Commonwealth Edison Company
1400 Opus Place
Downers Grove, IL 60515

September 1, 1995

Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Attn: Document Control Desk

Subject: Additional Information regarding Commonwealth Edison Company's Response to Questions Regarding the Increase in the Interim Plugging Criteria for Byron Unit 1 and Braidwood Unit 1
<u>NRC Docket Numbers:50-454 and 50-456</u>

Reference: D. Lynch letter to Commonwealth Edison Company dated August 23, 1995, transmitting Request for Additional Information

In the reference letter, the Nuclear Regulatory Commission transmitted to the Commonwealth Edison Company (ComEd) a request for additional information (RAI) questions 55 to 57, regarding the technical bases supporting the pending license amendments, which involves an increase in the interim plugging criteria for steam generator tubes at Byron Unit 1 and Braidwood Unit 1. Attached is ComEd's response to questions 55. With regard to questions 56 and 57, the ComEd RELAP5 calculations are currently being reviewed. Some additional cases are being evaluated to respond to review comments. This work will be completed and the analysis report provided to the Staff as soon as possible. ComEd is looking forward to meeting with the Staff to discuss any outstanding issues related to the hydrodynamic load model.

If you have any questions concerning this correspondence please contact this office.

Sincerely,

Denise M. Saccomando
Nuclear Licensing Administrator

Attachment

cc: D. Lynch, Senior Project Manager-NRR
R. Assa, Braidwood Project Manager-NRR
G. Dick, Byron Project Manager-NRR
S. Ray, Senior Resident Inspector-Braidwood
H. Peterson, Senior Resident Inspector-Byron
H. Miller, Regional Administrator-RIII
Office of Nuclear Safety-IDNS

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September 1, 1995

RESPONSE TO SUPPLEMENTAL QUESTIONS

NRC Request Number 55

In your letter dated August 14, 1995, you state that the anticipated uncertainty in the tube support plate (TSP) hydrodynamic load analysis using the TRANFLO code, as submitted, ranges from 25 to 30%. List the elements of your analysis which contribute to this range of uncertainty, quantitatively indicate the relative contribution of each element, and explain the basis for each element listed.

Response

A detailed discussion of uncertainty in the tube support plate hydrodynamic load analysis is provided as Enclosure 1.

NRC Request Number 56

Provide the results of the RELAP5 calculations cited in your letter dated August 14, 1995, including plotted time histories of the parameters used for your comparison to the TRANFLO results. As a minimum, provide the differential pressures for each TSP, the steam generator mass flow, and the steam pressure at the outlet nozzle.

Response

The ComEd RELAP5 calculations are currently being reviewed. Some additional cases are being evaluated to respond to review comments. This work will be completed and the analysis report provided to you as soon as possible.

NRC Request Number 57

Provide detailed information dexcribing the RELAP model discussed in your letter dated August 14, 1995. As a minimum, this information should indicate: (1) which version of the RELAP code was used; (2) the code options used for the calculations; (3) a detailed noding plan; (4) a description of the model explaining the noding plan; (5) and the input deck (in hard-copy and electronic form) of the hot standby case for a postulated main steamline break (MSLB).

Response

See response to Request Number 56.

Enclosure 1

Uncertainty in Prediction of TSP Hydrodynamic Loads

The characterisation of the hydrodynamic loads on the TSPs during a Main Steam Line Break (MSLB) event is primarily dependent on the ability of the predictive tool to accurately determine a number of key parameters that influence the loads. The primary parameters that can influence the loads on the support plates are:

1. Depressurization rate, particularly with respect to the initial period of the blowdown (0-2 seconds)

2. Local loss coefficient at the TSP.

3. The ability of the predictive tool to predict the two-phase fluid flow effects and their impact on the TSP local loss.

These factors will be examined in turn and their contribution to the overall calculational uncertainty will be discussed.

Depressurization Rate

The depressurization rate is a key parameter in the characterization of the load since it provides the driving force for the development of the pressure drop across the fluid regions. Both TRANFLO and RELAP have been tested against a number of blowdown tests, with the intent of demonstrating that they can accurately characterize the rate of blowdown as well as the gross fluid behavior (level swell) in the test apparatus. The tests that have the most bearing on the MSLB event analyzed to determine TSP loads are the GE "one foot" tests (RELAP and TRANFLO) and the Battelle B53B (TRANFLO) tests, which are steam break type tests. A number of other test comparisons have been done, particularly in RELAP5 developmental assessment studies to evaluate subcooled blowdowns and code interfacial relationships, but these have limited applicability to this case. These tests demonstrate that both RELAP and TRANFLO produce close agreement with test data, and can reliably predict the depressurization rate as well as the liquid behavior. Both codes tend to overpredict the depressurization rate to a small extent. Based on this information it can be estimated that the computer codes will overpredict the blowdown rate by a few percent. The TSP differential pressure will vary nearly linearly with changes in dome depressurization rate, and therefore the effect of this parameter on the load is in the conservative direction by several percent.

Local Loss Coefficient

The local loss coefficient plays a key role in determining the load on the support plates since the pressure drop is related to the local loss coefficient times the square of the velocity of the fluid flowing through the plate. The local loss coefficients used in the TRANFLO (and RELAP) models are based on considerable steady state test data as described in WCAP-14273 (Section 6). Typical engineering practice when selecting loss coefficients analytically from sources such as the Crane handbook or Idelchik's handbook is to calculate the most appropriate loss coefficient and then perform sensitivity studies in the range of plus/minus 10% to determine the impact of potential variance from the selected values. This sensitivity was performed with the RELAP model and the variation in the load was basically linear, as expected. A comparison of the TSP loss coefficients versus the remainder of the model, done by comparing K/A^2 shows that the TSPs are the dominant losses in the model and postulating uncertainties in other loss coefficients in the model will have a much reduced effect on the overall loads calculated. Therefore the uncertainty in load with respect to local loss coefficients can be estimated to be 10% or less.

Two-Phase Fluid Modeling Uncertainty

The pressure drop that is calculated is affected by two phase frictional effects. The ability of the code to accurately characterize the flow regime and assess appropriate multipliers is important in establishing both the local loss as well as the overall pressure drop in the steam generator. The uncertainty with respect to two phase modeling can be estimated by referring to a comparison of two phase models summarized in Reference 1. The data on a number of correlations reviewed in several studies shows mean errors of approximately 20% with standard deviations of about 35%, with respect to pressure drop prediction. Reference 2 discusses the results of a study performed by Whalley that looks at void fraction prediction by a number of two phase correlations. This also tends to support uncertainty ranges on the order of 20% or less. This is further reinforced by sensitivity studies performed with the RELAP5M2 code, calculating the TSP losses with the full two fluid model, as well as a HEM single momentum equation treatment. The observed variation was approximately 25% between cases. Therefore assuming a 25% uncertainty on the load as a result of two phase modeling uncertainty is a conservative approach.

Summary

Based on the above discussion, we believe that the uncertainty in prediction of the loads on the tube support plates is in the range of 25-30% or less. The use of a 2 times multiplier on the loads calculated by TRANFLO provides assurance that margin exists to bound these uncertainties.

References

1. "Nuclear Systems I", N. Todreas and M. Kazimi, 1990.

2. "Course Notes for Multiphase Flow Workshop-Void Fraction Prediction",
G. Kocamustafaogullari, 1988. Key pages attached.

REF. 1

The friction factor is given by:

1. For $\{\beta\} < 0.9$ and $\{\alpha\} < 0.5$, $\phi^2_{\ell o} = \dfrac{(1 - x)^{1.75}}{(1 - \{\alpha\})^{1.2}}$ (11-106a)

2. For $\{\beta\} < 0.9$ and $\{\alpha\} > 0.5$, $\phi^2_{\ell o} = \dfrac{0.48(1 - x)^{1.75}}{(1 - \{\alpha\})^{n}}$ (11-106b)

where $n = 1.9 + 1.48 \times 10^{-2} p$ (in MPa).

3. For $\{\beta\} > 0.9$, $\phi^2_{\ell o} = \dfrac{0.025p + 0.055}{(1 - \{\beta\})^{1.75}}(1 - x)^{1.75}$ (11-106c)

8 Comparison of various models. Eighteen two-phase friction pressure drop models and correlations were tested against about 2220 experimental steam–water pressure drop measurements under adiabatic conditions and about 1230 of diabatic flow conditions by Idsinga et al. [22]. The data represented several geometries and flow regimes and had the following property ranges:

Pressure 1.7–10.3 MPa (250–1500 psia)
Mass velocity 270–4340 kg/m²s (0.2 × 10⁶ to 3.2 × 10⁶ lbm/hr-ft²)
Quality Subcooled to 1.0
Equivalent diameters 2.3–33.0 mm (0.09–1.30 in.)
Geometry Tube, annular, rectangular channel, rod array

The four models and correlations that were found to have the best performance were the Baroczy correlation, the Thom correlation, and the homogeneous model two-phase friction multipliers.

$$\text{HEM 1: } \phi^2_{\ell o} = 1 + x\left(\frac{v_{fg}}{v_f}\right) \qquad (11\text{-}82)$$

$$\text{HEM 2: } \phi^2_{\ell o} = \left[1 + x\left(\frac{v_{fg}}{v_f}\right)\right]\left[1 + x\left(\frac{\mu_g}{\mu_f} - 1\right)\right]^{0.25} \quad (\text{with } n = 0.25) \qquad (11\text{-}83)$$

For geometries with equivalent diameter of about 13 mm (0.5 in.) i.e., BWR conditions, the Baroczy correlation performed the best for $x > 0.6$ while the Armand-Treschev correlation performed the best for $x < 0.3$. Other comparison studies of various models are listed in Table 11-5.

Example 11-4 Pressure drop calculations in condensing units

PROBLEM To predict the pressure drop in condensing equipment it is possible to relate the friction pressure drop to an all-gas (single-phase) pressure drop by defining a new two-phase multiplier ϕ^2_{vo} from Eqs. 11-76 and 11-77:

Table 11-5 Comparison of two-phase pressure drop correlations with steam–water data

	ESDU [11] Upflow, downflow, and horizontal flow			Friedel [16] Upflow only			Idsinga [22] Upflow and horizontal			well Up and horizontal		
Model	n	e	σ	n	e	σ	n	e	σ	n	e	σ
HEM 1	—	—	—	—	—	—	2238	−9.2	26.7	—	—	—
HEM 2	1709	−13.0	32.2	2705	−19.9	42.0	2238	−26.0	22.8	4313	−23.1	34.6
Baroczy [4]	1447	4.2	30.5	2705	−11.6	36.7	2238	−8.8	29.7	4313	−2.2	30.8
Chisholm-Sutherland [6]	1536	19.0	36.0	2705	−3.8	36.0	2238	0.5	40.5	4313	13.9	34.4
Martinelli-Nelson [27]	1422	16.3	36.6	—	—	—	2238	47.8	43.7	—	—	—

Source: Adapted from Collier [8].

Correlations: n = number of data points analyzed; e = mean error (%) = $(\Delta p_{cal} - \Delta p_{exp}) \times 100/\Delta p_{exp}$; σ = standard deviation of errors about the mean (%).

$$\left(\frac{dp}{dz}\right)_{\text{friction}} = \frac{f_{TP}}{D_e}\frac{G_m^2}{2\rho_m} = \phi^2_{vo}\frac{f_{vo}}{D_e}\frac{G_m^2}{2\rho_v} \qquad (11\text{-}107)$$

1. Using the HEM model, determine the multiplier in terms of the vapor density. Assume that the two-phase mixture viscosity is equal to the vapor viscosity.
2. Evaluate the pressure drop across a horizontal tube of length L and diameter D using the HEM approach. Assume axially uniform heat flux and the following conditions:

$D = 20$ mm
$L = 2$ m
$f_{TP} = f_{go} = 0.005$
$p_{in} = 1.0$ MPa (150 psi)
$\dot{m} = 0.1$ kg/s
Inlet equilibrium quality = 0.05
Exit equilibrium quality = 0.00

SOLUTION 1. From the problem statement and recognizing that $\rho_v = \rho_g$, we can write:

$$\phi^2_{go} = \frac{f_{TP}}{f_{go}}\frac{\rho_g}{\rho_m}$$

Using the HEM model, $\rho_m = \rho_m^+$, so Eq. 11-69 gives:

$$\frac{1}{\rho_m} = \frac{x}{\rho_g} + \frac{1 - x}{\rho_f} = xv_g + (1 - x)v_f$$

REF 2

$$E_1 \equiv 1.578\ Re^{-0.19} \left(\frac{\rho_f}{\rho_g}\right)^{0.22} \tag{23}$$

$$E_2 \equiv 0.0273\ We\ Re^{-0.51} \left(\frac{\rho_f}{\rho_g}\right)^{0.08} \tag{24}$$

where the Reynolds and Weber numbers, Re and We, are defined as follows:

$$Re \equiv \frac{G\ D}{\mu_f} \tag{25}$$

$$We \equiv \frac{G^2\ D}{\sigma\ \rho_f} \tag{26}$$

The void fraction α is calculated from Eq. (2)

$$\alpha = \frac{x/\rho_g}{x/\rho_g + S(1-x)/\rho_f} \tag{27}$$

2.7 Comparative Studies and Recommendations

There are several comparative studies appeared in the literature. These studies compared the accuracy of existing predictive void fraction correlations against a data bank. Friedel (1977) has examined statistically, using a data bank of 6784 items, the accuracy of 16 correlations: Alia et al. (1965), Beroczy (1966), Bruce (1972), Chawla (1969), Chisholm (1973), Hughmark (1962), Kowalczewski (1964), Lockhart and Martinelli (1949), Loscher and Reingardt (1973), Madsen (1974), Marchaterre and Hugland (1962), Mousalli and Chawla (1974), Nabizaden (1976), Premoli et al. (1970), Smith (1970), Thom (1964). Based on the statistical error limits of the mean density measurements, Friedel (1977) concluded that Chisholm (1973) correlation is superior to other correlations. The other methods, in particular of Baroczy (1966) and Premoli et al. (1970) are adequate for limited situations and are therefore not generally applicable. A similar study reported in ESDU (1977) gives a higher relative position to the Premoli et al. method.

Whalley (1981) made an extensive comparison between various published and unpublished (HTFS) correlations, and between the HTFS data bank which consists of over 25,000 data points. The result of the Whalley comparison is shown in Table 1 for void fraction. Whalley defined a correlation factor F which is the average value, over the whole data bank, of the ratio of the experimental to the calculated parameter. He also defined the range factor R which is defined such that there is a 99% probability and a 95% confidence that any given value will lie between R (F x value) and (F x value)/R. Ideally, F = R = 1. For a normal distribution, a value of R = 1.8 corresponds to a standard deviation of 30% and R = 2.2 corresponds to a standard deviation of 40%.

Table 1. Comparison of Experimental and Predicted Two-Phase Density, (Void Fraction), Using a Variety of Void Fraction Correlations (Whalley 1981)

Correlation Type	F	R
Homogeneous	2.41	9.6
Zivi (1963)	0.93	3.3
Chisholm (1973)	1.17	2.3
Smith (1970)	1.19	2.5
Premoli et al. (1971)	1.11	2.2
Zuber	0.97	3.1
HFTS	1.00	1.7
HFTS (steam-water)	0.98	1.5

Table 1 also shows values of F and R for various widely-used correlations for void fraction. The values are compared in terms of density. It is seen from Table 1 that the published correlations which perform best for two phase density (void fraction) is of Premoli et al. (1971).

In conclusion, it must be stressed that the data bank Friedel (1977) used in his comparative study was much less than the HFTS data bank. Therefore, the recommendations made by the Whalley (1981) should be considered more reliable than those of Friedel.

3. Phenomenological Void Fraction Prediction

Previously mentioned methods for predicting void fraction for horizontal flow such as the homogeneous model, Lockhart-Martinelli methods or other empirical approaches did not take into account the flow-pattern. Considering the fact that the void fraction is a characteristic of internal phase distributions, any void fraction correlation which do not take into account the flow patterns can not be accurate. It is clear that void fraction should be markedly different for, say slug flow, than for stratified flow even when the flow rates are not much different (namely, close to the transition boundary). Therefore, it is desirable to express the void fraction individually for each two-phase flow-pattern.

3.1 Drift-Flux Model

In practice, local velocity and local void fraction vary across the channel. To facilitate consideration of the case in which there is a distribution of velocity and void fraction across the channel, it is convenient, following Zuber and Findley (1965), to define average and void fraction weighted mean value of the local parameters. Let F be any one of the local parameters (for example, v_g, j, j_g). An area average value of F over a channel cross section A can be defined as follows: