FAQ Number 08-0053 **FAQ Revision** 0

FAQ Title Kerite FR Cable Failure Thresholds

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Purpose of FAQ:

The purpose of this FAQ is to establish that Kerite FR cable should be treated as a Thermoset material cable as indicated in NUREG 6850 Appendix H.

The existing industry guidance for the treatment of Kerite FR Cable as proposed in the ERATA sheet for NUREG 6850, dated August 30, 2007, and in IMC 0308, Attachment 3, Appendix F, Section 6.2.3.3 should not be implemented. The proposed amendment to treat Kerite FR Cable as a Thermoplastic instead of a Thermoset should be revoked based on reanalysis of the referenced test data.

Is this Interpretation of guidance? [Yes] / No

Proposed new guidance not in NEI 04-02? [Yes] / No

Details:

NEI 04-02 guidance needing interpretation (include section, paragraph, and line numbers as applicable):

N/A

Circumstances requiring guidance interpretation or new guidance:

NUREG/CR-6850 Appendix H, Table H-1, identifies the damage potential temperature criteria for Thermoplastic and Thermoset cable types as 205°C (400°F) and 330°C (625°F) respectively. Table H-3 identifies the recommended failure threshold for Kerite FR cable insulating material as 372°C (702°F).

The fire protection SDP specifies a unique treatment for Kerite FR in comparison to other thermoset cable products. The following paragraph is the guidance provided (IMC 0308, Attachment 3, Appendix F, Section 6.2.3.3):

> "There is a particular proprietary cable insulation material called "Kerite FR". While this material is a thermoset, experimental evidence suggests it is substantially more vulnerable to thermal damage than are other thermoset materials. In particular, NUREG/CR-5655 reports substantial degradation of the cable's insulation value at temperatures as low as 153°C (307°F). Testing by (*South Carolina Electric and Gas Co.*) SCE&G cites average temperatures at failure of 237° (458°F) (as reported by Salley). Hence, it is recommended that the Kerite FR should be analyzed using the failure criteria for a thermoplastic cable, not the values reported for a thermoset material."

A re-examination of the paragraph references indicates errors in the interpretation of the data. In this regard, the IMC 0308 paragraph recommendation should not be implemented. Instead, the original conclusions for Kerite FR as identified in NUREG/CR-6850, Appendix H should be followed with the determination that Kerite FR is a thermoset material and should be evaluated using the failure criteria for a thermoset material.

Detail contentious points if licensee and NRC have not reached consensus on the facts and circumstances:

None.

Potentially relevant existing FAQ numbers: N/A

Response Section:

Proposed resolution of FAQ and the basis for the proposal:

NUREG/CR-6850 [1] provides the guidance for the fire analysis temperature threshold value for Kerite FR cable. The conflicting guidance identified in the IMC should be revoked.

The following discusses the two Kerite FR test references identified in IMC 0308 Attachment 3 Appendix F Section 6.2.3.3.

Application of NUREG/CR-5655 [2] Data:

A. This test contained two different Kerite FR samples (conductor #36 and #37), both 1/C #12 AWG 600V with FR insulation/FR jacket, the difference being the thickness of the insulation and the jacket (see Tables 1 and 2 of NUREG/CR-5655). Both samples were thermally aged, irradiated, and subjected to a high temperature and pressure steam LOCA test with a profile similar to the one given in IEEE Std. 323-1974 for “generic” qualification. Following the LOCA test, the samples were exposed to an additional high temperature steam exposure test, the objective of which was to “obtain quantitative information on the failure thresholds of cables exposed to high temperature steam conditions”.

B. The high temperature steam exposure test (see Section 3.1 of NUREG/CR-5655) utilized steam at saturated conditions until the temperature exceeded about 165°C (329°F) after which dry (superheated) steam conditions prevailed. Due to a problem in the steam supply, the initial excursion was aborted at about 210°C (420°F); the peak temperature reached in the second attempt was 400°C (752°F) with pressure above 690 kPag (100 psig) for about 11 minutes. The cables were energized with 110Vdc and insulation resistance (IR) measurements were taken at intervals ranging from 10 seconds to 5 minutes (see Figures 4 and 5 of NUREG/CR-5655).

C. SAND92-1404C [3] proposed that the environment created by superheated steam is similar in nature to the hot dry environments typically encountered during fire testing. The distinction being that superheated steam does not introduce failure mechanisms associated with a moist saturated steam environment, e.g. condensate film layer [5], which would not be representative of a dry high temperature fire environment. Therefore, the use of the NUREG/CR-5655 test for the purpose of quantifying a high temperature threshold for fire analysis, only data obtained during the superheated steam portion of the test (above 165°C) should be considered.

D. Both Kerite FR samples in the NUREG/CR-5655 test displayed IR increases immediately after the point of transition from saturated steam to superheated steam. This phenomenon was also displayed by other single conductor cables, namely Anaconda conductor #26 (Fig. A-21 NUREG/CR-5655); BIW conductors #29 and #30 (Fig. A-24 & A-25); Okonite Okolon conductor #32 (Fig. A-27); and Samuel Moore Dekoron Dekorad conductors #34 and #35 (Fig. A-29 & A-30). These other single conductor cables had EPR (Anaconda, BIW, Okonite) or EPDM (Samuel Moore) insulation and CSPE jackets, i.e. thermoset materials. An explanation of this IR recovery [5] is that during the transition from saturated steam to the superheated steam region, a “dryout” (moisture revaporization) occurs and conduction paths (due to condensate film layer) evaporate.

E. Kerite FR Conductor #36 (see Figure A-31 of NUREG/CR-5655) - at about the point of transition from saturated steam to superheated steam conditions, 165°C (329°F), the IR of this conductor increased from about 100 Ω-100m to above 1 kΩ-100m and remained above or about this level until the temperature reached about 330°C (626°F) except for a dip down to about 0.5 kΩ-100m at about 310°C (590°F). From about 1 kΩ-100m at 330°C (626°F) the IR dropped to 0.1 kΩ-100m by about 380°C (716°F).

F. Kerite FR Conductor #37 (see Figure A-32 of NUREG/CR-5655) - at about the point of transition from saturated steam to superheated steam conditions, 165°C (329°F), the IR of this conductor increased to above 1 kΩ-100m and remained above this value until the temperature reached about 360°C (680°F). From about 1 kΩ-100m at 360°C (680°F) the IR dropped to 0.1 kΩ-100m by about 380°C (716°F).

G. NUREG/CR-5655 identifies the Kerite FR 1 kΩ-100m failure temperature as 153 – 171°C (307 – 340°F), however these temperatures hover around the test saturated steam to superheated steam transition point and do not account for the IR recovery identified above. The 1 kΩ-100m failure temperature for Kerite FR when used for fire analysis should be around the 330 – 360°C (626 – 680°F) range, which rectifies the saturated steam influence to the data. The 0.1 kΩ-100 m failure temperatures for Kerite FR is as identified in NUREG/CR-5655: 372 – 382°C (702 – 720°F).

Application of SCE&G [4] Data:

A. IMC 0308, Attachment 3, Appendix F, Section 6.2.3.3 states “Testing by SCE&G cites average temperatures at failure of 237°C (458°F)…” The only data from the SCE&G report [4] that matches this value is from “Item #4”, specifically the average maximum temperature of a bare #8 AWG wire inside of a 1” conduit was identified as 458°F (237°C). This average maximum temperature was derived from the average of 16 thermocouples (T/C) (TC310 to TC325) spaced about 6” apart (see pages 58 & 595 Ref. 4) on the #8 AWG bare wire. The lowest maximum T/C reading was 215°F (101.7°C) (TC325) and the highest maximum T/C reading was 606°F (318.9°C) (TC313). Note, the term “maximum” is used to denote the T/C maximum temperature recorded during the 60 minute test, which typically occurred at the 60 minute mark.

B. The only other cable inside of the 1” conduit other than the bare #8AWG and the T/C wires was the test sample 5/C #12 AWG Kerite FR cable. The T/C wires are insulated with high temperature Teflon and have a “nominal diameter” of 0.056 x 0.092 inches. A #8 AWG wire has a diameter of about 0.1285 inches which calculates to a circumference of about 0.40 inches. Assuming that the T/C wires are wrapped around the

#8 AWG wire, it would only take about 7 T/C wires (out of 16 T/Cs) to encircle the #8 AWG wire and insulate it from contact with the conduit. This could explain why the #8 AWG wire temperatures are about 100ºF to well over 200ºF lower than the conduit temperatures. The physical configuration of the conduit was "L" shaped with the vertical section dropping from a concrete ceiling and the horizontal section entering a vertical concrete wall.

C. The outside surface of the 1" conduit was also instrumented with 16 thermocouples (TC131 to TC146) with similar spacing (see pages 58 & 596 Ref. 4). The average maximum temperature of these T/Cs was 633°F (333.9°C) with the lowest maximum reading of 225°F (107.2°C) (TC146) and the highest maximum reading of 770°F (410°C) (TC134). Nine of the T/Cs had maximum temperatures equal to or greater than 700°F (371°C) (TC133 to TC141) for a conservative contiguous distance of about 48" (this distance also includes the bend in the conduit). The dwell at the 700+°F (371+°C) temperatures ranged from 5 minutes for one T/C (TC133); 4 minutes (TC134); 3 minutes (TC138) and; 2 minutes for 4 other T/Cs. Given the fill of the 1" conduit, it is highly likely that the Kerite cable was in contact with the conduit in this 700+°F (371+°C) section and given the dwell times, significant heat transfer would have occurred. Based on the NUREG/CR-5655 data, a 700+°F (371+°C) temperature is more probable and consistent in explaining the failure of the Kerite FR insulation resistance.

D. An IR test was performed pre-test (as baseline), post-test, and post-hose test for the Item #4 Kerite cable. The cable failed to sustain IR readings at 1000Vdc for the post-test and post-hose test. No IR measurements were taken during the fire test. Therefore, there is no evidence to correlate temperatures to a time of failure during the test. Cables with #12 AWG are typically used for control type applications where the voltage level would be 120VAC or 125VDC. Guidance from GL86-10 only requires a 500V Megger test voltage for control type cables. No IR testing was performed at lower voltage levels.

E. As demonstrated in the NUREG/CR-5655 test, IR failure criteria can be attributed to a certain temperature or temperature range. The statement "Testing by SCE&G cites average temperatures at failure of 237°C (458°F)" does not impart this same level of information. As identified, the 458°F (237°C) is an average of 16 temperature readings based on a bare #8 AWG wire ranging from 215°F (101.7°C) to 606°F (318.9°C) over a distance of about 90 inches. To document a threshold temperature based on this average temperature includes the uncertainty that the failure might not have occurred until the temperature reached 606°F (318.9°C), and the probability that it did not occur at 215°F (101.7°C). Since the cable was probably in contact with the conduit, the threshold uncertainty can go to above 700°F (371°C) to 770°F (410°C).

F. Based on the NUREG/CR-5655 data, there is support that the failure occurred around the time the temperature reached 700°F (371°C); there is no support that failure occurred around 458°F (237°C). Therefore, to use this SCE&G test sample as an example of the lower thermal threshold of Kerite FR for fire analysis purposes is unsubstantiated.

G. The SCE&G test contained other raceway configurations and samples; however, the same logic applies regarding higher raceway temperatures, the uncertainty in establishing a failure temperature point, and the level to which IR tests were conducted.

In summary, the data presented in the NUREG/CR-5655 test with clarification that data derived from saturated steam conditions is not applicable for use in fire analysis justifies that Kerite FR is a thermoset and has temperature threshold properties consistent with other thermoset materials. The data presented in the SCE&G test does not corroborate the interpretation in IMC 0308, Attachment 3, Appendix F, Section 6.2.3.3 of the NUREG/CR-5655 test data due to limitations in the test setup and data collection.

The basis for the cable thermal damage threshold in NUREG/CR-6850 is the data presented in NUREG/CR-5655. For Kerite FR cable, the data supports a failure temperature range of 372 – 382°C (702 – 720°F) which also satisfies the temperature criteria of 330°C (625°F) for Thermoset cable material. NUREG/CR-6850 is still correct with regard to Kerite FR cable and as such, the ERATA sheet for NUREG 6850, dated August 30, 2007, and IMC 0308, Attachment 3, Appendix F, Section 6.2.3.3 should not be implemented.

If appropriate, provide proposed rewording of guidance for inclusion in the next Revision:

No proposed rewording of NUREG/CR-6850 regarding this issue is required.

References:

1) U.S. NRC/EPRI, *EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities*, NUREG/CR-6850, EPRI TR-1011989, September 2005
2) M.J. JACOBUS, G.F. FUEHRER, *Submergence and High Temperature Steam Testing of Class 1E Electrical Cables,* NUREG/CR-5655, SAND90-2629, Sandia National Laboratories, May 1991.
3) S.P. NOWLEN, M.J. JACOBUS, *The Estimation of Electrical Cable Fire-Induced Damage Limits*, SAND92-1404C, presented at Fire and Materials 1st International Conference and Exhibition, Sept. 24-25, 1992, Washington DC.
4) South Carolina Electric & Gas Company, Virgil C. Summer Nuclear Station, Engineering Services Technical Report, *Kaowool Triple Wrap Raceway Fire*

Barrier Test For Conduits and Cable Trays, TR07870-001, Omega Point Laboratories, May 2000.

5) C.M. CRAFT, *An Assessment of Terminal Blocks in the Nuclear Power Industry*, NUREG/CR-3691, SAND81-0422, Sandia National Laboratories, September 1984.