UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
WASHINGTON, D.C. 20555-0001

June 4, 1998

NRC INFORMATION NOTICE 98-21: POTENTIAL DEFICIENCY OF ELECTRICAL CABLE/CONNECTION SYSTEMS

Addressees

All holders of operating licenses for nuclear power reactors, except those licensees who have permanently ceased operations and have certified that fuel has been permanently removed from the reactor vessel.

Purpose

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice to alert addressees to a potential deficiency relating to environmental qualification of electrical cable/connection systems. It is expected that recipients will review the information for applicability to their facilities and consider actions, as appropriate. However, suggestions contained in this information notice are not NRC requirements; therefore, no specific action or written response to this notice is required.

Description of Circumstances

Sandia National Laboratories (SNL), under contract to NRC, tested electrical cable connections to assess their accident performance if they were aged more slowly (i.e., at lower temperatures and radiation dose rates) than in typical industry qualification tests and to investigate the performance of connections aged to a nominal 60-year life. The results of this testing are contained in the report NUREG/CR-6412, "Aging and Loss-of-Coolant Accident (LOCA) Testing of Electrical Connections," January 1998 (Accession Number 9803180097). Electrical connection test specimens consisting of conduit seals, connectors, and splices were chosen on the basis of their usage in commercial nuclear power plants. The test program generally followed the guidance provided in the Institute of Electrical and Electronics Engineers (IEEE) Standard 323-1974, "IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations," and IEEE Standard 383-1974, "IEEE Standard for Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Stations."

Test program specimens consisted of 10 different electrical connection types: three types of conduit seals, two types of cable-to-device connectors, three types of cable-to-cable connectors, and two types of in-line splices. Environmental exposure for the test specimens consisted of two phases. The first phase consisted of simultaneous thermal and radiation

aging for 6 months at 99 °C (210 °F) and a total radiation dose of 200 kGy (20 Mrad) at a dose rate of 45.6 Gy/hr (4.56 krad/hr); the thermal exposure is equivalent to 60 years at 55 °C (131 °F) for an activation energy of 1.15 eV. The subsequent phase was a LOCA simulation that consisted of an accident irradiation exposure at a dose rate of 3 kGy/hr (300 krad/hr) for an accident dose of 1,000 kGy (100 Mrad) sequentially followed by a simulated accident steam exposure. The simulated accident steam exposure test profile generally followed the typical test profile contained in IEEE Standard 323-1974. During the simulated steam exposure test, the connections were energized at approximately 110 Vdc, 0 mA, to allow for online measurement of insulation resistance (IR). Following the steam exposure test, which did not include chemical spray, SNL performed several types of electrical measurements. Post-steam exposure measurements performed on the test specimens included dry IR, submerged IR, dry alternating current (ac) dielectric withstand, and submerged ac dielectric withstand.

Five of the 10 cable connection types did not pass a post-LOCA, submerged, ac dielectric withstand test. These types were the Conax Buffalo, Rosemount, Patel/EGS quick disconnect, Amphenol coaxial, and Litton-VEAM. In addition, all of the Conax Buffalo electrical conduit seal assembly cable connection conductors and approximately half of the Litton-VEAM connector and the Amphenol coaxial cable connection conductors did not pass a dry ac dielectric withstand test. The Conax Buffalo conduit seal assembly conductors had low IR values and the two non-grounded conductors repeatedly blew 1-ampere fuses when energized at 110 Vdc. Approximately one-third of the Litton-VEAM connector and all four Amphenol coaxial cable connector conductors had IR values below 10^7 ohms. The list of electrical cable connection types included in the test program and the test results from the NUREG/CR-6412 report are provided in Attachment 1.

SNL has performed similar testing of electrical cables to determine the minimum insulation thickness necessary for cable functional performance and long-term aging degradation of cables. Results from these testing programs were provided in NRC Information Notice (IN) 92-81, "Potential Deficiency of Electrical Cables with Bonded Hypalon Jackets," dated December 11, 1992, and IN 93-33, "Potential Deficiency of Certain Class 1E Instrumentation and Control Cables," dated April 28, 1993.

Discussion

The SNL test results provided in NUREG/CR-6412 raised potential issues relating to the long-term environmental qualification of electrical cable/connections that did not pass a dry ac dielectric withstand test, a submerged ac dielectric withstand test, or exhibited very low or marginal IR values. The staff reviewed the test data contained in the report and noted that some of the tested cable/connections exhibited low or marginal IR values as early as 3 days after the start of the simulated LOCA test exposure. It was also noted that Rockbestos Firewall III cross-linked polyethylene multiconductor and Rockbestos coaxial cables were installed by SNL on connection test specimens that were supplied to SNL without a length of cable.

Using these two nuclear-qualified cable types that were previously tested to the equivalent of 60 years helped to ensure that the testing isolated the effects of aging on the cable connections.

The aging research study sponsored by the NRC and performed by SNL included searches of licensee event reports (LERs) to identify and review those LERs that contained information relating to cable connection aging. The results of these searches and reviews are provided in NUREG/CR-5461, "Aging of Cables, Connections, and Electrical Penetration Assemblies Used in Nuclear Power Plants." In NUREG/CR-5461, SNL reported that electrical cable connections are highly reliable devices under normal plant operating conditions, and they exhibited no evidence of significant increases in failure rate under normal operating conditions with aging. However, NUREG/CR-5461 also reports that many of the causes of failures of electrical cable connections in accident conditions would not be detected during normal operations because of the absence of high temperatures and humidities, and that the expected most important failure mode is shorting or reduced electrical isolation. These conclusions are consistent with the recorded test data results obtained during the electrical cable connection testing in that there was no significant degradation in the measured insulation resistances of the test specimens during the aging and accident irradiation exposures.

In addition, NUREG/CR-6412 reports post-test examination results for the tested cable connection specimens. One primary reported result is that the jackets of a large fraction of the cables attached to the connections were cracked and would allow ingress of moisture into the cable, which could then migrate into the connection. Specifically, the jackets of the EGS conduit seal cables were not sealed. The jackets of the NAMCO EC 210 connector cables were split open and extensively cracked. Jackets over the Kapton-insulated conductors for the Conax Buffalo conduit seal cables were not sealed. The jackets of the Okonite tape splice and Litton-VEAM connector cables were split open and cracked all the way around. For the EGS Grayboot connector cable, the jacket was split open and was also not sealed. Generally, the main function of a cable jacket is to protect the insulation during installation. The SNL test results, however, indicate that cable jacket integrity may be important in preventing moisture intrusion at connections. Another post-test examination result was that the behavior of the Conax Buffalo conduct seal conductors was produced by degraded Kapton-insulated cable leads. Post-test examination results for the behavior of the Litton-VEAM connector revealed that the O-ring seals were brittle and had experienced compression set, which thereby reduced their sealing ability and allowed moisture to enter the connector body. No explanation for the behavior of the Amphenol coaxial connector or the Rosemount 353C conduit seal was identified during the post-test examination. Reported results also indicate that the test results for a particular connection type should be evaluated while considering the specific application and set of environmental conditions. However, in certain nuclear power plant circuit applications, degradation or failure of electrical cable/connection systems during and/or following design-basis events can significantly affect the functional performance of safety-related equipment.

This information notice requires no specific action or written response. If you have any questions about the information in this notice, please contact one of the technical contacts listed below or the appropriate Office of Nuclear Reactor Regulation (NRR) project manager.

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Attachments:
1. "Tested Electrical Cable Connections and Reported Test Results"
2. List of Recently Issued NRC Information Notices — Attachment FILED in Jacket

Tested Electrical Cable Connections and Reported Test Results

Electrical Connection	Connection Type	Number of Connection Type Conductors that Failed Submerged AC Dielectric Withstand Test	Number of Connection Type Conductors that Failed Dry AC Dielectric Withstand Test	Number of Connection Type Conductors with Insulation Resistance Values Below 10^7 Ohms During Steam Exposure Test
Conax Buffalo Electric Conductor Seal Assembly	Conduit Seal	4 of 4 failed	4 of 4 failed	4 of 4
Patel/EGS Conduit Seal	Conduit Seal	passed	passed	passed
Rosemount 353C Conduit Seal	Conduit Seal	3 of 6 failed	passed	passed
Namco EC210 ½" Series	Cable-to-Device Connector	passed	passed	passed
Patel/EGS ½"Quick Disconnect	Cable-to-Device Connector	5 of 6 failed	passed	passed
Amphenol 82-816/16100/34500 Coaxial Connector	Cable-to-Cable Connector	4 of 4 failed	2 of 4 failed	4 of 4
EGS GB-1 Grayboot Connector	Cable-to-Cable Connector	passed	passed	passed
Litton-VEAM CIR01/CIR06	Cable-to-Cable Connector	6 of 6 failed	2 of 6 failed	2 of 6
Okonite T-95/No.35 Tape Splice	In-Line Splice	passed	passed	passed
Raychem NPKC-3-31A Splice Kit	In-Line Splice	passed	passed	passed

passed - denotes no reported abnormalities

LIST OF RECENTLY ISSUED NRC INFORMATION NOTICES

Information Notice No.	Subject	Date of Issuance	Issued to
98-20	Problems with Emergency preparedness Respiratory Protection Programs	6/4/98	All holders of operating licenses for nuclear power reactor; non-power reactors; all fuel cycle and material licensees require to have an NRC-approval emergency plan
98-19	Shaft Binding in General Electric Type SBM Control Switches	6/3/98	All holders of operating licenses for nuclear power reactors
98-18	Recent Contamination Incidences Resulting from Failure to Perform Adequate Surveys	5/13/98	Part 35 Medical Licensees
98-17	Federal Bureau of Investigations (FBI) Awareness of National Security Issues and Responses (ANSIR) Program	5/7/98	All U.S. Nuclear Regulatory Commission fuel cycle and power and non-power reactor licensees
98-16	Inadequate Operational Checks of Alarm Ratemeters	4/30/98	All Industrial Radiography Licensees
98-15	Intergrity of Operator Licensing Examinations	4/20/98	All holder of operating licenses for nuclear power reactors except those that have permanently ceased operations and have certified that fuel has been permanently removed from the reactor vessel
98-14	Undocumented Changes to Non-Power Reactor Safety System Wiring	4/20/98	All holders of operating licenses or construction permits for test research reactors

OL = Operating License
CP = Construction Permit

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