TECHNICAL EVALUATION REPORT
TECHNICAL BASIS FOR REDUCTION OF TORUS SHELL CONDENSATION OSCILLATION LOADS FOR THE NIAGARA MOHAWK POWER CORPORATION NINE MILE POINT UNIT 1

by

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ABSTRACT

BNL's evaluation of the technical basis submitted by NMPC to justify a reduction in the NMP torus CO loads is documented in this report. The reduction was requested because thinning of the NMP torus shell due to corrosion implies that stress levels induced by these DBA loads would exceed allowables. The technical basis utilized in BNL's review includes a series of topical reports provided by the applicant as well as responses to RAIs generated during the course of the evaluation. In addition, the evaluation involved review of documents in which development of the original CO load specification and its basis are described. Also factored into the evaluation are the results of independent calculations performed by BNL to confirm the adequacy of the applicant's analytical results. Finally, the review's scope was expanded to include the impact of shell thinning on all DBA-related hydrodynamic loads. BNL's findings based on the above is that the requested reduction in CO loads is appropriate and has a sound technical basis.

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LIST OF ACRONYMS AND ABBREVIATIONS

AC	Acceptance Criteria
ABSS	Absolute Sum
BNL	Brookhaven National Laboratory
BWR	Boiling Water Reactor
BWROG	BWR Owners Group
CDI	Continuum Dynamics, Inc.
CO	Condensation Oscillation
DBA	Design Basis Accident
DNE	Department of Nuclear Energy
FSTF	Full Scale Test Facility
IBA	Intermediate Break Accident
LDR	Load Definition Report
MOI	Method of Images
NEP	Non-Exceedance Probability
NMP	Nine Mile Point Nuclear Station Unit 1
NMPC	Niagara Mohawk Power Corporation
NRC	Nuclear Regulatory Commission
PC	Personal Computer
PUAR	Plant Unique Analysis Report
RAI	Request for Additional Information
RF	Reduction Factor (for pressure amplitude)
SER	Safety Evaluation Report
SRSS	Square Root of the Sum of Squares
SRV	Safety/Relief Valve
TER	Technical Evaluation Report
TES	Teledyne Engineering Services
TLR	Technical Letter Report
TS	Technical Specification

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1.0 INTRODUCTION AND BACKGROUND

The generic CO load definition and its genesis are described in the Mark I LDR.[1] It was synthesized from pressures recorded during the worst case blowdown (Test Number M8) from the first FSTF test series.[2] This test simulated a large liquid break but was conducted at a pool temperature below the current Technical Specification (TS) for continuous operation (70°F vs 90-95°F). These loads were approved by the NRC, subject to the results of additional confirmatory tests.[3] Increased pressures were observed in these later tests[4] which were conducted at higher pool temperatures (95°F for Test M12). However, the original load specification was deemed acceptable[5] based on a favorable comparison between predictions and the stress levels observed during the high temperature test. In some cases, the prediction exceeded measurements by as much as 150%.

To understand why the LDR loads exhibit this conservatism it is necessary to describe how the load specification is derived and how it is to be applied. Reference 6 provides a detailed description of the design load's development. Here we note only the following: a single pressure signature was selected for processing (Figure 2-6 of Reference 6). A Fourier series representation of this signal was then developed. This was followed by a somewhat complex procedure that converted the Fourier coefficients to corresponding "rigid wall" values. From these, a table of rigid wall Fourier coefficients/pressure amplitudes was generated as a function of discrete frequency bands (Table 4.4.1-2 of Reference 1). The LDR then directs that these harmonic excitations be applied, within each frequency band, to structural models that represent each plant-specific torus, to establish the structure's response.

Because the design forcing function has been decomposed into a series of discrete harmonic excitations, a way of combining the corresponding stresses has to be prescribed. We note that if the excitation was given as a single, continuous pressure waveform as, for example, is specified for the Mark I SRV load (Section 5.2.2 of the LDR), this requirement does not arise. Thus, to complete the CO load specification, the LDR requires that the stresses be combined by the ABSS method which is the simplest and most conservative approach. The large margins between measured and predicted stresses noted above are a direct result of this approach.

The excessive conservatism of this approach was recognized by the BWROG even before the LDR loads were applied to specific plants. Accordingly, a series of studies were commissioned to develop improved procedures that reduced the excessive margins but retained an appropriate level of conservatism.[7,8,9] Based on a review of these studies, the NRC staff agreed that strict application of the ABSS method was not required and relaxed its original AC. For NMP, in particular, a modified CO load was approved during review of their PUAR.[10] This modification involved application of the ABSS method to only the four highest harmonic responses and addition, by a SRSS method, of the remaining ones. Note that this procedure does not modify the forcing function itself which consists of the pressure loads that are applied to the wetted torus boundaries. The revised method does,

however, reduce the total stress experienced by any particular structural element relative to that resulting from full ABSS application.

For most BWR plants, use of the LDR specified ABSS method was acceptable despite its inherent conservatism. In the case of NMP, however, the need to reduce the loads arose due to NMP's non-prototypically thin torus shell. With the passage of time, there has been a further reduction in the shell thickness due to corrosion. This corrosion is a continuing process which NMPC and its consultant estimate occurs at a rate of 0.00126 inches per year.[11] If the CO loads are not reduced even further, controlling stress levels are expected to exceed allowables during 1994. To delay the need to structurally reinforce the torus, NMPC has proposed a further reduction in the load specification. The technical justification for this reduction is described and evaluated in the ensuing sections.

2.0 DESCRIPTION OF THE PROPOSED METHODOLOGY

The information supplied by the applicant to justify a load reduction was transmitted in a variety of forms and at various times. The give and take between these submittals and the staff's responses extended over a considerable chronological period. In this section we will describe the applicant's method and its basis in a way that parallels this historical development.

The methods proposed by NMPC to demonstrate that a reduction in CO loads is justified were first described in two documents prepared by a consulting firm.[12,13] This material, as well as that provided in Reference 11, constituted the initial submittal to the NRC staff. The key elements of the information supplied there were as follows:

1. FSTF data are used to demonstrate that significant correlation of the CO process at the exit of the eight downcomers occurs only in the 5-6 Hz frequency range and that, at other frequencies, the process and its contribution to boundary pressures is random.

2. It is noted that the FSTF geometry, which consists of a single, torus-like bay with eight downcomers (cf: Figure 3.2-5 of Reference 2), does not correctly simulate the NMP torus since, in the latter, four downcomer bays alternate with eight downcomer bays (cf: Figure 3 of Reference 13). The consequence of this geometric feature is that the FSTF pressures are excessive for both the four and eight downcomer NMP bays. This is true over the entire frequency range of the pressure signature including the synchronous 5-6 Hz value.

3. It is also noted that the FSTF does not correctly simulate an actual Mark I torus because of the relatively rigid end caps which act as planes of symmetry between adjacent bays. In addition to implying that adjacent bays have the same number of downcomers as the FSTF as noted above, another consequence of this geometric feature is that asynchronous contributions to the measured pressures are amplified.

4. An acoustic model applied to an idealized version of the NMP torus (horizontal cylinder half filled with water) is developed and utilized to quantify the effects enumerated above. The results of this analysis are presented as reduction factors (cf: Table 1 of Reference 13) that are to be applied to the LDR pressure amplitudes (cf: Table 4.4.1-2 of Reference 1). These factors depend primarily on bay geometry and the nature of the CO process: i.e.: whether it is coherent or random. The reduction factors also exhibit a slight dependence on frequency. For uncorrelated CO their values are about 60% and 80% for the four and eight downcomer arrangements, respectively. The corresponding values for coherent CO are 70% and 95%. These all represent bay averaged values.

5. The correlated reduction factors are to be applied only for the 5 to 6 Hz pressure amplitude (about 3 psia). For the balance of the frequency spectrum the uncorrelated values are to be utilized.

6. The procedure to develop the structural response (stresses) to the revised hydrodynamic loads is also addressed. Reference 13 states (p. 14) that "the structural analysis should be undertaken as per the Load Definition Report". The analogous citation from Reference 11 appears on page 11. It states "total...stress was done by adding the absolute value of the four highest harmonic contributors to the SRSS combination of the others...".

Since the LDR dictates the use of the ABSS method for combining stresses, two contradictory procedures for combining stresses are specified in this original submittal according to what is cited in Item 6. Thus, in BNL's original evaluation[14] the distinction between the LDR's ABSS method and the alternative of combining only the four peak responses by ABSS and the remaining responses by SRSS* was highlighted and the acceptability of the proposed method made contingent on the assumption that the ABSS method was to be used. This position carried over into the SER issued by the NRC.[15]

Following the issuance of the SER, the NMPC took exception to the requirement that ABSS be used to compute total structural response.[16] It clarified the ambiguity implied in Item 6 by stating that the intent was to utilize the 4ABSS+SRSS method as was done in their original PUAR.[17] Additional information in support of this approach was also included in this submittal. A description and evaluation of this later information is included in Section 3.2.1 below.

In summary, the revised methodology consists of a set of multipliers (Table 1 of Reference 13) that are used to reduce the LDR pressure amplitudes (Table 4.4.1-2 of Reference 1). All other aspects of the method are identical to those used in the original NMP PUAR.[17]

* For convenience in the ensuing discussion, this method of combining the individual harmonic responses will be denoted by the acronym 4ABSS+SRSS.

3.0 EVALUATION OF THE PROPOSED METHODOLOGY

3.1 Evaluation Based on the Initial Submittal

As indicated above, an evaluation based on the initial submittal was completed and documented via a BNL TLR early in 1992. A copy of this TLR is included in this report as Appendix A. It was found that the proposed reduction was "reasonable, conservative and technically defensible".

The basis for this conclusion rested primarily on BNL's concurrence that the LDR pressure loads were overly conservative for the reasons cited (the randomness of the excitation for most of the observed frequency spectrum and the geometric differences between the FSTF and the NMP torus) and the acceptability of the analytical procedure utilized to develop an appropriate reduction. However, the incorrect assumption that it was NMPC/TES's intent to develop total stresses via an ABSS method also played a part in developing the overall finding in that it implied a source of additional conservatism. This position was even more emphatically stated in the NRC staff's SER. Finally, the TLR highlighted the fact that BNL did not critically review implementation of the analytical method nor accuracy of the numerical results that were generated. The confirmatory analysis presented in Section 3.2.2 represents an indirect way of evaluating the correctness of the NMPC method and results.

Summarizing this section, the findings from the initial evaluation regarding the pressure amplitude reduction factors remain qualitatively valid but require additional confirmation of their quantitative acceptability. This additional requirement as well as other considerations that have evolved since the issuance of the staff's SER[15] is addressed in Section 3.2.

3.2 Evaluation Based on Other Considerations

As a result of NMPC's response to the TER, further evaluation was undertaken based on the additional information that was supplied there and in References 8, 18, 19, and 20. The main focus of this new initiative was to establish the suitability of using the 4ABSS+SRSS method in combination with the reduced pressure loads. However, because it could be anticipated that acceptance of this combination inevitably would reduce existing margins, the staff felt that a more thorough examination of the newly developed excitation was appropriate. Specifically, the NRC formally requested BNL to expand the scope of its effort to include an independent, confirmatory set of calculations to demonstrate the load reducing effect of the geometry differences cited earlier (ie: Items 2 and 3 listed in Section 2.0). For completeness, the decision was also made to include an examination of the impact of reduced shell thickness on the ability of the NMP torus to withstand all other hydrodynamic (ie: besides CO) loads.

In the next sub-section, the acceptability of the method proposed to develop torus structural response (the 4ABSS+SRSS method) is addressed. Then, the BNL method for estimating

the effect of geometry on pressure is described and numerical results presented. Finally, BNL's findings resulting from examination of the NMP torus structural capability vis-a-vis all DBA hydrodynamic loads are discussed.

3.2.1 Acceptability of Total Structural Response Method

In Section 1.0 it was noted that the NRC staff's original AC were relaxed regarding use of the LDR ABSS method for combining stresses. The basis for accepting a less conservative version was documented in an August 1983 BNL Internal Memorandum.[21] A copy of this memo has been included here as Appendix B. The method approved there was intended to be generically applicable to all Mark I plants but has been utilized by relatively few utilities other than NMPC.

The evaluation was carried out by the late G. Bienkowski, of Princeton University acting as consultant to the Containment Systems Group of BNL's DNE. It reviewed essentially the same documentation NMPC supplied more recently. Using conventional, industry accepted statistical considerations, methods were developed there to obtain improved agreement between measured FSTF structural responses (stresses, displacements, forces) and those predicted using the LDR harmonic pressures. Common to all these methods was the notion that somewhere between pure ABSS and pure SRSS exists a way of combining the responses in a more realistic way. The "Naval Sum",[22] which combines the two highest peaks by ABSS and the remainder by SRSS (2ABSS+SRSS) is one example. In Reference 7 the recommended procedure was 3ABSS+SRSS implying a non-exceedance probability (NEP) of 84%. Although improved agreement was demonstrated, some exceedances were found, primarily in the area of membrane stresses. To provide sufficient conservatism to bound all the measured responses, it was recommended in Reference 21 that the proposed method be modified to the 4ABSS+SRSS method that was accepted by the staff and approved for use by NMPC in the NMP PUAR.

In summary, the 4ABSS+SRSS method that NMPC has used to develop total structural response to the CO excitation was approved by the staff earlier. Nothing that has transpired since that approval warrants withdrawal of this approval and/or modification of the procedure.

3.2.2 BNL Confirmation of Geometry Effect on CO Boundary Pressures

The methodology used by BNL to compute boundary loads on simulated versions of the NMP torus and the FSTF due to CO at downcomer exits is described in this section. Numerical results are also presented here. They include comparisons with corresponding NMPC results and sensitivity studies that exhibit the dependence of the loads on key geometric parameters that characterize the NMP suppression pool.

3.2.2.1 *Description of the Methodology*

The method used derives from an application of the classical Method Of Images (MOI) technique. The technique is particularly suitable for describing the hydrodynamic phenomenon occurring during the CO phase of a DBA blowdown. BNL's method is virtually identical to that employed by the General Electric Co. to estimate ramshead related, SRV hydrodynamic loads (Section 3.3.1, of Reference 23). The sole difference is that a rectangular array of images is used by BNL rather than GE's diamond pattern. This is because computer storage capacity and execution times have improved considerably since then (1978). Thus, the greater efficiency provided by the diamond shaped array is unnecessary. We were able to carry out these calculations on a PC (Gateway 2000). A brief description of the relevant describing equations used here are presented in Appendix C. It should be noted that these give the algorithm for developing the pressure at any point (x,y,z) due to the excitation induced by a single downcomer/source. To compute the pressure due to multiple sources, the computer code loops over all sources and combines the pressure contribution from each either by ABSS for "correlated" pressure or by SRSS for "uncorrelated" results.

3.2.2.2 *Geometric Considerations*

The geometry of the FSTF was modelled as a single, rectangular parallelopiped with platform XO by ZO and depth YO (see Figure 1). The specific values used for these parameters are given in Table 1 and were developed using the information given in Reference 20 as follows: YO was taken equal to the FSTF torus radius (a of Reference 20); XO, corresponding to the circumferential length of the FSTF bay, was taken to be four times the downcomer pair spacing (l_v of Reference 20); ZO, the lateral width of the computation cell, was selected so that the cross-sectional area of the cells equaled that of the FSTF; ie: we took ZO such that $(YO)(ZO) = \pi(YO)^2/2$. Four pairs of sources with lateral/radial spacing DS, were symmetrically located within the cell a distance HO above the torus bottom. HO and DS derive from the values given for r_v and θ_v in Reference 20 to define the location/submergence of the downcomer exit planes. This single computational cell was utilized to develop estimates of both the correlated and uncorrelated pressure loads. This is valid for the FSTF since, as noted earlier, the rigid end caps represent planes of symmetry so that asynchrony of the CO pulses can only occur among the eight downcomers contained within the single cell.

Modelling of the NMP geometry differed from that for the FSTF because of the need to correctly represent conditions when the CO process is asynchronous. In contrast to the situation for the FSTF, when this condition prevails in the NMP torus it implies that the CO pulses at all 120 downcomers (10 bays with 4 pairs; 10 bays with 2 pairs) are out of phase rather than just at the four or eight located in a single bay. The load reduction that would result from such a limited number of uncorrelated sources would be unrealistic.

In view of the above, two types of geometry were employed for the NMP simulations. For the correlated case, a single computational cell was employed analogous to that used for the FSTF except for the number and location of the sources/downcomers. These were arranged so that the calculation cell extended from the center (hence, plane of symmetry) of a non-vent, eight downcomer bay to the center of a four downcomer bay. Thus, only three pairs of sources were used for this simulation. All other pertinent dimensions for the single, NMP computational cell are given in Table 1. These values also derive from the information given in Reference 20. Referring to Table 1, it is interesting to note that the FSTF and NMP geometries are comparable except for downcomer pair clearance (HO) and spacing (DS). As can be seen, the NMP downcomer exits are significantly closer to each other and to the bottom of the torus. These geometric differences have a significant impact on the boundary pressures as will be discussed in Section 3.2.2.4.

For the case of uncorrelated sources in the NMP, the geometry must reflect the fact that incoherence between downcomers is not limited to those resident in a single or even in a pair of bays. So long as rigid walls are specified at the ends of the selected calculation cell, coherence between the sources in that cell and the array of images that are employed by the MOI is imposed. Unless this effect is properly accounted for, misleading results can be obtained. This is accomplished here by modeling the NMP torus as realistically as possible with respect to the total number of downcomers. As noted above, for NMP this number is 120. Our modelling has utilized half this number which would yield conservative results; i.e.: the pressure at any particular spatial location decreases as the rigid boundaries within which increasing numbers of <u>uncorrelated</u> sources are embedded recede from that location.

In summary, two types of geometries are employed in BNL's calculations. For correlated pressures, a single cell in which either four or three pairs of sources/downcomers are located is used. For uncorrelated pressures corresponding to NMP, the cell extends in the circumferential (X) direction approximately 180 feet corresponding to 10 bays. Each of these cells has three pairs of sources clustered in such a way that the alternating 8-4-8-4 pattern in the NMP is reproduced (cf: Figure 3 of Reference 13). The origin of the X coordinate is at the center of one or the other of these bays (both calculations were made with no significant difference found) corresponding to a plane of symmetry. For FSTF pressures, the calculation cell for both correlated and uncorrelated results is identical. This is consistent with the actual geometric configuration of the facility and correctly models the presence of the rigid walls.

3.2.2.3 Presentation of Results

It was noted in Section 2.0 that the NMPC method ultimately involves reduction of the LDR CO pressure amplitudes by what are referred to in Reference 13 as "Harmonic Amplitude Load Reduction Factors". The calculations performed here provide analogous reduction factors by generating boundary pressures for the modeled FSTF due to a unit excitation at each source and forming the ratio with the corresponding values obtained when identical strength sources are located in a simulated NMP torus geometry.

Results of BNL's calculations are given in three distinct ways. First, the maximum pressure computed within a given computational cell (PMAX) is tabulated as in Table 2. The table includes the results of a sensitivity study where key geometric parameters have been varied from the base case values given in Table 1. By focusing on these peak values, improved insight regarding the trends associated with changes in geometry is provided.

In addition to tabulating PMAX, the spatial variation of pressure at the bottom of the cell at the vertical plane of symmetry between pairs of downcomers has been generated and is plotted in Figure 1. Note that this figure includes an indication of the calculation cell geometry as it has been simulated here. Figure 2 compares the NMPC reduction factors (RF) with those developed by BNL. The latter derive from the results shown in Figure 1 by forming the appropriate ratios. Finally, graphical representation of the findings from the sensitivity studies is shown in Figure 3.

3.2.2.4 Discussion of Results

From the perspective of justifying a load reduction for NMP relative to the loads derived from FSTF tests, the key finding is the comparison between the values of PMAX obtained for Cases N1 and F1 for correlated results and N1(U) and F1(U) for uncorrelated CO sources. The reduction factor (RF) implied by the first of these is essentially unity; that is, PMAX = 1.45 for both Case F1 and Case N1 as indicated in Table 2. For uncorrelated sources, RF = 0.76 since PMAX = 0.42 for Case N1(U) and PMAX = 0.55 for Case F1(U). The corresponding values proposed by NMPC (from Table 1 of Reference 13) are 0.98 and 0.83. We consider this to be reasonable agreement particularly when the comparison shown in Figure 2 is also factored in.

Referring now to Figure 1, the most significant of the results shown there is the large reduction in pressure that is obtained when the sources are no longer correlated. Even for the FSTF, the pressures are reduced to only about one third of the correlated values. Interestingly enough, this is more or less the order of magnitude of reduction in pressure amplitude between the fundamental frequency (about 3 psi for 5 Hz) and the other non-synchronous values (1 psi maximum) as indicated in Table 4.4.1-2 of Reference 1.

Comparison of the BNL and NMPC values of the RFs shown in Figure 2 indicate clearly that they are in very good agreement. Note especially that the NMPC's uncorrelated RFs are more conservative than BNL's. That is, the LDR pressure amplitudes are reduced less when the NMPC RF's are used. Some nonconservatism is exhibited for correlated RF's but this difference is, at most, 6%. These differences are considered minor and, in our judgement, do not invalidate the acceptability of the proposed modifications.

With respect to the sensitivity studies that were performed, we note first that they were motivated by the result obtained for Case N2 of Table 2 corresponding to a computational cell with the NMP geometry but with four rather than three pairs of downcomers. Although

this case does not have direct applicability here, it was performed out of academic interest and for the sake of completeness.

As can be seen by referring to Table 2, the value of PMAX corresponding to Case N2 (1.66) not only exceeds that for Case N1 (1.45), which is to be expected, but also exceeds the value predicted for the basic FSTF case (Case F1). This increase can only be attributed to geometric differences since source number and strength are identical for those two cases. The same sort of difference is exhibited between the Case F2 (PMAX = 1.24) and the Case N1 (PMAX = 1.45) results. Note that these latter two cases correspond to 8-4-8-4 type configurations. These findings were the motivation for the sensitivity studies that were conducted; ie: to determine what feature of the NMP torus geometry gives rise to pressure loads higher than those expected in the FSTF <u>for the same number of downcomers</u>. As can be seen from the results shown in Figure 3, the noted increases are primarily the result of the significantly smaller clearance (7 vs 7.8 ft) that prevails in the NMP torus. One implication of this finding is that the FSTF geometry was not strictly applicable for NMP both with respect to the latter's 8-4-8 downcomer arrangement (a conservatism), but also with regard to downcomer clearance (a non-conservatism). The trade-off between these two opposing effects suggests that the original NMP design loads were suitable, notwithstanding that, to the authors' knowledge, no adjustment for the effect of reduced clearance was made or considered.

A more positive interpretation of this finding would be that CO loads could be reduced by an increase in clearance at NMP; ie: by shortening the length of the downcomers. According to Table 2 (Case N8 vs Case N1), a decrease in PMAX of almost 20% could be achieved by removing 12 inches from the downcomer ends. Of course, such a modification would involve significant expense but might be a cost-effective alternative to the structural modifications currently under consideration by NMPC in the event they become necessary. Note that a reduction of HO implies a corresponding reduction in downcomer submergence which tends to mitigate pool swell loads (Section 3 of Reference 3). However, it also potentially reduces the steam condensing performance of the suppression pool. Thus a total system analysis would be required to determine the merit of this concept.

4.0 IMPACT OF SHELL THINNING ON OTHER DBA-RELATED HYDRODYNAMIC LOADS

The approach here was to re-review the NMPC PUAR for the NMP Torus[24] with the focus on how thinning of the torus shell could potentially effect the earlier evaluation.[25] As a result of this review, an RAI was developed and transmitted to NMPC.[26] NMPC's response to this RAI[27] was provided to the NRC staff via letter dated September 28, 1993. BNL received and reviewed this information in October of 1993. Its findings[28] were that "it was responsive and complete. No open issues or concerns related to this submittal were identified." The content of the RAI and NMPC's response are included in this report as Appendix D.

The general thrust of the questions posed in the RAI was to confirm that sufficient margin was available to accommodate the increase in stress levels associated with reduced shell thickness for all the load cases mandated by the NRC staff's AC. A total of 27 such load cases are specified as enumerated in Figures 4.3-1, 4.3-2 and 4.3-3 of Reference 3. The RAI also requested that the contribution to stress level due to each event (eg: the DBA CO load) be itemized to determine their relative importance. Examples of the information obtained in this way is summarized below.

In response to the first RAI question, the applicant indicated that for Event Combination 20 (the controlling load case) only about 30% of the total stress is due to the CO load. Most of the stress (almost 60%) stems from the DBA internal pressure load. Thus, any reduction in total stress can only be a small fraction of the corresponding reduction in CO load. This clarifies the seemingly anomalous result that up to 60% reductions in the latter lead to, at most, a 10% reduction in total membrane stress as reported in NMPC's original submittal.[11]

Another question asked that the load combination inducing the next highest stress be identified. The response indicated this to be Event Combination 14. This event combines, among other loads, those stemming from SRV actuation and the IBA CO load.** Considerable reduction in total stress relative to Event Combination 20 is reported (from 16 ksi to about 13 ksi) with the internal pressure being even more dominant (almost 75% of the total). The IBA CO load contribution is only 6%, an amount equal to that from SRV actuation, a surprisingly small value.

In summary, the responses indicate that the margin between expected and allowable stress levels for all other Event Combinations are much greater than for that cited as the limiting case. Based on this information, it can be concluded that the capability of the NMP torus

** It is important to note that the original IBA CO load is used here. The modification requested by NMPC applies only to the DBA CO load.

to maintain its integrity during postulated DBA events is assured provided that this is demonstrated for Event Combination 20.

Finally, during review of the NMP torus PUAR, a concern relating to the way in which the CO loads are applied to develop the ring girder structural response (Section 5.0 of Reference 24) was identified. This concern arises due to the asymmetry introduced by the 8-4-8 downcomer arrangement. Specifically, the PUAR states that the half bay structural model of the NMP torus (Figure 3-3 of Reference 24) is used for the ring girder response for "all shell dynamic loads." Since the average CO pressure amplitudes that are applied in alternate bays differ by more than 20%, the question of how the gradient across the ring girder was accommodated arose. The issue was raised and resolved via telephone conference with NMPC personnel and consultants. First it was established that the issue had not been addressed. To resolve the issue, the applicant committed to utilizing a bounding approach[29] wherein the higher, non-vent bay loads would be applied on both sides of the ring girder to develop the stresses within the region immediately adjacent to the torus miter joint and miter offset. Since this loading creates the highest bending moment across what is, in effect a rigid connection, the structural response will be maximized. We consider this a conservative and, therefore, acceptable approach.

5.0 CONCLUDING REMARKS

Based on the evaluation documented here, BNL concludes that the reduction in the DBA CO loads that has been requested by NMPC is appropriate and technically justified. The geometric restraints imposed by the FSTF from which the LDR loads derive did introduce conservatisms that can safely be reduced. The absence of coherence for most of the frequency spectrum is also clear. The CDI analysis based on acoustics represents a rational procedure for estimating and quantifying these effects. Our independent calculations confirm that this analysis was correctly implemented.

The sole concern that we would highlight here relates to BWR plant operating procedures/technical specifications/emergency operating procedures. Specifically, it was noted in the introductory remarks that the FSTF test results exhibited an increasing trend of the CO loads with increasing pool temperature. Although the LDR loads and the NMP modified version can accommodate the observed increase, any further increase in the TS for the initiation of suppression pool cooling[30] can potentially invalidate their acceptability. In this connection we note that a request to permit a substantial increase in this TS is now being considered by the NRC staff.[31] We want to emphasize here the need to keep the connection between DBA loads and plant operating conditions in the forefront when considering any further modifications to currently acceptable design hydrodynamic loads. Additional evaluation and/or augmentation of the existing suppression pool hydrodynamic data base together with additional analysis could very well be needed to provide sound justification for such modifications.

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30. Mintz, S., "BWR Suppression Pool Temperature Technical Specification Limits.", General Electric Report NEDO-31695.

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Table 1 Values of Parameters Used to Define Calculation Cell Geometry

ITEM	FSTF VALUE	NMP VALUE
XO	19.5	19.6 (176.4)
YO	13.8	13.5
ZO	21.7	21.2
DS	8.0	6.0
HO	7.8	7.0
l_v	4.9	4.9
θ_v	56.3	65.2
r_v	7.2	7.2

NOMENCLATURE

DS	SPACING BETWEEN DOWNCOMER PAIRS IN THE Z DIRECTION
HO	VERTICAL DISTANCE BETWEEN TORUS BOTTOM AND DOWNCOMER EXIT
l_v	SPACING BETWEEN DOWNCOMER PAIRS IN THE X DIRECTION
ND	NUMBER OF DOWNCOMER PAIRS (SEE TABLE 2)
$\underline{P}$MAX	MAXIMUM PRESSURE IN 8 DOWNCOMER BAY
P′	INFLUENCE COEFFICIENTS - dPMAX/dDS, dPMAX/dYO,..etc.
r_v	RADIAL DISTANCE TORUS CENTER TO DOWNCOMER EXIT CENTER
XO	SIMULATED LENGTH OF TORUS BAY
YO	DEPTH OF SUPPRESSION POOL = TORUS RADIUS
ZO	SIMULATED TORUS DIAMETER
θ_v	POLAR COORDINATE ANGLE MEASURED FROM HORIZONTAL TO DOWNCOMER EXIT CENTER

UNITS

$\underline{P}$MAX - SOURCE UNITS (SU)
$\underline{P}$ - SU/FT
DS, HO, l_v, r_v, XO, YO, ZO - FEET
θ_v - DEGREES

Table 2 Results of BNL MOI Calculations

CASE	YO	ZO	ND	DS	HO	PMAX
F1	13.8	21.7	4	8.0	7.8	1.45
F1(U)	"	"	"	"	"	0.55
F2	"	"	3	"	"	1.24
N1	13.5	21.2	"	6.0	7.0	1.45
N1(U)	"	176.4	30	"	"	0.42
N2	"	21.2	4	"	"	1.66
N3	12.5	"	3	"	"	1.25
N4	14.5	"	"	"	"	1.63
N5	13.5	"	"	7.0	"	1.42
N6	"	"	"	8.0	"	1.39
N7	"	"	"	6.0	6.0	1.70
N8	"	"	"	"	8.0	1.21
N9	"	24.0	"	"	7.0	1.34
N10	"	27.0	"	"	"	1.27

Notes:

- * See Table 1 for nomenclature and units.
- * All results are for correlated sources unless otherwise indicated by the notation (U) following the Case Identifier Number.

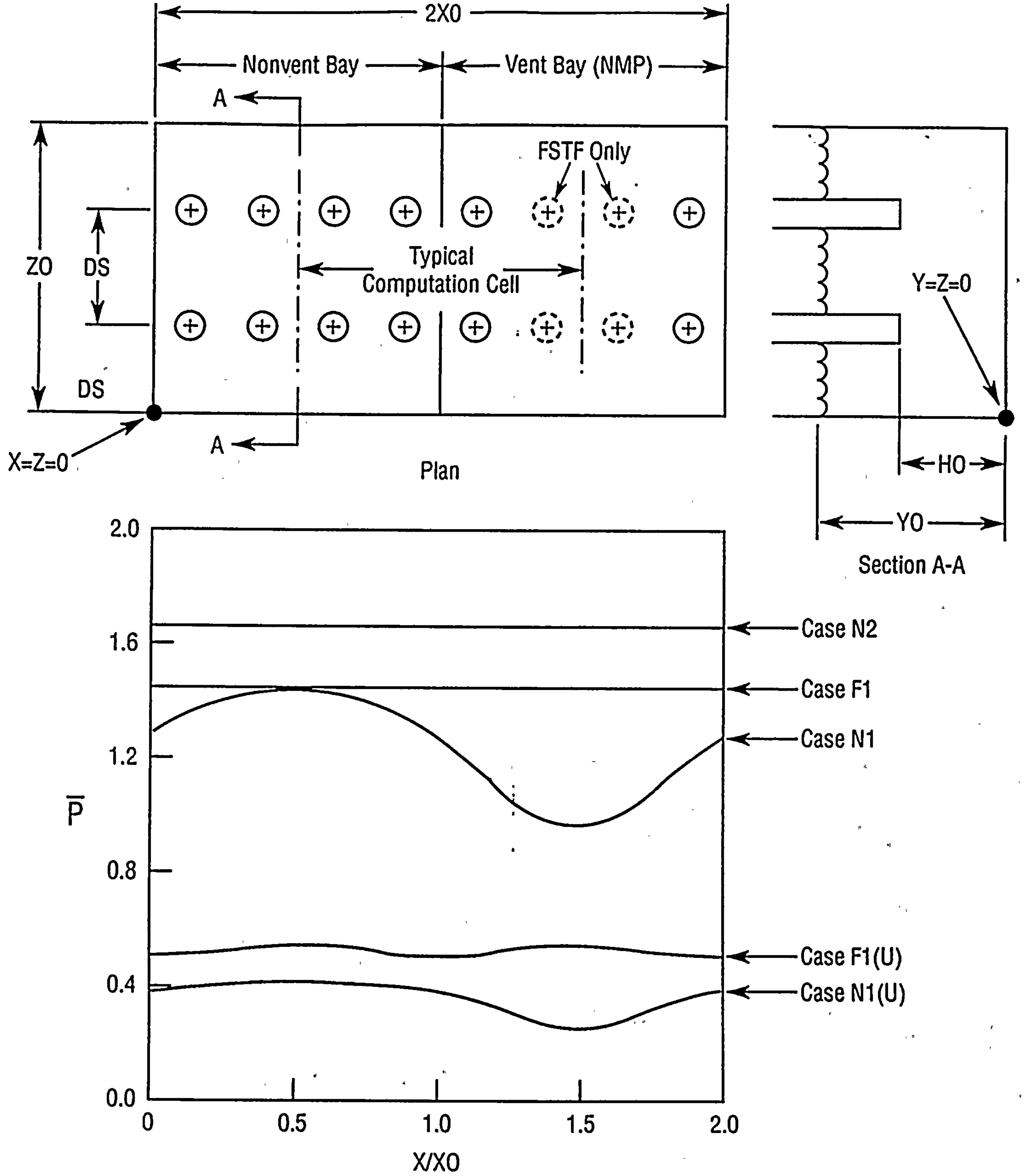

Figure 1-BNL Method of Images Predicted Variation of Pressure in the Computation Cell Plane of Symmetry-$\overline{P}$ (X,0,ZO/2)

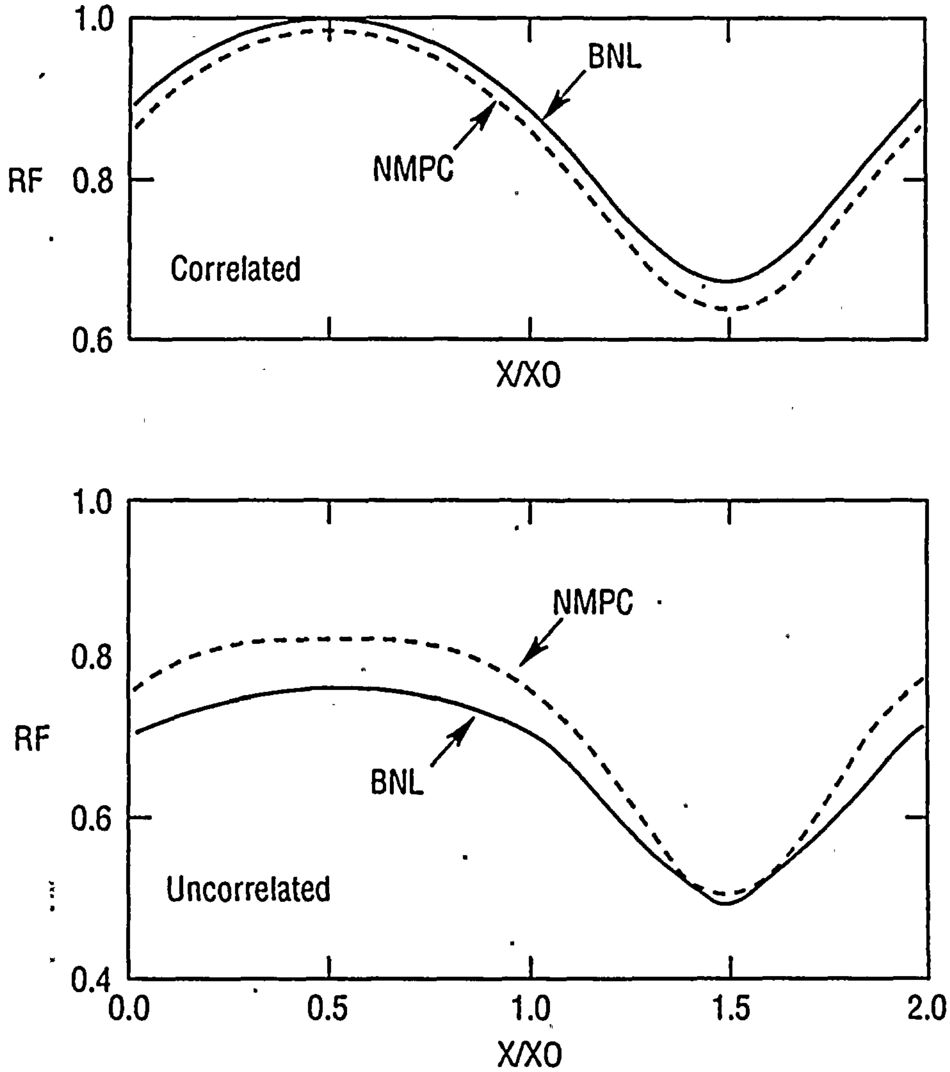

Figure 2- Comparison of BNL and NMPC Estimates for Pressure Amplitude Reduction Factors

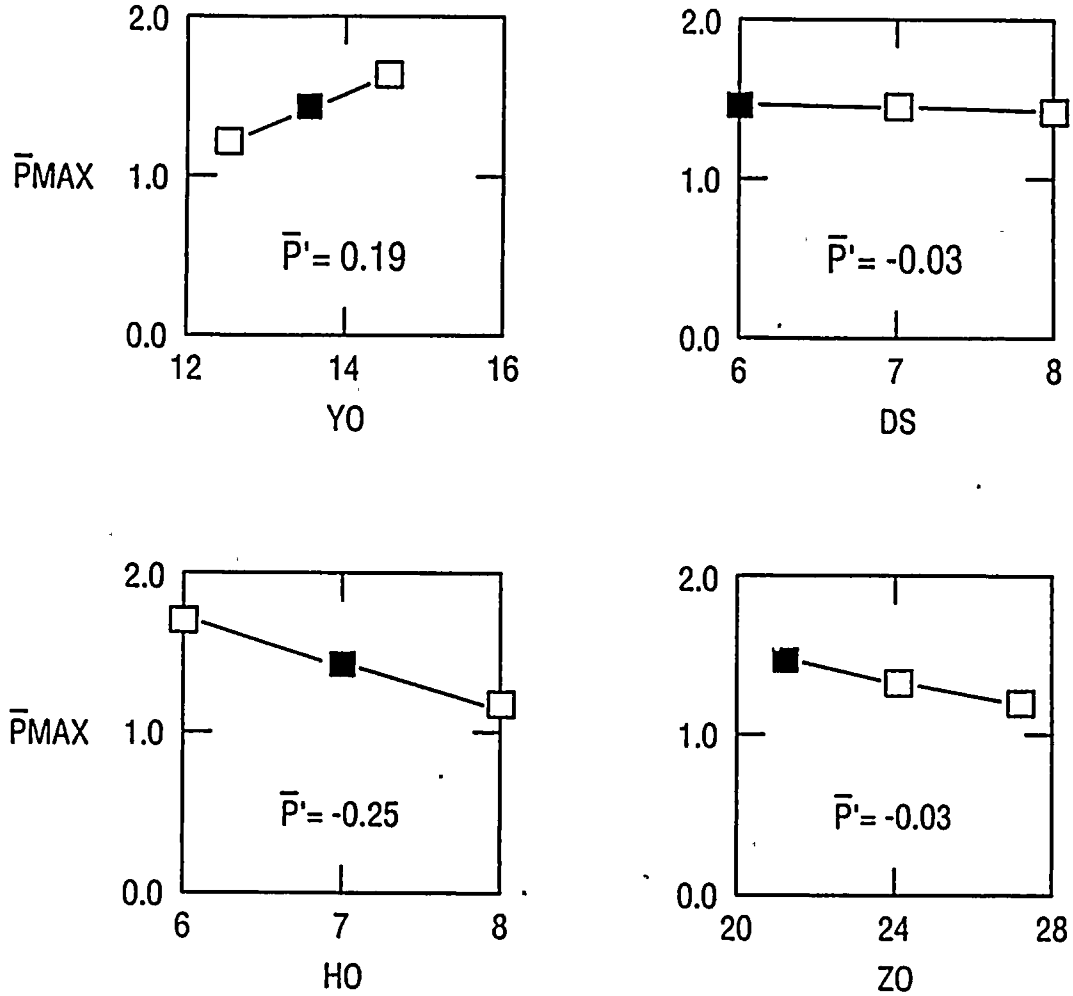

Figure 3- Results of Sensitivity Studies for NMP via the BNL Method of Images

Solid Symbols Denote Case N1 Parameters See Table 1 for Nomenclature and Units

APPENDIX A

THE BNL TECHNICAL LETTER REPORT

Evaluation of NMC* Technical Basis for Reduction of NMP Torus CO Loads

by

C. Economos, J. Lehner, and C.C. Lin
January 1992
Revised February 1992

Summary

BNL's evaluation of the technical basis submitted by NMC to justify a reduction in the NMP Torus CO loads is documented via this letter report. The evaluation includes a review of the historical developments that preceded the current submittal. These are pertinent because they represent the point of departure for the proposed modifications. BNL's finding is that the methodology used to demonstrate that a reduction in these loads is appropriate is technically sound and justifies the requested modifications.

Background

The generic CO load definition and its genesis are described in the Mark I LDR[1]. It was synthesized from the pressures recorded during the worst case blowdown (Test Number M8) from the first FSTF test series[2]. This test simulated a large liquid break but was conducted at the relatively low pool temperature of 70 °F, a value less than the current Technical Specification (TS) for continuous operation (the LCO). These loads were approved by the NRC, subject to the results of additional confirmatory tests[3]. The pressures observed in these later tests[4] were higher for liquid blowdowns conducted at somewhat higher pool temperatures. Specifically, Test Number M12, conducted at an initial pool temperature of 95 °F, gave rise to pressures that were about 15% higher than peak M8 values. Note that this temperature level is roughly equal to the current TS on the LCO (90 to 95 °F) and is somewhat less than the modified value of 100 °F that the BWROG has requested the NRC to approve[5]. Notwithstanding the increased loads observed during Test M12, the original load specification was found acceptable[6] based on a favorable comparison between the measured and predicted stress levels for the FSTF. In some cases, the prediction exceeded measurements by as much as 150%.

The conservatism of the LDR load specification stems primarily from the requirement that all of the harmonic component responses be added by absolute sum. This is equivalent to assuming that the excitation created by oscillation of the steam-water interface at the end of each of the eight downcomers is synchronized over the entire frequency range that was observed (up to 50 Hz). The staff recognized that this approach is conservative and relaxed the AC based on several later studies submitted by GE and its consultants[7,8,9]. For NMP, in particular, a modified CO load was approved during review of their PUAR[10]. This modification accounted for the absence of complete correlation between vents by taking the absolute sum of only the four highest harmonic responses and adding the SRSS of the

*See List of Abbreviations for definition of acronyms.

remaining ones. Note that this procedure reduces critical stresses but does not explicitly change the forcing function itself which consists of the pressure loading on the submerged boundaries. The basis for approving this approach was that it still bounded the measured response when applied to the FSTF. When applied to NMP, the critical stresses in the shell remained below allowables.

The need to reduce the CO loads below the generic LDR values arose because of NMP's thin torus shell. With the passage of time, there has been a further reduction in the shell thickness due to corrosion. This reduction is a continuing process which NMC and its consultant estimate occurs at a rate of .00126 inches per year[11]. If the CO loads are not changed, critical stress levels are expected to exceed allowables during 1994. To delay the need to structurally reinforce the torus, NMC has proposed a reduction in the load specification. The technical justification for this reduction is described and evaluated in the ensuing sections.

Description of the Proposed Methodology

The methods proposed by NMC to demonstrate that a reduction in CO loads is justified are described in two documents prepared by a consulting firm[12,13]. Key elements of the presentation are as follows:

1. FSTF test data are used to demonstrate that significant correlation of the CO process at the exit of the eight downcomers occurs only in the 5-6 Hz frequency range and that, at other frequencies, the process and its contribution to the pressure signature is random.

2. It is noted that the FSTF test facility is not prototypical of an actual Mark I torus because of the end caps which act as planes of symmetry between adjacent bays. It is claimed that the consequence of this geometric feature is that the incoherent contributions to the observed pressures are amplified.

3. It is further noted that the FSTF facility is also not prototypical of the NMP torus since, in the latter, four downcomer bays alternate with eight downcomer bays[14]. In this case it is claimed that this geometric discrepancy implies that the FSTF pressures are excessive for both the four and eight downcomer NMP bays, and that this is true over the entire frequency range including the synchronous 5-6 Hz value.

4. An acoustic model applied to an idealized version of the NMP torus (horizontal cylinder half filled with water) is developed and utilized to quantify the effects enumerated above. The results from this analysis are presented as reduction factors[15] that are to be applied to the LDR pressure amplitudes[16]. These factors depend primarily on bay geometry and the nature of the CO process, ie., coherent or random. They also exhibit a slight dependence on frequency. The reduction factors* are about 60% for the four downcomer geometry and 80% for the eight downcomer bay configuration for uncorrelated CO. The corresponding factors for the correlated case are approximately 70% and 95%, respectively. These represent bay averaged values.

*The term "reduction factor" is used here and in Reference 12 to indicate a multiplier of the original value.

5. Correlated reduction factors are to be applied only to the 5-6 Hz pressure amplitude. For the remaining frequency spectrum, uncorrelated values are to be utilized. After the LDR pressures are reduced by these factors, the structural analysis is to "be undertaken as per the LDR."[17]

With respect to the original analysis[18], these procedures yield a 4% reduction of the controlling stress (membrane) for an eight downcomer bay and a 10% reduction for a four downcomer bay[11]. In terms of shell thickness, these correspond to reductions of 16 and 44 mils, respectively. The corresponding values given in a more recent submittal[19] are 18 and 37 mils. It is stated there, that these correspond to a 17% and 30% reduction in the LDR CO loads, respectively.

Evaluation of the Proposed Methodology

In BNL's judgement, the reduction in the CO loads that NMC has requested are reasonable, conservative, and technically defensible. The basis for this conclusion are as follows:

1. The FSTF data support the notion that the CO process is random over most of the frequency spectrum considered in the load methods.

2. Because of the geometric differences, particularly the 4-8-4 downcomer arrangement, the pressure loads during a CO blowdown will tend to be greater in the FSTF relative to the NMP torus for the same thermodynamic flow conditions.

3. The procedure used to quantify the effect of Items 1 and 2 represents a straightforward application of a conventional hydrodynamic method. The results are reasonable and probably conservative because of the high sound speed used in the numerics*. We also consider the assumption that a correlation exists between bays to be a significant conservatism.

4. The overall reduction of the loads from LDR values is significantly less than that approved earlier by the staff[20]. This reduction was found acceptable because it was able to accommodate all of the stresses observed during the FSTF tests.

Concluding Remarks

There are three points we want to emphasize here. The first is that the procedure we have evaluated represents a more rigorous, almost first principles way, to accomplish what was done before in an approximate way. As we already noted in our background discussion, the modification that was utilized by NMP earlier did not involve any change in the LDR pressures. Relief was obtained by not summing the stresses induced by each and every one of the fifty harmonic excitations by absolute sum as required by the LDR methodology. That this was an acceptable procedure could only be demonstrated by comparing predicted FSTF

*Modeling of the torus as half filled with water is a minor nonconservatism (NWL in Mark I plants is well below the torus centerline), but is a reasonable simplification of an analysis which is already quite complex.

stresses with measured FSTF stresses. In distinct contrast, the present method provides relief by reducing the excitation (pressures) itself.

The second point is that the basis for Item 4 rests on our assumption that when the applicant refers to "LDR values" what is meant are the stresses that result by applying the LDR pressure amplitudes and then combining all of the individual peak stresses by absolute sum. The documents that we have in hand are somewhat ambiguous on this point and it would be prudent to obtain documented confirmation that our interpretation is correct.

Finally, we note that our review of the analysis does not include direct confirmation of any of the numerical results that were presented, e.g., the reduction factors. It is assumed that these derive from a correct application of the methodology.

References

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14. Figure 3 of Reference 12.

15. Table 1 of Reference 12.

16. Table 4.4.1-2 of Reference 1.

17. p. 14 of Reference 12.

18. TES Report TR-5230-1, Rev. 1, "Mark I Containment Program, Plant-Unique Analysis Report of the Torus Suppression Chamber for Nine Mile Point Unit 1 Nuclear Generating Station," dated September 21, 1984.

19. NMC letter NMP1L-0628 from C.D. Terry (VP Nuclear Engineering) to U.S. NRC, dated December 13, 1991.

20. Bienkowski, G., "Review of the Validity of Random Phasing Rules as Applied to CO Torus Loads," Internal BNL Memo, August 1983.

LIST OF ACRONYMS

AC	Acceptance Criteria
BNL	Brookhaven National Laboratory
BWROG	Boiling Water Reactor Owners Group
CO	Condensation Oscillation
FSTF	Full Scale Test Facility
GE	General Electric
LCO	Limiting Condition for Operation
LDR	Load Definition Report
NMC	Niagara Mohawk Power Corporation
NMP	Nine Mile Point - Unit 1
NRC	Nuclear Regulatory Commission
NWL	Normal Water Level
PUAR	Plant Unique Analysis Report
SRSS	Square Root of the Sum of Squares
TS	Technical Specification

APPENDIX B

THE BNL INTERNAL MEMORANDUM

Review of the Validity of Random Phasing Rules as Applied to CO Torus Loads

George Bienkowski

August 25, 1983

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INTRODUCTION

The LDR [1] specification for CO Torus loads is based on FSTF data (primarily test M-8). In order to resolve potential uncertainties in the conservatism of the data, supplementary tests M-11B and M-12 were conducted in the FSTF facility. While M-12 was not totally bounded by the LDR specification, the staff felt that the LDR procedure of summing the absolute values of the harmonic components was sufficiently conservative to bound any uncertainties in the data (Supplement to Mark I SER-NUREG-0661).[2]

Many of the individual Mark I plants have chosen to deviate from the LDR procedure and have reduced the conservatism inherent in the absolute sum load application through some use of random phasing between harmonics of the LDR CO rigid-wall pressure specification. The basis for all of these alternate load application procedures comes from GE report NEDE-24840[3] and some subsequent reports by Structural Mechanic Associates (SMA 12101.04-RODID, SMA 12101.04-R002D, SMA 12101, 04-R003D).[4,5,6] While individual plants obtain a reduction in load due to the effect of random phasing in different matter, a generic evaluation of the base for these procedures is necessary in order to establish the adequacy of each plant's exception to the Acceptance Criteria.

A. Review of GE NEDE 24840, "Evaluation of Harmonic Phasing for Mark I Torus"

The primary objective of this report is to reduce the excessive conservatism in the torus shell response due to the use of the absolute sum of harmonic amplitudes. The report demonstrates, by examining through Monte Carlo calculation both the FSTF data and an actual facility (Oyster Creek), that random phasing leads to a more realistic response. The report further proposes a design rule that is relatively easy to apply and provides 90% confidence of 50% non-exceedance probability.

The report further justifies this choice as being appropriate to preserve, at the response level, the non-exceedance probability or the degree of conservatism contained within the load data. Seven responses (BDC axial and hoop stress, BDC radial displacement, and four column forces) at the FSTF facility are analyzed on three different bases: (a) Fourier components of the measured spatially-averaged pressure time histories over 5 (second) intervals of Run Number M-8 are used as load input; (b) Monte Carlo trials based on random phasing between the 50 harmonic components representing the histories in (a) are applied; (c) Monte Carlo trials using random phasing among the 50 harmonics of the LDR load specification are used. The peak responses resulting from theses analyses are then compared to the measured peaks in the FSTF tests.

A comparison of the results of (a) to the measured responses suggests that the modelling of the facility and a representation of the data is adequate to match the column forces and radial displacement but yields peak membrane stresses that are from 13% to 30% (hoop) too low. The report goes into a number of explanations for the reasons for this discrepancy. While most of the suggested causes would not be applicable in a real facility, the suggestion

that shell membrane stresses will respond to local pressures while the input load has been averaged, can be assumed to be transferable to a plant calculation. This potential non-conservatism is eventually recognized in the final design rule.

The peak responses at the 50% NEP level resulting from 200 Monte Carlo trials with random phasing between harmonics (option b) generally either bound the results using actual phasing or are very close to them. The ratio of the responses, based on (a) divided by the 50% NEP result of (b) ranges from 0.88 for the column forces to 1.03 for the radial displacement, with the membrane stresses at 0.94. The 50% NEP result of (b) comes closer to bounding the experimental data but the membrane stresses are still low (9% axial and 15% hoop).

The 200 Monte Carlo trials are also performed for the LDR specification. Because of some additional conservatisms in the load harmonic amplitudes, the 50% NEP now bounds the column forces and radial displacement substantially, essentially matches the axial membrane stress, and underpredicts the FSTF peak hoop stress by only about 6%.

The report then proceeds to perform 200 Monte Carlo response calculations for the model of a real facility (Oyster Creek). Clearly in this exercise only the LDR harmonics can reasonably be applied and no direct comparison to experiments can be performed. The results, however, suggest that the cumulative probability distributions (CDP's) for the real facility are very similar to those for the FSTF facility. The ratio of the 50% NEP level to the absolute sum is about the same as in FSTF and lies in the vicinity of 50% for the monitored responses. The report's subsequent discussion of the proper way to combine stresses is outside the scope of this review and not directly relevant to the load specification issue.

On the basis of the information summarized above, the report recommends a simple design rule that will yield 90% confidence of 50% NEP. The results of (b) and (c) for FSTF, and the calculations for Oyster Creek demonstrate that taking an absolute sum of the three highest harmonics (at response level) coupled to a square root of the sum of the squares (SRSS) of the remaining harmonics always bounds and closely approximates the 50% NEP level. The report, therefore, suggests the use of this simple algorithm for the addition of the harmonic components in the frequency domain. In order to provide additional conservatism in a real facility, the harmonic load components that span a structural natural frequency are tuned to the natural frequency rather than applied at the average frequency in the interval. A comparison of the application of this design rule to the FSTF facility (where frequency tuning is not used) to the measured data shows that all peak responses are bound, except the hoop stress which is about 5% low. The report suggests a number of conservatisms in the loading that would compensate for this small discrepancy. The primary effect suggested is related to the damping of 2% used in analysis. In a real facility, where loads are combined and are thus higher, the 2% damping is a conservative representation of the structure and would thus lead to conservative responses.

B. Review of SMA report 12101.04-R001D, R002D and R003D

Report SMA 12101.04-R001D, "Evaluation of FSTF tests M12 and M11B Condensation Loads and Responses," was not available and thus not directly reviewed. The major results and conclusions of that report are, however, summarized in SMA 12101.04R002D, and were found to be consistent with both the original report NEDE-24840 and the FSTF Supplemental Test Letter Report M1-LR-81-01P.

Report SMA 12101.04-R002D, "Response Factors Appropriate for Use with CO Harmonic Response Combination Design Rules," summarizes all of the conclusion of NEDE-24820 and updates the comparison to include FSTF tests M12 and M11B. When test M12 is included in the comparison, the design rule application of the LDR harmonics to the FSTF torus underestimates peak measured membrane axial stress by 11% and underestimates the hoop stress by 14%, while bounding the other responses. On the basis of this comparison, the report suggests modifying the design rule by using a "response factor: $R_f = 1.0$ for other responses. In addition, the report adds an additional design rule for those circumstances where the combination of absolute sum and SRSS is not convenient, such as in the time domain. In this case the report states that a 90% confidence of 50% NEP level can be achieved by multiplying the peak response resulting from a single random phased trial by 1.15. Note that for membrane stresses and strains there is an additional 1.15 "response factor" described above. The conclusions provide criteria for design analyses along the lines just discussed, but an additional simplification of neglecting harmonic components above 30 HZ is suggested for structures with similar natural frequency content to the FSTF or Oyster Creek.

Report SMA 12101.04-R003D, "Statistical Basis for Load Factors Appropriate for Use with CO Harmonic Response Combination Rules," reiterates the design rules described above. In addition, recognizing potential uncertainties in the data, the report attempts to provide some justification for neglecting any additional factor to provide adequate conservatism. The report shows that, considering the specification is a result of three data points (M8, M12, M11B), the increase in response to achieve 75% confidence of 84% NEP ranges from 2% for inside column force to 33% for the hoop stress. The report further quotes an unreferenced communication from Dr. Alan Bilanin as stating a factor of 1.33 for the ratio of the FSTF data to that expected in a real full torus. This effect is purported to be the result of the rigid end effects, but no further explanation is provided. In Appendix A, this effect is examined. We conclude that for these frequencies that are not correlated between bays, the FSTF should produce 32% to 35% higher loads than would exist in a real facility. An examination of the FSTF data (in Supplemented Letter Report M1-LR-81-01-P) shows that only the fundamental frequency near 6 Hz shows any correlation between downcomers. If one assumes correlation between bays at that frequency and random phasing between bays at all other frequencies, the overall conservatism for the average pressure may be as low as 17%, while at the response level the FSTF conservatism will range form 18% for the hoop stress to 38% for the axial stress. If we now balance this versus the maximum expected uncertainty factor for hoop stress (1.33) as in report R003D, we could expect a

maximum degree of nonconservatism of about 13%. This is not serious for two distinct reasons. The additional conservatisms associated with the real structure due to the tuning of harmonic components to the natural frequencies and the closer match to the 2% damping factor can easily compensate for the slight nonconservatism. Secondly, the uncertainty estimate, using only three peak responses form the tests M8, M11B and M12 is probably excessively conservative. If one used 1 second averaged RMS pressures from 8-second high mass flow intervals, as was done in the SER Supplement, the ratio of mean to peak R = 0.72 and the standard deviation is σ_r = 0.172. The resultant load or response at $2\sigma_r$ from the mean (now providing a very high confidence level of non-exceedence) is only 7% above the design rule and can be easily compensated by the 1.18 conservatism factor for the FSTF.

C. Summary and Conclusions

On the basis of the review of these reports the staff concludes that a direct application of design rules as given in report SMA 12101.04R002D on page 41 or in report SMA 12101.04-R003D on pages 1-2 is acceptable. If harmonics above 30 Hz are neglected, as suggested for structures similar to FSTF or Oyster Creek, a specific justification in the form torus response frequency characteristic must be presented.

Any variation that produces at least as high a ratio of response to that produced by absolute sum as the highest observed in the FSTF and Oyster Creek analyses (63%) is also acceptable. Using the design rule as initially stated on NEDE-24840 (without the 1.15 factor for shell stresses) is not acceptable, but a modification using 4 harmonics summed absolutely added to the remaining summed SRSS is marginally acceptable, provided the reported shell stresses are not within a few percent of allowables. The addition of 1 harmonic, to be summed absolutely, provides only about a 10% increase in the responses rather than the 15% needed to bound FSTF measurements. The effect is sufficiently small, however, that further evaluation would be necessary only in the event the resultant stresses approached allowable values very closely.

In summary, the staff finds the analysis presented in the series of reports reasonable. Any conservative application of those results is thus acceptable. The direct application of the design rules, as stated in the final report SMA 12101-04-R003D is considered adequately conservative. Any alternate is acceptable, provided its application to FSTF data would bound all the measured stresses.

APPENDIX C

THE DESCRIBING EQUATIONS FOR THE BNL METHOD OF IMAGES

METHOD OF IMAGES

1. By the method of images, the image locations are defined by

$x_i = 2L_i \pm x_o$ $i, j, k = 0, \pm 1, \pm 2 \ldots$
$y_j = 2H_j \pm y_o$
$z_k = 2D_k \pm z_o$

The tank dimensions are L, H, D in the x, y and z direction respectively. y is the vertical direction, y = 0 is the tank bottom and y = H is the free surface. The origin of the coordinate system is at the lower left corner. x_o, y_o, and z_o define the location of the source with strength P_o.

The potential at any point (x, y, z) can be expressed as

$$P = \sum_i \sum_j \sum_k \frac{(-1)^j P_o}{\sqrt{(x_i - x)^2 + (y_j - y)^2 + (z_k - z)^2}}$$

Define

$\xi_1 = x_0 - x,\ \xi_2 = -x_0 - x,\ \xi_3 = -x_o + x,\ \xi_4 = x_0 + x$
$\eta_1 = -y_0 + y,\ \eta_2 = 2H - y_0 - y,\ \eta_3 = y_0 + y,\ \eta_4 = 2H + y_0 - y$
$\zeta_1 = z_o - z,\ \zeta_2 = -z_0 - z,\ \zeta_3 = -z_0 - z,\ \zeta_4 = z_0 + z$

and

$$I^{+}_{ijklmn} = \frac{1}{\sqrt{(2L_i + \xi_l)^2 + (4H_j + \eta_m)^2 + (2D_k + \zeta_n)^2}}$$

$$I^{-}_{ijklmn} = \frac{1}{\sqrt{(2L_i + \xi_l)^2 + (4H_j + 2H + \eta_m)^2 + (2D_k + \zeta_n)^2}}$$

so that

$$P = P_o \sum_{k=0}^{N} \sum_{h=1}^{NK} \sum_{i=0}^{L} \sum_{l=1}^{NI} \left\{ \left[\sum_{j=0}^{M} \sum_{m=1}^{4} \left(I^{+}_{ijklmn} - I^{-}_{ijklmn} \right) (-1)^{m+1} \right] + I^{+}_{i,M+1,k,l,1,n} - I^{+}_{i,M+1,k,l,2,n} \right\}$$

where

NI = 4		if	i ≠ 1
NI = 2		if	i = 1
NK = 4	if	k ≠ 1	
NK = 2	if	k = 1	

and L, M and N define the number of images used in the image array.

APPENDIX D

THE NRC REQUEST FOR ADDITIONAL INFORMATION AND THE NMPC RESPONSE

NIAGARA MOHAWK

NIAGARA MOHAWK POWER CORPORATION/301 PLAINFIELD ROAD, SYRACUSE, N.Y. 13212/TELEPHONE (315) 474-1511

September 29, 1993
NMP1L 0784

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

RE: Nine Mile Point Unit 1
Docket No. 50-220
DPR-63
TAC No. M85003

Gentlemen:

Subject: *NRC Request for Additional Information Regarding Re-review of Nine Mile Point Nuclear Station Unit 1 Torus Load Reduction Submittal of May 14, 1991*

By letter dated August 26, 1993, the NRC requested additional information necessary to complete the re-review of our May 14, 1991 request to reduce the condensation oscillation loads in the Nine Mile Point Unit 1 Torus. Attachment 1 to this letter provides our response to the requested information.

If you have any questions regarding the response, please contact W. David Baker at (315) 428-7029.

Very truly yours,

C. D. Terry
Vice President - Nuclear Engineering

MJM/lmc

xc: Regional Administrator, Region I
Mr. B. Norris, Senior Resident Inspector
Mr. R. A. Capra, Director, Project Directorate I-1, NRR
Mr. D. S. Brinkman, Senior Project Manager, NRR
Records Management

ATTACHMENT 1

RESPONSE TO THE NRC REQUEST FOR

ADDITIONAL INFORMATION REGARDING

RE-REVIEW OF MAY 14, 1991,

TORUS LOAD REDUCTION SUBMITTAL

NIAGARA MOHAWK POWER CORPORATION

NINE MILE POINT NUCLEAR STATION UNIT NO. 1

DOCKET NO. 50-220

P.03 10-12-1993 09:16

TELEDYNE ENGINEERING SERVICES
A DIVISION OF TELEDYNE BROWN ENGINEERING

RESPONSE TO THE NRC REQUEST FOR ADDITIONAL INFORMATION REGARDING REREVIEW OF MAY 14, 1991, TORUS LOAD REDUCTION SUBMITTAL NIAGARA MOHAWK POWER CORPORATION NINE MILE POINT NUCLEAR STATION UNIT NO. 1 DOCKET NO. 50-220

In Section 3.3.1 of the Nine Mile Point Plant-Unique Analysis Report of the Torus Suppression Chamber (Teledyne Engineering Services (TES) TR-5320-1, Rev. 1; September 21, 1984), it is stated that controlling load combination for the torus shell is that which combines DBA CO with the DBA hydrostatic pressure (P), deadweight (W) and the OBE (Case 20). The NRC staff requests the following additional information and/or clarification with respect to this statement:

1. What fraction of the total shell stress (membrane, local, etc.) derives from the CO loading? From the P loading? Etc.

   Answer:

   For Event Combination 20, Element No. 19 (the most limiting element), the stresses from each of the contributing loads are as follows:

Original Analysis, Unreduced CO

Load	Membrane Stress (PSI)	Percent of Total	Membrane + Bend'g (PSI)	Percent of Total
Deadweight	1,736	10.9%	1,812	10.8%
OBE Seismic	205	1.3%	207	1.2%
Internal Pressure (DBA)	9,219	57.0%	9,722	58.0%
DBA CO	4,970	30.8%	5,010	30.0%
Total	16,150 (16,025)	100.0%	16,751 (16,618)	100.0%
Code Allowable Stress	16,500		24,750	

Note: The stresses in parentheses are from the report (TR-7353-1) and are the principal stresses calculated after all the component stresses from the four load cases are summed. These are lower than the totals obtained by adding the principal stresses from each load case.

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2. After Case 20, what load combination involving CO loads induces the next highest stress in the torus shell? What percentage of the total stress is due to CO?

Answer:

The next controlling event combination is Event Combination 14 for limiting Element No. 19, which includes deadweight, OBE seismic, internal pressure, SRV and IBA CO. The stresses from each of the contributing loads are as follows:

Load	Membrane Stress (PSI)	Percent of Total	Membrane + Bend'g (PSI)	Percent of Total
Deadweight	1,756	13.0%	1,812	11.0%
OBE Seismic	205	1.5%	207	1.3%
Internal Pressure (IBA)	9,928	73.4%	10,470	63.6%
SRV	821	6.0%	2,385	14.5%
IBA CO	824	6.1%	1,596	9.6%
Total	13,534 (13,232)	100.0%	16,470 (15,148)	100.0%
Code Allowable Stress	16,500		24,750	

Note: The stresses in parentheses are the principal stresses calculated after all the component stresses from the five load cases are summed. These are lower than the totals obtained by adding the principal stresses from each load case.

3. What is the worst case load combination involving both CO and SRV loads? What are the stress levels and their split for this case?

Answer:

The worst case load combination, for the limiting element 19, involving both CO and SRV loads is Event Combination 14. See answer to Question 2.

4. What is the worst case load combination for the torus shell that does not involve CO? How are the stresses for that case affected by the thinning of the torus shell? How do they compare with the Case 20 stresses?

Answer:

The worst case event combination that does not involve CO is Event Combination 18 for Element No. 19, which includes deadweight, OBE seismic, and pool swell. The stresses from each of the contributing loads are as follows:

Load	Membrane Stress (PSI)	Membrane + Bending (PSI)
Deadweight	1,756	1,812
OBE Seismic	205	207
Pool Swell	5,968	6,203
Total	7,929	8,222
	(7,812)	(8,103)
Code Allowable Stress	16,500	24,750

Note: The stresses in parentheses are the principal stresses calculated after all the component stresses from the three load cases are summed. These are lower than the totals obtained by adding the principal stresses from each load case.

These stresses would increase slightly due to the thinning of the torus shell. However, as can be seen, these stresses are approximately half the Event Combination 20 stresses, so the latter would control by a wide margin.

Referring now to Section 5.3 of TES TR-7353-1, Rev. 2 (January 14, 1992), provide the following information/clarification:

5. Is the statement that "...Event Combination 20...is controlling" valid for both 8 and 4 downcomer bays? How is this established?

Answer:

Yes. It is established by comparing the stresses from the Event Combinations presented herein. (See response to question 8).

6. What shell thickness is used to calculate each of the "actual" stress levels tabulated in this section?

Answer:

The original thickness is used, t = 0.46 inches.

7. Is the split in stresses due to the various contributing loads identical for the thinner shell case? If it is not, state the fractional distribution.

Answer:

Yes. It would be the same.

8. Is the split in stresses due to the various contributing loads identical for the 4 downcomer bay cases? If it is not, state the fractional distribution?

Answer:

For Event Combination 20, Element No. 19, with reduced CO, the stresses from each of the contributing loads are as follows:

Reduced CO, 8 Downcomer Bays

Load	Membrane Stress (PSI)	Percent of Total	Membrane + Bend'g (PSI)	Percent of Total
Deadweight	1,756	11.3%	1,812	11.3%
OBE Seismic	205	1.3%	207	1.3%
Internal Pressure (DBA)	9,219	59.4%	9,722	60.3%
DBA CO	4,342	28.0%	4,381	27.1%
Total	15,522 (15,452)	100.0%	16,122 (16,044)	100.0%
Code Allowable Stress	16,500		24,750	

Reduced CO, 4 Downcomer Bays

Load	Membrane Stress (PSI)	Percent of Total	Membrane + Bend'g (PSI)	Percent of Total
Deadweight	1,756	12.1%	1,812	12.0%
OBE Seismic	205	1.4%	207	1.4%
Internal Pressure (DBA)	9,219	63.5%	9,722	64.3%
DBA CO	3,349	23.0%	3,375	22.3%
Total	14,529 (14,460)	100.0%	15,116 (15,040)	100.0%
Code Allowable Stress	16,500		24,750	

Note: The stresses in parentheses are from the report (TR-7353-1) and are the principal stresses calculated after all the component stresses from the four load cases are summed. These are lower than the totals obtained by adding the principal stresses from each load case.

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9. Provide the equivalent response to questions 2 and 3 for the 4 downcomer bays.

Answer:

Event Combination 20 is the only case involving DBA CO loads. The next controlling event combination is Event Combination 14 which includes IBA CO. This is also the worst case event combination involving both CO and SRV loads. Since the load reduction being sought is only for DBA CO, there are no changes to the original values for the IBA CO results for Event Combination 14. That is to say, there is no differentiation between the 4 and 8 downcomer bays for event combinations other than the revised Event Combination 20. The results are presented in Question 2.