Union of Concerned Scientists
Citizens and Scientists for Environmental Solutions

July 18, 2013

Cindy Bladey, Chief
Rules, Announcements and Directives Branch
Office of Administration
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: Draft Report titled "Consequence Study of a Beyond-Design-Basis Earthquake Affecting the Spent Fuel Pool for a U.S. Mark I Boiling Water Reactor," [NRC-2013-0136 and ML13133A132]

Dear Ms. Bladey:

The Union of Concerned Scientists provides the attached comments per the notice published July 2, 2013, in the *Federal Register* (Vol. 78, No. 127, pp. 39781-39782).

Sincerely,

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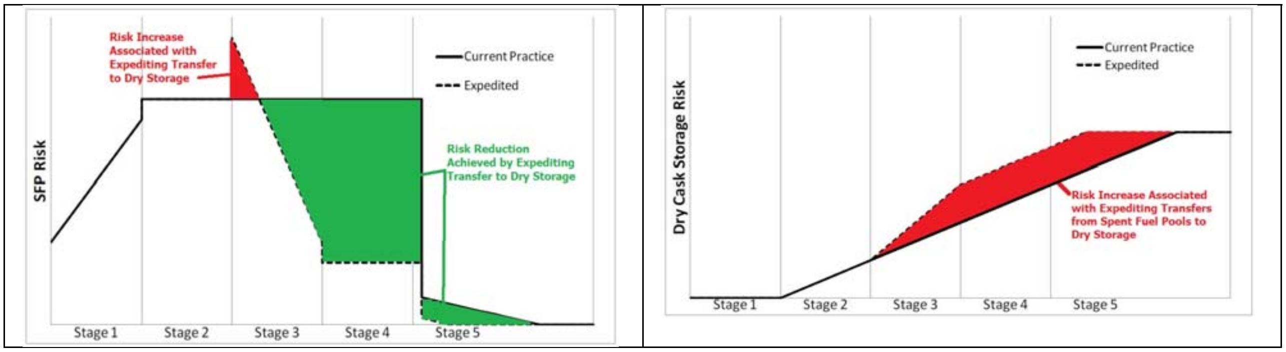
UCS believes the NRC's draft spent fuel pool study cannot inform ongoing discussions about risk management of onsite spent fuel until its many shortcomings and deficiencies are rectified. We have these concerns about the draft study:

These concerns are described in detail on the following pages.

Relative Risk of Spent Fuel Pool vs. Dry Storage Not Addressed

Figure 139 on page B-4 of the draft study (reproduced below with annotations in color added by UCS) represents the risk from irradiated fuel in spent fuel pools and dry storage under both current industry practices and for the proposed expedited transfer from pools to dry storage. The *relative* risk of these two storage options was the real need being served by the study, but the study utterly fails that goal.



UCS generally concurs with the qualitative representation of the relative risks shown in Figure 139 – the spent fuel pool risk declines upon expedited transfers while the dry storage risk is increased.

From discussions with many persons in industry, on the NRC staff, living near nuclear plants, and in local and state government, there is broad (but not universal) agreement with the concept shown in Figure 139.

What UCS expected this NRC study to accomplish was either quantitative assessment of the risks to allow them to be compared or, at a minimum, refinement of the qualitative assessment for that purpose. In other words, UCS expected this study to explain whether the areas in green on the graphs were larger, smaller, or the same as the areas in red.

If the areas are the same, than management of the risk from onsite spent fuel storage is neither aided nor impeded by expedited transfers – it remains the same either way.

If the green areas are larger than the red areas, than expedited transfer would lower the safety and security risk profile posed by onsite spent fuel storage.

If the red areas are larger than the green areas, than expedited transfer would increase the safety and security risk profile posed by onsite spent fuel storage.

That was the central question that needed to be answered by the NRC's study – what is the *relative* risk from the two onsite spent fuel storage options. That question remains shamefully unanswered in the study.

By one measure, the study at least suggests that the green areas are larger and therefore that dry storage has lower risk. Page 14 of the study states that dry storage "aggregate risk was an individual probability of a latent cancer fatality of $1.8x10^{-12}$ during the first year of service, and $3.2x10^{-14}$ per year during subsequent years of storage." Table 33 in the study shows the spent fuel pool "Individual Latent Cancer Fatality Risk Within 10 Miles" to be $2.4x10^{-11}$ to 2.1×10^{-12} per year. This implies that dry storage is 10 to 100 times "safer" than spent fuel pool storage, at least in terms of this one health measure.

The draft study properly points out that all dry storage practices are not equal, in terms of risk. On page 2, the study states that expedited transfer of irradiated fuel assemblies from spent fuel pools to dry storage "increases the frequency of postulated cask drops." This is true when expedited transfers result in few irradiated fuel assemblies being loaded into casks than are being loaded under current practices. This is not true when expedited transfers do not affect the number of casks being handled, only the timing of their handling. But various expedited proposals certainly have risk implications. (In other words, how expedited campaigns are undertaken affects the size of the green and red areas in the charts above.) The NRC would have done the U.S. Congress and the American public a great service had this study examined the relative risks and identified strategies and tactics that enhanced the risk reductions achievable (i.e., made the green areas as large as possible) and/or minimized the associated risk increases (i.e., made the red areas as small as possible). But this draft study fails to provide that very useful service.

This study could have, and should have, provided useful insights to the relative risk of spent fuel pool versus dry storage. The final report must remedy this fundamental flaw.

Apparent Double Standard

Figure ES-3 shows that the individual latent cancer fatality risk to persons living within 10 miles is at least 10,000 times lower than the NRC's safety goal of 2×10^{-6} per year for the postulated extreme earthquake event. In other words, even if the extreme earthquake happens and results in damage to a high-density loaded spent fuel pool that cannot be successfully mitigated, the consequences remain way lower than the NRC's safety goal – so far below that no further action is necessary.

In March 2012, the NRC ordered plant owners (of all plants, not just Peach Bottom Unit 3) to install instrumentation to monitor conditions inside the spent fuel pools at their facilities (see http://pbadupws.nrc.gov/docs/ML1205/ML12056A044.pdf). At the same time, the NRC also ordered plants owners to develop mitigation strategies to provide assurance of adequate cooling of reactor cores and spent fuel pools when permanent electrical supplies are unavailable for indefinite periods (see http://pbadupws.nrc.gov/docs/ML1205/ML12054A735.pdf).

The NRC has applied a double standard.

If the extreme earthquake scenario examined for a single reactor in the NRC's study is sufficiently thorough and bounding, what was the basis for the NRC's March 2012 orders that owners install spent fuel pool instrumentation and provide spent fuel pool cooling capabilities during extended power outages of infinite duration?

This NRC study wants us to believe that damage inflicted by an extreme earthquake on a high-density loaded spent fuel pool poses little threat to public health and safety, even if it is not successfully mitigated within three days.

The NRC's March 2012 orders and its June 2013 draft study cannot both be right.

Either the NRC lacked proper justification then to order owners to take costly measures to protect against a non-existent, or at best negligible, threat or the NRC lacks justification now to dismiss potential benefits from expediting the transfer of irradiated fuel assemblies from spent fuel pools to dry storage.

UCS believes the NRC was right in March 2012 and wrong now. The NRC must right this wrong before the final report is issued.

Non-conservative Mission Time

Page viii states "The study finds liner damage is the only way to cause a radiological release in less than 3 days for the scenarios and spent fuel pool studied. Other possible outcomes provide time to prevent a release by taking emergency actions"

Page 161 states "…the results of the study are presented as a range of mitigation effects related to successfully deployed mitigation and mitigation that is unsuccessful for 3 days."

The study's assumption that the battle is won or lost within 72 hours contradicts the mission time for other scenarios and the experience at Fukushima.

On October 9, 2012, the NRC issued a Severity Level IV non-cited violation to the owner of the Grand Gulf nuclear plant in Mississippi after determining that its inspection … "finding represented a loss of system safety function in that the standby service water system could not meet its 30-day mission time to provide decay heat removal" (ML12283A353). And Part 9900, "Technical Guidance," with the NRC's Inspection Manual (ML05206035) describes an example where vibration data – not required to be collected by any Technical Specification or industry code – indicates that an emergency diesel generator might not remain operable over its 30-day mission time.

The 30-day mission time is not applied across the board to every structure, system, and component in every scenario. When shorter mission times are applied, they are accompanied by solid justifications. The NRC study's 3-day mission time is an unverified assumption.

During the Fukushima accident, the NRC's concern about conditions in the Unit 4 spent fuel pool reached zenith late on March 15/early on March 16, 2011 – more than 3 days after the initiating earthquake. While mitigation for this pool and other spent fuel pools at Fukushima appears to have been successfully implemented after three days, those efforts were aided by the unplanned and undesired detonations that removed the roofs and upper walls of the reactor buildings on Units 1, 3, and 4. It's not obvious, and cannot be reasonably assumed, that mitigation measures would have been 100 percent successful but for these detonations.

The study's imposition of the 3-day mission time serves to dismiss other plausible scenarios that could cause damage to irradiated fuel in spent fuel pools after three days. The study must consider longer mission times, and other scenarios that longer mission times permit. Proper consideration of longer mission times and other scenarios might show the risk is low – but that and that alone would be the proper method for dismissing these scenarios. Dismissing them via an arbitrary, unjustified assumption is poor science.

Other Plausible Scenarios Not Properly Considered

The study only examined the potential overheating damage of irradiated fuel in spent fuel pools resulting from an extreme earthquake event. Other credible scenarios were summarily dismissed from consideration because they took longer than 3 days to play out (see our comment on Non-conservative Mission Time).

Table 3.1 of NUREG-1275 Vol. 12 (ML010670175) reported 38 actual and 55 precursor events involving loss of inventory from a spent fuel pool. For example, on December 28, 1994, a core shroud head bolt weighing 365 pounds dropped into the Hatch Unit 1 spent fuel pool puncturing its liner. About 2,000 gallons of spent fuel pool water drained from the pool over the next 23 minutes. On September 20, 1987, between 5 and 10 feet of water was inadvertently siphoned from the spent fuel pool at the River Bend nuclear plant in about 30 minutes.

This NRC report concluded "that loss of SFP coolant inventory greater than 1 foot has occurred at a rate of about 1 event per 100 reactor years. Loss of SFP cooling with a temperature increase greater than 20°F has occurred at a rate of approximately 3 events per 1,000 reactor years. The consequences of these actual events have not been severe. However, some events have resulted in several feet of SFP coolant level and have exceeded 24 hours. The primary cause of these events has been human error."

The extreme earthquake considered in the draft study may represent the fastest way to place the public in harm's way from a spent fuel pool hazard. But to fixate on it and exclude other scenarios seems to replicate the tunnel-vision that factored into the March 1979 meltdown at

Three Mile Island Unit 2. That accident was caused by a small-break loss of coolant accident. But the nuclear industry and the NRC prior to Three Mile Island fixated on the large-break loss of coolant accident, mistakenly thinking that if the plant had adequate protection against a double-ended guillotine break of the largest pipe connected to the reactor vessel, it was most assuredly protected against smaller breaks.

Page 8 of the study states “Note that sabotage events have been excluded from the scope of this study.” At a time when Americans cannot board a commercial airliner with more than 3 ounces of shampoo in a single container and without first removing footwear and all outwear to thwart terrorism, this study seems woefully deficient in summarily dismissing any and all acts of malice.

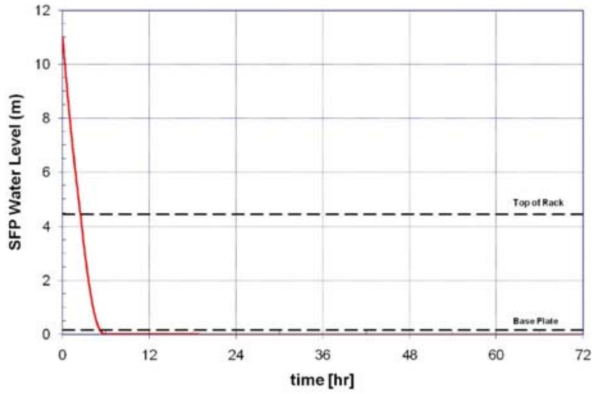


Figure 52 from the NRC draft study showing the timeline for water draining without mitigation from a high-density spent fuel pool experiencing a moderate leak along a seam between its walls and floor.

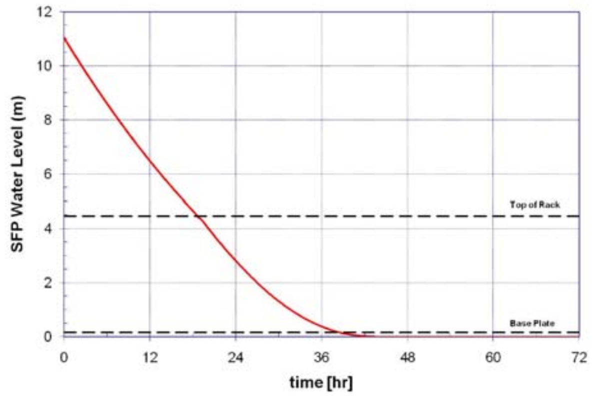


Figure 54 from the NRC draft study showing the timeline for water draining without mitigation from a high-density spent fuel pool experiencing a small leak along a seam between its walls and floor.

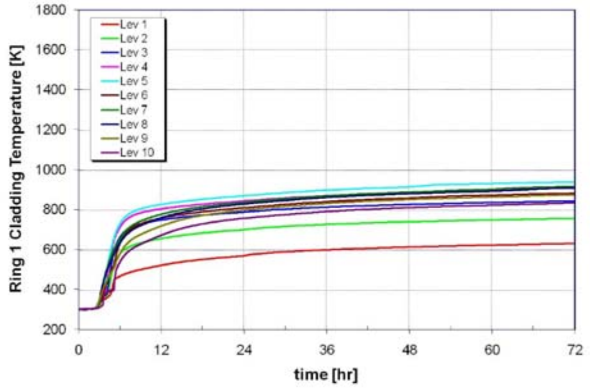


Figure 53 from the NRC draft study showing the spent fuel assembly temperature rise during the drainage event portrayed in Figure 52 above.

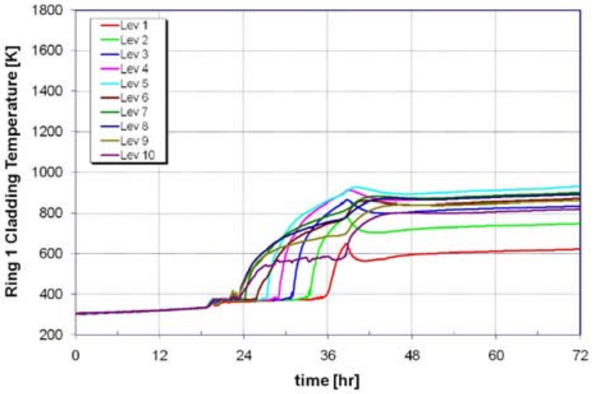
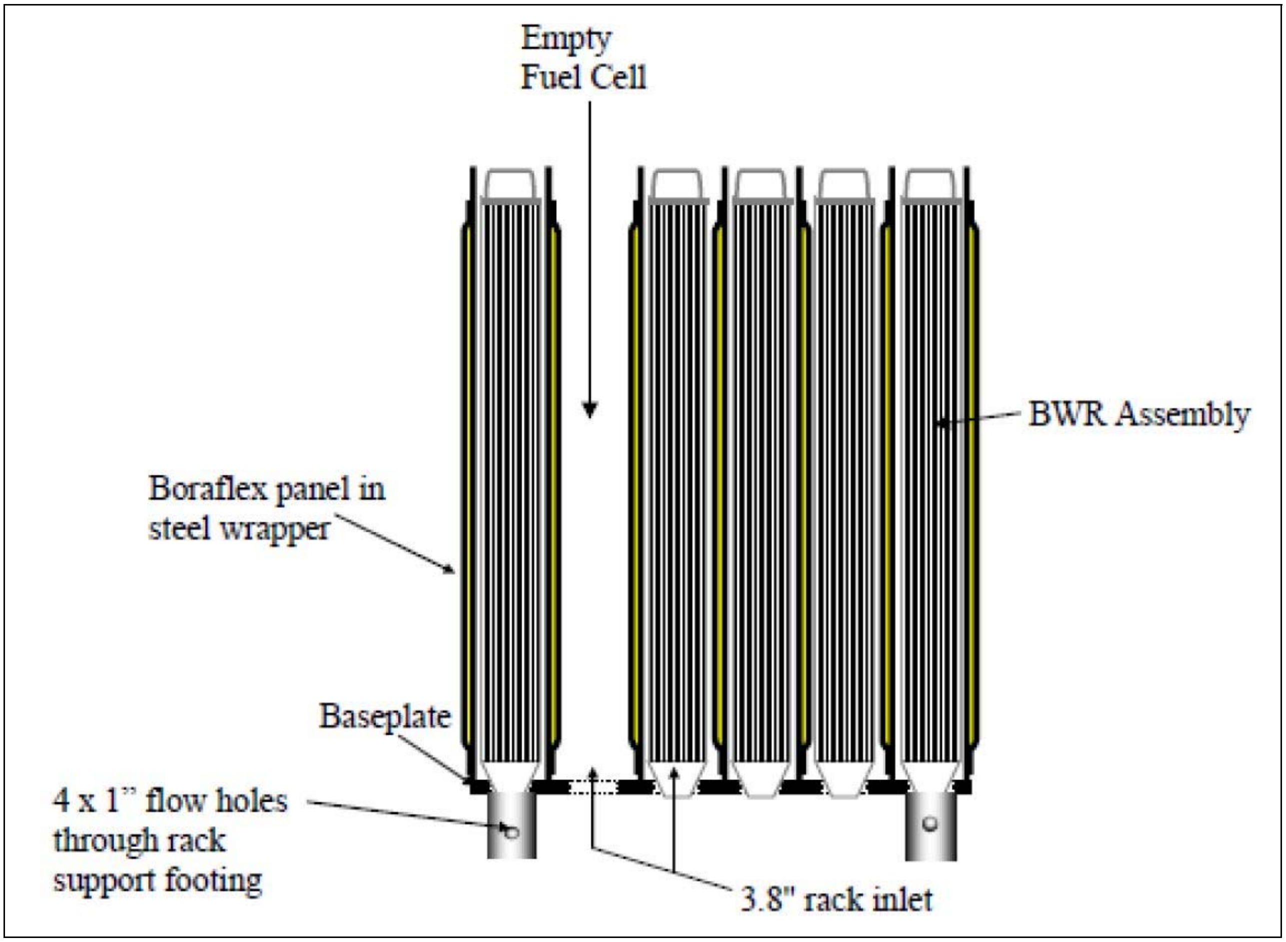


Figure 55 from the NRC draft study showing the spent fuel assembly temperature rise during the drainage event portrayed in Figure 52 above.

The NRC draft study only examined scenarios that completely drained water from the spent fuel pool. While it may appear that this scenario bounds ones in which only some of the water leaves the pool, this is not the case. Figures 52 and 54 in the NRC draft study (reproduced above) show the spent fuel pool water level during a postulated draining event caused when an extreme earthquake tears along a seam between the pool’s walls and its floor. Figure 52 modeled a moderate leak rate through the tear while Figure 54 modeled a smaller leak from a shorter tear.

In both cases, the leak drained the spent fuel completely. In each figure, dotted lines indicated the top of fuel assemblies in their racks as well as the bottom edge or baseplate of the racks.



The illustration above is part of Figure 39 in the NRC draft study. It shows a typical storage rack in a BWR spent fuel pool. The little white saucer-like items on the bottom of each fuel assembly are nosepieces – the conical metal ends of a fuel assembly. The nosepieces fit into holes in the spent fuel storage racks and earlier in holes inside the reactor core. The nosepieces have holes that allowing cooling flow through the fuel assembly. The storage racks have feet that keep the nosepieces several inches off the floor of the spent fuel pool. This arrangement allows cooling water to flow down and under the racks and move upwards through the spent fuel assemblies. If the pool is completely drained of water, it also allows air to flow down, under, and up through the spent fuel assemblies.

As Figures 53 and 55 in the NRC draft report show, spent fuel assemblies are adequately cooled as long as they are covered with water. As the water level drops below the top of the assemblies, their temperatures begin rising due to insufficient cooling. But once the water level drops below the baseplate, the temperature rise is halted because now air flow by the chimney effect can cool the spent fuel. It's not as effective as water cooling under normal conditions, but it's better than the cooling performed by water and water vapor when the fuel assemblies are only partially uncovered. Figure 55 clearly shows this phenomenon – the spent fuel assemblies temperatures rise as they become more and more uncovered and then drop after the baseplate is uncovered and air cooling picks up.

But what if a spent fuel pool only partially drains? In that case, the temperature rise is not checked (as shown in Figure 53) or turned around (as shown in Figure 55). Thus, a partially drained spent fuel pool represents a greater hazard than a fully drained one. Again, the NRC draft study opted for the better of these two choices to consider.

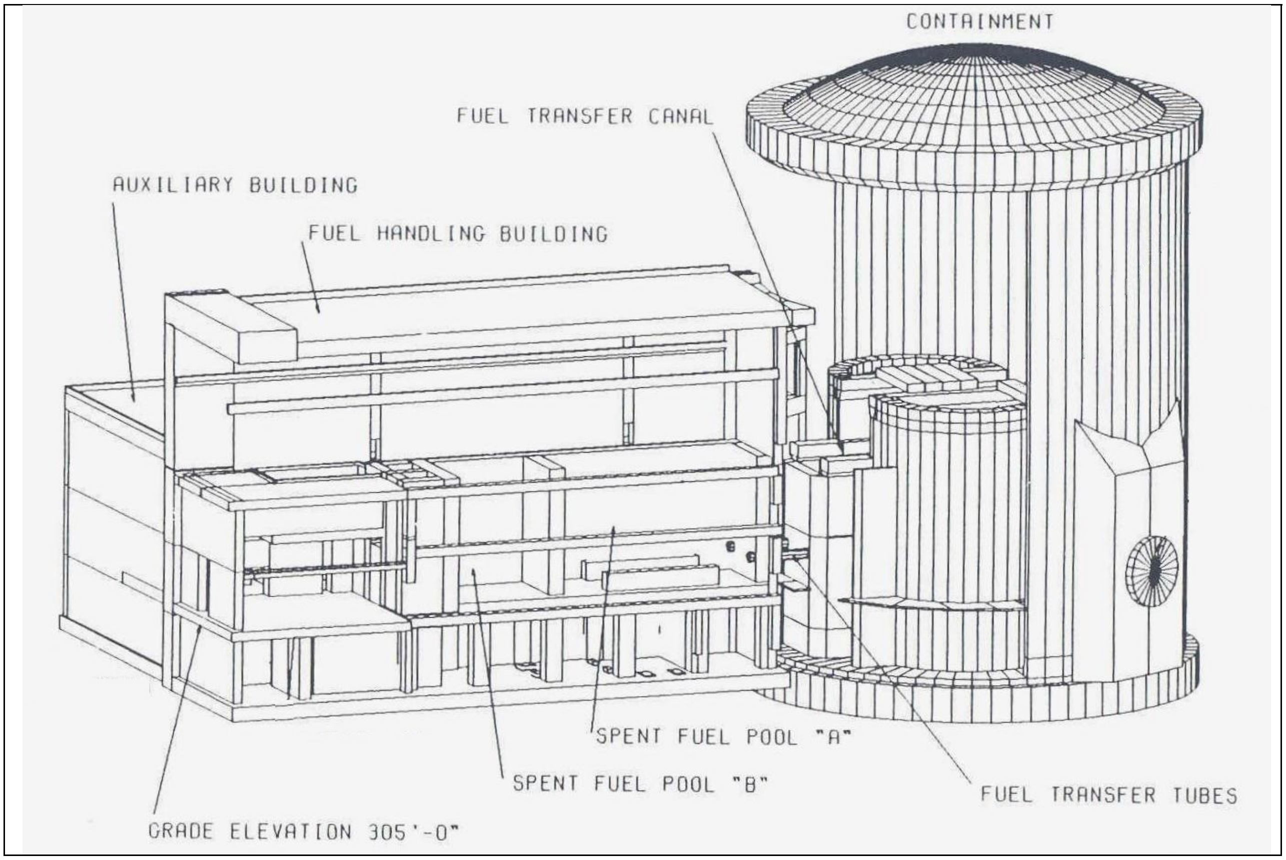
After 9/11, the NRC ordered owners to equip their nuclear power plants with means to provide water to spent fuel pools. As part of the orders issued to owners in March 2012, the NRC ordered owners to implement steps aimed at improving the reliability of this spent fuel pool makeup capability. For example, the NRC ordered owners to equip spent fuel pools with instrumentation able to monitor three points: (1) normal level, (2) abnormally low level, and (3) level just above the top of the spent fuel assemblies where immediate makeup is needed (see http://www.nrc.gov/reactors/operating/ops-experience/japan-dashboard/spent-fuel.html).

Those measures, even if fully implemented, do not help workers avoid the situation where the makeup rate is sufficient to bring the level above the baseplate height but not sufficient to fully recover the spent fuel assemblies. In other words, the workers efforts result in the partially drained condition being prolonged.

The study must consider scenarios other than that involving a 1 in 60,000 year earthquake leading to complete draindown of a spent fuel pool. Just as Three Mile Island demonstrated the fallacy of the large-break loss of coolant shield, the extreme earthquake obsession does not answer all the relevant questions that must be answered.

Non-conservative Configuration Assumption

Page 11 of the draft study states “The conditional probability of a Zircaloy cladding fire given a complete loss of water was found to be 1.0 for PWRs [pressurized water reactors] and 0.25 for BWRs [boiling water reactors] in high-density configurations based on differences in assumed rack geometry.” A 1.0 conditional probability means that there’s a 100 percent chance of a PWR spent fuel pool fire if it lost water. (Conditional probability literally cannot get any higher than that, yet it’s curiously been omitted from the draft study.) While BWR spent fuel pools might arguably be more vulnerable to water inventory losses, PWR spent fuel pools are by no means invulnerable. The “in-ground” configuration for PWR spent fuel pools is a fanciful notion lacking literal and figurative foundation, as shown below..



For example, and not a unique one, the figure above is a 3D drawing of a pressurized water reactor currently licensed to operate in the United States. The floor of the spent fuel pool is not embedded in the ground – there is open space within the fuel handling building that could accommodate the water rushing from a tear along the spent fuel pool wall to floor joint.

In this, and too many other instances, when faced with multiple choices, the NRC picked a non-conservative, non-bounding option. If the choices were made so as to model realistic versus worst-case conditions, that'd be one thing. But the choices seem made so as to model best-case versus realistic conditions. In this specific instance, the NRC must either examine a PWR spent fuel pool scenario in its final report or justify excluding a 100 percent conditional probability of fire along with its disastrous consequences.

The first paragraph on page viii states that the spent fuel that "pool is expected to remain intact during more likely, less severe earthquakes" than the 1 in 60,000 year earthquake frequency assumed in the study.

Table 19 on page 90 shows the 1 in 60,000 years (or 1.7 x 10^{-5} per year) earthquake considered in the study involves geometric mean acceleration of 0.7 g. The table also shows that earthquakes of lesser magnitude are more likely to occur. For example, an earthquake producing geometric mean acceleration of 0.2 g has a likelihood of occurring 1 in 2,000 years (5.2 x 10^{-4} per year) while an earthquake producing geometric mean acceleration of 0.4 g has a likelihood of occurring 1 in 40,000 years (2.7 x 10^{-5} per year). Yet there are other failure modes that may be caused by these lower accelerations, and these scenarios should be considered.

For example, Table 3 on page 22 describes the assumption that "The seals of the refueling gate to not fail."

The rapid drainage of 200,000 gallons from the refueling cavity due to the mechanical failure of a refueling cavity seal at the Haddam Neck nuclear plant was described in NRC Bulletin 84-03 (http://www.nrc.gov/reading-rm/doc-collections/gen-comm/bulletins/1984/bl84003.html). Figure 43 on page 109 shows that if the refueling cavity seal fails, the volume formed by the refueling cavity and the spent fuel pool when the connecting gate(s) are removed drains down to the lower end of the canal connecting the two regions. The refueling cavity continues to drain while the spent fuel pool water evaporates/boils away.

Table 15 on page 76 and Table 16 on page 78 indicate that the boiling water reactors typically only spend a few days during a 23-month operating cycle transferring fuel assemblies between the spent fuel pool and the reactor vessel.

Because a refueling cavity seal has failed in the past due to reasons other than forces resulting from an earthquake's ground motion, it is unjustified to merely assume such failure cannot possibly be caused by a seismic event. While the amount of time a reactor spends with the gate(s) between the spent fuel pool and refueling cavity is typically limited, the refueling cavity seal may be more vulnerable to seismic forces than the spent fuel pool itself. Consequently, the refueling cavity seal may fail when subjected to forces from a lesser magnitude earthquake (i.e., the 1 in 2,000 years one).

The study needs to examine the risk from draindown events, such as the one that happened at Haddam Neck, initiated by seismic events of less severity than that likely 1 in 60,000 year before dismissing such scenarios in favor of but one "bounding" case.

Table 3 of the study states that "A full core offload is not treated" despite the fact that entire reactor cores are offloaded to spent fuel pools and gates are installed between the pools and refueling cavities for reactor vessel internal inspections and other activities. This unrealistic assumption serves to reduce the decay heat level actually existing in spent fuel pools and non-conservatively lessens the consequences from postulated loss of water inventory events lasting merely three days. The final study must consider full core offloads (at least parametrically) – or the NRC should ban them from happening.

Table 3 of the study states that "Failure of nearby dams is not explicitly addressed." The disaster at Fuksuhima has been attributed to flooding from the tsunami caused by the earthquake rather than by earthquake damage directly. This study ignores that reality by assuming that an earthquake of severe magnitude likely to occur only once every 60,000 years (and yielding geometric mean acceleration of 0.7 g) has zero chance of causing nearby dam(s) to fail.

The first paragraph on page viii states that the NRC's study "considered an earthquake with ground motion roughly four to eight times stronger than that used in the plant design…". NRC officials and industry representatives often proclaim that nuclear power plants are the most robust parts of America’s private infrastructure. If these assertions are accurate, than a nuclear power plant’s design is less vulnerable to earthquakes than nearby dams. In other words, a postulated earthquake resulting in ground motion four to eight times stronger than used in designing a nuclear power plant cannot be reasonably assumed not to pose any chance of failing nearby dams of lesser robustness. But that’s precisely what the NRC did in this draft study.

Employing this same approach, analysts studying a postulated earthquake measuring 9.0 on the Richter scale with an epicenter a few miles northeast of Japan would identify no need to better protect the Fukushima Daiichi site; after all, it survived for nearly an hour after the earthquake. The tsunami water caused extensive damage – an outcome not allowed in this study via this study’s unjustified, unrealistic, and absurd assumption. The final study must consider the direct consequences from a postulated earthquake, such as failure of nearby dam(s) not protected against such ground motion, or be assigned to the fiction section of the NRC’s public document room.

Summary Dismissal of Criticality Concern

Page 30 of the draft study states “The [spent fuel storage] rack panels and poison material have a lower melting temperature than the cladding and fuel” and “The possibility of a criticality event cannot be summarily dismissed.” The study then summarily dismisses criticality events.

The high-density and low-density configurations affect more than merely fuel damage caused by inadequate cooling. A high-density configured spent fuel pool has a greater likelihood of criticality than a low-density configured pool.

As the draft study correctly observes, the mechanical features guarding against criticality in a high-density spent fuel pool (i.e, the metal storage racks equipped with neutron absorbers) have a lower melting temperature than the spent fuel assemblies.

If neutron absorbers have been adversely affected, the “magic” 3-day mission time (see our Non-conservative Mission Time concern) can be compromised. Re-filling a drained spent fuel pool may end an overheated spent fuel assembly scenario, but it could initiate a spent fuel pool criticality event.

The final study must not summarily dismiss the criticality concern associated with a high-density spent fuel pool.

Incomplete Hydrodynamic and Dead Load Analyses

Table 2 of the draft study shows that irradiated fuel assemblies removed from the reactor core longer than 10 years ago comprises 55 percent of the mass in the spent fuel pool. Information, such as that presented in Tables 8 and 9 of the draft study, imply that the NRC used a single configuration when evaluating the forces imparted on the spent fuel pool floor from dead and hydrodynamic loads during a postulated seismic event. During a meeting in late June 2013 of the National Academy of Sciences committee examining spent fuel storage issues, Frank von Hippel asked a question about this treatment and was told by NRC staff that the weight of the spent fuel pool walls and floor, along with that of the reactor building housing it, render the mass difference between the high-density and low-density loading configuration negligible.

Unlike a one-inch putt in golf, this matter isn't a "gimme." When spent fuel pools are reracked to store more irradiated fuel assemblies, the NRC carefully evaluates thorough seismic analyses to verify that margin reductions do not adversely affect structural integrity. The depth and breadth of these seismic analyses and of the NRC's independent reviews strongly suggest that allowing more fuel assemblies to be stored within pools reduces available margins, but care is taken to ensure that necessary margins are maintained.

This reality also strongly suggests that removing fuel assemblies from pools increases available margins, providing even more "cushion" to necessary margins. And since the sole scenario considered in the NRC's study involves an extreme earthquake of beyond design basis magnitude, additional seismic margin is clearly advantageous.

It is not apparent from the information in Tables 8 and 9 that removing 55 percent of the mass from spent fuel pools has only positive safety margin implications. Table 9 indicates that hydrodynamic loads on the spent fuel pool's floor are significantly larger than the dead loads from the spent fuel weight. Because fuel assemblies removed from the spent fuel pool are replaced by water, it's not apparent whether the gain from reducing the dead loads is matched or perhaps exceeded by increased hydrodynamic loads from additional water.

The NRC must, as a minimum, explain qualitatively why it only considered one configuration in its seismic evaluations.