Appendix J
Application of PIRT Results

J.1 Purpose:

The purpose of this Appendix is to provide implementing guidance to the Industry for the application of the results of the report on the Joint Assessment of Cable Damage and Quantification of Effects from Fires (JACQUE-FIRE), NUREG/CR-7150 Volume 1, Phenomena Identification and Ranking Table (PIRT) Exercise for Nuclear Power Plant Fire-Induced Electrical Circuit Failure into the evaluation of fire-induced circuit failures in the post-fire safe shutdown analysis. This document is herein referred to as the "PIRT Report". The group who prepared the PIRT Report is referred to in this appendix as the "PIRT Panel".

Included in this appendix is the guidance for:

- determining the "high consequence" set of components to which more conservative~~rigorous~~ fire-induced circuit failure criteria apply and,
- determining the revised or new fire-induced circuit failure criteria that apply:
  - only to "high consequence" components and,
  - to all "post-fire safe shutdown components"
- determining the "incredible" circuit failure types that should not be considered.

The "high consequence" components identified in this report are the set of components for which assurance is to be provided such that, even if these components are affected by any of the fire-induced circuit failures classified as "implausible", there is still an acceptable means of mitigating the effects of the fire-induced impact without affecting the ability to safely shutdown in the event of a plant fire. By applying the classification of "high consequence" to these components, it is assured that the basis for achieving post-fire safe shutdown is **not solely** the low likelihood of the "implausible" circuit failures.

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J.2 Background:

The information in the PIRT Report has two purposes:

~~-~~(1) To provide input to the PRA Expert Panel who will develop hot short/spurious operation probabilities for use in revising NUREG/CR-6850 or other guidance document; (2) To provide input for consideration by the NRC's Office of Nuclear Reactor Regulation (NRR) in revising the current circuit failure criteria and guidance used in the deterministic post-fire safe shutdown analysis.

~~–~~The revised circuit failure criteria may have applicability to licensee's maintaining compliance under 10 CFR 50, Appendix R (or their fire protection license condition), as well as to ~~l~~Licensee's transitioning to NFPA 805 under 10 CFR 50.48(c), as outlined in the next paragraph. The revised circuit failure criteria may be~~are also~~ applicable to the evaluation of MSOs.

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Although this appendix is intended to provide criteria applicable to all licensees and to obtain NRC endorsement of the criteria, neither of these actions changes a licensee's current licensing basis (CLB). Any changes to a licensee's CLB will only come about as a result of a voluntary effort by the licensee to alter the CLB, or by a regulatory action by the NRC to impose these criteria on a licensee as new requirements.

The revised circuit failure criteria outlined in this section also apply to the evaluation of MSOs, if a particular MSO Scenario includes any of the components classified in this Appendix as 'high consequence". The criteria changes in Appendix J should be addressed for the set of MSO Scenarios discussed in the previous sentence as OE in accordance with the guidance for new MSO scenarios in NEI 00-01 Section 4.5.3.

As a part of the PIRT Panel effort, the results of all recent cable fire testing, conducted for the purpose of assessing the likelihood of hot shorts causing spurious operations, was reviewed in detail. The assessments summarized in the PIRT Report will likely supersede the assessments provided in Reference 4, Expert Elicitation Process for the NEI EPRI Cable Fire Testing. The cable fire testing reviewed is the testing summarized in:

- -EPRI TR-1003326, "Characterization of Fire-Induced Circuit Faults: Results of Cable Fire Testing," Electric Power Research Institute, Palo Alto, California, December 2002 (Reference~~s~~ 3),
- -NRC NUREG/CR-6931, Vol. 1, "Cable Response to Live Fire (CAROLFIRE) Volume 1: Test Descriptions and Analysis of Circuit Response Data," April 2008 (Reference 5), and
- -NRC NUREG/CR-7100, "Direct Current Electrical Shorting in Response to Exposure Fire (DESIREE-FIRE): Test Result" April 2012 (Reference 8).

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–The data analysis for the characteristics determined by the PIRT Panel to be of most importance to hot shorts causing spurious operations was analyzed in- NUREG-2128 – Electrical Cable Test Results and Analysis During Fire Exposure (ELECTRA-FIRE).(~~R~~Reference 2~~), NUREG 2128~~. Reference 2 used the test results from References 3, 5 and 8 to determine the actual number of occurrence for each of the circuit characteristics determined by the PIRT Panel to be of importance. The PIRT Report used the data analysis from Reference 2 and applied specific circuit failure types to typical circuit designs considered to be most representative of the circuit designs used throughout the commercial nuclear power industry. This information was used by the PIRT Panel to make determinations as to whether specific circuit failure types were plausible, implausible or incredible. Those circuit failure types classified as "implausible" will be considered by this Appendix to be applicable to "high consequence" components only. (**Note**: The PIRT Report used both "plausible" and "possible" to refer to the same circuit failure types. This Appendix will use plausible to represent both plausible and possible.)

In Section 2.1.3 of the PIRT Report, the following definitions are provided as an aid to classifying the specific circuit failure types reviewed by the PIRT Panel.

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> **Incredible** – *"The term "incredible" used in conjunction with the phenomenon of a fire-induced circuit failure, signifies the PIRT panel's conclusion that the event will not occur. In these cases, the PIRT panel could find no evidence of the phenomenon ever occurring, and there were no credible engineering principles or technical arguments to support its happening during a fire. Any likelihood value assigned to these types of phenomena would have little meaning."*

It is the position of the industry that circuit failure types classified as "incredible" do not need to be considered in a deterministic or risk-informed (e.g., Fire PRA, NFPA 805) post-fire safe shutdown analysis. It is also the position of the industry that the circuit failure determinations provided in the appendix also apply to the analysis of MSOs. Licensees may use this appendix as the basis for removing consideration of these circuit failure types from their CLB. Removing these circuit failure types from consideration in a licensee's CLB can be evaluated to not have an adverse affect on the ability to achieve and maintain safe shutdown in the event of a fire using the information in this appendix.

> **Implausible** – *"The term "implausible" when used in conjunction with a fire-induced circuit failure phenomenon, supports the PIRT Panel's conclusion that the happening, while theoretically possible, would require the convergence of a combination of factors that are so unlikely to occur that the likelihood of the phenomenon can be considered statistically insignificant. In these cases, the PIRT Panel could find no evidence of the phenomenon ever occurring neither in operating experience nor during a fire test. Any likelihood value assigned to these types of phenomena would have little meaning."*

The term "implausible" was used by the PIRT Panel to describe those circuit failure types that, although theoretically possible, their likelihood can be considered statistically insignificant. It is the position of the industry that circuit failure types classified as "implausible" in the PIRT Report only need to be considered in the post-fire safe shutdown evaluation for "high consequence" components since the consequence of the fire-induced failure of these components is significant enough to warrant the treatment. To support this position, this appendix provides a definition of "high consequence" components. Conservatively defining a set of "high consequence" components provides assurance that the low likelihood of "implausible" circuit failures is not the **sole barrier** to assuring the ability to achieve and maintain safe shutdown in the event of a plant fire.

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Finally, the PIRT Report identified a new fire-induced circuit failure type called a ground fault equivalent hot short. This new failure type is described in this appendix.

J.3 Guidance:

Provided below is guidance for determining:

- the components in a post-fire safe shutdown analysis that are to be considered as "high consequence" components,
- the additional circuit failure types that need to be evaluated,
- the criteria, currently contained in the balance of NEI 00-01 and the current NRC Guidance, that need to be adjusted based on the changes outlined in this Appendix and
- the actions, upon formal interim acceptance by NRC of the information and approach outlined in this Appendix, that are recommended for licensees.

An understanding of the components classified as "high consequence" components is crucial to the application of the revised circuit failure criteria, since circuit failures classified as "implausible" must be applied only to components classified as "high consequence".

J.3.1 High Consequence Components:

The starting point for classifying components as "high consequence" is high/low pressure interface components. Appendix C of NEI 00-01 considers a set of high/low pressure interface components as those whose spurious opening could result in a loss of RPV/RCS inventory and, due to the lower pressure rating on the downstream piping, an interfacing LOCA outside of Primary Containment (i.e., pipe rupture in the low pressure piping). This could result in a release of radiation outside the three fission product barriers and potential release to the atmosphere. Appendix C concludes that the RHR/Shutdown Cooling Suction Isolation Valves are the only valves meeting the definition of high/low pressure interface. Note that the NRC has endorsed Appendix C in Regulatory Guide 1.189 Revision 2.

Based on discussions between the industry and NRC, it was determined that the NRC is also concerned about systems that could cause significant and rapid inventory losses resulting in fuel damage in less than 1 hour inside of containment as a result of fire-induced damage. Components with these characteristics also need to be evaluated as potential "high consequence" components. The inventory loss location, i.e. inside or outside containment, is not a distinguishing characteristic for determining the supplemental set of "high consequence" components. The important characteristic is whether the fire-induced failure can cause fuel damage in less than 1 hour.

Based on this, the criteria to be applied in determining those components that are to be classified as "high consequence" components are any of the following which could result in fire-induced damage resulting in "immediate and unrecoverable" conditions for the fuel, the reactor coolant system or the primary containment:

- The component or set of components is classified as a 'high/low pressure interface" component in Appendix C to NEI 00-01.

  - The components classified as "high/low pressure interface" components are the Shutdown Cooling Suction Valves.

- The spurious operation of a component or set of components that results in a significant, i.e., greater than the protected make-up capability, loss of inventory for the Reactor Coolant System (RCS) in a short period of time, i.e., less than 1 hour, such that fuel damage is likely.

The list of components developed jointly by the NRC and Industry for each reactor type to be evaluated as potential "high consequence" components using the criteria described above is provided below.

Potential "High Consequence" Components [NRC/Industry Joint List]:

For BWRs:

- Spurious opening of both shutdown cooling suction containment isolation valves [currently classified as high/low pressure interface valves]
- Spurious opening of multiple Safety Relief Valves (SRVs)

For PWRs:

- Spurious opening of the shutdown cooling suction valves (to SDC/LPSI/RHR – the high/low pressure interfaces).
- Spurious opening of a Pressurizer Power Operated Relief Valve (PORV) and failure of its associated block valve.
- Spurious opening of the normal or excess letdown flow path valves.

It is recommended that each licensee review this list and assure that it is representative of their plant, using a multi-discipline review process.

This set of components has been evaluated in Table J-1. Refer to Table J-1 for details. The components from the list above that are recommended to be classified as "high consequence" components are listed below. Each licensee should also verify that the generic dispositions provided in Table J-1 are applicable to their plant specific conditions.

High Consequence Components:

For BWRs:

- Spurious opening of both shutdown cooling suction containment isolation valves [currently classified as high/low pressure interface valves]
- Spurious opening of multiple Safety Relief Valves (SRVs)

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For PWRs:

- Spurious opening of the shutdown cooling suction valves (to SDC/LPSI/RHR – the high/low pressure interfaces).
- Spurious opening of a Pressurizer Power Operated Relief Valve (PORV) and failure of its associated block valve.

With respect to this set of "high consequence" components, should fire-induced circuit failures, even those classified as "implausible", result in a negative impact to the component with the potential to impact post-fire safe shutdown, one of acceptable mitigation strategies described in Table J-1 should be demonstrated to be available to prevent the impact to post-fire safe shutdown. Otherwise, the component's circuitry should be re-designed to prevent the impact.

Thermal hydraulic analysis performed in conjunction with this appendix may be performed using "best estimate" codes with "best estimate" parameters, along with the core damage measurement of PCT less than or equal to 1800^{o}F. These criteria are similar to those used for the Internal Events PRA thermal hydraulic analysis and for the evaluations outlined in NEI 00-01 Appendix H. The use of these same criteria for post-fire safe shutdown provides for a consistent approach and a cost effective use of the information developed on plant response to various transient conditions. The discussion above addresses which components are to be considered as "high consequence" components in the context of the PIRT Results. Refer to Section J.3.2 for a discussion of the circuit failure changes from the PIRT Report and those which apply specifically to "high consequence" components.

J.3.2 Circuit Failure Considerations:

The PIRT Panel provided technical recommendations on certain aspects of fire-induced circuit failures associated with control and power circuits in the analyses of post-fire safe shutdown circuits.

The PIRT Panel concluded that the following circuit failure types were **incredible**:

- The spurious operation of a three-phase ac motor due to proper polarity hot shorts on three-phase power cabling.
- The spurious operation of dc compound-wound motor due to proper polarity hot shorts in the motive/power cabling.
- The ignition of a secondary fire from an open circuited CT secondary circuit with turns ratio of 1200:5 or less. (Note: Additional testing may be performed for CT secondary circuits with turns ratio of >1200:5. No action is recommended for these circuits pending the completion of the proposed testing.)
- Circuit conductor and configuration specific failures having the following characteristics:

- Inter-cable hot shorts for double break circuit designs where the target and source conductors both have thermoset (TS) insulation.
- Inter-cable hot shorts for single and double break circuit designs where the target conductor has thermoset (TS) insulation and the source conductor has thermoplastic (TP) insulation.
- Double break circuit designs for ungrounded dc (or ungrounded distributed ac) involving one inter-cable hot short plus one ground fault equivalent hot short where the target and source cables have TS insulation on their conductors.
- Single or double break circuit designs involving at least one inter-cable hot short with the target cable including
  - A grounded metal, foil shield wrap, or
  - An Armored cable design

The PIRT Panel also concluded that

- The guidance given in Nuclear Energy Institute, NEI 00-01, Rev. 2, Appendix B.1, can be applied to post-fire safe-shutdown methodologies used for Appendix R Section III.G and III.L, as well as, NFPA 805 for addressing concerns associated with Multiple High Impedance Faults (MHIFs). (Note: Appendix B.1 of NEI 00-01, Rev. 2, which has not changed in Revision 3 or 4, offers a basis for concluding that MHIFs need not be considered for any circuits damaged by the fire provided the breaker for that circuit is coordinated and provided the breaker has been appropriately tested and is appropriately maintained).

The PIRT Panel concluded that the following circuit failure types were **implausible**:

- Circuit conductor and configuration specific failures having the following characteristics:
  - Inter-cable hot shorts for double break circuit designs where the target conductor has TP insulation and the source conductor has TS insulation.
  - Inter-cable hot shorts for single break circuit designs where the target and source conductors both have TS insulation.
  - Double break circuit designs for ungrounded dc (or ungrounded distributed ac) involving one inter-cable hot short plus ground fault equivalent hot short where the target cable has TP insulation on its conductors and the source cable has TS insulation on its conductors.
  - Inter-cable hot shorts for single break circuit designs with the target cable including an un-insulated grounded drain wire for a grounded ac circuit.

The PIRT Panel concluded that the following circuit failure type should be classified somewhere **between plausible and implausible** due to the fact that single inter-cable hot shorts were observed, but multiple circuit failures with the characteristics described below did not produce a spurious operation and the test circuits were not configured to

look for this specific failure type. The discussion below concludes that this failure type can be considered implausible.

- Circuit conductor and configuration specific failures having the following characteristics:
  - Inter-cable hot shorts, including ground equivalent hot shorts, for double break circuit designs where the target and source conductors both have TP insulation.

  For purposes of this appendix, this circuit configuration needs to be determined to be either "implausible" (applicable only to high consequence components) or "plausible" (applicable to all post-fire safe shutdown components). To make this determination, the following justification is supplied addressing both the regulatory and technical aspects of the circuit design.

  From a regulatory perspective, consideration of two (2) inter-cable hot shorts in a double break design has always been considered to be applicable only to "high low pressure interface components". NRC Generic Letter 86-10, Enclosure 2, Section 5.3.1, as clarified by the NRC Memorandum from Holahan to Crutchfield dated December 4, 1990 (ML062300013), forms the basis for this conclusion. The determinations made in these NRC Guidance documents never made any distinctions as a function of cable insulation type and the NRC Guidance provided was applied throughout the Industry without consideration of cable insulation type. Additionally, the NRC determination documented in FR Citation 48FR19963, related to ac and dc hot shorts, further emphasizes that the regulatory view of this type of fire-induced circuit failure has always been considered to be very low likelihood.

  From a technical perspective, all of the other double break designs evaluated by the PIRT Panel were classified as either "incredible" or "implausible". The double break configuration with TP target and source cables was not specifically tested in any of the cable fire tests. In general, TP insulated cables were shown to be exposed at a lower threshold temperature than their counterpart TS insulated cables. In a configuration with exposed conductors, two possible outcomes are available: (1) the exposed conductors can short to ground removing the potential from the circuit; (2) the exposed conductors (target) could contact exposed conductors from adjacent cables (source) transferring potential and, if the potential has the correct characteristics, a spurious operation could result. In the cable fire testing performed, very few instances of inter-cable hot shorts between TP insulated cables were observed.

  For this configuration, either two inter-cable hot shorts would need to occur or one inter-cable hot short and one ground equivalent hot short would need to occur. -Given that a single inter-cable hot short for TP insulated cables was unlikely, it can be concluded that coupling this unlikely failure type with another unlikely failure type would make the occurrence significantly more unlikely.

When the limited duration aspects of each of these hot shorts is also factored in, the occurrence of a spurious operation for either of the configurations discussed above, is considered to be that the happening, while theoretically possible, would require the convergence of a combination of factors that are so unlikely to occur that the likelihood of the phenomenon can be considered statistically insignificant.

Based on the technical evaluation provided above and based on the regulatory precedent already set for the configuration under evaluation, the configuration of a double break design using TP target and source cables and requiring two inter-cable hot shorts, or one inter-cable hot short and one ground equivalent hot short, to cause a spurious operation is classified as "implausible".

Since two (2) inter-cable hot shorts in a double break design using TP target and TS source cables is classified as 'implausible" based on Section 3.3.2 of the PIRT Report, and since the information provided above justifies classifying two (2) inter-cable hot shorts in a double break design using TP target and source cables as 'implausible", it can be concluded that a double break design requiring two (2) inter-cable hot shorts with TP target cables and one TP and one TS source cable is similarly classified as 'implausible"

Finally, the PIRT Panel also concluded that the following new circuit failure type was considered plausible such that it should be applied to all "post-fire safe shutdown components:

- Gground fault equivalent hot shorts for ungrounded circuits. Refer to Section J.3.3 of this Appendix for a description of how this change affects the current criteria in NEI 00-01 Revision 2.
- There are other circuit failures classified as plausible in the PIRT Report. These other circuit failure types, however, are not new circuit failure types used in a post-fire safe shutdown circuit analysis. Additionally, it was not the intent of the PIRT to include all possible circuit failure types in the PIRT Report. As such, only those additional circuit failure types considered to be new are listed here. Section 3.5 contains a comprehensive list of the circuit failure types required to be considered.

The circuit failure changes recommended by the PIRT Panel are summarized in Table J-2 to this appendix.

J.3.3 Adjustments to Current NRC and NEI Guidance

The information in this appendix provides conclusions that are different from that of the current NRC Guidance on post-fire safe shutdown circuit analysis and are different than some of the guidance provided in NEI 00-01 Revisions 2 and 3. Upon formal NRC interim acceptance of this appendix, the information in this appendix should be used and

where a conflict exist between the information in this appendix and the documents referenced, the information in this appendix will govern.

Refer to the comments in Table J-2 for information on where the guidance in this Appendix changes longstanding NRC Guidance. Additionally, the information in this appendix adjusts the information in NRC Generic Letter 86-10, Enclosure 2, Section 5.3.1, related to the consideration of hot short spurious operations of ac and dc motors. The information in this appendix adjusts the information in NRC Generic Letter 86-10, Enclosure 2, Section 5.3.8, related to the consideration multiple high impedance faults.

With respect to NEI 00-01, the following sections are affected:

NEI 00-01 Revision 2:

- Section 3.5.1.1 – This section does not acknowledge the potential failure type associated with ground fault equivalent hot shorts. Ground fault equivalent hot shorts can also provide conductor-to-conductor potential through the ground plane to cause affects similar to a hot short.
- Section 3.5.1.1 – The reference to the double-break design, the Holahan Memo and its applicability has been altered by this appendix.
- Section 3.5.2.2 – The upfront portion of this section does not acknowledge the potential failure type associated with ground fault equivalent hot shorts. Ground fault equivalent hot shorts can also provide conductor-to-conductor potential through the ground plane to cause effects similar to a hot short.
- Section 3.5.2.2~~3~~; Figure 3.5.2.-3 – This section and figure discuss ground fault equivalent hot shorts under 'Short-to-ground No. 2', but the guidance implies that the failure type is completely bounded by consideration of a hot short. This is only true if the 'hot probe' method of evaluating hot shorts is used and if placing a target cable in a dedicated conduit to mitigate the effects of a hot short is not used.
- Section 3.5.2.3 – This section does not adequately discuss ground equivalent hot shorts.

NEI 00-01 Revision 3:

- Section 3.5.1.1 - This section discusses ground fault equivalent hot shorts, but the guidance implies that the failure type is completely bounded by consideration of a hot short. This is only true if the 'hot probe' method of evaluating hot shorts is used and if placing a target cable in a dedicated conduit to mitigate the effects of a hot short is not used.
- Section 3.5.2.2 - This section discusses ground fault equivalent hot shorts, but the guidance implies that the failure type is completely bounded by consideration of a hot short. This is only true if the 'hot probe' method of evaluating hot shorts is used and if placing a target cable in a dedicated conduit to mitigate the effects of a hot short is not used.

- Section 3.5.2.3 – This section states that ground fault equivalent hot shorts only need to be considered when both cables/conductors are in the same raceway. This position is changed by Appendix J. Raceway-to-raceway ground fault equivalent hot shorts must be considered.
- Section 3.5.2.3; Figures 3.5.2-6, 3.5.2-7, 3.5.2-8 and 3.5.2-9 need to be reviewed against the information in this appendix to identify changes related to target and source cable conductor insulation.
- Section 32.5.2.4 – The information in this section has been altered by the information in this appendix.

As stated previously, the information in this appendix does not alter a licensee's CLB. A licensee's CLB will govern over the information in this appendix. Once the NRC has provided "formal interim acceptance", ~~T~~the information in this A~~a~~ppendix, however, can be used as the basis for making a "non-adverse" change to a licensee's CLB, e.g., elimination of 3-phase hot shorts on power feeds for hi/lo pressure interface components, or elimination of consideration of MHIF. Once that change is made, the information ~~in~~used from this A~~a~~ppendix should be~~and~~ included in ~~a~~the licensee's CLB ~~will govern~~.

~~The information in this Appendix should also be used in the analysis of MSOs.~~

After the formal NRC interim acceptance of this appendix, NEI 00-01 will be revised to make it consistent with this appendix. NRC will be asked to endorse the revised NEI document in a revision to Regulatory Guide 1.189.

J.3.4 Recommended Actions for Licensees

Although the information in this appendix does not become part of a Licensee's CLB, circuit failures falling into this classification can be inspected under the NRC Reactor Oversight Process (ROP), and the NRC can generate a "Finding" if they identify a concern with the treatment of such a circuit. As such, after the formal NRC interim acceptance of this appendix, it is recommended that Licensees, at a minimum, assess the significance of the circuit failure changes related to "high consequence" components to assure that any conditions with greater than very low safety significance, as defined in the ROP, i.e., greater than green, are addressed. This recommendation also applies to the evaluation of MSOs as outlined in this appendix.

As outlined above, once the NRC has provided "formal interim acceptance" of this Appendix, the information in this Appendix can be used as the basis for making a "non-adverse" change to a licensee's CLB, e.g., elimination of 3-phase hot shorts on power feeds for hi/lo pressure interface components, or elimination of consideration of MHIF.

Finally, the PIRT Report identified some new fire-induced circuit failure types. These are described in this appendix. Although the information in this appendix related to new fire-induced circuit failure types does not become part of a licensee's CLB, these new fire-induced circuit failure types can be inspected under the NRC ROP, and the NRC can

generate a "Finding" if they identify a concern with the treatment of such a circuit. As such, it is recommended that licensees after the formal NRC interim acceptance of this Appendix, at a minimum, assess the significance of the circuit failure changes related to new fire-induced circuit failure types to assure that any conditions with greater than very low safety significance, as defined in the ROP, i.e., greater than green, are addressed. This recommendation also applies to the evaluation of MSOs.

An acceptable means of documenting the evaluation of the conditions cited above is to enter the issues from this Appendix into a licensee's Corrective Action Program and evaluating it in a manner similar to any operating experience received.

References:

1. NUREG/CR-7150, Volume 1 - Phenomena Identification and Ranking Table (PIRT) Exercise for Nuclear Power Plant Fire-Induced Electrical Circuit Failure (JACQUE-FIRE), October 2012.

2. NUREG-2128 – Electrical Cable Test Results and Analysis During Fire Exposure (ELECTRA-FIRE), June 2012.

3. EPRI TR-1003326, "Characterization of Fire-Induced Circuit Faults: Results of Cable Fire Testing," Electric Power Research Institute, Palo Alto, California, December 2002.

4. EPRI TR-1006961, "Spurious Operation of Electrical Circuits Due to Cable Fires – Results of an Expert Elicitation" Electric Power Research Institute, Palo Alto, California, May 2002.

5. NRC NUREG/CR-6931, Vol. 1, "Cable Response to Live Fire (CAROLFIRE) Volume 1: Test Descriptions and Analysis of Circuit Response Data," April 2008.

6. NRC NUREG/CR-6931, Vol. 2, "Cable Response to Live Fire (CAROLFIRE) Volume 2: Cable Fire Response Data for Fire Model Improvement," April 2008.

7. NRC NUREG/CR-6931, Vol. 3, "Cable Response to Live Fire (CAROLFIRE) Volume 3: Thermally-Induced Electrical Failure (THIEF) Model," April 2008.

8. NRC NUREG/CR-7100, "Direct Current Electrical Shorting in Response to Exposure Fire (DESIREE-FIRE): Test Result" April 2012

Appendix J
Assessment Criteria for Determining "High Consequence" Components
Table J-1

Component(s)	RCS Inventory Loss	Inventory Loss has potential to damage fuel in less than 1 hour	Containment Bypass (potential radiation release to the atmosphere)	Mitigating Measures Considered [providing adequate mitigating capability]	Comments/Conclusion
BWR – List of Components Evaluated					
1. Shutdown Cooling Suction Containment Isolation Valves	Yes	Yes~~No~~, high pressure steam-driven systems are lost due to depressurization of the RPV as a result of the break. ~~, but t~~The low pressure systems could still loss unless protected from the effects of the fire~~be available~~. Additionally, the RPV inventory loss will be outside of Primary Containment which could affect the inventory available for make-up and the availability of make-up systems through room flooding.	Yes	This condition could result in a system interfacing LOCA outside of Containment with no acceptable mitigating actions, i.e., unrecoverable. Acceptable mitigating measures include assuring "implausible" circuits failures outlined in Table J-2 will not result in an adverse impact to the components.	Since the shutdown cooling containment isolation valves are classified as "hi/lo pressure interface components" in Appendix C to NEI 00-01, they are also classified as "high consequence" components based on the potential significant and immediate consequences of this event. Acceptable mitigating measures include assuring "implausible" circuits failures outlined in Table J-2 will not result in an adverse impact to the components.
2. Spurious Opening of Multiple SRVs	Yes	Yes~~No~~, high pressure steam-driven systems are lost. ~~, but l~~Low pressure make-up capability could ~~still~~ be lost ~~available~~ if not protected from the effects of the fire.	No	The availability of low pressure make-up systems provides adequate mitigating capability for this condition. Additionally, the RCS inventory loss is directed to the Suppression Pool which keeps the inventory within a closed system. Should low pressure make-up capability not be protected from the effects of the fire and an operator manual action outside of the Control Room be required to inject with the low pressure system, then the use of this approach would not be considered to be acceptable unless the use of this approach were accompanied by a detailed thermal-hydraulic analysis and operator action timing study which demonstrates a high degree of assurance of the success of the operator action. The use of NUREG-1852 provides an acceptable approach for addressing operator action timing considerations.	SRVs are classified as "high consequence" components. Should adequate mitigating not be readily available, a significant inventory loss to the RPV could occur uncovering the core in minutes and creating a condition for imminent damage to the fuel. Acceptable mitigating measures include assuring "implausible" circuits failures outlined in Table J-2 will not result in the adversely impact the components or assuring the availability of low pressure make-up systems controllable from the Control Room or, if not controllable from the Control Room, accompanied by thermal hydraulic analysis and operator timing studies that demonstrate any actions outside of the Control Room to be feasible and reliable.

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Assessment Criteria for Determining "High Consequence" Components
Table J-1

Component(s)	RCS Inventory Loss	Inventory Loss has potential to damage fuel in less than 1 hour	Containment Bypass (potential radiation release to the atmosphere)	Mitigating Measures Considered [providing adequate mitigating capability]	Comments/Conclusion
PWR – List of Evaluated Components					
3. Shutdown Cooling Suction Isolation Valves	Yes	Yes~~No~~, if normal make-up or high head injection is not protected from the effects of the fire.	Yes	This condition could result in a system interfacing LOCA outside of containment with no acceptable mitigating actions, i.e., unrecoverable. Acceptable mitigating measures include assuring "implausible" circuits failures outlined in Table J-2 will not result in an adverse impact to the components.	Since the shutdown cooling containment isolation valves are classified as "hi/lo pressure interface components" in Appendix C to NEI 00-01, they are also classified as "high consequence" components based on the potential significant and immediate consequences of this event. Acceptable mitigating measures include assuring "implausible" circuits failures outlined in Table J-2 will not result in an adverse impact to the components.
4. PZR PORVs	Yes	Yes~~No,~~ if normal make-up or high head injection is not protected from the effects of the fire.	No, PORV relief is into containment with no radiation release to the atmosphere.	With a stuck open PORV, the time to uncover the core and, subsequent, core damage could be < one hour even with make-up. In the event of a spuriously opened PORV, closing the PORV or block valve will mitigate the effects of the event. Should PORV or block valve closure be protected from the effects of fire and be available from the Control Room the use of this approach would be considered to be acceptable. Should an operator action outside of the Control Room be required to close the PORV or block valve (e.g., from an MCC or electrical panel), this approach would not be considered to be acceptable, unless the use of this approach were accompanied by a detailed thermal-hydraulic analysis and operator action timing study which demonstrates a high degree of assurance of the success of the operator action. The use of NUREG-1852 provides an acceptable approach for addressing operator action timing considerations.	PORVs are classified as "high consequence" components. Should adequate mitigating not be readily available, a significant inventory loss to the RPV could occur uncovering the core in minutes and creating a condition for imminent damage to the fuel. Acceptable mitigating measures include assuring "implausible" circuits failures outlined in Table J-2 will not result in the adversely impact the components or assuring the capability of closing the block valve (or PZR PORV) from the Control Room or, if the valve cannot be closed from the Control Room that there is a thermal hydraulic analysis and operator timing studies that demonstrate any actions outside of the Control Room are feasible and reliable.

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Appendix J
Assessment Criteria for Determining "High Consequence" Components
Table J-1

Component(s)	RCS Inventory Loss	Inventory Loss has potential to damage fuel in less than 1 hour	Containment Bypass (potential radiation release to the atmosphere)	Mitigating Measures Considered [providing adequate mitigating capability]	Comments/Conclusion
5. Normal Letdown to CVCS Isolation Valves	Yes	No, there will be adequate make-up capability provided by virtue of the characteristics of any selected inventory make-up path that would be included on any post-fire safe shutdown path to preclude fuel damage in less than 1 hour.	Yes, letdown lines terminate outside containment.	The letdown path is normally open. Failure to isolate letdown is only an issue if makeup is also lost. Sufficient make-up capability is available as a safe shutdown inventory make-up function using the normal or high head injection flow path to offset the inventory loss. There will be adequate make-up capability provided by virtue of the characteristics of any selected inventory make-up path that would be included on any post-fire safe shutdown path to preclude fuel damage in less than 1 hour. Should normal make-up or high head injection capability not be protected from the effects of the fire and an operator manual action outside of the Control Room be required to inject with one of these systems or if an action to close one of the isolation valves required actions outside of the Control Room, then the use of this approach would not be considered to be acceptable unless the use of this approach were accompanied by a detailed thermal-hydraulic analysis and operator action timing study which demonstrates a high degree of assurance of the success of the operator action. The use of NUREG-1852 provides an acceptable approach for addressing operator action timing considerations. If it can be demonstrated that even without a positive action to isolate one of these valves, if the isolation valves would reclose on their own when the hot short clears (20 minutes for ac circuits and somewhat longer for dc circuits), this is an adequate mitigation strategy provided it is supported by thermal hydraulic analysis demonstrating reactor conditions would be acceptable after a 20 minutes flow diversion. This latter approach is acceptable, since once the hot short clears, the spurious operation will end, the valve will return to its normal position and the event will be adequately mitigated.	Since there will be adequate make-up capability provided by virtue of the characteristics of any selected inventory make-up path that would be included on any post-fire safe shutdown path, such that the potential for impact to the fuel is extended to beyond the 1 hour timeframe, the Normal Letdown Valves are **not** classified as "high consequence" components. As such, circuits for these valves do not need to be designed for the "implausible" circuit failure types listed in Table J-2. Despite this, acceptable mitigating measures do need to be applied to these valves. Acceptable mitigating measures include: • assuring the capability of closing one of the isolation valves or providing adequate make-up from the Control Room, • if an isolation valve cannot be closed from the Control Room, that there is a thermal hydraulic analysis and operator timing studies that demonstrate any actions outside of the Control Room are feasible and reliable, • if adequate make-up cannot be supplied from systems available from the Control Room, that there is a thermal hydraulic analysis and operator timing studies that demonstrate any actions outside of the Control Room are feasible and reliable, • demonstrating that adequate make-up is still available despite the flow loss through the letdown line, or • demonstrating, in conjunction with thermal hydraulic analysis, that hot shorts would clear and valves would close to restore an acceptable condition within a 20 minute time frame.

Appendix J
Assessment Criteria for Determining "High Consequence" Components
Table J-1

Component(s)	RCS Inventory Loss	Inventory Loss has potential to damage fuel in less than 1 hour	Containment Bypass (potential radiation release to the atmosphere)	Mitigating Measures Considered [providing adequate mitigating capability]	Comments/Conclusion
6. Excess Letdown to CVCS Isolation Valves	Yes	No, there will be adequate make-up capability provided by virtue of the characteristics of any selected inventory make-up path that would be included on any post-fire safe shutdown path to preclude fuel damage in less than 1 hour.	Yes, excess letdown lines terminate outside containment.	The excess letdown path is normally closed. Failure to isolate excess letdown is only an issue if makeup is also lost. There will be adequate make-up capability provided by virtue of the characteristics of any selected inventory make-up path that would be included on any post-fire safe shutdown path to preclude fuel damage in less than 1 hour. Should normal make-up or high head injection, or even RCP cooling, capability not be protected from the effects of the fire and an operator manual action outside of the Control Room be required to inject with one of these systems or if an action to close one of the isolation valves required actions outside of the Control Room, then the use of this approach would not be considered to be acceptable unless the use of this approach were accompanied by a detailed thermal-hydraulic analysis and operator action timing study which demonstrates a high degree of assurance of the success of the operator action. The use of NUREG-1852 provides an acceptable approach for addressing operator action timing considerations. If it can be demonstrated that even without a positive action to isolate one of these valves, if the isolation valves would reclose on their own when the hot short clears (20 minutes for ac circuits and somewhat longer for dc circuits), this is an adequate mitigation strategy provided it is supported by thermal hydraulic analysis demonstrating reactor conditions would be acceptable after a 20 minutes flow diversion. This latter approach is acceptable, since once the hot short clears, the spurious operation will end, the valve will return to its normal position and the event will be adequately mitigated.	Since there will be adequate make-up capability provided by virtue of the characteristics of any selected inventory make-up path that would be included on any post-fire safe shutdown path, such that the potential for impact to the fuel is extended to beyond the 1 hour timeframe, the Excess Letdown Valves are **not** classified as "high consequence" components. As such, circuits for these valves do not need to be designed for the "implausible" circuit failure types listed in Table J-2. Despite this, acceptable mitigating measures do need to be applied to these valves. Acceptable mitigating measures include: • assuring the capability of closing one of the isolation valves or providing adequate make-up from the Control Room, • if an isolation valve cannot be closed from the Control Room, that there is a thermal hydraulic analysis and operator timing studies that demonstrate any actions outside of the Control Room are feasible and reliable, • if adequate make-up cannot be supplied from systems available from the Control Room, that there is a thermal hydraulic analysis and operator timing studies that demonstrate any actions outside of the Control Room are feasible and reliable, • demonstrating that adequate make-up is still available despite the flow loss through the letdown line, or • demonstrating, in conjunction with thermal hydraulic analysis, that hot shorts would clear and valves would close to restore an acceptable condition within a 20 minute time frame.

Appendix J
~~Application of~~ PIRT Classification of Circuit Failure Types~~Results~~
Table J-2

Table J-2 – Summary of PIRT Report Circuit Failure Changes

1. Incredible (Do not need to be considered)	Comments	2. Implausible (Consider for Components classified as "high Consequence" only – Refer to Section J.3.1)	Comments	3. New Circuit Failure Type (Consider for all affected safe shutdown components)	Comments
1.1. 3-phase hot shorts for ac motors **[NUREG/CR-7150, Vol. 1, Section 4.2]**	This changes the longstanding NRC Guidance contained in NRC Generic ~~Letter 86-10 Section 5.3.~~Letter 86-10, Enclosure 2, Section 5.3.1 related to the need to consider 3-phase hot shorts for ac motors for hi/lo pressure interface components in the post-fire safe shutdown analysis.	**2.1.** Single break design – inter-cable hot short with TS – target cable/TS – source cable **[NUREG/CR-7150, Vol. 1, Section 3.3.2; Figure 3-5 & 3-6; Table 3-3, 3-6 & 3-7]**	Should have been addressed for all components previously, but now is only applicable to "High Consequence" components. This configuration bounds the base case for an inter-cable and an intra-cable hot short for cables whose conductors are TS for both the source and target cables as shown in Table 3-6 & 3-7.	**3.1.** Ground fault equivalent hot shorts (in ungrounded circuits)	All licensees will need to evaluate this new failure type for all post-fire safe shutdown components. Affects ungrounded systems only (i.e., ungrounded circuits) and should only be a concern for licensee's who did not use the hot-probe analysis method or for cables placed in dedicated raceway to avoid hot short/spurious operations.
1.2. 2 hot shorts of proper polarity for dc compound motors **[NUREG/CR-7150, Vol. 1, Section 4.3]**	This changes the longstanding NRC Guidance contained in NRC Generic ~~Letter 86-10 Section 5.3.~~Letter 86-10, Enclosure 2, Section 5.3.1 related to the need to consider proper polarity hot shorts for dc compound motors for hi/lo pressure interface components in the post-fire safe shutdown analysis.	**2.2.** Double break design – inter-cable hot shorts with TP – target cable/TS – source cable **[NUREG/CR-7150, Vol. 1, Section 3.3.2; Table 3-6 & 3-7]**	Should have been addressed previously for hi/low pressure interface components based on the NRC Memorandum, Holahan to Crutchfield dated December 4, 1990, (ML062300013), for DC Cook. For PWRs could add a few additional components requiring consideration of this configuration.		
1.3. MHIF provided the affected breaker is coordinated **[NUREG/CR-7150, Vol. 1, Section 6.1.4]**	This changes the longstanding NRC Guidance contained in NRC Generic ~~Letter 86-10 Section 5.3.~~Letter 86-10, Enclosure 2, Section 5.3.8 related to the need to consider simultaneous high impedance faults (below the trip point for the breaker on individual circuits) in the post-fire safe shutdown analysis.	**2.3.** Double break design – ungrounded dc (or ungrounded distributed ac) – 1 inter-cable hot short + 1 ground fault equivalent hot short a. TP – target cable/TS – source cable **[NUREG/CR-7150, Vol. 1, Section 3.3.2 and Table 3-6 & 3-7]**	This failure mode would likely be addressed and resolved by addressing the "double break design - – inter-cable hot shorts with TP – target cable/TS – source cable" in Item 2.2 above. Affects ungrounded systems only (i.e., ungrounded circuits) and should only be a concern for licensee's who did not use the hot-probe analysis method or for cables placed in dedicated raceway to avoid hot short/spurious operations. For PWRs could add a few additional components requiring consideration of this configuration.		
1.4. Secondary fires from an open circuited CT secondary with turns ratios of 1200:5 or less[1] **[NUREG/CR-7150, Vol. 1, Section 6.2.4]**		2.4. Double break design – 2 inter-cable hot shorts [2] a. TP – target cable/TP – source cable [NEI 00-01 Appendix J] **[NUREG/CR-7150, Vol. 1, Table 3-3, 3-6 & 3-7]**	See Section J.3.2 for the justification for this classification.		

[1] Additional cable fire testing is recommended for CT secondaries with turns ratios >1200:5. No action required until testing is completed.

[2] The cases of two inter-cable hot shorts and one inter-cable hot short plus a ground fault equivalent hot short for TP – target and sources cables has been recommended for deferral by the PIRT Panel until the FPRA Expert Panel has ruled on the likelihood of occurrence of these cases. Appendix J to NEI 00-01, however, has provided the regulatory and technical basis for classifying these cases as "implausible".

Appendix J
~~Application of~~ PIRT Classification of Circuit Failure Types~~Results~~
Table J-2

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Table J-2 – Summary of PIRT Report Circuit Failure Changes					
1. Incredible **(Do not need to be considered)**	**Comments**	**2. Implausible** **(Consider for Components classified as "high Consequence" only – Refer to Section J.3.1)**	**Comments**	**3. New Circuit Failure Type** **(Consider for all affected safe shutdown components)**	**Comments**
1.5. Single break design – inter-cable hot short with TS –target cable/TP – source cable **[NUREG/CR-7150, Vol. 1, Section 3.3.2; Table 3-3]**	This change combines with the information in 1.7 below.	**2.5.** Double break design – ungrounded dc (or ungrounded distributed ac) – 1 inter-cable hot short + 1 ground fault equivalent hot short [2] a. TP – target cable/TP – source cable [NEI 00-01 Appendix J] **[NUREG/CR-7150, Vol. 1, Table 3-3, 3-6 & 3-7]**	See Section J.3.2 for the justification for this classification.		
1.6. Double break design – inter-cable hot shorts with a. TS – target cable/TP – source cable b. TS – target cable/TS- source cable **[NUREG/CR-7150, Vol. 1, Section 3.3.2; Table 3-3 & Table 3-6 & 3-7]**	Also need to consider an inter-cable hot short and a ground fault equivalent hot short as outlined This configuration is addressed in 1.7 below.	2.6. Double break design – 2 inter-cable hot shorts a. TP – target cable/ with one TP – source cable and one TS source cable **[NEI 00-01 Appendix J]**	Since two (2) inter-cable hot shorts in a double break design using TP target and TS source cables is classified as 'implausible" based on Section 3.3.2 of the PIRT Report, 2.2 above, and since the information provided in this appendix justifies classifying two (2) inter-cable hot shorts in a double break design using TP target and source cables as 'implausible", 2.4 above, it can be concluded that a double break design requiring two (2) inter-cable hot shorts with TP target cables and one TP and one TS source cable is similarly classified as 'implausible"		
1.7. Double break design – ungrounded dc (or ungrounded distributed ac) – 1 inter-cable hot short + 1 ground fault equivalent hot short a. TS – target cable/TS – source cable **[NUREG/CR-7150, Vol. 1, Section 3.3.2 and Table 3-6 & 3-7]**	A double break design using thermoset insulated conductors and designed to eliminate the possibility of intra-cable hot shorts does not need to be considered in the post-fire safe shutdown circuit analysis based on 1.7 to the left, which eliminates consideration of interactions with other TS cables, and 1.5 to the left and above, which eliminates consideration of interactions with other TP cables.	2.7 Single break design a. inter-cable hot short with the target cable including an un-insulated grounded drain wire for a grounded ac circuit. **[NUREG/CR-7150, Vol. 1, Section 3.4.1; Figure 3-5]**	This classification holds true for all combinations of insulation on the target and source cables.		

Appendix J

~~Application of~~ PIRT Classification of Circuit Failure Types~~Results~~

Table J-2

Table J-2 – Summary of PIRT Report Circuit Failure Changes					
1. Incredible **(Do not need to be considered)**	**Comments**	**2. Implausible** **(Consider for Components classified as "high Consequence" only – Refer to Section J.3.1)**	**Comments**	**3. New Circuit Failure Type** **(Consider for all affected safe shutdown components)**	**Comments**
1.8 Single or double break circuit designs involving at least one inter-cable hot short with the target cable including a. A grounded metal, foil shield wrap, or b. An Armored cable design **[NUREG/CR-7150, Vol. 1, Section 3.4.1; Figure 3-5, 3-6 & 3-7; Table 3-6 & 3-7]**	This classification holds true for all combinations of insulation on the target and source cables. This classification also includes for the double break design two inter-cable hot shorts, one inter-cable hot short plus one intra-cable hot short and one inter-cable hot short plus one ground equivalent hot short.				

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