ADDENDUM TO ENCLOSURE 1 OF COMSECY-13-0030,
"REGULATORY ANALYSIS FOR JAPAN LESSONS-LEANRED TIER 3 ISSUE ON EXPEDITED TRANSFER OF SPENT FUEL"

SUMMARY

As directed by the staff requirements memorandum (SRM) to COMSECY-13-0030, the staff prepared this addendum to the regulatory analysis in COMSECY-13-0030 to more fully explain why additional regulatory actions to impose a requirement to establish a "1 x 8" spent fuel loading pattern were not justified. The staff first conducted a safety goal screening evaluation using the Commission's safety goal policy statement. The safety goal screening evaluation for the 1 x 8 spent fuel loading pattern did not pass the screening criteria. Although the agency's guidance would normally allow the staff to stop the evaluation upon determining that the proposed action does not provide a sufficient safety enhancement to meet the threshold of the safety goal screening, the staff completed additional evaluation of the costs and benefits associated with requiring a 1 x 8 spent fuel loading pattern. The staff concludes that the 1 x 8 spent fuel loading pattern would provide only a minor safety benefit (i.e., less than safety goal screening criteria), and that its expected implementation costs would not be warranted.

BACKGROUND

In SRM-COMSECY-13-0030, "Staff Requirements – Staff Evaluation and Recommendation for Japan Lessons-Learned Tier 3 Issue on Expedited Transfer of Spent Fuel," dated May 23, 2014, the Commission directed the staff to modify the regulatory analysis in Enclosure 1 of COMSECY-13-0030 to explain why the 1 x 8 configuration was not found to provide a substantial increase in safety.

In SECY-13-0112, "Consequence Study of a Beyond-Design-Basis Earthquake Affecting the Spent Fuel Pool for a U.S. Mark I Boiling Water Reactor" (Spent Fuel Pool (SFP) Study), which was sent to the Commission on October 9, 2013, the staff compared the response of spent fuel to a loss of cooling water from high-density and low-density storage configurations . The staff considered various spent fuel loading patterns, as illustrated in Figure 1. The SFP Study base case considered a 1 x 4 high-density loading pattern where the hottest assemblies are surrounded by four older assemblies at each face. The NRC generally requires licensees achieve a distributed loading pattern within specific time periods, and most plants employ the 1 x 4 high-density loading pattern. However, the 1 x 8 loading pattern, where the hottest fuel assemblies are surrounded by eight cooler assemblies at each face and each corner in a repeating pattern, has been used at some facilities. The 1 x 8 loading pattern was analyzed as a sensitivity case in Section 9.2 of SECY-13-0112 and had more favorable results than a 1 x 4 high-density loading pattern.

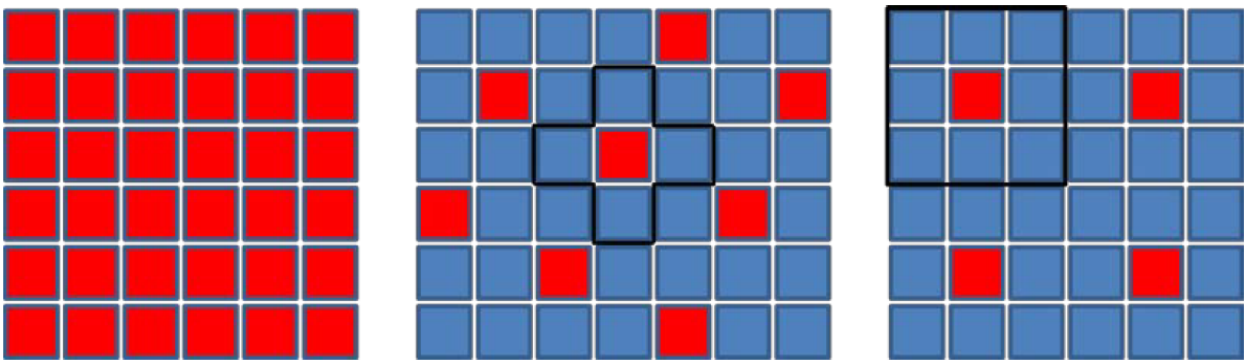

Figure 1 – Illustration of SFP patterns
From left to right: Uniform/contiguous; 1 x 4; and 1 x 8
Red = a recently discharged assembly; Blue = an older, lower decay heat assembly, black outline shows repeating pattern

COMSECY-13-0030 describes the staff's consideration of other possible improvements as follows:

> In addition to assessing whether further studies of expedited transfer of spent fuel to dry cask storage are warranted, the SFP study, and staff's interactions with stakeholders identified other possible improvements to the storage of spent fuel. Examples include the possible investigation of alternate loading patterns (e.g., the 1 x 8 high-density loading pattern assessed in the SFP study, in addition to the standard 1 x 4 high-density loading pattern), capability of licensees to directly offload fuel into more coolable patterns, and the possible enhancement of mitigation strategies during identified periods when the heat load from recently discharged fuel assemblies is especially high. The staff has considered these possible improvements, and notes that these alternatives would likely involve lower costs than would the expedited transfer of spent fuel to dry cask storage. However, these alternatives would provide only a limited safety benefit when using the QHOs [quantitative health objectives], and their implementation costs would not be warranted. This finding reflects the low probability of the initiating events that would challenge the integrity of the SFPs and the fact that these alternative actions would have similar or lesser safety benefit in comparison to those estimated for the expedited transfer of spent fuel. However, licensees will be informed of and encouraged to assess and implement, as appropriate, such improvements on their own initiative to help manage the risks associated with plant specific SFP designs, operating practices, and mitigation capabilities.

The staff did not prepare or provide to the Commission a cost/benefit assessment of other possible regulatory actions, such as requiring alternate loading patterns within a high density pool or requiring enhancements to accident mitigation capabilities. For these cases, the staff found that if the major action (expedited transfer of spent fuel to dry cask storage) is a marginal safety improvement, similar or lesser actions would likewise not provide a substantial safety improvement.

Several factors influenced the staff's approach to evaluating the alternatives and decision not to provide a detailed cost/benefit assessment on other possible regulatory actions. These factors included:

- Spent Fuel Pool Safety: As mentioned above, the staff's assessment of the safety of spent fuel pools in their current configurations, discussed in COMSECY-13-0030 and the related SFP Study, concluded that SFPs provide reasonable assurance of adequate protection of the public health and safety, common defense and security, and the environment. The contributions to the overall risks introduced by spent fuel pools located at nuclear power plants were minimal and in the range for which the NRC typically takes no regulatory actions.

- Availability of Information: The staff was able to take advantage of SECY-13-0112 and previous studies to estimate the benefits of expedited transfer of spent fuel. In addition, the reports from the Electric Power Research Institute were available for cost information. In the case of the other alternatives, the staff was only able to do a limited assessment because SECY-13-0112 provides only limited technical details of these alternatives.

DISCUSSION

To provide additional information on the 1 x 8 spent fuel pattern and the likelihood of proceeding with regulatory action on this issue, the staff has conducted the following supplemental analysis in accordance with the guidelines described in NUREG/BR-0058, "Regulatory Analysis Guidelines of the U.S. Nuclear Regulatory Commission," Revision 4, dated August 2004. The Regulatory Baseline described in Section 2.1 of the enclosure to COMSECY-13-0030 is used to estimate the incremental benefits of this alternative.

Analysis Limitations

Because the SFP Study was for a BWR Mark I with an elevated pool (SFP Group 1) and included only limited analyses of a 1 x 8 spent fuel loading configuration, there is insufficient information to develop a benefit model to analyze SFP Groups 2, 3, and 4 described in COMSECY-13-0030. Furthermore, data collected in response to core offload and discharge questions is incomplete and does not provide sufficient information to estimate costs to implement a 1 x 8 high-density loading pattern at the SFP Group 1, 2, 3, or 4 spent fuel pools. The industry one-time implementation costs to achieve a 1 x 8 loading pattern may include the need to: 1) shuffle the fuel assemblies from the current pattern into a 1 x 8 high-density dispersal pattern without any removal of aged spent fuel, 2) perform early transfer of spent fuel to dry cask storage, or 3) perform extensive plant modifications because the existing storage rack design or configuration precludes achieving a 1 x 8 loading pattern.

Due to the limited detailed analysis of 1 x 8 spent fuel loading patterns contained in SECY-13-0112, the staff is unable to easily conduct sensitivity studies, as was done in the staff's analysis for expedited transfer of spent fuel in COMSECY-13-0030. These sensitivities, in addition to factors such as the dollars per person-rem conversion factor and consideration of consequences beyond 50 miles, would generally increase the calculated benefits of changes to loading configurations, as they did for expediting the transfer of spent fuel.

Assumptions

The staff made the following assumptions listed in Table 1(next page) to perform an order-of-magnitude estimate of the benefits of two alternative loading patterns for Boiling Water Reactors with elevated spent fuel pools (SFP Group 1) when compared to the Regulatory Baseline.

Table 1 Spent Fuel 1 x 8 Loading Alternative Benefit Analysis Assumptions

Topical Area	Major Assumption	Comment
Unavailability of Natural Circulation Air Cooling	The percent of operating cycle that natural circulation cooling is insufficient for BWRs with a fully drained elevated pool (SFP group 1) with a 1 x 8 high-density loading pattern are: • Seismic bin 3 (0.7g earthquake) – 3.4% • Seismic bin 4 (1.2g earthquake) – 100% • Cask drop event – 100% • All other initiators – 100%	For BWRs with an elevated pool, the SFP Study analyzed that there is adequate air cooling of a 1 x 8 loading pattern configured by the end of operating cycle phase 2 (within 25 days) such that a spent fuel pool fire is not expected to occur (e.g., 25/730 = 3.4%). For other events, there may be insufficient air cooling available resulting from partial drain down scenarios. These estimates are consistent with COMSECY-13-0030 assumptions.
Cs-137 Release Fraction	To address the range of possible release fractions based on insights from SFP Study, the following estimates are used: • Regulatory baseline – 40% • 1 x 8 high-density spent fuel pool loading alternative – 20% • Expedited Spent Fuel Transfer (low-density 1 x 4 loading) alternative – 3%	The SFP Study calculated that 25 days after spent fuel is placed from the reactor into the spent fuel pool in a 1 x 8 loading pattern, there is adequate cooling to prevent a spent fuel fire for the scenario evaluated. The SFP Study calculated that for the high-density 1 x 4 loading pattern (Regulatory baseline alternative), the calculated cesium release fractions could range from 3% to 90%, with a base case estimate of 40% as analyzed in COMSECY-13-0030. The 1 x 8 loading configuration was judged to have a similar cesium release fraction as the regulatory baseline (i.e., high density 1x4) during the first 8 days (during Operating Cycle Phase 1 (OCP 1) as defined in Table 16 of the SFP Study). For OCP2 (between 8 to 25 days), the 1x8 base case calculation in SFP Study and additional sensitivity calculations showed a range of release fractions, resulting in a representative release fraction of 20%. The expedited spent fuel transfer alternative retained the 3-percent release fraction analyzed in COMSECY-13-0030.
Mitigation	No successful mitigation is assumed for any of the alternatives.	Although mitigation is likely to be successful, no mitigation is assumed for either alternative.
Spent fuel pool inventory	Regulatory baseline & 1 x 8 high-density spent fuel loading alternatives – 3,055 fuel assemblies Expedited Spent Fuel Transfer (low-density 1 x 4 loading) alternative – 852 fuel assemblies	The staff assumes the reactor core for a single unit BWR Mark I or Mark II reactor contains 764 assemblies and the SFP has a capacity of approximately 3,055 assemblies in a high-density loading pattern. This number is based on a pool capacity of 3,819 assemblies, reduced by 764 assemblies to accommodate a full core offload capability using the existing high-density racking. For the Expedited Spent Fuel Transfer alternative, the SFP stores 852 assemblies in which the newly discharged spent fuel is arranged in a low-density 1 x 4 configuration and the remaining fuel assemblies arranged in a checkerboard pattern.

Safety Goal Screening

As part of this supplemental regulatory analysis, the risks associated with a severe SFP accident at the plants studied are compared to the Commission's 1986 Safety Goal Policy Statement [51 FR 30028] to determine if requiring the 1 x 8 spent fuel pattern would provide more than a minor safety benefit. As there is limited information available to inform a direct comparison of the safety reduction from a 1 x 8 spent fuel pattern, the staff is relying on the safety goal screening evaluation conducted in Enclosure 1 of COMSECY-13-0030. This safety goal screening conservatively estimated the highest potential reduction in risk resulting in a spent fuel pool accident and compared it to the quantitative health objectives, as part of the Safety Goal Policy Statement. The safety goal screening evaluation in COMSECY-13-0030 concluded that SFP accidents are a small contributor to the overall risks for public health and safety (less than one percent of the QHOs). If the staff would conservatively assume that requiring a 1 x 8 spent fuel pattern would have as much of an effect as expedited transfer, the safety goal screening would still not be met. SECY-13-0112 showed that the 1 x 8 spent fuel pattern can reduce the risk of a potential spent fuel pool accident, but it also showed that conducting expedited transfer of spent fuel to dry cask storage would have more of an impact on lowering the risk. Therefore, the staff concludes that any reductions in risk associated with requiring a 1 x 8 spent fuel pattern would only have a marginal safety benefit.

Cost/Benefit Assessment

Applying the above assumptions provides for the following estimate of the relative benefits of the 1 x 8 high-density loading pattern alternative and the expedited spent fuel transfer alternative when compared to the regulatory baseline.

Table 2 Base Case Comparison of Benefits using $2k per person-rem conversion factor[1] and consequences within 50 miles for Boiling Water Reactors with an elevated pool

Attribute	SFP Group 1	
	Expedited Spent Fuel Transfer	1 x 8 Loading Configuration
Public Health (Accident)	$1,620,000	$480,000
Occupational Health (Accident)	$10,000	$10,000
Offsite Property	$5,350,000	$1,850,000
Onsite Property	$40,000	$40,000
Total Benefits	$7,020,000	$2,380,000

As shown in Table 2, the 1 x 8 loading configuration provides approximately one-third of the calculated benefits for the Boiling Water Reactors with an elevated pool (e.g., SFP Group 1), when compared to the calculated benefits for the 1 x 4 expedited spent fuel transfer alternative. Data was not available to perform a similar analysis for the other pool types.

As acknowledged in COMSECY-13-0030, the costs to achieve a 1 x 8 loading pattern is expected to be significantly less than moving to low density loading patterns. However, the rough estimate shows that these costs must be less than $2.4 million of the averted costs (i.e., benefits) shown in Table 2 to be cost-beneficial. Although sufficient data was not available to explicitly estimate costs for plant operators to implement and maintain a 1 x 8 loading pattern,

[1] The NRC staff is currently in the process of updating the dollar person rem conversion factor as described in SECY-14-0002, "Plan for Updating the U.S. Nuclear Regulatory Commission's Cost-Benefit Guidance," dated January 2, 2014.

it is the staff's opinion that the costs to shuffle fuel and/or perform early cask loadings is likely to exceed this amount. The staff acknowledges that if sensitivity studies were to be conducted (i.e. consideration of consequences beyond 50 miles and dollars per person-rem conversion factor) that some combinations of estimates for important parameters can result in large economic consequences, such that the calculated benefits from a 1 x 8 spent fuel loading pattern could outweigh the associated costs. However, even if it is determined through cost-benefit analysis that the potential benefits from implementing the 1 x 8 spent fuel loading pattern exceed the expected industry costs, available information continues to support the staff's conclusion that the safety benefits do not satisfy the routine thresholds established by the NRC for imposing additional regulatory requirements.

CONCLUSION

The staff prepared this addendum to the regulatory analysis in COMSECY-13-0030 to more fully document the staff's conclusion that the 1 x 8 spent fuel loading pattern does not provide a substantial increase in safety. The safety goal screening evaluation provided in this addendum concludes that SFP accidents are a small contributor to the overall risks for public health and safety (less than one percent of the QHOs) and therefore any reductions in risk associated with the 1 x 8 spent fuel loading pattern would only have a marginal safety benefit. Although the regulatory analysis guidelines would normally stop the evaluation at this step because the risk is a small fraction of the safety goals, the staff proceeded to perform a cost-benefit analysis to provide complete documentation of this issue. The staff's cost-benefit analysis finds that the potential safety benefits associated with the 1 x 8 spent fuel loading pattern would likely be surpassed by the costs involved with achieving such a requirement. As such, the staff concluded that no further regulatory action is justified in this area.