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Rates of Initiating Events at U.S. Nuclear Power Plants: 1987 - 1995

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Table 3-1. Frequency estimates of functional impact categories: mean, percentiles, and trends. (See text for detailed explanation.)

Event	Functional Impact Event Category	Number of Functional Impact Occurrences[a]	Mean Frequency (per critical year)[b,c,k]	Percentiles		Model Used	
				5th %ile	95th %ile	Trend	Plant Difference[j]
Loss-of-Coolant Accident (LOCA)	G						
Large Pipe Break LOCA: PWR	G7	0	5E-6[d]	1E-7	1E-5	Constant[e]	No
Large Pipe Break LOCA: BWR	G7	0	3E-5[d]	1E-6	1E-4	Constant[e]	No
Medium Pipe Break LOCA: PWR	G6	0	4E-5[d]	1E-6	1E-4	Constant[e]	No
Medium Pipe Break LOCA: BWR	G6	0	4E-5[d]	1E-6	1E-4	Constant[e]	No
Small Pipe Break LOCA	G3	0	5E-4[d]	1E-4	1E-3	Constant[e]	No
Very Small LOCA/Leak	G1	4	6.2E-3	2.3E-3	1.2E-2	Constant[e]	No
Stuck Open: Pressurizer PORV	G4	0	1.0E-3	3.9E-6	3.9E-3	Constant[e]	No
Stuck Open: 1 Safety/Relief Valve: PWR	G2	2	5.0E-3	1.2E-3	1.1E-2	Constant[e]	No
Stuck Open: 1 Safety/Relief Valve: BWR	G2	10	4.6E-2	2.5E-2	7.1E-2	Constant[e]	No
Stuck Open: 2 or More Safety/Relief Valves	G5	0	3.2E-4[d]	1.3E-6	1.2E-3	Constant[e]	No
Reactor Coolant Pump Seal LOCA: PWR	G8	2[d]	2.5E-3[d]	5.6E-4	5.4E-3	Constant[e]	No
Steam Generator Tube Rupture: PWR	F1	3	7.0E-3	2.2E-3	1.4E-2	Constant[e]	No
Loss of Offsite Power	B1	33	4.6E-2	8.2E-3	1.1E-1	Constant[e]	No
Total Loss of Condenser Heat Sink (combined):[f] PWR	L	75[f]	1.2E-1[c,f]	2.3E-2[i]	3.2E-1[i]	Decrease[f]	Yes[j]
Total Loss of Condenser Heat Sink (combined):[f] BWR	L	122[f]	2.9E-1[c,f]	2.0E-1	3.9E-1	Decrease[f]	No
Inadvertent Closure of All MSIVs: PWR	L1	35	3.8E-2[c]	1.9E-2	6.5E-2	Decrease	No
Inadvertent Closure of All MSIVs: BWR	L1	74	1.7E-1[c]	6.0E-2[i]	3.6E-1[i]	Decrease	Yes[j]
Loss of Condenser Vacuum: PWR	L2	35	6.9E-2	2.9E-5	3.0E-1	Constant[e]	Yes[j]
Loss of Condenser Vacuum: BWR	L2	46	2.0E-1	4.3E-2	4.6E-1	Constant[e]	No
Turbine Bypass Unavailable	L3	10	4.1E-3[c]	6.1E-4	1.2E-2	Decrease	No
Total Loss of Feedwater Flow	P1	159	8.5E-2[c]	1.3E-2[i]	2.5E-1[i]	Decrease	Yes[j]
General Transients (combined):[f] PWR	Q	1184[f,g]	1.2E+0[c,f]	6.1E-1[i]	2.1E+0[i]	Decrease[f]	Yes[j]
General Transients (combined):[f] BWR	Q	541[f,g]	1.5E+0[c,f]	8.5E-1[i]	2.5E+0[i]	Decrease[f]	Yes[j]
High Energy Line Steam Breaks/Leaks (combined)[h]	K	9[h]	1.3E-2	7.0E-3	2.1E-2	Constant[e]	No
Steam Line Break/Leak Outside Containment	K1	7	1.0E-2	5.0E-3	1.7E-2	Constant[e]	No
Steam Line Break/Leak Inside Containment: PWR	K3	0	1.0E-3	3.9E-6	3.9E-3	Constant[e]	No
Feedwater Line Break/Leak	K2	2	3.4E-3	7.9E-4	7.6E-3	Constant[e]	No

Event	Functional Impact Event Category	Number of Functional Impact Occurrences[a]	Mean Frequency (per critical year)[b,c,k]	Percentiles 5th %ile	Percentiles 95th %ile	Model Used: Trend	Model Used: Plant Difference[j]
Loss of Safety-Related Bus	C						
Loss of Vital Medium Voltage ac Bus	C1	13	1.9E-2	1.1E-2	2.8E-2	Constant[e]	No
Loss of Vital Low Voltage ac Bus	C2	3	4.8E-3	1.5E-3	9.7E-3	Constant[e]	No
Loss of Vital dc Bus	C3	1	2.1E-3	2.4E-4	5.4E-3	Constant[e]	No
Loss of Safety-Related Cooling Water	E						
Total Loss of Service Water	E1	1[d]	9.7E-4[d]	1.1E-4	2.5E-3	Constant[e]	No
Partial Loss of Service Water	E2	6	8.9E-3	4.0E-3	1.5E-2	Constant[e]	No
Loss of Instrument or Control Air: PWR	D1	15[c]	9.6E-3[c]	3.9E-3	1.9E-2	Decrease	No
Loss of Instrument or Control Air: BWR	D1	21[c]	2.9E-2[c]	1.3E-2	5.5E-2	Decrease	No
Fire	H1	39	3.2E-2[c]	1.7E-2	5.2E-2	Decrease	No
Flood	J1	2	3.4E-3	7.9E-4	7.6E-3	Constant[e]	No
		Total — PWR	1.4E+0[c]	6.9E-1[i]	2.4E+0[i]	Decrease[f]	Yes[j]
		Total — BWR	1.8E+0[c]	9.5E-1[i]	2.9E+0[i]	Decrease[f]	Yes[j]

a. Reactor trip events from 1987 through 1995, inclusive, except when noted for certain rare events.

b. Frequencies are presented in per critical year (8,760 critical hours per critical year).

c. For categories with a decreasing trend, the frequencies reported are based on the endpoint of the trend line (i.e., 1995, the last year of the study).

d. No failures were identified in the 1987–1995 operating experience. The Medium and Large Pipe Break LOCA estimates were based on review of current literature and fracture mechanic analyses and using world-wide experience. (Appendix J contains the results of the LOCA analysis.) Frequency estimates for Small Pipe Break LOCA, Reactor Coolant Pump Seal LOCA, Stuck Open: 2 or More Safety/Relief Valves, and Total Loss of Service Water categories were based on total U.S. operating experience (1969–1997).

e. Any evidence for a trend was weak, not statistically significant. The trend, if any, is too small to be seen in the data. Therefore, no trend is modeled.

f. Combined number of occurrences of all categories for each plant type (BWR, PWR) under this heading was used to calculate this frequency and trend.

g. Total number of initial plant-fault occurrences for this plant type.

h. The frequency was based on the combined number of occurrences in the categories under this heading.

i. The interval includes variability from plants with events early in life (for example, learning periods) and are wider than the plants' current performance. See Appendix G for results with the early-in-life events excluded.

j. Due to modeling assumptions with regard to independent random events, the between-plant variation was evaluated with the first four months from date of commercial operation (early-in-life events) excluded for the affected plants.

k. For categories modeled with no trend and no between-plant variation, the estimates were calculated using a Jeffreys noninformative prior (one-half of an event added to the total number of events) in a Bayes updated distribution.

Table D-11. Initial plant fault (IPF) and functional impact (FI) mean frequencies and associated uncertainty distributions based on all the operating experience from 1987 through 1995 (except for certain rare events).

Category	FI (per critical year)	Distribution[a]	IPF (per critical year)	Distribution[a]
B—Loss of Offsite Power	4.61E-2	gamma(1.99, 43.38)	2.37E-2	gamma(1.97, 83.35)
C—Loss of Safety-Related Bus				
C1—Loss of Vital Medium Voltage AC Bus	1.85E-2	gamma(13.5, 728.29)	1.44E-2	gamma(10.5, 728.29)
C2—Loss of Vital Low Voltage ac Bus	4.81E-3	gamma(3.5, 728.29)	2.06E-3	gamma(1.5, 728.29)
C3—Loss of Vital dc Bus	2.06E-3	gamma(1.5, 728.29)	6.87E-4	gamma(0.5, 728.29)
D, BWRs, 1995—Loss of Instrument or Control Air System	2.91E-2	lognormal(2.63E-2, 2.10)	1.27E-2	lognormal(1.06E-3, 2.69)
D, PWRs, 1995—Loss of Instrument or Control Air System	9.60E-3	lognormal(8.58E-3, 2.18)	5.82E-3	lognormal(4.85E-3, 2.70)
E1—Total Loss of Service Water	9.72E-4	gamma(1.5, 1543.30)	3.2 ~~9.72~~E-4	gamma(1.5, 1543.30)
E2—Partial Loss of Service Water	8.92E-3	gamma(6.5, 728.29)	6.87E-4	gamma(0.5, 728.29)
F, PWRs—Steam Generator Tube Rupture	7.02E-3	gamma(3.5, 498.55)	7.02E-3	gamma(3.5, 498.55)
G—Loss of Coolant Accident/Leak				
G1—Very Small LOCA/Leak	6.18E-3	gamma(4.5, 728.29)	3.43E-3	gamma(2.5, 728.29)
G2—Stuck Open: 1 Safety/Relief Valve: BWR	4.57E-2	gamma(10.5, 229.74)	4.57E-2	gamma(10.5, 229.74)
G2—Stuck Open: 1 Safety/Relief Valve: PWR	5.01E-3	gamma(2.5, 498.55)	5.01E-3	gamma(2.5, 498.55)
G3—Small Pipe Break LOCA	5.0E-4	lognormal(4.0E4, 3)	5.0E-4	lognormal(4.0E-4, 3)
G4— Stuck Open: Pressurizer PORV	1.00E-3	gamma(0.5, 498.55)	1.00E-3	gamma(0.5, 498.55)
G5— Stuck Open: 2 or more Safety/Relief Valves	3.24E-4	gamma(0.5, 1543.30)	3.24E-4	gamma(0.5, 1543.30)
G6—Medium Pipe Break LOCA: PWR	4.0E-5	lognormal(1.0E-5, 10)	4.0E-5	lognormal(1.0E-5, 10)
G6—Medium Pipe Break LOCA: BWR	4.0E-5	lognormal(1.0E-5, 10)	4.0E-5	lognormal(1.0E-5, 10)
G7—Large Pipe Break LOCA: PWR	5.0E-6	lognormal(1.0E-6, 10)	5.0E-6	lognormal(1.0E-6, 10)
G7—Large Pipe Break LOCA: BWR	3.0E-5	lognormal(1.0E-5, 10)	3.0E-5	lognormal(1.0E-5,10)
G8—Reactor Coolant Pump Seal LOCA : PWR	2.45E-3	gamma(2.5, 1018.77)	2.45E-3	gamma(2.5, 1018.77)
H, 1995—Fire	3.16E-2	lognormal(2.99E-2, 1.75)	2.34E-2	lognormal(2.17E-2, 1.91)
J—Flood	3.43E-3	gamma(2.5, 728.29)	2.06E-3	gamma(1.5, 728.29)
K—High Energy Line Break	1.30E-2	gamma(9.5, 728.29)	1.30E-2	gamma(9.5, 728.29)
K1—Steam Line Break Outside Containment	1.03E-2	gamma(7.5, 728.29)	1.03E-2	gamma(7.5, 728.29)
K2—Feedwater Line Break	3.43E-3	gamma(2.5, 728.29)	3.43E-3	gamma(2.5, 728.29)

Table D-11. (continued).

Category	FI (per critical year)	Distribution[a]	IPF (per critical year)	Distribution[a]
K3, PWRs—Steam Line Break Inside Containment	1.00E-3	gamma(0.5, 498.55)	1.00E-3	gamma(0.5, 498.55)
L, BWRs, 1995 —Loss of Condenser Heat Sink	2.86E-1	lognormal(2.81E-1, 1.38)	1.02E-1	lognormal(9.62E-2, 1.71)
L1, BWRs, 1995 —Inadvertent Closure of All MSIVs	1.71E-1	lognorntal(1.48E-1, 2.45)	3.12E-1	lognormal(2.61E-2, 2.66)
L2, BWRs —Loss of Condenser Vacuum	2.02E-1	gamma(2.344, 11.60)	1.19E-1	gamma(1.83, 15.33)
L, PWRs —Loss of Condenser Heat Sink	—	—	3.76E-2	gamma(0.662, 17.62)
L, PWRs , 1995—Loss of Condenser Heat Sink	1.17E-1	lognormal(8.46E-2, 3.76)	—	—
L1, PWRs—Inadvertent Closure of MSIVs	—	—	1.10E-2	gamma(5.5, 498.55)
L1, PWRs, 1995—Inadvertent Closure of MSIVs	3.80E-2	lognormal(3.54E-2, 1.85)	—	—
L2, PWRs—Loss of Condenser Vacuum	6.87E-2	gamma(0.354, 5.14)	2.58E-2	gamma(0.246, 9.56)
L3—Turbine Bypass Unavailable	—	—	2.06E-3	gamma(1.5, 728.29)
L3, 1995—Turbine Bypass Unavailable	4.10E-3	lognormal(2.72E-3, 4.44)	—	—
P, 1995—Total Loss of Feedwater Flow	8.45E-2	lognormal(5.70E-2, 4.30)	5.44E-2	lognormal(3.03E-2, 5.94)
Q-B, BWRs, 1995—Other Initial Plant Fault	1.55E+0	lognormal(1.46E-0, 1.73)	—	—
Q-P, PWRs, 1995—Other Initial Plant Fault	1.22E+0	lognormal(1.14E+0, 1.87)	—	—

Note: Refer to Tables 3-1 and D-12 for special notes concerning the specifics on the values in this table.

a. For the gamma(param1, param2), param2 is critical years and the mean is param1 divided by param2. For the lognomal(param1, param2), param1 is the fitted median while param2 is the error factor.