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Document Control Desk
U. S. Nuclear Regulatory Commission
Washington, DC 20555

TO: T. R. QUAY

SUBJECT: WESTINGHOUSE RESPONSES TO NRC REQUESTS FOR ADDITIONAL INFORMATION ON THE AP600.

Dear Mr. Quay:

Enclosed are three copies of the Westinghouse responses to open items on AP600 topics. Responses to nine RAIs are included in this transmittal. RAI 410.289 provides information on Section 9 of the SSAR. RAIs 440.375, 440.380, 440.381, 440.383 and 440.388 provide additional information on the OSU Scaling Report. Reference one for RAI 440.375, discussing depressurization behavior, is also attached. Responses to RAIs 440.571, 440.572, 440.573 and 440.574 discuss the OSU Test Analysis Report.

The NRC technical staff should review these responses as a part of their review of the AP600 design. These responses close, from a Westinghouse perspective, the addressed questions. The NRC should inform Westinghouse of the status to be designated in the "NRC Status" column of the OITS.

Please contact Brian A. McIntyre on (412) 374-4334 if you have any questions concerning this transmittal.

Cynthia L. Haag for BAM

Brian A. McIntyre, Manager
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/jml

enclosures

cc: T. Kenyon, NRC - (w/o enclosures)
W. Huffman, NRC - (w/enclosures)
N. Liparulo, Westinghouse - (w/o enclosures)

E004/1

Question 410.289

The staff has previously requested additional information on the hot water heating system (RAI Q410.261) regarding the information on (1) the pressures and temperatures of the hot water system piping that supply hot water to major areas of the plant, (2) the system line routed into the containment, (3) the potential consequences of a break of the system piping and the protection measures, and (4) whether the system lines run over or through the control room. The response to the RAI from Westinghouse was reviewed. Explain whether the response is still valid following the design changes as addressed in Revision 3 of the SSAR. Provide an updated response for RAI Q410.261 if needed (see Open Item No.3 in AP600 Open Item Tracking System Database Executive Summary).

Response:

This response to RAI 410.289 is still valid following the issue of Revisions 3,7 and 10 of the SSAR. That is:

(1) The operating pressure and temperature of the hot water heating system (VYS) is about 300 °F (supply), 220 °F (return) and 120 psig. The piping system design conditions are 320 °F and 200 psig.

(2) No VYS lines are routed inside containment. However, hot water from VYS is routed into containment via VWS. This allows heating of the containment with fan coolers when the reactor is shutdown. This mode of operation represents less than 2% of overall operation time.

(3) No VYS piping is routed in rooms that contain safety-related equipment. There are no adverse consequences on safety-related components or equipment due to postulated breaks in the VYS piping routed in nonsafety-related areas.

(4) The VYS lines are not routed over or through the main control room.

Revision 10 of the SSAR includes this information. Item 1 is included in subsection 9.2.7.2.2, first paragraph of "Component Description", for the Chilled Water System. Item 2 is included as both a design basis (Section 9.2.10.1.2, second bullet) and a design description (Section 9.2.10.2.1, fifth paragraph) for the Hot Water Heating System.

SSAR Revision: None

Question 440.375

Re: OSU Scaling Report

The last paragraph of Section 5.1 (p. 5-2) states, "For breaks equal to or exceeding two inches in diameter in the AP600, the depressurization rate is dominated by the break volumetric flow rate. For breaks equal to or less than one inch in diameter in the AP600, the depressurization rate is dominated by the system fluid volumetric expansion." However, the basis for this statement is not explained. Is the statement based on code calculations, test data, scaling relationships, or some other grounds? The quantitative basis for the statement should be presented and explained (e.g., break models, scaling equations, specific test data, etc.) This same comment applies to the first paragraph in Section 5.4.1 (p. 5-18), and to the first paragraph in Section 5.4.3 (p. 5-24), i.e., demonstrate that for the specified break size, the Π terms are as stated.

Response:

Reference 440.375-1 illustrates an order of magnitude analysis for the AP600 for the Π-groups developed from the depressurization rate equation; equation (5-61). It indicates that for breaks larger than 2 inches in diameter, the mass and energy leaving the system through the break, would greatly exceed the remaining mass and energy transport terms (i.e., the core decay heat, the wall heat transfer and the energy flow rate associated with the mass injected into the system).

Reference:

440.375-1 Reyes, J. N., "Scaling the Depressurization Behavior of Fluids in Phase Equilibria", Proceedings of the Japan-U.S. Seminar on Two-Phase Flow Dynamics at Kyushu University, Sponsored by the National Science Foundation, July 15-20, 1996

SSAR Revision: NONE

Question 440.380

Re: OSU Scaling Report

Demonstrate quantitatively (e.g., by order-of-magnitude analysis) that the assumption stated on p. 5-10 in going from Eq. (5-19) to Eq. (5-32) is justified.

Response:

The model presented in Section 5.3.1 was specifically developed for, and therefore limited to, the case where the transport processes at the break (mass and energy leaving the system) dominate the depressurization process. As shown in Refenence 440.380-1, an order of magnitude analysis for the AP600 indicates that for breaks larger than 2 inches in diameter, the energy leaving the system through the break, would greatly exceed the remaining energy transport terms (i.e., the core decay heat, the wall heat transfer and the energy flow rate associated with the mass injected into the system). This is illustrated in the enclosed order of magnitude analysis.

The model presented in section 5.3.1 was intended as an assessment of the depressurization rate equation (Eq. 5-60) for a limited set of simple blowdown conditions. Note however, that the depressurization scaling for the test facility was based on the broader dimensionless depressurization rate equation given by Eq. (5-61).

Reference:

440.380-1 Reyes, J. N., "Scaling the Depressurization Behavior of Fluids in Phase Equilibria", Proceedings of the Japan-U.S. Seminar on Two-Phase Flow Dynamics at Kyushu University, Sponsored by the National Science Foundation, July 15-20, 1996

SSAR Revision: NONE

Question 440.381

Re: OSU Scaling Report

In the development following Eq. (5-100) on p. 5-27, explain what is accomplished by "requiring the Y value in the model to be proportional to that in the prototype." Does this not effectively mean that the working fluid in the model and the prototype should be the same?

Response:

There are several reasons for requiring that the Y values, (v_{fg}/h_{fg}), be proportional. First, it arises as the fundamental fluid property scaling ratio in all of the coefficients of the two-phase natural circulation fluid velocity equation (Eqs. 4-106a through 4-106c). Second, it arises in the definition of the volumetric dilation term which governs depressurization processes. Last, it is consistent with previous work by Kocamustafaogullari and Ishii, *Pressure and Fluid to Fluid Scaling Laws for Two-Phase Loop Flow*, NUREG/CR-4584, (1986).

Requiring that the Y values, (v_{fg}/h_{fg}), be proportional does not preclude the use of other working fluids. Reference 440.381-1 shows that the Y value is part of the dimensionless group (Pv_{fg}/h_{fg}). When this dimensionless group is plotted against the dimensionless saturation temperature, as in Figure 8, it is shown to be linear for a variety of fluids in phase equilibria over a wide range of saturation temperatures and pressures. Since all of the fluids exhibit similar trends, they can be scaled by a single proportionality factor. That is, they can be collapsed onto a single line using their respective slopes. Therefore similar processes evolving along the saturation curve for different fluids can be scaled by constant proportionality factors for the dimensionless temperature range from 0 to 0.8.

References

440.381-1 Reyes, *A Theory of Decompression of Two-phase Fluid Mixtures in Equilibria*, Section 7.1, "Self-Similarity of Fluids in Phase Equilibria," OSU NE-9407, (1994).

SSAR Revision: NONE

Question 440.383

Re: OSU Testing

How general is the relationship described in the first paragraph of Section 5.6.2 (p. 5-29)? Is any arbitrary set of fluid property ratios scaleable "by a single constant," or are there limits to how property ratios are able to be scaled? Also, the "insight" stated here appears to be the fact that many properties of water are far less sensitive to pressure than other conditions (such as temperature)--especially (but not exclusively) liquid properties. Is there any more insight to be derived from this section?

Response:

Having established in Section 5.6.1 that the system pressure for events that evolve along the saturation curve can be scaled by a constant in terms of initial conditions, it was then necessary to demonstrate that the key thermodynamic properties associated with mass distribution within the system, and energy and mass flow entering or leaving the system, could also be scaled with pressure using a constant value. Section 5.6.2 responds to this need by demonstrating the linear trends of these key properties. The results are then summarizes in Figure 5-7. Because the focus of the analysis was restricted to the properties that impact the mass and energy balances, other fluid properties were not included in this section.

In conclusion, the following key insight can be stated for water as the working fluid: " For processes that evolve along the saturation curve, system pressure and the properties that impact the system mass and energy balances can be scaled using constants based on initial system conditions."

SSAR Revision: NONE

Question 440.388

Re: OSU Scaling Report

In the application of Eq. (5-142) and/or Eq. (5-144), how is the transition from critical to unchoked flow accounted for ? If it is accounted for, does this require foreknowledge of when the flow will unchoke ?

Response:

The transition from choked to unchoked conditions is expected to occur during ADS 4 operation. This transition is accounted for by sizing the ADS 4 valves, which dominate the system behavior during that time period, using the assumption of fluid property similitude. This is a reasonable assumption for the low pressure conditions at which ADS 4 is expected to unchoke. Thus when the ADS 4 valves unchoke, properly scaled mass flow rates are expected. That is, 1/96, the mass flow rate of the AP600 ADS-4 mass flow rate.

SSAR Revision: NONE

Question 440.571

Re: OSU FDR and TAR

Over a range of several thousand seconds in many tests, the PRHR HX wide range level appears to drift upwards considerably. Explain what is occurring: is this an actual change in level, or is an instrumentation problem?

Response:

A review of the data from test SB18 suggests that the apparent upward drift of the wide range level transducer output is an indication of an actual change in level until about 2250 seconds into the test. The interpretation of the data leading to this conclusion is as follows;

- For this test, the indicated level in the PRHR goes to zero at about 700 seconds. Coincidentally, the rate of change of the fluid temperature in the PRHR inlet header is observed to at first stop, and then continue to decrease at a very small rate to about 900 seconds. These data are interpreted as indicating that the pressure head on the hot leg side has decreased sufficiently that a slight suction is applied to the residual water in the PRHR discharge line through the heat exchanger tubes that supports a 5.0 inch head of water in the tubes.

- At about 930 seconds, 4th stage ADS is actuated. As the PRHR feed line and the 4th stage ADS line for loop 2 share a common takeoff from hot leg 2, the pressure in the PRHR feedline is further reduced, causing the water level in heat exchanger tubes to rise further. This rise in heat exchanger water level is coincident with a rapid decrease in the temperature of the fluid in the PRHR heat exchanger inlet header to about saturation temperature at 1 atmosphere. After that time the fluid temperature in the PRHR inlet header becomes and remains subcooled.

- From about 1200 seconds until about 1600 seconds, the water level in the tubes remains constant and the PRHR heat exchanger inlet header fluid temperature increases to near saturation at 1 atmosphere. This is taken to be the result of steam drawn into the header by condensation.

- Between about 1600 seconds and 2250 seconds, the indicated water level in the tubes again increases slightly, and the inlet header fluid temperature is observed to again decrease. This is consistent with the time period for which liquid flow is again measured as being discharged from the PRHR. Thus the indicated increase in water level, from about 5 inches to about 12 inches of water in the PRHR from about 1600 seconds to about 2250 seconds is interpreted as resulting from condensate forming on the inside surfaces of the PRHR tubes.

- After about 2250 seconds, the level measurements for the PRHR heat exchanger indicates that the water level in the PRHR tubes again increases. As the measured outlet flow remains at about zero, this increase in water level is evaluated as an indication of flashing of the reference leg rather than a build up of water in the exchanger tubes.

Thus, for test SB18, the level indication for the PRHR heat exchanger is interpreted as an actual increase in the water level in the PRHR heat exchanger tubes that occur when the hot leg pressure on the PRHR heat exchanger drops below the backpressure in the outlet plenum of SG2, and again when ADS 4 actuates. Later in time when the PRHR flow measurement drops to zero, the increase in indicated PRHR water level is interpreted as indication flashing of the levels transducer reference leg. This explanation applies to all tests for which a similar behavior was observed.

SSAR Revision: NONE

Question 440.572

Re: Presentation of data for Test SB18 in Section 5.1.2 of the OSU FDR.

The explanation for the holdup of CMT-2 injection is that the accumulator injection closed the CMT outlet check valve, thus preventing CMT-2 from draining. However, Figure 5.1.2-6 shows CMT-2 level hanging up between around 125 and 350 seconds, while Figure 5.1.2-16 does not show significant accumulator injection until about 400 seconds, by which time CMT-2 is draining at roughly the same rate as CMT-1. Is there another possible explanation for this behavior, such as condensation at the top of CMT-2?

Response:

The break location for this test is at the bottom of cold leg 3 (CL-3), the same cold leg as the CLBL for CMT-01. The effect of the break location is to allow the CLBL for CMT1 to drain earlier during the test than does the CLBL line for CMT-02. The difference in time of draining for the two CLBLs is readily noted in Figure 5.1.2-6.

From Figure 5.1.2-6, CMT-01 CLBL is noted to drain at about 125 seconds. With CMT-01 CLBL line drained, steam may enter CMT-01 and draining of that tank may begin. CMT-01 is noted to begin draining coincident with low level in its associated CLBL.

Similarly, CMT-02 remains full and in recirculation until its CLBL drains. Again referring to Figure 5.1.2-6, CMT-02 CLBL drain down is noted to be completed at about 350 seconds and, coincidentally, CMT-02 also begins to drain. Westinghouse concludes that the data from this test suggests that the draining of the CMTs is strongly dependant upon the time the CLBLs drain and not condensation.

SSAR Revision: NONE

Question 440.573

Re: Presentation of data for Test SB18 in Section 5.1.2 of the OSU FDR.

In comparing Test SB19 to SB18:

a. Why is the transition from recirculation from draining in the CMTs later in SB19 than in SB18?

b. Is there a systematic explanation for differences in core levels and timing of events during the initial depressurization phase?

c. Why are the break flows higher in SB19 for the first 400 seconds?

If the differences are ascribed to the simulation of an elevated containment backpressure in SB19, provide a detailed explanation of the ways in which the containment pressure influences early-phase reactor/safety systems performance. It is not clear how the containment pressure is "felt" by the RCS, since, for instance, critical flow out the break and ADS valves should be insensitive to the ambient pressure. In addition, the discussion should address possible influences of the BAMS upon RCS response; i.e., if the behavior noted in the OSU facility is in part related to that aspect of the loop design.

Response:

The difference in observed system performance is attributed to simulating an increase in containment backpressure. The increase in simulated containment backpressure results in the following;

a. One affect of the increased containment backpressure was to delay the draining of the CMT CLBLs in Test SB19 relative to their behavior observed for SB18. Thus, the CMTs did not begin to drain as early for test SB19 as for test SB18. From Figure 5.1.3-9, it is noted that the general behavior of the draining remains the same between the two tests; that is, the CLBL nearest the break drains earliest, allowing its associated CMT to begin to also drain.

b. The observed differences in core levels and timing of events between test SB19 and SB18 are the result of differences in the local pressure in the core region that are driven by the effects of a higher containment backpressure simulated for Test SB19. Specifically, the saturation temperature for SB19 is higher than that for test SB18 and the energy input to the working fluid from the core simulation is the same for tests SB19 and SB18. Thus, after the initial blowdown, it is expected that phenomena driven by boiling of core coolant will occur later in test SB19 than in test SB18.

c. The higher containment backpressure simulated in test SB19 is applied to the break separator. The quality of break flow is dependant upon its discharge backpressure. As the pressure in the break separator is higher for test SB19 than for test SB18, the quality of the break flow for SB19 is lower that for SB18. Thus, for the same pressure drop across the break, a larger amount of liquid is discharged from the break early in test SB19 than for test SB18.

SSAR Revision: NONE

Question 440.574

Re: Presentation of data for Test SB18 in Section 5.1.2 of the OSU FDR.

For test SB12, explain why ADS1-3 flow becomes negative (Figure 5.4.1-18).

Response:

The indicated negative flow of liquid through the loop seal of the ADS 1-3 separator is evaluated as being the result of a "sloshing" effect of liquid in the ADS 1-3 loop seal at that time. Note that the data of Figure 5.4.1-18 suggests oscillations in the flow measurements. The definitive calculation of ADS1-3 flow is presented in the OSU TAR and takes into account change in stored fluid (vapor and liquid) mass of the ADS1-3 separator and vapor flow as well as the liquid flow shown in Figure 5.4.1-18.

Note that the magnetic flow meters are not calibrated for reverse or back flow. The negative sign associated with the meter output is indicative of the direction of flow only; the magnitude of the signal is not a valid indication of the volume of flow in the reverse direction.

SSAR Revision: NONE