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'' Rev. 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).

This guidance is being developed to facilitate licensee self-assessments of potential circuit failures for both associated and necessary circuits. The intent is for licensees to use this guidance to prepare for the resumption of associated circuit inspection in the Fall of 2004. Several plants are expected to pilot the use of this guidance in the spring and summer of 2004. These pilot self-assessments will provide useful information to other plants intending to perform self-assessments; however, it is not necessary for licensees to await completion of the pilots before undertaking their own self-assessments. All licensees are encouraged to review their programs to some degree prior to their scheduled triennial inspections.

2 PURPOSE

The purpose of this document is to provide general guidance for assessing the Fire Safe Shutdown program, to identify risk-significant spurious actuations.

Licensees should focus on necessary[1] and associated circuits in up to two cables 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 first hour. Licensees should be able to develop credible fire scenarios that could produce a thermal insult resulting in cable damage. They should focus on conductor-to-conductor shorts within a multiconductor cable, since risk insights gained from cable fire testing have demonstrated that intractable shorting is the most probable cause of spurious actuations. They should also consider inter-cable shorting between thermoplastic cables. They should assume a maximum of two concurrent cable failures for each scenario evaluated.

[1] The term "necessary circuit" is used consistent with 10 CFR 50 Appendix R, to replace the commonly used term "required circuit."

3 OVERVIEW OF SELF-ASSESSMENT METHOD

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

3.1 PHASE 0

1. Identify fire areas to be evaluated based on risk significance.
2. Develop a list of documents needed to identify the licensing basis for those fire areas.
3. Identify 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

1. Identify the necessary and associated circuits in each fire area that could significantly impact the ability to achieve and maintain hot shutdown.
2. Identify credible fire scenarios for the fire areas chosen using NUREG-1805 or the revised fire protection SDP.
3. Identify cables that could be impacted by damaging fires in those fire areas, using cable route drawings or databases.

3.3 PHASE II

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. Circuits in thermoplastic cables
    c. Up to two cables containing necessary or associated circuits or both.

3.4 PHASE III

1. Determine whether there are fire scenarios that can damage the circuits of interest, and screen out those that are not likely to be damaged by the projected fire conditions.

2. Determine the risk significance of identified failures using NEI 00-01 Section 4 or the revised SDP (when available). Identify whether findings are licensing basis or beyond licensing basis.

3. Determine further action 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.

4. Determine additional evaluation to be performed prior to the resumption of associated circuit inspections.

4 APPENDIX R TERMINOLOGY

4.1 ASSOCIATED CIRCUIT

Those safety-related and nonsafety-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.

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.

4.2 BINS

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 - Areas where inspection should focus. Items may have risk significance; however plant-specific information will still have a large role in determining the risk significance.

Bin 2 - Areas where more discussion or research is required to better understand risk. Inspections won't resume for these items until they are better characterized, and moved to Bin 1 or Bin 3. Specific plans for research have not been identified.

Bin 3 - Areas where inspections need not be performed. There is ample evidence now that none of the items in this bin will be risk significant.

Only Bin 1 items will be assessed using this guideline.

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 CABLE FAILURE MODE

The mode by which a conductor or cable fails due to a fire. The four modes of cable failure are:

- A loss of conductor continuity is a physical break in the conductor that will result in electrical energy being unable to reach the intended circuit destination (i.e., an open circuit).
- A short circuit of one or more conductors to ground results in the diversion of electrical energy to ground. Electrical ground may be either external to the cable or one or more of the cable conductors.
- A conductor-to-conductor short circuit without ground may result in the diversion of electrical energy from one conductor (the source conductor) to one or more unintended conductors (the target conductor(s)). In Fire Protection Circuit Analysis, this has been referred to as a "hot short."
- Conductor insulation resistance degradation may result in the partial diversion of the available electrical energy to an unintended conductor path. Electrical ground may or may not be involved. In Fire Protection Circuit Analysis, this has been referred to as a "high impedance fault."

4.6 CIRCUIT ANALYSIS

The process of identifying cables and circuits that, if damaged by fire, could prevent a component of interest from operating correctly.

4.7 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.

4.8 CONDUCTOR-TO-CONDUCTOR SHORT

An abnormal connection (including an arc) of relatively low impedance between two conductors. A conductor-to-conductor short between an energized conductor of a grounded circuit and a grounded conductor results in a ground fault. A conductor-to-conductor short between an energized conductor and a non-grounded conductor results in a hot short.

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 RG 1.189 and 10 CFR 54.3]

4.11 Emergency Operating Procedures

Operating procedures that are utilized to manage a wide variety of plant transients from uncomplicated shutdowns to 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.

4.15 HOT SHORT

Individual conductors of the same or different cables come in contact with each other and may result in an impressed voltage or current on the circuit being reviewed. (RG 1.189)

Clarification: The term "hot short" is used to describe a specific type of short circuit fault condition between energized and deenergized conductors. Should a deenergized conductor come into electrical contact with an energized conductor (or other external source), the voltage, current, or signal being carried by the energized conductor (or source) would be impressed onto one or more of the deenergized conductors.

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.

4.17 HOT SHORT, INTERNAL

A hot short in which both the source conductor and target conductor are of the same multi-conductor cable. Synonymous with intra-cable hot short.

4.18 INTENDED SHUTDOWN STRATEGY

The combination of systems and strategies that the plant's safe shutdown Current Design Basis (CDB) and procedures show will remain available for a fire in a given fire area.

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."

4.22 Open Circuit

A loss of electrical continuity in an electrical circuit, either intentional or unintentional. As applied to wire and cable, open circuit faults may result, for example, from a loss of conductor continuity or from the triggering of circuit protection devices (e.g., a blown fuse or open circuit breaker).

4.23 Necessary safe shutdown circuits

Those clearly necessary to support the operation of a credited post-fire safe shutdown component in a particular fire area.

4.24 Sequential Multiple Spurious Operations

One fault causing a spurious operation is not mitigated before another fault is assumed to occur at a later time. This is the NRC staff interpretation of the term "any and all one at a time." (NUREG-1778)

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 either 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 Circuit (general)

An abnormal connection (including an arc) of relatively low impedance between two conductors or points of different potential. A short circuit might involve a ground fault or hot short, as applied to control circuit failures.

4.27 Short-to-Ground

A type of short circuit involving an abnormal connection between a conductor and a grounded conducting medium. The grounding medium refers to any conductive path associated with the reference ground of the circuit. This might include structural elements (tray, conduit, enclosures, metal beams, etc) or intentionally grounded conductors of the circuit (neutral conductor).

4.28 SIMULTANEOUS MULTIPLE SPURIOUS OPERATIONS

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

4.29 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, either simultaneously or sequentially).

4.30 "SOURCE" CONDUCTOR

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

4.31 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.

4.32 "TARGET" CONDUCTOR

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

4.33 THERMOPLASTIC

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

4.34 THERMOSET

A cable material that will not soften, flow, or distort appreciably when subjected to sufficient heat and pressure. Examples include rubber and neoprene. Note: Cables using thermoset insulation are usually qualified to IEEE Standard 383.

4.35 UNRECOVERABLE CONDITION

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

4.36 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. Cables 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 'necessary' 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 all the interim acceptance criteria proposed 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, fire induced failure of these circuits would not be a concern unless it could cause the component to spurious 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 'necessary' circuits if their loss could prevent the component from operating. For passive components, such as passive MOVs or solenoid valves that fail in the required position on loss of power, these control circuits are considered 'associated' circuits since their failure could cause spurious actuation of the component.

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 necessary or associated power and control circuits.

A 'necessary' 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 used to 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 is a physical break in the conductor that will result in electrical energy being unable to reach the intended circuit destination (i.e., an open circuit).

- A short circuit of one or more conductors to ground results in the diversion of electrical energy to ground. Electrical ground may be either external to the cable or one or more of the cable conductors.

- A conductor-to-conductor short circuit without ground may result in the diversion of electrical energy from one conductor (the source conductor) to one or more unintended conductors (the target conductor(s)). In Fire Protection Circuit Analysis, this has been referred to as a "hot short."

- Conductor insulation resistance degradation may result in the partial diversion of the available electrical energy to an unintended conductor path. Electrical ground may or may not be involved. In Fire Protection Circuit Analysis, this has been referred to as 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

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)
- Multiple high impedance faults
- 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. Evidence in this area indicates that 80% or more of all fire-induced multi-conductor cable failures will initially involve intra-cable conductor-to-conductor short circuits. This appears to apply to both thermoset and thermoplastic insulated electrical cables. (Recall that not all intra-cable conductor-to-conductor shorts involve hot shorts leading to spurious actuation as discussed further below.)

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 probably 0.5 or less. For thermoset insulated electrical cables the likelihood of inter-cable shorting is probably 0.1 or less. 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 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.

It also appears that loss-of-conductor continuity failures 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, but not all hot shorts will lead to a spurious actuation, so 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.

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.

5.5 Isolation Devices

5.5.1 Breaker Coordination

With proper breaker coordination, one will not have to consider common power supply and common enclosure in the self-assessment scope. Breaker 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 breaker coordination can also provide assurance in this area.

5.5.2 Multiple High Impedance Faults

Multiple High-Impedance Faults (MHIF) are in Bin 3 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:

- No more than two damaged cables for each scenario, except as noted below and in Section 5.6.2
- Associated/required circuits that could cause flow diversion, loss of coolant, or other scenarios that could significantly impair the ability to achieve and maintain hot shutdown
- Conductor-to-conductor hot shorts within a multi-conductor cable (not limited to two spurious operations), including proper-polarity hot shorts for DC circuits
- Inter-cable shorts for thermoplastic cables
- Instrument circuits impacting the ability to achieve and maintain hot shutdown

5.6.2 Circuits Not to Be Considered at This Time

Circuits not to be considered at this time pending additional research include:

- Inter-cable shorting between thermoset cables
- Inter-cable shorting between thermoset and thermoplastic cables
- Configurations involving three or more concurrent spurious operations involving more than three cables
- 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
- AOV or PORV control circuits where spurious operations will not impact the ability to achieve and maintain hot shutdown

Circuits not to be considered at this time because of low likelihood or risk include the following:

- Open circuits as an initial failure mode
- Inter-cable shorting between armored cables
- Inter-cable shorting between cables outside conduit and cables inside conduit
- Multiple high impedance faults on a common power supply
- Three-phase, proper polarity hot shorting (except that this should be considered for outboard Decay Heat Removal valves)
- Multiple proper-polarity hot shorts leading to spurious operation of a DC motor, unless located in a single multiconductor cable as described above
- Circuits involving only cold shutdown components

6 IMPLEMENTATION

Appendix A provides the steps to be taken for the four phases of this analysis, summarized below and described in detail later in this section. Appendix C provides a template for recording the information for the circuit reviews. An outline of the tasks in each of the 4 phases is provided in Section 3.

6.1 PHASE 0

6.1.1 Selection of Fire Areas/Zones

6.1.1.1 Selection of Risk Significant Zones

NEI-03-00, Section 6.1 provides guidance on the identification and selection of risk-significant fire areas/zone. Additionally, two other inputs should be considered in the selection of fire area/zones for the assessment. First, the NRC inspection guidance identifies areas of the plant that should be considered potentially important, even though the PRA did not show these areas as important. These include the Cable Spreading Room, Control Room, and Switchgear Rooms. Second, since the PRA may not identify fire scenarios involving multiple spurious operations, 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 SSD cabling or equipment should also be considered in the fire area selection.

6.1.1.2 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 within 1 hour from start of event)
- Are required for fire scenarios in risk significant areas of the plant
- May present a challenge to the manual action feasibility criteria
- Involve scenarios or fire areas where multiple 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 action feasibility criteria. This should be assessed separately.

6.1.2 Identification of Documents and Resources Needed

Licensees should then identify the licensing basis documents related to associated and necessary 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

These documents should assist the licensee in identifying the approved licensing basis (see also 10 CFR 54.3). This is important because the evaluation criteria from the Regulatory Information Summary used in the inspection are likely to be beyond the licensing basis, and a clear distinction between licensing basis and beyond licensing basis must be drawn.

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)
- Significant Accident Sequences listing (cutsets)
- Risk evaluation of GL 89-10 MOVs
- Risk evaluation of AOVs
- Risk significant rankings of systems/top events

6.1.3 Identify Assessment Resources

Licensees should identify external and internal resources needed to conduct self-assessments. Circuit analysis/safe shutdown and PSA will be required. A balance of licensee and external expertise should be considered. Licensee staff can provide knowledge of documents and methods 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 associated and necessary circuits is expected to take much longer than this initial self-assessment, which will review this area on a sampling basis.

6.2 PHASE I

6.2.1 Identify Circuits

6.2.1.1 General

The licensee should identify the circuits that result in circuit failures in up to two damaged cables that could prevent achieving or maintaining hot shutdown, regardless of whether the circuits are considered "necessary" or "associated." Phase I should limit consideration to component combinations whose maloperation 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 can be used in circuit selection.

These circuits should include those for which remedial manual actions are time critical (must be performed immediately or in less than one hour). Feasibility of these manual actions will be evaluated using accepted criteria published separately.

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 post-fire safe shutdown procedures

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

6.2.1.2 Use of Risk Insights for Circuit Identification

6.2.1.2.1 PRA Guidance on the Selection of Multiple-Spurious Actuation Scenarios

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.

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 is however, quite 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 SG 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 AOVs, and IPEEE/Fire PRA can provide additional insights.

When multiple failures are postulated that are beyond the current design basis for the plant, in some cases the intended shutdown equipment may be impacted. 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 under which the operator is expected to be (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.

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

6.2.1.2.1.1 Specific PWR Guidance

Reactivity Control

Reactivity Control and the supply of a boration flow path is most likely not risk-significant. 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 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. 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, CCW provides both seal cooling, and cooling to the seal injection (HPI or CVCS) 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 BWST/RWST, resulting in a failure of all injection if undetected. 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 VCT 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.

Reactor Pressure Control

1. PORV/Block: The risk importance of scenarios involving PORV spurious operation would depend on several 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), 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 a few minutes, which would result in an open PORV reclosing. Given a plant is able to recover from a PORV being open for about 10 minutes and prevent core damage, a spurious PORV opening would be most likely not risk-significant. 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.

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 from consideration.

4. Spurious Injection: The risk-significance of spurious injection failures would depend on the features and design of the plant. For example, plants with HPI pumps that do not lift primary PORVs or 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 blocks 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 safety lift and eventually a stuck open 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.

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.

2. Overfeed: SG 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 pump is the credited SG cooling source, then an overfeed event may result in failure of the TD pump following water intrusion in the steam lines.

Dominant Sequences

To be provided.

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, CCW, etc are almost always potentially risk-significant. However, it is often difficult to fail all of cooling water with one or two spurious operations. HVAC failures are typically not risk-significant, since the failures are typically self-identifying, sufficient time is available to identify the failure, perform recovery actions, and direct system failure does not occur. However, key HVAC system failures may be risk-significant, especially if operator recovery is not likely.

6.2.1.2.1.2 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 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 GE Report No. EDE 07—390 dated April 2, 1990, in response to NRC Generic Letter 89-19. The NRC subsequently accepted the 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. SRVs will cycle (or be opened by the operator) and will gradually reduce Reactor coolant levels back to the desired band. Terry Turbine HPCI and 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 (BWRs) in the 1960s and 1970s, that can be used to achieve and maintain safe shutdown per 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 Safety Relief Valves (SRVs) and low pressure systems (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 Dec. 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.

In BWRs, typically the fuel cladding and suppression pool integrity analyses have shown that "No Spurious Operations" of the SRVs presents the worst case scenario.

Pressure Control Systems

Safety Relief Valves (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 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 (ex., 30 minutes to TAF becomes 25). 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 (RHR-LPCI, Core Spray, 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.

Based on the EPRI/NEI testing, hot shorts capable of opening SRVs would not be expected to remain indefinitely, and may clear in approximately 10 minutes. 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 that will prevent a blowdown, if it is caused by instrument malfunction. ADS also includes logic to verify that a low pressure pump is running and ready to inject before a 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 it does not result in any fuel damage. 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, CRD) is generally not a concern, however, spurious operation of large flow high pressure injection systems (i.e. HPCI) may result in water intrusion into the main steam lines. Therefore, operator action may be required to trip the pump to prevent water intrusion.

Min-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 min flow for a long time without a flowpath 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. SPC removes heat from the suppression pool so that long-term net positive suction head 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 are required to be performed with considerations for 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 reducing system flow to satisfy NPSH.

Turbine-driven systems (HPCI/RCIC) are cooled by the process fluid, so are subject to reduced oil cooling efficiency at higher suppression pool temperatures. However, vendor data exists that 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.

Process Monitoring

The process monitoring function is provided for all safe shutdown paths. IN 84-09, Attachment 1, Section IX "Lessons Learned from NRC Inspections of Fire Protection Safe Shutdown Systems (10CFR50 Appendix R)" provides guidance on the instrumentation acceptable to and preferred by the NRC for meeting the process monitoring function. This instrumentation is that which 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.

Dominant Accident Sequences

Typically no single core damage sequence dominates the total frequency of core damage. 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), failure to depressurize. Core damage due lack of inventory.

Support Systems

Electrical Systems

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.

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 equipment.

The DC control centers may also supply power to various small horsepower Appendix R safe shutdown system valves and pumps. If the DC 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/DH 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 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 dependant 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 acceptable 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.

6.2.1.3 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.

6.2.2 Identify Cables That Could Be Impacted by the Credible Fire Scenarios

Using existing cable route drawings or databases, identify the cables (thermoset, thermoplastic, or armored) 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.

6.3 PHASE II

In Phase II plant representatives utilize the guidelines in Regulatory Information Summary 2004-03 to determine circuit failures, or pairs thereof, that can be considered potentially risk significant. "Potentially risk significant" means that the circuit failures are in Bin 1 or can impede hot shutdown within an hour of the event. 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.

6.3.1 Binning of Potential Failures

MOST RISK SIGNIFICANT

- Failures that impede hot shutdown within the first hour of event

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

- Scenarios involving up to two cable failures
- Intra – cable failure for thermoset and thermoplastic cables (up to 3-4 circuit failures)
- Any number of conductors/combinations possible within a cable with multiple components
- Inter – cable failures possible for thermoplastic cable

ISSUES REQUIRING FURTHER RESEARCH – Moderate Risk (Bin 2)

- Inter – cable shorting of thermoset cables
- Three or more cables for scenario
- Effects of control power transformers
- Duration of hot shorts

ISSUES REQUIRING FURTHER RESEARCH – Low Risk (Bin 3)

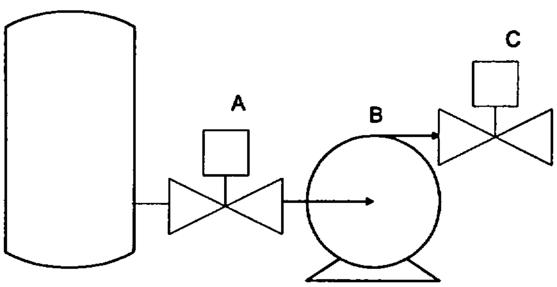
- Open circuits

- Inter – cable shorting involving conduits and armored cable
- Multiple high – impedance faults common power supply
- Three-phase failures occurring with proper polarity
- Reversible DC–motor power cable

Bin 2 and Bin 3 (see the Regulatory Information Summary) failures need not be assessed at this time.

6.3.2 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.



This example describes how you would apply the criteria in RIS 2004-03 to plant examples. 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

- If 2 cables contain conductors for all 3 components (A, B, and C) then all 3 could spuriously operate

- If 3 cables contain conductors for all 3 components (A, B, and C) then the spurious operation of all 3 would not be postulated

6.3.3 Analysis Assumptions

1. Thermoplastic cables (typically non IEEE 383 qualified) should be assumed to fail if exposed to the hot gas layer or plume temperatures of 424° F or greater for a minimum of 5 minutes. In the case of radiant heat transfer, the cable should be assumed to fail if exposed to a minimum 5kW/m^2 for 5 minutes.

When a thermoplastic cable is within the flame zone of the fire (direct flame impingement) or in a cable tray that is burning, damage should be assumed to occur in 5 minutes.

2. Thermoset cables (typically 383 qualified) should be assumed to fail if exposed to hot gas layer or plume temperatures of 700° F or greater for a minimum of 10 minutes. In the case of radiant heat transfer, the cable should be assumed to fail if exposed to a minimum 10 kW/m^2 for 10 minutes. When a thermoset cable of concern is in the fire zone of the fire (direct flame impingent), or in a cable tray that is burning, damage should be assumed to occur in 10 minutes.

6.3.4 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 out at this step will be evaluated for risk significance in Phase III.

6.3.5 Credible Fire Scenarios

6.3.5.1 Determining Credible Fire Scenarios

Credible fire scenarios can be determined from guidance in NUREG-1805 or the new fire protection SDP (when available). 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 (when available).

6.3.5.2 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 from further consideration and documented. Those that are damaged will be considered further in Phase III.

6.4 PHASE III

6.4.1 Risk Significance Determination

Determination of risk significance for identified self-assessment findings will be made using the latest revision of the SDP, if available, 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. The final version is not yet available.

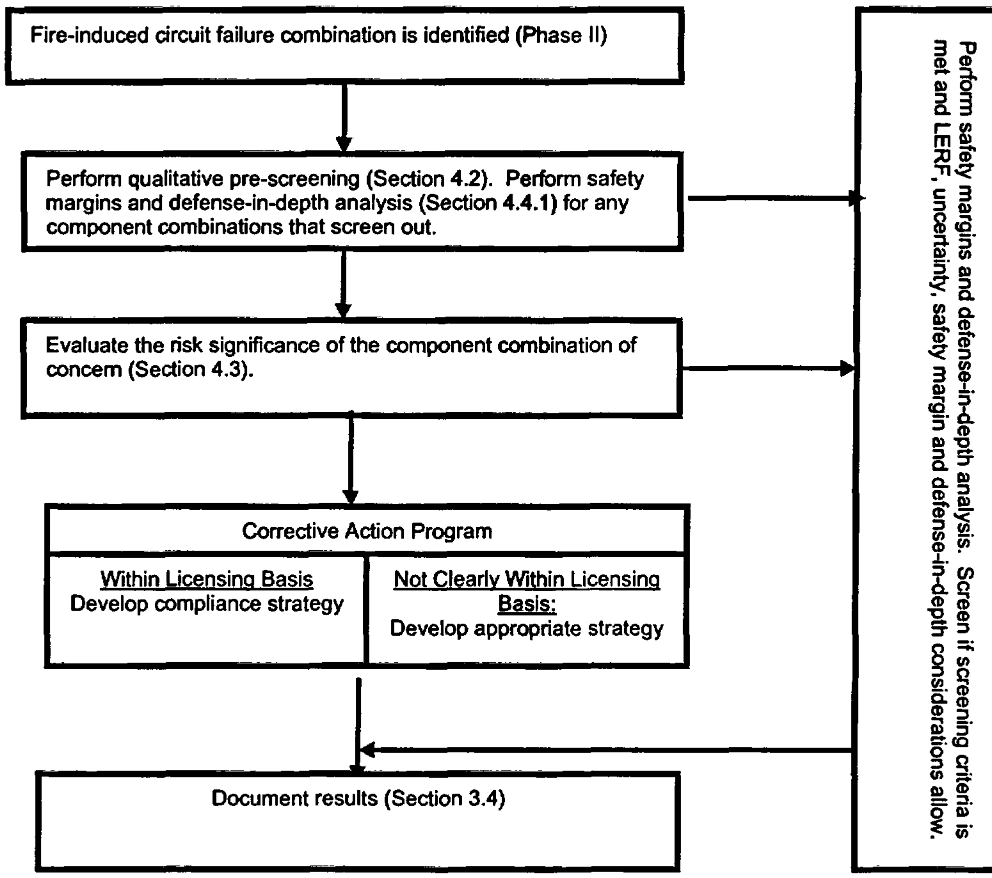
The NEI 00-01 method for risk significance determination is summarized below.

This section 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 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 6-1
Simplified Process
Diagram**



The methods in the revised fire protection SDP (when available). may be used as an alternative to those in NEI 00-01 Section 4.

6.4.2 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.

Post-fire safe shutdown is one part of each plant's overall defense-in-depth fire protection program. The extent to which the 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 are 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, as reflected in NEI 00-01 Section 3 but questioned by NRC in recent years, as noted above. The detailed NRC staff positions and views are not typically reflected in the plant's licensing basis. The NRC has also developed Regulatory Information Summary 2004-03 that reflects new risk-informed inspection guidance. In general, this guidance will identify circuit failure issues that are beyond the plant licensing basis, since it recommends consideration of more than one spurious actuation at a time.

The determination of whether a circuit failure issue of concern is inside or outside the licensing basis requires a clear delineation of the licensing basis. In some cases this 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; the NRC and the licensee may disagree over whether the issue is a violation of the licensing basis or a risk significant issue beyond the licensing basis that needs to be addressed.

For the purposes of this self-assessment, all findings will be classified as either licensing basis issues or risk-significant issues beyond the licensing basis. All cases of the latter will include a rationale for this classification. Risk significance is assessed for both types of findings.

Disposition of both types of findings, based on risk significance, is discussed below.

Issues Within the Licensing Basis

NEI 00-01 can be used to support exemptions or deviations in areas where the plant configuration clearly inconsistent with its own long-standing licensing basis. Section 4 provides probabilistic methods for identifying and assessing the risk significance of potential circuit failures. The risk significance screening will determine whether additional action to address these potential failures is warranted.

An example will illustrate the use of NEI 00-01 for issues clearly within the licensing basis. In this example, a licensee discovers an oversight in the implementation of its own licensing basis, and has failed to postulate a spurious actuation where one should have been postulated. The licensee can determine the significance of the issue using the methods of NEI 00-01, the revised fire protection Significance Determination Process (when available), or other plant-specific risk analyses. The licensee would place the issue in the plant Corrective Action Program (CAP). If the issue is risk significant according to the NEI 00-01 criteria (or other criteria) the licensee should correct the problem. Otherwise the licensee may choose to request an exemption or deviation, or change the fire protection plan, if it is not risk significant. Normal reporting guidelines would be followed.

Issues Beyond the Licensing Basis

The licensee may choose to place the issue into his CAP without a formal probabilistic risk significance determination.

The deterministic and probabilistic methods outlined in NEI 00-01 Sections 3 and 4 can also be used to determine the safety significance of identified issues such as multiple spurious signals/operations, and the potential for fire-induced circuit failure modes described in NRC IN 92-18 (Reference 6.3.37). As noted above, these issues are considered to be outside the licensing basis of many plants. If the user determines that additional measures are needed to prevent or mitigate the consequences of the spurious signals/operations, these methods can also be used to ensure the cost-effectiveness of these measures.

The 'additional measures' could include an evaluation for the potential impact of fire-induced spurious actuations on safe shutdown capability, considering all possible failure modes of the equipment or components under consideration. This includes, for example, the potential for fire-induced circuit/cable damage to cause mechanical failure of MOVs as described in IN 92-18. The evaluation should be performed using the circuit analysis criteria as outlined within this document.

Exemptions or deviations should not be required where there has been a legitimate and long-standing difference in interpreting the regulations. In these cases, a safety significance determination is useful in determining the action to be followed by the licensee without having to directly address the interpretive differences.

As an example, a licensee may have a long-standing licensing basis reflecting the postulation of any and all spurious actuations, one at a time. In line with the conclusions of the workshop described above (Reference 6.4-41), NRC inspectors identify a particular combination of simultaneous spurious actuations in two cables in a particular fire area to maintain one train free of fire damage. As in the example of Section 1.1.1, the licensee would perform a risk significance analysis using the methods in NEI 00-01. If the licensee finds the combination to be risk significant, he should place the issue resolution in the CAP. If the licensee finds the combination to not be risk significant, however, no exemption request is required. The licensee would update his fire protection plan. The licensee remains in compliance with his own licensing basis and there is no significant safety benefit to be gained in pursuing additional corrective action; therefore, the health and safety of the public are preserved.

6.4.3 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 associated and necessary circuit analysis
- Schedule for NRC triennial plant inspections

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.

7.3 POWER CIRCUITS

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

7.4 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.

8 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*

APPENDIX A: SAFE SHUTDOWN PROGRAM GENERAL ASSESSMENT

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

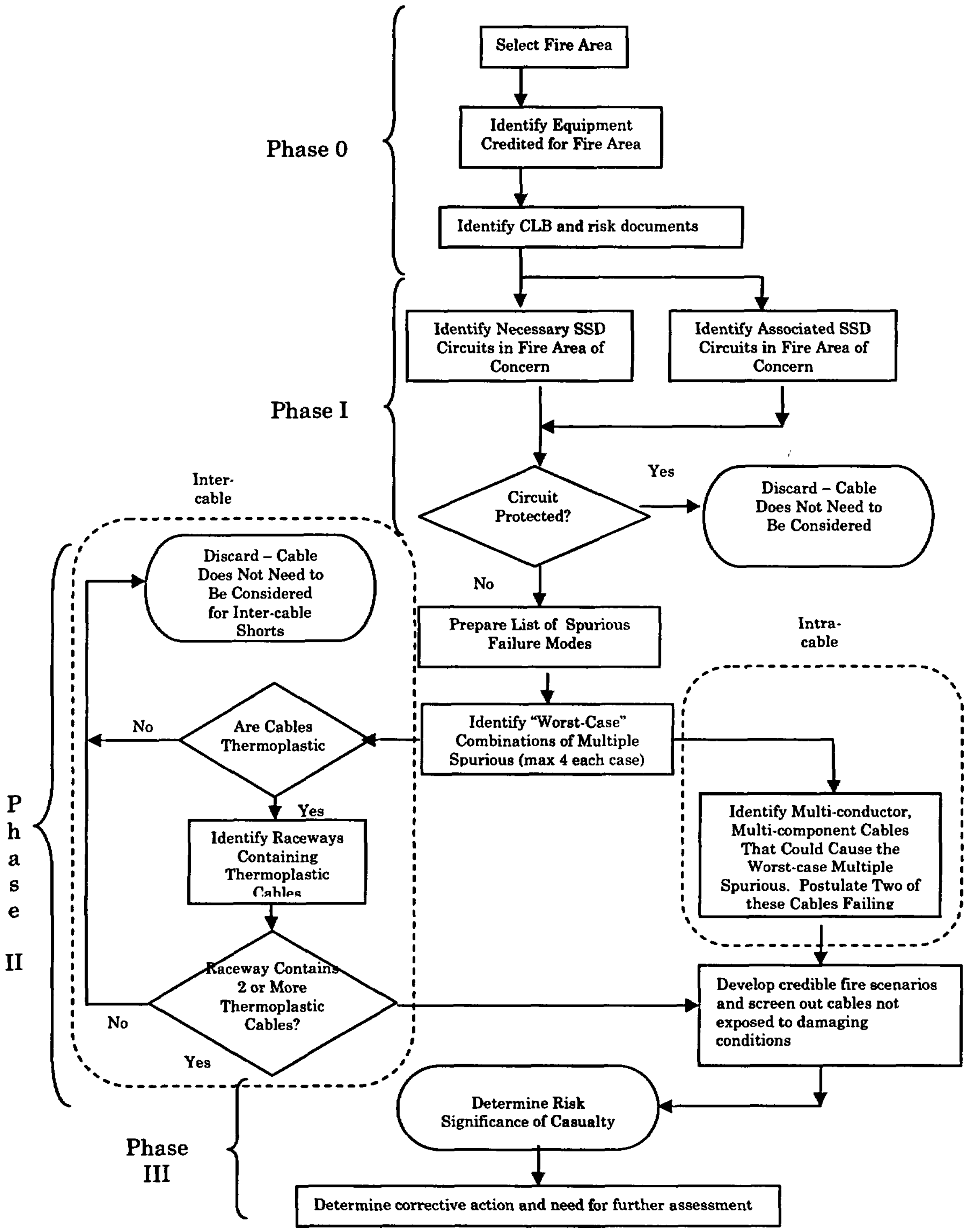

Phase 0
Select Fire Area
Identify Equipment Credited for Fire Area
Identify CLB and risk documents
Phase I
Identify Necessary SSD Circuits in Fire Area of Concern
Identify Associated SSD Circuits in Fire Area of Concern
Circuit Protected?
Yes
Discard – Cable Does Not Need to Be Considered
No
Prepare List of Spurious Failure Modes
Identify "Worst-Case" Combinations of Multiple Spurious (max 4 each case)
Inter-cable
Discard – Cable Does Not Need to Be Considered for Inter-cable Shorts
Are Cables Thermoplastic
No
Yes
Identify Raceways Containing Thermoplastic Cables
Raceway Contains 2 or More Thermoplastic Cables?
No
Yes
Phase II
Intra-cable
Identify Multi-conductor, Multi-component Cables That Could Cause the Worst-case Multiple Spurious. Postulate Two of these Cables Failing
Develop credible fire scenarios and screen out cables not exposed to damaging conditions
Determine Risk Significance of Casualty
Phase III
Determine corrective action and need for further assessment

Figure A-1

A.1 PHASE 0

Perform Phase 0 steps in advance of the actual assessment.

1. Select the fire risk significant areas of the plant to be evaluated in accordance with Section 6.1.1 of this document. 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)

   Include areas where manual actions are (1) time critical; (2) required in areas otherwise considered risk significant; (3) may present a challenge to the interim acceptance criteria; or (4) require multiple operators to carry out the actions.

   Fire areas/zones with a high fire ignition frequency, and containing significant SSD cabling or equipment should also be considered in the fire area selection.

   Typically, the Cable Spreading Room, Control Room, and Switchgear Rooms will be included.

2. For the selected areas, ensure that systems and equipment are identified that are capable of performing each of the following reactor shutdown functions:

   a. Reactivity control capable of achieving and maintaining subcritical reactivity conditions ($K_{eff} < 1.0$).

   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.

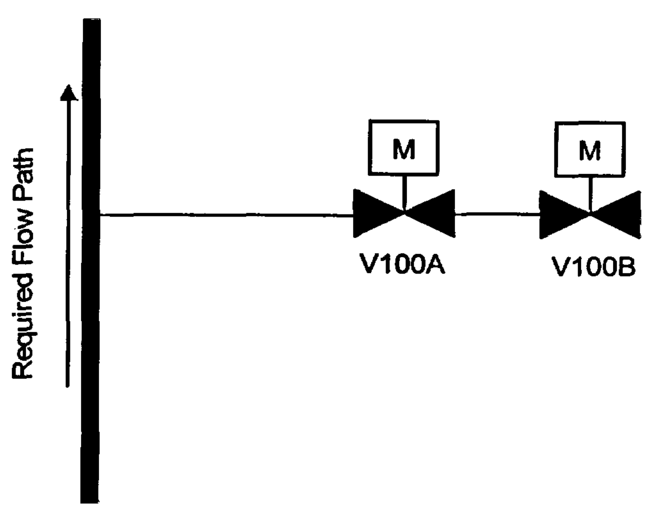
e. Supporting functions capable of providing process cooling, lubrication, electrical power, essential HVAC, etc. required to permit operation of the equipment used to achieve and maintain safe shutdown

3. Licensees should then identify the licensing basis documents related to associated and necessary 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

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.



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.

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.

A-2 PHASE I

The steps in Phase 1 begin the actual assessment.

1. 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 necessary 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
   Induced SBO
   HVAC failures affecting safe shutdown equipment
   DC power losses affecting safe shutdown equipment

   Circuits of interest for BWRs are those that can result in:

   Vessel overfill
   Multiple SRV opening
   Manual scram failure
   Spurious HPCI operation
   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

2. The focus should be on cables in tray and conduit rather than equipment or MCCs.

3. Determine if the circuit is protected from the effects of fire by one of the protective features required by III.G.2 of Appendix R. If so, these circuits are not considered vulnerable to fire induced circuit failure. (Note: The adequacy of this protection is beyond the scope of this assessment.) If not, proceed to Step 5.

4. Determine whether the cables of interest are impacted by the fire scenario(s). The remaining circuits are passed through to Phase II of the assessment.

A-3 PHASE II

In Phase II the reviewer determines, from those failures that can be impacted by fire scenarios, which circuit failures and pairs should be evaluated for risk significance. The following failure modes will not be considered in the scope of this assessment (except as noted). This guidance reflects criteria in Regulatory Information Summary 2004-03.

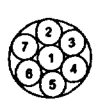
Mode	Cable Failure Mode & Related Cable Attribute	Bin	Comments And General Discussion EPRI / Sandia Testing
1	Open Circuit as an initial failure mode	3	An open circuit de-energizes or disconnects control from the device. It cannot cause a spurious operation of an associated circuit. Necessary circuits are covered by positive controls.
2	Inter-cable shorts involving conductors of one cable within a conduit and the conductors of any other cable outside the conduit.	3	This failure mode is virtually impossible to achieve without first shorting to a grounded surface.
3	Inter-cable shorts involving armored or metallically shielded cable.	3	Essentially the same as Item 2 above.
4	Three-phase, proper polarity hot shorting (except that this should be considered for outboard Decay Heat Removal valves)	3	In theory, three-phase proper polarity hot short power cable failures could cause a three-phase device to spuriously operate. However, such failures are considered of very low likelihood because the three distinct phases of power would have to align with the proper phase to operate. Licensees will continue to include the special case of high-low pressure interface valves.
5	DC hot shorts of the proper polarity on power cables of DC MOVs.	3	Essentially the same as AC MOVs above. While DC systems have only 2 poles, such failures are considered unlikely because there are also shunts and fields requiring five separate conductors to have the correct polarity and sequence in order to operate. Licensees will continue to include the special case of high-low pressure interface valves.
6	Multiple High Impedance Faults (MHIF)	3	NRC agreed that there are few if any cases where this is a concern. Although such faults have been considered using deterministic methods for critical safe shutdown circuits, such faults are considered of very low likelihood and often can be readily overcome by manual operator actions should they occur.

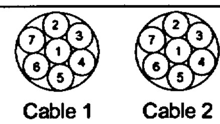
7	Circuits involving only cold shutdown components	3	Only hot shutdown impacts are considered risk significant
8	Inter-cable shorting between thermoset cables	2	Any inter-cable shorting involving thermoset cables is not seen to be risk significant pending additional research.
9	Inter-cable shorting between thermoset and thermoplastic cables	2	Any inter-cable shorting involving thermoset cables is not seen to be risk significant pending additional research.
10	Configurations involving three or more concurrent spurious operations involving more than three cables	2	Three independent failures are not deemed risk significant.
11	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	2	Control power transformers prevent enough current from flowing into the device actuator such that a hot short does not usually result in device actuation.
12	AOV or PORV control circuits where spurious operations will not impact the ability to achieve and maintain hot shutdown	2	AOVs and PORVs return to their safe position when the hot short ceases.

1. From the list of circuits that would be vulnerable to fire damage, prepare a list of the spurious failure modes that would be expected to occur if the vulnerable circuits were damaged.

2. From this list, identify the "worst-case" combinations of spurious failures that would be expected to lead to either an unrecoverable condition or unacceptable equipment damage. No more than 4 spurious actuations should be considered for each case.

3. Determine possible intra-cable failure modes in accordance with the following:

Mode	Cable Failure Mode & Related Cable Attribute	Bin	Comments And General Discussion EPRI / Sandia Testing
7A	Intra-cable shorts. Multiple shorts within a single thermoset or thermoplastic control cable. (Applicable to multi-conductor, single component and multi-component cables.)  Cable 1 Within Cable 1 up to 4 conductor to conductor shorts will be postulated.	1	For any individual multiconductor cable (thermoset or thermoplastic), any and all potential spurious actuations that may result from intra-cable shorting, including any possible combination of conductors within the cable, may theoretically be postulated to occur concurrently regardless of number. However, as a practical matter, only a few (three or four) of the most critical postulated combinations will be considered
7B	Multiple concurrent intra-cable shorts. Multiple occurrences of multiple shorts within individually distinct thermoset or thermoplastic control cable.	1	For cases involving the potential failure of more than one multiconductor cable, a maximum of two damaged cables should be assumed. For cases where more than two concurrent spurious actuations can occur as the result of intra-cable shorting within a single multiconductor cable

	 Up to 2 cables will be postulated.		they should be considered. The consideration of concurrent spurious operations in more than two cables will be deferred pending additional research.
7C	DC hot shorts of the proper polarity on control cables of DC circuits.	1	Postulate the potential spurious operation of a direct current (DC) circuit given failures of the associated control cables even if the spurious operation requires two concurrent hot shorts of the proper polarity (e.g., plus-to-plus and minus-to-minus) provided the required source and target conductors are each located within the same multiconductor cable.

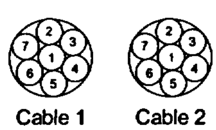
a. Identify multi-conductor cables that could cause one of the worst-case multiple spurious failures.

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.

4. Determine possible inter-cable failure modes in accordance with the following:

Mode	Cable Failure Mode & Related Cable Attribute	Bin	Comments And General Discussion EPRI / Sandia Testing
8	Inter-cable (cable to cable) shorts in thermoplastic control cable. (Single and Multiple occurrences of inter-cable shorts.)  Cable 1 shorting to Cable 2. Conductor-to-conductor shorts within Cable 1 and 2.	1	For any thermoplastic cable, any and all potential spurious actuations that may result from intra-cable and inter-cable shorting with other thermoplastic cables, including any possible combination of conductors within or between the cables, may be postulated to occur concurrently regardless of number. Note: Cables of concern must be routed in raceway with other cables for this to be of concern. (See Item 2 above.) Note: Inter-cable shorting between thermoplastic and thermoset cables is considered less likely than intra-cable shorting of either cable type or inter-cable shorting of thermoplastic cables. The spurious actuation issues involving inter-cable shorting between thermoplastic and thermoset cables is therefore being deferred pending additional research.

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.

5. Determine the potential fire scenarios in the fire areas of interest and screen out those not deemed to be damaged.

   a. Determine potential fire scenarios of interest using the guidance in NUREG-1805.

   b. Determine which of the circuits and cable identified in Steps 3 and 4 are likely to be damaged by the fire scenarios of interest.

   c. Screen out those deemed not to be damaged and document this process. The remaining circuits will be evaluated 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.

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.

2. Identify any necessary corrective actions to address risk-significant results using Section 6.4.2 and the referenced guidance in NEI 00-01. It is important to distinguish between licensing basis issues and beyond licensing basis issues wherever possible. Most issues identified as a result of following the RIS criteria will be beyond the licensing basis; however, all issues with risk significance should be properly addressed regardless of the licensing basis implications.

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 extended to other circuits and fire areas, and over what period of time.

APPENDIX B NECESSARY 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. 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.

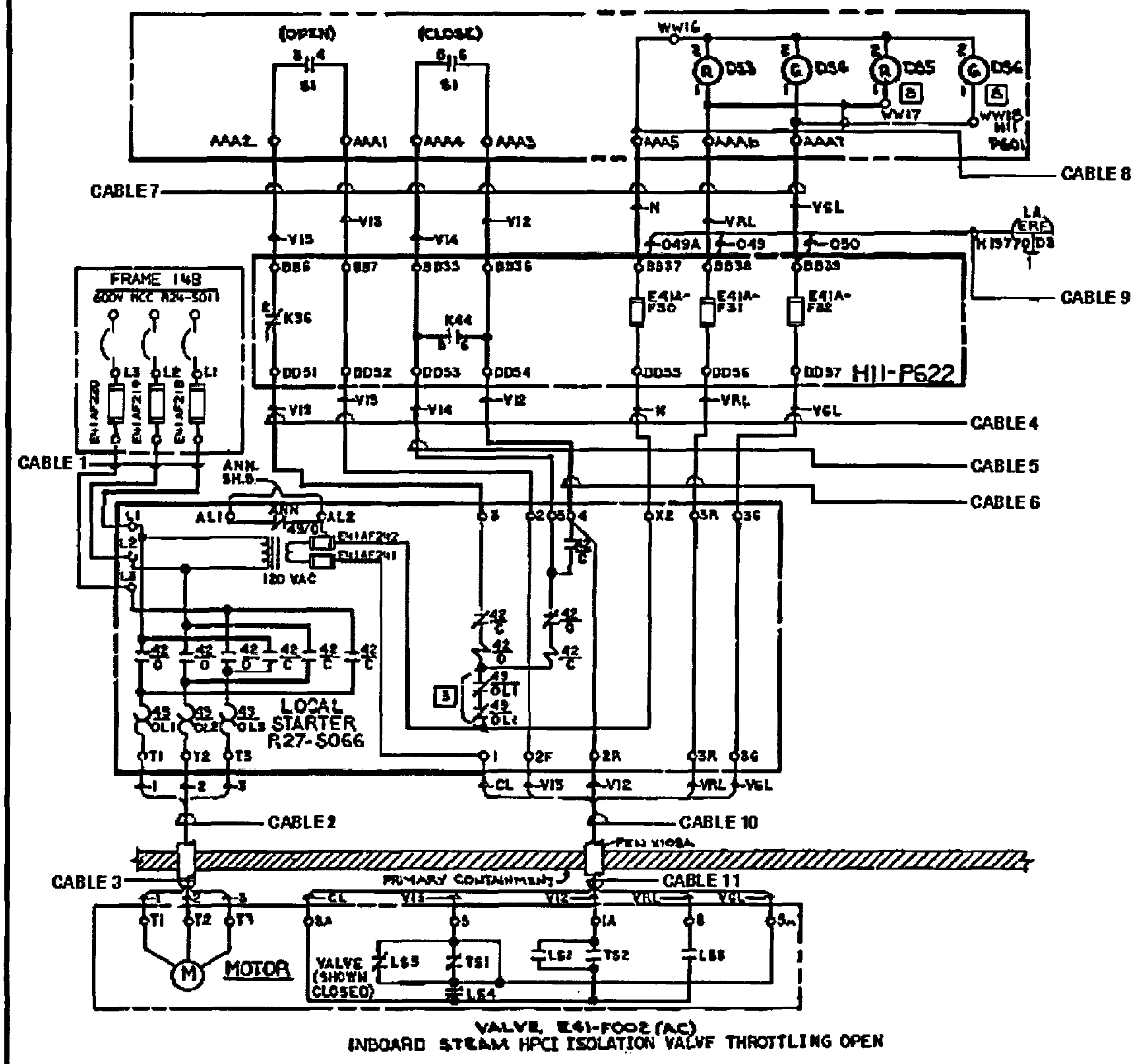

(OPEN)
(CLOSE)
CABLE 7
CABLE 8
CABLE 9
CABLE 4
CABLE 5
CABLE 6
CABLE 1
CABLE 2
CABLE 10
CABLE 3
CABLE 11
FRAME 14B
H11-P622
ANN.
SH.B.
120 VAC
LOCAL
STARTER
R27-S066
PRIMARY CONTAINMENT
MOTOR
VALVE
(SHOWN
CLOSED)
VALVE, E41-F002 (AC)
INBOARD STEAM HPCI ISOLATION VALVE THROTTLING OPEN

Figure 1

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 'necessary' circuit. Electrical power is required for this valve to operate. Intra-cable faults or shorts to ground of this cable will 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. 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 'necessary' 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'. 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

Cable #		Type		Analysis
				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 'necessary' circuit. An open circuit to this cable will prevent the valve from closing 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 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. 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 'necessary' 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 #		Type		Analysis
				cable is acceptable.
7		Control		For an active MOV, this is a 'necessary' 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'. 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.

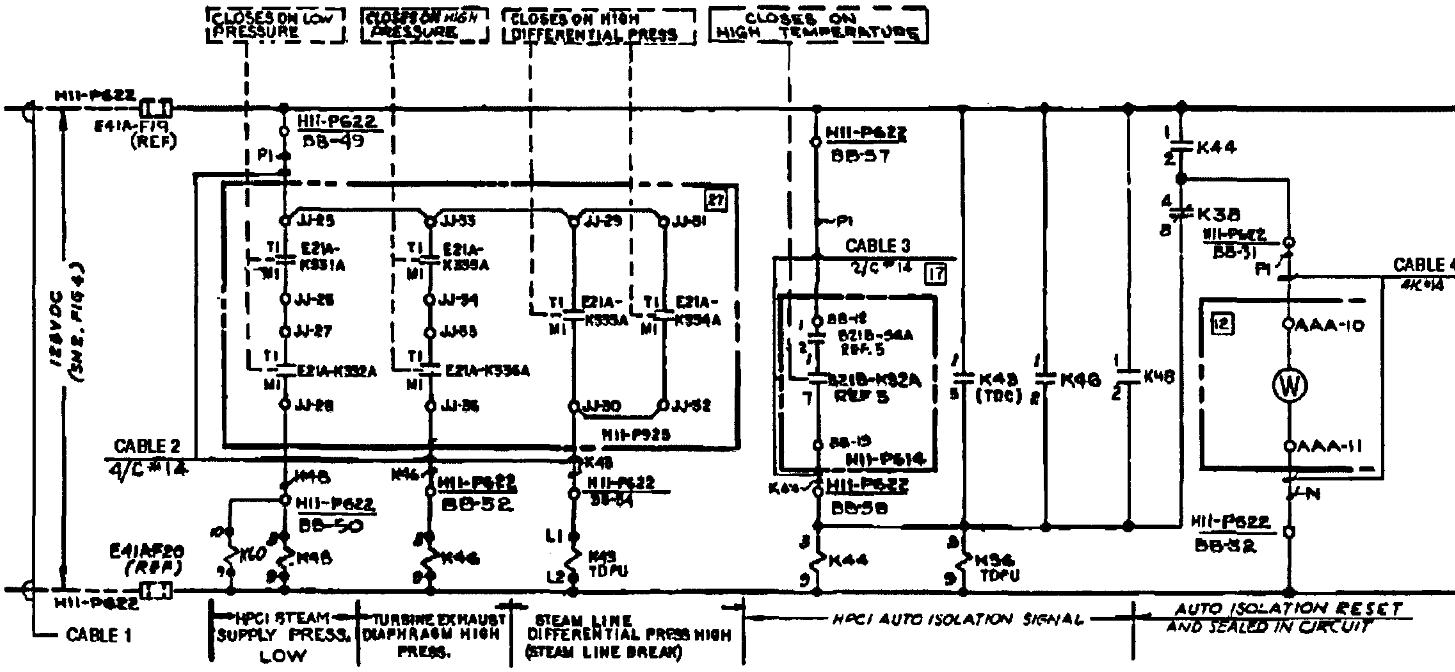

CLOSES ON LOW PRESSURE
CLOSES ON HIGH PRESSURE
CLOSES ON HIGH DIFFERENTIAL PRESS
CLOSES ON HIGH TEMPERATURE
H11-P622
E41A-F19 (REF)
H11-P622 BB-49
125VDC (SH2, FIG4)
CABLE 2 4/C #14
E41AF20 (REF)
CABLE 1
H11-P622 BB-50
H11-P622 BB-52
H11-P925
H11-P622 BB-57
CABLE 3 2/C #14
H11-P614
H11-P622 BB-58
K44
K38
CABLE 4 4/C #14
AAA-10
AAA-11
H11-P622 BB-82
HPCI STEAM SUPPLY PRESS. LOW
TURBINE EXHAUST DIAPHRAGM HIGH PRESS.
STEAM LINE DIFFERENTIAL PRESS HIGH (STEAM LINE BREAK)
HPCI AUTO ISOLATION SIGNAL
AUTO ISOLATION RESET AND SEALED IN CIRCUIT

Figure 2

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 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 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 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 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.

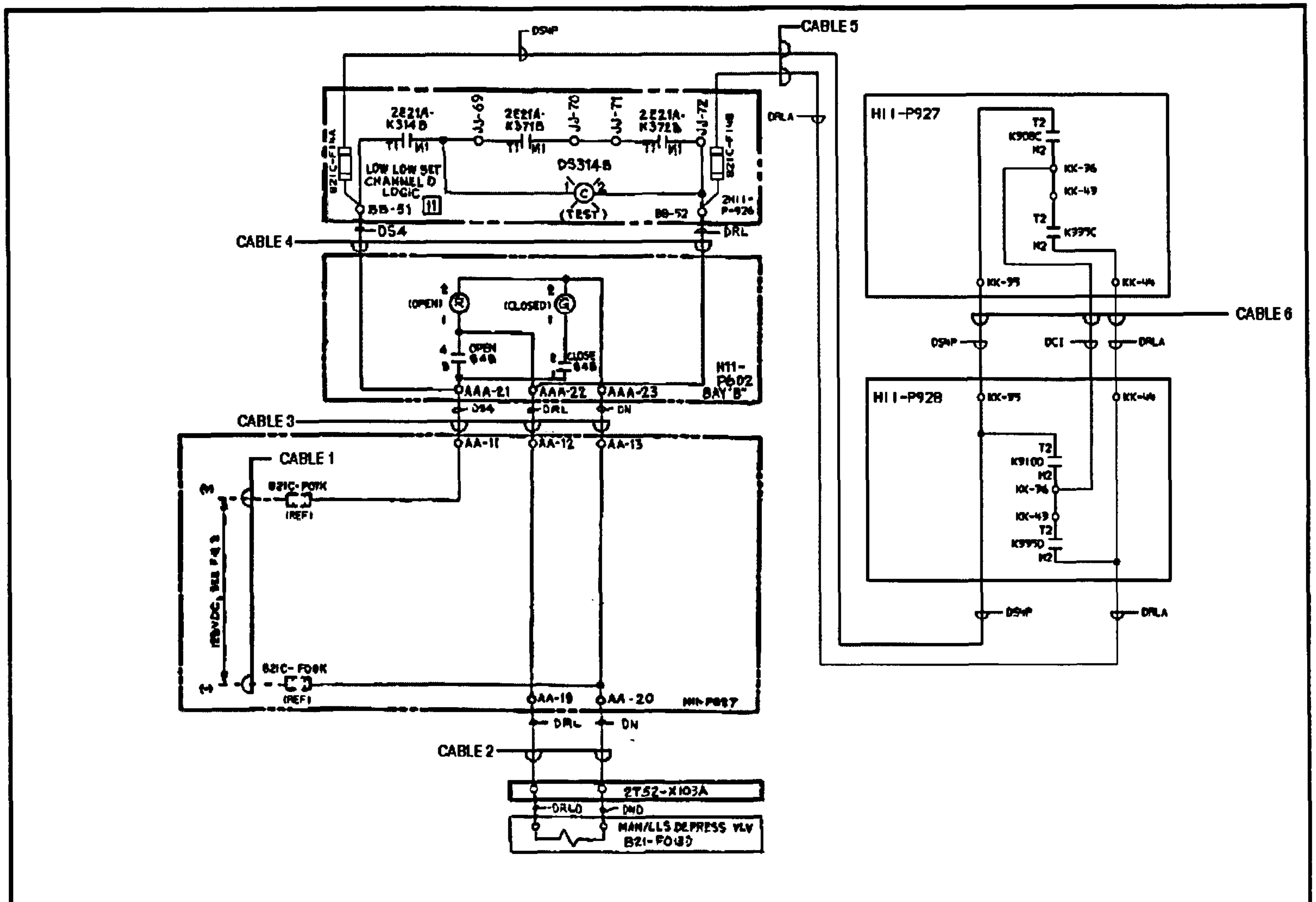

CABLE 5
CABLE 4
CABLE 3
CABLE 1
CABLE 2
CABLE 6
DS314B
(TEST)
BB-51
BB-52
LOW LOW SET
CHANNEL D
LOGIC
H11-P927
H11-P928
(OPEN)
(CLOSED)
AAA-21
AAA-22
AAA-23
AA-11
AA-12
AA-13
AA-19
AA-20
2TS2-X103A
MAN/LLS DEPRESS VLV
B21-F013

Figure 3

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 'necessary' 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 the feasibility criteria as outlined within this document. 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 'necessary' 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 the feasibility criteria as outlined within this document. 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

Cable #		Type		Analysis
				function. Intra-cable short would prevent 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 the feasibility criteria as outlined within this document. 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 the feasibility criteria as outlined within this document. 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 the feasibility criteria as outlined within this document. 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 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.

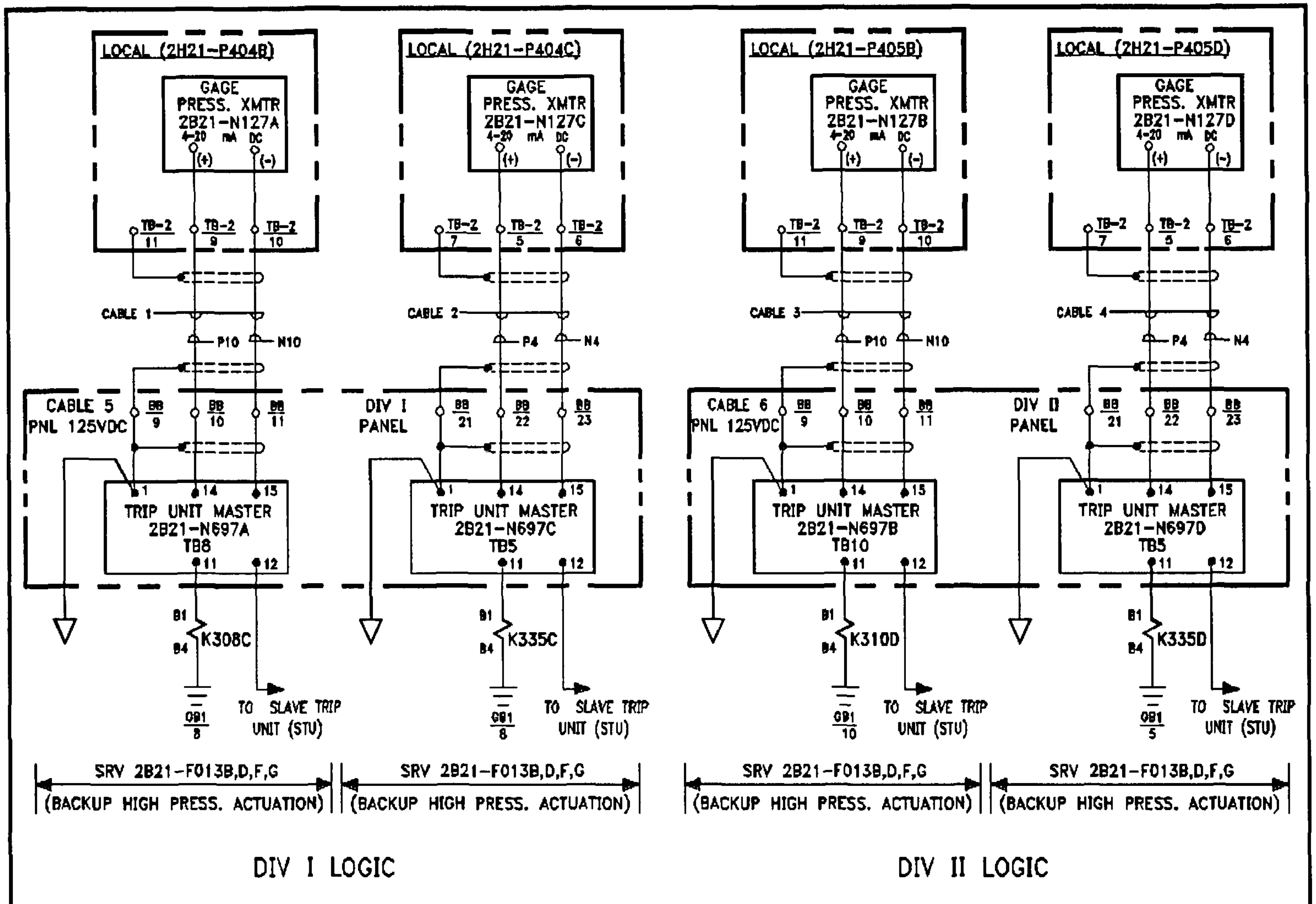

LOCAL (2H21-P404B)
GAGE PRESS. XMTR 2B21-N127A
4-20 mA DC
LOCAL (2H21-P404C)
GAGE PRESS. XMTR 2B21-N127C
4-20 mA DC
LOCAL (2H21-P405B)
GAGE PRESS. XMTR 2B21-N127B
4-20 mA DC
LOCAL (2H21-P405D)
GAGE PRESS. XMTR 2B21-N127D
4-20 mA DC
CABLE 1
CABLE 2
CABLE 3
CABLE 4
P10
N10
P4
N4
CABLE 5 PNL 125VDC
DIV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

Figure 4

Circuit analysis for this logic is as follows:

Table 5-4

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 the feasibility criteria as outlined within this document. 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_____

Cable Information

Number _____	Necessary ☐ Associated ☐	Cable Construction		Raceway
		Jacket	Insulation	Number _____
		Thermoset ☐	Thermoset ☐	Tray ☐
		Thermoplastic ☐	Thermoplastic ☐	Conduit ☐
		Armor ☐		Other _____

Component Information

Impacted Components	Circuit Failure Mode	Impact on Component	Comment