**Questions Associated with Loss-of-Coolant Accident (LOCA) Frequency Analysis**

1. Is there an updated document since presentation in July that fully describes the LOCA frequency estimation and provides an example with the latest approach for calculating these frequencies? Please explain.

STP Response: An updated report and expected final report for the 2011 scope of work on the LOCA frequency task has been completed and is provided as an attachment to these responses. There are significant changes and additional information contained in this report compared with the last version which was limited to developing a few examples.

2. Can the differences between the method for calculating frequencies in the July meeting be compared to what's currently being done be summarized and rationale provided for the reason for the change? Please explain.

STP Response: First it should be emphasized that the information provided in the July meeting was based on a work in progress rather than a completed and reviewed analysis. The approach described in the attached report has been completed and reviewed with many more details provided. The main differences in the approach compared to the information provided in July including the following:

- We have been able to analyze the information from the expert questionnaires that were used as input to NUREG-1829 compared to last time. In July our evaluation of NUREG-1829 had not yet been completed and was based on information contained in the report.
- The work reflected in the current report benefits from an independent technical review by Dr. Ali Mosleh. Dr. Mosleh will brief the NRC on the results of his review at the public phone call on June 3.
- We have evaluated different methods for developing a composite distribution of the NUREG-1829 expert inputs including the mixture distribution method and the geometric mean method. With the benefit of recommendations from Dr. Mosleh we have settled on a specific method for development of composite distribution using a particular geometric mean method, which is described in the report.
- We have revised our approach for selecting our target LOCA frequencies using a mixture distribution of the geometric mean composite distribution and the Lydell Base Case results again using a recommendation from Dr. Mosleh. This is described in our report.
- We have now applied our method to about 775 weld locations in the STP Class 1 pressure boundary. We have addressed these locations using 45 different LOCA frequency models based on combinations of system type, weld type, degradation mechanisms, and pipe size.
- We have developed a "bottom-up" estimate of LOCA frequencies for pipe induced LOCAs only (non-pipe contributions coming next year if needed) and have compared our results to NUREG-1829 and the comparison indicates reasonably good agreement. Details are in the report.

3. Please explain how are LOCAs due to seismic effects considered?

STP Response: LOCAs due to seismic events are not addressed within the scope of the LOCA frequency task in 2011 and will be considered in 2012 if necessary. Some preliminary thoughts on this question are included as follows.

- The seismic hazard curves for the STP site are relatively low compared to other US sites.
- LOCAs due to seismic events will need to be considered within the context of a seismic PRA in order to account for seismic induced failures other than just causing a LOCA. There was a seismic PRA completed for STP previously but we have not yet analyzed the results of that study for insights into GSI-191.
- One insight that can be offered from seismic PRAs is that large pipe breaks from a seismic event are more likely to occur as a result of failures of supports of large components (e.g. reactor pressure vessel, steam generators, etc. connected to the pipes rather than pipe failure per se. If all the large components' supports remain intact, the likelihood of a pipe break by itself is rather small.
- If a seismic event were severe enough to cause a LOCA of appreciable size, there is a significant probability that the break would be in multiple locations and the capability of mitigation via operation of the ECCS, for those sequences where the ECCS equipment and its support systems are not damaged by the earthquake, would be questionable.
- Seismic event sequences that involve a LOCA with a high potential for mitigation via the ECCS, such that the debris induced ECCS failure could be risk significant, are likely to be confined to small breaks ;e.g. failures of individual impulse lines . The importance of sump recirculation as a success path in such sequences may be reduced by depressurization of the RCS to permit closed loop RHR cooling, and thereby limiting the rate of leakage. In order to produce a seismic induced LOCA that is risk significant for the GSI-191 issue the following conditions must be satisfied:
    - The Seismic event causes a LOCA
    - The LOCA is within the success criteria of either the ECCS or of the PD charging pump (otherwise it leads directly to core damage and the question of debris formation is moot)
    - The seismic event does not cause failure of all the equipment capable of mitigating the LOCA including the equipment's support systems (otherwise core damage is certain and the question of debris formation is moot).

The above thoughts are only preliminary and the final evaluation of seismic induced LOCAs is deferred to 2012.

4. Please explain how at South Texas Project (STP, Units 1 and 2 the modeled degradation mechanisms (DMs) at each joint are comprehensive if there is no prior history of that mechanism at a piping location, or the particular piping location has never been inspected? Is

this rectified with the Risk-Informed Inservice Inspection (RI-ISI) expert judgment process at each plant?

STP Response: DM screening criteria were developed by EPRI for RI-ISI evaluations and this approach was applied to STP Class 1 piping in 2001. The screening criteria are documented in the EPRI Topical Report (Reference [9] in the current report) and are designed to conservatively rule out the potential for damage mechanisms. These are conservative and do not necessarily mean that if a pipe is inspected that actual degradation will be found. These criteria were accepted for use in RI-ISI evaluations by the NRC.

Have the DMs modeled for each joint been compared with more expansive studies such as Electric Power Research Institute's (EPRIs) materials degradation matrix (MDM) and the NRC's proactive materials degradation assessment (PMDA) (i.e., NUREG/CR-6923) assessments to ensure assessment of all possible mechanisms?

STP Response: Our assessment accounts for the STP-1/2 RI-ISI DM Analysis, relevant EPRI MRP information, SCAP-SCC, PMDA, OPDE, PIPExp and other relevant knowledge bases. A complete set of DM references is included in our report.

How do you know that certain mechanisms (i.e., thermal fatigue (TF) and vibration fatigue (VF)) can't occur at a specific location?

STP Response: the STP-1/2 DM Analysis addresses the potential for degradation at all locations. In addition our failure data query accounts for all DMs identified in the industry service data. All locations are assumed to be subjected to failure due to design and construction defects even if no degradation potential is identified. Finally, the strong emphasis placed on uncertainty analysis and in the use of expert elicitation data in our LOCA frequency method is intended to address such unknowns.

5. Please explain how mitigation of primary water stress corrosion cracking (PWSCC) is considered in the analysis to determine LOCA frequencies at STP, Units 1 and 2, especially for hot legs and cold legs as no mitigation methods have been identified for these systems in the information provided to date?

STP Response: STP has applied weld overlays to mitigate PWSCC at several B-F weld locations at the pressurizer, however no mitigation has been applied to other B-F welds susceptible to PWSCC. In the case of the weld overlays at the pressurizer, we have analyzed those using conservative assumptions by applying a design and construction defect failure rate to the weld overlay while ignoring the underlying material that may have degraded due to PWSCC. For unmitigated welds in the hot legs and cold legs, we have developed and applied PWSCC failure rates based on the service data. These locations have the highest LOCA frequencies in our evaluation and the details are documented in our report. (STP Reference Document NOC-AE-06002099, which is available for download from NRC-ADAMS).

6. Currently, each DM at a specific piping location is combined independently to determine the LOCA frequency distribution for that weld joint location. Please explain how are the synergistic effects of multiple DMs on either the failure frequency or the conditional probability of rupture considered? For example, TF could initiate at a design and construction (D&C) flaw and possibly combine with PWSCC to accelerate the degradation rate compared to each DM rate considered independently so that the failure frequency is increased. Also, the degradation may evolve in a manner that affects the likelihood of rupture.

STP Response: All failures that we observe in the failure data are believed to be the result of synergistic effects, e.g., PWSCC in dissimilar metal welds are pre-empted by D&C. When we list a given failure event as caused by, say, thermal fatigue, that is based on an assessment of what the predominate cause of failure is. When the root cause analysis identifies a specific error in design or fabrication, the cause is typically listed as "Design and Construction Defect" even though there may have been some kind of fatigue or corrosion or both that contributed to the actual failure. Most if not all pipe failures involve a combination of imperfections in the design and fabrication of the component and some kind of damage mechanism. Our analysis starts with review of DM Analysis results, followed by service experience review. We have not seen TF (as in cycling, stratification) combining with PWSCC. To the best of our knowledge, there are but a few known instances in BWR plants where TF has combined with IGSCC.

There are a subset of welds that were evaluated in the EPRI RI-ISI program that were found to be susceptible to two or more damage mechanisms (excluding design and construction defects, which we find to be applicable to all welds). Once we determine which locations in the Class 1 pressure boundary are most sensitive to debris formation risk, we plan to do sensitivity studies to evaluate the possible impact of synergy.

7. The approach for determining LOCA frequencies combines Lydell's base case results from NUREG-1829 with the distributions from all the experts. However, Lydell's estimates are part of the community of results. Doesn't this approach double-count Lydell's estimates? Please explain why is it appropriate to combine Lydell's estimates for specific DMs with the total LOCA frequency results (i.e., from all DMs) in NUREG-1829?

STP Response: It is true that our approach to selecting our target LOCA frequencies combines a composite distribution of a community of experts, which includes Lydell's input, and a separate Base Case analysis of Lydell for the same selected components ( hot leg, cold leg, surge line, HPI line). Lydell was one of nine experts providing input to the composite distribution. We do not agree that this constitutes double counting and believe its reasonable for the following reasons:

- Lydell's input to the community distribution was part of an expert elicitation for LOCA frequencies for the entire US industry of PWRs, whereas his base case analysis was for a specific 3-loop PWR design with assumed design characteristics. Hence the Base Case analysis and the input to the community distribution are not equivalent – related, but not equivalent.

- The expert composite distribution and the Lydell Base case analyses are viewed as two distinct models or approaches for developing LOCA frequencies. Hence it is appropriate to use both of them and to assign them equal weight to form our LOCA frequency distributions.
- The net effect of using both sets of inputs to forming our target LOCA frequency distribution is to increase the level of uncertainty which we believe is appropriate for this application which is seeking to quantify localized LOCA frequencies rather than total LOCA frequencies as in NUREG-1829.
- The final STP results for total LOCA frequency are found to be in reasonable agreement with those from NUREG-1829 when looking at pipe induced LOCAs.
- The above arguments notwithstanding, we have added a sensitivity analysis to the LOCA frequency report (Final Revision 1 which is being provided with these answers) to investigate the impact of removing Lydell's input from the community distribution and re-computing the CRP distributions using the methodology described in the base set of analyses. This sensitivity analysis shows that there are insignificant changes to the CRP distributions for the hot leg, cold leg and HPI line, and small changes for the surge line case which are not large enough to impact the results. Hence we have shown that the results are not sensitive to the issue raised in this question. Details are found in the revised report.

8. Please explain how were Lydell's estimates for multiple base cases added to form a single distribution? How were systems and DM that weren't part of Lydell's base case estimates analyzed?

STP Response: We did not combine Lydell estimates for different base cases together to form a single distribution. The base case analyses were developed just like they were in Appendix D of NUREG-1829. Separate target LOCA frequencies were developed for each of the 3 PWR base cases in NUREG-1829, namely the hot leg, surge line, and HPI line. We added another base case for the cold leg using the same approach as he used for the other components. We then derived the conditional rupture probability distributions from the target LOCA frequencies and the Lydell failure rate models. This resulted in 4 separate CRP models, one based on each of the hot leg, cold leg, surge line, and HPI line. The latter CRP model was used for each of the remaining small and medium bore piping systems. The details are described in our report.

9. Please more fully explain how composite LOCA frequency distributions are developed from the individual expert LOCA frequency distributions from NUREG-1829?

STP Response: We developed a composite distribution from the nine expert input sets of distributions using a geometric mean method that is fully described in our report.

How situations where the expert didn't provide any information for a particular system in NUREG-1829 are addressed, since the experts weren't required to assess all systems (only those that they thought were most important were assessed)?

STP Response: We only used expert inputs from NUREG-1829 for the hot leg, cold leg, surge line, and HPI line (the version with volume injection). For each of these all 9 experts who provided component level inputs provided the necessary input data.

10. Please verify that debris from vessel rupture is not considered in the GSI-191 analysis to determine plant debris sources, but is part of the general probabilistic risk assessment (PRA) modeling that is unaffected by plant changes to address GSI-191 resolution? If so, why is not considering vessel rupture as a debris source term appropriate?

STP Response: In the 2011 work scope only pipe induced LOCAs are being considered. LOCAs due to non-pipe components are to be addressed in 2012. This will include components attached to the reactor pressure vessel and other non-pipe components in the RCS pressure boundary. Vessel rupture is modeled in the PRA but is assumed to lead directly to core damage. Consideration of scenarios involving failure of vessel components that are within the capability of the ECCS will be considered in 2012.

11. Please more fully explain how the prior distributions in Step 4 (i.e., slide 6 in the presentation dated 8/22/11 for pre-licensing meeting) are determined?

STP Response: The priors were developed using gross industry data estimates for the means and an assumed range factor of 100. The range factor is based on early estimates of pipe break frequencies prior to the analysis of LWR service data (Wash-1400 era estimates). The technical basis is in EPRI TR-111880 and this was reviewed by the NRC as part of the RI-ISI review.

12. Please more fully explain the differences between the worst-case percentile method and the mixture distribution method (i.e., slides 11 – 13 in presentation dated 8/22/11 for pre-licensing meeting)?

STP response: The worst case percentile method is a heuristic method comprised of taking the highest of the 95%tiles of two distributions and the lowest of the 5%tiles of the same distributions to define a third distribution that is assumed to be lognormal, whose 95%tile is the maximum of the input 95%tiles and whose 5%tile is the minimum of the input 5%tiles. This was used to develop a first cut evaluation that was presented at the July meeting. Dr. Mosleh recommended that instead of this that we use a mixture distribution of the two input distribution, which is more internally consistent with our methodology. In the mixture distribution method we create a discrete distribution with 50% probability placed on one distribution and 50% on the other and in the Monte Carlo sampling process we sample from this discrete distribution to decide which input distribution to sample a number from. When comparing the results of the two distributions the mixture distribution produces a somewhat tighter distribution than the worst case percentile method, I,e. the resulting 95%tile is somewhat lower and the 5%tile is somewhat higher. On Monday we will discuss this in more detail.