RISK-INFORMED APPROACH TO ADDRESS GENERIC SAFETY ISSUE-191

SOUTH TEXAS PROJECT

Transition Break Size Approach

On December 23, 2010, the U.S. Nuclear Regulatory Commission (NRC, or Commission) issued Staff Requirements Memorandum (SRM) SECY-10-0113, "Closure Options for Generic Safety Issue [GSI]-191, Assessment of Debris Accumulation on Pressurized-Water Reactor [PWR] Sump Performance" (Agencywide Documents Access and Management System (ADAMS) Accession No. ML103570354). Option 2 of that SRM focused on development of additional guidance to support a risk-informed approach that would rely on the impending proposed rulemaking for Title 10 of the *Code of Federal Regulations* (10 CFR) Section 50.46a, "Acceptance criteria for reactor coolant system venting systems," or Section 6 of Nuclear Energy Institute (NEI) 04-07, "Pressurized Water Reactor Sump Performance Evaluation Methodology." Both of these approaches reduce the loss-of-coolant accident (LOCA) break area that must be treated as a design-basis accident (DBA) through use of a transition break size (TBS). The approaches classify LOCAs smaller than the TBS as design-basis accidents, and LOCAs larger than the TBS as beyond design-basis accidents. The TBS in 10 CFR 50.46a was selected to equal the cross-sectional flow area of the inside diameter of the largest piping attached to the reactor coolant system (RCS).

The Commission approved the staff's request to withdraw the draft final rule for 10 CFR 50.46a. The staff may resubmit the rule after responding to the Commission's direction to disposition Recommendation 1 of the Near-Term Task Force review of insights from the Fukushima Dai-ichi accident. The staff expects to respond to the Commission in February 2013.

Section 6 of NEI 04-07 is still available for licensee use, and implementation of the TBS approach for GSI-191 could benefit licensees by reducing the scope of potential modifications at some remaining plants. The largest LOCAs typically have the potential to generate the most debris and are usually the limiting breaks in licensees' sump performance analyses. However, the staff has not received any requests to use the TBS approach. One reason for the seeming lack of interest may be that this approach would require separate analyses for breaks above and below the TBS using different assumptions. This would potentially require separate demonstration tests for the suction strainer. In addition, the potential benefits from using this approach may be limited because the amount of fiber that may be problematic for in-vessel effects can still be generated by LOCAs smaller than the TBS, especially in plants with large quantities of fibrous insulation. Further, the TBS approach would most likely require an exemption from 10 CFR 50.46, due to the staff's withdrawal of the draft final rule.

South Texas Project Nuclear Operating Company Approach

Because no licensee has notified the staff of intent to pilot the TBS approach, the staff has focused on the Commission's direction (from the December 23, 2010, SRM) to fully explore the policy and technical issues of how the application of a "no-transition-break-size" approach might work. The Commission referred to a December 9, 2010, letter from South Texas Project Nuclear Operating Company (STP) that stated its intent to pursue a risk-informed approach to address GSI-191. One of the main objectives of the risk-informed approach is to estimate the difference in risk (delta risk) if some or all fibrous insulation were to remain installed at the plant.

These risk estimates would be used in combination with the guidance of Regulatory Guide (RG) 1.174, "An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis," to provide a basis for GSI-191 resolution. STP has stated that the risk-informed approach would be used to target those plant modifications with the highest risk significance. It is expected that resolution of GSI-191 using this approach will require an exemption from certain requirements in 10 CFR 50.46 (if the analyses are approved by the staff).

The STP approach does not consider a TBS. The STP approach attempts to characterize the physical behavior of debris generation and transport over a full range of plausible conditions. Some aspects of GSI-191 have limited data support; thus uncertainty characterization in the form of cumulative distribution functions is an important part of the description of the 20 parameters modeled as part of the initial quantification.

The STP approach uses the software platform called Containment Accident Stochastic Analysis (CASA) Grande to compile a spectrum of time-dependent results for many thousands of postulated accident sequences to estimate the risk of flow blockage leading to core damage during recirculation scenarios. CASA Grande can process uncertainty distributions on any number of input parameters. CASA Grande evaluates multiple sizes of breaks at every weld in containment, and it always includes the double-ended guillotine break condition for every weld. Nominal times to drain the refueling water storage tank (RWST) and reach recirculation are presently used for each LOCA size category, but break-size specific times based on thermal hydraulic calculations may soon be interfaced to improve fidelity of the accident time histories. STP plans to model up to 50 parameters in the future. As the complexity of the model grows, so do the staff resources needed to perform the review. This review has the potential to be one of the most resource-intensive risk-informed reviews undertaken by the staff. The review may require resources similar to those used for the pilot for National Fire Protection Association 805, "Performance-Based Standard for Fire Protection for Light Water Reactor Electric Generating Plants."

Discussions with STP have revealed the need for experimental testing to support some of the statistical distributions used in the evaluation, especially in the area of chemical effects and head loss models. The staff's past experience in these areas is that testing to demonstrate physical models or assumptions has often produced unexpected results. Head loss is a function of the type and quantity of chemical and non-chemical debris, along with the filtering debris bed characteristics. Determining the best estimate and distributions of these parameters is challenging since the debris bed constituents, properties, and chemical effects depend on additional factors such as break location, debris transport, and temperature. In addition, testing is not able to fully simulate the post-LOCA environment. The ability to accurately model head loss, including any chemical effects, represents a key concern with this risk-informed approach. Therefore, developing a defensible technical basis with the upcoming testing in 2012 will be a critical licensee action.

Detailed review of the physical model and assumptions will be necessary because of the heavy reliance on them. STP cannot adequately model chemical effects in the probabilistic risk assessment (PRA) until it justifies its assumptions with plant-specific testing that is scheduled for 2012. The current model makes assumptions that the staff does not accept as accurate or conservative. For example, the staff does not accept the use of the NUREG/CR-6224, "Parametric Study of the Potential for BWR [Boiling Water Reactor] ECCS [Emergency Core

Cooling System] Strainer Blockage Due to LOCA Generated Debris," correlation, coupled with a chemical bump up factor, to calculate strainer head loss. The staff does not accept the strainer bypass correlation used in the initial quantification due to insufficient data. The staff does not accept the current assumption that strainer blockage will not occur if the debris bed is less than 1/8th-inch; the staff currently accepts a 1/16th-inch debris bed for this assumption. The staff does not accept the assumption that chemical effects would not be a factor for in-vessel effects in the event of a cold-side break. Also, STP has not addressed the potential effects of debris on the timing of boric acid precipitation.

STP is currently conducting two major test programs, each of which has subcategories of tests. The first test program aims to validate the head loss correlation currently being used by STP. The second is a chemical effects program intended to determine realistic chemical effects for STP under varying post-LOCA scenarios. These test programs are interrelated. Head loss tests, to validate the STP head loss model, are being performed in a vertical loop. These tests will have to model multiple potential debris load combinations to accurately predict the strainer head losses that could occur due to debris. The chemical effects test program consists of multiple short- and long-term tests to determine the potential interactions that chemical precipitates could have with debris deposited on the emergency core cooling system strainer or in the core. After the chemical effects and strainer tests are completed, STP will need to model the interaction between debris and chemicals. Because of the potential combinations of debris that can reach the strainer and core and the potential variability of the chemicals that may be produced in the post-LOCA environment, the integration of the results of the test programs into a realistic prediction of strainer and in-vessel head losses will be complex.

Uncertainty becomes more important when dealing with complex phenomena. One way to address uncertainties is with defense-in-depth and safety margins. Although STP has not explicitly addressed defense-in-depth measures in support of its proposed resolution of GSI-191, NEI submitted a letter dated March 5, 2012 (ADAMS Accession No. ML120730661), addressing defense-in-depth. NEI stated in the letter that to ensure the availability of adequate defense-in-depth measures, it is important that PWRs maintain capabilities to detect and mitigate inadequate flow through recirculation strainer(s) and the reactor core. NEI provided a listing of potential defense-in-depth measures such as: (1) reducing flow through the strainer(s), (2) monitoring differential flow across the strainer, differential water level in the sump, pump distress, core exit thermocouples, and reactor water level indication, (3) refilling or realignment of the RWST for injection flow, (4) using injection flow from alternate sources, and (5) transfer to hot leg injection or combined hot leg/cold leg injection flow paths. STP has described similar capabilities and modeled them in the PRA, but has not explicitly identified them as defense-in-depth measures in support of GSI-191 resolution. The staff expects STP to include a description of such features that are modeled in the PRA or credited for addressing uncertainties in the license amendment request (LAR). In addition, appropriate regulatory controls, including possibly license conditions, will need to be included in the LAR to support the assumptions in the PRA and the defense-in-depth guidance in RG 1.174.

STP's preliminary quantification results are in Region 3, "Very Small Changes," of RG 1.174, which means the staff would consider the proposal to leave in place certain amounts of fibrous insulation. Key risk insights from the preliminary analyses and initial quantification are that blockage of the strainers sufficient to cause loss of net positive suction head is not predicted because of the decrease in containment temperature by the time the debris arrives. The dominant mechanism leading to fuel damage for medium and large LOCAs is in-vessel effects, not sump strainer blockage. In determining the amount of debris that reaches the core, STP's model shows that approach velocity at the strainer is as important to risk as, or more important than, break size or size of the zone of influence. Fluid approach velocity at STP has been greatly reduced by the addition of larger strainers at STP. Approach velocity is reduced further during smaller breaks. Switch over to hot leg injection can mitigate in-vessel effects, including boron precipitation. These risk insights show the importance of procedures and training to initiate hot leg injection, reducing injection flow to that needed, and procedures and training to refill and/or realign the RWST.

Validation of these risk insights is contingent on additional work by STP. For example, the initial quantification assumes high debris amounts for in-vessel effects. STP plans to justify these assumptions through proposed testing that it will perform in 2012. If the in-vessel debris limit is less than STP assumed in the initial quantification, STP would need to further plant modifications, such as selective insulation removal and/or installation of bypass eliminators.

Generic Applicability of the STP Approach

A licensee could use the guidance in RG 1.174 to support a proposed licensing basis change related to a proposed exemption. The STP alternative approach will most likely require an exemption from the long-term cooling requirements in 10 CFR 50.46. In accordance with 10 CFR 50.12, "Specific exemptions," the staff would inform the Commission before issuing such an exemption. The staff would plan to follow up the exemption with a proposed rulemaking unless the number of licensees applying this approach was ten or fewer. Industry has indicated that this approach may be pursued by six plants.

As discussed in Enclosure 2, licensees interested in pursuing this option must inform the staff of their intent by December 31, 2012 (consistent with the NEI proposal in its letter dated May 4, 2012). The staff would work with these licensees to develop submittal schedules and conduct preapplication meetings to reach agreement on plant-specific testing and analysis. Licensees would submit their risk-informed analyses in a staggered schedule all within 1 year following the staff's approval of the STP approach (staff-projected completion December 2014). These licensees would need a PRA that meets RG 1.200, Revision 2, "An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities," and that has been acceptably peer reviewed. For those supporting requirements not meeting Capability Category II, the licensee would have to provide sufficient information to demonstrate the acceptability of those supporting requirements to meet the STP approach. Alternatively, the licensee could have a focused-scope peer review performed on the required Capability Categories. The licensee would also have to commit to develop a model of plant piping and insulation, sufficient to follow the STP approach, in its next refueling outage after the December 31, 2012, letter (e.g., the first refueling outage (RFO) after January 1, 2013), and commit to perform any plant-specific testing needed to justify major assumptions (e.g., chemical effects or strainer head loss correlation) within two RFOs after January 1, 2013. If it becomes apparent that a risk-informed approach will not be successful (e.g., unexpected test results), licensees would be required to pursue a deterministic approach by the end of the third RFO after January 1, 2013.

The staff resources required to review the STP approach are still uncertain but appear to be significant. The staff would need to review the licensee's bases for approximately 20 probability distributions involving break size, zone of influence, debris generation, transport, strainer bypass, and chemical effects. In addition, the staff will have to review the results from the chemical effects test program, testing for strainer head loss, and possibly testing for in-vessel effects. The staff anticipates performing some verification of thermal-hydraulic codes for modeling RCS and containment behavior, evaluating the effects of boric acid precipitation, and reviewing human actions credited in the analyses. The staff has included resource estimates in the body of the paper and Enclosure 2.

In summary, the staff considers the STP approach to be viable and informative. Key elements such as event timing are evaluated for the range of accident conditions, resulting in a more thorough understanding of the sensitivities and uncertainties of GSI-191. A licensee would be better able to identify those modifications with the most impact on safety and/or focus its efforts on the appropriate defense-in-depth measures. However, this approach requires significant additional evaluation and/or testing compared to the deterministic methods to demonstrate that leaving existing fibrous insulation in place meets the risk acceptance guidelines of RG 1.174. As a result, success with this method will not be assured for several years.