NRCREP - Comments on CAROLFIRE Test Results

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Date: 07/30/2007 4:02 PM
Subject: Comments on CAROLFIRE Test Results

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RULES AND DIRECTIVES BRANCH USNRC

July 30, 2007

6/5/07
72FR 31097
(1)

Chief, Rules and Directives Branch
Office of Administration
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Subject: Comments on CAROLFIRE Test Results

Project Number: 689

On June 1, 2007, the Federal Register published for comment a report on the CAROLFIRE tests (NUREG/CR 6931, Volumes 1 and 2). The Nuclear Energy Institute (NEI) has consolidated some of the industry comments on CAROLFIRE testing in Enclosure 1. A summary of our main comments follows.

- Risk Significance (See comments 1, 9, 38 and 39)
  The foreword to Volume 1 states that "risk informed methods indicate that hot shorts can pose a significant risk, and that plant risk analyses should account for these additional risks..." Industry believes that the risk significance of hot shorts is inconclusive and depends on the scenario in question. The EPRI testing and CAROLFIRE project have tested many different configurations under a wide variety of conditions and, although inter-cable interactions have occurred, the fault dynamics appear to work in such a manner that the likelihood of inter-cable shorting coincident with a fault of sufficient "quality" to produce a spurious actuation is extremely remote. In addition, the short duration of hot shorts without grounding has been demonstrated through testing, which in many practical applications, could limit the risk significance of a fire induced hot short. In addition, risk significance depends on other factors besides the potential for damage given a fire of certain size, such as fire frequency, fire growth, failure to suppress, failure to mitigate, etc.

  The above industry position is supported not only by the CAROLFIRE tests, but also by the NEI/EPRI tests that were completed several years ago. Industry requests that the NRC remove any judgments about risk significance from the document and simply provide the results of the testing.

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SUNSI Review Complete
Template = ADM-013

E-RIDS = ADM-03
Add = M. H. Salley (MXS3)
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nuclear. clean air energy.

Mail Envelope Properties (46AE43D4.79E : 12 : 14238)

Subject:	Comments on CAROLFIRE Test Results
Creation Date	Mon, Jul 30, 2007 4:01 PM
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Created By:	jhr@nei.org

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07-30-07_NRC_Comments on CAROLFIRE Test Results_enclosure.pdf	68059	
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NUCLEAR ENERGY INSTITUTE

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July 30, 2007

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- Risk Significance (See comments 1, 9, 38 and 39)
  The foreword to Volume 1 states that "risk informed methods indicate that hot shorts can pose a significant risk, and that plant risk analyses should account for these additional risks..." Industry believes that the risk significance of hot shorts is inconclusive and depends on the scenario in question. The EPRI testing and CAROLFIRE project have tested many different configurations under a wide variety of conditions and, although inter-cable interactions have occurred, the fault dynamics appear to work in such a manner that the likelihood of inter-cable shorting coincident with a fault of sufficient "quality" to produce a spurious actuation is extremely remote. In addition, the short duration of hot shorts without grounding has been demonstrated through testing, which in many practical applications, could limit the risk significance of a fire induced hot short. In addition, risk significance depends on other factors besides the potential for damage given a fire of certain size, such as fire frequency, fire growth, failure to suppress, failure to mitigate, etc.

  The above industry position is supported not only by the CAROLFIRE tests, but also by the NEI/EPRI tests that were completed several years ago. Industry requests that the NRC remove any judgments about risk significance from the document and simply provide the results of the testing.

- Relation to Actual Plant Conditions (See comments 3, 6, 25 and 26)
  The report contains comparisons to the NEI/EPRI testing that appear to state that the CAROLFIRE tests more closely approximate the conditions expected at a nuclear power plant. Both the CAROLFIRE tests and the NEI/EPRI tests were designed to bound plant conditions. Nether series of tests can be easily extended to illustrate what may happen in actual plant conditions. Industry requests that the NRC revise the report to present the findings without this comparison.

- Correlation to DC Circuits (Comments 14 and 15)
  The CAROLFIRE tests were not performed on DC circuits. Appendix C indicates there is at least philosophical flexibility in Surrogate Circuit Diagnostic Unit design for a simulating DC effects, but very different sources, fuse sizes, target devices, and even monitoring transducers would be required. As a result extension of the existing test results to DC circuits will be very difficult. Since DC circuits constitute a significant fraction of the circuits of interest at plants and since some of the most challenging hot short-induced spurious actuations from a consequence standpoint are components powered from ungrounded DC sources, consideration should be given to correlating the results of the CAROLFIRE testing to DC circuits such as solenoid operated valves, air operated valves with solenoid pilot valves, and controls for switchgear circuit breakers.

  If this extension is undertaken, Industry would appreciate involvement in the effort.

- Application of Test Results (Comments 1 and 31)
  The results of the CAROLFIRE tests may affect both deterministic and probabilistic approaches to post-fire circuit analysis. Our thoughts on both of these applications follow.

  - Deterministic
    The cable fire testing conducted by the NRC and the Industry provides valuable insights into whether adjustments need to be made in the current approach used within the industry for addressing fire induced circuit failures in a deterministic post-fire safe shutdown analysis. However, neither the CAROLFIRE Testing nor the NEI/EPRI Testing provides a direct correlation to which fire induced circuit failures should be considered in a deterministic post-fire safe shutdown analysis. Each set of testing was designed to determine the probability of a hot short given cable damage. This approach, in essence, bypasses all of the fire protection defense-in-depth measures employed to prevent fires from starting, to detect fires that do occur and to rapidly extinguish any fires that are detected. These defense-in-depth measures, along with very conservative assumptions related to fire damage within each fire area, are major cornerstones of the deterministic approach to post-fire safe shutdown. The criteria for which fire induced circuit failures need to be addressed in

a deterministic post-fire safe shutdown analysis must give proper consideration to the factors mentioned above; it cannot solely be based on the results of the cable fire testing conducted to-date.

- Probabilistic
  With the large amount of data collected by the CAROLFIRE tests, it is believed that an analysis of the data using acceptable probabilistic methods could estimate the probability of spurious actuation given cable damage. Estimating this likelihood, while not part of the stated scope of the tests, would be beneficial and help to integrate the testing into plant applications.

The NEI Circuits Task Force plans on using the insights from the NRC and Industry Testing as a part of its effort to develop criteria to resolve the current Multiple Spurious Operations (MSOs) issue. Industry would appreciate involvement in any NRC effort to apply the CAROLFIRE test results to circuit analysis methods.

- Time to Failure (Comments 5, 48)
  The analysis results of the test data appear to show that the "time to failure" for like insulation types may be predictable and repeatable. While it is acknowledged that establishing "time to first failure" was not explicitly part of the stated objectives of the CAROLFIRE Project, it seems unfortunate to not capitalize on this very important data. General conclusions and observations pertaining to expected time to cable failure would have immediate and important relevance in helping address certain operator manual action issues facing NRC and industry.

Industry would be pleased to meet with the NRC to discuss our comments and the application of the CAROLFIRE test results.

If you have any questions, please contact me at 202-739-8080; am@nei.org or Jim Riley at 202-739-8137; jhr@nei.org.

Sincerely,

James H. Riley

Enclosure

NUREG/CR-6931 – *CAROLFIRE*

(Draft for Public Comment, March 2007)

Item	Section	Comment	Basis for Comment
1	Vol. 1, Foreword	The foreword to Volume 1 states that "risk informed methods indicate that hot shorts can pose a significant risk, and that plant risk analyses should account for these additional risks..." We do not believe that this is a correct statement. We believe that the only indication of risk significance we have related to hot shorts comes from the testing that has been performed, i.e. NEI/EPRI and CAROLFIRE. We also believe based on having reviewed both sets of test data that the risk significance has not really been demonstrated. In some case, e.g. inter-cable hot shorts, the opposite is true. In other cases, e.g. the need to consider effects on multiple cables and the need to consider the effects of impacts to multiple pieces of equipment that are required for a multiple spurious operation of concern to occur, the evidence is inconclusive. Finally, in some cases, e.g. solenoid valves and circuits like the GE elementary logic diagrams where the effects of a limited duration hot short can be inconsequential, the data suggests that hot shorts are, in fact, not a concern. Based on this, we think that the NRC should remove any judgments about risk significance from the document and make the document one that simply provides the result of their testing. We would then suggest that industry experts on the topic of fire induced circuit failures provide a paper that states the significance of the test results, both NEI/EPRI and CAROLFIRE, relative to performing a post-fire safe shutdown analysis under deterministic rules and under risk informed rules. We anticipate that each set of rules would involve different considerations.	Technical Clarification
2	Vol. 1, Executive Summary	P. xiii, 3rd par. Bin 2 items A & B (Penlight tests), these are Not Applicable to Duke's armored cables since the grounded armor makes inter-cable shorting a non-issue.	Technical Clarification
3	Vol. 1, Executive Summary	A statement is made that a propane (propylene) gas diffusion burner was used with fire intensities between 250 and 350 kw, a range that is representative of the fires in the industry. Although the statement is accurate, it should be noted that fires with the intensity of a propane burner would not likely occur as close to the cable locations as performed in the test (within 12 feet). Even the intermediate test structure was equivalent to the smallest of Nuclear Power Plant rooms containing cable. The test conditions were conservative.	Technical Clarification
4	Vol.1 – General Comment	With regards to cable shorts versus fire location, the inter-cable shorts between two TS-insulated cables and other mechanical failures are not explained in detail. Did the conductors between the two cables fuse momentarily (make contact). What was the condition of the cable insulation and jacket materials for both cables after the test? Were there radial or longitudinal tears in the cable insulation? Were there signs of ballooning or swelling of some of the failed insulation types?	Technical Clarification

Item	Section	Comment	Basis for Comment
5	Vol. 1 – General Comment	In a previous RIS draft there was a minimum time for faulting / spurious operation that disappeared in the final issue. The NRC later concluded that there was not enough supporting data from that series of Sandia Labs testing to support that minimum time for cable failures. CAROLFIRE adds an additional ~100 supporting testing data series (with no contradictions) showing that cables do not instantaneously fault / or cause spuriously operation. This is true for thermoplastic and thermoset. This is true for the penlight series testing or the much more vigorous larger scale testing. There should be a time element established for initial failures for thermoplastic and a separate time element established for thermoset since test data shows thermoset to be much more robust.	Technical Clarification
6	Vol. 1 – General Comment	There are many of comparisons to the NEI testing that appear to state that this testing is more closely tied to the conditions of a Nuclear Power Plant. Presentation of the findings without these statements is recommended.	Technical Clarification
7	Vol. 1 – General Comment	Although the applicability of the CAROLFIRE tests to (Duke Energy's) armored cables is reduced (e.g. N/A on inter-cable shorting) with no armored cables tested, significant research contributions are provided in this report relating to nuclear power plant (NPP) industry concerns for control-cable fire-induced spurious actuations. Most of this new research helps improve fire modeling for PRA. Also, the Bin 2 findings of no obvious limits on the number of potential multiple spurious actuations and the < 20-minute duration of any spurious actuation appear to be consistent with Duke Energy's 2006 testing.	Technical Clarification
8	Vol. 1 – General Comment	General Document – For better clarity and review of results, recommend the following editorial / administrative items: Sections 6 and 7 items – Recommend presenting time in minutes in addition to seconds to provide the user a better "first look" understanding of timing of failures. Providing times in the 1000's of second does not provide an intuitive understanding at the "first look". In addition, tests are started at a time other than "0" (e.g., Section 7.1.2 starts at t=632 sec. and the test times proceed from that point). Using this data to understand time dependencies requires subtraction of two numbers. While this information is obviously from recording equipment, recommend adjusting the numbers to a start at 0 to avoid this unnecessary step. Recommend including English units for all numerical values. All table headings should be repeated when the table "page breaks".	Editorial

Item	Section	Comment	Basis for Comment
9	Vol. 1 – General Comment	The term "risk-relevant" is used in many instances in the test report. This term is not defined and risk is the combination of likelihood and consequences. The testing only looked at likelihood given a damaging fire. The term should be defined, or preferably removed.	Technical Clarification
10	Vol. 1 – General Comment	Typos Page v – "hot shorts" Page xvii – "....Inter-cable shorting between ~~two~~ a TP-insulated ......" Typo – Figure C-1 is referenced on page 164. The figure on p. 165 is labeled as C.8.	Editorial
11	Vol. 1 – General Comment	The Penlight series of tests potentially provides very valuable data regarding the heat transfer properties of cable with respect to defined radiant thermal insults, however the level of detail provided in the report could be more comprehensive to allow for more practical application. In section 2.2 of the SANDIA attachment, the radiant heat flux to the targets is discussed, in a manner suggesting it would be a trivial exercise for the reader to determine the flux ("Given the geometry, the net heat flux at the cable surface is reduced substantially, but again, the effect is easily calculated based on simple geometric view factor calculations."), however insufficient information is provided for a reader to actually do this calculation (it appears that knowing the exact cable placement in the tray would be needed to do this). Because the estimated thermal flux is the property that a user would need to correlate his/her situation to a similar Penlight test, this type of analysis is recommended to be included in the report for each Penlight test.	Technical Clarification
12	Vol. 1 – General Comment	The Penlight test data provided is limited. Given that approximately 68 tests were run, only a few response curves appear to have been included in the report. For a user interested in finding a Penlight scenario that is similar to his/her configuration, all of the response curves need to be provided. Recommend additional response curves be provided.	Technical Clarification
13	Vol. 1 – General Comment	The Penlight test data does not indicate whether ignition of the cables occurred, and at which time ignition occurred. For a user interested in finding a Penlight scenario that is similar to their configuration, ignition information needs to be provided. Recommend additional ignition information be provided.	Technical Clarification
14	Vol. 1 – General Comment	Some of the most challenging hot short-induced spurious actuations from a consequence standpoint in the nuclear industry are components powered from ungrounded dc sources (e.g., pressurizer PORVs, SG PORVs, letdown valves, reactor head/pressurizer vents, SRVs, etc.). The entire scope of the report was ac control circuits (grounded and ungrounded). This configuration is directly applicable to motor operated valves, which are only a subset of components that are of concern from a fire-induced hot short concern. In order to use the information from this test (as well as the NEI/EPRI circuit testing) there should be a specific correlation of the test results to ungrounded dc control circuits.	Technical Clarification

NUREG/CR-6931 – *CAROLFIRE*

(Draft for Public Comment, March 2007)

Item	Section	Comment	Basis for Comment
15	Vol. 1 – General Comment	Was consideration given to testing or representing DC circuits such as controls for switchgear circuit breakers? Appendix C indicates there was at least philosophical flexibility in SCDU design for a DC possibility, but very different sources, fuse sizes, target devices, and even monitoring transducers would be required.	Technical Clarification
16	Vol. 1, p. xiii	P. xiii, 5th par., 2nd sentence: at least 7% of U.S. NPP cables are not directly represented in the CAROLFIRE testing, namely armored cables. Therefore, analyses of armored-cables circuits would need to reference other tests as well. Also in Table 3.1 (p. 7).	Technical Clarification
17	Vol. 1, p. xvi	P. xvi, editorial typo in Bin 2 item A conclusion: "(*given* cable failure)". This is also repeated on p. 149 section 9.1.1.	Editorial
18	Vol. 1, p. xvii	P. xvii on Bin 2 item B, 2nd par., 4th line "the TS cable had experienced internal faulting first" – may not be as surprising if at the fault location, the TP cable is on top of the TS cable (or otherwise shielded or less severe location relative to the heat source).	Technical Clarification
19	Vol. 1, p. xvii	Although no spurious actuations occurred, the report discusses the potential for a spurious actuation due to a "latching" feature such that a momentary hot short could lock in a circuit actuation signal. Please explain the mechanics involved in a hot short locking in a circuit actuation signal. Given the conditions of the test, using a propylene gas diffusion burner directly on the cables it's not clearly understood how the possibility of results are much worse than the test results that were actually received. The conclusions may reflect that the cables were exposed to conditions that envelop the fire conditions that they would normally see in an actual fire and thus it is very unlikely that a "latching" feature would occur.	Technical Clarification
20	Vol. 1, p. xvii	P. xvii, Bin 2 item B conclusions par., 1st line: delete "two". This is also repeated on p. 149 section 9.1.2.	Editorial
21	Vol. 1, p. xix	P. xix on Bin 2 item D, 3rd par., 3rd line: delete "observed at all" – redundant to previous "observed" in same statement. Also the 80% mentioned "as noted previously": where? P. xvii for Bin 2 item C says 70%.	Editorial
22	Vol. 1, p. xix	Somewhat related to Bin 2 item E is fire duration before the first spurious actuation. Were such durations trended for the different thermal exposures? The sections 6 and 7 events summary tables indicate clear time sequence to failures, but which of these result in spurious actuations is not clear.	Technical Clarification
23	Vol. 1, Table 3.1	P. 9, Table 3.1, CPT size: results and conclusions from the CAROLFIRE tests with relatively larger CPTs than in NEI/EPRI and Duke Energy tests are conservative for plants with relatively smaller (150VA) CPTs. There also may be other CPT variable effects like impedance and primary voltage.	Technical Clarification

Item	Section	Comment	Basis for Comment
24	Vol. 1, Section 3.2	P. 9, section 3.2, 2nd line typo: "know" = "*known*".	Editorial
25	Vol. 1, Section 3.3	The size of the closed PENLIGHT test structure is small in comparison to cable tray configurations in a Nuclear Power Plant. Under closed conditions the increased air flow would increase the amount of oxygen to the area as stated in the report, however, the other mechanism that occurs with increased air flow in such a small high temperature environment is an increase in the convective heat transfer coefficient to the cable surface that may not be a good simulation of the cooler ventilation flows of a Nuclear Power Plant. While it is understood that radiative effects from the fire (varying with temperature to the 4th power) are dominant, the convection effects if cooler would take away heat generated as a result of IR power losses generated in the cable itself. When we are discussing cable failure, it's the convective heat transfer (varying with temperature to the 2nd power) that plays a major role in the removal of cable heat generated due to power losses. It is hard to imagine that a hot gas layer at 900°C (1652°F) is conducive of the hot gas layer during a typical Nuclear Power Plant fire. The industry has experienced temperatures up to 250 to 300°F in some of our worst-case conditions in unofficial models. For most of our modeled fire conditions the hot gas layer would remain between 150°F to 300°F in rooms where redundant safe shutdown cables are present. Flashover conditions would likely occur in the hot gas layer of at atmospheric pressure with a temperature between 300°C to 600°C (572°F to 1172°F) as referenced by Section 13 of the text of Fire Dynamics Tools (FDT^s) Quantitative Fire Hazard Analysis Methods for the US NRC. It was noticed that the cable testing was done well within and above this range, some up to 700°C. How does flashover affect the cables that failed due to the hot gas layer conditions? Both test structures looks as if they could become pressurized during tests. Did either test structure become pressurized during test conditions? The conditions in the PENLIGHT drum at 550°C (1022°F) would be well within flashover conditions. How long would it take for a Nuclear Power Plant to reach flashover conditions in the overhead? This would not be seconds but realistically it would be far more than several minutes.	Technical Clarification

Item	Section	Comment	Basis for Comment
26	Vol. 1, Section 3.3	It was stated in the bottom paragraph on p. 15 about the CAROLFIRE intermediate –scale test structure that as the fire progresses the hot gas layer depth increases and ultimately smoke and hot gases spill out naturally, and that that this is typical of hot gas layer development behavior for a beam pocket configuration. It should be noted that Nuclear Power Plants usually do not run cable up in the beam pockets in a horizontal configuration. Cables usually only transverse the beam pockets if they are going into the room above. The configuration would not be the same as the configurations tested. Most cables mounted in a Nuclear Power Plant would be well below the structural beam pockets. Would conditions below the beam pockets be at much lower temperatures with cooler air flow?	Technical Clarification
27	Vol. 1, Figure 4.4	P. 33, Figure 4.4 for MOV-1 SCDU circuit: was conductor 8 simulating a 'spare' ever grounded? Spare conductors are typically grounded. Also, the figure or multiple places elsewhere in the report should confirm that the trays and conduits were always grounded for small-scale and intermediate tests.	Technical Clarification
28	Vol. 1, Section 4.5.1	Pp. 33 & 34 section 4.5.1 indicate that circuit path 7 or cable conductor 5 is "grounded", but per sections 7.2.5 and 9.2.3, this was only true for half of the SCDUs. The indication may more accurately be "connected to the CPT return" which was grounded or un-grounded, depending on which of the paired SCDU.	Technical Clarification
29	Vol. 1, Section 6	P. 50, section 6, 3rd line typo: "potentially" = "*potential*".	Editorial
30	Vol. 1, Sections 6 and 7	Recommend a clear, consistent high level test objective in the introduction (most of the sections do). The minimum level of information should be TS, TP, both (tray or conduit) without having to look in another table or source to determine that information. For example, section 6.2.2 requires looking at another table in the report to gain that high level understanding of the test scope.	Editorial

Item	Section	Comment	Basis for Comment
31	Vol. 1, Sections 6 and 7	The test was an extensive, comprehensive testing that specifically looked at the likelihood of inter-cable hot shorts that could result in spurious actuation. A large amount of data was measured and documented, with clear documentation and understanding on a conductor-by-conductor basis. The conclusion was that inter-cable hot shorts were "plausible". This conclusion, by itself, does not provide insight into inter-cable hot shorts and its "role": • In determining compliance • For inspection purpose • Likelihood values in NUREG/CR-6850 (based on Expert Elicitation panel, also reflected in NEI 00-01) With the large amount of data collected, it is believed that an analysis of the data using acceptable probabilistic methods could estimate the probability of spurious actuation given cable damage (P_{SACD}). Estimating this likelihood, while not part of the stated scope, would benefit the industry and help to integrate the testing into plant applications.	Technical Clarification
32	Vol. 1, Figure 6.1	P. 50, Fig. 6.1, may help to have a label of "In Conduit" for the 3 conductors configuration and "In Tray" for the 6 conductors configuration.	Technical Clarification
33	Vol. 1, Section 7.2.4	P. 129, section 7.2.4: Since Rockbestos-Surprenant has a few different sub-types of 'Vita-Link' cable types (Vita-Link -MC (metal-clad), -RHW, or -CI) please specify here and / or elsewhere appropriate in the report. Also, in first paragraph, last line: please define 'significant' failures?	Technical Clarification
34	Vol. 1, Section 7.2.5	P. 130, section 7.2.5, first par., 5th line, insert "grounded" before "spiral-wound metallic armor" to clarify the armor was always grounded. Similarly in last paragraph, line 2: replace "armored cables" with "cables with grounded armor".	Technical Clarification
35	Vol. 1, Section 7.2.5	P. 130, section 7.2.5, 3rd paragraph, one should logically expect an increase likelihood of fuse blow to grounded conductors within a cable, given a grounded control-power source. The degree of effect would depend on the ratio of the number of grounded conductors to energized power-source conductors within the cable. The same applies to p. 153 section 9.2.3 (in Summary).	Technical Clarification
36	Vol. 1, Section 7.2.5 & 9.2.3	These sections discuss test results for grounded versus ungrounded circuits. The testing appears to confirm that grounding configuration for non-armored cable has little impact on the relative proportion of failure modes. Although not stated in the report, for this observation to be consistently true, external cable ground paths (e.g., cable tray, other grounded metal structures, and grounded conductors from other cables) must be effectively insignificant as a circuit failure path in comparison to intra-cable ground paths. Once again, the dominate nature of intra-cable shorting is evident.	Technical Clarification

Item	Section	Comment	Basis for Comment
37	Vol. 1, Section 8	Footnote 13 on page 131 states: *"Note that during the workshop a listing of several 'Bin 3' items – items that would not be considered in future inspections based on demonstrated evidence of very low likelihood – was also developed, although the listing of Bin 3 items was not included in the final revision to RIS 2004-03."* Recommend changing to: Note that during the workshop a listing of several 'Bin 3' items – items that would not be considered in future inspections based on demonstrated evidence of very low likelihood – was also developed. Revision 1 of RIS 2004-03 did not specifically list the Bin 3 items. However, Revision 1 of RIS 2004-03 referred to the Bin 3 items from Revision 0 of RIS 2004-03. RIS 2004-03 did not repeat the listing of Bin 3 items since they were outside the scope of the inspection procedure.	Technical Clarification
38	Vol. 1, Section 8.1	Section 8.1.3 summarizes well the test results as applied to inter-cable hot shorting for thermoset-insulated cable. However, the summary and conclusions contained in Section 8.1.4 are not entirely clear as to the whether this failure mode is considered "risk significant" within the context of RIS 2004-03. For realistic surrogate circuits, inter-cable shorting between thermoset-insulated cables produced no spurious actuations in the CAROLFIRE test program, or in the previous EPRI test program. Nonetheless, the CAROLFIRE Project concludes that this failure mode is "plausible." The assertion of plausible is not without merit, given that several cases of clear inter-cable interactions were observed. However, within the context of RIS 2004-03 the operative question is whether or not this failure mode is "risk significant." Plausible does not directly correlate to risk significance. The complexities of quantifying the various influence factors for fire-induced circuit failures are numerous. Thus, the ability to predict with certainty the failure outcome for specific configurations is not by any means a refined science. However, the EPRI testing and CAROLFIRE project have tested many different configurations under a wide variety of conditions. And, although inter-cable interactions between thermoset-insulated cables have occurred, the fault dynamics appear to work in such a manner that the likelihood of inter-cable shorting coincident with a fault of sufficient "quality" to produce a spurious actuation is extremely remote.	Technical Clarification

Item	Section	Comment	Basis for Comment
39	Vol. 1, Section 8.2	The technical summary of this item is again well presented. However, it would appear that, in application, two specific cases should be considered: • Case 1: The likelihood of a thermoset-insulated cable initiating a hot short in the thermoplastic-insulated cable. • Case 2: The likelihood of a thermoplastic-insulated cable initiating a hot short in the thermoset-insulated cable. The discussion in Section 8.2 pertaining to the low likelihood of coincident failures of the different insulating materials provides a technically sound and compelling argument for the observed test results. This argument as applied to above cases would indicate: • For Case 1, the "target" conductors are located in the thermoplastic-insulated cable. Any source conductors within the thermoplastic-insulated cable would likely be de-energized by operation of the circuit protective device before the source conductors of any co-located thermoset-insulated cable. Thus, it is plausible that the thermoset-insulated cable "source" conductors could initiate a hot short to any yet ungrounded "target" conductor within the thermoplastic-insulated cable. As observed by the CAROLFIRE Project, the likelihood of this failure mode resulting in spurious actuation is very small in comparison to the likelihood of spurious actuation from intra-cable hot shorts. • For Case 2, the "target" conductors are located in the thermoset-insulated cable. Given the distinctly different insulation characteristics for thermoset and thermoplastic materials, it does not seem plausible that any potential "source" conductors within a thermoplastic-insulated cable would remain viable by the time a co-located, thermoset-insulated cable electrically failed. The fundamental material properties of the insulating materials, as supported by the test results, would indicate that Case 2 is not risk significant within the context of RIS 2004-03, and most likely is not even plausible.	Technical Clarification
40	Vol. 1, Section 8.4.2	P. 143, section 8.4.2, 2nd paragraph: the reference to the Duke Energy testing is appropriate for *at least* 5 return paths in that Duke Energy tested 8-conductor and 37-conductor cables. Pertaining to grounded raceways in the CAROLFIRE report, there are particularly more than 5 with grounded-source circuits.	Technical Clarification
41	Vol. 1, Section 8.4.3	P. 146, section 8.4.3, last sentence: "... despite the use of what appears to be a nearly identical circuit set-up and devices as were used by NEI/EPRI" – even though Duke Energy also tested with 150VA CPTs as installed in its plants, the CPTs have some inherent winding differences from the NEI/EPRI tests due to likely different primary voltage, namely 600v, again reflecting actual Duke Energy auxiliary voltage (vs. more common 480v MCC voltage in most U.S. NPPs).	Technical Clarification

Item	Section	Comment	Basis for Comment
42	Vol. 1, Section 9.2.2	P. 152, section 9.2.2, a difference that should contribute to the somewhat increased CAROLFIRE spurious actuation probability vs. the NEI/EPRI tests is that the NEI/EPRI tests apparently applied grounded control-power sources throughout the tests (per TR-100326 Fig. 4.9 and its App. B Fig. 2.1).	Technical Clarification
43	Vol. 1, Section 9.2.2	P. 152, section 9.2.2, last par., 1st line: delete first "to" after "CAROLFIRE".	Editorial
44	Vol. 1, Section 9.2.3	P. 153, section 9.2.3, 2nd par., last line: insert "grounded" before "raceway".	Editorial
45	Vol. 1, Appendix C	P. 170. The typical range of holding current for motor contactors is stated as 0.82-0.87 A. Based on the associated graph, it appears that this range should be 0.082-0.087A.	Editorial
46	Vol. 2, Executive Summary	P. viii, 4th par., 2nd sentence: at least 7% of U.S. Nuclear Power Plant cables are not directly represented in the CAROLFIRE testing, namely armored cables. Therefore, analyses of armored-cables circuits would need to reference other tests as well. This is also in the 3rd par. of the p. 147 section 7 Summary.	Technical Clarification
47	Vol. 2, Section 2.4	P. 18 section 2.4 item 2: the reference to 34/C (conductors) construction should be 37/C for a "popular ... round finished cable". This 37-conductor was also the larger of the armored cable type tested by Duke Energy.	Technical Clarification

Item	Section	Comment	Basis for Comment
48	Vol. 2, Section 5	The analysis results of Penlight test data shows the "time to failure" for like insulation types to be predicable and repeatable. While it is acknowledged that establishing "time to first failure" was not explicitly part of the stated objectives of the CAROLFIRE Project, it seems unfortunate to not capitalize on this very important data. Predicted *time to first circuit failure* is of paramount importance in helping answer the infamous question of what constitutes t = 0. The operational importance here is: *What is the safety significance and probability of success of taking certain pre-emptive actions – either from the Control Room or locally – immediately upon detection of a fire?* If these pre-defined actions can be accomplished with a very high degree of certainty, and if these actions greatly reduce or eliminate the possibility of certain high-consequence failures, it is self-evident that this line of inquiry is important to post-fire safe shutdown. For this reason, it is suggested that the analysis of cable electrical performance be expanded to include a discussion of time to first failure. Justifiably, it can be argued that this question is best addressed within the context of fire modeling. However, the data does lend itself to useful generic conclusion, within defined bounds. General conclusions and observations pertaining to expected time to cable failure would have immediate and important relevance in helping address certain manual action issues facing NRC and industry.	Technical Clarification
49	Vol. 2, Section 5.3.3	This section of the report summarizes performance of 7/C, 12 AWG Tefzel cable during Penlight tests. In describing the test results, it is observed that a higher shroud temperature caused the cable to heat much quicker, which "...apparently led to some changes in the electrical shorting behavior." This observation is potentially significant because it would indicate that the rate of cable heating alters the shorting behavior of a circuit. Since none of the current fault likelihood analysis methods consider rate of cable heating in assessing failure mode likelihood, it is important to understand better the implications of this observation. Because this observation is not made for any other cable tests, can it be characterized as unique to the Tefzel cable? Although this comment stems from Volume 2, which does not focus on specific electrical failure modes, it is recommended that this aspect of the test results be characterized in more detail so that potential implications to current analysis methods can be evaluated.	Technical Clarification
50	Vol. 2, Section 7	P.147, section 7, 2nd par., 4th line: "where" = "*were*".	Editorial
51	Vol. 2, Section 7	P. 148, section 7, 1st full par., last line: insert comma to make "... burn complete*ly, c*reating more realistic exposure conditions ..."	Editorial

Item	Section	Comment	Basis for Comment
52	Vol. 2, Section 7	P. 148, section 7, 2nd full par., last sentence: "There" = "*These*".	Editorial
53	Vol. 2, Section 7	P. 148, section 7, last paragraph: Didn't the NEI/EPRI and Duke Energy testing similarly accomplish isolation of thermocouple effects on electrical measurements by placing the thermocouples on identical cables adjacent to the SCDU cables as opposed to being placed on the electrically monitored SCDU cables themselves? Perhaps at least for armored cables, the concerns for externally placed TC effects may not be as significant.	Technical Clarification