FAQ Number 14-0009 **FAQ Revision** I

FAQ Title Treatment of Well Sealed MCC Electrical Panels Greater than 440V

Plant: Various Date: October 20, 2014

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Purpose of FAQ:

FAQ provides clarification for the treatment of fire propagation from well-sealed MCC electrical cabinets with voltage levels at 440V or greater

Relevant NRC document(s):

NUREG/CR-6850
NUREG/CR-6850, Supplement 1 (NFPA 805 FAQ 08-0042)

Details:

NRC document needing interpretation (include document number and title, section, paragraph, and line numbers as applicable):

See list of relevant NRC documents.

Circumstances requiring interpretation or new guidance:

NFPA 805 FAQ 08-0042 provides guidance and clarification for the treatment of fire propagation from Bin 15 electrical cabinets. When a well-sealed electrical cabinet at 440V or greater is considered, some ambiguity exists with respect to the wording in Chapter 6 of NUREG/CR-6850, its applicability to fire scenario development, and the clarification provided in NFPA 805 FAQ 08-0042. Notably, treatment of propagation probability for a well-sealed electrical cabinet is not explicitly addressed. The scope of this FAQ is limited to well-sealed, robustly-secured MCCs operating at 440V or greater, and does not apply to other electrical cabinets, notably those already covered by High Energy Arcing Fault (HEAF) analysis.

Detail contentious points if licensee and NRC have not reached consensus on the facts and circumstances:

The clarification to NFPA 805 FAQ 08-0042 was intended to reaffirm the intended treatment for MCCs. The treatment for MCCs operating at 440V or greater that satisfy the guidance provided in 11.5.1.7.3 of NUREG/CR-6850 as modified by NFPA 805 FAQ 08-0042 need not include fire propagation.

The NRC has indicated that the Chapter 6 wording should be used as criteria for addressing fire propagation, in addition to that provided in NFPA 805 FAQ 08-0042.

Potentially relevant existing FAQ numbers:

NFPA 805 FAQ 08-0042. It should be noted that there is no lack of consensus with the guidance provided in NFPA 805 FAQ 08-0042 for no fire propagation from "well sealed" electrical cabinets that are not MCCs.

Response Section:

Proposed resolution of FAQ and the basis for the proposal:

The treatment of postulated fires originating at MCCs should follow the guidance in NUREG/CR-6850 as modified by NFPA 805 FAQ 08-0042. The guidance provided in NFPA 805 FAQ 08-0042 identifies two attributes to be considered. Those two attributes are the adequacy of the sealing of openings and the robustness of the door attachments. NFPA 805 FAQ 08-0042 provides criteria and discussions to address these issues. However, questions have arisen regarding the behavior and risk implications of well-sealed MCCs operating at 440V or greater and their capability of propagating a fire to external targets. These questions are based on wording in Chapter 6 of NUREG/CR-6850 that states that cabinets housing circuits at 440V or greater should be counted because an arc fault induced fire could compromise cabinet integrity.

In order to address this, additional details and methodological treatment are necessary beyond that already published in NUREG/CR-6850 or its Supplement. A simplified approach is proposed as an interim treatment pending completion of ongoing industry and NRC research activities. This approach involves the consideration of two factors.

$$F = F_E \times F_D$$

Where:

F = fraction of fires originating from a well-sealed MCC that damages external targets

F_E = fraction of MCC fires that are energetic enough to breach the well-sealed MCC enclosure

F_D = fraction of MCC fires that damage targets above the well-sealed MCC based on fire modeling, severity factor (SF)

As indicated above, the fires energetic enough to breach a well-sealed and robustly secured cabinet originate from arcing faults. These faults, while not energetic enough to be considered HEAFs, still exhibit an arcing characteristic and generally exhibit energy greater than thermal fires caused by overheating.

Given that a fire has occurred at an MCC, it is not realistic or appropriate to assume that all such events would be capable of breaching the MCC. In order to address this consideration, it is necessary to consider empirical evidence from industry fire events for MCCs. An evaluation was performed on fire operating experience in MCC from 1990-2009 in Attachment 1 which supports a factor of 0.23 for arc fault induced fires which have the potential to breach a well-sealed MCC. This factor of 0.23 can be used to represent the fraction of fires assumed to breach a well-sealed MCC cabinet.

The review of industry experience is relatively consistent in that they reflect the occurrence of an energetic event that either caused MCC doors to be forced open or otherwise exhibited evidence of some strong force having occurred. This energetic event is treated as having a very short time duration that from a practical fire modeling standpoint can be taken as infinitesimal time. Given that a postulated fire scenario has breached an MCC, standard fire modeling techniques can then be applied to treat the fire scenario. This treatment would include a 12 minute growth rate, steady burning for 8 minutes and a decay phase lasting 19 minutes. The fire modeling should rely on already established methods, treatments, and data as provided in NUREG-1824 and Appendix E of NUREG/CR-6850.

A simplified and bounding fire model for thermoplastic cable targets can be used to illustrate the integration of fire modeling results to obtain the value of F_D. For convenience, this simplified treatment ignores any crediting for timing such as growth and manual suppression. The fires were simply evaluated to determine whether the plume temperature would cause cable damage using the plume centerline temperature correlation from NUREG-1805. This evaluation used the NUREG/CR-6850, Appendix E, Table E-4 heat release rate probability distribution applicable to an MCC (per NUREG/CR-6850, Appendix G, p. G-25, including Figures G-6 and G-7). The fire is treated with a characteristic surface area of 3 ft^2 (based on an MCC cubicle stack characteristic dimensions of 1.5 ft. wide by 2 ft. deep) with a cable tray target assumed to be located 6 in. above the top of the MCC. The MCC was assumed to be configured with four equal sized cubicles in each stack each 18 in. tall. The fire in each cubicle was assumed to be located at the horizontal centerline of the cubicle. The fire in the first cubicle was assumed to be located at a distance of 1.75 ft. below the cable tray (6 in. between top of MCC and cable tray, 6 in. wireway at the top of the MCC and 9 in. distance from top of the cubicle to the center of the cubicle). Each subsequent cubicle fire was assumed to be 18 in. below the location of the fire of the cubicle above it. The resulting spacings between each of the four MCC cubicles and the cable tray were 1.75 ft., 3.25 ft., 4.75 ft., and 6.25 ft.

This resulted in four cases to be evaluated for the MCC stack. For each assumed cubicle fire, the required heat release rate (HRR) to cause the plume centerline temperature at the cable tray location to be equal to the thermoplastic cable damage temperature (205 ^{o}C) was determined. The severity factor associated with the HRR was then determined using the Gamma distribution parameters of 1.6 and 41.5 for alpha and beta, respectively, from NUREG/CR-6850, Table E-1. This calculation was done as a steady state analysis with no credit for fire growth, decay, suppression, or time to damage.

This simplified treatment determined the fraction of postulated fires that could create centerline plume temperatures equal to or greater than 205 ^{o}C. This was repeated for each of the assumed cubicle fires. Each successive case increased the spacing between the postulated MCC cubicle fire and the postulated cable tray target above the MCC based on the dimensions noted earlier (18 inches greater than the spacing for the cubicle above). The results are summarized below.

Table 1 – Summary of Fire Severity Factors

MCC Cubicle Position	Spacing to Tray	Critical HRR	SF [1]	SF_{crit} [2]
Topmost Cubicle	1.75 ft.	19 kW	0.153	0.847
2^{nd} Cubicle	3.25 ft.	44 kW	0.418	0.582
3^{rd} Cubicle	4.75 ft.	83 kW	0.711	0.289
Bottom Cubicle	6.25 ft.	137 kW	0.902	0.098

Note 1 SF is the fraction of postulated fires that have an intensity less than the critical HRR

Note 2 SF_{crit} is the fraction of postulated fires that could damage the target and is taken as being equal to 1 – SF

The resultant Froude Number for the cases presented above was confirmed to not exceed the upper bound limit of 2.4 [3]. The resulting four severity factor values were then each weighted by 0.25 to reflect the equal likelihood of fire occurrence in one of the MCC cubicles and then summed to obtain an aggregate effective severity factor for the entire MCC stack. The resulting aggregate severity factor, F_D, was calculated to be 0.454 and represents the fraction of MCC fires that could damage the overhead target located 6 in. above the top given that it had already breached the MCC. This 0.454 severity factor is then combined with the previously calculated 0.23 term to yield a value for F of 0.104.

It is noted that other combinations MCC and target characterizations could exist. These combinations are:

- MCC contains non-qualified cables and targets are thermoset
- MCC contains qualified cables and targets are thermoplastic
- MCC contains qualified cables and targets are thermoset

The analysis presented earlier that yielded the 0.454 factor was repeated for the three combinations above. For the case where the MCC contains qualified cables, the NUREG/CR-6850, Appendix E, Table E-2 heat release rate probability distribution was used instead of that provided in Table E-4. For thermoset targets, a damage threshold of 330 ^oC was used instead of 205 ^oC applicable for thermoplastic targets. All other terms and inputs remained unchanged.

The resulting factors and integration with the multiplier noted above are provided below.

Table 2 – Summary of Treatment Factors

Combination	F_E	F_D	F_E x F_D
Non-Qualified in MCC – TP target	0.23	0.454	0.104
Non-Qualified in MCC – TS target		0.269	0.062
Qualified in MCC – TP target		0.327	0.075
Qualified in MCC – TS target		0.187	0.043

The conservative and bounding values above can be generically applied based on the plant specific combination of the wiring characterization within the MCC (qualified vs. non-qualified) and the target cable characterization (TS vs. TP). Because this simplified analysis does not consider timing, no credit for fire suppression should be taken unless separately addressed by additional analyses. In the absence of such further analyses, it should be assumed that target damage occurs with no delay. It should be noted that the conservatism when using this approach can be significant if the actual application specific spacing between the MCC and the overhead cable tray is larger than 6 in. Further vertical and horizontal fire propagation should be considered using existing guidance including any applicable credit for fire suppression based on the available timing. If manual fire suppression is credited, the applicable suppression rate term is the same as that which would have been applicable for electrical cabinet fires.

This FAQ does not prohibit or otherwise preclude the use of accepted fire modeling methods to take advantage of actual target spacing. For example, if for a particular installation the nearest overhead target is 2 ft. from the top of the MCC instead of 6 in., the resulting values would be 0.057, 0.022, 0.039, and 0.015 instead of 0.104, 0.062, 0.075, and 0.043, respectively. A separate assessment confirmed that flame height considerations do not alter these results.

It is noted that a more detailed treatment that includes the consideration of a t-squared 12 minute growth rate and the crediting of manual suppression is expected to result in further reductions of the calculated factors presented above. Incremental refinements can be further expanded to consider time to damage using either Appendix H of NUREG/CR-6850 or the THIEF model [1] which would further reduce the treatment factor.

The applicability of this FAQ is limited to well-sealed, robustly-secured MCCs operating at 440V or greater, and does not apply to other electrical cabinets. FAQ 08-0042 provides clarification on the guidance for fire propagation from electrical cabinets. That guidance refers to fire spread not being considered likely given a weather-tight or waterproof cabinet construction where multiple mechanical fasteners secure cabinet access plates and where all penetrations into the cabinet are sealed. MCC designs include isolation, compartmentalization, spacing and guarding to protect against accidental contact with energized parts. These design attributes limit the ventilation to MCC compartments. Provided that penetrations are sealed per FAQ 08-0042 clarifications, MCCs are typically of the well-sealed design. In addition, MCCs classified or marked as raintight, rainproof, watertight, or driptight [2], would be considered weather-tight or water proof per the intent of NUREG/CR-6850 fire propagation.

MCC configurations that should not be considered well-sealed include those where large openings exist at the top as a common cable entry. Cases where individual compartments (cubicles) have ventilation louvers or a perforated metal screen for ventilation would require that compartment be treated as not well-sealed but not otherwise impact the treatment of the remainder of the MCC. In addition, ventilation louvers or perforated metal screens on the rear bus section covers are immaterial to the assessment of whether the MCC is well-sealed because this section of the MCC contains minimal combustible materials and is separated from the front section of the MCC by a solid metal plate.

The guidance for multiple mechanical fasteners is based on tests [4] where the span between panel fasteners (7.4 ft.) was not sufficient to restrain the panel from warping due to localized thermal fire conditions altering the ventilation conditions of the cabinet. Unlike the configurations previously tested, MCC do not have long spans between fasteners but have multiple fasteners (thumb screws, wingnuts, or bolts) typically 6 – 24 in. apart (i.e., robustly secured). As such, the failure mode identified in the tests is unlikely to occur from a thermal fire origination in an MCC compartment given these differences.

If appropriate, provide proposed rewording of guidance for inclusion in the next Revision:

None – a more complete treatment will be available prior to the next NUREG/CR-6850 revision.

REFERENCES

1. McGrattan, K.B., “Cable Response to Live Fire (CAROLFIRE) Volume 3: Thermally-Induced Electrical Failure (THIEF) Model, NUREG/CR-6931, U.S. Nuclear Regulatory Commission, Washington, DC 20555, 2008.

2. NEMA 250, Enclosures for Electrical Equipment (1000 Volts Maximum), National Electrical Manufacturers Association, Rosslyn, VA, 2014.

3. NUREG-1934/EPRI 1023259, Nuclear Power Plant Fire Modeling Analysis Guidelines (NPP FIRE MAG), Final Report, November 2012.

4. VTT Publications 186, “Full Scale Fire Experiments On Electronic Cabinets,” J. Mangs and O. Keski-Rahkonen, VTT Technical Research Centre of Finland, 1994.

Attachment 1: Probability of Breaching Well-Sealed MCCs of 440V or Greater

Purpose: To establish a probability of breaching a well-sealed motor control center (MCC) in support of FAQ 14-0009.

Discussion: Fires capable of breaching a well-sealed MCC are arc fault induced fires. Arcing events applicable to the FAQ which this analysis supports are fires that exhibit arcing behavior, but do not exhibit the extent of energy in a high energy arcing fault (Appendix M of NUREG/CR-6850/EPRI 1011989). These fires are characterized as non-high energy arcing faults, or thermal fires in NUREG-2169/EPRI 3002002936, “Nuclear Power Plant Fire Ignition Frequency and Non-Suppression Probability Estimation Using the Updated Fire Events Database,” published December 2014.

The updated database, which is a significant improvement over the existing EPRI fire events database, is utilized for this analysis. The analysis is based primarily upon the database as it existed for EPRI 1025284 “The Updated Fire Events Database: Description and Content and Fire Event Classification Guidance”, July 2013, with a correction cited to the event 209 severity by NUREG-2169/EPRI 3002002936, “Nuclear Power Plant Fire Ignition Frequency and Non-Suppression Probability Estimation Using the Updated Fire Events Database,” December 2014. The updated database is a substantial improvement due to more plants reporting to this database and more complete event descriptions than in the preceding EPRI fire events database. The more complete database leads to an increased level of confidence in its use to inform fire PRA applications, such as the fraction of arc fault induced fires occurring in MCCs.

The following MCC events from the updated database may exhibit energy sufficient to breach a well-sealed MCC which could cause damage outside of the cabinet. The event descriptions are derived from the published database information, as well as from original sources of information collected as a part of the database development process.

- Event 144:

  Fire Severity Classification: Potentially Challenging from EPRI 1025284. Potentially Challenging in later NUREG-2169/EPRI 3002002936 (2000-2009 data).

  Conclusion for MCC application: Arcing conditions such as conductive vapor, molten metal, from a fault, where conductive path was created from bus bars to metallic pan in bottom of MCC. Also, significant scorching and smoke deposits indicative of a relatively energetic event are on the inside of the MCC. If upstream breaker had not tripped, overcurrent condition would have been extended, leading to a more significant event, e.g. potential explosion. The review panel is unable to confirm from the event description that the door wasn’t blown open, although the conditions cited in the report indicate that the door could have been forced open. Count for arcing fire is 0.5.

Description of event: Power was lost to the valves at 1238 when the supply circuit breaker for 480 VAC motor control cubicle (MCC) 2B-53 tripped as a result of a bus to ground electrical fault. At 1244, operators dispatched to investigate the breaker trip discovered a small fire in the MCC, which they immediately extinguished. The cause of the fire in MCC 2B-53 was determined to be a misalignment of the circuit breaker stabs that connect the 2VSF-1A circuit breaker to the bus bars that resulted in both sides of the "C" phase stab and its associated spring clip ending up on one side of the bus bar, thereby creating a high resistance connection. Subsequent starts of 2VSF-1A likely resulted in arcing which increased the resistance at the connection due to oxidation at the contact points. When an attempt to start 2VSF-1A was made on October 30, the large inrush current of the motor at the high resistance connection caused the spring clip to melt. It cannot be determined if the molten metal from the spring clip caused a fire in the bottom of the MCC which created a conductive vapor in the cabinet or if the clip simply vaporized, creating the conductive environment. Nonetheless, the result was that the conductive vapor created an arc path to ground between the bus bars and the metallic dust pan in the bottom of the MCC, resulting in significant damage to the bus bars. The upstream circuit breaker tripped immediately, terminating the over-current event. A photo of the MCC shows substantial scorching and smoke deposits on the inside of the cabinet, which is reflective of a relatively energetic arcing event.

- Event 152:
  Fire Severity Classification: Potentially Challenging from EPRI 1025284. Potentially Challenging in later NUREG-2169/EPRI 3002002936 (2000-2009 data).

  Conclusion for MCC application: Count of 1 due to door blowing open from fault. Intense heat as characterized by melting of metal and plastic in cabinet.

  Description of event: On 10/23/07, a fault occurred internal to Motor Control Center (MCC) 2B-52 associated with breaker 2B-52A5 when charging pump 2P 36A was started. The fault resulted in damage to the associated vertical bus bars in the MCC and a small fire that self-extinguished. Feeder load center breaker 2B-532 tripped, de-energizing MCC 2B-52. Unit 2 declared an Alert Emergency Class Declaration due to the fire and several safety related loads being electrically isolated when the feeder breaker tripped. During this event the heat from the fault caused the MCC plastic base pan and the space heater wires in the MCC to catch on fire and pressure from the fault caused the side wire way door to open exposing the adjoining wire way. A photo from the event shows the blown open door and the subsequent flash damage on the front of the MCC panel.

Additional inspection of the charging pump breaker with the cubicle door open was initially performed. Initial inspection results determined that the fault did not appear to originate inside the breaker cubicle, but rather behind the cubicle in the vertical bus channel. The inspection cover below the breaker was removed and a video-scope inspection of the breaker stabs and associated vertical MCC bus bars was performed prior to disturbing the starter cubicle. These photos revealed molten metal / slag at the outer C and B phases where the stabs engaged the bus bars. All stab fingers were properly aligned with the bus bars. All 3 vertical bus bars in the MCC cubicle were found to be melted (from the bottom up) up to the first horizontal bus brace (~ 4” of bus bars melted to within ~6” of the breaker stabs). The plastic bus seal-off channel below the buses was completely melted / burned away. Visual inspection following removal of the starter cubicle and bus safety barrier indicated questionable engagement/contact of the stab fingers on all 3 phase bus bars which is believed to be the root cause of the event.

- Event 209:
  Fire Severity Classification: Not Challenging from EPRI 1025284. Potentially Challenging in later NUREG-2169/EPRI 3002002936 (2000-2009 data). Obvious correction to potentially challenging from not challenging needed from description which cites flames, explosion, and cubicle door blown open.

  Conclusion for MCC application: Count of 1 due to explosion and door blowing open.

  Description of event: While removing Clearance 594741 on HS-P-1B places MCC pan back on bus, closed cubicle door and turned linestarter on. At the local pump controller the operator noted the green 'off' light flickering. When the control switch was placed to the "on" position a loud explosion was heard. Smoke and flames were seen at MCC 1-12 cubicle B (located in normal switchgear room in the control building). Cubicle door had blown open, MCC had tripped and Control Room noted loss of "F" 480 volt substation. A CO_2 fire extinguisher was used by the operator to extinguish the fire. MCC inspection revealed what appears to have been shorted bus-bars. Motor was cool to the touch. Both MCC supply breaker and substation feeder breaker tripped on overcurrent. It is suspected that a piece of foreign material (possibly broken stab spring) was jarred loose when contactor on MCC pan was pulled in resulting in a phase-to-phase short.

- Event 10338:
  Fire Severity Classification: Potentially Challenging/Challenging from EPRI 1025284. Potentially Challenging in later NUREG-2169/EPRI 3002002936 (2000-2009 data).

  Conclusion for MCC application: Count of 0.5 for MCC application. Although the event report states significant damage and catastrophic breaker failure, supplementary information led the working group to question behavior of this fire event. The MCC breaker cubicle door was cracked open to allow the motor starter to be observed for abnormalities at time of explosion. While the report does state that when the motor energized, the breaker flashed and forced panel door open, it could not be determined if the door would have opened if it were fully closed. Additionally, the energetic release in this event was limited by the successful breaker coordination of the upstream load center fast acting breakers.

  Description of event: Breaker underwent catastrophic failure. The breaker serves Steam Generator Blowdown Pump 1A (BB Pump 1A). At the time of the failure, the breaker was closed, the cabinet door was cracked open and one person was observing the motor starter relay to determine the time at which it actuated, so that current and transients could be measured by an inductive pickup installed on the pump motor power cable (located in the wiring raceway compartment adjacent to the breaker cubicle). When the pump start switch was actuated on the main control board, the breaker failed catastrophically. The breaker failure was more severe than plant personnel could recall. Electrical flash, fire, smoke, molten metal, metal fumes, metal parts, and plastic parts were produced. This was the occasion of a near-miss injury. Subsequent to extinguishing the fire, the status of the motor control center was thought to be de-energized, but was actually still energized. Live line supply leads had been blown off the breaker terminals and were hanging outside the cubicle doorway. The breaker assembly (‘bucket‘) was pulled outward to disconnect it from the electrical bus while the bus was unknowingly still powered. This was the occasion of a second near-miss injury. The severe injury risk and the severity of breaker failure prompted a management request for a root cause analysis that focuses on safety practices/injury prevention and the root cause/prevention of breaker failure.

- Event 20357:
  Fire Severity Classification: Potentially Challenging from EPRI 1025284. Potentially Challenging in later NUREG-2169/EPRI 3002002936 (1990-1999 data).

  Conclusion for MCC application: Count of 0.5. Door open at time of explosion in this fire event. Control Electrician being blown off ladder indicates a substantial event, but since the electrician was peering into the cabinet at the time of the explosion, it cannot be determined if he was blown off the ladder or reacted reflexively to the loud noise, etc. accompanying the explosion.

Description of event: At the time of the event, a plant Control Electrician was performing an independent pre-job walkdown evaluation (i.e., non-intrusive visual inspection) of a previously identified deficiency concerning missing mounting screws from a bus cover inside the back of MCC 208. The inner bus cover is secured in place with two bottom screws. He opened the main door on the back of Cubicle 14 (the rear of the cubicle has three entrances: a hinged door in the center, and outer cover plates at the top and bottom), looked up into the upper section and observed the inside bus cover plate out of its normal position, angled away from the bus bar. In order to get a clearer look at the inner cover plate, the Control Electrician retrieved a four-foot step-ladder, removed the upper cover plate and set it on the floor. He climbed up the ladder (keeping his flashlight outside the cubicle) and looked into the upper section for about 10 seconds. He saw the inner cover plate start to shift, heard a loud explosion, and found himself standing on the floor. He was not injured. He was wearing a hard hat and safety glasses. The safety glasses aided in preventing a potential eye injury, which involved metal splatter from the resultant electrical arc. The Control Electrician contacted his Assistant General Supervisor (AGS) reporting his near miss incident and the electrical explosion at MCC 208. The AGS dispatched supervisory personnel to MCC 208 and informed the Control Room of the incident.

Results: The Updated Fire Events Database contains 25 MCC fire events from 1990-2009. The descriptions, event narratives and supporting information were reviewed to determine split fractions for fire type (thermal, arcing, or unknown) and observed breach (yes, no, or unknown). To assist with the classification of fire types, definitions of arcing and thermal events are provided below:

- *Arcing:* events exhibiting energetic or explosive electrical equipment faults due to arcs between energized electrical conductors or between energized electrical components and neutral or ground. The energetic fault scenario consists of a short, rapid release of electrical energy and/or accompanying fire(s) involving the electrical device itself.
    - Example: bus to ground electrical fault / fault resulting in damage to the associated vertical bus bars
- *Thermal*: events exhibiting signs of thermal component decomposition (pyrolysis) that lead to flaming fire conditions. Thermal events were typically associated with overheating events.

  - Example: control power transformer (CPT) within MCC which fails due to internal winding failure and not from an over voltage condition on the primary side of the CPT
- *Unknown*: Not enough fire event information to inform split fraction classification.

Table 1-1 Motor Control Center Fire Characterization

FEDB Fire ID	Fire Type (Thermal, Arcing, Unknown)	Fire Severity (CH, PC ,U)	Fire Frequency Weight	Basis
29	Thermal/ Arcing	PC	0.5 (Thermal) 0.5 (Arcing)	Inspection revealed that the "C" and "B" phase power stabs had not been properly engaged with their respective bus bars. Contact between the stabs and bus bars was insufficient to carry the current with the turning gear running at its higher speed. This resistance created a large amount of heat which melted part of the breaker cubicle stabs.
45	Unknown	PC	1	Insufficient information in the database to characterize this event. Event excluded from calculation.
89	Thermal	PC	1	Root cause was an overheated CPT. This type of failure typically results in a slow thermal overheating condition.
144	Arcing	PC	1	Breach event; further discussion provided above.
152	Arcing	PC	1	Breach event; further discussion provided above.
188	Unknown	PC	1	Lightning event. Insufficient information in the database to characterize this event. Event excluded from calculation.
203	Unknown	CH	1	Insufficient information in the database to characterize this event. Event excluded from calculation.
209	Arcing	PC	1	Breach event; further discussion provided above.

FEDB Fire ID	Fire Type (Thermal, Arcing, Unknown)	Fire Severity (CH, PC ,U)	Fire Frequency Weight	Basis
219	Thermal	PC	1	Fire described as an insulation failure
224	Arcing	U	0.5	An electrician caused an electrical fault in a 480 volt MCC cubicle while cleaning
254	Thermal	PC	1	Fire described as an electrical overload
320	Thermal	PC	1	Breaker failure/ malfunction causing an overheating situation
10338	Arcing	PC	1	Breach event; further discussion provided above
20264	Thermal	U	0.5	Overheated Coil
20267	Unknown	U	0.5	Insufficient information in the database to characterize this event. Event excluded from calculation.
20268	Thermal	U	0.5	Overheated CPT
20270	Thermal	U	0.5	Transformer failure; most likely cause is thermal failure
20275	Thermal	U	0.5	Overheated CPT
20282	Thermal	U	0.5	Overheated CPT
20287	Thermal	U	0.5	Transformer failure; most likely cause is thermal failure
20295	Thermal	U	0.5	Overheated Transformer
20302	Unknown	U	0.5	Insufficient information in the database to characterize this event. Event excluded from calculation.
20334	Unknown	U	0.5	Insufficient information in the database to characterize this event.

FEDB Fire ID	Fire Type (Thermal, Arcing, Unknown)	Fire Severity (CH, PC ,U)	Fire Frequency Weight	Basis
				Event excluded from calculation.
20357	Arcing	PC	1	Breach event; Further discussion provided above
20362	Thermal	PC	1	Insulation burned off lead to motor starter contactor & fuse blocks above severely melted. Termination screws loose on starter input terminals. Thermography checks would have identified.

The fire type classification in Table 1-1 is then used to determine a split fraction for MCC fires. The split fraction calculates the fraction of fires which exhibit thermal characteristics versus arcing characteristics. A further review of the arcing events is needed to calculate the final breach factor.

Table 1-2 Motor Control Center Split Fraction Determination

	CH/PC	U	Weighted Total	Split Fraction
Arcing	5.5	1	6	6/15 (0.40)
Thermal	5.5	7	9	9/15 (0.60)
Unknown	Excluded	Excluded	Excluded	
Total	11	8	15	

The method review panel then investigated the “arcing” events for the potential to breach a well-sealed MCC to determine a breaching factor. Only the arcing events were evaluated based on the assumption that a well-sealed MCC can only be breached though an energetic arcing fault. That is, it is assumed that a thermal fire within a well-sealed robustly secured MCC does not have the potential to spread and will be confined to the initiating compartment. Therefore, the conditional probability of MCC breach for thermal fires is assumed to be zero.

The methods review panel dispositioned the arcing fire events into three categories with respect to a breach; Yes, No or Undetermined. A description of the breach classifications are explained in more detail in the following bullets.

- *Yes*: indicated that cabinet breach occurred OR supplementary information led the review panel to believe that cabinet breach could have reasonably occurred even if it was not specifically documented in the event report. Weighting factors were apportioned to events where enclosure breach was not directly observed but the conditions were deemed to be characteristic of an arcing event which could potentially cause breach.
- *No*: indicated that no enclosure breach occurred OR supplementary information was used as evidence that there was no breach. That is, additional information from the event reports was used to inform the fire behavior. For example, fire events involving control power transformers (CPTs) within an MCC typically fail due to internal winding failure and not from an over voltage condition on the primary side of the CPT. These type of winding failures exhibit slow thermal failures of insulation materials and are not likely to cause enclosure breach.
- *Undetermined*: indicated that insufficient information was available in the database to characterize these events. These events were then excluded from MCC breaching factor calculation. The MCC breaching factor was then estimated based on the events where sufficient information was available to disposition the events into either “Yes” or “No” categories for an arcing fault resulting in a breach of the MCC.

Table 1-3 Motor Control Center Fire Events Used for Breach Assessment

FEDB Fire ID	Thermal/ Arcing	Observed Breach	Weighted count of breach events	Fire Severity	Weighted count of arcing events	Basis
29	Thermal/ Arcing	N	0	1	0.5	Possible arcing event. Breaker cubicle stabs were melted.
144	Arcing	Y	0.5	PC	1	Breach event; further discussion provided above.
152	Arcing	Y	1	PC	1	Breach event; further discussion provided above.
209	Arcing	Y	1	PC	1	Breach event; further discussion provided above.
224	Arcing	N	0	U	0.5	Root cause analysis indicates personnel error while cleaning an

FEDB Fire ID	Thermal/ Arcing	Observed Breach	Weighted count of breach events	Fire Severity	Weighted count of arcing events	Basis
						MCC resulting in damage and personnel injury. Door was open prior to event and the cause. No cabinet breach occurred.
10338	Arcing	Y	0.5	PC	1	Breach event; further discussion provided above.
20357	Arcing	Y	0.5	PC	1	Breach event; Further discussion provided above.

The review concluded that given an arcing fire, the conditional probability of breach is 3.5/6. Table 1-4 summarizes the results.

Table 1-4 Factors of Well-Sealed Motor Control Center Breaches

Arcing Split Fraction	Conditional Probability of Breach	MCC fires energetic enough to breach well-sealed MCC (F_E)
6/15(0.40)	3.5/6 (0.58)	0.23

In summary, the split fraction of MCC events that are arcing events are combined with the conditional probability of breach to establish the factor of fires energetic enough to breach a well-sealed MCC (F_E). As discussed in the about FAQ discussion, this factor (F_E) is then combined with the fire modeling severity factor (F_D) to estimate the fraction of fires originated from a well-sealed MCC that could damage external targets (F). The fire ignition frequency per MCC vertical section should be calculated in the traditional manner (i.e. electrical cabinet fire frequency) and is multiplied by F to obtain the frequency of breach of a well-sealed MCC that may cause damage to external targets.