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# INSTRUMENTATION AND ELECTRICAL PROGRAM AT THE THREE MILE ISLAND UNIT 2 TECHNICAL INTEGRATION OFFICE

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ABSTRACT

The Three Mile Island Unit 2 accident of March 28, 1979 presents unique research opportunities that can provide valuable information on nuclear power plant safety philosophy and safety systems performance. The Technical Integration Office at Three Mile Island was established by the Department of Energy to manage a broad-based research and development program. One significant part of this effort is the Instrumentation and Electrical Program, which operates (a) to identify instruments and electrical components that failed during or since the accident, (b) to test and analyze them in order to identify the causes of failure, and (c) to assess the survivability of those that did not fail.

The basis for selection of equipment is discussed, and the testing methodology is described. Also, some results of Instrumentation and Electrical Program work to date are presented.

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THE MARCH 28, 1979 ACCIDENT at the Three Mile Island Unit 2 power plant (TMI-2) was the most severe test of nuclear power plant safety philosophy and safety systems performance ever encountered in a commercial light-water reactor system.

In its postaccident condition, TMI-2 offers unique research opportunities that are of potentially great value to the nuclear power industry. Four organizations--General Public Utilities Company (GPU), the Electric Power Research Institute (EPRI), the U.S. Nuclear Regulatory Commission (NRC), and the U.S. Department of Energy (DOE)--decided to capitalize on these opportunities. These four organizations, collectively called the GEND group--an acronym composed of the initial letters of their names--entered into an agreement designed to ensure that the research opportunities not be lost.

Day-to-day operation of the Department of Energy's portion of the Technical Information and Examination Program (TI&EP) is directed by the Technical Integration Office (TIO) located at Three Mile Island, which* is operated for DOE by EG&G Idaho, Inc. The underlying purpose of the TI&EP is to ensure that accident and recovery-related information of value to the nuclear power industry not be lost. To achieve this purpose, the TI&EP incorporates four major programs:

- Reactor Evaluation Program--designed to assess the extent of reactor core damage resulting from the accident

- Waste Immobilization Program--designed to identify, develop, and evaluate waste management techniques and technology for the abnormal wastes produced by the accident and recovery efforts

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*Work supported by the U.S. Department of Energy, Assistant Secretary for Nuclear Energy, Office of Coordination and Special Projects, under DOE Contract No. DE-AC07-76ID01570.

- Radiation and Environment Program--designed to obtain and analyze radiation, fission product, temperature, and decontamination data relating to the accident and cleanup

- Instrumentation and Electrical Program--designed to determine the effects of accident and postaccident environments on instrumentation and electrical equipment.

## INSTRUMENTATION AND ELECTRICAL PROGRAM OBJECTIVE

More specifically, the objective of the Instrumentation and Electrical (I&E) Program is to assess the ability of specific systems, instruments, and electrical components to perform their intended functions during and after an accident. The data collected will provide the nuclear power industry with valuable information concerning the adequacy of the following:

- Systems and equipment to withstand accident conditions

- Qualification procedures

- Current instrument and electrical standards

- Plant construction and installation procedures

- Plant operating and maintenance procedures.

## PROGRAM METHODOLOGY

During and after the accident, plant equipment experienced a wide range of temperature, radiation, and wetting conditions. The specific environments to which any given piece of equipment was subjected depend on that equipment's location within the reactor building. A thorough analysis of all the equipment located in the reactor building, while desirable, may not be effective from a cost, and more importantly, from a man-rem exposure stand-point.

Thus, I&E personnel from the TIO, with the guidance of an industry advisory group, devised a sampling of 15 categories of instrumentation and electrical components that had experienced varied environments. Instrumentation components include (1) resistance temperature devices, (2) pressure transducers, (3) self-powered neutron detectors, (4) radiation monitors, (5) vibration detectors, and (6) thermocouples; electrical components include (7) cables, (8) the polar crane, (9) motors, (10) motor control circuits, (11) relays, (12) solenoids, (13) switches, (14) heaters, and (15) valve controllers.

In order to determine whether these selected items are fully operational, non-operational, or are exhibiting degraded performance, I&E personnel are employing a two-part analysis. The first part involves remote testing of the equipment while it is still in place in the reactor building. This "in situ" testing allows information to be compiled on a large number of components without the expense of removing equipment and without disturbing the system under test.

In situ testing is used primarily to detect anomalies requiring detailed laboratory examination, which is the second part of the analysis--actually removing devices from the reactor building, packaging them, transporting them to a laboratory, and disassembling them for in-depth examination and analysis.

To date, in situ testing has comprised the major portion of I&E Program activities. A typical in situ test involves two major measurement techniques: (a) resistance and reactance, and (b) time domain reflectometry.

RESISTANCE AND REACTANCE TESTING - Resistance measurements provide evidence of such discontinuities as short circuits, if such failures exist. Figure 1 is a line diagram of a typical component chosen for in situ testing (a reactor coolant system limit switch). The diagram shows the component, the remote test point, and all the cabling and connections in between. Reactance testing--readings of inductance and capacitance--provides an additional confirmation of circuit integrity.

TIME DOMAIN REFLECTOMETRY - Although resistance and reactance measurements can quickly and easily indicate the presence of a discontinuity, such tests cannot pinpoint the location of the failure, which could be anywhere from inside the component out to the remote test point. Therefore, after these tests indicate that a discontinuity exists, additional testing is necessary to locate the exact point of discontinuity. Time Domain Reflectometry (TDR) measurement, which is slightly more elaborate than resistance and reactance testing, can indicate the location of a circuit discontinuity. TDR is similar to radar in that a pulse is sent down a cable and its reflection is monitored. Short circuits, open circuits, and other discontinuities are displayed as changes in reflected voltage on a cathode ray tube or a strip-chart recorder. Figure 2 shows a TDR stripchart trace that exhibits an open condition at the instrument (in this figure, a control rod drive motor). The horizontal scale is calibrated in units of length so that the point of discontinuity can be readily determined. The vertical scale is a measure of reflected signal amplitude and can be used to determine the impedance of a discontinuity. The small discontinuity labeled "penetration" is due to the normal impedance mismatch caused by terminations and splices in a reactor building penetration. If the cable were opened at the penetration, the trace would continue rising at that point.

## TESTING PROGRAM STATUS

In October 1981 the I&E Program began a systematic effort to perform in situ testing on a selected number of instruments and electrical components, and to use the results of these tests as a decision basis for removal and further testing of selected pieces of equipment. As of March 1982, 39 devices were tested. Of these devices, 29 were found to be operating properly, but 10 exhibited anomalies and have been or will be removed for in-depth examination. Also as of March 1982, 15 components have been removed from the reactor building for analysis, and testing is complete or underway on all of these.

## RESULTS TO DATE



Engineers performing examinations of these failed components have encountered two major contributors to failures--installation and electronic failure from radiation damage. Examples are discussed below.

An example of failure associated with installation is an area radiation detector that was located near the personnel access hatch in the reactor building. This detector was installed upside down. As a result, reactor building sprays (which operated properly during the accident) entered an improperly mated connector back-shell, allowing shorts and causing instrument failure.

An example of electronic failure also provides an excellent example of how the work of the I&E Program benefits the nuclear power industry. Charge converters used in the Loose Parts Monitoring (LPM) systems at TMI-2 apparently failed within the first two days of the accident. Detailed investigations into the failure of the LPM system indicated that the Metal Oxide Semiconductor (MOS) field-effect transistors contained in the converters are not suitable for use in high-radiation fields such as are found adjacent to a nuclear reactor core. This analysis was performed by Sandia National Laboratories in support of the TIO.*

Rockwell International (Rockwell), supplier of the LPM system, as well as the firm that supplied the charge converters to Rockwell, conducted independent examinations of the converters. Both examinations verified that the MOS field-effect transistors used in the charge converter would fail due to excessive radiation exposure at levels of approximately $10^5$ rad.

Although the TMI-2 LPM systems were mounted in areas where radiation doses during normal plant operations would be well below the damage threshold, the radiation release inside the containment during the accident was high enough to cause failure.

Degradation of charge converters has also been observed at the Tennessee Valley Authority's Sequoyah-1 nuclear generating station, where the LPM systems are mounted in high radiation areas near the reactor vessel and steam generators. At Sequoyah-1,

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*Michael B. Murphy, Geoffrey M. Mueller, and Frank V. Thome, Examination Results of the Three Mile Island Radiation Detector HP-R-211, GEND-014, October, 1981.

the MOS field-effect transistors were damaged after less than one year of reactor operation. At both TMI-2 and Sequoyah-1, radiation damage to the transistors did not produce sudden failure, but rather caused gradual transistor deterioration.

In a letter to the TIO, Rockwell expressed appreciation that useful information being developed through TMI-2 research is being passed on to industry. Rockwell went on to report development of their own charge converter using junction field-effect transistors. Rockwell tested three circuit designs in their gamma radiation facility, and five production prototypes, all anticipated to show radiation resistance in excess of $10^7$ rad, are now being prepared for irradiation testing.

## CONCLUSION

The I&E Program work to date indicates that most equipment at TMI-2 seems to be functioning properly. However, information of great value to the nuclear power industry is being gained from analysis of those devices that failed or that exhibit degraded performance because of the post-accident environment. The Instrument and Electrical Program, managed by the Three Mile Island Technical Integration Office, will continue its in situ testing and its removal and examination of selected equipment to increase knowledge of how to protect nuclear power plant equipment from accident damage and thus to improve industry-wide accident-mitigation capabilities.

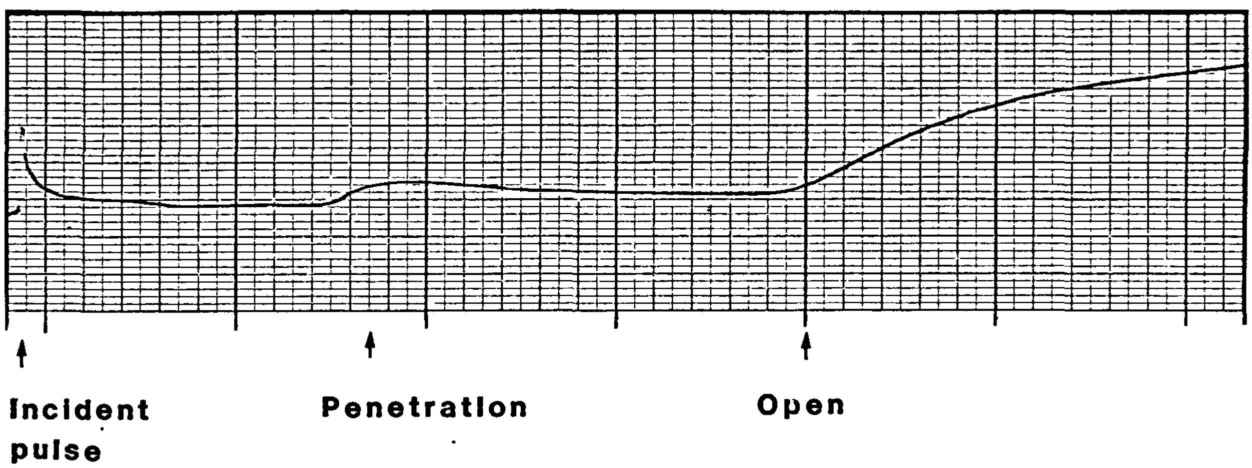
Fig. 1 - Interconnection diagram of AH-KS-5000, a limit switch in the TMI-2 reactor building cooling system

Fig. 2 - Time domain reflectometry trace

LORI ANN HECKER received a bachelor's degree in nuclear engineering from the Pennsylvania State University in May 1980.

While still a student, Lori worked as an intern at the EG&G Idaho, Inc. TMI-2 Technical Integration Office (TIO), and after graduation she returned to the TIO as an engineer assigned to the Instrumentation and Electrical Program. Her responsibilities include defining and conducting pretest, test, and posttest activities; assisting in preparing test procedures; evaluating test programs; reviewing and evaluating acquired data; and compiling data and summaries into reports for publication.

Ms. Hecker is a member of the Society of Women Engineers and an associate member of the American Nuclear Society.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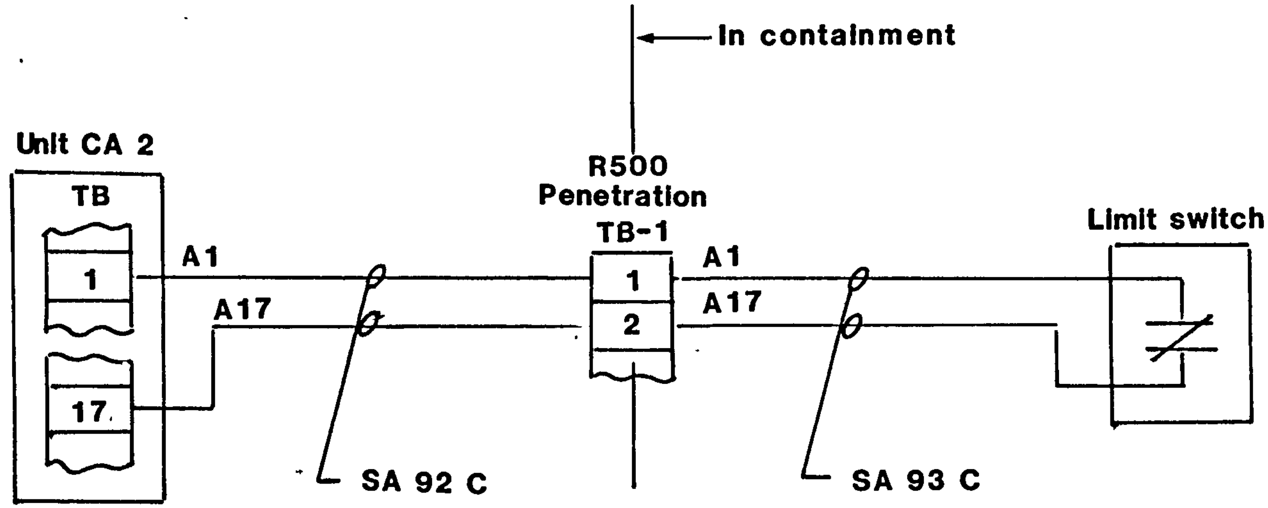


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