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B&W NUCLEAR TECHNOLOGIES

JHT/91-186
November 7, 1991

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Mr. A. C. Thadani
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

Subject: Post-LOCA Boron Precipitation

References: 1) BWNS letter (ESC-1370), dated November 1, 1991; Subject: Preliminary Safety Concern Regarding Post-LOCA Boron Precipitation (PSC 2-91).

2) BWNS letter (ESC-1384), dated November 7, 1991; Subject: Post-LOCA Boron Precipitation.

Dear Mr. Thadani:

The purpose of this letter is to provide copies of two recent communications between the B&W Nuclear Service Company and utilities which operate B&W plants. The issue involves the possibility of boric acid concentration during the long-term cooling period following a large break LOCA.

A copy of Reference 1 was transmitted to each of the utilities as a Preliminary Safety Concern. Discussions by telephone on November 4-7, 1991 led to Reference 2, which is a clarifying supplementary letter.

I believe you will find the attached letters helpful in understanding the communications between BWNS and the utilities.

We are aware that Mr. R. C. Jones, of your Staff, has also had telephone conversations with BWNS and representatives of some of the utilities.

Should you or your Staff have any questions, please call me at 804/385-2817.

Very truly yours,

J. H. Taylor, Manager
Licensing Services

JHT/bcc

cc: R. C. Jones/NRC
BWOG Executive Committee Members
BWOG Steering Committee Members

B&W NUCLEAR SERVICE COMPANY
Engineering & Plant Services Division

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November 1, 1991
ESC-1370

Subject: Preliminary Safety Concern Regarding Post-LOCA Boron Precipitation (PSC 2-91).

Dear

The purpose of this letter is to advise you of a Preliminary Safety Concern regarding the potential for post-LOCA boron precipitation in the reactor core. This concern first arose within B&W Nuclear Service Company (BWNS) as a result of a letter received from Duke Power Company (DPCo) dated August 6, 1990. The DPCo letter was transmitted to the utilities with 177FA plants for information purposes by BWNS September 5, 1990 together with BWNS' comments. Copy of Duke Power's and BWNS's letters are attached.

While the utilities may be aware of the concerns expressed by Duke Power, BWNS considers it necessary to advise the utilities of its own concerns, which in part, coincide with certain concerns in the DPCo letter.

Background

Following the core reflooding portion of a postulated cold leg large break loss-of-coolant accident (LOCA), core cooling will evolve into a mode in which a fraction of the low pressure injection (LPI) water flows into the core while the rest spills directly out the break. The portion of the LPI water entering the core is heated in the core and the resulting steam flows through the reactor vessel vent valves (RVVVs) and out the break. The current analysis assumes that at high decay heat levels some liquid will also spill over the vent valves.

In the current analyses, as long as the decay heat level is high enough to maintain a steam-liquid mixture flow through the RVVVS's, the boron concentration in the core will not increase. When the decay heat level decreases, however, the flow of the steam-water

mixture through the RVVVs stops, although the mixture in the core will continue to boil. Without the RVVV overflow, there will no longer be a circulation path within the RV to carry the highly borated water from the core to the break. Thus, borated water continues to enter the core from the downcomer to replace the steam leaving the core, but the steam will carry out little, if any, of the boron that is being brought into the core. Consequently, the boron concentration in the core will increase and eventually the concentration in the vessel may exceed the solubility limit. Boron precipitating out of solution in the core could block flow channels in the fuel assemblies and inhibit long-term core cooling by either forming a coating of solids on the fuel cladding surface or blocking the flow channels in the fuel assemblies or the lower RV flow distributor. Therefore, a means to preclude boron precipitation is required to demonstrate compliance with 10CFR50.46.

The prevention of boron precipitation is one of the requirements of long-term cooling. The onset of long-term cooling is defined as the time after a LOCA when operator action is required to ensure emergency core cooling systems (ECCS) are properly aligned and minimum performance requirements are met. A reasonable period of operator response time is assumed to be no earlier than 15 minutes after a LOCA. BWNS believes that the current operator guidance for the initiation of post-LOCA long-term cooling is within 24 hours for all B&W 177FA plants except Davis Besse (DB) and Rancho Seco (RS). BWNS believes that for DB and RS the operator guidance is to initiate action within 7 days.

For the 177FA plants, three alternate modes of equipment operation that can be used to prevent long-term boron concentration buildup are described in BAW-10103A, Rev. 3. The analysis presented in BAW-10103A, Rev. 3 was performed using 102% of an initial core power level of 2772 MWt, with the post-reactor trip decay heat generation rate determined based on 120% of the ANS 5.1 Standard (1971), with infinite previous operation. The analysis was also based on a boron concentration of 1800 ppm in the injection water, and did not account for the impact of any other materials that may be in the reactor building sump water on the solubility limits of the boron, such as sodium hydroxide or tri-sodium phosphate that may be used for pH control. For these conditions, the analysis supports the 7-day operator response times that are included in the current Emergency Operating Procedures (EOP) for the Davis-Besse and Rancho Seco plants, and the 24-hr operator response times in the EOPs for the other 177FA plants. The most limiting of the three cooling modes involves the injection of a minimum of 40 gpm of water into the pressurizer using the LPI system and the auxiliary pressurizer spray. The injected liquid will then follow a path from the pressurizer, through the lower hot leg and into the upper plenum region of the reactor vessel. This will create a reverse flow through the core and downcomer to the break once flow is adequate to match core boil-off.

Potential Concerns

In their letter, DPCo noted two potential non-conservatisms in the BAW-10103A Rev 3 analysis. The first non-conservatism is related to the slip model used in the FOAM2 Reactor Vessel mixture level calculations. Duke commented that the use of FOAM2 for that application violated the low pressure restrictions in the FOAM2 SER. DPCo also stated that, compared to their methods, the Wilson bubble rise model in the B&W analysis may underpredict the phase slip and therefore result in a higher mixture level.

The second potential non-conservatism noted by DPCo is related to the Reactor Vessel mixture level and the core decay heat level. The B&W calculations were performed with an initial power level of 102% of full power. DPCo's concern is that, at lower initial power levels, the liquid overflow through the RVVVs would terminate earlier and would potentially require that a long term cooling mode be established sooner than calculated in the B&W analysis.

As a result of DPCo's comments, BWNS has reviewed the use of FOAM2 with the Wilson bubble rise model and concludes that it is acceptable. A new submittal of FOAM2 by the B&W Fuel Company to the NRC for use in the fuel reload reports for Westinghouse plants provided justification for use of the code in the low pressure applications.

However, recent small break LOCA calculations performed by BWNS show that the Reactor Vessel upper plenum geometric model in FOAM2 is not appropriate when using the code to calculate two phase mixture overflow through the RVVVs. These recent calculations indicate that there is a potential for no two phase mixture overflow through the RVVVs at any core decay heat level regardless of break size. BWNS's concern is that if there is no mixture spillover through the RVVVs, the time to initiate a long term cooling mode would be significantly less than the 24-hour time used by most B&W plants. In addition, the injection flow rates modelled in the BAW-10103A calculations may not be adequate to prevent the increase in boron concentration to the solubility limit. The concerns on the time to initiate long term cooling and on the injection flow rates are applicable to all the 177FA and 205FA plants.

Since BWNS is not completely knowledgeable concerning the plant equipment, operating mode, and procedures that would be utilized for long term cooling at each plant, BWNS is unable to complete the evaluation to determine if the potential safety concerns described above, i.e., the concerns on initial power level, time to initiate injection flow, and required injection flow rate, are reportable under 10CFR21. In accordance with the requirements of 10CFR21, BWNS is therefore advising the 177FA and 205FA utilities of these concerns for their evaluation and will perform no further evaluations of these concerns unless authorized by the utilities.

Recommendation

It is recommended that analyses applicable to all utilities be performed to determine: (1) if there is two-phase spill-over through the RVVVs at high decay heat levels; (2) the most limiting core power levels; and (3) the minimum operator action time and minimum flow rates required, for each cooling mode discussed in BAW-10103A, Rev. 3, to prevent the buildup of boron and other dissolved salts. The analyses should consider that materials other than boric acid, such as materials to control the pH in the reactor building sump water, are in the injection water.

Davis-Besse and Rancho Seco Procedures

There is an additional matter applicable only to Davis-Besse and Rancho Seco which BWNS does not consider to be a potential safety concern but which is closely related to the concerns described above. A 7-day time interval is identified in the Emergency Operation Procedures at these two plants for initiating long term cooling post-LOCA. This time interval may not adhere to NRC guidelines. BWNS has informal information indicating that NRC guidelines require that switchover to the Long Term Cooling mode occur by the end of one day following the postulated LOCA.

It is also BWNS's understanding that, in connection with the acceptance of BAW 10103A Rev 3, the 177FA plants, except DB and RS, committed to the NRC to have procedures requiring operator action within 24 hours after a LOCA to prevent boron precipitation. However, BWNS does not have information on the basis for acceptance by the NRC of the 7-day operator action time frame in the Davis-Besse and Rancho Seco EOPs. It is recommended that Davis-Besse and Rancho Seco review the apparent disparity between the NRC guidelines and the operator action time frame at DB and RS.

If you have any questions concerning these matters, please contact the writer.

Very truly yours,

B&W NUCLEAR SERVICE COMPANY
Engineering & Plant Services Division

November 7, 1991
ESC-1384

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Subject: Post-LOCA Boron Precipitation

Reference: B&W Nuclear Service Company letter of November 1, 1991; same subject.

Dear _____:

The purpose of this letter is to clarify and supplement the above reference letter. This additional information reflects November 4-5, 1991 discussions with the utility representatives in four areas:

- Issue description
- Clarification of B&W's recommendations
- Additional investigative actions underway or planned
- Overall safety perspective

The above referenced letter stated that the issue may be of concern for breaks regardless of size. It is worth noting that this concern applies to large size breaks in the cold legs, specifically, between the RC pump discharge and the reactor vessel inlet nozzle. It is not believed to apply to breaks in the pipes connected to the RC pump discharge piping. The complete severance of the RC pump discharge pipe represents the worst case break and forms the basis for the recent analysis and the other information presented below.

The reactor vessel and internals are shown on Figure 1, attached. Previous analyses indicated that there would be an extended period of time during which the fluid cooling the core would reach the elevation of the large flow holes in the plenum assembly. After passing through these holes, the fluid would fill the annulus to the elevation of the internals vent valves and flow into the downcomer annulus thereby establishing a recirculation path and precluding boric acid concentration build up. The worst case situation is the double ended break of the cold leg in the horizontal run of pipe near the reactor inlet nozzle.

The recirculation path through the large flow holes, into the outlet plenum, and then through the internals vent valves was predicted to exist for 40 days, at which time further mitigative actions were required to prevent boric acid concentration.

Two mitigative modes of operation were available to preclude long-term boric acid concentration in the core region. One involved opening the DH drop line to establish positive flow out the hot leg. The other involved use of the auxiliary spray into the pressurizer from the LPI pumps.

During the long-term cooling period when the reactor coolant mixture height is no longer predicted to reach the large holes in the plenum assembly, opening the decay heat drop line valve was considered the preferred means of preventing boric acid concentration. The use of the auxiliary spray through the pressurizer was considered a backup in the event that the drop line valve could not be opened.

The most recent analyses indicate that the height of the two phase mixture may not be sufficient to provide flow of liquid phase through the reactor vessel vent valves. This then imposes the need to establish flow by other than natural circulation means at an earlier time than that currently called for by operating procedures. In addition, it means that the auxiliary spray flow of 40 gpm may not be adequate in and of itself to prevent boric acid concentration in the unlikely event that the decay heat drop line valve cannot be opened to preclude long-term boric acid concentration.

In view of the results of these preliminary calculations, BWNS recommends the following actions:

1. Procedures calling for opening the DH drop line valves should be revised. At this time, one calculation has been completed showing that opening the valves at 1-1/2 hours after the LB LOCA produces acceptable results with wide margins. Preliminary more realistic analyses indicate that for the worst case, 5-10 hours should be an acceptable valve opening time.

2. Because the 40 gpm spray flow was previously shown to be adequate, there were no efforts to determine how much greater flow could be achieved. Based upon recent telephone discussions with the utilities, it appears that significantly greater flows (approximately 70 gpm) would occur. Each utility should determine plant-specific spray flows.

3. The predicted flow through the hot leg nozzle to reactor internals interface joint under conditions expected to exist during the long term post-LOCA time period should be reanalyzed. Any flow through the gaps in this area would further supplement the auxiliary spray flow and thereby further reduce boric acid concentrations. Earlier analyses described in BAW-10103 and BAW-10091 were not pursued because of questions raised about the need for confirmatory testing and the availability of acceptable alternative resolutions. (This action is underway.)

4. Further time-dependent phenomenological investigations should be performed regarding predicted mixture heights. These investigations should include the heat removal capability of the predicted chemical concentrations in the reactor coolant.

5. Operating and maintenance records for the DH drop line valves should be reviewed to determine whether additional actions are justified to improve valve reliability.

Overall Safety Perspective

B&W believes that the recent analyses predicting lower mixture heights above the reactor core during long-term cooling do not justify restricting plant operation in any way. This position is based upon the following factors:

- This is a large break LOCA concern with the worst case being limited to a small portion of the reactor coolant piping.

- Leak-before-break analyses and experiments demonstrate that large break LOCA's will not occur. (NRC has approved the B&WOG justification for LBB presented in Topical Report BAW-1847, Rev. 1.)

- Even assuming this very low probability event, the recent analyses show that with earlier operator action to open the DH drop line valves, there will be no long-term boric acid concentration problem.

- The required operator action is not new; rather, it is required earlier. As mentioned above, preliminary calculations show action between 5-10 hours to be adequate. B&W understands that these simple procedure changes have been, or soon will be, implemented.

- More than 40 gpm auxiliary spray appears to be achievable for the backup mode of operation under the still lower probability situation where the decay heat drop line valve cannot be opened.

- In the earlier analyses, no credit was taken for any recirculation flow occurring between the upper plenum and the downcomer at the point where the RV internals interface with the reactor outlet nozzles. This flow would further supplement the larger auxiliary spray flow. Analyses in 1974 (BAW-10091) showed that gaps would exist at this interface.

- There is no clear evidence to indicate that concentrations of boric acid will cause flow channel blockage. This may not occur in the actual event, but for the purpose of addressing this issue it is assumed that boron precipitation could block the flow passages. This may introduce considerable conservatism into the analyses and resultant conclusions.

- Should the results of the above investigations (which will be completed in the near-term) show that the backup mode for preventing boric acid concentration is inadequate, the need for other longer term actions can be considered. However, the very low probability of occurrence for this event justifies treating additional efforts as longer term actions.

Should there be any questions about the information above, please give me a call at 804/385-2817 or Mr. J. R. Paljug at 804/385-3674.

Very truly yours,

J. H. Taylor, Manager
Licensing Services

JHT/bcc

Figure 1