INTRODUCTION

A proposed set of hot short induced spurious actuation probability curves were developed. The set of curves reflect the consideration of a 'C-Factor' used to increase the expected duration to account for differences between test conditions and those that would be expected for actual installed conditions. A number of possible influence factors were identified by the PIRT panel (NUREG/CR-7150 V1);

1. Fire Exposure Conditions (flame, plume, hot gas layer) - The slower the progression of fire damage to the cable, the longer will it take fully to erode the insulation from the conductors and thereby ground the cable. The grounding of the cable and the opening of the cable's protective device is the mechanism for stopping the spurious operation. Longer times to reach ground are related directly to longer spurious operations.
2. Time-Current Characteristics – fuses/breaker size. Larger fuse/breaker sizes are expected to take longer times to clear that, in turn, entail longer durations of spurious operations. Additionally, in some ungrounded DC circuits, larger fuse sizes did not clear immediately. Extended periods of arcing occurred.
3. Wiring Configuration (number of sources, targets, ground/neutrals and their locations) - The PIRT panel concluded that whilst an increased number of source and target conductors would add to the potential for a spurious operation, more ground conductors would lead to a higher potential for a blown fuse that could either prevent a spurious operation or reduce its duration.
4. Cable Routing/Raceway – Panel Wiring (ranked as HIGH due to a lack of available test data and the belief that testing of this parameter is important for its impact on post-fire safe shutdown).
5. Cable Raceway Fill – Bundles (Note: The PIRT panel considered this important even though they ranked it as medium) - The additional cable-to-cable pressure exerted by bundling appeared to make somewhat of a difference (i.e., an increase) in the propensity for spurious operations.

It was requested that the members of the Expert Panel review the set of curves and provide a recommended treatment supporting bases.

ASSESSMENT

The information provided to the Expert Panel included the five possible influencing factors noted above.

1. Fire Exposure Conditions: the summary discussion provided by the PIRT Panel suggests that the intensity of the thermal insult would have an influence on the duration of hot short induced spurious operations. While the intensity of thermal insult would have an impact on the time to cable damage, it is not clear that it has a predictable impact on the duration of hot short induced spurious operations.
    a. AC data: the pooled dataset used to generate the set of 'C' curves excluded the flame exposure test results. A review of the test data found that there was not a significant difference in the damage times for the pooled data (plume and HGL

exposure). The data did not show that one exposure type resulted notably longer durations as compared to the other. Further review of the test data found that the hot short induced spurious operation duration were all of relatively short duration regardless of the time to the onset of cable damage.

b. DC data: the review of the test data for the pooled dataset resulted in insights that were similar to that of the AC data. Further review of the test data found that there did not appear to be any correlation between time to the onset of cable damage and the duration of the spurious actuation.

An argument could be made that repeating the set of tests at a higher or lower thermal insult might yield different results. It is clear that a lower or higher thermal insult is likely to result in changes in the time measured to the onset of cable damage. However, the behavior of the circuit given the onset of insulation failure is the phenomenon that would affect the duration of hot short induced spurious operations. The existing test results do not indicate that there is any correlation between time to damage and duration.

It is the judgment of this reviewer that Fire Exposure Conditions does not have an influence that warrants or justifies the use of ‘C’ factor greater than 1.0.

2. Time-current characteristics: the behavior of the circuit over-current protective device does have an influence on the availability of a source of power for intra and inter cable hot shorts. However, it does not have any influence on the specific behavior of the target and ground conductors in the circuit of interest. The expected behavior of a mix of cables in a raceway in the context of hot short induced spurious operations involves two considerations. One is the shorting of energized conductors to ground and the consequential challenge to the circuit over-current protective device. The other is the shorting of the conductor(s) associated with the target device such that a bypass or short across the device essentially precludes spurious operations.

   It is reasonable to expect that Time-current characteristics might have an influence on the availability of energized source conductors in a raceway. However, the duration of spurious operation is expected to much more heavily influenced by the behavior of the target conductors. It is the judgment of this reviewer that Time-current characteristics does not have an influence that warrants or justifies the use of a ‘C’ factor greater than 1.0.

3. Wiring Configuration (number of sources, targets, ground/neutrals and their locations) - The PIRT panel concluded that while an increased number of source and target conductors would add to the potential for a spurious operation, more ground conductors would lead to a higher potential for a blown fuse that could either prevent a spurious operation or reduce its duration.

   The number of conductors within an individual cable and the nature of those conductors (targets, energized sources, grounds) are expected to have a significant influence on the behavior of the circuit given fire induced damage. Fortunately the tested circuit configurations reflect a reasonable simulation for the common types of circuits that are installed in a plant. However, instances can arise where circuit configurations deviate significantly from the tested configurations. A common instance where such a condition can occur is internal panel wiring. As an example, cables terminated at electrical cabinets/panels could have their jackets removed within a short distance after entering the interior of the enclosure. In such installations, the individual conductors from multiple cables are frequently bundled together along the length of terminal strip(s). The relationship of targets, sources, and grounds in such a bundle no longer has any similarity to the tested configurations.

The duration of hot short induced spurious operations in cases involving internal panel wiring with bundled individual conductors can be expected to be different that that associated with a jacketed cable. The obvious concern is that while the individual target conductor of concern remains, there is likely to be many more energized source conductors. It is not as clear that there will be an equivalent higher number of grounded conductors. This condition would tend to increase the possible duration of hot short induced spurious operations.

It is the judgment of this reviewer that Wiring Configuration has an influence that warrants or justifies the use of 'C' factor greater than 1.0 for cases involving wiring within a panel enclosure where many individual cables are present. Because of the complexity of this case, it is difficult to establish an analytical process to calculate a 'C' factor. A comparison of the tested hot short induced spurious operation times for ground versus ungrounded power supplies were compared and found the yield comparable results. Based on this comparison, a 'C' factor of 1.2 recommended.

4. Cable Routing/Raceway – Panel Wiring (ranked as HIGH due to a lack of available test data and the belief that testing of this parameter is important for its impact on post-fire safe shutdown).

   The influence that is address by this item is similar to that discussed in items 3, above and item 5, below. Refer to the discussion of those items for details.

5. Cable Raceway Fill – Bundles (Note: The PIRT panel considered this important even though they ranked it as medium) - The additional cable-to-cable pressure exerted by bundling appeared to make somewhat of a difference (i.e., an increase) in the propensity for spurious operations.

   The actual arrangement of cables in a cable tray is variable. In lightly filled trays, the behavior of cable to fire would be expected to comparable to the test results. However, if typical trays filled to 30% to 40% fill, a substantial mass of cables would exist. This introduces several factors that are not currently addressed in Fire PRAs.

   - The location of the cable within the cable mass can have a significant influence on the behavior given a fire that impacts the tray. Cables that are on the bottom of the cable tray would be expected to immediately be affected by the fire. In addition, the weight of the cables above them would also influence the likelihood and duration of any hot short induced spurious operations. This is contrasted by cables located on the top of the cable tray. These cables would be expected to experience a significant delay before damage occurs. However, since the location of any individual cable within a cable tray cannot be determined with any certainty, Fire PRAs typically assumed that they are conservatively located on the bottom.
   - Cables located on the bottom of the tray are in direct contact with the grounded cable tray. Cables located in the middle or top do not have this same ground source available. As such, cables in the middle or top of the tray could experience longer duration hot short induced spurious operations. However, they would also experience a delay before the onset of cable damage. This delay would translate to a lower fire suppression failure probability. In the absence of specific parameters, it is judged that any increase in the duration probability of hot short induced spurious operations is offset by the decrease in the suppression failure probability.

It is the judgment of this reviewer that Cable Raceway Fill does not have an influence that warrants or justifies the use of a ‘C’ factor greater than 1.0. While it is acknowledged that influences associated with this consideration could increase the duration of hot short induced spurious operations, those same influences would delay target damage time thus allowing for a reduction in the fire suppression failure probability.

6. Fire Suppression Activities – the PIRT panel (NUREG/CR-7150 V1) considered this factor to have a moderate influence on the duration of hot short induced spurious operations. However, there is no direct evidence to establish what its influence would be. It is believed that the predominant influence would be the introduction of additional shorts to ground. This may be preceded by additional short duration hot shorts. The belief that any additional hot shorts would be of short duration is based on the belief that the water will eventually cause all circuits to experience ground faults. Although the PIRT panel considered this factor to have a moderate influence, it is the judgment of this reviewer that Fire Suppression Activities does not have an influence that warrants or justifies the use of a ‘C’ factor greater than 1.0.