

Near Misses at U.S. Nuclear Power Plants in 2015

A UCS Nuclear Safety Review

HIGHLIGHTS

Ten nuclear safety near misses—problems that may increase the chance of a reactor core meltdown by a factor of 10 or more—were reported at U.S. nuclear power reactors in 2015. The good news: this total is about half the 19 near misses reported in 2010 and 2011, with the numbers in the intervening years steadily declining—a positive safety trend. The bad news: one owner, Entergy Corporation, had three of 2015’s near misses and nearly two-thirds (64 percent) of the safety regulation violations. Moreover, for both Entergy and other owners, repairs creating problems instead of solutions caused four near misses. As more equipment wears out, effective repairs are essential if safety levels are to be maintained rather than being eroded.

The U.S. Nuclear Regulatory Commission (NRC) reported nuclear safety near misses at 10 commercial nuclear power reactors in the United States in 2015¹ (see Table 1, p. 3). In each case, the NRC determined that an event, degraded condition, or newly discovered problem potentially increased the chance of a reactor core meltdown by a factor of 10 or more.

From the 10 near misses, the NRC identified 22 violations of safety regulations: of them, 14—that is, 64 percent—occurred at three reactors owned by Entergy Corporation. The record suggests there may be a common cause for Entergy’s many safety woes, such as low standards, ineffective corporate policies and procedures, inadequate training programs, or insufficient budgets. Because the NRC investigates each near miss separately, however, it cannot evaluate whether such common causes explain why one owner is having a disproportionate share of safety problems. The NRC should ask, and answer, this question.

The Cop on the Nuclear Beat

The NRC is to owners of commercial nuclear power reactors what local law enforcement is to a community: both are tasked with enforcing safety regulations to protect people from harm. Fundamentally, the NRC is the cop on the nuclear beat, monitoring reactors to ensure they are operating within regulations, and aggressively engaging owners over safety violations.

A key nuclear safety principle called defense-in-depth requires that many protective measures must fail for the reactor core to be damaged. When an event occurs at a reactor or when a degraded condition is discovered, the NRC estimates the degree to which the event or degraded condition reduced the number and effectiveness of protective measures. Most incidents have a small effect on the risk



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A transformer explosion at Indian Point Unit 3 on May 9, 2015, caused a fire suppression system component to fail, causing water to flood a room housing vital electrical distribution panels. This component failure is not new; it also malfunctioned during three previous tests, but had not been fixed. However, the NRC did not require Entergy, Indian Point’s owner, to install flooding sensors—a move Entergy itself deemed cost beneficial—because it did not address an aging-related safety issue.

of damage to the reactor core. When the event or condition did not affect that risk—or if the risk was increased only by a very small amount—the NRC relies on routine oversight measures to respond.

When an event or condition potentially increases the chance of reactor core damage by a factor of 10, the NRC sends out a special inspection team. When the potential risk rises by a factor of 100, the agency dispatches an augmented inspection team. And when the risk increases by a factor of 1,000 or more, the NRC sends an incident inspection team (NRC 2010). An NRC inspection team goes to a reactor to determine what happened, why it happened, and whether a similar type of incident poses any safety implications for other nuclear plants. The team takes many weeks to conduct an investigation, evaluate the information it gathers, and document its findings in a publicly available report.

When an event or discovery results in the NRC sending out such an inspection team, the Union of Concerned Scientists (UCS) terms it a “near miss” (see the box). UCS, which has evaluated safety issues at nuclear power plants for more than four decades, began reporting annually on near misses at U.S. nuclear power plants in 2011. We review the NRC’s reports on the near misses for insights on nuclear safety at the individual plants as well as generic implications across the nation’s fleet of nuclear reactors. As Table 2 (p. 6) indicates, from 2010 through 2015, there have been 91 near misses at 56 reactors. While the numbers are concerning, the trend is encouraging—there were 10 near misses in 2015 compared with 19 each in 2010 and 2011 with steadily declining numbers in between these endpoints.

Calvert Cliffs

The NRC sent a special inspection team to Calvert Cliffs to investigate electrical grid fluctuations from a failed power transmission line that caused both reactors to automatically shut down on April 27, 2015. The plant’s design called for the reactors to automatically shut down as a precautionary measure in response to any electrical grid disturbance—but the design called for the emergency diesel generators to step in and supply electricity to safety equipment such as that cooling the reactor core. But both of the emergency diesel generators for Unit 2 failed to respond properly.

Emergency diesel generator 2A automatically started. But none of the large equipment supplied by it automatically restarted due to a faulty load sequencer. The load sequencer was supposed to restart large loads (equipment that uses a lot of electricity) at approximately five-second intervals to avoid overtaxing the emergency diesel generator. The load sequencer failed and no large equipment automatically restarted.

Our “Near Miss” Label

UCS’s use of the “near miss” label has been unexpectedly controversial. We stand by the “near miss” label and point to the precedent set by the International Atomic Energy Agency (IAEA). A decade ago, the IAEA published a report on lessons that can be learned from near misses to improve nuclear safety (IAEA 2005). The IAEA’s near miss threshold was even lower than the criteria used by the NRC to dispatch inspection teams. UCS reviews the NRC’s reports on near misses for nuclear safety insights—reasons essentially identical to the reasons IAEA studied near misses.

Emergency diesel generator 2B automatically started, but it shut back down 11 seconds later due to a failed limit switch. The limit switch monitors the speed at which the diesel engine’s shaft rotates, and shuts down the diesel generator automatically if the speed is too high or too low. A faulty limit switch falsely indicated that the engine speed was too low, triggering an automatic shutdown.

The failure of both Unit 2 emergency diesel generators did not cause damage to the reactor core because the operators successfully connected alternate power supplies and restarted emergency equipment.

The NRC’s special inspection team identified no violations of regulatory requirements (NRC 2015a).

The load sequencer on emergency diesel generator 2A had been tested on July 25, 2014, and was found to be working then. The load sequencer on emergency diesel generator 2B had been successfully tested on March 18, 2015, less than six weeks earlier. Emergency diesel generators are perceived to be highly reliable safety equipment backing up electricity supplied from the offsite power grid. Yet both “highly reliable,” recently tested safety backups failed—for different reasons—when needed (Lochbaum 2015a).

Duane Arnold

The NRC sent a special inspection team to Duane Arnold on October 20, 2014, after workers discovered debris floating on the surface of this boiling water reactor’s torus—an integral part of the primary containment structure—and found that the coating recently reapplied to the inside surface of the metal torus was sagging in some places. Coating deficiencies could cause the torus to corrode and fail. The NRC was additionally concerned that debris from the degraded coating could clog the emergency pumps that draw water from the

TABLE 1. Nuclear Safety Near Misses in 2015

Reactor and Location	Owner	Event and Sanctions*
Calvert Cliffs Nuclear Power Plant, Units 1 and 2 Lusby, MD	Exelon Generation Co., LLC	Power grid problem caused both reactors to shut down complicated by emergency diesel generator problems. <i>No sanctions</i>
Duane Arnold Energy Center Palo, IA	NextEra Energy Duane Arnold, LLC	Coating misapplication caused containment and core cooling degradation. <i>1 White finding</i>
Fort Calhoun Station, Unit 1 Ft. Calhoun, NE	Omaha Public Power District	Rebuilt valves impaired safety makeup water system. <i>3 Green findings</i>
Indian Point Nuclear Generating, Unit 3 Buchanan, NY	Entergy Nuclear Indian Point 3, LLC	Flooding increased risk of station blackout. <i>1 Green finding</i>
North Anna Power Station Units 1 and 2 Mineral, VA	Virginia Electric & Power Co.	Security problem (unspecified) <i>2 Green findings</i>
Pilgrim Nuclear Power Station Plymouth, MA	Entergy Nuclear Operations, Inc.	Power grid problem caused reactor shut down complicated by equipment failures and operator errors. <i>6 Green and 1 White findings; 1 Severity IV violation</i>
River Bend Station Unit 1 St. Francisville, LA	Entergy Operations, Inc.	Non-repaired problem caused reactor shut down complicated by poor procedures and training. <i>4 Green and 1 White findings</i>
Virgil C. Summer Nuclear Station, Unit 3 Jenkinsville, SC	South Carolina Electric & Gas Co.	Inadequate controls during construction caused mis-positioned installations and damage to containment. <i>2 Green findings</i>

* The NRC characterizes violations of safety regulations as colors (Green, White, Yellow, and Red) or roman numerals (IV, III, II, and I) in increasing order of severity. The NRC color-coded system classifies the majority of violations based on their safety or security significance while the numerical system handles violations that do not lend themselves to significance determination, such as for deliberate or willful acts.

torus to cool the reactor core and containment during an accident (NRC 2015b).

The NRC determined that the increased risk of reactor core meltdown caused by the degraded coating material clogging the emergency pumps warranted a White finding, the third most serious among the four color-coded severity levels (NRC 2015c).

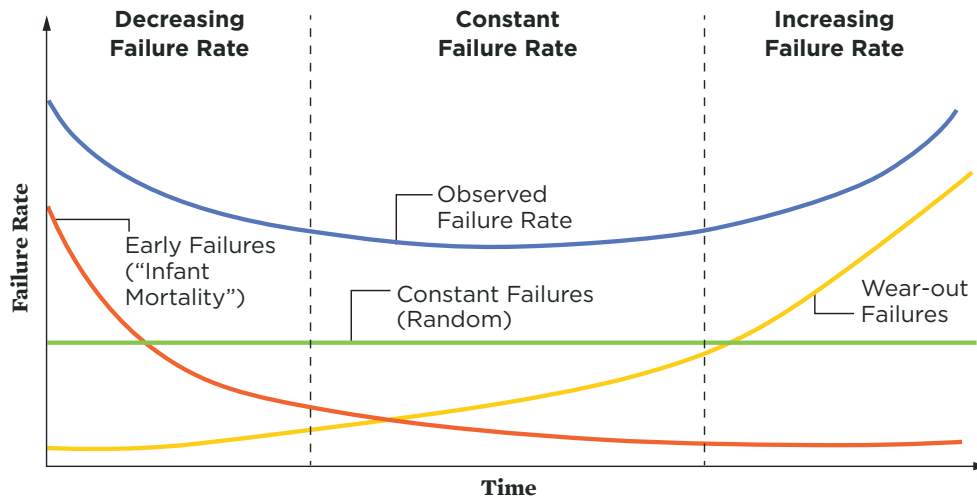
This incident demonstrates the bathtub curve (see the figure, p. 4) in action (Lochbaum 2015b). The NRC was properly concerned that the original torus coating at Duane Arnold might be approaching, if not already be within, the right-hand portion of the curve where age increases the chance of failure. So, the NRC compelled the owner to replace the original coating as a condition of getting a 20-year extension to the reactor operating license. But the new coating reset the clock and flipped things back to the left-hand portion of the curve, where the chance of failure is initially elevated due to material defects, improper installation, and other “infant mortality” factors. Thus, an effort to

sustain adequate safety margins for 20 more years actually undermined them in less than two years (Lochbaum 2015c).

Fort Calhoun

The NRC sent a special inspection team to Fort Calhoun on June 29, 2015, after workers declared the auxiliary feedwater system inoperable during an attempted restart from a refueling outage. The auxiliary feedwater system provides makeup water that cools the reactor core should the normal system fail. The valves that control the rate of makeup flow by this emergency backup system had been rebuilt during the outage because the original parts were susceptible to degradation from exposure to radiation. The replacement parts were made from materials less vulnerable to radiation degradation. However, some of the materials were prone to degradation at high temperatures. As the temperature rose when the reactor restarted, parts inside the valves deformed and impaired their opening and closing.

The Bathtub Curve



The bathtub curve illustrating the chance of failure (vertical axis) over a product's lifetime (horizontal axis).

SOURCE: LOCHBAUM 2015B.

The NRC's special inspection team identified three violations of safety regulations, all characterized as Green (NRC 2015d). The violations were assigned a low significance because the problem did not affect another pathway for the auxiliary feedwater pumps to supply makeup cooling water. By opening other valves not affected by this problem, the auxiliary feedwater pumps could supply makeup cooling water using the normal system's pipes. Thus, the problem impaired, but did not totally disable, the auxiliary feedwater system.

The bathtub curve claimed another victim (Lochbaum 2015b). Workers replaced parts within the valves because the original parts were susceptible to an aging mechanism that hastened their entry into the wear-out zone. Their efforts to avoid component failure were defeated when the replacement parts were even more susceptible to another problem. Within hours, the replacement parts failed, preventing the rebuilt valves from getting out of the break-in phase and heading towards the wear-out zone.

Indian Point Unit 3

The NRC sent a special inspection team to Indian Point after an electrical transformer for the Unit 3 reactor exploded on May 9, 2015, resulting in a fire and the automatic shutdown of the reactor. The NRC team was not investigating the cause of the transformer's explosion—it was concerned that

water had flooded an adjacent room housing vital electrical distribution panels. Had the flooding not been discovered and stopped in time, the panels could have been submerged, plunging Unit 3 into a dangerous station blackout, in which all alternating current (ac) electricity is lost. A station blackout led to the meltdown of three nuclear reactor cores at Fukushima Dai-ichi in 2011. Even when a reactor is shut down, ac electricity is needed to cool the reactor core.

The NRC's special inspection team documented that flooding of the room has been a recurring problem. It determined that the flooding was caused by a fire suppression system component that had malfunctioned when it was tested in March 2015, April 2013, and April 2011, but had not been fixed. Its failure once again caused flooding during the May 2015 explosion (NRC 2015e).

The NRC estimated that the component's malfunction allowed about 50 gallons per minute to flow into the room. Drains in the floor were designed to carry away 100 gallons per minute. But the drain pipes were so clogged with debris that only about 25 gallons per minute could exit through them. Workers tested the drains every two years but used a method woefully inadequate for determining whether the drains were clear or blocked (NRC 2015e).

For violating a federal regulation that requires safety problems to be fixed in a timely and effective manner, the NRC issued a Green finding, the least serious in its four color-coded sanction levels (NRC 2015e).

In 2007, Entergy had submitted an application to the NRC for a 20-year extension of the license to operate Indian Point. As part of this process, it evaluated hundreds of proposed modifications to the plant and revisions to procedures that could lessen the chances and/or consequences of accidents. Entergy's evaluation concluded that installing a sensor in the room with the electrical panels to alert the control room operators about flooding would reduce the total risk of core meltdown by about 20 percent and would be cost beneficial. The alarm's \$200,000 cost would be more than offset by the expected benefit of at least \$1.4 million from reducing the risk of core meltdown. Yet the NRC does not require that cost-beneficial modifications be made unless they address a problem related to aging. Because a flood alarm would address a problem that had been in existence since the reactor was built, the NRC has not required Entergy to install this cost-beneficial safety upgrade (Lochbaum 2015d).

The NRC has not required Entergy to install a flood alarm—a cost-beneficial safety upgrade—at Indian Point.

North Anna

The NRC sent a special inspection team to North Anna following a security-related event on August 15, 2015. Due to a policy adopted after the terrorist attacks of September 11, 2001, the NRC no longer publicly discloses the causes and corrective actions for security-related problems.

The NRC identified two violations of regulatory requirements, both classified as Green (NRC 2015f).

Pilgrim

The NRC sent a special inspection team to Pilgrim after Winter Storm Juno knocked out both high-voltage transmission lines to the plant on January 27, 2015. Per design, the reactor automatically shut down when the second power line was lost. But the plant's response deviated in several ways from expectations.

UCS developed a slideshow based on the report by the NRC's special inspection team describing the complicated sequence of events, the major equipment failures, and the operator errors that prompted the NRC's investigation (NRC 2015g; UCS 2015).

The NRC's special inspection team identified eight violations of regulatory requirements—six Green and one White finding in the agency's color-coded classification scheme and one Severity IV (lowest severity level) violation in its four-tiered system of Roman numerals for violations that do not lend themselves to significance determination (such as for deliberate or willful acts).

The most serious violation involved the safety relief valves to control pressure inside the reactor vessel. During an emergency, these valves would be used to lower the pressure inside the reactor vessel enough to allow pumps to supply cooling water for the nuclear core. During the January 27 event, the control room operators could not open one of these safety relief valves. A similar problem had occurred two years earlier following the reactor's shutdown on February 9, 2013. But workers had not properly identified the cause of that problem nor corrected it, allowing it to recur.

Pilgrim's owner cannot control the weather. But Pilgrim's owner can—and must—control whether the equipment and workers respond properly to such challenges (Lochbaum 2015e). Of the 22 violations of regulatory requirements in the near misses the NRC identified during 2015, Pilgrim racked up eight—more than a third of all the year's violations—in this single near miss.

River Bend

The NRC dispatched a special inspection team to River Bend following an unplanned reactor shutdown on December 25, 2014. A power supply failed and the plant's failsafe design conservatively shut down the reactor. That same power supply had also failed on December 6, but different conditions kept the reactor from automatically shutting down. Workers determined that the power supply's earlier failure was caused by either of two parts; they replaced one part and restored the power supply to service. The culprit was actually the other part, which failed again on Christmas Day.

The NRC's special inspection team examined problems the operators encountered controlling the water level inside the reactor vessel following the unplanned shutdown. The water level initially dropped too low, then rose too high, and then dropped too low again before the operators stabilized it at a safe level. The NRC found that the system providing makeup water to the reactor vessel had been operating outside its design limits for nearly 20 years. In addition, the NRC found that workers were using incorrect procedures to operate the system and that the training provided to the operators did not accurately reflect how the system really worked (NRC 2015h).

The NRC's special inspection team identified five violations of regulatory requirements—four characterized as

TABLE 2. Nuclear Safety Near Misses, 2010–2015

Reactor	Total Number of Near Misses	Near Misses by Year						
		2010	2011	2012	2013	2014	2015	
1	Arkansas Nuclear One Unit 1	2	1			1		
2	Arkansas Nuclear One Unit 2	2	1			1		
3	Braidwood Unit 1	2	1	1				
4	Braidwood Unit 2	2	1	1				
5	Browns Ferry Unit 1	1				1		
6	Browns Ferry Unit 2	1				1		
7	Browns Ferry Unit 3	1				1		
8	Brunswick Unit 1	1	1					
9	Brunswick Unit 2	2	1		1			
10	Byron Unit 1	1		1				
11	Byron Unit 2	2		1	1			
12	Callaway	1		1				
13	Calvert Cliffs Unit 1	3	1				1	1
14	Calvert Cliffs Unit 2	3	1				1	1
15	Catawba Unit 1	3	1		1		1	
16	Catawba Unit 2	1	1					
17	Clinton	1					1	
18	Columbia	3				3		
19	Cooper	1		1				
20	Crystal River Unit 3 ^a	1	1					
21	Davis-Besse	1	1					
22	Diablo Canyon Unit 2	1	1					
23	Duane Arnold Energy Center	1						1
24	Farley Unit 1	1			1			
25	Farley Unit 2	2	1		1			
26	Fermi Unit 2	1					1	
27	Fort Calhoun	5	1		2	1		1
28	Grand Gulf	1					1	
29	HB Robinson	2	2					
30	Indian Point Unit 3	1						1
31	Joseph M. Farley Unit 2	1					1	
32	LaSalle Unit 1	1				1		
33	LaSalle Unit 2	1				1		
34	Millstone Unit 2	2		1			1	
35	Millstone Unit 3	2					2	
36	North Anna Unit 1	2		1				1
37	North Anna Unit 2	2		1				1
38	Oconee Unit 1	1		1				

TABLE 2. Nuclear Safety Near Misses, 2010–2015 (continued)

Reactor		Total Number of Near Misses	Near Misses by Year					
			2010	2011	2012	2013	2014	2015
39	Oconee Unit 2	1		1				
40	Oconee Unit 3	1		1				
41	Oyster Creek	1				1		
42	Palisades	3		2	1			
43	Palo Verde Unit 1	1			1			
44	Palo Verde Unit 2	1			1			
45	Palo Verde Unit 3	1			1			
46	Perry	2		1	1			
47	Pilgrim	3		2				1
48	River Bend	3			1		1	1
49	San Onofre Unit 2 ^a	1			1			
50	San Onofre Unit 3 ^a	1			1			
51	Shearon Harris	2			1	1		
52	Surry Unit 1	1	1					
53	Susquehanna Unit 2	1				1		
54	Turkey Point Unit 3	1		1				
55	Virgil C. Summer Unit 2 ^b	1						1
56	Wolf Creek	4	1	1	2			
Total		91	19	19	18	14	11	10

NOTES:

a. This reactor has been permanently shut down.

b. This reactor is under construction and has not commenced operation.

Green and one as White (NRC 2015h). The most serious violation was that the control room simulator incorrectly modeled the makeup water system, thus providing the operators with inaccurate training lessons about the plant.

Virgil C. Summer Unit 2

The NRC sent a special inspection team to the site the last week of February 2015 to determine the cause and consequences of a problem that arose during the construction of the Unit 2 reactor. Workers boring holes in the concrete basement of the reactor had mistakenly cut through metal reinforcing bars (“rebar”) embedded in the concrete and the steel containment vessel shell. Workers had been instructed to bore holes at least 25 inches deep in the concrete, but had not been given a maximum depth limit.

The damaged rebar and containment vessel were not found by post-installation inspections or testing conducted by the workers. The problems were not discovered by quality control inspectors at the site. And the NRC’s inspectors did not identify the problems. Construction workers later discovered the problems during the course of other tasks.

The NRC identified two violations of regulatory requirements, both characterized as Green (NRC 2015i). The NRC’s special inspection team reported that neither craft nor field engineers received training at the site on drilling holes in concrete and “were not knowledgeable of the appropriate procedures governing core drilling” (NRC 2015i). Having untrained workers perform tasks that are not thoroughly checked to ensure proper results is not the proper way of constructing a safe and economical nuclear power plant.

Conclusion

Entergy's reactors experienced three of the near misses in 2015 and received 64 percent of the safety violations issued by the NRC in response to its near miss investigations. The NRC needs to determine whether corporate-wide issues contribute to near misses at multiple reactors operated by one owner. Four of the near misses involved recent repairs that caused problems instead of delivering solutions. Reactor owners must ensure that repairs are made correctly, or the aging U.S. fleet of reactors will experience more problems as safety equipment wears out and needs repair.

ENDNOTE

1 Two of the near misses happened in late 2014. The NRC takes at least six weeks (and sometimes much longer) to investigate near misses and issue its reports. UCS included near misses for which the NRC issued reports during 2015.

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