

[When Redundant Safety Systems Fail: The Peril of Blind Faith](#)

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Last June, as the world watched the metastasizing radiological disaster spreading from the Fukushima Daiichi nuclear power complex in Japan, industry leaders gathered at an International Atomic Energy Agency conference in Vienna to discuss the impact on future nuclear development. John Ritch, head of the industry's World Nuclear Association, said it was important to emphasize that there have been 14,500 "reactor years" of safe nuclear operation.

That figure has been widely circulated since, as nuclear proponents assured local media of the safety record of the technologically complex industry. But an examination of that figure may be less sanguine.

It is based on the cumulative years of operation of 582 nuclear reactors worldwide over the course of the history of commercial nuclear power: no individual reactor operated for 14,500 years. But simple division reveals the average reactor would have just under 26 years' operating experience. Out of the total of 582 reactors 137 have shut down permanently for a variety of reasons. And all of the reactors operated safely – until the day they didn't.

That 26 years of experience with each reactor operating today could be a reassuring figure – except that there have been 12 nuclear accidents resulting in full or partial meltdowns. History and simple division, therefore, reveal that the nuclear industry suffers its worst accidents at some plant – despite their experience, safety culture, and redundant safeguards – approximately every two years.

Since 1985, the stated goal of the Nuclear Regulatory Commission has been to achieve a safety level of not more than one core melt accident per 10,000 reactor years of operation. That has been a hard level to achieve.

Dr. Thomas Cochran, senior scientist at the Natural Resources Defense Council, testified at a Senate hearing in April, 2011, on lessons learned from Fukushima that "the historical frequency of core melt accidents worldwide does not measure up to the safety objectives of the NRC. On the whole, the operational reactors worldwide are not sufficiently safe."

There are features in proposed new reactors in the United States which could make them relatively safer than today's reactors, if they are ever built. But, said Cochran, the bulk of America's nuclear fleet are the existing, 104 ageing reactors operating at higher temperatures and decades longer than originally intended. The risks with those

plants do not decrease with age.

In an interview Cochran, who taught nuclear physics at the US Naval Academy, said that prior to Fukushima, “I argued that a principal factor that affects the safety of these reactors is the safety culture at the plant. What I am forced to rethink is the relative significance of the safety culture vs. the plant design vs. the precursors, such as whether you are in an earthquake zone and so forth.

“After Three Mile Island (in 1979), the nuclear industry did take a number of steps to improve the safety culture at U.S. plants. But if you look at the issue globally you can pick out countries where they don’t have a good safety culture and countries like China where you don’t know if they will have a good safety culture and you know they don’t have a good regulatory regime. It is more likely that something will happen abroad than here.”

Cochran compiled a chronological list of reactors which experienced core melt damage:

1. **Sodium Reactor Experiment (SER)**

Location: Santa Susana Field Laboratory, California

Reactor Type: Sodium-Cooled graphite-moderated thermal power reactor

Power: 20 Megawatts thermal (MWt); 6.5 Megawatts electric (MWe)

History: First produced electricity July, 1957. Partial core melt accident between July 12 and July 26, 1959, resulting in melting 1/3 of the fuel. Shutdown permanently Feb., 1964.

2. **Stationary Low-Power Reactor #1 (SL-1)**

Location: National Reactor Testing Station (now Idaho National Laboratory)

Reactor Type: Experimental, gas-cooled, water moderated

Power: 3.3 MWt; 300 KWe

History: Initial criticality March, 1960. Instant criticality due to improper removal of control rod caused steam explosion ejecting control rods and upper control mechanism, killing 3 operators. Shut down May, 1964

3. **Enrico Fermi Unit 1**

Location: Frenchtown Township, Monroe County, Michigan

Reactor Type: Liquid Metal Fast Breeder Reactor

Power: 200 MWt; 65 MWe

History: Commercial operation began August 23, 1966. Two of 105 fuel assemblies melt, Oct. 5, 1966. Plant closed Nov., 1972.

4. **Chapelcross Unit 2 Nuclear Power Plant**

Location: Annan, Dumfrieshire, Scotland, UK

Reactor Type: Gas-cooled, graphite moderated; Magnox

Power: 180 MWt, up-rated to 265 MWt; originally 23 MWe, up-rated to 60 MWe

History: Startup May, 1959. Damage to a single fuel channel in May, 1967 resulting in damage to one section of

the core. Shut down June, 2004.

5. **Saint-Laurent A-1 Nuclear Power Plant**

Location: St. Laurent-Nouan, Loir-et-Cher, Centre, France

Reactor Type: Gas-cooled, graphite moderated.

Power: 1570 MWt; 405 MWe

History: Grid connection March 12, 1969; Commercial Operation began June, 1969; 50 Kg of Uranium melted Oct. 17, 1969. Permanently shut May 27, 1992.

6. **Saint-Laurent A-2 Nuclear Power Plant**

Location: St. Laurent-Nouan, Loir-et-Cher, Centre, France.

Reactor Type: Gas-cooled, graphite moderated

Power: 1690 MWt; 465 MWe, up-rated to 530 MWe

History: Grid connection August, 1971; Commercial operation began November, 1971; Heat excursion caused partial fuel melt March 13, 1980. Permanently shut down May 27, 1992.

7. **Three Mile Island Unit 2 Nuclear Power Plant**

Location: Londonderry Township, Pennsylvania.

Reactor Type: Pressurized Water Reactor.

Power: 2,568 MWt; 776 MWe.

History: Initial criticality December, 1978; Partial core melt down, March, 1979. Decommissioned, 1979.

8. **Chernobyl Unit 4 Nuclear Power Plant**

Location: Pripyat, Ukraine.

Reactor Type: RBMK-1000 graphite moderated, water cooled.

Power: 3,200 MWt; 1,000 MWe

History: Destroyed in full core melt and explosion, April 26, 1986

9. Greifswald Unit 5 (KGR-5) Nuclear Power Plant

Location: Lubmin, Germany.

Reactor Type: VVER-440, Model V-230, Pressurized Water Reactor (PWR)

Power: 1,375 MWt; 440 MWe

History: Grid connection April, 1989; Commercial operation began November 1, 1989; Partial fuel meltdown November 24, 1989 when four of six cooling pumps were inoperable and control of reactor was lost. Permanently shut in 1991.

10. Fukushima Daiichi Unit 1 Nuclear Power Plant

Location: Ohkuma, Fukushima Prefecture, Japan.

Reactor Type: General Electric Boiling Water Reactor (BWR) Mark 1 Containment

Power: 1,380 MWt; 450 MWe.

History: Initial criticality October 10, 1970; commercial operation March 26, 1971. Core meltdown following earthquake and station blackout, March 11, 2011. Hydrogen explosion destroyed building frame and exposed elevated spent fuel pool. Water poured through missing roof and walls to keep spent fuel cool.

11. Fukushima Daiichi Unit 2 Nuclear Power Plant

Location: Ohkuma, Fukushima Prefecture, Japan.

Reactor Type: GE BWR, Mark 1 Containment.

Power: 2,381 MWt; 794 MWe.

History: Initial criticality May 10, 1973; Commercial operation July 18, 1974. Core meltdown following earthquake and station blackout, March 11, 2011. Hydrogen explosion destroyed building frame and exposed elevated spent fuel pool. Water poured through missing roof and walls to keep spent fuel cool.

12. Fukushima Daiichi Unit 3 Nuclear Power Plant

Location: Ohkuma, Fukushima Prefecture, Japan.

Reactor Type: GE BWR, Mark 1 Containment.

Power: 2,381 MWt; 794 MWe.

History: Initial criticality January 28, 1978; Commercial operation began Oct. 12, 1978. Core meltdown following earthquake and station blackout, March 11, 2011. Hydrogen explosion destroyed building frame and exposed elevated spent fuel pool. Unit 3 shared exhaust ducts with **Fukushima Daiichi Unit 4**. Hydrogen gas from Unit 3 migrated to Unit 4 and the explosion destroyed that building also. Water poured through missing roof and walls of both buildings to keep spent fuel cool.

At the time of the earthquake, Unit 4 was shut down for refueling, and some 100 tons of reactor fuel had been moved to its spent fuel pool, located within the building just above the reactor. It took several days for Japanese officials to realize that the pool at Unit 4 had not, in fact, experienced an evaporation of the water, causing a meltdown and exothermic fire among some or all of the fuel bundles. Utility workers kept the fuel covered by pouring in water from fire trucks and water cannon parked by the wrecked building.

It was a desperation effort which had the negative side effect of wrecking the electrical equipment needed to regain control of Unit 4's systems because this equipment was not designed to work under water. And the flooding only worked because the gases from Unit 3 had already blown off the roof and blown out the walls of Unit 4. Had it not been for the explosive gasses from Unit 3, there would have been no way to get water into the building to keep the spent fuel in Unit 4 from boiling away the water and then erupting and adding its radioactive plumes to those from the three damaged reactors.