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J. L. Rainsberry
Manager, Plant Licensing

August 20, 1997

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

Gentlemen:

Subject: **Docket Nos. 50-361 and 50-362**
Environmental Qualification
San Onofre Nuclear Generating Station
Units 2 and 3

Reference: February 10, 1997 letter from G. T. Gibson (Edison) to Document Control Desk (NRC), Subject: Docket Nos. 50-361 and 50-362, San Onofre Nuclear Generating Station, Units 2 and 3

As requested by the NRC Project Manager for San Onofre Units 2 and 3, enclosed are copies of references 6.8 and 6.9 in the Environmental Qualification (EQ) Report M85114, Rev. 0, "Loss of Coolant (LOCA) Test of 'Moisture Dam' Modified Rockbestos RS-6-104/LE Coaxial Cable, ABB/CE Mineral Insulated Triaxial Cable, and CONAX Coaxial Penetration Feedthroughs for the Regulatory Guide 1.97 High Range Radiation Monitoring (HRRM) System," November 15, 1996. EQ Report M85114 was sent to the NRC by the above reference.

The two references are:

6.8 Memorandum for File by L. Conklin (Edison), Subject: High Range Radiation Monitoring (HRRM) Coaxial Cable Test Results and Recommendations, dated January 24, 1996

6.9 Memorandum for File by L. Conklin (Edison), Subject: High Range Radiation Monitoring (HRRM) Coaxial Cable Engineering Analysis - Conclusions and Recommendations, dated June 4, 1996

C001/1

San Onofre Nuclear Generating Station
P. O. Box 128
San Clemente, CA 92674-0128
714-368-7420

These two references document previous investigations into the induced signal issue in the HRRM circuits. These references provide the results of various literature searches and test methods, including steam and chemical spray testing, related to the temperature induced signal phenomena.

The current plant configuration inside containment uses mineral insulated coaxial cable manufactured by Combustion Engineering and Conax feedthroughs at the containment penetrations. Therefore, these two references have no relevance to the installed HRRM configuration at San Onofre Units 2 and 3.

If you have any questions or would like additional information, please let me know.

Sincerely,

Enclosures

cc: E. W. Merschoff, Regional Administrator, NRC Region IV
K. E. Perkins, Jr., Director, Walnut Creek Field Office, NRC Region IV
J. A. Sloan, NRC Senior Resident Inspector, San Onofre Units 2 & 3
M. B. Fields, NRC Project Manager, San Onofre Units 2 and 3

CAP-96125

January 24, 1996

MEMORANDUM FOR FILE

SUBJECT. High Range Radiation Monitoring (HRRM) Coaxial Cable Test Results and Recommendations

REFERENCE: 1) NCR 951100073
2) Wyle Laboratories P.O. 6A2N5009

This memorandum serves to: 1) collect the results of all work performed to date associated with the High Range Radiation Monitor (HRRM) coaxial cable noise effects LOCA testing and; 2) provide recommendations for future actions.

Three documents prepared to address this subject are included as attachments to this memorandum. They are identified as:

Attachment 1, "Coaxial Cable LOCA Simulation, Procedure for Monitoring Test Specimen Electrical Parameters." This attachment provides the results of test specimen monitoring performed during the LOCA simulation testing at Wyle Laboratories, December 11 through 15, 1995.

Attachment 2, Engineering Evaluation, "Post Test Insulation Resistance Results." This attachment provides the results of the test specimen and test vessel penetration "post-mortem" evaluation performed to identify the cause of test failures.

Attachment 3, "Coaxial Cable LOCA Simulation Test Results." This attachment provides the evaluation of test specimen monitoring data provided in Attachment 1, and contains the conclusions regarding the coaxial cable LOCA testing.

The Wyle Laboratories test report (45145-1) for this effort will be issued when the proposed additional LOCA testing is complete.

From a review of the attached documents, the following recommendations are provided:

1. Identify The Impact on Plant Operations

Based on the coaxial cable testing performed to date, radiation monitors 2(3)7820-1 and -2 may exhibit transient spurious signals when exposed to inside containment high energy line break environmental conditions. This condition is caused primarily by triboelectric noise effects on the coaxial cable due to rapid heating. Preliminary information indicates these erroneous indications may last from 15 minutes to one hour and indicate a dose as high as 2,000 rads/hour.

Action: Linda Conklin to contact the Manager of Operations, Ray Waldo, by E-mail memorandum briefly explaining the situation and arranging a meeting to discuss this problem and how to minimize the potential for misleading the operators.

2. Additional LOCA Testing

In order to more accurately determine the magnitude and duration of the spurious signals, further LOCA testing of the coaxial cable should be performed. As discussed in detail in the Recommendations section of Attachment 2, test specimens should more empirically simulate the installed condition.

One 250' test specimen of Rockbestos RSS-6-104/LE coaxial cable should be routed 50% in conduit, and 50% in tray. This adequately represents the installed configuration. A second 250' test specimen of Rockbestos RSS-6-105/LE Low Noise coaxial cable should be routed 100% in conduit. This would represent a future installation of "low noise" cable routed completely in conduit.

Since the previous test failures were attributed to the test vessel penetration design, an improved test vessel penetration should be designed and tested prior to the coaxial cable test. This design is detailed in Attachment 2.

Action: Ken Trotta to provide the improved test vessel penetration design to Wyle Laboratories. Wyle Laboratories should construct a prototype and test the ability to maintain proper insulation resistance and continuity during LOCA test environmental conditions.

3. Brand Rex Cable Failure

As discussed in detail in Attachment 2, the Brand Rex cable failed to meet the required shield to ground insulation resistance following LOCA simulation. The EQ applications of this cable are identified as the TEC valve position monitor, equipment ID's: 2(3)XE02001, 2(3)XE02002, 2(3)XE02011 and 2(3)XE02012. The NEDO System Design Engineer for this equipment should be contacted to determine what affects the loss of cable shield to ground resistance may have on equipment accuracy.

Action: Linda Conklin to contact the NEDO System Design Engineer (BBA), Keith Reeser by E-mail memorandum briefly explaining the problem and arranging a meeting to identify the steps necessary for resolution.

4. Revision of NCR 95110073

NCR 95110073 was initiated to address the impact of this cable effect on the HRRM under accident conditions. Disposition Step 1 identified that testing is being performed at Wyle Laboratories in Huntsville, Alabama, and that when complete, the NCR would be updated with the test results. This was forecast for January 31, 1996. The NCR should be revised to reflect the testing performed to date, and the need for additional testing.

Action: Ron Wise to revise NCR 95110073 to reflect the new test completion date of April 30, 1996.

If you have any questions please call Ken Trotta at 89170 or myself at 87028.

L. Conklin

Attachments

cc: K. Johnson
KA K. Trotta
R. Wise
T. Hyde
S. Stilwagen
J. Beebe
D. Beauchaine
CDM

CAP-96125

Southern California Edison Company
San Onofre Nuclear Generating Station Units 2&3

Coaxial Cable LOCA Simulation
Procedure for Monitoring Test Specimen Electrical Parameters

Prepared By: ____________ Date 1/12/96
Bob Greene

KT
Reviewed By: ____________ Date 1/12/96
Ken Trotta

Attachment 1

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(Not included in distribution - Original Sent to CDM) available for audit at SONGS.

1.0 INTRODUCTION

This procedure establishes the requirements and instructions for measuring the performance of the coaxial cable test specimens before, during, and after simulated LOCA environmental conditions. The simulated LOCA conditions are identified in the WYLE Laboratories Test Procedure 45145 (Reference 1).

2.0 SCOPE/PURPOSE

The scope of this test measuring procedure is limited to the Southern California Edison supplied coaxial cable test specimens as identified in Table 1. The purpose of this procedure is to document the test specimen monitoring of "noise" affects occurring during simulated LOCA pressure, temperature and chemical spray conditions.

2.1 Continuity and Static Insulation Resistance Verification

Continuity and insulation resistance (IR) between the test specimen center conductor and shield must be verified prior to and following the end of LOCA simulation. Additional IR data may be taken as required.

This test will be performed using a megger with suitable test leads. Test data shall be recorded in Tables 2 through 8.

2.2 Dynamic Cable Performance

The purpose of this test is to identify and quantify any LOCA simulation induced "noise" on the individual coaxial cable test specimens. This cable noise may be from piezoelectric, triboelectric, or any other effects. Figure 1 shows schematically the test specimen and measuring equipment configurations.

Coaxial cable current levels during LOCA simulation will be monitored and recorded as described in Section 6.2.

3.0 TEST EQUIPMENT

All test measuring equipment used in this procedure is calibrated in accordance with the Wyle Laboratories Quality Assurance Program and is identified in the Wyle Test Report (Reference 2).

3.1 Static Insulation Resistance Test

(1) Eight test specimens with BNC connectors on each end.

(1) Megger, 500V

3.2 Dynamic Cable Performance Test

(1) Eight test specimens with BNC connectors on each

end.

(7) Keithly 610C or 610CR recorders

(1) Astromed MT95K2 Mainframe including the following subcomponents:

(3) AWP1 analog input cards

(1) AWP3 thermocouple lead plus 4 thermocouple plugs type J

(1) VOP1 video module

(1) SVGA compatible video monitor

(1) Keithly 263 for testing 610C (equipped with triax to coax adapters)

(3) "D" submini with BNC female connectors

(7) PL-259 connectors for 610C input

(7) Cables to go from Keithly 610C to Astromed recorder

(1) Pack of 400 sheet Z fold paper for Astromed

(1) configuration disk for Astromed recorder

4.0 REFERENCES

4.1 WYLE Laboratories Test Procedure 45145, "Test Procedure for LOCA Simulation of Coaxial Cable for Southern California Edison" Dated December 8, 1995.

4.2 WYLE Laboratories Test Report 45145-1, "Test Report for LOCA Simulation of Coaxial Cable for Southern California Edison" Dated

5.0 ACCEPTANCE CRITERIA

5.1 Continuity and Static Insulation Resistance Test

Pre and Post LOCA coaxial cable test specimens must have continuity and a minimum signal to shield resistance of 1E8 ohms.

5.2 Dynamic Cable Performance Test

As discussed in Section 2.1, the purpose of this test is to identify and quantify any noise induced on the test specimens by the simulated LOCA environmental conditions. This information will be used in some future, separate evaluation outside the scope of this test measuring procedure. Therefore, there is no specific acceptance criteria for the dynamic cable performance test.

6.0 PROCEDURE

6.1 Pre LOCA Continuity and Static Insulation Resistance Test

Prior to exposure to the simulated LOCA environmental conditions, the following steps shall be performed on each test specimen.

6.1.1 Connect the megger to the test specimen using the megger test lead.

6.1.2 Verify continuity. Apply megger voltage(500V)and derive insulation resistance. Record under "Pretest Value" in the applicable Table. Verify the resistance reading is greater than the acceptance criteria and indicate pass "P" or fail "F."

6.1.3 Turn megger off and disconnect test specimen.

6.2 Dynamic Cable Performance Test

6.2.1 Preliminary Checks.

Ensure test cables on the outside of chamber are wrapped with thermal insulating material.

Ensure thermocouples are affixed per Figure 1.

Ensure thermocouple field wires are installed and coming out of the penetrations per drawing.

Ensure test equipment is present as per Section 3.2

6.2.2 Setting up and configuring the Astromed recorder. Set up and checkouts: Install all cards in required position in back of recorder. See Figure 2.

6.2.3 Install connectors on analog module cards (AWP1).

6.2.4 Install cables from Keithly 610C into appropriate channels on AWP1 amplifier per drawing. Tape each BNC with scotch 33 tape.

6.2.5 Install thermocouple wires to AWP3 thermocouple amplifier. There will be a total of four inputs for thermocouple per Figure 2.

6.2.6 Connect Astromed recorder to a power source.

6.2.7 Turn Astromed to the ON position (1).

6.2.8 Set recorder internal date and time by performing the following.

6.2.8.1 Depress the front panel SYS key.

6.2.8.2 Depress the soft key above SYSTEM CLOCK.

6.2.8.3 Use selection arrows to select each component date and time.

6.2.8.4 Depress EXIT

6.2.9 Downloading of the configuration program.

6.2.9.1 Insert the disk labeled Wyle Labs Cable testing Astromed setup in disk drive.

6.2.9.2 Press the MODE key

6.2.9.3 Press the soft key above FROM DISK

6.2.9.4 Use the encoder wheel to select file you want to download.

6.2.9.5 Press the soft key above RUN. This should download the entire recorder configuration and labels.

6.2.9.6 Depress SAVE.

6.2.9.7 Depress the soft key above ENTIRE MODE in the left display.

6.2.9.8 Use INC or DEC to select one of four soft keys into which the mode will be saved.

6.2.9.9 Use the keypad to type a label for the grid.

6.2.9.10 Press the soft key above ACCEPT to store the chart into the selected soft key. This will be displayed whenever the MODE key is depressed.

NOTE: If any labels need to be changes depress EDIT and edit buffers 1-9 as required.

6.2.10 To activate recorder to begin recording

6.2.10.1 Ensure that inputs are approximately in the middle of each chart and that the temperature channels are reading approximately ambient. If not, the zero suppression may need to be used to center the channel.

6.2.10.2 Ensure there is enough paper in the recorder to last the duration of the test to be performed. This can be done by checking the printed number on the paper. The paper goes from 400 downward to 1. The lower the number, the less paper you have.

6.2.10.3 Verify chart speed is correct for application.

6.2.10.4 Start recording by depressing the RUN/HALT button.

6.2.11 Stopping the recorder.

6.2.11.1 Depress the RUN/HALT button

6.2.11.2 Remove, label and store the trace.

6.2.12 Setting up and configuring the Keithly 610C Electrometer (set up and checkouts).

6.2.12.1 Set METER SWITCH to POWER OFF

6.2.12.2 Lock ZERO CHECK

6.2.12.3 Set range switch to VOLTS and MULTIPLIER SWITCH to 1.0

6.2.12.4 Turn meter switch to CENTER ZERO. Meter should read the center zero. If not, adjust as required.

6.2.13 Current Measurement

6.2.13.1 Install Keithly 263 to input.

6.2.13.2 Ensure FEEDBACK switch is set to FAST.

6.2.13.3 Place MULTIPLIER SWITCH to the _____1 ____ position.

6.2.13.4 Place the RANGE SWITCH to the _____ .10-9____ position.

6.2.13.5 Hook up recorder leads to back of K hly to provide output to the Astromed.

6.2.13.6 Place meter switch to CENTER ZERO position.

6.2.13.7 Unlock the zero check lock.

6.2.13.8 Ensure that both Astromed and Keithly respond to input signals. Run through the listed range of -5E-10 to +5E-10 amps. If required, edit buffers to reflect true range of the testing being done on cable.

6.2.13.9 Disconnect Keithly 263.

6.2.13.10 Hook test specimen input cable to front input connection.

6.2.14 Testing procedure checklist.

6.2.14.1 Ensure all cables are connected to test equipment. This includes verifying that cables are installed per Figure 1.

6.2.14.1.1 Test cable to Keithly 610.

6.2.14.1.2 Keithly 610 recorder output to Astromed.

6.2.14.1.3 Thermocouple to Astromed AWP3 module.

6.2.14.2 Ensure all test equipment is powered up, functional and on the correct range.

6.2.14.2.1 Astromed

6.2.14.2.2 Keithly 610C

6.2.14.3 Ensure the Astromed recorder is selected to desired chart speed for testing. For the first 60 seconds or so, set recorder speed to 50 mm/sec.

6.2.14.4 Start the Astromed recorder.

6.2.14.5 Start steam testing.

6.2.14.6 Adjust Keithly range as necessary to avoid bottoming out on Astromed recorder. Annotate recorder with any range changes.

6.2.14.7 After readings stabilize somewhat, reduce chart speed to 1 mm/sec for balance of test.

6.3 Post LOCA Continuity and Static Insulation Resistance Test

Following exposure to the simulated LOCA environmental conditions, the following steps shall be performed on each test specimen.

6.3.1 Connect the megger to the test specimen using the megger test lead.

6.3.2 Verify continuity

6.3.3 Apply megger voltage 500VDC) and derive insulation resistance. Recorded under "Pretest Value" in the appropriate Table. Verify the resistance reading is greater than the acceptance criteria and indicate pass "P" or fail "F."

6.3.4 Turn megger off and disconnect test specimen.

TABLE 1

TEST SPECIMEN DESCRIPTIONS

SPECIMEN NUMBER	DESCRIPTION
1	30' Rockbestos RSS-6-105/LE coaxial cable in conduit fixture.
2	90' Rockbestos RSS-6-105/LE coaxial cable
3	250' Rockbestos RSS-6-105/LE coaxial cable
4	90' Rockbestos RSS-6-104/LE coaxial cable
5	196' Rockbestos RSS-6-104/LE coaxial cable
6	90' BrandRex CS 75146 coaxial cable
7	250' BrandRex CS 75146 coaxial cable
8	20' Rockbestos RSS-6-105/LE coaxial cable

Item 1 is installed in the conduit fixture such that 25' is installed inside the conduit. Flexible conduit is used to connect the test fixture junction box to the test chamber penetration. The conduit fixture contains drain holes at all low points.

Items 2,3,4,5,6 and 7 are marked with tape 20' from one end and 5' from the other. These cables were wrapped around the test mandrel are were installed in the test chamber such that the 20' and 5' marks are aligned with the inside edge of the test chamber penetration ports to ensure that a known amount of cable is exposed to the test chamber environment.

Item 8 is wrapped around the mandrel, with both end inside the chamber. This specimen is used to monitor cable surface and center conductor temperature only.

All cables outside the chamber are thermally insulated such that they are not appreciably affected by ambient temperature changes outside the chamber during testing.

TABLE 2

PRE-LOCA TEST
CONTINUITY AND STATIC INSULATION RESISTANCE TEST

Specimen Number	Time/Date	Continuity (Y/N)	Resistance @500 VDC	Acceptance Criteria	P/F
1	4PM 12/12/95	Y	8.4E11	$>10^8$ Ohms	P
2	4PM 12/12/95	Y	1.5E12	$>10^8$ Ohms	P
3	4PM 12/12/95	Y	1.4E12	$>10^8$ Ohms	P
4	4PM 12/12/95	Y	3.0E13	$>10^8$ Ohms	P
5	4PM 12/12/95	Y	1.1E12	$>10^8$ Ohms	P
6	4PM 12/12/95	Y	1.0E12	$>10^8$ Ohms	P
7	4PM 12/12/95	Y	6.4E11	$>10^8$ Ohms	P
8	Note 1	N/A	N/A	N/A	N/A

Notes:

1. This test specimen is the 20" of Rockbestos RSS-6-105/LE used to monitor cable surface and center conductor temperature only.

TABLE 3

POST-LOCA TEST (POST TRANSIENT)
CONTINUITY AND STATIC INSULATION RESISTANCE TEST

Specimen Number	Time/Date	Continuity (Y/N)	Resistance @500 VDC	Acceptance Criteria	P/F
1	1354 12/14/95	Y	3.08E8	$>10^8$ Ohms	P
2	1354 12/14/95	Y	1.5E7	$>10^8$ Ohms	F
3	1354 12/14/95	Y	3.5E8	$>10^8$ Ohms	P
4	1354 12/14/95	Y	2.8E8	$>10^8$ Ohms	P
5	1354 12/14/95	Y (NOTE 2)	3.05E6	$>10^8$ Ohms	F
6	1354 12/14/95	Y	500K @10VDC	$>10^8$ Ohms	F
7	1354 12/14/95	Y	100K @10VDC	$>10^8$ Ohms	F
8	Note 1	N/A	N/A	N/A	N/A

Notes:

1. This test specimen is the 20" of Rockbestos RSS-6-105/LE used to monitor cable surface and center conductor temperature only.

2 Can't use megger, 10V as low.

TABLE 4

POST-LOCA TEST (132.6F CHAMBER TEMPERATURE)
CONTINUITY AND STATIC INSULATION RESISTANCE TEST

Specimen Number	Time/Date	Continuity (Y/N)	Resistance @500 VDC	Acceptance Criteria	P/F
1	5PM 12/14/95	Y	4.5E7 NOTE 2	$>10^8$ Ohms	F
2	5PM 12/14/95	Y	1.6E6 @100VDC	$>10^8$ Ohms	F
3	5PM 12/14/95	Y	2.0E8 NOTE 2	$>10^8$ Ohms	P
4	5PM 12/14/95	Y	2.0E9 NOTE 2	$>10^8$ Ohms	P
5	5PM 12/14/95	Y	550 NOTE 3	$>10^3$ Ohms	F
6	5PM 12/14/95	Y	2.15E5 @10VDC	$>10^8$ Ohms	F
7	5PM 12/14/95	Y	2.9E5 @10VDC	$>10^8$ Ohms	F
8	Note 1	N/A	N/A	N/A	N/A

Notes:

1. This test specimen is the 20" of Rockbestos RSS-6-105/LE used to monitor cable surface and center conductor temperature only.

2. Unstable, average.

3. Hand held multimeter.

TABLE 5

POST-LOCA TEST MANDREL AND CONDUIT (NOTE 2)
CONTINUITY AND STATIC INSULATION RESISTANCE TEST

Specimen Number	Time/Date	Continuity (Y/N)	Resistance @500 VDC	Acceptance Criteria	P/F
1	10AM 12/15/95	N/A	2.5E13	$>10^8$ Ohms	P
2	10AM 12/15/95	N/A	6.5E10	$>10^8$ Ohms	P
3	10AM 12/15/95	N/A	3.5E10	$>10^8$ Ohms	P
4	10AM 12/15/95	N/A	4.0E10	$>10^8$ Ohms	P
5	10AM 12/15/95	N/A	3.9E10	$>10^8$ Ohms	P
6	10AM 12/15/95	N/A	1.3E11	$>10^8$ Ohms	P
7	10AM 12/15/95	N/A	2.5E10	$>10^8$ Ohms	P
8	Note 1	N/A	N/A	N/A	N/A

Notes:

1. This test specimen is the 20" of Rockbestos RSS-6-105/LE used to monitor cable surface and center conductor temperature only.

2 Post LOCA - mandrel mounted specimens and conduit. Penetration sections tested separately. Ambient temperature.

TABLE 6

POST-LOCA TEST SHORT PENETRATION (NOTE 2)
CONTINUITY AND STATIC INSULATION RESISTANCE TEST

Specimen Number	Time/Date	Continuity (Y/N)	Resistance @500 VDC	Acceptance Criteria	P/F
1	10:15 AM 12/15/95	N/A	NOTE 3	$>10^8$ Ohms	N/A
2	10:15 AM 12/15/95	N/A	2.5E7 NOTE 4	$>10^8$ Ohms	F
3	10:15 AM 12/15/95	N/A	1.8E8	$>10^8$ Ohms	P
4	10:15 AM 12/15/95	N/A	3.2E11	$>10^8$ Ohms	P
5	10:15 AM 12/15/95	N/A	NOTE 5	$>10^8$ Ohms	F
6	10:15 AM 12/15/95	N/A	3.5E6 NOTE 4	$>10^8$ Ohms	F
7	10:15 AM 12/15/95	N/A	2.5E5 @10VDC	$>10^8$ Ohms	F
8	Note 1	N/A	N/A	N/A	N/A

Notes:

1. This test specimen is the 20" of Rockbestos RSS-6-105/LE used to monitor cable surface and center conductor temperature only.

2. Short penetration section only (five foot pigtail end). Mandrel and conduit section evaluated separately. This penetration had a little too much epoxy in it, fouling the pipe union, and the cables had to be wrenched around to get the union loose. No visual physical damage to the cables. Ambient temperature.

3. See separate evaluation for the conduit penetration.

4. Reading very unstable, average.

5. 130K Ohm short.

TABLE 7

POST-LOCA TEST LONG PENETRATION (NOTE 2)
CONTINUITY AND STATIC INSULATION RESISTANCE TEST

Specimen Number	Time/Date	Continuity (Y/N)	Resistance @500 VDC	Acceptance Criteria	P/F
1	10:20AM 12/15/95	N/A	NOTE 3	>10^8 Ohms	N/A
2	10:20AM 12/15/95	N/A	5.7E11	>10^8 Ohms	P
3	10:20AM 12/15/95	N/A	5.6E10	>10^8 Ohms	P
4	10:20AM 12/15/95	N/A	5.5E10	>10^8 Ohms	P
5	10:20AM 12/15/95	N/A	7.3E10	>10^8 Ohms	P
6	10:20AM 12/15/95	N/A	6.8E10	>10^8 Ohms	P
7	10:20AM 12/15/95	N/A	1.1E5 @10VDC	>10^8 Ohms	F
8	Note 1	N/A	N/A	N/A	N/A

Notes:

1. This test specimen is the 20" of Rockbestos RSS-6-105/LE used to monitor cable surface and center conductor temperature only.
2. Long penetration section only (20'). Mandrel and conduit section evaluated separately.
3. Conduit penetration evaluated separately.

TABLE 8

POST-LOCA TEST CONDUIT PENETRATION (NOTE 2)
CONTINUITY AND STATIC INSULATION RESISTANCE TEST

Specimen Number	Time/Date	Continuity (Y/N)	Resistance @500 VDC	Acceptance Criteria	P/F
1 (NOTE 4)	10:30AM 12/15/95	N/A	2.1E7 (NOTE 3)	>10^8 Ohms	F
1 (NOTE 5)	10:30AM 12/15/95	N/A	5.4E10	>10^8 Ohms	P
3	N/A	N/A	N/A	>10^8 Ohms	N/A
4	N/A	N/A	N/A	>10^8 Ohms	N/A
5	N/A	N/A	N/A	>10^8 Ohms	N/A
6	N/A	N/A	N/A	>10^8 Ohms	N/A
7	N/A	N/A	N/A	>10^8 Ohms	N/A
8	Note 1	N/A	N/A	N/A	N/A

Notes:

1. This test specimen is the 20" of Rockbestos RSS-6-105/LE used to monitor cable surface and center conductor temperature only.
2. Conduit penetration only. Ambient temperature.
3. Unstable reading. Average.
4. Short section.
5. Long section (to test monitoring equipment).

FIGURE 1
ELECTRICAL TEST SCHEMATIC

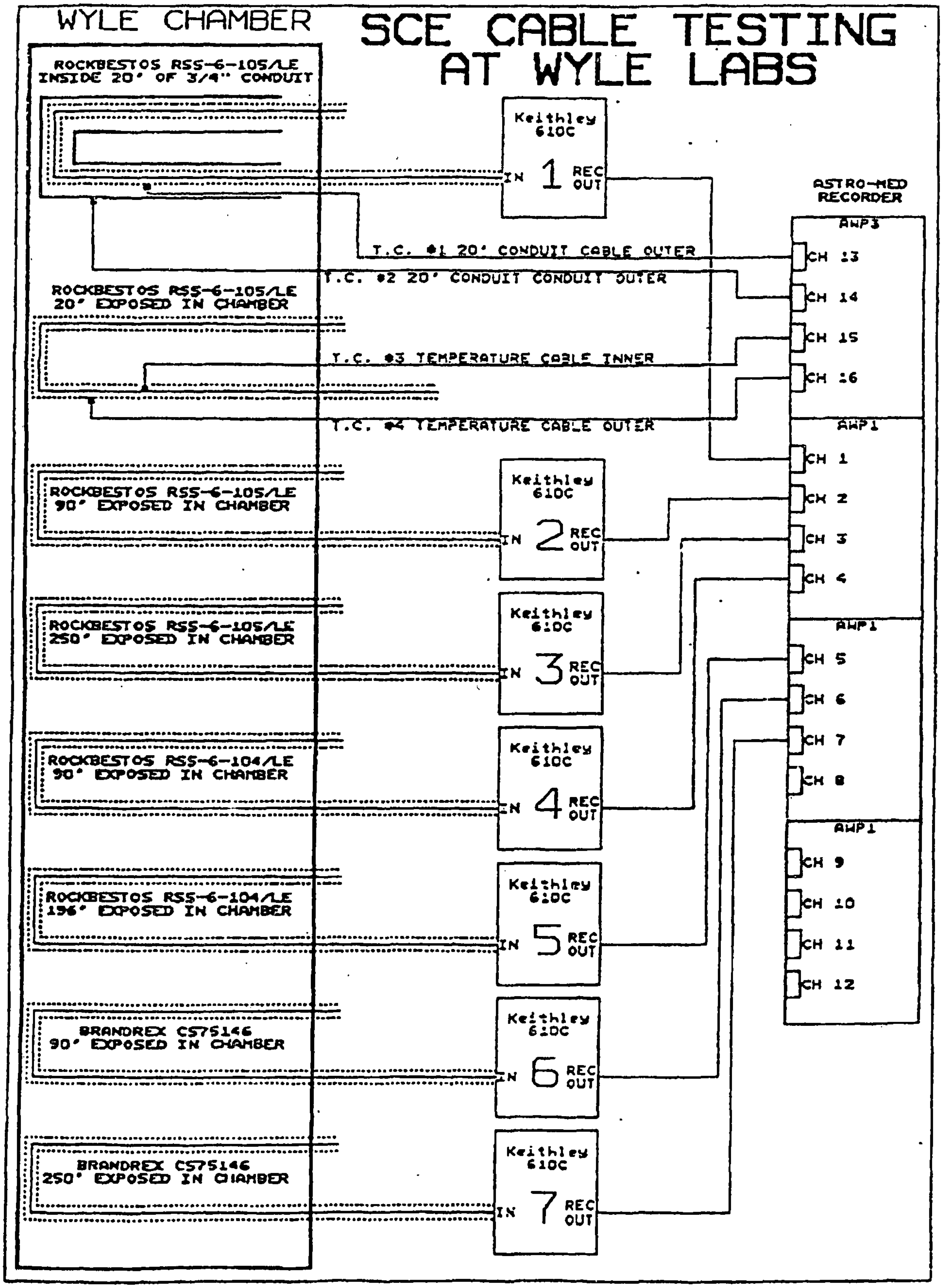


FIGURE 2
ASTROMED CONNECTION DIAGRAM

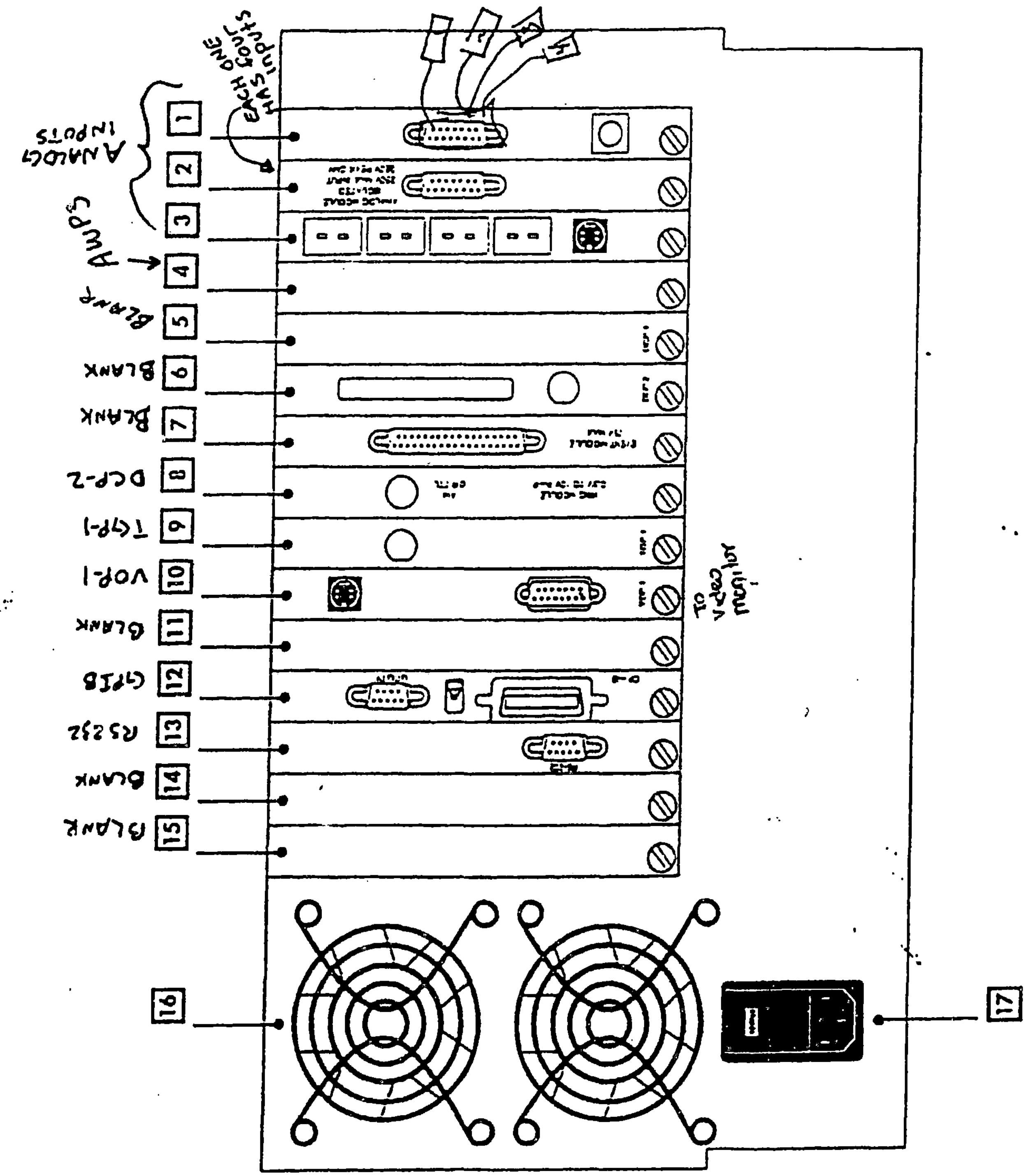
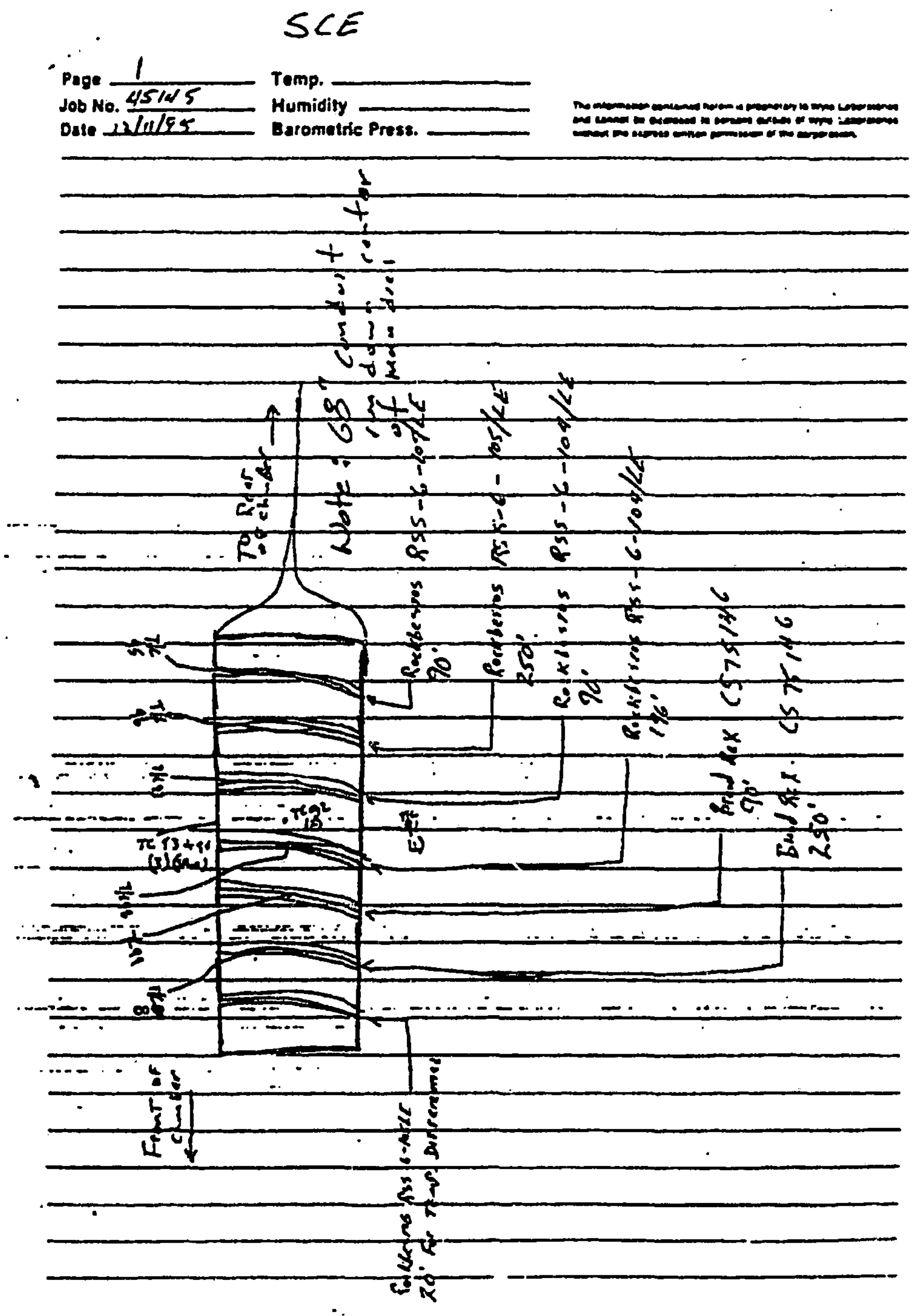


FIGURE 3
LOCATION OF TEST SPECIMENS



DATA SHEET

Customer ______ WYLE LABORATORIES
Specimen ______
Part No. ______ Amb. Temp. ______ Job No. ______
Spec. ______ Photo ______ Report No. ______
Para. ______ Test Med. ______ Start Date ______
S/N ______ Specimen Temp. ______
GSI ______

Test Title Post LOCA simulation

	Visual Inspection
Specimen #	Notes
1 (conduit)	Most of cable hiddin inside Conduit, What is visible looks good.
8 (20' 105)	Thermocouples intact. No visible signs of degradation. Dated 1994
2 (90' 105)	Cable slightly discolored greyish looking. No visible splits or bubbles in jacket. Dated 1994
3 (250' 105)	Same as #2 above.
4 (90' 104)	Cable has multiple (~15) bubbles in jacket, swelled to 2 or 3 times cable diameter. In some cases these bubbles hae melted and bonded to other cables. Note this cable dated 1992.

Tested By KT Date: 12/15/95
Witness ______ Date: ______
Notice of Anomaly ______ Sheet No. 1 of 5
Approved ______

DATA SHEET

WYLE LABORATORIES

Customer

Specimen

Part No. | Amb. Temp. | Job No.

Spec. | Photo | Report No.

Para. | Test Med. | Start Date

S/N | Specimen Temp.

GSI

Test Title Post LOCA Visual Inspection

5. (146' 104)	Cable looks good. Appears to have bonded to other wraps (itself). One small indentation, which did not peirce jacket, where thermocouple was attached. No bubbles. Note this cable is dated 1994.
6. (90' BR)	Cable looks good. No bubbles or splits in jacket. Still very flexible, soft, not ridgid like other specimens.
7. (250' BR)	Same as above. No visible damage.

General: The Rockbestos cables have become very ridgid and stuck to each other. Brand Rex is relatively soft and flexible.

Tested By | Date:

Witness | Date:

Sheet No. 2 of 5

Approved

Notice of Anomaly

Wyle Form WH 614A, Rev APR '84

DATA SHEET

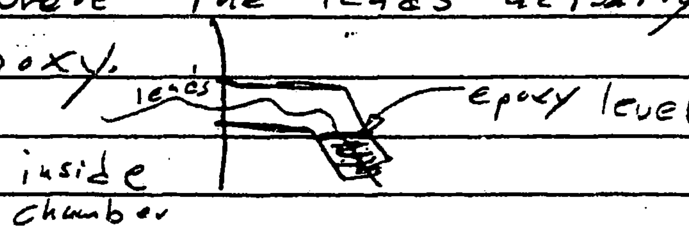
WYLE LABORATORIES

Customer ______
Specimen ______
Part No. ______ Amb. Temp. ______ Job No. ______
Spec. ______ Photo ______ Report No. ______
Para. ______ Test Med. ______ Start Date ______
S/N ______ Specimen Temp. ______
GSI ______

Test Title Post LOCA Simulation Visual Inspection

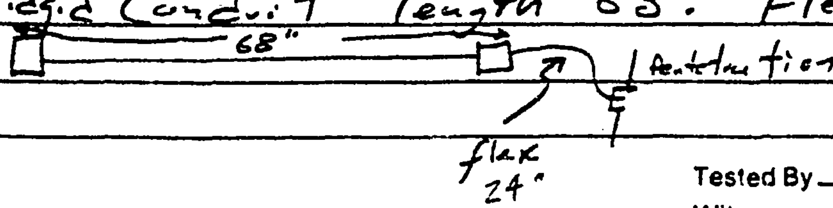
All cable dry. No moisture present
All cables have a white residue, probably chemicals from spray. Wherever two Rockbestos cable touched, they became bonded such that they had to be pulled apart.

Penetrations: The specimens have no visible cracks or splits where the enter the penetration. Although I can't see where the leads actually enter the epoxy.



Flexible conduit has bubbles all over it. It was intact when the chamber was opened.

Ridgid Conduit length 68". Flex length 24"



Tested By ______ Date: ______
Witness ______ Date: ______
Sheet No. 3 of 5
Approved ______

Notice of Anomaly ______

DATA SHEET

WYLE LABORATORIES

Customer ______
Specimen ______
Part No. ______ Amb. Temp. ______ Job No. ______
Spec. ______ Photo ______ Report No. ______
Para. ______ Test Med. ______ Start Date ______
S/N ______ Specimen Temp. ______
GSI ______

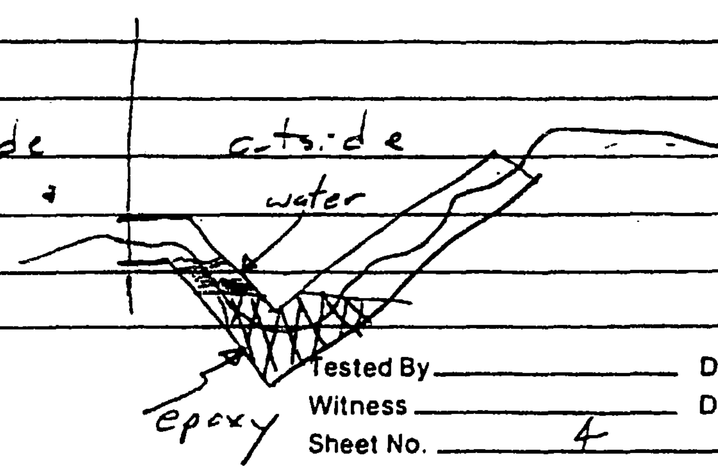
Test Title Post LOCA Simulation Visual-Inspection

When preparing the clipped cables for continuity measurements, we noted the following:

1. 90' Rockbestos 1992 jacket was melted to the braid.

2. In all cases it is difficult to get the braid off the insulation. The braid has attached itself to the insulation.

When removing penetrations from the rear of chamber, water was standing ~6" deep.



Tested By ______ Date: ______
Witness ______ Date: ______
Notice of Anomaly ______ Sheet No. 4 of 5
Approved ______

Wyle Form WH 614A, Rev. APR '84

DATA SHEET

Customer ____________ **WYLE LABORATORIES**

Specimen ____________

Part No.	Amb. Temp.	Job No.
Spec.	Photo	Report No.
Para.	Test Med.	Start Date
S/N	Specimen Temp.	
GSI		

Test Title *Post LOCA Simulation Visual Inspections*

Penetrations

Short Section (5' lead):
outboard – looks perfect, cable flow right into epoxy.
Inboard side – Too much epoxy made it necessary to twist pipe union guard, possibly – probably damaging the cables

Conduit Section:
No visible cable damage on inboard or outboard side of penetration

Long Section (20' lead):
No visible cable damage on inboard or outboard side of penetration.

Note: During steam testing both BrandRex specimens were leaking water (~1 drop/sec.) through the BNC connector on the short penetration pigtail.

Tested By ____________ Date: ______

Witness ____________ Date: ______

Sheet No. *5* of *5*

Approved ____________

Notice of Anomaly ____________

Wyle Form WH 614A, Rev. APR '84

CAP-96125

ENGINEERING EVALUATION
High Range Radiation Monitoring (HRRM) Coaxial Cable LOCA Test
Post Test Insulation Resistance Results

SAN ONOFRE NUCLEAR GENERATING STATION UNITS 2 & 3

Prepared By: ____________ Date: 1/23/96
Ken Trotta

Reviewed By: ____________ Date: 1/23/96
Steve Stilwagen

Attachment 2

TABLE OF CONTENTS

1.0 SUBJECT

The purpose of this engineering evaluation is to investigate and document the failure analysis of the LOCA test specimens and test vessel penetrations for the HRRM coaxial cable LOCA simulation as identified in Reference 2.1.

2.0 REFERENCES

2.1 SCE Document "Coaxial Cable LOCA Simulation Procedure for Monitoring Test Specimen Electrical Parameters." Dated January 12, 1996

2.2 SCE Document "Coaxial Cable LOCA Simulation Test Results." Dated January 18, 1996

2.3 Commerial Grade Item Dedication Test Lab Report 96-2978

3.0 PROBLEM DESCRIPTION

The results of the coaxial cable LOCA simulation test, as documented in Reference 2.2, indicate the test program failed to meet the intended objectives. It was uncertain whether the failure was due to the test setup (test vessel cable penetration) or the test specimens themselves. This evaluation will investigate and determine whether the test program failure was due to the test specimens, or the test setup.

4.0 CONCLUSION

The overall conclusion is that failure of the "short" test penetration strongly contributed to the test program failure. The contribution came in the form of low insulation resistance between shield to ground and conductor to shield within the penetration, affecting the entire circuit. This is evidenced by the low conductor to shield IR measurements taken immediately after the LOCA simulation (Reference 2.1, Table 6), and the shield to ground measurements taken 20 days later.

4.1 Cable Specimens

The Brand Rex cables are considered to have failed the LOCA test, with shield to ground insulation resistance measurements below acceptable levels. The Brand Rex cable jacket does not provide adequate insulation resistance as evidenced by it grounding to the mandrel, in addition to the low IR measurements at the test vessel penetrations. This grounding may have greatly contributed to the erratic behavior of these cables during the LOCA simulation. The Brand Rex cable test vessel penetrations had low conductor to shield (E7 to E8 ohms) and shield to ground (E8 to E9 ohms) IR. These measurements were taken in the dry condition, and it is expected that during the steam test these measurements would be decades lower.

The Rockbestos coaxial cable provided acceptable conductor to shield and shield to ground IR as evidenced by the high measurements (E12 ohms), with two notable exceptions. The 250' RSS-6-105/LE specimen at the "short" penetration showed low (E8 ohms) shield to ground IR, and was seen to be dripping water during the "wet" conductor to shield test. This indicates physical damage to the cable jacket inside the epoxy penetration. The 90' RSS-6-105/LE specimen also exhibited low conductor to shield IR (1E8 ohms) in the short penetration.

4.2 Test Vessel Penetrations

The "short" test vessel penetration showed visual damage to the epoxy potting, and there was evidence of moisture intrusion through the 250' Rockbestos RSS-6-105/LE cable jacket. Damage to the penetration was also evidenced by extremely low conductor to ground IR measurements taken the morning after the LOCA test. This indicates the penetration assembly had experienced the negative effects of moisture (steam) intrusion. These measurements were taken in the dry condition, and it is expected that during the steam test these measurements would be decades lower.

5.0 EVALUATION

The "post-mortem" evaluation of the test vessel penetration and mandrel was performed by measuring the IR of the various test specimens and test vessel penetrations.

Insulation Resistance (IR) Measurements

Two types of IR measurements were made: 1) center conductor to shield and; 2) shield to ground. The center conductor to shield measurement provides a measure of the ability of cable insulation to insulate the center conductor. The shield to ground IR measurement provides a measure of the cable jacket to insulate the cable shield from ground. When reviewing the information below, consider that new cables would be expected to exhibit a minimum IR readings on the order of E12 ohms.

For the purpose of this evaluation, the test specimens and vessel penetrations were divided into four groups (see Table 1 and Figure 1 for specimen descriptions):

1. Short penetration. This is the test vessel penetration that contains the "short" five foot pigtails exiting the chamber. The pigtails were left hanging in air, and were not connected to any test measuring equipment. This penetration contains the pigtails of test specimens two through seven.

2. Long Penetration. The test vessel penetration that contains the "long" 25 foot pigtails that were connected to the test instrumentation. This penetration contains the pigtails of specimens two through seven.

3. Mandrel. The test mandrel containing the individual test specimens (two through seven).

4. Conduit Penetration. The test vessel penetration that contains both the unconnected five foot pigtail and 25 foot pigtail connected to the test equipment for the inside conduit cable specimen (specimen 1).

Note: Specimen 8 was used only to monitor cable temperature and not signal characteristics.

5.1 Short Penetration - Dry and Wet Conditions - Center Conductor to Shield

From the post LOCA test measurements taken of all specimens immediately following steam testing, the short penetration exhibited the lowest (worst) IR readings. Only this specimen was tested again both dry and wet as shown in Tables 2 and 3. To summarize the results, the Brand Rex cables exhibited the lowest readings (E7 to E8 ohms), while the Rockbestos cables were generally very high (E8 to E14 ohms).

The penetration was wetted by holding it vertically upright in a vise, and standing water (about ½ cup) was applied to the internal portion of the penetration. In the wet condition, the IR values were similar to the dry condition. Since the penetration was only soaked for 10 minutes in room temperature tap water, and did not experience the high temperature and pressure steam as during the LOCA test, IR was not expected to be significantly affected by this wet test.

It should be noted the Rockbestos 250' RSS-6-105/LE test specimen was seen to be dripping water, coming from inside the cable jacket. See the shield to ground IR measurements discussed below.

5.2 All Groups - Dry Condition - Shield to Ground

The shield to ground measurement provides an insight into how well the shield will perform as a "drain." If grounded at only one end, the shield properly acts to draw off any extraneous signals. If grounded at more than one point, the shield itself may act as source of signal noise.

5.2.1 Short Penetration: See Table 4. All specimens exhibited acceptable IR measurements (E8 to E12 ohms). The lowest readings were for the Brand Rex cables (E8 ohms), while of the Rockbestos cables, only the 250' RSS-6-105/LE had a reading below E12 ohms. This is the same cable that was seen to drip water during the wet condition conductor to shield IR test discussed above, indicating cable jacket damage.

5.2.2 Long Penetration: See Table 5. All specimens exhibited acceptable IR measurements. The lowest readings were for the Brand Rex cables (E8 ohms), while the Rockbestos readings were on the order of E12 ohms.

5.2.3 Mandrel: See Table 6. All Rockbestos specimens exhibited reading on the order of E12 ohms. The Brand Rex specimens were grounded to the mandrel. This indicates the jacket provided no insulating function.

5.2.4 Conduit Penetration: See Table 7. The specimen exhibited readings on the order of E12 ohms.

5.3 X-ray Investigation of Short Penetration

Since the test vessel cables are encased in epoxy filled two inch diameter schedule 60 iron piping, x-rays did not reveal the cable configuration within the pipe. It was decided that to cut the pipe open to reveal the epoxy and cables would most likely have damaged the cables, making any further x-rays inconclusive.

5.4 Discussion of Rockbestos RSS-6-104/LE 1992 Cable Jacket Blistering

The cable jacket of the Rockbestos RSS-6-104/LE 1992 (specimen 2) had large blisters, or bubbles, approximately 40 total, over its 90' length. The large blisters were approximately three times the cable diameter. Although visually a problem, it did not affect the cable performance. Since shield to ground resistance remained high (2.5 E12 ohms), the jacket blisters are not considered an insulating problem. Interestingly, the 1994 version of this cable (specimen 5) showed no signs of blistering or bubbles. Samples of the 1992 and 1994 cables were sent to Rockbestos for further analysis.

The 1992 version of this cable was installed on the inside containment portion of the Unit 2 HRRM system (2RE7820-1 and -2). Since the cable jacket maintained an extremely high shield to ground resistance, the Unit 2 application is considered acceptable.

5.5 Test Monitoring Equipment Calibration

The responsibility for test monitoring equipment used during the LOCA test belongs to Wyle Laboratories. It should be noted that in a post-LOCA calibration check, some of the monitoring equipment was found to be slightly out of tolerance. These calibration problems will be addressed as an anomaly in the Wyle test report. For the purposes of this test program the minor accuracy problems do not change the conclusions or recommendations of this evaluation.

Test monitoring equipment used in this evaluation is the responsibility of SCE and is identified on the individual Tables and Reference 2.3 as appropriate.

6.0 RECOMMENDED ACTIONS

6.1 Brand Rex Cable Failure

The failure of the Brand Rex cable jacket to provide shield to ground electrical insulation indicates that applications of this cable may experience excessive noise during steam line break conditions. It is recommended that any EQ applications of this cable be reviewed to see if this an acceptable condition during post-accident operation.

6.2 Rockbestos Cable

The primary objective of the LOCA test was to quantify the maximum induced current from steam line break environmental conditions and confirm that the installed cable will properly function during accident conditions. All cables exhibited induced currents due to the steam line break conditions. As discussed in Reference 2.2, only the first 1,000 seconds of testing provided useful information. After that time the signals became erratic, indicating some type of cable failure. However, the LOCA testing has confirmed that there will be some induced current, but does not provide a clear picture of the expected magnitude or duration of the phenomenon.

Any future testing should incorporate the following concerns:

6.2.1 Test Vessel Cable Penetration Design

Since the signals being measured were so small, low shield to ground insulation resistance in the "short" penetration may have greatly contributed to the erratic test monitoring data. An improved test vessel penetration should be designed to eliminate any concern that localized submergence or steam intrusion may have contributed to the erratic signal problem. See Figure 2 for a simplified schematic of a proposed test vessel penetration. In this design, the test specimens are connected by MHV connectors to Teflon lead wires, physically separated within an epoxy filled pipe by a spinning wheel type arrangement. The MHV connectors are located inside the test chamber are covered in LOCA qualified Raychem heat shrink tubing.

6.2.2. Test Specimens

It is unnecessary to search for a relationship between cable length and induced signal strength if the tested configuration is representative of the installed condition. The test specimens should consist of the following:

One 250' specimen of Rockbestos RSS-6-104/LE coaxial cable with 125' in simulated conduit and 125' in simulated cable tray. This would be representative of the avaerage installed configuration. No cable mandrel should be used. The cable should be routed in a manner not too exceed the cable minimum bend radius.

One 250' specimen of Rockbestos RSS-6-105/LE coaxial cable in simulated conduit. This would be representative of a future installation of all low noise cable routed completely within conduit.

The test specimens should be tested with a small current (1E-11 amps) to simulate the HRRM detector keep alive source. The current source should be variable in case it becomes necessary to increase the signal current to search for a strength that is greater than any signal produced by triboelectric or piezoelectric affects.

Future testing should use unaged cable, since this would represent the worst case in terms of the generation of triboelectric effects. Thermal cycling of coaxial cable is known to "relax" the cable, lessening the effects of shield and insulation movement.

6.3 Revise Unit 2 And 3 Emergency Operating (EOI) Procedures

Determine where radiation monitors 2(3)RE7820-1 and -2 are cited in the Emergency Operating Instructions. These instructions should be revised to include a caution that these instruments may exhibit a transient spurious signal during an inside containment high energy line break environmental conditions indicating a high containment radiation condition. The high radiation conditions should be verified against other radiation monitors.

Table 1
Test Specimen Descriptions

Specimen Nunber	Description
1	30' Rockbestos RSS-6-105/LE coaxial cable in conduit fixture.
2	90' Rockbestos RSS-6-105/LE coaxial cable
3	250' Rockbestos RSS-6-105/LE coaxial cable
4	90' Rockbestos RSS-6-104/LE coaxial cable
5	196' Rockbestos RSS-6-104/LE coaxial cable
6	90' BrandRex CS 75146 coaxial cable
7	250' BrandRex CS 75146 coaxial cable
8	20' Rockbestos RSS-6-105/LE coaxial cable

TABLE 2

INSULATION RESISTANCE TEST
CENTER CONDUCTOR TO SHIELD

SHORT PENETRATION - DRY CONDITION

Specimen Number	Time/Date	Resistance @500VDC	Acceptance Criteria	P/F
1	NOTE 2	N/A	>10^8 Ohms	N/A
2	1/8/96 9:10AM	1.5E8 NOTE 3	>10^8 Ohms	P
3	1/8/96 9:10AM	1E14	>10^8 Ohms	P
4	1/8/96 9:10AM	1E14	>10^8 Ohms	P
5	1/8/96 9:10AM	1E14	>10^8 Ohms	P
6	1/8/96 9:10AM	1.5E8	>10^8 Ohms	P
7	1/8/96 9:10AM	1.2E7	>10^8 Ohms	F
8	Note 1	N/A	N/A	N/A

Notes:

1. This test specimen is the 20' of Rockbestos RSS-6-105/LE used to monitor cable surface and center conductor temperature only.

2. Not included in this test.

3. Unstable reading.

Test Measuring Equipment Calibration:
ID# I1-6044
cal 11/14/95
due 05/14/96
by SCE MET 28

TABLE 3

STATIC INSULATION RESISTANCE TEST
CENTER CONDUCTOR TO SHIELD

SHORT PENETRATION - WET CONDITION (NOTE 4)

Specimen Number	Time/Date	Resistance @500VDC	Acceptance Criteria	P/F
1	NOTE 2	N/A	$>10^8$ Ohms	N/A
2	1/8/96 9:25AM	4E8	$>10^8$ Ohms	P
3	1/8/96 9:25AM	7E13 NOTE 3	$>10^8$ Ohms	P
4	1/8/96 9:25AM	1E14	$>10^8$ Ohms	P
5	1/8/96 9:25AM	1E14	$>10^8$ Ohms	P
6	1/8/96 9:25AM	1.5E8	$>10^8$ Ohms	P
7	1/8/96 9:25AM	2E7	$>10^8$ Ohms	F
8	Note 1	N/A	N/A	N/A

Notes:

1. This test specimen is the 20' of Rockbestos RSS-6-105/LE used to monitor cable surface and center conductor temperature only.

2. Not included in this test.

3. This specimen is dripping water through cable (not on outside).

4. The penetration was held upright in a vise, and standing water (about ½ cup) was applied to the internal portion of the penetration.

Test Measuring Equipment Calibration:
ID# I1-6044
cal 11/14/95
due 05/14/96
by SCE MET 28

FIGURE 4

TABLE 4

INSULATION RESISTANCE TEST
SHIELD TO GROUND

SHORT PENETRATION

Specimen Number	Time/Date	Resistance @500VDC	Acceptance Criteria	Multi-Meter (3V)
1	NOTE 2	N/A	>10^6 Ohms	N/A
2	1/10/96 8AM	2E12	>10^6 Ohms	>200M Ohm
3	1/10/96 8AM	2E8	>10^6 Ohms	>200M Ohm
4	1/10/96 8AM	1E12	>10^8 Ohms	>200M Ohm
5	1/10/96 8AM	2E12	>10^8 Ohms	>67M Ohm
6	1/10/96 8AM	2.5E9	>10^8 Ohms	>200M Ohm
7	1/10/96 8AM	3E9	>10^8 Ohms	>200M Ohm
8	Note 1	N/A	N/A	N/A

Notes:

1. This test specimen is the 20' of Rockbestos RSS-6-105/LE used to monitor cable surface and center conductor temperature only.

2. Conduit penetration tested separately.

Test Measuring Equipment identified in Reference 2.3.

TABLE 5

STATIC INSULATION RESISTANCE TEST
SHIELD TO GROUND

LONG PENETRATION

Specimen Number	Time/Date	Resistance @500VDC	Acceptance Criteria	Multi-Meter (3V)
1	NOTE 2	N/A	>10^6 Ohms	N/A
2	1/10/96 8:15AM	1E12	>10^8 Ohms	>200M Ohms
3	1/10/96 8:15AM	1E12	>10^8 Ohms	>200M Ohms
4	1/10/96 8:15AM	2E12	>10^8 Ohms	>200M Ohms
5	1/10/96 8:15AM	1E12	>10^9 Ohms	>200M Ohms
6	1/10/96 8:15AM	4E8	>10^8 Ohms	>200M Ohms
7	1/10/96 8:15AM	3E8	>10^8 Ohms	>200M Ohms
8	Note 1	N/A	N/A	N/A

Notes:

1. This test specimen is the 20' of Rockbestos RSS-6-105/LE used to monitor cable surface and center conductor temperature only.

2. Conduit tested separately.

Test Measuring Equipment identified in Reference 2.3.

TABLE 6

INSULATION RESISTANCE TEST
SHIELD TO GROUND

MANDREL

Specimen Number	Time/Date	Resistance @500VDC	Acceptance Criteria	Multi-Meter (3V)
1	NOTE 2	N/A	$>10^8$ Ohms	N/A
2	1/10/96 7:45AM	>3E12	$>10^8$ Ohms	>200M Ohms
3	1/10/96 7:45AM	>3E12	$>10^8$ Ohms	>200M Ohms
4	1/10/96 7:45AM	1E12	$>10^8$ Ohms	>200M Ohms
5	1/10/96 7:45AM	2.5E12	$>10^8$ Ohms	>200M Ohms
6	1/10/96 7:45AM	Grounded	$>10^8$ Ohms	>200M Ohms
7	1/10/96 7:45AM	Grounded	$>10^8$ Ohms	15M Ohms
8	Note 1	N/A	N/A	N/A

Notes:

1. This test specimen is the 20' of Rockbestos RSS-6-105/LE used to monitor cable surface and center conductor temperature only.

Test Measuring Equipment identified in Reference 2.3.

TABLE 7

STATIC INSULATION RESISTANCE TEST
SHIELD TO GROUND

CONDUIT PENETRATION

Specimen Number	Time/Date	Resistance @500VDC	Acceptance Criteria	Multi-Meter (3V)
1 Short Lead	1/10/96 8:25AM	1.5E12	>10^8 Ohms	>200M Ohm
1 Long Lead	1/10/96 8:25AM	2E12	>10^8 Ohms	>200M Ohm
3	N/A	N/A	>10^8 Ohms	N/A
4	N/A	N/A	>10^8 Ohms	N/A
5	N/A	N/A	>10^8 Ohms	N/A
6	N/A	N/A	>10^8 Ohms	N/A
7	N/A	N/A	>10^8 Ohms	N/A
8	Note 1	N/A	N/A	N/A

Notes:

1. This test specimen is the 20' of Rockbestos RSS-6-105/LE used to monitor cable surface and center conductor temperature only.

Test Measuring Equipment identified in Reference 2.3.

Figure 1
Electrical Test Schematic

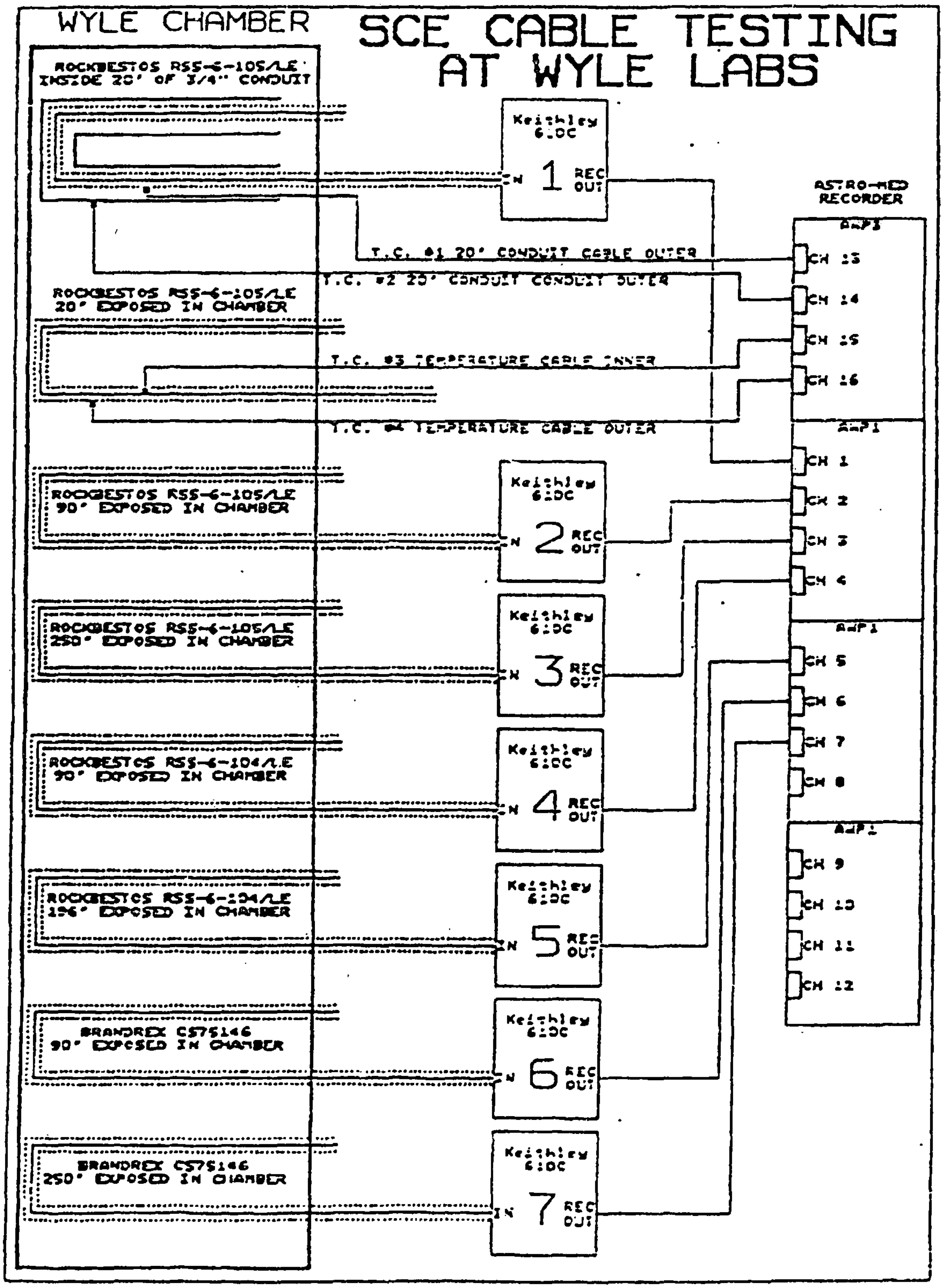
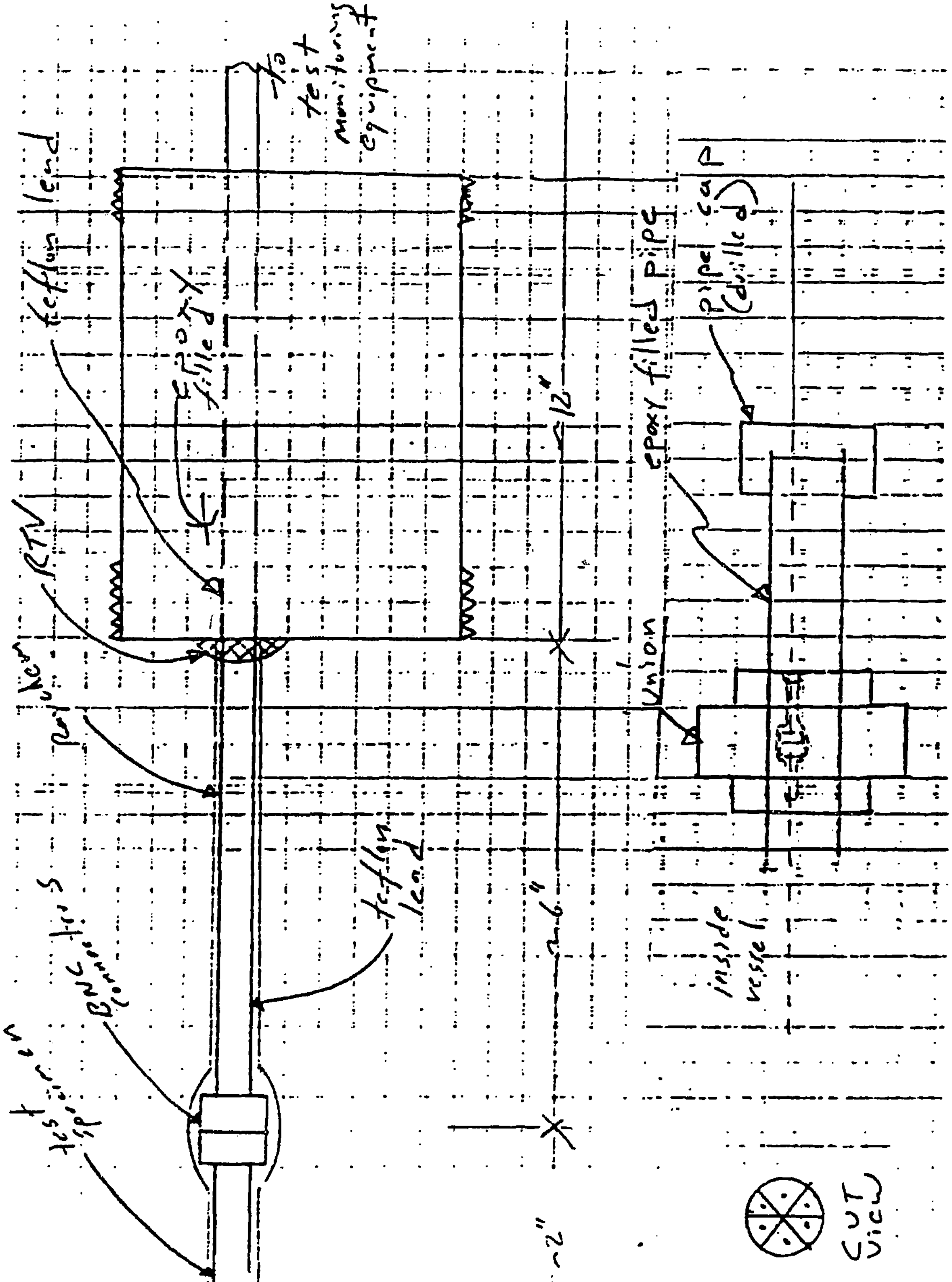


Figure 2
Improved Test Vessel Penetration Design



CAP-96123

1. General

These tests were originally planned to include LOCA and Main Steam Line break simulated accidents. After completion of the first LOCA test, it became apparent that each of the cables had suffered some loss of integrity. This was determined through significant changes in electrical resistance properties. Continuation of the testing was abandoned.

The objectives of the testing were to:
a. Quantify the maximum values of induced current in the cables from rapid changes in temperature.
b. Determine if the charge induced was a function of the cable length.
c. Confirm that the Rockbestos cable installed within the containment will withstand LOCA and Main Steam Line breaks without loss of function.
d. Determine thermal delay and effects on maximum induced currents of cable in conduit.

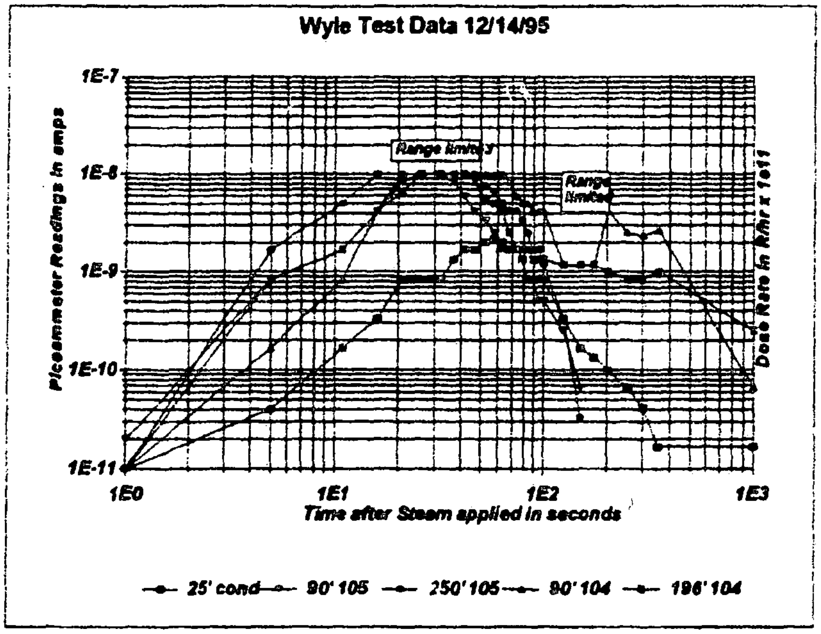
2. Induced Current Measurements

The application of steam into the autoclave produced initial positive increases in current in each Rockbestos cable. The Brand-Rex cables produced negative changes in current. The negative polarity current was different from previous tests performed with hot air heat guns or in a hot air test chamber. The data obtained from the Brand-Rex cables was considered suspect. Evidence of moisture dripping out of the connector ends during the test, confirmed the loss of jacket integrity. The initial current values indicate that the jacket boundary of the Brand-Rex cables were probably penetrated during the first steam application.

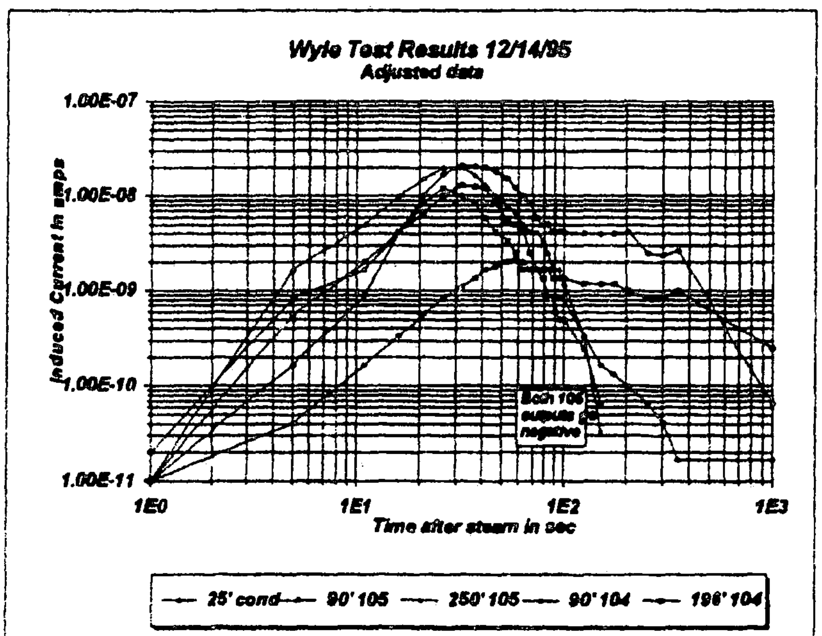
Graph 1 shows the induced currents measured from the Rockbestos cables during the first 1000 seconds of steam application. The maximum values above 1×10^{-8} amps have been fitted. The initial range of the picoammeter was set at $\pm 5 \times 10^{-9}$ amps and readable to about 20% over range or 6×10^{-9} amps. The general shape of the fitted data was determined by observations of previous tests performed by General Atomic Company and from heat gun and oven tests run at SCE facilities.

The projected maximum value from all cables given in graph 2 is 2.0×10^{-8} amps or 2000 R/hr equivalent dose. Slowly applied, dry heat chamber test results, in comparison, produced an average of 125 R/hr equivalent induced current for 100 ft of cable. Refer to table 1 for maximum induced current values.

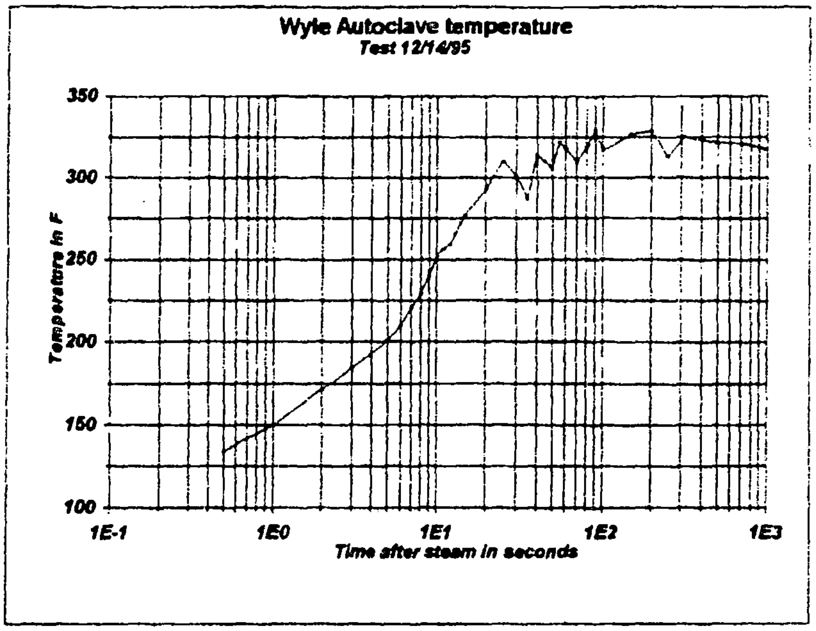
Attachment 3



Graph 1 Measured data from Wyle tests 12/14/95



Graph 2 Adjusted data from Wyle tests 12/14/95



Graph 3 Autoclave temperature vs. Time

Table 1 Maximum Induced Currents			
Cable No.	Length in feet	Max. Current in amps	Equivalent Dose in R/hr
Rockbestos RSS-6-104/LE	90'	2.1×10^{-8}	2100
Rockbestos RSS-6-104/LE	196'	1.3×10^{-8}	1300
Rockbestos RSS-6-105/LE	90'	1.2×10^{-8}	1200
Rockbestos RSS-6-105/LE	250'	2.0×10^{-8}	2000
RSS-6-105/LE in conduit	25'	2.2×10^{-9}	220

3. Charge vs. Cable Length

Referring to table 1, there does not appear to be a measurable relationship between induced current and the length of the cable. The Rockbestos RSS-6-105 type cable data reasonably fits the theory that the current is proportional to the length. However, the Rockbestos 104 cable current measurements seem in direct conflict. Post test examination took place to see if these cables could have been inadvertently switched. There was no evidence to suggest that a switch had taken place.

Ratios of the collected induced current data over the first 100 seconds of the test were averaged. The ratio of Rockbestos 105 cable currents from 250 ft to 90 ft was 2.3 to 1. The ratio of Rockbestos 104 cable currents from 196 ft to 90 ft was 0.72. If the 104 cables had been reversed, then the ratio would have been 2.1 to 1. Post test observations showed that the 196' Rockbestos cabling had blistered during the test. Further examination revealed that this cable was manufactured in 1992 and the non-blistered 90' piece was manufactured in 1994.

4. Steam Withstand Capability

As the test progressed, apparent large currents where flowing in the cables during the testing with many large noise spikes with generally erratic outputs. This behavior was similar to those experienced during the Sandia, some of the earlier General Atomic testing and tests performed at SCE facilities. The Sandia post accident insulation resistance (IR) measurements showed values well below expected IR values for any temperatures within the tested range. Further examination showed that splits had developed in the jackets. Moisture migrating into the cable dielectric caused these low and erratic readings.

A series of IR values were taken after the applied steam test. All values were below expected values. After overnight cooling of the autoclave, the bulk of the cable wound on the mandrel was cut from each of the epoxy potted, penetrations. The bulk cable on the mandrel produced IR values are shown in table 2. Values for each of the penetrations were also measured separately. These values are also given in table 2.

Table 2 IR Cable Values				
Cable No.	Total assy (132.6°F cool down)	Main cable (mandrel) ambient temp	Penetration (short length) ambient temp	Penetration (Long length) ambient temp
	Insulation Resistance in Ohms (Center conductor to shield)			
RSS-6-104 196'	5.0×10^{2}	3.9×10^{10}	1.3×10^{5}	7.3×10^{10}
RSS-6-104 90'	2.0×10^{9}	4.0×10^{10}	3.2×10^{11}	5.5×10^{10}
RSS-6-105 250'	2.0×10^{8}	3.5×10^{10}	1.8×10^{8}	5.6×10^{10}
RSS-6-105 90'	1.6×10^{6}	6.5×10^{10}	2.5×10^{7}	5.7×10^{11}
RSS-6-105 25' conduit	4.5×10^{7}	2.5×10^{13}	2.1×10^{7}	5.4×10^{10}
Brand Rex 90'	2.1×10^{5}	1.3×10^{11}	3.5×10^{6}	6.8×10^{10}
Brand Rex 250'	2.9×10^{5}	2.5×10^{10}	2.5×10^{5}	1.1×10^{5}

The total assembly IR values were taken with moisture still in the autoclave. The sectioned values were taken the following morning. The cables were dry because the residual heat within the autoclave had vaporized the remaining water which was free to escape.

With the exception of the RSS-6-104 90' cable, all cables showed lower than expected IR values in the short penetration assembly. The conduited cable used separate penetration assemblies. The short conduit penetration section also produced low IR values.

The failed cabling with IR values below 1.0×10^{9} ohms can be attributed to a faulty penetration assembly. The RSS-6-104 90' cable marginally passed in a wet environment at 132.6 °F but estimates of the complete cable system the next morning, after drying out, would have been a decade higher (Adding three values in parallel = $\sim 2.0 \times 10^{10}$ ohms). The Brand Rex 250 ft cable assembly failed at each penetration.

The ability of each cable to survive and function during and after a LOCA or Main Steam Line break has not been conclusively shown. However, the opposite has not been demonstrated either i.e. the cable failed during the test. The IR evidence implicates the short penetration assembly as failing.

5. Conduit Influence on Cable Currents

Peak induced current values were delayed from about 30 seconds after the test began for bare cables to 60 seconds after the test for the conduit cable. This delay value differs from the projected delay of 3 minutes. Failures after 1 hour and twenty minutes at each of the bare cable penetrations prevented a long term assessment of the usefulness of the conduit. The current had been steady and of low value during this initial period.

6. Conclusions

The tests were limited to a LOCA simulation only. The cabling assembly failed during the test. The IR measurements show that the cabling in at least one of the penetration sections failed. Penetrations similar to those used in this test are not used within the plant for coaxial cabling. The results are inconclusive as to whether the bulk of the cabling survived this LOCA test. It is possible that the cables failed but recovered during the cool down process overnight, allowing the moisture to escape and obtaining acceptable IR readings.

Peak induced currents of 2.1×10^{-8} amps or 2.1×10^{3} R/hr equivalent were produced during these tests. Projections for induced current based on testing performed at SONGS facilities for 250 feet of cable was 1.175×10^{3} R/hr. The maximum equivalent dose rate was underestimated by approximately a factor of 2.

Measurements did not support induced current as a function of cable length. If the Rockbestos 104 cabling was switched, then there would be strong evidence to support projecting expected currents based on cable length. The results are inconclusive on this issue.

The conduit test shows that the induced current generated in the conduit cable assembly was delayed by approximately 30 seconds compared with the bare cables. Since the induced current cannot be assumed proportional to the cable length, based on these tests, then we cannot draw any conclusions as to the estimated peak induced current in a 250 foot conduited cable. The 25 foot section tested produced peak currents of 2.2×10^{-9} amps or 220 R/hr.

If the current is subsequently found to be proportional to cable length, then the estimated current in a 250 foot conduited cable would be 2.2×10^{3} R/hr. This value is approximately the same as that measured in bare cables.

The data from this test showed conflicting time responses to the application of steam heat. One set of cables (Rockbestos 105) returned to close to the starting values within 100 seconds. The other set of cables (Rockbestos 104) took 350 to 450 seconds to get below a 100 R/hr and after 24 minutes were still above or close to 10 R/hr.

6. Recommendations

Before considering any further tests, a thorough examination of the failed penetration sections should be conducted. Alternate methods of sealing or feed through mechanisms should be used.

Further tests are required to establish the relationship between induced current and cable length. This knowledge will influence the option of conduited cable, if a peak value of 2×10^3 is considered unacceptable.

A fully conduited cable specimen should be included in any future testing with a cable length as long as practically possible.

Prepared By: Tony Hyde Date: 1/24/96
Tony Hyde

Reviewed By: Dennis Beauchaine Date: 1/24/96
Dennis Beauchaine

June 4, 1996

MEMORANDUM FOR FILE

SUBJECT: High Range Radiation Monitoring (HRRM) Coaxial Cable Engineering Analysis - Conclusions and Recommendations

REFERENCE:
1) NCR 951100073
2) Wyle Laboratories P.O. 6A2N5009

This memorandum serves to summarize and distribute the attached engineering analysis. The analysis was performed to determine the transient effects of high temperature and pressure conditions (such as Main Steam Line Break (MSLB) or Loss of Coolant Accident (LOCA)) on the coaxial signal cable used with the High Range Radiation Monitor (HRRM).

The attached analysis concludes that when operating at the HRRM detector "keep alive" source signal strength equivalent to approximately 1 R/hr, thermally induced currents generated from the coaxial signal cable will produce misleading radiation dose rate information following MSLB or LOCA. The coaxial signal cable current is generated by a phenomenon known as Thermally Stimulated Depolarization (TSD) of the dielectric. The duration of the thermally induced signals are expected to be approximately 15 minutes, with a resulting peak indication in the low thousands of R/hr. If significant radiation dose rates do exist, the HRRM detector will generate a signal current that will be additive to the coaxial cable thermally induced current.

Other conclusions are:

- The SONGS 2&3 installed HRRM signal cable design configuration of Rockbestos RSS-6-104/LE routed approximately one half in conduit and one half in tray is an acceptable condition and does not require a design change.

- Operator training initiated under disposition step 2 of NCR 951100073 should include the most recent technical information as summarized in Section 2.4 and detailed in Section 7.0 of the attached analysis. Operations should also review this information for any impact on the Emergency Operating Instructions.

- The problem of thermally induced currents is common to all HRRM systems operating with signals in the pico ampere operating range. Southern California Edison will seek industry participation in any further investigations into this issue.

The attached engineering analysis provides details regarding each of these conclusions. If you have any questions please call Ken Trotta at 89170 or myself at 87028.

M.V. Stillwaye For
L. Conklin

Attachment

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ENGINEERING ANALYSIS
High Range Radiation Monitoring (HRRM)
Coaxial Cable Testing

SAN ONOFRE NUCLEAR GENERATING STATION UNITS 2 & 3

Prepared By: Ken Trotta Date: 6/4/96
Ken Trotta

Reviewed By: Steve Stilwagen Date: 6/04/96
Steve Stilwagen

TABLE OF CONTENTS

1.0 PURPOSE

The purpose of this engineering analysis is to document the results of work performed to determine the transient effects of high temperature and pressure conditions (such as Main Steam Line Break (MSLB) or Loss Of Coolant Accident (LOCA)) on the coaxial cable used with the High Range Radiation Monitors (HRRM), Equipment ID's 2(3)RE7820-1 and 2(3)RE7820-2.

The scope of this analysis is limited to the inside containment HRRM coaxial signal cable installed at SONGS Units 2 and 3.

2.0 RESULTS/CONCLUSIONS AND RECOMMENDATIONS

Several conclusions were reached as a result of this analysis. The conclusions involve: 1) spurious signals generated during LOCA or MSLB; 2) the effects of containment heat up and cool down on the installed cable; 3) comparisons between cable types and cable routing methods (electrical conduit verses cable tray); 4) operator training and 5) licensing and industry considerations.

2.1 Spurious Signals

The Rockbestos RSS-6-104/LE coaxial cable used with the SONGS 2&3 HRRM will undergo significant induced positive and negative currents as a result of exposure to transient temperature conditions. The induced current is the result of temperature stress, specifically the rate of temperature change. In the presently installed configuration, operating at the detector "keep alive" signal of one R/hr, the HRRM will provide a false high radiation reading, for a duration of approximately 15 minutes, when exposed to extreme temperature transient conditions inside containment such as LOCA or MSLB. The magnitude of the false reading may be in the range of the low thousands of R/hr. The low thousands of R/hr indication spike will last less than one minute, then drop down to hundreds of R/hr, then return to below the alarm set point (<10 R/hr) in approximately 15 minutes. Following the initial temperature transient, the containment atmosphere will begin to cool, and spurious "fail" signals may occur as described in the next section.

Note that if significant radiation dose rates do exist, the resultant detector signal strength will be additive to the spurious signal. Example: If the coaxial cable thermally induced current is equivalent to 200 R/hr, a detector signal of 200 R/hr will be additive, with the RP2C reading 400 R/hr. However, the design basis LOCA dose rates are expected to be on the order of 1E6 R/hr (Reference 5.6), which will overcome the spurious signal..

2.2 Containment Heat Up and Cool Down

The sign of the current generated by the cable is a function of the temperature gradient across the cable insulation. When the cable is being heated, the induced current signal is positive, when the cable is cooling, the current signal is negative. A current signal with a negative charge will cause the HRRM to alarm "fail." Consequently, when the cable begins to "cool" following the initial temperature transient, the effect on the HRRM system will be to indicate a false "fail" signal on the RP-2C readout. This is true only if the cooling transient induces a current of sufficient magnitude to overcome the "keep alive" and/or detector dose rate signal. At high dose rates, the cooling effect may not cause a fail alarm. It was determined the pressure associated with steam line break conditions does not directly cause or influence the magnitude or sign (positive or negative) of the induced current.

Note that if significant radiation dose rates do exist, the resultant detector signal strength will be additive to the spurious signal. Example: If the coaxial cable thermally induced current is equivalent to -200 R/hr, a detector signal of +200 R/hr will be additive, with the RP2C reading 0 R/hr. However, the design basis LOCA dose rates are expected to be on the order of 1E6 R/hr (Reference 5.6), which will overcome the spurious signal.

2.3 Comparisons of Coaxial Cable Type and Conduit verses Tray

Various induced current performance tests, including high temperature steam testing, were performed on three cable types

1. Rockbestos RSS-6-104/LE (currently installed)
2. Rockbestos RSS-6-105/LE "low noise" (proposed installation)
3. Brand Rex CS 75146 (previously installed)

The results of the various testing described in Section 7.0 indicate the presently installed Rockbestos RSS-6-104/LE provides the best overall performance in terms of recovery time from spurious signals and maintaining a positively charged signal.

A comparison of steam test results for 250' cable lengths indicate that cable routed completely in conduit does not provide relief from thermally induced charges. The test specimens routed completely in conduit did experience a delay time of approximately 60 seconds, but the resultant thermally induced charge was of equal magnitude (thousands of R/hr range) to the one half conduited specimens.

It is concluded that the installed configuration of Rockbestos RSS-6-104/LE coaxial cable, routed approximately one half length in conduit, the other half in tray, is an acceptable configuration.

2.4 Operator Training

The results of this testing program demonstrate false high and "fail" indications will be provided to the Operators during LOCA or MSLB environmental conditions inside containment. The operator training initiated as a result of Non Conformance Report (NCR) 95110073, Disposition Step 2, should include the following two highlights: 1) The duration of the spurious signal will be approximately 15 minutes and may range into the thousands of R/hr and; 2) The spurious high R/hr signal will return to normal, and as the containment environment cools, a spurious "fail" signal may also occur as the thermally induced signal changes sign from positive to negative, masking any authentic low level dose rate. When accident temperature conditions stabilize, and/or significant dose rates exist, indicated radiation dose rates will be more accurate.

2.5 Licensing Considerations

The HRRM is a Regulatory Guide (RG) 1.97 post accident monitoring instrument. The RG 1.97 accuracy requirements for this equipment are that it be accurate within a "factor of two" over the entire range. It is concluded that the HRRM does not meet this requirement during the transient portion of high temperature environmental conditions such as LOCA or MSLB. Appropriate licensing actions should be taken to address the operation of the HRRM outside it's required accuracy range. It should be noted that the HRRM already does not meet the accuracy requirements, and licensing actions are ongoing to address this issue.

2.6 Industry Considerations

All commercial nuclear power plants have a RG 1.97 required HRRM detector manufactured by General Atomic (Sorrento Electronics), Victoreen, Kaman Sciences, or other detector manufacturer. Since these devices operate using extremely low signal strengths, and were tested separately from their associated signal cables, it is probable the issue of thermally induced coaxial cable signals is not addressed by existing qualification testing or documentation. A synopsis of the SONGS investigations of this issue will be presented to the Nuclear Utility Group on Equipment Qualification (NUGEQ) during their next meeting in June 1996.

3.0 ASSUMPTIONS

None.

4.0 METHODOLOGY

This section is intended to be a summary of the detailed information provided in the Appendices and References cited in this report.

4.1 Introduction

The High Range Radiation Monitor (HRRM) is a R.G. 1.97 post accident monitoring device used to monitor high radiation conditions inside containment during post LOCA environmental conditions. The primary function of this device is to estimate core damage following a LOCA. The HRRM operates using detector current signals ranging from 1E-11 (0 R/hr) to 1E-3 (1E8 R/hr) amps. See Table 1 for the signal current verses equivalent dose rate.

During a periodic test of the Unit 3 containment emergency coolers, the HRRM (3RE7820-2) was noticed to "fail" low for periods of up to 15 minutes This fail low period coincided with the initiation of the emergency cooler test. After completion of the cooler test, an upscale reading of approximately 1 R/hr occurred, decaying back to zero in about 15 minutes. The "keep alive" source within the detector maintains an indicated reading of 0.8 R/hr. Non Conformance Report (NCR) 950800177 (Reference 5.1) was prepared to address the HRRM signal problem and provides more detailed background information. NCR 950800177, Cause and Corrective Action Step 2, called for an evaluation of the transient response of all channels of the HRRM under postulated accident conditions. This document presents the summary, conclusions and recommendations based on the required transient response evaluation.

Table 1 Signal Current and Equivalent Dose Rate	
Signal Current (amps)	Dose Rate (R/hr)
1E-3	1E8
1E-4	1E7
1E-5	1E6
1E-6	1E5
1E-7	1E4
1E-8	1E3
1E-9	1E2
1E-10	1E1
1E-11	1

4.2 Investigations and Testing Performed to Date

Several testing methods have been used to investigate the thermally induced charge phenomena. Testing and investigation methods include in-service testing, simple bench tests such as mechanical motion and heat gun, heat oven and steam chamber testing. In addition, existing qualification test reports and published literature were reviewed. Discussion regarding these investigations and testing are provided in Section 7.0 of this report.

5.0 REFERENCES

5.1 NCR 950800177

5.2 Equipment Qualification Data Package (EQDP) M37609, General Atomic High Range Radiation Monitor (HRRM)

5.3 SCE Memorandum To File, Subject: High Range Radiation Monitoring (HRRM) Coaxial Cable Test Results and Recommendations, L. Conklin, Dated January 24, 1996.

5.4 WYLE Test Report 45145, LOCA/MSLB Simulation Test Program on Coaxial Cables, Revision 0

5.5 NCR 951100073

5.6 Bechtel Calculation N-1140-13, Post LOCA Equipment Doses Inside Containment, Revision 11

5.7 SCE Memorandum to File, Subject: Brand Rex Coaxial Cable used in the TEC Pressurizer Relief Valve Monitoring System, L. Conklin, Dated February 5, 1996

6.0 NOMENCLATURE

6.1 Trioboelectric Effects

Triboelectric effects are defined as an internally generated voltage which is created when a coaxial cable shield moves slightly over the wire insulation when the cable is in motion. Changing temperature conditions cause the cables organic insulation to expand and flex. When the shield moves over the insulation numerous minute voids momentarily form, disappear, and re-form. The opening and closing of these voids has the same effect as many capacitors charging and discharging.

6.2 Thermally Stimulated Depolarization (TSD)

The manner in which polarization can occur within a dielectric is by charges creating dipoles at impurity molecule sites within the dielectric. These dipoles require an electric field to initiate the dipole. It is theorized that the electric field is applied during dielectric withstand (5000 VAC) and insulation resistance (500 VDC) production testing. TSD is defined as the mechanism where current is released from a dielectric as a result of an increase in temperature.

7.0 INVESTIGATIONS AND RESULTS

The following sections summarize the investigations and testing performed to date, with further details provided in the associated Appendix as identified below.

7.1 In service Testing (November 1995)

Initially the HRRM signal problem was found to be linked to the testing of containment emergency cooler 3ME400. It was determined that the emergency cooler power cable was routed in the same cable tray as the HRRM signal cable. In-rush currents of approximately 800 amps were measured in the power cable, lasting only milliseconds. The in-rush current was ruled out as the source of the 15 minute HRRM signal current transient. A Cs-137 test calibration source of 10 R/hr was placed in front of the detector, then the emergency cooler was started. The indicated reading dropped from 10 R/hr down to 9 R/hr, recovering back to 10 R/hr in about 15 minutes. When the emergency cooler was shut off, the indicated reading went up to 11 R/hr, recovering back to 10 R/hr in about 15 minutes.

It is speculated that when the cooler operates, cool air is drawn over the HRRM coaxial cable located in nearby tray, creating a temperature gradient across the cable insulation, causing the cable to generate a negative charge resulting in a "fail" indication. As the negative charge decays, indication returns to normal. Further information on in service testing is presented in Section 3 of Appendix A.

7.2 Review of Existing Qualification Test Reports (November 1995)

Environmental qualification testing of the SONGS 2&3 HRRM detector was performed by General Atomic (now Sorrento Electronics) in 1981 and also Sandia Laboratories in 1988 (Reference 5.2).

During the General Atomic (GA) testing, only 18 inches of coaxial signal cable was included in the steam chamber. Although not discussed in the GA test report, an examination of the test recordings by SCE personnel indicate at the beginning of the transient a four minute up scale reading of about 25 R/hr occurred. The HRRM detector was tested using only the "keep alive" source and the acceptance criteria was based on steady state operation. Further information on the GA qualification testing is presented in Section 4 of Appendix A and Reference 5.2.

The Sandia Laboratories testing included simultaneous exposure to radiation and pressure-temperature conditions. The test report did not identify the length of coaxial cable included in the test chamber. Test laboratory personal were contacted and could not recall the approximate cable length included in the test chamber. The Sandia testing resulted in several large radiation readings (spikes) when only temperature and pressure were being applied. The magnitude of at least one of these spikes was in the ten thousands of R/hr range. The duration of these spikes was for approximately three minutes. Subsequent radiation exposure produced detector currents large enough to mask any temperature induced currents (> 10,000 R/hr). After 50 plus hours several negative excursions were noted. The report stated that the cable behavior during the test was not completely explainable. Further information on existing qualification testing is presented in Section 4 of Appendix A.

A review of Rockbestos, Brand Rex and Raychem coaxial cable environmental qualification testing indicates testing was performed using voltage and current levels significantly greater than the HRRM application. Coaxial cables are typically LOCA tested while carrying signals at the milliamp level (1E-3), while the HRRM application operates near the picoamp level (1E-11). No conclusions can be reached regarding cable performance near the picoamp range.

Mineral insulated cable performance was also investigated. Previous testing of mineral insulated (MI) cable by Kaman Sciences for thermal transient behavior indicates that MI cable also experiences significant transient current effects. There would be no benefit to replacing the existing organically insulated cable with MI cable since MI cable exhibits only marginally better performance. Further information on MI cable transient behavior is provided in Appendix B.

7.3 Mechanical Movement (November 1995)

By mechanically moving samples of the Rockbestos coaxial cables, the induced current corresponded to only a few R/hr. This indicates that significant induced current is not the result of cable motion effects. Further information on mechanical movement (motion) testing is provided in Section 6.1 of Appendix A and Section 2 of Appendix C.

7.4 Heat Gun Testing (November 1995)

Using an electric heat gun, Rockbestos coaxial cables were subjected to heated and unheated air flow over various lengths to monitor the induced currents. It was determined that peak currents were not a function of cable length subjected to heating. Applying heat produced positive charges (equivalent to 150 R/hr), and cooling (removal of the heat gun or blowing cold air) produced negative induced charges. At steady temperature, induced current decay times were approximately 15 minutes. Further information on heat gun testing is provided in Section 1 of Appendix C.

7.5 Heat Oven Testing (November 1995)

Samples of Rockbestos RSS-6-104/LE (100'), RSS-6-105/LE (50') and Brand Rex CS 75146 (100') were subjected to a series of heat oven tests to determine the thermally induced current. The temperatures ranged from ambient to approximately 300F and were held for five to 10 minutes. Testing was limited by the rise rate of the heat oven (4F/minute). This heat rise rate is significantly less than the postulated LOCA or MSLB conditions of >300F/minute. It was determined that the cables would generate only one or two decades of current (equivalent to tens or hundreds of R/hr) when exposed to the slow temperature rise rate. Further information on heat oven testing is provided in Appendix D.

7.6 Steam Chamber Testing - First Sequence (December 1995)

The primary objectives of the first steam chamber test sequence were to:

- Quantify the maximum values of induced current in the cables from rapid temperature changes.
- Determine if the induced charge is a function of cable length.

Steam chamber testing of various lengths of Rockbestos RSS-6-104/LE, RSS-6-105/LE and Brand Rex CS 75146 coaxial cables was performed during the week of December 11, 1995 at Wyle Laboratories in Huntsville, Alabama. The results of this testing are documented in an SCE Memorandum to File (Reference 5.3) and Wyle test report (Reference 5.4). The conclusions and recommendations may be summarized as follows.

Due to troubles with the test chamber penetrations (moisture intrusion and low insulation resistance), not all test objectives were met. Based on extrapolation of the test results, it was concluded that erroneous indication of dose rates as high as 2,000 R/hr may occur as a result of LOCA or MSLB temperature transients. NCR 951100073 (Reference 5.5) was revised to include a disposition step for the Operations Division to include training for all operators regarding accident temperature induced spurious signals on the HRRM. It could not be concluded that the induced charge is a function of cable length.

The Brand Rex cables failed at their test vessel penetration, shorting from shield to ground, and were not considered suitable for further testing. In light of this failure, the safety related EQ applications of Brand Rex CS 75146 coaxial cables were reviewed and found to be acceptable (Reference 5.7). More detailed information on the first sequence of steam chamber testing is provided in References 5.3 (test monitoring) and 5.4 (environmental conditions). Additional LOCA testing was recommended to empirically simulate the installed HRRM inside containment coaxial cable configuration (Rockbestos RSS-6-104/LE), and also a proposed future installation of low noise cable (Rockbestos RSS-6-105/LE) contained completely in conduit. The results of the supplementary LOCA testing are documented in the following Section (7.7).

7.7 Steam Chamber Testing - Second Sequence (March 1996)

The second sequence of LOCA testing had three objectives:

- Identify the magnitude and duration of the spurious signal that would be produced for a typical SONGS 2&3 inside containment HRRM coaxial cable configuration during LOCA or MSLB environmental conditions. Specifically, that configuration is represented by a 235' Rockbestos RSS-6-104/LE cable, located approximately one half length in conduit, one half in cable tray.

- Determine whether a "low noise" cable such as Rockbestos RSS-6-105/LE provides superior performance over the installed Rockbestos RSS-6-104/LE.

- Determine whether there is some improvement in coaxial cable performance when the cable is routed entirely in electrical conduit.

As described below, all three objectives were met.

Steam testing was performed during the week of March 25, 1996 at Wyle laboratories in Huntsville Alabama. The intent of this testing was to:

1. Empirically model a typical SONGS 2&3 inside containment HRRM coaxial cable run. A typical coaxial cable run was represented by a 235' of Rockbestos RSS-6-104/LE routed one half length in conduit, the other half in cable tray. A review of the Nuclear Consolidated Data Base (NCDB) indicates that most HRRM signal cables routed inside containment are approximately 50% in conduit.

2. Empirically model possible future installations of:
   a) 250' of Rockbestos RSS-6-104/LE 100% in conduit
   b) 250' of Rockbestos RSS-6-105/LE "low noise" 50% in conduit, 50% in tray
   c) 250' of Rockbestos RSS-6-105/LE "low noise" 100% in conduit

This would provide practical information on cable performance during postulated LOCA and MSLB environmental conditions. Rockbestos RSS-6-104/LE and RSS-6-105/LE coaxial cables as identified below were included in a LOCA/MSLB simulation as described in the Wyle Test Report (Reference 5.4).

250' Rockbestos RSS-6-104/LE (100% in conduit)
235' Rockbestos RSS-6-104/LE (50% in conduit)
250' Rockbestos RSS-6-105/LE (100% in conduit)
250' Rockbestos RSS-6-105/LE (50% in conduit)
Control Penetration (18" Loop of RSS-6-104/LE)

The use of a control penetration provided a baseline measurement to differentiate between what would be considered a cable failure, verses a test vessel penetration failure. The second steam test used an improved test vessel penetration design, since the previous steam test results were considered suspect due to test vessel penetration failures limiting the useful information relating to cable performance.

It should be noted that several test vessel penetration designs were tested and abandoned prior to the second sequence steam test. The final design does not include features that were discarded such as the use of PVC and Teflon insulated test leads. The PVC dielectric softened at high temperature, causing the center conductor to migrate through the dielectric, and short to the shield. Teflon twisted shielded pair test leads had a strong sensitivity to triboelectric effects, producing large spurious signals that could erroneously be attributed to the test specimens. The improved test vessel penetration design in presented is Figure 1 of the Wyle Test Report (Reference 5.4). The final design consisted of the coaxial cable specimen, covered with a Raychem sleeve, encased in an epoxy filled pipe nipple, with a BNC connector one foot outside the test chamber (see Figure 4).

7.7.1 Second Sequence Steam Test Results

The test specimens were arranged in the simulated conduit and cable tray fixture as described above and detailed in the SCE test monitoring procedure (Appendix E) and Wyle Test Report (Reference 5.4). Test monitoring is described in detail in Appendix E of this analysis. To summarize, the test specimens were energized with a current signal of 1E-11 amps, simulating the keep alive source of the HRRM detector. Thermally induced current signals were monitored and recorded over time. The thermally induced signals are presented graphically in Figure 1of this report. The complete recordings of induced current verses time during the two and one half hour warm up, and four hour steam test, for all test specimens is provided in Appendix H.

The test chamber was taken from ambient temperature to approximately 120F and held for two and one half hours. This allowed the specimens to stabilize since even the small rise in temperature from ambient (80F) to 120F produced significant thermally induced currents. Following test specimen signal stabilization, steam was supplied to the test chamber raising the temperature to approximately 420F in less than three minutes. The temperature was held at approximately 400F, sometimes reaching 425F for a total of 15 minutes. The steam test temperature profile is presented in Figure 2 of this report. As shown in Figure 1, all four cable test specimens (not the control channel) experienced thermally induced currents equivalent to the low thousands of R/hr within 100 seconds of steam initiation.

Test specimens routed completely in conduit experienced a delay time of approximately one minute before reaching their peak induced signal. This indicates that the conduit provides only a thermal lag effect, not complete protection. The cable samples in conduit experienced a secondary induced current spike of approximately 50% of the main spike occurring at approximately 250 seconds. The timing of this secondary spike corresponds to a sudden increase in test chamber temperature from 360F to 400F. The induced current quickly drifted down to the tens of R/hr and as low as the "keep alive" 1 R/hr signal within 15 minutes. All test specimens provided reasonable performance from approximately 15 to 30 minutes into the transient.

At approximately 30 minutes into the transient, all test specimens signals became erratic. It was discovered that moisture had migrated into the BNC connectors used to connect the test measurement leads to the test specimens located at the test vessel penetration. An examination of the test vessel penetration revealed the Raychem sleeve was being extruded through the penetrations epoxy potting. Due to the high test chamber pressure (70 psig) and temperature, moisture migrated through the cable jacket, along the cable braid, through the penetration, and into the BNC connectors. An attempt was made to dry out the connectors by disconnecting and shaking out the moisture. Only test specimen five responded to the drying efforts, and the signal immediately returned to normal (keep alive signal of 1 R/hr).

Since all test specimens signal became erratic at approximately the same time, and all connectors contained moisture (a few drops), it is reasonable to conclude that moisture within the connectors caused the erratic readings.

7.7.2 Performance of the SONGS 2&3 Simulated Installation

Since the test objective was to predict HRRM signal cable performance, interfaces such as terminations (connectors) with the RD-23 detector and containment electrical penetration assembly were not included in the test set up. The SONGS 2&3 inside containment HRRM coaxial cable installation was simulated using a 235' piece of Rockbestos RSS-6-104/LE coaxial cable routed one half its length in conduit, the other half in cable tray. In the test monitoring procedure (Appendix E), it is identified as test specimen number 4. The signal behavior of this specimen is considered representative of the installed condition, and may be used to predict the performance of the SONGS HRRM during LOCA or MSLB environmental conditions.

The following is a narration of the information of the signal behavior during the first 900 seconds (15 minutes) and is graphically presented in Figure 3. The indicted radiation dose in the first 60 seconds spiked to 3,800 R/hr, dropping down to approximately 900 R/hr in 90 seconds. A small secondary spike back up to 1150 R/hr occurs at 120 seconds. The indicated dose rate drifted down into the tens of R/hr in approximately nine minutes. At 13 minutes and until approximately 17 minutes the indicated dose went into "fail" due to a negative signal resulting from "cooling" of the test chamber. At 17 minutes the indicted dose rate returns to the tens of R/hr and less, approaching the keep alive source value (one R/hr) until approximately one half hour. At this point a negative signal was generated, and became erratic until the test was terminated at approximately four hours. As discussed above, it is concluded that moisture migrating into the test lead BNC connectors caused the erratic readings.

At SONGS 2&3, the inside containment HRRM coaxial cables are terminated at their Westinghouse containment electrical penetration assemblies using bulkhead HN connectors. Because the connector are terminated inside containment, no pressure differential or driving force operates to force moisture through the cable jacket, into the HN connector. It should be noted the bulkhead HN connectors are covered with an environmentally qualified Raychem heat shrink kit designed to prevent moisture intrusion. However, if moisture enters the cable through the jacket, there is a significant elevation difference between the detectors and the penetration, which may cause a gravity feed into the electrical penetration HN connectors. This is considered a separate issue from the coaxial cable performance and is being tracked by Action Request (AR) 951100073.

7.8 Theory of Thermally Induced Charges (May 1996)

Recent investigations reveal that a phenomena exists where currents are created from dielectric relaxation processes. This phenomena is called thermally stimulated depolarization (TSD) currents. TSD is defined as the mechanism where current is released from a dielectric as a result of an increase in temperature. The manner in which polarization can occur within a dielectric is by charges creating dipoles at impurity molecule sites within the dielectric. The current released is dependent on cable length, polarizing E-field, number of impurity sites, dipole activation energy and rate of temperature change. There are complex equations that can be solved to predict the current resulting from rapid temperature change, however, the many variables related to cable dielectric impurities make these calculations impractical in this application.

The TSD phenomena is a realistic explanation of the thermally induced currents that occur in the coaxial cables associated with the HRRM. Further information on the TSD phenomena can be found in Appendix G.

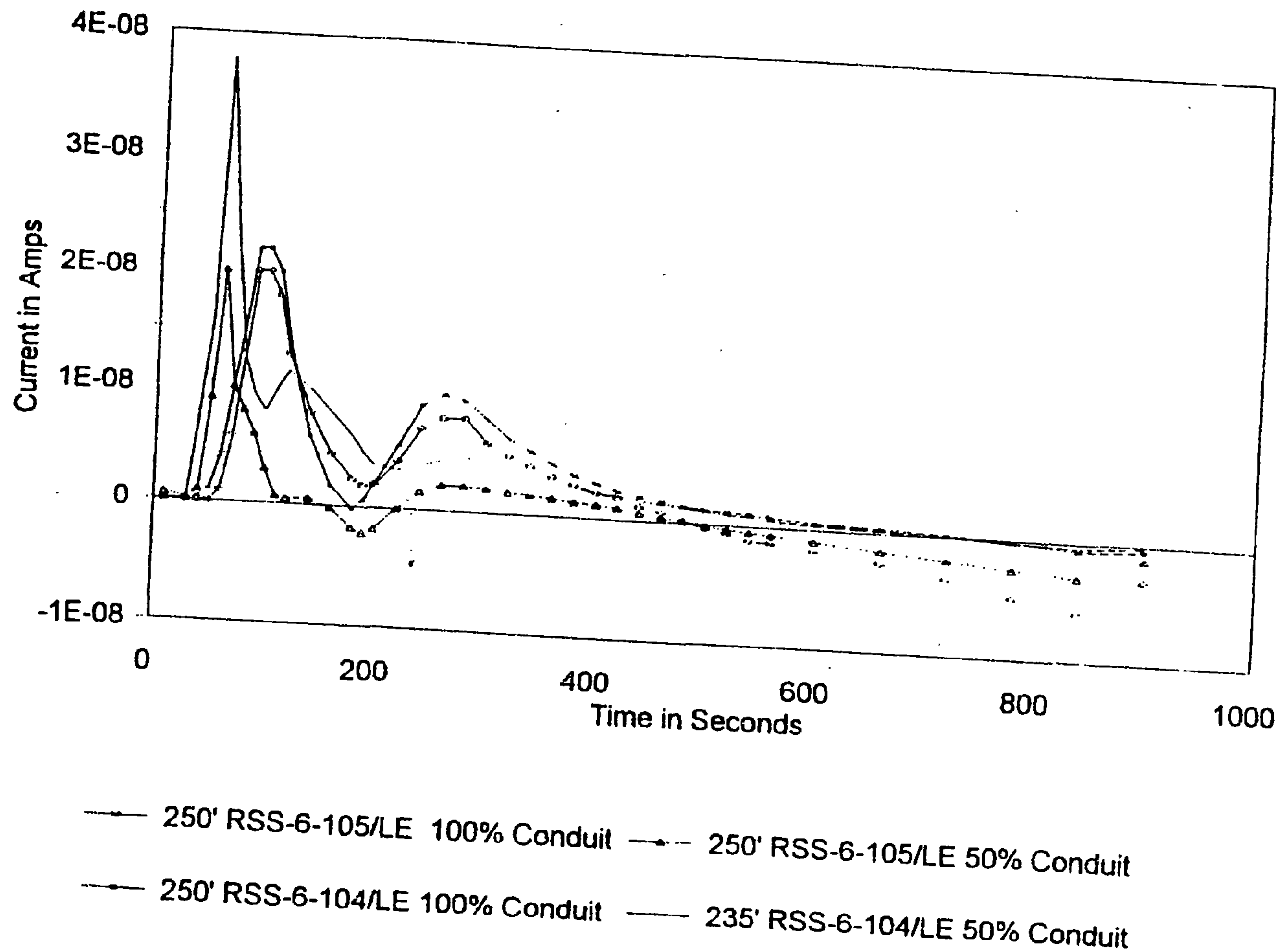


Figure 1
Coaxial Cable Test - Current Response to LOCA/MSLB Thermal Shock

Figure 2
SONGS 2&3 Installed Configuration - LOCA/MSLB Indicated Dose Rate

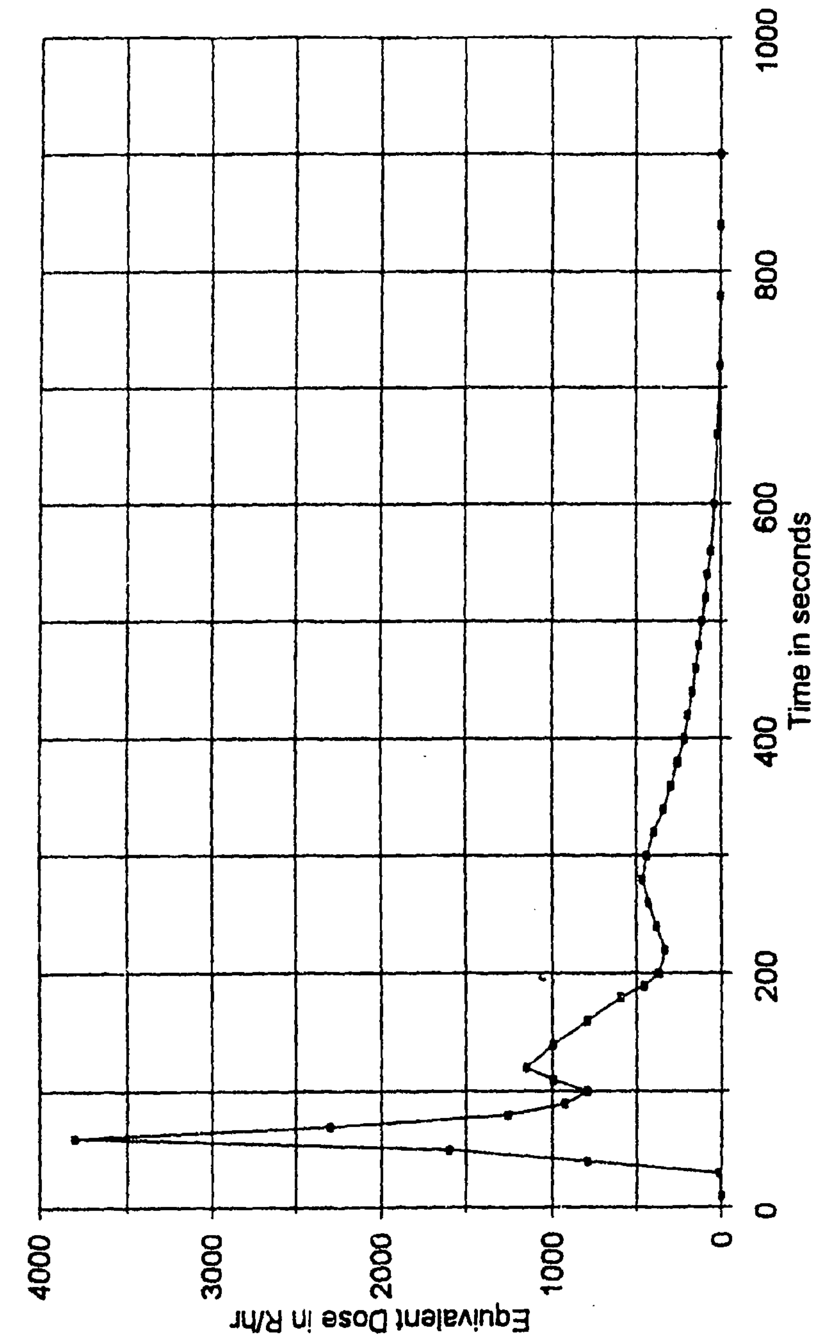


Figure 3
Second Test Sequence - LOCA/MSLB Temperature Curve

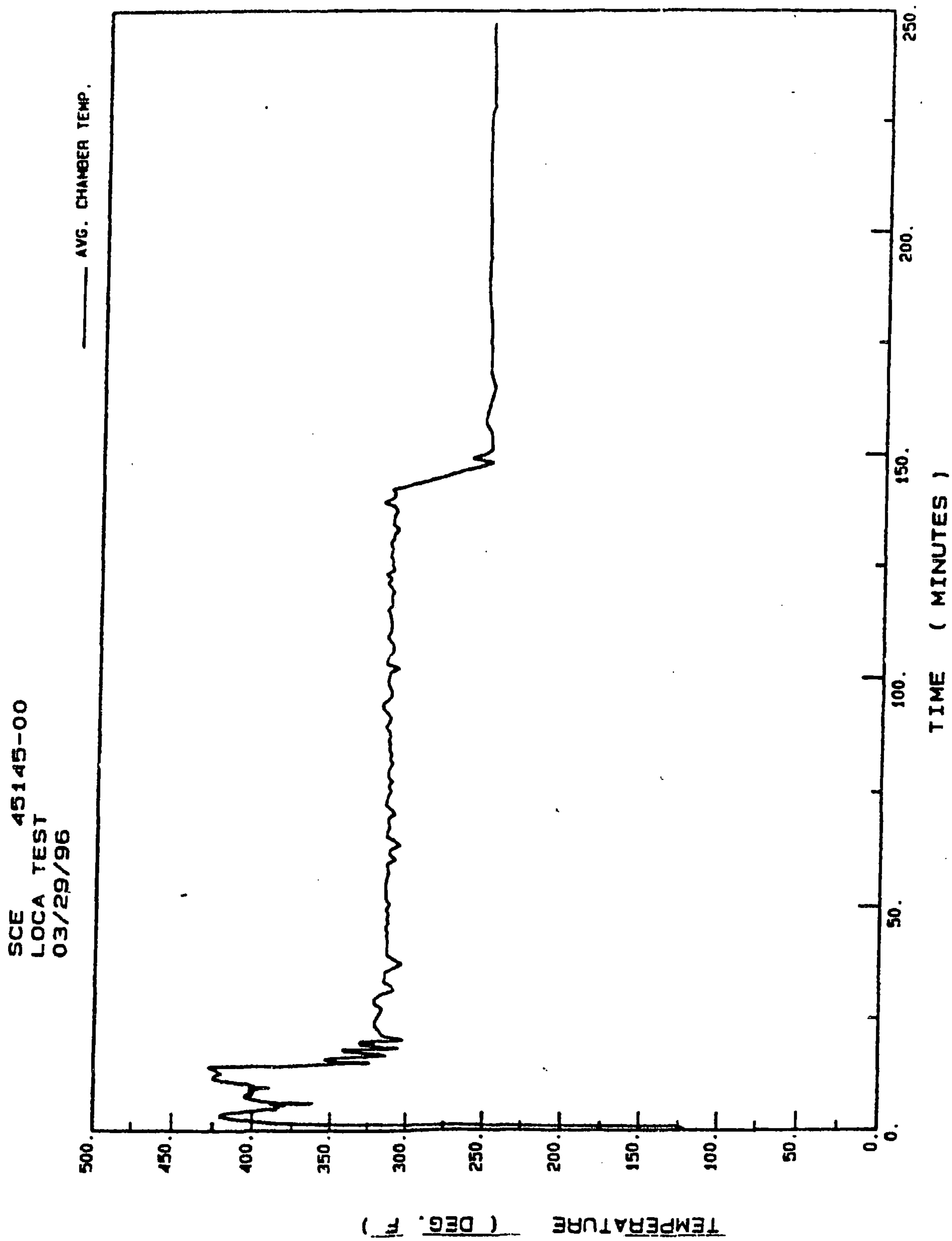
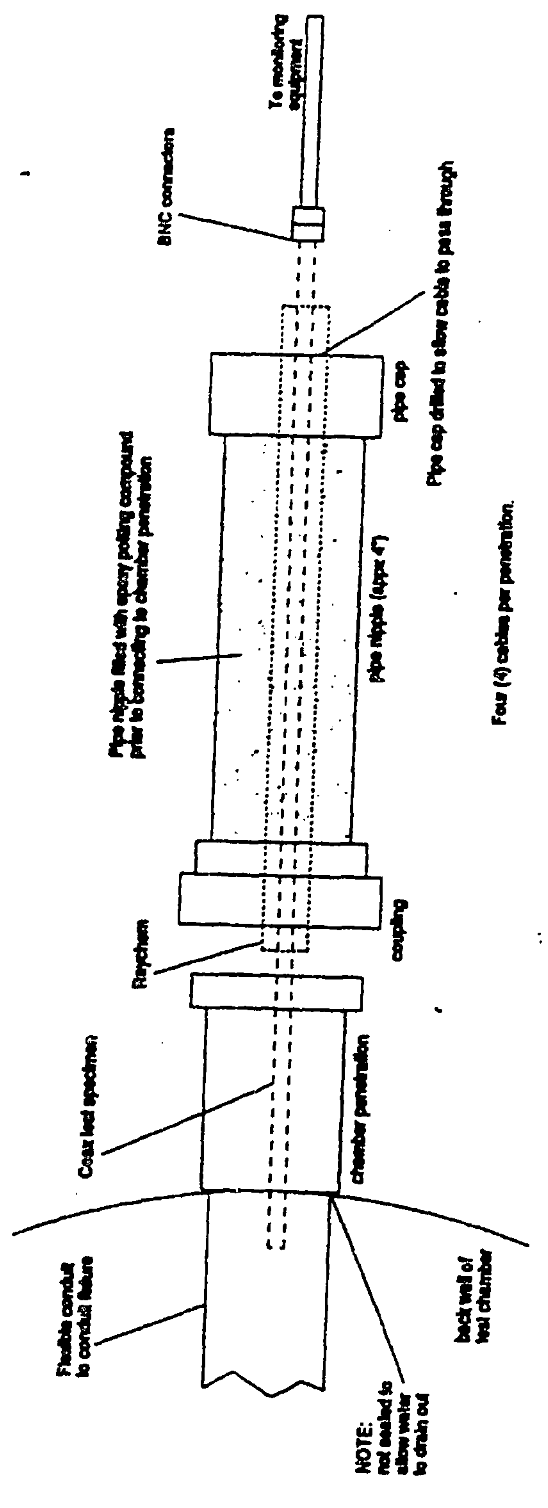


Figure 4
Second Test Sequence - Chamber Penetration Design



Preliminary Analysis of Radiation Detection Anomalies

1 Introduction

During a periodic test of the emergency coolers located within the containment, High Range Area Containment Radiation Monitor, RE7820-2, was noticed to go out of operation for periods up to 15 minutes. This period of non operation coincided with the initiation of the cooler test. After completion of the cooler test, the cooler was switched off. This action resulted in an upscale reading of monitor RE7820-2. The upscale reading produc[illegible] radiation equivalent dose rate of approximately 1R/hr and decaying back t[illegible] in about 15 minutes.

2. Pre-Start-Up Modifications

During the refueling outage, new coaxial cables were pulled for use with RE7820-1 & -2 monitors. These cables are partly located within conduit runs and partly in cable trays. The sections of cable run within the cable trays were laid on the top of the cable tray with no covering on the tray. This section of cable tray is in close proximity to the intake of the emergency cooler.

3. Initial In-situ tests

In order to better understand the nature of these anomalies, several tests were performed in the containment. The cooler power cabling is run in the same cable tray as the radiation monitor coaxial cables. In-rush currents of approximately 800 amps were measured in this power cable at the start of the coolers. The timing of the current, which lasted milliseconds in duration, was eliminated as a cause of the radiation reading anomalies.

A further test was performed using a Cs-137 test calibration source. This source was used to bias up the Ion Chamber detector with a field of about 10 R/hr. The emergency cooler was operated and the same magnitude negative and positive changes in radiation readings occurred. However, instead of going off scale, low when the cooler was turned on, the reading dropped from the 10 R/hr level to about 9 R/hr. This value recovered in about 15 minutes as before. When the cooler was switched off, the reading read about 11 R/hr, again recovering in about 15 minutes to 10 R/hr.

4. Review of Other Qualification Testing Results

The equipment was manufactured by the then, Electronics Systems Division of the General Atomic Company, now known as Sorrento Electronics. A visit was made to their facilities in San Diego. An examination of their qualification test data for this equipment showed that during seismic testing, the variations in recorded field values varied in the range of ±2 R/hr. Temperature and Pressure tests were performed during qualification testing. An examination of the recording showed only one anomaly at the begining of the testing. This value was an up scale reading at about 25 R/hr. The duration of this reading was about 4 minutes. This occurred at the begining of the testing. General Atomic qualification acceptance criteria was for values obtained during steady state. This value was not used in the acceptance/failure decision.

A review of a series of tests performed by the Sandia Labs as described in report NUREG/CR-4728 dated February 1988 was conducted. Several large radiation readings were noted during initial periods where only temperature and pressure testing was being conducted. The magnitude of one of these anomalies was in the 1×10^5 R/hr range. The duration of the spikes was approximately 3 minutes. Subsequent values of radiation remained high for the duration of the temperature and pressure testing. After 50+ hours of test, several negative excursions were noted.

In the summary of the Sandia report it stated that the nature of the cable behavior during the test was not completely explainable and suggested further testing be performed. The appendix described that the cabling had split during the test at about 53 hours with moisture probably seeping into the dielectric region.

5. Review of Available Test Notes/Literature

A review of the previous test data notes from General Atomic Co. , the Sandia Lab report and conversations with people involved in previous testing led to a postulated explanation for these anomalies. To explain the long time constants that have been observed in the containment measurements and accounts of short duration spikes(seconds) while at high temperature and pressure, required long time constants that changed value at high temperature.

If charge was being produced by static forces termed Triboelectric and charging up the distributed capacitance of the cabling, the discharge path would be through the insulation resistance of the cabling. The insulation resistance changes with high temperature. The IR value reduces about 3 orders of magnitude over the temperature range. This would then explain the long and very short time constants that had been noted. (Refer to secion 6.2)

6. Preliminary In-house Tests

In an attempt to support the distributed capacitance and insulation resistance theory, a simple set of tests were conducted. These consisted of several motion tests to determine magnitudes of induced currents. Several tests were performed by heating various lengths of cable to about 350 °F and adding external resistors to alter the effective insulation resistance. These tests were to determine the magnitude of the induced current and to see if the time decay constant would vary with the change in IR value.

The results of these tests were that:

6.1. The magnitude of current produced by motion is limited to approximately a reading of 5-6 R/hr. The frequency response of the current is proportional to the frequency of the motion input. Therefore it was concluded that the anomalies seen where not as a result of motion effects.

6.2. The distributed capacitance and Insulation resistance discharge path theory did not hold up. The addition of 100 Meg ohms and then 10 Meg ohms in shunt across the cable did not substantially change the discharge times. As a result of these tests, the internal resistance had some effect but was not the dominant factor in determining the decay path of the charge in the cable.

6.3. The positive going, induced current decayed in about 14 minutes while still subjected to a heat source of about 350°F. This decay time remained fairly constant for each length of cable and for each change in insulation resistance.

6.4. When the heat source was removed, the current rapidly decayed but then reverted into a decay pattern similar to that shown during the application of heat to the cable.

6.5. The maximum value obtained during these heat tests was 75 R/hr. The value was reached after about 1 minute of heat and decayed off after about 15 minutes while heat was continuing to be applied.

7. Interpretation of In-House Testing

A possible explanation for these long time constants is that charge is generated in the cable as a result of a temperature differential across the dielectric. As the external heat source initially produces a high delta temperature, a large displacement current is produced in the dielectric. As the heat flow occurs in the cable toward the center conductor, the temperature differential across the cable reduces in magnitude. The current is either bled off by external sources or by recombination within the dielectric. Some small delta temperature will always occur across the cable so that a small offset current remains.

When the heat source is removed a delta temperature exists from the center to the outside. An initial charge change appears to be produced in the opposite direction fairly rapidly but then the decay follows the same decay time constant as the heat flow occurs from the center to the outside.

The heating of the cable was performed on a portion of the cable as it was coiled in about a 12 inch diameter. The heat was therefore applied at about 3 foot intervals along the cable. Heat transfer from the point of heat application may have been moving out to the unheated sections of the cable. This maybe a better representation of the actual application of heat to the uncovered portion of the cabling within a cable tray than a total cable immersion into a heated test oven.

The heating and cooling explanation supports the observed responses in the containment monitor. The emergency cooler could be removing heat from the outer surface of the cable causing a negative charge to drive the picoammeter off scale-low. The thermal time constant of the cable is about 15 minutes. After reaching an equilibrium value, the cooler is turned off causing heat flow from the outside toward the center of the cable creating a positive charge. As thermal equilibrium is reached current ceases to flow from the induced charge.

The bench tests produced a maximum current value equivalent to 75 R/hr at 350° F. An oven test on a portion of the cable could support whether this value is consistant from both types of testing.

Prepared by: A.T. Hyde 11/13/95

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MI CABLE QUALIFICATION

Thermal Transient Investigation

During LOCA testing the signal current being recorded displayed a transient increase coinciding with the temperature ramp from 150°F to 385°F in thirteen seconds. See Figure K-1. The transient effect decayed in an exponential fashion after reaching a peak value of approximately 150 pA. The normal signal was approximately 10 pA plus or minus a factor of two.

Subsequent tests run on the ion chamber element did not show a similar behavior. However, subsequent tests run on the MI cable confirmed that the transient behavior could be repeated. An experiment was designed whereby three different lengths of cable were exposed to a rapid thermal transient to three different temperatures. Each cable-length/temperature combination was tested twice to improve the statistics. A total of 18 runs was made, with an additional 3 runs made to confirm some threshold effects.

The characteristic transient behavior appeared to break into two effects, which will here-in be called an initial and a secondary response. The initial response is characterized by a higher amplitude and faster decay effect, while the secondary response is characterized by a lower amplitude but longer decay effect. This evaluation will begin by postulating the cause of the effects observed, then empirically deriving an algorithm to predict the transient behavior, and conclude with suggested methods to minimize the effect of the transient.

Postulated Cause of the Transient Current

The initial and secondary responses are postulated to be due to thermally induced stresses on the dielectric.

The construction of the subject cable is triaxial with a copper center conductor and metallic coaxial and triaxial sheaths insulated from each other by dielectric material.

At thermal equilibrium, no transient stresses are present. However, due to impurities or defects in the dielectric material, charge traps exist within the band gap. Stresses that are applied (such as a thermal transient) which are sufficient to increase the energy of the trapped charge carriers may release those charges, giving rise to the thermal transient behavior.

As a thermal wave front hits the triax sheath, either the expansion of the triax sheath occurs or the thermal transient itself places the dielectric under a transient stress, releasing trapped charge into the return circuit (coax sheath). A picoammeter across the center conductor/coax sheath circuit measures this current as an offset from reference. Since the triax sheath is uninsulated from the thermal transient, and the thermal conductivity of the stainless steel sheath material is relatively high, this stress and resultant current are essentially concurrent with the step delta-T applied. Therefore, the fast rising edge of the transient current is observed. The subsequent decay is due to a re-trapping of free charge as the transient stress equilibrates.

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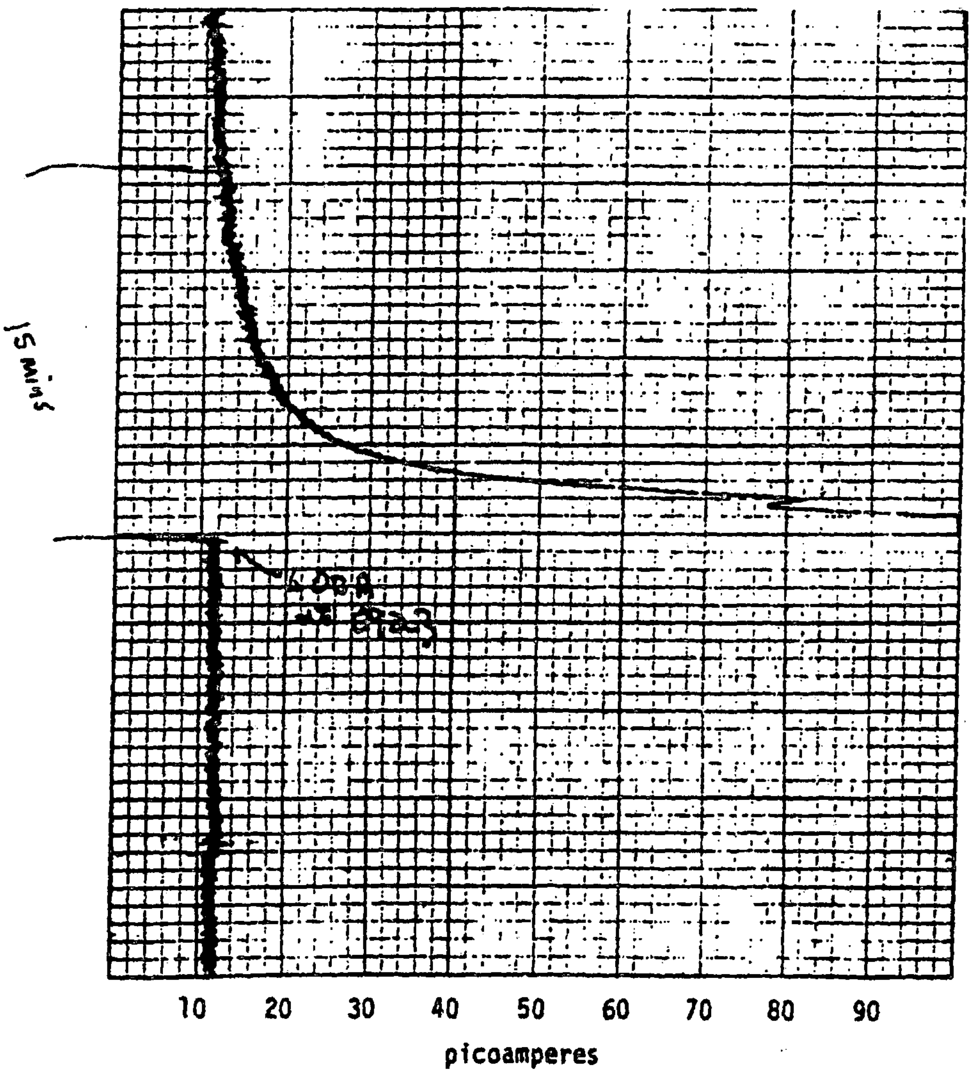

Chart trace recording of ion chamber S/N 22710 during LOCA temperature transient. Chart speed = 8 in/hr. Data recorded 16 Nov. 1984.

Figure K-1

A similar event occurs when the thermal front reaches the coax sheath, but is delayed by the thermal resistance of the dielectric.

The Initial Response Characteristic

Data was obtained during the thermal transient experiment that suggested the peak current generated is a function of the step temperature change applied, its rate of application, and the length of cable exposed to the transient. The transient current then decays in a classical exponential fashion. The initial peak current per cable-foot generated as a function of the temperature change (delta-T) as the parameter time rate of application (t) increases, is plotted in Figure K-2.

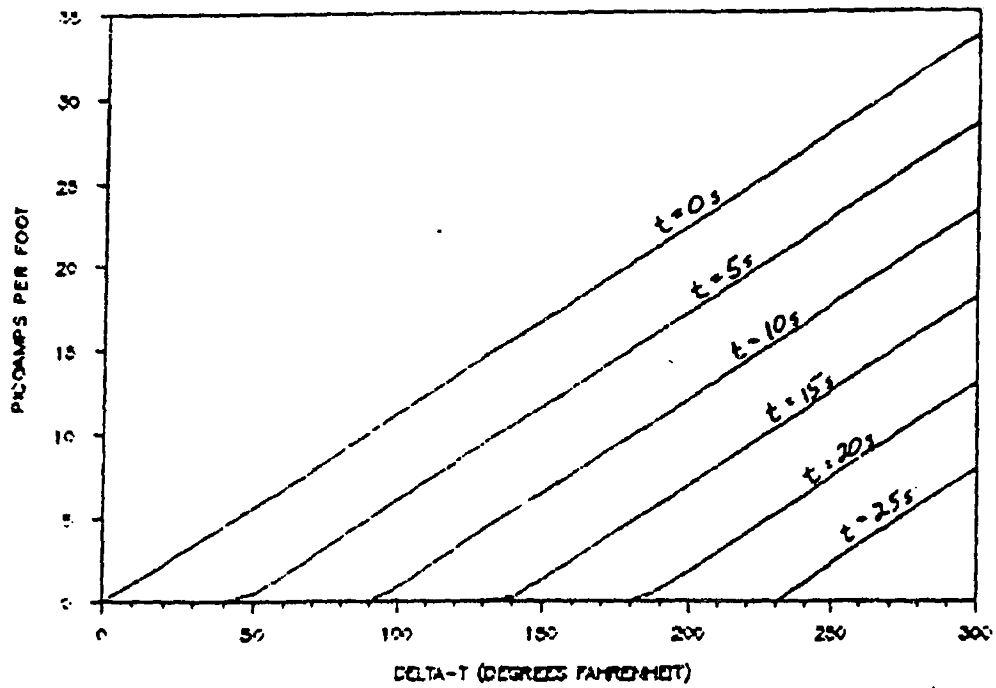

Figure K-2

Initial i_{pk}/ft as a function of delta-T and the rate parameter t.

The Secondary Response Characteristic

Similarly, the secondary response transient peak is dependent on the cable length, delta-T, and rate. However, since the secondary response is an effect of the coaxial sheath, the insulating dielectric delays and dampens the peak current. The delay of the peak is consistent with the cable diameter, and is essentially constant for all L, delta-T, and t. The peak current value is likewise reduced because of the reduction in the rate of temperature increase of the coaxial sheath. Further reduction of the peak magnitude will be realized as the rate of application of the temperature transient is reduced. Figure K-3 plots the secondary i_{pk} per cable-foot as a function of delta-T using t as a parameter.

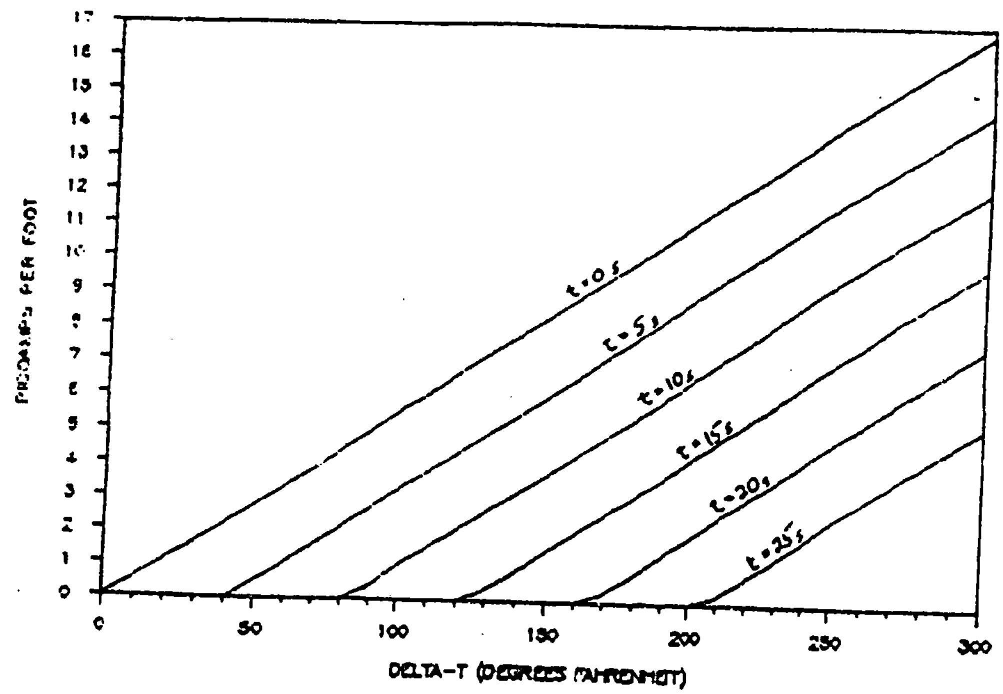

Figure K-3

Secondary i_{pk}/ft as a function of delta-T and the rate parameter t.

The decay of the secondary response is also exponential, and due to the isolated nature of the coax sheath (i.e. insulated on both sides by dielectric material) tends to equilibrate in a longer time than the initial peak. The time to reduce the transient current to less that 10 pA is a parameter of interest, as a detector in a radiation field of 1R/hr would then read within the factor of two specified accuracy at that level of noise current. Plotting the time required for secondary i = 10 pA yields results as shown in Figure K-4.

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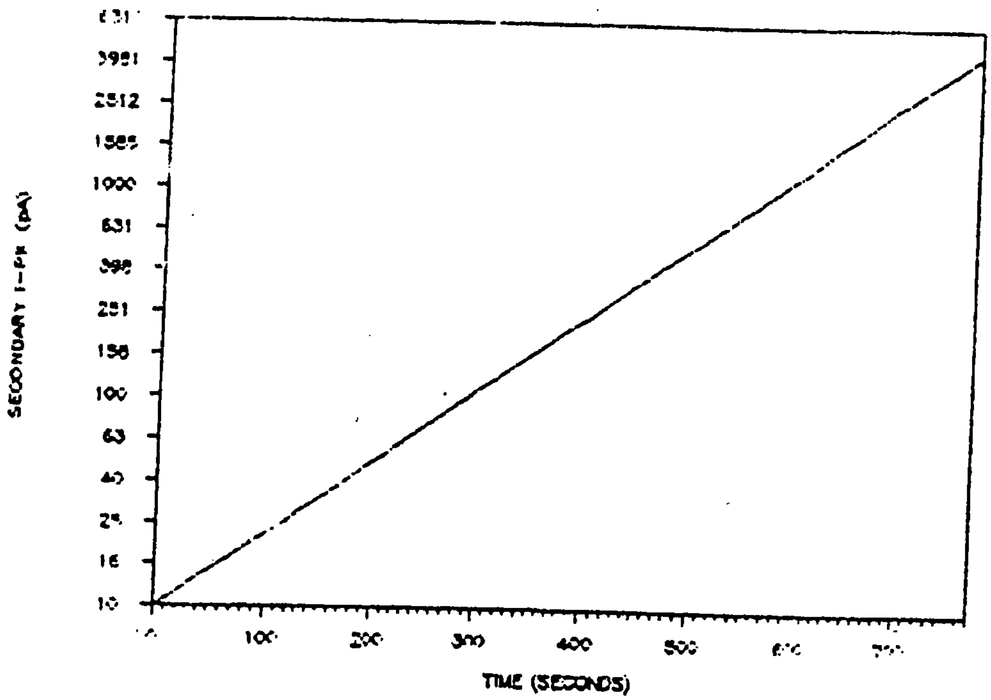

Figure K-4

Time to attain secondary $i \leq 10$ pA for various secondary i_{pk}.

Transient Prediction

The combined response for the initial and secondary transient events was analyzed and an algorithm was developed to predict the transient response for any cable length, delta-T, and rate combination. A typical transient response curve for a 150 foot cable exposed to a 200°F delta-T in 10 sec. is presented in Figure K-5.

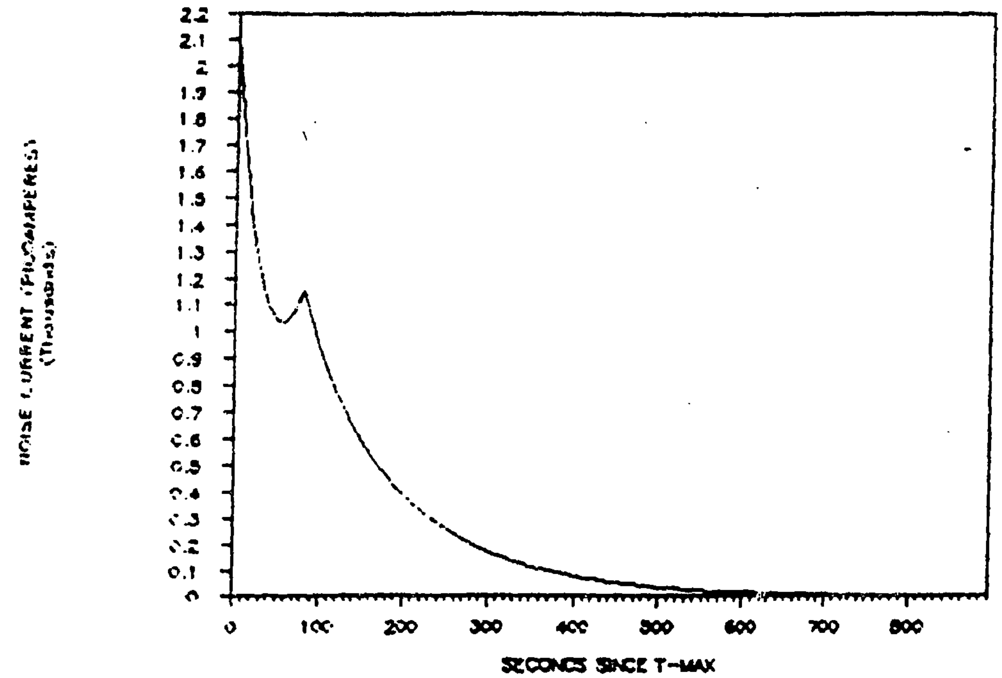

Figure K-5

Noise current (i) vs time since LOCA (typical)

Discussion

The effects described here-in have been observed by others, not only in mineral-insulated cables,[1,2] but also in polymer dielectric materials[3] used in traditional cable. The noise current produced by the rapid thermal transient will be additive to any signal current being generated by the detector when the cable is utilized as a signal cable. The effect is insignificant when the cable is utilized as a high-voltage cable, as the small current generated is well within the regulation range of the high voltage power supply.

The ramp to LOCA temperature may or may not be accompanied by a ramp increase in the dose rate at the detector. If there are accompanying and comparable changes in the dose rate, say of several tens to several thousand R/hr or more, then the noise current due to the thermal transient may be insignificant (i.e. less than factor of two error). If there is little or no accompanying dose rate increase with the LOCA temperature ramp, then a dose rate error condition of greater than a factor of two may be presented to the operator.

The magnitude of the noise current is dependent on the rate at which maximum LOCA temperature is attained, that is more accurately, the rate at which the triax sheath temperature is increased. It has been shown in Figures K-2 and K-3 that for rates of sheath temperature increase of greater than approximately 30 seconds to the maximum LOCA temperatures typical of most plants, that the noise current generation is sufficiently reduced to become insignificant, even at low (1R/hr) dose rates. The plant may want to explore methods by which the rate of heating of the M.I. cable can be reduced (e.g. thermal insulation vis-a-vis steam or hot water pipe lagging or other thermal barriers such as a

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conduit or wire tray). Studies have shown that for LOCA temperature ramps of 300° F increases in less than 1 second that a quarter-inch of insulating material with a thermal conductivity of 0.05 BTU/hr-ft-°F will limit the heating rate of the M.I. cable sufficiently to prevent interfering noise currents.

Since each plant must be considered on an individual basis due to unique cable lengths, unique LOCA temperatures and ramp rates, and unique accompanying dose rates, it is suggested that the plant utilize the information provided in this report to determine the adequacy of the supplied equipment to meet individual requirements.

References

1. G.F. Lynch and R.B. Shields, "On the Use of MgO as Insulation for Coaxial Signal Cables in a Reactor Environment", Atomic Energy of Canada Limited document AECL-4827, June 1974.

2. C.P. Cannon, "Comparative Gamma Radiation and Temperature Effects on SiO_2 and MgO Insulated Nuclear Cable", IEEE Transactions on Nuclear Science, 1982.

3. Jason Wilkenfield and Vesa Junkkarinen, "Thermal and Radiation Depolarization of Persistent Charge Stored in Polymer Dielectrics", IRT Corporation, Intel-RT 8124-005, August 13, 1976.

Be interested in this paper

279-5100

Appendix C p. 1/3

Notes on Cable Testing

Prior to formal testing of the Rockbestos cables, several informal test were conducted to get some first hand experience of the kind of noise that is generated by this cable and some level of understanding of how the noise is initiated. They fell into the following:

1. Heat Related Effects

1.1 Movement of unheated air over a coil of cable (~35'), at a flow of ~2-3 scfm, caused displacement currents. These currents were in the negative direction. The time for the maximum swing in current value was ~1 minute, guestimate. By maintaining a constant air flow on the cable, the current value recovered to its start value. This value was in the order of 10s of minutes. This is the phenomona that was previously analyzed as charge creation within the cable sheath with the discharge mechanism governed by the internal capacitance and internal insulation resistance. Further investigation should proove this or not.

1.2 Removal of the air flow during the recovery process created a chrge in the opposite direction that tended to counteract the previous charge. The time response was comparable with the initial charge change ~ 1minute. The sum of the charges at this point was a net positive charge that caused overshoot with an accompanying slower discharge time as before.

1.3 The magnitude of the response was about a factor of 2-3 larger than the steady state value of 1e-11 amps.

2. Mechanical Movement

2.1 Observation was that the frequency of the current generated in the cabling was proportional to the frequency of the cable movement.

2.2 The magnitude of the current generated in the cable was proportional to the magnitude of the displacement of the cable.

2.3 The ringing or naturally occuring oscillation generated within the cable were determined by the length of the free, unrestricted cable that was struck. By reducing the length of the restrained cable and stricking it, higher frequency oscillations were created. As the free length of the cable was extended. The oscillation created by stricking went down in frequency.

2.4 The cable generated current acted in all ways as the mechanical oscillations would occur in a naturally hanging cable. The steady state

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current in all these test was at 1e-11 amps. The estimated magnitude of these oscillations/impacts were about 1 to 1.5 decades up from steady state. Need some more refined tests to nail down exact values

Notes 11/10/95 ath & dgw

Further observations from test data taken in maintenance lab.

1. Mechanical Motion Effects

A correction to yesterdays results was that output current resulting from motion is proportional to the *rate of change of motion* not the change in motion.

The magnitude of current generated from motion is a function of cable length. With a 210'+ cable length, maximum displacement current is 1e-10 amps equivalent to 10 R/hr. This was generated with excessive force over the entire coil.

2. Heat Generated Current Effects

Data gathered showed the following:

2.1 *Added values of shunt resistance did not effect the time response* of the decay curves of various cable lengths after a heating sequence.

2.2 Maximum values of current generated with the cable at temperatures of ~350F were ~1.5e-9 amps. This equivalent to 150 R/hr. This test was a reasonable approximation of time response at the source.

2.3 Time decays were in the order of tens of minutes for both lengths of cable tested (30' & 210') with or without shunt resistors added.

2.4 The generated current peaked after ~1 minute in all cases.

2.5 The generated current decayed down from this peak with a constant heat being maintained on the cable

2.6 Decay fr[illegible]ent did not reduce dback down to the previous zero or of[illegible]

2.7 Re[illegible]al of t[illegible] after decay, further reduced the current in the circu[illegible]

3 Speculation as to what this all means

3.1 The capacitance charging theory does not hold up.

3.2 Suspect that explanation of previous data results is that the heat source produces charge in the cable within a minute.

3.3 Decay mechanism is governed by thermal decay constant rather than electrical.

3.4 Explanation of inferred data by GA in one of their notebooks where they talked about noise pulse in the order of seconds after heat test can be explained by moisture on the surface of the cable drastically effecting the heat transfer function. Our test did not have any moisture therefore not able to test this theory.

Prepared by: A.T. Hyde 11/09/95

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Appendix 3 p. 1/4

Synopsis of cable testing Nov 16/17/95 at CGI Labs

1. Tests performed on the following cables:

100' lengths of Rockbestos RSS-6-104/LE and Brand-Rex Cable No. ????
50' length of Rockbestos RSS-6-105/LE

2. Tests

Series of tests in oven cycling temperature from ambient to ~300F holding for 5-10 minutes and cycling back to ambient temperature. Temperature rates of rise and cooling determined by oven capabilities. Oven was manufactured by Tenney. Approximate inside dimensions were 3' x 3' x 3'.

3. Results of tests

See tables for synopsis of test observations, voltage and current conversions and estimates of maximum deviations from 0 R/hr and non operate state times.

Nature of GA picoammeter module is that it is designed for a positive polarity input. When subjected to a negative input it takes a long time to recover back to zero. The Keithley doesn't suffer from such recovery process since it is bipolar in design.

Prepared by: A.T. Hyde 11/22/95

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Table of Cable Test Results

Date of tests: Nov 16 & 17 1995	Heat rise rate: 4F/min	Cool Down rate: 14 F/min	Instrument 1. Keithley 600B Electrometer	Instrument 2: GA RP-2C Picoammeter
Cable Type	Test No.	Instrument No.	Heat up cycle comments	Cool Down cycle comments
RSS-6-104/LE	1	GA RP-2C	Negative offset to start, at 133F reverted +0.9 v rising to max 2.55 volts at 182F,falling back to 1.5 volts at 240F. 3.3 mins later at 253F reading went -ve. 6 min later at ~280F +ve reading. Output increased to 2.4 volts at 300F	Dropped from 2.4 volts to 0 volts in 6.6 min at 260F. Held at just negative till 195F went full -ve. Stayed full -ve through completion of test to ambient temp.
RSS-6-104/LE	2	GA RP-2C	Started with 2e-12 offset(causes slight -ve value). At 80F value of 0.75 volts reaching + value of 1.2 volts at 140F & max value of 1.65 volts at 230F. Recovered to cross 0 at 280 F. Crossed back +ve at 300F going to 1.5 volts	Started cool cycle at +ve offset. Held constant -ve value until 190F went full -ve. Remained full -ve until ambient
RSS-6-104/LE	3	Keithley	0 current at start +ve value of ~7.5e-10 at 140F.recovering to 3.0e-10 at 190F. High frquency noise present. Increased to +ve value of 1 38e-9 at ~240F. Noise reduced at 260F Recovered to 0 at 290F.Held at 0	Held steady at 0 until 190F. High frequency noise large +/-ve spikes. Went full -ve at 154F still with large noise spikes. Recovered to near 0 at ambient. Still noise present.
RSS-6-104/LE	4	GA RP-2C	Irrattic at begining prior to heat. After heating began, almost immediately went to +1.5 volts at 80F. Went to 2.25 volts at 120F & stayed at this value up to 220F Increased to 2.65 volts at 250 F. Reduced in value until constant at 0.15 volts at 315F. Began to increase to 0.9 volts at 325F	Reverted to 0 volts at 300F. At 195 rapidly went -ve Required +ve offset currents ranging from 5e-10 to 5e-9 to bring reading back on scale
RSS-6-105/LE	4	Keithley	No change in offset current until ~300F with i offset at -ve 1.5e-12 amps going to 2.6e-11 amps at ~325F	Reverted to 0 amps at 300F. At 190F noisy -ve max value of 5e-12 amps until 180F reverted to 0 amps at 140F
RSS-6-105/LE	5	GA RP-2C	Offset of 2e-12 amps (offset slightly -ve in polarity). Reading constant -ve(slightly) throughout heat cycle to 240F. Slow -ve increase until at 315F full -ve reading.	Offset current at 2e-12 but reading still full scale -ve. Came back to slight -ve reading at 230F. At 190 F increase in -ve direction but recovered at 160 F. Well behaved through rest of test at slight -ve value.
Brand-Rex	1	Keithley	Small -ve offset ~1.5e-11 at start 92F.Crossed 0 at 190F. +ve max value of 4.65e-10 amps at 220F. Reached +ve 3e-11 at 300F	On cool down max +ve value of 4.5e-11 amp at ~300F value reached 0 at ~150F Maintained 0 throughout rest of test
Brand-Rex	2	Keithley	Started at 0 amps At 230F slight +ve value reaching max 1.65e-10 amps at 310F. 1.65e-10 held to 321F	Starting at 1.65e-10 decreased to 0 at ~150F Held at 0 through rest of cycle
Brand-Rex	3	GA RP-2C	Started slightly -ve (offset of 2e-12). Went full -ve at ~150F. Recovered to slight -ve at 165F. Crossed 0 at ~260F going to max +ve value of 1.2 volts at 325F.	Started at 1.2 volts +ve crossed 0 at 140F Remained slightly -ve through rest of test.
Brand-Rex	5	Keithley	No observed changes up to 280 F. Went +ve to value of 3.0e-11 at 300 F.Max +ve value of 6e-11 at 320F. Some small noise at these temp.	+ve value of 9.0e-11 328F gradually reverting to 0 at 150F & remaining at 0 to ambient.

RP-2C/Keithley Conversion Table		
volts	R/hr	I equivalent
0	1×10^{0}	1×10^{-11}
1.25	1×10^{1}	1×10^{-10}
2.5	1×10^{2}	1×10^{-9}
3.75	1×10^{3}	1×10^{-8}
5.0	1×10^{4}	1×10^{-7}
6.25	1×10^{5}	1×10^{-6}
7.5	1×10^{6}	1×10^{-5}
8.75	1×10^{7}	1×10^{-4}
10.0	1×10^{8}	1×10^{-3}

Estimates of Maximum Deviation in Performance						
Cable Type	Test No.	Instrument	Maximum R/hr Equiv.		Estimate Max. Operate Fail time	
			Heat Cycle	Cool Cycle	Heat Cycle	Cool Cycle
RSS-6-104/LE	1	RP-2C	105 R/hr	0 R/hr	13 min	8.5 min
	2	RP-2C	21 R/hr	0 R/hr	5 min	8-15 min
	3	Keithley	138 R/hr	0 R/hr	0 min	~20 min
	4	RP-2C	132 R/hr	0 R/hr	0 min	8-15 min
RSS-6-105/LE	4	Keithley	2.6 R/hr	0 R/hr	0 min	0 min
	5	RP-2C	0 R/hr	0 R/hr	2 min	~6.5 min
Brand-Rex	1	Keithley	46.5 R/hr	0 R/hr	2 min	0 min
	2	Keithley	16.5 R/hr	0 R/hr	0 min	0 min
	3	RP-2C	9.1 R/hr	0 R/hr	4-6 min	? Min
	5	Keithley	6 R/hr	0 R/hr	0 min	0 min

Appendix E
28 pages

Southern California Edison Company
San Onofre Nuclear Generating Station Units 2&3

Coaxial Cable LOCA Simulation
Test Procedure and Results for Monitoring
Electrical Parameters

Second Test, March 25 through 30, 1996

Prepared By: Bob Greene Date APR 12 1996

Reviewed By: Ken Trotta Date 4/17/96
KT

Appendix E
28 pages

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1.0 INTRODUCTION

This procedure establishes the requirements and instructions for measuring the performance of coaxial cable test specimens before, during, and after simulated LOCA environmental conditions. The simulated LOCA conditions are identified in the WYLE Laboratories Test Procedure 45145 (Reference 1).

Note that this procedure applies to the second LOCA test sequence performed on four test specimens, and one control penetration. The test specimens and control penetration are identified in Table 1.

2.0 SCOPE/PURPOSE

The scope of this test measuring procedure is limited to the Southern California Edison supplied coaxial cable test specimens as identified in Table 1.

The purpose of this procedure is to document the test specimen monitoring of "noise" affects occurring during simulated LOCA pressure, temperature and chemical spray conditions, and to determine what detector signal strength is required to overcome this noise.

2.1 Continuity and Static Insulation Resistance Verification

Continuity and insulation resistance (IR) between the test specimen center conductor and shield, and shield to ground, must be verified prior to, during, and following the LOCA simulation. Additional IR data may be taken as required.

This test will be performed using a megger with suitable test leads. Test data shall be recorded in the format shown in Table 2.

2.2 Dynamic Cable Performance

The purpose of this test is to identify and quantify any LOCA simulation induced "noise" on the individual coaxial cable test specimens. This cable noise may be from piezoelectric, triboelectric, or any other effects.

Figure 1 shows schematically the test specimen and measuring equipment configurations. The Keithly 261 will be used to simulate the "keep alive" source within the Sorrento Electronics (General Atomic) RD-23 detector. The Keithly 610 will be used to monitor the signal "noise" effects of LOCA conditions on the coaxial cable. Coaxial cable current levels during LOCA simulation will be monitored and recorded as described in Section 6.2.

3.0 TEST EQUIPMENT

All test measuring equipment used in this procedure is calibrated in accordance with the Wyle Laboratories Quality Assurance Program and is identified in the Wyle Test Report (Reference 2).

3.1 Static Insulation Resistance Test

(4) Four test specimens with BNC connectors on each end.

(1) Control Test Vessel Penetration

(1) Megger, 500V

3.2 Dynamic Cable Performance Test

(4) Four test specimens with BNC connectors on each end.

(1) Control Test Vessel Penetration

(5) Keithly 610C or 610CR Electrometers

(5) Keithly 261 Current Source

(1) Astromed MT95K2 Mainframe including the following subcomponents:

(2) AWP1 analog input card

(1) VOP1 video module

(1) SVGA compatible video monitor

(2) "D" submini with four BNC female connectors

(5) PL-259 connectors for 610C input

(5) Cables to go from Keithly 610C to Astromed recorder

(1) Pack of 400 sheet Z fold paper for Astromed

(1) Configuration disk for Astromed recorder

4.0 REFERENCES

4.1 WYLE Laboratories Test Procedure 45145, "Test Procedure for LOCA Simulation of Coaxial Cable for Southern California Edison" Dated December 8, 1995.

4.2 WYLE Laboratories Test Report 45145-1, "Test Report for LOCA Simulation of Coaxial Cable for Southern California Edison"

5.0 ACCEPTANCE CRITERIA

5.1 Continuity and Static Insulation Resistance Test

Pre, Mid and Post LOCA coaxial cable test specimens must maintain center conductor continuity. Conductor to shield and shield to ground resistance measurements are taken for information only.

5.2 Dynamic Cable Performance Test

As discussed in Section 2.1, the purpose of this test is to identify and quantify any noise induced on the test specimens by the simulated LOCA environmental conditions, and to determine what current is required to overcome this noise. This information will be used in some future, separate evaluation outside the scope of this test measuring procedure. Therefore, there is no specific acceptance criteria for the dynamic cable performance test.

6.0 PROCEDURE

6.1 **Pre LOCA Continuity and Static Insulation Resistance Test**

Prior to exposure to the simulated LOCA environmental conditions, the following steps shall be performed on each test specimen (and control penetration).

6.1.1 Connect the megger to the test specimen using the megger test lead.

6.1.2 Verify continuity. Apply megger voltage(500V)and derive conductor to shield and shield to ground insulation resistance. Record in the applicable Table.

6.1.3 Turn megger off and disconnect test specimen.

6.2 **Dynamic Cable Performance Test**

6.2.1 **Preliminary Checks**

6.2.1.1 Ensure test equipment is present as per Section 3.2.

6.2.1.2 Ensure test cables on the outside of chamber are wrapped with thermal insulating material.

6.2.2 **Setting up and configuring the Astromed recorder.**

6.2.2.1 Install connectors on analog module cards (AWP1).

6.2.2.2 Install cables from Keithly 610C into appropriate channels on AWP1 amplifier per Figure 2.

6.2.2.3 Connect Astromed recorder to a power source.

6.2.2.4 Turn Astromed to the ON position (1).

6.2.2.5 Set recorder internal date and time by performing the following.

6.2.2.5.1 Depress the front panel SYS key.

6.2.2.5.2 Depress the soft key above SYSTEM CLOCK.

6.2.2.5.3 Use selection arrows to select each component date and time.

6.2.2.5.4 Depress EXIT

6.2.2.6 Downloading of the configuration program.

6.2.2.6.1 Insert the disk labeled Wyle Labs Cable Testing Astromed setup in disk drive.

6.2.2.6.2 Press the MODE key

6.2.2.6.3 Press the soft key above FROM DISK

6.2.2.6.4 Use the encoder wheel to select file you want to download.

6.2.2.6.5 Press the soft key above RUN. This should download the entire recorder configuration and labels.

6.2.2.6.6 Depress SAVE.

6.2.2.6.7 Depress the soft key above ENTIRE MODE in the left display.

6.2.2.6.8 Use INC or DEC to select one of four soft keys into which the mode will be saved.

6.2.2.6.9 Use the keypad to type a label for the grid.

6.2.2.6.10 Press the soft key above ACCEPT to store the chart into the selected soft key. This will be displayed whenever the MODE key is depressed.

NOTE: If any labels need to be changes depress EDIT and edit buffers 1-9 as required.

6.2.3 **To activate recorder to begin recording**

6.2.3.1 Ensure that inputs are approximately in the middle of each chart. If not, the zero suppression may need to be used to center the channel.

6.2.3.2 Ensure there is enough paper in the recorder to last the duration of the test to be performed. This can be done by checking the printed number on the paper. The paper goes from 400 downward to 1. The lower the number, the less paper you have.

6.2.3.3 Verify chart speed is correct for application.

6.2.3.4 Start recording by depressing the RUN/HALT button.

6.2.4 **Stopping the recorder.**

6.2.4.1 Depress the RUN/HALT button

6.2.4.2 Remove, label and store the trace.

6.2.5 **Setting up and configuring the Keithly 610C Electrometer (set up and checkouts).**

6.2.5.1 Set METER SWITCH to POWER OFF

6.2.5.2 Lock ZERO CHECK

6.2.5.3 Set RANGE SWITCH to VOLTS and MULTIPLIER SWITCH to 1.0

6.2.5.4 Turn METER SWITCH to CENTER ZERO. Meter should read the center zero. If not, adjust as required.

6.2.5.5 Set FEEDBACK switch to FAST

6.2.6 **Setting up and configuring the Keithly 261 Pico Ammeter (set up and checkouts).**

6.2.6.1 Connect test specimen input cable to front input connection.

6.2.6.2 Set POLARITY SWITCH to "OFF." Warm up 15 minutes.

6.2.6.3 Set mantissa to 1E-11.

6.2.6.4 Set polarity to "+."

6.2.6.5 Ensure that both Astromed and Keithly 610 respond to input signals. Run through the listed range of -5E-11 to +5E-11 amps.

6.2.7 **Testing procedure checklist.**

6.2.7.1 Ensure all cables are connected to test equipment. This includes verifying that cables are installed per Figure 1.

6.2.7.1.1 Test specimen to Keithly 610.

6.2.7.1.2 Keithly 610 recorder output to Astromed.

6.2.7.1.3 Keithly 261 output to test specimen.

6.2.7.2 Ensure all test equipment is powered up, functional and on the correct range.

6.2.7.2.1 Astromed

6.2.7.2.2 Keithly 610C

6.2.7.2.3 Keithly 261

6.2.7.3 Ensure the Astromed recorder is selected to desired chart speed for testing. For the first 60 seconds or so, set recorder speed to 5 mm/sec.

6.2.7.4 Start the Astromed recorder.

6.2.7.5 Start steam testing.

6.2.7.6 Adjust Keithly 610 range as necessary to avoid bottoming out on Astromed recorder. Annotate recorder trace with any range changes.

6.2.7.7 Adjust Keithly 261 range as necessary to avoid bottoming out on Astromed recorder. Annotate recorder trace with any range changes.

6.2.7.8 After readings stabilize somewhat, reduce chart speed to 1 mm/sec for balance of test.

6.3 **Mid LOCA Continuity and Static Insulation Resistance Test**

At some time during exposure to the simulated LOCA environmental conditions, the following steps shall be performed on each test specimen.

6.3.1 Connect the megger to the test specimen using the megger test lead.

6.3.2 Verify continuity

6.3.3 Apply megger voltage (500VDC) and derive conductor to shield and shield to ground insulation resistance. Recorded in the appropriate Table.

6.3.4 Turn megger off and disconnect test specimen.

6.4 **Post LOCA Continuity and Static Insulation Resistance Test**

Following exposure to the simulated LOCA environmental conditions, the following steps shall be performed on each test specimen.

6.4.1 Connect the megger to the test specimen using the megger test lead.

6.4.2 Verify continuity

6.4.3 Apply megger voltage (500VDC) and derive conductor to shield and shield to ground insulation resistance. Recorded in the appropriate Table.

6.4.4 Turn megger off and disconnect test specimen.

6.5 **Use Attachment 2 "IN CONTAINMENT CABLE TEST PROCEDURE" to document procedure execution.**

TABLE 1

TEST SPECIMEN DESCRIPTIONS

SPECIMEN NUMBER	**DESCRIPTION**
1	250' Rockbestos RSS-6-105/LE (100% in conduit)
2	250' Rockbestos RSS-6-105/LE (50% in conduit)
3	250' Rockbestos RSS-6-104/LE (100% in conduit)
4	250' Rockbestos RSS-6-104/LE (50% in conduit)
5	Control Penetration (18" Loop of RSS-6-104/LE)

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TABLE 2

PRE-LOCA TEST

CONTINUITY AND STATIC INSULATION RESISTANCE TEST

Time/Date: 0826 3/29/96

Specimen Number	Continuity (Y/N)	Conductor to Shield Resistance @500 VDC	Shield to Ground Resistance @500 VDC
1	Y	5.5E12	2E9
2	Y	2E13	2E9
3	Y	1.8E12	1.8E9
4	Y	1.5E12	1.5E9
5	Y	8.2E12	1.7E9

Notes:

TABLE 3

MID-LOCA TEST

CONTINUITY AND STATIC INSULATION RESISTANCE TEST

Time/Date: 1554 3/29/96

Specimen Number	Continuity (Y/N)	Conductor to Shield Resistance @500 VDC	Shield to Ground Resistance @500 VDC
1	Y	60K (Note 1)	1.8E8
2	Y	30K (Note 1)	8E7
3	Y	690K (Note 1)	2E8
4	Y	1M (Note 1)	1.4E8
5	Y	3E11	5.8E8

Notes:

1. Shorted at 500 and 10 VDC. Reading taken with hand held multi meter.

TABLE 4

POST-LOCA TEST

CONTINUITY AND STATIC INSULATION RESISTANCE TEST

Time/Date: 0800 3/30/96

Specimen Number	Continuity (Y/N)	Conductor to Shield Resistance @500 VDC	Shield to Ground Resistance @500 VDC
1	Note 1	Shorted (Note 3)	8E11
2	Note 1	1.8M (Notes 2 and 4)	1E12
3	Note 1	2.2E5 @ 10VDC	Shorted
4	Note 1	0.7M (Notes 2 and 5)	1E12
5	Note 1	Note 1	Note 1

Notes:

1. Not recorded.
2. Shorted at 500 and 10 VDC. Reading taken with hand held multi meter.
3. 150 mV battery effect measured by hand held multi meter.
4. 250 mV battery effect measured by hand held multi meter.
5. 85 mV battery effect measured by hand held multi meter.

TABLE 5

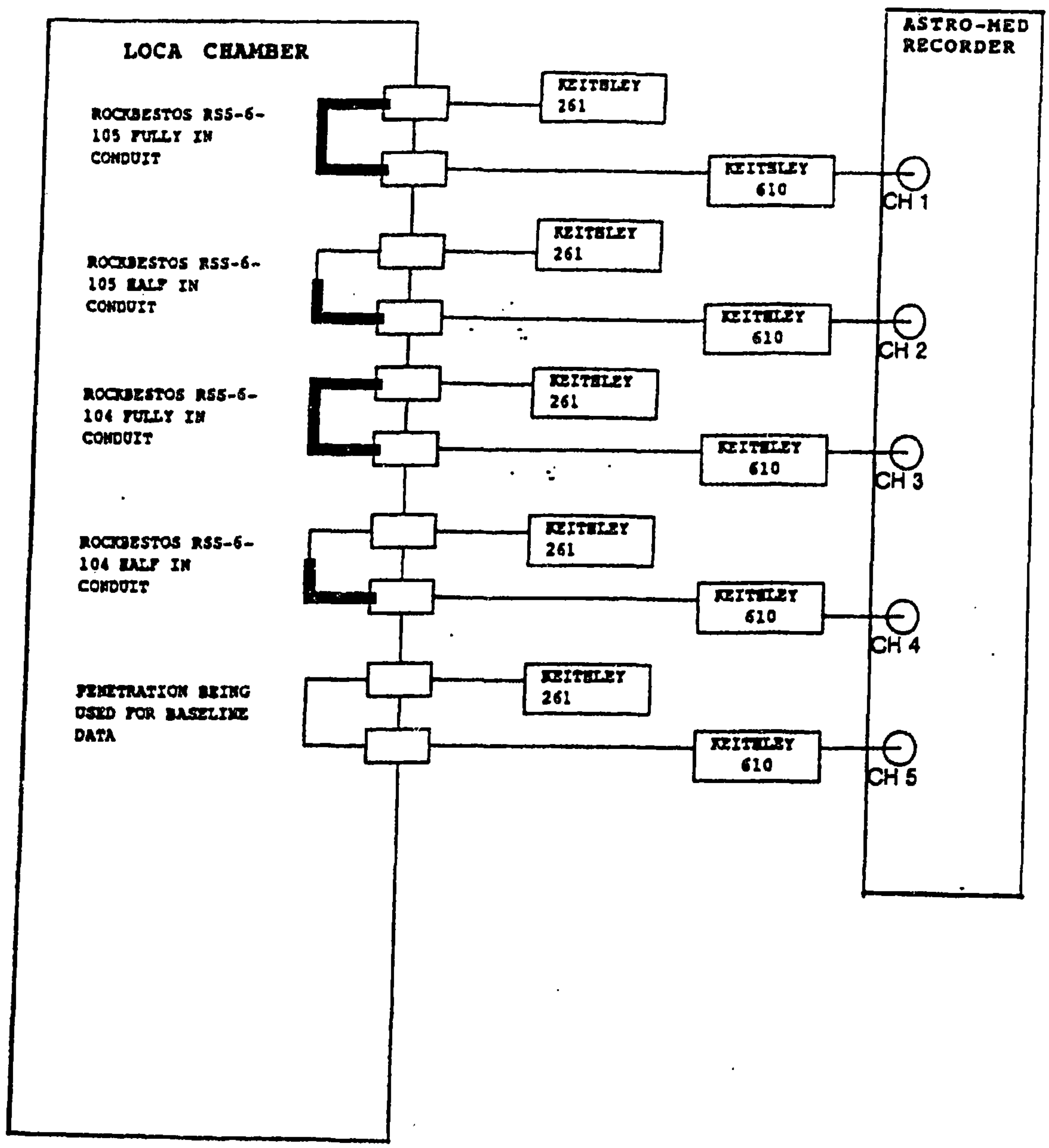
POST LOCA PENETRATION AND SPECIMEN IR DATA

Specimens Only @500 VDC Post LOCA IR Data, 3/30/96, 8:30AM		
Specimen	Conductor to Shield	Shield to Ground
1 (105 full)	3.0E11	2.5E11
2 (105 half)	1.0E12	1.0E11
3 (104 full)	2.2E12	2.0E11
4 (104 half)	7.5E9	5.0E11

Full Conduit Penetration Only Post LOCA IR Data, 3/30/96, 8:45AM		
Specimen	Conductor to Shield	Shield to Ground
1a (105 full)	9.0E5 @10VDC	1.3E13
1b (105 full)	2.0E9 @500VDC	1.2E13
3a (104 full)	1.0E8 @500VDC	3.0E12
3b (104 full)	1.0E9 @500VDC	1.2E13

Half Conduit Penetration Only Post LOCA IR Data, 3/30/96, 8:50AM		
Specimen	Conductor to Shield	Shield to Ground
2a (105 half)	3.0E12 @500VDC	4E12 @500VDC
2b (105 half)	9.0E4 @10VDC	3.5E12 @500VDC
4a (104 half)	4.5E7 @500VDC	5.0E12 @500VDC
4b (104 half)	1.5E12 @500VDC	4.5E12 @500VDC

FIGURE 1
ELECTRICAL TEST SCHEMATIC



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Here is the As-Found data for each of the cable samples after they have been cut to length and had connectors added to each end.

Sample #1
250' of RSS-6-105/LE
Insulation Resistance @ 500VDC: 300E12 Ohms Center to Center conductor resistance: 3.83 Ohms Shield to Shield conductor resistance: 1.93 Ohms

RSO-0314-96
Taken from Rockbestos Reel #93A1772G, 748', PO 6J236003 Cable is marked on outer jacket as:
"ROCKBESTOS (R) RSS-6-105/LE 1993 1/C 22AWG TCU XLPE 2300V 90 DEG C D86-01 3E-29 06114 FEET"

Sample #2
250' of RSS-6-105/LE
Insulation Resistance @ 500VDC: 300E12 Ohms Center to Center conductor resistance: 3.79 Ohms Shield to Shield conductor resistance: 1.89 Ohms

No RSO associated with this sample. The following data was taken from the metal tag affixed to the cable reel:
PRODUCT CODE H440105
DESCRIPTION RSS-6-105/LE BK
SHOP ORDER # 100476
CUST ORDER # 000000
REEL # 95K0875G
FOOTAGE 750

Cable is marked on outer jacket as:
"ROCKBESTOS (R) RSS-6-105/LE 1994"

Sample #3 and Sample #4
250' of Rockbestos RSS-6-104/LE
Insulation Resistance @ 500VDC: 300E12 Ohms Center to Center conductor resistance: 3.83 Ohms Shield to Shield conductor resistance: 1.88 Ohms

RSO-0322-96
Taken from reel# 94D0286G
PO# 6J236005
RSS-6-104/LE BK 600V
SCE MATL CODE: 027-75377
H44-0104
SPEC# RSS-6-104/LE

Spare #1
250' of RSS-6-105/LE
Insulation Resistance @ 500VDC: >300E12 Ohms Center to Center conductor resistance: 3.85 Ohms Shield to Shield conductor resistance: 1.94 Ohms

Same pedigree as Sample #1

Spare #2
120' of RSS-6-104/LE
Insulation Resistance @ 500VDC: >300E12 Ohms Center to Center conductor resistance: 1.88 Ohms Shield to Shield conductor resistance: 0.93 Ohms

Same pedigree as Samples #3 and #4

Insulation resistances measured with General Radio Megohm Bridge Model 1644A, SONGS M&TE ID I1-6044, recal date 5-14-96

Conductor resistances measured with Fluke 8050A DMM, SONGS M&TE ID I2-6697, recal date 4-5-96

ATTACHMENT 1
Test Specimen Traceability Information (one page)

IN CONTAINMENT CABLE TEST PROCEDURE

ATTACHMENT 2
TEST Procedure CheckList

E17/28

(R09-96) Duke Power Company (1) ID No HP/0/B/1009/22

INFORMATION ONLY PROCEDURE PROCESS RECORD Revision No 001

PREPARATION

(2) Station OCONEE NUCLEAR STATION

(3) Procedure Title On Shift Offsite Dose Projections

Main Procedure for Wyle Cable Testing

Pre Test

- [✓] Perform Instrument and test equipment inspection per Attachment 1
- [✓] Perform Configuration of Astro-Med Recorder by performing Attachment 2, "Installation and Clock set"
- [✓] Download Wyle test program from the disk labeled WYLE LAB CABLE TEST using Attachment 3.
- [✓] Configure Keithley 610 by performing Attachment 4
- [✓] Configure Keithley 261 by performing Attachment 5
- [✓] Perform Pre Test Continuity and Megger check for each sample of cable and record on attachment 6.
- [✓] Perform Pre Test Checklist per attachment 7.

LOCA TESTING

- [✓] Start the Astro-med recorder with chart speed set to 5 mm/sec.
- [✓] Start LOCA testing
- [✓] Adjust Keithley 610 as required to keep trace on chart
- [✓] Reduce Astro-med chart speed to 1 mm/sec when required
- [✓] Perform Mid test cable meggering and continuity testing. Record results on Attachment 6.
- [✓] At the end of LOCA testing, perform post LOCA megger and continuity checks recording values on Attachment 6

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Main Procedure for Wyle Cable Testing

POST LOCA

[✓] Disconnect all cable samples from test equipment

[✓] Power down all test equipment

[✓] Store test equipment and make provisions for shipping back to SCE.

[✓] Remove video tape from video camera and make provisions for sending to SCE

[✓] Remove recorder traces from astro-med recorder and make provisions to take to SCE.

[✓] Make provisions for sending cables, penetrations and anything else deemed required to SCE.

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Wyle Lab Cable Test

Preliminary Checks

A)✓ Ensure test cables are properly wrapped with no strain on the cable specimens

B) Perform Inspection of test equipment

✓1) 5 Keithley 610C electrometers

✓2) Astro-med MT95K2 Mainframe Recorder (with proper card configuration)

✓3) 5 Keithley 261 Current sources

✓4) "D" submini with BNC females connectors

✓5) PL259 (RCA) connectors for 610 Inputs

✓6) 5 cables that go from keithley 610 to astro-med

✓7) 2 packs of Z fold paper for astro-med recorder

✓8) Configuration disk for the astro-med recorder

ATTACHMENT 1

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Astro-med recorder Configuration

Installation and Clock Set

1. Ensure all input cards are installed and in the required position

2. Ensure connectors are installed on AWP 1 card.

3. Install cables from Keithley 610 to proper channel of the astro-med recorder.

4. Tape the connectors with scotch 33 electrical tape.

5. Connect astro-med to power source

6. Turn the astro-med to the "**ON**" position

7. Set the recorder's internal **date and clock** by performing the following:

   A) Depress the front panel **SYS** key

   B) Depress the soft key above "**SYSTEM CLOCK**"

   C) Use the selection arrows to select each component of the date and time.

   D) Use the encoder wheel to set each desired value.

   E) Depress **EXIT**.

ATTACHMENT 2

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Astro-med recorder Configuration
Downloading of Disk

1. Insert disk labeled WYLE LAB CABLE TEST into disk drive on the front of the astro-med recorder

2. Press the **MODE** key

3. Press the soft key above "**FROM DISK**"

4. Use the encoder wheel as required to select the file that you want to download.

5. Depress the soft key above **RUN**.

6. Depress **SAVE**

7. Press the soft key above "**ENTIRE MODE**" in the left display.

8. Use **INC** or **DEC** to select one of the four soft keys into which the program will be saved.

9. As required, use the keypad to type a label for the grid.

10. Check the scaling of the recorder channels and ensure that the program has been downloaded properly. Ensure that the inputs are approximately in the center of the chart's input.

11. Press the soft key above **ACCEPT** to store the chart into the selected soft key. The label will appear under the assigned key. This will be displayed whenever the MODE key is depressed.

ATTACHMENT 3

Configuration of Keithley 610 Electrometer

1. Set meter switch to power off position.
2. Lock zero check
3. On the back of the Keithley 610, ensure that the selector switch is set to the <u>3 volt position</u>.
4. Set range switch to Volts and the multiplier switch to 1.0
5. Turn meter switch to Center Zero. Meter should read zero. If not, adjust as required.
6. Return meter switch to the power off position.
7. Set range switch to E-10 and multiplier to 1.
8. Unlock zero check
9. Ensure feedback is in FAST.

ATTACHMENT 4

CONFIGURATION AND SETUP OF KEITHLEY 261

- [✓] Connect test cable to input
- [✓] select current output to 1E-11 A
- [✓] Place ~~power~~ POLARITY switch to "+"
- [✓] Let Keithley warm up for 15 minutes

ATTACHMENT 5

Center to Shield (Megger set to 500 Volts)

Sample	Date	Pre	Mid	Post
#1	03/29/96	5.5E12	60K *	2.2E5 @ 100VOL
#2	03/29/96	2E13	30K*	Shorted 150mV battery effect
#3	03/29/96	1.8E12	690K*	1.8M *
#4	03/29/96	1.5E12	1MEG*	Shorted @ 500VDC 0.7M *
#5	03/29/96	8.2E12	3E11	Not recorded
	@TIME	0826	1554	3/30/96 8AM

*HANDHELD METER USED

Shield to Ground (Megger set to 500 Volts)

Sample	Date	Pre	Mid	Post
#1	03/29/96	2E9	1.8E8	Shorted
#2	03/29/96	2E9	8E7	8E11
#3	03/29/96	1.8E9	2E8	1E12
#4	03/29/96	1.5E9	1.4E8	1E12
#5	03/29/96	1.7E9	5.8E8	Not recorded
	TIME	0826	1554	3/30/96 8Am

Continuity (Good / Bad) (center/center, shield/Shield)

Sample	Date	Pre	Mid	Post
#1	03/29/96	G	G	G **
#2	03/29/96	G	G	G **
#3	03/29/96	G	G	G **
#4	03/29/96	G	G	G **
#5	03/29/96	G	G	G **
	TIME	0826	1554	3/30/96 8Am

** = not recorded

ATTACHMENT 6

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Pre Test Checklist

1. Ensure all cables are installed properly per loop diagram.

   [✓] Test cable to Keithley 610

   [✓] Keithley 610 cable to Astro-med recorder

   [✓] Keithley 261 to test cable input

2. Ensure all test equipment is powered up and functional

   A) Keithley 610

   [✓] Powered Up

   [✓] Selected to 3 volt range, Mult set to 1 and mantissa set to E-10.

   [✓] Zero Lock has been removed

   B) Astro-med recorder

   [✓] Powered Up

   [✓] Inputs functional

   [✓] Chart drive speed is set to desired value

   [✓] Plenty of chart paper to last the duration of the test.

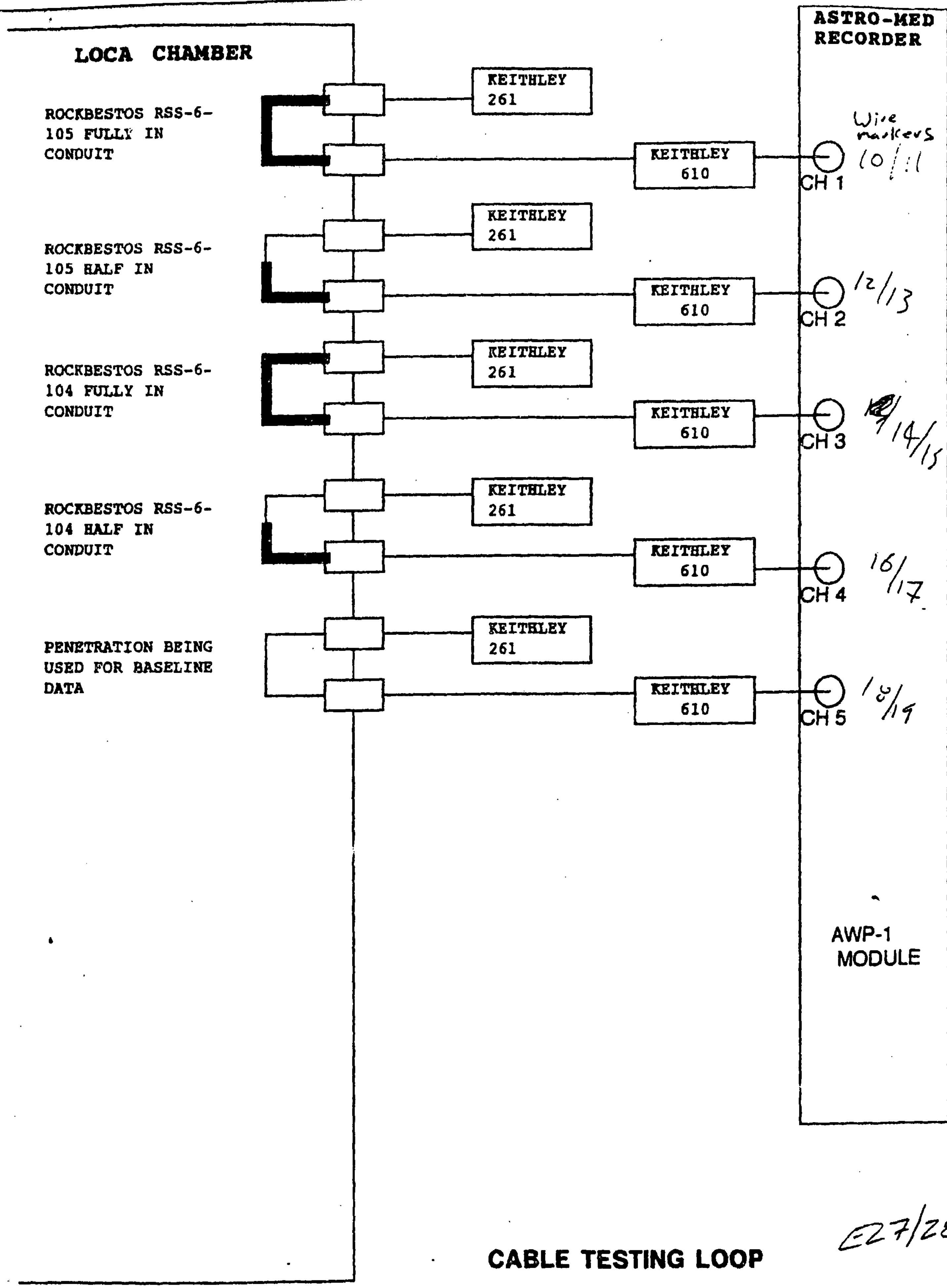
   [✓] Scaling is correct

   C) Keithley 261

   [✓] Powered up

   [✓] Instrument set to 1.00E-11 A.

ATTACHMENT 7



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CABLE TESTING LOOP

Checkout of System

1. Continuity Checks
   (Center and shield shorted)

2. Megger checks (Megger set to 500 volts)
   (Center / shield and Shield / Ground)

3. Install Keithley 261 to the test cable input.
   Set Keithley to 1.00E-11 A.

4. Input test current through the test cable and ensure that Keithley 610 indicates current and astro-med all reflects the current. Also ensure that the proper channel responds.

5. Repeat this for each test cable.

Wyle Test Results-March 29/96

High temperature steam testing of Rockbestos cables was conducted at Wyle Labs, Huntsville, AL on March 29 1996. Rockbestos cable types RSS-104 & RSS-105 were tested, mounted completely within a conduit housing. Two other sets of cables, using 104 & 105 types were tested with one half the cable in a conduit housing and the other half laying in an open cable tray.

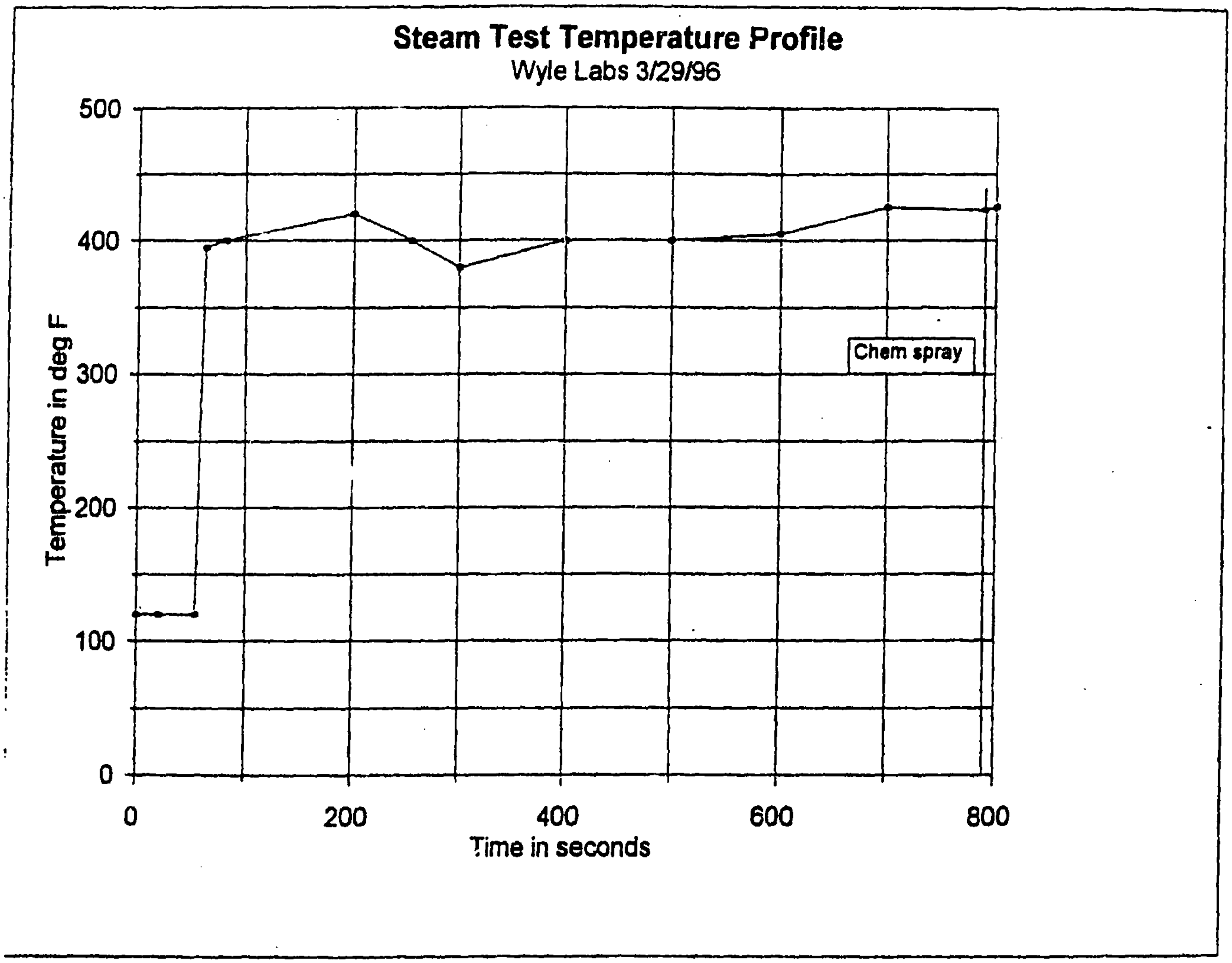
After initially heat soaking the cable test set ups for 2.5 hours at 120 F, the steam was introduced to raise the temperature in the autoclave up to 420 F. This temperature was maintained for more than 800 seconds. At 790 seconds into the test, chemical spray was introduced into the chamber.

A review of the thermally induced currents produced within the cables showed the following:

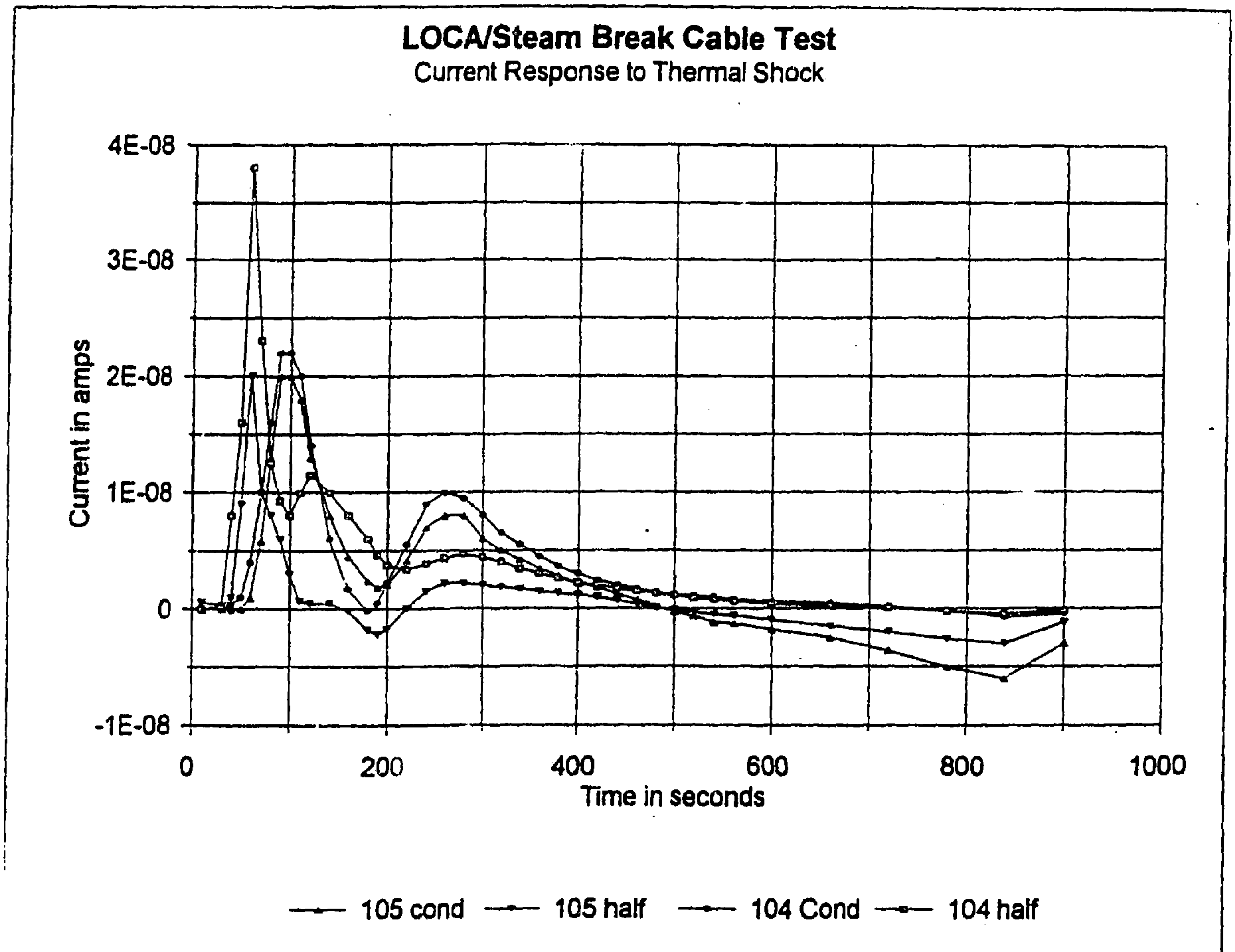
1. The completely conduited cables did not substantially reduce the peak induced values of current.
2. The induced current within the fully conduited cabled test set ups, showed a time delay of 60 seconds in reaching a peak induced current.
3. The maximum equivalent dose values were, as expected, in the 2,000 R/hr range. The half conduited, 104 cable was higher at 3800 R/hr.
4. A secondary induced peak reached a maximum at about 280 seconds after the application of steam. The magnitude of the secondary peak in the conduited set ups produced a peak about 50% of the main peak. In the half conduited set ups, this secondary peak only produced a peak of about a 10% of the main peak. (Stored energy effect?)
5. At about 500 seconds, the 105 cables swung negatively (Max. 6×10^{-9} amps), similar to previous testing. The 104 cables eventually went negative but later, at 800 seconds and at much lower levels of current (max. 10^{-11} range).
6. At about 900 seconds into the test, noise/oscillations appear as the current reduces into the lower current levels. Excess noise and/or oscillations, in the past, has indicated moisture leakage into the cable. At the end of the test (~2 hrs) low IR readings were obtained. The control cable/penetration change in reading after disconnecting the connector, removing a water droplet and then after re-connection the readings were back to normal levels supports the contention that only a small amount of water inside the cable can greatly impact the IR readings.
7. Based on the IR values taken after completion of the test, it seems that all cable suffered some form of moisture migration into the cabling.

Prepared by: A.T. Hyde 4/2/96 filename: 7820data\note4296

App. F p. 2/8


Steam Test Temperature Profile
Wyle Labs 3/29/96
Temperature in deg F
Time in seconds
Chem spray
0
100
200
300
400
500
0
200
400
600
800

App. F f 3/8


LOCA/Steam Break Cable Test
Current Response to Thermal Shock
Current in amps
4E-08
3E-08
2E-08
1E-08
0
-1E-08
0
200
400
600
800
1000
Time in seconds
105 cond
105 half
104 Cond
104 half

F. 20 F p. 4/18

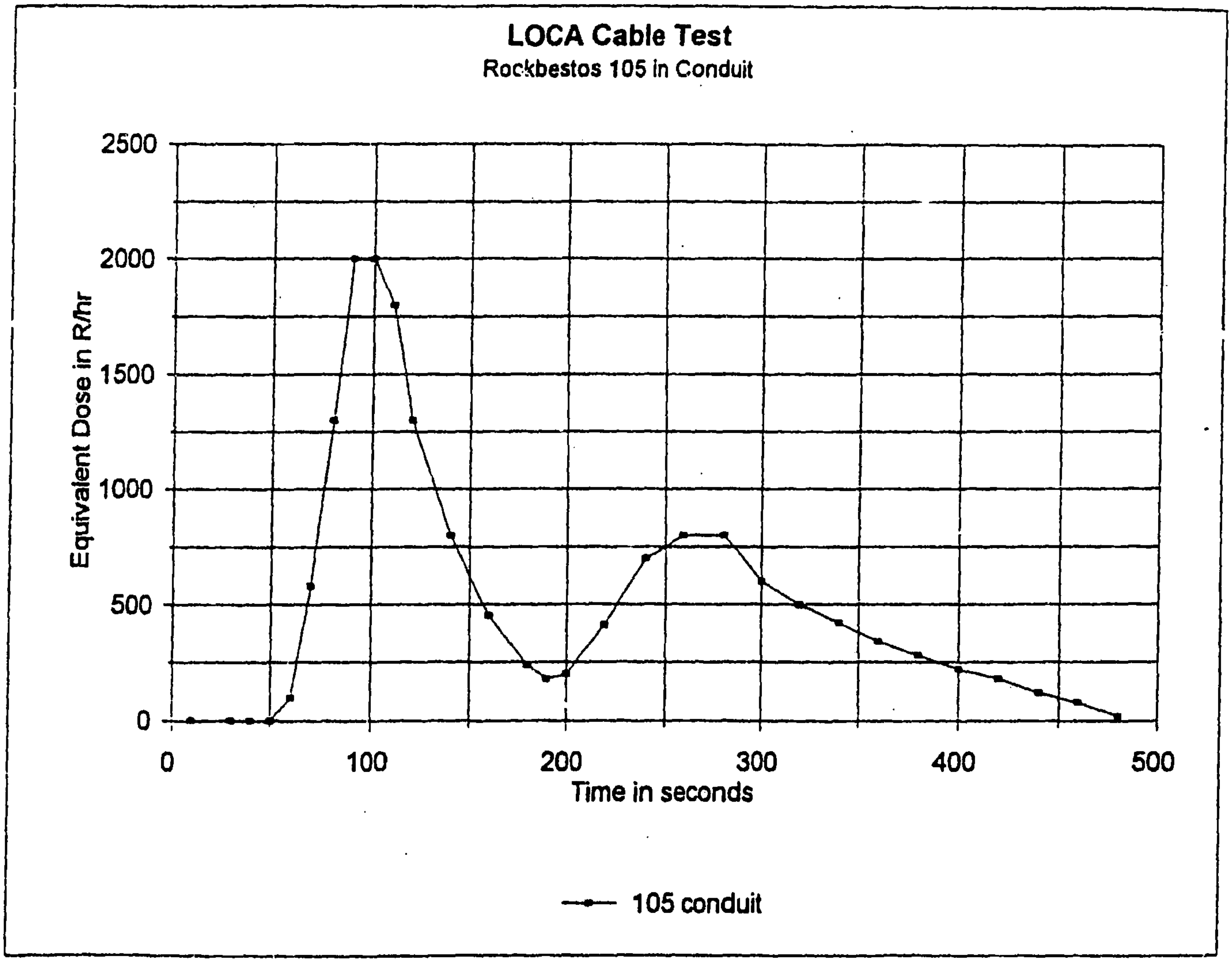
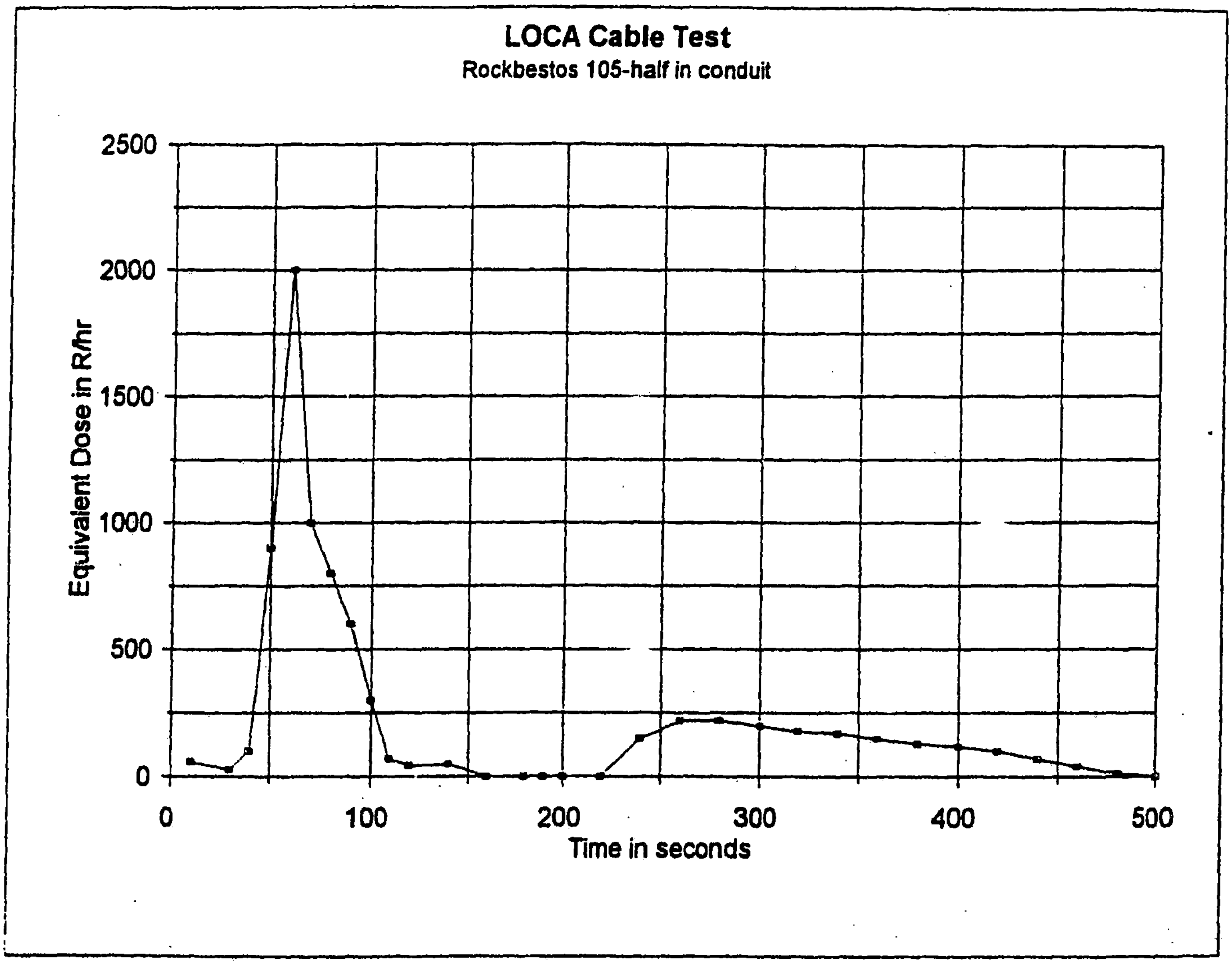
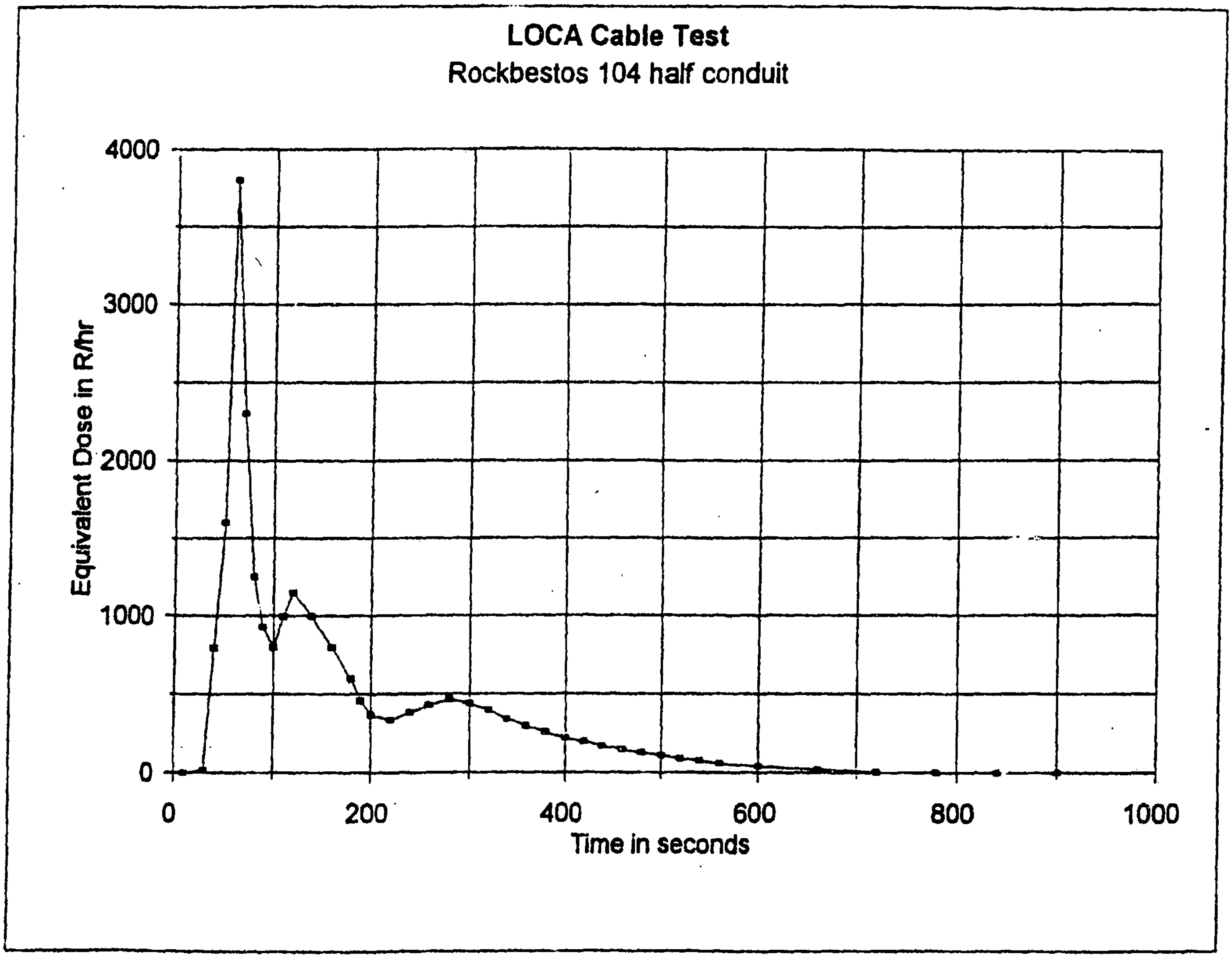

LOCA Cable Test
Rockbestos 105 in Conduit
2500
2000
1500
1000
500
0
Equivalent Dose in R/hr
0
100
200
300
400
500
Time in seconds
105 conduit

Fig. = F. 18



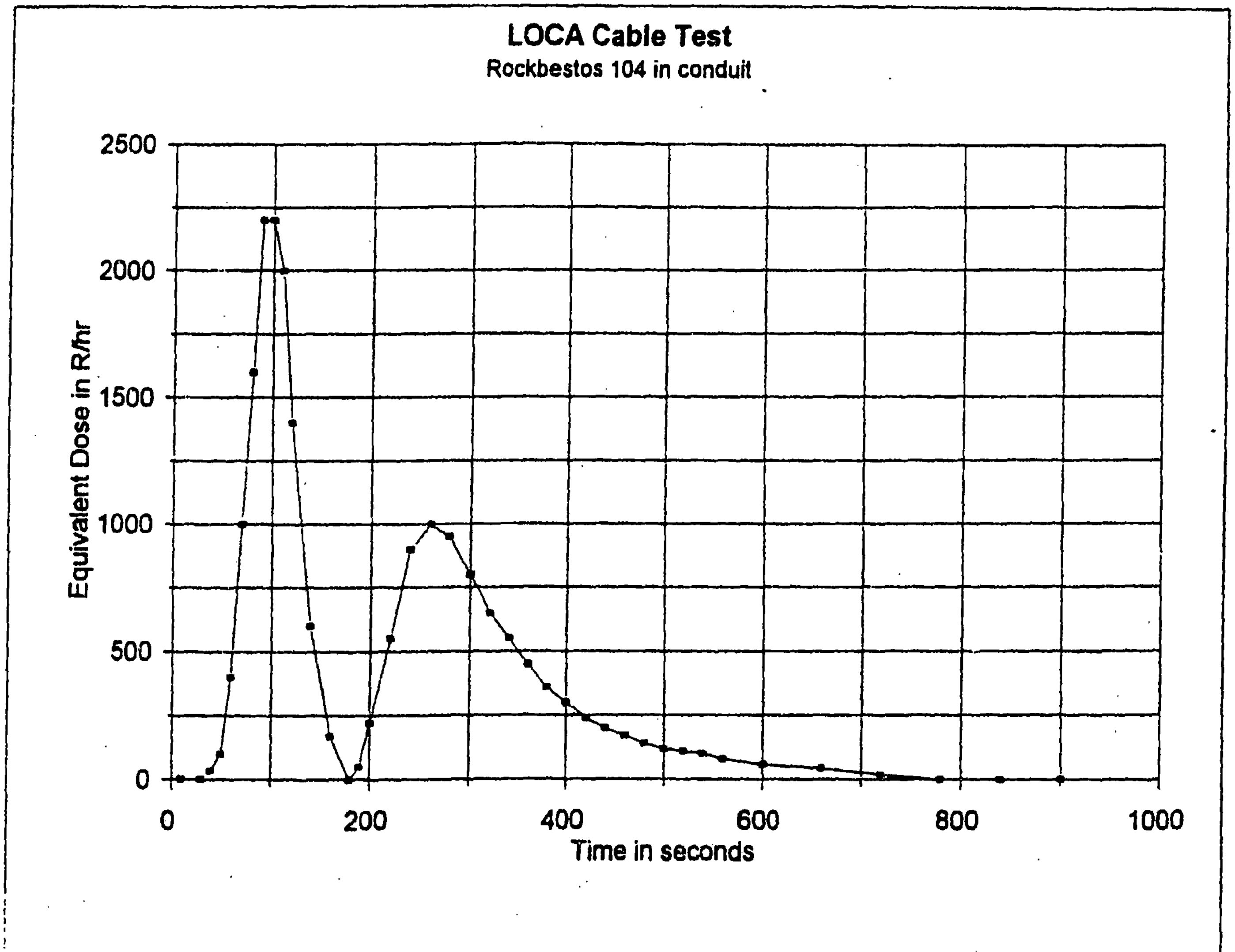
LOCA Cable Test
Rockbestos 105-half in conduit
Equivalent Dose in R/hr
2500
2000
1500
1000
500
0
0
100
200
300
400
500
Time in seconds

Att. F p 6/8



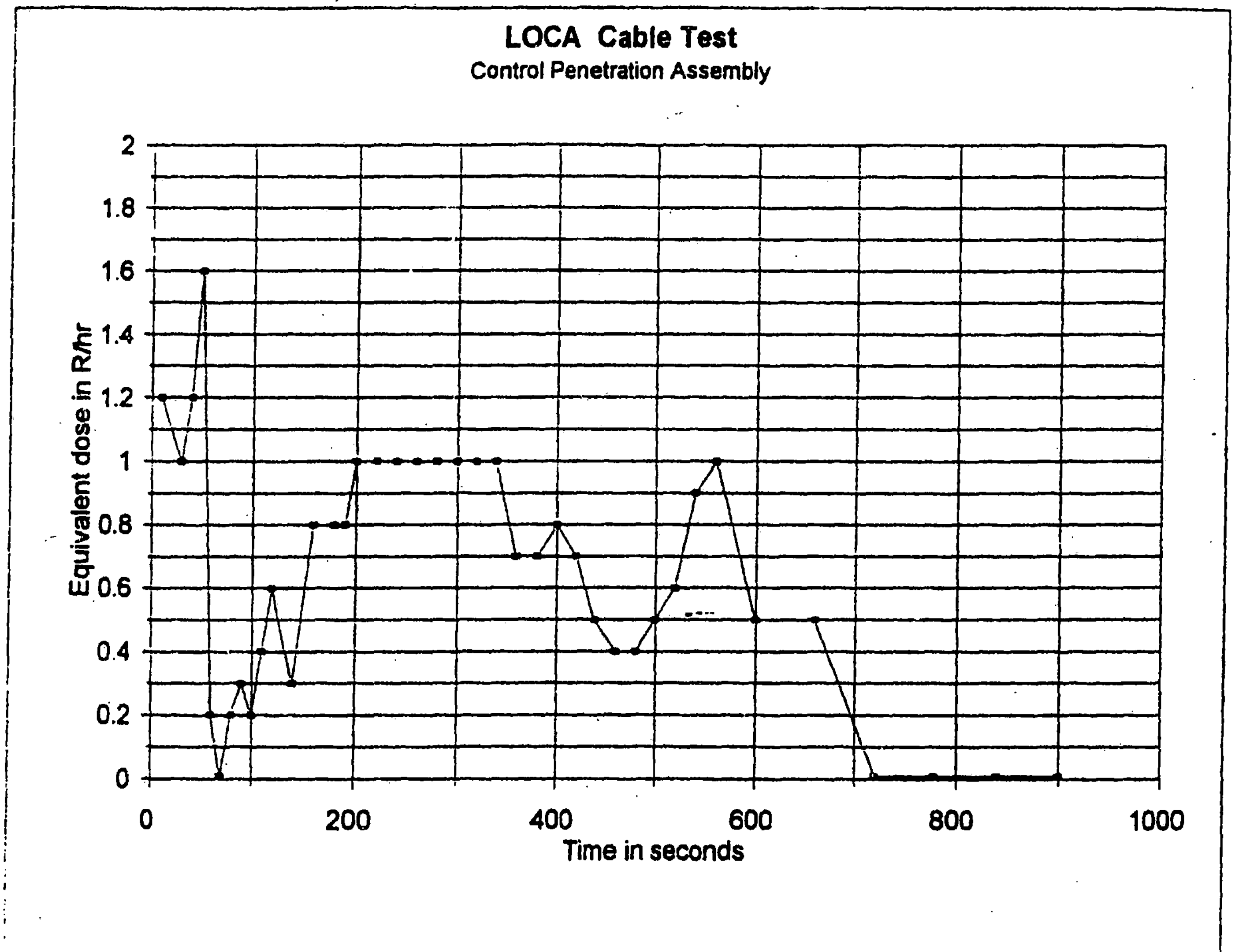
LOCA Cable Test
Rockbestos 104 half conduit
Equivalent Dose in R/hr
4000
3000
2000
1000
0
0
200
400
600
800
1000
Time in seconds

Att F p. 7/8



LOCA Cable Test
Rockbestos 104 in conduit
Equivalent Dose in R/hr
2500
2000
1500
1000
500
0
0
200
400
600
800
1000
Time in seconds

App F p. 8/8



LOCA Cable Test
Control Penetration Assembly
Equivalent dose in R/hr
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
200
400
600
800
1000
Time in seconds

Appendix G p.1/2

Notes on Thermally Stimulated Depolarization Currents

Ref. R. Chen, Y. Kirsh; Analysis of Thermally Stimulated Processes; 1981, Pergamon Press

This text identifies many mechanisms where current can be released from a dielectric as a result of raising the temperature. The manner in which polarization can occur within a dielectric is by charges creating dipoles at impurity molecule sites within the dielectric. These dipoles require an electric field to initiate the dipole.

The release of the dipole charge requires a certain amount of activation energy (eV). As the temperature of the dielectric rises, the activation energy level is reached and the charge is released. The time constant or relaxation time for this release can be expressed as:

$$\tau(T) = \tau_0 \exp(\frac{E}{kT})$$

where $\tau(T)$ is the relaxation time, τ_0 is a time factor independent of temperature, E is the activation energy in eV, k is Boltzmann's constant in eV/°K, T is temperature in °K.

The saturation polarization in coulombs/unit volume can be expressed as:

$$P_0 = \frac{\mu^2 E_p N \alpha}{k T_p}$$

Where P_0 is the saturation polarization, μ is the dipole moment, E_p is the applied electric field at temperature T_p, N is the concentration of dipoles in dipoles/unit volume, α is factor that depends on the dielectric lattice/crystal structure. This equation assumes that just one impurity type exists. For an array of impurities, similar equations exist.

Using a Bucci model, the current density of the released current is proportional to the number of remaining dipoles in the dielectric.

$$j(T) = -\frac{dP}{dt} = \frac{P}{\tau(T)} = \frac{P}{\tau_o} \exp(\frac{-E}{k\,T})$$

Where j(T) is the density of released current

If the heating rate is linear, i.e. $dT/dt = \beta$ or $dt = dT/\beta$ then the current density can be described as:

$$j(T) = \frac{N\mu^2 \alpha E_p}{kT_p \tau_0} \exp(\frac{-E}{kT}) \exp[(-\frac{1}{\beta \tau_0}) \int_{T_0}^{T} \exp(\frac{-E}{kT'}) dT']$$

It follows that if this model is representive of the current releases observed in our cable tests, then the released current is dependent on the length of the cable. It is also dependent on the polarizing E-field, the number of impurity sites in the dielectric, the dipole activation energy and the rate of temperature change during the heating.

Some possible solutions to reducing this depolarization current are to preheat/temperature soak the cable prior to installation in order to release the dipole currents. Dielectric tests would have to be minimized and greatly reduced in magnitude, Say <<10 volts rather than >500 volts.

Prepared by A.T Hyde 5/9/96