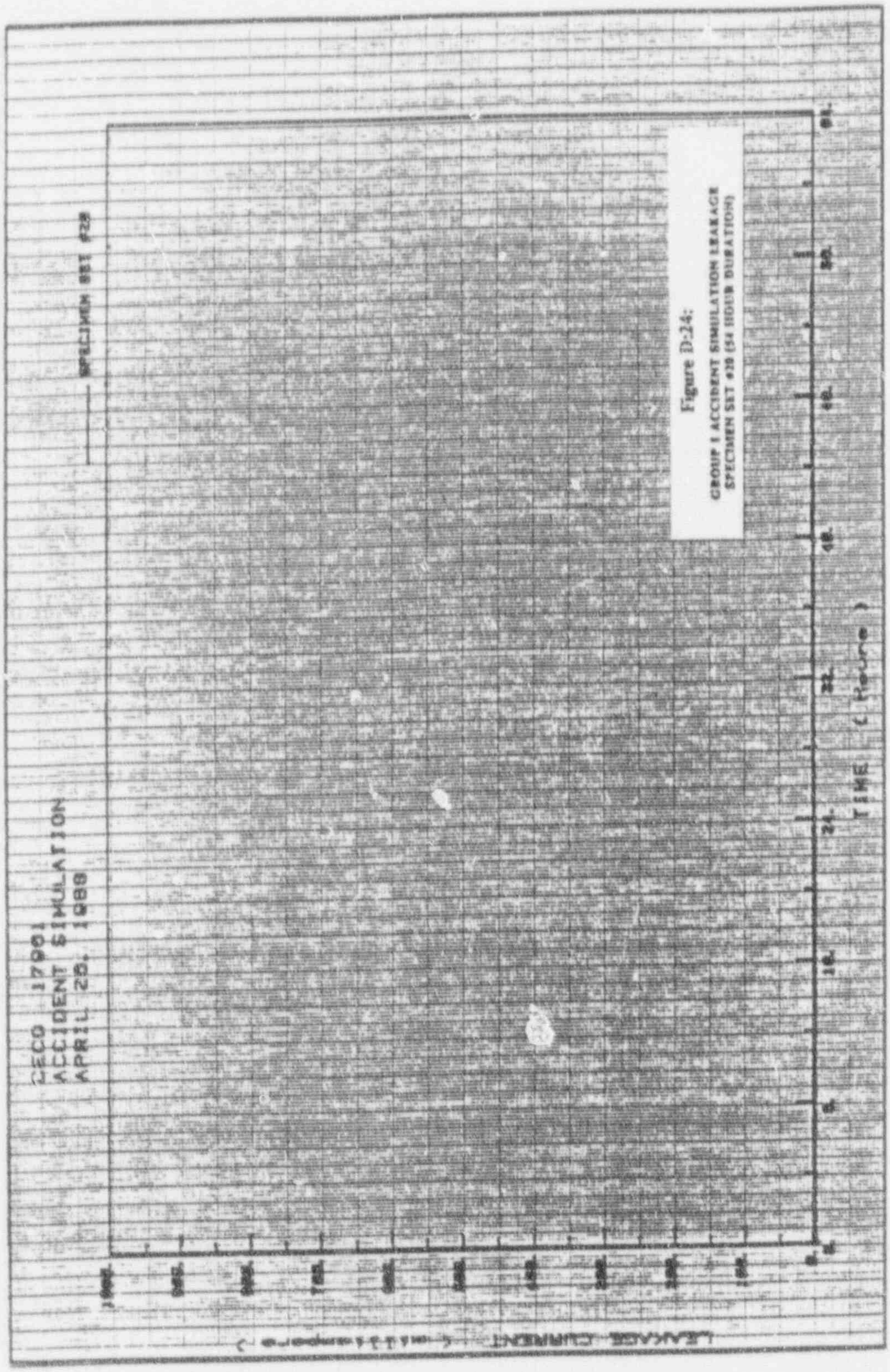
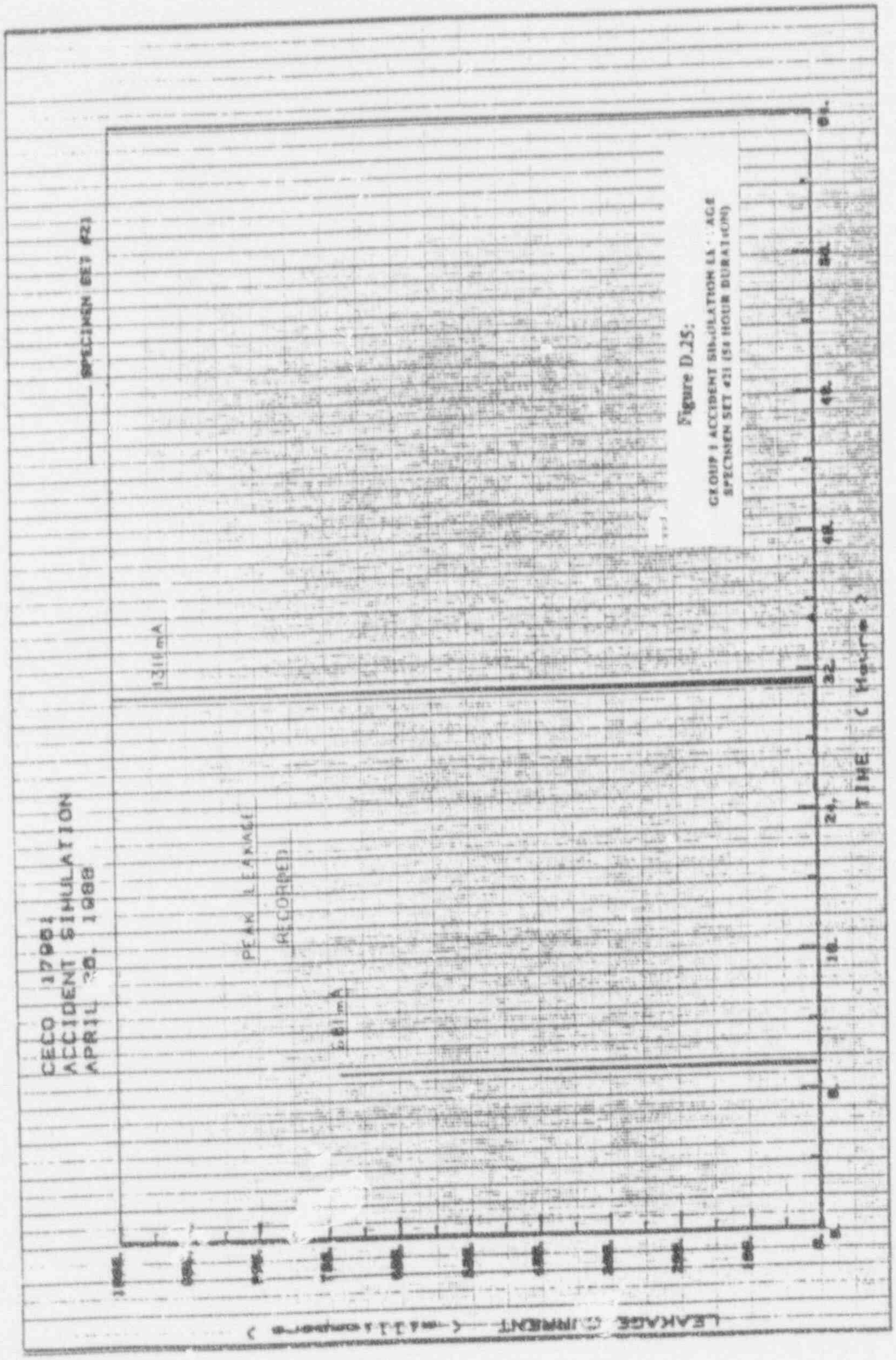



Figure D-24:
GROUP I ACCIDENT SIMULATION LEAKAGE
SPECIMEN SET #28 (54 HOUR DURATION)


CECO 1796:
ACCIDENT SIMULATION
APRIL 20, 1988
SPECIMEN SET #21
PEAK LEAKAGE
RECORDED
1318mA
581mA
LEAKAGE CURRENT ( milliamps )
TIME ( Hours )
Figure D.25:
GROUP I ACCIDENT SIMULATION LEAKAGE
SPECIMEN SET #21 (54 HOUR DURATION)

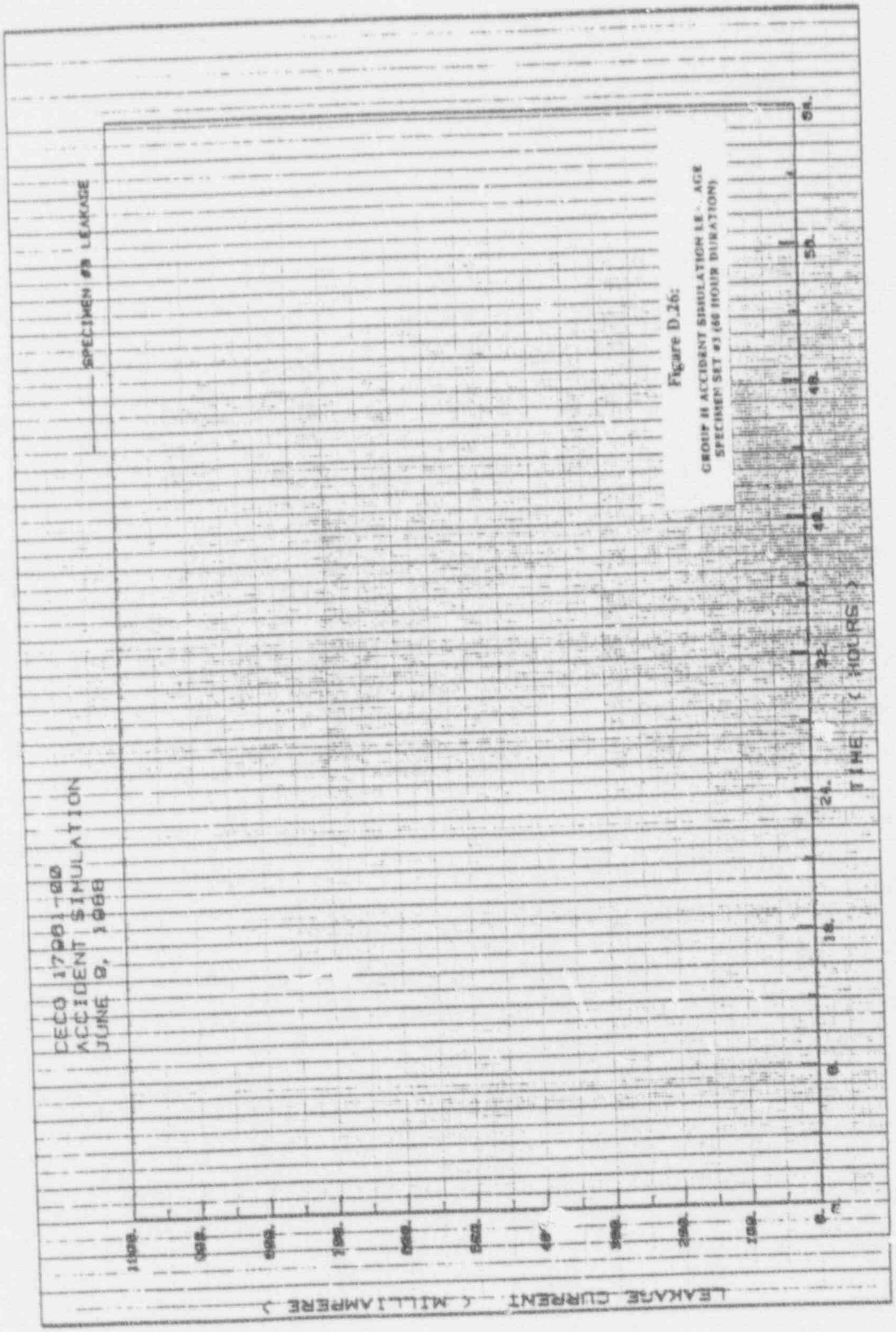



Figure D.26:
GROUP III ACCIDENT SIMULATION LE.. AGE
SPECIMEN SET #3 (48 HOUR DURATION)

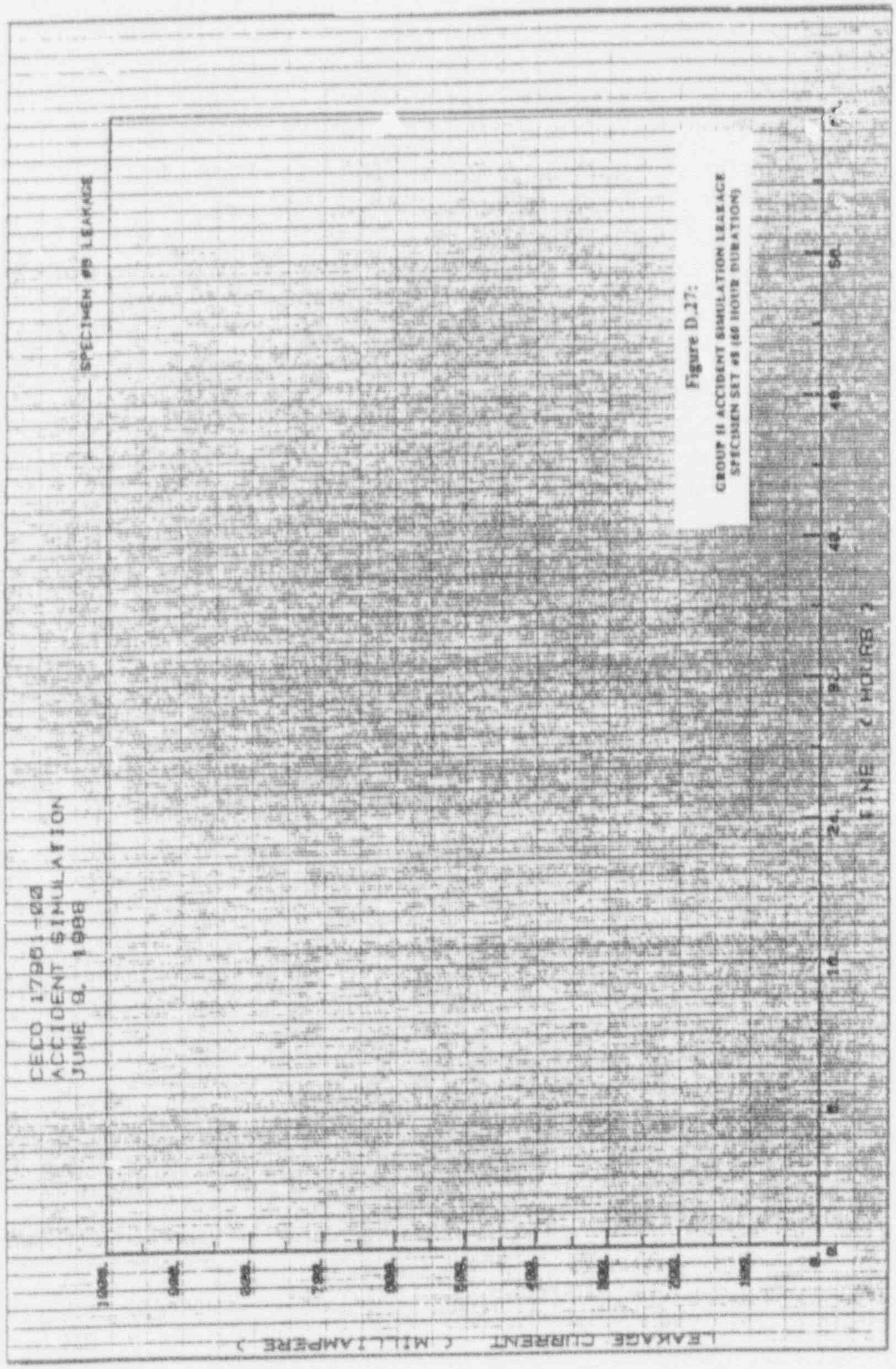



Figure D.27:
GROUP II ACCIDENT SIMULATION LEAKAGE
SPECIMEN SET #8 (60 HOUR DURATION)

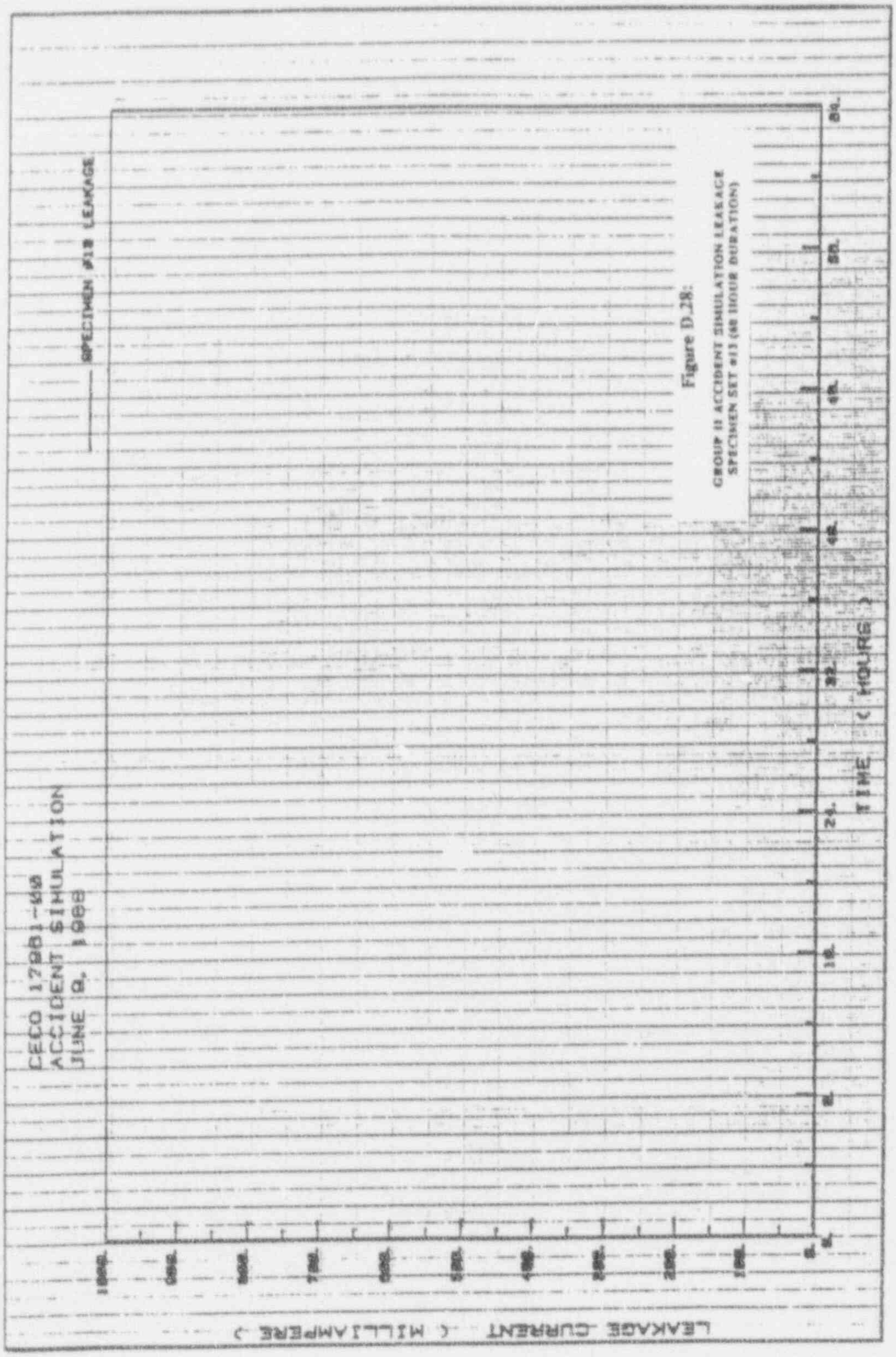



Figure D.28:
GROUP II ACCIDENT SIMULATION LEAKAGE
SPECIMEN SET #13 (48 HOUR DURATION)

## D.13 Post Test Disassembly

### Group I

Test specimen assemblies (i.e., splice plus connected cables) that had been removed from test circuits because of failure during the accident test, were located and notice was made as to potential areas of failure on the individual splice components. The enclosure was allowed to dry and the specimen sets were removed so that photographs of each specimen set could be taken (Ph^'ographs D.13, D.14 and D.15). Group I consisted of Specimen Sets 1, 2, 4, 6, 9, -1 14-21. Note the accumulation of water at the bottom of the junction box.

Upon completion of the inspection, the failed specimen assemblies were subjected to hi-pot tests to verify that the suspect areas of the splice assemblies were actually the weakest points of the individual splice assemblies.

### Group II

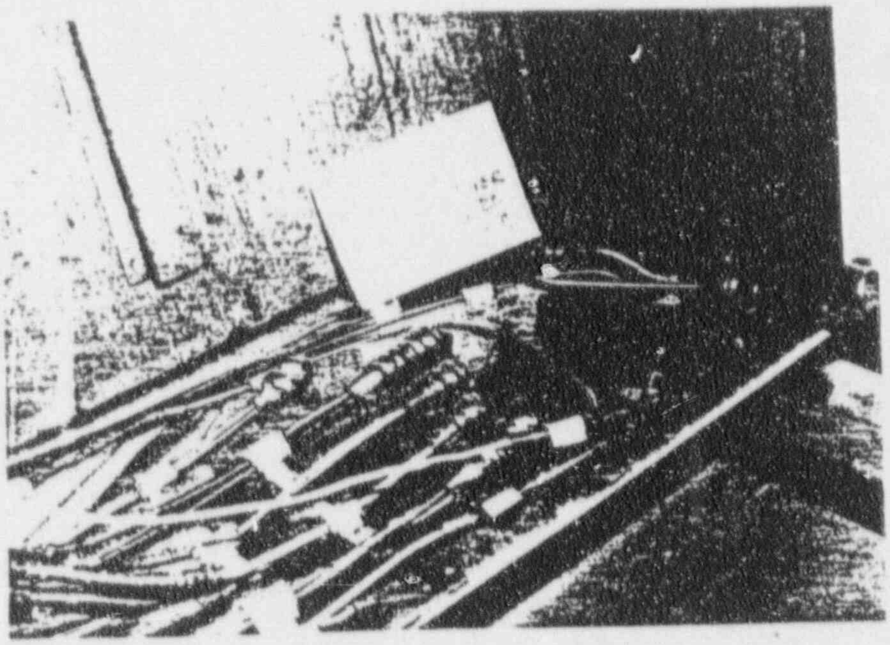
Upon completion of the post-test functional test, the test specimens (Sets 3, 8 and 13) visually inspected (Photographs D.16, D.17 and D.18). The NEMA 12 enclosure door was opened, with the enclosure mounted in the chamber, in order to determine the depth of the accumulated moisture in the bottom of the enclosure. The enclosure was then removed from the chamber and photographs were taken. The weep hole of the enclosure was unplugged and the accumulated water was allowed to drain out. The enclosure was allowed to dry and the specimen sets were removed so that photographs of each specimen set could be taken.

**PHOTOGRAPH D.13**

GROUP I POST-TEST INSPECTION
SPECIFIC MOUNTING OF SPLICES
NOTE MOISTURE ACCUMULATION IN BOTTOM OF ENCLOSURE

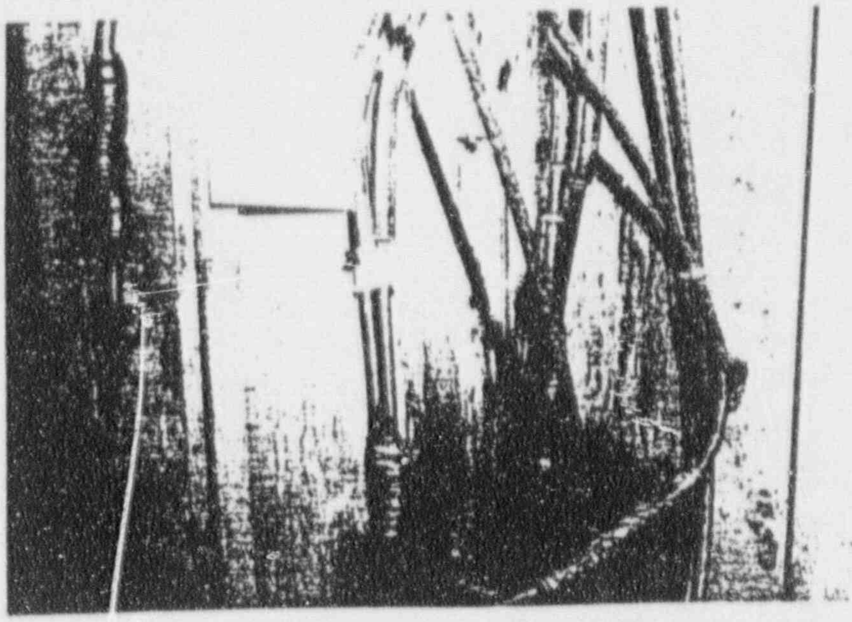

**PHOTOGRAPH D.14**

GROUP I POST-TEST INSPECTION
SPECIFIC MOUNTING OF SPLICES
NOTE MOISTURE ACCUMULATION IN BOTTOM OF ENCLOSURE



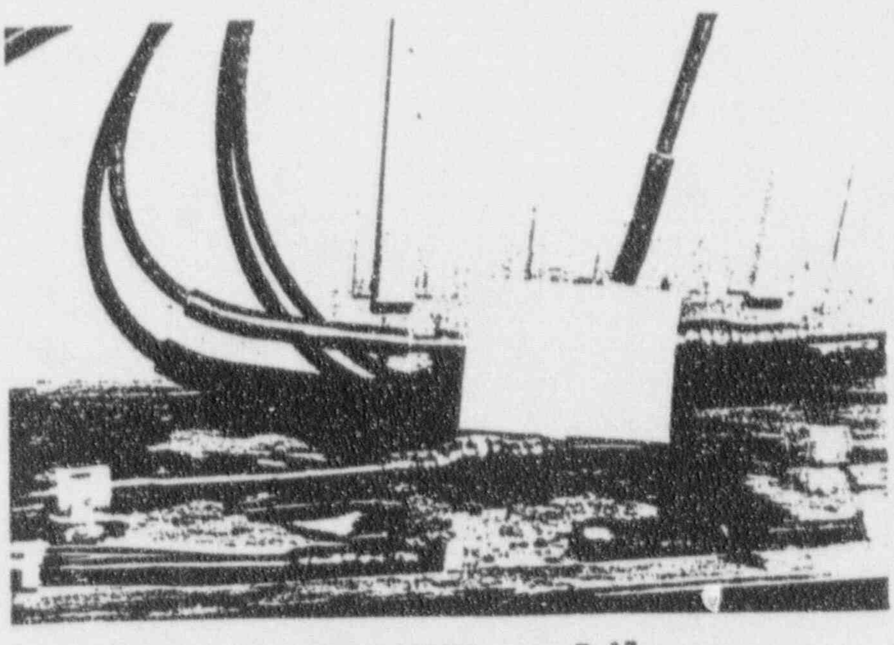
PHOTOGRAPH D.15

GROUP I POST-TEST INSPECTION
SPECIFIC MOUNTING OF SPLICES
NOTE MOISTURE ACCUMULATION IN BOTTOM OF ENCLOSURE
AND INDICATED FAILED AREA OF SPECIMEN 21A



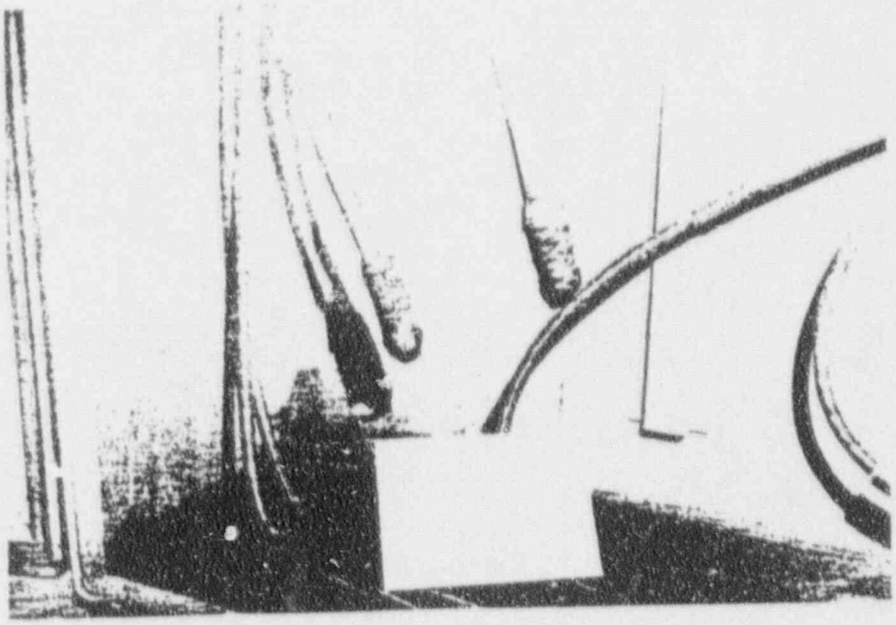
PHOTOGRAPH D.16

GROUP II POST-TEST INSPECTION
SPECIFIC MOUNTING OF SPLICES



PHOTOGRAPH D.17

GROUP II POST-TEST INSPECTION
SPECIFIC MOUNTING OF SPLICES



PHOTOGRAPH D.18

GROUP II POST-TEST INSPECTION
SPECIFIC MOUNTING OF SPLICES
NOTE MOISTURE ACCUMULATION IN BOTTOM OF ENCLOSURE

## D.14 Qualification Test Anomalies Wyle N.O.A. No. 2 (Reference D.2.1, Pages VI-13 and 14)

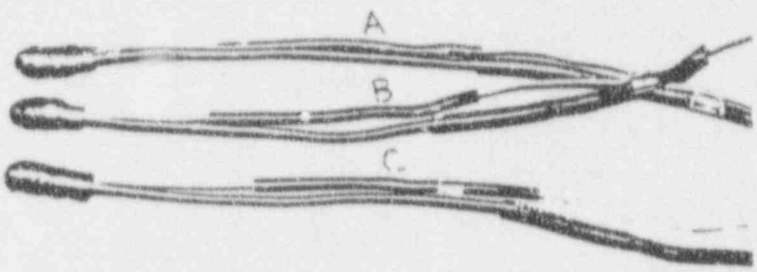
During the specified post-DBE conditions of the Group I specimens accident simulation, Specimen Splices 1A, 21A and 21C exhibited leakage in excess of 1 amp and were necessarily removed from their respective circuits (Specimen 21C at 9.5 hr., Specimen 21A at 31.5 hr., and Specimen 1A at 36.5 hr.). During the post-test visual inspection, it was determined that each failed specimen splice was constructed using at least one Reliance thermofit (Nomex) lead wire and that a burned/darkened area existed on the braided material of this lead wire on each specimen splice. Additional hy-pot testing verified that the burned/darkened area(s) on the braided material of the lead wire(s) were the weakest points of the specimen splices (Photographs D.19, D.20, and D.21). It was felt the Specimen Splice 21C had come into physical contact with the enclosure internal thermocouple No. 4, during the accident simulation, and that this contact was the cause of the excessive leakage exhibited through the lead wire to ground. This was caused by application of the initial DBE pressure transient which caused this free-to-swing specimen to move and come into contact with the enclosure.

Specimen Splices 1A and 21A were determined to have been at least partially immersed in water (Photographs D.13, D.14 and D.15), upon initiation of saturated conditions, during the accident simulation thus allowing a leakage path to ground through the lead wires of the failed splices. It should be noted that Specimen Set Numbers 2, 6, 7, 14, 15 and 20 were constructed using the same Reliance thermofit (Nomex) lead wire and maintained electrical integrity throughout the accident simulation.

Specimens 1A and 21A, using Nomex lead wire supplied by Reliance Electric Company in accordance with their Specification #4824-6-CM, exhibited excess leakage currents during the accident simulation. A post-test examination of these specimens isolated the cause of the excess leakage current to the Nomex leads (Photographs D.19, D.20, and D.21), both of which were immersed during the accident simulation. Specimen 21C excess leakage currents was judged to have been inadvertently caused by contact of the Nomex lead with the metal-sheathed thermocouple in the junction box. This happened during the initial pressure transient which caused the free-to-swing Specimen 21C to move such that its Nomex cable came into permanent contact with the thermocouple. Hence excess leakage current was the result and a leakage path to ground occurred via the thermocouple.

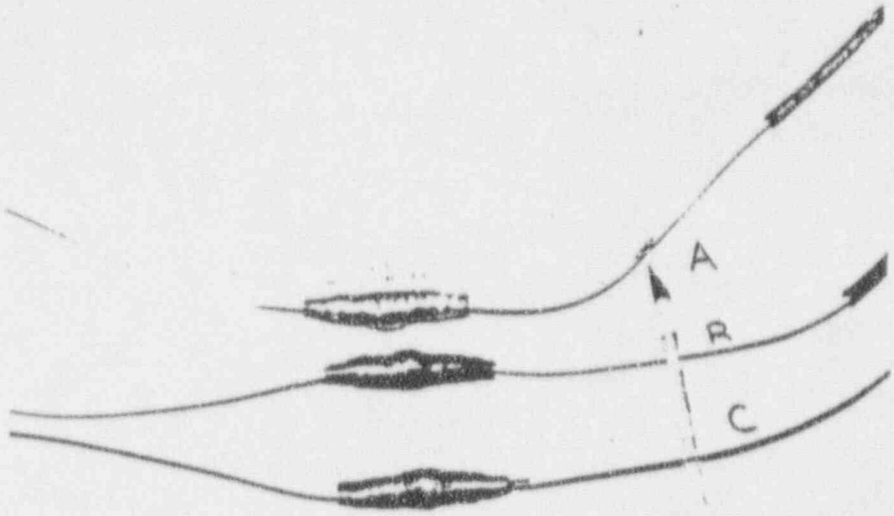
## D.15 Conclusion

Based upon the above evaluation, Okonite low voltage power and control splices are environmentally qualified for BWR/PWR on outside containment while under "local submergence."



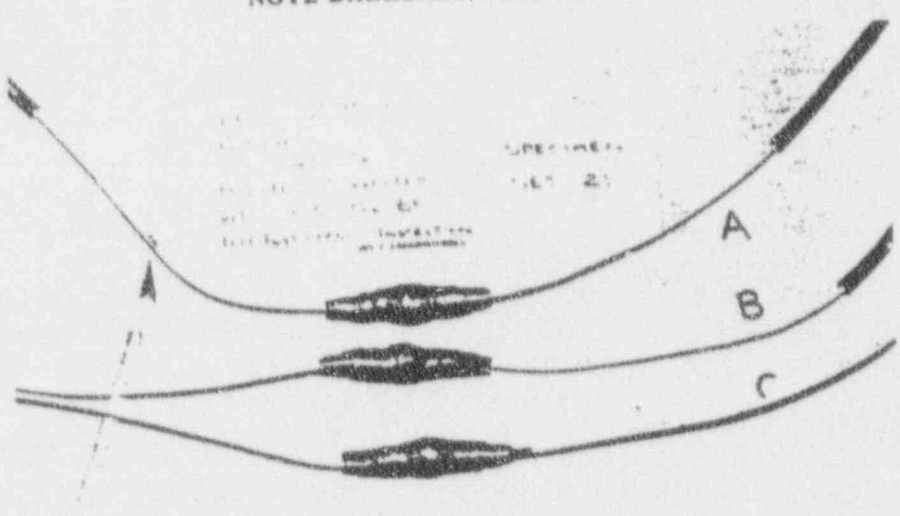

PHOTOGRAPH D.19

GROUP I POST TEST INSPECTION
SPECIMEN SET #1




PHOTOGRAPH D.20

GROUP I POST TEST INSPECTION
SPECIMEN SET #21
NOTE DARKENED/BURNED AREA




PHOTOGRAPH D.21

GROUP I POST TEST INSPECTION
SPECIMEN SET #21
NOTE DARKENED/BURNED AREA