

# FUKUSHIMA FALLOUT

REGULATORY LOOPHOLES AT U.S. NUCLEAR PLANTS



Fukushima Nuclear Plant

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## Table of Contents

Executive Summary .....	3
Introduction.....	5
Emergency Diesel Generators: Decades of Reliability and Maintenance Problems.....	9
Spent Nuclear Fuel: Regulatory Loopholes .....	10
Background:.....	10
Earthquakes and Spent Fuel Pool Integrity .....	11
Spent Nuclear Fuel Pools Contain No Protections from Hydrogen Explosions.....	12
There is No Regulatory Requirement for Some Spent Nuclear Fuel Pools to Have Emergency Power Capability .....	13
Hydrogen Explosions: NRC Regulations Are Lacking, and NRC Officials Have Made Misleading Statements Related to their Use .....	14
Seismic Safety: NRC Has Not Factored Modern Geologic Information Into Reactor Safety .....	16
Background:.....	16
Case Study: Diablo Canyon .....	17
Seismic Concerns: Not just at West Coast reactor sites.....	19
NRC’s Post-Fukushima Efforts: Scope Limitations and Secrecy Concerns.....	22
Table 1. National responses to Japanese nuclear disaster .....	24
Table 2 – Summary of Emergency Diesel Generator (EDG) Inoperability 2002-2010.....	25

## Executive Summary

In the wake of the Fukushima Daiichi meltdown in Japan, the Nuclear Regulatory Commission (NRC) established<sup>1</sup> an agency task force to conduct a review of the lessons that can be learned from the Tohoku earthquake and the tragic, ongoing events at the Fukushima nuclear power plant that have followed. The task force's stated goal is to "Evaluate currently available technical and operational information from the events that have occurred at the Fukushima Daiichi nuclear complex in Japan to identify potential or preliminary near term/immediate operational or regulatory issues affecting domestic operating reactors of all designs, including their spent fuel pools, in areas such as protection against earthquake, tsunami, flooding, hurricanes; station blackout and a degraded ability to restore power; severe accident mitigation; emergency preparedness; and combustible gas control."

However, an examination of NRC regulations demonstrates that flawed assumptions and under-estimation of safety risks are currently an inherent part of the NRC regulatory program, due to a long history of decisions made by prior Commissions or by the NRC staff that have all too often acquiesced to industry requests for a weakening of safety standards. Coupled with reports that the near-term inspections being conducted at United States nuclear power plants may be limited in scope<sup>2</sup> and subject to restrictions on public disclosure, it would be unwise to move forward with any pending licensing actions before the NRC fully completes its review and upgrades of its safety requirements.

The NRC's stated commitment to learn from the recent Japanese disaster is undermined both by its post-Fukushima approvals of license extension applications for Vermont Yankee Nuclear Power Plant in Vermont and Palo Verde Nuclear Generating Station Units 1, 2, and 3<sup>3</sup> in Arizona and by its apparent failure to fully explore all the vulnerabilities the Fukushima meltdown has revealed.

This report represents a partial summary of regulatory inadequacies, practices and decisions that impair effective nuclear safety oversight, some of which have occurred in the wake of the Japanese meltdown. Key findings include:

- The failure of the emergency diesel generators following the loss of off-site electricity led to the meltdowns at the Fukushima reactors. Despite decades of reported problems and NRC warnings, a review of NRC documents conducted by the staff of Congressman Edward J. Markey indicates that there have been recurrent and prolonged malfunctions of emergency diesel generators at nuclear power plants in the U.S. In the past eight years there have been at least 69 reports of emergency diesel generator inoperability at 33 nuclear power plants. A total of 48 reactors were affected including 19 failures lasting over two weeks and 6 that lasted longer than a month.

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<sup>1</sup> <http://www.nrc.gov/reading-rm/doc-collections/news/2011/11-055.pdf>

<sup>2</sup> [http://markey.house.gov/docs/4.15.11\\_nrc.pdf](http://markey.house.gov/docs/4.15.11_nrc.pdf)

<sup>3</sup> <http://www.nrc.gov/reactors/operating/licensing/renewal/applications/palo-verde.html>

- There never have been any requirements in the U.S. for spent fuel pools to include technologies to prevent the same kind of hydrogen explosions that reportedly occurred at spent nuclear fuel pools in Fukushima. Alarmingly, NRC's regulations do not require emergency diesel generators to be operational at times when there is no fuel in the reactor core, even though this could leave spent nuclear fuel pools without any backup cooling systems in the event of a loss of external electricity to the power plant. Finally, NRC has not required its licensees to reduce the amount of nuclear fuel stored in its spent nuclear fuel pools by moving it to dry cask storage, a safer means of storage that would reduce the risk of fire and radiation release in the event of an accident.
- NRC has removed its regulatory requirements for reactor containments to include technologies to prevent hydrogen explosions, even as NRC officials repeatedly and inaccurately asserted that such technologies were absent in Japan but are required in the U.S.
- The NRC has not factored modern geologic information into seismic safety requirements for nuclear power plants, and has not incorporated its technical staff's recommendation to do so even though the new information indicates a much higher probability of core damage caused by an earthquake than previously believed. In fact, the NRC has continued to process applications for license extensions for many nuclear reactors, including Pilgrim (which is approximately 38 miles from Boston) and Indian Point (which is approximately 25 miles from New York City), even in the absence of upgraded seismic safety requirements.
- NRC's post-Fukushima inspections in the U.S. appear to be limited in scope, and its U.S. nuclear reactor inspection reports will likely exclude vulnerabilities from both the NRC and the public due to limitations imposed by the NRC.

## Introduction

Four days before the Tohoku earthquake Rep. Markey wrote to the Nuclear Regulatory Commission (NRC) to urge it to postpone action on the pending NRC approval of the AP 1000, a new nuclear power plant design<sup>4</sup>. One of the NRC's most senior scientists had warned that the containment structure for this reactor design would not be able to withstand a strong earthquake, because 60% of it is made of a material that is so brittle it could shatter like a "glass cup" under sufficient stress.<sup>5</sup> As the non-concurring scientist noted, Brookhaven National Lab scientists found that Westinghouse appeared to have used an inappropriate "pushover" earthquake model that may have ignored the actual back-and-forth forces that occur in an actual earthquake, and instead assumed that such forces would only be imposed in a single direction.<sup>6</sup>

It is not just the designs for new nuclear power plants that raise serious concerns regarding the ability of domestic nuclear power plants to maintain safe operations and safe shut-down even in the face of a beyond design-basis event or near-concurrent series of events. The Fukushima Daiichi meltdown was initiated by the combination of an earthquake and tsunami, but it was the prolonged loss of external electricity coupled with the failure of the emergency backup diesel generators that ultimately prevented the safe shut-down of these nuclear reactors and led to the subsequent core meltdowns, spent fuel pool damage and radiation release.

Like all nuclear reactors, including those in the United States, the Fukushima Daiichi nuclear power plant needed electricity to run the plant's cooling systems, which prevent the reactors from melting down. The cooling systems also keep the spent nuclear fuel from overheating or releasing radiation. To deal with potential loss of electrical power to the plant, Fukushima Daiichi, like American nuclear power plants, had diesel-powered backup generators. But the water from the tsunami went right past the sea walls at Fukushima, swamping the generators. The water also flooded the electrical control rooms at the plant, preventing backup generators from being hooked up.

Without electricity to pump in fresh coolant to the reactor cores and their spent fuel pools, they overheated, resulting in hydrogen explosions (including suspected hydrogen explosions at spent nuclear fuel pools which have not previously been experienced or contemplated), partial core meltdowns, and continuing radiation release. Spent nuclear fuel rods are also leaking radiation into the water that is being used to cool them, which itself is leaking into other areas of the power plants and into the surrounding area. With no way to circulate water through the reactors or their spent fuel pools mechanically, the Japanese were forced to take the extraordinary step of attempting to flood them with seawater using helicopters and water

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<sup>4</sup> <http://markey.house.gov/docs/3-7-11.ejmtomrc.pdf>

<sup>5</sup> The dissenting Non-Concurrence is available under Accession Number ML103370648 within the NRC Agencywide Documents Access and Management System (<http://www.nrc.gov/reading-rm/adams/web-based.html>).

<sup>6</sup> R. Morante, M. Miranda, J. Nie. Technical Evaluation: AP1000 Shield Building Design Report, Revision 2. Dated 5/30/2010. Submitted as part of Dr. Ma's rebuttal to the staff response to the Non-Concurrence statement. Accession Number ML103370648 within the Agencywide Documents Access and Management System (<http://www.nrc.gov/reading-rm/adams/web-based.html>).

cannons, placing emergency responders in harm's way as they were undoubtedly exposed to dangerous radiation levels.

Once emergency responders began to utilize ocean water to flood the reactor vessels and spent fuel pools, the heat from the nuclear fuel rods caused the water to boil off, leaving a crust of salt that filled the reactor vessels and coated the fuel, making efficient cooling all but impossible. While the Japanese have since procured sufficient stores of fresh water in an attempt to mitigate the salt build-up, these and other efforts to cool the reactors have been delayed by the discovery of high levels of radioactive water that are reported to contain short-lived fission byproducts in the basements of Units 1-3, which caused two workers to receive serious radiation burns to their legs and again raised concerns that the reactor vessels may be more severely damaged than they were previously believed to be.<sup>7</sup> On April 4, the Tokyo Electric Power Company began dumping more than 11,000 tons of radioactive water, about 100 times more radioactive than Japan's legal limit, from the Fukushima Daiichi nuclear plant into the Pacific Ocean.<sup>8</sup> Workers also resorted to using shredded newspaper, sawdust, and a material used in diapers<sup>9</sup>, in attempts to stop a leak of seven tons an hour of even more highly radioactive water escaping from a pit near the reactor into the ocean<sup>10</sup>.

The radiation released from the Daiichi reactors has already caused considerable damage. The Department of Energy has projected what the dose could be to people living around the plant up to about 50 miles away over the first year of the nuclear disaster based on aerial radiation survey data<sup>11</sup>. People are expected to be exposed to about 2,000 millirems in the first year in a swath of land extending about 30 miles to the northwest of Fukushima Daiichi. The exposure estimate assumes that people did not evacuate and do not heed advice to shelter indoors throughout the year. The Japanese government has evacuated people out to 19 miles, and advised evacuation in selected places beyond that distance because of high localized fallout. Thousands of farmers have had to dump tons of produce and millions of gallons of dairy across a swath of north-central Japan where the government has determined radiation makes the food unsafe.<sup>12</sup> Residents in Tokyo, about 150 miles from the Fukushima reactors, were warned temporarily not to allow infants to drink tap water because it contained unsafe levels of radioactive iodine. On April 2, seawater leaking from a crack near unit 2<sup>13</sup> had levels of radioactive iodine-131 that were 7.5 million times Japan's legal limit, and radioactive cesium-134 at a concentration 2 million times that was allowed<sup>14</sup>. As seawater used to cool the reactor was released back to the ocean, radioactive iodine in the ocean 30 miles from Fukushima Daiichi spiked to 2800 times the legal limit on April 7th, while radioactive cesium-134 levels were at 1100 times the legal limit, and cesium-137 at 760 times the limit<sup>15</sup>. Radioactive cesium-134 remained at twice the legal limit at the same sampling location on May 6, 2011<sup>16</sup>. Thousands of miles away, radioactive

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<sup>7</sup> <http://www.nytimes.com/2011/03/30/world/asia/30japan.html>

<sup>8</sup> <http://www.nytimes.com/2011/04/05/world/asia/05japan.html>

<sup>9</sup> <http://english.kyodonews.jp/news/2011/04/82882.html>

<sup>10</sup> <http://www.nytimes.com/2011/04/05/world/asia/05japan.html>

<sup>11</sup> <http://news.sciencemag.org/scienceinsider/2011/04/a-map-of-fukushimas-radiation.html>

<sup>12</sup> <http://www.nytimes.com/2011/03/30/world/asia/30farmers.html?pagewanted=1>

<sup>13</sup> [http://www.tepco.co.jp/en/press/corp-com/release/betu11\\_e/images/110405e31.pdf](http://www.tepco.co.jp/en/press/corp-com/release/betu11_e/images/110405e31.pdf)

<sup>14</sup> <http://www.tepco.co.jp/en/press/corp-com/release/11040506-e.html>

<sup>15</sup> <http://www.tepco.co.jp/en/press/corp-com/release/11040815-e.html>

<sup>16</sup> <http://www.tepco.co.jp/en/press/corp-com/release/11050707-e.html>

iodine from Japan has been found in Boston rainwater, although at levels far lower than those that would pose a threat to human health.<sup>17</sup>

While radioactive iodine rapidly decays, with a half life of 8 days, other radioactive elements being released are longer-lasting. The three plutonium isotopes found in Japanese soil samples have environmental half-lives of 87 - 24,000 years. Cesium-134 has a half-life of 2 years, and cesium-137 a half-life of 30 years. Cesium is also absorbed by marine organisms. As of April 28, radioactive cesium has been detected in 41 species off the coast of Japan<sup>18</sup>. In the Pacific sandlance, radioactive cesium has been found at levels as high as 14,400 Bequerels per kilogram, about 29 times the legal limit. The Pacific sandlance is eaten by many in Japan, and additionally serves as food for other fish, and cesium tends to bio-magnify, becoming increasingly concentrated as it moves up the food chain<sup>19</sup>. The Pacific sandlance is eaten by many migratory species, including other fish (salmon, bluefin tuna, skates, cod), seabirds (murre, auklets), and marine mammals (minke whales, seals). When present in a person or other animals, plutonium and cesium continue, for years or even decades, to expose surrounding tissue to radiation that can lead to cancer.

In recognition of the high levels of radiation emitted, on April 12, Japanese authorities raised their assessment of the Fukushima Daiichi nuclear meltdown to a Level 7 “Major Accident”<sup>20</sup>. According to the International Nuclear and Radiological Event Scale of the International Atomic Energy Agency, level 7 means “A major release of radioactive material with widespread health and environmental effects requiring implementation of planned and extended countermeasures”. Only once before, during the Chernobyl meltdown of 1986, has there been such a severe nuclear disaster<sup>21</sup> that rated this highest possible classification.

It is clear that the environmental consequences of Fukushima will be broad, severe, long-lasting, not previously contemplated by nuclear regulators in any country, and significant. Yet these consequences were not even fully understood, let alone factored into any of the Commission’s post-Fukushima decisions to grant license extensions for four nuclear reactors by way of a revised or supplemental Environmental Impact Statement or by way of new safety requirements<sup>22</sup>.

In stark contrast to steps taken by other countries to cancel, postpone or otherwise re-assess nuclear reactor safety in the wake of the events in Japan (see Table 1 for a summary of other countries’ announcements), the NRC has continued to process applications for new licenses and licenses extensions even before it has completed its reviews of U.S. nuclear safety. As Martin J. Virgilio, NRC’s Deputy Executive Director for Reactor and Preparedness Program, stated on April 6 before the House Energy & Commerce Committee “We have been closely monitoring the activities in Japan and reviewing all currently available information. Review of this information combined with our ongoing inspection, licensing and oversight allows us to say

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<sup>17</sup> <http://www.wbur.org/2011/03/28/japan-radiation>

<sup>18</sup> [http://www.jfa.maff.go.jp/e/q\\_a/](http://www.jfa.maff.go.jp/e/q_a/)

<sup>19</sup> <http://www.ncbi.nlm.nih.gov/pubmed/12527234>

<sup>20</sup> <http://www.iaea.org/newscenter/news/2011/fukushima120411.html>

<sup>21</sup> [http://www.nytimes.com/2011/04/12/world/asia/12japan.html?\\_r=4](http://www.nytimes.com/2011/04/12/world/asia/12japan.html?_r=4)

<sup>22</sup> The NRC granted license extension to Vermont Yankee on March 21, 2011, and to Palo Verde Units 1, 2, and 3 on April 21, 2011. <http://www.nrc.gov/reactors/operating/licensing/renewal/applications.html>

with confidence that the U.S. plants continue to operate safely.” And at a May 4 House Energy & Commerce Committee Hearing, NRC Chairman Greg Jaczko said “As early as late summer, the commission may conduct the first mandatory hearings on new reactor licenses since the 1970s.”

This report provides a summary of some of the most egregious failings of previously adopted NRC safety regulations to protect against the vulnerabilities exposed by the Japanese melt-down, as well as the limitations in the steps NRC has taken to date to explore these vulnerabilities in the U.S.



## Emergency Diesel Generators: Decades of Reliability and Maintenance Problems

It is not just earthquakes that can lead to the loss of the external electricity supply at nuclear power plants. In the U.S., such outages have also been caused by squirrels<sup>23</sup> and hot weather,<sup>24</sup> and have also occurred at nuclear power plants. In 1990, a fuel truck accidentally backed into a power line at the Vogtle nuclear power plant, knocking out electricity; as with the Fukushima nuclear power plants, it turned out that the plant's emergency diesel generation was also disabled.<sup>25</sup>

In the U.S., nuclear power plants are required to have emergency diesel generators with sufficient fuel to last 7 days, and battery capacity that can further run for 4-8 hours (depending on the reactor) in the event the diesel generators fail. While emergency diesel generators in the U.S. are required to be better protected than in Japan (they are typically required to be in hardened locations that are not vulnerable to tsunamis), an examination of NRC documents nevertheless indicates significant and prolonged problems associated with their operation.

On January 25, 1989, the NRC issued an information notice<sup>26</sup> "to alert addressees to events involving breaks or cracking of small-diameter tubing which can render emergency diesel generators (EDGs) inoperable." On August 6, 2007, NRC issued an Information Notice entitled "Recurring Events Involving Emergency Diesel Generator Operability<sup>27</sup>," which describes some failures of emergency diesel generators that took weeks to resolve and referenced the 1989 notice. However, the document also stated that "no specific action or written response" was required.

A review of NRC documents indicates that there have been recurrent prolonged malfunctions of emergency diesel generators at nuclear power plants in the U.S. (see Table 2). In the past eight years there have been at least 69 reports of emergency diesel generator inoperability at 33 nuclear power plants. A total of 48 reactors were affected, including 19 failures lasting over two weeks and 6 that lasted longer than a month.

A weeks-long failure of the emergency diesel generators leaves these nuclear power plants with only 4-8 hours' worth of secondary emergency battery-powered generation in the event of a loss of offsite electricity. And even these minimal requirements do not apparently apply to spent nuclear fuel pools at nuclear reactors whose cores have been emptied of fuel assemblies. It is clear that the NRC has historically done little to address long-standing and serious problems associated with licensee maintenance of emergency diesel generators that leaves reactors vulnerable to a loss of offsite power.

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23 [http://www.usatoday.com/news/nation/2007-03-11-suicide-squirrels\\_N.htm](http://www.usatoday.com/news/nation/2007-03-11-suicide-squirrels_N.htm)

24 <http://www.cbsnews.com/stories/2006/07/26/national/main1836674.shtml>

25 <http://www.nrc.gov/reading-rm/doc-collections/gen-comm/info-notices/1990/in90025s1.html>

26 <http://www.nrc.gov/reading-rm/doc-collections/gen-comm/info-notices/1989/in89007.html>

27 <http://pbadupws.nrc.gov/docs/ML0717/ML071760544.pdf>

## Spent Nuclear Fuel: Regulatory Loopholes

### Background:

All U.S. nuclear plants store most of their highly radioactive spent nuclear fuel under water in pools, as was the practice at Fukushima Daiichi. Thirty-two General Electric Boiling Water Reactors locate their spent fuel storage pools on top of the reactor cores, as at Fukushima<sup>28</sup>. In Pressurized Water Reactors, spent fuel storage is typically “below grade,” meaning below ground level<sup>29</sup>. The water in these pools, which is cooled via circulation using pumps that require electricity, keeps the spent fuel rods from igniting, burning off their zirconium cladding, and releasing the vast quantities of radiation they contain.

The NRC has granted many reactor licensees permission to increase the amount of spent fuel that can be stored in these pools.<sup>30</sup> Spent nuclear fuel pools in this country are filled nearly to overflowing in some cases – for example, the NRC gave the Pilgrim nuclear power plant permission to pack almost 4,000 spent fuel assemblies (up from the 2,320 the NRC had previously allowed and the 880 the reactor was originally designed to hold<sup>31</sup>) into its spent nuclear fuel pool, which, like the Fukushima Daiichi reactors’, is located on top of the unit<sup>32</sup>. The tight packing of fuel rods at Pilgrim and many other spent fuel pools would make it more difficult to keep the rods cool, and increase the risk of radiation release, if cooling is lost or a spent fuel pool is damaged.

According to the Nuclear Energy Institute, there was 65,193 metric tons of spent fuel stored at nuclear plant sites across America in December 2010. Of this amount, 49,620 metric tons resided in spent fuel pools while 15,573 metric tons had been transferred to dry cask storage. By comparison, the reactor core of a large nuclear power reactor contains around 200 metric tons of irradiated fuel. There’s more than twice as much irradiated fuel in America’s spent fuel pools as in the reactor cores of all the nation’s operating reactors.

In Fukushima, the spent nuclear fuel pool associated with the unit 4 reactor was particularly troublesome as the loss of electricity needed to power the cooling system caused the water in the spent fuel pools to heat up. Unit 4’s spent fuel pool contained larger than normal quantities of fuel, because the reactor core for that unit was undergoing refueling at the time of the earthquake and all of the fuel had been off-loaded into the spent nuclear fuel pool. There has been speculation that the water in the spent fuel pool completely boiled off<sup>33</sup> and that there was a subsequent fire, that there may have been a hydrogen explosion in that pool (something that had

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<sup>28</sup> [http://www.ucsusa.org/nuclear\\_power/reactor-map/embedded-flash-map.html](http://www.ucsusa.org/nuclear_power/reactor-map/embedded-flash-map.html)

<sup>29</sup> <http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr0933/sec3/082r3.html>

<sup>30</sup> <http://www.nrc.gov/waste/spent-fuel-storage/pools.html>

<sup>31</sup> Safety Evaluation By The Office Of Nuclear Reactor Regulation Supporting Amendment No. 33 To Facility Operating License No. DPR-35 Boston Edison Company Pilgrim Nuclear Power Station, Unit No. 1 Docket No. 50-293

<sup>32</sup> <http://www.gpo.gov/fdsys/pkg/FR-1994-06-21/html/94-15024.htm>

<sup>33</sup> <http://www.nytimes.com/2011/03/17/world/asia/17nuclear.html>

never before been contemplated for spent fuel pools)<sup>34</sup>, and that the structure of the pool itself may have been damaged by either the earthquake or the explosion (because water that is being sprayed into the pool is evidently disappearing faster than it should if it were merely being boiled off)<sup>35</sup>.

Storing spent nuclear fuel in pools is not as safe as storing it in dry cask storage. Moving fuel into dry cask storage means fewer spent fuel rods remain in the pools, giving workers more time to cope with a loss of cooling power or loss of water from the pool, because fewer rods means less heat generated by the radioactive materials and thus a longer time for the water to heat up and boil away. Less fuel in the pool also allows for more water flow and better cooling for each fuel rod, and, even in the event of a loss of cooling function or water, less fuel also means a lower probability of a spent fuel fire and radiation release.

The safety benefits of dry cask storage were also noted in 2006, when the National Academy of Sciences issued a report<sup>36</sup> that described the following comparative advantages of dry cask storage over spent fuel pools:

- “Less spent fuel is at risk in an accident or attack on a dry storage cask than on a spent fuel pool.”
- “The potential consequences of an accident or terrorist attack on a dry cask storage facility are lower than those for a spent fuel pool.”
- “The recovery from an attack on a dry cask would be much easier than the recovery from an attack on a spent fuel pool.”

Then-NRC-Commissioner and now-Chairman Greg Jaczko has also articulated this view, stating in 2008 that “the most clear-cut example of an area where additional safety margins can be gained involves additional efforts to move spent nuclear fuel from pools to dry cask storage.” He went on to call for a rulemaking, stating that “in an effort to be ever vigilant about the safety of spent fuel, I believe the NRC should develop new regulations which require spent fuel be moved to dry cask storage after it has been allowed to cool for five years.”<sup>37</sup>

Despite this call for added safety measures to be implemented, no steps have been taken by the NRC to do so.

## **Earthquakes and Spent Fuel Pool Integrity**

The Fukushima Daiichi power remains in peril from further aftershocks, and is months from being fully under control. The fragility of the situation was highlighted when Fukushima Prefecture experienced a major aftershock of magnitude 7.0 on April 11. The aftershock forced the temporary evacuation of workers, and loss of power and water injection to units 1, 2, and 3

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<sup>34</sup> <http://www.iaea.org/press/?p=1248>

<sup>35</sup> <http://www.latimes.com/news/nationworld/world/la-fg-japan-quake-wrapup-20110318,0,2262753.story>

<sup>36</sup> [http://www.nap.edu/catalog.php?record\\_id=11263](http://www.nap.edu/catalog.php?record_id=11263) National Research Council. 2006. “Safety and Security of Commercial Spent Nuclear Fuel Storage: Public Report. P. 68-70.

<sup>37</sup> <http://www.nrc.gov/reading-rm/doc-collections/commission/speeches/2008/s-08-023.html>

for 50 minutes<sup>38</sup> With visible structural damage to the unit 4 spent fuel pool, which lacked a roof as of March 17 following fires in the pool on March 14<sup>th</sup> and 15<sup>th</sup>, there remain concerns that additional earthquakes or aftershocks could result in further damage to the spent fuel pools.<sup>39</sup> In California, earthquakes have also caused heavy water losses from sloshing at spent fuel storage pools there, partly because the pools are located high in reactor buildings as they are at Fukushima<sup>40</sup>.

Concerns have about spent fuel integrity have previously been raised in the United States, focusing primarily on the threat that terrorists could pose to spent fuel storage. In June 2006, the NRC lost a Ninth Circuit Court case to the San Luis Obispo Mothers for Peace, which had sued to require consideration of the environmental impacts of a terrorist attack on the Diablo canyon nuclear power plant spent fuel storage facility. Instead of requiring these assessments to be performed nationwide, the NRC chose instead to abide by it only within the Ninth Circuit Court, which excludes the Central and Eastern states where most nuclear facilities are found. In June 2006, the Commonwealth of Massachusetts' Attorney General sent the NRC a petition to amend its regulations to require Environmental Impact Statements for *all* nuclear power plant licensing decisions to consider the vulnerabilities of spent fuel storage pools nationwide, and sent a second petition on May 2, 2011 to suspend NRC's evaluation of the relicensing application for the Pilgrim nuclear power plant until the NRC has considered the spent fuel storage safety issues raised by Fukushima<sup>41</sup>. The NRC has not taken either requested action.

### **Spent Nuclear Fuel Pools Contain No Protections from Hydrogen Explosions**

Hydrogen can be produced in several ways during a nuclear reactor accident. One likely scenario at Fukushima is that under extreme heat, as the cooling systems lost power and fuel rods overheated, the zirconium cladding around the fuel rods reacted with water. This metal-water reaction gives off oxygen, and hydrogen, which is flammable. If the hydrogen is not removed, its build-up can lead to explosions that can further damage the reactor buildings and cause further radiation releases.

Protections against hydrogen explosions in the U.S. began when there was a hydrogen explosion, and threats of much greater explosions due to hydrogen buildup, during the 1979 Three Mile Island accident<sup>42</sup>. In 1981, NRC issued rules requiring nuclear power reactors to monitor hydrogen levels in the containment structure, and to have hydrogen recombiners (which act to combine hydrogen and oxygen to produce water before an explosion occurs) and/or vents (different reactor designs require different hydrogen mitigation technologies) to prevent hydrogen buildup,<sup>43</sup> although these rules are not themselves adequately enforced or implemented.

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<sup>38</sup> [http://www.jaif.or.jp/english/news\\_images/pdf/ENGNEWS01\\_1302521667P.pdf](http://www.jaif.or.jp/english/news_images/pdf/ENGNEWS01_1302521667P.pdf)

<sup>39</sup> <http://www.iaea.org/newscenter/news/2011/tsunamiupdate01.html>

<sup>40</sup> <http://www.nytimes.com/2011/03/18/world/asia/18spent.html>

<sup>41</sup> [http://www.mass.gov/?pageID=cagopressrelease&L=1&L0=Home&sid=Cago&b=pressrelease&f=2011\\_05\\_02\\_pi\\_lgrim\\_nrc&csid=Cago](http://www.mass.gov/?pageID=cagopressrelease&L=1&L0=Home&sid=Cago&b=pressrelease&f=2011_05_02_pi_lgrim_nrc&csid=Cago)

<sup>42</sup> <http://www.threemileisland.org/downloads/188.pdf>

<sup>43</sup> <http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr0737/final/sr0737.pdf>

However, there are no requirements whatsoever for hydrogen mitigation technologies to be included at spent nuclear fuel pools<sup>44</sup>, presumably because hydrogen explosions were never previously contemplated for these facilities. On March 15<sup>45</sup>, an explosion at the Unit 4 spent fuel pool is thought to have occurred, clearly illustrating this particular spent nuclear fuel vulnerability.

### **There is No Regulatory Requirement for Some Spent Nuclear Fuel Pools to Have Emergency Power Capability**

As has been previously noted, the loss of cooling function which was caused by the loss of external electricity and subsequent failure of all the emergency diesel generators and batteries at Fukushima led to both the core meltdowns and the radiation releases (and fires and potential hydrogen explosions) at the Fukushima nuclear power plant.

A review of the NRC's Standard Technical Specifications for nuclear power plants<sup>46</sup> indicates that spent fuel pools at nuclear reactors whose cores do not contain nuclear fuel (for example, because they were in the process of being refueled) do NOT require the presence of operable secondary emergency generation capacity. Thus, the circumstances that led to Japan's Unit 4 fire, potential explosion and radiation release would apparently be in compliance with NRC's requirements.

Additionally, Rep. Markey's staff has learned that licensees often perform maintenance on their emergency diesel generators when the reactors are undergoing refueling outages<sup>47</sup>. For example on November 11, 2009, the Wolf Creek Nuclear Operating Corporation submitted a report to the NRC regarding a loss of external operating power that occurred during a 2009 refueling of the Wolf Creek nuclear power plant in Kansas while one of the emergency diesel generators was also undergoing maintenance.

This regulatory loophole clearly represents an unacceptable risk to the safety of any decommissioned nuclear reactor or any reactor currently undergoing refueling.

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<sup>44</sup> Response of Mr. Martin J. Virgilio, NRC's Deputy Executive Director for Reactor and Preparedness Programs, to questions from Rep. Markey at an April 6, 2011 hearing of the Oversight and Investigations Subcommittee hearing of the House Energy and Commerce Committee.

<sup>45</sup> [http://www.world-nuclear-news.org/RS\\_Attempts\\_to\\_refill\\_fuel\\_ponds\\_1703111.html](http://www.world-nuclear-news.org/RS_Attempts_to_refill_fuel_ponds_1703111.html)

<sup>46</sup> See for example "Standard Technical Specifications General Electric Plants, BWR/4" and "Standard Technical Specifications for Westinghouse Plants"

<sup>47</sup> Private communications from an individual working inside an operating nuclear power plant obtained by Rep. Markey's office and discussions with nuclear safety experts.

## **Hydrogen Explosions: NRC Regulations Are Lacking, and NRC Officials Have Made Misleading Statements Related to their Use**

As noted, it is likely that hydrogen was generated at the Fukushima nuclear power plant when the zirconium cladding around the fuel rods reacted with water as they heated up. This metal-water reaction gives off oxygen, and hydrogen, which is flammable, and as the hydrogen concentrations built up the two gases likely then combined and exploded. Hydrogen explosions then blew apart the outer containments of the Units 1 and 3 reactors of the Fukushima Daiichi reactors, Unit 2's reactor containment was also damaged by an explosion (though its source is less clear), and the Unit 4 spent nuclear fuel pool is also likely to have experienced a hydrogen explosion<sup>48</sup>.

After the 1979 Three Mile Island accident,<sup>49</sup> which involved a hydrogen explosion, the NRC issued rules requiring nuclear power reactors to monitor hydrogen levels in the containment structure, and to include technologies to mitigate hydrogen build up as it occurred. The NRC rules for hydrogen control differed for various classes of reactor designs. Boiling Water Reactors (BWRs) were required to have vents, which allow hydrogen gas to be purged from the containment. For BWR Mark I and Mark II reactor designs, licensees were also required to pump the primary containment full of the inert gas, nitrogen, instead of air<sup>50</sup>. As a hydrogen explosion will not occur in the absence of oxygen, this “inerting” of the primary containments is a way of preventing them. For BWR Mark III and for Pressurized Water Reactors with smaller containments, a 1985 rule required plants to have the means to control the hydrogen produced if 75% of the fuel cladding reacted with water. The means to accomplish this was not specified; some plants have “igniter systems” that would burn off hydrogen before it could build up, and others have “hydrogen recombiners” that combine hydrogen with oxygen to form water before an explosion occurs.

However, almost immediately after issuing these rules to prevent hydrogen explosions, NRC began to relax them in response to pressure from industry. In 1984, the NRC agreed that “BWR Mark I Owners Group,” had demonstrated that Mark I reactors do not need vent and purge systems for hydrogen because they are inerted<sup>51</sup>. Pressurized Water Reactors with large containments were determined in 1989 to not need any hydrogen controls, because NRC decided the size of the containment could contain all of the hydrogen that could possibly be generated.

Finally, in 2003 NRC granted a request made by the Nuclear Energy Institute to eliminate the requirements for hydrogen recombiners and hydrogen and oxygen monitors. NRC invoked two conflicting arguments to justify “relaxing safety classifications” for hydrogen controls. First, the NRC concluded that hydrogen release poses a minimal risk of causing a radiation release, stating that “this hydrogen release is not risk-significant because the design-basis “loss of cooling accident” hydrogen release does not contribute to the conditional

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<sup>48</sup> [http://www.jaif.or.jp/english/news\\_images/pdf/ENGNEWS01\\_1304997042P.pdf](http://www.jaif.or.jp/english/news_images/pdf/ENGNEWS01_1304997042P.pdf)

<sup>49</sup> <http://www.threemileisland.org/downloads/188.pdf>

<sup>50</sup> <http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr0933/sec2/a48r1.html>

<sup>51</sup> <http://www.nrc.gov/reading-rm/doc-collections/gen-comm/gen-letters/1984/g184009.html>

probability of a large release up to approximately 24 hours after the onset of core damage<sup>52</sup>.” Secondly, the NRC concluded that “these systems were ineffective at mitigating hydrogen releases from risk-significant beyond design-basis accidents (DBAs).” As NRC spokesman Eliot Brenner said more plainly on March 31, 2001,<sup>53</sup> “They weren’t needed for design basis accidents and they didn’t help with severe accidents”. The result of this tortured logic was that NRC has allowed plants to remove a requirement for hydrogen mitigation technologies from their “Technical Specifications.” Some reactors may still have these features installed, but they are not required to keep them operational.

Yet despite the absence of these regulatory requirements in the U.S., the NRC has consistently made inaccurate statements that the Fukushima Daiichi reactors did not have hardened vents that could have prevented hydrogen explosions, and that in the U.S, such features were required. For example, at a March 21 hearing at the NRC,<sup>54</sup> Bill Borchardt, Executive Director for Operations for the NRC stated, in response to a question regarding what measures were in place at U.S. reactors to mitigate hydrogen explosions: “Well, the hardened vent, of course -- the U.S. design approach is to protect the containment... So it's at least my belief that you wouldn't have the hydrogen accumulation in the upper levels of the reactor building, which we believe is the cause of the explosions” at Fukushima Daiichi.”

These claims were repeated on April 6 at a hearing before the House Energy & Commerce Committee, when Martin J. Virgilio, NRC’s Deputy Executive Director for Reactor and Preparedness Program, stated that “The U.S. nuclear industry has implemented a number of equipment upgrades post 9/11 including hardened vents to prevent hydrogen explosions and systems that allow for reactor cooling and blackout conditions...” “One of the most significant features I would say that has been installed on those Mark I containments is what we called a hardened vent, and that allows the release of hydrogen gas that has built up inside the containment to be vented out safely. As we saw in Fukushima, there were a number of explosions which we are assuming related to that hydrogen gas buildup. Had they had the hardened vent or had they used the hardened vent, this would not have been an issue.”

According to an April 5 email<sup>55</sup> sent by NRC staff to the staff of Congressman Edward J. Markey, the Fukushima Daiichi reactors did have hardened vents. Moreover, under questioning by Congressman Markey, Mr. Virgilio also acknowledged that the regulatory requirement for the operability of these vents had been removed, that no such requirements had ever been in place for spent nuclear fuel pools, and that many such systems require electricity to operate.

Clearly, the NRC must revisit its decision not to require technologies for the mitigation of the build-up of hydrogen to be installed and operational on both reactor and spent nuclear fuel pool containment.

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<sup>52</sup> <http://www.nrc.gov/reactors/operating/licensing/techspecs/techspecs-pdf/447r1frn.pdf>

<sup>53</sup> <http://green.blogs.nytimes.com/2011/03/31/u-s-dropped-nuclear-rule-meant-to-avert-hydrogen-explosions/>

<sup>54</sup> <http://www.nrc.gov/reading-rm/doc-collections/commission/tr/2011/20110321.pdf>

<sup>55</sup> [http://markey.house.gov/docs/4-6-11markey\\_e-mail\\_2\\_-nrc\\_question\\_regarding\\_fukushima\\_unit\\_2.pdf](http://markey.house.gov/docs/4-6-11markey_e-mail_2_-nrc_question_regarding_fukushima_unit_2.pdf)

## Seismic Safety: NRC Has Not Factored Modern Geologic Information Into Reactor Safety

### Background:

The United States has many areas with the potential for strong seismic activity in the coming decades<sup>56</sup>. California has a historical record of 8 earthquakes of magnitude 7.3 or greater since 1700, including earthquakes close to both the Diablo Canyon and San Onofre nuclear power plants.<sup>57</sup> In 1700, the Cascadia subduction zone, which stretches offshore from British Columbia to Northern California, caused a 9.0 earthquake<sup>58</sup>. New research on underwater landslides caused by past Cascadia megaquakes shows that the average time between such events over the past 10,000 years is 240 years. The next earthquake is therefore overdue, and according to research led by University of Oregon geologist Dr. Chris Goldfiner, there is a 37% percent chance of a magnitude-9 quake over the next 50 years<sup>59</sup>. In the Southeast, Charleston, S.C. had a 7.3 earthquake in 1886. The New Madrid seismic zone, which includes southeastern Missouri, northeastern Arkansas, western Tennessee, western Kentucky and southern Illinois, produced a magnitude 7.7 earthquake in Arkansas in 1811<sup>60</sup>.

Eight nuclear power reactors are in the seismically active West Coast, approximately 27 are near the New Madrid seismic zone, and 5 are in earthquake-prone South Carolina (see Figure 1).<sup>61</sup> The 2011 report of the Independent Expert Panel on the New Madrid seismic zone notes: “The estimated hazard in the New Madrid region will evolve because of further analysis and better data.” NRC’s regulations must also continually evolve in response to scientists’ understanding of seismic hazard<sup>62</sup>.

According to NRC’s website, “Today, the NRC utilizes a risk-informed regulatory approach, including insights from probabilistic assessments and traditional deterministic engineering methods to make regulatory decisions about existing plants.” Historical data from a reactor’s site “is used to determine design basis loads from the area’s maximum credible earthquake, with an additional margin included.” But in the past 60 years, since the beginning of the commercial nuclear power industry, geologists have learned more about the likelihoods of earthquakes occurring throughout the country. For example, the geologic field of plate tectonics, which explains how the plates of the Earth’s crust move against each other, only emerged in the 1960s, after many nuclear power plants had already been sited.<sup>63</sup>

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<sup>56</sup> <http://earthquake.usgs.gov/hazards/products/graphic2pct50.jpg>

<sup>57</sup> [http://earthquake.usgs.gov/earthquakes/states/10\\_largest\\_us.php](http://earthquake.usgs.gov/earthquakes/states/10_largest_us.php)

<sup>58</sup> <http://earthquake.usgs.gov/research/structure/crust/cascadia.php>

<sup>59</sup> <http://www.nature.com/news/2010/100531/full/news.2010.270.html>

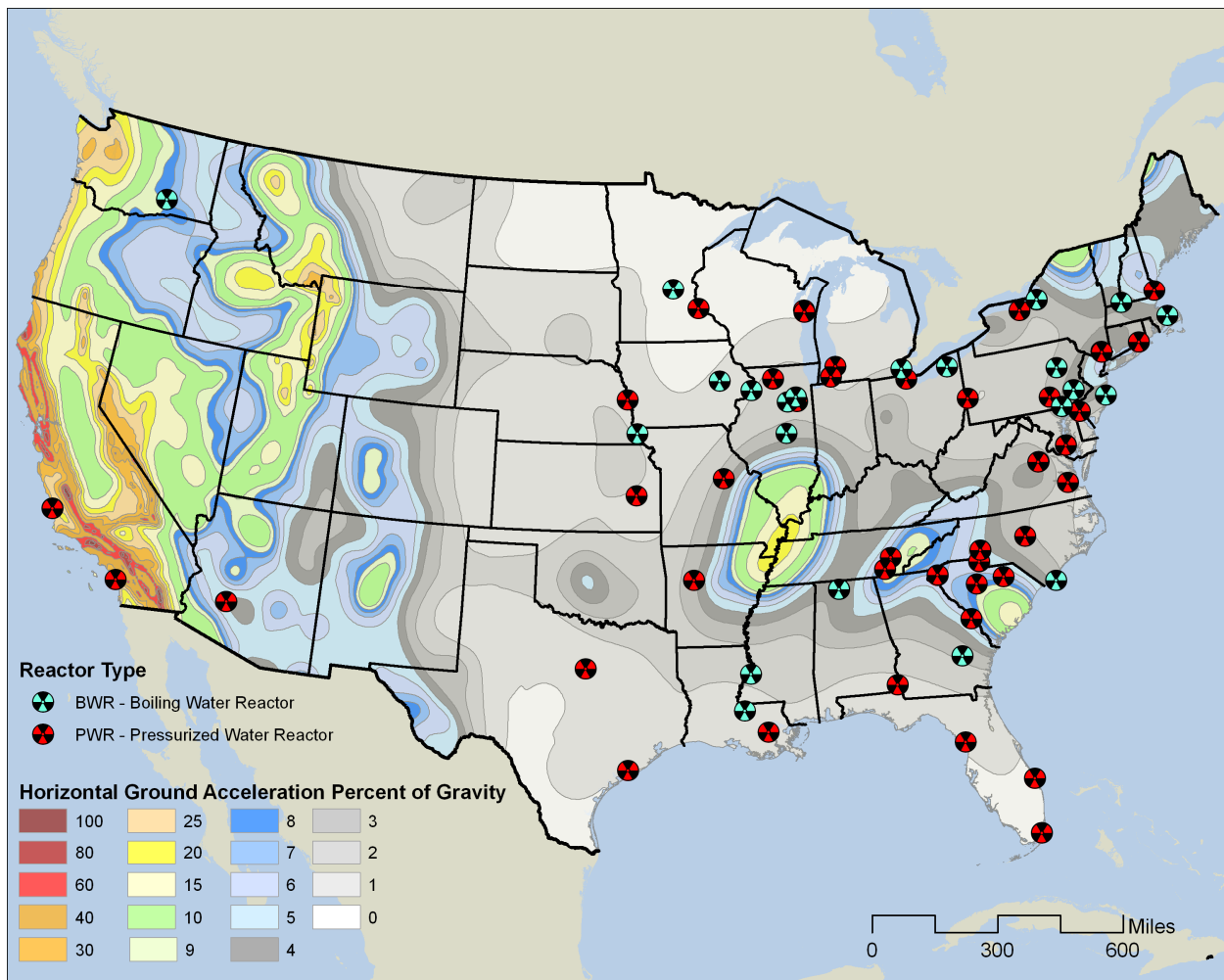
<sup>60</sup> <http://earthquake.usgs.gov/earthquakes/states/events/1811-1812.php>

<sup>61</sup> <http://earthquake.usgs.gov/hazards/products/conterminous/2008/maps/us/3hzSA.usa.jpg>

<sup>62</sup> [http://earthquake.usgs.gov/aboutus/nepec/reports/NEPEC\\_NMSZ\\_expert\\_panel\\_report.pdf](http://earthquake.usgs.gov/aboutus/nepec/reports/NEPEC_NMSZ_expert_panel_report.pdf)

<sup>63</sup> <http://www.ucmp.berkeley.edu/geology/techist.html>





**Figure 1: Operating Nuclear Power Plants vs Horizontal Ground Acceleration Percent of Gravity<sup>64</sup>**

### Case Study: Diablo Canyon

Even when presented with the discovery of previously unknown dangers, the NRC has typically assumed that plants remain safe. An example of this can be seen from the Diablo Canyon Nuclear Power Plant, whose application to be relicensed for another twenty years, until 2044 and 2045 respectively for the two units, is currently pending before the Commission.<sup>65</sup> Located 12 miles from San Luis Obispo, California, the nuclear power plant first became controversial in 1971, when the Hosgri Fault Zone was discovered 3 miles away from Diablo Canyon, requiring PG&E to spend \$4.4 billion on re-engineering (double what it had been expected to cost, as the first set of retro-fits were improperly conducted). According to the Southern California Earthquake Data Center, the Hosgri Fault may have been the location for a 7.1-magnitude earthquake that occurred in 1927.<sup>66</sup>

<sup>64</sup> Map constructed by the Congressional Cartography Program, Geography and Map Division, Library of Congress

<sup>65</sup> <http://www.nrc.gov/reactors/operating/licensing/renewal/applications/diablo-canyon.html#appl>

<sup>66</sup> [http://www.data.scec.org/chrono\\_index/lompoc.html](http://www.data.scec.org/chrono_index/lompoc.html)

Despite Diablo Canyon being three miles from an earthquake fault-line, the NRC concluded in 1984 that the probability of an earthquake causing a radiation release at Diablo Canyon, or happening at the same time as a radiation release, has “too low a probability to warrant mandatory consideration”.<sup>67</sup> This NRC belief, which has been emphatically refuted by the Japanese meltdowns, has been used by courts to deny requests for additional safety measures to be installed there.<sup>68</sup>

The NRC has also made the surprising conclusion that the Diablo Canyon area was “at most one of moderate seismicity,” an assertion based on data drawn from 1950 to 1974<sup>69</sup>. The NRC has thus far accepted Pacific Gas and Electric’s argument that the Diablo Canyon Power Plant remains safe despite the 2008 discovery of a new fault called the “Shoreline Fault” about 1 km from Diablo Canyon which extends to the Hosgri Fault, and the NRC has estimated this fault as being capable of leading to a maximum magnitude 6.85 earthquake<sup>70</sup>. According to the NRC, the Diablo Canyon nuclear power plant is rated for a 7.5-magnitude earthquake from the Hosgri fault.<sup>71</sup> Yet the assessment by the Southern California Earthquake Center is that there is a 46% probability of California having an earthquake of magnitude 7.5 or greater in the next 30 years, and this assessment is based on conservative analysis that excludes the possibility of an earthquake in the Cascadia subduction zone that could be even more catastrophic<sup>72</sup>.

Following calls for a halt to the NRC’s consideration of the license extension application for Diablo Canyon<sup>73</sup> in the wake of the Japanese meltdown, on April 11, Pacific Gas and Electric (PG&E) issued a press release indicating that it had requested a delay in its approval until the accelerated completion of new 3-dimensional seismic studies,<sup>74</sup> and issued a press release indicating that it had requested a delay in its approval until such studies were completed<sup>75</sup>.

However, this appears to be a hollow commitment. What PG&E actually requested was for the NRC to “delay the final processing of the license renewal application such that the renewed operating licenses, if approved, would not be issued until after PG&E has completed the 3-D seismic studies and submitted a report to the NRC addressing the results of those studies<sup>76</sup>.”

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<sup>67</sup> NRC Decision CLI-84-12. “In the Matter of Pacific Gas and Electric Company (Diablo Canyon Nuclear Power Plant Units 1 and 2.” Docket Nos. 50-275 OL, 50-323 OL.

<sup>68</sup> San Luis Obispo Mothers for Peace v. Nuclear Regulatory Commission.

[http://www.elawreview.org/summaries/environmental\\_quality/nepa/san\\_luis\\_obispo\\_mothers\\_for\\_pe.html](http://www.elawreview.org/summaries/environmental_quality/nepa/san_luis_obispo_mothers_for_pe.html)

<sup>69</sup> Nuclear Regulatory Commission Document CLI-84-12, In the Matter of Pacific Gas and Electric Company (Diablo Canyon Nuclear Power Plant Units 1 and 2). p. 8.

<sup>70</sup> Research Information Letter 09-001: Preliminary Deterministic Analysis of Seismic Hazard at Diablo Canyon Nuclear Power Plant from Newly Identified “Shoreline Fault”, p. 8. Available in ADAMS (<http://www.nrc.gov/reading-rm/adams/web-based.html>), by entering ML090330523.

<sup>71</sup> NRC. Safety Evaluation Report With Open Items Related to the License Renewal of Diablo Canyon Nuclear Power Plant, Units 1 and 2, Docket Nos. 50-275 and 50-323. January 2011. Available in ADAMS (<http://www.nrc.gov/reading-rm/adams/web-based.html>), by entering ML110100796

<sup>72</sup> <http://www.scec.org/core/public/scecontext.php/3935/13661>

<sup>73</sup> See for example, <http://www.scp.org/news/2011/03/24/congresswoman-wants-diablo-canyon-relicensing-put/>

<sup>74</sup> [http://www.pge.com/about/newsroom/newsreleases/20110411/pgampe\\_commits\\_to\\_finishing\\_3-d\\_seismic\\_studies\\_related\\_to\\_diablo\\_canyon\\_before\\_asking\\_for\\_renewed\\_licenses.shtml](http://www.pge.com/about/newsroom/newsreleases/20110411/pgampe_commits_to_finishing_3-d_seismic_studies_related_to_diablo_canyon_before_asking_for_renewed_licenses.shtml)

<sup>75</sup> <http://www.sanluisobispo.com/2011/04/11/1558606/pge-asks-for-delay-in-license.html>

<sup>76</sup> PG&E Letter DCL-11-047. Request for Deferral of Issuance of Diablo Canyon Power Plant Renewed Operating Licenses. April 10, 2011.

Since the NRC has already completed a draft Safety Evaluation Report on the renewal application, the gesture by PG&E appears to be meaningless, since it is not requesting that NRC reevaluate the application based on the results of these forthcoming studies. PG&E simply wants people to feel the “added assurance of the plant’s seismic integrity” that they appear certain will emerge from the forthcoming “advanced seismic research”.

### **Seismic Concerns: Not just at West Coast reactor sites**

It is not just West Coast nuclear power plants that have long been the subject of seismic examination that require a regulatory review. In 2010, the NRC used 2008 seismic risk data from the U.S. Geological Survey (USGS) and measures of the fragility of each reactor to conclude that the risks of core damage from earthquakes in the Eastern and Central States are greater than previously estimated. But the NRC has not taken steps to use this information in regulation.<sup>77</sup>

Core damage due to earthquake is expected to occur 0.0001 times per year at the Indian Point 3 reactor, according to NRC analysis based on 2008 seismic data from the United States Geological Survey<sup>78</sup>. The NRC is currently reviewing a license extension application for Indian Point<sup>79</sup>. This core damage estimate is 72% higher than the estimate that was based on seismic data from 1989. Indian Point is about 25 miles from New York City. Pilgrim Nuclear Power Station, about 38 miles from Boston and for which there is also an application for a twenty year license extension pending before the Commission<sup>80</sup>, is estimated to suffer 0.000069 core damage events per year due to earthquakes. The NRC’s risk estimate for Pilgrim is up more than 7 times (763%) from the estimate that was based on 1989 seismic hazard information.

The average number of core damage events for each reactor due to earthquakes, based on 2008 seismic data, is 0.000013 per year, according to an analysis of NRC data performed by MSNBC.<sup>81</sup> Based on 1989 seismic data, by contrast, the expected number of core damage events is 0.000038. While both of these are small numbers, the estimated risk has more than tripled based on the more current understanding of seismology. The NRC’s analysis also notes that it lacks detailed information regarding the physical vulnerability of nuclear power plants to earthquakes for about one third of reactors.

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<sup>77</sup> Generic Issue 199 (GI-199): Implications of updated probabilistic seismic hazard estimates in Central and Eastern United States on existing plants: Safety/Risk Assessment. August 2010. Available from NRC at <http://www.nrc.gov/reading-rm/adams/web-based.html> under accession number ML100270598.

<sup>78</sup> Generic Issue 199 (GI-199): Implications of updated probabilistic seismic hazard estimates in Central and Eastern United States on existing plants: Safety/Risk Assessment. August 2010. Appendix D, Table D-1: Table D-1: Seismic Core-Damage Frequencies Using 2008 USGS Seismic Hazard Curves. This is the value for the “weakest link model”. Available by searching for document ML100270756 in ADAMS: <http://www.nrc.gov/reading-rm/adams/web-based.html>

<sup>79</sup> <http://www.nrc.gov/reactors/operating/licensing/renewal/applications.html>

<sup>80</sup> <http://www.nrc.gov/reactors/operating/licensing/renewal/applications/pilgrim.html>

<sup>81</sup> [http://www.msnbc.msn.com/id/42103936/ns/world\\_news-asia-pacific/](http://www.msnbc.msn.com/id/42103936/ns/world_news-asia-pacific/) The MSNBC report used data from NRC document ML100270756, which is available by searching ADAMS: <http://www.nrc.gov/reading-rm/adams/web-based.html>. The NRC document contains seismic hazard estimates for 96 reactors; the NRC provided MSNBC estimates for the remaining 8 reactors. The data published by MSNBC appear to correspond to the NRC’s “weakest link model”.

The higher risks to reactors from earthquakes were so clear to the NRC staff who performed this Safety/Risk Assessment that they recommended further action be referred to “the Office of Nuclear Reactor Regulation for regulatory office implementation, and that this office “take further actions to address GI-199 outside the [General Issues Program] (i.e. obtain information and develop methods, as needed, to complete plant-specific value-impact analyses of potential backfits to reduce seismic risk).”<sup>82</sup>

Of course, any core damage event at a U.S. nuclear reactor would be of grave concern, and thus it is important to examine the potential frequency of such disasters caused by earthquakes across the entire fleet of nuclear reactors. Based on the expected number of events per year estimated for each nuclear reactor, we can sum the total number of expected core damage events per year for the nation’s fleet as a whole. According to calculations performed by the staff of Congressman Markey, the expected number of core damage events per year, across all the nuclear power plants in the country, is 0.0013.<sup>83</sup>

The threat of a nuclear disaster due to an earthquake is a long-term threat, because nuclear reactors operate for many years. Nuclear power reactors were originally licensed to operate for 40 years. The NRC has issued 20 year extensions to the operating licenses for 19 nuclear reactors since the beginning of 2007<sup>84</sup>, and is reviewing applications for 16 more such extensions, including applications for Indian Point and Pilgrim, the nuclear power plants in the central and eastern U.S. the NRC staff deemed to be most at-risk of core damage from earthquakes<sup>85</sup>. If the U.S. continues to have the same set of nuclear power plants over the next twenty years, the expected number of core damage events due to earthquakes is the per-year frequency times twenty, or 0.026, across the entire twenty year interval. This estimated national frequency of reactor core damage due to earthquakes does not factor in the additional hazards due to events that are independent of earthquakes, such as strong storms, wind, fires, operator error, reactor aging issues (for example, failures due to the corrosion of buried pipes that transport both cooling water and fuel to the emergency diesel generators and submerged cables), or terrorism.

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<sup>82</sup> Safety/Risk Assessment Results for Generic Issue 199, “Implications of Updated Probabilistic Seismic Hazard Estimates in Central and Eastern United States on Existing Plants”. August 2010.

<sup>83</sup> Staff took the sum of these core damage probabilities for each of the 65 nuclear power plant sites. Many nuclear power plant sites contain more than one nuclear reactor, and staff made the assumption, borne out by the Fukushima Daiichi melt-down, that the reactors that are co-located at a single nuclear power plant site are not independent; rather, they tend to be affected similarly by an earthquake. Additionally, they may impact one another as events unfold (explosions at one unit at Fukushima have been speculated to have damaged other units). For nuclear power plants with multiple reactors, the value chosen was that for the reactor with the highest core damage frequency as estimated by the NRC.

<sup>84</sup> Reactors given license renewals by NRC from 2007 to the present, and the States that host them: Palisades (MI); James A. FitzPatrick (NY); Wolf Creek, Unit 1 (KS); Harris, Unit 1 (NC); Oyster Creek (NJ); Vogtle, Units 1 and 2 (GA); Three Mile Island, Unit 1 (PA); Beaver Valley, Units 1 and 2 (PA); Susquehanna, Units 1 and 2 (PA); Cooper Nuclear Station (NE); Duane Arnold Energy Center (IA); Kewaunee Power Station (WI); Vermont Yankee Nuclear Power Station (VT); Palo Verde, Units 1, 2, and 3 (AZ).  
<http://www.nrc.gov/reactors/operating/licensing/renewal/applications.html>

<sup>85</sup> Pilgrim 1, Unit 1 (MA); Indian Point, Units 2 and 3 (NY); Prairie Island, Units 1 and 2; Crystal River, Unit 3 (FL); Hope Creek (NJ); Salem, Units 1 and 2 (NJ); Diablo Canyon, Units 1 and 2 (CA); Columbia Generating Station (WA); Seabrook Station, Unit 1 (NH); Davis-Besse Nuclear Power Station, Unit 1 (OH); South Texas Project, Units 1 and 2 (TX). <http://www.nrc.gov/reactors/operating/licensing/renewal/applications.html>;  
<http://www.nrc.gov/info-finder/reactor/>

Finally, the NRC has also failed to consider the impacts of multiple threats striking simultaneously because the NRC's regulations do not require them to. The Fukushima nuclear power plant was struck not only by the earthquake, but by its direct consequences, including a tsunami, fires, total station blackout due to loss of offsite power and damage to emergency diesel generators, overtaxed emergency responses resources due to crises elsewhere, and the inability to bring equipment to the site because of debris. Even the nuclear industry has recognized this assumption is flawed: "What clearly has shown up in Japan is multiple, stacked events. We've not analyzed for all those things," said Preston D. Swafford, the Tennessee Valley Authority's chief nuclear officer.<sup>86</sup>

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<sup>86</sup> [http://www.nytimes.com/2011/03/27/us/27reactor.html?\\_r=1](http://www.nytimes.com/2011/03/27/us/27reactor.html?_r=1)

## **NRC's Post-Fukushima Efforts: Scope Limitations and Secrecy Concerns**

On March 23, the NRC voted to require a multi-phase review<sup>87</sup> of U.S. nuclear reactor safety in the wake of the Japanese meltdown. The near-term review portion of these efforts called for the establishment of a task force to:

“Evaluate currently available technical and operational information from the events that have occurred at the Fukushima Daiichi nuclear complex in Japan to identify potential or preliminary near term/immediate operational or regulatory issues affecting domestic operating reactors of all designs, including their spent fuel pools, in areas such as protection against earthquake, tsunami, flooding, hurricanes; station blackout and a degraded ability to restore power; severe accident mitigation; emergency preparedness; and combustible gas control.”

The task force was additionally directed to develop near-term recommendations for regulatory and other changes, and is also required to inform its efforts using stakeholder input. The longer (90 day) review is supposed to include more extensive stakeholder input, and the task force was directed in this phase to “evaluate all technical and policy issues related to the event to identify potential research, generic issues, changes to the reactor oversight process, rulemakings, and adjustments to the regulatory framework that should be conducted by NRC.” All of the results of these efforts were supposed to be made public.

The NRC recently initiated inspections at each nuclear power plant in order to assess the operational or regulatory issues that may have arisen as a result of the Fukushima meltdown, and that the reports associated with these inspections are supposed to be submitted by May 13.

According to reports received by Rep. Markey<sup>88</sup>, the NRC may be artificially constraining the scope of these investigations and may keep the results of most of these investigations secret. These constraints and limitations include the following:

- The NRC only allowed<sup>89</sup> its inspectors 40 hours in which to perform each inspection for nuclear power plants that contain one nuclear reactor. For nuclear power plants with more than one unit, inspectors are being provided with only 50-60 hours total in which to complete their work. By contrast, the Institute of Nuclear Power Operations (INPO) reportedly spent hundreds of hours performing their inspections.
- The NRC inspectors were initially told to limit their inspections to the adequacy of safety measures needed to respond to Design Basis Events. This meant that inspectors would be assessing licensees' ability to withstand and respond only to events that have already been contemplated and analyzed by the NRC and for which regulatory

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<sup>87</sup> Tasking Memorandum – COMBJ-11-0002 – NRC Actions Following The Events In Japan

<sup>88</sup> Private correspondence from an individual working inside an operating nuclear power plant obtained by Rep. Markey's staff

<sup>89</sup> See NRC Temporary Instruction 2515/183 Followup To The Fukushima Daiichi Nuclear Station Fuel Damage Event

- requirements have been implemented, but not events such as the ones that occurred in Japan, which were previously believed to be impossible.
- After several NRC inspectors complained that it made no sense to limit the scope of the inspections to Design Basis Events, the guidance was changed to enable inspectors to look beyond them, and explicitly includes an examination of the measures that were implemented following the terrorist attacks of September 11, 2011 (some of which could help mitigate against some of the problems that occurred in Japan); however, they were also explicitly told not to record any of their beyond Design Basis observations or findings in documents that would be made public as part of the Commission's review or public report(s). Instead, these findings would be entered into a private NRC database and kept secret.
  - Inspectors were also told not to include matters in their reports that licensees had already identified. Since the INPO inspections were concluded before the NRC inspections began, none of the reportedly dozens of issues that were identified by INPO inspectors and reported to licensees will be included in the NRC inspection reports.

Although four of five NRC Commissioners, in response to questions from Congressman Markey, committed to a full investigation of all vulnerabilities and the public release of all non-security-sensitive findings at a May 4, 2011 hearing of the Energy and Commerce Committee<sup>90</sup>, the limitations imposed on NRC's inspectors appear to ensure that the full range of vulnerabilities of U.S. nuclear reactors to events that occurred in Japan will not be performed, or reported to the NRC or the public. The NRC needs to ensure that there is a full investigation of such vulnerabilities, and that all non-security sensitive findings and recommendations are made public.

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<sup>90</sup> Private communications from an individual working inside an operating nuclear power plant obtained after the May 4 hearing do not indicate that any changes to these inspections have occurred.

**Table 1. National responses to Japanese nuclear disaster**

Following the accident at the Fukushima Daiichi nuclear power plant in Japan, many other countries have announced new safety measures with regards to nuclear reactors. China, Venezuela, Switzerland, Italy, Japan, and Taiwan have suspended new reactor development. Germany and Japan announced it would shut down older reactors pending safety review.

Country	Reactors Shut Down	Halted New Reactors	Reduced Future Nuclear Role
Canada <sup>91</sup>	NO	NO	NO
China <sup>92</sup>	NO	YES	YES
France <sup>93</sup>	NO	NO	NO
Germany <sup>94</sup>	YES	YES	YES
India <sup>95</sup>	NO	NO	NO
Italy <sup>96</sup>	NO	YES	YES
Japan <sup>97</sup>	YES	YES	YES
Korea <sup>98</sup>	NO	NO	NO
Philippines <sup>99</sup>	NO	NO	YES
Russia <sup>100</sup>	NO	NO	NO
Spain <sup>101</sup>	NO	NO	NO
Switzerland <sup>102</sup>	NO	YES	NO
Taiwan <sup>103</sup>	NO	YES	NO
U.K. <sup>104</sup>	NO	NO	YES
Venezuela <sup>105</sup>	NO	YES	NO

<sup>91</sup> <http://www.theglobeandmail.com/news/national/after-japan-canadas-nuclear-industry-girds-for-change/article1952403/>

<sup>92</sup> [http://www.china.org.cn/business/2011-03/29/content\\_22244887.htm](http://www.china.org.cn/business/2011-03/29/content_22244887.htm)

<sup>93</sup> <http://www.bloomberg.com/news/2011-05-09/france-to-test-58-reactors-for-surviving-earthquakes-not-terrorist-attack.html>

<sup>94</sup> <http://af.reuters.com/article/energyOilNews/idAFLDE7300LY20110401?pageNumber=1&virtualBrandChannel=0>

<sup>95</sup> <http://www.google.com/hostednews/afp/article/ALeqM5hzaU34a1I4qtZekAQw1owqlahu-Q?docId=CNG.76b96a556a95cbd54e43eeafb4c0a866.821>

<sup>96</sup> <http://news.sciencemag.org/scienceinsider/2011/04/italy-puts-nuclear-power-on-indefinite.html?rss=1>

<sup>97</sup> <http://www.washingtontimes.com/news/2011/mar/29/japan-vows-review-nuclear-safety-standards/>

[http://www.nytimes.com/2011/05/11/world/asia/11japan.html?\\_r=1](http://www.nytimes.com/2011/05/11/world/asia/11japan.html?_r=1)

<sup>98</sup> [http://news.xinhuanet.com/english/2011-03/15/c\\_13780365.htm](http://news.xinhuanet.com/english/2011-03/15/c_13780365.htm)

<sup>99</sup> [http://news.yahoo.com/s/ap/20110316/ap\\_on\\_bi\\_ge/nuclear\\_energy\\_5](http://news.yahoo.com/s/ap/20110316/ap_on_bi_ge/nuclear_energy_5)

<sup>100</sup> [http://www.huffingtonpost.com/simon-saradzhyan/russia-nuclear-japan\\_b\\_839109.html](http://www.huffingtonpost.com/simon-saradzhyan/russia-nuclear-japan_b_839109.html)

<sup>101</sup> <http://www.financebusinessnews.net/spain-orders-review-of-nuclear-power/>

<sup>102</sup> <http://www.nytimes.com/2011/04/01/world/europe/01swiss.html>

<sup>103</sup> <http://www.chinapost.com.tw/taiwan/national/national-news/2011/03/19/295239/Government-delays.htm>

<sup>104</sup> <http://www.telegraph.co.uk/finance/newsbysector/energy/8393878/Chris-Huhne-Britain-may-scale-back-nuclear-plans-after-Japan-disaster.html>

<sup>105</sup> [http://news.yahoo.com/s/ap/20110316/ap\\_on\\_bi\\_ge/nuclear\\_energy\\_5](http://news.yahoo.com/s/ap/20110316/ap_on_bi_ge/nuclear_energy_5)



**Table 2 – Summary of Emergency Diesel Generator (EDG) Inoperability 2002-2010**

To determine cases of EDG inoperability staff used the U.S. NRC Licensee Event Report (LER) Search (<https://lersearch.inl.gov>). Staff searched between the dates 1/1/2002 and 5/1/2011 using keyword criteria "emergency diesel generators." Current reports are only available up to 3/15/2011. The search yielded 3102 total records. In order to determine which reports related to inoperable EDGs we used a word search for "diesel" and "EDG" in the title of LER record. The number of days inoperable was determined by either direct reporting of days inoperable in the LER record or simple subtraction between the dates when the EDG(s) were cited as inoperable. Inoperability of under 24 hours was rounded up to 1 day.

In the past eight years there have been at least 69 reports of EDG inoperability at 33 nuclear power plants. A total of 48 reactors were affected, including 19 failures lasting over two weeks and 6 that lasted longer than a month.

Power plant	Date	Problem	Days inoperable	Id number
Wolf Creek	12/6/2010	Technical Specification Required Shutdown due to Inadequate Planning Resulting in Extended Emergency Diesel Generator Inoperability	8	4822010014
Byron 2	11/17/2010	Unit 2 Emergency Diesel Generator Inoperable for Longer than Allowed by Technical Specifications due to Inadequate Work	5	4552011001
Palo Verde 1	9/15/2010	Inoperable Emergency Diesel Generator due to Fuel Oil Transfer Pump Failure	3	5292010002
Brunswick 1 &2	9/13/2010	Emergency Diesel Generator Inoperable for Greater than Technical Specification Completion Time	1	3252010004
Robinson 2	6/24/2010	Emergency Diesel Generator Inoperable due to Inverter Failure	3	2612010005
Turkey Point 3	6/7/2010	Fuel Transfer Pump Failure Renders 3B Emergency Diesel Generator	45	2502010002
Turkey Point 4	5/10/2010	Damaged Speed Sensor Caused the 4A Emergency Diesel Generator to be Inoperable	16.9	25120100003
Robinson 2	4/26/2010	Clearance Error Results in the 'A' Emergency Diesel Generator Becoming Inoperable	8	2612010004
Indian Point 2	3/13/2010	Inoperable Emergency Diesel Generators during Refueling Shutdown due to Inadvertent Isolation of Service Water Cooling Caused by Failure to Properly Verify the In-Service Cooling Header	1	2472010003
Robinson 2	2/22/2010	Emergency Diesel Generator Inoperable in Excess of Technical Specifications Allowed Completion Time	27	2612010001
Wolf Creek	10/22/2009	Loss of both Diesel Generators with all fuel in the Spent Fuel Pool	1	4822009005
Millstone 2	10/7/2009	Two Independent Diesel Generators Rendered Inoperable due to Common Cause	1	3362009003

Brunswick 1 &2	9/20/2009	Technical Specification Required Shutdown Due To Emergency Diesel Generator 4 Inoperability	8	3252009004
Turkey Point 4	8/11/2009	4B Emergency Diesel Generator Inoperable Due to Air-bound Main Fuel Pump	14.3	2512009001
Oyster Creek	8/3/2009	EDG #1 Inoperable due to Failure of its Output Breaker to Close	2	2192009006
Fitzpatrick	7/7/2009	Inoperable Emergency Diesel Generators due to Degraded Voltage Timers	1	3332009007
Robinson 2	4/20/2009	Emergency Diesel Generator Inoperable in Excess of Technical Specifications Allowed Completion Time	3	2612009001
Prairie Island 2	2/16/2009	LER 2-09-01, Clearance Order Renders Opposite train Emergency Diesel Generator Inoperable	2	3062009001
Kewaunee	1/23/2009	Emergency Diesel Generators Inoperable Requiring Notice of Enforcement Discretion	Unreported	3052009001
Palisades	10/9/2008	Emergency Diesel Generator Inoperable in Excess of Technical Specification Requirements	30	2552008007
Hope Creek	4/22/2008	Blown 1E Inverter Main Fuse With One Emergency Diesel Generator Inoperable Causes Loss Of Control Room Emergency Filtration Loss Of Safety Function	1	3542008002
Prairie Island 1	12/21/2007	Technical Specification Required Shutdown due to Both Emergency Diesel Generators Being Inoperable	3	2822007004
Columbia	12/10/2007	Inoperable Diesel Generator due to Inadequate Procedure That Caused Potential Transformer Fuses to Clear during Shut Down of the Diesel	83	3972007005
Comanche Peak 1	11/21/2007	Emergency Diesel Generator Inoperable for Longer Than Allowed by TS due to Paint on Metering Rod	1	4452007001
Prairie Island 2	10/8/2007	Emergency Diesel Generator Inoperable Longer than Allowed by Technical Specifications Due to Loose Switch	35	3062007002
Cooper Station	9/11/2007	Procedural Guidance Leads to Rendering Second Diesel Generator Inoperable	9	2982007006
Palisades	7/25/2007	Emergency Diesel Generator Inoperable in Excess of Technical Specification Requirements	23	2552007006
Wolf Creek	7/8/2007	Emergency Diesel Generator Out of Service Longer than Technical Specification Allowed Outage Time	4	4822007001
Duane Arnold	4/11/2007	Condition Prohibited by Technical Specifications; 'B' Emergency Diesel Inoperable	60	3312007008
Brunswick 1 &2	4/1/2007	Technical Specification Required Shutdown Due To Emergency Diesel Generator 4 Inoperability	10	3252007002
Fort Calhoun	2/16/2007	Inoperability of a Diesel Generator with an Inoperable Containment Cooling Fan from the Opposite Bus	1	2852007003

Peach Bottom 1 & 2	11/17/2006	Plant Modification Created Diesel Generator Building Carbon Dioxide Suppression Room Flooding Vulnerability	Unreported	2772006004
Brunswick 1 & 2	11/2/2006	Operations Prohibited by Technical Specifications due to Inoperable Emergency Diesel Generator 1	15	3252006007
Crystal River 3	11/1/2006	Emergency Diesel Generator in a Condition Prohibited by Technical Specifications due to Mispositioning	28	3022006002
Palo Verde 1,2,3	9/5/2006	Failure of Emergency Diesel Generator to Attain Required Voltage due to a Failed K1 Relay Contactor	18	5302006006
Seabrook	8/31/2006	Plant Shutdown due to Inoperable Emergency Diesel Generators	1	4432006006
Fermi 2	8/17/2006	Emergency Diesel Generators Out of Service due to Undersized Control Power Transformers	1	3412006004
Kewaunee	8/17/2006	Fuel oil leak on Swedgelock fitting renders Emergency Diesel Generator A inoperable	51	3052006009
South Texas	3/25/2006	Standby Diesel Generator Failed Surveillance Test Demonstrating Performance at 110% Load	3	4982006001
Calvert Cliffs 1	3/24/2006	Failure to adequately control design setpoints for feeder breaker supplying EDG support systems	1	3172006001
Prairie Island 2	2/5/2006	Unit 2 Shutdown Required by Technical Specifications due to Inoperable Emergency Diesel Generator	11	3062006001
River Bend	9/9/2005	Operation Prohibited by Technical Specifications due to Diesel Generator Malfunction	23	4582005003
Brunswick 1 & 2	8/6/2005	Voluntary Report – Shutdown of Units 1 and 2 Due to Emergency Diesel Generator Operability Concerns	Unreported	3252005006
San Onofre 3	6/26/2005	Emergency Diesel Generator (EDG) 3G003 Declared Inoperable due to Loose Wiring Connection on Emergency Supply Fan	1	3622005001
Cooper Station	6/21/2005	Both Diesel Generators Inoperable in Mode 4 Leads to Condition Prohibited by Technical Specifications	1	2982005003
Prairie Island 2	4/15/2005	Unit 2 Shutdown Required by Technical Specifications due to Inoperable Emergency Diesel Generator	14	3062005002
Crystal River 3	3/25/2005	Emergency Diesel Generator Inoperable due to Fuel Oil Header Check Valves Leaking Past Their Seats	30	3022005002
Perry	2/17/2005	All Emergency Diesel Generators Declared Inoperable due to Degraded Testable Rupture Discs	1	4402005002
Fort Calhoun	10/19/2004	Inoperable Diesel Generator for 28 Days Due to Blown Fuse During Shutdown	29	2852004002
Brunswick 1 & 2	8/15/2004	Operation Prohibited by Technical Specifications due to Inoperable Emergency Diesel Generator	47	3252004003

Fermi 2	8/8/2004	Technical Specification Required Shutdown Due to Emergency Diesel Generator Failure	8	3412004001
North Anna 2	5/9/2004	Inoperable Emergency Diesel Generators Due to Shims for Exhaust Support Missing or Not Secured	1	3392004001
Crystal River 3	4/23/2004	Emergency Diesel Generator Inoperable Due To Fuel Oil Header Outlet Check Valve Leaking Past Seat	2	3022004002
Cooper Station	3/28/2004	Failure to Follow Procedure Results in Both Diesel Generators being Inoperable	Unreported	2982004002
Cooper Station	3/23/2004	Both Diesel Generators Inoperable due to Voltage Regulator Design Results in Loss of Safety Function	Unreported	2982006003
Browns Ferry 1,2,3	2/16/2004	Inoperability of Diesel Generator 3D Beyond TS Allowable Outage Time	24	2962004001
Brunswick 1	1/4/2004	Emergency Diesel Generator No. 3 Condition Prohibited by the Technical Specifications	29	32520040010
South Texas 2	12/9/2003	Standby Diesel Generator 22 Failure	Unreported	4992003003
Waterford 3	9/29/2003	Failure of Emergency Diesel Generator A Fuel Oil Line	1	3822003002
Perry	8/20/2003	Unrecognized Diesel Generator Inoperability During Mode Changes	7	4402003003
LaSalle 1&2	4/23/2003	1A and 0 Diesel Generators Inoperable Simultaneously Due to Inadvertent Partial CO2 Actuation	1	3732003002
Cooper Station	2/28/2003	Inadequate Communication Results in Both Diesel Generators Inoperable Simultaneously	1	2982003001
Kewaunee	2/26/2003	Shutdown Initiated – Diesel Generator Failed Start Test – Unusual Event – Caused by Start Relay Failure	2	3052003002
Columbia	2/16/2003	Failure to Restore Emergency Diesel Generator Within TS Completion Time and Subsequent Plant Shutdown	14	3972003006
Catawba 1 & 2	2/12/2003	Loss of Safety Function Due to Inoperability of the 2B Diesel Generator Upon Loss of Vital Inverter 2EID with the 2A Diesel Generator Inoperable	1	4132003002
Indian Point 2	10/9/2002	Two of Three Emergency Diesel Generators Inoperable Due to Component Failures; a Condition Prohibited by Tech Specs	2	2472002006
Catawba 1	6/24/2002	Technical Specification Noncompliance – Inoperable Diesel Generator Caused by Inadequate Wire Lug Crimping at Closing Spring Motor Disconnect Switch	5	4132002006
Calvert Cliffs 2	1/24/2002	Pump Flexible Drive Gear Wear Causes Emergency Diesel Generator Inoperability	7	3182002001