UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
WASHINGTON, D. C. 20555-0001

March 2, 2004

NRC REGULATORY ISSUE SUMMARY 2004-03: RISK-INFORMED APPROACH FOR POST-FIRE SAFE-SHUTDOWN ASSOCIATED CIRCUIT INSPECTIONS

ADDRESSEES

All holders of operating licenses for nuclear power reactors, except those who have permanently ceased operations and have certified that fuel has been permanently removed from the reactor vessel.

INTENT

The U.S. Nuclear Regulatory Commission (NRC) is issuing this regulatory issue summary (RIS) to inform addressees of the risk-informed approach that will be used by the NRC to perform post-fire safe-shutdown associated circuit inspections.

BACKGROUND INFORMATION

The regulatory requirements, guidance, and NRC staff's positions regarding post-fire safe-shutdown are contained in various NRC documents, including Title 10 of the Code of Federal Regulations, Section 50.48 (10 CFR 50.48), "Fire Protection," and 10 CFR Part 50, Appendix A, General Design Criterion (GDC) 3. Nuclear power plants (NPPs) operating prior to January 1, 1979, were backfit to 10 CFR Part 50, Appendix R, Section III G. NPPs licensed later were evaluated against Section 9.5-1 of NUREG-0800, Standard Review Plan (SRP). Regulatory Guide 1.189, "Fire Protection," also provides regulatory guidance on post-fire safe-shutdown. The extent to which these requirements or guidance are applicable to a specific NPP depends on the plant's age, commitments made by the licensee in establishing its fire protection plan, and license conditions regarding fire protection. One objective of the fire protection requirements and guidance is to provide reasonable assurance that fire-induced failures of associated circuits that could prevent the operation, or cause maloperation, of equipment necessary to achieve and maintain post-fire safe-shutdown will not occur. As a part of its fire protection program, each licensee performs an associated circuit analysis to evaluate and protect against these failures.

Associated circuits are distinct from the circuits directly required for operation of post-fire safe-shutdown trains of equipment. Associated circuits are not required for post-fire safe-shutdown, but could interfere with post-fire safe-shutdown if damaged by fire.[1] If damage to the circuits or

ML040620400

[1]Associated circuits have previously been defined in the "Associated Circuit of Concern" section of the March 22, 1982, Generic Letter 81-12 clarification memorandum on the "Fire Protection Rule - Appendix R" from R. Mattson, Director, Division of Systems Integration, NRR, to D. Eisenhut, Division of Licensing, NRR.

cables under consideration would have a direct impact on the operation of equipment or systems that are relied on to perform an essential shutdown function, the circuits and cables are considered “required circuits.” The redundant train protection and alternative shutdown capability independence criteria for such required post-fire safe-shutdown circuits are not affected by this RIS.

Each NPP licensee has a post-fire safe-shutdown (SSD) program that was reviewed and approved by the NRC either as a part of the licensee’s compliance with the 10 CFR Part 50, Appendix R backfit or as a part of the initial operating licensing basis reviews. Licensees are required to maintain and update this analysis as a condition of their operating license. The NRC routinely inspects the post-fire safe-shutdown program as a part of the triennial fire protection inspection of each licensee.

SUMMARY OF THE ISSUE

Beginning in 1997, the NRC staff noticed that a series of licensee event reports (LERs) identified plant-specific problems related to potential fire-induced electrical circuit failures that could prevent operation or cause maloperation of equipment necessary to achieve and maintain hot shutdown. The staff documented these problems in Information Notice 99-17, “Problems Associated With Post-Fire Safe-Shutdown Circuit Analysis.” Based on the number of similar LERs, the NRC determined that the issue should be treated generically. In 1998, the NRC staff started to interact with interested stakeholders in an attempt to understand the problem and develop an effective risk-informed solution to the circuit analysis issue. Due to the number of different stakeholder interpretations of the regulations, the NRC decided to temporarily suspend the associated circuit portion of fire protection inspections. This decision is documented in an NRC memorandum from John Hannon to Gary Holahan dated November 29, 2000, (ML003773142). NRC also issued Enforcement Guidance Memorandum (EGM) 98-002, Revision 2 (ML003710123).

To address the stakeholders differing interpretations of the regulations, the NRC contracted with Brookhaven National Laboratory (BNL) to develop a post-fire safe-shutdown analysis letter report (ML023430533). This draft letter report provided a historical look at the essential elements of a post-fire safe-shutdown circuit analysis, regulatory requirements and NRC staff positions, successful industry implementations, and guidance for risk-informing the associated circuit analysis. During this period, the Nuclear Energy Institute (NEI) performed a series of cable functionality fire tests to be used in NEI’s risk-informed guidance. Revision D of NEI 00-01, “Guidance for Post-Fire Safe-Shutdown Analysis,” was issued in early 2003 (ML023010376). The results of the NEI cable functionality fire testing were reviewed by an expert panel. The purpose of this review was to develop risk insights into the phenomena of fire-induced failures of electrical cables. The Electric Power Research Institute (EPRI) coordinated this effort and issued the final report, “Spurious Actuation of Electrical Circuits Due to Cable Fires: Results of an Expert Elicitation” (Report No. 1006961, May 2002).

On February 19, 2003, the NRC conducted a facilitated, public workshop in Rockville, MD. The purpose of the workshop was to discuss, and gather stakeholder input on, proposed risk-informed post-fire safe-shutdown circuit analysis approach using the above referenced documents as background. The goals of the workshop were to identify:

Bin 1- the most risk-significant associated circuit configurations
Bin 2- other associated circuit configurations that require further research
Bin 3- low-risk-significant associated circuit configurations

The facilitated workshop was successful in meeting these goals.

The staff has completed drafting a risk-informed inspection approach for the most risk-significant associated circuit configurations (Bin 1), identified other configurations that require further research (Bin 2), and performed confirmatory research to verify the low-risk-significant configurations (Bin 3) (ML030780326).

CONCLUSION

The NRC’s approach to inspection will concentrate on associated circuits with a relatively high probability of failing and whose failure could cause flow diversion, loss of coolant, or other scenarios that could significantly impact the ability to achieve and maintain hot shutdown. The inspectors will pay particular attention to associated circuit failures that cause events to occur in the first hour of the fire. Inspectors will consider credible fire scenarios that could produce a thermal insult resulting in cable damage. The initial focus of the inspection will be on conductor-to-conductor shorts within a multiconductor cable, since risk insights gained from cable fire testing demonstrated that intra-cable shorting is the most probable cause of spurious actuations. Thermoplastic-cable-to-thermoplastic-cable interactions are also probable and should be considered. To focus on the most risk-significant aspects of scenarios, including multiple concurrent spurious actuations, inspectors will assume fire damage to no more than two separate cables for each scenario evaluated. This assumption applies only to scenarios involving multiple spurious actuations and does not limit the number of cables that may be damaged by fire. Fire damage to cables that could initiate other equipment failure modes, such as loss of function, must also be considered. The details of this inspection approach are contained in the attachment to this RIS.

This RIS was prepared and issued following the policy established in NRR Office Instruction No. LIC-503, “Generic Communications Affecting Nuclear Reactor Licensees” (ML023170311). In accordance with LIC-503 this RIS, “announces staff technical or policy positions on matters that have not been broadly communicated to the nuclear industry or are not fully understood.”

At the center of this issue, the root cause has been characterized as misunderstanding and confusion on a part of the licensees relative to the regulatory requirements. The RIS, in concert with NUREG 1778 (currently issued as draft for public comment), address this misunderstanding and confusion and establish risk-informed criterion for addressing the associated non-safety circuits identified in 10 CFR Part 50 Appendix R Section III.G. As a part of the development process, a facilitated public workshop was held in Rockville, Maryland on February 19, 2003 (ML030620006). The product of the workshop was a general consensus with stakeholders in on the technical issues for associated circuits. In accordance with SECY-99-143, the staff believes that a RIS is the appropriate regulatory vehicle to communicate the staff's position. This RIS will be revised or supplemented in the future pending the results of the additional research conducted on the deferred items in Bin 2.

The issuance of this RIS is an important first step in restarting the inspection of associated circuits. This RIS focuses primarily on the technical aspects of the approach. Prior to resuming inspection, the NRC will complete development of the necessary inspection procedures, significance determination process revisions, and any necessary changes to the reactor oversight process and enforcement program. Current plans provide for completion of these activities by June 2004, and resumption of inspection by December 2004. The NRC will be issuing future correspondence addressing these topics prior to the restart of inspections.

BACKFIT DISCUSSION

This RIS does not constitute backfitting as defined in 10 CFR 50.109 (a) (1) in as much as it does not establish new staff positions *imposed* on a licensee which *requires* changes in the design or procedures for a nuclear power plant. Consequently, the NRC staff did not perform a backfit analysis.

This RIS recognizes the importance of the licensing basis of each operating nuclear power plant. The RIS was prepared in accordance with Commission Guidance provided in SECY-99-143 (ML992850037) which states that a RIS is the appropriate regulatory vehicle for disseminating the technical information generated to date on this issue. This RIS is not intended to resolve questions related to the licensing basis.

***FEDERAL REGISTER* NOTIFICATIONS**

On February 19, 2003, the NRC staff held a facilitated public workshop in Rockville, MD., where public participation was solicited. A notice of the workshop was published in the *Federal Register* on December 27, 2002 (Vol. 67, No. 249, p. 79168).

The draft RIS including the draft inspection guidance was published in the *Federal Register* on August 18, 2003. (Vol. 68, No. 159, p.49529). The public comment period ended September 17, 2003.

PAPERWORK REDUCTION ACT STATEMENT

This RIS does not contain information collections and, therefore, is not subject to the requirements of the Paperwork Reduction Act of 1995 (44 U.S.C 3501 et seq.)

If you have any questions about this matter, please contact the person listed below.

/RA/
William D. Beckner, Chief
Reactor Operations Branch
Division of Inspection Program Management
Office of Nuclear Reactor Regulation

Technical Contact: Mark Henry Salley
301-415-2840
E-mail: mxs3@nrc.gov.

Attachments:
1. Approach for Risk-Informing NRC Inspection of Associated Circuits
2. List of Recently Issued NRC Regulatory Issue Summaries

APPROACH FOR RISK-INFORMING NRC INSPECTION OF ASSOCIATED CIRCUITS

BACKGROUND

In 1997, the NRC noticed an increase in the number of licensee event reports (LERs) which identified plant-specific problems related to potential fire-induced electrical circuit failures that could prevent operation or cause maloperation of equipment necessary to achieve and maintain hot shutdown in the event of a fire. The staff documented this information in Information Notice 99-17, "Problems Associated With Post-Fire Safe-Shutdown Circuit Analysis." On November 29, 2000, inspection of associated circuits was temporarily suspended (ML003773142). During this period, the Nuclear Energy Institute (NEI) developed NEI 00-01, "Guidance for Post-Fire Safe-shutdown Analysis" Rev. D (ML023010376)[1]. The staff contracted with Brookhaven National Laboratory (BNL) to develop a post-fire safe-shutdown analysis guidance letter report "Introduction to Post-Fire Safe-Shutdown Analyses" (ML023430533).[2] The Electric Power Research Institute (EPRI) assembled an expert panel and issued "Spurious Actuation of Electrical Circuits Due to Cable Fires: Results of an Expert Elicitation" (Report No. 1006961, May 2002).[3] Using the above-referenced documents as background, the NRC conducted a facilitated public workshop on February 19, 2003, in Rockville, MD.[4] Following the facilitated workshop discussions, the staff developed a draft risk-informed inspection approach. This approach, initially transmitted in a memorandum to Cynthia Carpenter from John Hannon dated March 19, 2003 (ML030780326), is essentially the same as the approach provided below with two notable exceptions. First, additional technical review indicated thermoplastic cable-to-cable interactions should have been located in Bin 1 rather than Bin 2. Second, the statement "Inspectors will not consider the impact of degraded control room instrumentation and indication circuits that might confuse operators pending additional research" can be easily misinterpreted and has been deleted. A new section on instrumentation has been added in place of this statement. These changes were made in the approach and issued in the draft RIS for public comment on August 18, 2003. After reviewing public comments the following final approach was developed.

---

[1]NEI 00-01 was subsequently issued as Revision 0 in May, 2003.

[2]The NRC issued this information for a 60 day public comment period as NUREG-1778, "Knowledge Base for Post-Fire Safe-Shutdown Analysis" (FRN Vol 69, No. 19, January 19, 2004)

[3]EPRI subsequently released "Characterization of Fire-Induced Circuit Faults: Results of Cable Fire Testing," Report 1003326.

[4] The transcript of the meeting is available in ADAMS (ML030620006).

DISCUSSION

1. Basic Risk Equation

The risk due to associated circuits can be evaluated using the following basic risk equation:

> Risk = (fire frequency) x (likelihood of fire effects & cable attributes that contribute to failure) x (likelihood of undesired consequences)

The three factors in this equation are defined as follows:

Fire Frequency

The fire frequency is based on a statistical analysis of nuclear power plant (NPP) operating experience. The fire protection significance determination process (SDP) provides a method and bases for estimating fire frequencies for plant areas. One unique aspect of circuit analysis is the potential need for evaluation of multiple areas (i.e., areas through which a cable or common set of cables is routed).

Likelihood of Fire Effects & Cable Attributes That Contribute to Failure

There needs to be a credible fire threat in the area under review to damage the cable of concern. This threat may consist of in situ combustibles, or the actual or maximum allowable amount of transient combustibles as controlled by plant-specific procedures, or a combination thereof. The fire protection SDP provides methods and bases for the identification and analysis of these fire scenarios.[5] When more than a qualitative analysis is necessary, the inspector should use the NRC Fire Dynamics Tools[6] to approximate the fire and its effects. The cable attributes should also be considered in assessing the likelihood of cable damage. Cable damage as a result of thermal insult from the fire may be caused by heating in the hot gas layer, immersion in the plume, immersion in the flame zone (direct flame impingement), or radiant heating. All modes of heat transfer should be considered, as appropriate, to a given fire scenario. The next revision of the fire protection SDP will provide methods, criteria, and basis for determining specific cable damage.

Cable Failure Modes. For multiconductor cables testing has demonstrated that conductor-to-conductor shorting within the same cable is the most common mode of failure. This is often referred to as "intra-cable shorting." It is reasonable to assume that given damage, more than one conductor-to-conductor short will occur in a given cable. A second primary mode of cable

---

[5]The fire protection SDP is currently under revision. The new revision will contain this detailed information.

[6]The NRC issued draft NUREG-1805 "Fire Dynamics Tools (FDTs) Quantitative Fire Hazard Analysis Methods for the U.S. Nuclear Regulatory Commission Fire Protection Program" on June 30, 2003 (ML031990145, ML031980360). The final issue of the NUREG is expected in the summer of 2004.

failure is conductor-to-conductor shorting between separate cables, commonly referred to as "inter-cable shorting." Inter-cable shorting is less likely than intra-cable shorting. Consistent with the current knowledge of fire-induced cable failures, the following configurations should be considered:

A. For any individual multiconductor cable (thermoset or thermoplastic),[7] any and all potential spurious actuations that may result from intra-cable shorting, including any possible combination of conductors within the cable, may be postulated to occur concurrently regardless of number. However, as a practical matter, the number of combinations of potential hot shorts increases rapidly with the number of conductors within a given cable. For example, a multiconductor cable with three conductors (3C) has 3 possible combinations of two (including desired combinations), while a five conductor cable (5C) has 10 possible combinations of two (including desired combinations), and a seven conductor cable (7C) has 21 possible combinations of two (including desired combinations). To facilitate an inspection that considers most of the risk presented by postulated hot shorts within a multiconductor cable, inspectors should consider only a few (three or four) of the most critical postulated combinations.

B. For any thermoplastic cable, any and all potential spurious actuations that may result from intra-cable and inter-cable shorting with other thermoplastic cables, including any possible combination of conductors within or between the cables, may be postulated to occur concurrently regardless of number. (The consideration of thermoset cable inter-cable shorts is deferred pending additional research.)

C. For cases involving the potential damage of more than one multiconductor cable, a maximum of two cables should be assumed to be damaged concurrently. The spurious actuations should be evaluated as previously described. The consideration of more than two cables being damaged (and subsequent spurious actuations) is deferred pending additional research.

D. For cases involving direct current (DC) circuits, the potential spurious operation due to failures of the associated control cables (even if the spurious operation requires two concurrent hot shorts of the proper polarity, e.g., plus-to-plus and minus-to-minus) should be considered when the required source and target conductors are each located within the same multiconductor cable.

E. Instrumentation Circuits. Required instrumentation circuits are beyond the scope of this associated circuit approach and must meet the same requirements as required power

---

[7] The terms "thermoset" and "thermoplastic" are general terms used to describe the two broad classifications of cable insulation and jacket material. Other factors such as cable location (e.g., tray, conduit, armor) are addressed in the fire protection SDP which provides supporting guidance and basis for understanding and qualifying the performance criteria. For the purpose of analysis, shielded cable may be considered as armored cable when the shielding metallic wire mesh envelops the insulated conductors (e.g., coaxial cable). When the shielding is constructed of thin foil, the cable should be treated consistent with either ordinary thermoset or thermoplastic cable. If the cable contains a drain, the uninsulated drain conductor may be treated as a ground conductor within the multiconductor cable.

and control circuits. There is one case where an instrument circuit could potentially be considered an associated circuit. If fire-induced damage of an instrument circuit could prevent operation (e.g., lockout permissive signal) or cause maloperation (e.g., unwanted start/stop/reposition signal) of systems necessary to achieve and maintain hot shutdown, then the instrument circuit may be considered an associated circuit and handled accordingly.

Likelihood of Undesired Consequences

Determination of the potential consequence of the damaged associated circuits is based on the examination of specific NPP piping and instrumentation diagrams (P&IDs)[8] and review of components that could prevent operation or cause maloperation such as flow diversions, loss of coolant, or other scenarios that could significantly impair the NPP's ability to achieve and maintain hot shutdown.[9] When considering the potential consequence of such failures, the inspector should also consider the time at which the prevented operation or maloperation occurs. Failures that impede hot shutdown within the first hour of the fire tend to be most risk significant in a first-order evaluation. Consideration of cold-shutdown circuits is deferred pending additional research.

2. Items To Be Deferred at This Time, Pending Additional Research

The following items are being deferred pending additional research:

A. Inter-cable shorting for thermoset cables is considered to be substantially less likely than intra-cable shorting. Hence, the inspection of potential spurious operation issues involving inter-cable shorting for thermoset cables is being deferred pending additional research.

B. Inter-cable shorting between thermoplastic and thermoset cables is considered less likely than intra-cable shorting of either cable type or inter-cable shorting of thermoplastic cables. The inspection of spurious actuation issues involving inter-cable shorting between thermoplastic and thermoset cables is therefore being deferred pending additional research.

C. Pending further research, inspectors will not consider configurations requiring damage to three or more cables for the necessary spurious operations.

D. Recent testing strongly suggests that a control power transformer (CPT) in a control circuit can substantially reduce the likelihood of spurious operation. The power output of the CPT relative to the power demands of the controlled device(s) appears critical. Pending additional research, inspectors may defer the consideration of multiple (i.e., two or more) concurrent spurious operations due to control cable damage if they can verify

[8] For NPPs that do not use P&IDs, the inspector will have to gather the same information from flow diagrams and cable routing/logic diagrams.

[9]Hot shutdown is defined in the NPP technical specifications.

that the power to each impacted control circuit is supplied via a CPT with a power capacity of no more than 150% of the power required to supply the control circuit in its normal modes of operation (e.g., required to power one actuating device and any circuit monitoring or indication features).

E. Recent testing strongly suggests that fire-induced hot shorts will likely self-mitigate (e.g., short to ground) after some limited period of time. Available data remains sparse, but there are no known reports of a fire-induced hot short that lasted more than 20 minutes. This is of particular importance to devices such as air-operated valves (AOVs) or power-operated relief valves (PORVs) which return to their de-energized position upon the

mitigation of a hot short cable failure. Pending further research, inspectors should defer consideration of such faults if they can verify that a spurious operation of up to 20 minutes duration will not compromise the ability of the plant to achieve hot shutdown.

3. Items Not To Be Considered at This Time in Inspections

The following items are considered of very low likelihood and/or low risk significance, and will not be considered in the risk-informed inspection process:

A. Open circuit (i.e., loss of conductor continuity) conductor failures as an initial mode of cable failure. (Note that cable shorting (e.g., a short to ground) may result in an open circuit fault due to the tripping of circuit protection features.)

B. Inter-cable short circuits involving the conductors of an armored cable with another cable. Such failures are considered virtually impossible unless the short involves the cable's grounded armoring.

C. Inter-cable short circuits involving the conductors of one cable within a conduit and the conductors of any other cable outside the conduit. As with armored cables, such faults are considered virtually impossible. (Note that intra-cable shorting for thermoplastic or thermoset cables and inter-cable shorting between thermoplastic cables inside a common conduit are possible.)

D. Multiple high-impedance faults on a common power supply. Multiple high-impedance faults are considered of very low likelihood. In addition, as part of the deterministic assessment, licensees have identified potentially vulnerable power sources and developed appropriate procedures for mitigating their effects. Therefore, since such faults are of low likelihood and can be readily overcome by manual operator actions should they occur, inspectors will not consider multiple high-impedance faults on a common power supply.

E. Three-phase, proper-polarity hot short power cable failures (with one exception). In theory, such failures could cause a three-phase device to spuriously operate. However, such failures are considered of very low likelihood because the three distinct phases of power would have to align in the proper phased sequence to operate. (Note that three-phase devices may still be subject to spurious operations due to faults in their related control and/or instrumentation circuits.) The one exception is the decay heat removal (DHR) system isolation valves. Spurious opening of these valves would result in the low-pressure portion of the DHR system piping located outside of containment being pressurized with the reactor coolant at or near normal reactor operating pressure.

F. Multiple proper-polarity hot shorts leading to the spurious operation of a DC motor or motor-operated device when the postulated failures involve only the DC device's power cables (e.g., those cables that run from the motor control center (MCC) to the device). Such failures are considered unlikely because a shunt and a field require five separate conductors to have the correct polarity and sequence in order to operate. DC devices may still be subject to spurious actuation given failures in their control and/or instrument circuits.

4. SUMMARY

In summary, the inspectors should focus on associated circuits whose failure could cause flow diversion, loss of coolant, or other scenarios that could significantly impair the ability to achieve and maintain hot shutdown, paying particular attention to those events that occur in the first hour. The inspectors should be able to develop credible fire scenarios that could produce a thermal insult resulting in cable damage. Risk insights gained from cable fire testing have demonstrated that intra-cable (conductor-to-conductor) shorting in a multiconductor cable and inter-cable (cable-to-cable) shorting between thermoplastic cables are the most probable causes of spurious actuations. Therefore, when considering potential cable damage scenarios involving the spurious actuation of equipment, the inspectors should focus on these two specific circuit configurations. The inspectors should assume a maximum of two cables damaged concurrently (with the resulting spurious operations) for each scenario evaluated.

LIST OF RECENTLY ISSUED
NRC REGULATORY ISSUE SUMMARIES

Regulatory Issue Summary No.	Subject	Date of Issuance	Issued to
2004-02	Deferral of Active Regulation of Ground-Water Protection at *in Situ* Leach Uranium Extraction Facilities	02/23/2004	All holders of materials licenses for uranium and thorium recovery facilities.
2004-01	Method for Estimating Effective Dose Equivalent from External Radiation Sources Using Two Dosimeters	02/17/2004	All U.S. Nuclear Regulatory Commission (NRC) licensees.
2003-18	Use of NEI 99-01," Methodology for Development of Emergency Action Levels," Revision 4, Dated January 2003	10/08/2003	All holders of operating licenses for nuclear power reactors and licensees that have permanently ceased operations and have certified that fuel has been permanently removed from the reactor vessel.
2003-17	Complying with 10 CFR 35.59, "Recentness of Training," for Board-certified Individuals Whose Training and Experience Were Completed More than 7 Years Ago	10/03/2003	All U.S. Nuclear Regulatory Commission (NRC) medical-use licensees and NRC master materials license medical-use permittees.

Note: NRC generic communications may be received in electronic format shortly after they are issued by subscribing to the NRC listserver as follows:

To subscribe send an e-mail to <listproc@nrc.gov >, no subject, and the following command in the message portion:

subscribe gc-nrr firstname lastname

OL = Operating License
CP = Construction Permit