TENNESSEE VALLEY AUTHORITY
CHATTANOOGA, TENNESSEE
37401

TVA 40TH ANNIVERSARY OF PEOPLE IN PARTNERSHIP

July 30, 1973

Mr. F. E. Kruesi, Director
Directorate of Regulatory Operations
U.S. Atomic Energy Commission
Washington, DC 20545

Dear Mr. Kruesi:

This is a final report related to TVA's June 1, 1973, letter concerning a failure of Browns Ferry Nuclear Plant unit 1 drywell penetration EF, connector 9E.

An initial report of penetration EF, connector 9E failure was made to W. S. Little of the DRO Region II office on May 3, 1973. An interim report was submitted to you on June 1, 1973, stating that a final report would be submitted by July 2, 1973. Due to the extended investigation required, an extension of the date for submitting the final report was requested on July 2, 1973. In accordance with paragraph 50.55(e) of 10 CFR 50, we submit the enclosed final report.

Very truly yours,

J E Gilleland

J. E. Gilleland
Assistant to the Manager of Power

Enclosure
CC (Enclosure):
Mr. Norman C. Moseley, Director
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ENCLOSURE

BROWNS FERRY NUCLEAR PLANT UNIT 1
FAILURE OF ELECTRICAL PENETRATION EF, CONNECTOR 9E
FINAL REPORT

An initial report of the failure of connector 9E on primary containment electrical penetration EF of Browns Ferry Unit 1 was made to W. S. Little, AEC-DRO Inspector of the Region II office, in accordance with paragraph 50.55(e) of 10CFR50, on May 3, 1973, while he was at the site on an inspection trip. An interim report of the failure was submitted to USAEC on June 1, 1973, and an extension of the date for submitting the final report was requested on July 2, 1973.

Electrical penetration EF contained nine connectors, with eight connectors grouped around one in the center. The center connector inside the drywell, designated as 9E, failed. Failure of the connector was discovered on April 23, 1973, by maintenance electricians during their investigation into the inoperability of the drywell sump pumps. The connector was supplied by Physical Sciences Corporation, and carried manufacturer's part No. 6502-2. It had 35 pins of No. 8 AWG size and had a rating of 600 volts AC. The pins were in the fixed portion of the connector, the sockets were in the movable portion. Thirty-three of the pins were used for eleven 3-phase, 480-volt 3-wire ungrounded loads as follows:

1. RCIC turbine steam line, isolation valve FCV-71-2 motor (0.333 horsepower),
2. Recirculation pump 1A, discharge valve FCV-68-3 motor (14 horsepower),
3. Recirculation pump 1A, suction valve FCV-68-1 motor (8.2 horsepower),
4. Recirculation pump 1B, discharge bypass valve FCV-68-80 motor (0.333 horsepower),
5. Drywell floor drain sump pump 1A motor (5 horsepower),
6. Drywell floor drain sump pump 1B motor (5 horsepower),
7. Drywell equipment drain sump pump 1A motor (5 horsepower),
8. Drywell equipment drain sump pump 1B motor (5 horsepower),
9. Equipment-handling platform outlet,
10. Recirculation pump 1A motor heater (3.6 kilowatts),
11. Recirculation pump 1B motor heater (3.6 kilowatts).

Equipment items 1, 2, 3, 4, 6, 8, and 9 receive power from 480-volt shutdown board 1B; items 5 and 7 receive power from 480-volt shutdown board 1A; and items 10 and 11 receive power from 480-volt unit board 1A. Each 480-volt board is equipped with a ground indicator. Equipment items 3 through 11 are not essential for safe shutdown. Equipment items 1 and 2 are important to safe shutdown in the degree described below:

1. Equipment item FCV-71-2 is one of two redundant valves that are closed in case of a break outside containment in the steam line to the RCIC turbine. The other valve is outside the drywell.
2. Equipment item FCV-68-3 in recirculation loop A is closed in order that the LPCI system can be effective in case a LOCA were initiated by failure of primary system lines connected to recirculation pump 1B. The LPCI system is redundant to the core spray systems.

The circuits through connector 9E to these two valves are all in electrical division II.

All of the equipment served by connector 9E had been in service for an extended period of time and all had been exercised and tested successfully. A review of the records disclosed no indication of abnormalities in the equipment or connector prior to the failure.

When connector 9E was examined after the failure, two pins, located at approximately the ten o'clock position on the fixed portion of the connector, when viewed from inside the containment, were found burned off at the joining plane between the fixed and removable parts of the connector. These two pins remained in their mating sockets when the connector was separated. (These pins were in the circuit serving the motor of valve FCV-68-1.) An adjacent pin was damaged and fell off when the connector was separated. Molten metal from the burned pins had run down and solidified at the bottom of the fixed part of the connector, bridging the four bottom pins together. There were two small holes in the pressure seal of the fixed connector, adjacent to the burned pins, and the pressure gauge on the penetration indicated a complete loss of pressure. (These penetrations are normally

pressurized at 15 psig.) Inner surfaces of the connectors, as well as all adjoining pins, were contaminated with arc products. It was noted that there was no gasket under the screwed backing ring that holds the parts of the connector together, as specified on the drawings. All wiring between the corresponding connector outside the drywell and the failed connector inside the drywell was checked with a Megger and was found to have very low, or zero, resistance between the various conductors and between the conductors and ground.

After removal from the attached cable, the movable portion of the connector was sawed in half on a longitudinal axis through a burned-off pin that had remained in its mating socket. Inspection after sawing showed good contact between the pin and the socket. Measurement of the depth of the remaining part of the pin in the socket indicated that there had been approximately 1/16 to 1/8 inch of separation between the faces of the two parts of the connector at the time of fault. No evidence of substandard workmanship was noted.

Overload heaters in the motor control center compartments serving the circuits to three of the sump pumps and to valve FCV-68-1 were found damaged. The insulation resistance of the motor on valve FCV-68-1 and the heater on recirculation pump motor 1B were each found to be zero ohms to ground, and the insulation resistance of the heater on recirculation pump motor 1A was 250,000 ohms to ground, as measured with a Megger. All the other equipment was clear of ground faults. Moisture was found in the valve motor when it was disassembled, and the lead wires to the recirculation pump heaters from the motor junction boxes were found to have an asbestos type insulation not suited for high humidity conditions.

It is postulated that failure of the connector was caused by moisture entering at the backing ring where the gasket was missing. A highly humid condition had been found in the drywell at the conclusion of a leakage test wherein the drywell had been pressurized to 6.5 psig on April 22, 1973. The RCIC pump and the HPCI pump had been operated

immediately before isolation of the containment and the beginning of the pressure test. The steam turbines driving these pumps exhausted into the torus water and could have produced the high humidity.

Burning of the pins in the circuit to the motor of valve FCV-68-1 probably initiated the connector failure when the circuit to the motor was energized after moisture had entered the connector. Damage to the penetration seal was caused by heat of the arc assisted by the pressure of expanded gases trapped in the connector. Secondary damage to overload heaters at the motor control centers was caused when attempts were made to start the equipment with the connector pins short circuited. This type of damage is to be expected if these circuits were energized with the connector in a short-circuited state.

It has not been possible to determine the exact time of the initial failure. The first evidence of trouble was found when the sump pumps failed to operate. The operating log has no entries associated with operation of valve FCV-68-1 during the period immediately preceding discovery of the penetration failure; however, operation of the valve had been observed on April 8 and 9, 2 weeks before the failed connector was discovered. At that time, the circuit design allowed valve FCV-68-1 to be operated by the LPCI logic network, which had been under test just prior to discovery of the failure; damage to the connector could have occurred, without being observed, as a result of the application of power to the motor circuit during this testing. Subsequently the circuit was modified so that valve FCV-68-1 is no longer operated by the LPCI logic network.

The low insulation resistance to ground found in some of the equipment did not contribute to the connector failure. The electric current capacity of the connector greatly exceeded that of the wiring in the equipment. There was no visible evidence of damage found in the motor on valve FCV-68-1 nor in the heater wiring of the recirculation pump motors. The motor was removed, baked dry, reinstalled and returned to service. The asbestos insulated lead wires of the recirculation pump heaters have been replaced with lead wires having an insulation suitable for service in a high humidity.

The cables that were on connector 9E have been moved to a spare connector in an adjacent penetration. The fixed end of the failed connector was sealed with Dow Corning Company RTV-3116 sealant, a brass cap was then installed to provide a permanent seal for the damaged connector, the penetration was pressure tested at 49 psig, and is now pressurized at 15 psig as before the failure. The other eight connectors on penetration EF remain in service.

During construction of Unit 1, it was necessary to perform a considerable number of disassemblies and reassemblies on the connectors. It is believed the missing gasket was omitted during one of these reassemblies. The connectors for Units 2 and 3 are designed to minimize the number of disassemblies required. All of the penetration connectors for Unit 1 have been inspected. All gaskets are now in plate, in proper physical condition, and the screwed backing rings are tight.

Failure of this connector would not have prevented reactor cooling needed for a safe shutdown, and the particular mode of failure would not have violated containment. Equipment items 1 and 2 (FCV-71-2 and FCV-68-3) would not have functioned. Failure of these valves to close, however, is acceptable as described below:

1. Failure of valve FCV-71-2 is acceptable since it is only one of two valves in series capable of shutting off the steam line to the RCIC turbine in case of a break outside the containment. The other valve is located outside the containment; therefore, the electrical circuits to it were not run through connector 9E.
2. Failure of valve FCV-68-3 is acceptable. The LPCI system would have failed in its core cooling function for a LOCA originating in the lines of recirculation pump 1B. The RHR function would not have been affected for cooling following anormal shutdown. The Interim Criteria for emergency core cooling can be satisfied by waterflow from three of the four LPCI pumps or by operation of the core spray systems. The LPCI system is vulnerable to a single failure; however, core spray systems would not have been affected by this failure. Only the identified circuits for the LPCI system and none of the electrical circuits for the core spray systems were run through connector 9E.

Failure of a connector in this manner would be highly unlikely during normal operation of the plant. The drywell atmosphere would be low in humidity and at a temperature in the 135-150 F range. In addition, the circuits would be energized continuously or energized for equipment tests at regular intervals; thus, the failure, if it occurred, would be detected.