PROBABILISTIC RISK ASSESSMENT (PRA) STRUCTURE AND RESULTS

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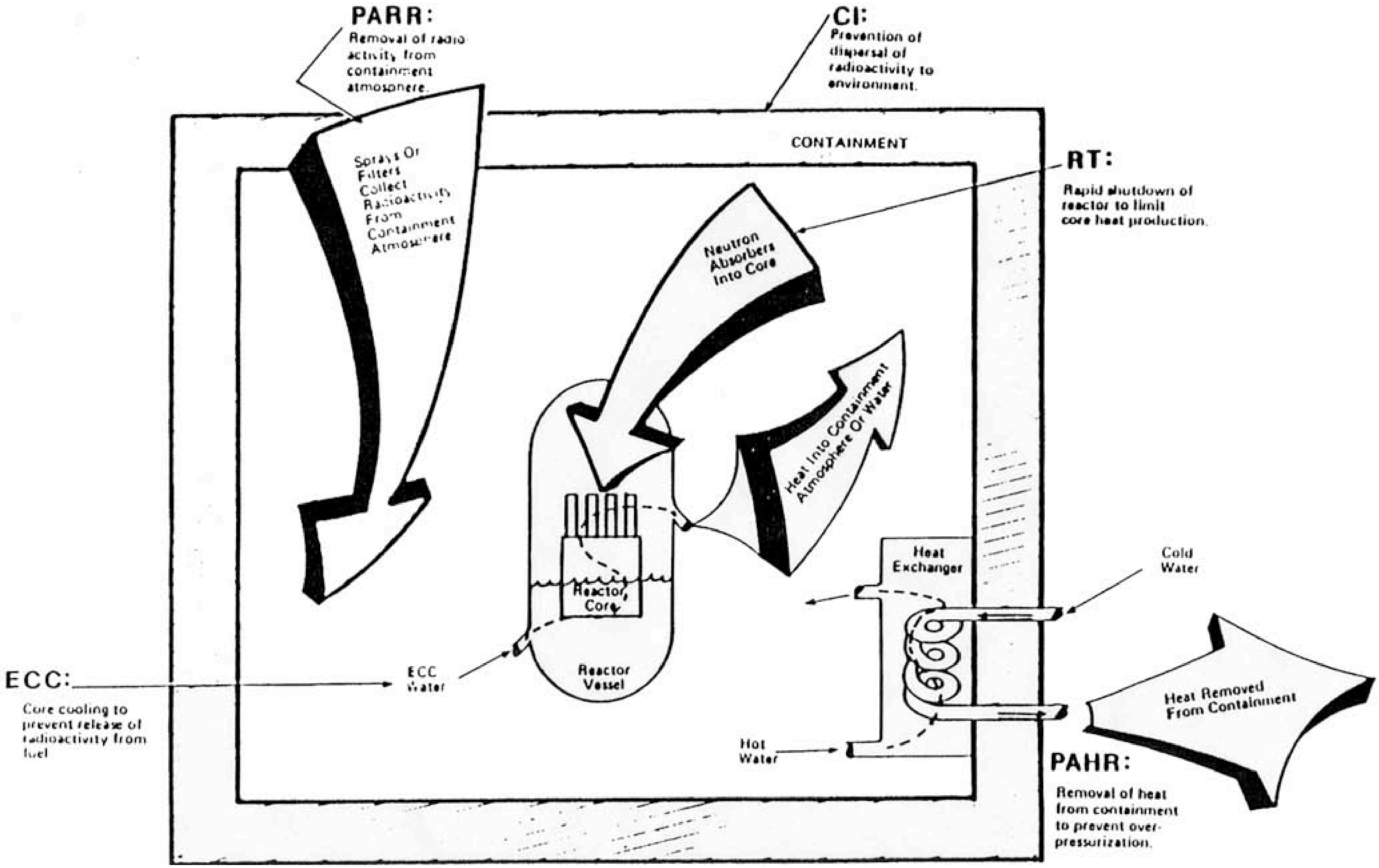
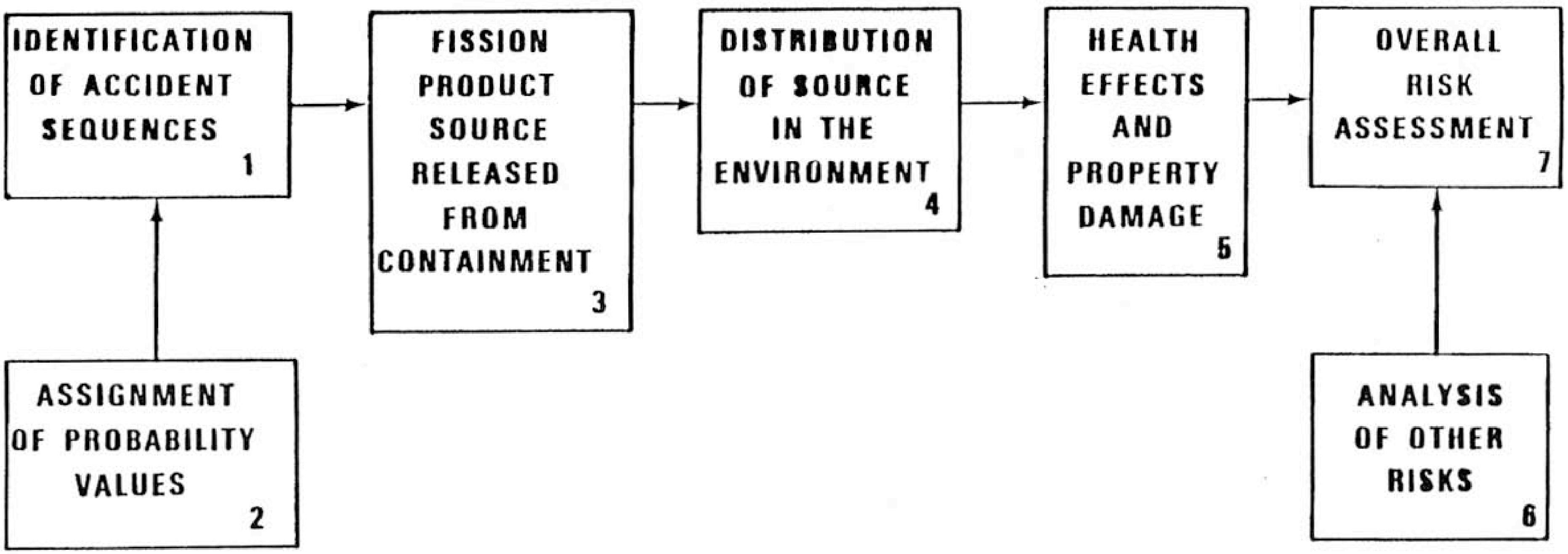
FUNCTIONS OF ENGINEERED SAFETY FEATURES



Courtesy of U.S. NRC.

BASIC SEVEN TASKS IN REACTOR SAFETY STUDY



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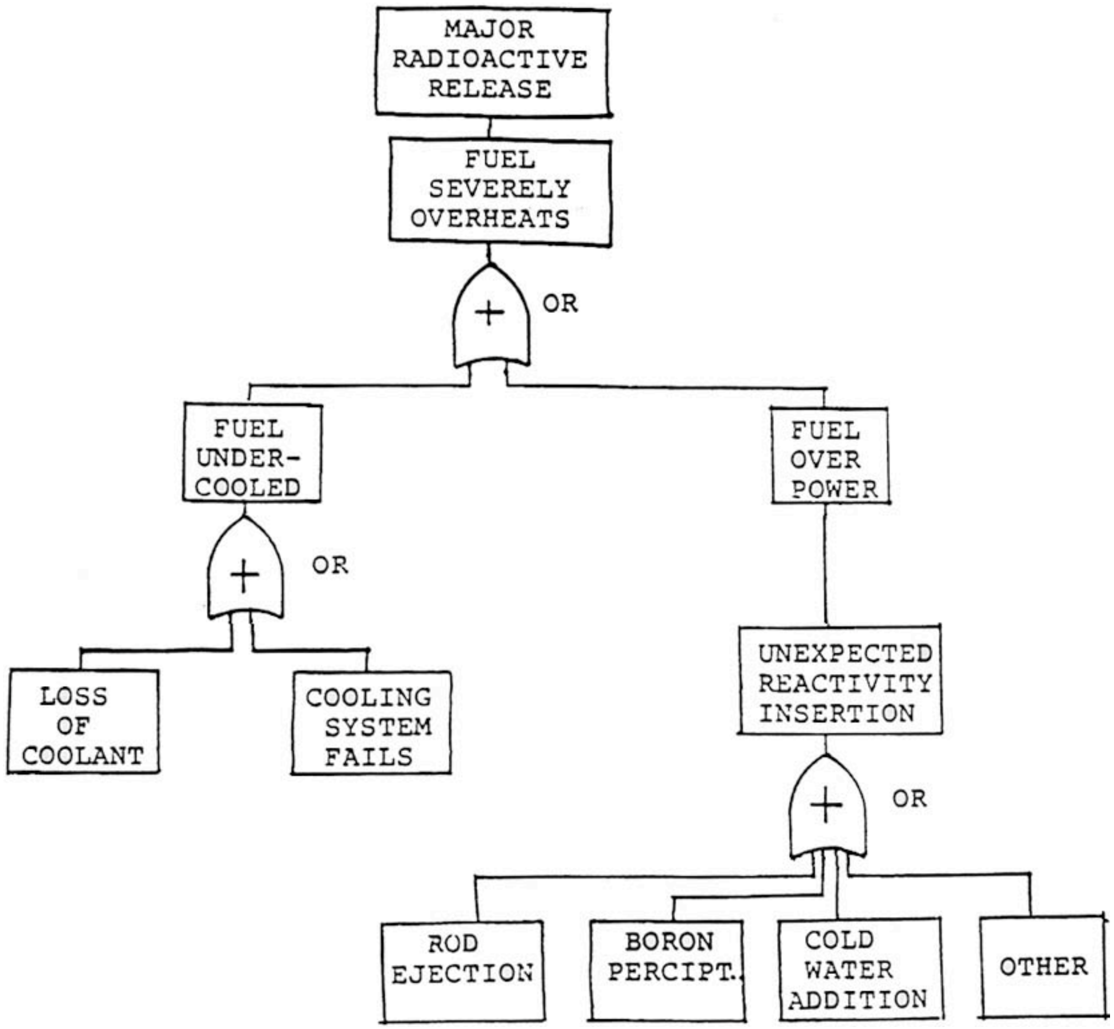
EXAMPLE MASTER LOGIC DIAGRAM



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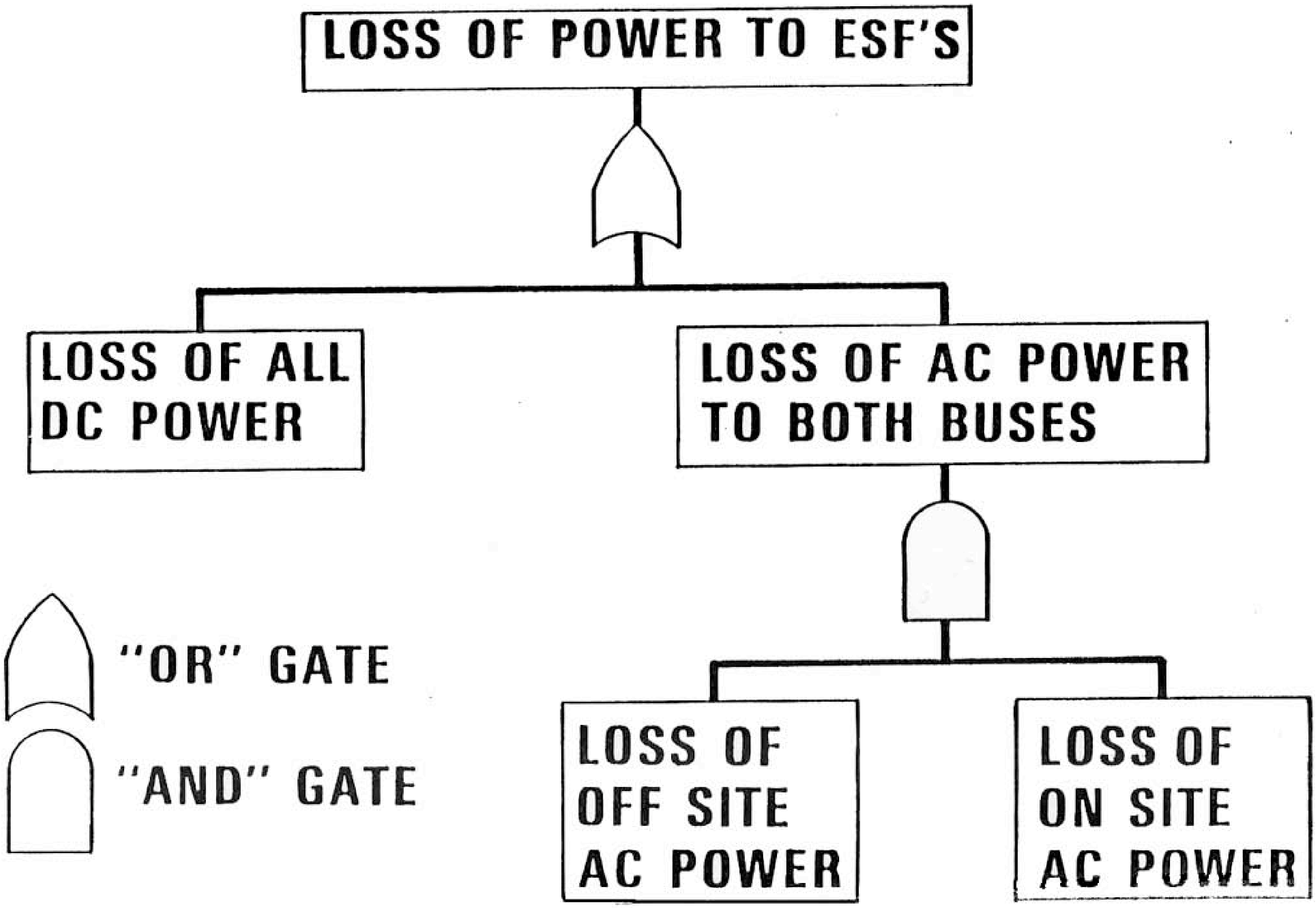
SIMPLE FAULT TREE ON ELECTRIC POWERS



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INITIATING EVENTS FROM WASH-1400

Loss of Coolant

1. Small Pipe Break
2. Medium Pipe Break
3. Large Pipe Break
4. Interfacing LOCA "V Sequence"
5. Vessel Rupture

Failure of Cooling System

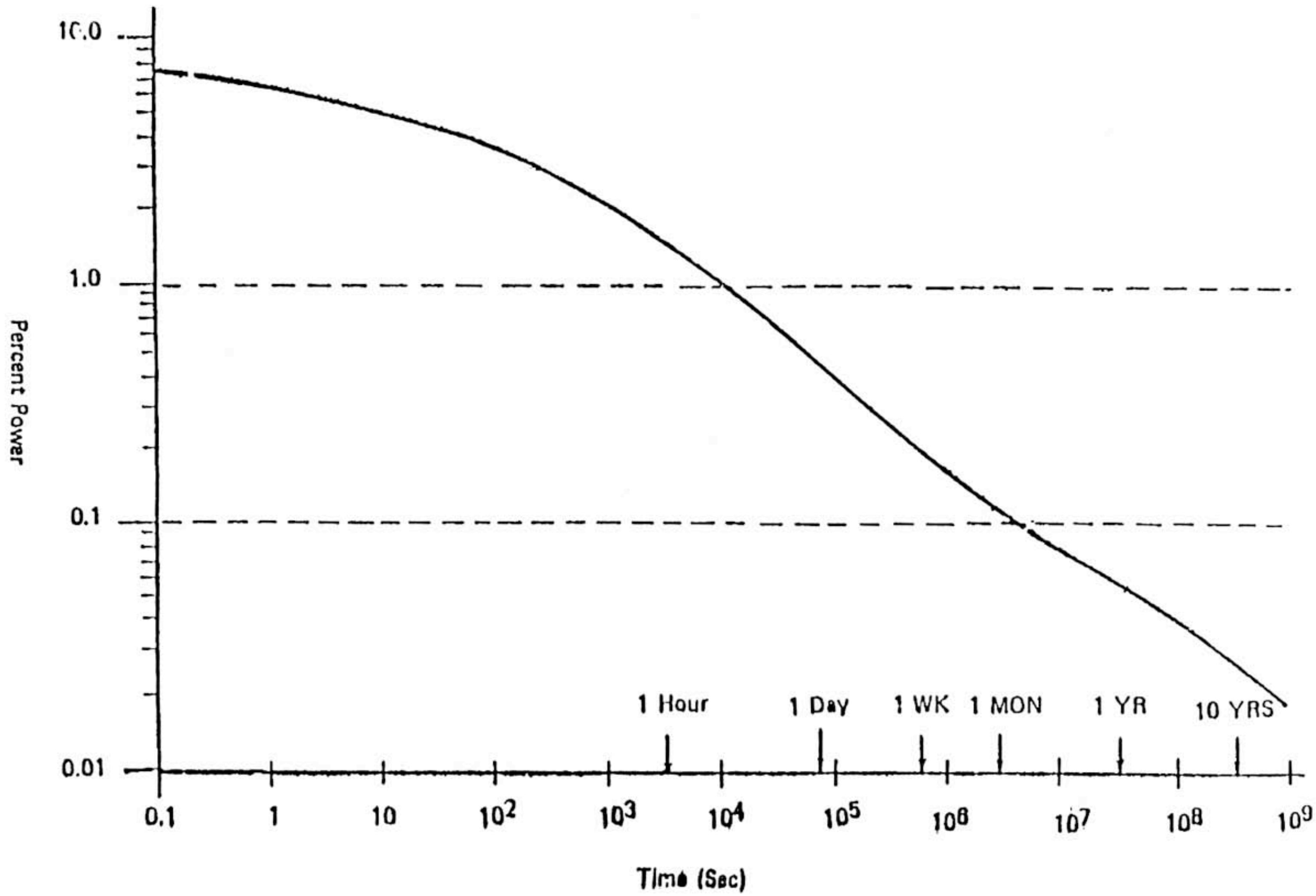
- Transients

Power Excursions*

- Control Rod Ejection
- Cold Water Addition

* This class of initiator found to have a negligible contribution to risk in WASH-1400

HEAT PRODUCTION BY DECAY OF FISSION PRODUCTS



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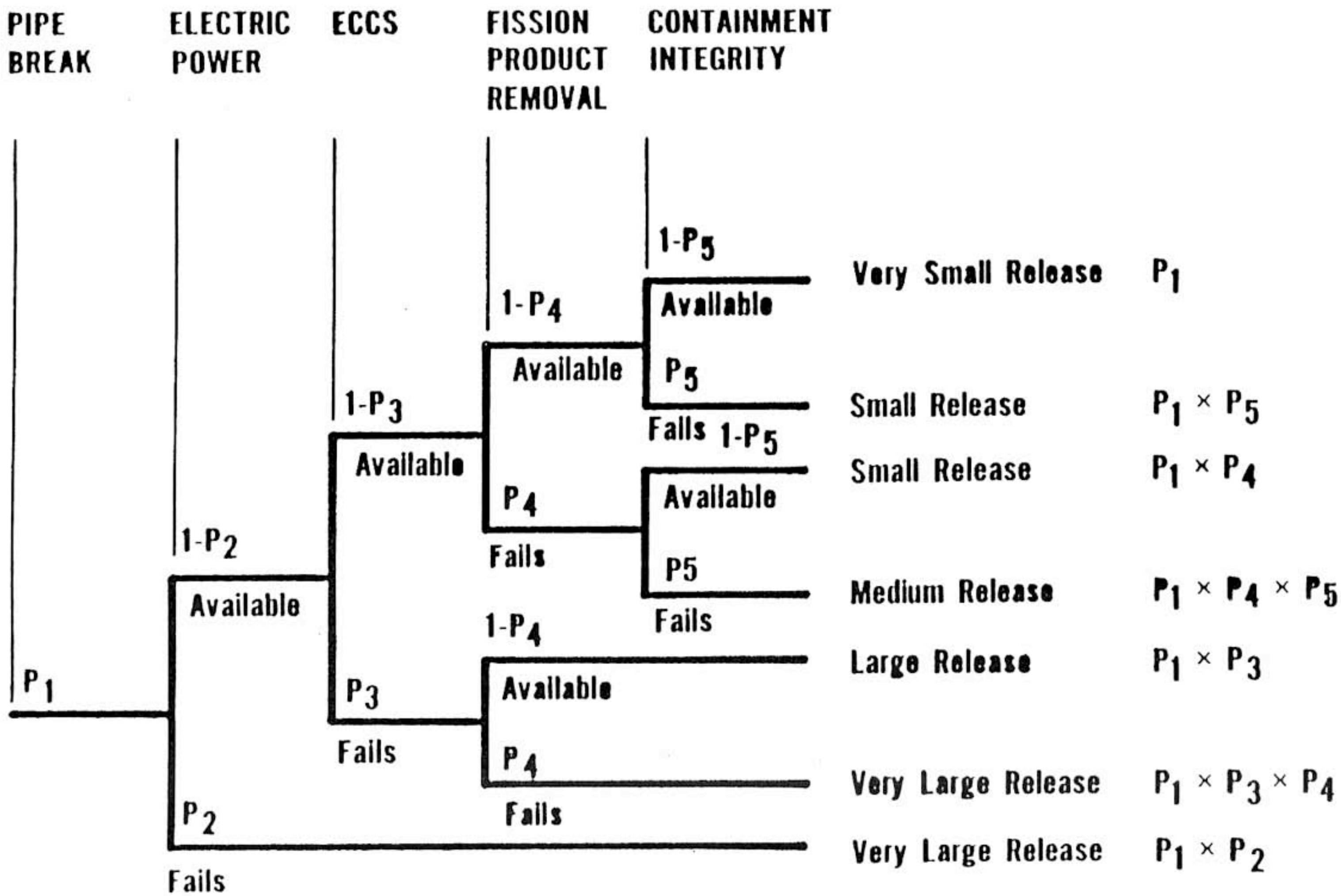
SIMPLIFIED EVENT TREE FOR A LOCA IN A TYPICAL NUCLEAR POWER PLANT



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INITIAL ACTIVITY OF RADIONUCLIDES IN THE NUCLEAR REACTOR CORE AT THE TIME OF THE HYPOTHETICAL ACCIDENT

No.	Radionuclide	Radioactive Inventory Source (curies x 10^{-8})	Half-Life (days)
1	Cobalt-58	0.0078	71.0
2	Cobalt-60	0.0029	1,920
3	Krypton-85	0.0056	3,950
4	Krypton-85m	0.24	0.183
5	Krypton-87	0.47	0.0528
6	Krypton-88	0.68	0.117
7	Rubidium-86	0.00026	18.7
8	Strontium-89	0.94	52.1
9	Strontium-90	0.037	11,030
10	Strontium-91	1.1	0.403
11	Yttrium-90	0.039	2.67
12	Yttrium-91	1.2	59.0
13	Zirconium-95	1.5	65.2
14	Zirconium-97	1.5	0.71
15	Niobium-95	1.5	35.0
16	Molybdenum-99	1.6	2.8
17	Technetium-99m	1.4	0.25
18	Ruthenium-103	1.1	39.5
19	Ruthenium-105	0.72	0.185
20	Ruthenium-106	0.25	366
21	Rhodium-105	0.49	1.50
22	Tellurium-127	0.059	0.391
23	Tellurium-127m	0.011	109
24	Tellurium-129	0.31	0.048
25	Tellurium-129m	0.053	0.340
26	Tellurium-131m	0.13	1.25
27	Tellurium-132	1.2	3.25
28	Antimony-127	0.061	3.88
29	Antimony-129	0.33	0.179

Continued

Courtesy of U.S. NRC.

INITIAL ACTIVITY OF RADIONUCLIDES IN THE NUCLEAR REACTOR CORE AT THE TIME OF THE HYPOTHETICAL ACCIDENT, cont'

No.	Radionuclide	Radioactive Inventory Source (curies x 10^{-8})	Half-Life (days)
30	Iodine-131	0.85	8.05
31	Iodine-132	1.2	0.0958
32	Iodine-133	1.7	0.875
33	Iodine-134	1.9	0.0366
34	Iodine-135	1.5	0.280
35	Xenon-133	1.7	5.28
36	Xenon-135	0.34	0.384
37	Cesium-134	0.075	750
38	Cesium-136	0.030	13.0
39	Cesium-137	0.047	11,000
40	Barium-140	1.6	12.8
41	Lanthanum-140	1.6	1.67
42	Cerium-141	1.5	32.3
43	Cerium-143	1.3	1.38
44	Cerium-144	0.85	284
45	Praseodymium-143	1.3	13.7
46	Neodymium-147	0.60	11.1
47	Neptunium-239	16.4	2.35
48	Plutonium-238	0.00057	32,500
49	Plutonium-239	0.00021	8.9×10^6
50	Plutonium-240	0.00021	2.4×10^6
51	Plutonium-241	0.034	5,350
52	Americium-241	0.000017	1.5×10^5
53	Curium-242	0.0050	163
54	Curium-244	0.00023	6,630

Courtesy of U.S. NRC.

SUMMARY OF ACCIDENT SEQUENCES WITH SIGNIFICANT RISK AND CORE MELT FREQUENCY CONTRIBUTIONS

Sheet 1 of 2

Initiating Event	Additional System Failures/ Human Actions	Resulting Dependent Failures	Sequence Frequency (per reactor year)	Sequence Ranking: Core Melt	Sequence Ranking: Latent Health Risk	Sequence Ranking: Early Health Risk
Loss of Offsite Power	Onsite AC Power, No Recovery of AC Power Before Core Damage	Component cooling, high pressure makeup (ECCS), reactor coolant pump seal LOCA, containment filtration and heat removal.	3.3-5	1	1	*
Loss of Offsite Power	Service Water, No Recovery of Offsite Power	Onsite AC power, component cooling, high and low pressure makeup (ECCS), reactor coolant pump seal LOCA, containment filtration and heat removal.	9.2-6	2	2	*
Small LOCA	Residual Heat Removal	None.	8.9-6	3	*	*
Control Room Fire	None	Component cooling, high and low pressure makeup (ECCS), reactor coolant pump seal LOCA, containment filtration and heat removal.	8.7-6	4	3	*
Loss of Main Feedwater	Solid State Protection System	Reactor trip, emergency feedwater, high and low pressure makeup (ECCS), containment filtration and heat removal.	8.3-6	5	4	*
Steam Line Break Inside Containment Heat Removal	Operator Failure to Establish Long Term		5.6-6	6	*	*
Reactor trip	Component Cooling	High and low pressure makeup (ECCS), reactor coolant pump seal LOCA, containment filtration and heat removal.	4.6-6	7	5	*
Loss of Offsite Power	Train A Onsite Power, Train B Service Water, No Recovery of AC Power Before Core Damage	Train B onsite power, component cooling, high and low pressure makeup (ECCS), reactor coolant pump seal LOCA, containment filtration and heat removal.	4.4-6	8	6	*
Loss of Offsite Power	Train B Onsite Power, Train A Service Water, No Recovery of AC Power Before Core Damage	Train A onsite power, component cooling, high and low pressure makeup (ECCS), reactor coolant pump seal LOCA, containment filtration and heat removal.	4.4-6	9	7	*
PCC Area Fire	None	Component cooling, high and low pressure makeup (ECCS), reactor coolant pump seal LOCA, containment filtration, and heat removal.	4.1-6	10	8	*

*Negligible contribution to risk.

NOTE: Exponential notation is indicated in abbreviated form; i.e., 3.3-5 = 3.3×10^{-5}.

Courtesy of U.S. NRC.

SUMMARY OF ACCIDENTS INVOLVING CORE

RELEASE CATEGORY	PROBABILITY per Reactor-Yr	TIME OF RELEASE (Hr)	DURATION OF RELEASE (Hr)	WARNING TIME FOR EVACUATION (Hr)	ELEVATION OF RELEASE (Meters)	CONTAINMENT ENERGY RELEASE (10^6 Btu/Hr)	FRACTION OF CORE INVENTORY RELEASED[a] Xe-Kr	Org. I	I	Cs-Rb	Te-Sb	Ba-Sr	Ru[b]	La[c]
PWR 1	9×10^{-7}	2.5	0.5	1.0	25	520[d]	0.9	6×10^{-3}	0.7	0.4	0.4	0.05	0.4	3×10^{-3}
PWR 2	8×10^{-6}	2.5	0.5	1.0	0	170	0.9	7×10^{-3}	0.7	0.5	0.3	0.06	0.02	4×10^{-3}
PWR 3	4×10^{-6}	5.0	1.5	2.0	0	6	0.8	6×10^{-3}	0.2	0.2	0.3	0.02	0.03	3×10^{-3}
PWR 4	5×10^{-7}	2.0	3.0	2.0	0	1	0.6	2×10^{-3}	0.09	0.04	0.03	5×10^{-3}	3×10^{-3}	4×10^{-4}
PWR 5	7×10^{-7}	2.0	4.0	1.0	0	0.3	0.3	2×10^{-3}	0.03	9×10^{-3}	5×10^{-3}	1×10^{-3}	6×10^{-4}	7×10^{-5}
PWR 6	6×10^{-6}	12.0	10.0	1.0	0	N/A	0.3	2×10^{-3}	8×10^{-4}	8×10^{-4}	1×10^{-3}	9×10^{-5}	7×10^{-5}	1×10^{-5}
PWR 7	4×10^{-5}	10.0	10.0	1.0	0	N/A	6×10^{-3}	2×10^{-5}	2×10^{-5}	1×10^{-5}	2×10^{-5}	1×10^{-6}	1×10^{-6}	2×10^{-7}
PWR 8	4×10^{-5}	0.5	0.5	N/A	0	N/A	2×10^{-3}	5×10^{-6}	1×10^{-4}	5×10^{-4}	1×10^{-6}	1×10^{-8}	0	0
PWR 9	4×10^{-4}	0.5	0.5	N/A	0	N/A	3×10^{-6}	7×10^{-9}	1×10^{-7}	6×10^{-7}	1×10^{-9}	1×10^{-11}	0	0
BWR 1	1×10^{-6}	2.0	2.0	1.5	25	130	1.0	7×10^{-3}	0.40	0.40	0.70	0.05	0.5	5×10^{-3}
BWR 2	6×10^{-6}	30.0	3.0	2.0	0	30	1.0	7×10^{-3}	0.90	0.50	0.30	0.10	0.03	4×10^{-3}
BWR 3	2×10^{-5}	30.0	3.0	2.0	25	20	1.0	7×10^{-3}	0.10	0.10	0.30	0.01	0.02	3×10^{-3}
BWR 4	2×10^{-6}	5.0	2.0	2.0	25	N/A	0.6	7×10^{-4}	8×10^{-4}	5×10^{-3}	4×10^{-3}	6×10^{-4}	6×10^{-4}	1×10^{-4}
BWR 5	1×10^{-4}	3.5	5.0	N/A	150	N/A	5×10^{-4}	2×10^{-9}	6×10^{-11}	4×10^{-9}	8×10^{-12}	8×10^{-14}	0	0

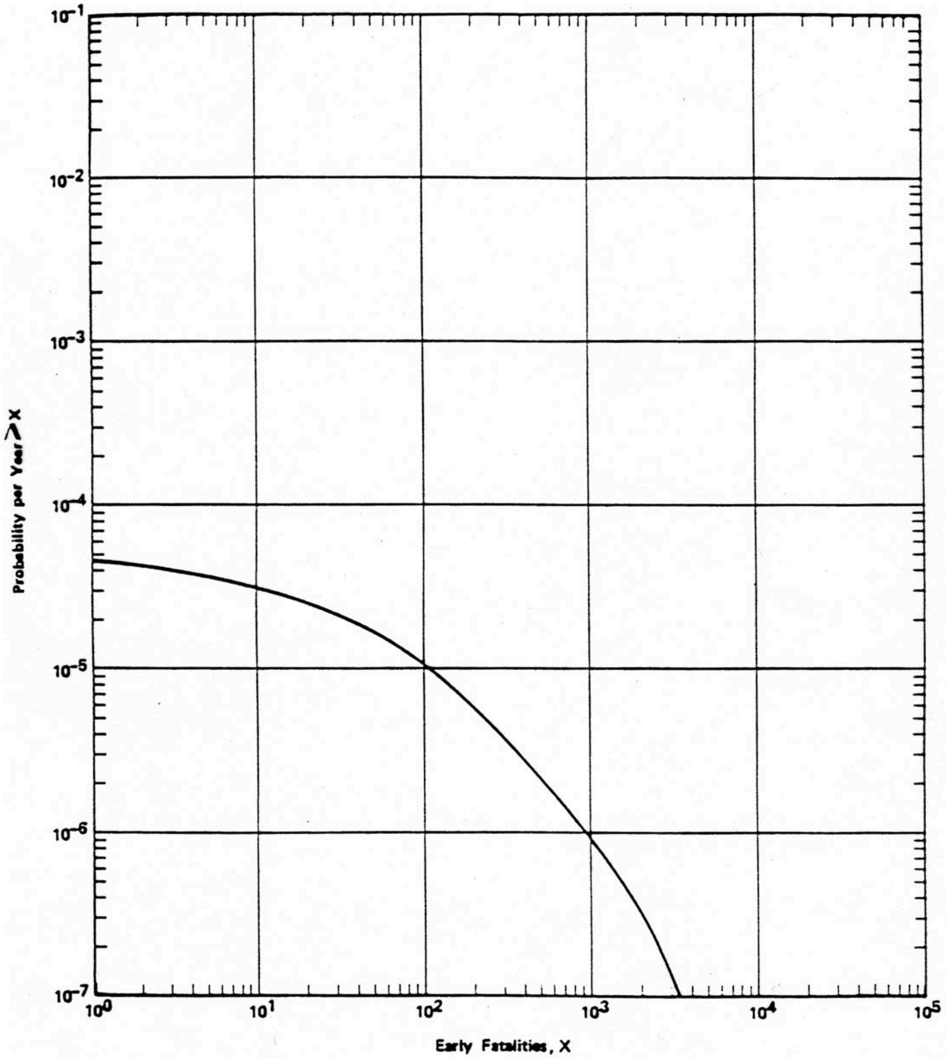
(a) A discussion of the isotopes used in the study is found in Appendix VI. Background on the isotope groups and release mechanisms is found in Appendix VII.

(b) Includes Mo, Rh, Tc, Co.

(c) Includes Nd, Y, Ce, Pr, La, Nb, Am, Cm, Pu, Np, Zr.

(d) A lower energy release rate than this value applies to part of the period over which the radioactivity is being released. The effect of lower energy release rates on consequences is found in Appendix VI.

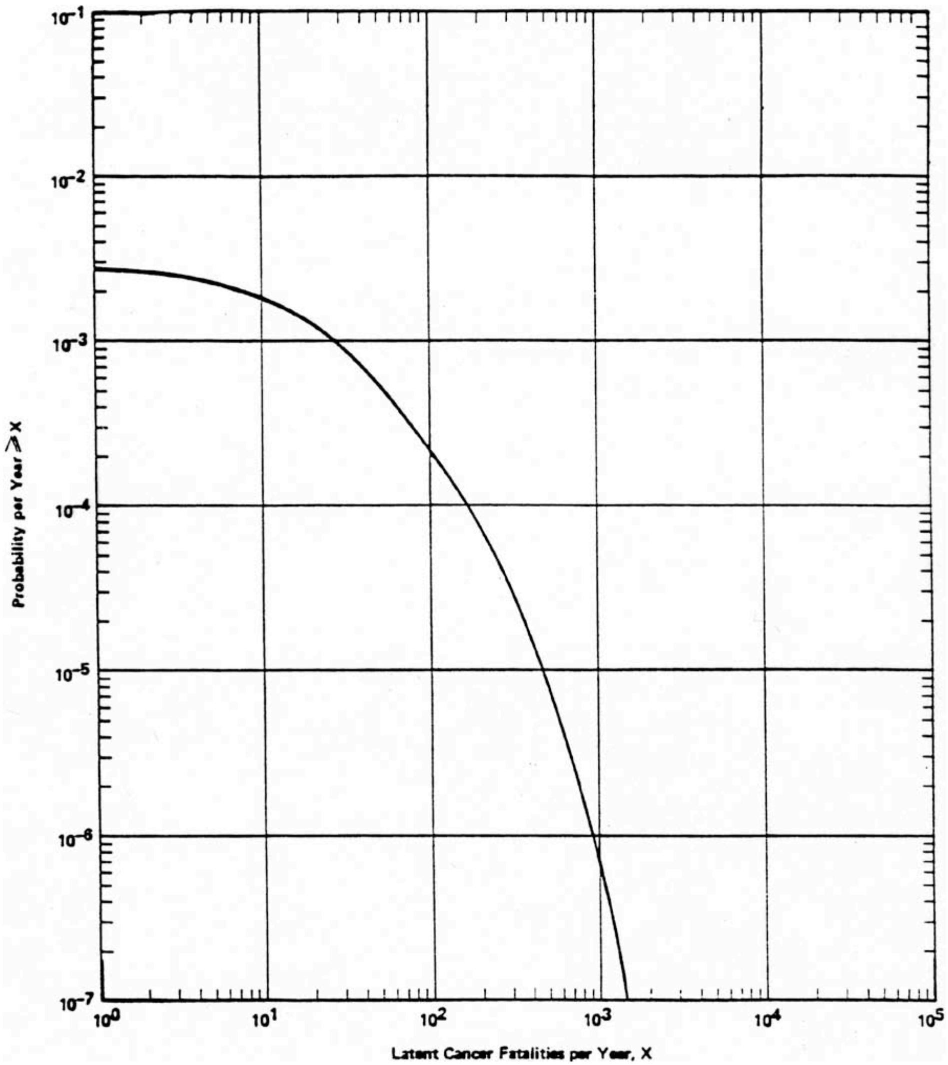
PROBABILITY DISTRIBUTION FOR EARLY FATALITIES PER YEAR FOR 100 REACTORS



Courtesy of U.S. NRC.

Note: Approximate uncertainties are estimated to be represented by factors of 1/4 and 4 on consequence magnitudes and by factors of 1/5 and 5 on probabilities.

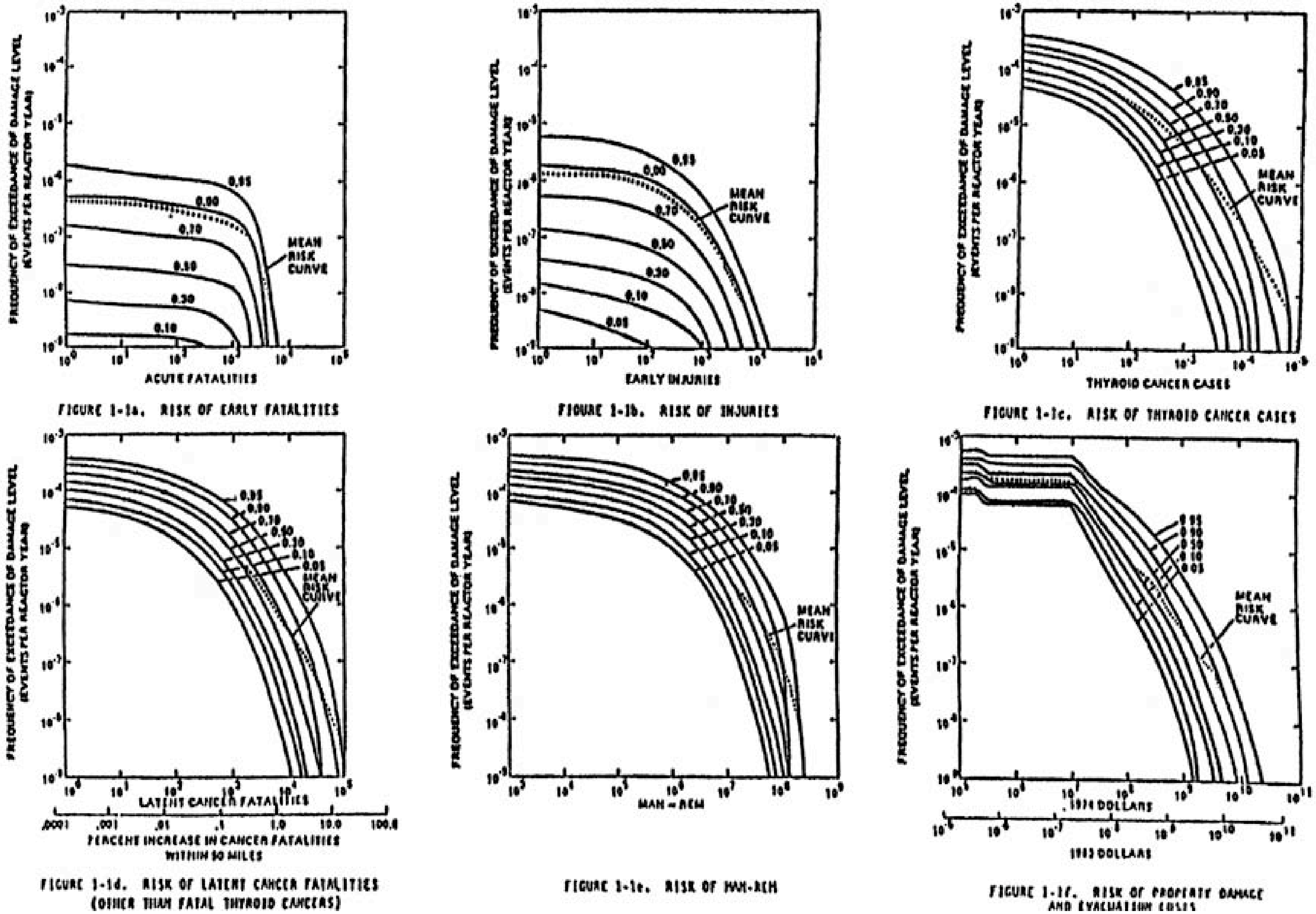
PROBABILITY DISTRIBUTION FOR LATENT CANCER FATALITY INCIDENCE PER YEAR FOR 100 REACTORS



Courtesy of U.S. NRC.

Note: Approximate uncertainties are estimated to be represented by factors of 1/6 and 3 on consequence magnitudes and by factors of 1/5 and 5 on probabilities.

RISK RESULTS



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NUMBER OF FAILURES OF RCP TAKEN FROM NPRDS (1/90 TO 12/95)

Failure Cause	Total Number of Failures
Design Failure	4
Procedural Error	2
Manufacturing Defect	0
Initial Installation Failure	2
Operational Human Error	0
Surveillance/Maintenance Human Error	9
Operational Failures of Hardware	46