

FAQ Number 17-0013

FAQ Revision C

FAQ Title High Energy Arcing Fault (HEAF) Non-Suppression Probability (NSP)

Plant: Various

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Purpose of FAQ:

This FAQ provides an update to the non-suppression probability (NSP) for high energy arcing fault (HEAF) fires based on a review of additional fire event data.

Relevant NRC document(s):

NUREG/CR-6850

NUREG/CR-6850 Supplement 1 (FAQ 08-0050)

NUREG 2169

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:

The non-suppression probability for high energy arcing fault (HEAF) fires provided in NUREG/CR-6850 Supplement 1 (FAQ 08-0050) and NUREG 2169 are considered overly conservative based on durations that extended past the control point in the fire event. As a result, the risk associated with HEAFs in critical fire areas may be artificially high.

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

Although recent guidance has sought to provide a better estimate of non-suppression probability, in the case of HEAF fire events, the probability of non-suppression is believed to be overly conservative.

Potentially relevant existing FAQ numbers:

FAQ 08-0050, “Manual Non-Suppression Probability”

Response Section:

Proposed resolution of FAQ and the basis for the proposal:

1. Introduction

The total duration for high energy arcing fault (HEAF) fires utilized in NUREG/CR-6850 Supplement 1 (FAQ 08-0050) to develop the lambda mean value for HEAFs is 276 minutes. Three events were used to develop this total, resulting in an average of 90 minutes per fire. In some cases, the long suppression duration has had significant impact on the total risk of a fire area. NUREG-2169 expanded the number of reviewed events to eight (8) with a total duration of 602 minutes. The resulting change to the lambda mean was nominal, increasing from the 0.011 established in NUREG/CR-6850 Supplement 1, to 0.013. A further review to verify the suppression rate has been performed, to ensure the analyses of HEAF fires are not providing overly conservative results, and that the results are providing appropriate risk insights for the scenarios.

The fire event times for the majority of the HEAF events in NUREG-2169 are one hour (60 minutes) or longer, with several exceeding two hours (120 minutes) in duration. The probability of non-suppression is based on the average time to suppression within a specific fire bin. The times reported and utilized in NUREG-2169 are excessive considering that many HEAF sources are located in accessible areas provided with automatic detection and the failures due to the HEAF often initiate a signal to the control room early in the event. Therefore, fire brigade response is expected to occur quickly after the initial HEAF. In addition, complete fire suppression is not required for an assessment of non-suppression probability. Arresting the fire spread and propagation eliminates additional target damage and effectively controls the fire, and may not necessarily correspond with a fire being extinguished.

This FAQ review expanded upon the data in NUREG-2169 by reviewing Licensee Event Reports (LERs) and related documentation (where available) for several of the extended duration fires in order to assess whether the fire was in fact under control earlier in the scenario than the event duration implies. During review of the LERs, it became apparent that there are several contributors that extend the reported fire duration beyond the time required to suppress and control the fire. First, it appears that there is a lag between when the fire is under control in the field and when it is reported to the control room as extinguished. It also appears that there is a potentially significant lag between when the fire is under control and when the fire is declared

extinguished due to the need to de-energize the high energy equipment. Both factors result in over-estimation of the fire duration in some event reports and affected fire events included in NUREG/CR-6850 Supplement 1 and NUREG-2169. For purposes of Fire PRAs, the time to control is a more appropriate time, since this is when the fire is no longer considered a challenging event. The fire events reviewed are described below. The fire event number provided represents the number assigned in the EPRI Fire Events Database (Ref. 3).

2. Revised Fire Event Times

- 2.1. **Fire Event #947 (OC 19890103):** This fire event was reported as having a 59 minute duration in NUREG-2169 and NUREG/CR-6850 Supplement 1 and a 46 minute duration in NUREG/CR-6850 (Ref. 2, 3, and 5). A review of the LER indicates that the fire event started at 1916 and the fire was “reported to be out” at 2015 (Ref. 11). However, further details indicate that the first attempt to extinguish the fire was at 1933 hours utilizing CO₂ and dry chemical extinguishers, which were unsuccessful due to reflash (Ref. 11). Plant personnel determined that water fog was required to extinguish the fire without continued risk of reflash. At 2002 hours the bus was de-energized, for personnel safety, and water was applied (Ref. 11). Given this timeline, it is likely that the fire was under control between 1933 and 2002 hours; however, the fire was definitively under control at 2002 establishing a 46-minute event duration for the purposes of calculating NSP (Ref. 11). This fire is an example of cautious firefighting resulting in a delay to fire suppression due to a fire in high energy equipment.
- 2.2. **Fire Event #74 (WF 19950610):** This fire event was reported as having a 136 minute duration in the FEDB and NUREG-2169 (as Fire Event #74); a 57 minute duration in NUREG/CR-6850 (reported as event number 2175); and a 76 minute duration in NUREG/CR-6850 Supplement 1 (as 2175) (Ref. 2, 3, 4 and 5). A review of the LER indicates that the event initiated at 0858, which varies only slightly from the FEDB which reports the event initiating at 0857 (Ref. 2 and 10). The fire brigade responded and attempted to extinguish the fire at 0935 via Halon, CO₂, and dry chemical extinguishers (Ref. 10). The fire was reported extinguished at 1022, after the local fire department applied water to the insulation above the bus at 1018 (Ref. 10). Since the fire was under control at 1018, the appropriate fire duration for the NSP calculation is 80 minutes. The extended fire duration time reported in the FEDB and NUREG-2169 coincides with the official declaration that the fire was extinguished (Ref. 10).
- 2.3. **Fire Event #100 (DC 20000515):** This fire event was reported as having a 78 minute duration in NUREG-2169 and the FEDB (Ref. 2 and 4). The event was not included in NUREG/CR-6850 or NUREG/CR-6850 Supplement 1 (Ref. 3 and 5). The event was reported to begin at 0025 hours on May 15, 2000. The fire was declared out at 0143 hours, providing the 78 minute duration. However, additional details provided in the Preliminary Notification of Event or Unusual Occurrence (Ref. 7) as reported by the Region IV staff, indicates that the fire was extinguished “using carbon dioxide, by 1 a.m.” Although PNO is not the official documentation of the fire event, such as the LER, the additional information agrees with the LER (Ref. 6) which states:

When the fire brigade entered the room, they quickly extinguished the fire with a CO2 extinguisher, before offsite assistance arrived. After clearing smoke from the room, the fire was declared out at 0143 PDT.

This suggests that a significant time lag may have occurred between extinguishing what is referred to as the “small fire” and the official declaration. A 35 minute fire duration is considered reasonable based on the available data and is a refinement on the original, conservative duration provided in the FEDB and utilized in NUREG-2169.

- 2.4. **Fire Event #106 (SG 20010203):** This fire event was reported as having a 154 minute duration in NUREG-2169 and a 156 minute duration in the FEDB (Ref. 2 and 4). The event is also cited as 141 minutes in NUREG/CR-6850 Supplement 1, which is a revision from the NUREG/CR-6850 duration of 136 minutes (Ref. 3 and 5). There is no explanation provided in NUREG-2169 or NUREG/CR-6850 Supplement 1 for the discrepancy between the documents. The LER for this event details that the event began around 1513 (1514 was reported in the FEDB and is used here) and that fire responders reported the fire extinguished at 1544; it was later determined that the fire was not extinguished at that time, but flames were no longer visible (Ref. 8). The delay is attributed to extinguishing due to high energy and resistance to using water; however, the fire was under control and limited to the cubicle at the time of the report (Ref. 8). Therefore, an event duration of 31 minutes is appropriate for use in the NSP curve, as this reflects the time required for the fire to be suppressed and controlled.
- 2.5. **Fire Event #127 (VY 20040618):** This fire event was reported as having a 71 minute duration in NUREG 2169 and the FEDB (Ref. 2 and 4). The event was not included in NUREG/CR-6850 or NUREG/CR-6850 Supplement 1 (Ref. 3 and 5). The FEDB reports that the fire was under control by 0717; however, the FEDB utilizes the time to extinguishment of 0751 to calculate the fire duration (Ref. 3). The LER for this event establishes that the event occurred at 0640 and that the fire brigade declared the fire under control at 0717, resulting in a 37 minute duration (Ref. 9). Therefore, an event duration of 37 minutes is appropriate for use in the NSP curve, as this reflects the time required for the fire to be controlled.

3. Additional Fire Events

This FAQ review also identified two fire events that were binned as electrical fires for the calculations of non-suppression probability in NUREG-2169 but which are bin 16.1 and 16.2 HEAF fires for fire ignition frequency (Ref. 2). The fire events in this category are #922 and #792 with a fire duration of 5 minutes and 3 minutes respectively. The LER for fire event #922 was reviewed and it was determined that several of the characteristic challenges that have been shown to inhibit fire suppression in HEAF events, specifically the need to de-energize the high energy equipment and suppress secondary fires, were present in this scenario (Ref. 12). The fire originated in a bus bar connecting the Main Auxiliary Transformers from 6160 volt busses due to a phase to ground (Ref. 12). In order to suppress the fire, the Main Auxiliary Transformer

was de-energized and plant personnel manually suppressed a secondary fire caused by slag emitted from the bus (Ref. 12). Based on the characteristics of this fire, although it occurred outside of an electrical panel, the fire is considered to represent the same challenges as a typical HEAF scenario and inclusion in the HEAF non-suppression probability calculations is considered appropriate.

Fire event #792 occurred in the “A” isolated-phase bus duct due to damaged ground straps and a deteriorated gasket (Ref. 13). Although the fire does not represent similar combustibles to that of a typical electrical cabinet, the challenges related to the fire are similar to that of a typical HEAF; specifically, that the bus ducts were required to be de-energized prior to suppression (Ref. 13). Therefore, inclusion of this fire event in the calculations for the HEAF non-suppression probability of a HEAF fire is considered more appropriate than inclusion in the electrical fire bin.

In addition, the most recent revision to the EPRI FEDB includes an additional published event that was not available for review at the time of NUREG-2169. Fire Event #162 occurred on August 5, 2009 and is reported to have a 46 minute fire duration (Ref. 4). The event was detected at 0751 hours when the conductor in one of the supply busses catastrophically failed, melting all three phases of the conductor (Ref. 14). The fire was declared out at 0811 hours (Ref. 14).

These three fire events, as well as the refined event durations above have been included in the updated calculations of HEAF non-suppression probability.

The re-binning of Fire Events #792 and #922 as HEAF fires versus electrical fires for the non-suppression probability necessarily results in a revision to the electrical fire non-suppression probability. The changes are reflected in the proposed revisions to NUREG-2169 included as part of this FAQ.

4. Comparison with International Events

The scope of the previous non-suppression probability analyses has been limited to events occurring in the United States. However, the Organisation for Economic Co-operation and Development (OECD) has recently released Fire Project Topical Report No. 1 “Analysis of High Energy Arching Fault (HEF) Fire Events” (Ref. 1). This report identified 48 HEAF events that had been reported to the OECD from Canada, Czech Republic, Finland, France, Germany, Japan, Korea, Spain, Sweden and the United States. The database includes 11 events in the United States, although this included non bin 16 HEAFs (e.g., cable HEAFs and HEAFs occurring in the Yard transformers). The OECD report included 18 bin 16 HEAF events occurring outside of the United States. The average duration for these fires was 31.3 minutes; while the average time for the US only events reviewed as part of this FAQ is 35 minutes. The average time for all events, both US and international, is 32.7 minutes. The use of an average time of 35 minutes for US HEAF events is, therefore, considered conservative and in agreement with the trend of HEAF fire event durations internationally.

5. Summary/Conclusion

Based on the documentation review and considering the expanded data set, the mean suppression rates proposed in NUREG/CR-6850 Supplement 1 and NUREG 2169 are overly conservative. It is proposed that the mean suppression rate should be increased by approximately a factor of two (from 0.011/0.013 to 0.029) to reflect the revised average fire duration for HEAFs originating in high energy equipment in the US.

A chi squared distribution was applied, consistent with NUREG-2169, to calculate the percentiles based on the number of events and total durations presented in table 5-1.

Attachment 1 and Attachment 2 to this FAQ are provided to summarize the fire event data review and the resulting average durations and non-suppression probability that would result from expanding the data set. The unique identifier in Attachment 2 represents an identification number based on plant and/or country of origin and date.

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

The following are proposed revisions to NUREG 2169:

Table 5-1

Probability distribution for rate of fires suppressed per unit time, λ (Originally, Table P-2 from NUREG/CR-6850)

Suppression Curve	Number of Events in Curve	Total Duration (minutes)	Rate of Fire Suppressed (λ)			
			Mean	5th Percent	50th Percent	95th Percent
T/G fires	30	1167	0.026	0.019	0.025	0.034
Control room	12	37	0.324	0.187	0.315	0.492
PWR containment (AP)	3	40	0.075	0.020	0.067	0.157
Containment (LPSD)	31	299	0.104	0.075	0.103	0.136
Outdoor transformers	24	928	0.026	0.018	0.026	0.035
Flammable gas	8	234	0.034	0.017	0.033	0.056
Oil fires	50	562	0.089	0.069	0.088	0.111
Cable fires	4	29	0.138	0.047	0.127	0.267
Electrical fires	175	1807	0.097	0.085	0.097	0.109
Welding fires	52	484	0.107	0.084	0.107	0.133
Transient fires	43	386	0.111	0.085	0.111	0.141
HEAFs	11	385	0.029	0.016	0.029	0.044
All fires	443	6358	0.070	0.064	0.070	0.075

Table 5-2

Updated numerical results for suppression curves (Originally, Table 14-1 from NUREG/CR-6850, Supplement 1)

Time (min)	T/G fires	HEAFs	Outdoor Transformers	Flammable Gas	Oil fires	Electrical fires	Transient fires	PWR containment (AP)	Containment (LPSD)	Welding	Control Room	Cable Fires	All Fires
0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
5	0.879	0.867	0.879	0.843	0.641	0.616	0.572	0.687	0.595	0.584	0.198	0.502	0.705
10	0.773	0.751	0.772	0.710	0.411	0.380	0.328	0.472	0.355	0.341	0.039	0.252	0.497
15	0.680	0.651	0.678	0.599	0.263	0.234	0.188	0.325	0.211	0.200	0.008	0.126	0.350
20	0.598	0.565	0.596	0.505	0.169	0.144	0.108	0.223	0.126	0.117	0.002	0.063	0.247
25	0.526	0.490	0.524	0.425	0.108	0.089	0.062	0.153	0.075	0.068	*	0.032	0.174
30	0.462	0.424	0.460	0.359	0.069	0.055	0.035	0.105	0.045	0.040	*	0.016	0.123
35	0.407	0.368	0.404	0.302	0.044	0.034	0.020	0.072	0.027	0.023	*	0.008	0.087
40	0.358	0.319	0.355	0.255	0.028	0.021	0.012	0.050	0.016	0.014	*	0.004	0.061
45	0.314	0.276	0.312	0.215	0.018	0.013	0.007	0.034	0.009	0.008	*	0.002	0.043
50	0.277	0.240	0.274	0.181	0.012	0.008	0.004	0.024	0.006	0.005	*	0.001	0.030
55	0.243	0.208	0.241	0.153	0.007	0.005	0.003	0.016	0.003	0.003	*	*	0.021
60	0.214	0.180	0.212	0.129	0.005	0.003	0.002	0.011	0.002	0.002	*	*	0.015
65	0.188	0.156	0.186	0.108	0.003	0.002	*	0.008	0.001	0.001	*	*	0.011
70	0.165	0.135	0.164	0.091	0.002	0.001	*	0.005	*	*	*	*	0.007
75	0.145	0.117	0.144	0.077	0.001	0.001	*	0.004	*	*	*	*	0.005
80	0.128	0.102	0.126	0.065	*	*	*	0.002	*	*	*	*	0.004
85	0.112	0.088	0.111	0.055	*	*	*	0.002	*	*	*	*	0.003
90	0.099	0.076	0.098	0.046	*	*	*	0.001	*	*	*	*	0.002
95	0.087	0.066	0.086	0.039	*	*	*	*	*	*	*	*	0.001
100	0.076	0.057	0.075	0.033	*	*	*	*	*	*	*	*	0.001

FAQ Title High Energy Arcing Fault (HEAF) Non-Suppression Probability (NSP)

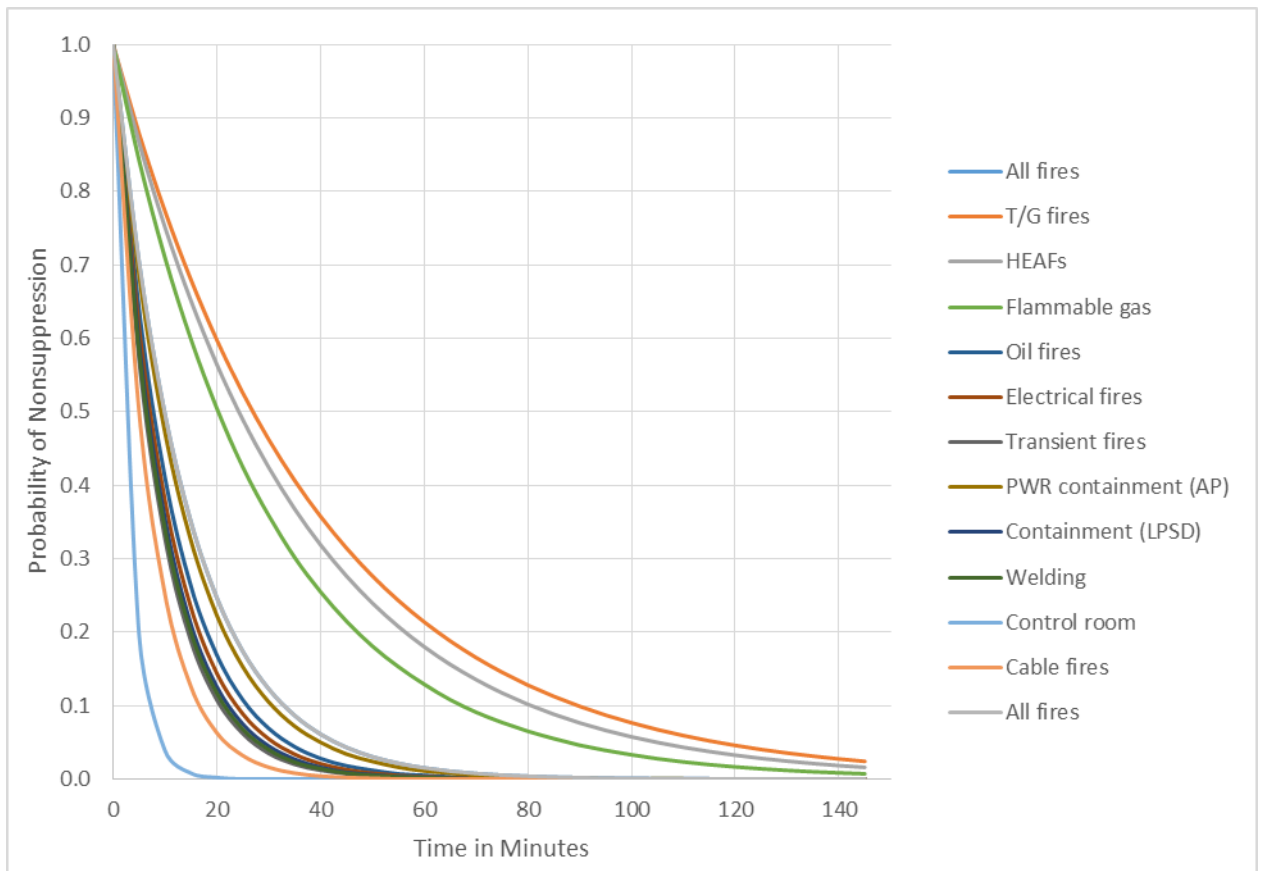


Figure 5-2
Non-suppression curve plots: probability vs. time to suppression

References

1. NEA/CSNI/R(2013)6, Nuclear Energy Agency OECD Fire Project – Topical Report No. 1, “Analysis of High Energy Arcing Fault (HEAF) Fire Events,” June 25, 2013
2. NUREG 2169, “Nuclear Power Plant Fire Ignition Frequency and Non-Suppression Probability Estimation Using the Updated Fire Events Database,” December 2014
3. NUREG/CR-6850 Supplement 1, “Fire Probabilistic Risk Assessment Methods Enhancements,” September 2010
4. EPRI 1025284, “The Updated Fire Events Database: Description of Content and Fire Event Classification Guidance,” July 2013
5. NUREG/CR-6850, “Fire PRA Methodology for Nuclear Power Facilities,” September 2005
6. PG&E Letter DCL-00-115, Licensee Event Report 1-2000-004-01, “Unit 1 Unusual Event Due to a 12kV Bus Fault,” August 30 2000
7. Preliminary Notification of Event or Unusual Occurrence, PNO-IV-00-011, “Unusual Event Because of a Fire Lasting Greater than 15 Minutes,” May 15, 2000
8. Southern California Edison Docket No. 50-362, Licensee Event Report 2001-001, “Fire and RPS/ESF Actuations Caused by the Failure of a Non-Safety Related 4.16kV Circuit Breaker” April 2, 2001
9. Entergy Licensee Event Report 2004-003-01, “Vermont Yankee Nuclear Power Station License No. DPR-28 (Docket No. 50-271) Reportable Occurrence No. LER 2004-003-01,” June 14, 2005
10. Waterford Licensee Event Report 95-002-01, Accession # 9801160136, “Reactor Trip and Non-Safety Related Switchgear Fire,” January 13, 1998
11. Oconee Nuclear Station Unit 1 Licensee Event Report, “Fire in ITA Switchgear Due to Unknown Cause,” February 2, 1989
12. Kewaunee Nuclear Power Plant Licensee Event Report 87-009-00, “Electrical Bus Bar Failure Causes Under voltage on RXCP Buses and Reactor Trip,” August 10, 1987
13. EPRI 1003111, “Fire Events Database and Generic Ignition Frequency Model for U.S. Nuclear Power Plants,” November 2001
14. US Nuclear Regulatory Commission Region IV Report 05000397/2009010, “Columbia Generating Station – NRC Special Inspection Report,” November 23, 2009

FAQ Number 17-0013

FAQ Revision 0 (Draft C)

FAQ Title High Energy Arcing Fault (HEAF) Non-Suppression Probability (NSP)

Attachment 1: Data Summary Table

FAQ Number 17-0013

FAQ Revision 0 (Draft C)

FAQ Title High Energy Arcing Fault (HEAF) Non-Suppression Probability (NSP)

BIN 16 HEAF Analysis	# Events	Total Duration	AVG time/event	Mean Suppression Rate (/min)
NUREG/CR-6850	3	239	79.67	0.013
NUREG/CR-6850 Supplement 1	3	276	92.00	0.011
NUREG 2169	8	602	75.25	0.013
International and US Fire Events	29	948	32.69	0.031
International Events Only	18	563	31.28	0.032
FAQ 17-0013 Proposed Values – US Events Only	11	385	35.00	0.029

FAQ Number 17-0013

FAQ Revision 0 (Draft C)

FAQ Title High Energy Arcing Fault (HEAF) Non-Suppression Probability (NSP)

Attachment 2: Fire Event Data Summary

FAQ Title High Energy Arcing Fault (HEAF) Non-Suppression Probability (NSP)

Unique Identifier	BIN	*Reference	FEDB #	Include/Exclude	Reason for Include/Exclude	Outlier (Y/N)/ Basis	Country	Plant	Date	Event Title	Component	Voltage Level	Location	Fuel	Damage Limited to Initial Component	Extinguished by (all means involved)	Time Data	Duration [h:min]
GER 20040823	12	1	None	Exclude - BIN 12	Cable HEAF	Yes - No suppression time available	Germany	GER009	20040823	Failure in the auxiliary power supply with consequential reactor scram	high voltage cable	10 kV	outside the plant, Not switchyard, other cable room	cable insulation materials	No	self- extinguished	Unknown	0:00
USA 20100328	12	1	None	Exclude - BIN 12	Cable HEAF	N/A	USA	USA027	20100328	Plant trip due to electrical fault	cable run (self-ignited): power cables	4 kV	turbine building	cable insulation material	No	on-site plant fire brigade; people available in the fire area	Unknown	0:15
GER 19790811	16.b	1	None	Exclude	No suppression time is available	N/A	Germany	GER027	19790811	High energy electric arc at circuit breaker and isolator	circuit breaker (sub-distribution board)	Unknown	auxiliary building, room for ventilation	cable insulation materials	Yes	self- extinguished	Unknown	Unknown
USA 19840802	16.a	1, 2	434	Exclude	Event time undetermined	N/A	USA	Unknown	19840802	Electrical cabinets with HEAF	Electrical cabinet	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
JPN 19850831	16.b	1	None	Include	Bin 16	N/A	Japan	JPN044	19850831	Fire at the cabinet containing 6.9 kV bus for start-up	high or medium voltage electrical cabinet	6.9 kV	turbine building, switchgear room	cable insulation materials	Yes	fixed extinguishing system, manually actuated; external fire brigade participated	Unknown	2:14
GER 19860530	16.a	1	None	Include	Bin 16	N/A	Germany	GER011	19860530	Damage of the 380 V busbar CR (auxiliary power supply of train 4) by a fire	bus bar	380 V	electrical building, cable spreading room	cable insulation materials; other insulations	No	on-site plant fire brigade	Unknown	0:25
KW 19870710	16.1	2, 4	922	Include	Bin 16	N/A	USA	Kewaunee	19870710	Bus-duct	Bus duct	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	0:03
GER 19870909	16.b	1	None	Include	Bin 16	N/A	Germany	GER022	19870909	Short circuit in the exciter system of an emergency diesel generator unit	high or medium voltage electrical cabinet (emergency diesel)	Unknown	electrical building, switchgear room	cable insulation materials	Yes	on-site plant fire brigade	Unknown	0:09
GER 19880419	16.b	1	None	Include	Bin 16	N/A	Germany	GER024	19880419	Short circuit in the 220 kV/380 kV switchgear with consequential loss of offsite power	high voltage switchgear	220 kV	switchyard	hardly inflammable liquid	Yes	on-site plant fire brigade	Unknown	0:46
USA 19880715	16.2	2, 4	792	Include	Bin 16	N/A	USA	Unknown	19880715	Iso-phase bus ducts	Iso-phase bus ducts	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	0:05
OC 19890103	16.b	2, 4	947	Include	Bin 16	N/A	USA	Oconee	19890103	During power escalation after startup following a trip a Fire occurred in the Unit 1 6900 V switchgear	6.9 KV Switchgear	6.9kV	Switchgear Room	Unknown	Unknown	fire brigade (water, CO2, dry chemical)	1916-2002	0:46
GER 19890517	16.a	1	None	Include	Bin 16	N/A	Germany	GER025	19890517	Electric arc at a feeder control panel in the 380 V switchgear	switchgear (380 V switchgear, injection area)	380 V	electrical building, switchgear room	cable insulation materials	Yes	people available in the fire area	Unknown	0:12

FAQ Title High Energy Arcing Fault (HEAF) Non-Suppression Probability (NSP)

Unique Identifier	BIN	*Reference	FEDB #	Include/Exclude	Reason for Include/Exclude	Outlier (Y/N)/ Basis	Country	Plant	Date	Event Title	Component	Voltage Level	Location	Fuel	Damage Limited to Initial Component	Extinguished by (all means involved)	Time Data	Duration [h:min]
GER 19890908	16.b	1	None	Include	Bin 16	N/A	Germany	GER001	19890908	Short circuit in the auxiliary electrical system	high voltage switchgear (10 kV injection cell); circuit breaker	10 kV	electrical building, switchgear room	cable insulation materials; plastics / polymeric materials	No (multiple components)	on-site plant fire brigade	Unknown	0:26
USA 19900713	16.b	2, 4	18	Include	Bin 16	N/A	USA	Unknown	19900713	HEAF for medium voltage electrical cabinet (>1000V)	Electrical cabinet	>1kV	Unknown	Unknown	Unknown	Unknown	Unknown	0:10
FRA 19901030	16.b	1	None	Include	Bin 16	N/A	France	FRA042	19901030	Loss of a 6.6 kV emergency switchboard.	high or medium voltage electrical cabinet	6.6 kV	electrical building, switchgear room	cable insulation materials	Yes	shift personnel	Unknown	0:07
FIN 19910412	16.b	1	None	Include	Bin 16	N/A	Finland	FIN001	19910412	Fire at 6.6 kV switchgear	electrical cabinet, high or medium voltage (current transformer inside cabinet)	6.6 kV	electrical building, switchgear room	cable insulation materials, other insulations	No (multiple components)	on-site plant fire brigade	Unknown	0:37
USA 19911014	16.b	2, 4	20284	Include	Bin 16	N/A	USA	Unknown	19911014	HEAF - other electrical or electronic equip	Unknown	Unknown	Unknown	in-situ	Yes	Unknown	Unknown	0:02
WF 19950610	16.b	2, 3, 4	74	Include	Bin 16	N/A	USA	Waterford	19950610	Fault on lightning arrester in the switchyard, reactor trip, and then fire in a 4.16kV Non-safety related bus. Damage limited "mainly" to breaker and adjoining cabinet	fault in 230kV/34.5kV transformer, fire in 4.16kV Switchgear	230kV/34.5kV transformer (4.16kV)	TG Building	Unknown	No	brigade (halon, CO2 and dry chem extinguishers), fire department (water)	0858-1018	1:20
GER 19960208	16.b	1	None	Include	Bin 16	N/A	Germany	GER017	19960208	Disconnection of a main bus due to a short circuit in a switching module	electrical cabinet (busbar, breaker subassembly)	500 V	auxiliary building, switchgear room	cable insulation materials	Yes	on-site plant fire brigade	Unknown	0:17
JPN 19960907	16.1	1	None	Include	Bin 16	N/A	Japan	JPN029	19960907	Fire of the bus-duct in the power supply room for the emergency diesel generator	bus duct	460 V	reactor building, EDG switchgear room	cable insulation materials	No	shift personnel; external fire brigade participated	Unknown	0:42
DC 20000515	16.1	1, 2, 4	100	Include	Bin 16	N/A	USA	Diablo Canyon	20000515	Unit 1 unusual event due to a 12 kV bus fault and fire	12kV bus, busbar/ bus duct	12kV	12kV Switchgear room, auxiliary building	other solid material; plastics, solid material; plastics/ polymeric materials	No	fire brigade extinguished the small fire with C02	0025-0100	0:35
FRA 20010119	16.b	1	None	Include	Bin 16	N/A	France	FRA008	20010119	Incipient fire on ultimate emergency diesel generator	high or medium voltage electrical cabinet	6.6 kV	diesel generator building, electrical / process room	other insulations, plastics / polymeric materials	No (multiple components)	self- extinguished	Unknown	0:05

FAQ Title High Energy Arcing Fault (HEAF) Non-Suppression Probability (NSP)

Unique Identifier	BIN	*Reference	FEDB #	Include/Exclude	Reason for Include/Exclude	Outlier (Y/N)/ Basis	Country	Plant	Date	Event Title	Component	Voltage Level	Location	Fuel	Damage Limited to Initial Component	Extinguished by (all means involved)	Time Data	Duration [h:min]
SG 20010203	16.b	1, 4	437	Exclude	Duplicate	This event occurs on the same day and at the same time as FEDB event 106. FEDB event 437 was not included in NUREG 2169.	USA	SONGS	20010203	Fire and RPS/ESF actuations caused by the failure of a Non-safety related 4.16 kV circuit breaker	4.16kV bus 3A07	4.16kV	turbine switchgear room	cable insulation, solid materials	No second breaker in same bus failed & arced due to smoke	fire brigade	1514-1544	0:31
SG 20010203	16.b	2, 3, 4	106	Include	Bin 16	There are two entries in the FEDB for the same day and time (106 and 437). NUREG 2169 cites only event 106	SG	SONGS	20010203	The event was caused when breaker x faulted which caused arcing, localized overheating and started a fire within the breaker cubicle.	HEAF medium voltage electrical cabinet (>1kV)	4kV	Auxiliary building	circuit breaker	No	on-site plant fire brigade, external fire brigade participated	1514-1544	0:31
Pr Isl 20010803	16.b	2, 4	112	Include	Bin 16	N/A	USA	Prairie Island	20010803	During startup, operators transferring power, closed breaker and breaker failed initiating a fire in bus cubicle. It was a "c-phase to ground arcing event, which quickly involved all phases. The arcing led to actuation of the protective relaying, which resulted in a turbine/reactor trip"	4 kV Bus	4 kV	Bus 12			fire brigade	Unknown	1:30
FRA 20010918	16.b	1	None	Include	Bin 16	N/A	France	FRA022	20010918	Loss of 400 kV power supply following a fire in the 6.6 kV AC Normal distribution system cubicle	high or medium voltage electrical cabinet	6.6 kV	electrical building, switchgear room	hardly inflammable liquid, plastics / polymeric materials	No (multiple components)	shift personnel; external fire brigade participated	Unknown	1:11
GER 20020811	16.b	1	None	Include	Bin 16	N/A	Germany	GER017	20020811	Fire in the 500 V switchgear of one train of the independent emergency system	switchgear	500 V	independent emergency building, switchgear room	cable insulation materials	No	on-site plant fire brigade	Unknown	1:25
GER 20021030	16.b	1	None	Include	Bin 16	N/A	Germany	GER009	20021030	HEAF with consequential fire occurred by exchange of a 0.4 kV switchgear subassembly	switchgear	400 V	electrical building, room for electrical control equipment	cable insulation materials	No	self- extinguished	Unknown	< 00:03
VY 20040618	16.2	1, 2, 4	127	Include	Bin 16	N/A	USA	Vermont Yankee	20040618	Iso-phase bus duct two- phase electrical fault and fire with secondary fires	22kV iso-phase bus	22kV	turbine building and yard (main xfmr)	flammable liquid, hydrogen; other solid material	No	auto suppression, fire brigade extinguished using hose stream and nearby hydrant	0640-0717	0:37

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Unique Identifier	BIN	*Reference	FEDB #	Include/Exclude	Reason for Include/Exclude	Outlier (Y/N)/ Basis	Country	Plant	Date	Event Title	Component	Voltage Level	Location	Fuel	Damage Limited to Initial Component	Extinguished by (all means involved)	Time Data	Duration [h:min]
CAN 20051015	16.a	1	None	Include	Bin 16	N/A	Canada	CAN004	20051015	Electrical arc resulting in injury	low voltage electrical cabinet	600 V	electrical building, switchgear room	cable insulation materials	Yes	on-site plant fire brigade	Unknown	< 00:05
GER 20080314	16.b	1	None	Include	Bin 16	N/A	Germany	GER003	20080314	Fire in a circuit breaker and switch-off of the emergency busbar FB	high voltage circuit breaker	660 V	electrical building, switchgear room	plastics / polymeric materials	Yes	on-site plant fire brigade	Unknown	0:34
USA 20080727	16.1	2, 4	10584	Exclude	No suppression time is available	Indeterminate Supp Time	USA	Unknown	20080727	HEAF for segmented bus duct	HEAF for segmented bus duct	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
CO 20090805	16.b	2, 4	162	Include	Bin 16	event duration Not well established	USA	Columbia	20090805	Cable tray HEAF?	Non-safety related 6.9kV feed bus	7KV	Turbine Building	Insulation	confined to floor of origin	self-extinguished	0750-0811	0:46
CZE 20100217	16.a	1	None	Include	Bin 16	N/A	Czech Republic	CZE003	20100217	Fire at 0.4 kV switchgear	switchgear	0.4 kV	electrical building, switchgear room	cable insulation materials	Yes	on-site plant fire brigade	Unknown	0:05
JPN 20110311	16.b	1	None	Consider Excluding	Seismic event initiates the HEAF and may explain the significant duration time compared to other events	Yes - duration is significantly greater than all other reported events	Japan	JPN022	20110311	Seismic induced arcing fault in Non-emergency metal clad (M/C) switchgear cabinet	high or medium voltage electrical cabinet	6.9 kV	turbine building, switchgear room	cable insulation materials	No	on-site fire brigade	Unknown	7:58
USA 20050825	21	2, 4	135	Exclude	A condensate pump is the initiating component	N/A	USA	Unknown	20050825	Electrical Failure (overheating, spark, HEAF) Contained to the object of origin	electric motor driven pumps	7KV	Turbine Building	in-situ	Yes	fire brigade	1125-1317	
SWD 20060915	21	1	None	Exclude	Pump	N/A	Sweden	SWD007	20060915	Fire in a 6 kV electrical cabinet in room D2.21, cabinet feed power to the pump 725 P1. A breaker in the cabinet is burning	electrically driven pump	6 kV	turbine building, process room	other solid material	No	on-site plant fire brigade	Unknown	1:05
USA 20061212	21	1, 4	1	Exclude	The circ water pump is the initiating component,	N/A	USA	USA066	20061212	Automatic reactor trip due to circulating water pump surge capacitor failure	electrically driven pump	12 kV	intake building, process room	capacitor, insulation material	Yes	on-site plant fire brigade	0025-0100	0:34
USA 20070925	21	4	10472	Exclude	The fault originated in a circ water pump	N/A	USA	Unknown	20070925	HEAF - other electrical or electronic equip	Unknown	Unknown	Unknown	in-situ	Yes	Unknown	Unknown	Unknown
SWD 20061114	23	1	None	Exclude	A transformer is the originating component	N/A	Sweden	SWD010	20061114	Fire in transformer supplying the 6 kV on-site electrical systems train A and C from the generator 20 kV busbar c	medium or low voltage transformer - oil filled	6 kV / 20 kV	outside plant buildings	hardly inflammable liquid	No	on-site plant fire brigade; external fire brigade participated	Unknown	2:40:00

FAQ Title High Energy Arcing Fault (HEAF) Non-Suppression Probability (NSP)

Unique Identifier	BIN	*Reference	FEDB #	Include/Exclude	Reason for Include/Exclude	Outlier (Y/N)/ Basis	Country	Plant	Date	Event Title	Component	Voltage Level	Location	Fuel	Damage Limited to Initial Component	Extinguished by (all means involved)	Time Data	Duration [h:min]
GER 20070628	23	1	None	Exclude	The main transformer is the initiating component	N/A	Germany	GER014	20070628	Reactor trip caused by a temporary loss of station service supply due to a short circuit with a subsequent fire in a generator transformer	high voltage transformer (main transformer)	400 kV	other building / area, other type of room	flammable liquid, paper, wood	Yes	fixed extinguishing system, automatically actuated; on-site plant fire brigade; external fire brigade participated	Unknown	6:58
SPN 19880622	27	1	None	Exclude	The main transformer is the initiating component	N/A	Spain	SPN001	19880622	Trip of main transformer, followed by fire in phase "S" due to manufacturing defect. Subsequently, turbine trip and, with permissive P- 7, reactor trip	high voltage transformer (main transformer)	20 kV /400 kV	outside plant buildings (Not switchyard)	hardly inflammable liquid	Yes	fixed extinguishing system, actuated; on- site plant fire brigade; shift personnel	Unknown	0:58
SPN 19880820	27	1	None	Exclude	The main transformer is the initiating component	N/A	Spain	SPN001	19880820	Trip of main transformer, followed by fire in phase "S" due to manufacturing defect. Subsequently, turbine trip and, with permissive P- 7, reactor trip	high voltage transformer (main transformer)	20 kV / 400kV	outside plant buildings (Not switchyard)	hardly inflammable liquid	Yes	fixed extinguishing system, actuated; on- site plant fire brigade; shift personnel	Unknown	0:15
SPN 19881202	27	1	None	Exclude	The main transformer is the initiating component	N/A	Spain	SPN001	19881202	Main transformer tripped, followed by fire in phase "R"	high voltage transformer (main transformer)	20 kV /400 kV	outside plant buildings (Not switchyard)	hardly inflammable liquid	Yes	fixed extinguishing system, actuated; on- site plant fire brigade; shift personnel	Unknown	Unknown
CZE 19940203	27	1	None	exclude	A transformer is the originating component	N/A	Czech Republic	CZE003	19940203	Fire of the station service load transformer 3BT02 caused by a defect on the power part of the branch lines switch followed by an explosion	medium and low voltage transformer - oil filled	15.75 kV/ 6 kV	outside the plant, Not switchyard, voltage transformers near to main transformer	flammable liquid	No	on-site plant fire brigade	Unknown	0:16
USA 20000524	27	2, 4	50701	Exclude	Binned as "Transformer Yard" in NUREG 2169	N/A	USA	Unknown	20000524	HEAF - other electrical or electronic equipment	XFMR	Unknown	Yard	in-situ	Yes	automatic suppression	Unknown	Unknown
KOR 20010130	27	1	None	Exclude	The main transformer is the initiating component	N/A	Korea	KOR010	20010130	High energy arcing fault on phase 'B' of the main transformer which led to the reactor trip	high voltage transformer (main transformer)	22/345kV	outside plant buildings	insulation material	Yes	self- extinguished	Unknown	0:00
KOR 20020422	27	1	None	Exclude	The main transformer is the initiating component	N/A	Korea	KOR001	20020422	Fire on the main transformer leading to a generator trip	high voltage transformer (main transformer)	> 50 kV	outside	flammable liquid	Yes	fixed extinguishing system, automatically actuated,	Unknown	0:13

FAQ Title High Energy Arcing Fault (HEAF) Non-Suppression Probability (NSP)

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FRA 20040929	27	1	None	Exclude	The main transformer is the initiating component	N/A	France	FRA035	20040929	Electric fault on the main transformer leading to a reactor trip	high voltage transformer (main transformer)	> 50 kV	other building	cable insulation materials	Yes	shift personnel	Unknown	0:20
USA 20080816	27	4	127	Exclude	The main transformer is the initiating component	N/A	USA	Unknown	20080816	Transformer oil - HEAF confined to object of origin	Main bank transformer	13kV or greater	Main Transformer or Switch Yard	XFMR oil	Yes	Unknown	2357-0202	2:05
USA 20090201	27	4	157	Exclude	The main transformer is the initiating component	N/A	USA	Unknown	20090201	Transformer oil - HEAF confined to object of origin	Main transformer	13kV or greater	Main Transformer or Switch Yard	XFMR oil	Yes	Unknown	2156-2227	0:31
FRA 20100725	27	1	N/A	Exclude	The main transformer is the initiating component	N/A	France	FRA012	20100725	Automatic shutdown of the reactor following an explosion and a consequential fire on the main power transformer	high voltage transformer (main transformer)	225 kV	switchyard (transformer room / bunker)	hardly inflammable liquid, cable	No	fixed extinguishing system, automatically actuated; on-site plant fire brigade; external fire brigade participated	Unknown	2:45
USA 20021003	28	1, 2, 4	116	Exclude	A transformer is the originating component	N/A	USA	USA095	20021003	Failure of start-up transformer ST 20	high voltage transformer	> 50 kV	transformer yard	hardly inflammable liquid	Yes	fixed extinguishing system	1513-1738	< 00:10
USA 20051029	28	1, 2, 4	137	Exclude	A yard transformer is the originating component	N/A	USA	USA064	20051029	Reactor trip due to main transformer fault and fire	high voltage transformer	> 50 kV	outside the plant building (Not switchyard), main transformer	hardly inflammable liquid	Yes	fixed extinguishing system; on-site plant fire brigade	Unknown	0:28
USA 20070406	28	1, 2, 4	148	Exclude	A yard transformer is the originating component	N/A	USA	USA043	20070406	Automatic reactor trip due to a turbine generator trip caused by a fault on the 31 main transformer phase B high voltage bushing	high voltage transformer	34.5 kV	transformer yard	hardly inflammable liquid	Yes	on-site plant fire brigade	Unknown	0:12
USA 19991009	29	1, 2, 4	7	Exclude	A yard transformer is the originating component	N/A	USA	USA039	19991009	Under voltage actuation due to a loss of reserve station service transformer	busbar	4.16 kV	outside turbine building	cable connector / insulation materials	Yes	on-site plant fire brigade	Unknown	0:09
FRA 20030830	29	1	None	Exclude	A transformer is the originating component	N/A	France	FRA024	20030830	Explosion of an oil-filled current transformer leading to a fire in the 400 kV platform	high voltage transformer (current transformer)	6.6 kV / 400 kV	switchyard	hardly inflammable liquid	No	fixed extinguishing system, manually actuated; shift personnel; external fire brigade participated	Unknown	0:48
CAN 20050415	29	1	None	Exclude	A transformer is the originating component	N/A	Canada	CAN002	20050415	Unit 6 forced outage due to M.O.T. failure	high voltage transformer	500 kV	switchyard, switchgear room	flammable liquid (transformer insulating oil)	Yes	fixed extinguishing system, automatically actuated	Unknown	< 00:08

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FIN 20060927	29	1	None	Exclude	A transformer is the originating component	N/A	Finland	FIN002	20060927	Voltage transformer fire due to human error during maintenance outage	medium or low voltage transformer - oil filled	15.1 kV	outside the plant (Not switch yard), voltage transformers near to main transformer	hardly inflammable liquid; other insulations	No (multiple components)	on-site plant fire brigade (one fire); self-extinguished (another fire)	Unknown	0:05
JPN 20070716	29	1	None	Exclude	A transformer is the originating component	N/A	Japan	JPN047	20070716	House transformer fire induced by the Niigata- Chuetsu-Oki earthquake	medium or low voltage transformer - oil filled	19 kV /6.9 kV	outside	flammable liquid	Yes	fixed extinguishing system, manually actuated; external fire brigade participated	Unknown	1:55
SWD 20021030	33	1	None	Exclude	The rectifier is part of the exciter for the turbine.	N/A	Sweden	SWD007	20021030	Auto fire alarm about an arc event in a rectifier. The failure led to stop of one turbine.	rectifier	600 V	turbine building, process room	other solid material; plastics / polymeric materials	No (multiple components)	on-site plant fire brigade; external fire brigade participated	Unknown	2:31
USA 20011026	9999	4	10624	Exclude	Fire originated in the primary power distribution pole that feeds the HEEC transformer.	N/A	USA	Unknown	20011026	HEAF - other electrical or electronic equip	Unknown	Unknown	Unknown	in-situ	No	Unknown	Unknown	Unknown
USA 20080917	9999	4	50566	Exclude	basket contacts power line causing explosion	N/A	USA	Unknown	20080917	HEAF - other electrical or electronic equip	Unknown	13kV or greater	Unknown	in-situ	Yes	self-extinguished	0930-unknown	<0:05
SWD 20110510	9999	1	None	Exclude	Vacuum Cleaner	N/A	Sweden	SWD008	20110510	Fire in the reactor containment: Arc in an electrical part in the portable vacuum cleaner	vacuum cleaner	Unknown	containment	plastics / polymeric materials	No	self - extinguished	Unknown	Unknown
USA 20020612	SB4	1, 2, 4	113	Exclude	"Special bin, Not FPRA applicable" per NUREG 2169	Yes, special Bin	USA	USA059	20020612	Switchyard fire in 34.5 kV circuit breaker	high voltage breaker	34.5 kV	switchyard	flammable liquid	Yes	on-site plant fire brigade	Unknown	Unknown

*Reference 1: NEA/CSNI/R (2013)6, Nuclear Energy Agency OECD Fire Project – Topical Report No. 1, “Analysis of High Energy Arcing Fault (HEAF) Fire Events,” June 25, 2013

*Reference 2: NUREG 2169, “Nuclear Power Plant Fire Ignition Frequency and Non-Suppression Probability Estimation Using the Updated Fire Events Database,” December 2014

*Reference 3: NUREG/CR-6850 Supplement 1, “Fire Probabilistic Risk Assessment Methods Enhancements,” September 2010

*Reference 4: EPRI 1025284, The Updated Fire Events Database: Description of Content and Fire Event Classification Guidance,” July 2013