IE notice
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#4

Sandia National Laboratories

Albuquerque, New Mexico 87185

July 15, 1981

Mr. W. C. Farmer
Electrical Engineering Branch
Division of Engineering Technology
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Mr. Farmer:

Enclosed is a preliminary account of the Commission directed test of the Duke Power, Catawba Units 1 and 2, Type K electric penetration connectors. This enclosure addresses tests performed, test results, and conclusions based on observed connector behavior.

The tests were conducted in accordance with the 1-30-81 version of the "Connector Assembly Test Plan for Duke Power, Catawba Units 1 and 2 Connectors."

Test plan approval and permission (Feit to Bonzon, 4-8-81) to proceed with the test were received on 4-13-81.

Upon final analysis of the test data, a formal Sandia report documenting detailed procedures and results will be issued. In the interim, should you have any questions concerning the connector test, please call me.

Sincerely,

W. H. Buckalew
Systems Safety Information
Division 4445

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IE

CONNECTOR ASSEMBLY TEST
OF THE
DUKE POWER, CATAWBA, UNITS 1 AND 2
TYPE K PENETRATION/CONNECTOR ASSEMBLY

A BRIEF LOOK

SUMMARY

The following is a brief account of pertinent events that occurred during the execution of a Commission directed verification test of certain connectors. The test was performed on behalf of NRC(RES) under the NRC-sponsored Sandia QTE research program.

The purpose of this test was to subject a D. G. O'Brien Type K instrumentation penetration assembly, complete with mating connectors and interconnecting cabling, to the thermal aging, radiation, and steam accident phases of the qualification tests performed by O'Brien, during the development stages of the penetration and prior to its subsequent installation in the Duke Power, Catawba Units 1 and 2 plants. Details of the D. G. O'Brien tests are contained in the O'Brien Report ER-252, 8-15-77. Although the complete penetration assembly was subjected to these verification tests, of primary interest was the mating connector assembly and, in particular, the sealing components identified in Figure 1 as the cable grommet and interfacial seal. Briefly, during the development stages of the penetration, circumstances dictated additional development emphasis be placed on connector design. As a result, not all components of the penetration assembly were fully tested. Ultimately, Sandia was requested to duplicate the qualification tests on a complete, as installed, unit.

A complete Type K penetration unit, with cables and connectors, was purchased from the Duke Power Company. Included in the purchase were funds necessary for wiring of the unit by a Duke Power installation crew. This assembly task was observed by I&E personnel.

The unit was received at Sandia on 4-15-81. Testing of the unit commenced on 5-19-81 and was completed on 6-21-81. By 6-26-81, a limited postmortem on the unit had been completed. Testing was in accordance with the Enclosure 1 test plan and with more detailed procedures which will be included in the final report.

The index of satisfactory assembly performance was based on insulation resistance (IR) measurements of the 104 individual circuits comprising the assembly. Specifically, resistance of any circuit to the electrical ground plane was required to remain above five megohms when tested at 500V DC.

Insulation resistance measurements remained high during and after both thermal aging and radiation. Loosening of connector coupling rings, Figure 1, was observed after both thermal and radiation aging. This condition was not without precedent and the coupling rings were retorqued, according to specifications, following each phase.

The first insulation resistance measurements during the steam accident phase were taken four hours after start of this phase and when saturated steam conditions had been achieved (see Fig. 2 and 3). At that time, 12 circuits were observed to be either erratic or below the minimum prescribed IR requirement. At the conclusion of the accident (steam) phase, six circuits remained suspect. Three circuits indicated short or near short circuit conditions, and three circuits indicated IR values of less than one megohm.

The postmortem, starting two days after the test conclusion, revealed the following.

1) Cable grommet material had extruded through the conductor feed-through openings in the plug sleeve. In Figure 4 coupling rings have been removed and the extruded black grommet material is clearly visible. Figure 5 is a closeup of the phenomenon.

2) Where grommet extrusion occurred, conductor insulation was necked down, and in some instances, insulation was stripped from the conductor. Figure 6 shows both conditions, this conductor was removed from a connector which had passed all IR tests.

3) The extrusion process, in some cases, forced bared conductors to the very near vicinity of the plug sleeve - a possible short circuit condition. The right hand connector, in Figure 7, is a good example of this process.

4) Mositure intrusion at the connector module interface was observed in many instances - a possible cause of low IR measurements and/or short circuit indications. Figure 8 shows moisture accumulation on the interfacial seal.

TEST SYNOPSIS - SALIENT FEATURES

Receipt

The unit was received on 4-15-81. At that time, the penetration was inspected for damage, unpackaged, and moved to a controlled area. Following receipt of the torque spanner on 5-12-81, both inboard and outboard coupling rings were torqued to the specified 25 ft-lbs. Coupling ring rotation necessary to torque was on the order of 90 degrees for all rings.

Thermal Aging

Thermal aging facilities were provided by the Sandia Climatic, Centrifuge, and Devices Testing Division. The aging was performed in a large walk-in chamber. Just prior to the aging phase, Climatic Division personnel calibrated the chamber and ran a lengthy regulating performance test.

Following the calibration and performance runs, the entire penetration unit was placed in the temperature chamber. Figure 9 shows the unit positioned in the oven. The cables exiting the test chamber, at the left, allow IR measurements to be taken during the aging phase. Thermocouples were installed to monitor both the inboard connector temperature and "free air" inside the junction box. Chamber environment temperature control and measurements were provided by the Climatic Test Division.

Just prior to start up on 5-19-81 and with the test chamber at room temperature, IR and continuity measurements were taken. The chamber temperature stabilized at 150°C in approximately 30 minutes. Free air thermal equilibrium was achieved in about 3.5 hours and the connectors stabilized in 6 hours. IR and continuity measurements were taken daily. Pre and post test measurements were almost identical - 4000 to 8000 megohms. Although IR measurements decreased at the test onset, a monotone increase toward the post-test values was then observed.

Post Thermal Aging

The unit was taken to the Sandia Area-5 High Intensity Adjustable Cobalt Array (HIACA) facility for radiation aging preparation. At this time, the inboard junction box was removed. All inboard and outboard coupling rings were loose.

Retorquing of inboard and outboard coupling rings was accomplished prior to radiation aging. In all cases approximately 360 degrees ring rotation was required to retorque. One complete coupling ring revolution translated into an axial traverse of 60 mils.

Radiation Aging

Placement of the unit, in the HIACA, was facilitated by previously obtained dose-rate maps of the facility, Fig. 10.

In sequence, the following steps were taken:

1) Thermocouples were mounted on inboard connectors and in the "free air" region surrounding both the inboard and outboard penetration regions.
2) HIACA dose-rate values were re-confirmed with a calibrated air ionization chamber as 0.722 Mrad(air)/hr.
3) The junction box perturbation to dose/dose rate was experimentally determined to be 0.917.

Radiation aging was begun on 5-29-81. Figure 11 shows the unit, with inboard junction box removed, being positioned in the test chamber.

An inboard "free air" equilibrium temperature of 50°C was reached in about 5 hours. Inboard connector termperature stabilized at 64°C in approximately 7 hours, while the radiation cell temperature was variable between 32 and 42°C.

On 6-1-81, the Co-60 sources were lowered so that provision for forced air circulation of the penetration could be provided. Following fan installation, free air and connector temperatures stabilized at 42 and 46°C respectively.

The radiation aging was completed on 6-9-81. Total exposure time was 237.5 hours resulting in an integrated exposure dose of 183 Mrad (Air). Recall that the junction box dose rate perturbation was .917, hence had the junction box been installed, the exposure dose to the junction box would have been 200 Mrad.

IR values at the conclusion of radiation aging were about one half the post-thermal/pre-irradiation values - i.e., in the range of 2000 to 4000 megohms. All connector coupling rings were loose and approximately 30 degrees rotation was required to retorque the rings.

Steam (Accident Simulation) Phase

Instrumentation for the steam test was extensive. Included in the thermal measurements were multiple (spatial) measurements near the junction box exterior surface, junction box interior "free field", and connector surface. Thermocouples were placed on the junction box exterior as shown in Figure 12. Test chamber internal pressure was also monitored. Several detectors were included at each thermocouple spatial location. Steam system and data acquisition and display systems performance were characterized on several trial runs using a dummy thermal load in the test chamber.

The accident phase was started on 6-15-81. Initial IR measurements were deferred until major transient temperature/pressure excursions had occurred and saturated steam and thermal equilibrium conditions had been established in the test chamber. These conditions occurred about four hours into the test, Figures 2 and 3.

Initial IR measurements detected several circuits with IR values below specification and several circuits exhibiting erratic readings. Since several circuits were suspect at this time, a second set of IR measurements was taken approximately 5 hours later. This set of measurements identified 12 circuits as being suspect, i.e., either erratic IR readings or IR values below 5 megohms. Erratic IR readings were of concern since it was reasoned that moisture intrusion had occurred.

These 12 suspect circuits were closely monitored for the duration of the steam test. Just prior to the conclusion of the steam test phase, three circuits had been removed from the AC power source because of excessive current demands on the power supply. These circuits drew currents in excess of 5 milliamps at 30 VAC, i.e., short circuit conditions. In addition, five other circuits failed to meet the minimum IR specification. However these circuits would withstand 600V AC to ground with leakage currents in the order of 1/2 milliamperes - about average for all other circuits in the assembly.

At the steam test conclusion, all heater power was removed, the test chamber was purged of spray chemicals and vented to the atmosphere. Approximately one hour following the test chamber venting, the 600V AC power was removed from all penetration assembly circuits.

On 6-22-81, with a chamber temperature of 35°C, IR measurements were again taken on all circuits. At that time all but about 15 circuits, out of 104, exhibited IR values below the minimum specified value. Without benefit of penetration disassembly we conjectured moisture had intruded the connector assemblies causing the low readings.

Post-Test Disassembly

On 6-23-81, representatives (see Enclosure 2) of Duke Power, NRC-IE, Brand-Rex Cables, and Sandia met to devise a plan for connector-penetration disassembly that would yield maximum failure information with minimum disassembly steps. The plan format was left flexible so that changes in disassembly procedure would not be discouraged.

Salient features of the disassembly procedure were as follows.

1) Examine a connector module combination with best performance characteristics for use as a base line pair,
2) Determine if the interconnecting cables could be eliminated as a cause of poor performance,
3) Disassemble the three module connector pairs that exhibited short circuit conditions. Identify the defective module-connector of each pair, and
4) If possible determine mechanisms of failure for the defective module-connector.

Using the procedures, it was determined that the external cabling was not a cause of any circuit failure. Additionally, during the course of disassembly it was observed that most connector coupling rings were loose--no more than finger-tight, and in most instances the torque-to-loosen was below the lower indicating limit of the torque tool.

Examination of the "good" connector assembly showed that the cable grommet had extruded through the conductor feed-through holes in the sleeve plug back surface. In Figure 13 the black material is the extruded grommet. Further examination of the "good" assembly (see again Figure 6) indicated that in the course of grommet extrusion, connector insulation was pinched or necked down and, in some instances, stripped from the conductor.

Disassembly of three failed connector-module pairs showed the same extrusion of grommet material through the plug sleeve back surface conductor feed-through openings. Moisture was found to be present at the connector-module interface in all cases.

Of the three failed circuits, two were traced to the connector assembly and one traced to the module. Of the two failures traced to the connector assembly, both were attributed to shorting of the conductor to the plug sleeve at the point of conductor passage through the plug sleeve. It was substantiated in the case of a sectioned connector, that grommet extrusion stripped insulation from the conductor allowing a shorting path between exposed conducter and the plug sleeve. The other connector failure was also attributed to a short between connector and plug sleeve. The one module failure has been attributed to moisture or contamination on the module insulator. For example, from Figure 8 which shows a module with the interfacial seal intact, it may be observed that moisture has intruded and is present on the interfacial seal surface. A vacuum was applied to the module, with interfacial seal present, for approximately 1 1/2 hours and at the conclusion the suspect module pin IR had increased from 1/2 megohm at 500V to approximately 50 megohm at 500V.

Removal of the remaining connectors revealed, in almost all cases, some degree of moisture at the connector module interface. It is believed that this accumulation of moisture occurred during post-test cooldown and was responsible for the poor IR performance of most circuits during the post-accident (steam) IR measurements. Examination of the removed connectors showed evidence, in all cases, of grommet extrusion through the plug sleeve back surface.

CONCLUSIONS

Based on test data it is concluded that the basic cause of observed circuit failures can be attributed to failure mechanism(s) involved with the connector assemblies. That is to say, neither interconnecting cables nor penetration modules, per se, were primary causes of failure.

Specifically, evidence would tend to indict the connector assembly cable grommet. It was observed (see again Figures 5 6, and 7) that grommet material had extruded through the conductor feed-through holes in the plug sleeve back surfaces. During the extrusion process conductor insulation was "pinched down" or stripped from the conductor or, in some cases, a combination of both. These alterations to conductor insulation could lead to either a conductor short circuit condition or the intrusion of moisture. Moisture intrusion would manifest itself in low IR observations. It is possible to speculate that moisture intrusion would be most likely to occur during wet conditions and cycling temperatures.

Any cooling cycle could then lead to shrinkage in remaining grommet material and possible moisture intrusion along a conductor at the plug sleeve back surface. It is less likely but not impossible that some moisture intrusion could have occurred at the connector-module interfaces.

Grommet extrusion is very likely the result of thermal expansion rather than connector retorquing. The preponderence of material extrusion no doubt occurred during the thermal aging phase of the test. The following is considered a reasonable explanation of events. Prior to thermal aging, the connector assemblies were torqued, thus assuring a close fit of all connector components. During the thermal aging cycle, thermal expansion of the grommet and interfacial seal occurred. Pressure relief was constrained to the axial direction and most specifically through the plug sleeve/cable interface holes. At the conclusion of thermal aging, the cable grommet and interfacial seal then contracted. Extrusion of the grommet material resulted in a void within the connector assembly which

It was in this case!

was manifested by loose connector coupling rings. It is believed retorquing at this stage resulted, mainly, in void reduction within the connector. Assuming connector ring observed rotation to torque is a measure of extrusion created void then maximum extrusion occurred during the thermal aging cycle.

true!

Since the connector coupling rings were loose following the radiation and steam tests, it is possible that additional thermal extrusion occurred during both radiation aging and steam accident phases. Thermo-physical properties data for the grommet material were recently made available to us. These data make note of the grommet materials large bulk coefficient of thermal expansion and suggest that in some applications allowance for this property may be necessary.

We should have checked after aging!

Figure 1

CONNECTOR–MODULE SCHEMATIC

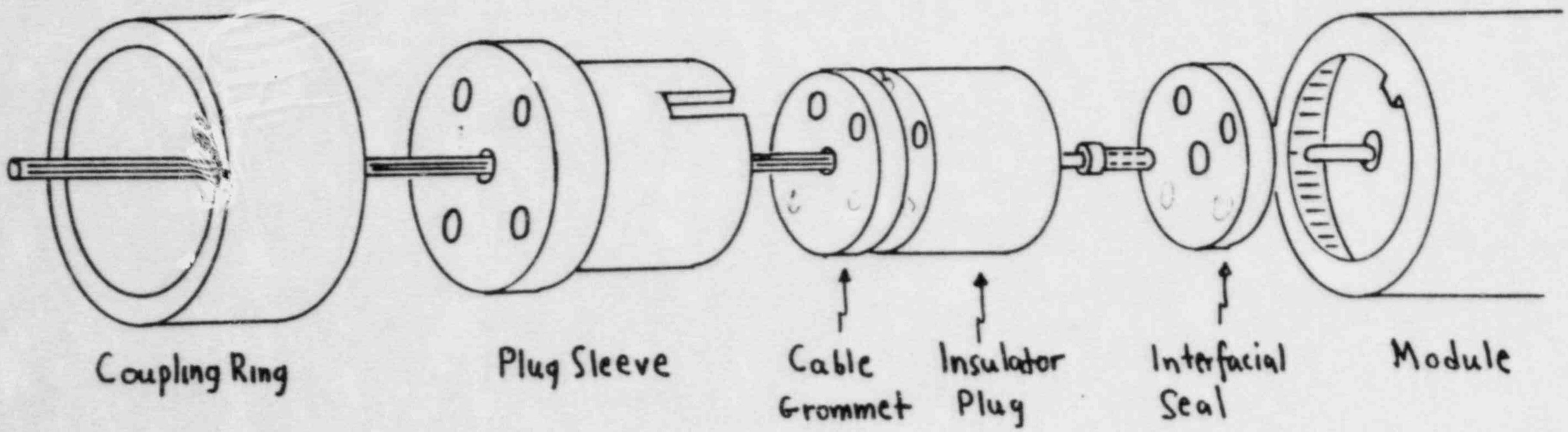


Figure 2

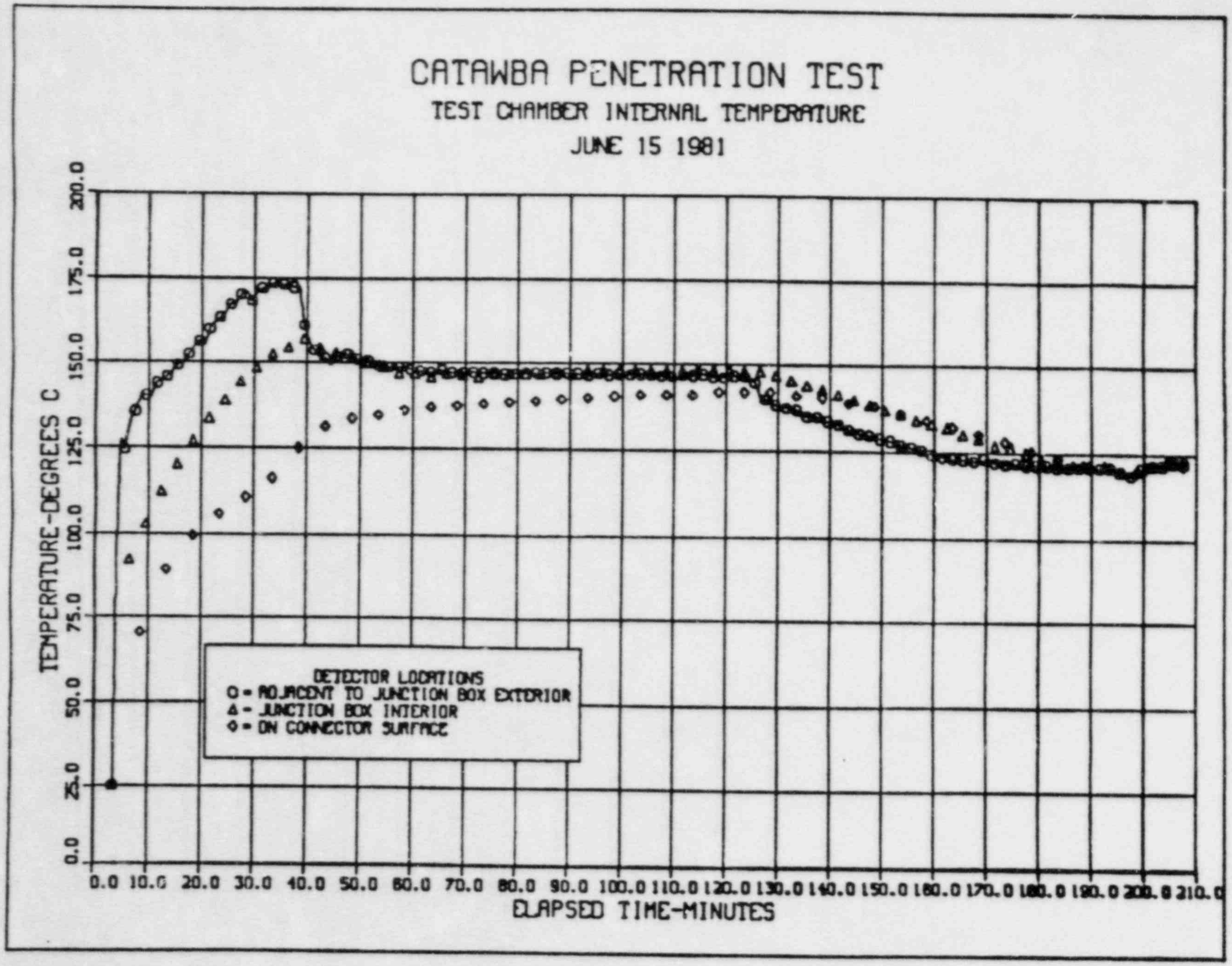

CATAWBA PENETRATION TEST
TEST CHAMBER INTERNAL TEMPERATURE
JUNE 15 1981
TEMPERATURE-DEGREES C
0.0
25.0
50.0
75.0
100.0
125.0
150.0
175.0
200.0
0.0 10.0 20.0 30.0 40.0 50.0 60.0 70.0 80.0 90.0 100.0 110.0 120.0 130.0 140.0 150.0 160.0 170.0 180.0 190.0 200.0 210.0
ELAPSED TIME-MINUTES
DETECTOR LOCATIONS
○ = ADJACENT TO JUNCTION BOX EXTERIOR
△ = JUNCTION BOX INTERIOR
◇ = ON CONNECTOR SURFACE

Figure 3

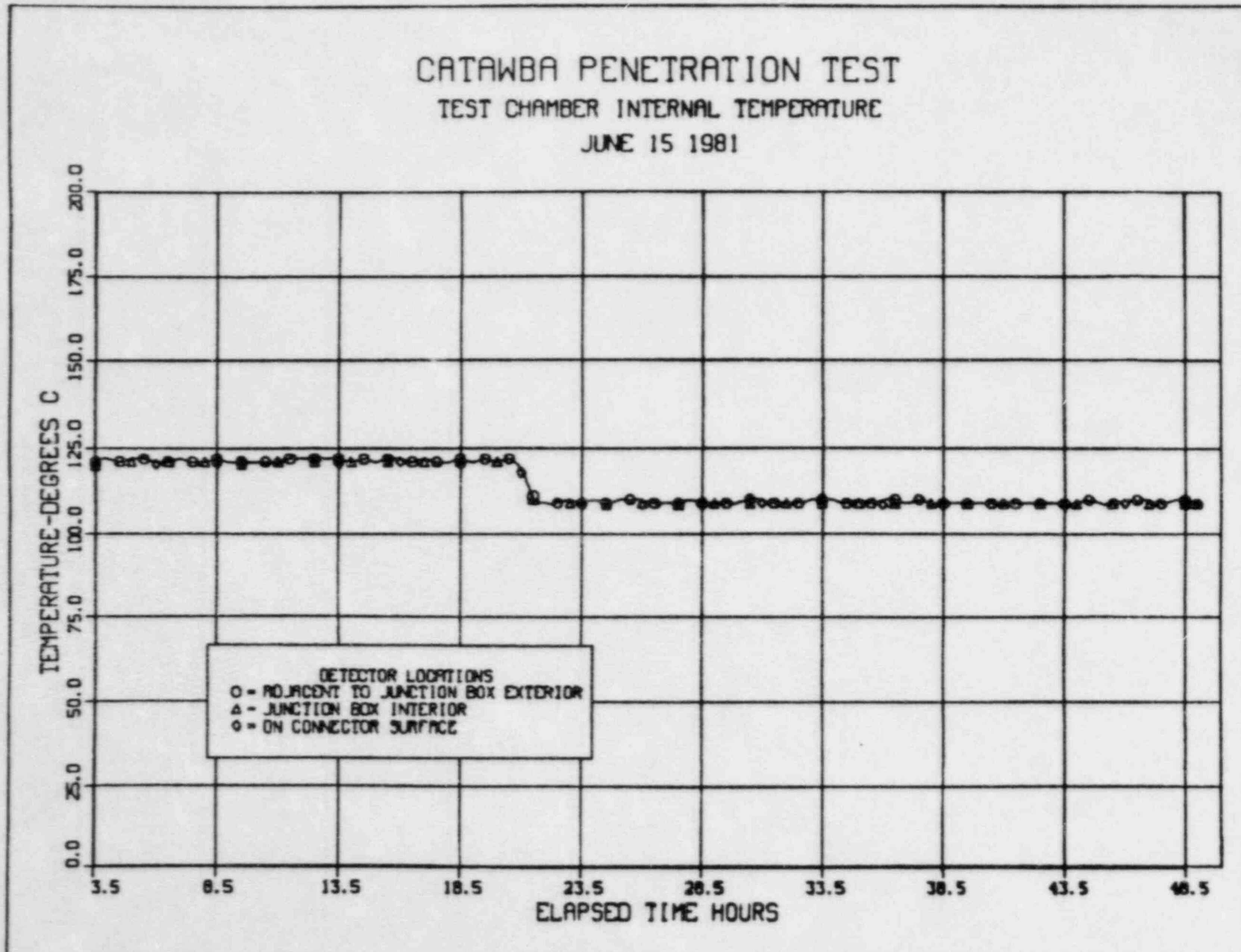
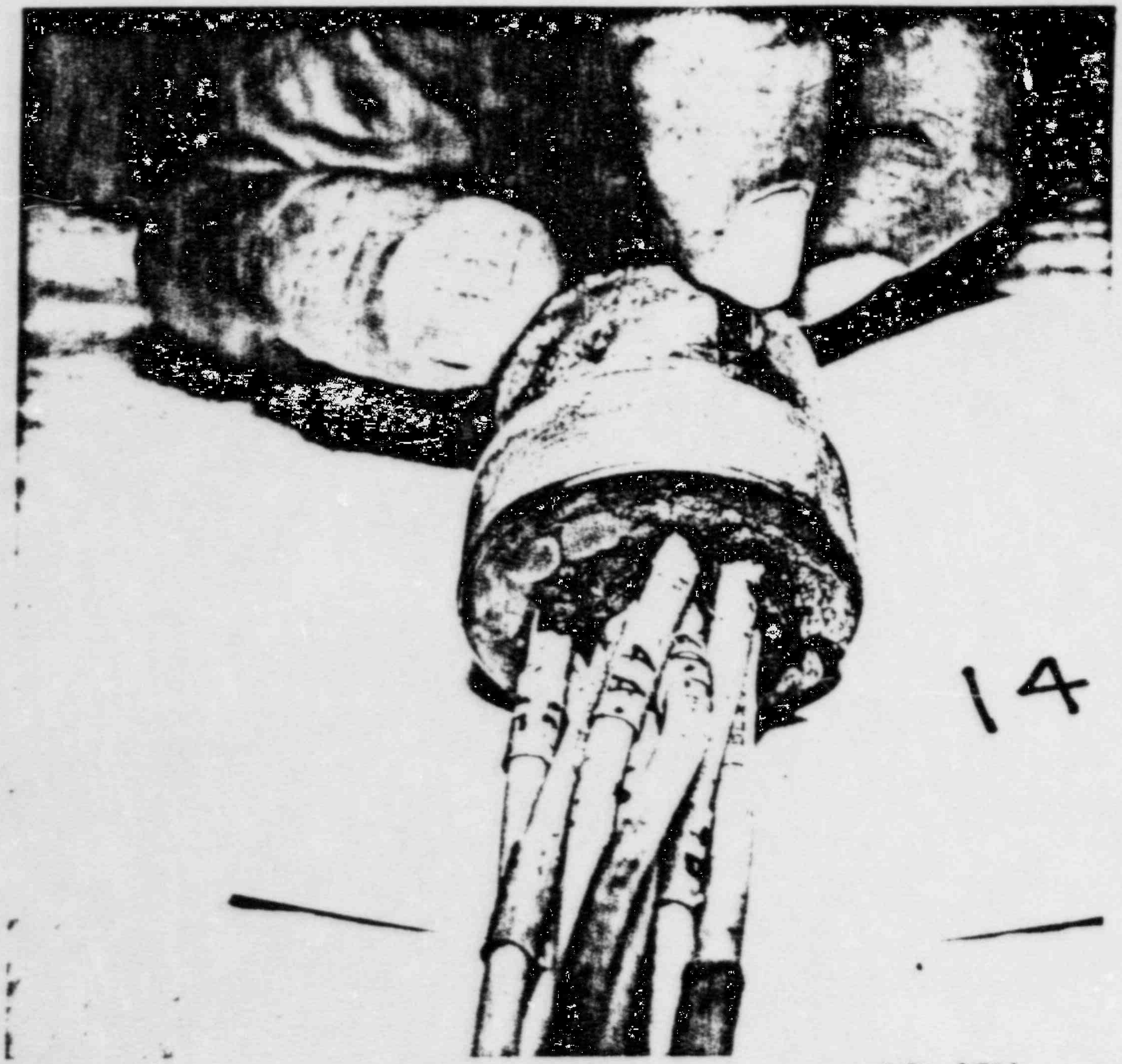

CATAWBA PENETRATION TEST
TEST CHAMBER INTERNAL TEMPERATURE
JUNE 15 1981
TEMPERATURE-DEGREES C
0.0
25.0
50.0
75.0
100.0
125.0
150.0
175.0
200.0
3.5
8.5
13.5
18.5
23.5
28.5
33.5
38.5
43.5
48.5
ELAPSED TIME HOURS
DETECTOR LOCATIONS
○ - ADJACENT TO JUNCTION BOX EXTERIOR
△ - JUNCTION BOX INTERIOR
◇ - ON CONNECTOR SURFACE

Figure 4

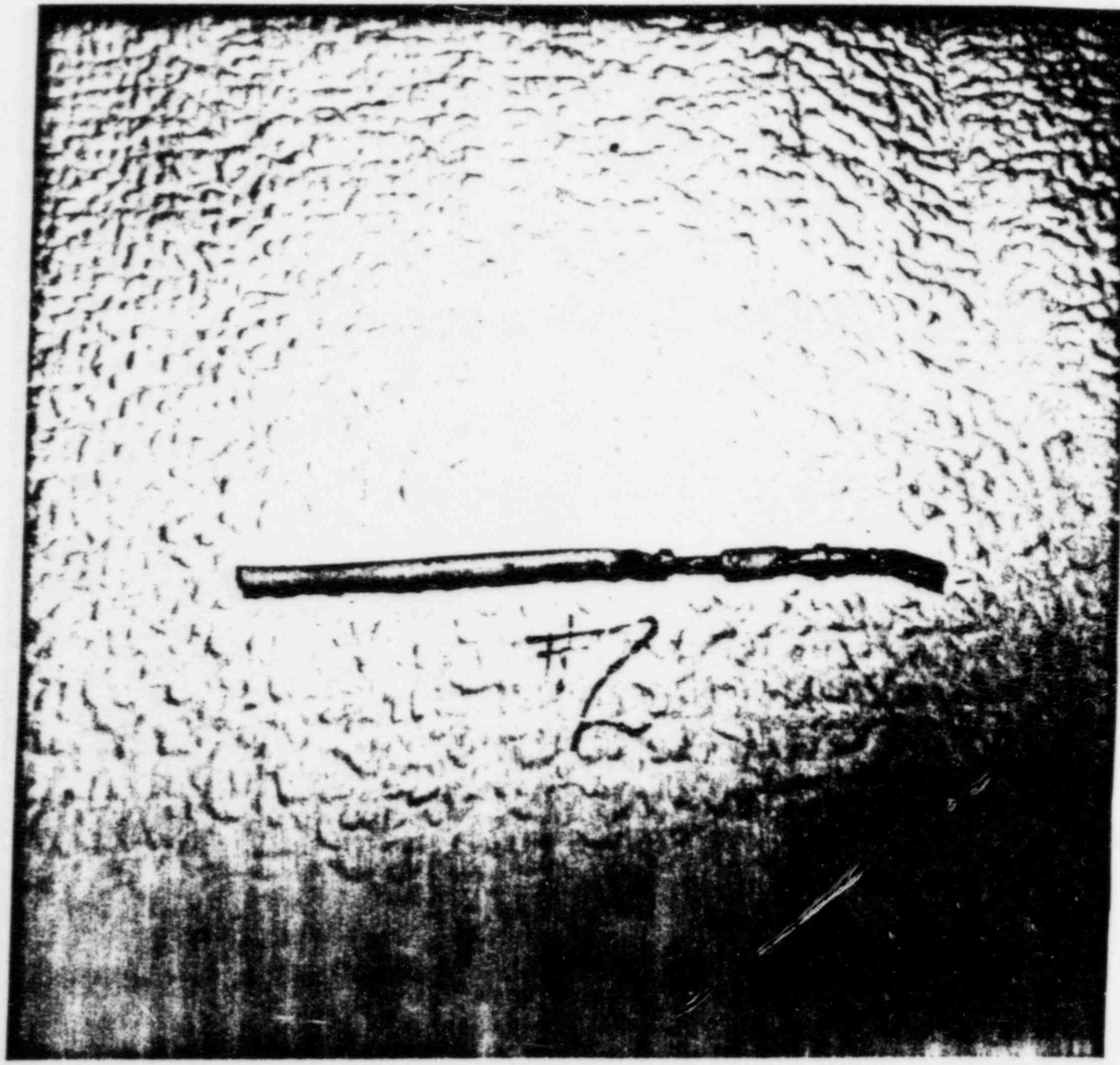
C81-4350

Figure 5



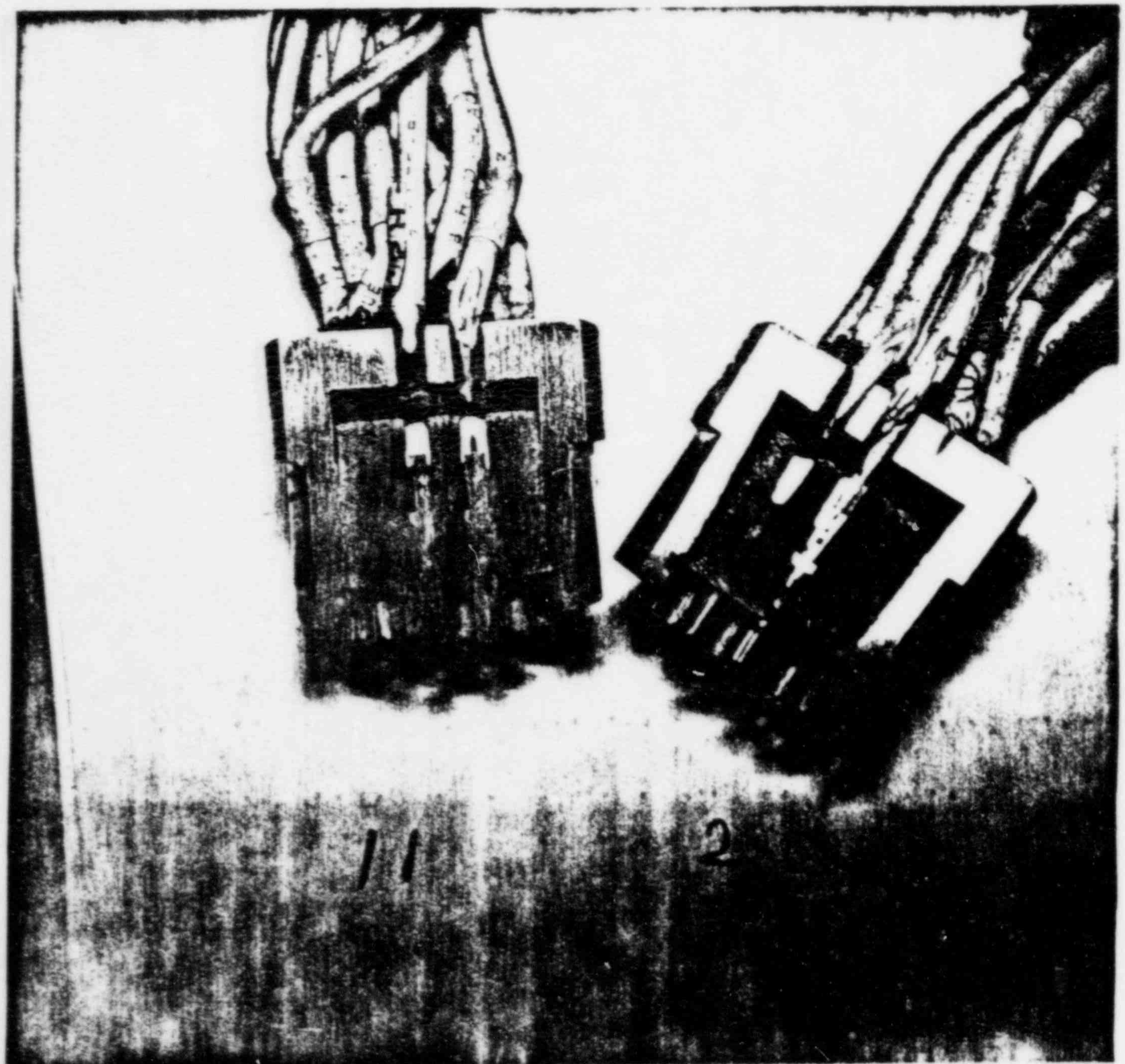
C81-4361

Figure 6



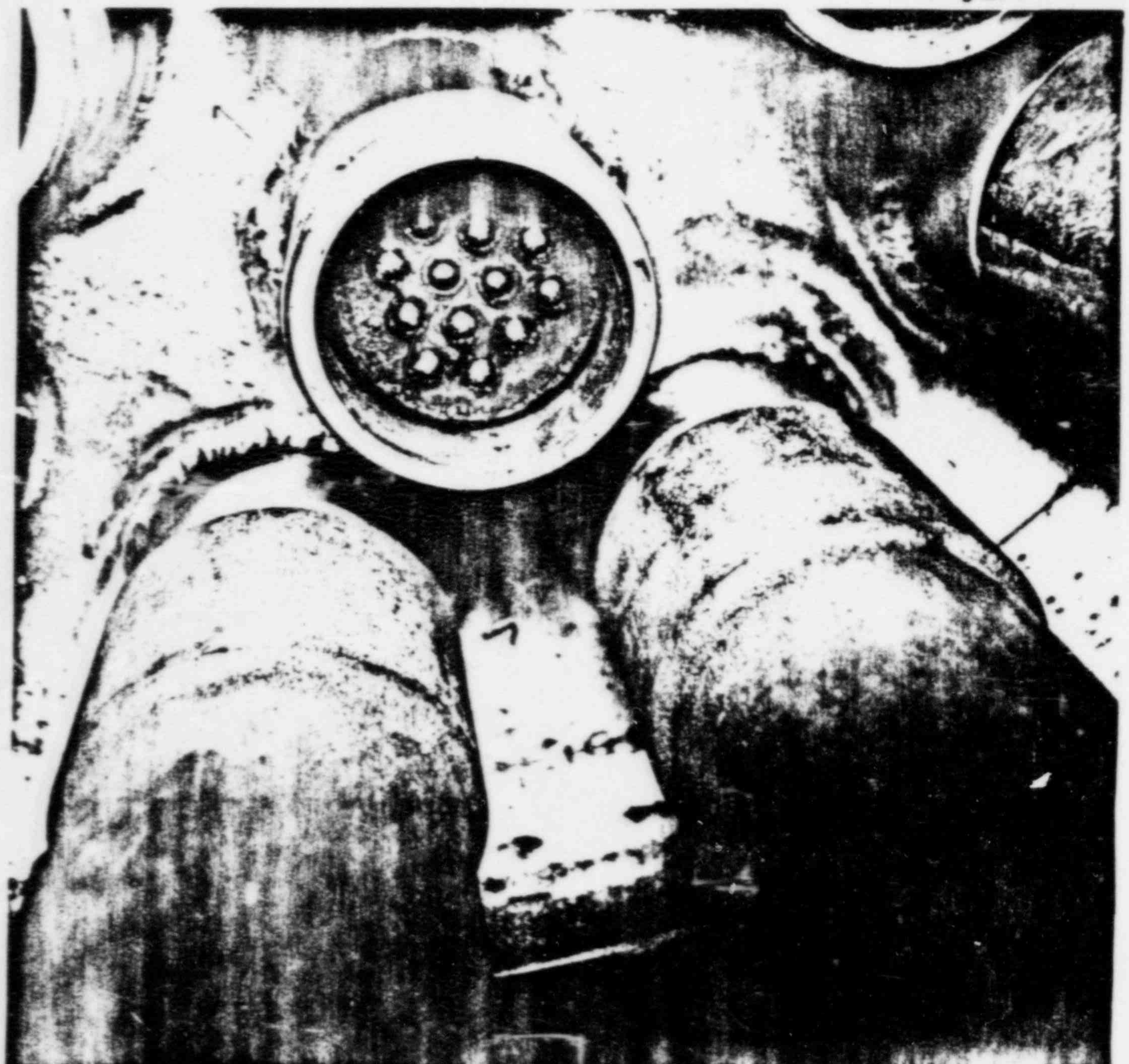
C81-4373

Figure 7



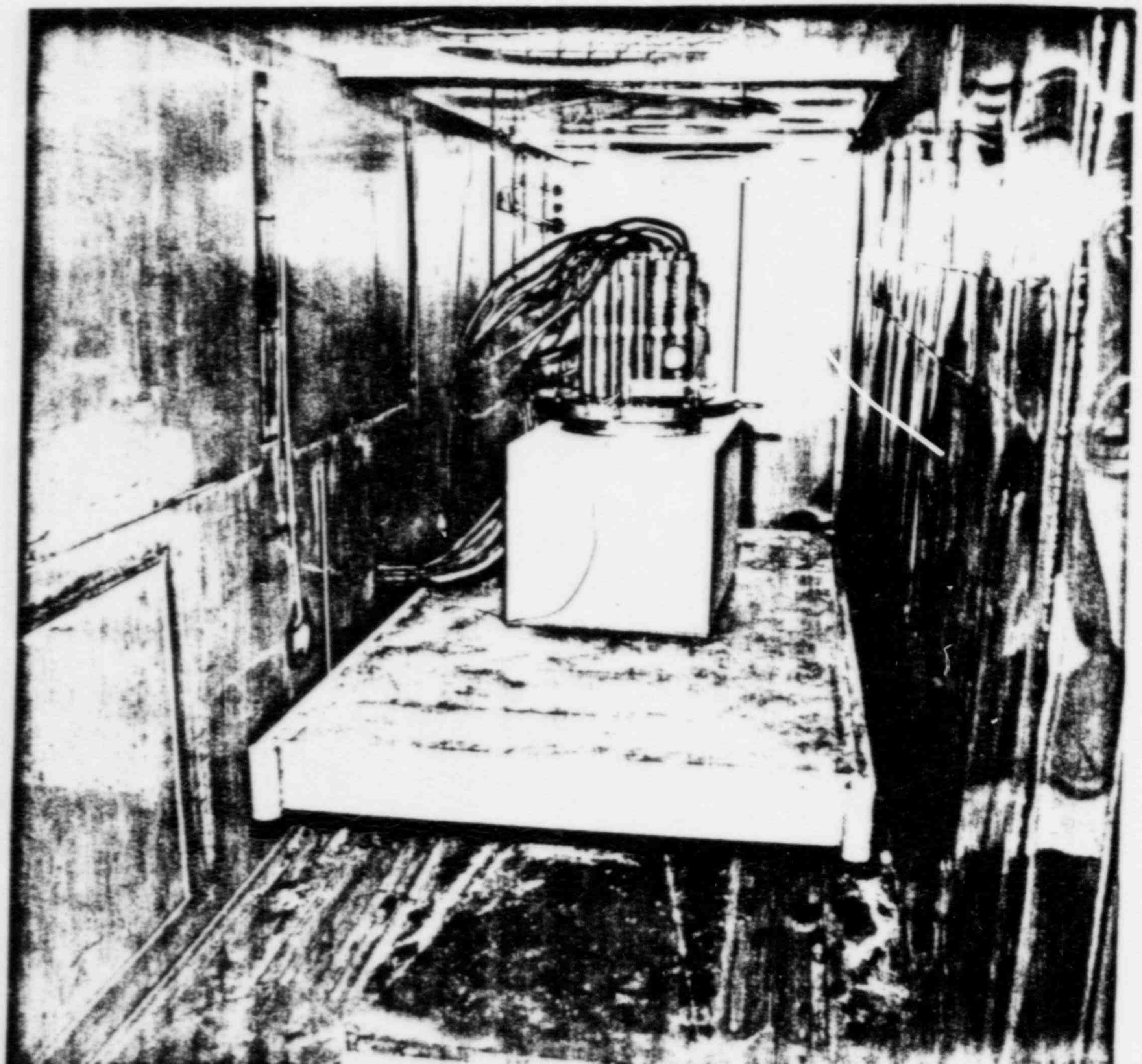
C81-4357

Figure 8



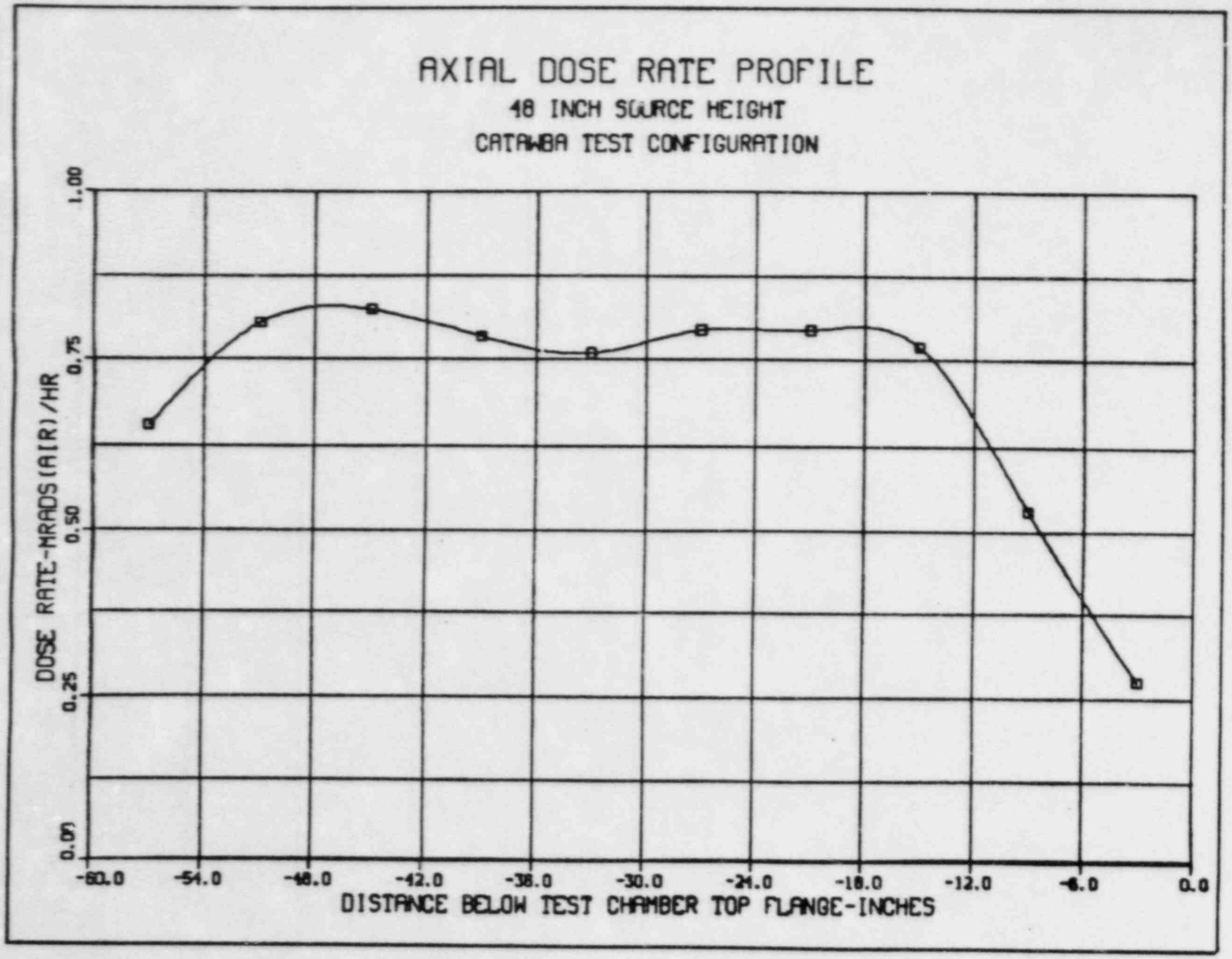
C81-4359

Figure 9



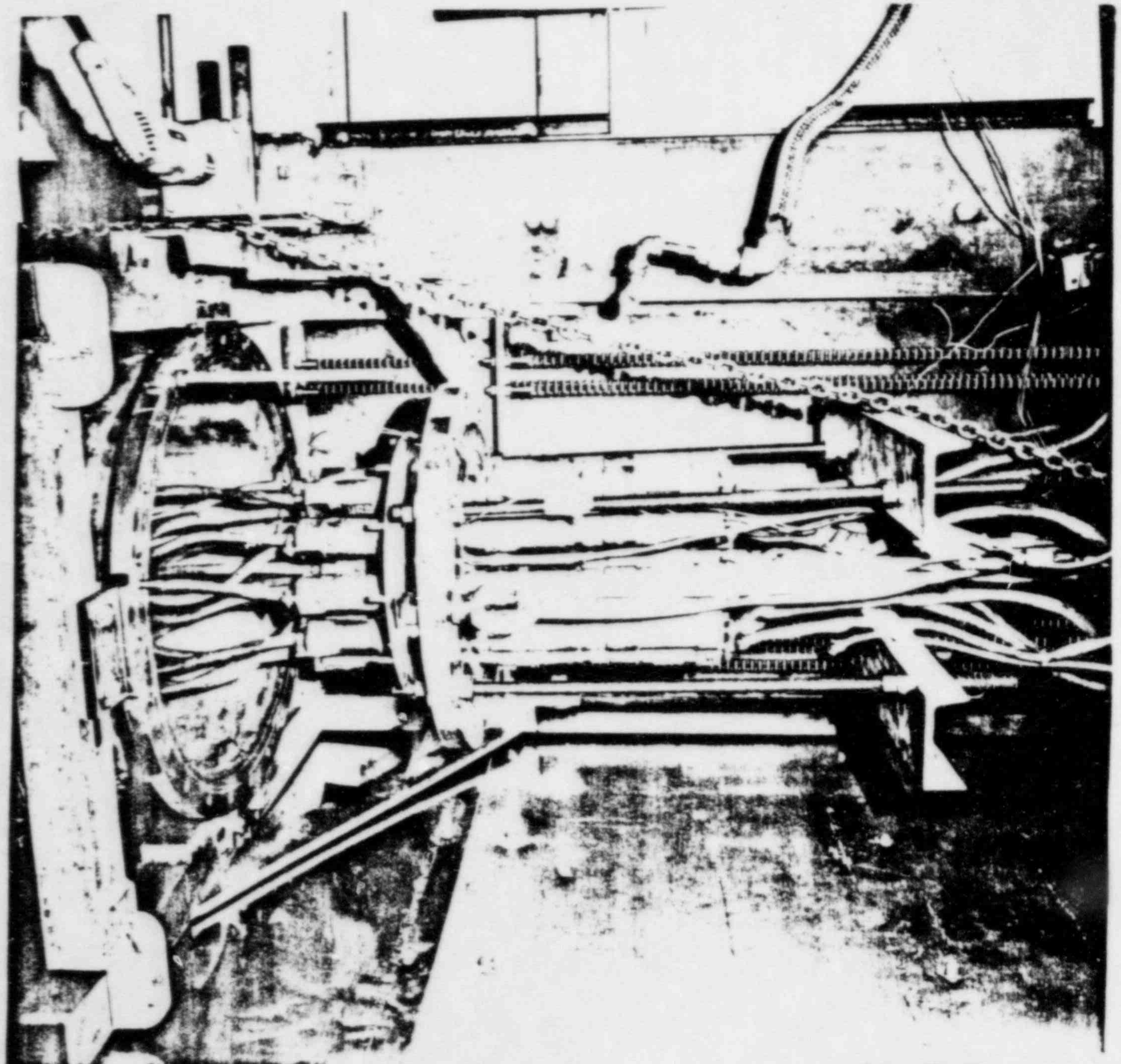
C81-3157

Figure 10



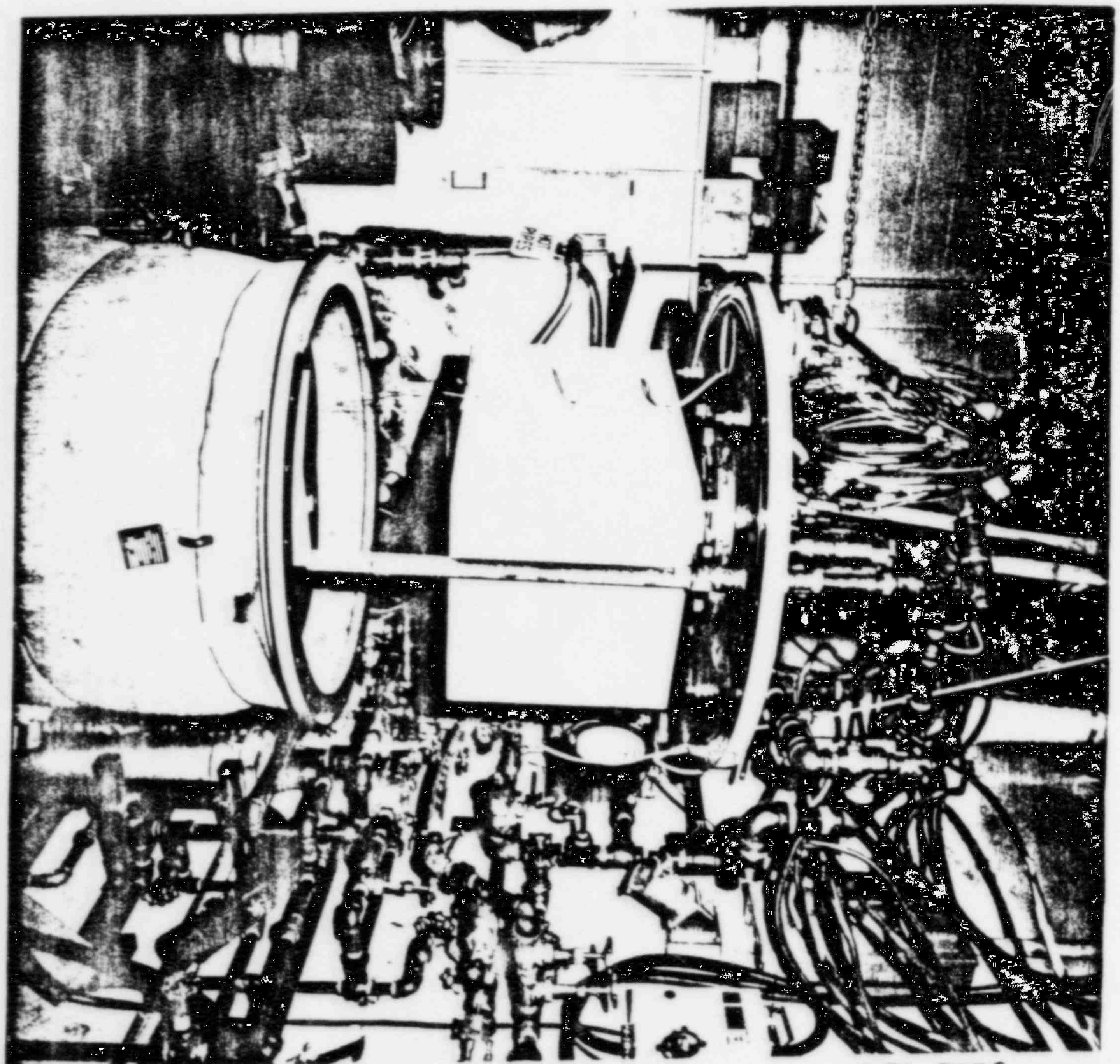
AXIAL DOSE RATE PROFILE
48 INCH SOURCE HEIGHT
CATAWBA TEST CONFIGURATION
DOSE RATE-MRADS(AIR)/HR
1.00
0.75
0.50
0.25
-60.0
-54.0
-48.0
-42.0
-36.0
-30.0
-24.0
-18.0
-12.0
-6.0
0.0
DISTANCE BELOW TEST CHAMBER TOP FLANGE-INCHES

Figure 11



C81-3376

Figure 12



C81-3378

Figure 13

C81-4353

Enclosure 1

Connector Assembly Test Plan

for

Duke Power, Catawba 1 and 2, Connectors

to be coordinated for the

U. S. Nuclear Regulatory Commission
Research Support Branch, RSR

by

Sandia Laboratories, Albuquerque

Submitted:	4/28/80
Second Draft:	11/1/80
Third Draft:	12/22/80
Fourth Draft:	1/30/81

4/28/80
11/1/80
12/22/80
1/30/81

Proposed Verification Program for the Duke Power/D. G. O'Brien Type K Penetration Connector Assembly

Program Objective

Following the Union of Concerned Scientist's petition of November 4, 1977, the NRC Commissioners directed the NRC staff to:

> "Arrange for a repeat of the tests to obtain data for the verification of current methodology for environmental qualification of electrical components. These tests should be performed with a representative sample of commercially available electrical connectors qualified in accordance with IEEE-323 (1974) and in use in nuclear power reactor safety systems. When available, the test results are to be promptly provided to the Commission."

The staff have interpreted this action to be aimed at providing information on the methodology of qualification testing using electrical connectors which meet the provisions of IEEE-323. The staff responded by directing that electrical connectors previously qualified by licensees for use in operating plants be tested in accordance with the applicable version of IEEE-323.

To the extent practicable, connector assemblies will be subjected to the actual aging, radiation, and LOCA-stimulation tests for which the connector assemblies have been qualified.

Inspection and Enforcement (IE) staff have evaluated some of the various utilities' connector hardware and qualification documents. The first test in this series, selected by IE, used Bendix connector assemblies as installed in Browns Ferry Unit 3; that test was documented as SAND 79-2311, NUREG/CR-1191, dated December 1979. The second in the series, as selected by IE staff and outlined in this test plan, will use D. G. O'Brien connector assemblies mated to an O'Brien instrumentation penetration. The connectors and penetration were among those acquired for installation in Catawba Units 1 and 2.

During the development program of the Type K module-connector assembly, circumstances were such that only certain items of the assembly were subjected to the entire sequence of aging, radiation and LOCA/MSLB environments. Specifically the assembly connector component was only partially qualified by test.

4/28/80
11/1/80
12/22/80
1/30/81

It is the objective of this program to subject a Type K penetration assembly to the entire environmental and accident aging processes. The complete assembly is to include mated cables and connectors and at least one junction box.

Test Item Description

The Type K penetrations and auxiliaries are manufactured by the D. G. O'Brien Co. in accordance with Duke Power specification CNS-1361.00-00-0003. Units of this type are used to penetrate the containment at Catawba Units 1 and 2.

The unit to be used in this test is currently on hand at the Catawba Station. It was acquired, by Duke Power, at the time of acquisition of the instrumentation penetration units presently being installed at the Catawba Station. In Figure 1, a drawing of the type K instrumentation penetration is presented. The penetration is shown complete with module, connectors (plugs), junction boxes, and flange pressure gauge. For purposes of clarity only one module appears in the drawing. However, the unit being acquired for this test has eight each of two module types for a total of 16 modules.

Assembly of Test Items

Using mating connectors (plugs) and appropriate cabling, the penetration unit will be wired so that pairs of like modules will be interconnected. In Figure 2 a typical interconnection between like modules is shown. Note the straightforward approach, i.e. Pin A is connected to Pin A, etc.

The wiring necessary to interconnect the paired modules will be the responsibility of Duke Power Company. The standard Duke procedures, CNM-1361.00-0011 and CNS-1390.01-0073, will be followed during connector (plug) wiring. Quality Control Inspection will be in effect to insure that the above procedures are followed. Assembly of the wired mating connectors to the appropriate modules will be by Duke Power personnel. Every effort will be made to assure a product typical of field-installed units. Since the assembly of connectors to modules requires a special torquing tool, a Duke Power representative will retorque all connectors on the penetration assembly after its receipt at Sandia and prior to any tests on the unit.

Background

The qualification history of the type K module/connector was discussed in detail in the April 1980 draft of this test plan.

In that draft, the partially qualified component of the penetration assembly was identified as the connector unit. As a result it was proposed that the connector, along with sufficient mating assembly, be subjected to the aging and accident sequence. The purpose of the mating assembly was not for verification but to serve as an interface during functional tests. The concept of a partial assembly was rejected on the basis the assembly would need to be manufactured and hence would not necessarily be representative of the presently installed units.

It was subsequently proposed that a Duke Power penetration unit available at the Catawba Station be used in the connector verification program. This penetration assembly, acquired with installed units, when assembled with mating connectors and interconnecting cabling would be quite representative of installed items; certainly more so than any after the fact fabricated item.

Test Procedures

General

The penetration assembly will undergo the aging - accident sequence in the as-received condition i.e., with a junction box installed on the inboard side of the assembly. An example of the test configuration is shown in Figure 3. In Figure 3 the penetration assembly is shown positioned in the LOCA/MSLB test chamber. Note that the inboard portion of the penetration assembly is completely enclosed in the inboard junction box. Note also the instrumentation/test cabling extending from the outboard side. Because the penetration assembly is mounted vertically, the pressure equalizing-condensation drain vent shown in Figure 3 was repositioned from position V' to position V.

One exception to the above configuration will occur during the radiation aging cycle. Dimensions of the Cobalt-60 irradiation chamber are such that the inboard assembly complete with junction box cannot be accommodated. It will be necessary to irradiate the inboard penetration unit without the junction box. The junction box dose attenuation effect will be measured and appropriate adjustment made in the irradiation time.

Environments to which the assembly will be subjected are:

1. Thermal aging
2. Radiation
3. LOCA-MSLB

The above tests will be, generally, in accordance with those described in the D. G. O'Brien reports ER-252 and conforming to QA-TM-185/191 of that report. The test will be performed in the following sequence and will adhere to the concepts contained in the Sandia Department 4440 Quality Assurance Program Plan.

1. Baseline - visual and functional
2. Thermal aging
3. Post aging functional - visual
4. Radiation
5. Post radiation functional - visual
6. Accident
7. Post accident - functional - visual

Acceptable performance of the assembly will be on the basis of accept-reject criteria listed in a succeeding section of this proposal.

<u>Specific</u>

I. Pretest - Baseline

A. Visual inspection

1. general appearance
2. radiographs if appearance warrants

B. Functional

1. continuity - check for continuity and correctness
2. insulation resistance - 5×10^6 ohms @ 500 VDC between each conductor and all other conductors connected to ground (shell).
3. Penetration internal pressure - note and record

II. Thermal Aging

A. General

Thermal aging shall be conducted in a forced circulating air furnace. There shall be no obstruction to flow across the test specimen. Equipment is to be isolated from furnace walls and from any primary radiant energy source.

B. Test requirements

1. 150°C ± 2°C
2. 168 hours duration
3. check continuity and insulation resistance once daily
4. internal pressure - note and record

C. Post test

1. insulation resistance
2. continuity
3. visual
4. internal pressure - note and record

III. Radiation Exposure

A. General

The penetration assembly will be subjected to the dose rate and integrated dose specified in the succeeding section on test requirements. Configuration of the Sandia irradiation source geometry is adjustable so that dose rate and/or radiation field dimensions may be tailored to specific needs. Considering the penetration dimensions-less junction box-and the requirement to maintain the radiation dose rate below 1 megarad/hr a source configuration, considered compatible with the requirements, was assembled and mapped. In Figure 4 the results of that mapping are presented. As may be observed, extent of uniformity of the radiation field exceeds the penetration dimensions. Additionally radial placement of source pencils assures dose uniformity in the radial direction.

Concerning removal of the inboard junction box, the following steps will be taken. With the desired source configuration, Figure 4, dose rate will be determined with a calibrated air ionization chamber both with and without the junction box. Very simply these differences in observed dose rates can be attributed to junction box perturbations. Then the penetration aging time will be adjusted to reflect the dose rate observed with the junction box in place. Temperature of the environment is to be monitored and maintained at or below the normal 110°F operating temperature. Dose measurement techniques and detector calibration will be traceable to the NBS.

B. Test requirements
1. 2×10^8 rads (AIR) $\pm 10\%$
2. dose rate not to exceed 10^6 rad/hr
3. internal pressure - note and record

C. Post test requirements
1. continuity
2. insulation resistance
3. internal pressure - note and record

IV. Accident Test

A. General

This test is to be a combination of LOCA, MSLB, and thermal shock environments. The LOCA and thermal shock environments are straight forward although the duration of the thermal shock has not been specified.

The steam line break phase of this environment, as outlined in the Duke Power Specification CNS-1361.00-00-0003, calls for an initial rise in temperature and pressure from ambient to 340°F and 15 psig, respectively, in 10 seconds. The Sandia facility, at this time, cannot duplicate the specified transient rather, the temperature-time profile appearing in the Figure 5 is more typical of the Sandia facility capability. For improved perspective, Figure 6 has been included. In this figure are plotted the Duke Power specified transient, an actual D. G. O'Brien qualification profile, and the estimated Sandia capability. Consideration of the specified thermal transient and the Sandia capability prompted an inquiry of several commercial laboratories as to their transient temperature capabilities. At the present time, none of those laboratories polled could duplicate the specified temperature-time profile. The rise time of the Sandia facility could probably be "sharpened" some with the variation of available parameters but it would in no way approach the specified 10 second value. However, when the thermal lag introduced by the junction box presence is considered, the actual connector environment probably rises much more slowly than the specified environment rise time.

Actual positioning of temperature sensors in the test chamber and about the penetration will depend upon the temperature distribution within the test chamber. This distribution will be determined during pretest steam performance evaluation of the chamber. A tentative temperature and pressure diagnostic scheme is shown in Figure 7. Temperature sensors will be placed so that spatial temperature distributions near the junction box surface may be monitored. At least one temperature sensor will be positioned in box interior so that some knowledge of module temperature history may be obtained. Access to the junction box interior will be through vent "V"--a pressure equalizing and condensate drain vent.

B. Test Requirements (see also Figure 8)

1. 340°F ± 10°F @ 15 psig ± 5 psig for 10 minutes -- rise time 10 seconds, but see also above and enclosed temperature profile
2. drop to 300°F in 10 to 30 minutes

3. 300°F ± 10°F @ 15 psig ± 5 psig for 80 minutes
4. drop to 250°F ± 5°F @ 15 psig ± 5 psig hold for 18 hours

   a. when temperature stabilizes @ 250°F a thermal shock to consist of either water spray at 40°F directly onto junction box - time duration to be not less than one minute.
   b. following thermal shock - chemical spray to be used for duration of test. Composition of the spray (IEEE-323(1974)) is as follows:
      .028 molar H_3BO_3
      .004 molar $Na_2S_2O_3$
      NaOH to make a pH of 10.5 @ 77°F

5. drop to 228°F ± 5°F @ 5 psig ± 5 psig hold for 120 hours

   a. spray continues

6. 600 VAC to be applied between all conductors and the connector shell during entire test--see Figure 9.
7. continuity and insulation resistance to be checked daily
8. penetration internal pressure - note and record daily

C. Post test

1. insulation and continuity tests
2. internal pressure - note and record

<u>Acceptance-Rejection Criteria</u>

General

Acceptable electrical performance of the penetration assembly is based on the Duke Power Company specification CNS-1361.00-00-0003. This specification requires that "Type K penetration assemblies shall be designed to maintain a minimum insulation resistance of 1 x 10^7 ohms when tested at a potential of 500 volts DC.... All resistance measurements are to be made between each conductor and all other conductors connected to ground."

So that functional tests may be performed, the penetration unit to be supplied to Sandia will have like pairs of modules connected, electrically, in series. Although Duke Power selected this wiring configuration, they questioned the applicability of the CNS-1361.00-00-0003 insulation resistance requirement for this wiring configuration and agreed to determine what effect, if any, interconnecting modules should have on the minimum acceptable insulation resistance requirements.

The Duke position, regarding series connected modules was transmitted to Sandia in a letter dated January 23, 1981, Dover (Duke Power) to Buckalew (Sandia)*. The Duke position is as follows. Since the series arrangement of modules will provide parallel resistance paths to ground for the interconnected modules, the minimum insulation resistance should be lowered to reflect this condition. This position is interpreted, by Sandia, to mean that the minimum acceptable insulation resistance requirement should be lowered from 1×10^7 ohms to 5×10^6 ohms.

Response

It is not anticipated that performance criteria will influence the mechanics of this test, i.e. the test will proceed to completion regardless of measured insulation resistance values. During the performance of this test the following actions will apply.

A. Aging Sequences -- nonpowered phases

Should insulation resistance less than 5×10^6 ohms be observed at the specified measurement intervals, appropriate NRC and Duke Power persons will be promptly advised. Suspect circuits will continue to be tested throughout the aging sequences.

B. Accident Sequence -- 600 VAC power phase.

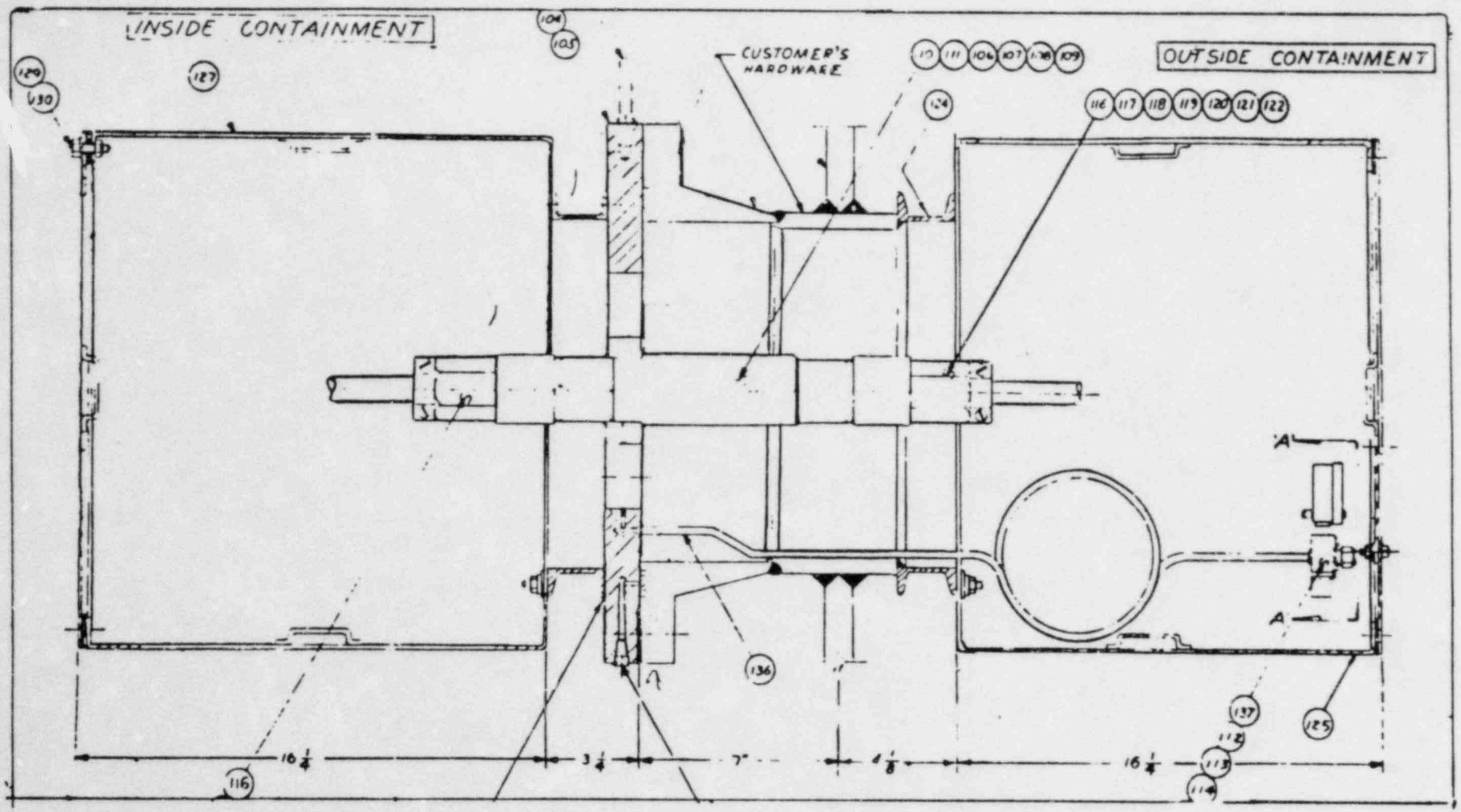
The actions of A (above) will be appropriate except in the case that the insulation resistances fall to a level that leakage currents become excessive. In the case of excessive leakage current, the circuits responsible for the excessive current will be removed from the power buss. Again this condition will be promptly reported.

Final Report

A final report will be issued on this test. It will include all data sheets and other pertinent details.

*See also the addendum to this test plan.

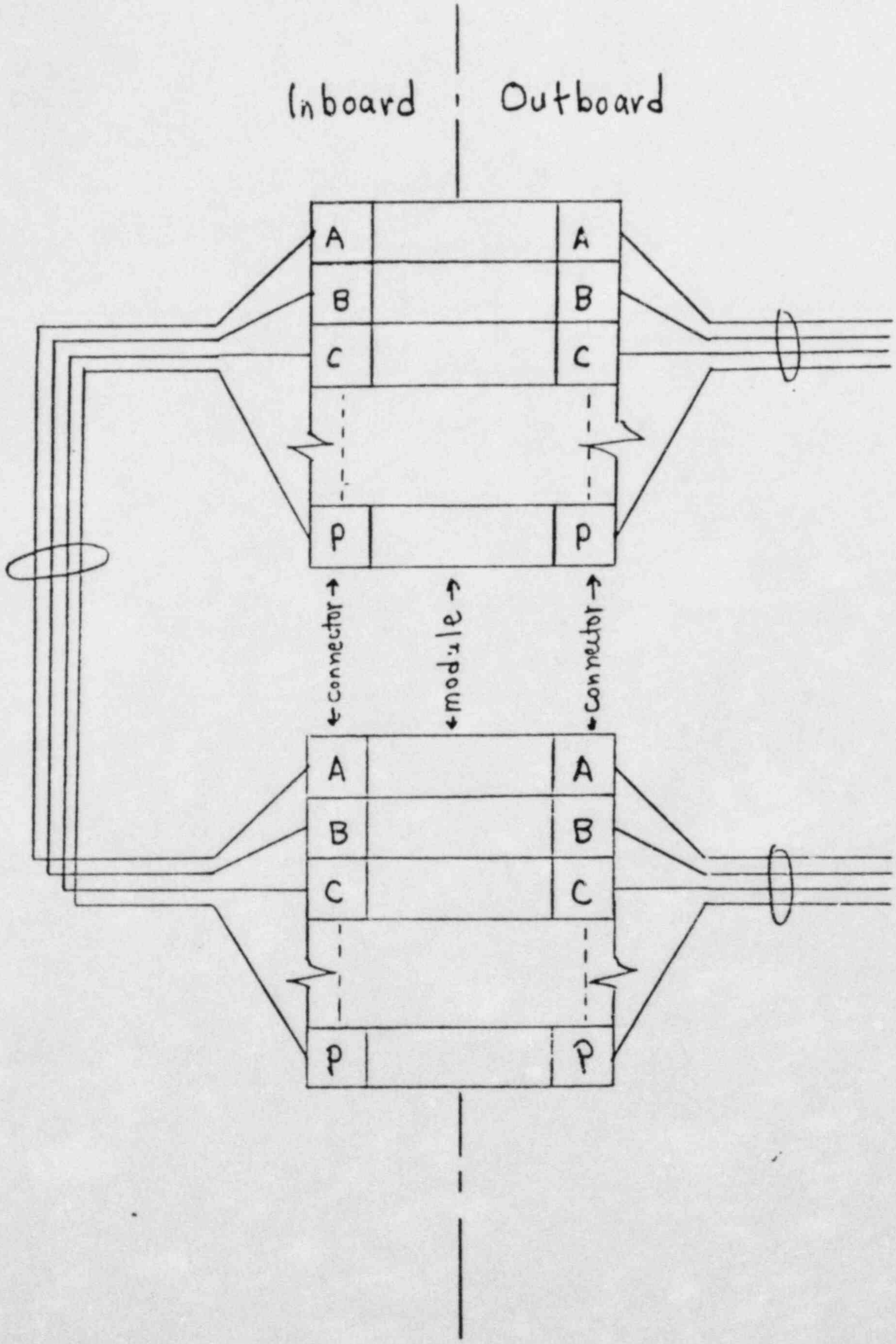
FIGURE 1.



Penetration Assembly - Complete

FIGURE 2.

Typical Wiring Between Like Modules on the Penetration Assembly



Test Chamber & Penetration Schematic

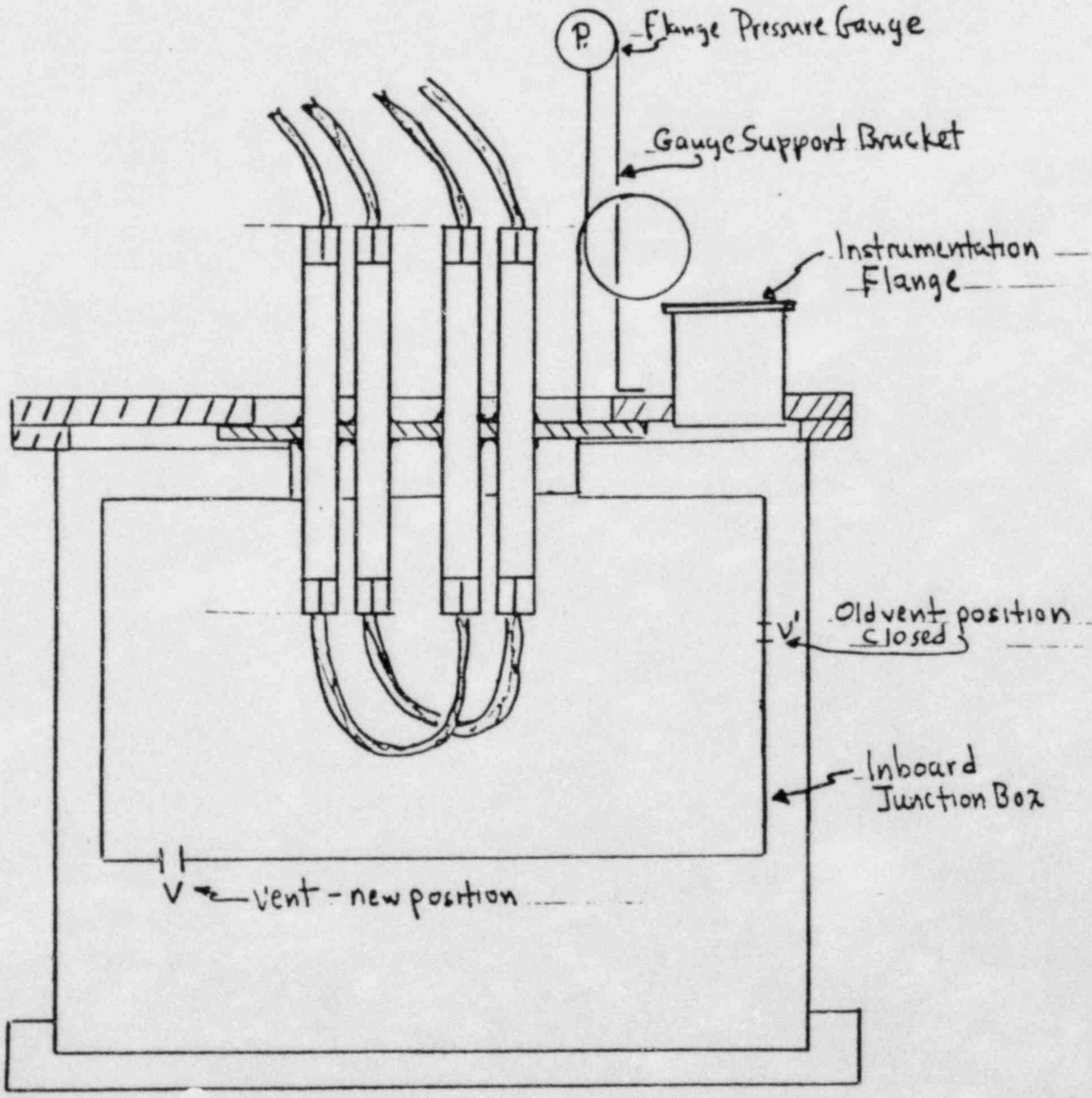
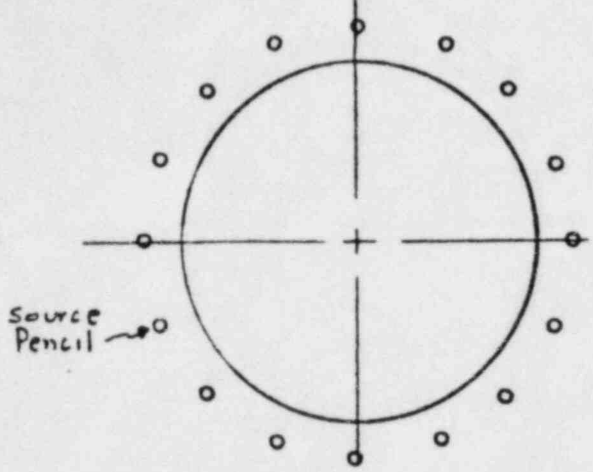
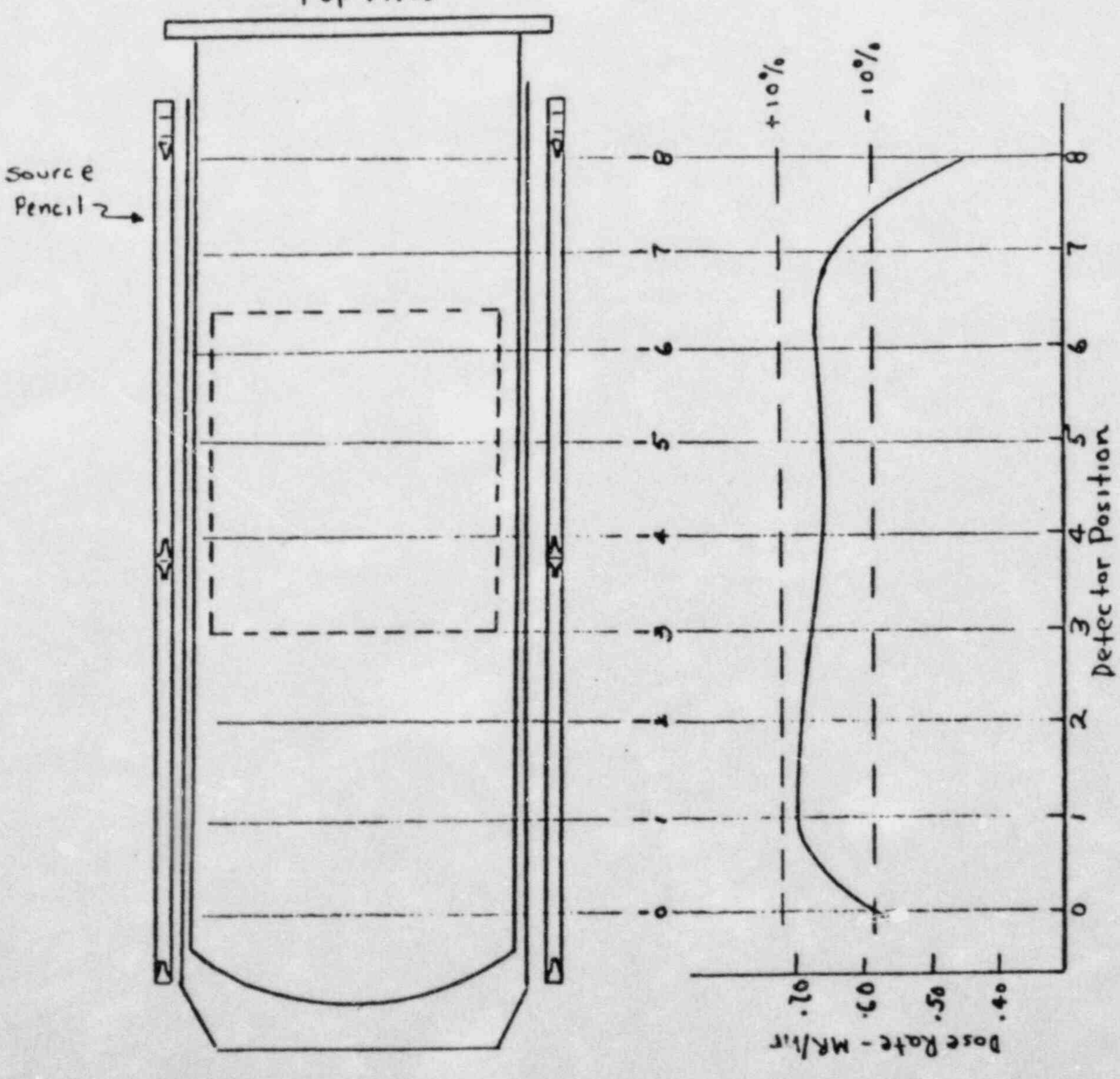


FIGURE 4.

Schematic - Irradiation Chamber Showing Approximate Penetration Location



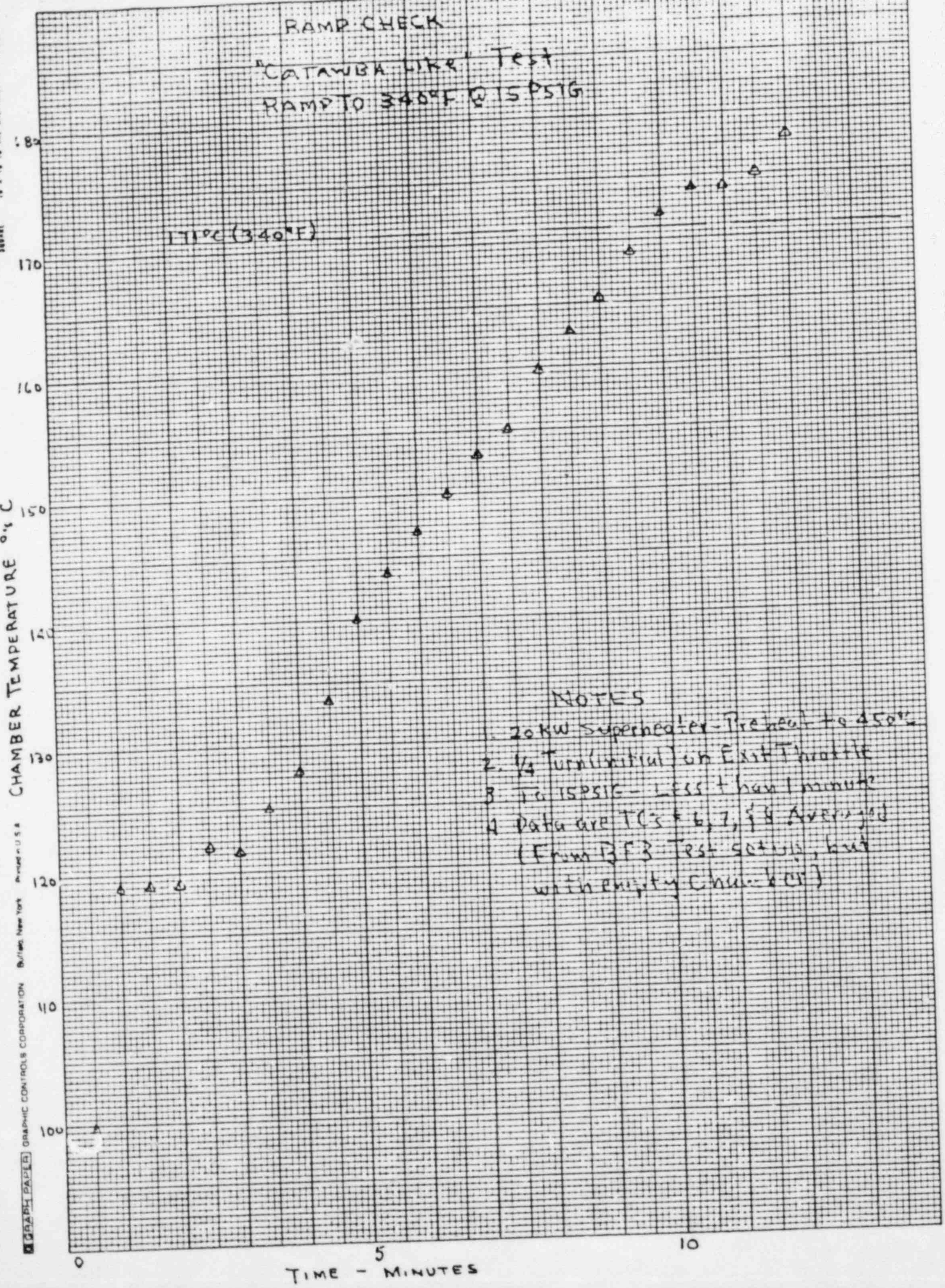
Test Chamber
Top View



Test Chamber

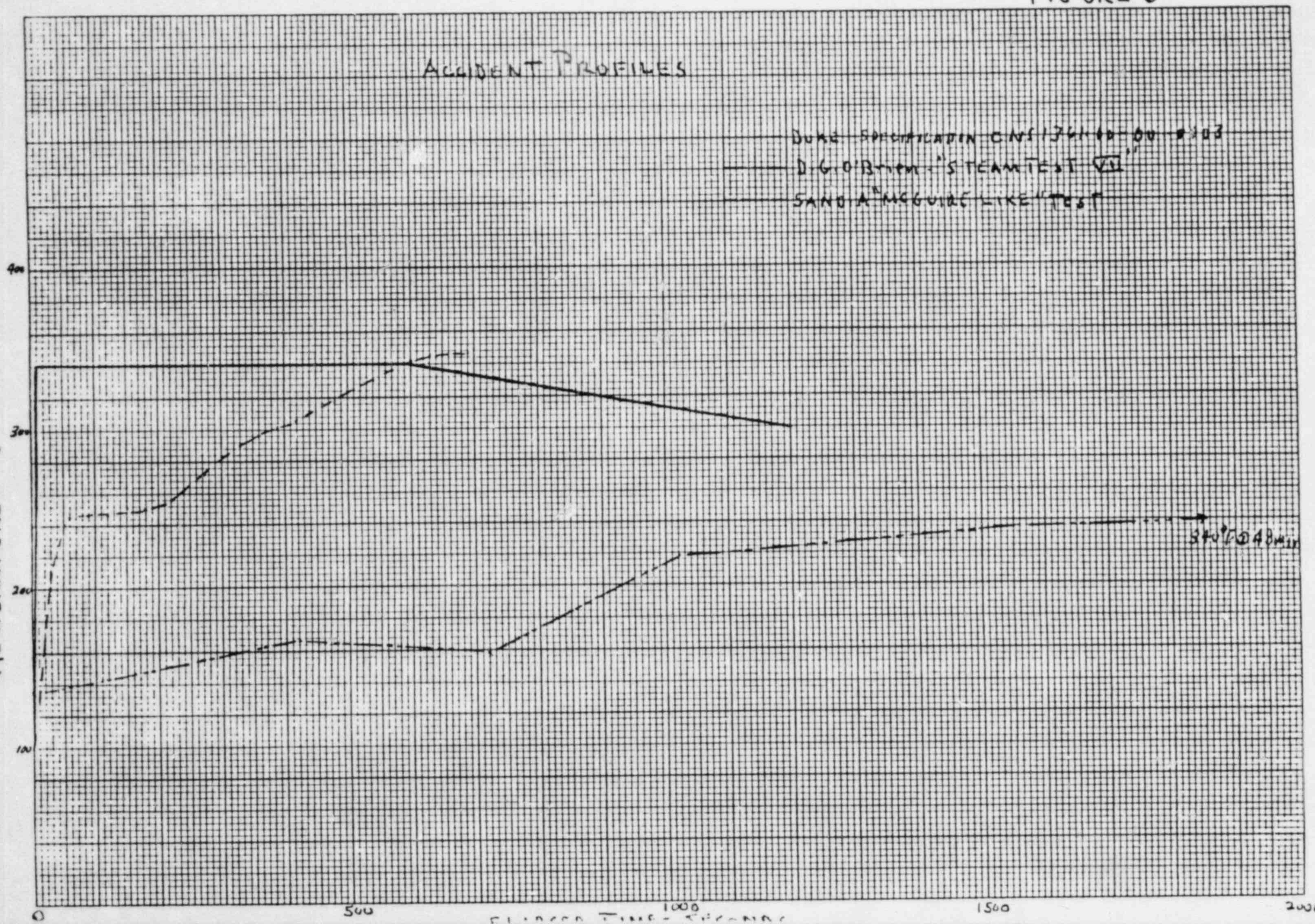
Vertical Dose Profile

Figure-5



RAMP CHECK
"CATAWBA LIKE" Test
RAMP TO 340°F @ 15 PSIG
171°C (340°F)
NOTES
1. 20 KW Superheater - Preheat to 450°F
2. 1/4 Turn (initial) on Exit Throttle
3. To 15PSIG - Less than 1 minute
4. Data are TC's # 6, 7, & 8 Averaged
(From BF3 Test setup, but
with empty Chamber)
CHAMBER TEMPERATURE °C
TIME - MINUTES
0
5
10
100
110
120
130
140
150
160
170
180
GRAPH PAPER GRAPHIC CONTROLS CORPORATION Buffalo, New York Printed in U.S.A.
SQUARE 10 X 10 TO THE HALF INCH

FIGURE 6


ACCIDENT PROFILES
DUKE SPECIFICATION CNS 1361.00-00-0003
D.G. O'BRIEN - "STEAM TEST VII"
SANDIA "MCGUIRE LIKE" TEST
340°F @ 48 min
400
300
200
100
0
500
1000
1500
2000

Test Chamber & Penetration
Thermocouple Locations

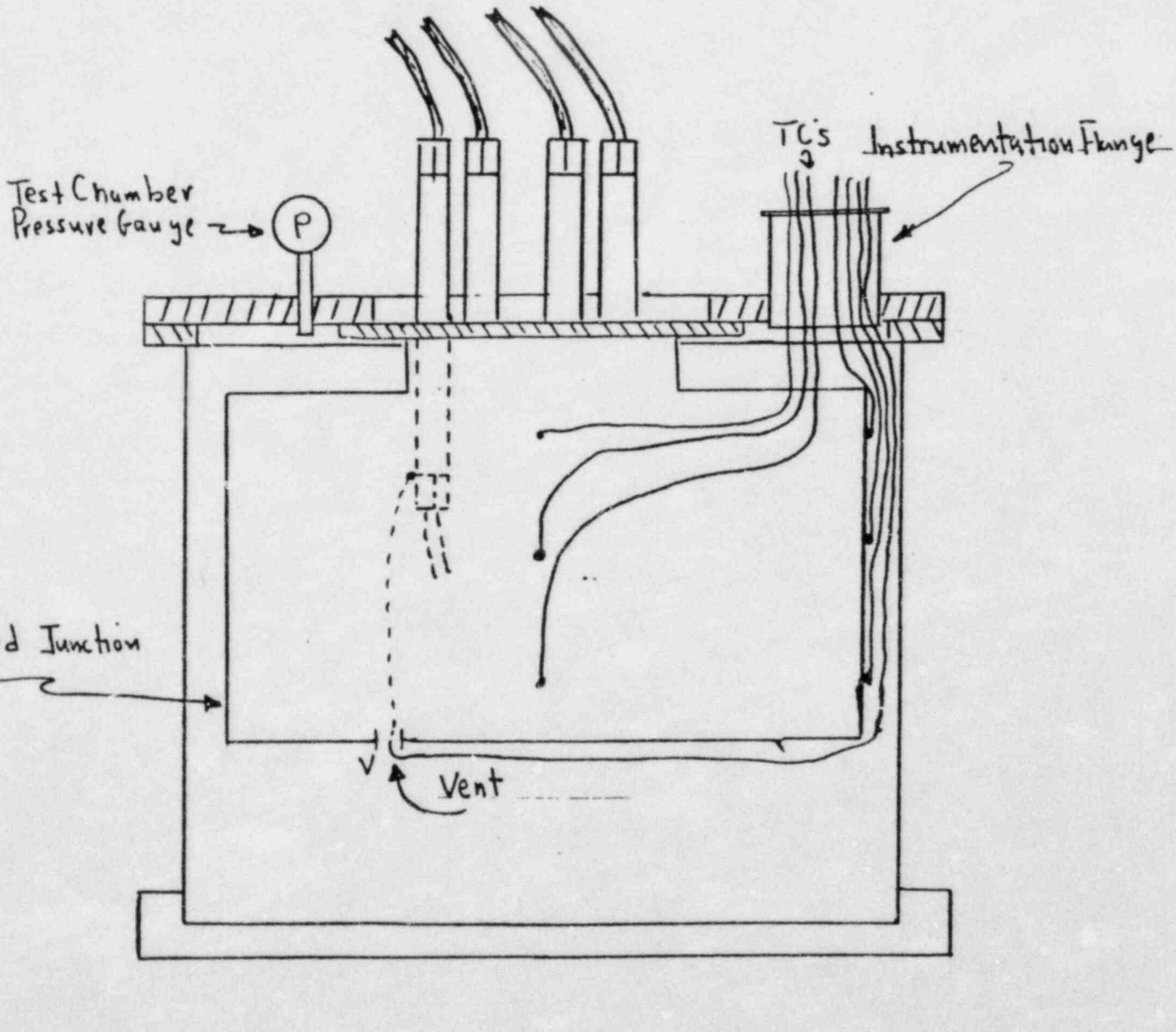
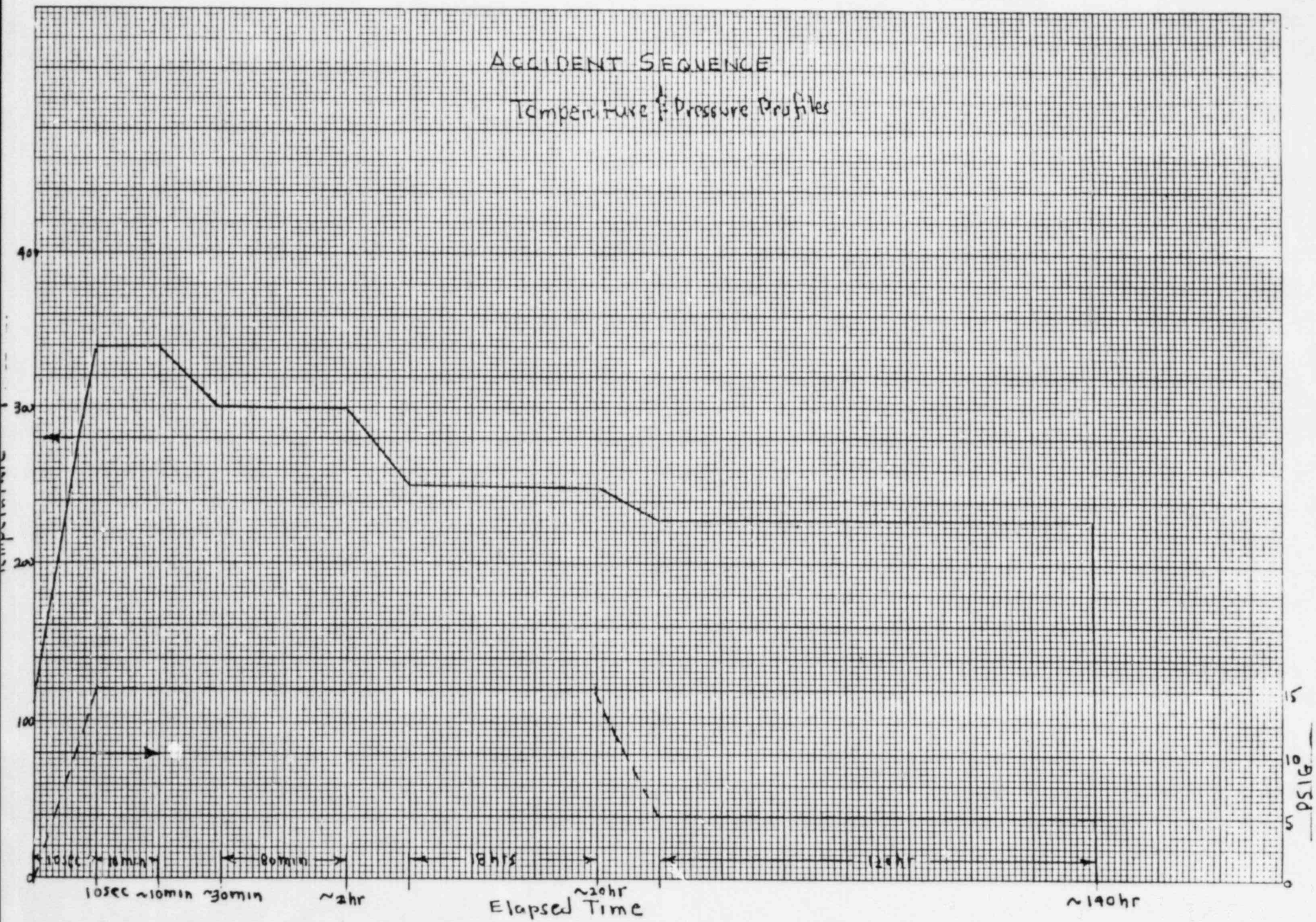
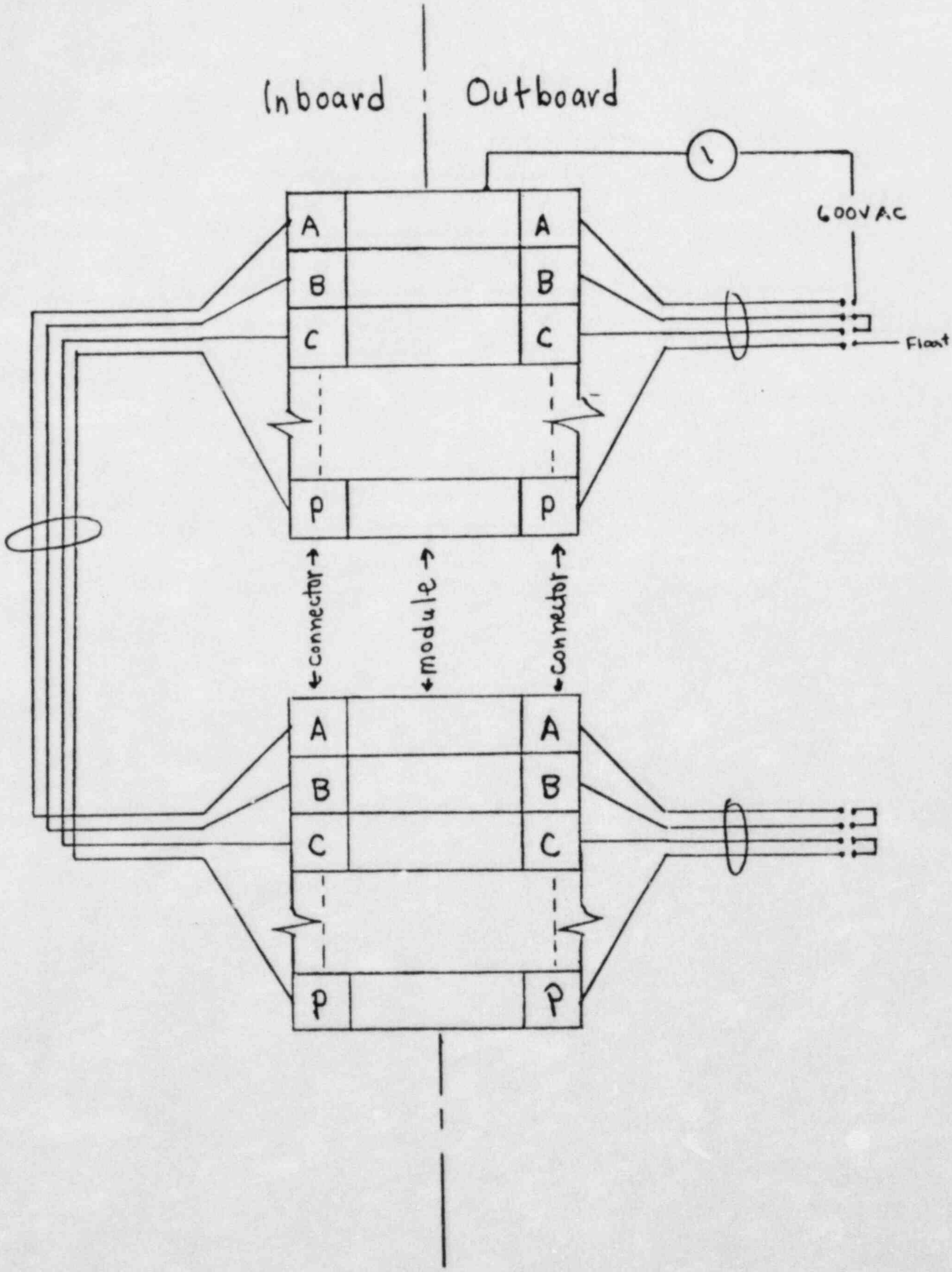


FIGURE 8


ACCIDENT SEQUENCE
Temperature & Pressure Profiles
400
300
200
100
0
15
10
5
0
PSIG
10sec
10min
80min
18hrs
124hr
10sec
~10min
~30min
~2hr
~20hr
~140hr
Elapsed Time

Typical Wiring Between Like Modules on the Penetration Assembly with 600 VAC Applied



ADDENDUM #1

Electrical Penetration Specification for Series Connected Modules

DUKE POWER COMPANY
GENERAL OFFICES
422 SOUTH CHURCH STREET
CHARLOTTE, N. C. 28242

P. O. BOX 33189

TELEPHONE: AREA 704
373-4011

January 23, 1981

Sandia Laboratories
Division 4445
Albequerque, New Mexico 87185

ATTENTION: W. H. Buckalew

SUBJECT: Duke Power Company
Catawba Nuclear Station
Electrical Penetrations
Specification CNS-1361.00-00-0003
FILE: CN-1361.00

REFERENCE: 1) NRC Environmental Qualification Confirmation Testing of one (1) Catawba Type "K" electrical penetration
2) Acceptance criteria for electrical penetrations

We have investigated the acceptance criteria required for the Catawba Type "K" electrical penetrations. As you are aware, our specification CNS-1361.00-00-0003 requires that the Catawba Type "K" electrical penetrations maintain a minimum insulation resistance of 1×10^7 ohms when tested at a potential of 500 VDC in the qualification environments. This insulation requirement is between each individual pin to each other individual pin and between each individual pin to ground in a single module. It should be noted that this required insulation resistance value is conservatively higher than the actual requirement of the instrument system and that this is the same acceptance criteria as used in the original qualification testing.

The test plan that you have proposed to use for the NRC environmental qualification confirmation test requires two (2) modules to be wired in series. This arrangement provides parallel resistance paths to ground which will decrease the test readings to below what would be experienced for a single module. We feel that this should be incorporated into the test proposal.

There were additional acceptance criteria requirements in the test procedures and test reports which were established by D.G. O'Brien, Inc. These requirements included Hypot testing at 2200 VAC and maintaining an insulation resistance of a minimum of 1×10^8 ohms when tested at a potential of 500 VDC in the qualification environments. These D.G. O'Brien requirements were not required by Duke Power Company or IEEE Std. 317-1972 for qualifying the Catawba Type "K" electrical penetration assemblies.

If you have any questions please contact R. P. Dover at (704) 373-4627, or P. M. McBride at (704) 373-4398.

Yours truly,

C. J. Wylie, Chief Engineer
Electrical Division

R. P. Dover

BY: R. P. Dover

T J Al-Hussaini

APPROVED: T. J. Al-Hussaini

CJW/TJA/RPD/kkm

cc: T. J. Al-Hussaini
P. M. McBride
J. L. Crenshaw
W. J. Foley
W. Rutherford, USNRC

Enclosure 2

Attendance List
Pre-Disassembly Conference

Daniel McDonald	NRC Consultant	LASL
J. R. Agee	Equip. Qual. Engr.	NRC, O.I.E., Arlington
P. M. McBride	Equip. Spec.	Duke Power
G. C. Rogers	Assistant Eng. Qual. Test.	Duke Power
R. J. Flaherty	Constultant	Life Cycle Engineering
E. Walton	Engr. Mgr.	Brand-Rex Co.
P. K. Das	Mg-R/D	Brand-Rex Co.
H. P. Hilberg	Eng. Mgr.	D.G. O'Brien
E. Salazar		Sandia
D. Jeppesen		Sandia
F. Thome		Sandia
L. Bonzon		Sandia
W. Buckalew		Sandia