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Mr. John Hannon
Chief, Plant Systems Branch
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Mail Stop O11-A11
U. S. Nuclear Regulatory Commission
Washington, DC, 20555-0001

PROJECT NUMBER: 689

Dear Mr. Hannon:

We are providing for your review and comment Draft Revision L of NEI 04-06, *Guidance for Self-Assessment of Circuit Failure Issues*. This document is being reviewed concurrently by the industry. We request that you provide any comments by April 30, 2005.

This document reflects the guidance in RIS 2004-003, Revision 1, *Risk-Informed Approach for Post-Fire Safe-Shutdown Circuit Inspections*, which is also the basis for the NRC inspections of this area. Thus, self-assessments using NEI 04-06 should provide results consistent with inspections. This guidance has also been evaluated in pilot assessments at three plants and reflects their results.

If you have any questions about this information, please contact me at 202-739-8080; am@nei.org or Fred Emerson at 202-739-8086; fae@nei.org.

Sincerely,

Alexander Marion

Enclosure

c: Mr. Sunil Weerakkody, NRC
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GUIDANCE FOR SELF-ASSESSMENT OF CIRCUIT FAILURE ISSUES

1 INTRODUCTION

Beginning in 1997, the NRC noticed that a number 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 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. During this period, the Nuclear Energy Institute (NEI) developed NEI 00–01, ''Guidance for Post-Fire Safe Shutdown Analysis'' Revision 0. 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). NEI 00-01 Revision 1 was issued on January 28, 2005[1].

NEI 04-06 is being developed to facilitate licensee self-assessments of potential circuit failures for both required[2] and associated circuits. The intent is for licensees to use this guidance, which is based on Regulatory Issue Summary (RIS) 2004-03[3], to prepare for the resumption of circuit failure inspections in January 2005. NRC intends that the criteria in RIS 2004-03, be used in the inspection of all post-fire safe shutdown circuits, regardless of whether they are considered associated or required circuits.

This guidance provides methods consistent with those to be used in the inspection of circuit failures. These inspections will both assess compliance with the licensing basis and review for potentially risk-significant circuit failures or combinations whether they are inside or outside the plant licensing basis[4]. Assumptions and methods used in this guidance and in the inspections to determine risk significant circuit failures may not be consistent with traditional regulatory assumptions. As an example, providing 20 feet of separation between redundant trains with no intervening combustibles is an acceptable method for compliance but may not, on a case-by-case basis, assure that the risk is low. Care must be taken not to use such traditional assumptions to prematurely screen out potential findings when assessing risk significance. More specific guidance on the

[1] All references to NEI 00-01 are references to Revision 1 of that document unless otherwise noted.
[2] The NRC uses the terms "required" and "necessary" in 10 CFR 50 Appendix R to describe circuits for components that must operate to achieve safe shutdown. To be consistent with current NRC usage, the term "required" will be used in this guidance document.
[3] All references to RIS 2004-03 are references to Revision 1 of that document unless otherwise noted.
[4] The term "inside the licensing basis" describes those circuit failures issues or findings that potentially constitute violations from, or compliance issues with, the current licensing basis or regulations. "Outside the licensing basis" refers to those circuit failure issues or findings that are not potential violations or compliance matters, but could be risk significant.

application of 10 CFR 50 Appendix R Section III.G assumptions is provided in Section A-2.3.

Three plants have piloted the use of this guidance. These pilot self-assessments are intended to provide useful information to other plants intending to perform self-assessments. All licensees are encouraged to review their programs to some degree prior to their scheduled triennial inspections.

2 PURPOSE

2.1 PURPOSE OF NEI 04-06

The purpose of this document is to provide general guidance for assessing the circuit failure analysis portion of the Fire Safe Shutdown program. The assessment will identify risk-significant associated and required circuit spurious actuations or combinations thereof, consistent with the current NRC inspection focus.

2.2 SUMMARY OF ASSESSMENT FOCUS

Licensees should focus on post-fire safe shutdown circuits whose fire-induced 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 earliest stages of the fire. Licensees should be able to develop credible fire scenarios that could produce a thermal insult resulting in cable damage. They should assume a maximum of two concurrently damaged cables, for each scenario evaluated. Risk insights gained from cable fire testing have demonstrated that conductor-to-conductor shorting in multiconductor cable and cable-to-cable shorting between thermoplastic cables are the most probable cause of spurious actuations.

The consideration of circuit failures using the guidelines in this document and RIS 2004-03 does not exempt a licensee from meeting the requirements of Appendix R to provide reasonable assurance that one train of systems necessary to achieve and maintain safe shutdown equipment is free of fire damage. When selecting circuits for consideration, the guideline indicates at this time that damage to up to two cables should be considered in determining the effects of spurious actuations. Damage to other equipment or cables credited in the intended safe shutdown strategy that results in a loss of function must also be considered (from a fire in the fire area under consideration) if these components or cables are not adequately protected from the effects of fire.

2.3 INTENT OF SCREENING PROCESS

The processing of findings from licensee circuit failure self-evaluations should be performed consistently with ROP methods in Inspection Manual Chapter 0612 Appendix B. While licensees are not expected to follow all of the steps in “coloring” a finding, they should place potential findings in the Corrective Action Program with appropriate levels of priority based on their risk significance, and not screen them from further consideration too early in the process. An example of this follows.

A licensee might determine that fires in a certain fire area are extremely unlikely based on existing fixed combustibles and stringent controls over transient combustibles. He might use this information to screen out potential circuit failures in this area without actually determining whether there were potentially consequential circuit failures. Even if the likelihood of a damaging fire is extremely low, the licensee would not have met the intent of RIS 2004-03 and this document in determining whether consequential circuit failures are possible in that area. It is more appropriate to determine whether potentially consequential circuit failures exist, and then screen them to Green if there is no credible fire scenario. This is consistent with Inspection Manual Chapter (MC) 0609F, the fire protection SDP.

MC 0612B indicates that before an inspection finding is subjected to the SDP process, it must first be determined to be a performance deficiency and “greater than minor” according to MC 0612E. The criteria for classifying a finding as “minor” are all of the following:

- No actual safety consequences
- Little or no potential to impact safety
- No impact on the regulatory process
- Not involve willfulness

Currently it would be difficult to classify potential circuit failures in safe shutdown systems as minor. Therefore, it is appropriate to follow existing regulatory processes for screening potential findings.

3 OVERVIEW OF SELF-ASSESSMENT METHOD

A summary of the four-phase process is provided below.

3.1 PHASE 0: PREPARATION

1. Identify the fire areas to be evaluated based on risk and possible consequences from fire-induced losses of systems, structures, and components for safe shutdown.

2. Develop a list of and obtain the documents needed to identify the licensing basis for those fire areas.

3. Identify and obtain the internal and external resources needed to perform the self-assessment on a sampling basis during a one-week period. Additional resources are likely to be necessary to perform a complete self-assessment.

3.2 PHASE I: IDENTIFICATION

1. Identify the safe shutdown circuits and multiple spurious actuation scenarios for each fire area that could significantly impact the ability to achieve and maintain hot shutdown.

2. Identify cables that could be impacted by damaging fires in those fire areas, using cable route drawings or databases.

3.3 PHASE II: ANALYSIS AND EVALUATION

1. For impacted cables, evaluate those failures that could cause flow diversion, loss of coolant, or other scenarios that could significantly impair the ability to achieve and maintain hot shutdown. Consider:

    a. Multiple circuits in single multiconductor cables

    b. Cable-to-cable interactions for circuits in thermoplastic cables

    c. Up to two cables containing safe shutdown circuits.

2. Determine whether there are fire scenarios that can damage the circuits of interest, and screen to Green those that are not likely to be damaged by the projected fire conditions. Credible fire scenarios may be determined from guidance in NUREG-1805, the new fire protection SDP (MC 0609F), or other acceptable methods. Note that potential circuit failure issues that are possible compliance issues (as measured against the plant licensing basis) may require additional action.

3.4 PHASE III: CORRECTIVE ACTION DETERMINATION

1. Determine the risk significance of identified failures using the Significance Determination Process (SDP) or NEI 00-01. Identify whether findings are within or beyond licensing basis. Findings within the licensing basis should be considered potential violations.

2. Determine further action (possibly including reporting potential violations) to be taken for each finding. Generally, all risk significant failures (whether licensing basis or beyond licensing basis) will be addressed with appropriate priority in the Corrective Action Program. RIS 2004-03 provides information on enforcement discretion availability for self-assessment findings.

3. Determine what, if any, additional evaluation should be performed prior to NRC circuit failure inspections.

3.5 ALTERNATE SELF-ASSESSMENT METHOD – SCENARIO DEVELOPMENT APPROACH

An alternate method of performing the self-assessment is by the system scenario development approach. In this approach, risk-significant systems and components are identified that could impact the ability to achieve and maintain hot shutdown as discussed in Phase I, step 1 above. Once these components are identified, the fire areas containing cables that impact the equipment are identified. The screening of each fire area for potential damage (Phase II, step 2), and the risk significance screening (Phase III) is then performed for each fire area on a scenario basis.

This approach differs from the self-assessment approach above in that fire areas to be assessed are not pre-determined, but rather determined by the scenario development process.

4 POST-FIRE SAFE SHUTDOWN ANALYSIS TERMINOLOGY

4.1 ASSOCIATED CIRCUIT

Those safety-related and non-safety-related Class 1E and non-Class 1E cables that have a physical separation less than that specified in Section III.G.2 of Appendix R to 10 CFR Part 50 and have one of the following: (Reference GL 81-12 Clarification, Enclosure 2)

a. A power source that is shared with the shutdown equipment (redundant or alternative) and is not electrically protected from the circuit of concern by coordinated breakers, fuses, or similar devices. *(not the focus of this document)*

b. A connection to circuits of equipment for which spurious operation would adversely affect the shutdown capability [e.g., residual heat removal (RHR)/reactor coolant system (RCS) isolation valves, automatic depressurization system (ADS) valves, power-operated relief valves (PORVs), steam generator atmospheric dump valves, instrumentation, steam bypass].

c. An enclosure (e.g., raceway, panel, or junction box) that is shared with the shutdown cables (redundant or alternative) and (1) is not electrically protected by circuit breakers, fuses, or similar devices, or (2) will allow propagation of the fire into the common enclosure. *(not the focus of this document)*

4.2 BINS (RIS 2004-03)

Bins are categories of risk significance for determining whether certain types of circuit failures should be reviewed. Bins 1, 2, and 3 are defined as follows:

Bin 1 – Circuit configurations most likely to fail and areas where inspection should focus. Items may have high risk significance; however plant-specific information may still have a role in determining the final risk significance.

Bin 2 - Circuit configurations that need more research to better understand risk. Inspections won't resume for these items until and unless research has shown them to be Bin 1 type failures. Specific plans for research have not been identified.

Bin 3 – Circuit configurations unlikely or least likely to fail, and therefore areas where inspections should not focus. There is ample evidence that the items in this bin will of low risk significance.

Only Bin 1 items will be assessed using this guideline. However, non-compliance with the regulations must be addressed regardless of the bin classification.

4.3 CABLE

A conductor with insulation or a stranded conductor with or without insulation and other coverings (single-conductor cable) or a combination of conductors insulated from one another (multiple conductor cable). (IEEE Std. 100-1988)

4.4 CABLE FAILURE

A breakdown in the physical and/or chemical properties (e.g., electrical continuity, insulation integrity) of the cable conductor(s), such that the functional integrity of the electrical circuit cannot be ensured (e.g., interrupted or degraded).

4.5 CIRCUIT FAILURE MODES

The following are the circuit failure modes that are postulated in the post-fire safe shutdown analysis as a result of a fire:

Hot Short
A fire-induced insulation breakdown between conductors of the same cable, a different cable or from some other external source resulting in a compatible but undesired impressed voltage or signal on a specific conductor.

Open Circuit
A fire-induced break in a conductor resulting in a loss of circuit continuity. (Based on the EPRI/NEI testing, open circuits are not expected as the initial circuit failure mode.)

Short-to-Ground
A fire-induced breakdown of a cable's insulation system resulting in the potential on the conductor being applied to ground/neutral.

4.6 CIRCUIT

IEEE Standard 100-1984 – A conductor or system of conductors through which an electric current is intended to flow.

4.7 CIRCUIT ANALYSIS

An evaluation of the impact of fire-induced circuit failures (hot shorts, open circuits, and shorts to ground) on safe shutdown capability.

4.8 CONCURRENT MULTIPLE SPURIOUS OPERATIONS

Multiple faults causing spurious operations occur at discrete points in time, but some endure for a sufficient period of time such that they overlap.

4.9 Current Design Methodology (CDM)

Current Safe Shutdown Analysis design methodology.

4.10 Current Licensing Basis (CLB)

The set of NRC requirements applicable to a specific plant and a licensee's written commitments for ensuring compliance with and operation within applicable NRC requirements and the plant-specific design basis (including all modifications and additions to such commitments over the life of the license) that are docketed and in effect. The CLB includes the NRC regulations contained in 10 CFR Parts 2, 19, 20, 21, 26, 30, 40, 50, 51, 54, 55, 70, 72, 73, and 100, as well as the appendices thereto; orders; license conditions; exemptions; and technical specifications (TSs).

The CLB also includes the plant-specific design basis information defined in 10 CFR 50.2, as documented in the most recent final safety analysis report (FSAR), as required by 10 CFR 50.71 and the licensee's commitments remaining in effect that were made in docketed licensing correspondence such as licensee responses to NRC BLs, GLs, and enforcement actions, as well as licensee commitments documented in NRC safety evaluations or licensee event reports. [See also 10 CFR 54.3]

4.11 Emergency Operating Procedures (EOPs)

Operating procedures that are utilized to manage a wide variety of plant transients from uncomplicated shutdowns to potential severe accidents. EOPs are typically symptom-based procedures, and provide operators with guidance for a wide range of events and possible contingencies.

4.12 Fire-Induced Circuit Failure (FICF) Effects (e.g. Circuit Failure Mode)

The manner in which a circuit fault is manifested in the circuit. Circuit failure modes include loss of motive power, loss of control, loss of or false indication, open circuit conditions (e.g., a blown fuse or open circuit protective device), and spurious operation.

4.13 Fire Safe Shutdown Procedures/Guidelines

Procedures specifically used to guide the post-fire safe shutdown of the plant. These procedures may be symptom-based or prescriptive. The safe shutdown procedures also may rely on the EOPs to provide overall shutdown guidance, or may override the EOPs and provide prescriptive instructions for post-fire shutdown.

4.14 Ground Fault

Synonymous with short-to-ground. See 4.5 "Circuit Failure Modes."

4.15 HOT SHORT

See 4.5 "Circuit Failure Modes."

4.16 HOT SHORT, EXTERNAL

A hot short in which the source conductor and target conductor are from separate cables. Synonymous with inter-cable hot short and cable-to-cable hot short. See 4.5 "Circuit Failure Modes."

4.17 HOT SHORT, INTERNAL

A hot short in which both the source conductor and target conductor are within the same multi-conductor cable. Synonymous with intra-cable hot short. See 4.5 "Circuit Failure Modes."

4.18 INTENDED SHUTDOWN STRATEGY

The Intended Shutdown Strategy is the Required Safe Shutdown Path credited in the current design basis. When postulated failures are beyond the current design basis, the intended shutdown path may be impacted. However these deviations from the intended shutdown path must be analyzed further to determine if they are risk significant.

4.19 INTRA-CABLE CONDUCTOR-TO-CONDUCTOR SHORT CIRCUIT

A specific subset of conductor-to conductor short circuit cable failures wherein all conductors involved in a given short circuit are within a single multi-conductor cable.

4.20 INTER-CABLE CONDUCTOR-TO-CONDUCTOR SHORT CIRCUIT

A specific subset of conductor-to-conductor short circuit cable failures wherein the short circuit formed involves the conductors of two or more separate cables.

4.21 MANUAL ACTION

Manual manipulation (operation) of equipment. These actions may be subdivided into the broad categories of “operator action” or “operator manual action.”

Operator Actions
Those actions taken by operators from inside the MCR to achieve and maintain post-fire safe shutdown. These actions are typically performed by the operators controlling equipment that is located remote from the MCR.

Operator Manual Actions
Those actions taken by the operators to manipulate components and equipment from outside the MCR to achieve and maintain post-fire safe shutdown. These actions are performed locally by operators typically at the equipment.

4.22 OPEN CIRCUIT

See 4.5 "Circuit Failure Modes."

4.23 REQUIRED SAFE SHUTDOWN PATH

The safe shutdown path selected for achieving and maintaining safe shutdown in a particular fire area. (NEI 00-01)

4.24 REQUIRED SAFE SHUTDOWN CIRCUITS

Circuits and cables needed to support operation or prevent the maloperation of components identified as being necessary to achieve and maintain safe-shutdown for a particular fire area (i.e., part of the Intended Shutdown Strategy). (In general, a circuit/cable is considered to be required for safe shutdown if it is needed to ensure the operation of required equipment and fire-induced faults in the circuit (cable) can cause the required component(s) to fail and/or maloperate in an undesired condition for safe-shutdown. The circuits that are required will vary from fire area to fire area, depending upon which systems and equipment are being credited for a particular fire area.)

4.25 SHIELD

A conductive sheath or wrap around an insulated conductor or group of conductors within a cable. A shield is typically formed of a metallic ribbon, a braided sheath of metallic wires, or a composite metal coated tape. Shields are commonly applied where electromagnetic interference is a potential concern, either as a source (e.g., power cable) or a target (e.g., control, communications and instrument cables).

4.26 SHORT-TO-GROUND

See 4.5 "Circuit Failure Modes."

4.27 SIMULTANEOUS MULTIPLE SPURIOUS OPERATIONS

Fire-induced faults causing spurious operations occur at essentially the same moment in time.

4.28 SINGLE SPURIOUS ASSUMPTION

A common approach used by many licensees where all potential spurious operations are identified; however when considering the need to mitigate them, only one spurious actuation is assumed to occur (i.e., combinations are not postulated to occur at the same time). Many licensees have used this approach, but it is not consistent with current NRC views.

4.29 "SOURCE" CONDUCTOR

The energized conductor of a hot short – the conductor representing the source of energy.

4.30 SPURIOUS OPERATION

An operational occurrence initiated (in full or in part) by the failure(s) of one or more components (including cables) in a system. This is also known as a spurious actuation.

4.31 "TARGET" CONDUCTOR

The non-energized conductor of a hot short – usually connected to one or more circuit components.

4.32 THERMOPLASTIC

A cable insulation or jacket material that will soften, flow, or distort appreciably when subjected to sufficient heat and pressure. Examples include polyvinyl chloride (PVC) and polyethylene (PE).

4.33 THERMOSET

A cable insulation or jacket material that will not soften, flow, or distort appreciably when subjected to sufficient heat and pressure. Examples include rubber and neoprene.

4.34 UNRECOVERABLE CONDITION

One in which fuel damage has occurred or will likely occur later in the event given a postulated plant condition.

4.35 UNRECOVERABLE EQUIPMENT DAMAGE

Damage to safe shutdown equipment that cannot be mitigated by subsequent actions. For example, the suction valve of the normally running charging pump closes (spurious operation). That charging pump has been credited for shutdown in that fire area and damage occurs before the condition can be mitigated.

5 CIRCUITS TO BE CONSIDERED

Analysis of power, control, and instrument circuits must be performed to determine the effects on safe shutdown due to fire-induced failure of the cables. Cable failures to be considered are hot shorts, open circuits, and shorts to ground. Hot shorts may be from intra-cable conductor-to-conductor short circuits (for thermoset and thermoplastic cables) or inter-cable conductor-to-conductor short circuits for thermoplastic cables. When performing circuit analysis, if intra-cable shorts result in unacceptable conditions, inter-cable shorts need not be postulated provided any mitigating action performed would also mitigate the inter-cable shorts. Open circuits are a result of a loss of electrical continuity in an electrical circuit. As applied to cables, open circuit faults may result from a loss of conductor continuity or from triggering of circuit protection devices (e.g., a blown fuse or open circuit breaker). Shorts to ground involve an abnormal connection between a conductor and a grounded conducting medium. This might include structural elements (trays, conduits, enclosures, metal beams, etc.) or intentionally grounded conductors of the circuit (neutral conductor).

5.1 POWER CIRCUITS

Power circuits are used to carry electricity that operates a load, such as motive and control power to operate safe shutdown equipment.

For active components, such as pump motors or active motor operated valves (MOVs), these circuits would be required circuits; that is, the circuits would be required to remain free of fire damage unless it can be shown that loss of the circuit can be mitigated by a manual action or other means. Any manual action credited must meet the acceptance criteria approved by the NRC.

For passive components, such as passive MOVs or solenoid valves that fail to the required position on loss of power, these power circuits are considered associated circuits. Typically, a fire-induced failure of these circuits would not be a concern unless it could cause the component to spuriously operate.

Examples of power circuit analysis are provided in Appendix B.

5.2 CONTROL CIRCUITS

Control circuits carry the electrical signals for directing the performance of a component but do not carry the main power circuit. A control circuit is a low voltage (typically 120-VAC or 125-VDC) circuit, consisting of switches, relays, and indicating devices which direct the operation of remotely located plant equipment. For active components, such as pump motors or active motor operated valves (MOVs), these circuits would be required circuits if their loss could prevent the component from operating, unless it can be shown that loss of the circuit can be mitigated by a manual action or other means. Any manual action credited must meet the acceptance criteria approved by the NRC.

Examples of control circuit analysis are provided in Appendix B.

5.3 INSTRUMENT CIRCUITS

Instrumentation circuits are low voltage and low current loops (typically 4-20 milliamps or 1-5 volts) which connect transmitters to indication instruments or trip units. These instruments are used for providing signals of system parameters or for actuation signals for plant equipment. Instrument circuits must meet the same requirements as required or associated power and control circuits, unless it can be shown that loss of the circuit can be mitigated by a manual action or other means. Any manual action credited must meet the acceptance criteria approved by the NRC.

A required instrument circuit would be needed to provide a signal of a system parameter, such as pressure or level. A loss of these circuits would prevent the component from performing its safe shutdown function.

An associated instrument circuit typically would be one not required for safe shutdown but could provide a signal for actuating a component at some designated setpoint. A loss of these circuits could cause spurious actuation of a safe shutdown component but could not prevent it from performing its required safe shutdown function.

Examples of instrument circuit analysis are provided in Appendix B.

5.4 CABLE FAILURE MODES

The four modes of fire-induced cable failure are:

- A loss of conductor continuity
- A short circuit of one or more conductors to ground
- A conductor-to-conductor short circuit without ground, or a “hot short.”
- Conductor insulation resistance degradation, or a “high impedance fault.”

The cable failure modes may result in various effects. For ease of discussion, these effects can be summarized based upon circuit type (i.e., power, control, and instrumentation).

Power circuits:

- Loss of primary or motive power to a system or component (due to either open circuits or short circuits including ground)
- Hot shorts leading to spurious operation(s)
- Multiple high impedance faults (not addressed in this report)

Control/Indication Circuits:

- Loss of control function or power (due to either open circuits or short circuits including ground)
- Hot shorts leading to spurious operation(s)
- Loss of control indications
- False control indications

Instrumentation circuits:

- Failed instrument readings (high or low)
- Erratic instrument measurement readings
- Cable Failure Modes may be related to cable attributes. Examples of cable attributes are conductor size, number of conductors within a cable, insulation type, raceway type, etc. These attributes, where known, are described in Appendix A-3.

For multi-conductor electrical cables the dominant mode of cable failure anticipated is intra-cable conductor-to-conductor short circuits. This appears to apply to both thermoset- and thermoplastic-insulated electrical cables.

Thermoplastic materials are made from compounds that will re-soften and distort from their original form due to heating above a critical temperature peculiar to the material. Polyvinyl chloride (PVC) and polyethylene (PE) are examples of thermoplastic compounds. Thermoset insulation and jacket compounds will not re-soften or distort from their original form due to by heating until a destructive temperature is reached. Insulation and cable outer jackets made from cross-linked polyethylene (XLPE), chlorosulfonated polyethylene (CSPE, commonly called Hypalon), and Neoprene are examples of thermoset materials.

Where a high degree of physical protection is desired, cables may be furnished with a metallic outer sheath (or armor) made from interlocked aluminum or steel. Cables of this type are called "armored cables." Armoring protects the cable from penetration by sharp objects, crushing forces, and damage from gnawing animals or boring insects. Armored cables may be bare (i.e., exposed metal armor), or the armor may be covered with an additional layer of polymer jacket.

The available data indicate that inter-cable conductor-to-conductor shorting is possible, but is less likely to occur than is intra-cable conductor-to-conductor shorting. The data also indicate that inter-cable shorting is more likely given thermoplastic-insulated electrical cables than it is for thermoset-insulated electrical cables. The available data on inter-cable shorting is not sufficient to provide firm estimates of conditional probabilities. However, for thermoplastic insulated electrical cables, the likelihood of inter-cable conductor-to-conductor short circuits is 0.2 (NRC Inspection Manual Chapter 0609F Section 6.2.8). For thermoset insulated electrical cables the likelihood of inter-cable shorting is 0.02. For both electrical cable types the likelihood of inter-cable shorting may be much lower depending on the cable raceway configuration and fire exposure conditions. For current probability values the analyst should reference the current SDP (NRC Inspection Manual Chapter 0609F Section 6.2.8).

For both electrical cable types, thermoplastic and thermoset, the likelihood of a hot short versus a short to ground will depend on a number of configuration factors that are currently not well characterized. While some of these factors may have little influence on the intra-cable shorting behavior, they likely have a stronger influence on the likelihood of inter-cable shorting. That is, for some configurations inter-cable shorts cannot be considered a rare event while for others, the likelihood may be very low. Factors that are believed to have a significant impact on the likelihood of inter-cable shorting include the following (NUREG/CR-6776):

- The nature of the fire exposure: Direct flame/plume exposures that heat the cables from below may be more prone to cause shorts to ground than would radiant heating that heats the cables from above.

- The loading of the raceway: A tray with many electrical cables would be more likely to experience inter-cable shorting than a sparsely loaded cable tray.

- Trays with maintained spacing of the electrical cables: For such configurations (generally used only for larger power cables), inter-cable shorting independent of the grounded raceway appears to be highly unlikely.

- The position of the critical electrical cables within the raceway: Electrical cables located at the bottom of a tray would be more likely to short to ground than electrical cables located on top of a cable layer.

- Cable tray type: Cable tray type (e.g., ladder back versus solid bottom) impacts the cable support loading and may impact the failure behavior, but this parameter has not been investigated.

- Use of conduits: Electrical cables in conduits appear to have a higher likelihood of shorts to ground and a lower likelihood of hot-short induced spurious actuation in comparison to electrical cables in cable trays. This appears to apply to both intra- and inter-cable shorting behaviors.

EPRI/NEI test results indicate that loss-of-conductor continuity failures (open circuits) are unlikely to occur as an initial failure mode. Such failures could occur, but only after extended fire exposures or after repeated arcing faults for higher energy electrical cables. This failure mode is not expected to contribute significantly to fire risk.

A spurious actuation is generally caused by hot shorts. However, since not all hot shorts will lead to a spurious actuation, care must be taken in estimating the likelihood of a spurious actuation. The short circuit must involve the right set of conductors. For many circuits, a specific pair of conductors must be involved in a common short. For grounded circuits, the short must not involve an external ground or grounded conductor. For ungrounded DC circuits, a pair of correct-polarity hot shorts is required. The exact configuration of shorts that could cause spurious actuation is potentially unique for each circuit in the plant; however, in practice many circuits will share common configurations and common failure/fault modes.

5.5 Isolation Devices

5.5.1 Breaker/Fuse Coordination

With proper breaker/fuse coordination, one will not have to consider common power supply and common enclosure in the self-assessment scope. Breaker/fuse coordination does not need to be specifically assessed in this guidance, since it is likely that previous assessments and inspections have reviewed this area. Strong configuration management of coordination can also provide assurance in this area.

5.5.2 Multiple High Impedance Faults

Multiple High-Impedance Faults (MHIF) are not addressed by RIS 2004-003 and do not need to be considered in the self-assessment scope.

5.6 Summary of Circuits to be included and Excluded from Consideration

5.6.1 Circuits to be Considered

Circuits to be considered include the following (RIS 2004-03):

- For any individual multiconductor cable (thermoset or thermoplastic) failure that may result from intra-cable shorting, any possible combination of conductors within the cable may be postulated to occur concurrently regardless of number. For cases involving the potential damage of more than one multiconductor cable, assume a maximum of two cables to be damaged. Licensee self-evaluations should consider only a few (three or four) of the postulated combinations whose failure is likely to significantly impact the ability to achieve and maintain hot shutdown.

- For any two thermoplastic cables, failures of any combination of conductors that may result from inter-cable shorting (i.e., between two cables) may be postulated to occur concurrently. Licensee self-evaluations should consider only a few (three or four) of the postulated combinations whose failure is likely to significantly impact the ability to achieve and maintain hot shutdown. [Clarification: In no case are more than two cables considered in any inter-cable interaction that results in spurious actuations. It is not necessary to consider two "target" cables plus two additional "aggressor" cables.]

- For cases involving direct current (DC) control circuits, consider the potential spurious operation due to failures of the 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). Consider potential spurious actuations when the source and target conductors are each located in the same multiconductor cable.
  [Clarification: IP 71111.05T dated 12/01/04 does not match this criterion, and NRC has stated that they will revise the IP. The source and target conductors

must be in the same cable, regardless of whether it is of thermoplastic or thermoset construction.]

- The decay heat removal (DHR) system isolation valves at high-pressure/low-pressure interfaces may be subject to three-phase, proper-polarity hot short cable failures. Although this failure is unlikely, it could cause the opening of these valves which would pressurize the low-pressure portion of the DHR system piping outside of containment with the reactor coolant at or near normal reactor operating pressure. These three-phase power cables (either thermoset or thermoplastic jacketed) should be evaluated to ensure that they are not subject to three-phase hot shorts that could cause the DHR valves to spuriously open. [Clarification: This criterion applies only to the RHR shutdown cooling suction containment isolation valves (i.e., "drop line"). This criterion requires assessment of only two cables (target and aggressor), and therefore should be bounded by plant actions already taken to satisfy high-low pressure interfaces issues from GL 81-12 and GL 86-10. In lieu of evaluating failures against this criterion, NEI recommends that the analyst verify that the high-low pressure interface criteria committed to in addressing GL 81-12 and/or GL 86-10 are still being met.]

5.6.2 Circuits Not to Be Considered at This Time

Circuits not to be considered at this time pending additional research include the following (RIS 2004-03:

- Inter-cable shorting for thermoset cables, since the failure mode is considered to be substantially less likely than intra-cable shorting.
  [Clarification: Other criteria are used to address high/low pressure interfaces. See the high/low pressure interfaces discussion in Section 5.6.1.]

- Inter-cable shorting between thermoplastic and thermoset cables, since this failure mode is considered less likely than intra-cable shorting of either cable type or inter-cable shorting of thermoplastic cables.
  [Clarification: Other criteria are used to address high/low pressure interfaces. See the high/low pressure interfaces discussion in Section 5.6.1.]

- Configurations requiring failures of three or more cables, since the failure time and duration of three or more cables require more research to determine the number of failures that should be assumed to be “likely.”
  [Clarification: Other criteria are used to address high/low pressure interfaces. See the high/low pressure interfaces discussion in Section 5.6.1.]

- Multiple spurious operations in control circuits with properly sized control power transformers (CPTs) on the source conductors, since CPTs in a circuit can substantially reduce the likelihood of spurious operation. Specifically, where multiple (i.e., two or more) concurrent spurious operations due to

control cable damage are postulated, and it can be verified that the power to each impacted control circuit is supplied via a CPT with a power capacity of no more than 150 percent of the power required to supply the control circuit in its normal mode of operation (e.g., required to power one actuating device and any circuit monitoring or indication features).
[Clarification: This criterion may serve to reduce the number of circuit failures to be considered. However application of this criterion has not been piloted.]

- Fire-induced hot shorts that must last more than 20 minutes to impair the ability of the plant to achieve hot shutdown, since recent testing strongly suggests that fire-induced hot shorts will likely self-mitigate (e.g., short to ground) in less than 20 minutes. This is of particular importance for devices such as air-operated valves (AOVs) or power-operated relief valves (PORVs) which return to their deenergized position upon abatement of the fire-induced hot short.

- Consideration of cold shutdown circuits, since hot shutdown can be maintained and the loss of cold shutdown circuits is not generally a significant contributor to risk.

6 IMPLEMENTATION

Appendix A provides the steps to be taken for the four phases of this analysis along with additional information pertinent to each step. An outline of the tasks in each of the four phases is provided in Section 3.

The steps to be performed are likely to vary from plant to plant. The available databases, drawings, PSA analyses, and personnel capabilities and experience are some of these variables. Overall, however, each plant using this guidance document should accomplish the following:

1. Identify the fires areas and circuits to be reviewed within the week of the initial assessment

2. Put together a team of safe shutdown, fire protection, and PSA experts to perform the review

3. Identify circuits to be reviewed using the guidelines of RIS 2004-03, that are embodied in this guideline document

4. Develop a list of circuit combinations with potentially consequential failures, considering credible fire scenarios in the fire areas of interest

5. Determine the risk significance and compliance status of these issues

6. Assign corrective actions for the failures that are determined to be risk significant or potential compliance issues

7. Document findings for later staff review

NRC has stated an intent to apply enforcement discretion for circuit failure findings from self-assessments in 2005.

7 SUPPLEMENTAL REVIEW CONSIDERATIONS

This section references detailed information that will facilitate the performance of the review. More information will be added based on lessons learned from the pilot self-assessments that use this document.

7.1 POWER CIRCUITS

The reviewer is referred to NUREG-1778 Section 8.6.1, *Power Circuit Fault Modes*, for a detailed discussion in this area.

7.2 CONTROL AND INDICATION CIRCUITS

The reviewer is referred to NUREG-1778 Section 8.6.2, *Control and Indication Circuit Fault Modes*, for a detailed discussion in this area.

7.3 GENERAL CIRCUIT SELECTION METHODS

The reviewer is referred to the following documents for detailed discussions of general circuit selection methods and damage assumptions:

- NEI-00-01
- RIS 2004-03
- NRC Inspection Manual Chapter 0609F (Fire Protection SDP)

7.4 GENERAL RISK EVALUATION METHODS AND FIRE SCENARIO EVALUATION

The reviewer is referred to NEI 00-01 and the Fire Protection SDP.

7 REFERENCES

1. EPRI 1003326, *Characterization of Fire Induced Circuit Faults*

2. EPRI 1006961, *Spurious Actuation of Electrical Circuits Due to Cable Fires: Results of an Expert Elicitation*

3. NUREG/CR-6776, *Cable Insulation Resistance Measurements Made During Cable Fire Tests*

4. NRC February 19, 2003, Workshop Transcript (ADAMS ML030620006)

5. NEI 00-01, *Guidance for Post-Fire safe Shutdown Analysis*, Rev 0, May, 2003

6. NRC 3/19/2003 Inspection Guidance letter (ADAMS ML030780326)

7. NRC Regulatory Issue Summary 2004-03, *Risk-Informed Approach for Post-Fire Safe-Shutdown Associated Circuit Inspections*

8. NRC presentation material, September, 2003 NEI Fire Protection Information Forum

9. NEI 03-00, *Guidance for Implementing a Periodic Fire Protection Self-Assessment Program*, Draft Revision 1

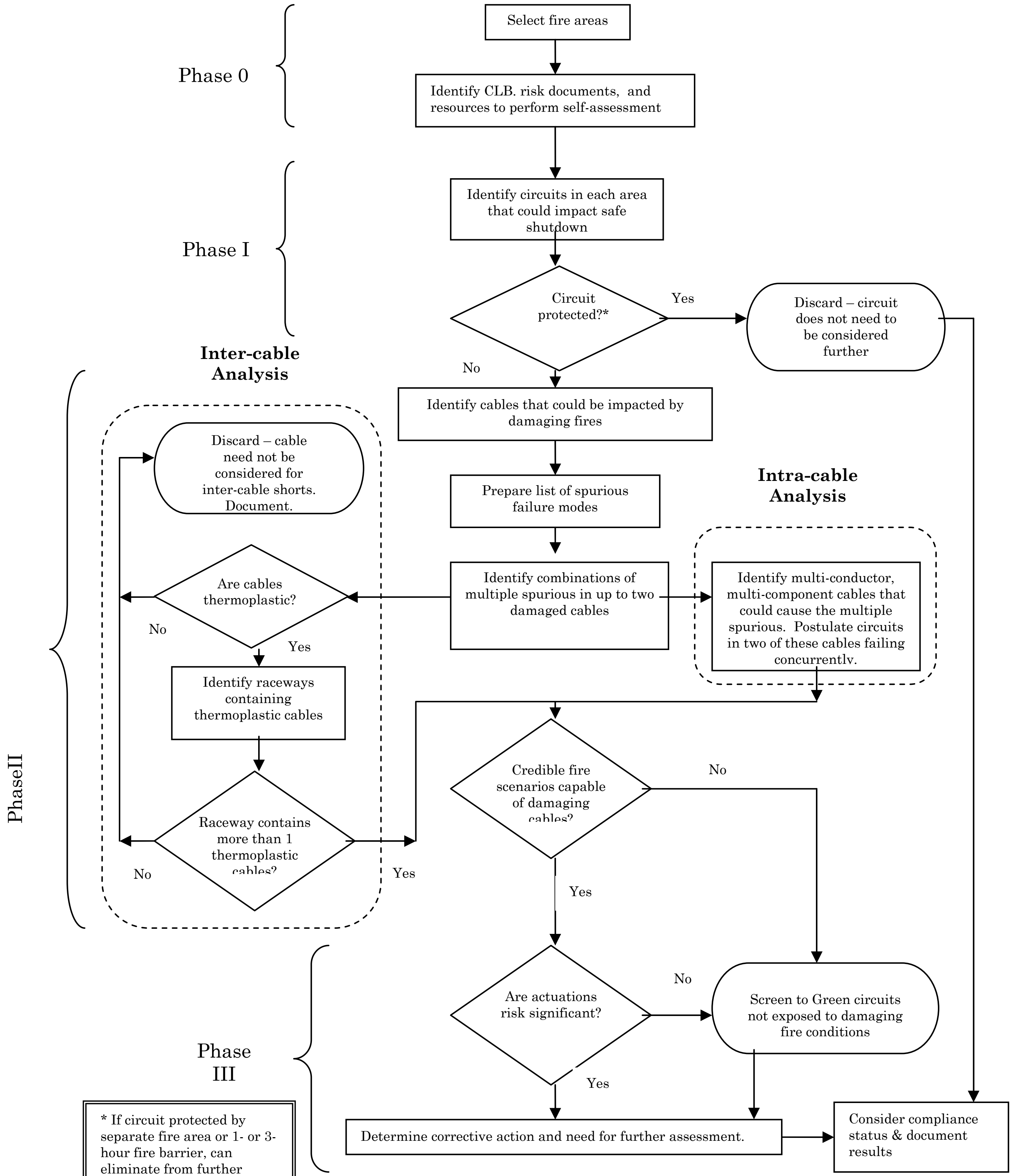
10. Nuclear Regulatory Commission, *Proposed Generic Communication; Risk-Informed Inspection Guidance for Post-Fire Safe-Shutdown Inspections*. Federal Register / Vol. 68, No. 150 / Monday, August 18, 2003 / Notices 49529 – 49533

11. Information Notice 99–17, *Problems Associated With Post-Fire Safe-Shutdown Circuit Analysis*

12. Inspection Manual Chapter 0609F, *Fire Protection Significance Determination Process*, May 28, 2004

APPENDIX A: SAFE SHUTDOWN PROGRAM GENERAL ASSESSMENT

Refer to the Flowchart in Figure A-1 for an outline of the methodology.



* If circuit protected by separate fire area or 1- or 3-hour fire barrier, can eliminate from further analysis, can discard from further analysis. Further analysis needed if protected only by spatial separation. See SDP Table 2.1.2.

Figure A-1

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A-1 SELF-ASSESSMENT STEPS AND EXPLANATORY INFORMATION

The steps to be followed in the self-assessment are provided in Tables A-1 through A-4 along with additional explanatory information following each table. It is possible to alter the order that the steps are taken, and to substitute steps that reflect plant-specific information as long as the goal of each phase of the assessment is met.

TABLE A-1
Phase 0

Phase	Step	Step
0		NOTE: Perform Phase 0 steps in advance of the actual assessment.
0	1 See also Sections A-1.1 and A-1.2	Select the fire risk-significant areas of the plant to be evaluated. These may be determined using the following criteria: a. Risk-significant fire areas/zones. However, consider that multiple spurious actuations may not have been addressed in the fire PRA or IPEEE. b. Fire induced risk-significant sequences (fires resulting in loss of offsite power, loss of emergency diesels, loss of high or low pressure injection systems, etc.) c. Important mitigating systems or features (FSSD, fire protection, etc.) d. Areas that have been the subject of recent safe shutdown problems at the plant (or other plants), e.g. from the Institute of Nuclear Power Operations (INPO) operating experience review e. Areas that rely heavily on a single element of defense-in-depth (i.e., areas with exemptions or deviations) Consider including areas where manual actions (1) are time critical; (2) are required in areas otherwise considered risk significant; (3) may present a challenge to the interim acceptance criteria; or (4) require multiple plant operators to carry out the actions. Consider including areas with high numbers of control cables including areas with cables routed between the control room and switchgear or motor control centers. Consider including fire areas/zones with a high fire ignition frequency, and containing significant SSD cabling or equipment . Typically, the Cable Spreading Room, Control Room, and Switchgear Rooms will be considered. During the analysis of selected areas, it may become apparent that circuit pairs continue from the selected area into an adjacent area. The adjacent area may also be selected for analysis.

Phase	Step	Step
0	2a See also Section A-1.3	Identify the licensing basis documents related to associated and required circuits for the fire areas chosen, including: ■ Regulations ■ Regulatory Guides committed to ■ Applicable regulatory guidance documents ■ FSAR sections ■ Approved SERs ■ Inspection reports ■ GL 86-10 and 10 CFR 50.59 evaluations ■ Safe shutdown analyses ■ Manual actions feasibility studies ■ Current IPEEE/Fire PRA (should have incorporated the latest EPRI fire events data base and PRA model) ■ Significant Accident Sequences listing (Cutsets) ■ Risk evaluation of GL 89-10 MOVs ■ Risk evaluation of AOVs ■ Risk significant rankings of systems/top events
0	2b See also Section A-1.4	Identify and obtain the internal and external assessment resources needed to perform the initial assessment (typically one week).

The following additional information is provided to support this table.

A-1.1 Selection of Risk Significant Zones

Inspection Procedure 71111.05T (12/01/04) provides the following guidance on the identification and selection of risk-significant fire areas/zones for inspections.

The initial selection of areas to be inspected should be based on inputs from a senior reactor analyst (SRA), a fire protection specialist and an electrical/instrumentation and control specialist. For each area the selection process will consider but will not be limited to the following:

- *review of the fire risk analyses;*
- *potential ignition sources;*
- *configuration and characteristics of combustible materials;*
- *routing of circuits important to accomplish and maintain safe shutdown condition;*
- *licensee's fire protection and fire fighting capability;*
- *licensee's use of operator manual actions.*

A similar approach to the self-evaluation would suggest that these parameters be evaluated by individuals of similar skill for selecting areas to be evaluated for circuit failures. Additionally, other inputs should be considered in the selection of fire area/zones for the assessment.

- Some areas of the plant are often considered potentially important, even if the Probabilistic Risk Assessment (PRA) does not show these areas as important. These include the Cable Spreading Room, Control Room, and Switchgear Rooms.

- Since the PRA or the Safe Shutdown Analysis may not identify fire scenarios involving multiple spurious operations (because of the consideration of only one circuit failure at a time), the risk associated with multiple spurious operations may not have been previously quantified. Fire areas/zones with a high fire ignition frequency, and containing significant safe shutdown cabling or equipment should also be considered in the fire area selection.

- In cases where there are a large number of potential fire areas with approximately equal risk significance, areas with systems known to be important to safe shutdown should be considered; for example, PORVs and block valves for PWRs or SRVs for BWRs.

- Areas with a high concentration of control cables or cables traveling between the control room and the component's breakers/MCCs should be considered.

- The Fire Hazards or Safe Shutdown Analysis may indicate that an area or failure scenario should not be considered because multiple spurious actuations are necessary for unacceptable consequences to occur. This area or scenario should be considered for review, since the impact of multiple spurious actuations has not been previously considered.

A-1.2 Consideration of Manual Actions

Manual actions may be required for mitigation of spurious equipment operation due to cable damage in the fire area of concern. Phase 0 should identify fire areas and zones involving manual actions that:

- Are time-critical in nature (completion required in the earliest stages of a fire event)
- Are required for fire scenarios in risk-significant areas of the plant
- May present a challenge to the manual action acceptance criteria, as defined in the most current NRC guidance
- Involve scenarios or fire areas where multiple plant operators are required to perform manual actions

Manual actions meeting these criteria help define fire areas and potential scenarios to be reviewed. The self-assessment should not attempt to evaluate manual actions against the NRC acceptance criteria. This should be assessed separately.

A-1.3 Identify Documents Needed

Licensees should then identify the following licensing basis documents (from 10 CFR 54.3) related to associated and required circuits for the fire areas chosen:

- Regulations
- Orders
- Fire protection license conditions
- Exemptions
- Technical specifications (if applicable)
- Plant-specific design basis information as documented in the FSAR
- Licensee commitments made in response to bulletins, generic letters, and enforcement actions
- Licensee commitments documented in LERs or SERs

The following documents not specifically identified in 10 CFR 54.3 may be useful:

- Regulatory Guides committed to
- Applicable regulatory guidance documents
- Inspection reports
- GL 86-10. 10 CFR 50.59, and NEI 02-03 evaluations
- Safe shutdown analyses
- Manual actions feasibility studies
- Approved fire protection plan

These documents should assist the licensee in identifying the approved licensing basis and the assumptions used in the existing safe shutdown analysis. This is important because the evaluation criteria from RIS 2004-03, used in the inspection are likely to be considered beyond the licensing basis for many plants, and a clear distinction between licensing basis and beyond licensing basis should be drawn in order to assure an appropriate response to identified findings. As noted earlier, however, it may be difficult to document NRC's previous acceptance of the licensing basis.

Licensees should also identify those of the following documents that are available that will assist in making risk-informed decisions:

- Current IPEEE/Fire PRA (preferably incorporated the latest EPRI fire events data base and PRA model)
- Risk evaluation of GL 89-10 MOVs
- Risk evaluation of AOVs
- Risk significance rankings of systems/top events

A.1.4 Identify and Obtain Assessment Resources

Licensees should identify external and internal resources needed to conduct self-assessments. Circuit analysis/safe shutdown and PSA expertise will be required. A balance of licensee and external expertise should be considered. Licensee staff can provide in-depth knowledge of licensee documents and safe shutdown methods and assumptions to facilitate the assessment, and external experts (peers from other licensees or contract staff) can provide an independent perspective. It should be noted that a full-scope review of circuit failures is expected to take much longer than this initial self-assessment, which reviews circuits on a sampling basis.

A-2 PHASE I

The steps in Phase 1 begin the actual assessment. See the Note in Section A.3.1.1.

Phase	Step	Step
I	1 See also Sections A-2.1 and A-2.2	For the selected areas, ensure that circuits are identified whose system and equipment failure could impact any of the following reactor shutdown functions: a. Reactivity control capable of achieving and maintaining subcritical reactivity conditions (Keff < 1.0). b. Reactor coolant system inventory control (makeup & isolation capabilities) capable of providing sufficient core cooling to preclude fuel cladding failure. c. Reactor Heat Removal function capable of achieving and maintaining decay heat removal. d. Process monitoring to accomplish the above functions. e. Supporting functions capable of providing process cooling, lubrication, electrical power, essential HVAC, etc. required to permit operation of the equipment used to achieve and maintain safe shutdown.
I	2 See also Sections A-2.1 and A-2.2	When the list of components that are credited for safe shutdown in the fire area is compiled, review the list and determine which circuits for these components are routed in the fire area of concern. This includes both required and associated circuits. Circuits of interest for PWRs include those that can result in: RCP seal cooling loss Flow diversion Flow isolation (such as VCT inlet/outlet) PORV isolation Letdown isolation Seal bleedoff Spurious injection Steam generator cooling diversion Steam generator overfeed EDG cooling loss Feed breaker opening

Phase	Step	Step
		Induced station blackout HVAC failures affecting safe shutdown equipment DC power losses affecting safe shutdown equipment Circuits of interest for BWRs include those that can result in: Vessel overfill Multiple SRV opening Manual scram failure Low pressure system min flow loss Suppression pool cooling loss Loss of instruments for Reactor Coolant level, pressure; suppression pool level, temperature; emergency or isolation condenser level; diagnostic instrumentation for safe shutdown systems; tank level indications EDG cooling loss DC system loss Loss of some HVAC systems The focus should be on cables in tray and conduit rather than equipment or MCCs based on exposure to fire conditions.
I	3 See also Section A-2.3	Screen the circuit from further consideration if it is protected from the effects of fire by (1) physical separation into a separate fire area; (2) separation by a 3-hour rated localized fire barrier; (3) separation by a 1-hour fire rated localized fire barrier plus automatic fire detection and suppression coverage for the fire area. Spatial separation alone or other means of protection are not a basis screening the circuit from further consideration at this point in the review. If the circuit is screened out at this step consider the compliance status of the finding and document as discussed in Phase III. If it is not screened out, continue to Phase II. Note: The adequacy of the barriers noted above is beyond the scope of this assessment .

A-2.1 Identify Circuits

A-2.1.1 General

NOTE: In implementing this guideline for identifying and evaluating circuits, the same criteria are to be used for evaluating both required and associated circuits (RIS 2004-03). Both types of circuits should be evaluated because spurious actuations in either type of circuit, or in a combination of associated and required circuits, can result in unacceptable consequences.

The licensee should identify the circuits in up to two damaged cables that result in circuit failures that could prevent achieving or maintaining hot shutdown. Phase I should limit consideration to component combinations whose maloperation or failure to operate could result in loss of a key safety function, or in immediate, direct, and unrecoverable consequences. Phase I exclusions may include, but are not limited to; cold shutdown circuits. PRA insights or deterministic methods such as P&ID review can be used in circuit selection.

As noted in above, these circuits should include those for which remedial manual actions are time critical (must be performed in the earliest stages of the fire). Evaluating the acceptability of these manual actions against current regulatory criteria is a separate exercise outside the scope of this self-assessment.[5] The only reason for considering manual actions here is the fact that fire areas with time-critical or complex manual actions are more likely to be risk significant, and are therefore more relevant to selecting fire areas for review.

Plant specific vulnerabilities to spurious operation can be developed from a number of sources.

- Review of PRA accident sequences
- Review of manual actions
- Review of Appendix R provisions
- Review of post-fire safe shutdown procedures
- Review of P&IDs for combinations of failures that will result in a loss of safe shutdown function or unrecoverable consequences

The assessment should focus on the sequences that appear to be the most likely to be risk-significant, but is not expected to involve all potentially risk-significant sequences.

A-2.1.2 Circuit Identification Methods

NEI-00-01 Appendix F provides guidance on the selection of potential scenarios of interest for the assessment. The assessment should focus on scenarios that would have the highest potential to be risk-significant. The NEI 00-01 guidance provides two general paths for identifying risk-significant scenarios, including the review of P&IDs or logic diagram "pinch points" and the use of PRA accident sequences. Additional guidance on specific scenarios that may be reviewed is provided in the sections below.

A-2.1.2.1 P&ID Reviews for Selection of Multiple Spurious Actuation Scenarios

The information presented in this section is taken from NEI 00-01 Appendix F.

The first step is to select target components/combinations that could impact safe shutdown. This first step limits consideration to combinations of multiple spurious actuation evaluations whose maloperation could result in loss of a key safety function, or immediate, direct, and unrecoverable consequences comparable to high/low pressure interface failures. These consequences are noted hereafter as "unacceptable consequences." Potential circuit failures affecting these safe shutdown target components may have been considered in previous

[5] Final acceptance criteria will be provided during the manual actions rulemaking process.

circuit analyses, but perhaps not for IN 92-18 or multiple spurious actuation concerns.

A system engineer can identify component combinations that can result in a loss of system safety function or immediate and unrecoverable consequences. Then, an electrical or safe shutdown engineer can identify areas where these component combinations have power, control, or instrument cables routed in the same fire area.

The review for component combinations can be performed with P&IDs or safe shutdown logic diagrams (if available) or both. The review should focus in on "pinch points" where the system function or hot shutdown (SSD) function (flow diversion, loss of coolant, or other scenarios that could significantly impair the ability to achieve and maintain hot shutdown) would be failed. Failure of the entire SSD function is not necessary for identification of component combinations but would be a limiting case assuming all identified components can fail with the same fire. Component combinations that do not fail the entire SSD function can be as important as combinations failing the entire function, especially if there is only a single component or manual/operator action remaining for the SSD function, or if the remaining SSD equipment is potentially unreliable. Some internal events PRA input may be helpful for determining potentially unreliable equipment or manual/operator actions.

This review should also consider the possibility that a combination of component failures in more than one system can result in undesirable consequences.

Some pre-knowledge of component cable routing is useful in this review. This would save time in the process by eliminating component combinations where cables are known to not be located in the same fire area. Without some cable routing knowledge, an identified component combination would be analyzed through several steps of NEI-00-01 prior to screening, which may require detailed cable routing.

The results of the P&ID or logic diagram review would be a list of potentially important component combinations to be evaluated further. Since the internal events PRA scope and fire protection SSD scope are different, the SSD review may provide potential combinations that have not been included in the internal events PRA. Also, it is possible for this review of the P&ID to identify component combinations not identified by SSD analysis (because it requires multiple spurious operations) or internal events PRA (because of a high level of redundancy). The final list of identified component combinations should be combined with any internal events PRA combinations (from the PRA review below) for a final list for analysis.

Further information on possible system failures causing undesirable consequences (based on risk insights) is provided in Section A-2.1.2.2 below.

A-2.1.2.2 Use of Risk Insights for Selection of Multiple-Spurious Actuation Scenarios

As discussed above, scenarios involving failure of cold shutdown equipment, is most likely not risk-significant and should not be reviewed. Loss of decay heat removal capability in BWRs can however, be risk-significant. Additionally, scenarios involving failures where shutdown or design margin is not maintained is also not of interest, unless the failure can lead to a core damage event. For example, a steam generator overfeed event that does not result in significant voiding in the primary system, would result in the primary system not being within its design parameters, but would not lead to a core damage event unless additional failures occurred. Review of plant risk evaluations of GL 89-10 MOVs and air-operated valves (AOVs), and Individual Plant Examination for External Events (IPEEE)/Fire PRA can provide additional insights.

When multiple failures are postulated that are beyond the current NRC-reviewed and approved licensing basis for the plant, the intended shutdown equipment may be impacted in some cases. The reviewer should consider whether there are other available ways of performing the function, including using systems that are not normally considered in the fire safe shutdown analysis (offsite power, feedwater, condensate, etc). The reviewer should also consider the procedure framework in which the operator is expected to be during a fire event (EOPs with supplemental fire guidance vs. prescriptive fire event procedures), and consider crediting other success paths that are available within the operator's procedure guidance. Similarly, actual expected fire damage should be postulated (vs. area-wide damage), which in many cases will yield additional surviving systems and trains that may be useful for mitigation even though they are not part of credited safe shutdown systems..

Examples of dominant sequences are discussed below for PWRs and BWRs.

A-2.1.2.2.1 Specific PWR Guidance

Reactivity Control

Reactivity Control and the supply of a boration flow path should be considered for spurious actuation combinations if PSA results show them to be risk significant; however, they are not expected to be. Generally, boration provides sufficient shutdown margin to allow the plant to cool down to cold shutdown. Several unlikely failures, such as stuck rods or a dilution event, would have to occur and go undetected in order for a recriticality to occur and cause core damage. Typically, cooldown for a pressurized water reactor (PWR) includes verification of shutdown margin (SDM). Thus, cooldown can be delayed if necessary until the required shutdown margin is verified and/or achieved.

Reactor Coolant Makeup Control

Plant specific designs may determine the potentially risk-significant scenarios to review as a part of this assessment. Potential scenarios include:

1. Reactor Coolant Pump (RCP) Seal Cooling/Injection: A seal LOCA can occur when seal injection and cooling fail. Potential scenarios may involve time critical actions to either trip the RCPs initially, or to recover seal injection or cooling prior to the seal LOCA occurring. For fire areas where the RCP control circuits are located, a RCP trip may not be possible, and this should be considered in any scenario development. Scenarios may involve failure of the injection flow path and the cooling flow path, or may involve failure of a common cooling system. For example, at some plants, Component Cooling Water provides both seal cooling, and cooling to the seal injection (High Pressure Injection or Chemical and Volume Control System) pumps. Pinch points in the cooling water systems should be reviewed to see if there are likely scenarios involving one or two spurious operations that results in failure of all injection and cooling to the RCP seals. Plants with reliable seals that have a low conditional seal LOCA probability (i.e., <1E-02) are less likely to have risk-significant scenarios as a result of failure of seal injection and cooling.

2. Diversions: Diversion of suction or discharge flow paths for makeup control can be risk-significant. For example, spurious operation of a containment sump valve may drain the Borated Water Storage Tank/Refueling Water Storage Tank (BWST/RWST), resulting in a failure of all injection if undetected. Spurious operation of a containment spray pump or other system can also drain the BWST/RWST. However, if letdown is isolated, and injection is only provided for RCP seal injection, then additional failures would have to occur in order for the scenario to become important. In a fire scenario, injection is primarily required to overcome shrinkage of reactor coolant during the cooldown. Cooldown can also be delayed until an injection source is restored.

3. Flow Path Isolation: Isolation of common flow paths can be risk-significant, including scenarios such as Volume Control Tank inlet or outlet valve spurious operation. Similar to the diversion category above, if letdown is isolated, and injection is only provided for RCP seal injection, then additional failures would have to occur in order for the scenario to become important.

<u>Reactor Pressure Control</u>

1. PORV/Block: The risk importance of scenarios involving PORV spurious operation would depend on two factors: 1) Manual actions to close the PORV or PORV block valve prior to or following spurious operation (note: PORV block valve actions performed prior to spurious operation may not prevent re-opening), or 2) the ability to prevent core damage following a fire-induced LOCA, such as the availability of sump recirculation. Note also that EPRI fire testing has indicated that most spurious operations will short to ground within 20 minutes (see RIS 2004-

03,), which would result in an open PORV reclosing. Given that a plant is able to recover from a PORV being open for about 20 minutes and prevent core damage, a spurious PORV opening should be considered for spurious actuation combinations if PSA results show it to be risk significant; however, it is not expected to be (values lower than 20 minutes may be used if supported by plant-specific analysis). The availability of injection may provide additional mitigation as well.

2. Letdown: The risk-importance of a spurious opening of letdown would depend on whether post-fire injection is provided to makeup for the letdown, and the ability to close additional letdown isolation valves given the initial failure. Additionally, many of the letdown valves are air operated, fail closed valves, and would reclose once the hot short shorted to ground in 20 minutes or less.

3. Seal Bleed-off: Generally, failure to close seal bleed-off is not risk-significant, since it typically does not lead to a seal LOCA or core damage sequence. The effect of failure to close seal bleed-off should be reviewed prior to screening seal isolation valve failures to Green.

4. Spurious Injection: Spurious injection may involve too much flow for normal makeup or spuriously starting standby injection pumps. The risk-significance of spurious injection failures would depend on the features and design of the plant and the pump being used. For example, plants with HPI pumps that do not lift primary PORVs or code safety valves would most likely not result in any risk-significant spurious injection sequences. An additional factor includes the procedural actions taken to close the PORVs or block valves following a fire, and the indication and procedures available to terminate SI prior to water relief of the safety valves. If the PORV is closed, then a spurious injection results in a code safety lift and eventually a stuck open code safety due to water release. The risk importance of this type of sequence would depend on the plant's ability to mitigate a LOCA event following a fire, including the availability of sump recirculation.

   Other concerns may include a spurious start of the protected pump without having the proper system conditions. If the pump starts with no suction/discharge or min flow capability (fire affected) the protected pump may become damaged and unrecoverable. If the system needs keep fill capability (which may be affected) and the pump starts, water hammer is a concern.

5. Diversion of Makeup/Injection to the Pressurizer Spray Line: Spray of injection into the pressurizer spray line may cause rapid depressurization and a possible loss of natural circulation. Loss of the steam generator cooling function may result.

Decay Heat Removal

1. Diversions and Flow Path Isolation: Spurious operation resulting in failure of the credited SG cooling train should be reviewed. This can include any number of flow path isolations or diversions, including scenarios such as closure of common suction line valves, draining of the condensate storage tank, opening of crosstie valves, etc. Of particular importance are failures that may occur prior to transfers to local control (or removing power) such as a spurious pump start and a spurious suction valve closure.

2. Overfeed: Overfeed of a single SG is typically not risk-significant, since the overfeed provides the decay heat removal function and does not result in a core damage event. However, combinations of an overfeed event and other failures may result in either significant voiding of the core, or exceeding the SG design requirements resulting in a potential SG tube rupture. Additionally, if the turbine driven AFW/EFW (Auxiliary Feedwater/Emergency Feedwater) pump is the credited SG cooling source, then an overfeed event may result in failure of the turbine-driven pump following water intrusion in the steam lines. Additionally, overfeeding the steam generator not being used as the steam supply for the turbine-driven pump may result in eventual failure to provide steam to the turbine-driven pump.

Process Monitoring

Spurious operation of process monitoring is typically not risk-significant, unless it can result in one of the sequences described above. This can either be as a direct result of the spurious operation, or indirectly through operator actions or failures. Circuits such as the Reactor Protection System (RPS), or other actuation systems than can result in spurious injection or SG overfeed sequences should be reviewed. In the case of this type of actuation, it is common that the spurious actuation would result following a grounded circuit, and may not require a hot short.

Electric Power

Sequences involving failure of the credited power supply following a fire should be reviewed. Sequences of importance may be plant specific, but could involve:

1. Failure of Emergency Diesel Generator cooling

2. Spurious opening of power feed breakers

3. Induced station blackout

Support System Failures

As discussed under RCS makeup above, failure of common support systems can be important. This can include failures of cooling water systems, HVAC, and DC systems. Cooling water system failures such as Service Water and Component Cooling Water are almost always potentially risk-significant. The likelihood of failing all trains of cooling water or other support systems is plant-specific and should be reviewed. HVAC failures are typically not risk-significant, since (1) the failures are typically self-identifying; (2) sufficient time is available to identify the failure and perform recovery actions; and (3) direct system failure does not occur. However, key HVAC system failures may be risk significant, especially if operator recovery is not likely.

A-2.1.2.2.2 Specific BWR Guidance

General

1. Although an inadvertent reactor vessel overfill condition is not a safe shutdown function listed above, the NRC has identified this as a concern. The acceptability of the current design features of the Boiling Water Reactor (BWR) to mitigate the effects of an inadvertent reactor vessel overfill condition as a result of either a fire or equipment failure has been addressed by the BWROG in General Electric Report No. EDE 07—390 dated April 2, 1990, in response to NRC Generic Letter 89-19. The NRC subsequently accepted the BWR Owners Group (BWROG) position in a Safety Evaluation dated June 9, 1994. (See also the section on Inventory Control.)

   The risk significance of an overfill event is low. An overfill event represents a deviation from the intended shutdown strategy and reactor response, but does not result in any immediate core cooling challenges. Since an overabundance of coolant is injected, the plant's response post-fire (required time for injection, pool cooling, etc) will be more gradual than predicted in typical thermo-hydraulic calculations. Safety Relief Valves (SRVs) will cycle (or be opened by the operator) and will gradually reduce Reactor coolant levels back to the desired band. Terry Turbine High Pressure Coolant Injection (HPCI) and Reactor Core Isolation Cooling (RCIC) systems are not sensitive to water in the steam supply. Isolation condensers have sloped steam lines which will drain back to the reactor, so that they can be placed back in service once the reactor coolant level has decreased back below the steam lines.

2. GE Report GE-NE-T43-00002-00-01-R01 entitled "Original Safe Shutdown Paths For the BWR" addresses the systems and equipment originally designed into the GE boiling water reactors in the 1960s and 1970s, that can be used to achieve and maintain safe shutdown in accordance with Section III.G.1 of 10CFR 50, Appendix R. Any of the

shutdown paths (methods) described in this report are considered to be acceptable methods for achieving redundant safe shutdown.

3. GE Report GE-NE-T43-00002-00-03-R01 provides a discussion on the BWR Owners' Group (BWROG) position regarding the use of SRVs and low pressure systems (Low Pressure Coolant Injection/Core Spray, or LPCI/CS) for safe shutdown. The BWROG position is that the use of SRVs and low pressure systems is an acceptable methodology for achieving redundant safe shutdown in accordance with the requirements of 10CFR50 Appendix R Sections III.G.1 and III.G.2. The NRC has accepted the BWROG position and issued an SER dated December 12, 2000.

Reactivity Control

Control Rod Drive System: The safe shutdown performance and design requirements for the reactivity control function can be met without automatic scram/trip capability. Manual scram/reactor trip is credited. The post-fire safe shutdown analysis must only provide the capability to manually scram/trip the reactor.

Pressure Control Systems

SRVs: The SRVs are opened to maintain hot shutdown conditions or to depressurize the vessel to allow injection using low pressure systems. These are operated manually. Automatic initiation of the Automatic Depressurization System (ADS) is not a required function. Typically the fuel cladding and suppression pool integrity analyses have shown that “No Spurious Operations” of the SRVs presents the worst case scenario.

A single spurious SRV opening is typically not risk significant. For plants with HPCI and/or RCIC, a single open SRV will not prevent operation of the steam driven systems. For large BWRs, a stuck open SRV accelerates the need for injection by a few minutes (for example, 30 minutes to boil-off to top of active fuel (TAF) becomes 25 minutes). For plants with isolation condensers, some calculations have been performed that show adequate reactor inventory with no injection for over 1 hour.

If multiple SRVs open, fuel damage is not expected to occur, however steam-driven systems will most likely be affected. Due to the number and diversity of other systems capable of injecting (Residual Heat Removal (RHR)-LPCI, CS, HPCS, Feedwater, Condensate) multiple SRVs opening is not expected to be risk significant, unless all of these systems could be affected by a credible fire. It is expected that there are very few plant locations where this would need to be investigated.

As noted in RIS 2004-03, hot shorts capable of opening SRVs would not be expected to remain indefinitely, and may clear in approximately 20 minutes. A lower value may be used if supported by analysis. If the SRV(s) reclose in a relatively short period of time (10 minutes), there will be very little impact to the overall shutdown. ADS systems are typically provided with an "inhibit" switch in the control room that will prevent a blowdown, if it is caused by instrument malfunction. BWR symptom-based EOPs typically include instruction to "inhibit ADS" for non-LOCA events. ADS also includes logic to verify that a low pressure pump is running and ready to inject before an automatic blowdown will occur.

Inventory Control

Systems selected for the inventory control function should be capable of supplying sufficient reactor coolant, such that no fuel cladding damage occurs through boil-off. Momentary core uncovery is acceptable as long as adequate core cooling is maintained. Manual initiation of these systems is acceptable. Automatic initiation functions are not required.

Spurious operation of the low flow high pressure injection systems (i.e. RCIC, Control Rod Drive or CRD) is generally not a concern since EOPs provide guidance to manage these systems and there is sufficient time available to intervene, however, spurious operation of large flow high pressure injection systems (i.e. HPCI/HPCS) may result in water intrusion into the main steam lines. Therefore, operator action may be required to trip the pump to prevent water intrusion, if flow control does not respond.

Minimum flow protection is not expected to be risk significant for high pressure systems capable of injecting against full reactor pressure, since flow to the vessel is always available. It may be more important for a low pressure system if it is being expected to run on minimum flow for a long time without a flow path to the suppression pool or the reactor. It is recommended to establish depressurization prior to low pressure injection if minimum flow is not guaranteed to prevent pump dead head operation.

Decay Heat Removal

Suppression pool cooling (SPC) is typically considered a hot shutdown function for BWR plants without isolation condensers. SPC removes heat from the suppression pool so that long-term net positive suction head (NPSH) is maintained for systems taking suction from the pool (HPCI/RCIC/RHR/Core Spray), and so that containment failure due to overpressurization does not occur.

Analyses for large BWRs with small suppression pools have shown that the SPC function can typically be delayed for 3-4 hours without challenging NPSH. As the pool heats up, vapor pressure is generated inside containment which also assists in meeting NPSH requirements, and may allow for even longer delays in establishing SPC. NPSH calculations must consider suppression pool pressure, temperature and decay heat removal pump flow rates. BWR EOPs provide operator guidance for maintaining adequate NPSH to operating pumps at elevated suppression pool temperatures, including managing system flow to satisfy NPSH.

Turbine-driven systems (HPCI/RCIC) are cooled by the process fluid, and so are subject to reduced oil cooling efficiency at higher suppression pool temperatures. However, vendor data shows these same turbine skids operate continuously in fossil plants at much higher process fluid temperatures. Containment failure pressures are quite high, and are not challenged.

Based on this, it is unlikely that a loss of the SPC function (or its associated service water systems) would be risk-significant, unless the SPC function was unable to be restored within several hours. EOPs typically contain contingencies if SPC cannot be restored that will prevent a containment rupture and remove decay heat by controlled venting of the suppression pool airspace. Note that some plant PRAs may have shown SPC as risk-significant.

<u>Process Monitoring</u>

The process monitoring function is provided for all safe shutdown paths. Information Notice (IN) 84-09, Attachment 1, Section IX “Lessons Learned from NRC Inspections of Fire Protection Safe Shutdown Systems (10 CFR 50 Appendix R)” provides guidance on the instrumentation acceptable to and preferred by the NRC for meeting the process monitoring function. This instrumentation monitors the process variables necessary to perform and control the functions specified in Appendix R Section III.L.1. Such instrumentation must be demonstrated to remain unaffected by the fire. The IN 84-09 list of process monitoring is applied to alternative shutdown (III.G.3). IN 84-09 did not identify specific instruments for process monitoring to be applied to redundant shutdown (III.G.1 and III.G.2). In general, process monitoring instruments similar to those listed below are needed to successfully use existing operating procedures (including Abnormal Operating Procedures). For a BWR these include:

- Reactor coolant level and pressure
- Suppression pool level and temperature
- Emergency or isolation condenser level
- Diagnostic instrumentation for safe shutdown systems
- Level indication for all tanks used

The specific instruments required may be based on operator preference, safe shutdown procedural guidance strategy (symptom-based vs. prescriptive), and systems and paths selected for safe shutdown.

<u>PRA Dominant Accident Sequences</u>

Typically no single core damage sequence dominates the total core damage frequency (CDF) in the BWR plant's PRA. A large number of sequences make up the total CDF. Following are some examples of risk-significant accident sequences:

- The classic station blackout (i.e. loss of offsite power combined with failure of diesel generators), resulting in failure of Emergency Equipment Cooling Water (EECW), which causes core damage due to failure of components requiring EECW

- Loss of offsite power followed by failure of diesel generators, resulting in loss of cooling to RHR heat exchangers

- Loss of raw cooling water (RCW) followed by failure of both HPCI and RCIC. The loss of RCW causes failure of CRD system. All high pressure injection is failed. Operator fails to depressurize and core damage results

- MSIV closure or turbine trip without bypass, followed by failure of high pressure injection (HPCI, RCIC, CRD), and failure to depressurize. Core damage occurs due lack of inventory

<u>Support Systems</u>

<u>Electrical Systems</u>

1. AC Distribution System: Power for the Appendix R safe shutdown equipment is typically provided by a medium voltage system such as 4.16 KV Class 1E busses either directly from the busses or through step down transformers/load centers/distribution panels for 600, 480 or 120 VAC loads. For redundant safe shutdown performed in accordance with the requirements of Appendix R Section III.G.1 and 2, power may be supplied from either offsite power sources or the emergency diesel generator depending on which has been demonstrated to be free of fire damage. No credit should be taken for a fire causing a loss of offsite power. Refer to NEI 00-01 Section 3.1.1.7 for further information.

2. DC Distribution System: Typically, the 125 VDC distribution system supplies DC control power to various 125 VDC control panels including switchgear breaker controls. The 125 VDC distribution panels may also supply power to the 120 VAC distribution panels via static inverters. These distribution panels typically supply power for instrumentation necessary to complete the process monitoring functions.

For fire events that result in an interruption of power to the AC electrical bus, the station batteries are necessary to supply any required control power during the interim time period required for the diesel generators to become operational. Once the diesels are operational, the 125 VDC distribution system can be powered from the diesels through the battery chargers.

Certain plants are also designed with a 250 VDC distribution system that supplies power to Reactor Core Isolation Cooling and/or High Pressure Coolant Injection valves and auxiliary oil pumps.

The DC control centers may also supply power to various small horsepower Appendix R safe shutdown system valves and pumps. If the DC power system is relied upon to support safe shutdown without battery chargers being available, it must be verified that sufficient battery capacity exists to support the necessary loads for sufficient time (either until power is restored, or the loads are no longer required to operate).

Cooling Systems

Various cooling water systems may be required to support safe shutdown system operation, based on plant-specific considerations. Typical uses include:

- RHR/SDC (Shutdown Cooling)/DH (Decay Heat) Heat Exchanger cooling water
- Safe shutdown pump cooling (seal coolers, oil coolers)
- Diesel generator cooling
- HVAC system cooling water

Essential Service Water System(s) – Essential service water systems vary from plant to plant, and are typically designed by the architect-engineer. Some designs and arrangements may result in configurations that are more susceptible to multiple spurious operations. Some general considerations:

Service water to ECCS room coolers is likely to be of low risk significance. Some plants have evaluated the loss of ECCS room cooling for fire safe shutdown and found that the ECCS pumps will operate at elevated room temperatures for the duration of the event. Operators can also take additional precautionary actions to prop open doors to increase room cooling unless adjacent to areas with poor environmental conditions due to fire.

For plants where diesel cooling is dependent on service water, the plant should determine if the diesel would trip on high temperature. This may temporarily interrupt some ECCS injection while service water is restored, but protect the diesel from damage so that it will be available once cooling is restored. Temporary interruption of ECCS is not likely to challenge core cooling.

Pump seals and motor oil coolers for RHR and Core Spray may also be cooled by service water. Evaluations may be performed to show that the pumps will continue to function acceptably for fire safe shutdown without oil or seal cooling.

HVAC Systems: HVAC Systems may be required to assure that safe shutdown equipment remains within its operating temperature range, as specified in manufacturer’s literature or demonstrated by suitable test methods, and to assure protection for plant operations staff from the effects of fire (smoke, heat, toxic gases, and gaseous fire suppression agents).

HVAC systems may be required to support safe shutdown system operation, based on plant-specific configurations. Typical uses include:

- Main control room, cable spreading room, relay room, battery room
- ECCS pump compartments
- Diesel generator rooms
- Switchgear rooms

Plant-specific evaluations are necessary to determine which HVAC systems are essential to safe shutdown equipment operation.

A-2.1.2.3 Review of Post-Fire Safe Shutdown Procedures

This section provides deterministic guidance for identifying potential plant-specific spurious actuation component combinations for further review. The component combinations represent cable from tray and conduit runs in fire areas throughout the plant. It is not necessary to examine spurious actuations from fires in MCCs, panels, and switchgear for the following reasons:

- Tray and conduit runs represent the great majority of cable exposure to fires in the plant.

- Cables entering panels are reviewed in a similar fashion to those in trays. The risk significance of motor control center (MCC), panel, and switchgear fires is generally low because they typically affect only one train of hot shutdown equipment.

- For fires in control room cabinets, it would be appropriate to use the risk methods in this section with spurious actuation probabilities for single-conductor to single-conductor failures (see Table B-4). Internal wiring within control room cabinets typically consists of single conductor "SIS" wiring. The wiring is routed from terminal strips (where, at least initially, the individual conductors are physically separated from other conductors) into wireways or wire bundles (vertical and horizontal, tie-wrapped together) until the individual conductor "breaks out of the pack" and terminates at the individual electrical connection.

In addition to identifying combinations of circuit failures based on the guidelines in RIS 2004-03 and this document, it is possible that the assessment will uncover deficiencies in existing safe shutdown analyses. These deficiencies should be placed into the Corrective Action Program (and reported if applicable) in accordance with existing plant procedures.

A-2.2 Identify Cables That Could Be Impacted by the Credible Fire Scenarios

Using existing cable route drawings, schematics, block diagrams, and/or databases, identify the cables and their locations in the affected fire areas for the circuits to be reviewed. These are cables that may, during significant fires, reach the temperature thresholds described in Section 3 of this document. Determine the type of cable (thermoset, thermoplastic, or armored). Reviewers for plants using thermoplastic cable should assume that all of the cable in a tray or conduit is thermoplastic unless it can be demonstrated that some or all of the cable is thermoset.

A-2.3 Determine Circuit Protection

If any of the circuits identified in Phase I is protected by one of the following features, screen the circuit from further consideration.

(1) physical separation into a separate fire area;

(2) separation by a 3-hour rated localized fire barrier;

(3) separation by a 1-hour fire rated localized fire barrier plus automatic fire detection and suppression coverage for the fire area.

[Note: The adequacy of the barriers noted above is beyond the scope of this assessment.]

Spatial separation or other means of protection are not a basis for screening the circuit from further consideration at this point in the review.

If the circuit is screened out at this step, the rationale for that action should be documented. If the circuit is not screened out at this step proceed to Phase II.

The rationale for this assumption is that the protection schemes in Section III.G.2, (except for separation) are adequate to assure that the circuit is free of fire damage and does not need to be analyzed further. This assumption is consistent with the Fire Protection SDP Table 2.1.2, which provides criteria for crediting safe shutdown path independence. No single or multiple spurious actuations, shorts to ground, or open circuits need to be considered further if they can be screened out using this assumption.

A-3 PHASE II

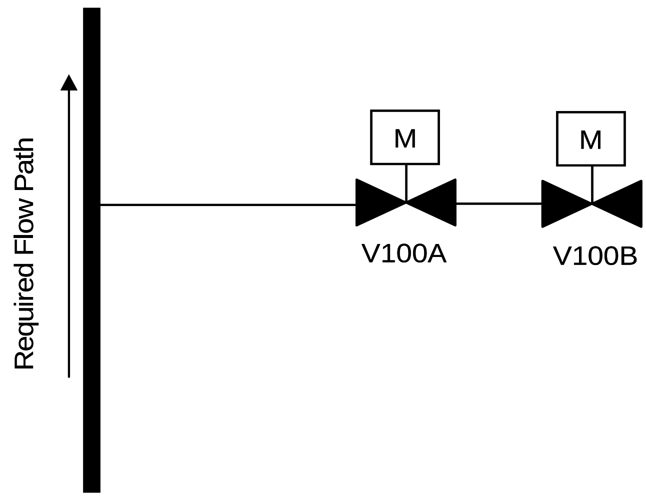
In Phase II the reviewer determines which circuit failures and pairs should be evaluated for risk significance. Prior to beginning this phase the analyst should review the following types of failures to be considered by NRC inspectors, according to RIS 2004-03. Specific paragraph references to the RIS Attachment 1 are denoted in the "Ref" column as "1A," "1B," 1C," etc.

Ref	Cable Failure Mode & Related Cable Attribute	Bin	Comments And General Discussion
1A	For any individual multiconductor cable (thermoset or thermoplastic) failure that may result from intra-cable shorting, any possible combination of conductors within the cable may be postulated to occur concurrently regardless of number. For cases involving the potential damage of more than one multiconductor cable, assume a maximum of two cables to be damaged. Inspectors should consider only a few (three or four) of the postulated combinations whose failure is likely to significantly impact the ability to achieve and maintain hot shutdown.	1	The analyst should consider a maximum of two cables to be damaged, and up to 3 or 4 of the most significant circuit failures affecting hot shutdown in each cable. Concurrent loss of function of other components whose cables are damaged by fire must be considered in addition to the spurious actuations in the two cables.
1B	For any two thermoplastic cables, failures of any combination of conductors that may result from inter-cable shorting (i.e., between two cables) may be postulated to occur concurrently. Inspectors should consider only a few (three or four) of the postulated combinations whose failure is likely to significantly impact the ability to achieve and maintain hot shutdown.	1	For thermoplastic cables only, the analyst should consider inter-cable interactions, up to three or four (total, not each cable) of the most significant combinations of spurious actuations affecting hot shutdown.
1C	For cases involving direct current (DC) control circuits, consider the potential spurious operation due to failures of the 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). Consider potential spurious actuations when the source and target conductors are each located in the same multiconductor cable.	1	This is similar to 1A above, Consider intra-cable interactions for DC control (not power) circuits. Inter-cable interactions do not need be considered for DC circuits.

Ref	Cable Failure Mode & Related Cable Attribute	Bin	Comments And General Discussion
1D	The decay heat removal (DHR) system isolation valves at high-pressure/low-pressure interfaces may be subject to three-phase, proper-polarity hot short cable failures. Although this failure is unlikely, it could cause the opening of these valves which would pressurize the low-pressure portion of the DHR system piping outside of containment with the reactor coolant at or near normal reactor operating pressure. These three-phase power cables (either thermoset or thermoplastic jacketed) will be inspected to ensure that they are not subject to three-phase hot shorts that could cause the DHR valves to spuriously open.	1	Consider three-phase hot shorts in power cables for high-low pressure interface valves
1	Failures that impede hot shutdown in the earliest stages of the fire are the most significant.	1	Failures that impact hot shutdown in the earliest stages of the fire should be weighted more heavily than those with impacts later in the fire.

Phase	Step	Step
II	1 See also Sections A-3.1 through A-3.4	Determine possible intra-cable failure modes in accordance with the following: a. Identify multi-conductor cables that could cause one of the worst-case multiple spurious failures. b. Identify pairs of cables that could contribute to one of the worst-case multiple spurious failures c. Any of these types of cables will be passed onto Phase III for a risk significance determination. d. It should be noted that these cables still have to be evaluated for inter-cable shorts in accordance with the section below.
II	2 See also Sections A-3.1 through A-3.4	Determine possible inter-cable failure modes in accordance with the following: a. Identify those cables that contain circuits related to the worst-case multiple spurious failures that have thermoplastic construction. b. From this list, compile a list of raceways that contain thermoplastic cables c. Determine which raceways contain two or more of these cables of concern. Cables in these raceways will be passed onto Phase III for determination of risk significance.

Phase	Step	Step
II	3 See also Sections A-3.1 through A-3.4	The following failure modes should be deferred from this assessment pending any additional NRC research (except as noted). This guidance reflects criteria in Regulatory Information Summary 2004-03. Note that these are all Bin 2 items. a. Circuits involving only cold shutdown components [only hot shutdown impacts are considered pending additional research] b. Inter-cable shorting between thermoset cables [any inter-cable shorting involving thermoset cables is not seen to be risk significant pending additional research] c. Inter-cable shorting between thermoset and thermoplastic cables [any inter-cable shorting involving thermoset cables is not seen to be risk significant pending additional research] d. Configurations involving concurrent spurious operations in three or more cables [three independent failures are not deemed risk significant] Two or more concurrent spurious operations among circuits that have control power transformers or other current limiting devices, if it can be verified that the current is limited to 150% of the normal control power (one device and monitoring/indication). [Control power transformers prevent enough current from flowing into the device actuator such that a hot short does not usually result in device actuation.] AOV or PORV control circuits where spurious operations of up to 20 minutes duration will not impact the ability to achieve and maintain hot shutdown. Shorter durations may be used if supported by analysis or testing. [AOVs and PORVs return to their safe position when the hot short ceases. 20 minutes is the maximum fault duration to be considered.]
II	4 See also Sections A-3.1 through A-3.4	Bin 3 items identified in the earlier revision of the RIS are not explicitly addressed in RIS 2004-03. These items include ■ Open circuits as an initial failure mode ■ Inter-cable shorts between cables inside and outside conduit, ■ Inter-cable shorts between armored cables ■ 3-phase hot shorts in power cable for other than hi-lo pressure interface valves ■ Shorts of the proper polarity in DC power cable ■ Multiple high impedance faults on a common power supply While these are not explicitly excluded by the RIS, the focus on Bin 1 items above effectively excludes them from inspector review. Neither should any emphasis be placed on them in the self-assessment.

Phase	Step	Step
II	5 See also Sections A-3.1 through A-3.4	In general, the safe shutdown analysis will be reviewed to determine the equipment credited for safe shutdown in a given fire area. The assessment should also identify any additional equipment that may be required to be reviewed for multiple spurious operations. An example is shown in Figure 1 below.  In this example, V100A and V100B are normally closed valves in a line that is a potential flow diversion path from the required flow path. Under the multiple spurious assumption, the circuits for the motor operators for both V100A and V100B will have to be considered associated circuits, and analyzed for potential concurrent spurious operation. Not all analyses would have picked up both of these valves as associated components. Some licensees may have documented specific cases where valves or components were excluded based on assumptions of the number of spurious actuations to be considered. Identified cases like this should be reviewed specifically. Existing open issues or URIs involving associated circuits may be reviewed as well. A review of flow and/or logic diagrams will be required to identify that similar situations as that depicted in Figure 1 are included in the assessment.
	6 See also Section A-3.5	Determine if there are credible fire scenarios using the guidance in NUREG-1805 or the new fire protection SDP (MC-609F).
	7 See also Section A-3.5	Determine whether the cables of interest are impacted by the fire scenario(s). If not, the analysis is terminated and these failures are screened to Green. If so, the circuits are passed through to Phase III of the assessment.

In Phase II plant representatives utilize the guidelines in Regulatory Information Summary 2004-03 to determine circuit failures, or combinations thereof, which can be considered potentially risk-significant. "Potentially risk-significant" means that the circuit failures are in Bin 1 or can impede hot shutdown within the earliest stages of the fire. The actual determination of risk-significance is performed in Phase III.

Note that circuit failures in Bins 2 and 3 may be identified for possible consideration at a later time, but need not be considered further in this self-assessment unless the potential risk significance or consequences indicate a need for immediate consideration. The use of risk significance for selecting circuit failures to be evaluated does not changes the regulatory requirement to provide reasonable assurance that one train of systems necessary to achieve and maintain hot shutdown is free of fire damage.

A-3.1 Binning of Potential Failures

MOST RISK SIGNIFICANT

- Failures that impede hot shutdown in the earliest stages of the fire

NUMBER OF CABLE FAILURES TO CONSIDER – High Risk Scenarios (Bin 1)

- For any individual multiconductor cable (thermoset or thermoplastic) failure that may result from intra-cable shorting, any possible combination of conductors within the cable may be postulated to occur concurrently regardless of number. For cases involving the potential damage of more than one multiconductor cable, assume a maximum of two cables to be damaged. Licensee self-evaluations should consider only a few (three or four) of the postulated combinations whose failure is likely to significantly impact the ability to achieve and maintain hot shutdown.

- For any two thermoplastic cables, failures of any combination of conductors that may result from inter-cable shorting (i.e., between two cables) may be postulated to occur concurrently. Licensee self-evaluations should consider only a few (three or four) of the postulated combinations whose failure is likely to significantly impact the ability to achieve and maintain hot shutdown. [Clarification: In no case are more than two cables considered in any inter-cable interaction that results in spurious actuations. It is not necessary to consider two “target” cables plus two additional “aggressor” cables.]

- For cases involving direct current (DC) control circuits, consider the potential spurious operation due to failures of the 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). Consider potential spurious actuations when the source and target conductors are each located in the same multiconductor cable. [Clarification: IP 71111.05T dated 12/01/04 does not match this criterion, and NRC has stated that they will revise the IP. The source and target conductors must be in the same cable, regardless of whether it is of thermoplastic or thermoset construction.]

- The decay heat removal (DHR) system isolation valves at high-pressure/low-pressure interfaces may be subject to three-phase, proper-polarity hot short cable failures. Although this failure is unlikely, it could cause the opening of these valves which would pressurize the low-pressure portion of the DHR system piping outside of containment with the reactor coolant at or near normal reactor operating pressure. These three-phase power cables (either thermoset or thermoplastic jacketed) should be evaluated to ensure that they are not subject to three-phase hot shorts that could cause the DHR valves to spuriously open. [Clarification: This criterion applies only to the RHR shutdown cooling suction containment isolation valves (i.e., "drop line"). This criterion requires assessment of only 2 cables (target and aggressor), and therefore should be bounded by plant actions already taken to satisfy high-low pressure interfaces issues from GL 81-12 and GL 86-10. In lieu of evaluating failures against this criterion, NEI recommends that the analyst verify that the high-low pressure interface criteria committed to to address GL 81-12 and/or GL 86-10 are still being met.]

ISSUES REQUIRING FURTHER RESEARCH – Moderate Risk (Bin 2)

- Inter-cable shorting for thermoset cables, since the failure mode is considered to be substantially less likely than intra-cable shorting. [Clarification: Other criteria are used to address high/low pressure interfaces. See the high/low pressure interfaces discussion above.

- Inter-cable shorting between thermoplastic and thermoset cables, since this failure mode is considered less likely than intra-cable shorting of either cable type or inter-cable shorting of thermoplastic cables. [Clarification: Other criteria are used to address high/low pressure interfaces. See the high/low pressure interfaces discussion in Section 5.6.1.]

- Configurations requiring failures of three or more cables, since the failure time and duration of three or more cables require more research to determine the number of failures that should be assumed to be “likely.” [Clarification: Other criteria are used to address high/low pressure interfaces. See the high/low pressure interfaces discussion in Section 5.6.1.]

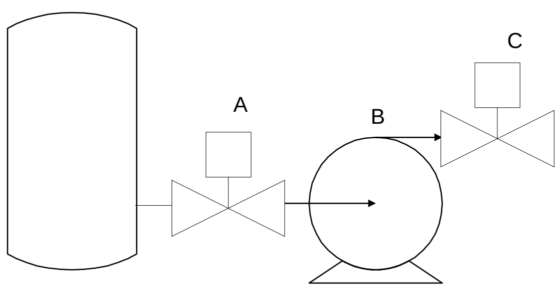
- Multiple spurious operations in control circuits with properly sized control power transformers (CPTs) on the source conductors, since CPTs in a circuit can substantially reduce the likelihood of spurious operation. Specifically, where multiple (i.e., two or more) concurrent spurious operations due to control cable damage are postulated, and it can be verified that the power to each impacted control circuit is supplied via a CPT with a power capacity of no more than 150 percent of the power required to supply the control circuit in its normal mode of operation (e.g., required to power one actuating device and any circuit monitoring or indication features). [Clarification: This criterion may serve to reduce the number of circuit failures to be considered. However application of this criterion has not been piloted.]

- Fire-induced hot shorts that must last more than 20 minutes to impair the ability of the plant to achieve hot shutdown, since recent testing strongly suggests that fire-induced hot shorts will likely self-mitigate (e.g., short to ground) in less than 20 minutes. This is of particular importance for devices such as air-operated valves (AOVs) or power-operated relief valves (PORVs) which return to their deenergized position upon abatement of the fire-induced hot short.

Bin 2 and Bin 3 (see RIS 2004-03) failures need not be assessed at this time unless the potential risk significance or consequences indicate a need for immediate consideration, or unless they involve a potential violation of current regulations.

A-3.2 Example of Cable Selection

The following example illustrates the general application of RIS 2004-03, criteria in determining which cables should be reviewed, based on the routing of power, control, and instrument circuits in those cables.



Given this example, the RIS inspection guidance would lead to the following conclusions:

- Stop evaluation at two cables per scenario
- If 1 cable contains conductors for all 3 components (A, B, and C), then all 3 could spuriously operate simultaneously
- If 2 cables contain conductors for all 3 components (A, B, and C) then all 3 could spuriously operate simultaneously
- If 3 cables contain conductors for all 3 components (A, B, and C) then the spurious operation of all 3 would not be postulated. The worst case of two cable failures should be postulated.

A-3.3 Analysis Assumptions

- Thermoplastic cables (typically non-IEEE 383 qualified) should be assumed to fail if exposed to the hot gas layer or plume temperatures greater than those shown in the SDP, unless analysis supports different failure temperatures.

- Thermoset cables (typically IEEE 383 qualified) should be assumed to fail if exposed to hot gas layer or plume temperatures greater than those shown in the SDP, unless analysis supports different failure temperatures.

A-3.4 Detailed Consideration of RIS Criteria

After determining which scenarios are the most potentially risk significant, the RIS 2004-03 criteria will be used to determine which cable configurations contain circuits of risk significance. These criteria utilize the tables shown in Appendix A-3. Circuits not screened to Green at this step will be evaluated for risk significance in Phase III.

A-3.5 Credible Fire Scenarios

A-3.5.1 Determining Credible Fire Scenarios

Credible fire scenarios may be determined from guidance in NUREG-1805, the new fire protection SDP (MC-609F), or other acceptable methods. The following excerpts from NUREG-1805 indicate its purpose in the inspection arena.

The U.S. Nuclear Regulatory Commission (NRC), Office of Nuclear Reactor Regulation (NRR), Division of Systems Safety and Analysis (DSSA), Plant Systems Branch (SPLB), Fire Protection Engineering and Special Projects Section has developed quantitative methods, known as "Fire Dynamics Tools (FDTs)," to assist regional fire protection inspectors in performing fire hazard analysis (FHA). These methods have been implemented in spreadsheets and taught at the NRC's quarterly regional inspector workshops conducted in 2001–2002. The goal of the training is to assist inspectors in calculating the quantitative aspects of a postulated fire and its effects on safe nuclear power plant (NPP) operation. FDTs were developed using state-of-the-art fire dynamics equations and correlations that were pre-programmed and locked into Microsoft Excel® spreadsheets. These FDTs will enable the inspector to perform quick, easy, first-order calculations for the potential fire scenarios using today's state-of-the-art principles of fire dynamics. Each FDT spreadsheet also contains a list of the physical and thermal properties of the materials commonly encountered in NPPs.

The FDTs are intended to assist fire protection inspectors in performing risk-informed evaluations of credible fires that may cause critical damage to essential safe-shutdown equipment.

The primary objective of this NUREG [1805] is to provide a methodology for use in assessing potential fire hazards in the NRC-licensed NPPs. The methodology *uses simplified, quantitative fire hazard analysis (FHA) techniques to evaluate the potential for credible fire scenarios. One purpose of these evaluations is to determine whether a potential fire can cause critical damage to safe shutdown components, either directly or indirectly by igniting intervening combustibles.*

When inspectors develop a fire scenario, they should postulate the worst-case, realistic fire, provided that the compartment and configuration of the fire area, room, or zone can support such a fire. For example, a large cabinet fire is one in which fire damage initially extends beyond the cabinet in which the fire originated. The fire damage attributed to a large cabinet fire often extends into the overhead cabling, an adjacent cabinet, or both. A large fire for a pump or motor can often be based initially upon the largest (worst-case) oil spill from the equipment. If the configuration of the compartment, combustibles, etc., supports further growth of the large fire, the fire scenario should postulate that growth. Since scenarios that describe large fires are normally expected to dominate the risk-significance of an inspection finding, scenarios with small fires typically are not included unless they spread and grow into large fires.

More detailed guidance on developing credible fire scenarios is found in NUREG-1805, or in the revised SDP.

The potential for energetic fires resulting from electrical faults in switchgear should be considered in the appropriate fire areas.

A-3.5.2 Screening of Circuit Failures Considering Credible Fire Scenarios

After determining the credible fire scenarios for each fire area, the reviewer should determine which circuit failures or combinations of interest will be subject to damaging fire conditions. Those that are not deemed to be damaged should be screened to Green and documented. Those that are damaged will be considered further in Phase III.

A-4 PHASE III

In Phase III the reviewer determines the actual risk significance of those circuit failures identified in Phase II, determines how the findings will be addressed by the plant, and determines the extent of additional program review required.

Phase	Step	Step
III	1 See also Section A-4.1	Determine the risk-significance of each circuit failure or pair identified in Phase II as potentially risk significant. This is done using NEI 00-01 Section 4 or the revised fire protection SDP, as described in Section 6.4.1.
III	2 See also Section A-4.1	Circuit failures initially analyzed with SDP or NEI 00-01 as potentially risk-significant may be analyzed with a more detailed fire PRA.

Phase	Step	Step
III	3 See also Section A-4.2	Place risk-significant findings in the Corrective Action Program and identify any necessary corrective actions using Section A-4.2 and the referenced guidance in NEI 00-01. Distinguish between licensing basis issues and beyond licensing basis issues wherever possible. Appropriate reporting procedures should be followed for compliance issues. Many issues identified as a result of following the RIS criteria may be beyond the licensing basis; however, all issues with risk significance should be properly addressed regardless of the licensing basis implications. Compensatory measures should be taken in accordance with the NRC Enforcement Manual Section 8.1.7.1.
III	4	As an interim measure, place findings that are not risk-significant in the Corrective Action Program with a lower priority that those identified in Step 3. Possible corrective actions may include blanket exemption requests, industry topical reports, or other generic resolutions that may be developed in the near future. Corrective actions should also be employed in accordance with the NRC Enforcement Manual Section 8.1.7.1.
III	5 See also Section A-4.3	Determine any additional evaluation required. The entire review to this point has been on sampling basis, both for the fire areas selected and the circuits to be reviewed within the fire area. Based on the number and significance of the findings, the reviewer should consider the extent to which the review is to be expanded to other circuits and fire areas, and over what period of time.
III	6	Document all findings and results of this assessment in accordance with existing plant practices

A-4.1 RISK SIGNIFICANCE DETERMINATION

Determination of risk significance for identified self-assessment findings will be made using the latest revision of the SDP, NEI 00-01 Chapter 4, or a plant-specific fire PRA. The fire SDP addresses only single fire areas and does not address defense-in-depth considerations, but it may be applied multiple times in each fire area. Any number of source/target pairs may be considered for each room.

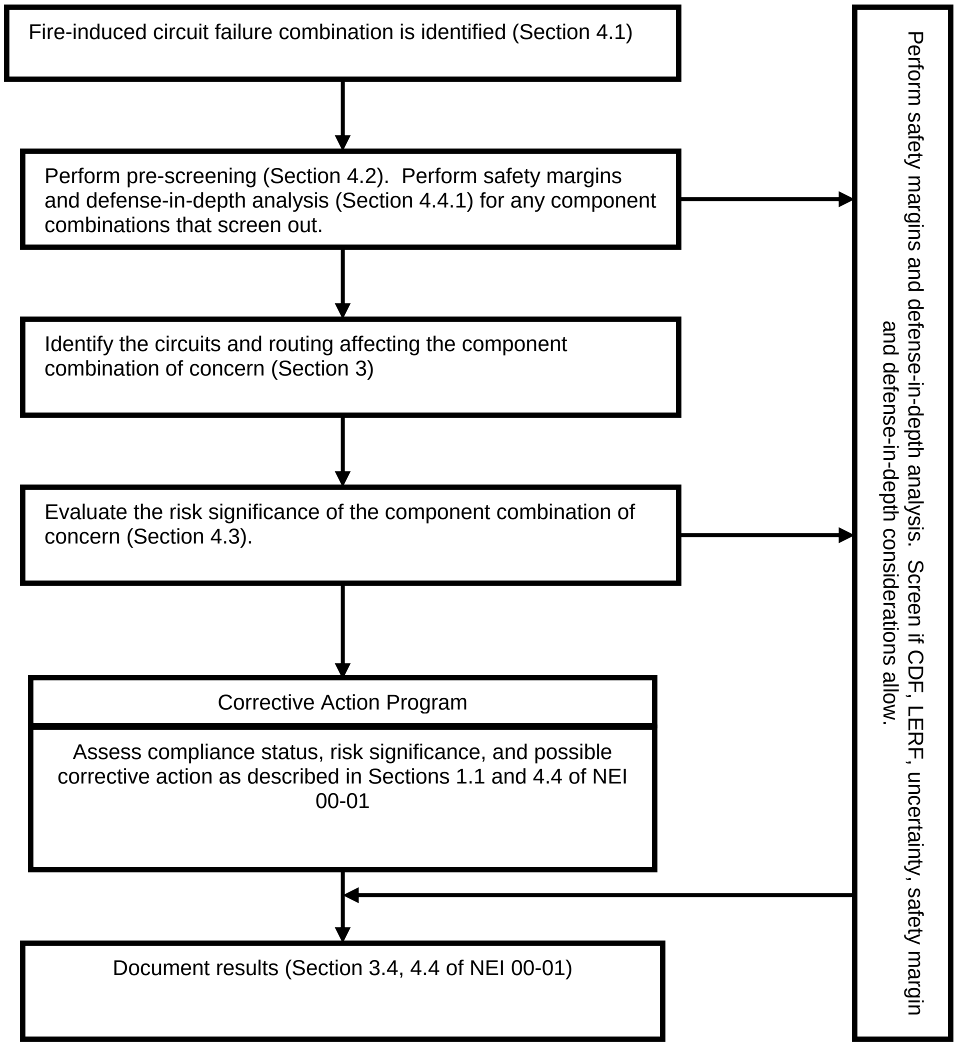
The NEI 00-01 method for risk significance determination is summarized below.

Section 4 provides a method for determining the risk significance of identified fire induced circuit failure component combinations to address the risk significance of the current circuit failure issues between the NRC and the industry. [Note: references to Section 3 and Section 4 apply to NEI 00-01.] The discussion below provides general information about the risk significance screening process, but the actual process should be performed using the SDP or Section 4 of NEI 00-01.

Section 4.2 focuses on the preliminary screening of these circuit failures prior to the application of deterministic analysis methods. Section 4.3 provides a quantitative method for evaluating the risk significance of identified component combinations. Section 4.4 covers integrated decision making for the risk analysis, including consideration of safety margins and defense-in-depth considerations.

The simplified process shown below is a modified version of Figure 4-1 in NEI 00-01.

Figure A-1
Simplified Process Diagram



The methods used in NEI 00-01 are consistent with the revised fire protection SDP. The most recent version of the SDP should be consulted to determine the most up-to-date method for risk significance determination.

If a simplified PRA using SDP or NEI 00-01 indicates an issue is potentially risk-significant, a detailed fire PRA analysis may be warranted.

A-4.2 DISPOSITION OF FINDINGS

This guidance in this document reflects the position that licensees should address potential risk-significant issues regardless of whether they involve compliance with the licensing basis.

The extent to which post-fire safe shutdown requirements and guidance are applicable to a specific plant depends upon the age of the plant and the commitments established by the licensee in developing its fire protection program. However, there have been interpretive differences over regulatory guidance concerning certain circuit analysis assumptions in plant post-fire safe shutdown analyses. One such difference is whether to consider the effects of fire-induced spurious actuations and subsequent effects one at a time. The detailed NRC staff positions and views may not be reflected in the plant's licensing basis. RIS 2004-03 provides a new risk-informed inspection focus, but restates the position that licensees need to provide reasonable assurance that one train of systems necessary to achieve and maintain safe shutdown is free of fire damage. Circuit failure issues involving multiple spurious actuations, as identified by following the guidance in RIS 2004-03 may be beyond the plant licensing basis.

In some cases the circuit failure licensing basis is well documented; in others the documentation is less clear. Some of this lack of clarity is based on nonspecific SER language provided by NRC. Such SERs may have approved an entire safe shutdown program but not discussed specific elements of the program in detail. It may not be clear whether the licensee assumptions related to spurious actuations have been approved by NRC.

When issues are identified, the licensee should therefore consider whether they involve violations of the licensing basis, are beyond the licensing basis, or are of uncertain compliance status and subject to possible disagreement with NRC. Licensees should also consider the risk significance of the findings consistent with the fire protection SDP. Consideration of these parameters is illustrated in the following table from NEI 00-01[6]:

Type of Issue	**Action to Address Issue**	
	Issue Risk Significant	**Issue Not Risk Significant**
Finding (issue outside CLB)	Address in CAP	Green finding; action at licensee's discretion
Violation of CLB	Address in CAP	Address in CAP or provide licensing basis changes (using approved regulatory processes)
Compliance status/ CLB not clear	Address in CAP	Address in CAP or provide licensing basis changes (using approved regulatory processes)

As seen in the table, NEI 00-01 concludes that the licensees should address risk-significant circuit failure issues regardless of whether they involve potential violations. Issues that are both risk-insignificant and outside the licensing basis should be treated in

[6] This table from NEI 00-01 is also consistent with Inspection Manual Chapter (MC) 0612 Appendix B, MC 0609F, and MC 0612E.

accordance with current ROP guidelines as illustrated in the table. Remaining low significance issues potentially involving compliance should be addressed consistently with current regulatory guidelines; licensing basis changes (using approved regulatory processes) may be in order, supported by the risk analysis performed using NEI 00-01 Section 4 risk analysis or the fire protection SDP methods.

An example will illustrate the use of NEI 00-01. In this example, assume that the licensee conducts a self-evaluation using NEI 04-06 and determines that he should postulate more than one simultaneous spurious actuation in a certain fire area. Further assume that the licensing basis is inconclusive. The licensee could determine the significance of the issue using the methods of NEI 00-01, the revised fire protection Significance Determination Process, or other plant-specific risk analyses. The licensee should place the issue in the plant Corrective Action Program (CAP) if it is significant according to the risk criteria used, or could request licensing basis changes (using approved regulatory processes), or change the fire protection plan, if it is not. The compliance aspects would also be addressed in cases where it is not clear whether an issue is within the licensing basis (a "compliance issue") or not.

A-4.3 DETERMINE ADDITIONAL EVALUATION REQUIRED

The result of this preliminary evaluation will be a "snapshot" of the risk significant findings in one or a few fire areas and for one or a few fire scenarios. However, additional evaluation will be necessary for a more complete perspective of the plant's readiness to address the types of issues the NRC's resumed inspections will ascertain. The extent of and schedule for any additional reviews should be determined in consideration of these factors:

- Number and significance of findings from this self-assessment
- Extent of findings that are clearly compliance (licensing basis) related, as opposed to those that are beyond the licensing basis
- Clarity of the plant licensing basis related to circuit analysis
- Schedule for NRC triennial plant inspections

APPENDIX B REQUIRED AND ASSOCIATED CIRCUIT EXAMPLES

B-1 CIRCUIT ANALYSIS EXAMPLES ASSOCIATED WITH FIGURE 1

Figure 1 is a typical elementary for a normally closed, 3-phase motor operated valve that is located inside containment, has a local starter, and an ungrounded control power transformer. The switch is spring return to center and contacts are not maintained. The control of this valve is through an ungrounded control power transformer. Due to the high impedance of the transformer, it is not assumed that a short to ground through trays, conduits, enclosures, metal beams, etc. will blow the control power fuse. Only shorts to neutral conductors within the control power loop will blow the control power fuse.

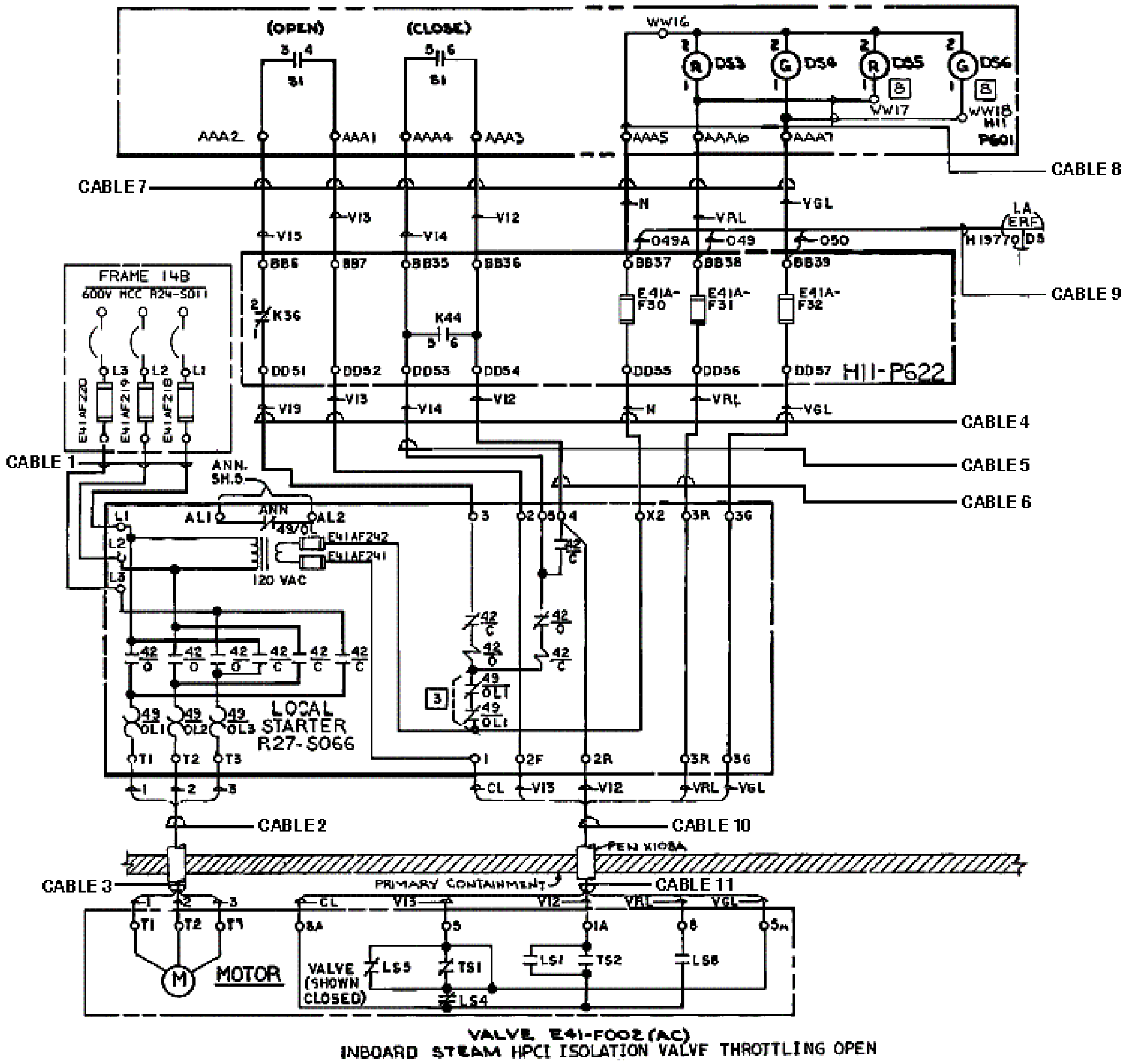


Figure 1

ACAD Figure 1

The circuit analysis for this logic is as follows:

TABLE B-1
Circuit Failure Analysis Scenarios Associated with Figure 1

Cable #		Type		Analysis
1		Power		For an active MOV, this is a 'required' circuit. Electrical power is required for this valve to operate electrically. Intra-cable faults or shorts to ground of this cable will prevent the valve from performing its safe shutdown function; unless it can be shown that the valve could be manually operated as needed and the action meets the feasibility criteria as outlined within this document. If so, loss of this cable would be acceptable. For a passive MOV, this is an 'associated' circuit. Electrical power is not required for this valve to perform its safe shutdown function. It is not postulated that multiple inter-cable conductor-to-conductor hot shorts of the proper polarity will cause a 3-phase valve to change position. Loss of this cable is acceptable since it would not cause the valve to spuriously operate.
2		Power		Same as Cable 1
3		Power		Same as Cable 1; except for inside inerted containments where Section III.G. 2 requirements are not applicable.
4		Control		For an active MOV, this is a 'required' circuit. Intra-cable faults or shorts to ground of this cable may cause spurious actuation or prevent the valve from operating and performing its safe shutdown function; unless it can be shown that the valve could be manually operated as needed and the action meets the feasibility criteria as outlined within this document. If so, loss of this cable would be acceptable. For a passive MOV, this is an 'associated' circuit. Intra-cable faults of this cable may cause spurious actuation and prevent the valve from performing its safe shutdown function; unless it can be shown that the valve could be manually operated as needed and the action meets the feasibility criteria as outlined within this document. If so, loss of this cable would be acceptable.
5		Control		This is a single conductor cable and intra-cable conductor-to-conductor shorts are not postulated. Also, for thermoset cables, inter-cable conductor-to-conductor shorts are not postulated to cause spurious actuation of the valve. For an active MOV, this is a 'required' circuit. An open circuit to this cable will prevent the valve from closing and performing

Cable #		Type		Analysis
				its safe shutdown function; unless it can be shown that the valve could be manually operated as needed and the action meets the feasibility criteria as outlined within this document. If so, loss of this cable would be acceptable. For a normally closed MOV that is only required to open but not re-close, this is an 'associated' circuit. An open circuit to this cable will prevent the valve from closing but would not prevent the valve from opening and performing its safe shutdown function. No other cable failures are postulated to occur that could prevent operation or cause spurious actuation of the valve. For a passive MOV, this is an 'associated' circuit. No cable failures are postulated to occur that could cause spurious actuation of the valve. A short to ground on this cable is not expected to blow the valve's control fuse, because the circuit is not normally connected to potential (switch Sq and relay K44 are normally open). Note: The lack of a control power transformer or the grounding of the control power loop could adversely change the above analysis.
6		Control		For an active MOV, this is a 'required' circuit. Intra-cable shorts of this cable will cause spurious actuation (closing) of the valve; an open circuit could prevent closing of the valve. These failures will prevent the valve from operating and performing its safe shutdown function; therefore it will not be 'free of fire damage'. This cable is required to meet the separation requirements of Appendix R Section III.G.2 unless it can be shown that the valve could be manually operated as needed and the action meets the feasibility criteria as outlined within this document. If so, loss of this cable would be acceptable. For a normally closed, passive MOV, this is an 'associated' circuit. Intra-cable faults of this cable could only cause the valve to close, which is acceptable. There are no postulated cable failures which could cause the valve to open. Thus, loss of this cable is acceptable.
7		Control		For an active MOV, this is a 'required' circuit. Intra-cable faults or shorts to ground of this cable will cause spurious actuation or prevent the valve from operating and performing its safe shutdown function; therefore it will not be 'free of fire damage'.

Cable #		Type		Analysis
				This cable is required to meet the separation requirements of Appendix R Section III.G.2 unless it can be shown that the valve could be manually operated as needed and the action meets the feasibility criteria as outlined within this document. If so, loss of this cable would be acceptable. For a passive MOV, this is an 'associated' circuit. Intra-cable faults of this cable could cause spurious actuation and prevent the valve from performing its safe shutdown function; therefore it will not be 'free of fire damage'. This cable is required to meet the separation requirements of Appendix R Section III.G.2 unless it can be shown that the valve could be manually operated as needed and the action meets the feasibility criteria as outlined within this document. If so, loss of this cable would be acceptable.
8		Control		This cable is isolated from the required portion of the circuit with coordinated fuses. Failure of this cable will blow the fuses and disable the valve position indication but would not prevent the valve from operating or cause it to spuriously operate. For an active MOV, this is an 'associated' circuit. Intra-cable faults or shorts to ground of this cable will disable the valve position indication but could not prevent the valve from operating or cause it to spuriously operate. Thus, loss of this cable would be acceptable. For a passive MOV, this is an 'associated' circuit. Intra-cable faults or shorts to ground of this cable will disable the valve position indication but could not prevent the valve from operating or cause it to spuriously operate. Thus, loss of this cable would be acceptable.
9		Control		Same as cable 8.
10		Control		Same as cable 4.
11		Control		Same as cable 4, except for inside inerted containments where Section III.G. 2 requirements are not applicable.

B-2 Circuit Analysis Examples for Typical MOV Control Logic

Figure 2 is the control logic for relays K36 and K44 which are used for controlling the motor operated valve in Figure 1. The relay logic is powered from an ungrounded 125VDC power source. Shorts to ground from trays, conduits, enclosures, metal beams, etc. are not postulated for ungrounded DC systems; however, intra-cable and inter-cable conductor-to-conductor shorts are postulated as applicable. This logic is not required to operate for the valve to perform its required safe shutdown function (automatic function not required). However, spurious actuation of the valve due to fire-induced cable failures must be addressed.

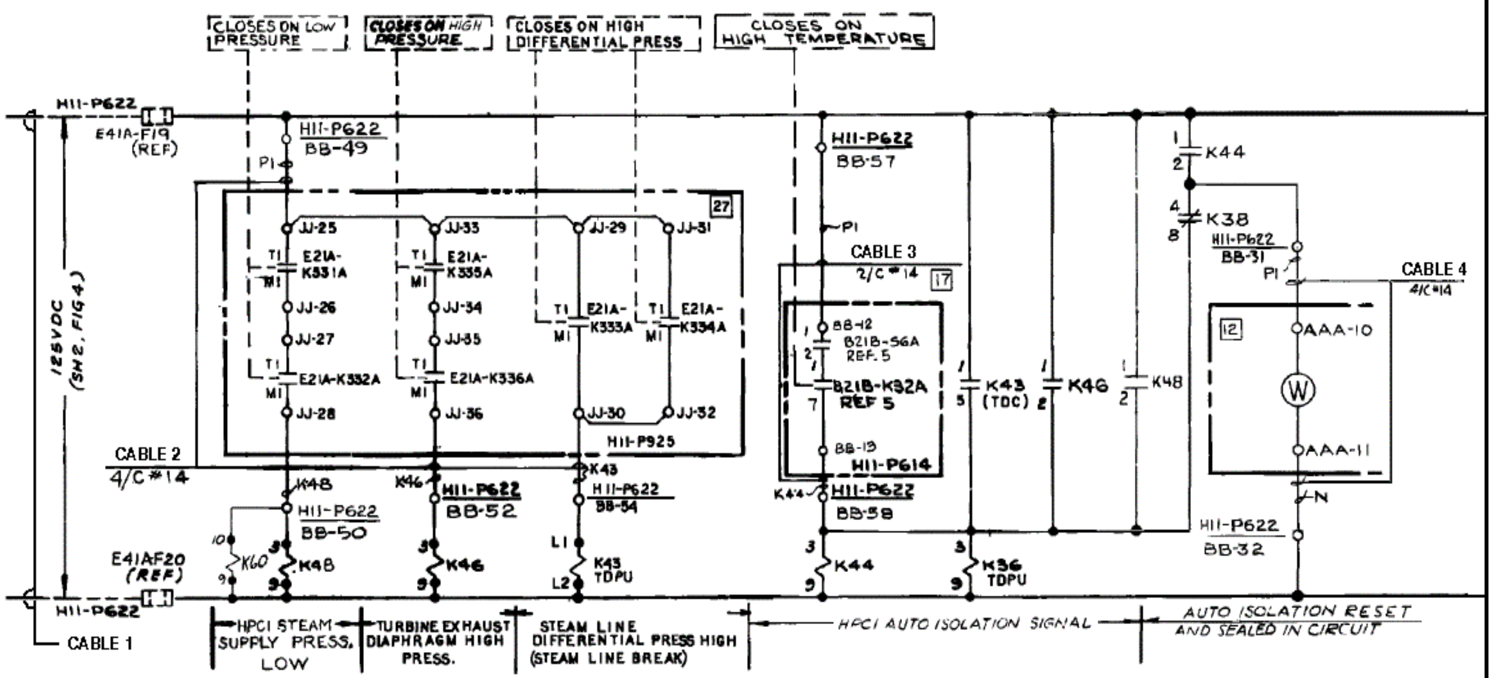


Figure 2

ACAD Figure 2

The circuit analysis for this logic is as follows

Table B-2

Circuit Analysis Examples Associated with Figure 2

Cable #		Type		Analysis
1		Control Power		For an active MOV, this is an 'associated' circuit. Electrical power to this logic is not required for this valve to perform its safe shutdown function and loss of this cable will not cause the valve to spuriously operate or prevent it from operating using its control switch. Thus, loss of this cable is acceptable. For a passive MOV, this is an 'associated' circuit. Electrical power to this logic is not required for this valve to perform its safe shutdown function and loss of this cable will not cause the valve to spuriously operate. Thus, loss of this cable is acceptable.
2		Control		For an active MOV, this is an 'associated' circuit. Intra-cable shorts could energize relays K36 and K44 and cause the valve to spuriously operate or prevent it from operating using its control switch; therefore the valve will not be 'free of fire damage'. This cable is required to meet the separation requirements of Appendix R Section III.G.2 unless it can be shown that the valve could be manually operated as needed and the action meets approved NRC feasibility criteria. If so, loss of this cable would be acceptable. For a passive MOV, this is an 'associated' circuit. Intra-cable shorts could energize relays K36 and K44 and prevent it from opening but can not cause the valve to spuriously open or prevent it from closing using its control switch. Thus, loss of this cable is acceptable.
3		Control		Same as Cable 2.
4		Control		For an active MOV, this is an 'associated' circuit. Intra-cable conductor-to-conductor shorts (if K44 is energized) could blow the

Cable #		Type		Analysis
				fuses and remove power to the logic. Inter-cable conductor-to-conductor hot shorts (to conductor P1) would energize relays K44 and K36 cause it to close and prevent it from being opened using its control switch. Electrical power to this logic is not required for this valve to perform its safe shutdown function but a loss of this cable could cause the valve to spuriously operate or prevent it from operating using its control switch; therefore the valve will not be 'free of fire damage'. This cable is required to meet the separation requirements of Appendix R Section III.G.2 unless it can be shown that the valve could be manually operated as needed and the action meets NRC-approved feasibility criteria If so, loss of this cable would be acceptable. For a passive MOV, this is an 'associated' circuit. Intra-cable conductor-to-conductor shorts (if K44 is energized) could blow the fuses and remove power to the logic but could not cause the valve to open. Inter-cable conductor-to-conductor hot shorts (to conductor P1) would energize relays K44 and K36 cause it to close and prevent it from being opened using its control switch but could not cause the valve to open. Thus, loss of this cable would be acceptable.

B-3 Circuit Analysis Examples Associated with Figure 3

Figure 3 is an elementary for a typical normally closed safety/relief valve (solenoid valve). The S/RV is powered from an ungrounded 125VDC power source. Shorts to ground from trays, conduits, enclosures, metal beams, etc. are not postulated for ungrounded DC systems; however, intra-cable and inter-cable conductor-to-conductor shorts are postulated as applicable.

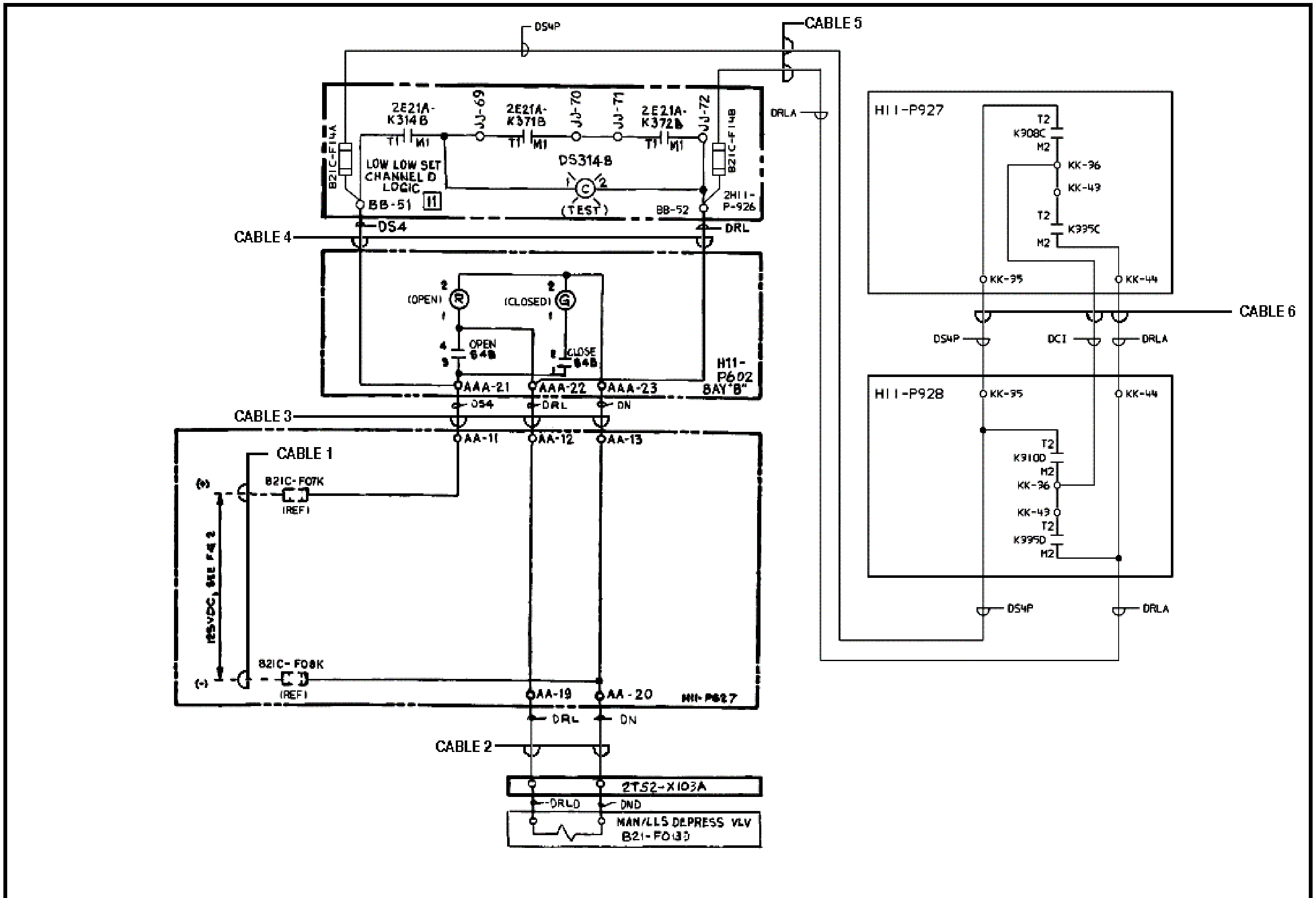

CABLE 5
DS4P
DRLA
2E21A-K314B
JJ-69
2E21A-K371B
JJ-70
JJ-71
2E21A-K372B
JJ-72
B21C-F14A
B21C-F14B
LOW LOW SET CHANNEL D LOGIC
DS314B
(TEST)
BB-51
BB-52
2H11-P-926
DS4
DRL
CABLE 4
(OPEN)
(CLOSED)
OPEN 64B
CLOSE 64B
H11-P602 BAY "B"
AAA-21
AAA-22
AAA-23
DS4
DRL
DN
CABLE 3
AA-11
AA-12
AA-13
CABLE 1
B21C-F07K
(REF)
125VDC, SEE FIG 2
B21C-F08K
(REF)
AA-19
AA-20
H11-P627
DRL
DN
CABLE 2
2TS2-X103A
DRLD
DND
MAN/LLS DEPRESS VLV B21-F013D
H11-P927
T2
K908C
M2
KK-36
KK-43
K395C
KK-35
KK-44
CABLE 6
DS4P
DCI
DRLA
H11-P928
K910D
K395D
ACAD Figure 3

Figure 3

The circuit analysis for this logic is as follows:

Table B-3

Circuit Analysis Associated with Figure 3

Cable #		Type		Analysis
1		Control Power		For an active solenoid valve, this is a 'required' circuit. Electrical power to this valve is required for this valve to open. Intra-cable short would cause a loss of power to the valve and prevent it from opening and performing its safe shutdown function. This cable is required to meet the separation requirements of Appendix R Section III.G.2 unless it can be shown that the valve could be manually opened as needed and the action meets NRC-approved feasibility criteria. If so, loss of this cable would be acceptable. For a passive solenoid, this is an 'associated' circuit. Electrical power to this valve is not required for this valve to perform its safe shutdown function and loss of this cable will not cause the valve to spuriously open. Thus, loss of this cable is acceptable.
2		Control		For an active solenoid valve, this is a 'required' circuit. Electrical power to this valve is required for this valve to open. Intra-cable shorts (DRL to DN) would prevent the valve from opening and performing its safe shutdown function. This cable is required to meet the separation requirements of Appendix R Section III.G.2 unless it can be shown that the valve could be manually opened as needed and the action meets NRC-approved feasibility criteria. If so, loss of this cable would be acceptable. For a passive solenoid valve, this is an 'associated' circuit. Electrical power to this valve is not required for this valve to remain closed and performing its safe shutdown function. An intra-cable short would prevent

Cable #		Type		Analysis
				the valve from opening but could not cause it to close. Inter-cable conductor-to-conductor shorts (for thermoplastic cables only) could cause the valve to spuriously open. This cable would be required to meet the separation requirements of Appendix R Section III.G.2 unless it can be shown that the valve could be manually closed as needed and the action meets NRC-approved feasibility criteria. If so, loss of this cable would be acceptable.
3		Control		Similar to cable 2 except intra-cable shorts (DS4 to DRL) could also cause the valve to spurious open.
4		Control		Similar to cable 3.
5		Control		For an active solenoid valve, this is an 'associated' circuit. It is isolated from the 'required' portion of the circuit with coordinated fuses. Intra-cable shorts would cause the valve to spuriously open, remain open, and prevent the valve from performing its safe shutdown function. This cable is required to meet the separation requirements of Appendix R Section III.G.2 unless it can be shown that the circuit can be manually isolated from the required portion of the circuit as needed and the action meets NRC-approved feasibility criteria. If so, loss of this cable would be acceptable. The analysis for a passive solenoid valve is similar to an active solenoid valve; intra-cable shorts could cause the valve to spuriously open and prevent it from performing its safe shutdown function. This cable is required to meet the separation requirements of Appendix R Section III.G.2 unless it can be shown that the circuit can be manually isolated from the required portion of the circuit as needed and the action meets NRC-approved feasibility criteria. If so, loss of this cable would be acceptable.
6		Control		Same as cable 5.

Note: Circuit analysis for the cables affecting relays 2E21A-K314B, K371B, and K372B will be similar to the analysis for the cables in Figure 4.

B-4 CIRCUIT ANALYSIS EXAMPLES ASSOCIATED WITH FIGURE 4

Figure 4 is an elementary for a portion of the instruments which controls the safety/relief valves in Figure 3. The instrument loops are 4-20ma circuits that receive power from sources in their trip unit panels. The trip unit panels are powered from an ungrounded 125VDC power source. Shorts to ground from trays, conduits, enclosures, metal beams, etc. are not postulated for ungrounded DC systems; however, intra-cable and inter-cable conductor-to-conductor shorts are postulated as applicable.

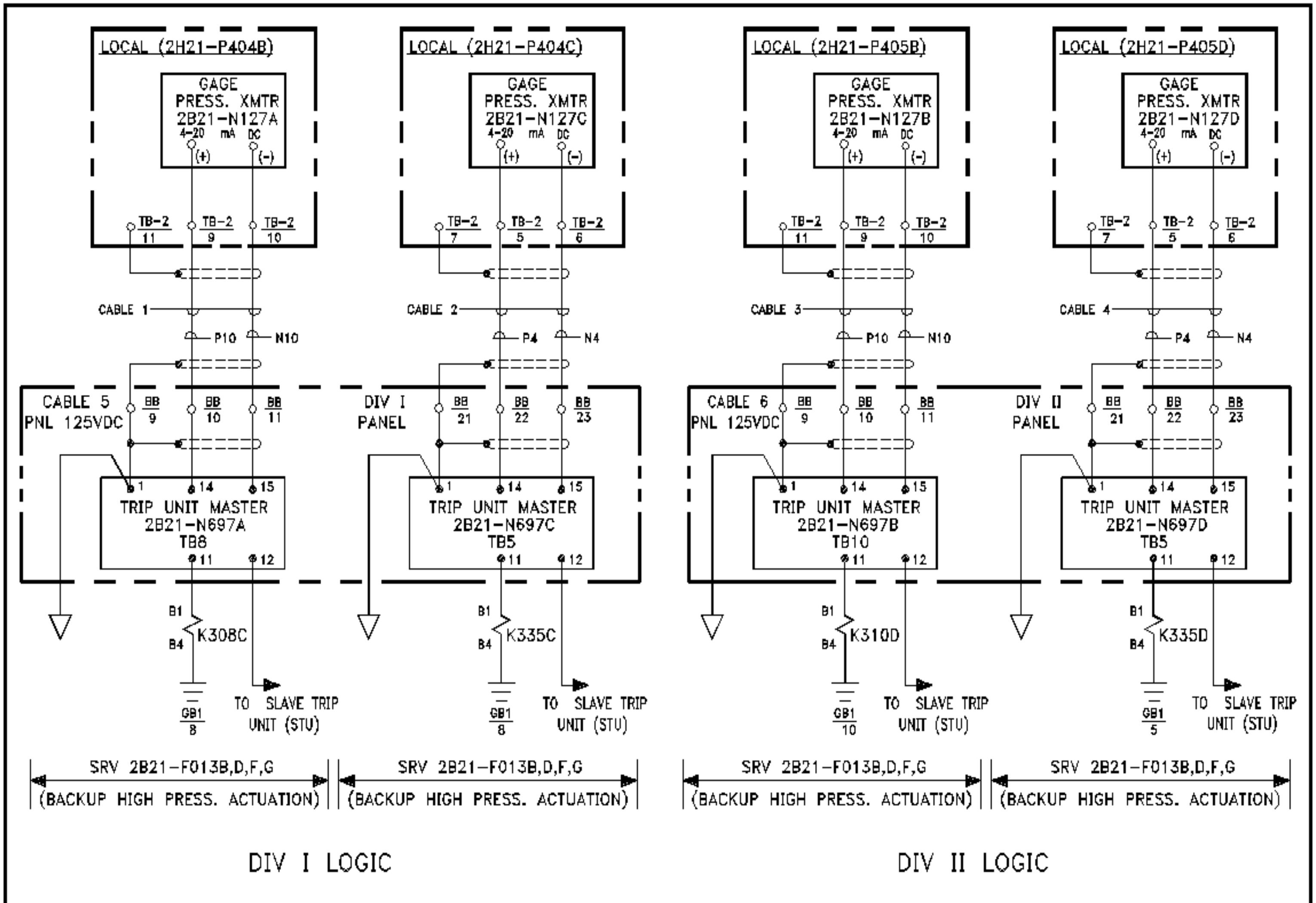

LOCAL (2H21-P404B)
GAGE PRESS. XMTR 2B21-N127A
4-20 mA DC
TB-2 11
TB-2 9
TB-2 10
LOCAL (2H21-P404C)
GAGE PRESS. XMTR 2B21-N127C
TB-2 7
TB-2 5
TB-2 6
LOCAL (2H21-P405B)
GAGE PRESS. XMTR 2B21-N127B
LOCAL (2H21-P405D)
GAGE PRESS. XMTR 2B21-N127D
CABLE 1
CABLE 2
CABLE 3
CABLE 4
P10
N10
P4
N4
CABLE 5 PNL 125VDC
DIV I PANEL
CABLE 6 PNL 125VDC
DIV II PANEL
BB 9
BB 10
BB 11
BB 21
BB 22
BB 23
TRIP UNIT MASTER 2B21-N697A TB8
TRIP UNIT MASTER 2B21-N697C TB5
TRIP UNIT MASTER 2B21-N697B TB10
TRIP UNIT MASTER 2B21-N697D TB5
B1
B4
K308C
K335C
K310D
K335D
GB1 8
GB1 10
GB1 5
TO SLAVE TRIP UNIT (STU)
SRV 2B21-F013B,D,F,G
(BACKUP HIGH PRESS. ACTUATION)
DIV I LOGIC
DIV II LOGIC
ACAD Figure 4

Figure 4

The circuit analysis for this logic is as follows:

Table B-4

Circuit Analysis Associated with Figure 4

Cable #		Type		Analysis
1 2 3 4		Instrument		For an active solenoid valve (figure 3), this is an 'associated' circuit. Intra-cable conductor-to-conductor shorts of the proper leakage current to simulate a trip signal would provide one of the required permissives to open the S/RVs. Failure of two of the four cables could simulate signals and cause the S/RVs to open. These cables are required to meet the separation requirements of Appendix R Section III.G.2 such that spurious operation will not occur unless it can be shown that the valves could be manually closed as needed and the action meets NRC-approved feasibility criteria. If so, loss of this cable would be acceptable. The analysis for a passive solenoid valve is similar to an active solenoid valve.

APPENDIX C SAMPLE TEMPLATE

The following template can be used for recording the results of the assessment

Fire Area(s)_____					
Cable Information					
Number _____	Required ☐ Associated ☐ [Note: Analysis of required and associated circuits is the same]	**Cable Construction**		**Raceway**	
		Jacket	Insulation	Number _____	
		Thermoset ☐	Thermoset ☐	Tray ☐	
		Thermoplastic ☐	Thermoplastic ☐	Conduit ☐	
		Armor ☐		Other _____	

Component Information				
Impacted Components / Combinations	**Circuit Failure Mode**	**Impact on Component/ System/ Safe Shutdown Function**	**Results of Risk Analysis**	**Disposition/Comment***
*** Screened out, Screened to Green, CAP disposition, other comments**				