

Supplemental Comments of the Union of Concerned Scientists on
The Tier 3 Recommendation for Expedited Transfer of Spent Fuel from Pools to Dry casks

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UCS supports the accelerated transfer of spent fuel from pools to dry casks. A chief advantage of expedited transfer of spent fuel from densely packed pools to dry storage is to increase the safety margin for events (either severe accidents or terrorist attacks) that cause a loss of pool water inventory and result in spent fuel heatup to the zirconium ignition temperature, a self-sustaining zirconium fire, fuel damage and massive radiological release. Additional safety margin would be achieved through enhancing defense-in-depth by strengthening the **passive** safety response of a pool to such events. It is remarkable that the nuclear industry and the NRC point to the so-called passive safety features of new nuclear reactors as a major advantage over the current generation, yet they are content to rely on active measures to respond to a spent fuel pool fire at current reactors, and oppose operational changes that could enhance the passive safety response and reduce reliance on active measures. This would be desirable for situations, such as Fukushima-type events, when the prompt and effective implementation of active mitigative measures cannot be guaranteed.

To explain further, the first issue is whether spent fuel pools should be configured to minimize the risk of a zirconium fire even in the absence of active mitigative measures. This would be achieved by maximizing the potential for natural circulation to provide sufficient heat removal to prevent heatup of the cladding to the zirconium ignition temperature, a requirement known as “coolability.” The next consideration is whether the spent fuel is configured so that even if ignition does occur in hotter fuel assemblies, there is little risk that the fire will propagate to cooler assemblies. The third consideration is that even in the event the fire does propagate to cooler assemblies, the source term for radiological release will be limited by the reduced inventory in the pool. And the fourth consideration is to what extent, if all else fails, mitigation by emergency water makeup flows and/or sprays can effectively cope with these situations and prevent zirconium ignition.

Sandia National Laboratories has identified the following topics as germane to the issue of spent fuel pool loss-of-coolant accident (LOCA) mitigation:¹

- Make-up water and leak repair
- Well organized (i.e., dispersed) fuel configurations

¹ K.C. Wagner and R.O. Gauntt, “Mitigation of Spent Fuel Pool Loss of Coolant Inventory Accidents and Extension of Reference Plant Analyses to Other Spent Fuel Pools,” Sandia Letter Report, Revision 2, November 2006, (redacted). <http://pbadupws.nrc.gov/docs/ML1209/ML120970086.pdf>

- Emergency sprays
- Building ventilation
- Pool configuration

After the 9/11 attacks, the NRC commissioned Sandia National Laboratories to carry out vulnerability assessments of U.S. nuclear power plants to aircraft attacks, considering both reactors and spent fuel pools. Partly in response to the results of these classified studies, the NRC ordered licensees to take steps known as “B.5.b” measures to reduce the risk of core and spent fuel damage in the event of aircraft attacks. With regard to spent fuel pools, it is now publicly known that the B.5.b. measures included requirements and recommendations to cope with loss-of-coolant inventory in spent fuel pools by both rearranging spent fuel in pools to achieve configurations more conducive to heat removal, and acquiring equipment to provide emergency water makeup and sprays.

The list of mitigating strategies presented to the industry in 2004-2005 included (1) dispersal of high-decay power assemblies, (2) locations to avoid (e.g., above rack feet), (3) maintenance of empty spaces in fuel racks, (4) promoting passive ventilation of air space above the pool, and (5) emergency makeup water sources.²

It is also now known that, with respect to item (1), the NRC specified that licensees try to achieve a configuration known as 1x4, in which recently discharged, relatively high power assemblies are surrounded on four sides by older, relatively low powered assemblies. However, it is not known if all current licensees are required to maintain this configuration if it is infeasible. For new reactors, a document released under FOIA states that the NRC “expects New Reactor licensees to be able to place spent fuel in the final 1x4 pattern as it comes out of the reactor ... until such time that the amount of spent fuel in the fuel pool is so great that it becomes infeasible and impractical, consistent with safe handling practice, to do this.”³

This statement implies that NRC only requires a 1x4 pattern until the pool is too full to accommodate such an arrangement. **But if the 1x4 arrangement is so important, it is not clear why the NRC does not require that excess spent fuel be removed to ensure that a 1x4 arrangement can be maintained at all times.**

The first issue is whether these mitigating strategies, assuming they are fully implemented, provide a sufficient reduction in the risk of a large SFP radiological release, or if there is still significant safety benefit in reducing the spent fuel density and inventory by transferring spent fuel to dry casks as soon as it is cool enough to do so. The second issue is the extent to which current licensees actually implement these strategies.

A major obstacle to better public understanding of the current level of fire risk associated with spent fuel pool storage is the restriction of information associated with the NRC-commissioned analytical and experimental studies on spent fuel pool fires that have taken place over the last

² U.S. NRC, “The Evolution of Mitigating Measures for Large Fire and Explosions: A Chronological History From September 11, 2001 Through October 7, 2009.”

³ <http://pbadupws.nrc.gov/docs/ML1117/ML11175A160.pdf>

decade. The results of these studies have been protected in categories ranging from classified (Secret) to Official Use Only – Security Related Information. Over the last couple of years, fragments of information pertaining to these studies have been released to the public. However, the public still does not have access to sufficient technical information to be able to make informed judgments regarding the current risks of pool storage. UCS understands that later this year the NRC intends to release a “Spent Fuel Scoping Study” that will evaluate a seismically induced pool fire. We expect that this study will contain enough declassified information for the public to be able to evaluate NRC’s conclusions regarding the resolution of the pool fire risk issue.

However, until NRC releases sufficient information for the public to fully understand and evaluate its policy on spent fuel pool storage, the public will have to rely on the fragments of information that are currently available. A document that has recently become public sheds some light on the technical basis for NRC’s B.5.b SFP mitigating strategies, although most of the details of the results have been redacted.⁴ This report documents some of the results of the spent fuel pool accident studies conducted at Sandia National Laboratories, which involved both computer simulation and experimental validation. The document identifies two distinct accident scenarios of concern. The first is a complete loss-of-coolant inventory accident, which leaves natural circulation of air as the only cooling mechanism. The second is a partial loss-of-coolant inventory accident, in which the pool is only partially drained, leading to a complex configuration in which the lower parts of the fuel assemblies are submerged in water and the upper parts are immersed in steam. The effectiveness of the SFP mitigating strategies is different for the two different scenarios.

In particular, the document concludes that “some options are only effective for complete loss-of-coolant inventory accidents where a natural convection air flow can be established.” In fact, providing makeup water after the pool has already drained could block natural convection air cooling and actually lead to reduced coolability, depending on the nature of the makeup flow. The study did identify three options that it judged as having a “very high” to “high” impact on assembly coolability regardless of the accident type,” but the public does not know what these options are because they have been redacted.

The publicly released version of the report did not contain any of the quantitative results regarding coolability. However, some of those results have become public through FOIAs of NRC internal e-mails following Fukushima. For instance:⁵

From: Zigh, Ghani
To: Sheron, Brian; Santiago, Patricia
Cc: Uhle, Jennifer; Gibson, Kathy; Scott, Michael
Sent: Sat Mar 19 07:09:11 2011
Subject: RE: NEW URGENT REQUEST -- SNL BWR tests - (OUO-Privileged Information)
Yes, SNL did perform other studies about 5 years ago.
These studies are in ADAMS under ML062550218, ML082261433, and ML0816800640.

⁴ Wagner and Gauntt (2006), op cit.

⁵ <http://pbadupws.nrc.gov/docs/ML1121/ML11216A188.pdf>.

These reports discuss the coolability limits (i.e. age of the assembly) for PWR and BWR assemblies for different configurations (i.e. management).

Five configurations were analyzed (Uniform, Checkerboard, 1X4, Checkerboard with empties, and

1x4 with empties)

for the BWR, the following results were found:

for Uniform configuration, the coolability limit is 310 days old fuel.

for Checkerboard configuration, the coolability limit is 117 days old fuel.

for 1x4 configuration, the coolability limit is 20 days old fuel.

for Checkerboard with empties configuration, the coolability limit is 25 days old fuel

for 1x4 with empties configuration, the coolability limit is 20 days old fuel.

From these results, it is apparent why the NRC may have concluded that requiring a 1x4 configuration would achieve a significant risk reduction compared to a uniform or either a checkerboard configuration, and why further measures, such as further reductions in pool density, might not be necessary. If it were impossible to have a self-sustaining zirconium fire 20 days or more after discharge, one might regard that as a manageable window of risk.

However, it can be inferred from the redacted Sandia report (e.g. p. viii) that coolability through configuration management alone can only be achieved in complete LOCAs. The summary of the report does not say that there is a well-defined time beyond which a given configuration will be coolable for partial LOCAs. Instead, for partial LOCAs the report only says that “the dispersed configurations provided additional time for mitigative actions before the release of fission products versus a non-dispersed configuration.” This suggests that mitigative actions other than dispersed configurations would be needed to prevent fission product release in partial LOCAs. UCS does not know if this also applies to configurations that are much less densely packed than a 1x4 arrangement. However, the consequences of a spent fuel pool fire could be reduced by further reductions in the pool spent fuel inventory, even if the probability of a fire was not reduced.

In the 2000 report NUREG-1738, the NRC staff determined that it was not feasible to calculate a generic critical decay time necessary to prevent clad temperature from reaching the temperature of self-sustaining zirconium oxidation “absent setting strict requirements or restrictions on plant rack fuel configurations, fuel burnup and building ventilation ...” The staff also note that “fuel assembly geometry and rack configuration are plant specific, and both are subject to unpredictable changes after an earthquake or cask drop that drains the pool.”

The Sandia report is an attempt to reduce the conservatism of this finding by trying to develop generic critical decay times. However it is apparent that the analysis of spent fuel pool LOCAs is quite complicated, both for complete and for partial LOCAs. For instance, site-specific factors, such as the presence, location, structure and size of open regions in the pool for dry cask loading, have a big impact on the flow patterns. Unfortunately, the document is so heavily redacted that it is not possible for a reader to make any judgment regarding the magnitude of the safety margin that is obtained from implementation of the 1x4 configuration and the other B.5.b strategies, especially in the context of additional plant-specific factors. Therefore, one cannot

determine whether the study has in fact narrowed the range of uncertainty to the extent that well-defined generic critical decay times can be determined regardless of the accident scenario and that the 2000 finding is no longer applicable.

It is also important to note that the active B.5.b measures as currently implemented, such as provisions for makeup water, are designed only to be usable in the event of an aircraft attack, and not in the event of severe natural phenomena such as large earthquakes or floods. So if such means are necessary to preclude the risk of a spent fuel pool fire resulting from any initiating event, the current provisions are not adequate. As part of NRC's post-Fukushima lessons learned process, licensees have been ordered to develop strategies to provide core and spent fuel pool cooling following a wide range of external events, but the requirements for functionality of the equipment to be used are still under evaluation and ultimately may not be stringent enough to fully address the problem. In any event, the B.5.b measures require active intervention by operators and thus are inherently less reliable than measures that establish a passively safe pool configuration.

In summary, the NRC has still not provided sufficient evidence to the public to demonstrate why the B.5.b mitigative measures reduce the risk of a self-sustaining zirconium fire in densely packed spent fuel pools to the extent that further actions, such as expedited transfer of spent fuel to dry casks, are not necessary. However, UCS believes that the information that has been released to date supports our view that the uncertainties in pool fire analysis are so large that substantial safety margins are needed to maintain defense-in-depth. These margins can be achieved only through reduction of the pool inventory well below the densely packed, 1x4 configuration that the NRC currently advises licensees to maintain.