NUCLEAR ENERGY INSTITUTE

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Mr. John Hannon
Chief, Plant Systems Branch
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Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, DC 20555

SUBJECT: Industry Integrated Methods for Addressing Circuit Failure Issues

PROJECT NUMBER: 689

Dear Mr. Hannon:

As you requested at our meeting on December 20, 1999, enclosed is a revised copy of the draft outline of a risk-informed industry method for addressing the issue of fire-induced circuit failures (hot shorts, shorts to ground, or open circuits). Attached to this draft is a revised description of three generic tasks still in progress that are central to completion of the industry method. Also enclosed is a revised schedule for activities to support issue resolution.

As with our December 14 transmittal, these enclosures should be considered outlines rather than full descriptions of the method, and should be considered works in progress. They do not represent firm industry positions, but rather a substantive description of a suggested industry approach.

We request that NRC staff review these documents in the same spirit that industry reviewed drafts of the NRC Fire Protection Risk Significant Screening Method and the baseline inspection procedures – as working documents subject to further optimization through comment. We have additional work in the near future to further develop the method, but welcome feedback at any time that would help achieve an acceptable outcome.

Please call me at 202-739-8084 if you have further questions.

Sincerely,

David J. Modeen

FAE/edb
Enclosures

D046 1/1

c: Mr. Eric Weiss, U.S. Nuclear Regulatory Commission
Mr. Mark Cunningham, U.S. Nuclear Regulatory Commission
Dr. Nathan Siu, U.S. Nuclear Regulatory Commission

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Draft Outline

Industry Method for Addressing IN 92-18 Failure Modes and Multiple Spurious Actuations

January 17, 2000

Please provide any comments to Fred Emerson at fae@nei.org or 202-739-8086.

I. INTRODUCTION

Difficulties in interpreting NRC requirements and regulatory guidance, along with numerous variations in plant design, have resulted in plant-specific post-fire safe shutdown analysis approaches. Some of these approaches are based on long-held industry interpretations of regulations which differ from the NRC staff interpretations expressed in their letter to NEI of March 11, 1997.

As the industry moves forward, a greater emphasis is being placed on risk-informed methodologies such as those used in the on-line maintenance and outage risk management areas. NRC has indicated its receptivity to a risk-informed industry proposal for resolving the circuit failures issues. Industry is proposing this risk-informed approach for addressing circuit failures issues, which integrates the deterministic approach proposed by the BWR Owner's Group on November 15, 1999, with circuit failure characterization and probabilistic elements developed by the NEI Circuit Failures Issue Task Force.

II. OBJECTIVE

This document presents a method for licensees to determine the safety significance of concurrent spurious actuations, and potential fire-induced circuit failure modes indicated in Information Notice 92-18. If the user determines that additional measures are needed to prevent or mitigate the consequences of the spurious actuations, this method can also be used to ensure the cost-effectiveness of these measures.

This method, including the documentation of its use and any additional measures taken to address its results, should constitute an acceptable method for resolving these circuit failure issues.

III. METHOD

General Description

This screening method evaluates the likelihood and consequences of concurrent spurious actuations, and fire-induced spurious actuations that could result in valve failure modes as described in IN 92-18 (which can result in irrecoverable damage to valves because of bypassing valve motor protective devices). The criterion for determining risk significance is whether the increase in core damage frequency (Δ CDF) for each component (or component pair) is less than the Regulatory Guide 1.174 guideline of 1E-6 per reactor year. The analysis involves a phased approach which successively multiplies the previously calculated risk factors by new ones at each phase, and compares the Δ CDF against the 1E-6 criterion. This allows the option of stopping the analysis at any phase where the Δ CDF or probabilistic contributors thereto have been determined to be "insignificant" because they are less than 1E-6 per reactor year.

It should be noted that a Δ CDF of 1E-6 per reactor year establishes a lower bound for truncating both analyses and needs for further action. Regulatory Guide 1.174, Figure 3, "Acceptance Guideline for Core Damage Frequency," also illustrates the concept of relative risk measure; that is, the Δ CDF of importance is based on the baseline CDF. The larger the baseline, the less significant is a Δ CDF of 1E-6.

Before any component or component pair is screened out, SM (safety margins) and DID (defense-in-depth) degradations are considered in accordance with Regulatory Guide 1.174. The SM and DID evaluation guidance currently being developed for NFPA 805 may also be useful.

If, when all evaluation phases are completed, the Δ CDF remains greater than or equal to 1E-6 per reactor year, further actions to address the results of the analysis will be evaluated consistent with appropriate regulatory guidance. The complexity of possible corrective measures can be kept to a minimum by defining the additional risk reduction needed to render the Δ CDF less than 1E-6 per reactor year. As an example, if a potential spurious actuation has been determined to have a Δ CDF of 1E-5 per reactor year after completing the screening process, a corrective action which applies an additional reduction factor of at least 10 would result in an acceptable configuration.

These screening steps are provided generally in the order of ease of analysis and robustness of acceptable methods, but they may be conducted in any order of the factors noted below.

The probabilistic formula used for this analysis follows. The factors listed below are considered to be independent.

$$\Delta \ \mathbf{CDF} = \mathbf{F_f} * \mathbf{P_{SA}} * \mathbf{P_{DS}} * \mathbf{P_M} * \mathbf{P_{CCD}} \text{ (per reactor-year)}$$

$\mathbf{F_f}$ = fire frequency
$\mathbf{P_{SA}}$ = probability of spurious actuations
$\mathbf{P_{DS}}$ = probability that detection and automatic suppression will not control the fire
$\mathbf{P_M}$ = probability of failure of manual suppression to control the fire
$\mathbf{P_{CCD}}$ = conditional probability of core damage given fire-induced spurious actuations

The initial focus of the assessment methodology contained within this document for IN 92-18 type failures is the Control Room. This is the area of the plant with the largest population of circuits from both divisions in the closest proximity to each other. As such, if this area can be demonstrated to have low safety significance, then the remaining plant areas could be considered to be less of a concern. Additionally, any modifications performed on Control Room circuits to alleviate IN 92-18 issues will not eliminate them, but will rather relocate them to an alternate location in the plant.

Although Control Room fires are the initial focus for IN-92-18 evaluations, it may be appropriate (depending upon plant-specific configurations) to evaluate fires in other locations for IN 92-18 failure modes. Plants should consider the extent to which they perform such evaluations.[a]

Step-By-Step Analysis

Selection

This selection process builds on prior deterministic circuit analysis work. Configurations are defined in this selection step for both BWR and PWR plants. Industry expects to provide additional considerations for PWR plants in the BWROG guidance document or reflect them in the NEI guidance document which incorporates this method.

1. Select target components (or combinations of two components for multiple spurious actuation evaluations) which could impact safe shutdown to be evaluated. This first step limits consideration of multiple spurious actuation evaluations to pairs with immediate and direct consequences comparable to high/low pressure interface failures. Potential circuit failures affecting these safe shutdown target components may have been considered in previous circuit

[a] At a later date, NEI will provide criteria in this guideline to assist plants in determining whether such evaluations should be considered.

analyses, but perhaps not for IN 92-18 or multiple spurious actuation concerns. Only one component at a time needs to be considered for IN 92-18 evaluations.

2. Apply the BWROG method to selection of safe shutdown equipment, their associated target cables, and the physical location of target cables. These steps are accomplished by completing steps 3.1.3.1 through 3.4.2.5 of the BWROG guidance document for the components and fire areas in question.

3. For IN 92-18 evaluations, determine the type of actuator for these valves. Bistable relays require only a momentary signal to drive the valve open or closed; other types require a sustained signal. If bistable relays are not employed in the control circuitry, determine the length of time it takes for the valve to open or close given an actuation signal.

4. If potential circuit failures in any of these target conductors are addressed by the deterministic mitigation techniques in the BWROG guidance, then no further analysis is needed.

<u>Screen One</u>

The purpose of Screen One is to quickly and qualitatively determine the safety significance of the component failure(s) in question, regardless of the likelihood of occurrence. This significance results from the adverse failure mode of this component(s). The method outlined below is one way to do this.

5. Use Table 1 to qualitatively determine the risk significance of a postulated fire capable of causing these failure modes. The qualitative criteria used for the screening are based on an event tree analysis of bounding quantitative estimates of the parameters in the probabilistic formula above, considering plant specific features. The criteria for risk significance are based on Reg Guide 1.174 guidance.

   The numbers in Table 1 represent the number of risk reducing activities (represented by parameters of the probabilistic formula) that would need to be deterministically credited for evaluated components in order to screen out that component(s) from further analysis. Several examples:

   a. If for evaluated components the fire frequency (**F_f**) is qualitatively judged to be low and the circuit failure modes probability (**P_{CF}**) is judged to be low, no further screening is required. Explained in another way, the combination of a low fire frequency and a low circuit failures probability given a damaging fire makes it very unlikely that spurious actuation(s) will result.

   b. If for evaluated components the fire frequency (**F_f**) is qualitatively judged to be medium and the circuit failures probability (**P_{CF}**) is judged to be high, the components can be screened out as risk insignificant if at least two other reducing factors (such as automatic detection and suppression and manual suppression) can be credited deterministically as effective. Explained in another way, a medium fire frequency and a high circuit failures probability given a damaging fire will require at least two other mitigating factors (such as automatic detection and suppression, and protected safe shutdown equipment) to be credited deterministically to prevent the spurious actuation(s).

c. If for evaluated components the fire frequency (**F_f**) is qualitatively judged to be high and the circuit failures probability (**P_{CF}**) is judged to be high, the remainder of this probabilistic screening analysis must proceed at least to Screen Two in order to screen out the component. Explained in another way, if both the fire frequency and the circuit failures probability given a damaging fire are high, one cannot rule out spurious actuation(s) at this stage without detailed probabilistic analysis.

<u>Screen Two</u>

The purpose of Screen Two is to screen out potential spurious actuations based on fire frequency times a spurious actuation conditional probability, the former derived from generic data or plant-specific data. The spurious actuation conditional probability will be derived from hot short probabilities, which will in turn be available from the generic Delphi process described in the attachment, and assume a fire size based on a conservatively realistic evaluation of combustibles and initiators (no fire modeling). The spurious actuation probabilities reflect this conservative fire size, which may or may not be large enough to cause significant damage to cable insulation.

6. Obtain a circuit failure probability given a damaging fire (**P_{CF}**) from the results of the generic Delphi process described earlier. The fire size and location assumed in this step is one that results in extensive cable insulation damage but not melting of conductors. As such, it may be larger and cause more damage to cable insulation than the reasonable and conservative fire postulated in Step 8.

7. Determine the characteristics (combustible types and potential initiators) of the fire areas where the target conductors are located.

8. Using the fire hazards analysis, determine a reasonable and conservative fire size, duration, and energy level (without using detailed fire modeling codes) in the vicinity of the components. This involves consideration of fixed and

transient combustibles and ignition sources.[b]

9. Using fire initiator data, determine the frequency of this fire **(F_f)**.

Steps 10-12 address the determination of a spurious actuation probability **(P_{SA}).**

10. For the fire determined in Step 8, determine a fire size parameter **(P_E)** from the results of the generic Delphi process described earlier. This parameter reflects the fact that the fire determined in Step 8 is smaller than the **(P_{CF})** fire in Step 6. Therefore, the probability for circuit failures (and spurious actuations) from the Step 8 fire is smaller by some factor than **(P_{CF})**. **(P_E)** represents this factor, and also reflects that below some fire energy threshold the likelihood of insulation damage is very small.[c]

11. Calculate the probability of spurious actuation(s) **(P_{SA})** given a fire of the size determined in Step 8. The formula is:

    $$P_{SA} = P_E * P_{CF}$$

12. If F_f * P_{SA} < 1E-6 per reactor year, screen this component from further review if SM and DID considerations permit.

Screen Three

The purpose of Screen Three is to credit the capability of the automatic detection and suppression systems for restraining the fire before it reaches damaging proportions.

13. Determine whether automatic detection and suppression capabilities available in the area are adequate to restrain the fire. This evaluation should consider the characterization of the area, type of the fire (fire with significant smoke generating capability before generating a lot of heat versus other fires), design features of the detection and suppression equipment available in the area, the design requirements committed to by the licensee, and the time available before fire severity reaches unacceptable levels.

14. Calculate the probability that automatic detection and suppression systems do not prevent undesirable consequences to the cables **(P_{DS})**, using established fire PSA techniques for automatic detection and suppression systems. These techniques are described in EPRI documents such as NSAC-179L, the FIVE

[b] At a later date, NEI will provide criteria in this guideline to assist plants in making this determination.

[c] Circuit failure test results will be used to establish thresholds and probabilities.

method, and the PRA guide. In general, **(P_{DS})** equals the unavailability of the detection and suppression systems if these systems fulfill the committed NFPA code requirements.

15. If $\mathbf{F_f} * \mathbf{P_{SA}} * \mathbf{P_{DS}} < 1E\text{-}6$, screen from further review if SM and DID considerations permit.

Screen Four

The purpose of Screen Four is to apply the probability that manual suppression will not control the fire before it reaches damaging proportions. Manual suppression is considered effective if it is timely and uses the correct techniques and suppressants for the fire in question. This calculation will consider the dependency between automatic and manual suppression.

16. Using the results of Step 13, calculate the probability that manual suppression fails to extinguish the fire before cable damage thresholds are reached **(P_M)**

17. If $\mathbf{F_f} * \mathbf{P_{SA}} * \mathbf{P_{DS}} * \mathbf{P_M} < 1E\text{-}6$, screen from further review if SM and DID considerations permit.

Screen Five

When Screen Four is complete, one has calculated the probability of a spurious actuation which could result in irrecoverable valve damage. The purpose of Screen Five is to determine the conditional core damage probability given the spurious actuation(s) have occurred.

This analysis may be performed in two steps using the internal events PSA: (1) Determine the CCDP (conditional core damage probability) crediting only safe shutdown systems; (2) determine the CCDP for all available mitigation systems, some of which may not have been credited in safe shutdown analyses. This evaluation may be performed to determine the incremental risk reduction benefit provided by systems or equipment not previously credited for safe shutdown, to mitigate the unacceptable consequences of the spurious actuation. Note that if potential circuit failures in the target conductors are not addressed by the deterministic mitigation techniques in the BWROG guidance (see Step 3), then further analysis to address the value of potential recovery actions may be useful.

18. Using an internal events PSA analysis, determine the CCDP ($\mathbf{P_{CCD1}}$) of the failure mode of concern for the target component(s) and other safe shutdown components damaged by a fire. This is done by assigning a failure probability of 1.0 for these damaged components that are in the PSA, using the area fire frequency as the initiating event and an appropriate event tree. This analysis

does not quantify the size or extent of the fire, except that it is confined to the fire area in question, and does not credit components beyond those identified in the safe shutdown analysis.

19. If $\mathbf{F_f} * \mathbf{P_{HS}} * \mathbf{P_{DS}} * \mathbf{P_M} * \mathbf{P_{CCD1}} < 1E\text{-}6$, screen from further review if SM and DID considerations permit

20. Using conventional circuit analysis practices (see Reference 5), determine whether systems not previously credited, and are capable of mitigating the consequences of the spurious actuation, have components or cables located outside the fire area. The configuration management of this alternate equipment needs to be addressed.

21. Similar to step 18, using the internal events PSA, calculate the conditional core damage probability $\mathbf{P_{CCD2}}$ that this alternate equipment is not available.

22. If $\mathbf{F_f} * \mathbf{P_{HS}} * \mathbf{P_{DS}} * \mathbf{P_M} * \mathbf{P_{CCD2}} < 1E\text{-}6$, screen from further review if SM and DID considerations permit

<u>Screen Six</u>

The purpose of Screen Six is to use fire modeling techniques to recalculate $\mathbf{F_f}$ for a realistic fire.

23. Using accepted fire modeling techniques, determine the probability that a fire size, duration, and location sufficient to cause target conductor insulation damage will not develop.

24. Modify $\mathbf{F_f}$ using this probability to calculate a more accurate fire frequency

25. If $\mathbf{F_f} * \mathbf{P_{HS}} * \mathbf{P_{DS}} * \mathbf{P_M} * \mathbf{P_{CCD}} < 1E\text{-}6$, screen from further review if SM and DID considerations permit. Note that $\mathbf{P_{CCD}}$ could either be $\mathbf{P_{CCD1}}$ or $\mathbf{P_{CCD2}}$ depending on at what stage of the analysis Screen 6 is performed.

Corrective Action

If, when all evaluation phases are completed, the Δ CDF remains greater than or equal to 1E-6 per reactor year, further actions to address the results of the analysis will be evaluated. The complexity of possible corrective measures can be kept to a minimum by defining the additional risk reduction needed to render the Δ CDF less than 1E-6 per reactor year. As an example, if a potential spurious actuation has been determined to have a Δ CDF of 1E-5 per reactor year after completing the screening process, a corrective action which applies an additional reduction factor of at least 10 would result in an acceptable configuration. Any regulatory reporting should be in accordance with existing regulations.

Documentation

The accurate and comprehensive documentation and preservation of documentation of this process is essential to the maintenance of a manageable and auditable Appendix R or BTP 9.5.1 (whichever is applicable) program. Appendix B criteria contained within 10CFR 50 specify the basic documentation requirements while the fire-related regulations contain more detail-specific expectations which will enable the licensee to maintain a compliant program and the NRC inspectors' ability to verify compliance over the life of the nuclear unit.

REFERENCES:

1. Appendix R to 10 CFR 50
2. Branch Technical Position 9.5.1
3. NRC Generic Letter 86-10
4. NRC Information Notice 92-18
5. GE-NE-T43-0002-00-02, Rev 0 (BWROG Generic Guidance for Post-Fire Safe Shutdown Analysis)
6. NFPA 805 Draft 7.0
7. EPRI reports, numbers to be supplied

Table 1

Screen One

Probability of Circuit Failures	Fire Frequency		
	H	**M**	**L**
H	Analyze	3	2
M	3	2	1
L	2	1	OK

Attachment 1

Generic Activities to Support Industry Method for Resolving Fire-Induced Circuit Failures Issues

Industry recommends that three generic activities be carried out in the next six to nine months to support the use of the industry circuit failure resolution method, which is described separately:

- Develop guidance for use of Table 1 in Screen One
- Develop quantitative probabilities for circuit failure modes given a damaging fire
- Develop quantitative parameter values for the likelihood of cable damage for fires below the threshold where damage might normally be expected

Guidance for Use of Table 1

Table 1 is used in Screen One to qualitatively determine the risk significance of a postulated fire capable of causing spurious actuations, and the need for additional screening. The values in this table are based on a preliminary event tree involving conservative values for the probabilistic elements in the Δ CDF equation above. Industry plans to develop the supporting event tree and Table 1 further, and plans to request feedback from NRC.

Probabilities of Circuit Failure Modes

Industry is currently developing criteria to characterize qualitatively the likelihood of circuit failure modes including hot shorts, shorts to ground, open circuits, and other failure modes which may be relevant. Industry recommends developing these characterization criteria into a spectrum of quantitative probabilities for these circuit failure modes **(P_{CF})** to address expected plant equipment and conditions. This would done by using a modified Delphi process performed one time by an expert panel representing combinations of regulatory, industry, and independent views, as well as PSA and circuit analysis expertise. This work would make use of available and relevant test results (some of these tests are still being planned) and operating experience. The **(P_{CF})** values resulting from this process would be used in the analysis method described separately.

The characterization criteria and the Delphi process may consider such factors as:

- Cable construction (including grounding and number of conductors in each cable) and insulation materials

- Voltage type and magnitude and available fault current

- Need for sustained versus momentary hot shorts to achieve device actuation
- Proximity of hot short sources to targets and compatibility of voltages
- Suspected leakage currents and current necessary to actuate components
- Sequence or timing of failure modes

Results from individual plant analyses of circuit failure probabilities will also be considered where available.

Fire Size Parameter

Industry also recommends using this Delphi process to determine a fire size parameter **(P_E)** for use in the method below. This parameter reflects that the fire determined in Step 8 is smaller than the **(P_{CF})** fire in Step 6. Therefore, the probability for circuit failures (and spurious actuations) from the Step 8 fire is smaller by some factor than **(P_{CF})**. **(P_E)** represents this factor, and also reflects that below some fire energy threshold the likelihood of insulation damage is very small. Based on preliminary conclusions from test results, **(P_E)** might range from a very small fraction for fires with severity of less than 20,000 BTU/hr up to 1.0 for fires with severity greater than 70,000 BTU/hr. The fire severity levels noted here are based on fires impinging directly on the cable; fires with greater severity may have the same effect if only a portion of the heat is applied directly to the cable and the rest to other room locations.

Circuit Failure Issue Resolution
Industry Task Plan and Schedule
January 17, 2000

1st Quarter 2000

- NRC extend moratorium on circuit failure enforcement actions (EGM 98-002, Revision 1) to allow full method development
- EPRI and NEI complete circuit failure characterization criteria draft
- NRC and BWROG address issues with BWROG guidance
- BWROG and NEI address applicability of BWROG guidance to PWRs
- NEI drafts guideline NEI 00-01 for use of industry method and provides draft to NRC by early April
- NEI and NRC agree on expert panel (Delphi process) composition, objectives, scope, and process
- NEI ITF begins developing material to support Table 1 (postulating reasonable but conservative fire sizes)

2nd Quarter 2000

- NRC, NEI and BWROG address issues with methods / guidance documents
- NRC issues SER on BWROG guidance
- Expert panel begins developing fire size parameters and probabilities for conductor faults in single conductors using existing test results
- NEI and EPRI begin additional circuit failure testing
- NEI develops scope for pilots for NEI 00-01 and identifies pilot plants
- NEI ITF completes draft of Table 1 and provides to NRC for review along with supporting information
- NEI ITF addresses issues related to effectiveness of detection, automatic suppression, and manual suppression

3rd Quarter 2000

- NEI and EPRI complete any confirmatory circuit failure testing
- EPRI and NEI revise circuit failure characterization as needed
- Expert panel develops circuit failure probabilities and fire size parameters based on results of further testing and other available information
- NEI ITF completes planning for pilot evaluations
- NEI ITF addresses issues related to conditional core damage probability calculations related to use of either safe shutdown equipment or equipment not previously credited
- NEI ITF proposes to NRC fire modeling methods to be considered for use in industry method; NRC provides feedback

<u>4th Quarter 2000</u>

- Expert panel addresses any remaining issues, completes work
- NEI proposes (1) which circuit failures can be screened out generically and (2) which circuit failures are subject to plant-specific screening methods using NEI 00-01
- NEI conducts pilot evaluations of NEI 00-01 and shares results with NRC
- NEI and NRC resolve issues for use of NEI 00-01

<u>1st Quarter 2001</u>

- NRC and NEI resolve all issues related use of NEI 00-01.
- NRC endorses, possibly in an RIS (Regulatory Issue Summary) that NEI 00-01 is acceptable method for addressing circuit analysis issues
- NEI makes NEI 00-01 guidance available for industry use
- NRC issues any revised inspection and enforcement guidance
- Generic circuit failure issues closed