November 18, 2009

MEMORANDUM TO: AFPB File

FROM: Alexander R. Klein, Chief ***/RA/***
Fire Protection Branch
Division of Risk Assessment
Office of Nuclear Reactor Regulation

SUBJECT: PUBLIC RELEASE OF DRAFT INTERIM POSITION REGARDING NATIONAL FIRE PROTECTION ASSOCIATION 805 FREQUENTLY ASKED QUESTION 08-0051 HOT SHORT DURATION

The purpose of this memorandum is to release for comment the enclosed draft interim position regarding National Fire Protection Association (NFPA) Standard 805 Frequently Asked Question (FAQ) 08-0051 to the public and the Nuclear Energy Institute NFPA 805 Task Force. Comments on the enclosed draft interim position are due by December 31, 2009. Comments should be sent to the contact below.

The enclosed draft interim position was previously sent for comment under the joint U. S. Nuclear Regulatory Commission's (NRC) Office of Nuclear Regulatory Research (RES) / Electric Power Research Institute Memorandum of Understanding (MOU) process. RES and the NRC's Office of Nuclear Reactor Regulation (NRR) collaborated on resolving the comments that were received from the MOU, and the enclosed position represents a joint position on this FAQ between RES and NRR.

Enclosure:
As Stated

CONTACT: Charles Moulton, NRR/DRA
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DRAFT NRC INTERIM POSITION

FAQ 08-0051: Hot Short Duration

Guidance on the Probability of Duration of Spurious Actuations from Hot Shorts in AC Circuits for Use in Conjunction with NUREG/CR-6850

Background:

Frequently Asked Question (FAQ) 08-0051 was proposed by the Nuclear Energy Institute (NEI), through its National Fire Protection Association (NFPA) 805 Task Force, to clarify the guidance from NEI 04-02, "Guidance for Implementing a Risk-Informed, Performance-Based Fire Protection Program under Title 10 of the *Code of Federal Regulations* Part 50 (10 CFR) 50.48(c)." No guidance on the duration of hot shorts was provided in NUREG/CR-6850 (EPRI 1011989), "EPRI/NRC-RES Fire Probabilistic Risk Assessment (PRA) Methodology for Nuclear Power Facilities". The purpose of this FAQ is to provide guidance for the probabilistic treatment of the duration of hot shorts and therefore spurious actuations in AC circuits, and discuss conditions under which this duration is to be applied.

Testing will be conducted on spurious actuations on DC circuits in the ~~summer/~~fall of 2009 and spring of 2010. Once the duration data is collected and processed, an analysis will be performed to provide probabilities of hot short duration for DC circuits.

In order to achieve closure of this FAQ in a timely manner, the Nuclear Regulatory Commission (NRC) developed a draft interim staff position, as discussed below. This position was developed using currently existing information, databases, and experimental results, and should not be seen as prejudicing the NRC's view of future developments in this area.

Discussion:

<u>Introduction</u>:

According to NUREG/CR-6834, "Circuit Analysis - Failure Mode and Likelihood Analysis," a hot short is defined as a "conductor to conductor short circuit in which one or more non-energized, non-grounded conductors become energized due to the cable failure." Hot shorts are important in fire PRA because of their ability to produce undesirable conditions for pumps and valves, e.g., spurious starting/stopping of pumps and repositioning or "sealing in" undesirable positions of valves. For example, a motor-operated valve (MOV) may be repositioned from a hot short, whereas an air-operated valve (AOV) may be sealed in from a hot short on the related solenoid-operated valve (SOV) control circuit. The duration of a particular hot short is important since a corresponding pump or valve may be unable to perform its credited function during the time it is undesirably positioned due to the spurious actuation. Furthermore, a hot short on the circuit can complicate the recovery of affected equipment since the recovery may be delayed until the hot short has cleared. In some cases, a hot short may be unable to clear. In those cases where the hot short can clear, recovery of equipment and its associated function may be allowed and may require manual actions. In other cases, such as the AOV/SOV case, clearing of the hot short may also clear the spurious actuation (e.g., an AOV may return to its desired state once the SOV hot short clears).

When accounting for hot short duration in a fire PRA, the duration is paired with the occurrence of the spurious actuation. It should be emphasized that the probability that the hot short duration equals or exceeds a particular time, i.e. P(T≥t), is used to characterize the likelihood that a hot short condition persists beyond the specified time. Therefore, in the context of an event tree, the failure path or downward branch would be characterized by P(T≥t), and the complement, 1 - P(T≥t), is used to characterize the success path or upward branch. In practice, the duration time of interest would be a characteristic of the PRA scenario.

For example, the spurious opening of a power-operated relief valve (PORV) might be risk-important only if it persists beyond some time window. The available time window would need to be defined by the PRA accident sequences, in this example case, likely based on thermal-hydraulic calculations. For a PORV control circuit, clearing of a hot short would typically allow the PORV to return to a closed state. Hence, the likelihood that a hot short induces a spurious actuation that persists beyond the available time window is a relevant consideration in the risk quantification.

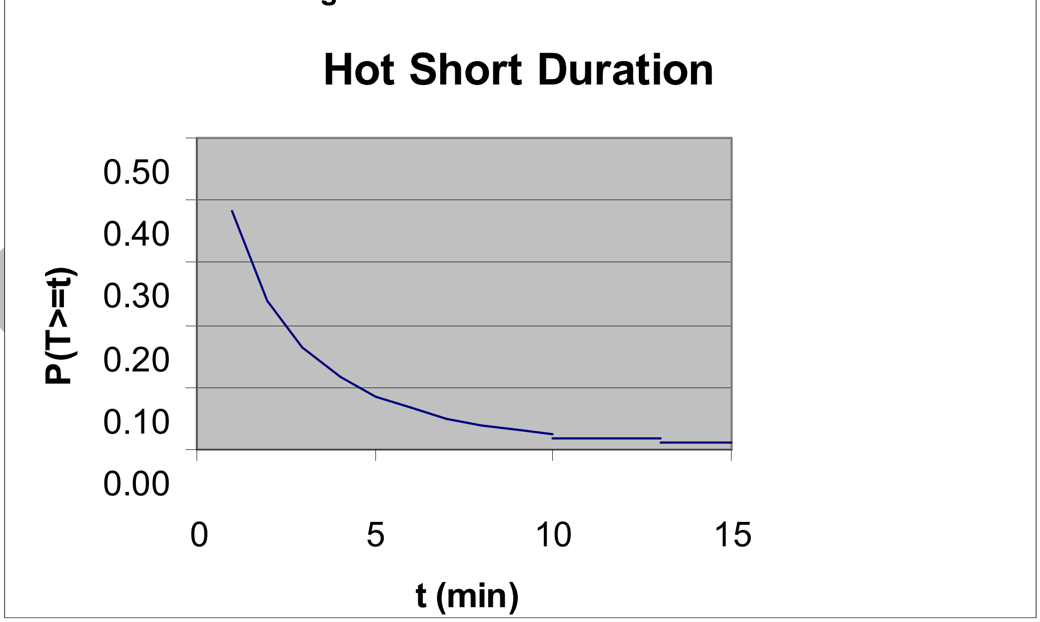
<u>The interim solution</u>:

Figure 1 shows the probability of the duration of a spurious actuation from a hot short lasting greater than or equal to time, t, in minutes for two types of hot shorts. Those hot shorts are from intra-cable hot shorting, and inter-cable hot shorting. Each distribution in the figure is the complementary cumulative distribution function (CCDF) of a Weibull distribution, and of the form:

$$P(T \geq t) = \exp(-\lambda t^{\beta})$$

The λ and β factors for hot short duration are 0.963 and 0.579.

Figure 1. Durations of hot shorts



The following table provides the corresponding probabilities of spurious actuation duration from a hot short lasting greater than or equal to time, t, in minutes. Due to the significant uncertainty with the duration probabilities, 0.01 is the minimum recommended probability to be used in fire PRA. Identifying a minimum is consistent with other probabilistic approaches, such as with the manual non-suppression probability.

Table 1. Probability of duration ≥ time (min) for hot shorts

t (min)	P(T≥t)
0	1.00E+00
1	3.82E-01
2	2.37E-01
3	1.62E-01
4	1.17E-01
5	8.67E-02
6	6.60E-02
7	5.12E-02
8	4.03E-02
9	3.22E-02
10	2.59E-02
11	2.11E-02
12	1.73E-02
13	1.42E-02
14	1.18E-02
15	1.00E-02
>15	0.01

It must be noted that the above hot short duration probabilities should not be used under certain conditions. These conditions are:

~~*1) The spurious operation duration probabilities should not be used as a basis for omitting/removing cables or equipment from the plant model, or screening sequences from the plant model. The consequences of applying the duration factors to risk quantification and insights should be made clearly available to reviewers. This limitation is imposed in recognition of the large uncertainty associated with hot short duration.*~~

~~The duration probabilities should not be applied as selection/exclusion criteria in the context of Task 2, Component Selection, or Task 3, Cable Selection, as defined in NUREG/CR-6850, EPRI TR 1011989. The factors should also not be used as a basis for determining the scope of NUREG/CR-6850 Task 5, Development of the Fire-Induced Risk Model (e.g., they should not be used as a basis for excluding plant accident sequences from the risk model). These factors should be used in NUREG/CR-6850 Task 10, Circuit Failure Mode and Likelihood Analysis, and Task 14, Fire Risk Quantification.~~

1~~2~~) *The hot short duration probabilities should not be applied to spurious actuation of equipment caused by grounding of one or more conductors (i.e., for those spurious actuations not caused by hot shorts). For these cases, no credit should be given for hot short duration.*

The hot short duration probability is based on circuits where spurious actuations are induced from hot shorts between an energized source conductor and a de-energized target conductor. When the insulation resistance between these two conductors is reduced as a result of fire-induced effects, then the target conductor becomes energized and sufficient current or voltage will cause the end device of the target cable to change states or actuate.

Testing showed that cable hot shorts are a transient condition whose duration is limited by the eventual grounding of the damaged cable. In most cases, it is the actual clearing of the protective devices, caused by a single or multiple grounds that result in the hot short termination. For hot-short induced spurious operations, termination of the hot short can be correlated to termination of the hot short signal. In some cases, however, a spurious operation can be caused by a short to ground, which is generally a more likely initial failure mode than a hot short. For example, if multiple transmitter cables became grounded, the associated signal may register off scale high or low and may cause equipment to spuriously actuate. The grounding of the cable conductors in such cases will generally not clear the spurious actuation, since this is the most electrically stable state for the failed circuit. As such, the hot short duration probability is not applicable to these circuit configurations.

2~~3~~) *The hot-short duration probability should not be applied if the spurious actuation produced by the hot short would not clear once the cable is grounded. For this case, no credit should be given for hot short duration. A review should be completed to ensure that clearing the hot short will clear the spurious actuation, including identification of the device (e.g., fuse or circuit breaker) that would clear the hot short given cable grounding.*

During the EPRI/NEI[1] and CAROLFIRE[2] testing, the eventual cable grounding resulted in a blown fuse that stopped the hot short (i.e., the circuit transitioned from a transient hot short condition to its electrically stable state for the damaged condition). A review of numerous valve control circuits resulted in the identification of some cables that if eventually grounded, might not result in a blown fuse or hot short cessation. In these example circuits, cables routed to an Auxiliary Shutdown Panel Transfer Switch, where the transfer switch did not indicate the valve position, would not cause the fuse to blow if an eventual ground occurs. These particular circuits would, when grounded, result in the valve transferring position from open to closed and back to open, repeatedly. It is likely the valve motor operator would eventually burn out (depending on circuit design, it is also possible that the valve overloads would heat up and open), given this scenario. However, the valve position when the valve motor failed would not be predictable. In the specific case of MOVs, for example, mitigation of the hot short and opening of the circuit fuse would leave the control circuit de-energized, but would also leave the valve in whatever position it assumed as a result of the original hot short (i.e., a MOV will not automatically return to its pre-failure state).

The hot short duration probability is based on test results where grounding of the cable (source, target conductors) caused protective devices (i.e. fuse or circuit breaker) to clear and de-energize the circuit resulting in termination of the spurious actuation (i.e., relay actuation). Some circuits have been identified where grounding of the cable will not de-energize the control circuit. These types of circuits are not bounded by the testing results and associated hot short duration probability. As such, use of the hot short duration probability is unacceptable for these types of circuit. Furthermore, if clearing of the hot short will not cause the end device to return to its pre-failure condition, then the analysis should not assume that the spurious actuation will clear given that the hot short clears. The available tests did not include explicit treatment of such cases. All of the available AC spurious actuation tests were based on motor contactor relays as the target

[1] EPRI TR-1003326, "Characterization of Fire-Induced Circuit Faults," Dec. 2002;

[2] NUREG/CR-6931-V1, "Cable Response to Live Fire (CAROLFIRE) Volume 1: Test Descriptions and Analysis of Circuit Response Data," April 2008.

device. These relays would close given a hot short but open given hot short clearing. The behavior of these control relays, however, may not reflect the behavior of the end device (e.g., the actual MOV itself) which could be left in a faulted state even after the control circuit is de-energized. Therefore, the hot-short duration probability should not be applied if the spurious actuation produced by the hot short would not clear once the cable is grounded.

34) *Credit ~~should not be taken~~ for recovery of a spurious actuation if a short to ground on an auxiliary or "off-scheme" circuit ~~would impede recovery~~ needs to include a functional circuit analysis demonstrating the effect of a short to ground on the auxiliary circuit. For these cases, no credit can be given for hot short duration since the short to ground will not clear by itself.*

Hot shorts from auxiliary or "off-scheme"[3] circuits that are powered from a separate power supply should be reviewed for the impact of grounding the circuit. The spurious operation may not stop when the ground occurs and the hot short on the auxiliary circuit terminates. The functional impact depends on the circuit design, whether a "seal-in" contact is in the circuit, and the component failure mode once the auxiliary circuit has grounded.

It should be noted that a constraint exists on recovery where the hot short duration may be applicable. Regardless of whether the hot short duration is applicable, credit should not be taken for functional recovery of electrical control functions for circuits that become inoperable as a result of a spurious actuation. Manual operation or recovery of the end device (e.g., manual operation of a valve or a manual pump start/stop) may be possible, but analyses must be performed to demonstrate the feasibility of the manual operation and, as appropriate, the reliability of these actions should be factored into the fire PRA.

Motor Operated Valve (MOV) and certain pump control circuits generally cannot be electrically recovered once their control circuit goes to ground. Almost all MOVs fail-as-is, and cannot be remotely operated once the cable failure mode transitions from a hot short (spurious actuation) to ground. Credit for manual operation of the MOV locally (for restoration of the MOV) should consider that the hot short might not have cleared. Additionally, credit for local MOV operation should consider the circuit design to ensure that prolonged operation of the MOV motor (i.e., torque and limit switches do not deactivate the motor) does not damage the valve stem or actuator (local operation may no longer be possible if significant stem or actuator damage occurs).[4] Larger pumps that use medium voltage or low voltage power circuit breakers as their "on/off" control device will generally fail as-is once a hot short on the breaker's control circuit eventually clears and power to the control circuit is lost due to the control circuit fuse clearing.

Restoration of control functions failed by fire will likely require significant repair actions. Manual operation may be plausible, but may also be compromised by persistent faults, including loss of control power faults, on either the primary portions of the control circuit or on off-scheme circuits (e.g., loss of a permissive signal might prevent pump start).

4) *The spurious operation duration probabilities should not be used for DC Circuits.*

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[3] "Off-scheme" circuits are circuits that have common connections to the control circuit of interest, but do not perform the primary control functions. Off-scheme circuits may, for example, be associated with certain auto-start or auto-stop functions, provide permissive signals that allow system actuation, be using system status indications to generate permissive signals for other circuits, or simply monitor system status.

[4] See, e.g., Information Notice 92-18, "Potential for Loss of Remote Shutdown Capability During a Control Room Fire."

Basis for analysis:

The statistical analysis was performed using the entire set of NEI/EPRI test data and CAROLFIRE test data. The duration data analyzed for this FAQ comes from a set of experiments designed to emphasize coverage of potentially important characteristics and not to develop sample statistical representations of field conditions. For purposes of this interim solution, it is judged adequate to treat the duration data using a simple statistical approach. Insufficient data exists to justify splitting the data into factors that would affect hot short duration. Thus, no examination of factors was performed in this analysis.[5]

Probability plots were constructed for typical candidate distributions (Weibull, Lognormal, and Exponential) and parameters estimated using ordinary least squares regression. Because of the better fit, the Weibull distribution was selected. The R-squared value corresponding to the hot short duration is 0.99, and confirms, along with examination of the predicted versus observed data, that the Weibull distribution provides a reasonable fit to the data sets. Table 2 includes the NEI and CAROLFIRE data.

[5] A research task to consider probability of spurious actuation duration is being discussed. This task will likely examine durations and occurrence of hot shorts via expert elicitation, which is appropriate for the duration data since it is limited from a statistical perspective.

Table 2. Duration data (min) from NEI and CAROLFIRE tests

Index	NEI data duration	Index	CAROLFIRE data duration
1	7.6	1	0.58
2	0.9	2	0.02
3	0.4	3	0.1
4	2.1	4	0.02
5	0.4	5	0.25
6	0.8	6	0.4
7	1.9	7	0.08
8	1.9	8	7.62
9	0.4	9	0.18
10	0.4	10	0.1
11	1.9	11	3.82
12	1.9	12	5.78
13	1.4	13	0.18
14	1.4	14	1.63
15	2	15	0.27
16	2	16	1.77
17	0.9	17	3.77
18	0.9	18	1.05
19	0.2	19	1.05
20	0.1	20	0.48
21	2	21	2.03
22	0.1	22	0.32
23	0.1	23	0.77
24	0.1	24	0.03
25	3.4	25	3.85
26	0.7	26	0.7
27	0.9	27	0.73
28	1.1	28	0.52
29	5.7	29	0.4
30	5.2	30	0.55
31	0.1	31	0.3
32	0.1	32	0.15
33	0.1	33	0.02
34	0.1	34	0.02
35	8.2	35	0.02
36	4.7	36	0.02
37	10.1	37	0.22
38	1.1	38	0.02
39	1.1	39	0.02
40	0.1	40	0.02
41	0.3	41	0.02
42	0.1		
43	2.1		
44	11.3		
45	8.1		
46	0.2		
47	3.2		

References:

1. Revision 0 to FAQ 08-0051, December 4, 2008, Accession No. ML083400188

2. NEI 04-02, Guidance for Implementing a Risk-Informed, Performance-Based Fire Protection Program Under 10 CFR 50.48(c), Revision 1, Accession No. ML052590476

3. NFPA 805, Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants, 2001 Edition (available through the Public Document Room or NFPA)

4. Regulatory Guide 1.205, Risk-Informed, Performance-Based Fire Protection for Existing Light-Water Nuclear Power Plants, Accession No. ML061100174

5. NRC Regulatory Information Summary 2007-19, Process for Communicating Clarifications of Staff Positions Provided in Regulatory Guide 1.205 Concerning Issues Identified During The Pilot Application of National Fire Protection Association Standard 805, Accession No. ML071590227

6. NUREG/CR-6850 (EPRI 1011989), Accession Nos. ML050940183 (Vol. 1) and ML050940189 (Vol. 2)

7. NUREG/CR-6834, Accession No. ML032731464

8. NRC Information Notice 1992-18, Accession No. ML031200477

9. NUREG/CR-6931, Available through the NRC public web site

10. EPRI TR-1003326, Characterization of Fire-Induced Circuit Faults, Accession No. ML023500265