RESPONSE SHEET

TO: Annette Vietti-Cook, Secretary

FROM: Chairman Allison M. Macfarlane

SUBJECT: COMSECY-13-0030 - STAFF EVALUATION AND RECOMMENDATION FOR JAPAN LESSONS-LEARNED TIER 3 ISSUE ON EXPEDITED TRANSFER OF SPENT FUEL

Approved __X__ Disapproved __X__ Abstain _____

Not Participating _____

COMMENTS: Below ___ Attached __X__ None ___

SIGNATURE

4/8/14

DATE

Entered on "STARS" Yes __X__ No ___

Chairman Macfarlane's Comments on COMSECY-13-0030
Staff Evaluation and Recommendation for
Japan Lessons-Learned Tier 3 Issue on Expedited Transfer of Spent Fuel

The issue of the expedited transfer of spent fuel from pools to dry storage is not a new one. In fact, it has been debated over many years, most recently in the 2000s as a result of concerns raised after the terrorist attacks on September 11, 2001 in the United States.[1] All reactors require pools to cool the fuel discharged from the reactor core and to shield its radiation. When light water reactors were originally designed in the United States, the fuel was only supposed to spend a relatively short time in the pool before being sent to a reprocessing facility. With the failure of reprocessing in the 1970s on security, economic, and political grounds, fuel began to build up at reactors, requiring the re-racking of spent fuel pools to accommodate additional spent fuel stocks. Congress and the Administration worked toward a solution to this build up with the enactment of the Nuclear Waste Policy Act of 1982, amended in 1987, the goal of which was to remove the spent fuel from reactor sites and emplace it in a permanent repository starting in 1998. No permanent repository exists to this day. The issue under consideration here, whether to require the expedited transfer of spent fuel, is a collateral impact of the inability of the federal government to successfully site a repository for nuclear waste disposal.[2]

The question at hand is whether spent fuel pools, often currently containing four times the originally-planned volume of spent fuel, are safe in the event of loss of coolant, or whether there are significantly safer configurations for the pools that may involve a lower volume of spent fuel, different configurations of fuel in the pool, different types of racks, or other factors that could reduce the impact of a severe pool accident. Most spent fuel pools with many cores' worth of fuel now present a source term potentially much larger than that of the core of the reactor. In the event of a loss of coolant and subsequent fire in the pool, it is theoretically possible for much more longer-lived radioactivity to be released over greater distances than from a single reactor accident alone. This realization prompted concern during the Fukushima-Dai'ichi accident in Japan in 2011. The spent fuel pool of the unit 4 reactor was relatively full with recently-discharged spent fuel from the reactor core. Although the spent fuel pools did not drain or release radioactive material, we still learned from Fukushima that the environmental and societal/human costs of land contamination from the reactor releases were extraordinarily high.

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[1] See for example: U.S. Nuclear Regulatory Commission, "Technical Study of Spent Fuel Pool Accident Risk at Decommissioning Nuclear Power Plants," NUREG-1738, February 2001; Alvarez et al, 2003, Reducing the Hazards from Stored Spent Power-Reactor Fuel in the United States, Science and Global Security, 11: 1-51; National Research Council. *Safety and Security of Commercial Spent Nuclear Fuel Storage: Public Report*. Washington, DC: The National Academies Press, 2006; Gordon R. Thompson, "Risks and Risk-Reducing Options Associated with Pool Storage of Spent Nuclear Fuel at the Pilgrim and Vermont Yankee Nuclear Power Plants," May 25, 2006; U.S. Nuclear Regulatory Commission, "Denial of Two Petitions for Rulemaking Concerning the Environmental Impacts of High-Density Storage of Spent Nuclear Fuel in Spent Fuel Pools (PRM-51-10 and PRM-51-12)," SECY-08-0036 dated March 7, 2008 and SRM-SECY-08-0036 dated June 19, 2008.

[2] It is the responsibility of the Congress and the Administration to develop a strategy for disposing of spent nuclear fuel and high-level nuclear waste; the role of the Nuclear Regulatory Commission is to regulate civilian uses of nuclear materials and facilities in order to protect human health and safety and the environment, and minimize danger to life or property, as required by U.S. law.

In July 2011, in response to the ongoing debate over expedited transfer of spent fuel, the staff in NRC's Office of Nuclear Regulatory Research began a scoping study of the impacts of a seismic event on a spent fuel pool, using input data from the Peach Bottom reactor in Pennsylvania. Though the spent fuel pool scoping study was narrowly defined, it produced some interesting results, including the safety advantages of a 1x8 spent fuel loading pattern in pools. Most notably, it clearly indicated the susceptibly of spent fuel to zirconium fire from a pool drain-down event during the first one to three months after discharge, and the importance of discharging fuel into dispersed patterns. Though this study was supposed to be an initial step in the process of addressing the Japan Lessons Learned Tier 3 activity to investigate the benefits of expedited transfer, the study was truncated at this initial phase. In an attempt to link public information needs associated with the Waste Confidence decision to the efforts on the spent fuel pool scoping study, the staff accelerated and transformed the scoping study into a "consequence study" and performed a generic regulatory analysis of one limited option of expediting transfer of fuel into casks over five years. Staff concluded that predicted risks were below reactor quantified health objectives (QHO) and that the costs of 10 to 15 additional casks per reactor (depending on spent fuel pool type) outweighed the frequency-weighted benefits of requiring expedited transfer.

In my view, the staff has not adequately explored the issue of spent fuel management in the pool and as a result, I do not have adequate information on which to base a view on the need to require approaches that may lead to some form of expedited transfer of spent fuel from pools to dry casks. The staff has not properly explored all potential initiating events – in this case only considering seismic initiators. A more thorough analysis would holistically consider the potential of all natural and human-induced (*e.g.*, accidental, malevolent) events that could cause pool drain-down, a facility's inability to passively mitigate consequences, and the potential benefits of additional spent fuel management approaches. In considering the potential benefits of different spent fuel pool management options, the staff considered only the limited situation of arranging fuel in a 1x4 configuration with either cold fuel or no fuel surrounding the hottest fuel. As a sensitivity study, the staff also examined discharging into a 1x8 configuration as implemented by Peach Bottom. Staff didn't fully consider alternative fuel arrangements, different rack types, longer transfer times, and most importantly, they did not fully explore the vulnerabilities in the first few months after discharge. The staff judges that these alternatives would provide a limited safety benefit because of the low probability of a seismic initiating event that would challenge the pool during this time.

As a result, I <u>do not</u> approve the staff recommendation to eliminate further generic assessment of expedited transfer of spent fuel as it relates to broader spent fuel management alternatives that should be explored. I do approve the staff discontinuing the generic expedited transfer assessment defined in the current three-phased program plan. It is not clear whether it is realistically possible to rapidly defuel several thousand fuel assemblies from U.S. plants across the nation within 5 years, and broader spent fuel management approaches should be evaluated instead.

Background

The consequence study examines the behavior of spent fuel in a pool given a seismic event initiator and the consequences of spent fuel fires with a "high density" configuration (*i.e.*, a pool with hot fuel assemblies surrounded by four cold fuel assemblies) or a "low density" configuration (i.e., a pool with hot fuel assemblies surrounded by four empty locations). The study evaluates the robustness of the Peach Bottom spent fuel pool against seismically-induced pool damage, probabilities of a self-propagating zirconium fire, and potential contamination events for mitigated and unmitigated scenarios. The low probabilities for initiating events were calculated from the 2008 United States Geological Survey (USGS) model for a large seismic event and the point estimate frequency of an assumed cask drop into a pool.[3] The staff model suggests that there would be no significant doses to the public during or immediately after the hypothetical release because of offsite protective actions that are credited in evacuating and relocating affected populations. The cumulative doses are dominated by long-term exposure to the surrounding public that returns to live in the contaminated zone around the plant. The contamination zone is considered by staff to be habitable in the analysis once annual doses fall below 20 millisieverts (2 rem) the first year and 5 millisieverts (500 mrem) in each year thereafter.

The staff subsequently determines in the generic regulatory analysis that a pool configuration with fewer fuel assemblies (*i.e.*, "low density") did not provide a substantial safety benefit because the calculated latent cancer risk is well below the QHOs for reactors. Although a high density configuration can result in much higher consequences, it is fairly insensitive to the QHOs given the calculated low probability of a fire in spent fuel pools. Likewise, the staff determines that the low density alternative is not cost-justified because the 100 billion dollar economic cost of a release is low when weighted by the calculated frequency of a fire. This averaged cost is below the dry cask storage costs needed to maintain a low density approach.[4] The staff paper also mentions other potential options for spent fuel management. But the staff qualitatively determines that these too, provide only a limited safety benefit when using the reactor QHOs.

However, the staff consequence study and generic regulatory analysis also highlight the significant range of potential contamination events and environmental costs. These potential costs are highly influenced by the distribution of recently discharged fuel in the pool, the overall cesium content in the pool, the success of post-accident water make-up capabilities, and the successful evacuation of the surrounding population during the event sequence. Unweighted by probability, the source term in a high density spent fuel pool is assumed to range from approximately 40 to 140 million curies of cesium-137 with a nominal 40% to 75% release fraction for various fuel pool types.[5] The source term

[3] The staff notes that the regulatory analysis uses the USGS 2008 model instead of the current model under development in an on-going regulatory program. The staff notes that while the USGS model is not sufficiently detailed for regulatory decisions, it is appropriate for use in this analysis because it is the most recent and readily available hazard model for the central and eastern U.S. plant sites.

[4] The staff notes that this cost could be heavily discounted if and when the Federal Government takes possession of spent nuclear fuel at utilities.

in an assumed low density pool is approximately 2-3 times lower.[6] Based on the consequence study for Peach Bottom, a fire in a high density pool is calculated to result in a collective dose of 350,000 person-sieverts, while a low density configuration is calculated to result in a collective dose of 27,000 person-sieverts (assuming unsuccessful mitigation). The land interdiction is estimated to be 9,400 square miles with a long-term displacement of 4,000,000 persons for a high density loading. A low density loading would lead to approximately a factor of 50 reduction in interdiction and population displacement.[7] [8] Similarly, a low density pool configuration could result in approximately a 100 billion dollars savings in economic costs, using the staff's current guidance for estimating cost benefits.[9]

It is important to note that the staff uses the Environmental Protection Agency (EPA) Protective Action Guidelines (PAGs) for the Intermediate Phase as the best-available metric for the analysis. The studies note that there is no Commission policy on acceptable decontamination and land reoccupation values.[10] Regardless of Commission direction on expedited transfer, the staff should not consider the EPA intermediate PAGs as an acceptable environmental policy metric, unless it is brought before the Commission as a policy matter.

Risk Perspectives and Defense in Depth

A comprehensive safety and security case for spent fuel pools should consider the full range of potential hazards (natural or human-induced) that could initiate an accident, the spectrum of potential options for addressing hazards, risk insights, defense-in-depth, scientific and engineering judgment, and other qualitative factors. I agree that probability and risk analysis are valuable tools to provide insights on safety decisions and rulemaking analysis. However, events with potentially significant consequences will always be a policy matter that requires additional consideration.

We should consider the uncertainties and limitations in predicting large earthquakes or other initiating events, and resultant consequences. We have a limited seismic record and limited database to make

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[5] For comparison, various organizations have estimated that approximately 0.2 to 0.8 million curies of cesium-137 was released into the air environment from the Fukushima reactor accidents. See, for instance, "Fukushima Daiichi Status Report," International Atomic Energy Agency, June 28, 2012. The estimated fraction of source term released to the environment from a spent fuel pool fire is based in part on the assumed damage-state of the reactor building surrounding the spent fuel pool.

[6] See tables 35 and 52 of "Regulatory Analysis for Japan Lessons Learned Tier Issue on Expedited Transfer of Spent Fuel" - enclosure 1 to COMSECY-13-0030, "Staff Evaluation and Recommendation for Japan Lessons-Learned Tier 3 Issue on Expedited Transfer of Spent Fuel," November 2013.

[7] The input parameters for the consequence analyses are based on those developed for Peach Bottom for the recently completed "State-of-the-Art Reactor Consequence Analyses" research project (NUREG-1935), including site specific population distributions, meteorology, and evacuation timing parameters.

[8] See section 7.3 of "Consequence Study of a Beyond-Design-Basis Earthquake Affecting the Spent Fuel Pool for a U.S. Mark 1 Boiling Water Reactor," October 2013.

[9] I believe these economic calculations are riddled with uncertainty, given uncertainties in evacuation and reoccupation doses of a large population, the immeasurable complexity of local and regional economics, and the uniqueness of populations and environments at individual reactors.

[10] The EPA guidance also notes that the intermediate phase guidelines have an objective of limiting total dose to 50 millisieverts (5 rem) over 50 years.

severe earthquake forecasts. The inability of seismologists to predict the Tohoku earthquake off the east cost of Japan is a case in point.[11] Forecasts are subject to professional judgment and hopefully conservative risk assessments of Earth processes near each reactor plant. In terms of human-induced initiators, while our security professionals have a strong understanding of malevolent scenarios, vulnerability, and physical protection methodology, it is not possible to apply the same risk and cost-benefit analyses to quantify security risks in a similar manner as safety risks. As a result, it is not feasible to determine the cumulative probability of all initiators, and completely assess the numerical or total risks for each unique spent fuel pool in the nation. Therefore, it is important to have a continued focus on the holistic benefit of spent fuel management approaches that provide a common safety and security layer of defense against all potential initiators.

Fundamentally, spent fuel pools do not benefit from a surrounding primary containment structure to repress large releases of fission products during a loss of cooling emergency and energetic fuel damage. The consequence analysis identifies a period in which spent fuel may not be naturally air-coolable during a drain-down event without human intervention. As a result, over the life of a reactor, spent fuel pools may not have natural cooling ability for approximately 1 to 5 years of a 20-year operating life.[12] There are additional spent fuel management measures that should be evaluated to address this vulnerable state, for all types of initiating events.

The consequence study provides new, valuable insights on the importance of spent fuel loading patterns and overall cesium content, which cannot be dismissed qualitatively. For example, the consequence study reiterates the advantage associated with dispersed fuel patterns at time of discharge. The "base case" of the regulatory analysis assumes that spent fuel is discharged directly into a 1x4 loading pattern, although there is no direct requirement to do so under 10 CFR 50.54(hh). The staff implementing guidance suggests an undisclosed timeframe for achieving such a pattern.[13] In the consequence study, the staff performed a sensitivity analysis for non-dispersed patterns of the hottest fuel assemblies. It shows that deployment of water makeup capabilities is not as effective in a non-dispersed pattern as compared to 1x4 pattern. A non-dispersed pattern may also have more detrimental hydrogen combustion events than a 1x4 pattern and lead to significantly higher consequences and contamination of the surrounding environment.[14]

In contrast to the work done for the generic regulatory analysis of expedited transfer, the staff provided a comprehensive analysis on the addition of filtered containment venting systems to BWRs with Mark I

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[11] Prior to the 2004 Sumatra earthquake that created the massive Indian Ocean tsunami, seismologists believed that only certain subduction zones could cause megaquakes (greater than magnitude 8.8). Only in the years after Sumatra did the seismological community begin to accept that all subduction zones of sufficient length could create megaquakes. The Tohoku quake of 2011 proved their new understanding to be correct.

[12] In the consequence study, the staff estimates spent fuel is vulnerable to ignition is between 37 – 107 days after discharge, without mitigation within 72 hours. Reactors typically discharge fuel on a one to two year cycle.

[13] The time to achieve a 1x4 pattern is security-related information.

[14] See section 9.3 of "Consequence Study of a Beyond-Design-Basis Earthquake Affecting the Spent Fuel Pool for a U.S. Mark 1 Boiling Water Reactor," October 2013.

and Mark II containments, to address lessons learned from the events at the Fukushima. For filtered vents, the staff considered both safety risk and cost benefits. To complement their analysis, the staff systematically examined qualitative factors such as providing defense in depth (including the importance of containment function), addressing significant uncertainties (frequencies and consequences), supporting severe accident management and response, improving hydrogen control, addressing external events, improving emergency planning, and addressing international experience and practices. While the staff touched upon some qualitative issues with expedited transfer, it did not provide a similar review of options and qualitative factors that are important to this decision before the Commission.

Spent Fuel Management Options

The staff should therefore consider spent fuel management actions that promote inherent defense-in-depth against accidents and events that could generate very large releases, particularly with regard to the vulnerabilities that exist in spent fuel pools during the first one to three months after fuel discharge. The staff should systematically assess these options for reducing these vulnerabilities by considering all of the following factors:

- **Longer Transfer Times to Dry Cask Storage**

The only option before the Commission is continuing the analysis of requiring the rapid defueling of all spent fuel older than five years by 2019. First, even if there is a significant safety benefit to do so, it is not clear if it is physically possible to complete such a significant task within five years - - given the current loading and handling infrastructure of individual U.S. power plants and the manufacturing capabilities of cask vendors. A study by Electric Power Research Institute on this topic, which the staff relied upon in their analysis, concluded the same and they examined transfer of fuel over longer 10-year and 15-year time frames.[15] Second, when considering consequences beyond 50 miles and a more up-to-date conversion value of $4,000 per rem, the base cases for some reactor plants are actually cost beneficial.[16] All "high cases," which are meant to use more conservative assumptions to bound possible site-specific plant configurations, are cost-beneficial even assuming an aggressive five-year schedule.[17]

The staff should further investigate the option of significantly reducing the overall cesium content in spent fuel pools, but over longer time frames, such as 10 years. This analysis may demonstrate a significant reduction in accident source terms for defense in depth, while requiring a lower number of

[15] "Impacts Associated with Transfer of Spent Nuclear Fuel from Spent Fuel Storage to Dry Storage After Five Years of Cooling," Revision 1, Electric Power Research Institute, 1023206, August 2012.

[16] See Table 10 and Tables 27 -30 of "Regulatory Analysis for Japan Lessons-Learned Tier 3 Issue on Expedited Transfer of Spent Fuel," COMSECY-13-0030, November 12, 2013.

[17] The staff considers the "high cases" to be overly conservative.

additional dry storage casks. This approach may also be more feasible when using existing dry storage cask technologies to full capacity.

- **Direct Discharge into dispersed pattern**

The consequence study illustrates the inherent value of dispersing the hottest fuel within the spent fuel pool. As noted earlier, the 1x4 pattern promotes natural cooling and reduces the likelihood and consequence of a release. As noted in the consequence study, licensees may not be directly discharging the hottest fuel from the core directly into a 1x4 pattern for some time. It appears that most licensees are achieving a 1 x4 pattern at an undisclosed time after discharge, under implementing guidance associated with the requirements of 10 CFR 50.54(hh). The staff should, at a minimum, re-examine the technical basis of the implementing guidance for 10 CFR 50.54(hh) in light of the potential benefits shown in the consequence study. The staff should survey and understand the specific discharge and spent fuel management practices of each plant as part of this examination. The staff should also consider requiring dispersed loading patterns at the time of actual discharge, when fuel is hottest and most susceptible to self-ignition without the pool coolant boundary. This requirement should be considered in conjunction with the unique attributes and vulnerabilities of each individual spent fuel pool. The staff should also evaluate the safety benefits of full core off-load capabilities during reactor operations and outages, and examine regulatory options for requiring this spent fuel management approach together with the other alternatives discussed here.

- **Alternate Dispersal Patterns (e.g. 1x8)**

Alternative loading patterns, beyond the 1x4 arrangement may provide additional margin and reduced risks. The staff sensitivity analysis shows that a 1x8 arrangement has superior heat removal capabilities compared with a 1x4 pattern. The larger mass of cold fuel in a 1x8 pattern provides a larger heat sink and results in lower heatup of recently discharged fuel in a drained pool environment. For one calculation of the 1x8 pattern, no release occurred from fuel through the first 72 hours, compared to the 1x4 pattern, which resulted in a zirconium fire that began after 40 hours and led to a 42 percent release of the cesium inventory into the environment. The Advisory Committee for Reactor Safeguards (ACRS) also notes that the 1x8 pattern can significantly reduce the consequences of seismically induced damage. The ACRS stated this approach should be further explored as a measure to provide additional defense in depth against spent fuel pool accidents. The staff should therefore pursue the option of alternate dispersal patterns (such as a 1x8) in conjunction with analyzing the benefit of directly discharging spent fuel into a dispersed pattern.

- **Alternative Storage Rack Designs**

The staff's analysis assumed the current closed, high-density rack configuration in the technical analysis. The staff's regulatory analysis estimates a significant cost for re-racking spent fuel pools to an open frame rack design. It qualitatively notes that staff believes that within the first few months after discharge, the decay heat in the freshly unloaded spent fuel is high enough to cause a zirconium

fire even in the presence of convective cooling. Therefore, re-racking the spent fuel pool to install open frame racks even with BWR channel boxes removed to allow potential cross flow, would not necessarily prevent a radiological release during this time.

While this may be generally intuitive, it has not been substantively modeled or physically tested. I note that the consequence study illuminated other approaches that showed significant benefits (*e.g.*, 1x8 configuration), which may not have been intuitive at first glance. To lay this question to rest, the staff should adjust its current models to approximate the open frame rack configuration. The staff should evaluate if the additional cross-flow geometries would significantly increase time margins for mitigative actions or substantially reduce radiological consequences. The staff should also examine international spent fuel pool designs and practices to determine if alternate rack designs are being used to mitigate accident risks.

- **Longer-Term Research - Accident Tolerant Fuel**

The Department of Energy is researching accident tolerant fuel for improved reactor and spent fuel pool safety. New cladding materials and coatings for zirconium fuel are being considered as benign materials against steam reactions at high temperatures. A new generation of spent fuel with tolerant cladding is a potential passive safety measure that may significantly reduce uncertainties in both reactor and spent fuel pool loss-of-coolant accidents. The staff should support, within its regulatory role, the on-going research on accident tolerant fuel designs. This work is important as current fuel designs continue to increase to higher burnups, with growing heat loads and cesium source terms at time of discharge.

Other Factors

In moving forward, the staff should engage the international community in their efforts to enhance spent fuel management from a safety and security standpoint. The Commission has recently directed staff to further examine international practices for spent fuel pool management. The practices, technical analyses, and decision rationale of other nations should be considered in future work on this issue. For example, it appears that because of recent Canadian Nuclear Safety Commission's efforts to examine lessons learned from the Fukushima accident, reactor plants in Canada have apparently opted to transfer spent fuel within 7 years of discharge.[18] The staff should also consider the pending National Academy of Science's (NAS) study on this topic, and report to the Commission the NAS findings and how they comport with further work on spent fuel pool management.

I also expect that staff's work on economic consequences, qualitative factors, and recommendations for disposition of Near Term Task Force (NTTF) Recommendation 1 will lead to addressing broader framework questions for considering beyond-design basis accidents. These efforts contain regulatory elements that are integral to the NRC consideration of severe accidents for both reactors and spent

[18] Personal communication with Dr. Michael Binder, President of the Canadian Nuclear Safety Commission, January 2014.

fuel pools. Potential policy issues include systematic consideration of defense-in-depth, the use of qualitative factors, and environmental restoration and rehabitation of contaminated land.

Equally, the staff should endeavor to engage the public early in the process of examining improved spent fuel management approaches in order to garner valuable insights and ensure NRC actions are effectively communicated. This may be most beneficial in not just understanding varying technical perspectives, but also the other environmental consequences and economic impacts in local communities. I do not agree with the staff's approach in engaging the public near the very end of the current two-year regulatory review process, without the ability to fully provide input on key regulatory factors or review the draft regulatory analysis that was provided to the Commission. In accelerating this Tier 3 activity to align with the Waste Confidence environmental activities for public transparency, the staff may have ironically impeded the same public from fully vetting this issue in the safety and security arenas.

Conclusion

I appreciate the work that staff has performed thus far on spent fuel pool safety. I recognize the importance of the risk analysis and backfit analysis tools. I have also weighed some of the deterministic arguments regarding the robustness of spent fuel pools, physical security measures, and the capability of supplying supplemental cooling after a severe event. These factors provide significant comfort that we do not need to rush to take drastic actions today.

But as a precautionary principle, the Agency should continue to focus on enhancing defense-in-depth in a reasonable manner. Uncertainties in forecasting the next severe event (*e.g.,* in the assumptions and judgments that go into modeling complex scenarios), as well as in other human factors, are difficult to quantify. The potential consequences would be intolerable to the surrounding human environment. These types of environmental impacts cannot be wholly measured and evaluated through frequency weighting of dose and quantified health objectives alone. We should holistically consider safety and security concerns and further evaluate potential defense-in-depth measures to compensate for these uncertainties. This regulatory approach can be pursued at a pace that is commensurate with the calculated risks that such events pose and in parallel with broader efforts to enhance our severe accident regulatory framework.

Summary of Necessary Actions

1. The staff should provide a plan to the Commission that prioritizes spent fuel management options that may provide the greatest safety benefit and describe further research needs to determine which regulatory actions will ensure adequate defense-in-depth.

2. The staff should consider spent fuel management actions that promote inherent defense-in-depth against accidents and events that could generate very large releases, particularly with regard to the

vulnerabilities that exist in spent fuel pools during the first one to three months after fuel discharge. The staff should systematically assess the following approaches for reducing these vulnerabilities:

a. Reduction of the overall cesium content in spent fuel pools by transfer to dry cask storage, but over longer time frames, such as 10 years.

b. Direct discharge of spent fuel into a dispersed pattern. The staff should re-examine the technical basis of the implementing guidance for 10 CFR 50.54(hh) in light of the potential benefits shown in the consequence study. The staff should survey and understand the specific discharge and spent fuel management practices of each plant as part of this examination. The staff should also consider requiring dispersed loading patterns at the time of actual discharge, when fuel is hottest and most susceptible to self-ignition without the pool coolant boundary. This requirement should be considered in conjunction with the unique attributes and vulnerabilities of each individual spent fuel pool. The staff should also evaluate the safety benefits of full core off-load capabilities during reactor operations and outages and examine regulatory options for requiring this spent fuel management approach together with the other alternatives discussed here.

c. Use of alternate dispersal patterns (such as a 1x8).

d. Use of alternate rack designs. The staff should adjust its current models to approximate the open frame rack configuration. The staff should evaluate if the additional cross-flow geometries would significantly increase time margins for mitigative actions or substantially reduce radiological consequences. The staff should also examine international spent fuel pool designs and practices to determine if alternate rack designs are being used to mitigate accident risks.

e. Use of accident tolerant designs. The staff should support, within its regulatory role, the on-going research on accident tolerant fuel designs.

3. The staff should engage the international community in their efforts to enhance spent fuel management from a safety and security standpoint.

4. The staff should also consider the pending National Academy of Science's (NAS) study on this topic, and report to the Commission the NAS findings and how they comport with further work on spent fuel pool management.

5. The staff should endeavor to engage the public early-on in the process of examining improved spent fuel management approaches.

6. The staff should not consider the EPA intermediate PAGs as an acceptable environmental policy metric, unless it is brought before the Commission as a policy matter.

4/8/14

Allison M. Macfarlane Date

RESPONSE SHEET

TO: Annette Vietti-Cook, Secretary

FROM: COMMISSIONER SVINICKI

SUBJECT: COMSECY-13-0030 - STAFF EVALUATION AND RECOMMENDATION FOR JAPAN LESSONS-LEARNED TIER 3 ISSUE ON EXPEDITED TRANSFER OF SPENT FUEL

Approved XX Disapproved _____ Abstain _____

Not Participating _____

COMMENTS: Below ___ Attached XX None ___

SIGNATURE

01/9/14
DATE

Entered on "STARS" Yes ✓ No ___

Commissioner Svinicki's Comments on COMSECY-13-0030
Staff Evaluation and Recommendation for Japan Lessons-Learned Tier 3 Issue on Expedited Transfer of Spent Fuel

I approve the staff's recommendation to close the Tier 3 Japan lessons-learned activity related to evaluation of the expedited transfer of spent fuel to dry cask storage. As additionally recommended by the staff, no further generic assessments should be pursued related to possible regulatory actions to require the expedited transfer of spent fuel, unless specifically directed by the Commission.

The body of evidence provided by the staff in support of this recommendation includes an evaluation of the broad history of NRC oversight of spent fuel storage (spanning over 30 years); operating experience (both domestic and international); past studies of spent fuel pool safety; original, contemporary technical analysis ("Consequence Study of a Beyond-Design-Basis Earthquake Affecting the Spent Fuel Pool for a U.S. Mark Boiling-Water Reactor," SECY-13-0112 – the assumptions of which were conservative and were purposefully skewed in the direction of favoring regulatory action); and a regulatory analysis. The NRC staff provided an opportunity for public comment and conducted public meetings on the study and regulatory analysis. The staff documented its response to public comments and questions in Appendix E of the Consequence Study and Appendix G of the regulatory analysis.

I conclude that this record, taken as a whole, overwhelmingly supports the staff's recommendation. Commission approval of this recommendation is consistent both with the analysis conducted and with the Reliability Principle of Good Regulation, which requires that regulation be based on the best available knowledge from research and operational experience and that systems interactions and uncertainties be taken into account so that risks are maintained at an acceptably low level.

Kristine L. Svinicki 01/ 9 /14

RESPONSE SHEET

TO: Annette Vietti-Cook, Secretary

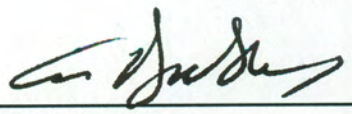
FROM: Commissioner Apostolakis

SUBJECT: COMSECY-13-0030 - STAFF EVALUATION AND RECOMMENDATION FOR JAPAN LESSONS-LEARNED TIER 3 ISSUE ON EXPEDITED TRANSFER OF SPENT FUEL

Approved X **Disapproved** _____ **Abstain** _____

Not Participating _____

COMMENTS: **Below** ___ **Attached** X **None** ___



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April 11, 2014

DATE

Entered on "STARS" Yes x **No** ___

Commissioner Apostolakis' Comments on COMSECY-13-0030
Staff Evaluation and Recommendation for Japan Lessons-Learned Tier 3 Issue
On Expedited Transfer of Spent Fuel

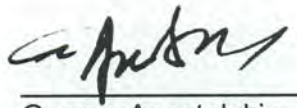
I commend the staff for the significant amount of work accomplished given the breadth and complexity of this issue. The staff conducted additional research following the Fukushima accident to assess the consequences of a beyond-design-basis earthquake affecting the Spent Fuel Pool (SFP) for U.S. Mark I Boiling Water Reactors and developed a Regulatory Analysis regarding the transfer of spent fuel to dry casks after five years. As a result, the staff has improved the state of knowledge on this subject. In my deliberations, I also benefited from the comments provided by public interest groups.

The staff's recommendation is bolstered by an extensive history of research and analysis that includes reviews of international and domestic experience and practices. The Advisory Committee on Reactor Safeguards noted the staff's use of conservative assumptions in the Regulatory Analysis and agreed with the staff's conclusions and recommendations.

After careful consideration of the staff's evaluation, the views expressed in the non-concurrence, the Regulatory Analysis, the Spent Fuel Pool Study, as well as the many previous studies of SFP safety, I find there is no compelling evidence to warrant expedited transfer of spent fuel to dry cask storage or further generic assessments related to possible regulatory actions on this matter. I also found the body of evidence on spent fuel pool safety and the staff's conclusion that the expedited transfer of spent fuel would provide only a minor or limited safety benefit very compelling. Therefore, I approve the staff's recommendation that this Tier 3 Japan lessons-learned activity be closed.

Nonetheless, I agree with Chairman Macfarlane and Commissioner Magwood that there are areas for which further study might be beneficial. A preliminary exploration of the broader issue of potential enhancements in spent fuel management should be undertaken. Staff should provide an information paper to the Commission that addresses the specific issues that Chairman Macfarlane raises in her vote (items #2 a through d, and #4). This paper should be provided to the Commission within 3 months from the date of the Staff Requirements Memorandum. The staff's preliminary exploration could also contribute to the Information Notice suggested by Commissioner Magwood.

Finally, I am confident that, as the NRC's long history demonstrates, the agency will take the steps necessary to continue to ensure adequate protection of public health and safety, if new and significant information warrants such action in the future.



George Apostolakis
April 11, 2014

RESPONSE SHEET

TO: Annette Vietti-Cook, Secretary

FROM: Commissioner Magwood

SUBJECT: COMSECY-13-0030 - STAFF EVALUATION AND RECOMMENDATION FOR JAPAN LESSONS-LEARNED TIER 3 ISSUE ON EXPEDITED TRANSFER OF SPENT FUEL

Approved X Disapproved _____ Abstain _____

Not Participating _____

COMMENTS: Below ___ Attached X None ___

SIGNATURE

29 January 2014

DATE

Entered on "STARS" Yes X No ___

Commissioner Magwood's Comments on COMSECY-13-0030,
"Staff Evaluation and Recommendation for
Japan Lessons-Learned Tier 3 Issue on Expedited Transfer of Spent Fuel"

I appreciate staff's considerable work in engaging this matter. The issue of whether the agency should require the accelerated transfer of spent nuclear fuel from storage pools to dry casks is one that has garnered much public and policymaker attention in recent years. Obviously, the public discourse regarding the condition of the spent fuel pools at the Fukushima Daiichi nuclear plant during the nuclear crisis of 2011 has sparked these concerns. Ill-considered and scantly-supported public statements were made to the effect that the pools had been damaged by the earthquake and tsunami, the water had drained away, and the spent fuel in the pools was on fire. All the while, Japanese authorities maintained consistently that there was no such damage and that the pools remained intact. Inspections after the height of the crisis confirmed that despite a large earthquake of historic magnitude, a 15 meter tsunami wave, and subsequent hydrogen explosions, the spent fuel pools at the Fukushima Daiichi site maintained their integrity and, to this day, continue to protect public health and safety.

Nevertheless, the Commission believed it prudent to consider this matter further. The impact of the high density loading of spent fuel at nuclear plants in the U.S. and around the world present factors that the Commission found appropriate to evaluate in the aftermath of the Fukushima disaster - despite the reassurance one might gain from the operating experience at the Fukushima plant itself.

In anticipation of such a review, staff launched a research project in the summer of 2011 called "Consequence Study of a Beyond Design-Basis Earthquake Affecting the Spent Fuel Pool for a U.S. Mark I Boiling Water Reactor." The results of this work were issued in an October 2013 report that has become known as the "SFP Study." This study found that even in the event of a very large, beyond design basis isotopic seismic event, a BWR Mark I pool would likely survive entirely intact and, under a range of unrealistically conservative assumptions, at worse develop a modest leak in its liner. This result reinforced the staff's view that spent fuel pools, which are purposely designed to withstand large earthquakes and other events, are fully protective of public safety.

Additionally, the study highlighted two other important factors, both of which are associated with measures taken by NRC in the wake of the September 11, 2001 terrorist attacks. First, the equipment and procedures already in place at all U.S. nuclear power plants to respond to events that result in significant damage at a nuclear plant would enable plant personnel to act and mitigate any damage to spent fuel pools. All spent fuel pools in this country are supplemented by pumps, hoses, spray nozzles, and other equipment that would enable plant operators to add cooling water to a damaged pool. The ability to reliably mitigate damage to a pool is a central aspect of the U.S. approach to responding to extreme events, and this capability will be further enhanced by the orders issued by the agency in response to the lessons learned from the Fukushima disaster.

Staff also found, to the surprise of many well-informed observers, that the post-9/11 strategy of requiring each hotter, newer spent fuel assembly to be surrounded by a number of cooler, older fuel assemblies slightly mitigates the onset of a spent fuel fire in comparison to loading hotter spent fuel in a lower density configuration (due to the fact that the older spent fuel absorbs and dissipates heat from the hotter assemblies). This finding is, in fact, new knowledge that further informed staff's review.

I note that some have criticized this study for not considering initiators other than seismic events. Specifically, some observers believe that the agency should have reviewed the effect of various terrorist attack scenarios. I find this critique uncompelling. First and foremost, while the SFP Study focused on seismic events, I have seen no informed analysis that suggests the outcome of staff's analysis would differ significantly if another class of precursor events were chosen. However a leak develops in a pool, there is little cause to believe that the mitigation and behavior of the fuel in the pools would not be largely consistent with that considered in the SFP study. Second, I am quite confident in the security at U.S. plants and do not believe the scenarios postulated by some critics should alter our decision-making.

The NRC staff's analysis of the specific question of expedited transfer took two generally independent routes in response to their charge. First, staff performed a safety goal analysis that concluded that any safety benefit from expedited transfer would be very small. Second, staff performed a generic cost-benefit analysis that found the costs of expedited transfer would not be justified by the safety benefit. Both analyses are characterized by very conservative assumptions - so conservative that the ACRS highlighted them as unrealistic. Despite that criticism, the ACRS agrees with staff's overall recommendation.

Given these considerations, I find no evidence to overturn staff's overall conclusion that the expedited transfer of spent fuel to dry cask storage would provide only a minor or limited safety benefit. Therefore, I approve the staff's recommendation that no further generic assessments be pursued related to possible regulatory actions to require the expedited transfer of spent fuel to dry cask storage and that this Tier 3 Japan lessons-learned activity be closed.

That said, I note that staff's analysis is not wholly unassailable. Using currently accepted (and probably overly conservative) models for health effects and land contamination, a spent fuel pool accident has the potential for effects that would be more geographically widespread than those following the reactor accidents the staff methodology was originally designed to evaluate. This fact makes it reasonable to question some aspects of the staff's cost-benefit analysis. However, the safety goal screening evaluation supports staff's conclusion on its own, and both analyses are characterized by very conservative assumptions (which staff notes were designed to bias the conclusion in favor of regulatory action) that provide confidence in staff's recommendation.

In addition, staff could have considered more thoroughly the potential safety benefits of alternate configurations for spent fuel pools. As noted by the ACRS and staff nonconcurrences, the benefits of the "1 X 8" arrangement assessed in the SFP Study received no detailed

consideration in staff's regulatory analysis. While staff has asserted that a regulatory proposal to require utilities to use this configuration would be unlikely to pass a rigorous backfit analysis, the NRC's current requirement for plants to apply a "1 X 4" arrangement was made on the basis of adequate protection and security considerations. Had the Commission been aware of the results of the SFP study when the "1 X 4" requirement was implemented after the 9/11 attacks, it is quite possible that many plants, particularly BWRs, would have been required to apply the "1 X 8" arrangement in their pools at that time.

While I accept staff's overall judgment, I recommend, for completeness, that the regulatory analysis be modified to explain why the "1 X 8" configuration was not found to provide a substantial increase in safety. Further, to the degree that this configuration does provide some enhancement in safety margin, I suggest that staff develop an Information Notice to inform licensees of the potential added safety benefit of adopting a "1 X 8" configuration.

Finally, another element of staff's analysis that appears not to have been explored is the treatment of off-loading of spent fuel into pools. First, the full-core offload capability assumed in the SFP Study is not a regulatory requirement and is not available to a small, but not insignificant, number of U.S. reactors. If staff's analysis in support of the agency's consideration of the expedited transfer issue has identified any information not already widely available to licensees, it should be included in the Information Notice mentioned above.

Second, I note that staff's analysis assumes that certain, short-term states of spent fuel pools, while presenting higher risk, are not viewed with concern because of the very short time periods these states persist over the life of an operating reactor. This appears to be a reasonable view; however, the agency does not appear to treat all limited-term operational vulnerabilities consistently. For example, some U.S. plants are required to employ special equipment to protect against the tip-over of a spent fuel transfer cask in the unlikely event that a large earthquake should occur while the cask is in a "freestanding stack-up" configuration. While such a combination of events is highly unlikely given the long odds of a seismic event during an operation that occurs during a short time period perhaps once every one to two years, the safety benefits of the extra equipment were found to warrant a regulatory requirement. That philosophy appears to be absent from the subject analysis. One might decide to take either approach, but having both suggests that either some agency requirements are arbitrary and unnecessary, or others are insufficiently protective of public safety.

In closing, I note that many observers who were concerned about spent fuel pool safety in the aftermath of Fukushima will likely remain concerned once this matter is closed by the Commission. Our confidence in our decision will not quiet all the worries generated as a result of the Fukushima crisis. However, the structure and rigor of our process is designed to assure that regulatory actions are focused on those matters of greatest safety significance and it is the staff's analysis and my conclusion that there is no technical basis to make the expedited transfer of spent fuel a regulatory requirement. Staff's analysis has found that high-density spent fuel pools are not at greater risk for a release than low-density pools; in fact, high density pools with a post-9/11 configuration slightly mitigate the onset of zirconium fires in pools as the result of beyond design-basis events.

However, it is my view that public concern over spent fuel related issues largely originate from the lack of a definitive disposition path for these materials. While it is not within NRC's power to resolve this matter of national policy, we do have a vital responsibility to take the actions necessary to assure that the spent fuel maintained on reactor sites is stored safely. While the matter of expedited transfer should now be concluded, the agency should remain open to the consideration of future analysis to further enhance confidence in the safety of spent fuel stored on reactor sites.

1/29/14

William D. Magwood, IV **Date**

RESPONSE SHEET

TO: Annette Vietti-Cook, Secretary

FROM: COMMISSIONER OSTENDORFF

SUBJECT: COMSECY-13-0030 - STAFF EVALUATION AND RECOMMENDATION FOR JAPAN LESSONS-LEARNED TIER 3 ISSUE ON EXPEDITED TRANSFER OF SPENT FUEL

Approved __X__ Disapproved _____ Abstain _____

Not Participating _____

COMMENTS: Below ___ Attached _X_ None ___

_____
SIGNATURE

_____
DATE

Entered on "STARS" Yes ___ No ___

Commissioner Ostendorff's Comments on COMSECY-13-0030, "Staff Evaluation and Recommendation for Japan Lessons-Learned Tier 3 Issue on Expedited Transfer of Spent Fuel"

I approve the staff's recommendation that this Tier 3 Japan lessons-learned activity be closed and that no further generic assessments be pursued related to possible regulatory actions to require the expedited transfer of spent fuel to dry cask storage

I commend the staff for exercising due diligence in conducting a thorough and systematic Spent Fuel Pool Study and regulatory analysis of expedited transfer of spent fuel to dry cask storage. These efforts build on past studies of spent fuel safety and spent fuel pool operating experience. The results of the staff's 2013 Spent Fuel Study are consistent with past studies' conclusions that spent fuel pools are likely to withstand severe earthquakes without leaking, and that the risk of a large release due to spent fuel pool accidents is very low. Further, operating experience, including the experience of the Niigataken Chuetsu-Oki Earthquake in July 2007 and the Great Tohoku Earthquake in March 2011, which collectively affected 20 operating reactors and spent fuel pools in Japan, including Fukushima Dai-ichi, and the U.S. experience at the North Anna plant, has shown that spent fuel pools have safely withstood challenging events and maintained structural integrity.

Following the events of September 11, 2001, the staff imposed requirements to enhance licensee capability to maintain and restore spent fuel pool cooling. These measures are being further enhanced as a result of the insights from the Fukushima accident. Specifically, Orders EA-12-051, "Issuance of Order to Modify Licenses with Regard to Reliable Spent Fuel Pool Instrumentation," and EA-12-049, "Order Modifying Licenses with Regard to Requirements for Mitigation Strategies for Beyond-Design-Basis External Events," are currently being implemented by all operating U.S. nuclear power plants which should serve to further reduce spent fuel pool accident risk by increasing the capability of nuclear power plants to mitigate beyond-design-basis external events.

The NRC's regulatory framework allows for new requirements to be added based on operating experience or other insights when the Commission determines they are necessary to ensure adequate protection or they are shown to be a cost-justified substantial safety increase. This process protects public health and safety while maintaining the NRC as a predictable and stable regulator and providing regulatory certainty. In response to the Fukushima Accident, as described in SECY-11-0137, the staff has focused its priorities and resources on those regulatory actions with the greatest potential for safety improvement. In the case of expedited transfer of spent fuel, the body of information available does not support taking any additional regulatory action to address spent fuel pool safety.

I appreciate the work of the ACRS in conducting a thorough review of the staff's analysis in this area. The ACRS provides valuable advice to the Commission to support its deliberations and the ACRS was fully supportive of the staff's recommendation on this topic.

Lastly, I would like to address the issue of spent fuel pool security. The NRC received a number of stakeholder comments on the Spent Fuel Pool Study calling into question the protection of spent fuel pools from attack. I have full confidence in the ability of our licensees to protect spent fuel pools. U.S. nuclear power plants are robust facilities that are protected by comprehensive security measures, which were enhanced following the events of September 11, 2001. In addition, well-trained and armed security officers, physical barriers, access controls, and intrusion detection and surveillance systems are used to protect commercial power reactors. Licensee protective strategies are subject to continual NRC oversight and are tested by the NRC in Force-on-Force exercises every three years. Protection of spent fuel pools is an integral part of these protective strategies.

In conclusion, I agree with Commissioner Svinicki that approval of this recommendation is consistent with the Principles of Good Regulation in that regulations should be based on the best available knowledge from research and operational experience, and that the record, taken as a whole, overwhelmingly supports the staff's recommendation.