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TMI-2 CABLE/CONNECTION PROGRAM: A LOOK AT IN SITU TEST DATA

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ABSTRACT

At the Three Mile Island (TMI) Unit 2 Reactor Building, the Instrumentation and Electrical Program in 1981 initiated a major analysis of cable systems. These cable systems were exposed to varying degrees of radiation, steam, humidity, pressure suppression spray, submergence, and a hydrogen burn event. By studying the electrical and physical properties of selected representative cables and the ways in which these cables responded to the accident and post-accident environments, the Cables/Connections Task group is generating information with which government and the nuclear industry can develop guidelines to make components more radiation resistant, re-evaluate qualification testing procedures and regulatory mandates, and contribute to nuclear power plant safety.

This report presents an overview of the TMI Unit 2 cable analysis program and, as examples, the findings for the first 49 cables tested. These cables are in electrical penetration R607.

FOREWORD

In a cooperative effort, a representative sample of the cables and connections in Three Mile Island's Unit 2 Reactor Building are being studied to determine how they were affected by and reacted to the accident and post-accident conditions. Anyone interested in obtaining preliminary in situ test data (as presented in this report for the first 49 cables tested) should contact H. J. Helbert or L. A. Hecker at EG&G Idaho, Inc., P.O. Box 88, Middletown, PA 17057. Those interested in more information regarding the overall cables and connections task should contact C. P. Cannon, Westinghouse Hanford Company, P.O. Box 1970, Richland, WA 99352, or R. D. Meininger, Instrumentation and Electrical Program Manager, EG&G Idaho, Inc., P.O. Box 88, Middletown, PA 17057.

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TMI-2 CABLE/CONNECTION PROGRAM: LOOK AT IN SITU TEST DATA

INTRODUCTION

The Three Mile Island Unit 2 (TMI-2) nuclear power plant continues to be the focus of national and international attention. Nearly every system and component in the Reactor Building was affected in some way by the March 28, 1979, accident.

The cable systems, for example, were subjected to a moisture laiden environment, with considerable humidity and high radiation levels, contributing to their degradation. Following the accident, the cable systems were exposed to "rain," caused by evaporation and then condensation of the water that flooded the basement. Other probable sources of moisture were the Reactor Building spray following the hydrogen burn incident and the hot-water spray of the gross decontamination experiment.

Prevention or mitigation of accidents such as the one experienced at TMI-2 can be enhanced by learning more about the physical limitations and performance of such instrumentation and electrical equipment exposed to the accident environment. Examination, testing, and analysis will provide data for better assessment of reliability and performance and for improvements in design, manufacture, and installation of instrumentation, electrical, and cable systems equipment.

Late in 1981, cable systems became a major concern to the Instrumentation and Electrical (I&E) Program at TMI. This concern was elevated from a minor one to a major one because (a) General Public Utilities Nuclear Corporation (GPU Nuclear) requested information about the survivability of the electrical cables for use in recovery planning; (b) there are more than 500,000 ft of cables in the Reactor Building--a major cost element; (c) all controls and information operate and flow via cables; and (d) analysis of these systems would provide valuable information for monitoring post-accident conditions, developing cleanup plan parameters, and ensuring greater plant safety.

Through its Cables/Connections Task, the I&E Program group seeks to determine the effects of the TMI-2 accident and post-accident conditions on the cables and connections within the Reactor Building. The I&E Program defines cables and connections as all components in a given electrical channel, or circuit, from the Reactor Building penetration assembly up to but excluding the instrument or unit at the end of the channel. The components encompassed by this definition include penetration assemblies, penetration boxes, terminal boxes, terminal blocks, splices, bulk cable, and connections.

The information and understanding generated by the Cables/Connections Task group will be specific to the TMI-2 components and will reflect their specific responses to the loss-of-coolant accident (LOCA) and post-LOCA environment at TMI-2. But while these task results will be TMI-2 site specific, they will help to generate basic guidelines regarding the response of cable and connection components to a LOCA experience. Such guidelines will serve to help government and the nuclear industry make components more resistant to conditions like those encountered in the TMI-2 Reactor Building, as well as help them re-evaluate qualification testing procedures and regulatory mandates in light of this actual LOCA experience data.

The byproduct of this task will be an analytical tool that will predict total channel condition. This tool will be used to check actual functional impairment at TMI-2.

The components in the TMI-2 Reactor Building were exposed to varying degrees of radiation, steam, humidity, Reactor Building spray, submergence, and a hydrogen burn event. By studying the electrical and physical properties of selected representative components, the task group will be able to estimate how the cables and connections responded to these environments. The resulting data, when compared to equivalent data taken on cables and connections that were not exposed to the LOCA, should help determine the extent to which the accident affected the properties and useful lifetime characteristics of these cables.

Clearly, the identification of failed or faulty components, which compromise the ability of a given electrical channel to function, is of prime interest to the nuclear industry. Such a finding, and subsequent identification of a failure mechanism, would permit measures to be devised to rectify the faulty or failed component and thus contribute to nuclear power plant safety.

This report is intended to explain the TMI-2 Cable/Connection Program and provide examples of the data being obtained through in situ tests, as well as the preliminary conclusions I&E engineers are arriving at after conducting early analyses of these data. Serving as examples for this report are the first 49 cables (all in penetration R607) that were subjected to the mass scan. Similar data will be collected for 200 to 400 electrical channels in the Reactor Building.

The in situ test data for cables in penetration R607, along with the rest of the mass scan data, will be more deeply analyzed and compared with laboratory data. The final information will then be issued in a GEND formal report.

TESTING PROGRAM

A registry of the approximately 1800 electrical channels in the Reactor Building has been made. These channels have been sorted according to safety or nonsafety status, previous in situ testing data, and location. A representative number (10 to 20%) of these channels are being subjected to appropriate in situ electrical scan tests. The intent of the scan is to: (a) identify anomalous channels for more comprehensive in situ characterization tests, (b) identify impaired channels for removal and laboratory examination, and (c) estimate what fraction of the channels may have been impaired.

The following sets of in situ scan tests are being performed from the outer penetration on cables in the TMI-2 Reactor Building:

- o Initial Voltage Characterization
- o Time Domain Reflectometry
- o Capacitance
- o Inductance
- o Insulation Resistance
- o Direct Current Loop Resistance.

MASS SCAN TESTING IN PENETRATION R607

This report provides preliminary data obtained in the mass scan testing performed on cables in the Balance of Plant electrical penetration R607, which is an instrumentation and control penetration containing 137 channels.

The 49 cables that were selected for testing in electrical penetration R607 were chosen based on five factors:

1. Results from prior in situ tests

2. End instrument has been removed

3. Location in the Reactor Building

4. Representative of cable types

5. Provides supporting data for tests to be performed in other penetrations or on other cables in the same penetration.

In Table 1, each of the 49 cables is listed along with its basis for selection, as indicated by number (1 through 5 above). Appendix A contains the actual test procedure, which was approved by GPU Nuclear.

TABLE 1. BASIS FOR SELECTION OF CABLES IN PENETRATION R607

Cable Identification	Basis for Selection[a]	Cable Identification	Basis for Selection[a]
H279I	1	IT2457I	5
H281I	5	IT2459I	5
H291I	1	IT2464I	5
H293I	5	IT2468I	5
H303I	1	IT2478I	5
H305I	5	IT2737I	1&2
H315I	1	IT2738I	1&2
H317I	5	IT2739I[b]	1&2
IT1320I	5	IT2740I	1&2
IT1322I	5	IT2741I	1&5
IT1535I[c]	4	IT2742I[d]	1&2
IT1554I[e]	4	IT2743I[f]	1&5
IT1769I[g]	4	IT2744I[h]	1&2
IT2074I	5	IT2822I[i]	1
IT2310I	5	IT3079I	1
IT2312I	5	IT3080I	5
IT2314I	5	IT3081I	5
IT2433I	5	IT3082I	5
IT2437I	5	IT4078I	5
IT2441I	5	IT4119I	5
IT2443I	5	IT4121I	5
IT2445I	5	IT4123I	5
IT2447I	5	IT4125I	5
IT2449I	5	TD657I[j]	3
IT2451I	5		

a. See page 5 of this report for definitions of selection factors 1 through 5.
b. See GEND-INF-017, Vol II.
c. Type FR-9CC.
d. See GEND-INF-017, Vol V.
e. Type FR-9BB.
f. See GEND-INF-017, Vol I.
g. Type FR-9GG.
h. See GEND-INF-017, Vol IV.
i. See GEND-INF-017, Vol VI.
j. From inner penetration box resistance thermometer.

DATA ANALYSIS

Software was developed for the Hewlett-Packard 85 computer to perform a preliminary quick evaluation of the test data. Figure 1 is an outline of the quick evaluation report form generated by this computer program. Appendix B contains the final quick evaluation reports for a representative sample of cables tested in penetration R607. Following is an explanation of the quick evaluation report form (refer to Figure 1 for better understanding).

The heading at the top of the form contains identifying information, specifically the cable identification number, instrument tag number, cable type, instrument elevation, the penetration and terminal identification, and the date the cable was tested.

Data provided in the "Control Cable" column are obtained through a laboratory test on an unused sample of cable of the same type undergoing the in situ test. Laboratory test samples are obtained from GPU Nuclear or the cable manufacturer and have not been exposed to the TMI-2 LOCA environment. The laboratory tests are performed using the same procedures and equipment to be used for the in situ tests (Appendix A). The resulting data serve as a basis for predicting expected in situ test results.

In the column labeled "Predicted," the data are obtained by combining the control cable data with an estimate of the length of the cable undergoing the in situ test. This length is obtained from GPU Nuclear records of cable pull lengths. If the cable to be tested is connected to an instrument, estimates are included for that instrument's resistance, inductance, and capacitance, which will add to the measured values. The end instrument's contribution is obtained by analyzing its electronic circuit diagram, on file with GPU Nuclear.

"Instr. Adds," appearing in the lower right corner of the report form, lists the end instrument's resistance, inductance, and capacitance values, which were added to the predictions for the cable itself to obtain the predicted values provided in the column above.

CABLE # ________ TYPE ________ PENETRATION AND TERMINALS ____________________

INSTRUMENT TAG # __________ ELEVATION ________ DATE ________

PARAMETERS	CONTROL CABLE	PENETRATION	TEST LEADS	INSITU TEST	PREDICTED
LOOP RESISTANCE	ohms	ohms	ohms	ohms	ohms
TOTAL INDUCTANCE	microH	microH	microH	microH	microH
TOTAL CAPACITANCE	nf	nf	nf	nf	nf
INSUL. RESISTANCE	ohms	ohms	ohms	ohms	ohms
DISSIP. FACT.					
PROP. DELAY	ns/ft	ns/ft	ns/ft	T/TIME	ns/ft
Z1=[SQR(L/C)]	ohms	ohms	ohms	ohms	ohms
Z2=SQ(1+P/1-P)	ohms	ohms	ohms	ohms	ohms
AVE. L/FT.					
AVE. C/FT.					
AVE. RES. /FT.					
TDR LENGTH	ft	ft		ft	ft
IND. LENGTH	ft	ft		ft	ft
CAP. LENGTH	ft	ft		ft	ft
RES. LENGTH	ft	ft		ft	ft
1/V=[C/(SQR K)]					INSTR. ADDS:
RANDOM NOISE	volts	volts		volts	
PENETRATION AND INSITU TEST DATA HAVE TEST LEAD DATA SUBTRACTED					
PREDICTED R, L AND C INCLUDE INSTR. CONTRIBUTION					

Figure 1. Sample quick evaluation report form.

The test engineer uses the quick evaluation report, with the heading information and the "Control Cable," "Predicted," and "Instr. Adds" columns completed, as a guideline during in situ testing. The predictions give the test engineer an estimate of the values expected from the measurements he is taking.

In the report column labeled "Test Leads," the data provided are specific to the test leads, which are wires connecting the measuring equipment to the cables to be tested. The tests and equipment used to obtain these data are the same as those used in the in situ test (Appendix A). The test lead data are later subtracted from the in situ test data.

In order to evaluate each cable, the measured value of penetration wires must be subtracted from the total measured value. Thus, the "Penetration" column contains a characterization specifically of the penetration wires (wires without a cable connected inside the Reactor Building).

The "In Situ Test" column contains measured values from which penetration and test lead values were subtracted. Data in this column, when compared with the predictions in the adjacent column, provide a characterization of the present status of the cable under examination.

RESULTS AND INDICATIONS

The quick evaluation plots for some of the cables tested in penetration R607 are contained in Appendix B. These charts are to serve as examples of the kinds of information available through this I&E research. The "In Situ Test" and "Predicted" columns of the charts have been compared for all 49 cables tested in penetration R607, and resulting preliminary comments are provided in Table 2. Also see Table 3 for a summary of those cables found to be impaired and those found to be in good condition. (Table 3 also provides an additional byproduct of the in situ tests: findings of the condition of end instruments to which the tested cables were connected. These findings have been sent to outside laboratories for possible future analysis.)

Analysis of the data indicates there are several broken wires and corroded contacts in penetration R607 (see Table 2 for specific locations). Insulation resistance measurements made between wires of different cables in penetration R607 yielded evidence of "cross talk," an interference between two parallel wires in the penetration. The centerline of penetration R607 is at the 292-ft elevation. Records of the 1979 accident indicate that the water level in the Reactor Building basement reached a peak elevation of 300 ft but settled at approximately 292 ft, partially submerging the inner penetration box of R607. The "cross talk" encountered may be due to water which remained in the penetration box when the water level in the Reactor Building was lowered.

The most predominant cable anomaly encountered during the tests is a shift in the cable's characteristic impedance, which could have been caused by moisture ingress through the cable's insulation. Note that the mass screening tests are not designed to assess the extent of damage to the cables. Additional in situ tests are being developed for those cables exhibiting an anomaly during the mass scan test.

TABLE 2. PRELIMINARY ANALYSIS OF TESTS ON PENETRATION R607 CABLES

Cable Number	Cable Type	End Instrument	Instrument Mfr	Class 1E	Notes
H279I	FR-15VVV	RCP56-PS16	Static "O" Ring	No	Insulation resistance slightly low.
		RCP60-LS7	Static "O" Ring	No	Insulation resistance slightly low.
H281I	FR-15WW	RCP-1B Warrick Relay	Allis-Chalmers	No	No anomalies.
		RCP61-LS7A	Static "O" Ring	No	No anomalies.
		RCP61-LS8A	Static "O" Ring	No	No anomalies.
H291I	FR15VV	RCP58-FS1	Static "O" Ring	No	Low insulation resistance and low capacitance. Cable wet and end instrument contacts corroded. Retest and removal candidate.
		RCP60-LS1	Static "O" Ring	No	Low impedance. Cable wet and end instrument contacts corroded. Retest and removal candidate.
H293I	FR-15WW	RCP-1A Warrick Relay	Allis-Chalmers	No	No anomalies.
		RCP61-LS2A	Static "O" Ring	No	No anomalies.

TABLE 2. (continued)

Cable Number	Cable Type	End Instrument	Instrument Mfr	Class 1E	Notes
H293I	FR-15WW	RCP61-LS1A	Static "O" Ring	No	High contact resistance. Retest and removal candidate.
H303I	FR-15VVV	RCP58-FS3	Static "O" Ring	No	No anomalies.
		RCP60-LS3	Static "O" Ring	No	Low insulation resistance and low impedance. Cable wet. Retest and removal candidate.
H305I	FR-15HHH	RCP-2A Warrick Relay	Allis-Chalmers	No	No anomalies.
		RCP61-LS3A	Static "O" Ring	No	No anomalies.
		RCP61-LS4A	Static "O" Ring	No	No anomalies.
H315I	FR-15VVV	RCP58-FS5	Static "O" Ring	No	Low insulation resistance and low impedance. Contacts corroded. Retest and removal candidate.
		RCP60-LS6	Static "O" Ring	No	Low insulation resistance and low impedance. Cable wet. Contacts corroded. Retest and removal candidate.
H317I	FR-15WW	RCP-2B Warrick Relay	Allis-Chalmers	No	No anomalies.
		RCP61-LS5A	Static "O" Ring	No	No anomalies.

TABLE 2. (continued)

Cable Number	Cable Type	End Instrument	Instrument Mfr	Class 1E	Notes
H317I	FR-15WW	RCP61-LS6A	Static "O" Ring	No	No anomalies.
IT1320I	FR-15AA	RR-FT-1028	Foxboro	No	Impedance slightly low, insulation resistance low. Cable may be wet.
IT1322I	FR-15AA	RR-FT-1029	Foxboro	No	Impedance slightly low, insulation resistance low. Cable may be wet.
IT1535I	FR-15WW	SP-1A-LT3	Bailey	No	Cable open at end instrument. Insulation resistance and capacitance low. Cable wet. Retest and removal candidate.
		SP-1A-LT5	Bailey	No	Insulation resistance and capacitance low. Cable wet. Retest and removal candidate.
		Pins D-J no instr.	NA	NA	Insulation resistance slightly low.
IT1554I	FR-15WW	SP-6A-PT1	Foxboro	No	No anomalies.
		Pins S-K no instr.	NA	NA	No anomalies.
		Pins D-J no instr.	NA	NA	Insulation resistance slightly low.
IT1769I	FR-15AA	RC-3A-PT5	Foxboro Rosemount	No	Characteristic impedance changed. Low insulation resistance. Retest and removal candidate.

TABLE 2. (continued)

Cable Number	Cable Type	End Instrument	Instrument Mfr	Class 1E	Notes
IT2074I	FR-15W	SP-1A-LT1	Bailey	No	Instrument appears to have failed.
		RC22-PT1	Foxboro	No	No anomalies.
		RC22-PT2	Foxboro	No	No anomalies.
IT2310I	FR-15AA	WDL-PT-1202	Foxboro	No	No anomalies.
IT2312I	FR-15AA	WDL-PT-1207	Foxboro	No	Characteristic impedance low from penetration out to approximately 83 ft. Cable wet in the area. Suggest removal of 50-ft to 115-ft section.
IT2314I	FR-15AA	WDL-PT-1211	Foxboro	No	Characteristic impedance low. Cable wet.
IT2433I	FR-15AA	SP-1B-LT1	Bailey	No	Instrument appears to have failed.
IT2437I	FR-15AA	SP-1B-LT2	Bailey	No	Characteristic impedance low. Cable wet. Instrument damage (corrosion).
IT2441I	FR-15AA	SP-1B-LT4	Bailey	No	Characteristic impedance change. Cable wet. Instrument appears to have failed.
IT2443I	FR-15AA	RR-FT-1035	Foxboro	No	No anomalies.
IT2445I	FR-15AA	RR-FT-1026	Foxboro	No	Capacitance high. Possible wet cable.
IT2447I	FR-15AA	RR-FT-1027	Foxboro	No	Capacitance low.

TABLE 2. (continued)

Cable Number	Cable Type	End Instrument	Instrument Mfr	Class 1E	Notes
IT2449I	FR-15AA	RC22-PT3	Foxboro	No	No anomalies.
IT2451I	FR-15AA	RC22-PT4	Foxboro	No	Capacitance high. Possible wet cable.
IT2457I	FR-15AA	RC1-LT1	Bailey	No	Instrument appears to have failed.
IT2459I	FR-15WW	SP-6A-PT2	Foxboro	No	No anomalies.
		Pins S-K no instr.	NA	NA	No anomalies.
IT2464I	FR-15WW	SP-1A-LT2	Bailey	No	Characteristic impedance change.
		SP-1A-LT4	Bailey	No	Characteristic impedance change.
		Pins L-M no instr.	NA	NA	No anomalies.
IT2468I	FR-15AA	RCP-LT3	Bailey	No	Instrument appears to have failed (shorted at input).
IT2478I	FR-15AA	RC1-LT2	Bailey	No	Instrument appears to have failed due to corrosion.
IT2737I	FR-15AA	CF1-PT1	Foxboro	No	Capacitance low. Retest.
		with instr. removed	NA	NA	No anomalies.
IT2738I	FR-15AA	CF2-LT1	Bailey	No	Instrument appears to have failed.
		with instr. removed	NA	NA	No anomalies.

TABLE 2. (continued)

Cable Number	Cable Type	End Instrument	Instrument Mfr	Class 1E	Notes
IT2739I	FR-15AA	YM-UR-2	--	No	No anomalies.
IT2740I	FR-15AA	no instr.	NA	NA	Characteristic impedance change. Wet cable.
IT2741I	FR-15AA	CF1-PT2	Foxboro	No	Capacitance low.
IT2742I	FR-15AA	CF2-LT2	Bailey	No	Instrument appears to have failed.
		with instr. removed	NA	NA	No anomalies.
IT2743I	FR-15AA	CF1-PT4	Foxboro	No	Capacitance low.
IT2744I	FR-15AA	CF2-LT4	Bailey	No	Instrument powered during testing.
IT2822I	FR-15AA	IC10-dPT	Bailey	No	Instrument appears good. Suggest removal of instrument for comparison.
IT3079I	FR-15BB	MU10-FT1	Brooks	No	Instrument appears to have failed.
IT3080I	FR-15BB	MU10-FT2	Brooks	No	No anomalies.
IT3081I	FR-15BB	MU10-FT3	Brooks	No	Instrument appears corroded.
IT3082I	FR-15BB	MU10-FT4	Brooks	No	No anomalies.
IT4078I	FR-15AA	SP-6B-PT1	Foxboro	No	Capacitance low.
IT4119I	FR-155AA	RC22-PT5	Foxboro	No	Capacitance low.
IT4121I	FR-15AA	RC22-PT6	Foxboro	No	No anomalies.

TABLE 2. (continued)

Cable Number	Cable Type	End Instrument	Instrument Mfr	Class 1E	Notes
IT4123-I	FR-15AA	RC22-PT7	Foxboro	No	Capacitance low.
IT4125-I	FR-15AA	RC22-PT8	Foxboro	No	Capacitance low.
TD657I	FR-15BB	RB-TE-3339	--	No	Instrument has failed.

TABLE 3. SUMMARY OF CONDITION OF CABLES AND INSTRUMENTS BY TYPE

Nomenclature	Number of Cables Tested	Condition: Number Impaired	Condition: Number Good	Description
Cable Type				
FR-15WW	7	2	5	Anaconda: 6 conductors (3 pairs #16 twisted & shielded)
FR1-15VVV	4	3	1	Anaconda: 12 conductors (6 pairs #16 twisted & shielded)
FR-15HHH	1	0	1	Anaconda: 6 conductors #16 shielded (Special Jacket)
FR-15AA	31	17	14	Anaconda: 2 conductors #16 shielded
FR-15BB	5	1	4	Continental: 3 conductors #16 shielded
FR-15VV	1	1	0	Anaconda: 12 conductors (6 pairs #16 twisted & shielded)
Instrument Type				
Pressure Switch	1	0	1	Static "O" Ring
Level Switch	6	1	5	Static "O" Ring
Flow Switch	1	1	0	Static "O" Ring
Warrick Relay	2	0	2	Allis-Chalmers
Pressure Transmitter	18	3	15	Foxboro-Rosemount
Level Transmiter	14	13	1	Bailey
Flow Transmitter	9	4	5	Foxboro
Differential Pressure Transmitter	1	0	1	Bailey
Temperature Element	1	1	0	
Particulate Monitor	1	0	1	

CONCLUSIONS

Special in situ tests will be designed to establish fault locations. The faulty or damaged component will then be removed and retested at TMI when practical to confirm the failure. The penetration will also be retested to confirm that the faulty component has been removed and to establish that there is only one failure mode. The failed or damaged component will then be shipped off site for further electrical and material testing beyond the scope of this task.

By October 1984, engineers participating in the characterization program hope to be able to define the extent to which cable and connector degradation impaired the functional capability of the instrumentation in the TMI-2 Reactor Building. By late 1985, information from laboratory tests characterizing the nature of impairment to the cables and connectors that will have been removed by then will be available for inspection by utilities and by manufacturers of cable and connector equipment, as well as by the Nuclear Regulatory Commission and other standard-setting organizations.

APPENDIX A

PROCEDURE FOR IN SITU CABLE TESTING AS APPROVED BY GENERAL PUBLIC UTILITIES NUCLEAR CORPORATION

GPU Nuclear	TMI-2 Implementing Procedure Data Management and Analysis	Number 4550-IMP-3700.01
Title Post Accident Testing of Electrical Equipment		Revision No. 0
Applicability/Scope All Electrical Cable Systems at TMI-2		Responsible Office 7141
This document is important to safety ☒ Yes ☐ No		Effective Date 04/12/83

List of Effective Pages

Page	Revision	Page	Revision	Page	Revision	Page	Revision
1.0	0						
2.0	0						
3.0	0						
E1-1	0						
E1-2	0						
E1-3	0						
E2-1	0						
E2-2	0						
E2-3	0						
E3-1	0						
E3-2	0						
E3-3	0						
E4-1	0						
E4-2	0						
E4-3	0						
E5-1	0						
E5-2	0						
E5-3	0						
E6-1	0						
E6-2	0						
E6-3	0						

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FORM 1000-ADM-1218.01-1 (11-82)

A000951 11-82

Document ID: 0054W

GPU Nuclear	TMI-2 Implementing Procedure Data Management and Analysis	Number 4550-IMP-3700.01
Title Post Accident Testing of Electrical Equipment		Revision No. 0

1.0 PURPOSE

1.1 The purpose of this procedure is to establish tests that identify and locate faulty or failed cable system components of the power and instrumentation channels. The test is designed to examine penetrations, cables, connectors, splices, terminal strips and pull boxes. This document is EG and G Number 007 007 311.

2.0 APPLICABILITY/SCOPE

2.1 This procedure is applicable to all electrical cable systems at TMI-2. Testing will be performed in the reactor building outer penetration boxes whenever possible. If the penetration box is not accessible, testing will be performed in the control or relay room cabinet.

3.0 DEFINITIONS

3.1 None

4.0 PROCEDURE

4.1 System or component to be worked on will be described in Unit Work Instruction (UWI) 4000-ADM-3000.01.

4.2 Prerequisites

4.2.1 Special tools and materials are defined in individual test requirements. All measurement and test instrumentation shall be in current calibration traceable to National Bureau of Standards.

4.2.2 Personnel making measurements will be trained in measurement techniques by EG and G personnel. An EG and G test engineer will be present during the testing.

4.3 Notify Shift Supervisor/Foreman of beginning of testing.

4.4 On each component, perform checks and tests identified on the Unit Work Instruction 4000-ADM-3000.01 per instructions for tests from Exhibits 1 to 6.

4.5 Notify Shift Supervisor/Foreman of completion of testing.

NOTE 1: Section 7.0 lists tests by number and a brief description.

NOTE 2: Unit Work Instruction 4000-ADM-3000.01 identifies which tests, by number, are to be performed on a component or system.

NOTE 3: Exhibit 1 to 6 describes each test in greater detail and identifies how data is recorded.

INFORMATION ONLY

4.5.1 Attach all data sheets to the UWI package. Record test equipment, calibration due date, sign and date the data sheets.

4.5.2 Submit copies of test data to the EG and G Test Engineer.

5.0 RESPONSIBILITIES

5.1 Responsibilities are as stated in Section 4.0 of this procedure.

6.0 REFERENCES

6.1 TMI-2 Administrative Procedure 1002, Rules for the Protection of Employees Working on Electrical and Mechanical Apparatus.

6.2 TMI-2 Administrative Procedure 1013, Bypass of Safety Functions and Jumper Control.

6.3 Radiation Protection Plan

6.4 Met Ed Safety Manual

6.5 Applicable Drawings

7.0 ATTACHMENTS

7.1 Exhibit 1 - Initial Voltage Characterization Test

7.2 Exhibit 2 - Time Domain Reflectometry

7.3 Exhibit 3 - Capacitance Measurement

7.4 Exhibit 4 - Inductance Measurement

7.5 Exhibit 5 - Insulation Resistance Test

7.6 Exhibit 6 - D.C. Loop Resistance Test

FOR INFORMATION ONLY

EXHIBIT 1

TEST 01 - Initial Voltage Characterization:

Equipment

A. 1 Megohm resistor

B. HP3455 Volt-ohm meter

C. HP5420A digital signal analyzer or HP85 computer system

NOTE: Test equipment will be supplied by EG and G Idaho, Inc. and equivalents may be substituted.

Method

A. Connect 1 Megohm resistor across wires designated on Unit Work Instruction.

NOTE: Resistance value may be varied at the discretion of the test engineer.

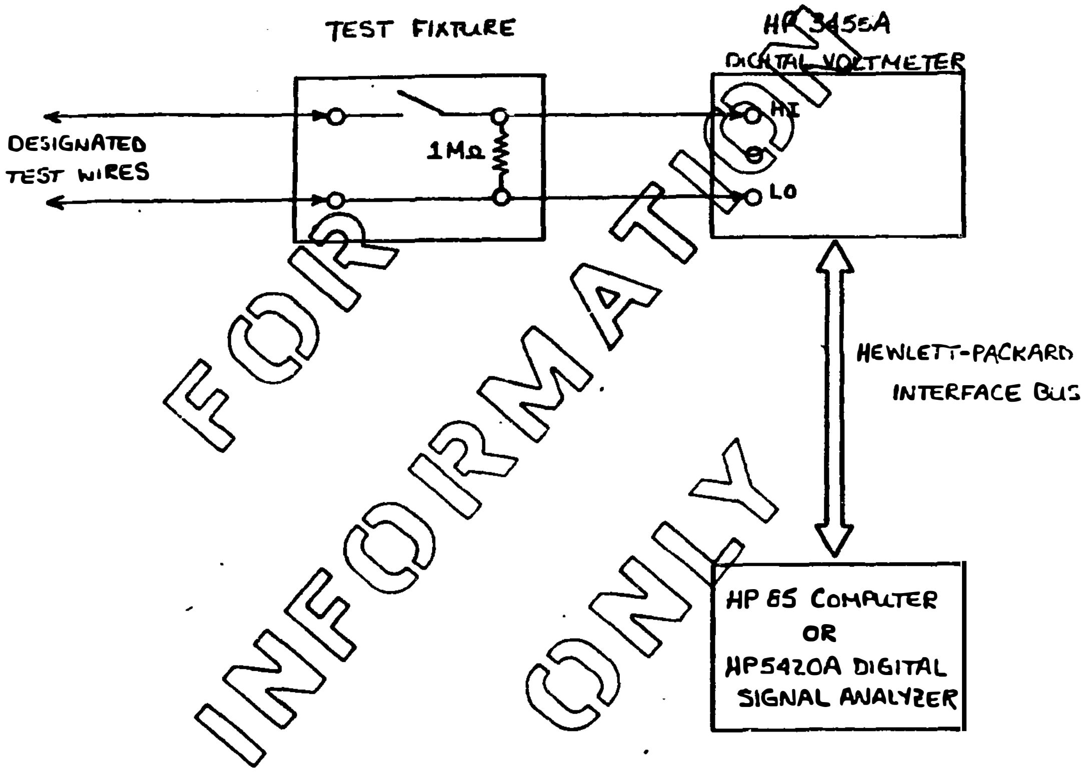
B. Measure voltage across the resistor for one (1) minute.

NOTE: Time may be varied up to ten (10) minutes at the discretion of the test engineer.

C. Store data on disc (or tape) and note storage location on data sheet.

FOR INFORMATION ONLY

EXHIBIT 1



FOR INFORMATION ONLY

Figure E-1. Block Diagram of Initial Voltage Characterization Test.

FORM 1000-ADM-1218.01 2 (11 82)
A0001050 11-82

EXHIBIT 1

Data Sheet 1, Sh ____ of ____ .

Test 01 - Initial Voltage Characterization

Cable Number ________________ Penetration ________________

Test Point (+)	Test Point (-)	File Label	Resistance Value

Equipment Used	Serial No.	Last Cal. Date	Cal. Due Date

Signature/Date ________________________ / ________________

FOR INFORMATION ONLY

FOR INFORMATION ONLY

EXHIBIT 2

TEST 02 - Time Domain Reflectometry:

Equipment

A. Velonix pulser or Tektronix 109 pulser

B. HP85 computer system

C. Tektronix 7854 sampling scope

D. Tektronix voltage probe

E. Current Probe

NOTE: Test equipment will be supplied by EG and G Idaho, Inc. and equivalents may be substituted.

Method

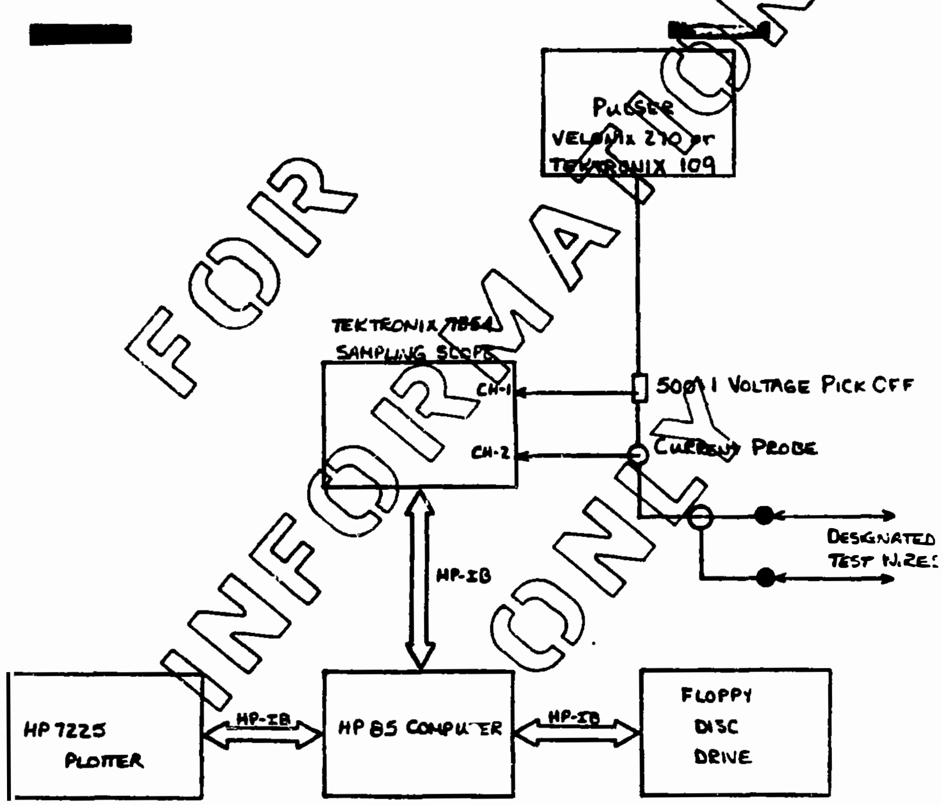
A. Set up test equipment as shown in block diagram.

B. Take 10 data samples and average to eliminate noise.

C. Store data on disc and note file label on data sheet.

EXHIBIT 2

[redacted]



FOR INFORMATION ONLY

Figure E-2. Block Diagram of Time Domain Reflectometry Test.

EXHIBIT 2

Data Sheet 2, Sh ____ of ____

Test 02 - Time Domain Reflectometry

Cable Number ______________ Penetration ______________

Test Point (+)	(-)	File Label

Equipment Used	Serial No.	Last Cal. Date	Cal. Due Date

Signature/Date ______________________ / ______________

FOR INFORMATION ONLY

EXHIBIT 3

TEST 03 - Capacitance Measurement:

Equipment

A. HP4261 or HP4262 digital LCR meter

B. Tektronix power supply

NOTE: Test equipment will be supplied by EG and G Idaho, Inc. and equivalents may be substituted.

Method

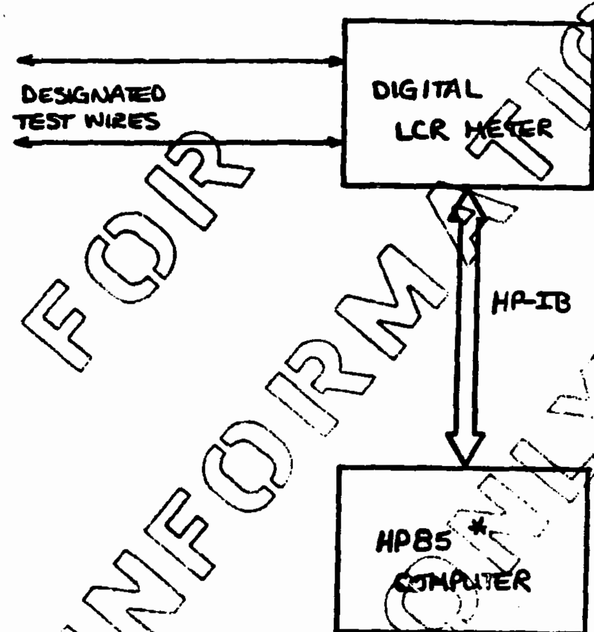
A. Set up test equipment as shown in block diagram.

B. Measure capacitance at 120, 1000 and 10,000 Hz.

C. Log capacitance values and associated dissipation factors on data sheet.

FOR INFORMATION ONLY

EXHIBIT 3



FOR INFORMATION ONLY

* Computer will be used to record data if LCR meter is compatible, otherwise, data will be hand recorded on data sheet.

Figure E-3. Block Diagram of Capacitance Test.

GPU Nuclear	TMI-2 Implementing Procedure Data Management and Analysis	Number 4550-IMP-3700.01
Title Post Accident Testing of Electrical Equipment		Revision No. 0

EXHIBIT 3

FOR INFORMATION ONLY

Data Sheet 3, Sh ____ of ____

Test 03 - Capacitance Measurement

Cable Number ____________ Penetration ____________

Test Point (+)	Test Point (-)	Frequency Hz	Capacitance Series C	Capacitance Series D	Capacitance Parallel C	Capacitance Parallel D	Auto C	Auto D	File Label
		120							
		1K							
		10K							
		120							
		1K							
		10K							
		120							
		1K							
		10K							

Equipment Used	Serial No.	Last Cal. Date	Cal. Due Date

Signature/Date ______________________ / ______________________

FORM 1000 ADM 1218 (11 82)

A0001050 11-82

EXHIBIT 4

TEST 04 - Inductance Measurement:

Equipment

A. HP4261 or HP4262 digital LCR meter

B. Tektronix power supply

NOTE: Test e uipment will be supplied by EG and G Idaho, Inc. and equivalents may be substituted.

Method

A. Set up test equipment as shown in block diagram.

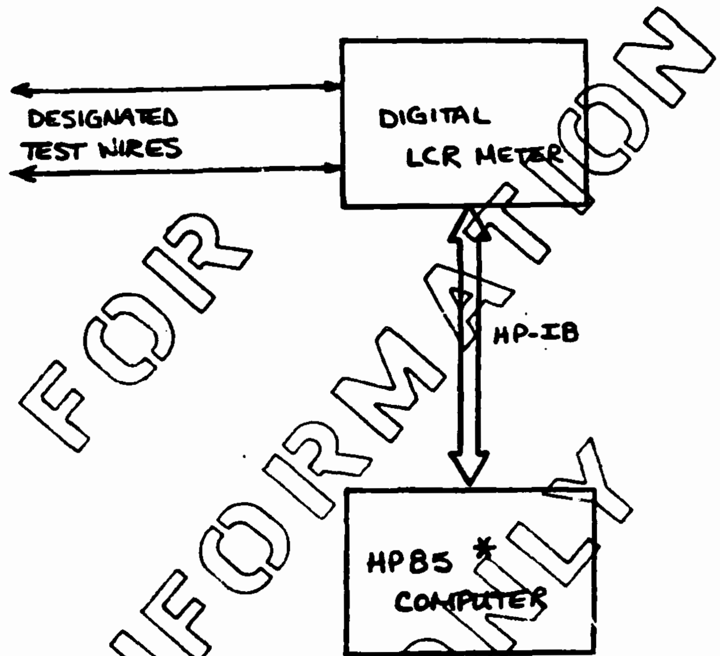
B. Measure inductance at 120, 1000 and 10,000 Hz.

C. Log inductance on data sheet.

FOR INFORMATION ONLY

GPU Nuclear	TMI-2 Implementing Procedure Data Management and Analysis	Number 4550-IMP-3700.01
Title Post Accident Testing of Electrical Equipment		Revision No. 0

EXHIBIT 4



FOR INFORMATION ONLY

* Computer will be used to record data if LCR meter is compatible, otherwise, data will be hand recorded on data sheet.

Figure E-4. Block Diagram of Inductance Test.

FORM 1000 ADM 1218.1 2 (11 82)

A0001050 11-82

EXHIBIT 4

Data Sheet 4, Sh ____ of ____

Test 04 - Inductance Measurement

Cable Number ______________ Penetration ______________

Test Point (+)	Test Point (-)	Frequency Hz	Series L	Series Q	Inductance Parallel L	Inductance Parallel Q	Auto L	Auto Q	File Label
		120							
		1K							
		10K							
		120							
		1K							
		10K							
		120							
		1K							
		10K							

Equipment Used	Serial No.	Last Cal. Date	Cal. Due Date

Signature/Date ______________________ / ______________________

FOR INFORMATION ONLY

FORM 1000 ADM 1218.01 2 (11 82)

A0001050 11-82

EXHIBIT 5

TEST 05 - Insulation Resistance:

Equipment

A. HP4329 insulation resistance meter

B. HP5420A digital signal analyzer

C. Biddle resistance decade box

NOTE: Test equipment will be supplied by EG and G Idaho, Inc. and equivalents may be substituted.

Method

A. Set up test equipment as shown in block diagram.

B. Apply voltage designated on unit work instruction. This voltage will be determined after referencing maximum allowable voltage for all circuit components.

C. Record resistance for two (2) minutes.

NOTE: Time may be varied up to ten (10) minutes at the discretion of the test engineer.

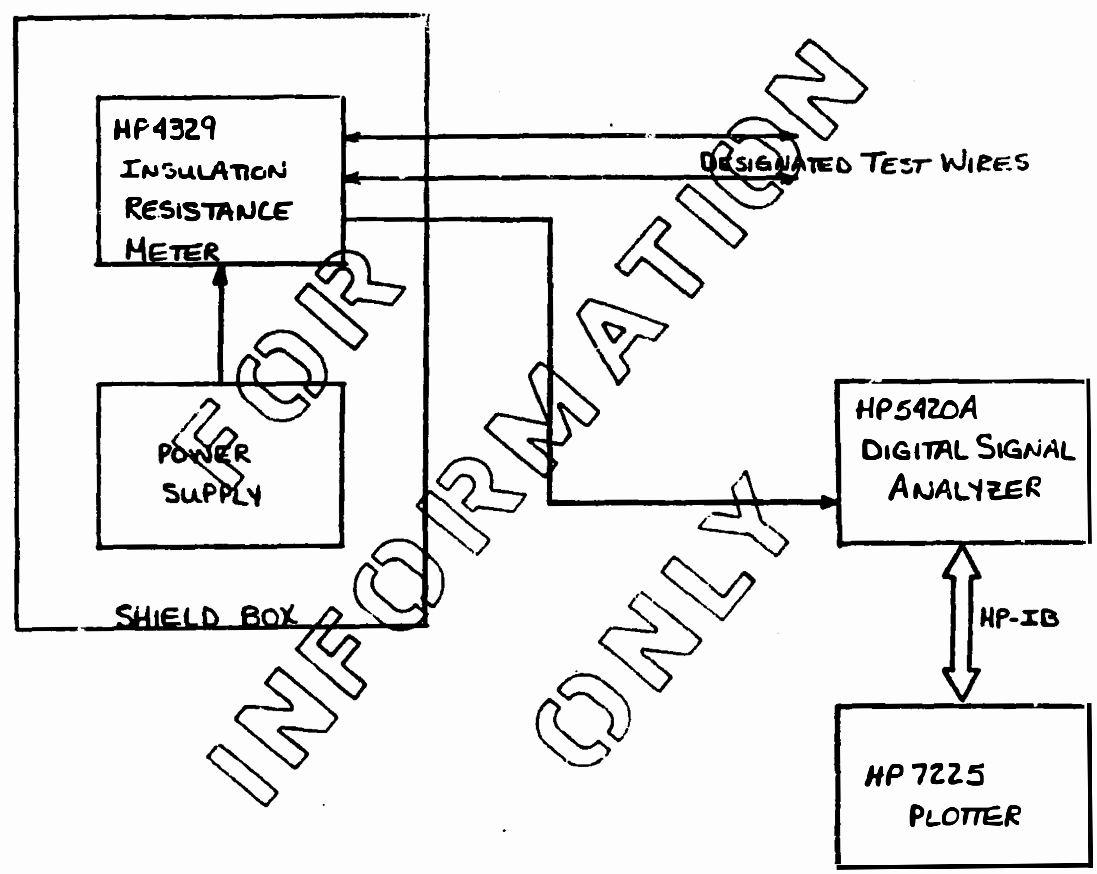
D. Store data on disc and note file label on data sheet.

E. Repeat steps B, C and D using one-half the voltage used previously.

F. If insulation resistance is too low to register on meter, ensure that Test 05--DC Loop Resistance is performed.

FOR INFORMATION ONLY

EXHIBIT 5



FOR INFORMATION ONLY

Figure E-5. Block Diagram of Insulation Resistance Test.

EXHIBIT 5

Data Sheet 5, Sh ____ of ____

Test 05 - Insulation Resistance

Cable Number ________________ Penetration ________________

Test Point (+)	Test Point (-)	Test Voltage	File Label

Equipment Used	Serial No.	Last Cal. Date	Cal. Due Date

Signature/Date ____________________/____________

FOR INFORMATION ONLY

EXHIBIT 6

TEST 06 - DC Loop Resistance:

Equipment

A. HP3455 Volt-ohm meter

B. HP5420A digital signal analyzer or HP85 computer system

NOTE: Test equipment will be supplied by EG and G Idaho, Inc. and equivalents may be substituted.

Method

A. Set up test equipment as shown in block diagram.

B. Take 100 samples of noise (voltage) and average. Record average voltage on data sheet.

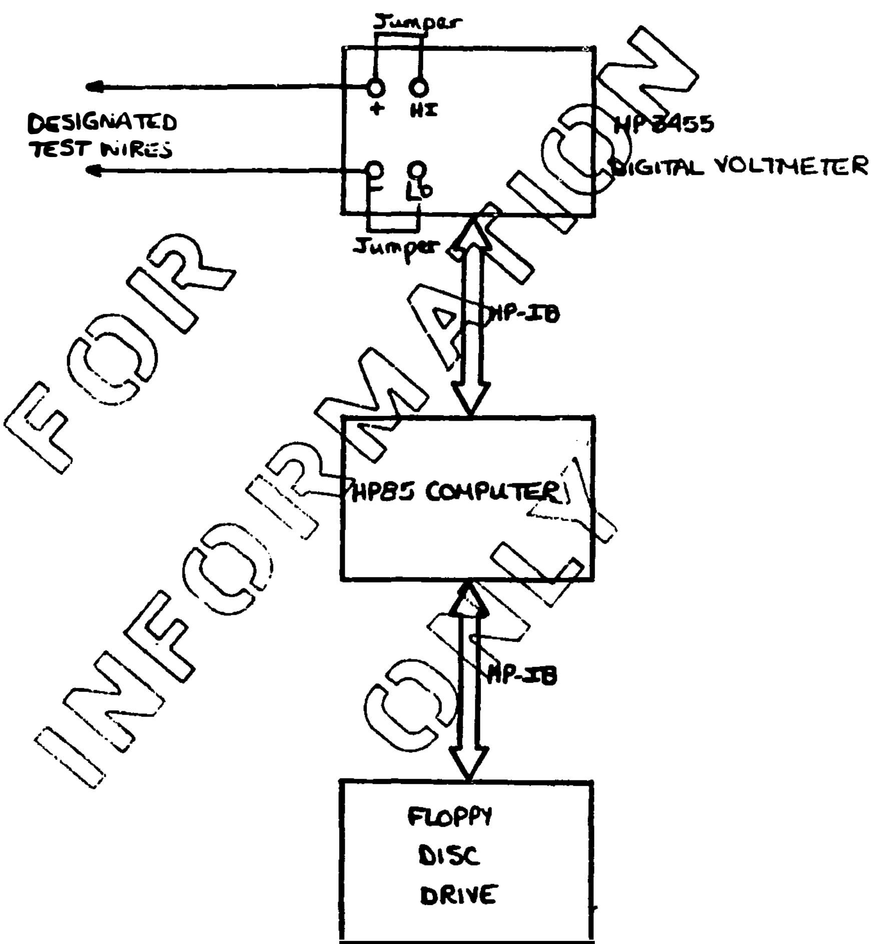
C. Input constant current source.

D. Subtract average voltage from step B and calculate loop resistance.

E. Store data on disc and record file label on data sheet.

FOR INFORMATION ONLY

EXHIBIT 6



FOR INFORMATION ONLY

Figure E-6. Block Diagram of DC Loop Resistance Test.

EXHIBIT 6

Data Sheet 6, Sh ____ of ____

Test 06 - DC Loop Resistance

Cable Number ________________ Penetration ________________

Test Point (+)	Test Point (-)	Average Voltage	File Label

Equipment Used	Serial No.	Last Cal. Date	Cal. Due Date

Signature/Date ____________________________/____________

FOR INFORMATION ONLY

APPENDIX B

SAMPLE OF QUICK EVALUATION PLOTS FOR CABLES IN PENETRATION R607

CABLE # H279I TYPE FR-15VVV PENETRATION AND TERMINALS R607/J1/D-J

INSTRUMENT TAG # RCP60-LS7 ELEVATION 305'0" DATE 08/26/83

PARAMETERS	CONTROL CABLE	PENETRATION	TEST LEADS	INSITU TEST	PREDICTED
LOOP RESISTANCE	.505 ohms	.0908 ohms	.411 ohms	OPEN ohms	OPEN ohms
TOTAL INDUCTANCE	13.2 microH	3.0412 microH	3.45 microH	OPEN microH	OPEN microH
TOTAL CAPACITANCE	1.83 nf	.089 nf	.594 nf	7.187 nf	7.979256 nf
INSUL. RESISTANCE	.8E12 ohms	ohms	.65E11 ohms	3.45E8 ohms	>10E9 ohms
DISSIP. FACT.	OUT OF RANGE			.015	OUT OF RANGE
PROP. DELAY	1.775 ns/ft	1.5883 ns/ft	1.4845 ns/ft	890.6 T/TIME	1.775 ns/ft
Z1=[SQR(L/C]	60.055 ohms	184.85 ohms	ohms	NA ohms	60.055 ohms
Z2=50(1+P/1-P)	73.426 ohms	ohms	ohms	76.279 ohms	73.426 ohms
AVE. L/FT.	.22	.22667			.22
AVE. C/FT.	.030083	.0066334			.030083
AVE. RES. /FT.	.0085139	.0067675			.0085139
TDR LENGTH	60 ft	13.417 ft		222.14 ft	232 ft
IND. LENGTH	60 ft	13.417 ft		NA ft	NA ft
CAP. LENGTH	59.988 ft	13.417 ft		205.66 ft	232 ft
RES. LENGTH	59.992 ft	13.417 ft		NA ft	NA ft
1/V=[C/(SQR K)]	1.7602E-9				INSTR. ADDS:
RANDOM NOISE	0 volts	.21527 volts		.185 volts	0 ohms
PENETRATION AND INSITU TEST DATA HAVE TEST LEAD DATA SUBTRACTED				.2081 RHO.	0 microH
PREDICTED R.L AND C INCLUDE INSTR. CONTRIBUTION					1 nf

CABLE # H279I TYPE FR-15VVV PENETRATION AND TERMINALS R607/J1/A-E

INSTRUMENT TAG # RCP56-PS16 ELEVATION 305'0" DATE 08/25/83

PARAMETERS	CONTROL CABLE	PENETRATION	TEST LEADS	INSITU TEST	PREDICTED
LOOP RESISTANCE	.505 ohms	.0908 ohms	.411 ohms	2.0542 ohms	1.9752 ohms
TOTAL INDUCTANCE	13.2 microH	3.0412 microH	3.45 microH	50.809 microH	51.04 microH
TOTAL CAPACITANCE	1.83 nf	.089 nf	.594 nf	SHORTED nf	SHORTED nf
INSUL. RESISTANCE	.8E12 ohms	ohms	.65E11 ohms	3.45E8 ohms	>10E9 ohms
DISSIP. FACT.	OUT OF RANGE			OUT OF RANGE	OUT OF RANGE
PROP. DELAY	1.775 ns/ft	1.5883 ns/ft	1.4845 ns/ft	917.9 T/TIME	1.775 ns/ft
Z1=[SQR(L/C]	60.055 ohms	184.85 ohms	ohms	NA ohms	60.055 ohms
Z2=50(1+P/1-P)	73.426 ohms	ohms	ohms	75.865 ohms	73.426 ohms
AVE. L/FT.	.22	.22667			.22
AVE. C/FT.	.030083	.0066334			.030083
AVE. RES. /FT.	.0085139	.0067675			.0085139
TDR LENGTH	60 ft	13.417 ft		229.83 ft	232 ft
IND. LENGTH	60 ft	13.417 ft		230.95 ft	232 ft
CAP. LENGTH	59.988 ft	13.417 ft		NA ft	NA ft
RES. LENGTH	59.992 ft	13.417 ft		241.28 ft	232 ft
1/V=[C/(SQR K)]	1.7602E-9				INSTR. ADDS:
RANDOM NOISE	0 volts	.21527 volts		0 volts	0 ohms
PENETRATION AND INSITU TEST DATA HAVE TEST LEAD DATA SUBTRACTED				.2055 RHO.	0 microH
PREDICTED R,L AND C INCLUDE INSTR. CONTRIBUTION					0 nf

CABLE # H281I/283C TYPE FR-15WW PENETRATION AND TERMINALS R607/J1/S-K

INSTRUMENT TAG # RCP61-LS8A ELEVATION 305'0" DATE 09/18/83

PARAMETERS	CONTROL CABLE	PENETRATION	TEST LEADS	INSITU TEST	PREDICTED
LOOP RESISTANCE	.505 ohms	.0908 ohms	.411 ohms	2.2182 ohms	1.9649 ohms
TOTAL INDUCTANCE	13 microH	3.0412 microH	3.45 microH	48.509 microH	51.02604 microH
TOTAL CAPACITANCE	1.59 nf	.151 nf	.594 nf	SHORTED nf	SHORTED nf
INSUL. RESISTANCE	1.75E11 ohms	ohms	.65E11 ohms	2.5E8 ohms	>10E9 ohms
DISSIP. FACT.	OUT OF RANGE			.2	OUT OF RANGE
PROP. DELAY	1.6242 ns/ft	1.5883 ns/ft	1.4845 ns/ft	867.1 T/TIME	1.6242 ns/ft
Z1=[SQR(L/C)]	63.938 ohms	141.92 ohms	ohms	NA ohms	63.938 ohms
Z2=50(1+P/1-P)	66.279 ohms	ohms	ohms	67.096 ohms	66.279 ohms
AVE. L/FT.	.21806	.22667			.21806
AVE. C/FT.	.0261	.011254			.0261
AVE. RES. /FT.	.0083972	.0067675			.0083972
TDR LENGTH	59.999 ft	13.417 ft		235.53 ft	234 ft
IND. LENGTH	59.997 ft	13.417 ft		222.46 ft	234 ft
CAP. LENGTH	59.985 ft	13.417 ft		NA ft	NA ft
RES. LENGTH	59.999 ft	13.417 ft		264.16 ft	234 ft
1/V=[C/(SQR K)]	1.7602E-9				INSTR. ADDS;
RANDOM NOISE	0 volts	.55 volts		0 volts	0 ohms
PENETRATION AND INSITU TEST DATA HAVE TEST LEAD DATA SUBTRACTED				.146 RHO.	0 microH
PREDICTED R,L AND C INCLUDE INSTR. CONTRIBUTION					0 nf

CABLE # H281I/H282C TYPE FR-15WW PENETRATION AND TERMINALS R607/J1/g-a

INSTRUMENT TAG # RCP61-LS7A ELEVATION 305'0" DATE 09/19/83

PARAMETERS	CONTROL CABLE	PENETRATION	TEST LEADS	INSITU TEST	PREDICTED
LOOP RESISTANCE	.505 ohms	.0908 ohms	.411 ohms	1.8274 ohms	1.9398 ohms
TOTAL INDUCTANCE	13 microH	3.0412 microH	3.45 microH	49.509 microH	50.37186 microH
TOTAL CAPACITANCE	1.59 nf	.151 nf	.594 nf	SHORTED nf	7.0291 nf
INSUL. RESISTANCE	1.75E11 ohms	ohms	.65E11 ohms	4.9E8 ohms	>10E9 ohms
DISSIP. FACT.	OUT OF RANGE			.2	OUT OF RANGE
PROP. DELAY	1.6242 ns/ft	1.5883 ns/ft	1.4845 ns/ft	750 T/TIME	1.6242 ns/ft
Z1=[SQR(L/C)]	63.938 ohms	141.92 ohms	ohms	NA ohms	63.938 ohms
Z2=50(1+P/1-P)	66.279 ohms	ohms	ohms	54.058 ohms	66.279 ohms
AVE. L/FT.	.21806	.22667			.21806
AVE. C/FT.	.0261	.011254			.0261
AVE. RES. /FT.	.0083972	.0067675			.0083972
TDR LENGTH	59.999 ft	13.417 ft		199.48 ft	231 ft
IND. LENGTH	59.997 ft	13.417 ft		227.04 ft	231 ft
CAP. LENGTH	59.985 ft	13.417 ft		NA ft	231 ft
RES. LENGTH	59.999 ft	13.417 ft		217.62 ft	231 ft
1/V=[C/(SQR K)]	1.7602E-9				INSTR. ADDS;
RANDOM NOISE	0 volts	.55 volts		0 volts	0 ohms
PENETRATION AND INSITU TEST DATA HAVE TEST LEAD DATA SUBTRACTED				.039 RHO.	0 microH
PREDICTED R,L AND C INCLUDE INSTR. CONTRIBUTION					1 nf

CABLE # H281I/H284C TYPE FR-15WW PENETRATION AND TERMINALS R607/J1/p-n

INSTRUMENT TAG # RC-P-18 ELEVATION 305'0" DATE 09/19/83

PARAMETERS	CONTROL CABLE	PENETRATION	TEST LEADS	INSITU TEST	PREDICTED
LOOP RESISTANCE	.505 ohms	.0908 ohms	.411 ohms	OPEN ohms	OPEN ohms
TOTAL INDUCTANCE	13 microH	3.0412 microH	3.45 microH	OPEN microH	OPEN microH
TOTAL CAPACITANCE	1.59 nf	.151 nf	.594 nf	14.245 nf	10.7614 nf
INSUL. RESISTANCE	1.75E11 ohms	ohms	.65E11 ohms	NO DATA ohms	>10E9 ohms
DISSIP. FACT.	OUT OF RANGE			.0632	OUT OF RANGE
PROP. DELAY	1.6242 ns/ft	1.5883 ns/ft	1.4845 ns/ft	1410.5 T/TIME	1.6242 ns/ft
Z1=[SQR(L/C)]	63.938 ohms	141.92 ohms	ohms	NA ohms	63.938 ohms
Z2=50(1+P/1-P)	66.279 ohms	ohms	ohms	53.306 ohms	66.279 ohms
AVE. L/FT.	.21806	.22667			.21806
AVE. C/FT.	.0261	.011254			.0261
AVE. RES. /FT.	.0083972	.0067675			.0083972
TDR LENGTH	59.999 ft	13.417 ft		402.81 ft	374 ft
IND. LENGTH	59.997 ft	13.417 ft		NA ft	NA ft
CAP. LENGTH	59.985 ft	13.417 ft		507.47 ft	374 ft
RES. LENGTH	59.999 ft	13.417 ft		NA ft	NA ft
1/V=[C/(SQR K)]	1.7602E-9				INSTR. ADDS:
RANDOM NOISE	0 volts	.55 volts		0 volts	0 ohms
PENETRATION AND INSITU TEST DATA HAVE TEST LEAD DATA SUBTRACTED				.032 RHO.	0 microH
PREDICTED R,L AND C INCLUDE INSTR. CONTRIBUTION					1 nf

CABLE # H291I TYPE FR-15VY PENETRATION AND TERMINALS R607/J2/A-E

INSTRUMENT TAG # RCP58-FS1 ELEVATION 305'0" DATE 08/26/83

PARAMETERS	CONTROL CABLE	PENETRATION	TEST LEADS	INSITU TEST	PREDICTED
LOOP RESISTANCE	.508 ohms	.0908 ohms	.411 ohms	OPEN ohms	3.4634 ohms
TOTAL INDUCTANCE	12.2 microH	3.0412 microH	3.45 microH	OPEN microH	84.4801 microH
TOTAL CAPACITANCE	1.82 nf	.089 nf	.594 nf	5.767 nf	SHORTED nf
INSUL. RESISTANCE	1.4E11 ohms	ohms	.65E11 ohms	<10E6 ohms	>10E9 ohms
DISSIP. FACT.	OUT OF RANGE			.13	OUT OF RANGE
PROP. DELAY	1.6767 ns/ft	1.5883 ns/ft	1.4845 ns/ft	1438 T/TIME	1.6767 ns/ft
Z1=[SQR(L/C]	57.893 ohms	184.85 ohms	ohms	NA ohms	57.893 ohms
Z2=50(1+P/1-P)	63.379 ohms	ohms	ohms	72.399 ohms	63.379 ohms
AVE. L/FT.	.20361	.22667			.20361
AVE. C/FT.	.030386	.0066334			.030386
AVE. RES. /FT.	.0084472	.0067675			.0084472
TDR LENGTH	59.999 ft	13.417 ft		398.4 ft	410 ft
IND. LENGTH	59.999 ft	13.417 ft		NA ft	410 ft
CAP. LENGTH	59.999 ft	13.417 ft		189.79 ft	NA ft
RES. LENGTH	59.999 ft	13.417 ft		NA ft	410 ft
1/V=[C/(SQR K)]	1.7602E-9				INSTR. ADDS:
RANDOM NOISE	0 volts	.0029 volts		0 volts	0 ohms
PENETRATION AND INSITU TEST DATA HAVE TEST LEAD DATA SUBTRACTED				.183 RHO.	1 microH
PREDICTED R,L AND C INCLUDE INSTR. CONTRIBUTION					0 nf

CABLE # H291I TYPE FR-15VV PENETRATION AND TERMINALS R607/J2/D-J

INSTRUMENT TAG # RCP60-LS1 ELEVATION 305'0" DATE 08/26/83

PARAMETERS	CONTROL CABLE	PENETRATION	TEST LEADS	INSITU TEST	PREDICTED
LOOP RESISTANCE	.508 ohms	.0908 ohms	.411 ohms	3.4082 ohms	OPEN ohms
TOTAL INDUCTANCE	12.2 microH	3.0412 microH	3.45 microH	85.509 microH	OPEN microH
TOTAL CAPACITANCE	1.82 nf	.063 nf	.594 nf	SHORTED nf	13.45826 nf
INSUL. RESISTANCE	1.4E11 ohms	ohms	.65E11 ohms	NO DATA ohms	>10E9 ohms
DISSIP. FACT.	OUT OF RANGE			OUT OF RANGE	OUT OF RANGE
PROP. DELAY	1.6767 ns/ft	1.5883 ns/ft	1.4845 ns/ft	1484 T/TIME	1.6767 ns/ft
Z1=[SQR(L/C]	57.893 ohms	184.85 ohms	ohms	NA ohms	57.893 ohms
Z2=50(1+P/1-P)	63.379 ohms	ohms	ohms	77.551 ohms	63.379 ohms
AVE. L/FT.	.20361	.22667			.20361
AVE. C/FT.	.030386	.0066334			.030386
AVE. RES. /FT.	.0084472	.0067675			.0084472
TDR LENGTH	59.999 ft	13.417 ft		412.12 ft	410 ft
IND. LENGTH	59.999 ft	13.417 ft		419.96 ft	NA ft
CAP. LENGTH	59.999 ft	13.417 ft		NA ft	410 ft
RES. LENGTH	59.999 ft	13.417 ft		403.47 ft	NA ft
1/V=[C/(SQR K)]	1.7602E-9				INSTR. ADDS;
RANDOM NOISE	0 volts	.0029 volts		.00068 volts	0 ohms
PENETRATION AND INSITU TEST DATA HAVE TEST LEAD DATA SUBTRACTED				.216 Rh.J.	0 microH
PREDICTED R,L AND C INCLUDE INSTR. CONTRIBUTION					1 nf

CABLE # H293I/H294C TYPE FR-15WW PENETRATION AND TERMINALS R607/J2/p-n

INSTRUMENT TAG # RCP61-LS1A ELEVATION 305'0" DATE 09/19/93

PARAMETERS	CONTROL CABLE	PENETRATION	TEST LEADS	INSITU TEST	PREDICTED
LOOP RESISTANCE	.505 ohms	.0906 ohms	.411 ohms	450 ohms	3.5856 ohms
TOTAL INDUCTANCE	13 microH	3.0412 microH	3.45 microH	OPEN microH	93.11162 microH
TOTAL CAPACITANCE	1.59 nf	.156 nf	.594 nf	3.95 nf	12.1447 nf
INSUL. RESISTANCE	1.75E11 ohms	ohms	.65E11 ohms	NO DATA ohms	>10E9 ohms
DISSIP. FACT.	OUT OF RANGE			OUT OF RANGE	OUT OF RANGE
PROP. DELAY	1.6242 ns/ft	1.5883 ns/ft	1.4845 ns/ft	1296.5 T/TIME	1.6242 ns/ft
Z1=[SQR(L/C]	63.938 ohms	139.62 ohms	ohms	NA ohms	63.938 ohms
Z2=50(1+P/1-P)	66.279 ohms	ohms	ohms	57.197 ohms	66.279 ohms
AVE. L/FT.	.21806	.22667			.21806
AVE. C/FT.	.0261	.011627			.0261
AVE. RES. /FT.	.0083972	.0067675			.0083972
TDR LENGTH	59.999 ft	13.417 ft		367.72 ft	427 ft
IND. LENGTH	59.997 ft	13.417 ft		NA ft	427 ft
CAP. LENGTH	59.985 ft	13.417 ft		113.03 ft	427 ft
RES. LENGTH	59.999 ft	13.417 ft		NA ft	427 ft
1/V=[C/(SQR K)]	1.7602E-9				INSTR. ADDS:
RANDOM NOISE	0 volts	.5 volts		.05 volts	0 ohms
PENETRATION AND INSITU TEST DATA HAVE TEST LEAD DATA SUBTRACTED				.06714 RHO.	0 microH
PREDICTED R, L. AND C INCLUDE INSTR. CONTRIBUTION					1 nf

CABLE # H293I/H296C TYPE FR-15WW PENETRATION AND TERMINALS R607/J2/S-K

INSTRUMENT TAG # RC-P-1A ELEVATION 305'0" DATE 09/19/83

PARAMETERS	CONTROL CABLE	PENETRATION	TEST LEADS	INSITU TEST	PREDICTED
LOOP RESISTANCE	.505 ohms	.0908 ohms	.411 ohms	4.7E6 ohms	OPEN ohms
TOTAL INDUCTANCE	13 microH	3.0412 microH	3.45 microH	OPEN microH	OPEN microH
TOTAL CAPACITANCE	1.59 nf	.156 nf	.594 nf	18.15 nf	12.7107 nf
INSUL. RESISTANCE	1.75E11 ohms	ohms	.65E11 ohms	NO DATA ohms	>10E9 ohms
DISSIP. FACT.	OUT OF RANGE			.45	OUT OF RANGE
PROP. DELAY	1.6242 ns/ft	1.5883 ns/ft	1.4845 ns/ft	1609.5 T/TIME	1.6242 ns/ft
Z1=[SQR(L/C)]	63.938 ohms	139.62 ohms	ohms	NA ohms	63.938 ohms
Z2=50(1+P/1-P)	66.279 ohms	ohms	ohms	52.775 ohms	66.279 ohms
AVE. L/FT.	.21806	.22667			.21806
AVE. C/FT.	.0261	.011627			.0261
AVE. RES. /FT.	.0083972	.0067675			.0083972
TDR LENGTH	59.999 ft	13.417 ft		464.07 ft	487 ft
IND. LENGTH	59.997 ft	13.417 ft		NA ft	NA ft
CAP. LENGTH	59.985 ft	13.417 ft		695.4 ft	487 ft
RES. LENGTH	59.999 ft	13.417 ft		NA ft	NA ft
1/V=[C/(SQR K)]	1.7602E-9				INSTR. ADDS:
RANDOM NOISE	0 volts	.5 volts		1.2 volts	0 ohms
PENETRATION AND INSITU TEST DATA HAVE TEST LEAD DATA SUBTRACTED				.027 RHO.	0 microH
PREDICTED R, L AND C INCLUDE INSTR. CONTRIBUTION					0 nf

CABLE # H293I/H295C TYPE FR-15WW PENETRATION AND TERMINALS R607/J2/g-a

INSTRUMENT TAG # RCP61-LS2A ELEVATION 305'0" DATE 09/19/83

PARAMETERS	CONTROL CABLE	PENETRATION	TEST LEADS	INSITU TEST	PREDICTED
LOOP RESISTANCE	.505 ohms	.0908 ohms	.411 ohms	2.7882 ohms	3.5856 ohms
TOTAL INDUCTANCE	13 microH	3.0412 microH	3.45 microH	79.109 microH	93.11162 microH
TOTAL CAPACITANCE	1.59 nf	.156 nf	.594 nf	SHORTED nf	SHORTED nf
INSUL. RESISTANCE	1.75E11 ohms	ohms	.65E11 ohms	NO DATA ohms	>10E9 ohms
DISSIP. FACT.	OUT OF RANGE			0	OUT OF RANGE
PROP. DELAY	1.6242 ns/ft	1.5883 ns/ft	1.4845 ns/ft	1386.5 T/TIME	1.6242 ns/ft
Z1=[SQR(L/C)]	63.938 ohms	139.62 ohms	ohms	NA ohms	63.938 ohms
Z2=50(1+P/1-P)	66.279 ohms	ohms	ohms	60.047 ohms	66.279 ohms
AVE. L/FT.	.21806	.22667			.21806
AVE. C/FT.	.0261	.011627			.0261
AVE. RES./FT.	.0083972	.0067675			.0083972
TDR LENGTH	59.999 ft	13.417 ft		395.43 ft	427 ft
IND. LENGTH	59.997 ft	13.417 ft		362.79 ft	427 ft
CAP. LENGTH	59.985 ft	13.417 ft		NA ft	NA ft
RES. LENGTH	59.999 ft	13.417 ft		332.04 ft	427 ft
1/V=[C/(SQR K)]	1.7602E-9				INSTR. ADDS:
RANDOM NOISE	0 volts	.5 volts		.02 volts	0 ohms
PENETRATION AND INSITU TEST DATA HAVE TEST LEAD DATA SUBTRACTED				.0913 RHO.	0 microH
PREDICTED R,L AND C INCLUDE INSTR. CONTRIBUTION					0 nf