Conax Buffalo

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FOIA/PA REQUEST
Case No: 97-0039
Date Rec'd: 2-7-97
Action Off: Reed
Related Case:

February 7, 1997

FOIA/LPDR - BR
U.S. Nuclear Regulatory Agency
Mail Stop T-6D8
Washington D.C. 20555

Subject: Freedom of Information Act

Reference: Draft NUREG/CR-6412

To Whom It May Concern:

We respectfully request a copy of the comments received by the U.S. NRC on the referenced document. Our product was one of the specimens tested and the comments provided would aid in our evaluation of the test methods and results reported.

Thank you for your cooperation in this matter and should you need further information or clarifications please do not hesitate to contact us.

Sincerely,

Conax Buffalo Corporation

William C. Federick

William C. Federick
Vice President, Power Group

BROOKHAVEN NATIONAL LABORATORY
ASSOCIATED UNIVERSITIES, INC.

P.O. Box 5000
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Department of Advanced Technology

Building 130

October 28, 1996

Mr. Satish Aggarwal
U.S. Nuclear Regulatory Commission
Mail Stop T-10 E8
North Bethesda, MD 20852

Subject: **Review of Draft NUREG/CR-6412, "Aging and Loss-of-Coolant Accident Testing of Electrical Connections," Sandia National Laboratory, July 1996.**

Dear Satish:

Thank you for the opportunity to review the subject document. In general, the report was found to be well written and presents a good scoping study of electrical connectors. BNL's comments are attached for your use.

If you have any questions on this or wish to discuss these comments further, please contact me.

Sincerely,

Robert J. Lofaro, Group Leader
Engineering and Testing Group
Engineering Technology Division

RJL/pvg
Attachment: BNL Comments on Draft NUREG/CR-6412
cc: w/out attachment
R. Bari
R. Hall
J. Taylor
J. Vora, NRC/RES

DISK: LETTERS #6 FILE: BOB\NURG6412.LTR DATE: 10/28/96

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TELEX 6852516 BNL DOE

Brookhaven National Laboratory
Comments on Draft NUREG/CR-6412
October 28, 1996

BNL has reviewed draft NUREG/CR-6412 entitled "Aging and Loss-of-Coolant Testing of Electrical Connections." The following comments were generated from this review.

1. The report presents a good scoping study on electrical connections. Based on the conclusions drawn in this report, additional testing should be considered to better understand why the failures occurred.

2. It would be helpful if pictures of the test specimens before and after the steam chamber tests were included in the report.

3. This study had the following two objectives: 1) to assess the accident performance of electrical connections aged more slowly than in typical industry qualification tests and under simultaneous conditions, and 2) to investigate the performance of connections aged to a 60-year life to determine their suitability for life extension beyond the current nominal 40-year qualified life. The second objective may justify the manner in which the experiments were conducted. However, it is unclear how the study was to accomplish the first objective. All of the connections were aged to simulate 60-years of operation, which precludes a comparison to typical industry tests which simulate 40-years of operation. In fact, no discussions were provided to compare the 60-year results with 40-year results. It is recommended that this discussion be provided, or the objectives of the study be modified to be consistent with the results obtained.

4. Additional justification is needed for the 60-year radiation dose of 20 MRads and accident dose of 100 MRads since these numbers are much lower than those recommended by IEEE qualification standards, and are even lower than those used by Sandia in earlier studies. The report states that these doses are more representative of actual power plant conditions, however, no basis is provided for this statement. Also, no discussion is provided on how the results of this study can be compared to previous qualification results. It is recommended that this be clarified in the report.

5. In light of the failures noted in this study for some of the connections, which were preaged using lower radiation doses than the original qualification tests, a question that should be addressed is how these connections passed the original qualification tests, and why they failed during these tests. It is recommended that a discussion be provided to address this question.

6. The report does not provide any discussion of the correlation between different test results, or whether this was even investigated. This is an important tool which could potentially provide useful insights into the effectiveness of the techniques being studied. For example, IR and post-LOCA submerged dielectric test results could be compared with TDR results to see if there is any correlation between the findings. It is recommended that this be considered for inclusion in the report.

7. The results of the TDR tests are included in the Appendix while other test results are in the main body of the report. It is recommended that all test data be presented in a consistent manner.

8. In the Summary and Conclusions, many of the bullet items do not appear to be consistent with the stated first objective of the study; namely to assess the accident performance of connectors using slow aging versus typical industry aging. It is recommended that the bullet items and/or the first objective be reviewed and revised to be consistent.

Northeast
Nuclear Energy

Rope Ferry Rd. (Route 156), Waterford, CT 06385

Millstone Nuclear Power Station
Northeast Nuclear Energy Company
P. O. Box 128
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The Northeast Utilities System

(2)

November 13, 1996
MP3-DE-96-818

Mr. Curtis F. Nelson
Sandia National Laboratories
Albuquerque, NM 87185

Subject: Draft Report NUREG/CR-6412, *Aging and Loss-of -Coolant Accident (LOCA) Testing of Electrical Connections*

Attachment: Comments to subject report

Dear Mr. Nelson:

We at Northeast Utilities Millstone Unit 3 have received a copy of your draft report as a member of the Nuclear Utility Group on Equipment Qualification. It is apparent from the wealth of data retrieved from the test that the test was very carefully thought out and executed. It is especially noted that you have employed a novel approach to baseline pre-steam and post-steam test configuration impedance characteristics by using Time Domain Reflectometry (TDR). We believe that this approach provides excellent insight into the performance dynamics of the test specimens as well as the entire test setup.

We appreciate the opportunity to comment on this draft report before final issue. Attached to this letter are our comments. Hopefully our comments may add to this document by identifying areas of improvement which could alleviate any misleading or misunderstanding of the results of this report. Should you have any questions regarding our comments please do not hesitate to contact W.J. (Budd) Hayes (860) 447-1791 extension 6702 or e-mail him through the internet at HayesWJ@GWSMPT.NU.com.

Best regards,

Robert A. Andren
Millstone Unit 3 Design Engineering Manager

wjh/wf

c: Paul Grossman, Millstone 3 Engineering Director
Budd Hayes, Millstone 3 EEQ Lead
Phil Holzman, Nuclear Utility Group on Equipment Qualification
Barbara Smith, Millstone 2 EEQ Lead
Pete Tutinas, Seabrook Design Supervisor
Mike Wadkins, Millstone 1 EEQ Lead
Bob Young, Millstone 3 Design Supervisor

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ATTACHMENT

1. With regard to the 1.15 activation energy, some test specimens were under aged and many were over aged by quite some margin over the 60 year objective. A listing for each test specimen should be provided as to its equivalent temperature aged life at 55°C for comparison to the 60 year objective. This needs to be factored into the discussion of the results, i.e. could over aging have been a factor in some of the poorer evaluation tests results or in some cases could under aging have contributed to better results.

2. It is not clear how the cables going into and out of the test chamber were sealed at the test chamber wall, e.g. were they potted, or compressed, etc. This may be a very relevant concern as questions regarding the Time Domain Reflectometry (TDR) data and the lack of its evaluation are identified. Could electrical degradation have occurred at the point where cables entered and/or exited the test chamber (See comment 5)? It may be very misleading to state for example on page 43 that certain test specimens had low IRs when the low IRs may be due to other parts of the circuit instead of the test specimens themselves.

3. It is not clear on the manner of steam entrance into the test chamber during the LOCA simulation. The steam appears to enter the test chamber from the top of the test chamber just as the cables enter and exit the test chamber. Was there a steam baffle to distribute the steam as it entered the test chamber? Was there direct steam impingement on the test items and cabling? If so, this may be contrary to some of the manufacturers recommendations and should be identified. For example Kapton insulation is not recommended to be placed in such a situation and may explain the blown fuses encountered for the Conax ECSA during the LOCA test. In this case it may be misleading to identify to product as "failed" instead of the test setup.

4. Visual observations post LOCA were not identified. There was no mention if the "device enclosures" had moisture inside of them when they were opened. There was no mention of the condition of the tested equipment after the test. This type of information should be provided and evaluated.

5. It is refreshing to see "state of the art"/new methods used to provide additional data which provide insight into what may have actually happened during a test. It appears as if the TDR provides this type of information. However, this TDR data was provided in an unevaluated manner. There should be an evaluation/analysis of the data with specific correlation to the test specimen and its performance during the LOCA test and other post test results.

   a. For example, for the 60ft cable test specimens, the test specimen would be located at the 30ft mark. If there were indications of potential problems with the test specimen, then there may appear a negative ρ spike, at the 30ft mark indicative of potential or actual shorting to ground. From Figures B.1, B.3, and others, the negative ρ spikes are at the 60ft mark and would be indicative of a problem at the test chamber wall rather than at the test specimen. This needs to be explained.

b. For example, for the conduit seal, Figure B.2 a 30ft sample, the negative ρ spike is at the 5ft mark also indicative of test chamber wall area rather than test specimen.

c. As another example, examining Figure B.6, a 30ft sample, there is definitely a change between the pre and post steam TDR curves. The post-steam curve shows a marked tendency toward short-circuit in the 20 to 30 foot section of the curve which could indicate the test specimen rather than the connecting cable. This data should be correlated with the performance of the test specimen during the LOCA test and other post tests data and also followed up with visual observation as to whether or not moisture was notice in the device enclosure.

As identified in comment 2 and in this comment, there may be results identified in the present draft report that may be misleading as to the performance of the actual test specimen. Some performance or lack of performance indicators may be as a results of the test set-up rather than the test specimen. Only through identification and evaluation of all of the test data can such be accurately disseminated.

(3) Fax: 301-415-5074

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United States Nuclear Regulatory Commission
Office of Nuclear Regulatory Research
Washington, D.C., 20555-0001

Attn: Satish K. Aggarwal, Senior Program Manager

Subject: NUREG/CR6412, **Draft Copy**, "Aging and Loss-of-Coolant Accident (LOCA) Testing of Electrical Connectors", dated July 31, 1996.

Dear Mr. Aggarwal:

Conax Buffalo has reviewed the above referenced draft report, and offers the following comments for the NRC's consideration:

1.) **Para. 2.3.1, (p.10)**: Selection of one activation energy (1.15 eV) to calculate the aging temperature (98.8°C) by Arrhenius methodology for all of the test samples is very likely to lead to significant over or under aging of many samples, compared to using the actual activation energies listed per item in table 2.4.

For example, the Namco EC210 connector with an activation energy of 0.8 eV, is aged to the equivalent of only 14 years at 55°C at the Sandia aging temperature of 98.8°c and 182.625 days.

Similarly, the Conax Buffalo ECSA, with it's given activation energy, aging at 98.8°C and 182.625 days, produces an equivalent service life of over **6 million** years at 55°C! This means the ECSAs were **drastically** over-aged, and hence not at all representative of an installed condition.

2.) **Para. 2.2, (p.7)**: The report states the connections were installed in accordance with the manufacturers instructions, as listed in table 2.3. Based on the descriptions and details given, or excluded from, para. 2.1 and 2.2, and the results of the testing, Conax Buffalo questions if the ECSAs were installed and handled as required by I & M manual, IPS-725, in that:

a.) Adherence to minimum bend radii of the conductors; and/or

b.) The use of flexible conduit over the six (6) foot conductor pigtail inside the test chamber; and/or

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c.) Installation of the recommended heat shrink on the conductor pigtails inside the test chamber; and/or

d.) The required "NPT" Grafoil® thread sealant for the threaded connection of the ECSA to the test "device enclosure".

3.) **References [3] and [4], (p.45)**: The Conax Buffalo reports, IPS-725 and IPS-1079 are proprietary reports and should be referred to as "Conax Buffalo Proprietary Report" versus "Conax IPS-724 (or IPS-1079)" specifically.

4.) **Table 2.4, (p.10)**: The Conax Buffalo activation energy value is considered proprietary data and cannot be reprinted in the subject report.

5.) **General**: The correct name of our company is "Conax Buffalo Corporation", not "Conax".

As you can appreciate, circulation of a report with misleading information, even in draft mode, serves no useful purpose. Based on these points, Conax Buffalo believes these comments raise questions regarding the validity of the reported test program experimental design, conduct and results.

We request that the above comments be addressed as soon as possible, certainly prior to report issuance. Also, we believe further technical discussions would be both very informative and useful for all parties, and hence would welcome such.

Should you have any questions, please contact us immediately.

Best regards,

CONAX BUFFALO CORPORATION

W. C. Federick

W. C. Federick,
Vice-President, Power Group

cc: Conax Buffalo: Dr. R. E. Dulski,
Director of Engineering

NUCLEAR UTILITY GROUP
ON EQUIPMENT QUALIFICATION

SUITE 800
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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

Attachment (1)

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

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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 and some other specimens 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 the States blocks mounted below the Marathon blocks. 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.

(5)

From: <LOFARO@dnenet.nov.dne.bnl.gov>
To: TWD2.TWP0(ska)
Date: 12/2/96 2:47pm
Subject: Jim Gleason's Comments to NUREG/CR-6412

Satish:

In addition to the BNL comments sent to you on October 28, attached are comments from Jim Gleason on Sandia NUREG/CR-6412.

Bob Lofaro

------- Forwarded Message Follows -------

Date: Mon, 02 Dec 1996 00:14:04 -0600
To: LOFARO@dne... nov.dne.bnl.gov
From: glsinc@Traveller.COM
Subject: Jim Gleason's Comments to NUREG/CR-6412

The subject NUREG/CR-6412 has several flaws. The most obvious are :
1. The 5 connector "failures" in submerged dielectric testing are an artifact of the test performed by Sandia and are not an indication of an Environmental Qualification problem. The failures are do to a lack of understanding of the connectors' safety related functions, lack of understanding of the different connector categories represented by the test specimens, and a lab induced failure mode. The ten connector types tested actually represent four categories of connectors. All five failures came from one category of connector and would all be susceptible to the same lab induced failure mode.
2. Of the twelve connector types tested, 11 out of 12 passed all of the requirements for environmental qualification. The one that failed is indicative of handing damage and may have been damaged by Sandia.
3. The objectives of the testing were to A) Assess accident performance of electrical connectors aged at lower temperatures and dose rates than typical industry tests and B) Investigate the performance of connectors aged to 60-year life. The testing clearly shows that both objectives have been met and that A) lower temperature and lower dose rate testing do not impact qualification and B) there is no performance degradation in extending the life to 60 years.
4. The results of the terminal block testing demonstrate that the previous issues reported by "Craft (5,6)," have been shown to be non-issues.

I will gladly discuss these results with you at your earliest convenience. Please note that Satish Aggarwal and Paul Schemanski had asked for my input on this NUREG/CR-6412 and would be interested in hearing that the failures at Sandia, in my opinion, were caused by Sandia. I do recommend a review of Sandia's data and a review of their failure analysis to confirm my conclusions.

A/5

(6)

IEEE

POWER ENGINEERING SOCIETY

NUCLEAR POWER ENGINEERING COMMITTEE

NATURE SAVER™ FAX MEMO 01616	Date 12/16/96	# of pages ▸ 4
To Satish Aggarwal	From Gary Toman	
Co./Dept. USNRC	Co. Nutherm	
Phone #	Phone # 618-244-6000	
Fax # 301-415-5074	Fax # 618-244-6641	

December 16, 1996

U.S. Nuclear Regulatory Commission
Office of Research
Washington, DC 20555

ATTN: Mr. Satish K. Aggarwal

Subject: Comments on Draft NUREG/CR-6412

Dear Satish:

Comments on the draft NUREG concerning testing of connectors at Sandia National Laboratories follows. The persons that were at the SC-2 96-2 meeting who expressed interest in reviewing the document have provided these comments. If you have any questions concerning the comments, please do not hesitate to contact me at 618-244-6000.

Yours truly,

GJT

Gary J. Toman
Vice Chairman, SC-2

Attachment

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9702130095 SPD

COMMENTS ON DRAFT NUREG/CR-6412, DATED JULY 1996 AGING AND LOSS-OF-COOLANT ACCIDENT (LOCA) TESTING OF ELECTRICAL CONNECTIONS

Comments Prepared 12/16/96 By:

A. Alsammarae, ComEd
W. Hadovski, ABB Electro-Mechanics, Inc.
J. Hutchinson, Electric Power Research Institute
R. J. Smith, Duke Power
G. J. Toman, Nutherm International

1. Abstract, last sentence. A statement that further work is necessary seems gratuitous. This sentence should be reworded to state that "If the aging levels simulated in the program and the submergence performed in the program are required by plant applications, failures would be expected in 5 of 10 connector types." The aging levels were much more severe in the program than used in the related industry programs and most applications do not involve submergence. This report should not presuppose that current qualifications have requirements that are the same as, or more severe than the conditions assumed in the test program.

2. Section 1.1, second bullet. The plan for this program assumes that a device must be aged to 150% of the original aging for the device to be useful for 60 years. This assumption is not the assumption of the industry. For the most part, the industry is verifying that temperatures and doses are low enough that the pre-conditioning of the original 40 year qualification actually envelops the needs of 60 years at the actual service condition. The pre-conditionings of the industry's qualifications were not gentle. Adding 50% more aging to them is significant and very damaging. Failures of connectors and cables would not be unexpected with this type of additional aging.

3. Section 1.1, last paragraph, last 2 sentences. With the exception of the level of aging, for the most part, the tests performed were the equivalent of a qualification test under current standards. This paragraph infers that qualification would only be valid if statistically sound sample sizes were employed. The industry has addressed this issue and this statement (i.e., "to test enough of each type to get a statistical sample") should be removed.

4. Section 2.3.1, first paragraph and Table 2.4. A 6 month aging period at a 98.8°C thermal condition was chosen based on the arbitrary selection of 1.15 eV, when the range of activation energies for the devices was 0.8 to 3.916 eV. The result of the selection of 1.15 eV as the activation energy is that some devices were significantly underaged (0.23 times the desired life goal) but most were severely overaged (from 1.4 to 106,400 times the desired life goal). While the industry generally selects the component with the lowest activation energy for a device as the weak link, this is only done on a device by device basis; not on the basis of a set of different devices produced by different manufacturers. While underaging would not lead to failures, severe overaging could. Given the large amounts of overaging on top of an attempt to attain 150% aging of the original aging, failures would be expected to the seals and cables in the program.

5. Section 2.1, sixth paragraph. A rough description of the mounting of the connectors is provided. However, there is no description of the actual mounting method including slack in

the cables for expansion and support or lack of support of the connectors and cables. Insufficient information has been provided to allow the reader to understand the full nature of the test setup.

6. Page 7, right hand column, first full paragraph. Rockbestos Firewall III XLPE cable is listed as being used for leads. However, no indication of the jacket type used on the cable is indicated. The jacket could be either neoprene or Hypalon.
Also, there is no indication as to whether the XLPE is cured by irradiation or chemicals. There are differences in properties between the cure methods that could bare on insulation resistance results.

7. Figure 2.9. These figures indicate a lack of control of the aging temperature. Industry programs strive for ±3°C or better. The upper figure indicates limits of ±10°C and more over nearly the entire period of the 6 month test. Again a mix of gross underaging and overaging is indicated. A discussion of the effects of these wide swings in temperature is desirable.

8. Table 2.5. This table compares the test profile with that given in IEEE Std 323-74. First, the profile in the appendix of the standard is not a requirement of the standard (See disclaimer at start of Appendix A). While the BWR table states 200°F for 100 days, this has rarely been used as a licensing basis for power plants. Older plants have used durations of 17 to 30 days. Only later plants use 100 and 180 day durations. However, the nearly all of the plant specific profiles have much lower tails with long-term temperatures of 120 to 150°F, not 200°F.

9. Section 3.2.2, second paragraph, second sentence. The text states that "Each plotted point is the average..." Please state what the average is. Is it the average of each individual conductor to the surrounding grounded conductors? In addition, giving separate plots for the outliers as compared to the well insulated conductors would be highly informative to the engineering mind.

10. Post-LOCA Inspection. There is no discussion of the condition of the specimens from physical and visual inspection following the LOCA test. Statements from NRC Research personnel indicate that the cable jackets had degraded significantly. Given that the cable jacket often forms part of the seal system with the connector backshell, some indication of the physical condition of the interface with the backshell should be given. Before and after photographs of the connectors would be highly desirable.

11. Section 3.3, Bulleted Conditions. The use of 1000 Vac and 2400 Vac high potential tests at the end of the complete test program under full submerged conditions is excessive and outside of the guidance of industry practice. No qualification standard requires such tests. There are no control and instrumentation circuits that operate at such voltage and no manufacturer would recommend such a test on a device that by definition has to be degraded from its original condition. The highest voltage in use on most of these connectors is 480 Vac and that is only for a limited number of them. Most will not be operated above 130 Vac or 142 Vdc and most will be operated at 24 to 50 Vdc. Connectors are not tested as if they were field cables.

12. Section 3.3. With regard to TDR shifts, the cable jackets and insulation would be infused with water from the pressurized steam exposure. The infusion of water would increase the capacitance of the insulation which would greatly affect the transmission properties and would

cause the results to seem as if the cable lengthened.

13. Page 26, first full paragraph. Without information from a careful dissection of the connectors and cables, the data from 13 months after the test is of little value. While one would surmise that the cables had "dried out," many other phenomena may have occurred that have not been accounted for.

14. Page 27, first and second paragraphs. No useful information is imparted by stating that the conductors under tests "tripped the test set." What was the setting for the test set? Was it set on the most sensitive level or did a significant leakage current have to flow before the set tripped?

15. Page 27 second paragraph. Submitting a component to a second dielectric test after it failed the first is adding insult to injury. Electrical failures are rarely self healing. The devices did not fail two tests; they were failed at the end of the first test.

16. Section 4 top of right hand column. The requirement for device qualification is to adequately function under specified conditions. Most connectors are not used in submerged conditions. Those that are would not be operated at the test set voltage levels. Without an indication of the current required to "trip the test set," few inferences can be made with respect to actual applications that do involve submergence.

17. Section 4, last paragraph. As stated above, most utilities only plan to use existing qualifications for use beyond 40 years based on the existence of less severe normal conditions than were assumed in developing a 40 year qualified life. As such the overaging that occurred in this program, especially with respect to a number of the devices that failed, can help explain the failures. Any further work should not use the basis that was used in this program and should be tailored to device specific activation energies rather than an assumed generic activation energy. The last bullet should be deleted, it does not appear to be correct (the inline splices did not fail) and it adds nothing to the technical content of the report.

18. Section A.2 Second paragraph. This paragraph states "The slow test chamber flooding that occurred through day 5 caused even larger reductions in the measured IR values..." This flooding should be explained in detail in the context of the terminal blocks and in the main part of the report. No mention is made in the main report of such a significant event as chamber flooding.

19. Appendix B, last paragraph on page 63. This paragraph is too terse for the average reader to understand what is being said. Breaking the discussion of increases and decreases into two sentences rather than using parenthetical statements would help. TDR testing is not a common test to most engineers. More explanation would be highly beneficial.

    This section should also explain why multiple plots are given in each figure. Are these merely the results of multiple tests? If so why are there gross differences between some of the upper and lower plots as has occurred in the left hand plot in Figure B.1.

20. Figure B.1. What is the significance of the left hand and right hand portion of the plots? Does one apply to open circuit conditions and the other apply to closed circuit conditions? Or does one apply to conductor to shield and the other shield to ground? An explanation is necessary.

Also, an explanation of the meaning of the plots is necessary. The reader needs to know that the step change on the right hand plots indicates the connector interface (if it really does). For the left hand plot the reader needs to know what it is and what it means. This concept applies to all of the Figures. Very little information has been imparted.

(7)

From: <glsinc@traveller.com>
To: TWD2.TWP0(ska)
Date: 12/19/96 3:02pm
Subject: Draft NUREG/CR-6412.

To : Mr. Satish Aggarwal
From : Jim Gleason, GLS

Per your request, the following are my detailed comments on the Draft NUREG/CR-6412.

1. It is my opinion that the setup used by Sandia was flawed in that it did not represent actual nuclear safety related applications for Namco EC210, Patel/EGS =BD -inch Quick Connect, Conax ECSA, Patel/EGS Conduit Seal or the Rosemount 353C Conduit seal. Sandia used a Sand· fabricated "through device" instead of a safety related end device.

Sandia notes on page 7, last paragraph " The conduit seals and connections that would normally be installed in a device such as a limit switch or pressure transmitter had their device side terminated into small, sealed chambers, called a "device enclosure", that simulate such devices. Each such connection had its own device enclosure, which was fabricated from stainless steel tube and Swagelock tube fittings (Swagelock Co., Solon, OH) as shown in Figure 2.6."=20

Sandia notes that a Helium leak test was done. Then the "conductors were inserted into the device enclosure, using phenolic inserts=85There was no attempt to physically check if connections were leaking during the test. Leaking connections could be identified during the test only if data measurements begin to show anomalies, or at the conclusion of the test if the device enclosure had moisture inside when it opened."

Sandia=92s Figure 2.6 shows that the wires enter the Sandia enclosures= through the connectors under test and exit out of the other end of the Sandia enclosure. This is not how these connectors are installed in safety related applications and it is not how the wires are routed in safety related applications.=20

Sandia did not identify exactly which of the connectors were connected in this fashion. Since Namco EC210, Patel/EGS =BD -inch Quick Connect, Conax ECSA, Patel/EGS Conduit Seal or the Rosemount 353C Conduit seals were qualified for this type of application, I have assumed that Sandia used their "sealed enclosure" on these connectors.

Sandia claims that this represents pressure transmitters and limit switches. It does not. There are no safety related transmitters or switches that allow the wires to enter with the safety related connector and exit without going back through the same safety related connector. Pressure transmitters and switches are "end devices", which mean that they are at the terminating point of a cable. Thus this installation is not representative of nuclear safety related applications. Additionally, this "Sealed enclosure" is flawed and allows leakage into the back side of the connectors in a fashion that is precluded in actual safety related applications. By letting cables exit the back side of the Sandia enclosure, and not performing a leak test after the cables were installed, the leakage path through the cable conductor, under the

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insulation was not sealed and therefore no pressure boundary was present. This lets moisture enter the back side of the connectors under test, through the Sandia enclosures.

The connectors being tested by Sandia rely on the integrity of the safety related end device to provide integrity to this end of the connector. Sandia did not simulate an actual installation.=20

During the 1980=92s peer review of Sandia=92s research, one of the strong recommendations was for Sandia to utilize actual safety related equipment rather than fabricating fixtures simulating applications since critical design elements can be missed.=20

Additionally, had Sandia known that the actual way that pressure transmitters and switches are wired, they should have realized that the cable comes into the end device through the connector, is terminated in the end device and another wire starts in the end device and exits back out of the end device through the same connector. Thus the wiring also did not simulate actual safety related installations.

As noted, Sandia did not leak test the enclosure after the wires were installed, and failed to question the integrity of their enclosures when anomalies occurred, apparently in violation of their procedure, instead, they concluded that the connectors had failed.=20

It is my opinion that when a root cause failure analysis is performed, the cause of the failures is moisture in the Sandia "sealed enclosures" and thus these failures were caused by Sandia=92s test setup and thus are a Lab= induced artifact of the testing and not indicative of the qualification status of this equipment.

2. The Failure criteria and functional tests by Sandia are not per IEEE 323-74 nor 10CFR50.49. Both of these require that the safety related function be demonstrated. The safety related function of connectors is to provide adequate sealing and a uninterrupted power source thus having no significant loss of signal or power to and from the end device.=20

Sandia=92s electrical set up relied on "open circuits" and IR measurements= and not actual safety related circuits, or safety related functions.=20 Again during the 1980=92s Sandia Peer Review it was pointed out that Sandia should utilize actual nuclear test loops in order to judge safety related performance of circuits. The standards and requirements emphasize the demonstration of actual installed conditions. This was not done in these= tests.=20

3. The failure of the Conax ECSA at the start of aging, where it was found to have an internal short circuit, is indicative of handling damage by= Sandia.=20

I am aware of other laboratories having damaged ECSA=92s upon initial installation. The damage caused the seal to break internally and the wires to short together, similar to Sandia=92s experience.=20

I am also aware that caution, which had not been sufficiently present at the first installation, was improved after the initial failures occurred and

subsequent failures were eliminated. Handing damage to ECSA=92s has occurred because the conduit extension was misaligned during installation, inadvertent torque was applied to the assembly and not the stem nuts, and because bending and unsupported attached cable or enclosures applied forces which damaged the seal during movement during testing. All of these were a result of mishandling and were eliminated in subsequent testing.=20

I=92m surprised that Conax did not point this out to Sandia after the= initial failure. In any event, Sandia should have had an immediate concern when a safety related device had failed in its initial setup test and performed a root cause failure analysis with the help of Conax. I=92m confident that all commercial laboratories with whom I have worked, would have stopped the testing and immediately investigated the source of the failure with Conax, since they are aware that much care is provided by manufacturers of safety related devices and that failures are rare at the starting point.

The failure of the Conax ECSA during the LOCA, could be do to handing damage that went undetected by Sandia. Also, the Sandia "sealed enclosure" , if it was used on the ECSA, may have lead to failure on the ECSA from the Sandia enclosure side. =20

4. Thus I am of the opinion that the 5 connector "failures" in submerged dielectric testing are an artifact of the test performed by Sandia and are not an indication of an Environmental Qualification problem. The failures were most likely do to a lack of understanding of the connectors' safety related functions, lack of understanding of the different connector categories represented by the test specimens, and a lab induced failure mode. The ten connector types tested actually represented four categories of connectors. All five failures came from one category of connector and would all be susceptible to the same lab induced failure mode.

5. The safety related function is normally demonstrated by LOCA testing, including Post-LOCA testing per IEEE 323 and 10CFR50.49. These requirements do not require another submerged dielectric test 13 months after the Post-LOCA test. It was during this "Post 13 month submerged test" that the majority of failures of the connectors occurred. Since I think that Sandia= =92s
"sealed enclosures" leaked, I also think that their "sealed enclosures" allowed corrosion over this 13 month period and thus these failures are lab induced. Lab induced since the test was un-natural and Lab induced since it was Sandia=92s "sealed enclosure" that caused the leakage. The "Post 13= month submerged test" is un-natural because qualification requires the demonstration of the safety related function during the DBA and Post DBA period, which was simulated in the Sandia chamber. The condition of connectors that are then submerged 13 months "After the LOCA and After the Post-LOCA period", is immaterial. I am unaware of any safety related device which is postulated to perform a safety related function in a submerged condition 13 months "After the LOCA and After the Post-LOCA period."

6. One of the conclusions that Sandia should have made was related to LOCA performance. Of the twelve connector types tested, 11 out of 12 passed all of the requirements for environmental qualification. (The one that failed is indicative of handing damage and may have been damaged by Sandia.)