UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001

November 13, 2007

MEMORANDUM TO: ACRS Members

FROM: Girija Shukla, Senior Program Manager **/RA/**
Reactor Safety Branch, ACRS

SUBJECT: TRANSMITTAL OF STATUS REPORT, AND PROPOSED SCHEDULE FOR THE RELIABILITY AND PRA SUBCOMMITTEE MEETING REGARDING ESTIMATING LOSS-OF-COOLANT ACCIDENT (LOCA) FREQUENCIES THROUGH THE ELICITATION PROCES, AND SEISMIC CONSIDERATIONS FOR THE TRANSITION BREAK SIZE ON NOVEMBER 27, 2007

The Reliability and PRA Subcommittee will meet on November 27, 2007, to discuss estimating Loss-of-Coolant Accident (LOCA) frequencies through the elicitation process, and seismic considerations for the transition break size. The full Committee will also discuss this at the December 6-8, 2007 ACRS meeting.

Attendance by the following members is anticipated at the November 27, 2007, Subcommittee meeting:

| | | |
|---|---|---|
| Apostolakis | Bonaca | Shack |
| Bley | Maynard | Stetkar |

To prepare for this meeting, the following information is attached:

1. Status Report
2. Proposed Schedule for November 27, 2007, Subcommittee meeting
3. Proposed Schedule for December 6-8, 2007, full Committee meeting

The following review materials were provided on November 5, 2007:

1. NUREG-1829, “Estimating Loss-of-Coolant Accident (LOCA) Frequencies through the Elicitation Process” and associated Appendixes A through M.

2. NUREG-XXXX, “Seismic Considerations for the Transition Break Size”

If you have any questions, please contact me at (301) 415-6855 or by email at gss@nrc.gov.

cc w/o Attachments: F. Gillespie
S. Duraiswamy
C. Santos

**ADVISORY COMMITTEE ON REACTOR SAFEGUARDS**
**THE RELIABILITY AND PRA SUBCOMMITTEE MEETING**
**ROCKVILLE, MD**
**NOVEMBER 27, 2007**

## STATUS REPORT

PURPOSE

The purpose of this Subcommittee meeting is to review the NUREG-1829 on estimating LOCA frequencies through the elicitation process, and the NUREG-XXXX on seismic considerations for the transition break size. The full Committee will also discuss this matter in the 548th ACRS meeting during December 6-8, 2007.

BACKGROUND

The Subcommittee on Regulatory Policies and Practices reviewed the draft NUREG report, "Estimating Loss-of-Coolant Accident (LOCA) Frequencies through the Elicitation Process," during a meeting on November 16, 2004. During the 518th meeting on December 2-4, 2004, the Committee reviewed the draft NUREG report and recommended that it should be revised prior to being issued for public comment.

During the 520th meeting on March 3-5, 2005, the Committee reviewed the revised draft NUREG report and recommended that the revised draft NUREG report should be issued for public comment. During the 537$^{th}$ meeting on November 1-3, 2006, the Committee reviewed the proposed draft final rule to risk-inform 10 CFR 50.46 and recommended, in part, that NUREG-1829 should be completed before the revised rule is issued.

NUREG-1829 was completed and issued for public comments and comments have been incorporated in the report. This NUREG will be finalized after the ACRS review.

- **NUREG-1829, "Estimating Loss-of-Coolant Accident (LOCA) Frequencies Through the Elicitation Process"**

In a staff requirements memorandum (SRM) dated March 31, 2003, the Commission directed the staff to develop a risk-informed alternative to the current requirements in 10 CFR 50.46 related to the analysis of the performance of ECCS during LOCAs. The focus of this effort is the selection of a risk-informed transition break size (TBS) for the alternative design-basis LOCA. In an SRM dated July 1, 2004, the Commission directed the staff to use LOCA frequencies derived from an expert-opinion elicitation process, supported by historical data and fracture mechanics and other relevant information to determine an appropriate alternative break size. This alternative break size could be the break size that has a mean frequency of occurrence of 1 05 per reactor year.

Expert-opinion-based probability distributions of uncertain quantities have been used extensively in probabilistic risk assessments (PRAs) starting with WASH-1400. The NUREG-1150, "Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants," dated December 1990, studies formalized the process of elicitation and utilization of expert judgments.

Loss-of-coolant accident (LOCA) frequencies (i.e., the estimated frequencies of pipe rupture as a function of pipe size) are used in a variety of regulatory applications, including PRA. Currently, the NRC is using such information to develop a risk-informed alternative to the ECCS requirements in 10 CFR 50.46. Current requirements consider pipe breaks in the reactor coolant pressure boundary, up to and including breaks equivalent in size to the double-ended rupture of the largest pipe in the reactor coolant system. One aspect of this activity is to evaluate the technical adequacy of redefining the design-basis break size (the largest pipe size described in 10 CFR 50.46) to a smaller size that is consistent with the estimated frequency of pipe failures as a function of pipe size.

To provide the technical basis for a risk-informed definition of the design-basis break size, this study developed LOCA frequency estimates using an expert elicitation process. This process consolidated service history data and insights from probabilistic fracture mechanics studies with knowledge of plant design, operation, and material performance. This elicitation process is well-recognized for quantifying phenomenological knowledge when modeling approaches or data are insufficient. The process used in this study is an adaptation of the formal expert judgment process used in NUREG-1150.

The results from the expert elicitation provide separate LOCA frequency estimates for piping and nonpiping passive systems, as a function of effective break size and operating time through the end of license extension, for both boiling-water and pressurized-water reactors. In addition, this study considered the sensitivity of the results to various analysis approaches. The greatest sensitivity, and therefore the greatest uncertainty, is a function of the method used to aggregate the individual panelists' estimates to obtain group estimates. The ranges of results from the sensitivity analyses have been used as a baseline for defining the transition break size in the proposed risk-informed alternative to 10 CFR 50.46.

- **NUREG-XXXX, “Seismic Considerations for the Transition Break Size”**

This report has been issued for public comments and comments have been incorporated in the report. This report will be finalized after the ACRS review.

The NRC staff has been considering revision of the regulatory requirements for the ECCS, as set forth in 10 CFR 50.46; Appendix K to 10 CFR Part 50; and General Design Criterion (GDC) 35. In particular, those requirements state that the ECCS shall be sized to provide adequate makeup water to compensate for a break of the largest diameter pipe in the primary system [i.e., the so-called “double-ended guillotine break” (DEGB)].

Consequently, in order to risk-inform the break size, the NRC staff proposed the concept of transition break size (TBS). In addition, the NRC developed pipe break frequencies as a function of break size using an expert elicitation process for degradation-related pipe breaks in reactor coolant systems of typical boiling- and pressurized-water reactors. That elicitation focused on determining event frequencies that initiate by unisolable primary side failures that can be exacerbated by material degradation with age under normal operating conditions. The purpose of this study was to assess potential seismic effects on the postulated TBS, and to provide information to facilitate review and comment regarding the proposed risk-informed revision of ECCS requirements in 10 CFR 50.46. Thus, this report evaluates the seismic effects, using different approaches to evaluate flawed and unflawed piping, and indirect failures of other components and component supports that could lead to piping failure.

DISCUSSION

- **NUREG-1829, "Estimating Loss-of-Coolant Accident (LOCA) Frequencies Through the Elicitation Process"**

The ECCS requirements are contained in 10 CFR 50.46, Appendix K to part 50, and GDC 35. Consideration of an instantaneous break with a flow rate equivalent to a double-ended guillotine break (DEGB) of the largest primary system in the plant generally provides the limiting condition in the required ECCS analysis. However, the DEGB is widely recognized as an extremely unlikely event. Therefore, the NRC is developing a risk informed revision of the design-basis break size requirements for operating commercial nuclear power plants. A central consideration in selecting a risk-informed design basis break size is an understanding of the LOCA frequency as a function of break size.

LOCA frequency estimates have been developed using an expert elicitation process to consolidate service history data and insights from PFM studies with knowledge of plant design, operation, and material performance. This elicitation process is well-recognized for quantifying phenomenological knowledge when data or modeling approaches are insufficient. Separate BWR and PWR piping and non-piping passive system LOCA frequency estimates have been developed as a function of effective break size and operating time through the end of license extension. The elicitation focused solely on determining event frequencies that initiate by unisolable primary system side failures that can be exacerbated by material degradation with age. The expert elicitation process employed in this study is an adaptation of the formal expert judgment process used in NUREG-1150. This current elicitation process included the decomposition of the complex technical issues which impact LOCA frequencies into fundamental elements in order to more easily assess these important contributing factors. The elicitation process required each member of the elicitation panel to qualitatively and quantitatively assess these LOCA contributing factors and also indicate their uncertainty in this assessment. This information was collected from each panelist in an individual elicitation session.

The qualitative insights provided by the panel members are reasonably consistent. Most panelists agreed that a complete break of a smaller pipe, or non-piping component, is more likely than an equivalent size opening in a larger pipe, or component. Many panelists thought that aging may have the greatest effect on intermediate diameter (6 to 14-inch nominal diameter) piping systems due to the large number of components within this size range and the fact that this piping generally receives less attention than larger diameter piping and is harder to replace than the more degradation-prone smaller diameter piping.

Frequency estimates are not expected to change dramatically over the next fifteen years, or even the next thirty-five years. While aging will continue, the consensus is that mitigation procedures are in place, or will be implemented in a timely manner, to alleviate possible LOCA frequency increases.

The quantitative responses were analyzed separately for each panel member to develop individual BWR and PWR total LOCA frequency estimates of the mean, median, 5th and 95th percentiles. The LOCA frequencies for the individual panelists were then aggregated to obtain group LOCA frequency estimates, along with measures of panel diversity. While there was general qualitative agreement among the panelists about important technical issues and LOCA contributing factors, the individual quantitative estimates are much more variable. Additionally, as the LOCA size increased, the panel members generally expressed greater uncertainty in

their predictions, and the variability among individual panelists' estimates increased. Both trends are expected given the underlying scientific uncertainty.

The elicitation LOCA frequency estimates are generally much less than the prior WASH-1400 estimates and more consistent with the NUREG/CR-5750 estimates. The small break (SB) LOCA frequency estimates are similar once the steam generator tube rupture frequencies are added to the NUREG/CR-5750 PWR results. The elicitation medium break LOCA estimates are higher than the NUREG/CR-5750 estimates by factors of approximately 4 and 20 for BWR and PWR plant types, respectively. These increases are partly due to PWSCC of piping and nonpiping (CRDM) components, as well as the general aging concerns with piping in this size range. The NUREG/CR-5750 LB LOCA frequency estimates, most comparable to the elicitation LOCA Category 4, tend to be slightly higher (approximately a factor of 3) than the current elicitation results.

Sensitivity analyses were conducted to examine the robustness of the quantitative results to the analysis procedure. These sensitivity analyses investigated the effect of distribution shape on the mean, correlation structure, panelist overconfidence, panel diversity measure, and aggregation method on the estimated parameters. The mean calculation used a split lognormal distribution truncated at the 99.9th percentile to obtain reasonably conservative values. The correlation structure assumed maximal correlation, which the NUREG states is reasonably representative of the elicitation structure and provides conservative 95th percentile estimates. However, based on selected Monte Carlo simulations, assuming an independent correlation structure results in larger median and 5th percentile estimates. The means are unaffected by the correlation structure. The analysis procedure adjusted some panelists' responses that had relatively narrow uncertainty ranges to account for a known tendency for people to be overconfident when making subjective judgments.

Sensitivity analyses examined the effects of other overconfidence adjustments as well as no adjustment of the nominal subjective confidence levels supplied by the panelists. The NUREG states that while blanket overconfidence adjustments can result in large, unsupportable increases in the frequency estimates, no adjustment results in modest decreases in the mean and 95th percentile estimates. The analysis procedure used confidence intervals for the aggregated estimates as a measure of panel diversity to reflect variability in the individual estimates. An alternative approach used quartiles of the individual estimates, leading to comparable but narrower intervals.

Finally, the largest sensitivity is to the method used to aggregate the individual panelist estimates to obtain group estimates. The analysis procedure used the geometric mean. Arithmetic mean or mixture distribution aggregation can lead to significantly higher mean and 95th percentile estimates. The NUREG states that the analysis procedure develops consensus-type results which are designed to best represent the panel's state of knowledge regarding LOCA frequencies for the stated study objectives.

The NUREG states that the mixture distribution method does not represent a consensus-type group estimate; rather, it is based on the fundamental assumptions that the panel is a random sample from the population of all experts and that the goal is to obtain an unbiased estimate of the aggregate distribution function of LOCA frequency averaged over the population of all experts. The NUREG states that while chosen to be broadly representative of the international community, the selected panel of 12 panelists is not a random sample from this community, and that consequently, there is no basis for extrapolating the study results to the population of all experts.

- **NUREG-XXXX, "Seismic Considerations for the Transition Break Size"**

LOCA frequencies (i.e., the estimated frequencies of pipe rupture as a function of pipe size) are used in a variety of regulatory applications, including PRAs. Currently, the NRC is using such information to develop a risk-informed alternative to the ECCS requirements in 10 CFR 50.46. Current requirements consider pipe breaks in the reactor coolant pressure boundary, up to and including breaks equivalent in size to the double-ended rupture of the largest pipe in the reactor coolant system.

To provide the technical basis for a risk-informed alternative, the NRC staff developed LOCA frequency estimates using an expert elicitation process. This process consolidated service history data and insights from probabilistic fracture mechanics studies with knowledge of plant design, operation, and material performance. This elicitation process is well-recognized for quantifying phenomenological knowledge when modeling approaches or data are insufficient. This elicitation focused on determining event frequencies that initiate by unisolable primary side failures that can be exacerbated by material degradation with age under normal operating conditions.

On the basis of the expert elicitation, the NRC staff established a baseline break size corresponding to a break frequency of once per 100,000 years (i.e., $10^{-5}$ per year). The staff then adjusted this baseline break size to account for other significant contributing factors that were not explicitly addressed in the expert elicitation to define an alternative risk-informed break size, termed transition break size (TBS). In addition, because the elicitation did not include effects of rare event loadings, such as seismic events, a separate study was undertaken to assess potential seismic effects on the postulated TBS. This report describes the results of this study.

Ideally, to make this study directly comparable with the elicitation, it would be desirable to produce results of this study in terms of the conditional probabilities of break sizes for piping of various diameters, given the occurrence of postulated seismic events associated with different frequencies (i.e., once per 1,000 years, once per 10,000 years, etc.). However, for this study, the staff adopted a hybrid deterministic and probabilistic approach to evaluate flawed and unflawed piping, and indirect failures of other components or component supports that could lead to piping failure. In particular, the study for flawed piping was directed to address the question of what the critical flaw sizes would be in the large piping systems associated with stresses resulting from seismic loads with a frequency of occurrence of $10^{-5}$ per year and $10^{-6}$ per year. This question focuses on the extent of degradation that would have to be present in a piping system to affect the TBS.

The results of this study indicate that the critical flaws associated with the stresses induced by seismic events with an annual probability of exceedance of $10^{-5}$ and $10^{-6}$ are generally large and, coupled with other mitigative aspects, the probabilities of pipe breaks larger than the TBS are likely to be less than $10^{-5}$ per year.

Inclusion in a PRA of the passive components that are subject to time-dependent degradation and accidental loads presents significant challenges and requires in-depth understanding and data related to the degradation mechanisms and failure modes. The approach used in this study could serve to determine the extent at which degradation of a component becomes risk-significant, and whether such degradation can be managed so that the component failure probabilities remain low.

POTENTIAL ISSUES FOR DISCUSSION

- A reasonable criticism of any expert elicitation process is that the resulting estimates are extrapolated where little or no data is available. The results are somewhat based on expert opinion, not on physical observations (from which "data" is usually taken). Therefore, the treatment of the results as data and the aggregation of the individual estimates may not lend itself as a well-posed exercise (at least in a physical observation sense). In the end, there are arguments for such a process, and against it, but one may be reasonable to believe that the estimates are either more certain or less certain than one may calculate in a statistical evaluation.

- It is not clear if the recent experience with PWSCC at Wolf Creek and other plants invalidates any of the estimates in any way, since this experience was not available during the expert elicitation. At the time of the elicitation, the observed PWSCC was limited mostly to short, axial cracks, not the long, deep, circumferential cracks found at Wolf Creek.

- The frequencies of occurrence of seismically induced LOCAs are based on earlier seismic hazard estimates. More recently, GSI-199 has generated updated seismic hazard estimates which are generally larger than the earlier estimates. Is there margin in the estimated frequencies of occurrence of seismically induced LOCAs which would offset the effects of the larger GSI-199 hazard estimates?

EXPECTED SUBCOMMITTEE ACTION

During the upcoming meeting on November 27, 2007, the Subcommittee will be expected to review these NUREG reports on the estimation of frequencies of occurrence of LOCA through the expert elicitation process, and seismic considerations for the transition break size, and report its recommendations to the full Committee for its consideration at the 548th ACRS meeting during December 6-8, 2007.

References:

1. NUREG-1829, "Estimating Loss-of-Coolant Accident (LOCA) Frequencies Through the Elicitation Process" and associated Appendixes A through M.

2. NUREG-XXXX, "Seismic Considerations for the Transition Break Size"

**Advisory Committee on Reactor Safeguards**
**The Reliability and PRA Subcommittee Meeting**
**Rockville, MD**
**27 November 2007**

- Proposed Schedule -

Cognizant Staff Engineer: Girija Shukla (301-415-6855, gss@nrc.gov)

| | Topic | Presenter(s) | Time |
|---|---|---|---|
| | Opening Remarks | G. Apostolakis, ACRS | 8:30 - 8:35 am |
| I | Current status of 50.46 rulemaking | Dick Dudley, NRR | 8:35 - 9:00 am |
| II | Overview of NUREG-1829, "Estimating Loss-of-Coolant Accident (LOCA) Frequencies Through the Elicitation Process" | Rob Tregoning, RES<br>Lee Abramson, RES | 9:00 - 10:00 am |
| Break | | | 10:00 - 10:15 am |
| | Overview of NUREG-1829 (contd.) | Rob Tregoning, RES<br>Lee Abramson, RES | 10:15 - 11:00 am |
| III | Public comments on NUREG-1829 | Rob Tregoning, RES<br>Lee Abramson, RES | 11:00 - 12:00 pm |
| Lunch | | | 12:00 - 1:00 pm |
| | Public comments on NUREG-1829 (contd.) | Rob Tregoning, RES<br>Lee Abramson, RES | 1:00 - 1:45 pm |
| IV | Seismic Considerations For the Transition Break Size | Nilesh Chokshi, NRO | 1:45 -2:45 pm |
| Break | | | 2:45 - 3:00 pm |
| | Seismic Considerations For the Transition Break Size (contd.) | Nilesh Chokshi, NRO | 3:00 - 4:00 pm |
| V | Subcommittee Discussion | G. Apostolakis, ACRS | 4:00 - 4:45 pm |

Notes:

- Presentation time should not exceed 50% of the total time allocated for a specific item.
- An electronic copy and 35 hard copies of the presentation materials to be provided to the Subcommittee.

**Advisory Committee on Reactor Safeguards**
**NRC Staff Activities for Reliability and PRA**
**December 6-8, 2007**
**Rockville, MD**

**- Proposed Schedule -**

Cognizant Staff Engineer: Girija Shukla, gss@nrc.gov 301-415-6855

| Topics | Presenters | Time |
|---|---|---|
| **Opening Remarks** | G. Apostolakis, ACRS | 5 minutes |
| **NUREG-1829, "Estimating Loss-of-Coolant Accident (LOCA) Frequencies Through the Elicitation Process"** | Rob Tregoning, RES<br>Lee Abramson, RES | 50 minutes |
| **Seismic Considerations For the Transition Break Size** | Nilesh Chokshi, NRO | 50 minutes |
| **Committee Discussion** | G. Apostolakis, ACRS | 15 minutes |

Notes:

- Presentation time should not exceed 50% of the total time allocated for a specific item.
- An electronic copy and 35 hard copies of the presentation materials to be provided to the Subcommittee.