Technical Justification for Appendix J to NEI 00-01

1.0) Purpose:

The purpose of this paper is to provide the technical justification for the circuit failure type classifications, e.g., incredible, implausible, plausible, provided in Appendix J to NEI 00-01. Differences between Appendix J to NEI 00-01 and JACQUE-FIRE Volumes 1 based on the insights provided in JACQUE-FIRE Volume 2 are also addressed in this paper.

The circuit failure classifications discussed in this paper are summarized in Appendix J to NEI 00-01. Appendix J to NEI 00-01 provides implementing guidance to the nuclear power industry for application of the results presented in Joint Assessment of Cable Damage and Quantification of Effects from Fires (JACQUE-FIRE), NUREG/CR-7150 Volume 1 / EPRI 1026424, "Phenomena Identification and Ranking Table (PIRT) Exercise for Nuclear Power Plant Fire-Induced Electrical Circuit Failure" and Joint Assessment of Cable Damage and Quantification of Effects from Fires (JACQUE-FIRE), NUREG/CR-7150 Volume 2 / EPRI 3002001989, "Expert Elicitation 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." NUREG/CR-7150 Volume 1 may also be referred to as the "PIRT Report." The group who prepared the PIRT Report may also be referred to in this paper as the "PIRT Panel". NUREG/CR-7150 Volume 2 may also be referred to as the "PRA Expert Panel Report". The group who prepared the PRA Expert Panel Report may also be referred to in this paper as the "PRA Expert Panel". The term "JACQUE-FIRE Volume 1 and 2" may also be used when referring to both reports in this paper.

The justification for any differences identified in the work by the PIRT Panel and the PRA Expert Panel are reconciled in NUREG/CR-7150 Volume 3, JACQUE-FIRE Volume 3[1] by the JACQUE-FIRE Volume 3 Working Group. The documents involved in this process are depicted in Figure 1.0 below.

Figure 1.0

[1] Seven of the eight members of the Working Group for JACQUE-FIRE Volume 3 were members of the PIRT Panel for JACQUE-FIRE Volume 1. Three of these seven members were also part of the PRA Expert Panel Process for JACQUE-FIRE Volume 2.

2.0) Background:

The PIRT Panel in JACQUE-FIRE Volume 1 provided technical recommendations for the classification of certain fire-induced circuit failures associated with control and power circuits as they pertain to the analysis of post-fire safe shutdown circuits. The classifications are either "plausible", "implausible" or "incredible". The PIRT Panel deferred providing a classification for the case of two (2) inter-cable hot shorts on thermoplastic insulated conductors. This case is included in JACQUE-FIRE Volume 1, Table 3-3. The classification of this latter case was deferred until completion of the probability of occurrence work by the PRA Expert Panel in JACQUE-FIRE Volume 2.

JACQUE-FIRE Volume 1 provided input to the PRA Expert Panel who developed hot short induced spurious operation conditional probabilities, as documented in NUREG/CR-7150, Volume 2. Although the PRA Expert Panel in JACQUE-FIRE Volume 2 did not specifically review all of the recommended classifications provided by the PIRT Panel in JACQUE-FIRE Volume 1, the work performed by the PRA Expert Panel did provide insights for enhancing the recommendations provided by the PIRT Panel.

JACQUE-FIRE Volume 3 provides a recommendation for classifying the JACQUE-FIRE Volume 1 Table 3-3 case of two (2) inter-cable hot shorts on thermoplastic insulated conductors, as well as, enhancing the recommendations from JACQUE-FIRE Volume 1 based on the insights gained from JACQUE-FIRE Volume 2, refer to Table 1.0 and 2.0 below.

In performing this work, the JACQUE-FIRE Volume 3 Working Group changed some of the classification recommendations provided in JACQUE-FIRE Volume 1. The technical justification for the final positions taken by the JACQUE-FIRE Volume 3 Working Group on the classification of fire-induced circuit failures is documented below and summarized in Table 3.0 below.

3.0) Changes Included:

The following changes to the conclusions provided in JACQUE-FIRE Volume 1 are recommended by the JACQUE-FIRE Volume 3 Working Group based on the risk-insights from JACQUE-FIRE Volume 2.

1. Consideration of insulation type for the aggressor (i.e., source) cable conductors is eliminated. The classifications provided by the PIRT Panel in JACQUE-FIRE Volume 1 were predicated on the insulation characteristics of both the aggressor (i.e., source) and target conductors. The PRA Expert Panel in JACQUE-FIRE Volume 2 eliminated consideration of the insulation characteristics on the aggressor (i.e., source) conductor. For the reasons cited below, the JACQUE-FIRE Volume 3 Working Group also eliminates consideration of the insulation characteristics of the aggressor (i.e., source) conductor in determining their final classification for each of the circuit failure types. The elimination of consideration of the insulation characteristics of the aggressor (i.e., source) conductor, in some cases, contributes to the change in classification of a circuit failure type.

2. The classification of an inter-cable hot short for thermoset insulated conductors is changed from "implausible" to "plausible". This change impacts the classification of circuit failure types for both single and double break designed circuits, refer to the Table 1.0 and 2.0.
3. Due to the similarity in circuit failure type classification, ungrounded AC single break designed circuits from a common CPT are grouped with ungrounded DC and ungrounded distributed AC circuits for purposes of classifying the circuit failure type. Refer to Table 1.0.
4. The PIRT Panel in JACQUE-FIRE Volume 1, Table 3-3 deferred classifying the case of two (2) inter-cable hot shorts for a double break designed circuit with thermoplastic insulated conductors until the PRA Expert Panel completed their likelihood of occurrence work in JACQUE-FIRE Volume 2 for this case. This case and other similar cases were reviewed by the JACQUE-FIRE Volume 3 Working Group based on insights from JACQUE-FIRE Volume 3 to determine the classification appropriate for the likelihood of occurrence. As a result of this review, a recommended classification of "implausible" for latching circuits and "incredible" for non-latching circuits was developed. This classification was applied to other circuit failure types with similar likelihood of occurrence. Refer to Table 2.0.

4.0) Technical Justification for Changes:

The reasons for making the changes cited above and the technical justification for each change is provided below.

4.1) Description of Change 1 - Consideration of insulation type on the conductors for the aggressor (i.e., source) cable conductors is eliminated.

Reason for Change 1:

The classifications provided by the PIRT Panel in JACQUE-FIRE Volume 1 were predicated on the insulation characteristics of both the aggressor (i.e., source) and target conductors. The PRA Expert Panel in JACQUE-FIRE Volume 2 did not determine probabilities of occurrence for conductor insulation type on the aggressor (i.e., source) conductors, due to the impracticality of tracking, from a configuration control perspective, the conductor insulation type for all possible aggressor (i.e., source) conductors. This made a one-to-one comparison between the classifications made in JACQUE-FIRE Volume 1 with the relative probabilities of occurrence determined in JACQUE-FIRE Volume 2 impossible. As such, in the determination made by the JACQUE-FIRE Volume 3 Working Group, the classifications are revised to be a function of the conductor insulation on the target conductor only.

Technical Justification for Change 1:

Other than in specifically controlled circumstances, identification and design configuration control of all insulation types on all conductors in each raceway is a difficult, if not impossible, task from a practical perspective. Thus, elimination of the classifications based on both target and aggressor (i.e., source) conductor insulation types is fully consistent with typical capabilities of the existing design organizations and the cable and raceway management systems within the nuclear power industry. Although insulation types for most conductors in a nuclear power plant are known and controlled, the task of comparing and controlling the insulation types for all conductors on a raceway-by-raceway basis is an unreasonable configuration control expectation.

4.2) Description of Change 2 – The classification of an inter-cable hot short for thermoset insulated conductors is changed from "implausible" to "plausible". This change impacts the classification of circuit failure types for both single and double break designed circuits, refer to the Table 1.0 and 2.0.

Reason for Change 2:

The PRA Expert Panel in JACQUE-FIRE Volume 2 determined the probability of occurrence for a single inter-cable hot short on a single break grounded AC circuit with a TS insulated conductor to be on the order of 1E-02. Similarly, the PRA Expert Panel in JACQUE-FIRE Volume 2 determined the probability of occurrence for a single inter-cable hot short on a single break ungrounded AC or DC circuit with a TS insulated conductor to be on the order of 6.3E-03. The PIRT Panel previously classified these circuit failure types as "implausible".

In reviewing the test data used by the PRA Expert Panel to develop their probabilities, the JACQUE-FIRE Volume 3 Working Group concluded that the test data, in fact, did support a higher probability of occurrence for a single inter-cable hot short on a single break grounded AC circuit with a TS insulated conductor and that the probability established by the PRA Expert Panel did **not** support a classification of "implausible". Accordingly, the JACQUE-FIRE Volume 3 Working Group changed the classification for a single inter-cable hot short on a single break grounded AC, ungrounded distributed AC and ungrounded DC circuit with a TS insulated conductor to "plausible".

Due to this change and the higher probability of occurrence of intra-cable hot shorts (i.e., on the order of 0.28 to 0.64), the classification for double break designed circuits with thermoset insulated conductors requiring an inter-cable hot short and an intra-cable hot short is also changed from "implausible" to "plausible".

Technical Justification for Change 2:

With respect to the single inter-cable hot short on a single break grounded AC circuit, the following discussion applies. The PRA Expert Panel used eight (8) inter-cable interactions from the EPRI Testing and one (1) inter-cable interaction from the CAROLFIRE IRMS Testing as evidence to support their elicitation for calculating the conditional probability of occurrence. In reviewing this data, the JACQUE-FIRE Volume 3 Working Group concludes that seven (7) of the eight (8) interactions in the EPRI Testing are valid and representative of actual plant fire conditions for specific configurations. The only interaction questioned is the interaction in EPRI Test #3. This interaction was questioned because the cable tray was inadvertently ungrounded in this test. The lack of grounding may have contributed in some way to the inter-cable interactions. Additionally, in CAROLFIRE Test IT-1 valid indications of inter-cable interactions were found. Finally, in the DESIREE Inter-cable Testing, Section 6.5 of the DESIREE Report, many of the cable bundles showed signs of inter-cable interactions. For this testing, however, spurious operations did not occur because this testing was designed to simulate a double break circuit design that would require two circuit failure interactions in order for a spurious operation to occur. Although the DESIREE testing did effectively show the very low likelihood of spurious operations in double break circuit designs, the cable interactions observed during the testing preclude eliminating this failure mode for single break designs, since a number of the tested configurations showed indications of a number of single inter-cable interactions.

The JACQUE-FIRE Volume 3 Working Group concludes that intra-cable hot shorts would, in an overwhelming number of cases, be the first fire-induced circuit failure mode for multi-conductor cables and that this failure mode bounds the effects of inter-cable hot shorts. Despite this, with respect to single conductor, or even multi-conductor, cable configurations in grounded AC, ungrounded AC or ungrounded DC circuits, conductor interactions involving external hot shorts are likely to appear with the same frequency seen in the Industry and NRC Cable Fire Tests where a path to ground or to a grounded conductor does not readily exist. This likelihood, estimated by the PRA Expert Panel to be on the order of 1E-02, does **not** support a classification of "implausible". Based on this information, the JACQUE-FIRE Volume 3 Working Group recommends a classification of "plausible" for inter-cable hot shorts in grounded AC, ungrounded distributed AC and ungrounded DC circuits where the target conductor has TS insulation. It is recognized by the JACQUE-FIRE Volume 3 Working Group that the same classification is being used for cases ranging in probability from 1E-02 to about .64, which is a broad range. Regardless, within the bounds of a deterministic analysis, "plausible" will inevitably cover a broad range of fault types and likelihoods.

Due to this change and the higher probability of occurrence of intra-cable hot shorts (i.e., on the order of 0.28 to 0.64), the classification for double break designed circuits with thermoset insulated conductors requiring an inter-cable hot short and an intra-cable hot

short is also recommended by the JACQUE-FIRE Volume 3 Working Group to be changed from “implausible” to “plausible”.

Table 1.0 - Single Break Control Circuits					
Power Supply	**Grounded AC**		**Ungrounded AC (from CPT[2] or distributed) or DC**		
	Conductor Hot Short Failure Mode				
Target Cable Configuration	**Intra-Cable**	**Inter-Cable**	**Intra-Cable**	**Inter-Cable**	**Ground Fault Equivalent**
Thermoset Insulated Conductor Cable	Plausible	Plausible[3]	Plausible	Plausible[4]	Plausible
Thermoplastic Insulated Conductor Cable	Plausible	Plausible	Plausible	Plausible	Plausible
Metal Foil Shield Wrap Cable	Plausible	Incredible	Plausible	Incredible[5]	Plausible
Armored Cable	Plausible	Incredible	Plausible	Incredible[6]	Plausible

[2] Ungrounded AC from common CPT included with distributed ungrounded AC and ungrounded DC. Refer to Technical Justification for Change 3. For the classification of the special case of an isolated target conductor also refer to the Technical Justification for Change 4.
[3] Classification changed from "implausible" to "plausible". Refer to Technical Justification for Change 2.
[4] Classification changed from "implausible" to "plausible". Refer to Technical Justification for Change 2.
[5] The shield wrap or the armor prevents a conductor from an external cable from interfacing directly with the target conductor. A GFEHS on the metal foil shield or armor, however, can cause a spurious operation. The plausibility of this phenomenon is addressed in the Column for Ground Fault Equivalent.
[6] The shield wrap or the armor prevents a conductor from an external cable from interfacing directly with the target conductor. A GFEHS on the metal foil shield or armor, however, can cause a spurious operation. The plausibility of this phenomenon is addressed in the Column for Ground Fault Equivalent.

Table 2.0 - Double Break Control Circuits (includes single break control circuits with control power fuses removed) [Ungrounded AC w/CPTs, Ungrounded DC (Ungrounded AC w/o CPTs)]					
Target Cable Configuration	**Intra-Cable & Intra-Cable**	**Intra-Cable & Inter-Cable**	**Inter-Cable & Inter-Cable**	**Intra-Cable & Ground Fault Equivalent**	**Inter-Cable & Ground Fault Equivalent**
Thermoset Insulated Conductor Cable	Plausible	Plausible[7]	Incredible[8]	Plausible	Implausible (latching)[9] Incredible (non-latching)
Thermoplastic Insulated Conductor Cable	Plausible	Plausible	Implausible (latching)[10] Incredible (non-latching)	Plausible	Implausible (latching)[11] Incredible (non-latching)
Metal Foil Shield Wrap Cable	Plausible	Incredible[12]	Incredible	Plausible	Incredible
Armored Cable	Plausible	Incredible[13]	Incredible	Plausible	Incredible

[7] Classification changed from "implausible" to "plausible". Refer to justification for Change 2.
[8] Refer to Change 4 for the justification for this classification.
[9] Classification changed to "implausible" for latching circuits and "incredible" for non-latching circuits. Refer to Technical Justification for Change 4.
[10] Classification changed to "implausible" for latching circuits and "incredible" for non-latching circuits. Refer to Technical Justification for Change 4.
[11] Classification changed to "implausible" for latching circuits and "incredible" for non-latching circuits. Refer to Technical Justification for Change 4.
[12] The shield wrap or the armor prevents a conductor from an external cable from interfacing directly with the target conductor. A GFEHS on the metal foil shield or armor, however, can cause a spurious operation. The plausibility of this phenomenon is addressed under the Column for Intra-Cable & Ground Fault Equivalent.
[13] The shield wrap or the armor prevents a conductor from an external cable from interfacing directly with the target conductor. A GFEHS on the metal foil shield or armor, however, can cause a spurious operation. The plausibility of this phenomenon is addressed under the Column for Intra-Cable & Ground Fault Equivalent.

4.3) Description of Change 3 –Due to the similarity in circuit failure type classification, ungrounded AC single break designed circuits from a common CPT are grouped with ungrounded DC and ungrounded distributed AC circuits for purposes of classifying the circuit failure type. Refer to Table 1.0.

Reason for Change 3

Ungrounded AC single break designed circuits from a common CPT will behave very similarly to ungrounded distributed AC or ungrounded DC single break design circuits, unless the target conductor required for spurious operation is isolated from other possible aggressor conductors off of the same CPT. Since a circuit configuration with the target conductor isolated is more of a very limited exception rather than the rule for ungrounded circuits off of a common CPT, the classifications for this circuit type are lumped in with the classification for ungrounded distributed AC and ungrounded DC. The very limited exception is described as such in Appendix J to NEI 00-01 and an alternative classification is provided as a part of that description.

Technical Justification for Change 3

Typically, an ungrounded AC circuit from an individual CPT will have multiple cables as a part of the circuit: One (1) cable running from the MCC to the valve; One (1) cable running from the MCC to the Control Room; and possibly other cables running to interlock or permissive contacts. With this configuration, depending on the routing of the two (2) cables, interactions between the two (2) cables, either an inter-cable hot short or GFEHS, can cause a spurious operation. Either of these circuit failure types would be classified as “plausible”. In addition, ungrounded CPT configurations may have conductors from both legs (i.e., positive and neutral) that leave the MCC. In these configurations, if either CPT conductor is grounded due to fire damage, the likelihood of hot shorts on the opposite ungrounded conductor from aggressor circuits changes from only those conductors powered by the individual CPT to any grounded aggressor circuit (i.e., grounded by the fire or grounded by design). This configuration would make the hot short probability more like that of ungrounded distributed AC and ungrounded DC.

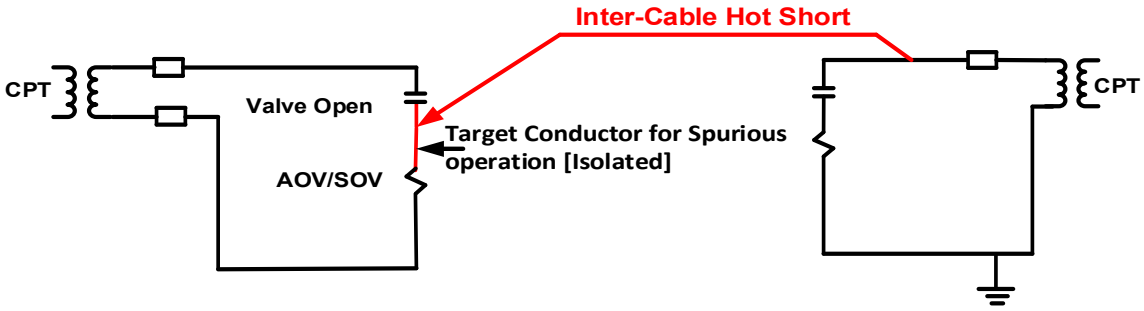
For the “special case” where the target conductor required for the spurious operation is isolated from any other conductors associated with the CPT powering the circuit, a single inter-cable hot short or a GFEHS cannot cause a spurious operation. The figures below describe this circuit.

- For this “special case”, a spurious operation cannot be caused by a single inter-cable hot short (or GFEHS) since there is no aggressor conductor from the same CPT with the potential to interact with the target conductor that can be affected by the same fire, refer to Figure 2.0.

- For a spurious operation to occur, either two (2) inter-cable hot shorts or an inter-cable hot short in combination with a GFEHS from a common power source would be required, refer to Figure 3.0.

- If the aggressor circuit were a grounded AC circuit, then a spurious operation could occur with one (1) inter-cable hot short and a ground, refer to Figures 4.0 and 5.0.

This latter combination of fire-induced circuit failures is similar to the types of circuit failures required to cause a spurious operation in a double break designed circuit. Therefore, for this special case of an isolated target conductor, the classification is the same as for the similar double break designed circuits. Refer to the technical justification for Change 4. Without an isolated target conductor, the classification is "plausible".



Target Circuit - Ungrounded AC

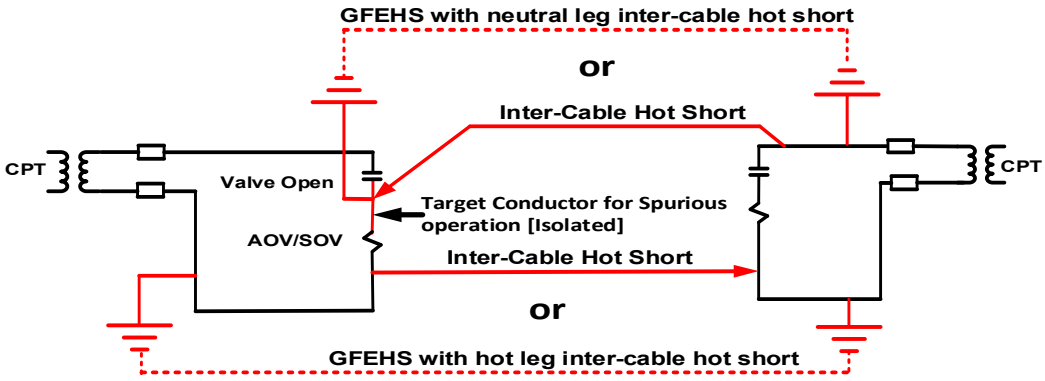
Aggressor Circuit – Grounded AC

Possible Spurious Operations:

1. Spurious Operation not possible since the single inter-cable hot short is from a separate CPT.

Sub-case 1 – Single Inter-cable Hot short

Figure 2.0



Target Circuit - Ungrounded AC

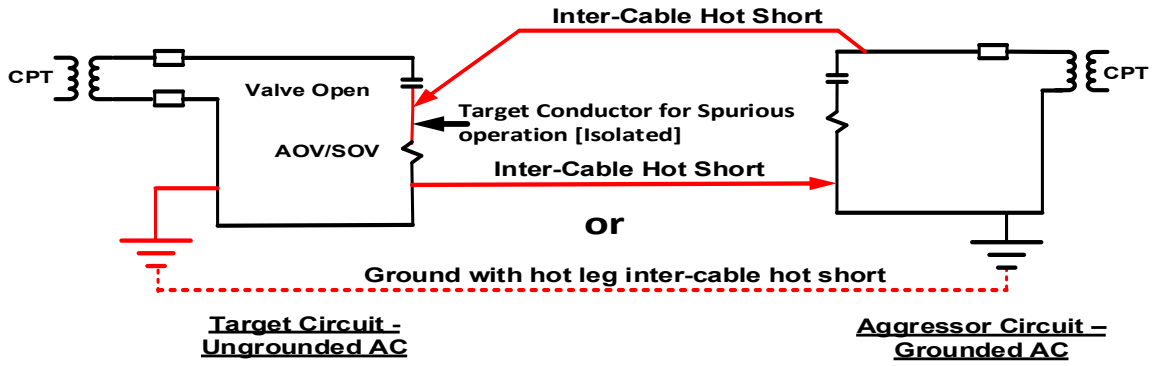
Aggressor Circuit – Ungrounded AC

Possible Spurious Operations:

1. Two (2) inter-cable hot shorts.
2. One (1) inter-cable hot short (hot leg) and one (1) GFEHS (neutral leg).
3. One (1) inter-cable hot short (neutal leg) and one (1) GFEHS (hot leg).

Sub-case 2 – Multiple Inter-cable Hot Shorts or Single Inter-cable Hot Short & GFEHS

Figure 3.0

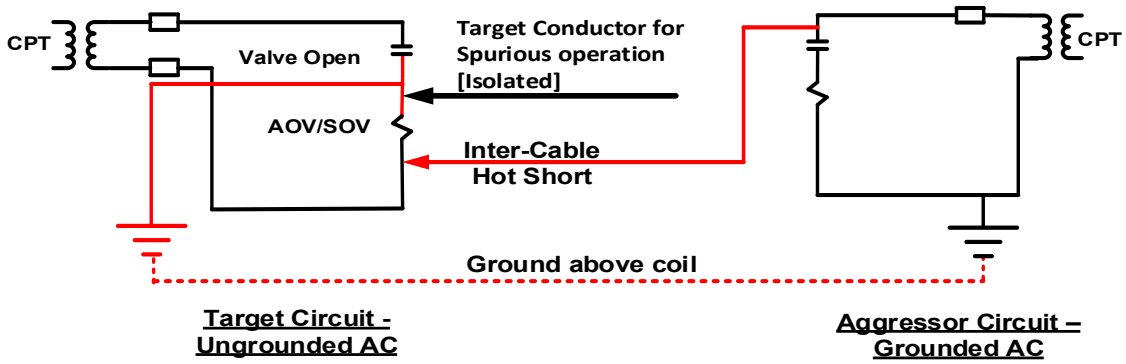


Possible Spurious Operations:

1. Two (2) inter-cable hot shorts.
2. One (1) inter-cable hot short (hot leg) and one (1) ground (neutral leg).

Sub-case 3a – Inter-cable Hot Short & Ground

Figure 4.0



Possible Spurious Operations:

1. One (1) inter-cable hot short (below coil) and one (1) ground (above coil).

Sub-case 3b - Inter-cable Hot Short & Ground [reverse polarity]

Figure 5.0

4.4) Description of Change 4 - The PIRT Panel in JACQUE-FIRE Volume 1, Table 3-3 deferred classifying the case of two (2) inter-cable hot shorts for a double break designed circuit with thermoplastic insulated conductors until the PRA Expert Panel completed their likelihood of occurrence work in JACQUE-FIRE Volume 2 for this case. This case and other similar cases were reviewed by the JACQUE-FIRE Volume 3 Working Group based on insights gained from JACQUE-FIRE Volume 2 to determine the classification appropriate for the likelihood of occurrence. As a result of this review, a recommended classification of "implausible" for latching circuits and "incredible" for non-latching circuits was developed. This classification was applied to other circuit failure types with similar likelihood of occurrence. Refer to Table 2.0 above.

Reason for Change 4:

The PIRT Panel in JACQUE-FIRE Volume 1, Table 3-3 deferred classifying the case of two (2) inter-cable hot shorts for a double break designed circuit with thermoplastic insulated conductors until the PRA Expert Panel completed their likelihood of occurrence work in JACQUE-FIRE Volume 2 for this case. Insights provided by the PRA Expert Panel in JACQUE-FIRE Volume 2 are used here by the JACQUE-FIRE 3 Working Group to develop a classification for this case.

As a result of this review, a recommended classification of "implausible" for latching circuits and "incredible" for non-latching circuits was developed. This classification was applied to other circuit failure types with similar likelihood of occurrence as listed below.

- The case of a double break designed circuit subjected to one (1) inter-cable hot short and one (1) GFEHS with thermoset (TS) insulated target conductors.
- The case of a double break designed circuit subjected to one (1) inter-cable hot short and one (1) GFEHS with thermoplastic (TP) insulated target conductors.
- The case of a double break designed circuit subjected to two (2) inter-cable hot shorts with thermoplastic (TP) insulated target conductors.
- The special case of an ungrounded AC single break designed circuit from a common CPT with an isolated target conductor as described in Change 3 above.

Technical Justification for Change 4:

Double break designed circuits with thermoset and thermoplastic insulated conductors were specifically tested in the DESIREE test program for the occurrence of inter-cable hot shorts. The inter-cable testing performed under the DESIREE testing program is discussed in Section 6.5 and Appendix A.5 of the DESIREE Testing Program. Although a limited number of single cable-to-cable interactions did occur, there were no instances where the two cable-to-cable interactions required to produce a spurious operation occurred. In no case for all tests performed did a spurious operation occur. This testing

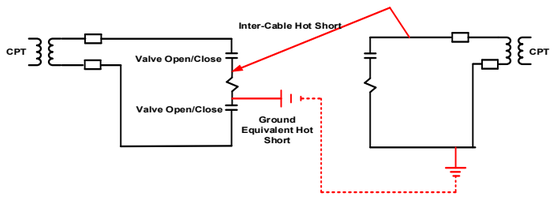
forms a solid basis for concluding that the occurrence of two (2) inter-cable hot shorts on a double break designed circuit with thermoset insulted conductors is "incredible". In Penlight Test #47, however, which used TP insulated conductors there were signs of a voltage cascade across the target conductors starting to form, but the voltage was insufficient to cause a spurious operation. This result suggests that the likelihood of two (2) inter-cable hot shorts in double break designed circuits with TP insulated conductors is slightly more likely than for thermoset insulated conductors. Based on this, in Table J-2 of Appendix J to NEI 00-01, the case of a double break design with two (2) inter-cable hot shorts with TS insulated conductors is classified as "incredible" and the case of a double break design with two (2) inter-cable hot shorts with TP insulated conductors is classified as "incredible" for non-latching circuits and "implausible" for latching circuits.

Other than in the DESIREE Inter-cable test circuit testing described above, the double break configuration with TP target and aggressor (i.e., source) cables was not specifically tested in any of the other 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 reference ground removing the potential from the circuit; (2) the exposed conductors (target) could contact exposed conductors from adjacent cables (i.e., source) transferring potential and, if the potential has the correct characteristics, a spurious operation could result. In the cable fire testing performed, only a few instances of inter-cable hot shorts between TP insulated cables were observed. With respect to double break designed circuits, the testing cited above provides a good basis for the classification of circuit failure modes involving two (2) inter-cable hot shorts in cables with either TS or TP insulated conductors. Due to a lack of specific testing performed with respect to circuit failure modes involving one (1) inter-cable hot short and one (1) ground fault equivalent hot shorts (or a ground for the case of a grounded ac aggressor circuit), the insights for classifying this circuit failure type comes from the information provided by the PRA Expert Panel in JACQUE-FIRE Volume 2.

The possible failure modes for double break designed circuits involving an inter-cable hot short and a ground fault equivalent hot short (or a ground in the case of a grounded ac aggressor circuit) are depicted in Figures 6.0 through 11.0 below. Figures 6.0 through 11.0 include actual double break designed circuits which use an open contact above and below the actuating device and "pseudo" double break designed circuits which are single break design circuits with their control power fuses removed giving them similar characteristics for preventing spurious actuation to the actual double break designed circuits.

Technical Justification for Appendix J to NEI 00-01

Case 1



Ungrounded AC [Spurious Operation]

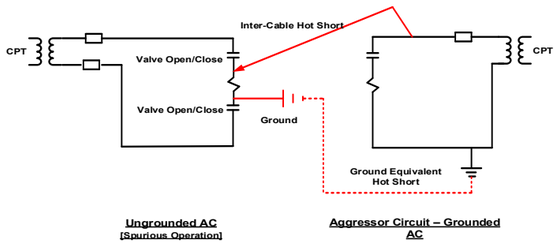
Aggressor Circuit – Ungrounded AC

Notes:
1. For this case, the classification is "implausible" for latching circuits and "incredible" for non-latching circuits. The classification of this circuit failure combination is bounded by the classification of the circuit for Case 2 involving an inter-cable hot short and a ground.

"implausible" for latching circuits and "incredible" for non-latching circuits

General Notes:
1. The cases shown in this figure depict a specific proper polarity alignment. By depicting only one proper polarity alignment, there is no intent to exclude other proper polarity alignments. Other proper polarity alignments may also apply. Additionally, the potential exists for an aggressor ac circuit to energize a dc coil and an aggressor dc circuit to energize an ac coil, if specific conditions exist. For a detailed discussion of the sub-cases with alternate proper polarity alignments and how they are to be addresses, refer to the section of this document on proper polarity. Regardless of the proper polarity alignment of any of the sub-cases, the circuit failure type classification, e.g., "implausible", is not changed.

Case 2



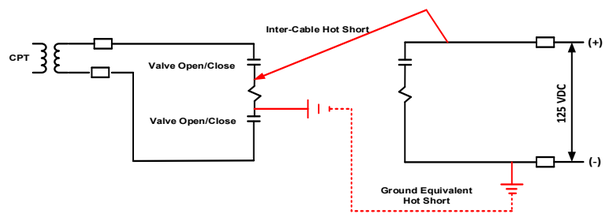
Ungrounded AC [Spurious Operation]

Aggressor Circuit – Grounded AC

Notes:
1. For this case, the classification is "implausible" for latching circuits and "incredible" for non-latching circuits. Although the required circuit failure types are an inter-cable hot short and a ground, the inter-cable hot short must come from a specific circuit type, i.e., a grounded AC circuit. Additionally, the inter-cable hot short from the aggressor (i.e., source) grounded AC circuit cannot go to ground prior to the ground forming on the target circuit. Once the inter-cable hot short on the aggressor (i.e., source) grounded AC circuit goes to ground, the control power fusing on the aggressor circuit will blow and remove the potential for the spurious operation. This circuit failure timing consideration, in combination with the likelihood a circuit grounds and the unlikelihood of these two (2) specific circuit types both becoming involved, makes this combined failure mode of sufficiently low likelihood to classify it as "implausible" for latching circuits. The additional timing considerations for a non-latching circuits makes the classification of this case, "incredible" for non-latching circuits.

"implausible" for latching circuits and "incredible" for non-latching circuits

Case 3



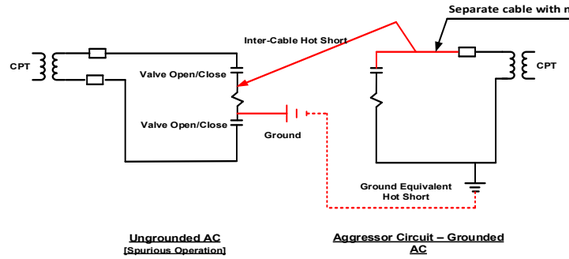
Ungrounded AC [Spurious Operation]

Aggressor Circuit – Ungrounded DC

Notes:
1. For this case, the classification is "implausible" for latching circuits and "incredible" for non-latching circuits. The classification of this circuit failure combination is bounded by the classification of the circuit for Case 2 involving an inter-cable hot short and a ground.

"implausible" for latching circuits and "incredible" for non-latching circuits

Case 4



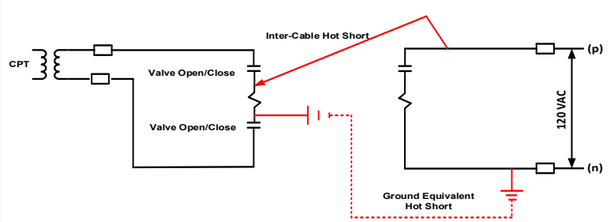
Ungrounded AC [Spurious Operation]

Aggressor Circuit – Grounded AC

Notes:
1. For this case, the classification is "implausible" for latching circuits and "incredible" for non-latching circuits. This case is similar to Case 2 with the exception that it assumes that the possible aggressor conductor is contained within a cable with no grounded conductor. This condition, however, is judged to have very limited impact on the classification, since for an inter-cable hot short to occur, the aggressor conductor must be exposed. With the aggressor conductor exposed, the likelihood of it coming into contact with the ground plane is by far the most likely outcome. Once the exposed aggressor conductor contacts the ground plane the control power fuse for the aggressor circuit will blow eliminating the possibility of a spurious operation. The other aspects of this circuit performance for this case are identical to those described for Case 2.

"implausible" for latching circuits and "incredible" for non-latching circuits

Case 5



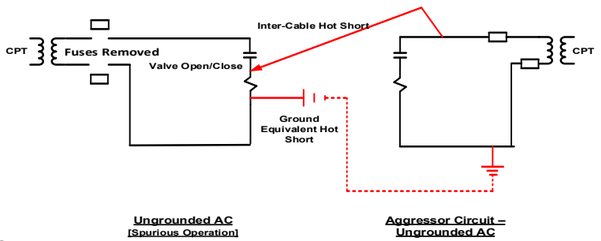
Ungrounded AC [Spurious Operation]

Aggressor Circuit – Ungrounded AC

Notes:
1. For this case, the classification is "implausible" for latching circuits and "incredible" for non-latching circuits. This case is bounded by Case 2.

"implausible" for latching circuits and "incredible" for non-latching circuits

Figure 6.0 - Ungrounded AC from a CPT – Double Break Design

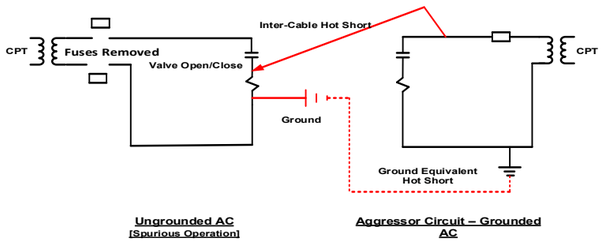


Case 1a

Notes:
1. This case is considered to be equivalent to Case 1, since the conductors above and below the coil are still the only conductors that can be involved in causing the spurious operation.

"implausible" for latching circuits and "incredible" for non-latching circuits

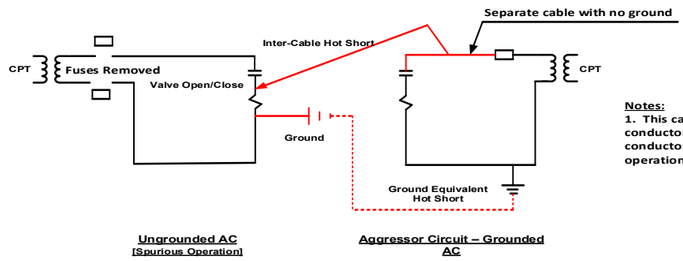
General Notes:
1. The cases shown in this figure depict a specific proper polarity alignment. By depicting only one proper polarity alignment, there is no intent to exclude other proper polarity alignments. Other proper polarity alignments may also apply. Additionally, the potential exists for an aggressor ac circuit to energize a dc coil and an aggressor dc circuit to energize an ac coil, if specific conditions exist. For a detailed discussion of the sub-cases with alternate proper polarity alignments and how they are to be addresses, refer to the section of this document on proper polarity. Regardless of the proper polarity alignment of any of the sub-cases, the circuit failure type classification, e.g., "implausible", is not changed.



Case 2a

Notes:
1. This case is considered to be equivalent to Case 2, since the conductors above and below the coil are still the only conductors that can be involved in causing the spurious operation.

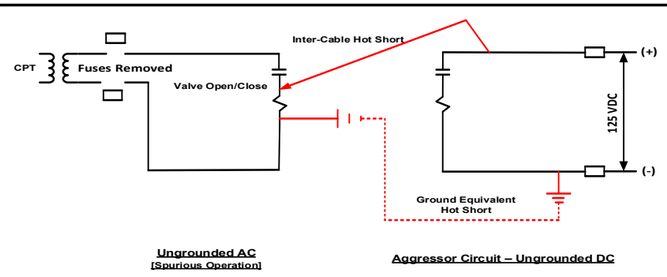
"implausible" for latching circuits and "incredible" for non-latching circuits



Case 4a

Notes:
1. This case is considered to be equivalent to Case 4, since the conductors above and below the coil are still the only conductors that can be involved in causing the spurious operation.

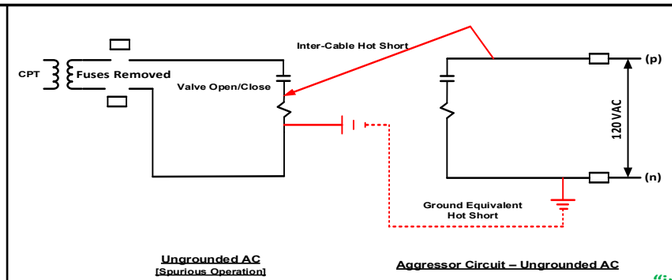
"implausible" for latching circuits and "incredible" for non-latching circuits



Case 3a

Notes:
1. This case is considered to be equivalent to Case 3, since the conductors above and below the coil are still the only conductors that can be involved in causing the spurious operation.

"implausible" for latching circuits and "incredible" for non-latching circuits

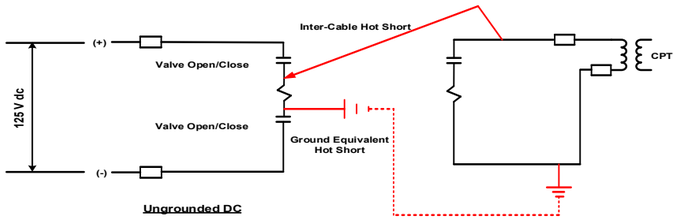


Case 5a

Notes:
1. This case is considered to be equivalent to Case 5, since the conductors above and below the coil are still the only two conductors that can be involved in causing the spurious operation.

"implausible" for latching circuits and "incredible" for non-latching circuits

Figure 7.0 - Ungrounded AC from a CPT – Pseudo-Double Break Design

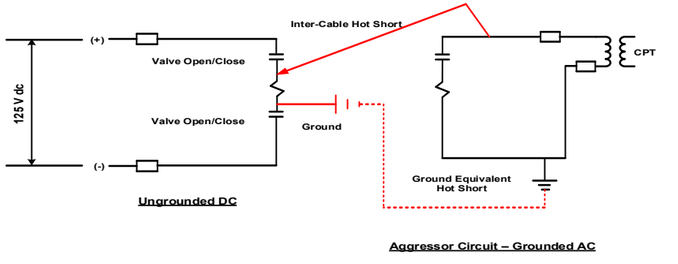


Case 6

Notes:
1. For this case, the classification is "implausible" for latching circuits and "incredible" for non-latching circuits. The classification of this circuit failure combination is bounded by the classification of the circuit for Case 7 involving an inter-cable hot short and a ground.

"implausible" for latching circuits and "incredible" for non-latching circuits

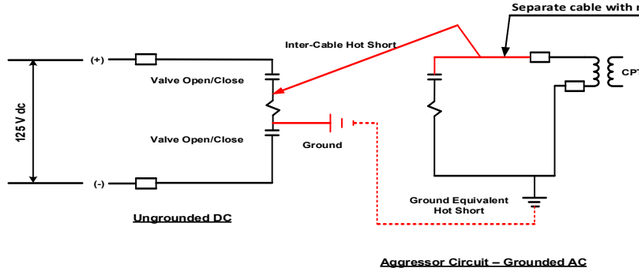
General Notes:
1. The cases shown in this figure depict a specific proper polarity alignment. By depicting only one proper polarity alignment, there is no intent to exclude other proper polarity alignments. Other proper polarity alignments may also apply. Additionally, the potential exists for an aggressor ac circuit to energize a dc coil and an aggressor dc circuit to energize an ac coil, if specific conditions exist. For a detailed discussion of the sub-cases with alternate proper polarity alignments and how they are to be addresses, refer to the section of this document on proper polarity. Regardless of the proper polarity alignment of any of the sub-cases, the circuit failure type classification, e.g., "implausible", is not changed.



Case 7

Notes:
1. For this case, the classification is "implausible" for latching circuits and "incredible" for non-latching circuits. Although the required circuit failure types are an inter-cable hot short and a ground, the inter-cable hot short must come from a specific circuit type, i.e., a grounded AC circuit. Additionally, the inter-cable hot short from the aggressor (i.e., source) grounded AC circuit cannot go to ground prior to the ground forming on the target circuit. Once the inter-cable hot short on the aggressor (i.e., source) grounded AC circuit goes to ground, the control power fusing on the aggressor circuit will blow and remove the potential for the spurious operation. This circuit failure timing consideration, in combination with the likelihood a circuit grounds and the unlikelihood of these two (2) specific circuit types both becoming involved, makes this combined failure mode of sufficiently low likelihood to classify it as "implausible". The additional timing considerations for a non-latching circuits makes the classification of this case, "incredible" for non-latching circuits.

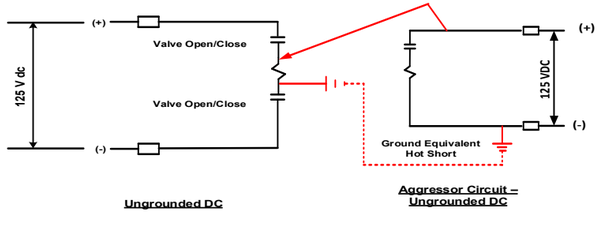
"implausible" for latching circuits and "incredible" for non-latching circuits



Case 9

Notes:
1. For this case, the classification is "implausible" for latching circuits and "incredible" for non-latching circuits. This case is similar to Case 7 with the exception that it assumes that the possible aggressor conductor is contained within a cable with no grounded conductor. This condition, however, is judged to have very limited impact on the classification, since for an inter-cable hot short to occur, the aggressor conductor must be exposed. With the aggressor conductor exposed, the likelihood of it coming into contact with the ground plane is by far the most likely outcome. Once the exposed aggressor conductor contacts the ground plane the control power fuse for the aggressor circuit will blow eliminating the possibility of a spurious operation. The other aspects of this circuit performance for this case are identical to those described for Case 7.

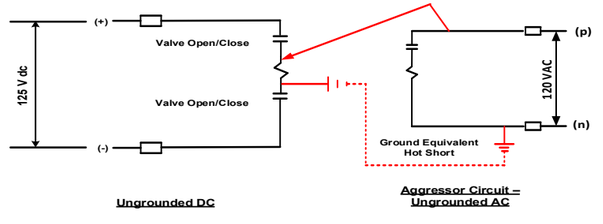
"implausible" for latching circuits and "incredible" for non-latching circuits



Case 8

Notes:
1. For this case, the classification is "implausible" for latching circuits and "incredible" for non-latching circuits. The classification of this circuit failure combination is bounded by the classification of the circuit for Case 7 involving an inter-cable hot short and a ground.

"implausible" for latching circuits and "incredible" for non-latching circuits



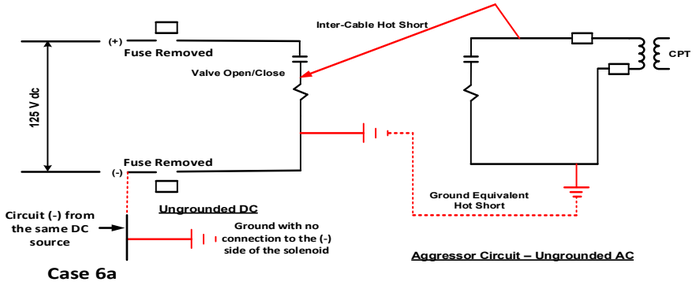
Case 10

Notes:
1. The circuit for this case is identical to the circuit for Case 8 except for voltage differences.

"implausible" for latching circuits and "incredible" for non-latching circuits

Figure 8.0 - Ungrounded DC – Double Break Design

Technical Justification for Appendix J to NEI 00-01

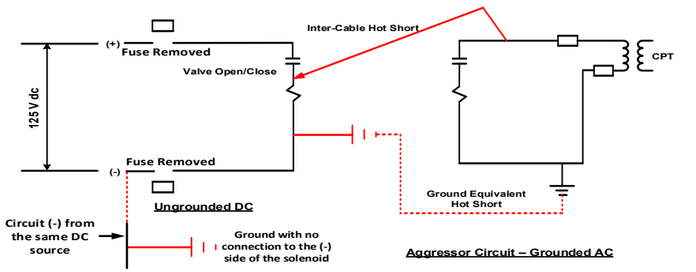


Case 6a

Notes:
1. For this case, the classification is "implausible" for latching circuits and "incredible" for non-latching circuits. The classification of this circuit failure combination is considered to be bounded by the classification of the circuit for Case 7a involving an inter-cable hot short and a ground.

"implausible" for latching circuits and "incredible" for non-latching circuits

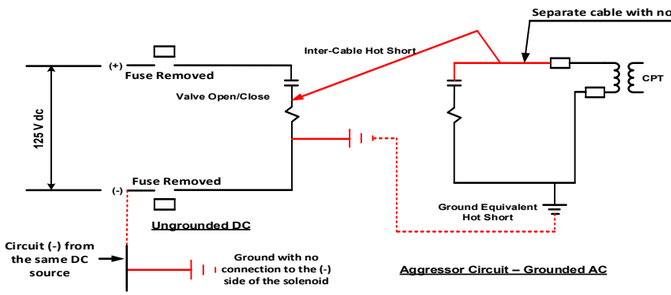
General Notes:
1. The cases shown in this figure depict a specific proper polarity alignment. By depicting only one proper polarity alignment, there is no intent to exclude other proper polarity alignments. Other proper polarity alignments may also apply. Additionally, the potential exists for an aggressor ac circuit to energize a dc coil and an aggressor dc circuit to energize an ac coil, if specific conditions exist. For a detailed discussion of the sub-cases with alternate proper polarity alignments and how they are to be addresses, refer to the section of this document on proper polarity. Regardless of the proper polarity alignment of any of the sub-cases, the circuit failure type classification, e.g., "implausible", is not changed.



Case 7a

Notes:
1. For this case, the classification is "implausible" for latching circuits and "incredible" for non-latching circuits. The classification of this circuit failure combination is considered to be similar to the circuit for Case 7 involving an inter-cable hot short and a ground. The only difference between this circuit and the circuit in Case 7 is that an additional conductor may be involved running back to the (-) fuse. The presence of an additional conductor, however, is not considered to be sufficient to alter the classification. The (-) fuse removal prevents grounds on the balance of the distributed system from impacting the circuit shown in Case 7a.

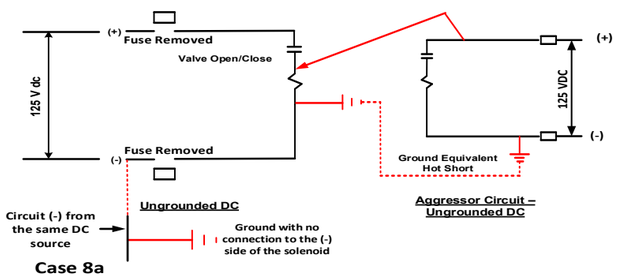
"implausible" for latching circuits and "incredible" for non-latching circuits



Case 9a

Notes:
1. For this case, the classification is "implausible" for latching circuits and "incredible" for non-latching circuits. Although this case is considered to be slightly more likely than the failure modes depicted in Case 7a, since the possible aggressor conductor is in either a single conductor cable or in a multi-conductor cable without any grounded conductor, likelihood of a blown fuse on the aggressor circuit due to exposing of the (+) conductors would still be expected to dominate. The lack of a ground conductor in the aggressor cable is insufficient to alter the classification. This case is similar to Case 8. Refer to Case 8 for additional details.

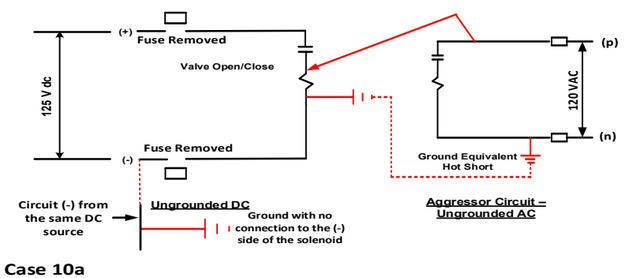
"implausible" for latching circuits and "incredible" for non-latching circuits



Case 8a

Notes:
1. For this case, the classification is "implausible" for latching circuits and "incredible" for non-latching circuits. The classification of this circuit failure combination is considered to be bounded by the classification of the circuit for Case 7a involving an inter-cable hot short and a ground.

"implausible" for latching circuits and "incredible" for non-latching circuits

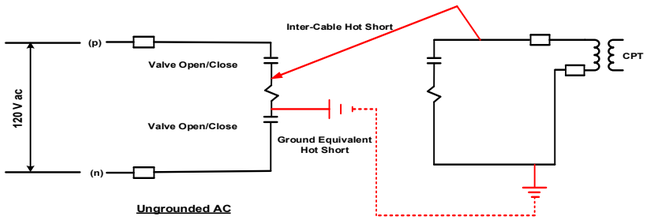


Case 10a

Notes:
1. The circuit for this case is identical to the circuit for Case 8a except for voltage differences.

"implausible" for latching circuits and "incredible" for non-latching circuits

Figure 9.0 - Ungrounded DC – Pseudo-Double Break Design

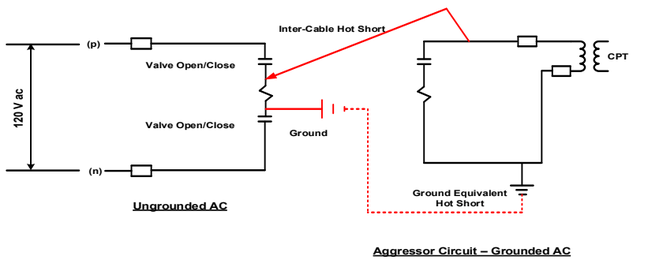


Notes:
1. For this case, the classification is "implausible" for latching circuits and "incredible" for non-latching circuits. The classification of this circuit failure combination is bounded by the classification of the circuit for Case 12 involving an inter-cable hot short and a ground.

"implausible" for latching circuits and "incredible" for non-latching circuits

Case 11

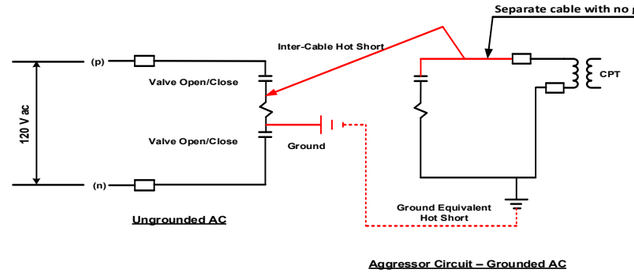
General Notes:
1. The cases shown in this figure depict a specific proper polarity alignment. By depicting only one proper polarity alignment, there is no intent to exclude other proper polarity alignments. Other proper polarity alignments may also apply. Additionally, the potential exists for an aggressor ac circuit to energize a dc coil and an aggressor dc circuit to energize an ac coil, if specific conditions exist. For a detailed discussion of the sub-cases with alternate proper polarity alignments and how they are to be addresses, refer to the section of this document on proper polarity. Regardless of the proper polarity alignment of any of the sub-cases, the circuit failure type classification, e.g., "implausible", is not changed.



Notes:
1. For this case, the classification is "implausible" for latching circuits and "incredible" for non-latching circuits. Although the required circuit failure types are an inter-cable hot short and a ground, the inter-cable hot short must come from a specific circuit type, i.e., a grounded AC circuit. Additionally, the inter-cable hot short from the aggressor (i.e., source) grounded AC circuit cannot go to ground prior to the ground forming on the target circuit. Once the inter-cable hot short on the aggressor (i.e., source) grounded AC circuit goes to ground, the control power fusing on the aggressor circuit will blow and remove the potential for the spurious operation. This circuit failure timing consideration, in combination with the likelihood a circuit grounds and the unlikelihood of these two (2) specific circuit types both becoming involved, makes this combined failure mode of sufficiently low likelihood to classify it as "implausible".

"implausible" for latching circuits and "incredible" for non-latching circuits

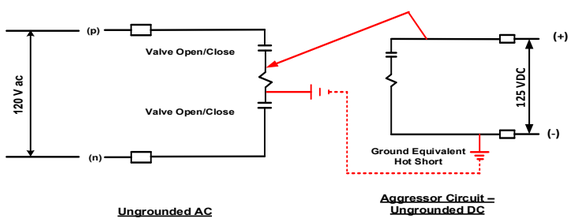
Case 12



Notes:
1. For this case, the classification is "implausible" for latching circuits and "incredible" for non-latching circuits. This case is similar to Case 12 with the exception that it assumes that the possible aggressor conductor is contained within a cable with no grounded conductor. This condition, however, is judged to have very limited impact on the classification, since for an inter-cable hot short to occur, the aggressor conductor must be exposed. With the aggressor conductor exposed, the likelihood of it coming into contact with the ground plane is by far the most likely outcome. Once the exposed aggressor conductor contacts the ground plane the control power fuse for the aggressor circuit will blow eliminating the possibility of a spurious operation. The other aspects of this circuit performance for this case are identical to those described for Case 12. The lack of a ground conductor in the aggressor cable is insufficient to alter the classification.

"implausible" for latching circuits and "incredible" for non-latching circuits

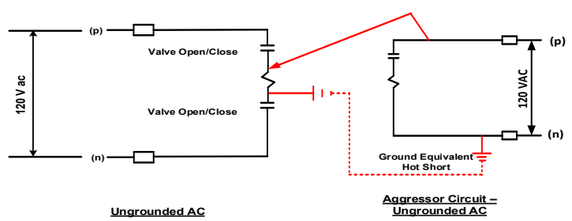
Case 14



Notes:
1. For this case, the classification is "implausible" for latching circuits and "incredible" for non-latching circuits. The classification of this circuit failure combination is bounded by the classification of the circuit for Case 12 involving an inter-cable hot short and a ground.

"implausible" for latching circuits and "incredible" for non-latching circuits

Case 13

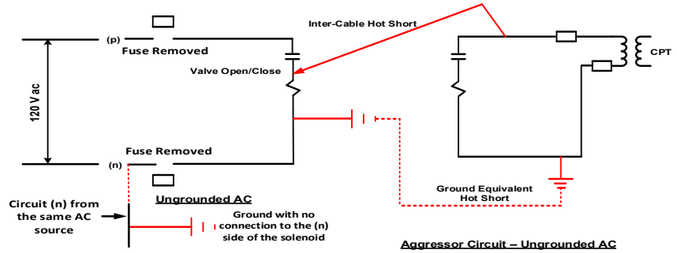


Notes:
1. The circuit for this case is identical to the circuit for Case 13 except for voltage differences.

"implausible" for latching circuits and "incredible" for non-latching circuits

Case 15

Figure 10.0 - Ungrounded AC Distributed – Double Break Design

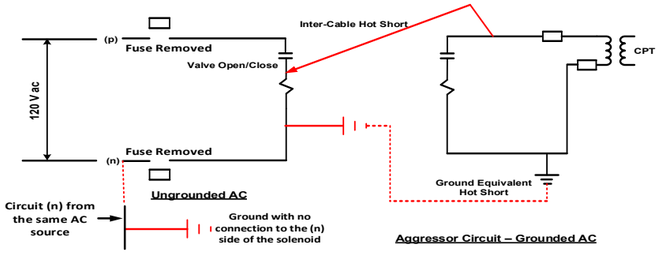


Case 11a

Notes:
1. For this case, the classification is "implausible" for latching circuits and "incredible" for non-latching circuits. The classification of this circuit failure combination is bounded by the classification of the circuit for Case 12a involving an inter-cable hot short and a ground.

"implausible" for latching circuits and "incredible" for non-latching circuits

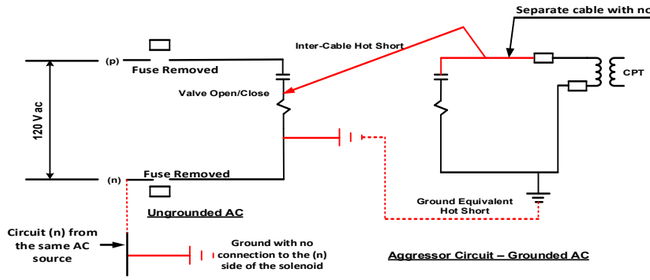
General Notes:
1. The cases shown in this figure depict a specific proper polarity alignment. By depicting only one proper polarity alignment, there is no intent to exclude other proper polarity alignments. Other proper polarity alignments may also apply. Additionally, the potential exists for an aggressor ac circuit to energize a dc coil and an aggressor dc circuit to energize an ac coil, if specific conditions exist. For a detailed discussion of the sub-cases with alternate proper polarity alignments and how they are to be addresses, refer to the section of this document on proper polarity. Regardless of the proper polarity alignment of any of the sub-cases, the circuit failure type classification, e.g., "implausible", is not changed.



Case 12a

Notes:
1. For this case, the classification is "implausible" for latching circuits and "incredible" for non-latching circuits. The classification of this circuit failure combination is considered to be similar to the circuit for Case 12 involving an inter-cable hot short and a ground. The only difference between this circuit and the circuit in Case 12 is that an additional conductor may be involved running back to the (n) fuse. The (n) fuse removal prevents grounds on the balance of the distributed system from impacting the circuit shown in Case 12a.

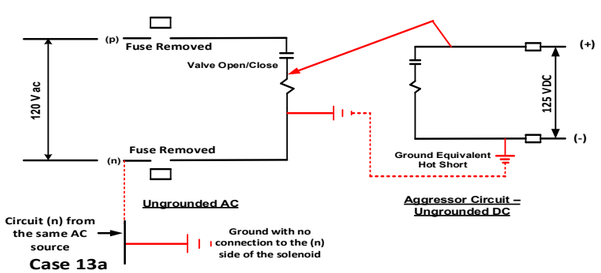
"implausible" for latching circuits and "incredible" for non-latching circuits



Case 14a

Notes:
1. For this case, the classification is "implausible" for latching circuits and "incredible" for non-latching circuits. Although this case is considered to be slightly more likely than the failure modes depicted in Case 12a, since the possible aggressor conductor is in either a single conductor cable or in a multi-conductor cable without any grounded conductor, likelihood of a blown fuse on the aggressor circuit due to exposing of the (+) conductors would still be expected to dominate. The lack of a ground conductor in the aggressor cable is insufficient to alter the classification. This case is similar to Case 12. Refer to Case12 for additional details.

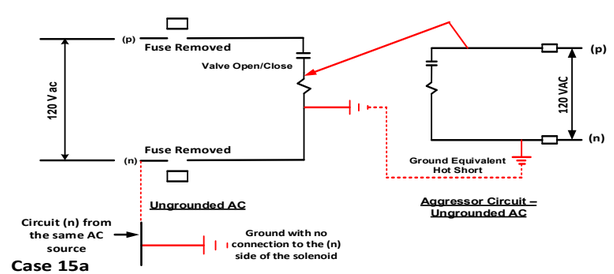
"implausible" for latching circuits and "incredible" for non-latching circuits



Case 13a

Notes:
1. For this case, the classification is "implausible" for latching circuits and "incredible" for non-latching circuits. The classification of this circuit failure combination is bounded by the classification of the circuit for Case 12 involving an inter-cable hot short and a ground.

"implausible" for latching circuits and "incredible" for non-latching circuits



Case 15a

Notes:
1. The circuit for this case is identical to the circuit for Case 13a except for voltage differences.

"implausible" for latching circuits and "incredible" for non-latching circuits

Figure 11.0 - Ungrounded AC Distributed – Pseudo-Double Break Design

The cases shown in Figures 6.0 through 11.0 depict potential spurious operations resulting from one (1) inter-cable hot short and one GFEHS or, in the case of a grounded ac aggressor circuit, one (1) inter-cable hot short and one (1) ground. These figures also depict double break designed circuits and "pseudo" double break designed circuits.

All of the cases depicted in Figures 6.0 through 11.0 involve multiple fire-induced circuit failures in order for a spurious operation to occur. Each involves, at least, one (1) inter-cable hot short. In addition, either a ground fault equivalent hot short or a ground, for a grounded ac aggressor circuit, must be involved. Since each case involves an inter-cable hot short coupled with a ground path back to a common power source and since in order to have an inter-cable hot short, conductors in both the aggressor and target circuits must be exposed, i.e., conductor insulation burned off, grounding of the conductor providing the inter-cable hot short is highly likely. With the insulation removed from the conductor providing the inter-cable hot short and with the need for the involvement of a ground path back to the common power source, it is highly likely that the exposed conductor will, by some means, contact the ground plane and, in so doing, given the presence of a return path ground, resulting in a fuse blow on the aggressor circuit.

The bounding cases, i.e., those with the highest probability of occurrence, for this phenomenon are those involving a grounded ac aggressor circuit and in particular a grounded ac circuit for which the aggressor cable does not have a ground conductor. This configuration provides a more challenging path to ground for the exposed conductor providing the inter-cable hot short. Additionally, a "pseudo" double break designed circuit would bound a true double break designed circuit, since in the "pseudo" double break designed circuit, there would be more than one (1) conductor below the coil that could ground and provide a return ground path for the inter-cable hot short to the common power supply.

Even for this most bounding configuration, however, the classification of "implausible" for latching circuits and "incredible" for non-latching circuits is justified for the reasons cited below.

With respect to the case of a grounded ac aggressor circuit involving an inter-cable hot short in combination with a ground on the target circuit which completes the circuit path to the aggressor circuit, the inter-cable hot short must come from a specific circuit type, i.e., a grounded ac circuit. Additionally, the inter-cable hot short from the aggressor (i.e., source) grounded ac circuit cannot go to ground prior to the ground forming on the target circuit. Once the inter-cable hot short on the aggressor (i.e., source) grounded ac circuit goes to ground, the control power fusing on the aggressor circuit will blow and remove the potential for the spurious operation. This circuit failure timing consideration, in combination with the likelihood of circuit grounds and the unlikelihood of these two (2) specific circuit types from a common power source both becoming involved simultaneously with the target circuit, makes this combined failure mode of sufficiently low likelihood to classify it as "implausible". Even if the ground plane does not exist within the aggressor cable, the lack of a ground plane would have limited impact on the

likelihood of occurrence since with the conductors exposed on both the aggressor and target circuit, the potential for an interaction with the ground plane is high. Finally, even if the target circuit is a "pseudo" double break designed circuit, there is still a very finite number of conductors in the target circuit with the potential to provide the return ground path. Therefore, even for this type of circuit, very specific circuit failure types on very specific circuit conductors must occur concurrently for the spurious operation to occur. Note that for target circuits that are "pseudo" double break designs in distributed ac or dc systems, only those conductors on either side of the coil can provide the required potential and the required return ground path. This is true since all other conductors in the distributed system are isolated from the coil by the removal of the control power fuses.

The circuit failures described in the paragraph above have been further evaluated and classified with supporting insights from the information provided in JACQUE-FIRE Volume 2 and the information available in the Industry and NRC/EPRI Cable Fire Testing Programs. Given that a single inter-cable hot short for TP insulated cables is unlikely, when this failure mode must be combined with another unlikely failure mode, i.e., a GFEHS, in order for the spurious operation to occur, it is concluded that coupling these unlikely failure types together would make the occurrence significantly less likely. For two inter-cable hot shorts or the combination of one inter-cable hot short and one ground equivalent hot short, the very low likelihood of these combined failures occurring at the same time for the same circuit, has led to a classification of implausible for this combination of circuit failure types. When the limited duration aspects of each of these circuit failure types is also factored in, the likelihood of occurrence of a spurious operation, as described above for either of the configurations discussed above, becomes even more unlikely. For the case of a grounded ac aggressor circuit, specific conductors from both the target and aggressor circuits must become involved concurrently in a prescribed way. Based on these factors, a classification of "implausible" is justified for each of the configurations discussed above when the circuit is a latching circuit. This classification is consistent with the definition of "implausible" in that, while the combinations discussed above are theoretically possible, their occurrence 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.

For non-latching circuits, when the two circuit failures are required to co-exist, the spurious operation will not occur without concurrent existence of the failures. Additionally, if either of the two circuit failures terminates, the spurious operation will also terminate. Based on this set of conditions, the occurrence of a spurious operation in a non-latching circuit is judged to be even less likely by the Working Group.

For a spurious operation in a non-latching circuit to occur, the same convergence of a combination of unlikely circuit failure types required for a latching circuit must occur. Additionally, the unlikely combination of circuit failure types must co-exist. With regard to the concurrence, testing has shown that hot shorts do not last an infinite duration and the insulation resistance tends to cascade quickly (avalanche) at the onset of fire induced

cable damage. Given the relatively short duration of circuit failure modes observed during testing and the stochastic nature of cable failures associated with the timing of the onset of the cable failure mode, the required combination of the two circuit failure types co-existing at the same time and on the required conductors is extremely unlikely. In fact, testing performed under the DESIREE Cable Fire Testing Program specifically aimed at testing for the occurrence of two hot shorts causing a spurious operation in a double break designed circuit did not result in the occurrence of a spurious operation. [Reference Section 6.5 and Appendix A.5 of the DESIREE Testing Program.] Although the DESIREE testing referenced above, did not specifically test for the combination of an inter-cable hot short and a GFEHS, this combination of failures is similar to those tested and the combination was not observed to occur in any other Industry or NRC/EPRI Cable Testing Programs. Based on this, the Working Group recommends that these non-latching circuit failure types be classified as 'incredible" for either of the configurations discussed above. This classification is consistent with the definition of "incredible" in that the testing performed in an attempt to demonstrate the occurrence of this phenomenon could find no evidence of the phenomenon ever occurring.

Based on the arguments provided above, a classification of "implausible" for latching circuits and "incredible" for non-latching circuits applies to:

- Double break designed circuits with TP insulated target cables subjected to two (2) inter-cable hot shorts.
- Double break designed circuits with TP or TS insulated target cables subjected to one (1) inter-cable hot short and one (1) GFEHS. [**Note**: The case of aggressor grounded ac "pseudo" double break designed circuit with no ground conductor in the aggressor cable and with the target circuit being either an ungrounded ac or dc circuit is considered to be the bounding case. Even for this bounding case, however, the classification of "implausible" for latching circuits and "incredible" for non-latching circuits applies.]
- The special case of an ungrounded AC circuit from a common CPT with isolated target conductors. Refer to the Technical Justification for Change 3 for additional information related to this case.

5.0 Conclusions:

This paper provides the technical justification for the circuit failure type classifications made in Appendix J to NEI 00-01 and for the changes made by the JACQUE-FIRE Volume 3 Working Group to the recommendations provided by the PIRT Panel in JACQUE-FIRE Volume 1 based on the insights provided by the PRA Expert Panel in JACQUE-FIRE Volume 2. These changes have been incorporated by the JACQUE-FIRE Volume 3 Working Group into a revision of Appendix J to NEI 00-01. The revision to Appendix J has been transmitted to the NRC Staff at NRR and the NEI Circuit Failures Issue Task Force for use in their work related to fire-induced circuit failures.

Table 3.0 – Summary of PIRT Report Circuit Failure Changes based on NUREG/CR 7150 Volume 1

1. Incredible Circuit Failure Types as determined by PIRT Panel **(Do not need to be considered)**	JACQUE-FIRE Volume 3 Position on Circuit Failure Type	2. Implausible Circuit Failure Types as determined by PIRT Panel **(Consider for Components classified as "high impact" only)**	JACQUE-FIRE Volume 3 Position on Circuit Failure Type	3. New Circuit Failure Type Circuit Failure Types as determined by PIRT Panel **(Consider for all affected safe shutdown components)**	JACQUE-FIRE Volume 3 Position on Circuit Failure Type
1.1. 3-phase hot shorts for AC motors **[NUREG/CR-7150, Vol. 1, Section 4.2]**	**The JACQUE-FIRE Volume 3 Working Group agrees with the classification on this item.**	**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]**	**The JACQUE-FIRE Volume 3 Working Group eliminates this item since it relies upon the insulation characteristics of the source conductor. (Refer to the discussion for Change 1.) The JACQUE-FIRE Volume 3 Working Group re-classifies this circuit failure type as "plausible" for all cases except for the special consideration cases described for ungrounded AC from a CPT. (Refer to the discussion for Change 3.)**	**3.1.** GFEHSs (in ungrounded circuits)	**The JACQUE-FIRE Volume 3 Working Group agrees with the classification on this item.**
1.2. Consequential hot shorts for DC compound motors **[NUREG/CR-7150, Vol. 1, Section 4.3]**	**The JACQUE-FIRE Volume 3 Working Group agrees with the classification on this item.**	**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]**	**The JACQUE-FIRE Volume 3 Working Group eliminates this item since it relies upon the insulation characteristics of the source conductor. (Refer to the discussion for Change 1.) The JACQUE-FIRE Volume 3 Working Group agrees with the classification on this item for latching circuits. In addition, the JACQUE-FIRE Volume 3 Working Group concludes that for non-latching circuits, the item can be classified as "incredible". (Refer to the discussion for Change 4.)**		

Table 3.0 – Summary of PIRT Report Circuit Failure Changes based on NUREG/CR 7150 Volume 1

1. Incredible Circuit Failure Types as determined by PIRT Panel **(Do not need to be considered)**	JACQUE-FIRE Volume 3 Position on Circuit Failure Type	2. Implausible Circuit Failure Types as determined by PIRT Panel **(Consider for Components classified as "high impact" only)**	JACQUE-FIRE Volume 3 Position on Circuit Failure Type	3. New Circuit Failure Type Circuit Failure Types as determined by PIRT Panel **(Consider for all affected safe shutdown components)**	JACQUE-FIRE Volume 3 Position on Circuit Failure Type
1.3. MHIF provided the criteria of NEI 00-01, Rev.2 are met. **[NUREG/CR-7150, Vol. 1, Section 6.1.4]**	**The JACQUE-FIRE Volume 3 Working Group agrees with the classification on this item.**	**2.3.** Double break design – ungrounded dc (or ungrounded distributed ac) – 1 inter-cable hot short + 1 GFEHS a. TP – target cable/TS – source cable **[NUREG/CR-7150, Vol. 1, Section 3.3.2 and Table 3-7]**	**The JACQUE-FIRE Volume 3 Working Group eliminates this item since it relies upon the insulation characteristics of the source conductor. (Refer to the discussion for Change 1.) The JACQUE-FIRE Volume 3 Working Group agrees with the classification on this item for latching circuits. In addition, the JACQUE-FIRE Volume 3 Working Group concludes that for non-latching circuits, the item can be classified as "incredible". (Refer to the discussion for Change 4.)**		
1.4. Secondary fires from an open circuited CT secondary with turns ratios of 1200:5 or less[14] **[NUREG/CR-7150, Vol. 1, Section 6.2.4]**	**Based on additional testing performed at Brookhaven National Laboratory in 2015-2016, the JACQUE-FIRE 3 Working Group recommends that the ignition of a secondary fire from an open circuit CT secondary circuit for CT applications up to 15kV primary circuit voltage be classified as "incredible."**	**2.4** 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]**	**The JACQUE-FIRE Volume 3 Working Group agrees with the classification on this item.**		
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]**	**The JACQUE-FIRE Volume 3 Working Group eliminates this items since it relies upon the insulation characteristics of the source conductor. (Refer to the discussion for Change 1.) The JACQUE-FIRE Volume 3 Working Group, however, does agree with the classification in Table 3-3 of NUREG/CR 7150 Volume 1.**				

[14] Additional cable fire testing is recommended for CT secondaries with turns ratios >1200:5.

Table 3.0 – Summary of PIRT Report Circuit Failure Changes based on NUREG/CR 7150 Volume 1

1. Incredible Circuit Failure Types as determined by PIRT Panel **(Do not need to be considered)**	JACQUE-FIRE Volume 3 Position on Circuit Failure Type	2. Implausible Circuit Failure Types as determined by PIRT Panel **(Consider for Components classified as "high impact" only)**	JACQUE-FIRE Volume 3 Position on Circuit Failure Type	3. New Circuit Failure Type Circuit Failure Types as determined by PIRT Panel **(Consider for all affected safe shutdown components)**	JACQUE-FIRE Volume 3 Position on Circuit Failure Type
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]**	**The JACQUE-FIRE Volume 3 Working Group eliminates this item since it relies upon the insulation characteristics of the source conductor. (Refer to the discussion for Change 1.) The JACQUE-FIRE Volume 3 Working Group, however, does agree with the classification in Table 3-3 of NUREG/CR 7150 Volume 1.**				
1.7. Double break design – ungrounded dc (or ungrounded distributed ac) – 1 inter-cable hot short + 1 GFEHS a. TS – target cable/TS – source cable **[NUREG/CR-7150, Vol. 1, Section 3.3.2 and Table 3-7]**	**The JACQUE-FIRE Volume 3 Working Group eliminates this item since it relies upon the insulation characteristics of the source conductor. (Refer to the discussion for Change 1.) The JACQUE-FIRE Volume 3 Working Group, however, does agree with the classification in Table 3-7 of NUREG/CR 7150 Volume 1, but only for non-latching circuits. For latching circuits, the JACQUE-FIRE Volume 3 Working Group has classifies the circuit failure type as "implausible". This change was driven by the higher probability of occurrence of inter-cable hot shorts on TS insulated conductors.**				

Table 3.0 – Summary of PIRT Report Circuit Failure Changes based on NUREG/CR 7150 Volume 1					
1. Incredible Circuit Failure Types as determined by PIRT Panel **(Do not need to be considered)**	**JACQUE-FIRE Volume 3 Position on Circuit Failure Type**	**2. Implausible Circuit Failure Types as determined by PIRT Panel** **(Consider for Components classified as "high impact" only)**	**JACQUE-FIRE Volume 3 Position on Circuit Failure Type**	**3. New Circuit Failure Type Circuit Failure Types as determined by PIRT Panel** **(Consider for all affected safe shutdown components)**	**JACQUE-FIRE Volume 3 Position on Circuit Failure Type**
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. A grounded Armored cable design **[NUREG/CR-7150, Vol. 1, Section 3.4.1; Figure 3-5, 3-6 & 3-7; Table 3-6 & 3-7]**	**The JACQUE-FIRE Volume 3 Working Group agrees with the classification on this item.**				