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ADVANCED TECHNOLOGIES FOR MAINTENANCE OF ELECTRICAL SYSTEMS AND EQUIPMENT AT THE SAVANNAH RIVER SITE DEFENSE WASTE PROCESSING FACILITY (U)

by

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SUMMARY

An enhanced maintenance program is being established to characterize and monitor cables, components, and process response at the Savannah River Site, Defense Waste Processing Facility. This facility was designed and constructed to immobilize the radioactive waste currently stored in underground storage tanks and is expected to begin operation in 1993. The plant is initiating the program to baseline and monitor instrument and control (I&C) and electrical equipment, remote process equipment, embedded instrument and control cables, and in-cell jumper cables used in the facility.

This program is based on the electronic characterization and diagnostic (ECAD) system which was modified to include process response analysis and to meet rigid Department of Energy equipment requirements. The system consists of computer-automated, state-of-the-art electronics. The data that are gathered are stored in a computerized database for analysis, trending , and troubleshooting. It is anticipated that the data which are gathered and trended will aid in life extension for the facility.

INTRODUCTION

The Savannah River Site (SRS) has been in operation since 1953. The mission of the site is to produce nuclear materials for the Department of Energy (DOE).

Radioactive waste resulting from the production of nuclear materials at the site is presently being stored in large double-wall, shielded underground storage tanks. Approximately 33 million gallons of this waste are being stored.

The Defense Waste Processing Facility (DWPF) was designed and constructed to immobilize the radioactivity in the SRS waste. Construction of the DWPF was initiated in 1983 and is essentially complete.

Three types of waste are to be processed at the DWPF: highly radioactive insoluble sludge, highly radioactive precipitate, and less radioactive water-soluble salts. The waste will be processed in two main facilities: the Vitrification Facility (S Area), and the Saltstone Facility (Z Area).

The Saltstone Facility mixes decontaminated salt solution with cement, furnace slag, and fly ash. This immobilizes any radioactive components. The grout produced by this process is pumped to aboveground storage vaults, where it hardens into concrete blocks. The hardened product is referred to as saltstone. Each block will consist of about 1.35 million cubic feet of saltstone, containing 6.0 million gallons of salt solution. The facility is designed to handle approximately 9 million gallons of decontaminated salt solution per year. The Saltstone Facility has been constructed, checked out, started up, and is presently processing low level radioactive waste.

The Vitrification Facility is used to process the high level radioactive portion of the waste. The waste is chemically neutralized, then mixed with borosilicate glass frit. The resulting glass slurry is then melted to incorporate the components in a borosilicate glass matrix, thus reducing the mobility of the radionuclides.

The molten glass is poured into stainless steel canisters. The glass hardens in the canisters and the canisters are decontaminated, welded shut, and transported to a temporary storage facility. They will be permanently stored in the federal waste repository when it is completed.

The DWPF vitrification equipment is presently in the final stages of checkout, to be followed by water runs, cold chemical runs, and finally hot startup. Because of the intense radiation involved in the vitrification process, most of the operations are conducted in closed concrete cells, contained in a canyon shielded by thick concrete walls, and observed with closed circuit television or through lead-glass shielding windows. Installation and removal of equipment in the cells is performed remotely using overhead cranes and manipulators. All processes conducted in these cells are designed for totally remote operation and maintenance.

Process and electrical connections in the canyon are made with remotely coupled jumpers. The jumpers are, primarily, rigid stainless steel pipe assemblies containing the required instrumentation and electrical conductors; however, some flexible jumpers are being used.

DISCUSSION

Power and instrumentation signals for in-cell process equipment are routed from service corridors external to the canyon, through circuits embedded in the shielding walls, to removable jumpers (equipped with Hanford connectors), and then to the process equipment. The embedded wiring, process equipment, and jumpers have been designed for remote removal and replacement.

One of the objectives for the DWPF is to obtain at least 75% of process design capacity. This requires the ability to quickly identify, locate, and replace any failed cables or equipment and the ability to determine when a piece of equipment or a process is degrading and will need to be monitored or replaced.

SRS operates most facilities using a "Replace and Repair" maintenance philosophy. The strong point of this concept is that it minimizes personnel radiation exposure and equipment downtime. If instituted properly, Replace and Repair also ensures that installable operating spares are available for the process. The negative side of Replace and Repair is that there is a tendency to replace the final element, such as a motor or a resistance temperature detector (RTD), rather than the possibly failed jumper wires or Hanford connector. Replacement of the wrong component wastes time, spreads contamination, and stresses equipment.

The DWPF Works Engineering Department has initiated a program to minimize misidentifying/replacing the wrong parts. Two major components provide the framework for this innovative program; the ECAD System 1000 (ECAD Division of Pentek, Inc., Pittsburgh, PA) and Protuner PC-1200 (Techmation, Tempe, AZ). Both of these components are used to monitor the process or equipment and to gather and store dynamic and stimuli/response related information in an electronic database.

The database organizes the information and forms the basis for trending and analysis. Periodic retesting of the equipment or process adds to existing data and enables evaluation as to how well the systems are withstanding the environment. Aging and component degradation information may be used for predicting further maintenance requirements and plant life extension. Stimuli/response data may be used to tune the process and optimize performance.

The predictive maintenance program is presently being implemented. Works Engineering engineers and Electrical and Instrumentation mechanics have been trained on how to acquire baseline data and troubleshoot circuits, equipment, and processes.

The first data obtained using the diagnostic system revealed unanticipated plant equipment problems (see CASE STUDIES article). Testing procedures were developed in the course of the troubleshooting these problems.

DIAGNOSTIC SYSTEM DESCRIPTION

ECAD is an acronym for electronic characterization and diagnostics, and is applied to the testing of instrumentation, control, and power circuits. The ECAD approach is based on viewing the plant circuit as an rf transmission line with a load, and analyzing the lumped and distributed circuit elements. Typical transmission lines include parallel wires, wire over a ground plane, and coaxial cable. Direct current and radio frequency testing techniques can be applied to determine and monitor those electrical characteristics necessary for circuit functionality assessment. The direct current or low frequency measurements provide the lumped values of circuit loop resistance, shunt resistance, inductance, and capacitance. These measurements provide the best indication of circuit degradation, but cannot determine where the degradation is occurring. Using the radio frequency technique of analyzing reflected electromagnetic pulses in the time domain, the circuit is analyzed as an rf transmission line, consisting of a series of resistors, inductors, and capacitors. This technique, known as time-domain reflectometry (TDR), identifies the distributed resistance, inductance, and capacitance of the circuit, and can accurately detect the location of circuit degradation. The information acquired by these two testing techniques not only reveals the degree of circuit degradation, but also the nature and location of the problem (Figure 1 and Table I).

The ECAD System 1000 is a completely automated data acquisition system consisting of state-of-the-art electronic test equipment and a computer. The computer provides complete control of the test instrumentation through the IEEE-488 interface bus using specially designed software. The basic measurements acquired by the system include AC/DC voltage (noise), insulation resistance, DC loop resistance, impedance, inductance, capacitance, and time-domain reflectometry signature. These measurements, along with circuit identification information and testing history, form the ECAD portion of the database. The ECAD System conducts all measurements remotely using a 2-wire connection to the circuit under test. Presently, the system is able to monitor a circuit with the load approximately 3000 ft from the test point.

Figure 2 is a one-line diagram for a typical RTD circuit. To completely characterize this RTD circuit, a total of nine tests would be performed. Time per test ranges from 1 to 3 minutes, depending on the circuit configuration and whether or not an insulation resistance test is required. For example, a test across an RTD element would show a low ohmic value and would not require an insulation test resulting in a one-minute test duration. A test from the shield to ground would indicate an open circuit at the end device and an insulation resistance test would be automatically conducted at an operator specified voltage.

Upon test completion a quick-look data chart is produced as shown in Figure 3. This chart displays circuit descriptive information, lumped element data and the TDR signature. If previous data exists for the device under test, the computer automatically recalls and prints the baseline data for trend comparisons.

APPLICATION OF THE DIAGNOSTIC SYSTEM AT THE DWPF

DWPF Works Engineering has selected the following circuits or processes for initial testing and baseline using the diagnostic system:

- all safety circuits
- all embedded circuits
- all canyon jumpers and process equipment
- circuits with a history of problems
- distributed control system network cables
- closed circuit television cables

Additionally, any circuit being replaced is considered for testing.

The baseline program is being implemented as follows:

Known good equipment and circuits are first identified and a computerized testing strategy is proposed. In cases where the vendor has made recommendations on how to test the equipment, recommended tests are incorporated into the strategy. In cases where no recommended tests have been identified, a similar circuit is built using new components.

The good circuit is then tested and the testing strategy is verified. All circuits which may be tested using this strategy are identified. The test strategy is duplicated into a file for each circuit. This ensures that all similar circuits are tested in the same manner.

The circuits are then tested and the data stored in the database. Once all the circuits have been tested, the tests are grouped by test configuration and statistical analysis is performed on the data. Circuits which deviate from the norm are identified and the test data are reviewed. In some cases, retesting or troubleshooting of the deviate circuit is required.

This represents a different approach to traditional testing and establishing a baseline. Because the data are stored in the database, computer analysis can easily be accomplished and problems resulting from infant mortality, improper installation, or poor construction practices can often be identified. Having test data on known good circuits to use for comparison is a great aid in trouble shooting.

In case of the removal/repair and subsequent replacement of canyon equipment, the following procedure is followed:

Prior to removal, the circuit and equipment are analyzed using the diagnostic system. If required, the equipment is removed for repair. Following removal, the circuits embedded in the canyon wall are analyzed. After the jumper or equipment is repaired, it is again tested with the diagnostic system before re-installation. The installation is made and the entire circuit is again diagnosed. Comparing the data obtained after re-installation with the data obtained on the embedded circuits and jumper/equipment allows a thorough evaluation of the new installation.

CASE STUDIES

The most dramatic results from the use of the diagnostic system have been obtained as a result of the baseline effort. During baseline and the subsequent troubleshooting of suspected circuits or processes, design and installation problems were discovered.

The following problems are representative of situations identified and resolved with the aid of the diagnostic system. Most of the equipment diagnosed was previously checked out and tested using conventional methods such as continuity and megger testing before it was analyzed by the diagnostic system.

In discussing these problems, some situations have necessarily been simplified since complete information would require detail outside the scope of this paper.

Loose Hanford Connector. In September 1988, ECAD representatives were at the DWPF to test circuits and give a demonstration of the system. Works Engineering suggested that they look at an RTD circuit that had been giving problems. After collecting data, the problem was identified as a poorly made (partially open) connection at a Hanford connector. This problem was evident in the resistance, impedance, and time-domain reflectometry data. Investigation revealed that the Hanford connector had been tightened with a knock wrench instead of an impact wrench and that there was indeed a poor connection. Re-impacting the jumper fixed the problem.

Improper Installation of RTD's. Statistical analysis of baseline data on numerous RTD circuits showed that a number of jumper mounted RTD's had the reference lead and shield switched in the jumper. The TDR identified this problem by indicating an impedance mismatch at the jumper. Although the RTD would function, it needed to be rewired correctly.

Improper Cabling and Installation for Flow Meters. The flow meters being used were designed to develop a microvolt signal which is proportional to flow. Data obtained during baseline for these circuits showed 70+ millivolts of noise on the circuits. Investigation revealed that the wrong cable type had been installed. The proper cable was obtained and installed. This lowered the noise level but did not eliminate it. Further testing revealed that the remaining noise was being impressed on the circuit at a terminal strip. Additional shielding resolved this problem.

Dirt and Debris in Electrical Connectors. A failed mass flow meter which had been repaired was baselined before re-installation. After re-installation the circuit was again tested. One of the test configurations revealed 3 ohms more resistance than predicted by the statistical value obtained from the accumulated baseline data for this type of circuit. The jumper was loosened then tightened, the resistance increased. Analysis of the TDR data determined that the change had occurred at the upper Hanford connector. The jumper was removed and personnel were lowered by crane to the wall connector inside the cell. Visual inspection revealed that dirt and debris had entered the connector while the jumper was being repaired.

Bad Coax Connectors. The canyon processes are observed via closed circuit-television. Cables used to operate the cameras contain 40 conductors. Conventional test methods had been used to troubleshoot a failed camera; however, the problem could not be determined. The diagnostic system was employed and , based on the data obtained from similar video circuits, the problem was found to be a bad coax connector.

Cold Solder Connections in Hanford Connectors Resistance greater than expected from the statistically developed profile for a particular jumper configuration led to the removal of a suspect jumper. Investigation revealed that there were poor solder connections inside the jumper.

CONCLUSION

To date, the use of this innovative trending and diagnostic tool has identified many problems which could have gone unchecked and have led to plant operating problems after startup. It is expected that continued application of the system for baselining plant circuits and ongoing performance monitoring will provide a key function in the overall maintenance strategy at the DWPF.

ACKNOWLEDGEMENT

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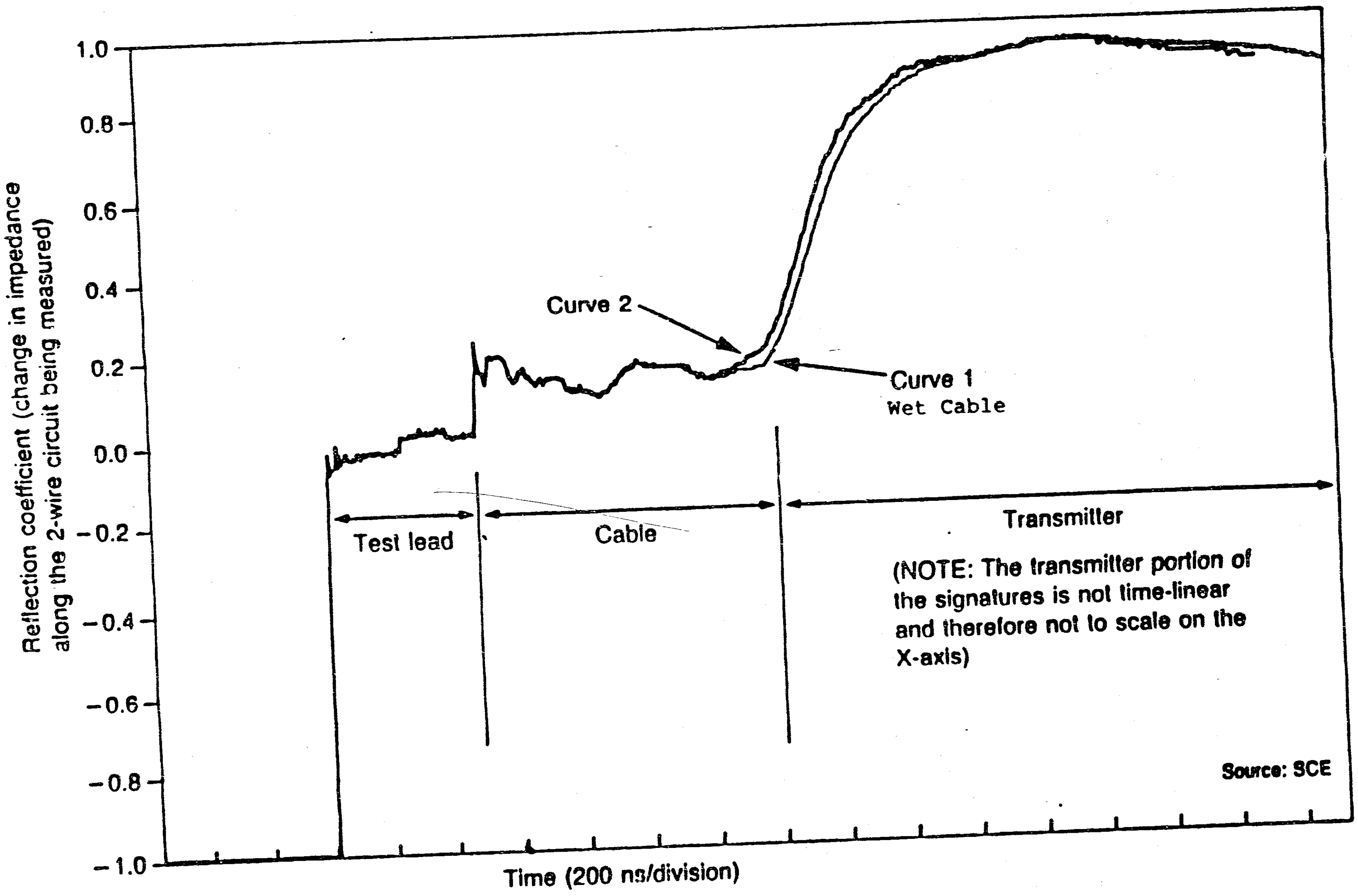


(NOTE: The transmitter portion of the signatures is not time-linear and therefore not to scale on the X-axis)

Source: SCE

Figure 1. TDR Data Showing Location of Wet Cable

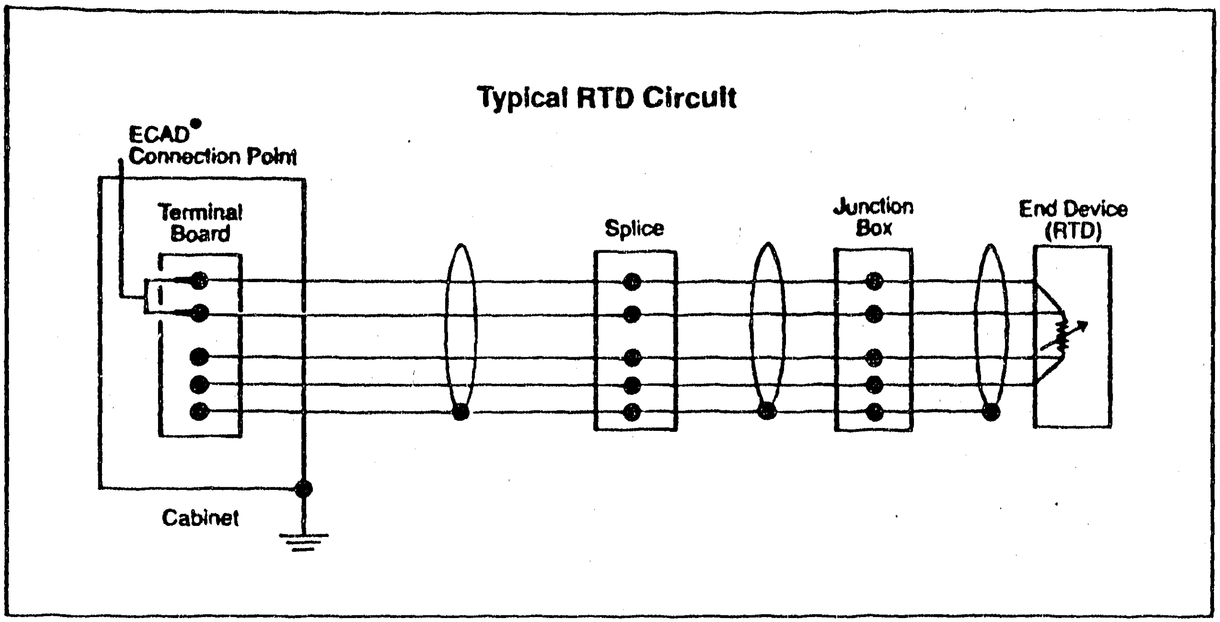


Figure 2. One-Line Diagram Showing ECAD Testing Connection

ECAD SERVICES INC. EF 100

CIRCUIT IDENTIFICATION
DEVICE CODE: 11E101
DESCRIPTION: 4 WIRE RTD TRAINING MODEL
DEVICE TYPE: RTD4 CONFIGURATION: A

OPERATOR IDENTIFICATION
LAST NAME: SERENA FIRST: KEN SS#: - -
LAST NAME: FIRST: SS#: - -

TEST AREA: ECAD SHOP TERMINATION: TERM. BLK. ID CODE: TB-A MO#: 000000000002
HIGH TEST POINT: TB ID CODE: A PIN: 1
LOW TEST POINT: TB ID CODE: A PIN: 2

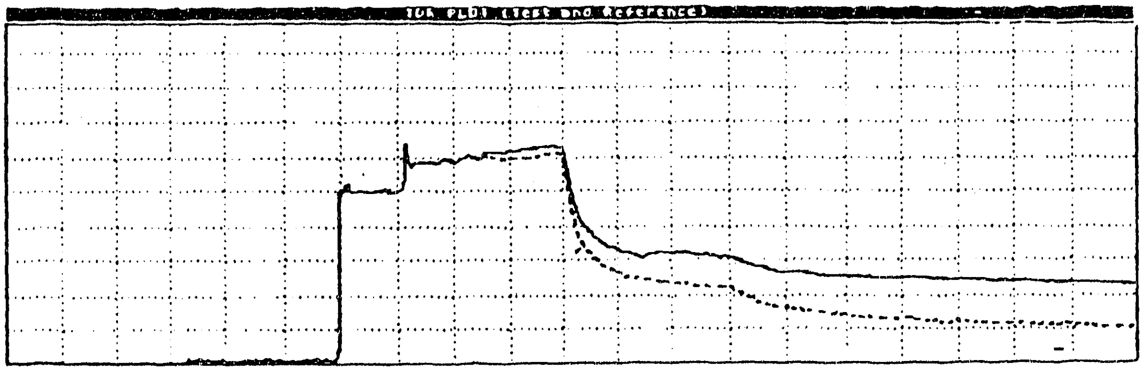
U MEASUREMENT UNDEFINED
L INDUCTANCE/QUALITY (H/UNITY)
C CAPACITANCE/DISSIPATION (F/UNITY)

	VOLTAGE(V)	DC RESISTANCE(OHMS)		AC RESISTANCE(OHMS)		REACTANCE(OHMS)			
	VAC + VDC	FIRST	FINAL	1 KHZ	10 KHZ	1 KHZ	10 KHZ	1 KHZ	10 KHZ
(R)	6.44 m	1.50	1.50	1.53	1.57	111.80 m	1.09	L 17.67 u/ 72.60 m	L 17.40 u/697.51 m
(T)	4.77 m	11.69	11.69	11.72	11.76	109.00 m	1.08	L 17.35 u/ 9.30 m	L 17.11 u/ 91.39 m

IR Test Voltage: 0 V Polarization Index: 1.00 IR Test Duration: 0 Seconds

(R) REFERENCE DATA -- DATE: 08/29/90 TIME: 16:15
(T) CURRENT DATA -- DATE: 08/30/90 TIME: 13:44

G = Giga M = Mega K = Kilo
m = milli u = micro n = nano p = pico



Horizontal Distance

Test 1 (Solid)
Instrument Cables: 32 ft/div (approx)
Power Cables: 25 ft/div (approx)
Time Base: 100 nS

Reference (Dashed)
Instrument Cables: 32 ft/div (approx)
Power Cables: 25 ft/div (approx)
Time Base: 100 nS

Vertical Rho = .2/div

Figure 3. ECAD Data Chart

Table I. Flow Transmitter Data Following Cable Replacement

```
                                        ECAD  SYSTEM  2000

                                                                                        Page:  2
                                                                                        Date:  05/05/90
=======================================================================================================
                    Test         DC       1 Khz AC   10 KHz AC          1 KHz                   10 KHz
Date      Time    Voltage    Resistance  Resistance  Resistance            Capacitance/Dissipation)
-------------------------------------------------------------------------------------------------------


DEVICE: S1-RCS-FT-420          DESCRIPTION: RCS FLOW XMITTER LOOP C

                  ┌─ August test with wet cable
                  │          ┌─ Current test with good cable
                  │          │
08/04/89  17:22 ──┘  < 6.5   │     0.00        4.85K      98.63     31.36 nf / 954.89 m    16.56 nf / 102.64 m
05/01/90  12:32      < 6.5 ──┘    31.00 M      1.05 K     33.32     11.20 nF /  74.00 m    10.89 nF /  22.80 m
05/01/90  12:35      100           3.78 G      9.61        6.31     16.24 nF /   0.98 m    16.28 nF /   6.45 m
05/01/90  12:38      100           3.84 G      9.48        6.23     16.35 nF /   0.97 m    16.38 nF /   6.41 m
05/01/90  12:42      100          26.45 M      2.43 K    151.49     11.63 nF / 177.39 m     9.60 nF /  91.41 m
```

Table I.   Flow Transmitter Data Following Cable Replacement

```
                                  E C A D   S Y S T E M   2 0 0 0

                                                                                          Page:  2
                                                                                          Date:  05/05/90
==========================================================================================================
                      Test        DC        1 Khz AC    10 KHz AC     -    1 KHz                10 KHz
  Date      Time     Voltage   Resistance   Resistance  Resistance          Capacitance/Dissipation)
----------------------------------------------------------------------------------------------------------


DEVICE: S1-RCS-FT-420        DESCRIPTION: RCS FLOW XMITTER LOOP C

                   ┌─ August test with wet cable
                   │      ┌─ Current test with good cable
                   │      │
  08/04/89  17:22 ─┘ < 6.5 │     0.00        4.85K       98.63      31.36 nf /  954.89 m     16.56 nf /  102.64 m
  05/01/90  12:32   < 6.5 ─┘    31.00 M      1.05 K      33.32      11.20 nF /   74.00 m     10.89 nF /   22.80 m
  05/01/90  12:35    100         3.78 G      9.61         6.31      16.24 nF /    0.98 m     16.28 nF /    6.45 m
  05/01/90  12:38    100         3.84 G      9.48         6.23      16.35 nF /    0.97 m     16.38 nF /    6.41 m
  05/01/90  12:42    100        26.45 M      2.43 K     151.49      11.63 nF /  177.39 m      9.60 nF /   91.41 m
```

END

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