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Document Control Desk
U.S. Nuclear Regulatory Commission
Washington D.C. 20555-0001

Attention: Mr. J. L. Birmingham

Subject: B&WOG Post-LOCA Core Boron Dilution Management

Gentlemen:

The purpose of this letter is to provide the B&WOG resolution plan and schedule for addressing the boron dilution management issue that was discussed with the Staff at the July 9, 1996 BWOG Regulatory Response Group/NRC meeting.

If there are any questions on the attached material please feel free to call me or Bob Schomaker (Framatome Technologies) at 804-832-2917.

Sincerely,

John A. Selva by RJ Schomaker

John A. Selva
Chairman
B&WOG Regulatory Response Group

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B&WOG POST-SBLOCA CORE BORON DILUTION MANAGEMENT

1. BACKGROUND

In 1991, Framatome Technologies Inc. (FTI) identified a Preliminary Safety Concern (PSC) with the analyses performed to define the operator actions necessary to successfully manage core boron concentration control during the long-term cooling phase of a LBLOCA located in the cold leg pump discharge region. The PSC questioned the long-term reactor vessel vent valve (RVVV) liquid overflow credited in the licensing analyses performed with the FOAM2 code. Without the long-term RVVV overflow, the operator initiated active dilution paths needed to be established much sooner than the times reported in calculations supporting the plant design bases. The timing shift also rendered the pressurizer auxiliary spray method ineffective because the required decay heat reduction would not be obtained for about a month after trip using 1.2 times ANS 1971. Without this active dilution method, some of the B&W-designed plants did not have a redundant active boron dilution method that was single failure proof.

The B&W Owner's Group funded an analytical effort to determine the post-LBLOCA hot leg nozzle gap size and liquid gap flow as a function of time after the large LOCA. This passive hot leg gap flow was used as the redundant boron dilution method to replace the RVVV liquid recirculation method. The results of the analyses were presented to the NRC in December of 1992, and the passive nozzle gap flows were deemed adequate as a backup for the active boron dilution method for LBLOCAs. At the same meeting, SBLOCAs were discussed. Engineering judgement was used in 1992 to separate the SBLOCA break spectrum into three groups to show why the SBLOCA boron concentration was bounded by the LBLOCA value without gap flow. The larger SBLOCAs would evolve to the same post-core refill conditions as the

LBLOCA and the LBLOCA results with gap flow were directly applicable. The smallest LOCAs (<0.01 ft^2) would result in long-term system refill which would significantly limit the maximum core concentrations. Intermediate CLPD SBLOCA's were dispositioned by assuming SBLOCA cooldown would be achieved within the timeframe that LBLOCA active boron precipitation control methods could be initiated without reliance on gap flow.

The validity of these engineering judgements has been questioned recently by the NRC, primarily because the time and rate of steam generator cooldown used in the SBLOCA disposition are not readily found in the emergency operating procedures (EOPs). All plant EOPs support use of the steam generator cooldowns to depressurize the RCS following an SBLOCA, but neither the initiation time nor the rate are quantified. Given the complex post-SBLOCA thermal-hydraulics of the B&W-designed plants, the absence of rigorous analytical calculations for the SBLOCA boron concentration added to the NRC concerns. These concerns were expressed in terms of questions (listed in Appendix A) sent to the B&WOG. The B&WOG Regulatory Response Group (RRG) was activated on June 26, 1996 to quickly and effectively address the NRC questions. An initial written response defining the issues and quantifying the safety significance was provided by letter on July 3 and an initial meeting to provide new technical assessments were provided in a meeting on July 9.

2. SBLOCA BORON DILUTION EVALUATIONS for the JULY 9 NRC MEETING

As a result of the nine NRC post-SBLOCA boron dilution questions, listed in Appendix A, new analysis was performed prior to the initial NRC meeting to support the original engineering judgements and provide justification that the core boron concentrations were successfully managed throughout the transient. This work initially focused on addressing Questions 2, 3, and 4, by performing calculations to substantiate adequate dilution without steam generator cooldown. The new analyses calculated the core boron concentration versus time using boron carryover in steam, boron solubility versus temperature and pressure, and transient hot leg gap flows. The boron carryover in the steam is a function of RCS temperature and core transient boron concentrations. The hot leg gap flows are a function of RCS levels and reactor vessel internals and shell temperatures. Thermal expansion of the reactor vessel shell and internals were calculated with as-built (measured) plant nozzle gap dimensions. The functionality of each of these parameters is based on the long-term RCS pressure and temperature evolution. Therefore, the first step in determining the transient core boron concentration was to calculate a spectrum of SBLOCA transients.

The break spectrum was performed with a simplified RELAP5/MOD2-B&W model specifically designed to estimate the RCS conditions at long times following an SBLOCA. This set of analyses did not credit operator initiated steam generator or other RCS cooldown mechanisms, rather the RCS was allowed to evolve based on the leak-HPI cooling for the most limiting, bottom-of-the-pipe CLPD break with one HPI pump. Using these transient RCS pressures and temperatures, conservative calculations were performed to quantify the maximum core boron concentrations with and without hot leg nozzle gap flows. Calculations were performed with minimum and maximum gap sizes and variations in the gap flows were evaluated. The variation of the core concentrations with simulated steam generator cooldowns was also studied. It was concluded from these preliminary engineering calculations and evaluations that:

1. A very limited range of break sizes (0.015 to 0.05 ft^2), located on the bottom of the CLPD piping, represent the areas of greatest concern regarding elevated core boron concentrations. The passive flows obtained through the hot leg nozzle gaps halt the concentration increase and decrease the core concentration in the long term.

2. At the time the core concentrations are most elevated, the RCS pressure and temperature are high, such that the solubility limit is elevated and is not approached.

3. Significant variations in the nominal gap flow for the smallest gap sizes will not cause the core concentration to continue to increase.

4. An operator assisted cooldown (SG, PORV, high point vents) will shorten the time period in which the core concentrations are increasing and reduce the maximum concentration reached.

5. The gaps provide a reliable, passive boron dilution mechanism that provides time to establish the currently identified active boron dilution means, without compromising the integrity of the reactor building sump screens.

These conclusions demonstrate that the core boron concentrations will be successfully managed during the SBLOCA transient with the hot leg nozzle gap flow. These results also demonstrate that there is not a significant safety concern related to post-SBLOCA boron concentration control. Therefore continued plant operation is supported. Nonetheless, documentation of these preliminary analyses must be completed. Additional work will be performed to minimize long term reliance on the gaps and still demonstrate long term boron concentration control.

3. SBLOCA BORON RESOLUTION

Preliminary information was presented at the July 9 meeting to address some of the questions raised by the NRC (Appendix A). Analyses that have been performed to support methods used to prevent boron precipitation (Question 2) were addressed by the preliminary information disseminated at the July 9 meeting between the Regulatory

Response Group of the B&WOG and the NRC. This information indicates that no interim actions are needed (Question 8). Information on gap sizes (Question 3) were also provided on July 9 Question 9 addresses the long-term plans for resolution which are addressed herein. Based on the time necessary to prepare responses to these questions, and perform the analyses needed to complete the resolution, the B&WOG proposes both a short- and long-range plan with intermediate status reports. Specific responses to all of the questions will be provided during the course of the long range plan.

3.1. SHORT-RANGE PLAN

The first step in the resolution process is to formalize the preliminary information provided to the NRC in the July 9 meeting. This includes supporting benchmarks, documentation, and qualification of the simplified RELAP5/MOD2-B&W model for long-term RCS cooling analyses and the documentation and validation of the boron dilution spreadsheet analyses. The initial analyses presented during the meeting used a combination of power levels and ECCS flow to conservatively demonstrate the dilution from a bounding generic perspective. The second step includes evaluation of plant-specific differences in licensed power level, ECCS flows, gap sizes, and RCS geometry to confirm that the most limiting results were calculated. This process may also identify unnecessary conservatisms used in the generic approach. One action item identified in the meeting was to obtain and provide the boron solubility limit at higher temperatures and pressures. This limit will be used to demonstrate the minimum solubility margin as a function of time for the SBLOCA transients that did not credit steam generator cooldowns. The finalization of these short-range tasks will be completed by October 15,1996.

3.2. LONG-RANGE PLAN

The long-range plan is focused on providing a formal response to the first seven NRC questions and recommends an integrated approach that is supported with analyses for SBLOCA boron concentration control. The boron dilution analysis will be accomplished with both passive and active mechanisms in a generic approach that will encompass each plant-specific means that may be available. The key to successful boron management is demonstration of an RCS depressurization and cooldown until a long term boron dilution control method can be established. A consistent, proceduralized approach to cool down the RCS and initiate an active boron dilution flow path will be developed for inclusion in the Technical Bases Document. Revised TBD guidelines will ensure that the operator will initiate cooldown with SGs at an acceptable rate (to be defined during this effort) when the core exit is saturated, and will provide appropriate criteria for initiation of an active dilution flow path if subcooled margin (SCM) is not restored. The cooldown will improve the ECCS delivery to the RCS and maximize the likelihood that core exit subcooling can be re-established. The cessation of boiling will halt the core boron concentration buildup and will lead to initiation of additional passive dilution mechanisms associated with partial system refill. If SCM cannot be regained, the cooldown guidelines would be bounded by analysis to demonstrate that boron precipitation will not occur prior to establishment of an active dilution method. The analyses will credit any passive dilution mechanisms, including the hot leg nozzle gap flow, until an active dilution path is established. If an active dilution path is not available (which includes single failure considerations), it will be demonstrated that the hot leg nozzle gap flow is adequate as a backup until an active method can be established.

A comprehensive task that must be completed during the long-range activities is identification of additional plant-specific active or passive dilution mechanisms and a method to access them. These mechanisms may include possible RCS refill, Reactor Vessel Vent Valve liquid overflow from partial RCS refill, hot leg nozzle gap flow, PORV and high point vent dilution paths, dedicated dump-to-sump or dump-to-containment paths, decay heat dropline dump-to-sump, decay heat removal system actuation, and auxiliary pressurizer spray. Evaluation of these potential methods with the worst break size and the most-limiting dilution method will dictate the number and extent of the analyses that are needed. These analyses will determine the minimum boron precipitation margin that bounds the B&WOG plants, either collectively or on a plant-specific basis.

If it is determined that a plant must delay the initiation of all active dilution methods, there may be an extended time when hot leg nozzle gap flows must be relied upon. The time interval over which nozzle gap flow reliance is needed would then be quantified based on the demonstrated proceduralized actions taken to achieve acceptable cooldown rates. For the demonstrated RCS cooldowns, the methods used, including the equipment and its classification or redundancy, will be quantified. The objective of this process is to demonstrate the variety of methods that will be available to the operator to cool down and control boron concentration for the class of SBLOCAs that can lead to significant periods of extended core boiling.

4. SCHEDULE FOR RESOLUTION

Due to the complexity of the long-term tasks, including the variety of plant-specific analyses and possible TBD changes, it is estimated that the final resolution will take five to twelve months to complete. Because of this extended resolution schedule extending beyond the end of 1996, status reports to update the progress will be provided. The first update will occur following completion of the short-term plan tasks on October 15. The updates will continue approximately every three months until the final resolution is complete. During the resolution process, the NRC will be informed promptly if any significant changes to the information previously disseminated to the NRC are discovered.

APPENDIX A

Preliminary NRC Questions on SBLOCA Boron Concentration Control

1. Only a plant by plant basis, what is (are) the method(s) used to prevent boron precipitation and permit long-term cooling per 50.46 for both large and small break LOCAs? How have you addressed single failure?

2. What analysis has been performed to support these methods? If no detailed analysis is available, what is the justification for continued operation?

3. In the analysis and justification, if credit is taken for a gap in the reactor internals, please address the following considerations:

   a. Was the as-manufactured gap ever measured and compared to the nominal specification? What are the nominal and actual tolerances?

   b. What is the gap size versus temperature?

   c. How has the potential for clogging of the gap from corrosion, boron precipitation, plateout or other means been considered in the analysis?

4. Identify and justify other important assumptions, behaviors, and actions in the analyses and justification, including, boron solubility versus time and temperature, reactor coolant pressure and temperature versus time, method of depressurization, procedures to implement active method and its timeliness and effect of DH drop line throttling on depressurization, cooldown, boron disposition, and other event behaviors.

5. What procedures are used to cool the plant to permit use of the hot-leg nozzle gap or other methods to prevent boron precipitation for a SBLOCA?

6. Are any plants currently analyzed as being fully capable of using the pressurizer spray as a method to prevent boron precipitation? If so, what flow rates and other conditions have been found necessary to permit this mode of preventing boron precipitation?

7. What assurance is there that plants do not have sump screens that would be damaged by excessive differential pressure while using the decay heat drop line method of preventing boron precipitation?

8. What are the interim actions to address the concerns?

9. What are the long term plans for resolution?