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October 29, 1982

Dr. Brian Sheron
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Office of Nuclear Reactor Regulation
7920 Norfolk Avenue
Bethesda, Maryland 20014

Subject: Responses to NRC Question from B&W Owners Presentation on SB LOCA Methods, December 16, 1981.

Reference: Letter from Lou Lanese, Chairman, B&W Owners Group Analysis Subcommittee to Dr. Brian Sheron, "NRC Questions from B&W Owners Presentation on SB LOCA Methods, December 16, 1981", SAPC/026, February 25, 1982.

Dear Mr. Sheron:

The responses to the seven questions raised by the Staff in the December 16, 1981 meeting with the B&W Owners and as identified in the reference are attached.

These responses are being submitted on behalf of the Owners Group of B&W 177 and 205 Fuel Assembly NSS Systems as part of their program to address NUREG-0737 Item II.K.3.30.

If you have any questions, please call R. A. Dieterich (916/452-3211).

Very truly yours,

R. A. Turner for R. A. Dieterich

R. A. Dieterich, Chairman
B&W Owners Group Analysis Subcommittee

cc: Analysis Subcommittee Members
Executive Committee Members

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Question No. 1

Does steam outsurge from the pressurizer into a subcooled hot leg occur in a small break LOCA? If so, is the resultant depressurization unreal?

Response

A review of previous SB LOCA transient analyses shows that the hot leg saturates prior to the complete emptying of the pressurizer. These results are shown in the table below. With the current evaluation model, steam outsurge from the pressurizer into a subcooled hot leg does not occur.

Table 1. Hot Leg and Pressurizer Responses During SB Transients

Break Size (sq.ft.)	Time for Hot Leg Saturation (sec.)	Time for Pressurizer Emptying (sec.)
.01	110	160
.02	55	160
.04	30	120
.05	5	70
.055	20	25
.07	15	70
.085	15	110
.1	10	200
.13	10	65
.15	10	105
.17	4	65
.2	1.5	65
.3	1.0	50
.5	.5	80

The results for the .01 sq.ft. break with the revised CRAFT 2 Code show the same relationship.

Question No. 2

Can subcooled insurge into the pressurizer cause condensation at the steam water interface? What is the basis for the interface heat transfer model? How sensitive is it?

Response

In response to these questions, an isolated pressurizer model was set up using a digital computer code to simulate transients in the pressurizer for which surge flow and temperature/enthalpy are known. B&W pressurizer general geometry was used for this model. A sensitivity analysis of pressure transients with respect to steam/mixture heat transfer coefficient (HINTC) was conducted for a range of insurge flow rates and temperatures, pressures and liquid levels shown below.

Table 1. Range of Parameters Studied

Insurge Flow Rate	0 - 1200 lbm/sec
Insurge Temperature	550 - 610°F
System Pressure	1100 - 2500 Psia
Liquid Level	0 - 40 ft.

A similar study was performed for the coefficients that are used to calculate heat transfer between the pressurizer wall and the fluid in the pressurizer. These are:

HTCWL: Heat transfer coefficient between vessel wall and liquid.

HTCSW: Heat transfer coefficient between vessel wall and steam, used when $T_{steam} \geq T_{wall}$.

To evaluate the sensitivity of the pressure transients with respect to HINTC, the latter was varied from 0 to 100 times its nominal value. Further a parametric study was accomplished by varying one of the parameters about its nominal value (Table 2) within the range specified in Table 1, while holding the others constant at their respective nominal values given in Table 2.

Table 2. Average Values of the Respective Parameter Ranges

Average Insurge Flow	600 lbm/sec.
Average Insurge Temperature	580°F
Average Pressure	1800 Psia
Average Liquid Level	20 ft.

From the study, it was concluded that pressurizer pressure is insensitive to variations in the heat transfer coefficients within the ranges studied. The heat transfer coefficient HTCSW is most effective in influencing the pressure transients due to the comparatively larger temperature differential between the steam region and pressurizer wall.

It was also concluded that subcooled insurge into the pressurizer can cause condensation at the steam/mixture interface.

Question No. 3

The RC pump model is based on CE/EPRI data using side entry suction pipe. How representative is this of a bottom entry suction pipe?

(We understand the question is related to the potential for stratified inlet flow causing stratified outlet flows.)

Response

During normal RCP operation under design reactor operating conditions, the water entering the pump is sufficiently subcooled at the pump inlet to prevent any void formation. In abnormal situations, such as a SBLOCA, when the subcooling of the water is less than required or the fluid is at a saturated condition, voids exist in the water when it enters the pump. In the EPRI/C-E Pump Test Program, tests were run with single and two-phase steam/water under both steady-state and transient conditions.

During the very early stage in the EPRI/C-E program planning stage, the impact of using a side entry pump was considered. It was concluded that the side versus bottom entry pump inlet configuration was of no importance for normal operation and the major portion of abnormal RCP operation. In general, as long as the two-phase mixture is in the turbulent flow regime, the orientation of the pump inlet is of secondary importance. It should be noted that, during the planning and test period of the EPRI/C-E program, Dr. W. Beckner of the Reactor Safety Research Branch was actively following the program and participating in the regularly held review meetings.

The conditions under which the inlet orientation could make a difference are:

1. Low mass flow rates in combination with a high void fraction,

   and

2. At high void fraction conditions.

During such conditions, the flow into a side entry pump would be stratified, i.e. water in the bottom of the pipe and steam above it, each phase moving at different velocities. Separated flow would not be expected with a bottom entry pump.

Evaluations of SBLOCA behavior with the RC pumps operational have shown that it takes several minutes, and depending on the break size may be hours, for the primary system to evolve to high void fractions. Present emergency procedures require prompt tripping of the RC pumps for a SBLOCA. As a result, high void fractions are not expected to occur within the RCS. Thus, the two-phase pump performance data from the EPRI/C-E Pump Test Program is sufficient for assessing the consequences of a SBLOCA with the RC pumps initially operating.

Question No. 4

What basis is there for using the steam donor control volume for the slip model?

Response

The real concern is not what basis exists for selecting the steam donor control, but whether the steam donor differencing scheme used by the CRAFT-2 Code alters the propogation of the density wave. This question is addressed as follows:

Considering a system of first order partial differential equations of the form,

$$A \frac{\partial U}{\partial t} + \sum_{j=1}^{k} Bj \frac{\partial U}{\partial x_j} = C, 1 \leq j \leq k$$

where A and B are square N x N matrices and C is a column vector all of which are dependent on $(U, t, x_1, x_2 \ldots . x_k)$, and U is the column vector of N dependent variables. The classification of this system i.e., elliptical, hyperbolic or parabolic is determined from the A and B matrices alone (Reference 1). If the characteristics of a set of field equations are all real (non-complex) the system is hyperbolic in nature. Given that the system is hyperbolic (well posed) and a finite difference approximation to its solution satisfy the consistency condition as stated by Lax (Reference 2) then a stable solution should also be convergent. That is a difference approximation of the form

$$U^{N+1} (x) = \Sigma D_j U^N (x+\Delta j)$$

will be convergent if all linear combinations $\Sigma \mu_j D_j$ of the coefficient matrices D_j have only real eigenvalues (characteristics) and if each D_j is non-negative, i.e., all eigenvalues of D_j are non-negative. Since CRAFT2 uses this differencing form and its field equations are well-posed its solution will be both stable and convergent.

In summary, the CRAFT2 differencing scheme should not alter the representation of the physics embodied in its governing equations. This conclusion, in conjunction with those previously cited provide the basis for selecting the donor cell differencing technique.

References:

1. R. W. Lyczkowski et al., "Characteristics and Stability Analyses of Transient One-Dimensional Two-Phase Flow Equations and Their Finite Difference Approximations," NUC:SCI. & ENG. 66 (3), 378-396 (1978).

2. P. D. Lax, "Comm. Pure Applied Math.," 11, 175 (1958).

Question No. 5

The present ECC injection model appears adequate due to the high liquid content in the downcomer. What is the limit on the downcomer volume before the present model becomes unacceptable?

Response

A review of previous SBLOCA evaluation has shown that a high liquid content would always occur in the downcomer provided that the RC pumps are tripped promptly for the event. As a result, the present ECC injection model is adequate and there is no incentive to further study the limits of the present model. However, the hand calculations which have been performed show that a downcomer volume filled with 37.5% liquid would still not show a substantial pressure decrease as a result of CFT actuation. As future calculations are performed, the acceptability of the present ECC injection model will be verified by ensuring that the system pressure is not grossly altered as a result of CFT actuation.

Question No. 6

The steam generator model appears to be formulated correctly, but the NRC needs further details on the basis for the model. Specifically, the ARC LOFW test data.

Response

"The CRAFT2 Prediction of the Alliance Research Center (ARC) Loss of Feedwater Data (LOFW)" was submitted in B&W Document No. 12-1132544-00 to the NRC on April 9, 1982.

Question No. 7

Could pressurizer surge line modelling cause preferential slipping of steam into the hot leg or the pressurizer? If so, what is the effect on the transient?

Response

The pressurizer surge line modelling used by B&W does not allow the possibility of the preferential slipping of steam into the hot leg or the pressurizer. Hence the question required the determination of the impact of possible preferential slipping of steam in the surge line on the SB LOCA transient response. To accomplish this, hand calculations using conservative assumptions were performed to determine the effect on the transient response. The results of this analysis conclude that if preferential slipping of steam in the surge line were modelled, there would be no significant impact on the transient response. Therefore, it can be concluded that the current surge line modelling is adequate.

Discussion

To respond to this question, it was necessary to determine the possible situations in which preferential slipping of steam occur. For the cases where the flow is from the pressurizer to the hot leg, the significant preferential slipping of steam is not very likely due to the typical B&W surge line geometry and the tendency for the bubbles in a fluid mixture to rise. For the cases where flow is into the surge line from the hot leg, steam could preferentially slip to the surge line from the hot leg. In these hand calculations, the bounding case of total steam slippage was assumed. Two break cases were examined, one 0.01 $ft.^2$ break at the pump discharge and the other at the PORV.

For the 0.01 $ft.^2$ break at the pump discharge, the effect of preferential slipping of steam in the surge line would lead to a slightly lower mixture height in the hot leg. The difference in the mixture level in the hot leg was calculated to be approximately 4 inches. This is not expected to make any significant effect on the overall transient response.

For the PORV break, the effect of preferential slipping of steam in the surge line would lead to a higher mixture level in the pressurizer. This will fill the pressurizer slightly faster and cause the break flow to be two-phase earlier. The time difference of filling the pressurizer was calculated to be small to make any significant impact on the overall transient response.

In conclusion, the pressurizer surge line modelling used by B&W does not allow for the possibility of the preferential slipping of steam; therefore, the effect of preferential slipping of steam was assessed using a conservative approach. The results of this analysis show no significant effect on the transient response, therefore, the current surge line modeling is adequate.