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ON EQUIPMENT QUALIFICATION

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November 26, 1996

Mr. Satish K. Aggarwal
Senior Program Manager, Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dear Satish,

Attached to this letter please find consolidated Nuclear Utility Group on Equipment Qualification (NUGEQ) comments on NUREG/CR-6412, *Aging and Loss-of-Coolant Accident (LOCA) Testing of Electrical Connections*, July 31, 1996.

We understand that some NUGEQ members, including Northeast Utilities, have provided comments directly to Sandia. These comments are not included here.

We recommend that NRC provide all cable, connector, and splice material manufacturers whose dqualified devices were tested by Sandia with copies of the draft report. These manufacturers should have an opportunity to comment and may have important information or insights related to test performance.

If you or Sandia require further clarification please feel free to call me at (617) 729-9212 or Bill Horin at (202) 371-5737. We appreciate the opportunity to provide comments on this draft and believe the final report will benefit from the meaningful review provided by utilities and others in the industry.

Sincerely

Phil Holzman
NUGEQ Consultant

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Attachment (1)

A001

cc: Alex Marion (NEI)
Bill Horin (Winston & Strawn)
John Hutchinson (EPRI)

I & P-11 Guides/Manuals

NUGEQ Comments - NUREG/CR-6412

1. Abstract and Section 4: The report concludes that further investigations of connectors for suitability for life extension are warranted because only 5 of 10 non-terminal block connection types passed a post-LOCA submerged dielectric withstand test. We disagree on several counts. First, post-LOCA dielectric withstand tests (and post-LOCA IRs) are not required to demonstrate qualification. Rather they provide some information on available margin and are a basis to compare various designs. Secondly, most of these connectors and the devices they interface with (e.g., SOVs, transmitters, MOVs) have not been qualified for submerged conditions. Consequently, submerged high potential tests (and to some extent IRs) are unnecessary to establish qualification and are inappropriate.

2. Abstract and Section 4: Functionality during LOCA, based on IR data, should be the fundamental concern for this testing. The post-LOCA tests, particularly the submergence tests and the dielectric withstand voltage values are not appropriate for many of the tested devices. IEEE 572-1985, *IEEE Standard for Qualification of Class 1E Connection Assemblies for Nuclear Power Generating Stations*, does not require post-LOCA submergence testing to establish qualification for connector assemblies. The standard suggests that IR and dielectric withstand tests be performed as baseline tests and, as appropriate, during subsequent test phases. It further indicates that for instrument and signal connection assemblies (e.g., Rosemount 353C conduit seal) the test requirements shall be as specified for the applications. As part of a qualification test it is inappropriate to apply 1000 - 2400 Vac post-LOCA to devices in a submerged condition that are intended to operate unsubmerged at much less than 100 Vdc. Consequently, Sandia's suggestion that, "*further detailed investigation of electrical connections related to life extension is warranted*", because of failures during these submerged dielectric withstand test is unjustified.

3. Section 1.2 pg. 1: We agree with the observation that 20 Mrads, as a 60-year radiation aging dose, and 100 Mrads accident dose are more representative of nuclear plant conditions than the radiation values used in prior programs. However, these values may still be overly conservative. For example, since beta doses are attenuated by connector shells and enclosures, the PWR accident dose to internal connector components would typically be only 20 Mrads.

4. General: Several of the IR figures (e.g., Figures 3.13 and A.7) contain IR spikes that coincide with the discrete IR measurements. Are these actual specimen effects or artifacts of the testing method? If artifacts they should be removed from the figures.

5. Section 2.3.2; pg. 16: This section indicates that condensate flooding of the vessel occurred that resulted in temperature drops during days 4 and 5. The report should clarify the extent and duration of the flooding including discussion of effects on any of the specimens or associated cabling. The only current discussion of specimen flooding is contained in Section A.2 which states: "*The terminal blocks were also mounted lower in the test chamber than the other connections, which caused the terminal blocks to be submerged before the other connections*". This suggests that the terminal blocks <u>and some other specimens</u> were submerged during the test.

6. General: Our review of the test data, particularly the IRs, suggests that chamber flooding may have been more extensive that suggested by the draft report. We believe it is significant that a marked drop in all the States terminal block continuous IRs occurred at roughly 35 hours (see Figures A.8, A.9, A.14, A.17, and A.18). A similar IR drop in all the Marathon blocks continuous IRs occurred at roughly 100 hours (see Figures A.7, A.10, A.11, A.15, and A.16). According to the report, both enclosures had <u>the States blocks mounted below the Marathon blocks</u>. It seems quite plausible that these IR decreases represent submergence of the terminal blocks and associated exposed cable conductors as early as 35 hours into the test. No other differences in chamber environmental conditions or circuit electrical parameters would seem to explain the apparently simultaneous initiation of these IR decreases. We also note the coincidental and somewhat simultaneous IR drop in the Conax ECSA specimens at roughly 10 hours and the Amphenol specimens at roughly 40 hours and suspect that submergence may have played a part in this unusual behavior.

7. Section 2.2: A more detailed representation of the specimens' (connector and cable) vertical orientations may help others examine the data and draw conclusions regarding results, particularly possible submergence effects. Photographs and examination of the vessel, mandrel, and specimens for flooding water marks (if any remain after the immersion high potential tests) may also clarify the severity of chamber flooding.

8. Section 2,2: A better depiction of the specimen designs and configurations should be presented. For example, absent the associated references and some imagination it is difficult to envision exactly how the Amphenol connectors, cables, and heat shrink tubes were configured. Similarly, the existence, configuration, and Kapton coverage provided by the Conax ECSA protective tubing may be relevant to interpreting these results. Finally, for devices fabricated by Sandia (e.g., Litton-Veam connectors) it would be appropriate to summarize the fabrication steps. Diagrams and photographs would help in all cases.

9. Section 2.2, pg. 8: It states that at the conclusion of the test the device enclosures would be opened to determine if moisture existed. These is no discussion of these post-test observations in subsequent report sections.

10. Section 2.2: Little information is provided on the Sandia chamber epoxy seals. A recent NRC publication (NUREG/CR-6384) has suggested that this method of chamber sealing might produce failures that are not representative of field conditions. Since low IRs and other unexpected results may be related to the seal design, a more detailed explanation of the seals and the method of interfacing with specific specimen leads should be provided. For example, were the ECSA leads individually potted or were they and the protective tubing potted as an assembly.

11. Section 2.2: Since a majority of the connectors tested in this Sandia test were purchased to specific vendor qualification reports, Sandia should provide a summary of the test conditions and results reported in the vendor's qualification program. At a minimum, Sandia should list the relevant manufacturer qualification test documents.

12. Section 2.2: It would be helpful for Sandia to compare the thermal aging and radiation conditions used by this program with those originally used by the manufacturers to establish qualification for the connectors and terminal blocks.

13. Section 2.2: Although the Amphenol connectors were not environmentally qualified by the manufacturer, they have been qualified in accordance with applicable regulations and standards. It is inappropriate to describe them as "unqualified". It is appropriate to describe the HN-N adapter as unqualified since it apparently was not used in prior qualification efforts. Sandia should identify the dielectric and plating materials for this previously unqualified adapter.

14. Section 2.2: The Litton-Veam connectors are used in the industry in a number of configurations with different mating cables and backshell potting designs. Sandia should be specific about the configurations used in this test.

15. Section 2.3.1, Table 2.4: Sandia uses an equivalent aging concept to simulate a 60 year life at 131°F for all the test specimens assuming a common activation energy. However, the thermal aging represents a significant distribution of equivalent life values based on the activation energies presented in Table 2.4. For many of the devices (i. e., Conax ECSA, EGS conduit seal, Rosemount conduit seal, Okonite tapes, Raychem splice materials and Rockbestos cables) this represents substantial overaging and may have influenced the LOCA and post-LOCA test results. Sandia should add a column to the table that represents the "equivalent life" values based on the thermal aging and published activation energies.

16. Section 3.2, pg. 25: The report (page 12) states that one of the two Litton-Veam connectors was mated/demated during aging. On page 25, the report states that two of the six conductors had low IRs while on page 43 it suggests that three conductors have low IRs. Were these conductors (2 or 3) all on the same connector? Was it the mated/unmated connector? In previous testing by Litton-Veam the connectors were not mated/demated. Combustion Engineering (CE) testing revealed that mating/demating could cause problems during LOCA tests. NRC IE Notice 89-23 indicates that CE testing of similar connectors identified low IR problems. CE modified their design. Some utilities, based on analysis of the relevant test data, require replacement of interfacing gaskets whenever the connectors are demated.

17. Section 3.2: We suggest that separate figures be presented in an Appendix for each of the specimens that exhibit unexpected IR behavior during the LOCA simulation. It is difficult to analyze the existing data (discrete and continuous) since they reflect averages over a number of conductors and specimens. The standard deviation bars are similarly difficult to interpret and might be replaced by the measured "high" and "low" values.

18. Section 3.2.2 and 3.3: All of the "so called" failures were not explained. Were they due to test setup problems, monitoring equipment, cables, leads, or connectors. Without knowing why some of the connectors performed the way they did, how can you conclude that it was a connector failure?

19. Section 3.2.2 and 3.3: Sandia has not made any efforts to evaluate the low IRs and circuit failures. It cannot be assumed that all the problems are due to the connectors. The test leads (inside or outside the chamber) or the epoxy seals could be causing some of the anomalous results. Sandia could have performed IRs tests while progressively submerging the specimens to help identify suspect locations for the low IR and dielectric results. Absent such evaluations the test results cannot be meaningfully used to draw any conclusions regarding performance of the problematic devices.

20. Section 3.3: Internal cable moisture was suggested by the post-LOCA TDR readings. This may be related to the chamber epoxy seal design since moisture/water diffused into the specimen leads outside the chamber. However, moisture diffusion and migration in the cables may be strongly related to the differential pressures across the cable insulation produced when the cable ends are "vented to atmosphere" outside the vessel. There is particular interest in the response of the coaxial cables and the existence, extent, and timing of moisture outside the test vessel.

21. Section 3.3; pg. 27: How long were the cables allowed to "fully dry" before the dielectric withstand tests were performed?

22. Section 3.3, Tables 3.2 and 3.3: The text and tables confuse the post-LOCA test sequences. After several misinterpretations it appears the following sequence was used:
    - 3 days post-LOCA - dry IRs and TDRs
    - 13 months post-LOCA - dry IRs, and wet IRs (30 min. and 3 hr.)
    - 23 months post-LOCA - dry dielectric withstand and wet dielectric withstand

    If this is correct please clarify the introductory text in Section 3.3.

23. Section 2.4.3: We applaud Sandia for investigating the use of TDR techniques as a diagnostic tool. However, the data is difficult to interpret and often appears in conflict with the IR measurements. Sandia should attempt to explain and interpret the data where possible. For example, the Amphenol post-LOCA IRs (Figure 3.13) are quite low in comparison to the coaxial cable IRs (Figure 3.15); yet, one connector's TDRs (Figure B.1 - 49 and 50) are virtually identical to the cable TDRs (Figure B.3). Further, the other connector's TDRs (Figure B.1 - 51 and 52) appear quite unusual but are unexplained in the text. Similarly, the Rosemount 353C TDRs (Figure B.12) are quite confusing. Since all the conductors of a specimen are apparently of equal length, the pre-steam TDRs for 25 and 26 suggest an open circuit at roughly the 15 ft mark. Further, the "0" ft. data is anomalous to the "0" ft. data for all the other specimens. For many of the figures much of the post-steam data is off the chart (low). Please clarify these qobservations. Finally, it might be instructive to present vertical lines on the figures depicting which portion of the overall cable distance is actually inside the test vessel.