Attachment to UC-34198

RESPONSE

TO

NRC

(FRANKLIN RESEARCH CENTER)

REQUEST FOR ADDITIONAL INFORMATION
MARK I CONTAINMENT LONG TERM PROGRAM
PLANT UNIQUE ANALYSIS REPORT

STRUCTURAL EVALUATION

FOR

BRUNSWICK STEAM ELECTRIC PLANT

UNITS 1 & 2

Prepared By: R. Toland 8·24·83
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8·24·83
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8/24/83
K. L. Bar Date

QA Review: J. Freeman 8/24/83
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L. R. Scott Date

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INDEX

Responses To

Franklin Research Center

MARK I CONTAINMENT LONG TERM PROGRAM

PLANT UNIQUE ANALYSIS REPORT - STRUCTURAL EVALUATION

REQUEST FOR ADDITIONAL INFORMATION

FOR BRUNSWICK UNITS 1 & 2

(FRANKLIN RESEARCH CENTER)

RAI 1	Indicate whether the vent penetration in the drywell has been analyzed and whether the calculated stresses are within the allowable specified in the criteria (1).
RAI 2	Provide a summary of the anslysis with regard to the (Torus) vacuum breaker piping systems and the vacuum breaker valves; indicate whether they are considered Class 2 components as required by the criteria (1).
RAI 3a	Provide a summary of the analysis for each safety relief valve (SRV) discharge piping which should include the analytical model with piping and supports, from nozzle at main steam line to discharge in suppression pool, discharge device, and its supports.
RAI 3b	Also, the information should indicate that the time history has been used for discharge thrust loads, and spectrum analysis or dynamic load factors for other loads. Justification should be provided if the above criteria are not met.
RAI 4a	Provide a summary of the analysis with regard to the piping systems and supports which provide a drywell-to-wetwell pressure differential, and also provide classification for these piping systems as essential or non-essential.
RAI 4b	Indicate whether the pumps and valves associated with these piping systems are active or inactive components.

RAI 5 With reference to Table 1 of Appendix B, indicate whether all loads have been considered in the analysis and/or provide justification if any load has been neglected.

RAI 6 With reference to Table 1.4.2 in the PUA report (4), provide justification for not considering the following load factors in load cases 1, 16, 52, 64 and 65, respectively: 1.7 HL, 1.1. VEQ, 1.1 LOCA P, 1.7 HL and 1.3 HL as required by the criteria (1).

RAI 7a Indicate whether the liner has been analyzed in accordance with the boundary conditions described in Section 5.6 of the criteria (1).

RAI 7b Also, indicate that the load combinations defined by Table 5-3 (1) with all load factors taken as unity have been considered. Provide justification if the above criteria are not met.

RAI 8 Justify the reasons for using a damping ratio of 5% for structural steel instead of 4% for welded structures for SSE as recommended by NRC Regulatory Guide 1.61 (5).

RAI 9 Provide information showing that the equivalent static and dynamic load factor analysis for the Torus has yielded conservative results compared to the time history required by the criteria (1).

RAI 10 Provide and justify the reasons for not considering a 180° segment of the Torus in order to determine the effects of seismic and other nonsymmetric loads.

RAI 11a Indicate whether each Torus attached piping and its supports have been classified as Class 2 or Class 3 piping, Class 2 or Class 3 component supports, essential or non-essential piping systems.

RAI 11b Also, indicate whether a pump or valve associated with the piping mentioned above is an active or inactive component, and is considered operable.

RAI 12a Provide a summary of the analysis of Torus attached piping consisting of an analytical model which represents piping and supports from Torus to first rigid anchors (or where the effect of Torus motion is insignificant), and classification of piping systems as essential or non-essential for each load combination.

RAI 12b Also, indicate whether a response spectrum or time history analysis for dynamic effectg of Torus motion at the attachment points has been considered.

RAI 13 Provide details of fatigue analysis for piping systems.

RAI 14 Provide justification for the validity of analyzing SRV piping in two separate lengths (above and below the vent header) as indicated in Section 2.3.1.1 of PUA report (4).

RAI 15 With reference to Section 3.8.4.2 of the PUA report (4), provide justification for using the SRSS method for combining responses due to SRV and chugging loads, specifically indicating whether the stress intensity value corresponds to 84% probability of non exceedance as determined from the cumulative distribution function.

RAI 16 Indicate whether the fatigue usage factors for the SRV piping and the Torus attached piping are sufficiently small so that a plant-unique fatigue analysis is not warranted for piping. The NRC is expected to review the conclusions of a generic presentation (6) and determine whether it is sufficient for each plant-unique analysis to establish that the expected usage factors for piping are small enough and do not warrant a plant-unique fatigue analysis of the piping.

RAI 17 The ASME Code provides an acceptable procedure for computing fatigue usage when a member is subject to cyclic loadings of random occurrence, such as might be generated by excitations from more than one type of event (SSE and SRV discharge, for example). This procedure requires correction be made to the stress-range amplitudes considered and to the associated number of cycles, in order to account for the interspersion of stress cycles of unlike character. State whether or not the reported usages reflect use of this method. If not, indicate the effect on reported results.

RAI 18 During foal swell and seismic events, local concentrated loads are applied to the suppression chamber at eight vent locations, 45° apart. For example, on page 1-31 (4), it is stated that the vent header load during foal swell is 342 kips. In the overall analysis of the suppression chamber, these descrete loads are represented as a uniform line load (of equal total magnitude) instead of invoking the Wilson 2 capability to expand the load in Fowner series with approximating load peaks at eight equally spaced stations. Develop the justification of your procedure in greater detail.

RAI 19a Provide justification for neglecting the discontinuities in the overall structure of the suppression chamber (a 16-sided polygonal ring).

RAI 19b Also, provide justification for the implicit assumption that stress distributions and magnitudes so obtained conservatively represent those of the actual structure. In particular, address the situation at joints between adjacent straight segments.

RAI 20 Section 1.5 states that the thermal effects were considered, assuming a linear temperature gradient between the liner and the exterior surface of the concrete. Although a linear temperature distribution is substantially correct for steady state conditions in the wall structures with concentric inner and outer boundaries, it is not theoretically correct for the case of a thick section with a circular inner boundary and approximately square outer one. Discuss the adequacy of this assumption to predict the onset of thermal cracking in the concrete.

RAI 21 In Section A.1.1, a normal mode and frequency response analysis for CO loading, made to assess effects of fluid/structure interaction, is described. Provide the total number of modes used in the summation, the total percentage of modal effective mass thus included, and discuss provisions which may be incorporated in the computer program to account for effects of the unsummed portion of the modal effective mass.

RAI 22a Provide a summary of the results for the submerged structures listed in Section 2.1.1. (b), page 2-1 and contained in the calculation books listed in Appendix A-2 (D & E), pages 2-21 and 2-11 (4).

RAI 22b Also include the results of the strainer analysis performed by the supplier, as referenced in Section 2.3.1.2 (4).

RAI 23 Section 3.8.4.3, page 3-47 and Item 4 of Table 3.4.1.1 (4), second page, indicate that the limits on the local membrane stress intensity and on primary - membrane - plus - primary - bending stress intensity were modified by using 1.3 S_{mc} in place of S_{mc} and certain restrictiions are mentioned in a note related to this section. Conform whether these limitations have been applied in the analysis.

RAI 24 The stiffness matrix for the downcomer/vent header intersection given in Table 3.6.1.1-1 (4) and used for the beam model analysis (Section 3.6.2) shows the diagonal terms only, i.e., no-off-diagonal terms indicated. Justify and state the assumptions for not including other significant off-diagonal terms.

RAI 25a The downcomer/vent header finite element model shown on Figure 3.6.1.1-12 (4) indicates that large elements with non-conventional aspect ratio were used at some regions of discontinuities, such as the stiffening plate regions attached to the downcomer and to the vent header. Indicate the calculated stress intensity values at such locations.

RAI 25b Also indicate on Figure 3.6.1.1-12 and -13 (4), the locations corresponding to the high stress intensity values given in Table 3.8.4.3.1 (4).

RAI 26 Provide a justification for using a stress concentration factor of 2, stated on page 3-48 (4).

RAI G1 With reference to Section 1.5 in the PUA report (4), justify the assumption that the fluid structure interaction and dynamic load factors for post-chugging are the same as those for condensation oscillation.

RAI G2 Provide information indicated that the water mass has been included in the seismic analysis of the Torus. Provide justification if it has not been considered.

RAI G3a With reference to Section A-1.2.5 in the PUA report (4), provide information on the stress results for condensation oscillation load at modal points listed in Table A-1-10 (4).

RAI G3b Also provide justification for considering those stresses which yielded dynamic load factors greater than 1.45 not reliable or typical.

RAI G4 Provide details and schedules for the relocation of the electric penetration box which was found to be overstressed as indicated in Section 2.3.2.9 of the PUA report (4).

RAI G5 With reference to Table 2.3.2-3 of the PUA report (4), indicate the schedule for modifications of the platform structure.

RAI 1 Indicate whether the vent penetration in the drywell has been analyzed and whether the calculated stresses are within the allowable specified in the criteria (1).

RESPONSE

The vent penetration in the drywell was not analyzed for the following reason. The major load transmitted to the drywell penetration by the vent is pool swell impact and drag acting on the bottom of the vent system. It was determined that a modification, consisting of additional upper columns at the vent/ring header intersection, would be required to help resist these loads. To assure adequacy of the modification, the pool swell loads on the vent and the vent/ring header intersection were calculated very conservatively. Using the conservative pool swell loads, the ratio of calculated stress to allowable stress in the vent ranged between 8% and 19%. These ratios represent an upper bound and could be significantly reduced by removing conservatism from the load definition. Since the vent transmits only a small portion of its allowable load back to the penetration, there is no need to perform an analysis of the penetration.

RAI 2 Provide a summary of the analysis with regard to the (Torus) vacuum breaker piping systems and the vacuum breaker valves; indicate whether they are considered Class 2 components as required by the criteria (1).

RESPONSE

(See also the response provided to Item 4.)

The Brunswick vacuum breaker valves were designed and manufactured in accordance with the ASME Code Section III, Subsection B, i.e., Class 1, without N-stamps. The drywell-wetwell vacuum breakers for Brunswick are inside the torus and do not have a piping system.

RAI 3a Provide a summary of the analysis for each safety relief valve (SRV) discharge piping which should include the analytical model with piping and supports, from nozzle at main steam line to discharge in suppression pool, discharge device, and its supports.

RESPONSE

The safety relief valve (SRV) discharge piping analysis is divided into two models. The upper model includes the primary steam line with the attached SRV discharge piping lines in the drywell down to the vent header. The lower model includes the SRV discharge piping from the vent header downstream into the suppression pool and is discussed in detail in the Plant Unique Analysis Report section 2.3.11.

The upper model of SRV discharge piping including primary steam line was analyzed for the usual thermal, dead weight, and seismic loading conditions as well as SRV discharge transients. The piping model with supports is shown on the attached isometric drawing, sheets 514, 624 and 626.

Seismic analysis used the dynamic response spectrum approach in accordance with NRC, IE Bulletin 79-07.

ISOMETRIC DRAWINGS

SHEETS 514, 624 and 626

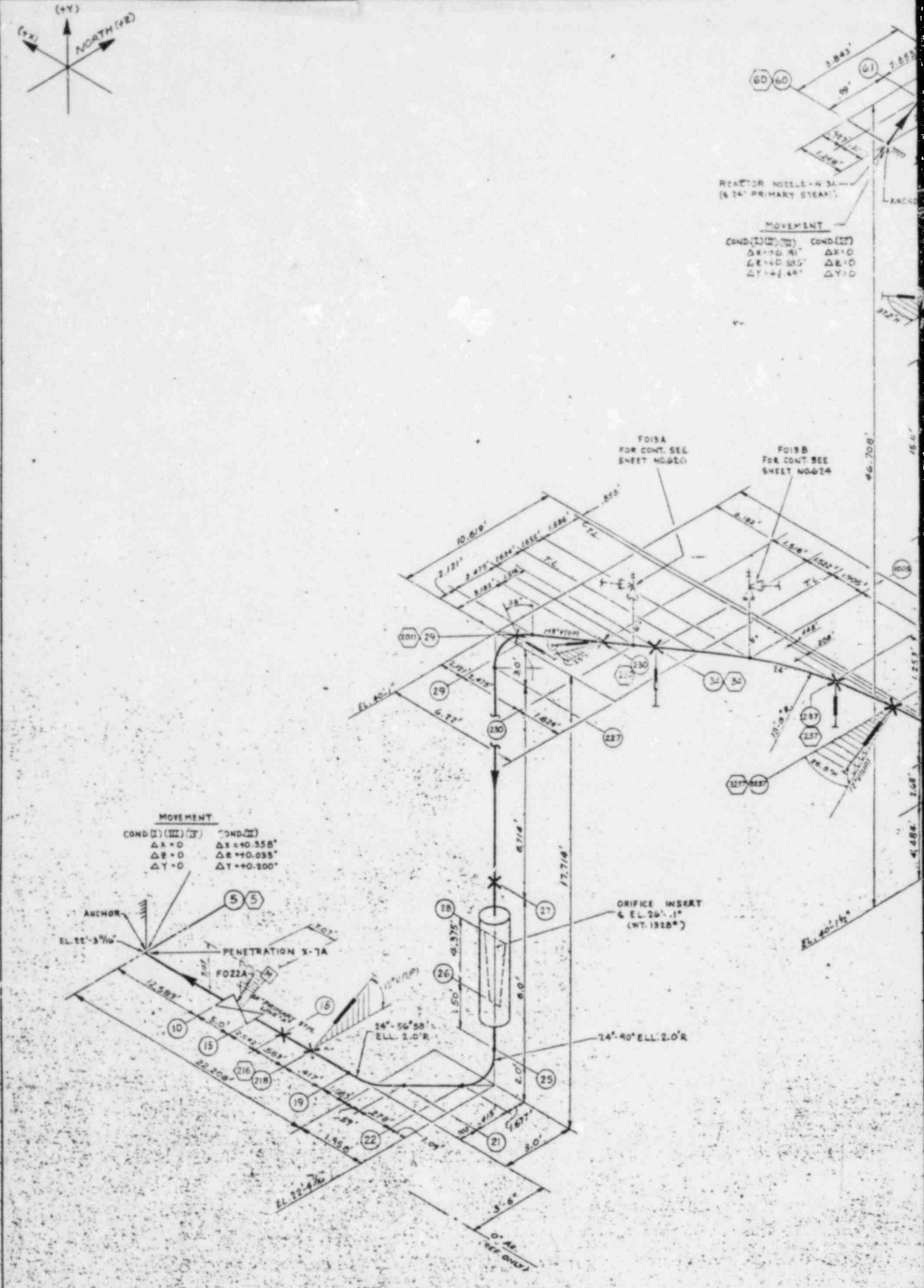
(3 Sheets)

CAROLINA POWER & LIGHT COMPANY

BRUNSWICK STEAM ELECTRIC PLANT

UNITS 1 & 2

Attachment RAI-3a



PIPE PROPERTIES			
SIZE (IN.)	24	10	—
LINE CLASS	–	602	
MATERIAL	C.S.	C.S.	
SCHEDULE	80	100	
O.D. (IN.)	24.0	10.75	
t (IN.)	1.218	.718	
METAL AREA (IN²)	87.17	22.63	
PIPE WT. (LB/FT)	291	76.93	

ANALYSIS TO BE PERFORMED	
THERMAL FLEXIBILITY	YES
DEAD WEIGHT	YES
SEISMIC	YES
SRV TRANSIENT	YES

SYSTEM DWG. (REF.)
F.P. 9527-5140

CONDITIONS	I	II	III	IV
TYPE	NORMAL OPERATION	ACCIDENT	[illegible]	REFUEL
TEMPERATURE (°F)	560°	560°	[illegible]	70°
PRESSURE (PSIG)	1118	1118	—	—
ANCHOR MOVEMENTS AS NOTED	YES	YES	YES	NONE

VALVE PROPERTIES					
VALVE NO.	F022A	F002			
SIZE	24"	10"			

SUPPORT

NUMBER	LOC	DESCRIPTION
1PSN-A2CH29	70	SPRING
1PSN-A2SS30	255	SNUBBER(Z)
1PSN-A2SS31	254	SNUBBER(X)
1PSN-A3SS32	227	SNUBBER(Z)
1PSN-A3SS33	237	SNUBBER(Y)
1PSN-A3SS34	34	SNUBBER(Y)
1PSN-A3SS35	57	SNUBBER(X)
1PSN-A3SS292	230	SNUBBER(Z)
1PSN-A4VH36	27	SPRING
1PSN-A5VH37	16	SPRING
1PSN-A5SS36	218	SNUBBER(Z)
1E41-4CH43	175	SPRING
1E41-4SS44	140	SNUBBER(X)
1E41-4SS45	140	SNUBBER(Y)
1E41-4CH46	165	SPRING
1E41-4SS47	136	SNUBBER(Z)
1E41-4CH48	131	SPRING
1E41-4SS49	121	SNUBBER(Z)
1E41-4SS50	116	SNUBBER(X)
1E41-4SS51	320	SNUBBER(Z)
	6	ANCHOR
	105	ANCHOR
	60	NOZZLE
1E41-4SS270	125	SNUBBER (Z)

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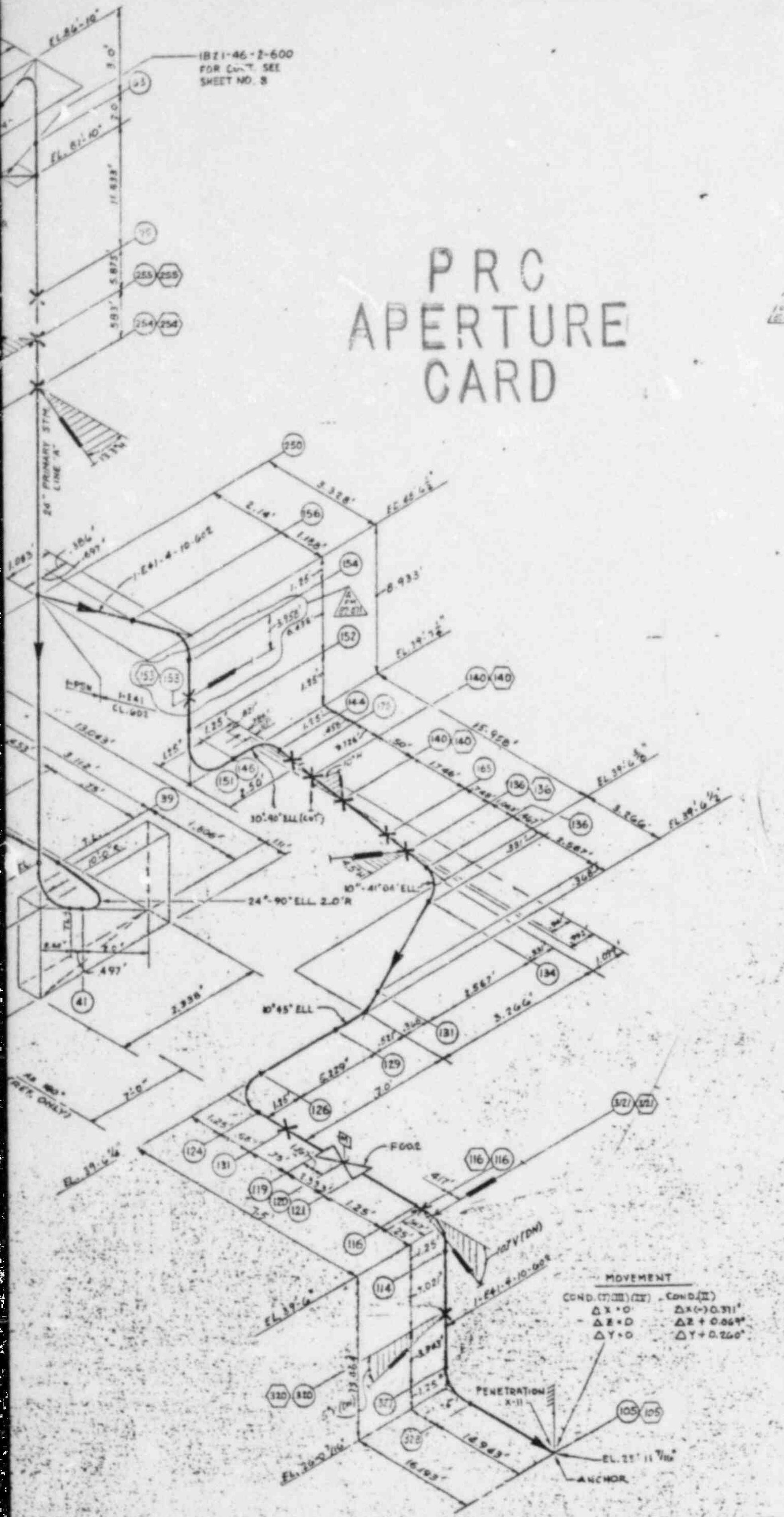
CARD



NOTES:

|—✕—| INDICATES POINT OF SUPPORT (SPRING, GUIDE, SNUBBER, ETC.)

○ INDICATES SEISMIC, THERMAL, & WEIGHT DATA POINT LOCATION.

⬡ INDICATES TRANSIENT DATA POINT LOCATION

PM-82-071
REF. 9527-F-28046 SHT. 514

FIRST ISSUE REDRAWN FOR PM-82-
DATE
ENGINEER F.A. COOK
STATE REG. NORTH CAROLINA NO. 9925

CAROLINA POWER & LIGHT COMPANY
BRUNSWICK STEAM ELECTRIC PLANT

STRESS ANALYSIS DIAGRAM
NUCLEAR STEAM SUPPLY SYSTEM
24" PRIMARY STEAM LINE "A" &
10" HPCI STEAM SUPPLY
UNIT NO.1 SHEET NO.514

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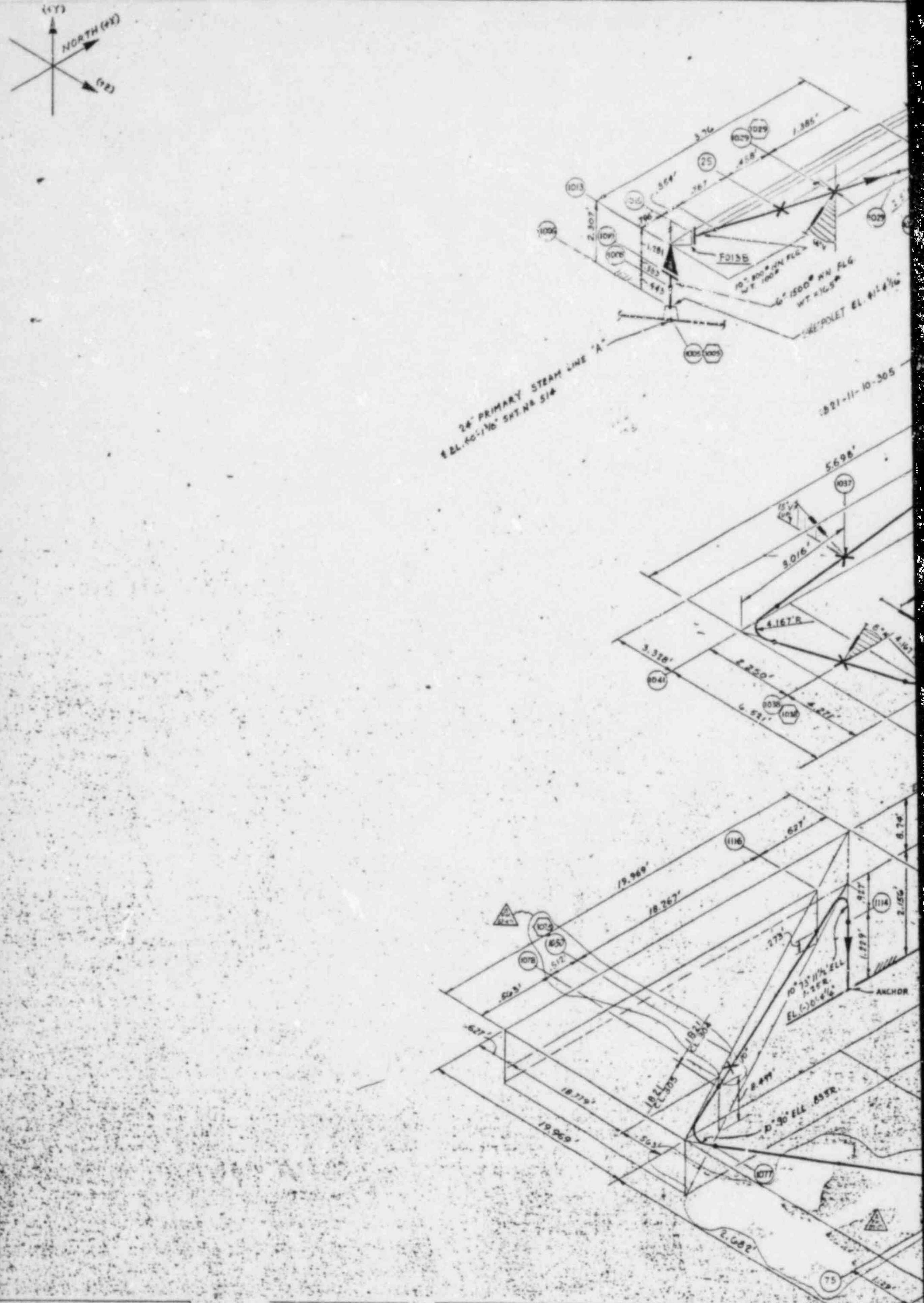


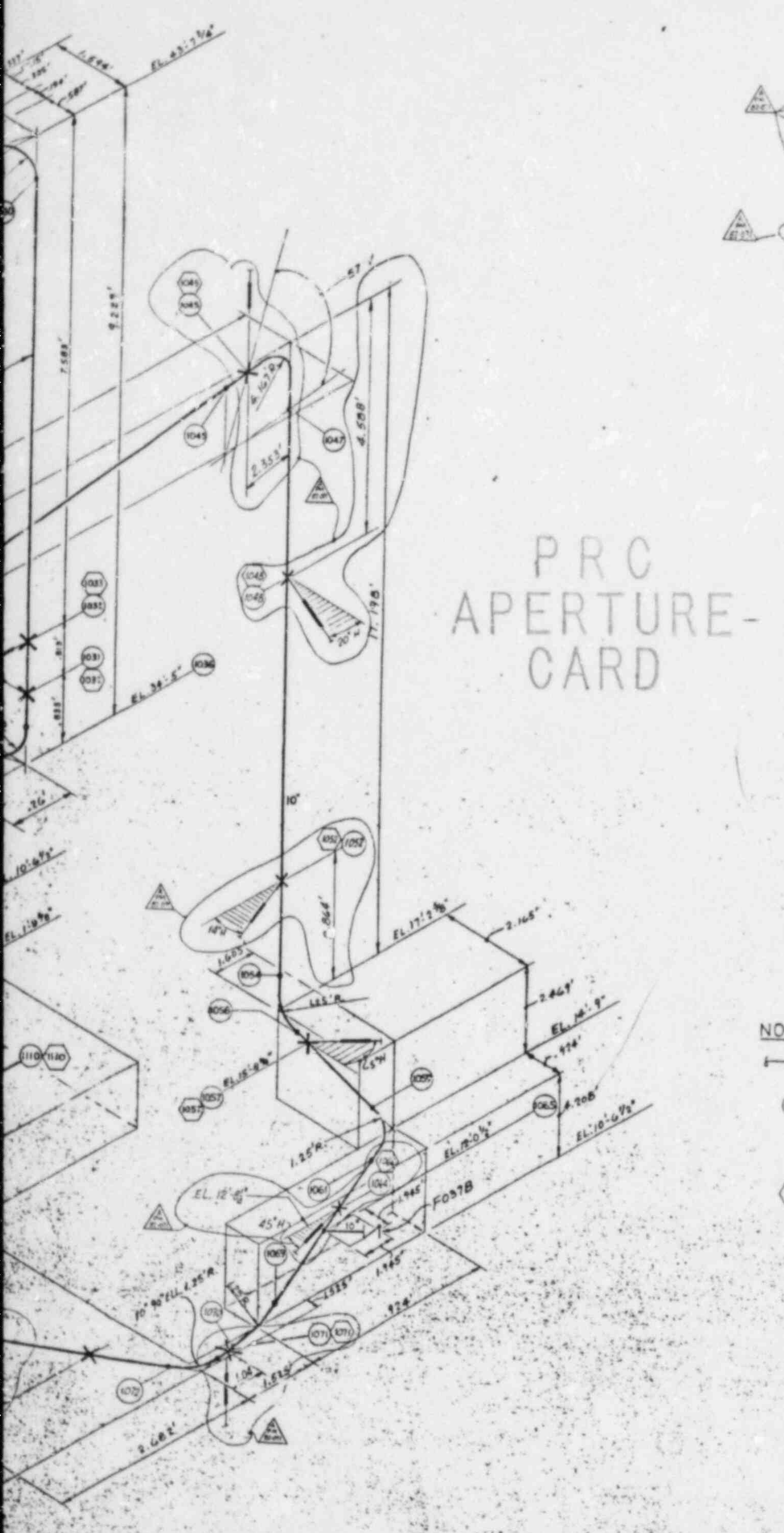
PIPE PROPERTIES			
SIZE (IN.)	10	6	
NE CLASS	304/305	-	
ATERIAL	C.S.	C.S.	
HEDULE	80	160	
D. (IN.)	10.75	6.625	
(IN.)	.593	.718	
TAL AREA (IN²)	18.92	13.32	
E WT. (LB/FT)	64.30	45.30	
TER WT. (LB/FT)	34.11	19.46	
LATION WT. (LB/FT)			

ANALYSIS TO BE PERFORMED	
THERMAL FLEXIBILITY	YES
DEAD WEIGHT	YES
SEISMIC	YES
SRV TRANSIENT	YES

SYSTEM DWG. (REF.)
9527-D-27092
9527-D-27093

CONDITIONS	I	II	
TYPE	NORMAL OPERATION	ACCIDENT	
TEMPERATURE (°F)	560	560	
PRESSURE (PSIG)	1118	1118	
ANCHOR MOVEMENTS AS NOTED	YES	YES	

VALVE PROPERTIES					
VALVE NO.	F013 B	F031-B			
SIZE (IN)	6 X 10	10			
DRY WEIGHT	350	340			



SUPPORT		
NUMBER	LOC.	DESCRIPTION
1B21-11VH 219	25	SPRING
1B21-11SS 220	1029	SNUBBER (Y)
1B21-11SS 221	[illegible]	SNUBBER (X)
1B21-11PG 222	[illegible]	GUIDE (Z)
1B21-11SS 225	1036	SNUBBER (X)
1B21-11SS 224	1032	SNUBBER (Z)
1B21-11SS 225	1040	SNUBBER (Y)
1B21-11VS 226	75	SPRING
1B21-11PG 313	1057	GUIDE (Z)
1B21-11PG 342	1052	GUIDE (X)
1B21-11SS 344	1071	SNUBBER (Y)
	1005	SWEEPOLET
	1110	ANCHOR
1B21-11PG 345	[illegible]	GUIDE (Y & Z)
1B21-11SS 343	1064	SNUBBER (X, Z)
1B21-11SS 341	1048	SNUBBER (Z)
~~1B21-11SS 314~~	~~1073~~	~~SNUBBER (X)~~
~~1B21-11SS 315~~	~~1073~~	~~SNUBBER (Y)~~

NOTES:

- ⊢✕⊣ INDICATES POINT OF SUPPORT (SPRING, GUIDE, SNUBBER, ETC.)
- ○ INDICATES SEISMIC, THERMAL & WEIGHT DATA POINT LOCATION
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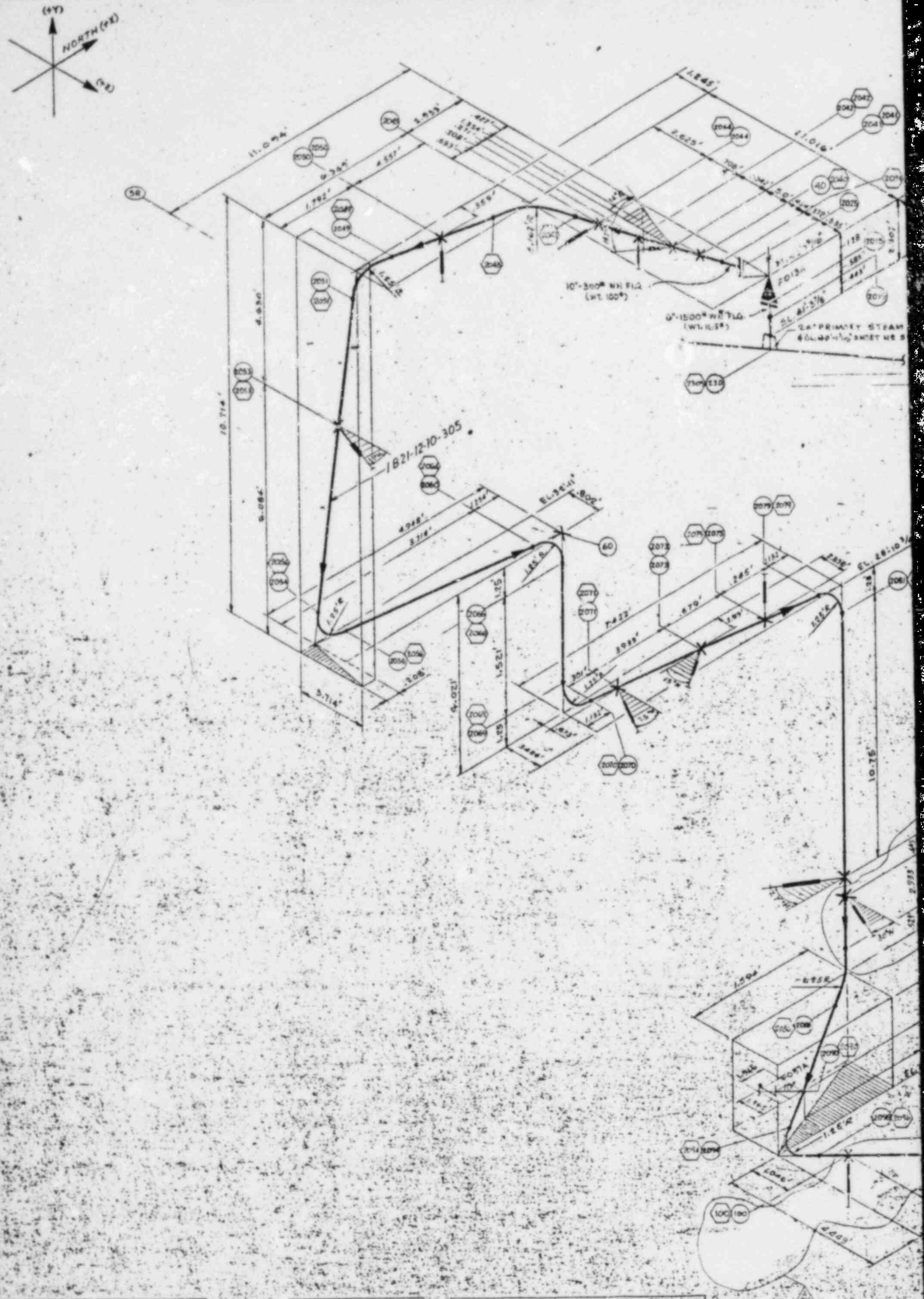
PM 82-071
REF. 9527-F-28046 SHEET No 624

A	[illegible]	FIRST ISSUE - REDRAWN FOR PM 82-071
	DATE	
ENGINEER	F.A. COOK	
STATE REG	NORTH CAROLINA NO 9923	

CAROLINA POWER & LIGHT COMPANY
BRUNSWICK STEAM ELECTRIC PLANT

STRESS ANALYSIS DIAGRAM
NUCLEAR STEAM SUPPLY SYSTEM
RELIEF VALVE F013-B DISCH. PIPING
UNIT NO.1 SHEET NO.624



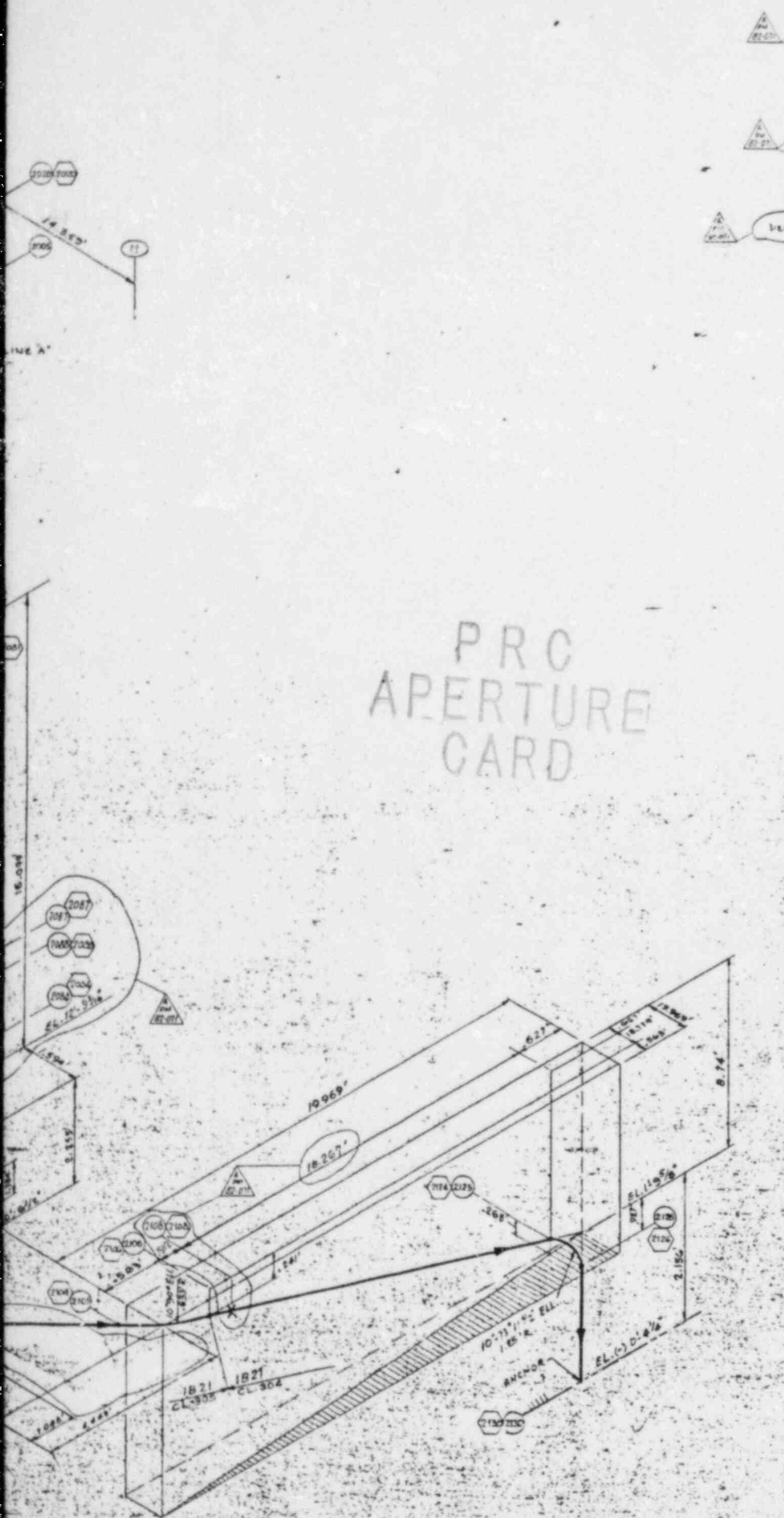
PIPE PROPERTIES			
SIZE (IN.)	10	6	
LINE CLASS	1304 & 305		
MATERIAL	C.S.	C.S.	
SCHEDULE	80	160	
O.D. (IN.)	10.75	6.625	
t (IN.)	.593	.718	
METAL AREA (IN²)	18.92	13.32	
PIPE WT. (LB/FT)	64.30	45.30	
WATER WT. (LB/FT)	31.1	[illegible]	

ANALYSIS TO BE PERFORMED	
THERMAL FLEXIBILITY	YES
DEAD WEIGHT	YES
SEISMIC	YES
TRANSIENT	YES

SYSTEM DWG. (REF.)
8527-D-27092

CONDITIONS	I	II	
TYPE	NORMAL OPERATION	ACCIDENT	
TEMPERATURE (°F)	560	560	
PRESSURE (PSIG)	1118	1118	
ANCHOR MOVEMENTS AS NOTED	YES	YES	

VALVE PROPERTIES					
VALVE NO.	F013A	F013A			
SIZE	6X10	10			



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SUPPORT

NUMBER	LOC	DESCRIPTION
1B21-12PG-283	100	GUIDE (Y)
1B21-12SS-284	2075/73	SNUBBER (Y)
1B21-12VH-285	60	SPRING
1B21-12PS-286	2053	GUIDE (Z)
1B21-12SS-287	2050	SNUBBER (Y)
1B21-12SS-288	2044	SNUBBER (X)
1B21-12SS-289	2042	SNUBBER (Y)
1B21-12SS-290	2041	SNUBBER (Z)
1B21-12VH-291	40	SPRING
1B21-12PG-308	2071	GUIDE (Z)
1B21-12SS-309	2073	SNUBBER (X)
1B21-12SS-310	2087	SNUBBER (X)
1B21-12PG-347	2108	GUIDE (Y, Z)
1B21-12SS-350	2050	SNUBBER (Z)
	2132/2130	[illegible]
	2132/180	ANCHOR
1B21-12SS-311	2093/[illegible]	SNUBBER (X)
1B21-12SS-312	2102/[illegible]	SNUBBER ([illegible])

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NOTES:

- ✕ INDICATES POINT OF SUPPORT (SPRING, GUIDE, SNUBBER, ETC.)
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PM-82-071
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		DATE					
	ENGINEER	F. A. COOK					
	STATE REG.	NORTH CAROLINA NO. 4925					

CAROLINA POWER & LIGHT COMPANY
BRUNSWICK STEAM ELECTRIC PLANT

STRESS ANALYSIS DIAGRAM
NUCLEAR STEAM SUPPLY SYSTEM
RELIEF VALVE F013-A DISCH PIPING
UNIT NO. 1 SHEET NO. 626

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RAI 3b Also, the information should indicate that the time history has been used for discharge thrust loads, and spectrum analysis or dynamic load factors for other loads. Justification should be provided if the above criteria are not met.

RESPONSE

Time-history fluid force transient analysis of the SRV discharge lines was performed to determine the forces, moments, and stresses in the SRV discharge piping. The input for this analysis utilized the General Electric - Mark I fluid force time-history resulting from SRV fluid transient discharge analysis. To account for a single SRV discharge effect on a primary steam line, the resulting fluid transient loads from each SRV time-history analysis were statically applied one at a time to the corresponding primary steam line with a dynamic load factor of 2.0. To account for the effects of all SRV discharges simultaneously, the resulting fluid transient loads from all SRV time-history analyses were statically applied simultaneously to the corresponding primary steam line with a maximum dynamic load factor of 2.0.

RAI 4a Provide a summary of the analysis with regard to the piping systems and supports which provide a drywell-to-wetwell pressure differential, and also provide classification for these piping systems as essential or non-essential.

RESPONSE

The Brunswick plants do not have piping systems which provide a drywell-to-wetwell pressure differential.

The comment is not pertinent to Brunswick since Brunswick does not provide a drywell to wetwell pressure differential.

RAI 4b Indicate whether the pumps and valves associated with these piping systems are active or inactive components.

RESPONSE

See response to RAI 4a.

RAI 5 With reference to Table 1 of Appendix B, indicate whether all loads have been considered in the analysis and/or provide justification if any load has been neglected.

RESPONSE

All applicable loads, listed below, were considered in the torus shell analysis. See PUAR Section 1.3 for detail.

a) Containment Pressure and Temperature	Included	Section 1.3.2 and 1.3.3
b) Pool Swell		
i) Torus net vertical loads	Neglected	Section 1.3.7
ii) Torus shell pressure histories	Included	Section 1.3.7
iii) Froth impingement	Neglected	Section 1.3.7
c) Condensation Oscillation	Included	Section 1.3.9
d) Chugging	Included	Section 1.3.10
e) T-Quencher Loads	Included	Section 1.3.4
f) Ramshead Loads	Not Applicable	

All loads pertinent to the vent system were taken into account in the analysis except the following:

i) Containment temperature and pressure loads

Containment temperature and pressure loads were not significant for vent system structure.

ii) Jet loads on submerged structures

Jet loads on submerged structures were not applicable to vent-header, vents and downcomers.

RAI 5 (Continued)

RESPONSE (Continued)

iii) Froth impingement

This load was covered implicitly by the conservatism in the impact and drag load on the vent.

All applicable loads were considered for the S/RV piping and other wet wall interior structures.

RAI 6 With reference to Table 1.4.2 in the PUA report (4), provide justification for not considering the following load factors in load cases 1, 16, 52, 64 and 65, respectively: 1.7 HL, 1.1 VEQ, 1.1 LOCA P, 1.7 HL and 1.3 HL as required by the criteria (1).

RESPONSE

The hydrostatic pressure was considered as dead load not live load per Ref. (1). A load factor of 1.4 for the hydrostatic pressure has been used for load cases 1 and 64 and 1.0 for load case 65. The hydrodynamic effect of the pool water is due to SRV, condensation oscillation, chugging and pool swell has already been included in the loading cases.

The loading combination for cases 16 and 52 should have been as follows:

$$\text{D.L} + \text{H.L} + T_2 + 1.1\text{P} \pm \sqrt{(1.1\ \text{HEQ})^2 + (1.1\ \text{VEQ})^2} \pm 1.1\ \text{SRV}$$

Case 16 (Correct)

$$\text{D.L} + \text{H.L} + T_2 + 1.1\text{P} \pm \sqrt{(1.1\ \text{HEQ})^2 + (1.1\ \text{VEQ})^2} \pm 1.1\ \text{Pre-chug}$$

Case 52 (Correct)

The following combination has been used due to input error to the load combination program.

$$\text{D.L} + \text{H.L} + T_2 + 1.1\text{P} \pm \sqrt{(1.1\ \text{HEQ})^2 + (\text{VEQ})^2} \pm 1.1\ \text{SRV}$$

Case 16 (Incorrect)

$$\text{D.L} + \text{H.L.} + T_2 + \text{P} \pm \sqrt{(1.1\ \text{HEQ})^2 + (1.1\ \text{VEQ})^2} \pm 1.1\ \text{Pre-chug}$$

Case 52 (Incorrect)

RAI 6 (Continued)

RESPONSE (Continued)

When load cases 16 and 52 are compared with load cases 18 and 54, shown below, it is obvious that the internal forces due to load case 18 are greater than those due to load case 16; the internal forces due to load case 54 are greater than load case 52, because post-chugging loads are higher than pre-chugging (see Section 1.3.10.1 of PUAR). In our opinion, it is not required to correct the input error in load cases 16 and 52 since they are not governing load combinations.

$$D.L + H.L + T_2 + 1.1P \pm \sqrt{(1.1\ HEQ)^2 + (1.1\ VEQ)^2} \pm 1.1\ SRV \pm 1.1\ \text{Pre-chug}$$

(Case 18)

$$D.L + H.L + T_2 + 1.1P \pm \sqrt{(1.1\ HEQ)^2 + (1.1\ VEQ)^2} \pm 1.1\ \text{Post-chugging}$$

(Case 54)

RAI 7a Indicate whether the liner has been analyzed in accordance with the boundary conditions described in Section 5.6 of the criteria (1).

RESPONSE

The liner has been analyzed in accordance with the boundary conditions described in Section 5.6 of the criteria (1).

RAI 7b Also, indicate that the load combinations defined by Table 5-3 (1) with all load factors taken as unity have been considered. Provide justification if the above criteria are not met.

RESPONSE

The load combinations defined by Table 5-3 (1) with all load factors taken as unity have been considered.

Condensation oscillation, chugging and S/RV exert upward pressure on the liner due to the oscillatory nature of the loads. The maximum suction (negative pressure) on the liner, occurring during IBA, is less than 28 psi including the effect of fluid interaction and dynamic load factor and assuming unit load factors in load combination.

The stresses in the liner were obtained for the maximum suction of 28 psi using finite element analysis and assuming that only the anchors provide support for the liner as per Section 5.6 of criteria (1). A 30" by 30" liner plate with appropriate support condition was used in the analysis. The maximum tensile stress in the liner due to local bending of the liner is 12.83 ksi and the maximum compressive stress is 14.85 ksi. The total conservative stress in the liner when seismic and thermal loads are also added are 24.25 ksi compressive and 24.40 tensile. These stresses are below yield stress of the liner.

RAI 8 Justify the reasons for using a damping ratio of 5% for structural steel instead of 4% for welded structures for SSE as recommended by NRC Regulatory Guide 1.61 (5).

RESPONSE

The 5% damping value (pg. 3-37) was used for the Reactor Building structural steel in the seismic analysis of the coupled Reactor Building/vent system model. This value was obtained from the Brunswick FSAR, Table C-1. In accordance with the "Plant Unique Analysis Application Guide" (GE document NEDO-24583-1), it is acceptable to use the methods employed in the original plant design for those loads, such as seismic, that are not redefined by the Mark I Containment Program. Therefore, a damping ratio of 5% for welded steel structures is acceptable for SSE. However, in spite of this, 4% damping was used for the vent system for the SSE.

RAI 9 Provide information showing that the equivalent static and dynamic load factor analysis for the Torus has yielded conservative results compared to the time history required by the criteria (1).

RESPONSE

Time history analysis was used for hydrodynamic loads to study the effect of fluid structure interaction and calculate dynamic load factors. It was noted that the hydrodynamic effect on the reinforced concrete torus is minimal as compared to a steel torus. For seismic analysis, results (maximum accelerations) from the original analysis, based on a response spectra method, was used in accordance with the Section 6.2-a of Reference (1) which justifies the use of such results.

RAI 10 Provide and justify the reasons for not considering a 180° segment of the Torus in order to determine the effects of seismic and other nonsymmetric loads.

RESPONSE

The Wilson II Program, developed by Ghosh & Wilson in 1969, was modified and verified by UNITED for use in the analysis of the torus under quasi-static seismic and other nonsymmetric loads. The concrete portion of the axisymmetric torus is discretized using axisymmetric ring elements of triangular and quadilateral cross section. The liner and the reinforcing bars are modelled using truncated conical shell elements. The nonsymmetric load is expanded in terms of Fourier series to account for variation of the load in the global hoop direction. The solution algorithm used in the program solves a three dimensional structure by combining the results from each coefficient in the Fourier series. The stresses for each element at several locations around the global hoop direction are obtained. The complete torus is, therefore, evaluated in the analysis.

RAI 11a Indicate whether each Torus attached piping and its supports have been classified as Class 2 or Class 3 piping, Class 2 or Class 3 component supports, essential or non-essential piping systems.

11b Also, indicate whether a pump or valve associated with the piping mentioned above is an active or inactive component, and is considered operable.

RESPONSE

All torus internal piping has been analyzed in accordance with the requirements of the ASME Boiler & Pressure Vessel Code Section III, Subsection NC (Class 2). All new support components have been designed in accordance with ASME Section III, Subsection NF criteria. There are no active components attached to the torus internal piping. All active components associated with these piping systems are located outside of the torus and because of the concrete backing, are unaffected by torus induced loads. The torus section strainer qualification is attached to the response of question 22b. The application of these criteria in this manner and incorporation of the required modifications result in the torus internal piping being designed in complete accordance with ASME Section III requirements.

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(Total 6 pages)

CAROLINA POWER & LIGHT COMPANY

BRUNSWICK STEAM ELECTRIC PLANT

UNITS 1 & 2

Attachment RAI 11a

FRC RAI 11A

ATTACHMENT: ITEM # (FRC)

Form 5604

CALC. NO: 7453-119-8-53-60-F

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CALCULATION CONTROL SHEET

CALC. SET NO.	
PRELIM.	
FINAL	✓
VOID	

PROJECT TITLE Carolina Power & Light DISCIPLINE Mech. Nuclear

SYSTEM Nuclear Systems

SUBJECT MARK I Containment Program - Plant Unique Analysis Information to NRC for the Torus Attached Piping

DESIGN CLASSIFICATION Nuclear Safety Related

STARTED BY B. C. Gandhi DATE 5/26/83

AUTHORIZED BY F. A. Cook DATE 5/26/83

PROBLEM STATEMENT

THE NRC STAFF AND ITS CONSULTANT FRANKLIN RESEARCH CENTER (FRC) ARE REVIEWING MARK I CONTAINMENT PROGRAM - PLANT UNIQUE ANALYSIS. FOR THIS PURPOSE NRC HAS REQUESTED (LETTER DATED 4/14/83) TO INDICATE ESSENTIAL/NONESSENTIAL PIPING SYSTEMS THAT ARE ATTACHED TO THE TORUS AND IDENTIFY CLASSIFICATION (CLASS 2/CLASS 3) FOR THESE ATTACHED PIPING AND ITS SUPPORTS. IN ADDITION, STATE WHETHER A PUMP OR VALVE ASSOCIATED WITH THIS PIPING IS CONSIDERED AS AN ACTIVE/INACTIVE AND OPERABLE/INOPERABLE.

(SEE PAGE 3 FOR PROCEDURE USED)

DESIGN BASIS

ASME III, CLASS 1 : THIS IS SAME AS CP&L GROUP CLASS IA.

ASME III, CLASS 2 : THIS IS SAME AS CP&L GROUP CLASS IB.

ASME III, CLASS 3 : THIS IS SAME AS CP&L GROUP CLASS II.

ESSENTIAL : REQUIRED TO MITIGATE AN ACCIDENT

ACTIVE : CHANGES ITS STATE (e.g. N.O. → N.C.)

OPERABLE : OPERABLE TO MITIGATE AN ACCIDENT

NRTO : NOT REQUIRED TO MITIGATE AN ACCIDENT.

TOTAL NUMBER OF SET COMPUTATION SHEETS 6

FINISHED BY BCGandhi CHECKED BY

	CHECKER	DESIGN SUPER	COGNIZANT ENG'R	DESIGN REVIEW
BY			BCGandhi	
DATE	[illegible]/83		6/7/83	

REVISION 1 STARTED DATE ______ BY ______

FRC RAI 11A

Form 5603

#7453-119-B-SS-60-F

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CALCULATION SUMMARY & REFERENCE SHEET

PROJECT TITLE OP&L DISCIPLINE MECH./NUCL

CALC. SET NO.	
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FINAL	✓
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REV	COMP. BY	CHK'D BY
0	BCGandhi DATE 6/7/83	DATE 6/7/83
	DATE	DATE

SYSTEM NUCLEAR SYSTEMS

SUBJECT MARK I CONT. PROGRAM - TORUS INFO. FOR NRC

DESIGN CLASSIFICATION NUCLEAR SAFETY RELATED

SUMMARY/CONCLUSIONS

(1) TORUS INFO REQUIRED FOR NRC IS TABULATED ON PAGE 4,5&6.

(2) INFO SHOWN ON DWG. 9527-F-1131 MUST BE REVISED TO AGREE WITH THOSE SHOWN ON P&ID'S AND 9527-LL-7080.

REFERENCES: (SPECIFICATIONS, DRAWINGS, CODES, CALCULATION SETS, TEXTS, REPORTS, COMPUTER DATA PSAR ETC.)

9527-F-1131 (2/12/82) : CONTAINMENT LINER SUPPRESSION CHAMBER PENETRATIONS

TS822011 (2/2/82) : R.B. 1E EQUIP LIST REVIEW CAC SYSTEM (P&ID: 9527-D-2515)

TS822014 (3/10/82) : R.B. 1E EQUIP LIST REVIEW Rx RECIRC. SYST. (P&ID: 9527-D-2518)

TS822018 (2/2/82) : R.B. 1E EQUIP LIST REVIEW HPCI SYSTEM (P&ID: 9527-D-2523)

TS822019 (2/2/82) : R.B. 1E EQUIP LIST REVIEW CS SYSTEM (P&ID: 9527-D-2524)

TS822020 (3/10/82) : R.B. 1E EQUIP LIST REVIEW RHR SYSTEM (P&ID: 9527-D-2525)

TS822021 (3/10/82) : R.B. 1E EQUIP LIST REVIEW RHR SYSTEM (P&ID: 9527-D-2526)

TS822024 (3/10/82) : R.B. 1E EQUIP LIST REVIEW RCIC SYSTEM (P&ID: 9527-D-2529)

TS822030 (2/2/82) : R.B. 1E EQUIP LIST REVIEW Rx RECIRC. SYST. (P&ID: 9527-D-2548)

TS822033 (2/2/82) : R.B. 1E EQUIP LIST REVIEW KEEP FILL CHARGE SYSTEM (P&ID: 9527-D-2698)

9527-LL-7080 (5/23/77): NUCLEAR SYSTEMS - INSTRUMENT SCHEMATIC DETAILS

FRC RAI 11A

FORM 5007 REV. 7/79

GENERAL COMPUTATION SHEET

(DISCIPLINE)

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NAME OF COMPANY CP&L UNIT/S BSEP 1&2

SUBJECT MARK I CONT. PROGRAM TORUS INFO FOR NRC

#7453-119-B-SS-60-F

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PROCEDURE USED TO DEVELOP TORUS INFO FOR NRC

(1) ALL TORUS PENETRATIONS WERE LISTED FROM DWG. NO: 9527-F-1131. THIS IS TO ENSURE THAT NO PENETRATION IS MISSED.

(2) REVIEW INSTRUMENT SCHEMATIC DETAIL DRAWINGS (#9527-LL-7080) LINE SIZE, LINE NO., PIPE CLASS AND PENETRATION NO.

(3) REVIEW R.B. 1E EQUIP. LIST REVIEW DRAWINGS ('T' DRAWINGS LISTED ON PAGE 2 OF THIS DOCUMENT) TO DETERMINE ESSENTIAL/NONESSENTIAL PIPING, ACTIVE/INACTIVE COMPONENT AND OPERABLE/INOPERABLE COMPONENT.

(4) PER PROJECT GUIDELINES ALL SUPPORTS FOR ESSENTIAL PIPING ARE SEISMIC DESIGN.

FRC RAI 11A

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GENERAL COMPUTATION SHEET

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NAME OF COMPANY Carolina Power & Light UNIT/S BSEP 1&2

SUBJECT Mark I Cont. Program Torus Info. for NRC

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PENETRATION NO.	SLEEVE SIZE/LINE SIZE	DESCRIPTION (DWG. NO: 9527-F-1131)	SYSTEM/P&ID	LINE NO/PIPECLASS	ESSENTIAL OR NON ESSENTIAL	PIPE SUPPORT CLASS	ACTIVE OR INACTIVE	OPERABLE OR NRTO
X-200A&B	48"	ACCESS HATCH	(BY LINER CONTRACTOR)	NA	NA	NA	NA	NA
X-201A	6'-4"/	VENT LINE	(BY LINER CONTRACTOR)	↓	↓	↓	↓	↓
X-201B	6'-4"	"	"					
X-201C	6'-4"	"	"					
X-201D	6'-4"	"	"					
X-201E	6'-4"	"	"					
X-201F	6'-4"	"	"					
X-201G	6'-4"	"	"					
X-201H	6'-4"	"	"					
X-203	8"/1"φ	SPARE	—	—	—	—	—	—
X-205	20"/20"φ	VAC. RELIEF FROM BLDG AND VENT PURGE INLET	CAC/D-2515	3-20-152/CL.1B	ESSENTIAL	SEISMIC	ACTIVE	OPERABLE
X-206A	8"/1"φ	a-SAMPLE LINE, b-SPARE c&d-LIQUID LEVEL	a&b SPARES d-EA1/D-2523 c-CAC/D-2515	— 717/½"S.S.80S/CL1B 720/½"S.S.80S/CL1B	— ESSENTIAL ESSENTIAL	— SEISMIC SEISMIC	— INACTIVE ACTIVE	— OPERABLE OPERABLE
X-206B	8"/1"φ	a-SPARE b&c-LIQUID LEVEL d-PRESS. TRANS.	— b-CAC/D-2515 c-CAC/D-2515 d-EA1/D-2323	701/½"S.S.80S/CL1B 722/½"S.S.80S/CL1B 715/½"S.S.80S/CL1B	— ESSENTIAL ESSENTIAL ESSENTIAL	— SEISMIC ↓	— INACTIVE ACTIVE INACTIVE	— OPERABLE ↓
X-206C	8"/1"φ	a&d-SPARES b&c-LIQUID LEVEL	d-EA1/D-2323 c-CAC/D-2515 a&b-SPARES	716/½"S.S.80S/CL1B 721/½"S.S.80S/CL1B —	ESSENTIAL ESSENTIAL —	—	INACTIVE ACTIVE —	—
X-206D	8"/1"φ	a&d-SPARES b&c-LIQUID LEVEL	d-EA1/D-2523 c-CAC/D-2515 a&b SPARES	714/½"SS.80S/CL1B 723/½"SS 80S/CL1B —	ESSENTIAL ESSENTIAL —	SEISMIC SEISMIC —	INACTIVE ACTIVE —	OPERABLE OPERABLE —
X-209A (UNIT 1)	8"/1"φ	a&c-SPARES b&d-EMERG. SAMPLE SYSTEM DRAIN TO TORUS	— NOT SHOWN ON P&ID D-25015	— —	— —	— —	— —	— —
X-209B (UNIT 1)	8"/1"φ	a-SAMPLE LINE, CAC H_2 MON b,c&d-SPARES	NOT SHOWN ON P&ID D-25015 —	— —	— —	— —	— —	— —
X-209A (UNIT 2)	8"/1"φ	SPARES	—	—	—	—	—	—
X-209B (UNIT 2)	8"/1"φ	a&c-SPARES b&d-EMERG. SAMPLE SYSTEM DRAIN TO TORUS	— b - CAC/D-2515 d - CAC/D-2515	— 5A-3/4-152/CL.1B 5B-3/4-152/CL.1B	— ESSENTIAL ESSENTIAL	— SEISMIC SEISMIC	— INACTIVE INACTIVE	— OPERABLE OPERABLE

FRC RAI 11A

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GENERAL COMPUTATION SHEET

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SUBJECT MARK I CONT. PROGRAM TORUS INFO. FOR NRC

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PENETRATION NO.	SLEEVE SIZE/LINE SIZE	DESCRIPTION	SYSTEM/P&ID	LINE NO/PIPE CLASS	ESSENTIAL OR NON ESSENTIAL	PIPE SUPPORT CLASS	ACTIVE OR INACTIVE	OPERABLE OR NRTO
X-210A	24"/16"φ	RHR SYST. TEST LINE	E11/D-2525	78-16-152/CL 1B	ESSENTIAL	SEISMIC	ACTIVE	OPERABLE
X-210B	24"/16"φ	RHR SYST. TEST LINE	E11/D-2526	81-16-152/CL 1B	ESSENTIAL	↓	ACTIVE	OPERABLE
X-211A	12"/6"φ	RHR SYST. CONT. COOLING	E11/D-2525	73-16-300/CL.1B	ESSENTIAL	↓	ACTIVE	OPERABLE
X-211B	12"/6"φ	RHR SYST. CONT. COOLING	E11/D-2526	75-16-300/CL.1B	↓	↓	ACTIVE	↓
X-212	14"/8"φ	RCIC TURB. EXHAUST	E51/D-2529	5-8-152/CL.1B	↓	↓	INACTIVE	↓
X-214	30"/24"φ	HPCI TURB. EXHAUST	E41/D-2523	6-24-152/CL.1B	↓	↓	INACTIVE	↓
X-216	8"/2"φ	RCIC VAC. BREAKER	E51/D-2529	56-2-152/CL.1B	↓	↓	INACTIVE	↓
X-217	8"/—	SPARE W/PIPE CAP	—	—	—	—	—	—
X-218	8"/2"φ	HPCI VAC. BREAKER	E41/D-2523	74-2-152/CL 1B	ESSENTIAL	SEISMIC	INACTIVE	NRTO
X-220	20"/20"φ	VENT PURGE OUTLET	CAC/D-2515	5-20-152/CL 1B	↓	↓	ACTIVE	OPERABLE
X-221	8"/2"φ	CONDENSATE FROM RCIC BAROMET. CONDENS	E51/D-2529	32-2-152/CL 1B	↓	↓	INACTIVE	OPERABLE
X-222	8"/2"φ	CONDENSATE FROM HPCI TURB. DRAIN POT	E41/D-2523	36-2-152/CL 1B	↓	↓	INACTIVE	OPERABLE
X-223A	16"/10"φ	CORE SPRAY TEST LINE	E21/D-2524	16-10-152/CL 1B	ESSENTIAL	SEISMIC	ACTIVE	OPERABLE
X-223B	16"/10"φ	CORE SPRAY TEST LINE	E21/D-2524	29-10-152/CL 1B	ESSENTIAL	SEISMIC	ACTIVE	↓
X-224	12"/6"φ	RCIC PUMP SUCTION	E51/D-2529	1-6-150/CL 1A	ESSENTIAL	SEISMIC	ACTIVE	↓
X-225A	30"/¾"φ & 24"φ	RHR PUMP SUCTION PRESS/TEMP.	E11/D-2525 CAC/D-2515	7-24-150/CL 1A INSTR LINE 733/CL 1A	ESSENTIAL ESSENTIAL	SEISMIC SEISMIC	ACTIVE INACTIVE	↓ NRTO

FRC RAI 11A

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NAME OF COMPANY CP&L UNIT/S BSEP 1&2

SUBJECT MARK-I CONT. PROGRAM TORUS INFO FOR NRC

PENETRATION NO.	SLEEVE SIZE/LINE SIZE	DESCRIPTION	SYSTEM/P&ID	LINE NO./PIPE CLASS	ESSENTIAL OR NON ESSENTIAL	PIPE SUPPORT CLASS	ACTIVE OR INACTIVE	OPERABLE OR NRTO
X-225B	30"/½"φ & 24"	WIDE RANGE TORUS LEVEL INSTR. &	CAC/D-2515	INST. LINE 734/CL 1A	ESSENTIAL	SEISMIC	INACTIVE	NRTO
		RHR PUMP SUCTION	E11/D-2526	113-24-152/CL 1B	ESSENTIAL	SEISMIC	ACTIVE	OPERABLE
X-226	24"/16"φ	HPCI PUMP SUCTION	E41/D-2523	1-1C-150/CL 1A	ESSENTIAL	SEISMIC	ACTIVE	OPERABLE
X-227A	20"/14"φ	CORE SPRAY PUMP SUCT.	E21/D-2524	1-14-150/CL 1A	ESSENTIAL	SEISMIC	ACTIVE	OPERABLE
X-227B	20"/14"φ	CORE SPRAY PUMP SUCT.	E21/D-2524	5-14-150/CL 1A	ESSENTIAL	SEISMIC	ACTIVE	OPERABLE
X-229A THRU X-229C	8"/1"φ	SPARES	—	—	—	—	—	—
X-230	12"/—	SPARE W/PIPE CAP	—	—	—	—	—	—
X-231	8"/8"φ	TORUS DRAIN	TD/D-2698	3-3-150/CL 1A	ESSENTIAL	SEISMIC	INACTIVE	OPERABLE
X-232A&D	12"/—	ELECT. SPARE W/PIPE CAP	NOT APPLICABLE	—	—	—	—	—
X-232B&C	12"/—	ELECT. POWER & CONTROL	NOT APPLICABLE	—	—	—	—	—
X-240	12"/¾"φ	SPARES	—	—	—	—	—	—
X-241	12"/¾"φ	a&f - RECIRC Pump B P.D. SUCT/DISCH.	a - B32/D-254B	714/½"SS. 80S/CL 1B	ESSENTIAL	SEISMIC	INACTIVE	OPERABLE
			b -	715/½"SS. 80S/CL 1B	ESSENTIAL	SEISMIC	INACTIVE	OPERABLE
		b - RECIRC. Pump A SUCTION FLOW	c -	712/½"SS. 80S/CL 1B	NONESSENTIAL	NONSEISMIC	INACTIVE	NRTO
		c&d - RECIRC. PUMP A SEAL CHAM PRESS.	d -	711/½"SS. 80S/CL 1B				
			f - ↓	713/½"SS. 80S/CL 1B	↓	↓	↓	↓
		e - SPARE	—	—	—	—	—	—
X-242	12"/¾"φ	SPARES	—	—	—	—	—	—
X-243	12"/¾"φ	e&f - RECIRC. Pump A DISCH. FLOW	a - B32/D-254B	708/½"SS. 80S/CL 1B	NONESSENTIAL	NONSEISMIC	INACTIVE	NRTO
		a&d - RECIRC. PUMP B SUCT. PRESS.	d-	709/				
			e-	707/				
		b&c - SPARES	f- ↓	706/ ↓	↓	↓	↓	↓
			—	—	—	—	—	—
X-244	12"/¾"φ	a&d - REC. PUMP A DISCH.	a - B32/D-2518	716/½"SS. 80S/CL 1B	ESSENTIAL	SEISMIC	INACTIVE	OPERABLE
		e&f - REC. Pump B. DISCH.	d-	717/	NONESSENTIAL	NONSEISMIC	↓	NRTO
		b - H_2 & O_2 MONITORS!	e-	719/	↓	↓	↓	↓
		c - SPARES	f- ↓ b/ CAC/D-2515 (NOT ON P&ID)	718/ ↓ 718/1"SS. 80S/CL 1B	ESSENTIAL	SEISMIC	ACTIVE	OPERABLE
X-245	12"/¾"φ	FOR RECIRC. PUMP A	a - B32/D-2518	705/½"SS. 80S/CL 1B	ESSENTIAL	SEISMIC	INACTIVE	OPERABLE
		a&f - P.D. SUCTION/DISCH.	b - B32/D-2518	710/½"SS. 80S/CL 1B	ESSENTIAL	SEISMIC		OPERABLE
		b - SUCTION FLOW	c -	703/½"SS. 80S/CL 1B	NON ESSENTIAL	NONSEISMIC		NRTO
		c&d - SEAL CHAM. PRES	d -	702/½"SS. 80S/CL 1B				
			f - ↓	704/½"SS. 80S/CL 1B	↓	↓	↓	↓
		e - H_2 & O_2 MONITORS	e - CAC/D-2515 (NOT ON P&ID)	703/1"SS. 80S/CL 1B	ESSENTIAL	SEISMIC	ACTIVE	OPERABLE

RAI 12a Provide a summary of the analysis of Torus attached piping consisting of an analytical model which represents piping and supports from Torus to first rigid anchors (or where the effect of Torus motion is insignificant), and classification of piping systems as essential or non-essential for each load combination.

RESPONSE

The Brunswick Torus is a steel lined, reinforced concrete structure. It is very rigid (unlike all other Mark I toruses which are steel structures); no significant motion is input to torus attached piping at anchor points where each pipe penetrates the torus. Therefore, no analysis for torus attached piping was required.

RAI 12b Also, indicate whether a response spectrum or time history analysis for dynamic effect of Torus motion at the attachment points has been considered.

RESPONSE

See response to RAI 12a.

RAI 13 Provide details of fatigue analysis for piping systems.

RESPONSE

Details of the generic augmented fatigue evaluation performed for Torus Attached and SRV Piping Systems is presented in Section 2.0 and Appendix A of MPR-751, Attachment RAI-13.

MARK I CONTAINMENT PROGRAM

MPR-751

(45 Pages)

CAROLINA POWER & LIGHT COMPANY

BRUNSWICK STEAM ELECTRIC PLANT

UNITS 1 & 2

Attachment RAI 13

MARK I CONTAINMENT PROGRAM
AUGMENTED CLASS 2/3 FATIGUE EVALUATION METHOD AND RESULTS FOR TYPICAL TORUS ATTACHED AND SRV PIPING SYSTEMS

November 1982

MPR-751

Prepared by

MPR ASSOCIATES
Washington, D.C.

MARK I CONTAINMENT PROGRAM
AUGMENTED CLASS 2/3 FATIGUE EVALUATION METHOD AND RESULTS FOR TYPICAL TORUS ATTACHED AND SRV PIPING SYSTEMS

November 1982

MPR-751

Prepared by

MPR Associates
Washington, D.C.

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TABLE OF CONTENTS

1.0 INTRODUCTION AND SUMMARY

The fatigue approach being followed in the Mark I Long-Term Containment Program for torus piping attached and SRV discharge piping is to follow applicable Class 2 piping rules of Section III of the ASME Code (Reference 1). The Code requirements address cyclic thermal and anchor motion stresses. In August 1981 the NRC raised a concern regarding the cyclic stress due to the Mark I cyclic mechanical loads. The Mark I Owners Group and GE met with the NRC to discuss this concern in September 1981 and proposed that a task group be assigned to evaluate whether the Mark I Containment Program loadings and acceptance criteria already contained sufficient margin for fatigue effects and to define a course of action for a generic Mark I response to the NRC concern. The approach was to develop a method for piping fatigue evaluation and to apply the method on piping systems representative of the most limiting in Mark I plants. It was agreed that the fatigue approach should be developed along the lines of the Class 2/3 piping design methods since these methods were already being applied for Mark I Containment Program plant-unique torus piping analyses.

The Mark I fatigue task group was comprised of several of the Mark I A/E's and coordinated by the General Electric Company. The objectives of the group were as follows:

- Determine the loading cycles and loading cycle combinations applicable to the Mark I Containment Program load definitions.

- Develop a methodology for performing an "augmented" Class 2/3 fatigue evaluation on torus piping to account for cyclical mechanical loads.

- Provide the methodology to the Mark I Architect/Engineers for their use in evaluating representative limiting piping systems.

- Prepare a generic evaluation of the torus attached and SRV discharge piping with regard to mechanical fatigue.

The differing analytical approaches used for Mark I piping analysis required close coordination between the A/E's in developing the fatigue methods to ensure that the fatigue method could be applied with analysis results available from each A/E's plant-unique piping analyses.

The final augmented Class 2/3 fatigue evaluation method described in this report reflects the input and comments from all Mark I A/E's and guidance provided by the General Electric Company.

Tables 1-1 and 1-2 indicate the scope of the fatigue evaluations performed with the final fatigue procedure. As can be seen, essentially all of the Mark I plants were addressed. A total of 36 piping systems were included in the evaluation. SRV discharge lines comprised 30% of the systems.

The results of the evaluation of the piping for fatigue due to mechanical loadings in addition to thermal and anchor motion show that fatigue usage for Mark I torus piping is generally low, with fatigue usage typically well below 0.3. None of the lines has a fatigue usage greater than 0.5. It should be noted that the stress results for the most limiting piping systems and locations were selected for each plant. Thus, these results are representative of the most limiting locations for fatigue usage and the remainder of these torus piping systems would have even lower fatigue usage.

TABLE 1-1

SUMMARY OF PLANTS AND TORUS ATTACHED PIPING SYSTEMS INCLUDED IN MARK I CONTAINMENT PROGRAM AUGMENTED CLASS 2/3 FATIGUE EVALUATION

PLANT	TYPE	NUMBER OF TORUS ATTACHED PIPING SYSTEMS ANALYZED
Hatch 1 and 2	BWR-4	2
Peach Bottom 2 and 3	BWR-4	2
Cooper	BWR-4	4
Oyster Creek	BWR-2	3
Pilgrim	BWR-3	3
Millstone 1	BWR-3	1
Vermont Yankee	BWR-4	1
Brunswick 1 and 2	BWR-4	
Quad Cities 1 and 2 and Dresden 2 and 3	BWR-3	1
Duane Arnold	BWR-4	1
Browns Ferry 1, 2 and 3	BWR-4	3
Nine Mile Point 1	BWR-2	2
TOTALS		25

TABLE 1-2

SUMMARY OF PLANTS AND SRV DISCHARGE PIPING SYSTEMS INCLUDED IN MARK I CONTAINMENT PROGRAM AUGMENTED CLASS 2/3 FATIGUE EVALUATION

PLANT	TYPE	NUMBER OF SRV DISCHARGE PIPING SYSTEMS ANALYZED
Hatch 1 and 2	BWR-4	1
Peach Bottom 2 and 3	BWR-4	1
Cooper	BWR-4	1
Fitzpatrick	BWR-4	3
Millstone 1	BWR-3	1
Brunswick 1 and 2	BWR-4	1
Fermi 2	BWR-4	1
Monticello	BWR-3	1
Browns Ferry 1, 2 and 3	BWR-4	1
TOTALS		11

2.0 DISCUSSION OF EVALUATION METHOD

This section contains a description of the evaluation procedure developed for the Mark I torus piping fatigue evaluation: (i) the basis for the method, (ii) the key assumptions made and (iii) the principal conservatisms in the method. Each of these subjects is covered in a separate section below. The abbreviations and nomenclature used in this section are defined in Section 2.0 of Appendix A.

2.1 Basis for Evaluation Method

In developing the basis for the Mark I piping fatigue evaluation two approaches were considered: (i) use of the ASME design fatigue rules for Class 1 piping; or (ii) use of the ASME design rules for Class 2/3 piping augmented to include both mechanical and thermal cyclic stresses in the applicable evaluation equation. The latter approach was followed since the Mark I analysis guidelines already specify that Class 2/3 piping design should be used for the plant-unique evaluation and thus the results of plant-unique evaluations which were already available could be used. In this way the considerable effort of reanalysis of piping with the Class 1 rules could be avoided.

There are two ASME Class 2/3 piping design equations which account for repeated loadings: Equations 10 and 11 of Paragraph NC-3652.3 (Reference 1). As has been shown in Reference 4, there is reasonably good agreement between the Class 2/3 method and the Class 1 (previously B31.7) method, especially below 20,000 cycles where all of the Mark I loadings fall. Reference 4 also describes the basis for the Class 2/3 design equations which were developed by Markl (Reference 5). Markl developed his design equations from piping fatigue data. The stress range reduction factors, which are included in the Class 2/3 design equations, are basically a "stepped" approximation of Markl's equations.

The augmented Class 2/3 method uses the original Markl equations (one for carbon steel and one for stainless steel). A comparison with the current ASME Class 1 design fatigue curve and the Class 2/3 "stepped" approximation is shown in Figure 2-1. As can be seen, there is reasonable agreement between the Markl equation used in the augmented Class 2/3 procedure and the Class 1 design fatigue curve and the Markl equation is conservative when compared to the Class 1 curve below 10,000 cycles.

Tables 2-1 through 2-3 cover the details of the evaluation method including the loadings considered, the loading durations and the load combinations. These loadings are consistent with the loadings defined in the Mark I Load Definition Report (Reference 3) and the load combinations specified in the PUAAG (Reference 6). As shown in Tables 2-2 and 2-3, two evaluations were performed for each piping system: (i) design break accident (DBA) plus normal operating conditions (NOC); and (ii) intermediate or small break accident (IBA/SBA) plus NOC. Each evaluation includes both safe shutdown and operating basis earthquakes. The IBA/SBA evaluation was performed so as to envelope the loading cycles of both the IBA and SBA events.

The stress results for each loading typically correspond to the maximum value which will not, in general, occur for each cycle of the loading. Many time history analyses of these loadings have been performed on Mark I piping systems which show that most of the response cycles are less than the maximum value. To account for this variation, factors were computed to convert the calculated fatigue cycles into effective full stress cycles. The method used to compute these factors involved analysis of the time history responses for each of the loadings on a number of typical Mark I torus piping systems.

2.2 Assumptions

This section lists the principal assumptions which were made in developing the augmented piping fatigue analysis methodology.

- A typical loading history for a piping system attached to a Mark I containment includes:
  - Periodic SRV actuations for the life of the plant (NOC) with the total number of actuations determined for the specific plant. One combined thermal and anchor motion load is assumed to act during each actuation.
  - Five operating basis earthquakes (Reference 2).
  - One accident condition - either DBA or IBA/SBA which includes; (i) one combined thermal and anchor motion loading, (ii) operating basis earthquake (OBE) and safe shutdown earthquake (SSE) earthquake stresses, and (iii) periodic SRV actuations during IBA/SBA with the total number of actuations determined for the specific plant.
- Other thermal cycles due to normal operating conditions (for example, system testing) are considered negligible.
- Stresses due to thermal gradients in the wall of SRV discharge piping do not significantly contribute to fatigue usage. See Appendix B for a discussion of the basis for this assumption.

- Loads are grouped according to the combinations listed in Reference 6 considering the number of cycles for each loading. Equation 11 from ASME Section III, Class 2, Paragraph NC-3652.3 is the basis for calculating fatigue stress ranges.

- To evaluate the allowable number of fatigue cycles the Markl equations are used (Reference 4):

  $N = (245/iS)^5$ -- carbon steel

  $N = (281/iS)^5$ -- stainless steel

  where:

  N = number of cycles

  iS = intensified stress range in ksi

- The fatigue usage due to SRV discharge actuations taking place prior to the Mark I Long-Term Containment Program is accounted for by including an estimated number of discharge actuations corresponding to the full 40-year plant lifetime.

- Each earthquake load contains ten (10) significant response cycles (Reference 2).

- Prechug and IBA condensation oscillation (IBACO) loads are assumed to act at the highest load frequency of 9.5 Hertz, thus giving a reasonable estimate of the number of response cycles per second for this loading.

2.3 Conservatisms in Evaluation Method

This section summarizes the principal conservatisms in the fatigue evaluation method.

- Stresses from hydrodynamic loads were computed on the basis of peak loads which bound full-scale test results.
- Absolute summation was used to combine all dynamic responses.
- All effective full stress cycles were assumed to be in phase when two events are combined; further, events were assumed to combine peak on peak for the duration of the combined event.
- Deadweight (DW) is not a fatigue load and would not normally be included in the fatigue stress summation; however, it is included in all combinations since it is a required loading for ASME Class 2 piping, Equation 11 (Reference 1) and it is conservative to do so.
- Stresses for operating and safe shutdown basis earthquakes are combined with most limiting DBA/IBA/SBA stresses for the appropriate number of full stress cycles.
- Thermal stresses for accident events are combined with the appropriate mechanical stresses although thermal loadings are single cycle loads whose contribution to fatigue would not normally be considered.

- Stresses for the safe shutdown earthquake (SSE) are considered in the fatigue analysis. Typically fatigue analyses do not require consideration of SSE stresses. It is noted that fatigue requirements in the PUAAG (Reference 6) specify that only operating basis earthquake need be considered in the fatigue analysis of Mark I torus shells.

TABLE 2-1

MARK I LOCA EVENT AND LOADING DURATIONS

(Reference 3)

	LOCA EVENT DURATION (seconds)		
LOCA TYPE	DBACO	PRECHG/IBACO	CHUG
DBA	30	30	30
IBA (with steam-driven feed pumps)	--	300	200
IBA (with motor-driven feed pumps)	--	1100	200
SBA	--	900	900

NOTE:

1. Since the augmented Class 2/3 fatigue method was applied generically with IBA and SBA combined as one LOCA event, the following bounding LOCA loading times were used in determining the fatigue loading cycles:

   PRECHG (same as IBACO) -- 1100 seconds

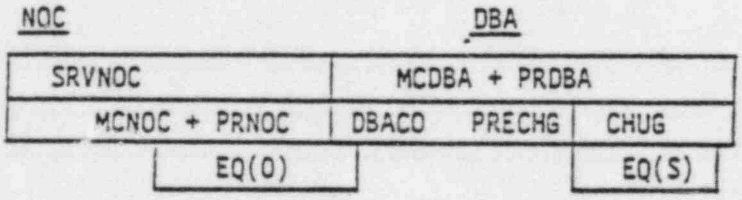
   CHUG -- 900 seconds

   The most limiting IBA event duration (i.e., motor-driven feed pumps) was used to determine the bounding IBA/SBA LOCA event durations.

TABLE 2-2

FATIGUE LOADING COMBINATIONS AND CYCLES FOR NOC + DBA CONDITIONS

COMBINATION (Note 4)	CYCLES
DBACO + EQ(O) + MCDBA + PRDBA	1
DBACO + EQ(O)	9
DBACO	890
CHUG + EQ(S)	10
CHUG	(Note 1)
PRECHG	102
SRVNOC + EQ(O) + MCNOC + PRNOC (Note 3)	40
SRVNOC + MCNOC + PRNOC (Note 3)	(Note 2)
SRVNOC	(Note 2)



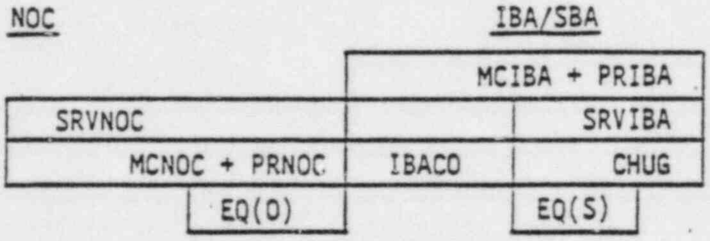
NOTES:

1. Number of cycles depends on dominant piping response frequency.
2. Number of cycles depends on plant evaluation of number of normal SRV actuations and reactuations over the life of the plant (See Appendix A).
3. MCNOC and PRNOC are the thermal expansion and pressure stress ranges and are applicable to SRV discharge piping only under normal operating conditions (NOC).
4. Pool swell excluded from fatigue analysis per guidelines contained in the PUAAG (Reference 6). For nomenclature, see Appendix A.

TABLE 2-3

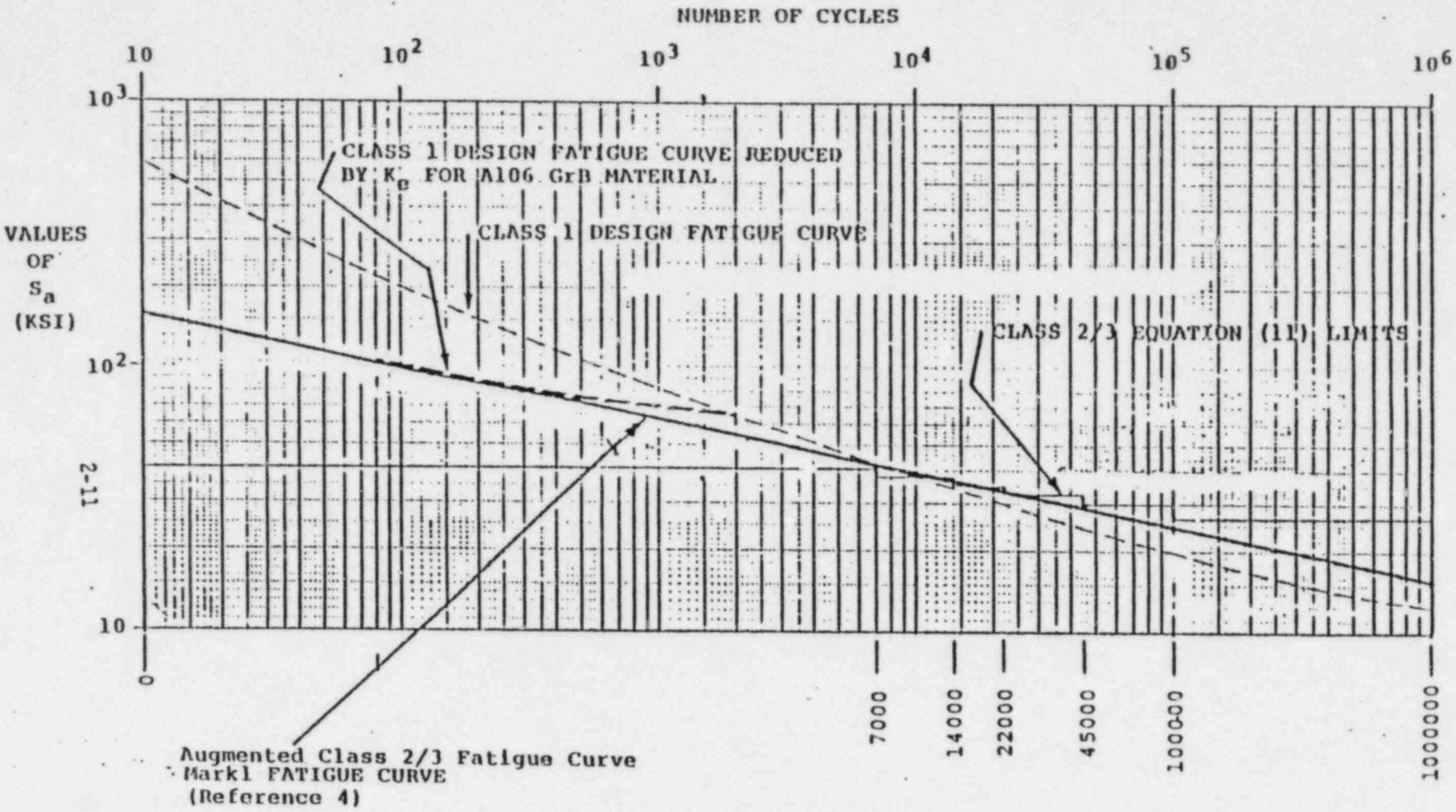
FATIGUE LOADING COMBINATIONS AND CYCLES FOR NOC + IBA/SBA CONDITIONS

COMBINATION (Note 5)	CYCLES
CHUG + SRVIBA + EQ(S) + MCIBA + PRIBA	1
CHUG + SRVIBA + EQ(S)	9
CHUG + SRVIBA	(Note 1)
CHUG	(Note 2)
IBACO (same as PRECHG)	10,450
SRVNOC + EQ(O) + MCNOC + PRNOC (Note 4)	50
SRVNOC + MCNOC + PRNOC (Note 4)	(Note 3)
SRVNOC	(Note 3)



NOTES:

1. Number of cycles depends on plant evaluation of the number of SRV actuations (See Appendix A).
2. Number of cycles depends on frequency of piping (See Appendix A).
3. Number of cycles depends on plant evaluation of number of normal SRV actuations and reactuations over the life of the plant (See Appendix A).
4. MCNOC and PRNOC are the thermal expansion and pressure stress ranges and are applicable to SRV discharge piping only under normal operating conditions (NOC).
5. For nomenclature, see Appendix A.



COMPARISON OF AUGMENTED CLASS 2/3 FATIGUE
LIMITS WITH CLASS 1 DESIGN FATIGUE CURVE

FIGURE 2-1

3.0 RESULTS AND CONCLUSIONS

This section contains the results of the fatigue evaluations performed on over 30 torus piping systems. These systems were selected by each A/E as representative of the most highly stressed torus piping systems in their respective plants. Thirty percent of these were SRV discharge lines and the remainder were lines attached to the torus with sizes ranging from 2-inch to 24-inch. All torus piping systems had a fatigue usage less than 0.5. The fatigue evaluation results, which are tabulated in Table 3-1, are summarized as follows:

- SRV Discharge Piping:

  Percent less than 0.3 fatigue usage -- 72.7%
  Percent less than 0.5 fatigue usage -- 100%

- Other Torus Attached Piping:

  Percent less than 0.3 fatigue usage -- 92.0%
  Percent less than 0.5 fatigue usage -- 100.0%

A very conservative methodology has been developed for fatigue analysis of Mark I Class 2 piping. The fact that the calculated fatigue usage factors are low coupled with the very conservative approach used to develop the fatigue analysis methodology shows that fatigue is not a concern for attached piping. Thus this report answers the concern expressed by the NRC regarding the effect of cyclic mechanical loads on fatigue. Accordingly, there is no need for a complete evaluation of torus piping fatigue on a plant-unique basis.

TABLE 3-1

SUMMARY OF RESULTS OF AUGMENTED CLASS 2/3 PIPING FATIGUE EVALUATIONS FOR REPRESENTATIVE MARK I PIPING SYSTEMS

ARCHITECT ENGINEER Utility Plant	SYSTEM (Size)	FATIGUE USAGE	
		NOC+DBA	NOC+IBA/SBA
A. **Bechtel-Gaithersburg**			
Georgia Power Hatch-2	1. HPCI Pump Suction (16-inch)	0.000	0.002
	2. Core Spray Pump (10-inch)	0.001	0.002
	3. SRV Discharge (10-inch)	0.077	0.096
B. **Bechtel-San Francisco**			
Philadelphia Electric Peach Bottom-3	1. Core Spray System - P-14-5 (16 and 14-inch)	0.001	0.022
	2. Inerting System P-9-2 (20-inch)	0.013	0.004
	3. SRV P-1-5 (12-inch)	0.046	0.202

TABLE 3-1 (Cont'd)

SUMMARY OF RESULTS OF AUGMENTED CLASS 2/3 PIPING FATIGUE EVALUATIONS FOR REPRESENTATIVE MARK I PIPING SYSTEMS

ARCHITECT ENGINEER Utility Plant	SYSTEM (Size)	FATIGUE USAGE NOC+DBA	 NOC+IBA/SBA
C. EDS-Nuclear			
Nebraska Public Power Cooper	1. Core Spray Suction - X227A (16-inch)	0.113	0.149
	2. Core Spray Suction- X227B (16-inch)	0.009	0.012
	3. RCIC Turbine Exhaust (8-inch)	0.279	0.280
	4. HPCI Turbine Exhaust (24-inch	0.020	0.058
	5. a. SRV Discharge (10-inch)	0.116	0.246
	b. SRV Discharge (10-inch)	.005	.006

TABLE 3-1 (Cont'd)

SUMMARY OF RESULTS OF AUGMENTED CLASS 2/3 PIPING FATIGUE EVALUATIONS FOR REPRESENTATIVE MARK I PIPING SYSTEMS

ARCHITECT ENGINEER Utility Plant	SYSTEM (Size)	FATIGUE USAGE NOC+DBA	 NOC+IBA/SBA
D. MPR Associates			
GPU Nuclear Oyster Creek	1. Vacuum Relief-Type 2 (24 and 18-inch)	0.434	0.258
	2. Demineralizer Relief (20-inch)	0.087	0.067
	3. Core Spray Suction (12, 16 and 20-inch)	0.131	0.084

TABLE 3-1 (Cont'd)

SUMMARY OF RESULTS OF AUGMENTED CLASS 2/3 PIPING FATIGUE EVALUATIONS FOR REPRESENTATIVE MARK I PIPING SYSTEMS

ARCHITECT ENGINEER Utility Plant	SYSTEM (Size)	FATIGUE USAGE NOC+DBA	 NOC+IBA/SBA
E. Teledyne			
PASNY Fitzpatrick	1. SRV Discharge-C (10-inch)	0.189	0.117
	2. SRV Discharge-B (10-inch)	0.022	0.027
	3. SRV Discharge-A (10-inch)	0.252	0.303
Boston Edison Pilgrim	1. HPCI Turbine Exhaust (24-inch)	0.000	0.000
	2. RCIC Pump Suction (6-inch)	0.000	0.000
	3. Core Spray Suction (18-inch)	0.000	0.000
Northeast Utilities Millstone 1	1. Heat Exchanger x 210A (8-inch)	0.053	0.003
	2. SRV MS-8F (10-inch)	0.027	0.034

TABLE 3-1 (Cont'd)

SUMMARY OF RESULTS OF AUGMENTED CLASS 2/3 PIPING FATIGUE EVALUATIONS FOR REPRESENTATIVE MARK I PIPING SYSTEMS

ARCHITECT ENGINEER Utility Plant	SYSTEM (Size)	FATIGUE USAGE NOC+DBA	 NOC+IBA/SBA
Yankee Atomic Vermont Yankee	1. Core Spray - Part 6 (10-inch)	0.002	0.002
Niagara Mohawk Nine Mile Point	1. Containment Spray X8-326(3-inch)	.012	.000
	2. Pump II X5-337(12-inch)	.001	.036
F. United Engineers			
Carolina Power Brunswick	1. RCIC Turbine Exhaust (8-inch)	0.086	0.340
	2. RCIC Barom. Condenser (2-inch)	0.001	0.003
	3. SRV Discharge (12-inch)	0.486	0.475

TABLE 3-1 (Cont'd)

SUMMARY OF RESULTS OF AUGMENTED CLASS 2/3 PIPING FATIGUE EVALUATIONS FOR REPRESENTATIVE MARK I PIPING SYSTEMS

ARCHITECT ENGINEER Utility Plant	SYSTEM (Size)	FATIGUE USAGE NOC+DBA	 NOC+IBA/SBA
G. NUTECH			
Commonwealth Edison Quad Cities Unit 1	HPCI Turbine Exhaust (24-inch)	0.047	0.056
Iowa Electric Duane Arnold	Core Spray Suction (12-inch)	0.059	0.039
Detroit Edison Fermi II	SRV Discharge Piping (12-Inch)	0.099	0.056
Northern States Monticello	SRV Discharge Piping (10-inch)	0.307	0.197
H. TVA			
Browns Ferry	RCIC Turbine Exhaust (2-inch)	.010	.021
	RCIC Turbine Exhaust (12-inch)	0.003	0.095
	ECCS Suction Line (16-inch)	.007	.023
	(a) SRV - Line H Elbow (10-inch)	0.003	.232
	(b) SRV - Line H Ramshead (10-inch)	.047	.318

4.0 REFERENCES

1. ASME Boiler and Pressure Vessel Code, Section III, 1977 Edition with Addenda through Summer 1977.
2. NUREG-75/087, Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants, May 1980.
3. NEDO-21888, Revision 2, Containment Program Load Definition Report, General Electric, November 1981.
4. ORNL-TM-3520, "Comparisons of Test Data with Code Methods for Fatigue Evaluation"; E. C. Rodabaugh and S. E. Moore, Oak Ridge National Laboratory, November 1971.
5. Markl, A.R.C., "Fatigue Tests of Piping Components," Transactions ASME, Volume 74, pp. 287-303, 1952.
6. NEDO-24583-1, Mark I Containment Program Structural Acceptance Criteria Plant-Unique Application Analysis Guide, General Electric, October 1979.

APPENDIX A

AUGMENTED CLASS 2/3 FATIGUE EVALUATION METHOD, TABLES AND NOMENCLATURE

1.0 STEPS FOR AUGMENTED ASME CLASS 2/3 PIPING FATIGUE ANALYSIS

In performing the augmented ASME Class 2/3 piping fatigue analysis first enter information on each piping system in the blanks shown in Table A-1. Then proceed with Steps A-G as follows:

STEP A: Calculate stress resultants for each DBA, IBA/SBA and NOC occasional, thermal and anchor motion loading condition. See Tables A-2 and A-3 for individual loads and Section 2.0 for nomenclature.

STEP B: For SRV piping, determine the discharge pressure (P_{SRV}) and the stresses due to thermal expansion and anchor motions (MCNOC) and discharge conditions (SRVIBA).

STEP C: Determine number of SRV actuations that would be expected to occur:

(1) During normal and transient operation over the life of the plant - n_{SRVNOC}

(2) During an IBA or SBA - n_{SRVIBA}

STEP D: Determine maximum characteristic frequency of the piping system for dynamic loadings (f_{max}).

STEP E: Determine the location in the piping system with the most limiting intensified stress conditions. When piping systems have both stainless and carbon steel runs, limiting stresses in both runs should be considered in determining the most limiting location for fatigue.

STEP F: Perform the NOC + DBA fatigue evaluation by completing the information in Table A-2.

STEP G: Perform the NOC + IBA/SBA fatigue evaluation by completing the information in Table A-3.

2.0 NOMENCLATURE

CHUG = Flexural stresses due to chugging loading for DBA/IBA/SBA as defined in Section 4.5 of the LDR (Reference 3). Include stresses due to underwater drag and fluid structure interaction for submerged piping segments (ksi).

D = Nominal outside diameter of piping in inches at location where fatigue evaluation is performed.

DW = Stress in ksi due to deadweight of piping system including fluid where appropriate. Corresponds to M_A/Z in Equation 11 of Section NC-3652.3 of Section III, ASME Code (Reference 1).

DBACO = Flexural stresses due to condensation loading as defined in Section 4.4 of the LDR (Reference 3). Include stresses due to underwater drag and fluid structure interaction for submerged piping segments (ksi).

EQ(O) = Flexural stresses due to operating basis earthquake (ksi).

EQ(S) = Flexural stresses due to safe shutdown earthquake (ksi).

f_{max} = Highest characteristic or participating frequency of the piping system in Hertz. Use f_{max} = 30 Hz unless a lower value can be justified from analysis of the piping system.

i = Stress intensification factor for ASME Class 2 piping analysis (Section NC-3673.2(b)).

IBACO (PRECHG) = Flexural stresses due to IBA/SBA condensation oscillation loading or DBA prechug loading as defined in Section 4.4 and 4.5 of the LDR (Reference 3) (ksi).

MCDBA, MCIBA = Flexural thermal stresses due to thermal expansion of piping during the most limiting condition of DBA or IBA (whichever is applicable) plus the corresponding flexural stresses due to anchor motion (ksi). The MCIBA stresses should also include the flexural stresses due to anchor point motion resulting from SRV actuation during IBA or SBA.

MCNOC = Flexural thermal stresses due to thermal expansion of SRV discharge piping and anchor motions during SRV actuation (ksi).

n_{CYC} = Number of significant response cycles for loadings included by SRV actuation. A value of 15 is used which is arbitrary since it is used in the calculation of R_{SRV}; however, 15 is a reasonable estimate of the number of significant response cycles for SRV thrust loadings.

n_k = Effective full stress cycles for load combination k.

N_K = Allowable cycles for total combination stress S_{TE} calculated as follows (Reference 5):

$N_K = (245/S_{TE})^5$ for carbon steel, S_{TE} (ksi)

$N_K = (281/S_{TE})^5$ for stainless steel, S_{TE} (ksi)

n_{SRVIBA} = Number of SRV actuations and reactuations that would occur during an IBA or SBA accident (whichever is greater).

n_{SRVNOC} = Number of SRV actuations that would occur under normal operating conditions over the remaining life of the plant.

P_A = Pressure range inside the piping due to the most limiting pressure condition of DBA, IBA or SBA, whichever is applicable (ksi).

P_{SRV} = Pressure range in SRV discharge piping due to SRV actuation. This load is only applicable to SRV piping evaluation (ksi).

PRDBA = Stress range in ksi due to maximum internal pressure occurring during a DBA event (ksi).

$PRDBA = P_A \times D/4\ t_n$

PRIBA = Stress range in ksi due to maximum internal pressure occurring during an IBA or SBA event (ksi).

$PRIBA = P_A \times D/4\ t_n$

PRNOC = Stress range in ksi due to internal pressure resulting from SRV actuation (ksi).

$PRNOC = P_{SRV} \times D/4\ t_n$

R_{CHUG} = Equivalent maximum stress cycle factor for the CHUG loading. For recommended value, see Table A-4.

R_{DBACO} = Equivalent maximum stress cycle factor for DBACO loading. For recommended value, see Table A-4.

R_{IBACO} = Equivalent maximum stress cycle factor for the IBACO (or PRECHUG) loading. The recommended value is 1.0 since the load is essentially a single frequency harmonic loading.

R_{SRV} = Equivalent maximum stress cycle factor for the SRV loadings including thrust bubble drag and torus SRV excitation. For recommended values, see Table A-4.

S_1, S_2, etc. = Intensified stress ranges in ksi calculated using the resultant moment and section modulus as defined in Section III, ASME Code (Reference 1).

SRVIBA = Flexural stresses due to actuation and reactuation of SRV system during an IBA or SBA accident. Includes stresses due to thrust and SRV bubble drag where appropriate (ksi).

SRVNOC = Flexural stresses due to actuation of SRV system during normal operating conditions. Include stresses due to thrust and SRV bubble drag where appropriate (ksi) unless included in SRVTQF below.

SRVTQF = Flexural stresses due to bubble drag resulting from actuation of SRVs if not included with SRVNOC stresses.

S_{TE} = Total intensified stress range in ksi for combination based on Equation 11 of NC-3652.3 of Section III, ASME Code (Reference 1). Calculated as follows:

$$S_{TE} = S_1 + S_2 + ... + (0.75\ i \times DW)$$

t_n = Nominal thickness of piping in inches at location where fatigue evaluation is performed.

TABLE A-1

MARK I PROGRAM ATTACHED PIPING
AUGMENTED ASME CLASS 2/3 FATIGUE EVALUATION

I. GENERAL INFORMATION

A. PLANT (UNIT): ____________________

B. UTILITY: ____________________

C. ARCH/ENGR: ____________________

D. PREPARED BY: ____________ DATE: ____

II. PIPING SYSTEM INFORMATION

A. SYSTEM IDENTIFICATION: ____________________

B. NOMINAL PIPE SIZE: ____________________

C. MATERIAL: ____________________

III. PIPING ANALYSIS INFORMATION

A. ANALYSIS METHOD: ____________________

B. INTENSIFICATION FACTOR(i): ____________________

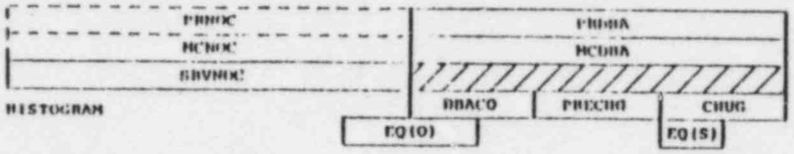
C. LOCATION OF MAXIMUM STRESS: ____________________
(Describe briefly ____________________
or attach figure) ____________________

D. DEADWEIGHT STRESS (DW): ____________________

E. NOMINAL THICKNESS (t_n): ____________________

F. OUTSIDE DIAMETER (D): ____________________

CONDITION (K)	ACTUAL CYCLES	EFFECTIVE CYCLES (n_k)	ASME CLASS 2/3 DBA STRESSES (ksi)				$\frac{\square}{DM}$ S_{SR} $(\Sigma S_j + .75i \times DM)$	FATIGUE USAGE	
			S_1	S_2	S_3	S_4		ALLOWABLE CYCLES (N_k)	USAGE (n_k/N_k)
1		1	$\frac{\square}{2i \times DBACO}$ +	$\frac{\square}{2i \times EQ(O)}$ +	$\frac{\square}{i \times MCDBA}$ +	$\frac{\square}{PRDBA}$ →	= ☐	☐	☐
2		9	$\frac{\square}{2i \times DBACO}$ +	$\frac{\square}{2i \times EQ(O)}$ →			= ☐	☐	☐
3	30 (SEC) × $\frac{\square}{N_{DBACO}}$ × $\frac{\square \; HZ}{f_{max}}$ − 10 (CYC) =	$\frac{\square}{n_3}$	$\frac{\square}{2i \times DBACO}$ →				= ☐	☐	☐
4		10	$\frac{\square}{2i \times CHUG}$ +	$\frac{\square}{2i \times EQ(S)}$ →			= ☐	☐	☐
5	10.7 (SEC) × $\frac{\square}{N_{CHUG}}$ × $\frac{\square \; HZ}{f_{max}}$ − 10 (CYC) =	$\frac{\square}{n_5}$	$\frac{\square}{2i \times CHUG}$ →				= ☐	☐	☐
6	10.7 (SEC) × $\frac{1.0}{N_{DBACO}}$ × 9.5 (HZ) =	$\frac{102}{n_6}$	$\frac{\square}{2i \times PRECHG}$ →				= ☐	☐	☐
7		40	$\frac{\square}{2i \times SRVNOC}$	$\frac{\square}{i \times MCNOC}$	$\frac{\square}{2i \times EQ(O)}$	$\frac{\square}{PRNOC}$ FOR SRV PIPING ONLY →	= ☐	☐	☐
8	1 (Cycles per Actuation) × $\frac{\square}{n_{SRVNOC}}$ − 40 =	$\frac{\square}{n_8}$	$\frac{\square}{2i \times SRVNOC}$	$\frac{\square}{i \times MCNOC}$	$\frac{\square}{PRNOC}$ FOR SRV PIPING ONLY →		= ☐	☐	☐
9	$\frac{\square}{n_{CYC}}$ × $\frac{\square}{N_{SRV}}$ × $\frac{\square}{n_{SRVNOC}}$ − $\frac{\square}{n_8}$ − 40 =	$\frac{\square}{n_9}$	$\frac{\square}{2i \times SRVNOC}$ →				= ☐	☐	☐
10	$\frac{\square}{n_{CYC}}$ × $\frac{\square}{N_{SRV}}$ × $\frac{\square}{N_{SRVNOC}}$ =	$\frac{\square}{n_{10}}$	$\frac{\square}{2i \times SRVTOF}$ →				= ☐	☐	☐



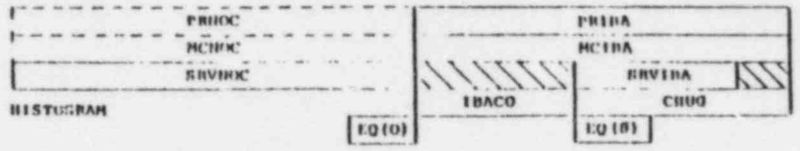
HISTOGRAM

NOTE:
POOL SWELL LOADS EXCLUDED FROM FATIGUE ANALYSIS AS SPECIFIED IN NUREG-0661.

TOTAL USAGE = ☐

TABLE A-2
DBA FATIGUE EVALUATION

[illegible] (K)	ACTUAL CYCLES	EFFECTIVE CYCLES (n_k)	ASME CLASS 2/3 IBA/SBA STRESSES (ksi)						FATIGUE USAGE	
			S_1	+ S_2	S_3	S_4	S_5	S_{TE} $(\Sigma S_j + .75i \times DW)$	ALLOWABLE CYCLES (N_k)	USAGE (n_k/N_k)
1		1	$\frac{\quad}{21 \times CHUG}$	+ $\frac{\quad}{21 \times SRVIBA}$	+ $\frac{\quad}{21 \times EQ(S)}$	+ $\frac{\quad}{1 \times MCIBA}$	+ $\frac{\quad}{PRIBA}$	=		
2		9	$\frac{\quad}{21 \times CHUG}$	+ $\frac{\quad}{21 \times SRVIBA}$	+ $\frac{\quad}{21 \times EQ(S)}$	→	→	=		
3	15 (Cycles per Actuation) × $\frac{\quad}{N_{SRV}}$ × $\frac{\quad}{n_{SRVIBA}}$ − 10 =	$\frac{\quad}{n_3}$	$\frac{\quad}{21 \times CHUG}$	+ $\frac{\quad}{21 \times SRVIBA}$	→	→	→	=		
4	321 (SEC) × $\frac{\quad}{N_{CHUG}}$ × $\frac{\quad HZ}{f_{max}}$ − $\frac{\quad}{n_3 + 10}$ =	$\frac{\quad}{n_4}$	$\frac{\quad}{21 \times CHUG}$	→	→	→	→	=		
5	1100 (SEC) × $\frac{1.0}{N_{IBACO}}$ × 9.5 (HZ)	$\frac{10,450}{n_5}$	$\frac{\quad}{21 \times IBACO}$	→	→	→	→	=		
6		50	$\frac{\quad}{21 \times SRVNOC}$	+ $\frac{\quad}{1 \times MCNOC}$	+ $\frac{\quad}{21 \times EQ(O)}$	+ $\frac{\quad}{PRNOC}$ FOR SRV PIPING ONLY	→	=		
7	1 (Cycles per Actuation) × $\frac{\quad}{n_{SRVNOC}}$ − 50 =	$\frac{\quad}{n_7}$	$\frac{\quad}{21 \times SRVNOC}$	+ $\frac{\quad}{1 \times MCNOC}$	+ $\frac{\quad}{PRNOC}$ FOR SRV PIPING ONLY	→	→	=		
8	$\frac{\quad}{n_{CYC}}$ × $\frac{\quad}{N_{SRV}}$ × $\frac{\quad}{n_{SRVNOC}}$ − $\frac{\quad}{n_3}$ − 50 =	$\frac{\quad}{n_8}$	$\frac{\quad}{21 \times SRVNOC}$	→	→	→	→	=		
9	$\frac{\quad}{n_{CYC}}$ × $\frac{\quad}{N_{SRV}}$ × $\frac{\quad}{N_{SRVNOC}}$ =	$\frac{\quad}{n_9}$	$\frac{\quad}{21 \times SRVTOF}$	→	→	→	→	=		
10										



TOTAL USAGE =

TABLE A-3

IBA/SBA FATIGUE EVALUATION

TABLE A-4

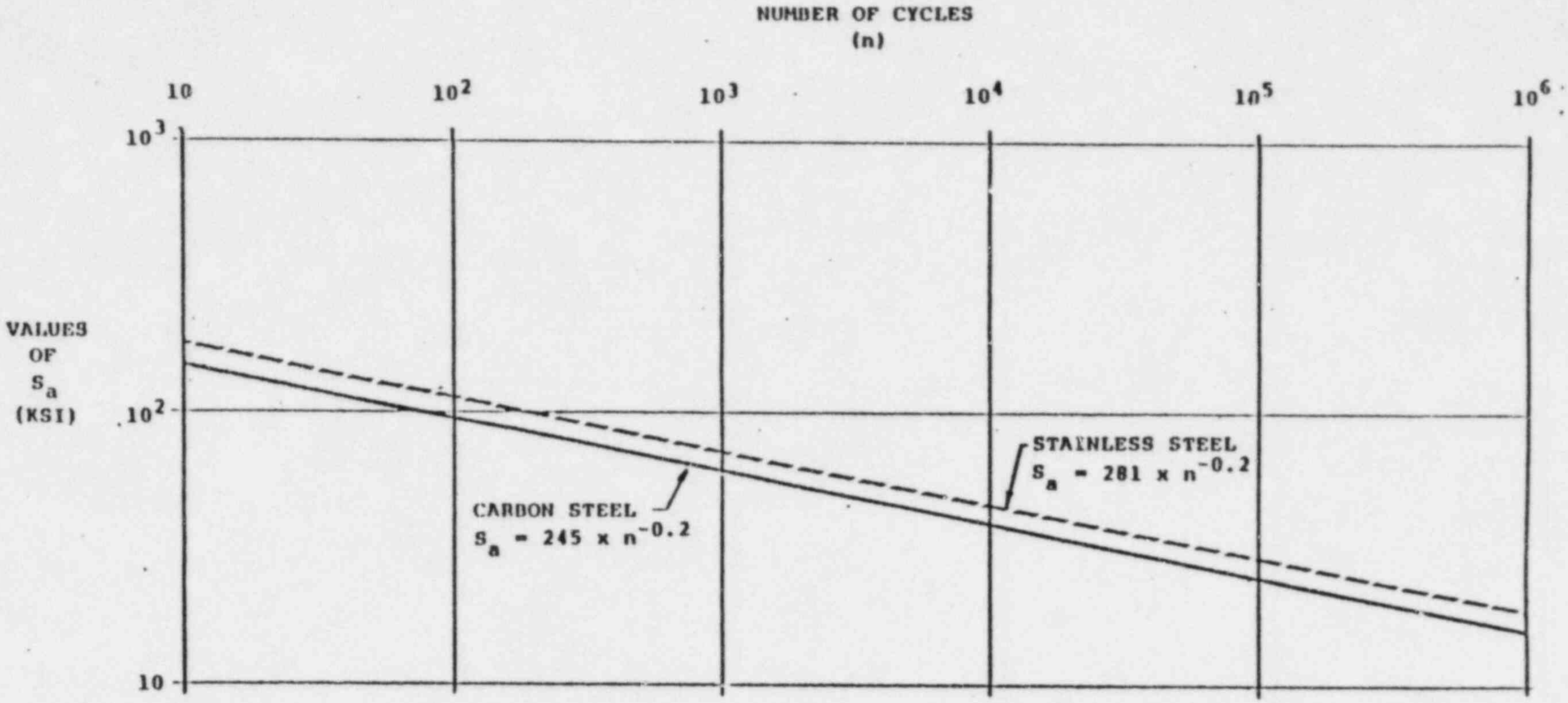
CYCLE REDUCTION FACTORS FOR MARK I DYNAMIC LOADINGS
(Reference: ASME Code Section III, Subsection NC-3611.2)

	Type of Load (Abbreviation)	Significant Load Cycles (n)	Cycle Reduction Factor (R)
1.	Acceleration due to SRV discharge (SRVNOC)	15	0.3
2.	Thrust due to SRV discharge (SRVNOC)	15	0.3
3.	Bubble drag due to SRV discharge (SRVNOC)	15	0.3
4.	Acceleration due to DBA condensation oscillation (DBACO)	900(Note 1)	$3/f_{max}$ or 0.1 (whichever is greater, Note 2)
5.	Acceleration due to IBA condensation oscillation (IBACO or PRECHG)	102 DBA 10,450 IBA/SBA	1.0
6.	Acceleration due to chugging (CHUG)	321(Note 1) DBA 9600(Note 1) IBA/SBA	$2/f_{max}$ or 0.1 (whichever is greater, Note 2)

NOTES:

1. Based on a 30 Hertz maximum participating frequency (actual f_{max} could be used).

2. f_{max} = highest participating frequency of piping system.



FATIGUE CURVE
FOR
AUGMENTED CLASS 2/3 FATIGUE EVALUATION

FIGURE A-1

APPENDIX B

RESPONSES TO NRC QUESTIONS
AND COMMENTS
STAFF PRESENTATION OF SEPTEMBER 10, 1982

This Appendix provides additional information and justifictaion for several of the assumptions employed in developing the Augmented Class 2/3 fatigue evaluation methodology. This material is provided in response to comments and questions resulting from a presentation to the NRC staff on September 10, 1982. The NRC staff comment or question is listed first followed by the corresponding response.

1. Comment:

   Provide documentation of the fatigue methodology for the NRC staff.

   Response:

   Section 2.0 of the body of this report and Appendix A contain the requested documentation.

2. Comment:

   Identify which piping systems were evaluated for each plant considered and the fatigue usage results for each.

   Response:

   Table 3-1 in the body of this report contains the requested information in tabular form.

3. Comment:

   Document how prior fatigue usage has been considered in the fatigue evaluation methodology.

Response:

The number of SRV actuations used in the analyses was based on the expected number of SRV actuations over a 40-year plant lifetime. Thus, the results reported in Table 3-1 of the body of this report account for prior fatigue usage.

In many cases the support arrangements for the SRV discharge piping have been upgraded to withstand all of the Mark I Containment Program loadings. The stress distributions of original piping arrangements are not generally available and in any event would not be comparable to the stress distributions in the upgraded piping arrangements. Thus, it was concluded that a reasonable approach would be to extrapolate the fatigue evaluation results for the upgraded piping configuration for the full 40-year life of the plants.

4. Comment:

Provide a rationale to justify not including thermal gradient stresses in the fatigue evaluation methodology.

Response:

ASME Class 2/3 piping design equations do not include stresses due to thermal gradient stresses since they are generally not significant to the design of these systems. To justify the assumption for the fatigue evaluation methodology, calculations were performed of the fatigue usage resulting from the thermal gradient stresses. Typical values for key parameters were taken as follows:

- Temperature of steam inside the SRV discharge piping in the wetwell - 350°F.

- Initial temperature of torus water adjacent to SRV discharge piping in the wetwell - 70°F.

For these conditions and typical sizes of piping used in Mark I plant SRV discharge piping, the peak thermal gradient stress ranges were calculated as follows for the two types of materials used for this piping:

- Carbon Steel - 3,900 psi (compressive)
- Stainless Steel - 15,500 psi (compressive)

These stresses are compressive and occur on the inside of the pipe wall. Stresses which occur on the outside of the pipe are tensile and are somewhat lower in magnitude. The calculated stresses for the stainless steel piping are larger due to the lower thermal conductivity of stainless steel compared to carbon steel. The effect of the maximum stresses on fatigue usage was estimated based on a bounding number of SRV actuations of 3,100 (500-1000 is more typical) occurring over a plant lifetime. For the two materials, the fatigue usage was calculated using the methods of Appendix A with the result as follows:

- Carbon Steel - less than .001
- Stainless Steel - less than .002

Since all fatigue usages due to stresses other than thermal gradient stresses were calculated for all Mark I plants to be less than 0.5, the effect of the usage due to thermal gradient stresses on fatigue lifetime would be insignificant.

RAI 14 Provide justification for the validity of analyzing SRV piping in two separate lengths (above and below the vent header) as indicated in Section 2.3.1.1 of the PUA report (4).

RESPONSE

Penetration thru vent header is considered as an anchor point for each piping analytical model (for description of analytical models see response RAI 3a). The penetration is reinforced with plate and structural members which makes it very rigid in comparison with piping downstream and upstream and as such justifies assumption for analytical anchor.

RAI 15 With reference to Section 3.8.4.2 of the PUA report (4), provide justification for using the SRSS method for combining responses due to SRV and chugging loads, specifically indicating whether the stress intensity value corresponds to 84% probability of non-exceedance as determined from the cumulative distribution function.

RESPONSE

Justification for using the SRSS method to combine responses due to SRV and chugging loads is provided in "SRSS Response Combination of Multiple Dynamic Responses" by R. P. Kennedy, Structural Mechanics Association, dated August 1982 (September 9, 1982 NRC Presentatioin Document).

FRC

RAI 15

ATTACHMENT TO ~~[illegible]~~ 15 (FRC)

SRSS RESPONSE COMBINATION OF MULTIPLE DYNAMIC RESPONSES

MARK I

by

R. P. Kennedy

August, 1982

STRUCTURAL
MECHANICS
ASSOCIATES
A Calif. Corp.

5160 Birch Street, Newport Beach, Calif. 92660 (714) 833-7552

PARAMETRIC STUDIES TO JUSTIFY SRSS RESPONSE COMBINATION FOR MARK I SHOULD NOT BE REQUIRED

1) LOADINGS AND RESPONSES SIMILAR TO THOSE FOR MARK II AND MARK III

2) GENERIC PARAMETRIC STUDIES HAVE BEEN PERFORMED FOR MARK II AND MARK III TO JUSTIFY SRSS RESPONSE COMBINATION FOR THESE LOADINGS

3) SUCH STUDIES ARE COSTLY AND UNNECESSARY TO REPEAT FOR MARK I BECAUSE OF THE AVAILABLE MARK II AND III RESULTS

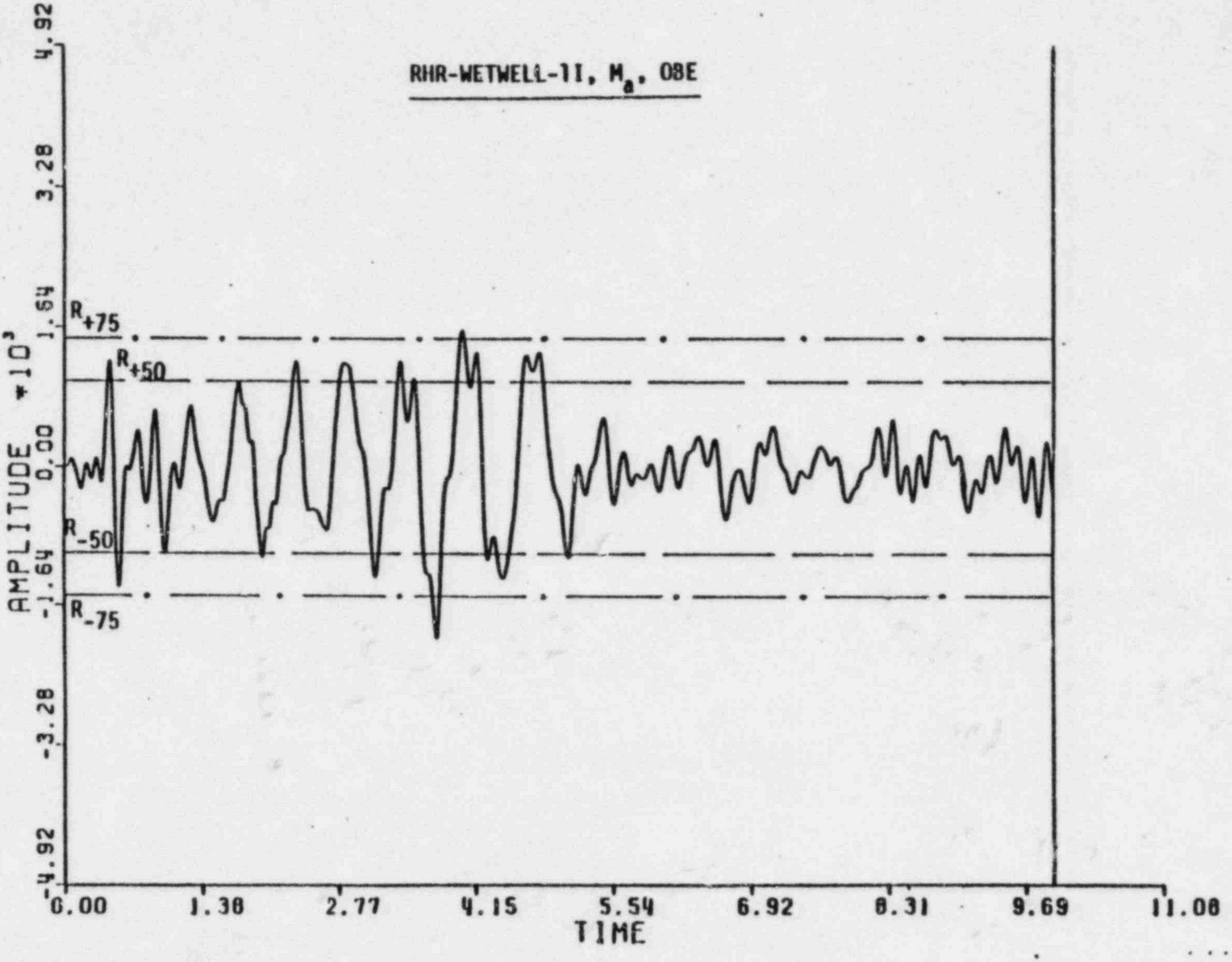
4) LIMITED MARK I STUDY SHOWS RESULTS SIMILAR TO MARK II AND MARK III

(N. M. NEWMARK AND R. P. KENNEDY, NEDO-24010-2, DECEMBER, 1978)

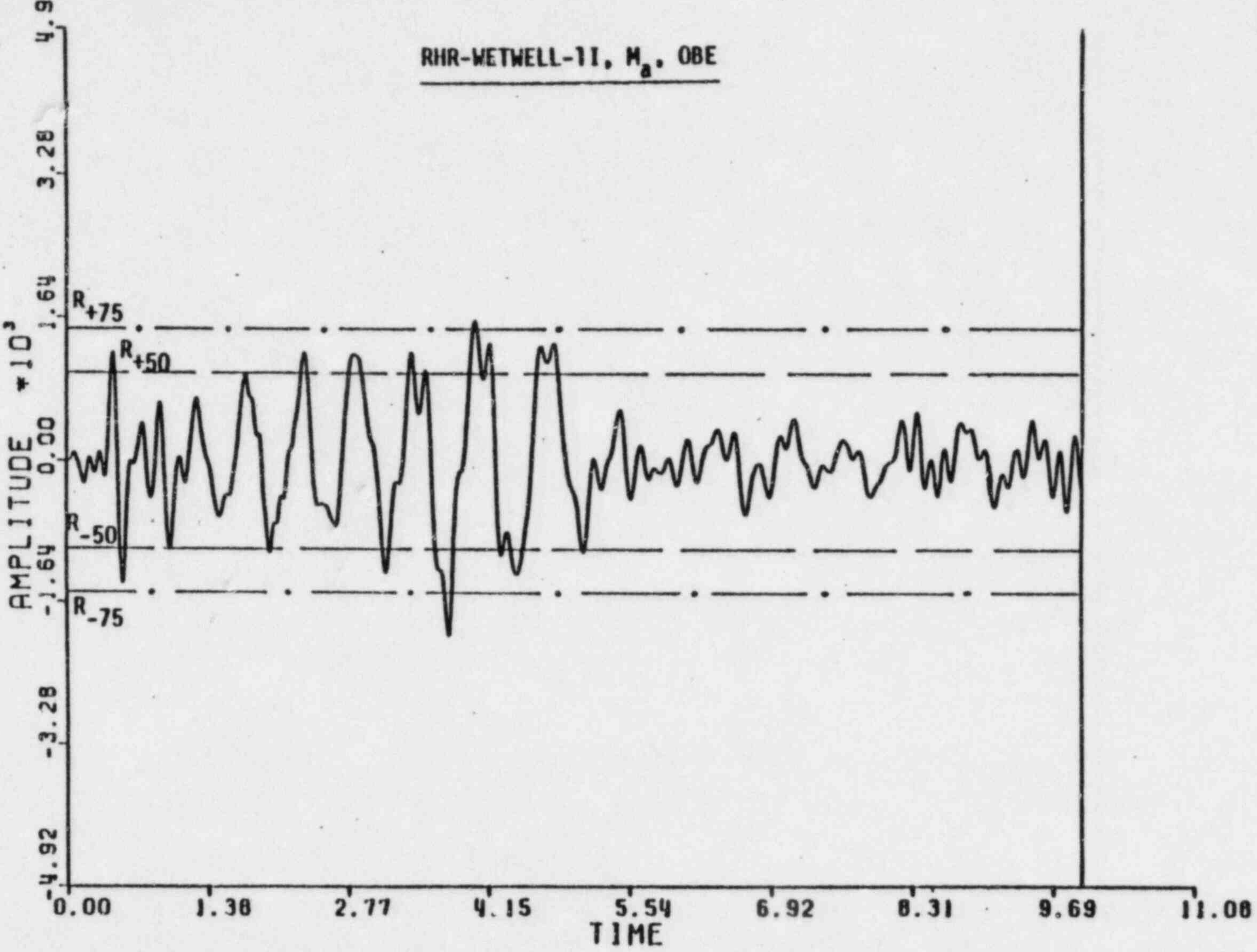
BASIC ASSUMPTION BEHIND CRITERIA FOR SRSS COMBINATION OF RESPONSES

- MANY SOURCES OF CONSERVATISM EXIST IN DESIGN AND EVALUATION PROCESS.
- ADDITIONAL CONSERVATISM DOES NOT HAVE TO BE INCORPORATED WITHIN THE RESPONSE COMBINATION PROCESS.
- IT IS NOT NECESSARY FOR THE COMBINED RESPONSE TO HAVE A LOWER PROBABILITY OF EXCEEDANCE THAN THE INDIVIDUAL RESPONSES.
- AN 84% NEP FOR COMBINED RESPONSE ASSUMING CONCURRENT APPLICATION OF LOADINGS IS SUFFICIENT

TIME - RESPONSE



TIME - RESPONSE



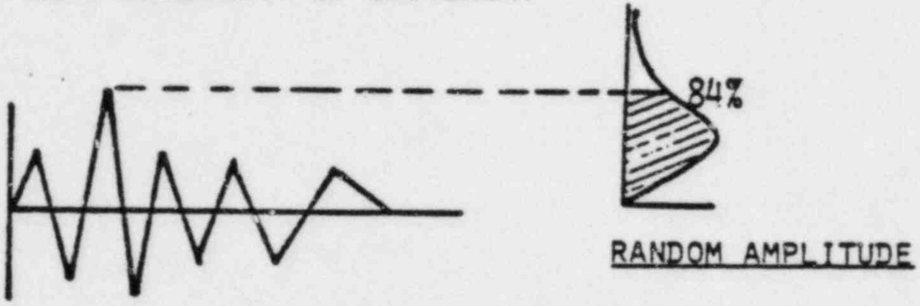
MULTIPLE RESPONSE TIME HISTORIES

1. TIME HISTORIES HAVE RANDOM RELATIVE START TIMES. (UNCORRELATED)

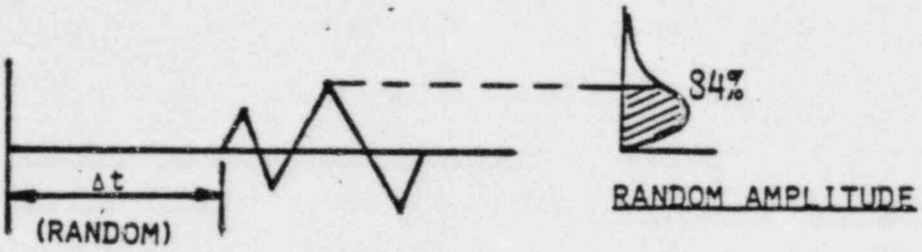
2. TIME HISTORIES ALSO HAVE RANDOM AMPLITUDES.

3. DESIGN AMPLITUDES ARE DEFINED TO BE AT THE 84% NON-EXCEEDANCE PROBABILITY BY CRITERIA.

(A)



(B)



4. HOW SHOULD PEAK INDIVIDUAL RESPONSE BE COMBINED?

CRITERION 2

$R_{SRSS_{84}}$ = SRSS COMBINED RESPONSE WHERE EACH INDIVIDUAL RESPONSE HAS BEEN DEFINED CONSERVATIVELY AT 84TH PERCENTILE OR 1.15 TIME MEDIAN, WHICHEVER GREATER.

$R_{T_{84}}$ = RANDOM TIME PHASE COMBINED RESPONSE WHERE ALL AMPLITUDES DEFINED AT 84TH PERCENTILE.

R = COMBINED RESPONSE CONSIDERING BOTH RANDOM AMPLITUDE AND TIME PHASING.

GOAL OF SRSS COMBINATION

$$P\left[R \leq R_{SRSS_{84}}\right] \geq 84\% \tag{1}$$

CRITERION 2 REQUIREMENT

$$P\left[R_{T_{84}} \leq R_{SRSS_{84}}\right] \geq 50\% \tag{2}$$

&

$$P\left[R_{T_{84}} \leq 1.2\ R_{SRSS_{84}}\right] \geq 85\% \tag{3}$$

(DR. HOU, MECHANICAL BRANCH, NOVEMBER, 1980)

Brief Summary of
NRC POSITION ON SRSS

- Shall not be applied universally without justification.
  - — Results of parametric studies (NUREG/CR-1330)
- Justification shall base on case investigation of response functions (not load functions).
- SRSS may be used for combining responses to LOCA + SSE within RCPB and its supports, and all ASME Class 1, 2, 3 piping systems.
- SRSS may be used for combining more than 2 responses

Plant Key
1 = River Bend
2 = Grand Gulf
3 = Allens Creek
4 = Perry
5 = Clinton
6 = Leibstadt

TABLE 1-2: MARK III SRSS EVALUATION MATRIX

	NSSS				BOP PIPING							BOP EQUIPMENT							TOTALS
	RPV & INTERNALS	MAIN STEAM PIPING	RECIRCULATION PIPING	PIPE MOUNTED EQUIPMENT	DRYWELL	CONTAINMENT (FREE-STANDING STEEL)	CONTAINMENT (CONCRETE BACKED)	CONTAINMENT (CONCRETE)	SHIELD BUILDING FREESTANDING STEEL)	SHIELD BUILDING (CONCRETE BACKED)	AUXILIARY BUILDING (CONCRETE)	DRYWELL	CONTAINMENT (FREESTANDING STEEL)	CONTAINMENT (CONCRETE BACKED)	CONTAINMENT (CONCRETE)	SHIELD BUILDING (FREESTANDING STEEL)	SHIELD BUILDING (CONCRETE BACKED)	AUXILIARY BUILDING (CONCRETE)	
OBE + SRV_1	5-5	6-4 6-5 6-7	4-8 4-10 4-11 4-12	6-2 4-6	1-2 1-3 2-5 2-8		4-18 4-21	5-17 5-14		4-17 4-15	5-7 5-10	1-9 1-13			5-23 (M-S) 2-9		4-25	5-29	28
OBE + SRV_{ALL}	5-4	6-5 6-6 6-9	4-9 4-12 4-13	6-3 4-7	1-1 1-4 2-6 2-7	3-1 3-3	4-20 4-19	2-2 2-3	3-8 3-6	4-14 4-16		1-6	3-12	4-23	2-9	3-10	4-25		29
OBE + SRV_{ADS}	5-5					3-1 3-3		5-16 5-18	3-4 3-7 3-6		5-11 5-12		3-11 3-12		5-25 (K-M) 5-26	3-9 3-10		5-29 5-22	18
SSE + SRV_1	5-5	6-4 6-8 6-9	4-9	6-1 4-5	1-1 1-4 2-8		4-18	5-15 2-1 2-4		4-17	5-13				2-9 5-23 (M-S)		4-26		19
SSE + SRV_{ALL}	5-4	6-8	4-10 4-11	6-1	1-3 1-4 2-8		4-20	5-19 2-2 3-3		4-14	5-8	1-11		4-23	2-9			5-28	18
SSE + SRV_{ADS}						3-1 3-2			3-4				3-11			3-9			5
CHUG + SRV_1	5-5 4-4		4-9	4-6	1-2 1-4 2-7 2-8			5-15 5-16			5-8 5-12	1-5		4-22	5-26 2-9		4-26	5-22	18
CHUG + SRV_{ADS}	5-6 4-3 4-2					3-1 3-2		5-17 5-14	3-5 3-6		5-13 5-11		3-11 3-12		5-24 5-27	3-9 3-10		5-22	18
CHUG + SRV_{ALL}				6-3	1-1 1-4	3-1 3-2		5-16 5-20	3-4 3-5		5-7 5-9	1-9 1-12						5-21	14
Totals	10	10	11	9	20	10	6	18	10	6	12	7	6	3	12	6	4	7	167

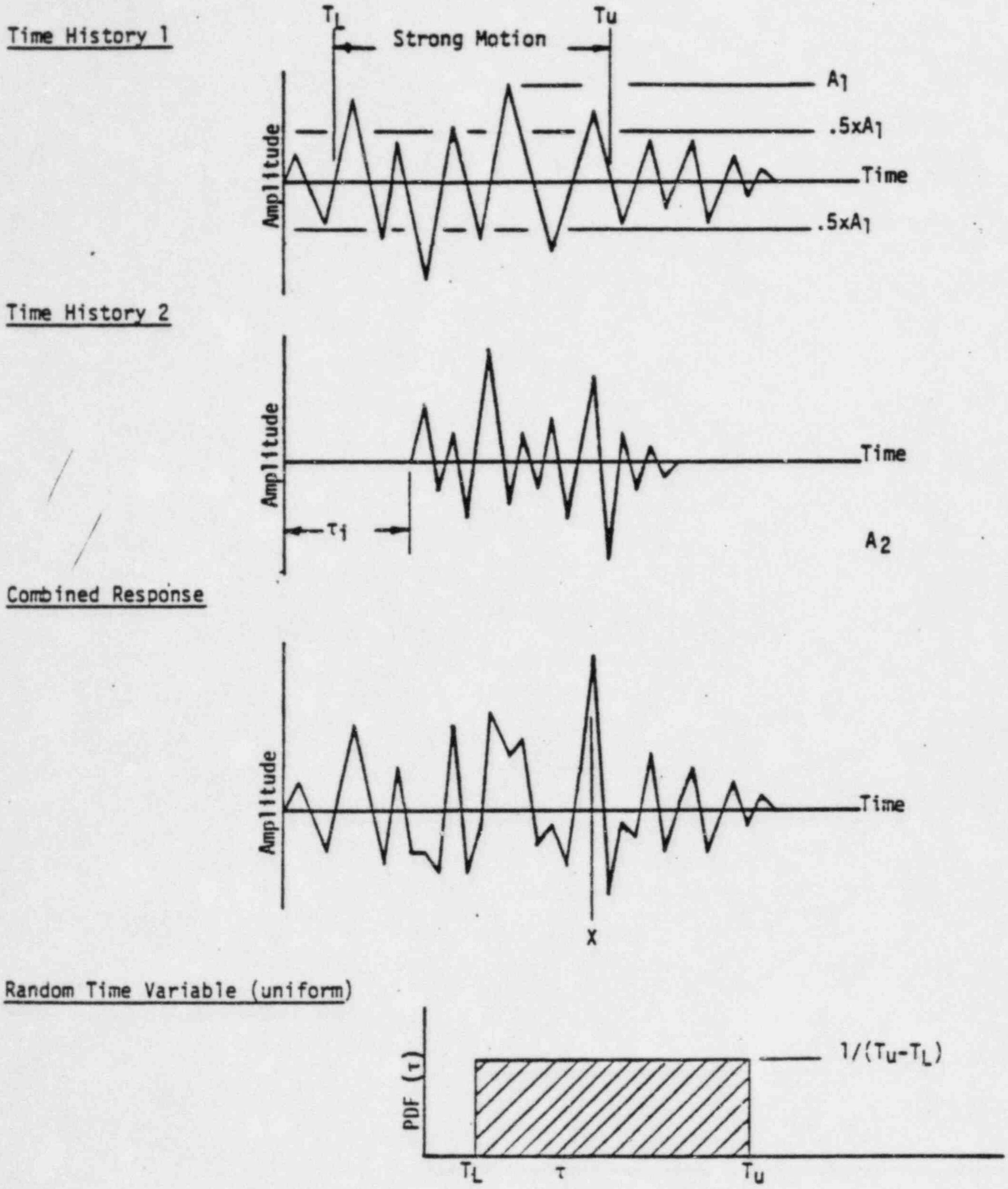


FIGURE 2-1. METHOD OF TIME PHASED RESPONSE COMBINATION

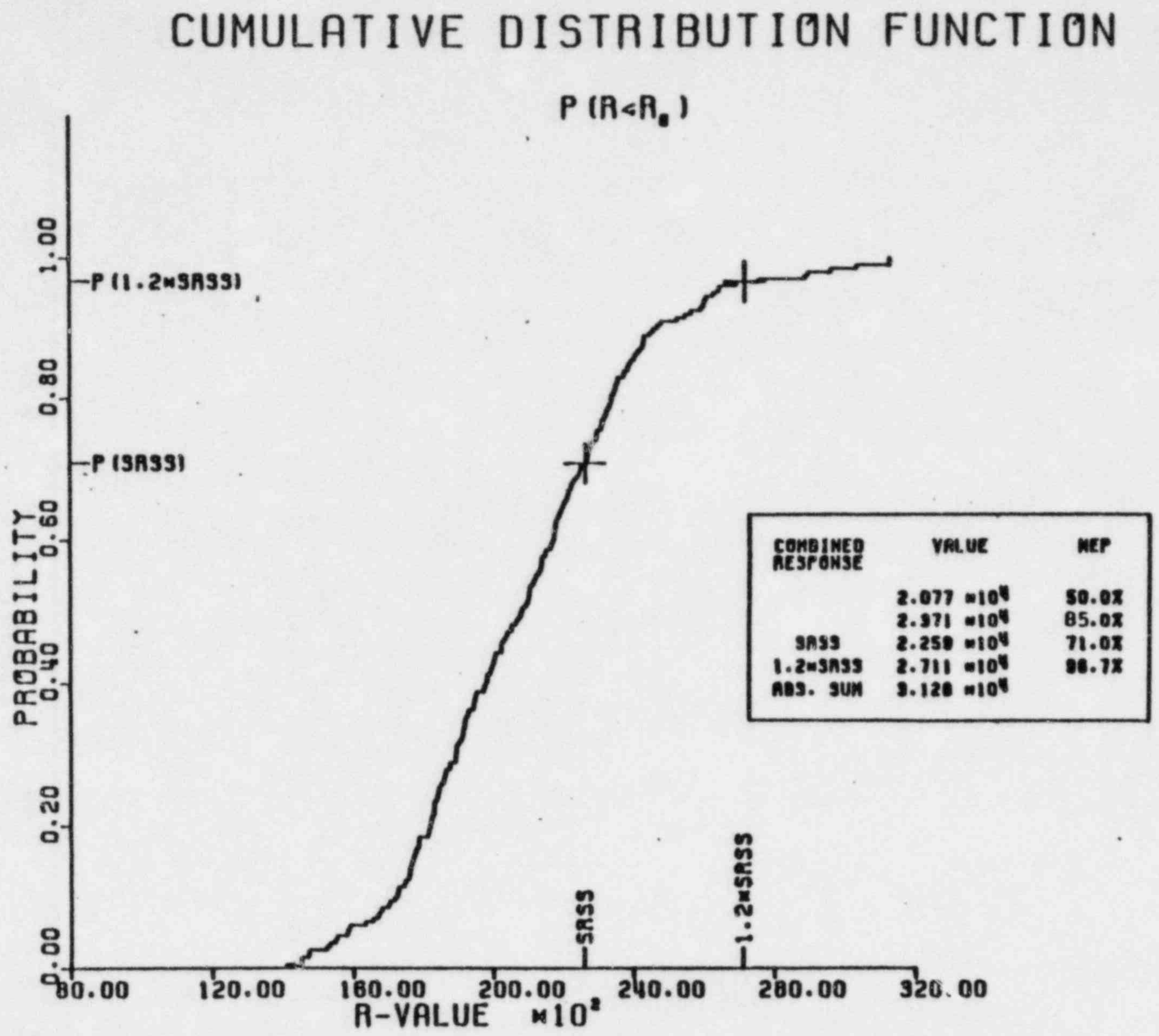


FIGURE B-25. NSSS RECIRCULATION PIPING ELBOW , LOCATION 4-9
OBE + SAV-ALL LOAD COMBINATION, MOMENT (FT-LBS)

BASED ON CONSERVATIVELY BIASED RESULTS

- ALL 167 CASES MEET INTENT OF NEWMARK-KENNEDY CRITERION 2
- SRSS METHOD CONSERVATIVE IN MOST CASES
- SRSS METHOD IS A REALISTIC APPROACH FOR CASES WHERE HIGH FREQUENCY RESPONSE IS PREDOMINANT
- SRSS METHOD IS IN NO CASE UNCONSERVATIVE
- SRSS METHOD IS GENERICALLY APPLICABLE TO BOTH ASME AND NON-ASME COMPONENTS FOR LOADINGS CONSIDERED

MARK II PIPING AND COMPONENTS

- GENERIC STUDY OF 291 RESPONSE COMBINATION CASES

  (NEDE-24010-P, JULY 1977)

  (NEDO-24010-2, DEC. 1978)

- ALL 291 CASES MEET INTENT OF NEWMARK-KENNEDY CRITERION 2

- SRSS METHOD IS GENERICALLY APPLICABLE FOR LOADINGS CONSIDERED

BROOKHAVEN CONTAINMENT AND DRYWELL STRUCTURE

GENERIC STUDIES

(NUREG/CR-2039, JUNE 1982)
(NUREG/CR-1890, JUNE 1982)

	NO. OF CASES	MEAN NEP (%)	
		SRSS	1.2* SRSS
MARK II 3 OR MORE LOADS	400	87.8	98.8
MARK II 2 LOADS	400	80.7	97.5
MARK III	3904	75.0	97.0

- IF INDIVIDUAL LOADS ARE CONSERVATIVELY DEFINED (84% NEP OR 1.15 TIMES MEDIAN, WHICHEVER GREATER) THEN SRSS RESPONSE COMBINATION ACCEPTABLE FOR STRUCTURES EXCEPT WHEN ABS/SRSS <1.25 IN WHICH CASE 1.1* SRSS OR ABS (WHICHEVER LESS) IS PREFERRED.

RECOMMENDATION FOR MARK I

- SRSS RESPONSE COMBINATION BE ACCEPTED FOR FOLLOWING:
  - STRUCTURES & COMPONENTS

    TORUS, TORUS SUPPORTS, ATTACHED PIPING,
    & EQUIPMENT

  - ALL COMBINATIONS OF RESPONSES INVOLVING FOLLOWING INDEPENDENT LOADINGS WITH RANDOM RELATIVE START TIMES

    OBE, SSE, SRV, CHUG, CO, POOL SWELL

- SRSS RESPONSE COMBINATION HAS NOT BEEN STUDIED FOR MULTIPLE RESPONSES FROM SAME LOADING WITH LIKELY CORRELATION BETWEEN PEAK RESPONSES
  - EXAMPLE: DIRECT FLUID DRAG AND SUPPORT SHAKING EFFECTS ON SUBMERGED PIPING FROM SRV

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

MAR 10 1983

Mr. H. C. Pfefferlen, Manager
BWR Licensing Programs
General Electric Company
175 Curtner Avenue
San Jose, California 95125

Dear Mr. Pfefferlen:

SUBJECT: ACCEPTABILITY OF SRSS METHOD FOR COMBINING DYNAMIC RESPONSES IN MARK I PIPING SYSTEMS

We have evaluated General Electric Report NEDE-24632, "Mark I Containment Program Cumulative Distribution Functions for Typical Dynamic Responses of Mark I Torus and Attached Piping Systems" that was transmitted by letter from you dated October 7, 1982 and the information provided by R. P. Kennedy of Structural Mechanics Associates during a September 9, 1982 meeting with the staff. Based on our evaluation we have concluded that the use of the SRSS method for combining peak responses of Mark I piping and supports under dynamic loads is acceptable. A copy of our safety evaluation is enclosed.

Sincerely,

DBVassallo

Domenic B. Vassallo, Chief
Operating Reactors Branch #2
Division of Licensing

Enclosure:
As stated

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION
FOR ACCEPTABILITY OF THE SRSS METHOD FOR COMBINING
DYNAMIC RESPONSES IN MARK I PIPING SYSTEMS

Intorduction

The information provided in References 1 and 2 by the Mark I Owners Group is intended for justifying the use of the Square-Root-of-the-Sum-of-Squares (SRSS) Method for combining responses of torus structures and attached piping systems under various dynamic loads. The following is our evaluation of SRSS acceptability for Mark I piping and supports. The portion of NEDE-24632 concerning torus structures is beyond the scope of this evaluation and hence is not addressed.

Information Summary

The provided information consists of 111 actual cases of response combinations, of which 72 cases were selected from the following three typical Mark I piping systems: (1) RCIC turbine exhaust piping (2) HPCI turbine exhaust piping, and (3) vacuum relief piping systems. Response time functions consist of stress resultants, modal displacements, and support reactions, which were induced by suppression pool swelling and chugging from safety relief valve discharges. Components in horizontal and vertical directions were considered separately. In each case of response combination, the non-excedance probability (NEP) of SRSS was determined by generating a cumulative distribution function (CDF) of the response peak resultant from combining the response time functions with random time lags. For 72 piping cases investigated, the average NEP is 87% with a standard deviation of 6%, which is comparable with the results of previous Mark II piping SRSS investigates.

Evaluation

The referenced report with respect to the SRSS method for combining dynamic responses in Mark I piping systems is acceptable for the following reasons: (1) The response functions for the Mark I design are very similar to those previously reviewed in great detail for Mark II and Mark III designed plants (Refs. 4 & 5), (2) although somewhat limited in number, for each of the 72 cases of piping and support location response combinations investigated the NEP levels are greater than those prescribed in NUREG-0484 Rev. 1 (Ref. 3), (3) the presented NEP levels are compatible and consistent with those in the Mark II and III SRSS evaluations, and (4) although seismic loads were not included in the response calculation, the combination of seismic load response with other hydrodynamic load responses has been adequately represented in the Mark II and III SRSS evaluation and need not be separately conducted.

Conclusion

Based on our evaluation, we concluded that the use of the SRSS method for combining peak responses of Mark I piping and supports under dynamic loads is acceptable.

Dated: **MAR 1 0 1983**

Principal Contributor: S. Hou, DE/MEB

REFERENCES

1. Topical NEDE-24632, "Mark I Containment Program Cumulative Distribution Functions for Typical Dynamic Responses of Mark I Torus and Attached Piping Systems", Prepared by Nutech for GE, 12/80.

2. Presentation, "SRSS Response Combination of Multiple Dynamic Responses", by R. P. Kennedy of Structural Mechanics Associates, 8/82.

3. NUREG/0484, Rev. 1, "Methodology for Combining Dynamic Response", 5/80.

4. Memo, J. P. Knight to R. L. Tedesco, Evaluation of GE Topical NEDE-24010 and Supplement 1, 2, 3, "Technical Basis for the use of SRSS Method for Combining Dynamic Loads for Mark II Plants," 5/28/80.

5. Memo, S. Hou to J. Stefano, "MEB Resolutions to LRG II Issues", including Acceptability of SRSS for Mark III Mechnical Components, 4/8/82.

RAI 16 Indicate whether the fatigue usage factors for the SRV piping and the Torus attached piping are sufficiently small so that a plant-unique fatigue analysis is not warranted for piping. The NRC is expected to review the conclusions of a generic presentation (6) and determine whether it is sufficient for each plant-unique analysis to establish that the expected usage factors for piping are small enough and do not warrant a plant-unique fatigue analysis of the piping.

RESPONSE

Plant specific usage factors for the following lines are presented in Table 3-1 (Ref. 1) for the Brunswick Plant:

(1) RCIC Turbine Exhaust Line

(2) RCIC Barometric Condenser Line

(3) SRV Discharge Line

Usage factors tabulated are less than 0.5.

Table 3-1 also presents usage factors for other plants as determined by that plant's Architect/Engineer. A review of the table indicates a reresentative sampling of Torus Attached pipe lines and SRV discharge lines has been included. Typically, the usage factors associated with the SRV lines are higher than those associated with torus attached pipe lines. Since usage factors are less than 0.5, a plant unique fatigue analysis is not warranted.

REFERENCES

(1) "Mark I Containment Program Augmented Class 2/3 Fatigue Evaluation Method and Results for Typical Torus Attached and SRV Piping Systems"; MPR-751, November, 1982; MPR Associates, Washington, D.C.

RAI 17 The ASME Code provides an acceptable procedure for computing fatigue usage when a member is subject to cyclic loadings of random occurrence, such as might be generated by excitations from more than one type of event (SSE and SRV discharge, for example). This procedure requires correction be made to the stress-range amplitudes considered and to the associated number of cycles, in order to account for the interspersion of stress cycles of unlike character. State whether or not the reported usages reflect use of this method. If not, indicate the effect on reported results.

RESPONSE

The ASME procedure for superposition of cycles of various origins was not used to compute usage factors for the vent system. Stresses from seismic loads are very low and were considered to be negligible. SRV discharge and LOCA loads are the only significant cycle loads which can occur simultaneously. Of the 400 postulated SRV actuations, 350 occur during normal operating conditions. Therefore, the simultaneous occurrence of cyclic loads not explicitly addressed in the "Plant Unique Analysis" is limited to 50 SRV actuations (of a specific valve) concurrent with a LOCA. Justification for this is based on the conservative assumptions used in the fatigue analysis. Therefore, the overall effect results in calculated usage factors that are conservative.

The following conservative assumptions were made for the fatigue analysis of the vent system:

1. The assumption of 50 actuations of a particular safety relief valve during a LOCA is conservative.

RAI 17 (Continued)

RESPONSE (Continued)

2. For the analysis, 5 equivalent peak stress cycles were used for each SRV actuation. For a typical SRV time history applicable to the vent system (e.g. Figure 3.8.1-3 of the PUAR), the number of equivalent peak stress cycles per SRV actuation is 3.5.

3. CO fatigue was calculated conservatively because each of the three harmonics was considered to individually cause the peak stress. However, the peak stress is actually caused by the summation of the three harmonics.

The total combined effect of all of the above is that the calculated usage factors are conservative.

RAI 18 During pool swell and seismic events, local concentrated loads are applied to the suppression chamber at eight vent locations, 45° apart. For example, on page 1-31 (4), it is stated that the vent header load during pool swell is 342 kips. In the overall analysis of the suppression chamber, these discrete loads are represented as a uniform line load (of equal total magnitude) instead of invoking the Wilson 2 capability to expand the load in Fourier series with approximating load peaks at eight equally spaced stations. Develop the justification of your procedure in greater detail.

RESPONSE

There are eight columns (4 existing and 4 proposed new columns) at each vent header intersection that apply a total concentrated load of 684 kips at the suppression chamber. The total number of columns at all the vent headers is 64. The maximum concentrated load in each column is 102 kips. These 64 point loads applied to the suppression chamber have two effects, local and overall on the structure.

The overall effect of the concentrated loads is to induce stress in the critical sections of the torus such as Section 1 and 5 shown in Figure 1.8-1 of PUAR. The local effect of each concentrated load is to produce punching shear in the torus wall. The allowable shear stresses,however, depend upon the meridional and hoop stresses around the assumed failure surfaces. Therefore, an overall analysis of the torus due to the concentrated loads is required to determine these overall stresses at the critical section.

To perform the overall analysis of the torus for eight equally spaced sets of eight concentrated loads along the circumference

RAI 18 (Continued)

RESPONSE (Continued)

of the torus, it was assumed that the maximum possible load per unit length along circumference, obtained from maximum concentrated load of each pair of column divided by the minimum distance between two concentrated loads, is applied along the circumference of the torus instead of eight discrete locations. This assumption gives higher stresses in Sections 1 and 5 far from the point of application of the concentrated loads. It also gives higher meridional stresses at the vicinity of the applied loads which results in lower allowable punching shear stresses and therefore, are conservative. The punching shear stresses due to the concentrated loads are then compared with the calculated allowable punching shear stresses. The factor of safety for local punching shear is around 5.

RAI 19a Provide justification for neglecting the discontinuities in the overall structure of the suppression chamber (a 16-sided polygonal ring):

RESPONSE

The suppression chamber is a 16-sided polygonal ring with a circular inner boundary at its attachment to the circular drywell. All the top bars, seismic bars and global hoop bars are curved forming concentric circles with centers on the drywell axis. The local hoop bars are circles and together with the global hoop bars form a torus. However, the wetwell lining is composed of 16 right angle cylinders with tapered ends.

The analysis for all loading conditions which include internal pressure (60 cases out of 65 load cases, with controlling cases among them) is performed assuming concrete is totally cracked in the local and global hoop directions. The reinforced concrete suppression chamber is thus, in fact, a toroidal structure with the cylindrical liner. The liner is assumed as a torus in the analysis.

The joints between adjacent straight segments of the liner have an enclosed angle of 157.5°. Local stress concentratioin may occur at any discontinuity, but according to ASME, Section III, Division 2, since the liner is anchored to the concrete at relatively close intervals (about 2" at joints and 11" at other places) its integrity shall be examined by checking the liner strain under service and factored loads. The liner anchor analysis was performed and strains are reported in Section 1.11 of PUAR.

RAI 19b Also, provide justification for the implicit assumption that stress distributions and magnitudes so obtained conservatively represent those of the actual structure. In particular, address the situation at joints between adjacent straight segments.

RESPONSE

See response to RAI 19a.

RAI 20 Section 1.5 states that the thermal effects were considered, assuming a linear temperature gradient between the liner and the exterior surface of the concrete. Although a linear temperature distribution is substantially correct for steady state conditions in the wall structures with concentric inner and outer boundaries, it is not theoretically correct for the case of a thick section with a circular inner boundary and approximately square outer one. Discuss the adequacy of this assumption to predict the onset of thermal cracking in the concrete.

RESPONSE

The inside temperature of 140°F and 168°F for SBA and IBA, respectively, is occurring with the high internal pressure of LOCA conditions for 61 load cases given in load combinatiion Table 1.4-1 of PUAR. The torus is assumed to be totally cracked in local hoop and global hoop (S and T) directions due to high internal pressure. Therefore, only the liner and the reinforcing bars, which are approximately 26" apart (R_{liner} =200", $R_{einforcing}$ = 174"), resist the thermal loads. At the iniciation of the LOCA condition the temperature distribution across the torus wall is nonlinear. The liner has a high temperature reducing sharply across the wall. This temperature distribution has the same effect as an internal pressure that produces tension in almost the entire section of the concrete. This phenomena is not different from the cracking assumption made in the analysis. Using the totally cracked concrete for each of the 61 load combinations, which includes the internal pressure, is a reasonable assumption. Therefore, the assumption of linear or nonlinear

RAI 20 (Continued)

RESPONSE (Continued)

distribution of the thermal load is immaterial in predicting the onset of thermal cracking in the concrete. As the LOCA condition progresses in time, the steady state condition prevails and the assumption that there is a linear distribution of thermal load become more valid in predicting the total forces and moments developed in the concrete cross sections.

For the four load cases where no internal pressure exists (cases 2, 3, 64 and 65), the concrete is assumed to be partially cracked. The thermal load for these cases is the normal operating temperature which varies between 76°F and 92°F with changes occurring over a long period of time. Steady state temperature (100°F inside to normal temperature on outside of the torus) is realistic for these cases.

The assumption that the torus is totally cracked in the S and T directions due to high internal pressure eliminates the need for a vigorous cracking pattern investigation which is an iterative process, since the thermal load in the torus is not high. The membrane stresses in the liner from the load combination are all below yield. ASME Section III, Division 2, permits membrane liner strain under factored load to reach between 3 and 5 times the yield strain.

RAI 21 In Section A.1.1, a normal mode and frequency response analysis for CO loading, made to assess effects of fluid/structure interaction, is described. Provide the total number of modes used in the summation, the total percentage of modal effective mass thus included, and discuss provisions which may be incorporated in the computer program to account for effects of the unsummed portion of the modal effective mass.

RESPONSE

NASTRAN Rigid Format 26, used to study the fluid-structure interaction per Section A.1.5 of PUAR, is a direct method of frequency response analysis in which the entire differential equations of motion are transformed to the frequency domain. The resulting equations are solved for all frequency ranges of the input load. The condensation oscillation load is defined in terms of frequency and amplitude from 1 to 50 Hz. in the Load Definition Report (2). The modal formulation of the frequency response analysis is not used.

RAI 22a Provide a summary of the results for the submerged structures listed in Section 2.1.1. (b), page 2-1 and contained in the calculation books listed in Appendix A-2 (B & E), pages 2-21 and 2-11 (4).

RESPONSE The subject submerged structures were evaluated for various load case combinations and the resultant piping stresses were found to be acceptable in accordance with applicable stress limits. The moments of selective load cases were combined absolutely using the Stardyne "Post" program. The moments were evaluated against applicable piping stress levels in accordance with the following:

(1) ASME Boiler & Pressure Vessel Code
Section III - Division 1;
Summer 1977 Addenda

(2) Mark I Containment Program Load
Definition Report (NEDO-21888, Class I,
December 1978, Rev. 0) by General Electric
Nuclear Energy Engineering Division

(3) Mark I Containment Program Structural
Acceptance Criteria, Plant Unique
Analysis Application Guide, Task 3.1.3
(NEDO-24583-1, 79 NED 125, Class I,
October 1979) by General Electric
Nuclear Energy Engineering Division

RAI 22b Also include the results of the strainer analysis performed by the supplier, as referenced in Section 2.3.1.2 (4).

RESPONSE

See Attachment RAI-22b for results of the strainer analysis performed by the supplier.

ZURN INDUSTRIES INC.

DESIGN REPORT

1281A

(Total 15 pages)

CAROLINA POWER & LIGHT COMPANY

BRUNSWICK STEAM ELECTRIC PLANT

UNITS 1 & 2

Attachment RAI 22b

FRC

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RAI 22B

DESIGN REPORT 1281A

STRESS ANALYSIS CALCULATION
OF
SUPPRESSION POOL STRAINERS
FOR

CUSTOMER: United Engineers & Constructors, Inc.

UTILITY: Carolina Power & Light Co.
Brunswick Steam Electric Station

DESIGN SPECIFICATION: Spec. No. 9527.001-236-21, Rev. 2

PURCHASE ORDER NO: 9527.001-236-21, CP542

MANUFACTURED BY: ZURN INDUSTRIES, INC.
Fluid Handling Division

Order No's: 82-N-4965
-4966
-4967
-4968

ORIG. 1/27/82

PREPARED BY: Ira Schnall 12-21-81

CHECKED BY: Joseph M. Wertman 1-15-82

APPROVED BY: 1/27/82

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RECORD OF REVISIONS

Rev.	Description	Revised by	Checked by	Approved by
0	Original issue	12/21/81	JMW 1-15-82	1/27/82

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ABSTRACT

The purpose of this report is to verify the adequacy of the primary containment suppression chamber suction strainers for Carolina Power & Light Co.'s Brunswick Steam Electric Plant to meet the requirements of UE&C Spec. 9527-001-236-21, Rev. 2, 9-11-81, and ASME Section III, Class 2.

CONCLUSION

The strainers are analyzed for stress, function, and elastic stability when subjected to seismic accelerations, submerged structural loads, live loads, dead loads, and operating loads.

Stresses due to these loads are within ASME Code limits. Preload is sufficient to assure function under all load combinations. Elastic stability is assured.

The strainers are considered satisfactory for the specified service.

IRA H. SCHNALL
20034-E

I. H. Schnall
12/21/81

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SUMMARY OF RESULTS

Component (worst case)	Calculated	Allowable
Stud preload safety factor	1.227 min.	1.0 req'd.
Preload bearing stress	16,647. psi	24,375. psi
Maximum stud stress	32,656. psi	39,068. psi
Cover plate thickness	0.487" req'd.	0.500" available
Ring bending stress	1,899. psi	17,500. psi
Collapse pressure (Uniform load)	1,388. lb./inch	217:1 Safety factor

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DESCRIPTION OF EQUIPMENT

Suction strainers for the primary containment suppression chamber of Carolina Power & Light Co.'s Brunswick Steam Electric Plant, Units 1 & 2.

Specification: UE&C #9527-071-236-21, Rev. 2, 9-11-81

Design life: 40 years, flow from outside in

Design basis: 125 psig water at 225°F, ANSI 150# std.

Integrated gamma total dose: 1.2×10^8 rads

Normal condition: 110°F, 14.7 psia

Accident condition: 196°F, 75. psia

Static seismic load: 3.0 "g" horizontal, 2.0 "g" vertical

Load combination: Seismic + Submerged structural + live + dead + operating

Strainer Size	6"	14"	16"	24"
Tag Number	1&2-E51-S2	1&2-E21-S2A&B	1&2-E41-S2	1&2-E11-S1&2
Operating pressure drop, 50% clogged, psi	0.30	1.85	0.65	2.25
Submerged (see note) Structural P1/P2	0.57/3.21	90.6/23.3	0.53/5.03	31.3/50.9

Note: Submerged structural loads are in psi, for Level B service limit. P1 is axial pressure acting on strainer axial area. P2 is normal pressure acting perpendicular to the strainer axis, on the projected area, at the centroid. These loads include dynamic effects (live loads) per G.E. Mark I containment.

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WEIGHT & CENTER OF GRAVITY

Size		6"	14"	16"	24"
Perforated discs and Spacers	Wt. x	37.2612# 3.826"	402.1049# 16.623"	483.7683# 16.623"	1,210.6252# 22.095"
Cover Plate	Wt. x	9.8410# 7.5895"	47.4458# 33.121"	59.4267# 33.121"	112.4750# 44.065"
Flange Plate	Wt. x	3.7111# 0.1347"	17.8887# 0.1954"	21.5170# 0.1957"	32.6361# 0.1975"
Mtg. Rods & Nuts	Wt. x	14.9152# 3.4505"	116.4745# 15.9250"	155.2993# 15.8937"	395.6586# 21.1575
TOTAL	W, lbs. $\bar{x}$, inch.	65.73 4.096	583.9 17.321	720.0 17.336	1,751.4 22.886

Strainer axial Area, A_1, in.^{2}	97.2053	342.2495	429.1342	810.5432
Strainer projected area, A_2, in.^{2}	98.3535	728.2281	823.8536	1,494.655
Centroid of projected area, d_A, inches	4.5436	17.6650	17.8208	23.4521

Note: Nominal dimensions used throughout.

x, $\bar{x}$, and d_A are measured from the face of the mating flange (1/16" below the raised face surface).

Projected area includes outboard studs & nuts.

Note: Combined seismic & deadweight load $= \sqrt{3.0^2 + 3.0^2 + (2.0+1)^2}$
$= 5.2$ "g"

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LOADS ON STRAINERS

Size		6"	14"	16"	24"
Seismic plus Deadweight	Force	342. lb.	3,036. lb.	3,744. lb.	9,107. lb.
	$\bar{x}$	4.096"	17.321"	17.336"	22.886"
Submerged structural plus live	Axial Force	55.4 lb.	31,008. lb.	227.4 lb.	25,370. lb.
	Transverse Force	315.7 lb.	16,968. lb.	4,144. lb.	76,078. lb.
	d_A	4.5436"	17.665"	17.821"	23.452"
Operating, Axial		29.2 lb.	633. lb.	279. lb.	1,824. lb.
Max. Loads	Axial, F	427. lb.	34,677. lb.	4,250. lb.	36,301. lb.
	Transverse, V	653. lb.	20,004. lb.	7,888. lb.	85,185. lb.
	Moment, M	2,835. in-lb.	352,326. in-lb.	138,756. in-lb.	1,992,604. in-lb.
Stud Stress Area		8×0.334	12×0.6051	16×0.6051	20×0.9985
Preload = P_L = 28,000×Area		37,408. lb. **	203,314. lb.	271,085. lb.	559,160. lb.
Req'd. coefficient of friction = μ = $V/(P_L - F)$		0.0178	0.119	0.030	0.163
Safety Factor $\frac{0.2}{\mu}$ *		11.2	1.68	6.67	1.227

* 0.2 is conservatively the minimum expected value of static friction coefficient.

** Reduced preload on 6" size to 50% of stud allowable.

	6"	14"	16"	24"
Required torque (for preload)	59. ft.lb.	283. ft.-lb.	283. ft.-lb.	583. ft.-lb.

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PRELOAD STRESS

Size		6"	14"	16"	24"
Matching washer areas, nom.	R_o	0.53125"	0.78125"	0.78125"	1.03125"
	R_i	0.410156"	0.535156"	0.535156"	0.660156"
	N	8	12	16	20
$A_w = N\pi(R_o^2 - R_i^2)$		2.86509 in²	12.21298 in²	16.28397 in²	39.43769 in²
Bearing stress, $S = \frac{P_L}{A_w}$		13,056. psi	16,647. psi	16,647. psi	14,178. psi
Allowable, S_y		S_y = 24,375. psi (SA-240, Gr. 304, @ 225°F.) NC-3216.3(2)(1) & Table I-2.2			

The bolt holes in the perforated discs are the same size as the washer area bolt holes, and the perforated discs extend beyond the outside of the washer areas. The bearing area under the washer is not perforated, therefore the bearing area and the stresses are the same as above, with the same allowable stresses, and all components are satisfactory for the stud preload.

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STUD STRESS

Size	6"	14"	16"	24"
Moment, p. 3, M	2,835. in-lb.	352,326. in-lb.	138,756. in-lb.	1,992,604. in-lb.
Stud geometry N	8	12	16	20
BC	9.5"	18.75"	21.25"	29.5"
Stress Area = A_T	0.334 in^2	0.6051 in^2	0.6051 in^2	0.9985 in^2
(p.6) $S_B = \frac{M}{N \cdot A_T} \times \left[\frac{4}{BC}\right]$	447. psi	10,351. psi	2,698. psi	13,529. psi
S_L = Pre-load, p. 3	14,000. psi	28,000. psi	28,000. psi	28,000. psi

Since the increased load due to "M" is taken partially by increase of stud preload stress and partially by reduction of washer compressive stress:

$$AE_{bolt} = N \times A_T \times 28.7 \times 10^6 \quad (\text{at } 196°\text{F.})$$

$$AE_{wash} = A_{W_{(p.4)}} \times 27.7 \times 10^6$$

$$\delta_p = \text{Preload deflection of bolt} = \frac{S_L \times N \times A_T \times L}{AE_{bolt}}$$

$$\Delta\delta = \text{Additional deflection due to } M = \frac{S_B \times N \times A_T \times L}{AE_{bolt} + AE_{washer}}$$

$$S_T = \text{Total stress, bolt} = \frac{E_{bolt}}{L} \times \left[\delta_p + \Delta\delta\right]$$

yielding:

L, in.	9.4485"	35.6675"	35.73"	47.3445"
Total Stress S_T, psi	14,220.	31,946.	29,028.	32,656.
Allowable $1.1 S_m$	$1.1 \times 35,516. = 39,068.$ psi	{ Table NC-3217.1, Level B, & Table I-1.3 @ 196°F.		

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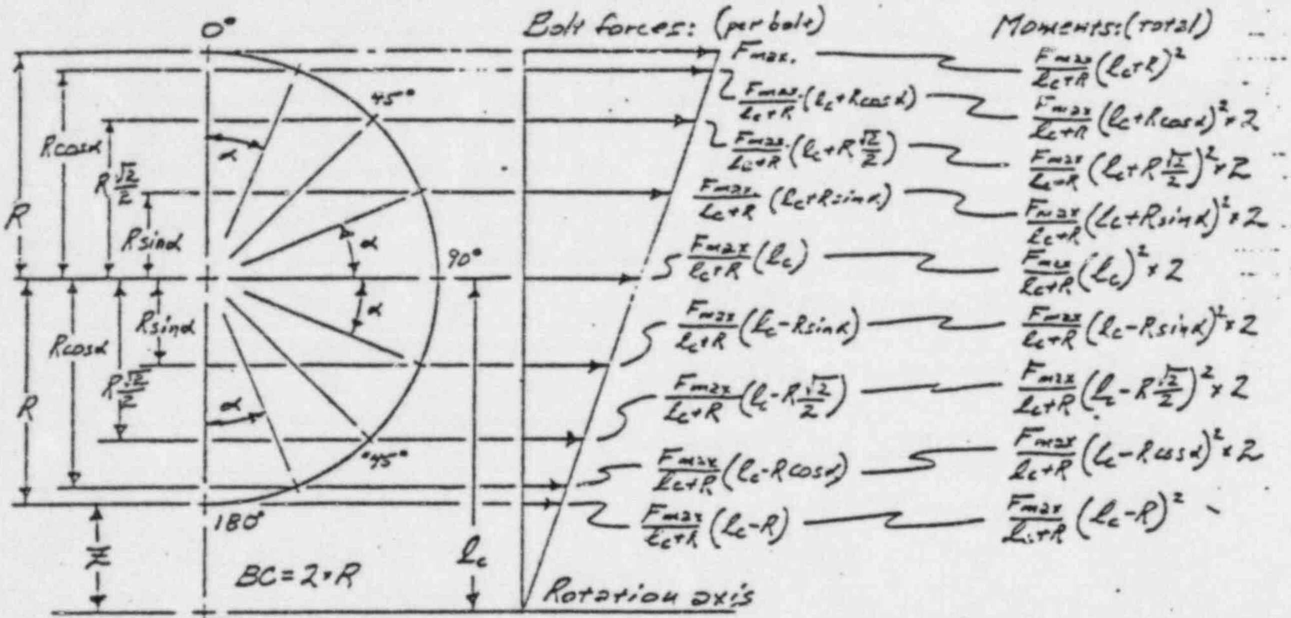
Maximum bolt force due to applied moment "M" on (N) equispaced bolts:



$$\Sigma M = \frac{F_{max}}{l_c+R}\Big[(l_c+R)^2+2(l_c+R\cos\alpha)^2+2(l_c+R\tfrac{\sqrt{2}}{2})^2+2(l_c+R\sin\alpha)^2+2(l_c)^2+2(l_c-R\sin\alpha)^2+2(l_c-R\tfrac{\sqrt{2}}{2})^2+2(l_c-R\cos\alpha)^2+(l_c-R)^2\Big]$$

Re-arranging into quadrant, 45°, and angle α groups:

$$\Sigma M = \frac{F_{max}}{l_c+R}\Big[\big\{(l_c+R)^2+2l_c^2+(l_c-R)^2\big\}+\big\{2(l_c+R\tfrac{\sqrt{2}}{2})^2+2(l_c-R\tfrac{\sqrt{2}}{2})^2\big\}+\big\{2(l_c+R\cos\alpha)^2+2(l_c+R\sin\alpha)^2+2(l_c-R\sin\alpha)^2+2(l_c-R\cos\alpha)^2\big\}\Big]$$

Expanding within each group:

$$\Sigma M = \frac{F_{max}}{l_c+R}\Big[\big\{l_c^2+2l_cR+R^2+2l_c^2+l_c^2-2l_cR+R^2\big\}+\big\{2l_c^2+2\sqrt{2}l_cR+R^2+2l_c^2-2\sqrt{2}l_cR+R^2\big\}+\big\{2l_c^2+4l_cR\cos\alpha+2R^2\cos^2\alpha+2l_c^2+4l_cR\sin\alpha+2R^2\sin^2\alpha+2l_c^2-4l_cR\sin\alpha+2R^2\sin^2\alpha+2l_c^2-4l_cR\cos\alpha+2R^2\cos^2\alpha\big\}\Big]$$

$$\Sigma M = \frac{F_{max}}{l_c+R}\Big[\big\{4(l_c^2+\tfrac{R^2}{2})\big\}+\big\{4(l_c^2+\tfrac{R^2}{2})\big\}+\big\{8l_c^2+4R^2(\sin^2\alpha+\cos^2\alpha)\big\}\Big] = \frac{F_{max}}{l_c+R}\Big[N \times (l_c^2+\frac{R^2}{2})\Big]$$

$R = \frac{BC}{2}$, $l_c = R+Z$, ΣM = applied moment $M = \frac{N \times F_{max}}{BC+Z}\left(\frac{3}{8}BC^2+Z \cdot BC+Z^2\right)$

Maximum bolt force $= F_{max} = \frac{M}{N}\left[\frac{BC+Z}{\frac{3}{8}BC^2+Z(BC+Z)}\right]$ for any multiple of 4 bolts.

For 6 bolts:

$$\Sigma M = \frac{F_{max}}{l_c+R}\Big[(l_c+R)^2+2(l_c+R\sin 30°)^2+2(l_c-R\sin 30°)^2+(l_c-R)^2\Big] = \frac{F_{max}}{l_c+R}\Big[6l_c^2+2R^2+4R^2\sin^2 30°\Big]$$

or, with $\sin^2 30 = \frac{1}{4}$, $\Sigma M = \frac{F_{max}}{l_c+R}\Big[N \times (l_c^2+\frac{R^2}{2})\Big]$, which is the same as the "4 bolt" case.

For 10 bolts:

$$\Sigma M = \frac{F_{max}}{l_c+R}\Big[(l_c+R)^2+2(l_c+R\cos 36°)^2+2(l_c+R\sin 18°)^2+2(l_c-R\sin 18°)^2+2(l_c-R\cos 30°)^2+(l_c-R)^2\Big]$$

or $\Sigma M = \frac{F_{max}}{l_c+R}\Big[10l_c^2+R^2(2+4\cos^2 36°+4\sin^2 18°)\Big]$; $\cos^2 36+\sin^2 18 = 0.75$,

therefore $\Sigma M = \frac{F_{max}}{l_c+R}\Big[N(l_c^2+\frac{R^2}{2})\Big]$, also the same as the "4 bolt" case.

This does not work for 2 bolts; $F_{max} = \frac{M}{2}\left[\frac{BC+Z}{\frac{1}{2}BC^2+Z(BC+Z)}\right]$

Notes: For $Z = -\frac{BC}{2}$ (moment about center), $F_{max} = \frac{M}{N}\left[\frac{4}{BC}\right]$ for 4 or more bolts.

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COVER PLATE

Size	6"	14"	16"	24"
Fig. NC-3325.1, (L) d	9.5"	18.75"	21.25"	29.5"
$t_{avail.}$	0.375"	0.5"	0.5"	0.5"
C	0.25	0.25	0.25	0.25
$P_{op.} + P_1 = P$ (p.1)	0.87 psi	92.45 psi	1.18 psi	33.55 psi
Required thickness, t_r (note #1)	0.0335"	0.6814"	0.087"	0.6458"
$t_{avail.} \geqslant t_r$	Satisfactory	See note #2	Satisfactory	See note #3

Note #1: $t_r = d\sqrt{\frac{CP}{S}}$, where S=17,500. psi { SA-240, Gr. 304 Table I-7.2 @ 225°F.

Note #2: The submerged structural loads include dynamic effects, which should not contribute to the required thickness. The "P1" value for the 14" strainer is 90.6 psi, which is much greater than the operating pressure drop of 1.85 psi. We will conservatively assume that 50% of the "P1" load is dynamic, and can be omitted from the "Design Pressure" used for ASME Code required thickness computation. This yields a pressure $P = 1.85 + \frac{90.6}{2} = 47.15$ psi, and $t_r = 0.487"$, which is satisfactory for the 14" strainer.

Note #3: As per note #2, for the 24" strainer, $P = 2.25 + \frac{31.3}{2} = 17.90$ psi, and $t_r = 0.472"$, which is satisfactory for the 24" strainer.

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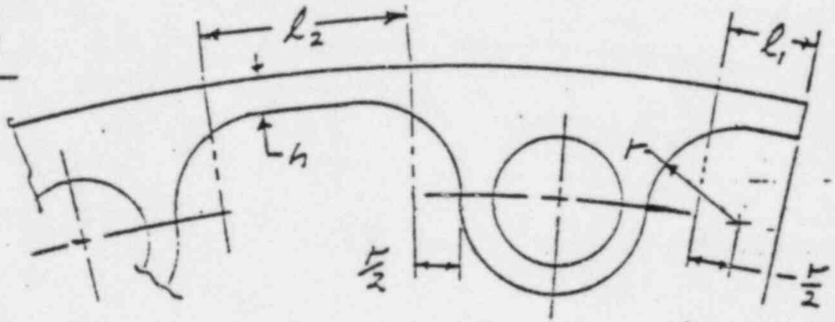
SEGMENTED RING



Size	6"	14"	16"	24"
Geometry l_1	1.227"	1.411"	1.000"	0.829"
$2 \times l_1 = l_2$	2.454"	2.822"	2.000"	1.658"
Load, lb/in (P_{oo}+PZ), p.1 w	3.51	25.15	5.68	53.15
Bending stress	200. psi	1,899. psi	215. psi	1,385. psi
Allowable	17,500. psi (p.7)			

All rings have a uniform nominal thickness $h = 0.28125"$; yielding a uniform section modulus of $Z = \frac{h^2}{6} = 0.0131836$ in³/inch of width. The maximum bending moment of the cantilevered end $= M_1 = \frac{w(l_1)^2}{2}$ in-lb/inch of width. The maximum moment of the center, as a simply supported beam, is $M_2 = \frac{w(l_2)^2}{8}$, or since $l_2 = 2 \times l_1$, $M_2 = M_1$.

ZURN a step ahead of tomorrow

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Checked by ______　Subject Seismic Analysis　Sheet 9 of ____

ELASTIC STABILITY

For a uniform arch with hinged ends under radial pressure, Roark & Young, Table 34, Case 9:

$$w' = \frac{EI}{R^3}\left(\frac{\pi^2}{\alpha^2}-1\right)$$, collapse load, lb./inch

where: $E = \frac{0.12\times(0.28125)^3}{12} = 0.000222473 \text{ in}^4$

$I = 27.7\times10^6$ psi

$\alpha = \frac{\ell_2}{R}$, radians (p.8)

$w_{actual} = 0.12 \times w'$ (p.8)

Size		6"	14"	16"	24"
Geometry	ℓ_2	2.454"	2.822"	2.000"	1.658"
	R	5.421875"	10.296875"	11.546875"	15.921875"
Collapse load, w'		1,824.	736.	1,313.	1,388.
Actual, $w_{act.}$		0.4212	3.018	0.6816	6.378
Safety Factor		4,331:1	244:1	1,926:1	217:1

signed by IHS Job 82N4965/8 Date 12/21/81 No. 1281A
hecked by Subject Seismic Analysis Sheet 10 of 10

REFERENCES

1) ASME BOILER AND PRESSURE VESSEL CODE, Section III, Nuclear Power Plant Components.

2) "Formulas for Stress and Strain", Roark & Young, 5th Edition, McGraw-Hill.

3) "Mark's Standard Handbook for Mechanical Engineers", Baumeister, 7th Edition, McGraw-Hill.

RAI 23 Section 3.8.4.3, page 3-47 and Item 4 of Table 3.4.1.1 (4), second page, indicate that the limits on the local membrane stress intensity and on primary - membrane - plus - primary - bending stress intensity were modified by using 1.3 S_{mc} in place of S_{mc} and certain restrictions are mentioned in a note related to this section. Confirm whether these limitations have been applied in the analysis.

RESPONSE

The limitations given in the "Plant Unique Analysis Application Guide" (GE document NEDO-24583-1), Table 5-1 and repeated in Table 3.4.1-1 of the PUAR on the use of 1.3 S_{mc} in place of S_{mc} were used in the analysis.

RAI 24 The stiffness matrix for the downcomer/vent header intersection given in Table 3.6.1.1-1 (4) and used for the beam model analysis (Section 3.6.2) shows the diagonal terms only, i.e., no-off-diagonal terms indicated. Justify and state the assumptions for not including other significant off-diagonal terms.

RESPONSE

In the Mark I Containment long term program, it was determined that for all Mark I plants, the downcomers are at least 50 times stiffer than their junctions. These results are summarized in Table 4-1 page 4-21 of Reference 1. For Brunswick Units 1 and 2, the ratio of downcomer to junction stiffness is 82. Due to symmetry in the header geometry at this location and due to the downcomer being so rigid with respect to the flexible downcomer/vent header junction, six independent degrees of freedom with no significant coupling can be assigned to the center of intersection. Thus, the downcomer responds as a single degree of freedom structure in each of the six degrees of freedom. This was also shown by an analytical study described on page 4-3 of Reference 1.

In the modified intersection, changes in intersectioin stiffness were accounted for and again, due to the geometry, it was noted that still no significant coupling occurred in each of the six degrees of freedom. Because of the validity of the six independent degrees of freedom assumption, the contribution of the off-diagonal terms to the junction stiffness was again considered minimal.

RAI 24 (Continued)

Reference:

1. Mark I Containment Long Term Program
   Development of Downcomer Lateral Loads From Full
   Scale Test Facility
   Data - Task Number 7.3.2 - NEDE 24537-P, May 1979

RAI 25a The downcomer/vent header finite element model shown on Figure 3.6.1.1-12 (4) indicates that large elements with non-conventional aspect ratio were used at some regions of discontinuities, such as the stiffening plate regions attached to the downcomer and to the vent header. Indicate the calculated stress intensity values at such locations.

RESPONSE

The STARDYNE QUAD4 element is well-behaved for aspect ratios up to 10. The elements in question in the downcomer model have an aspect ratio of 8.16. The model provides an accurate representation of the primary membrane plus primary and secondary bending stresses in the downcomer shell in the local region immediate to the discontinuity between downcomer shell and stiffener. A stress concentration factor of 2.0 was used to account for the peak stress intensity at this local discontinuity for fatigue evaluation.

RAI 25b Also indicate on Figure 3.6.1.1-12 and -13 (4), the locations corresponding to the high stress intensity values given in Table 3.8.4.3.1 (4).

RESPONSE

The calculated maximum stress intensity values at element locations in the regions of discontinuity are shown on Figure Item 25-A, Attachment RAI 25b-1. Locations corresponding to high stress intensity values given in Table 3.8.4.3.1 are marked on Figure 3.6.1.1-12, Attachment RAI 25b-2 and Figure 3.6.1.1-13, Attachment RAI 25-2, (attached).

FIGURE ITEM 25-A

(ONE SHEET)

CAROLINA POWER & LIGHT COMPANY

BRUNSWICK STEAM ELECTRIC PLANT

UNITS 1 & 2

Attachment RAI 25b-1

FRC RAI 25B-1

MAX. CALCULATED STRESS INTENSITY VALUE AT REGIONS OF DISCONTINUITY

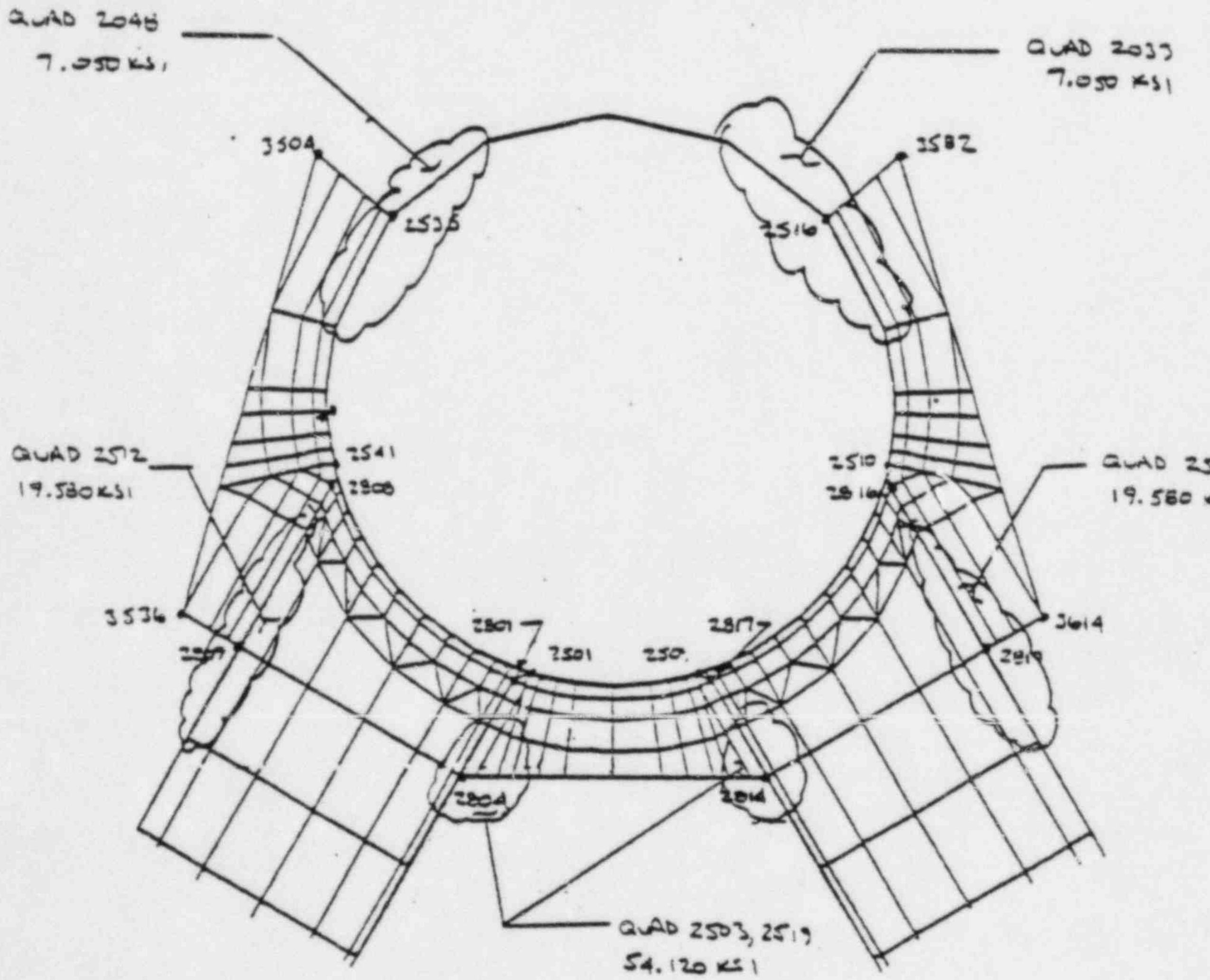


FIGURE ITEM 25-A

PLANT UNIQUE ANALYSIS REPORT

Figure 3.6.1.1-12

Figure 3.6.1.1-13

(Two Sheets)

CAROLINA POWER & LIGHT COMPANY

BRUNSWICK STEAM ELECTRIC PLANT

UNITS 1 & 2

Attachment RAI 25b-2

FRC RAI 25B-2

LOCATIONS CORRESPONDING TO HIGH STRESS INTENSITY

VALUES GIVEN IN TABLE 3.8.4.3-1

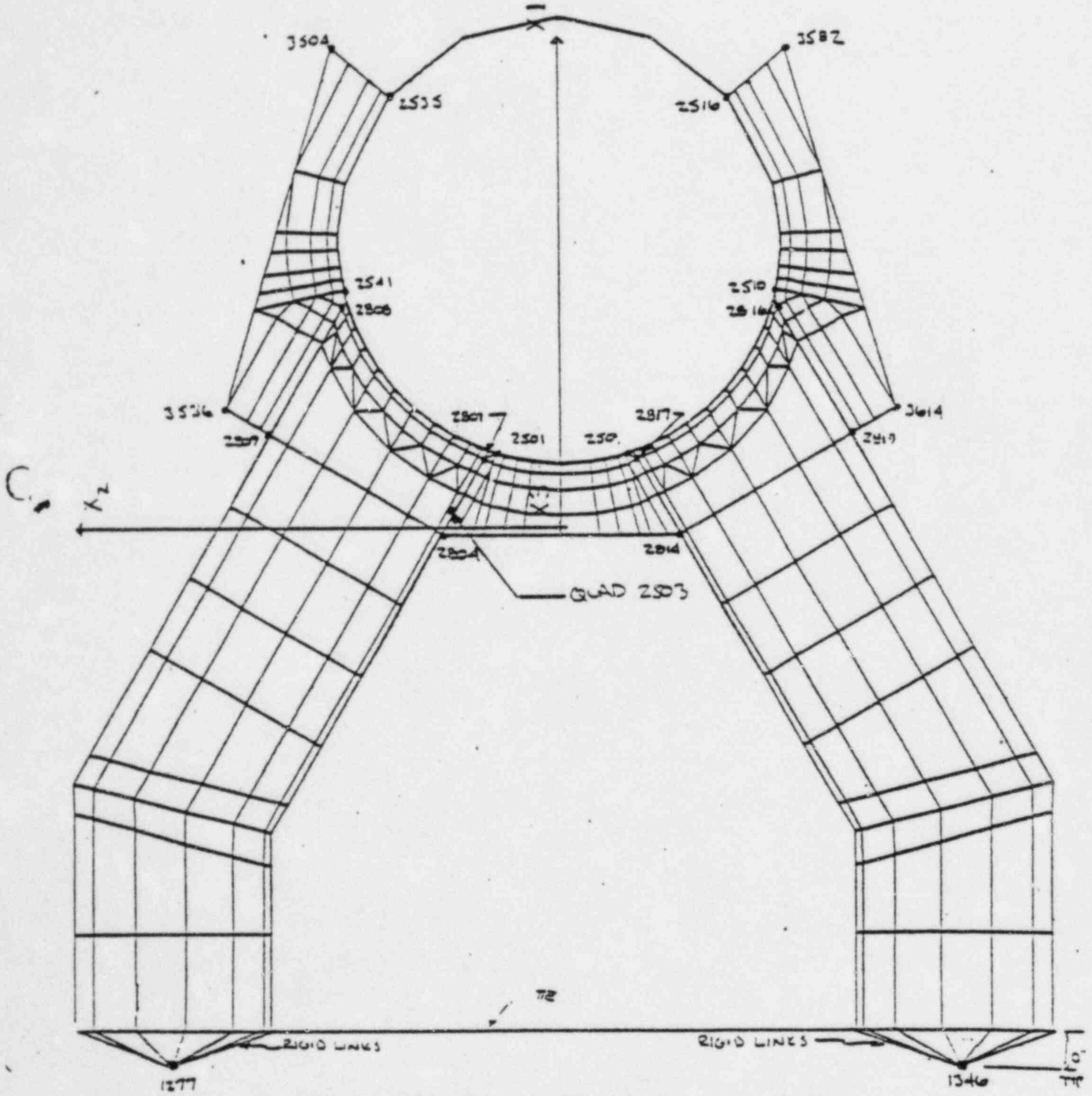
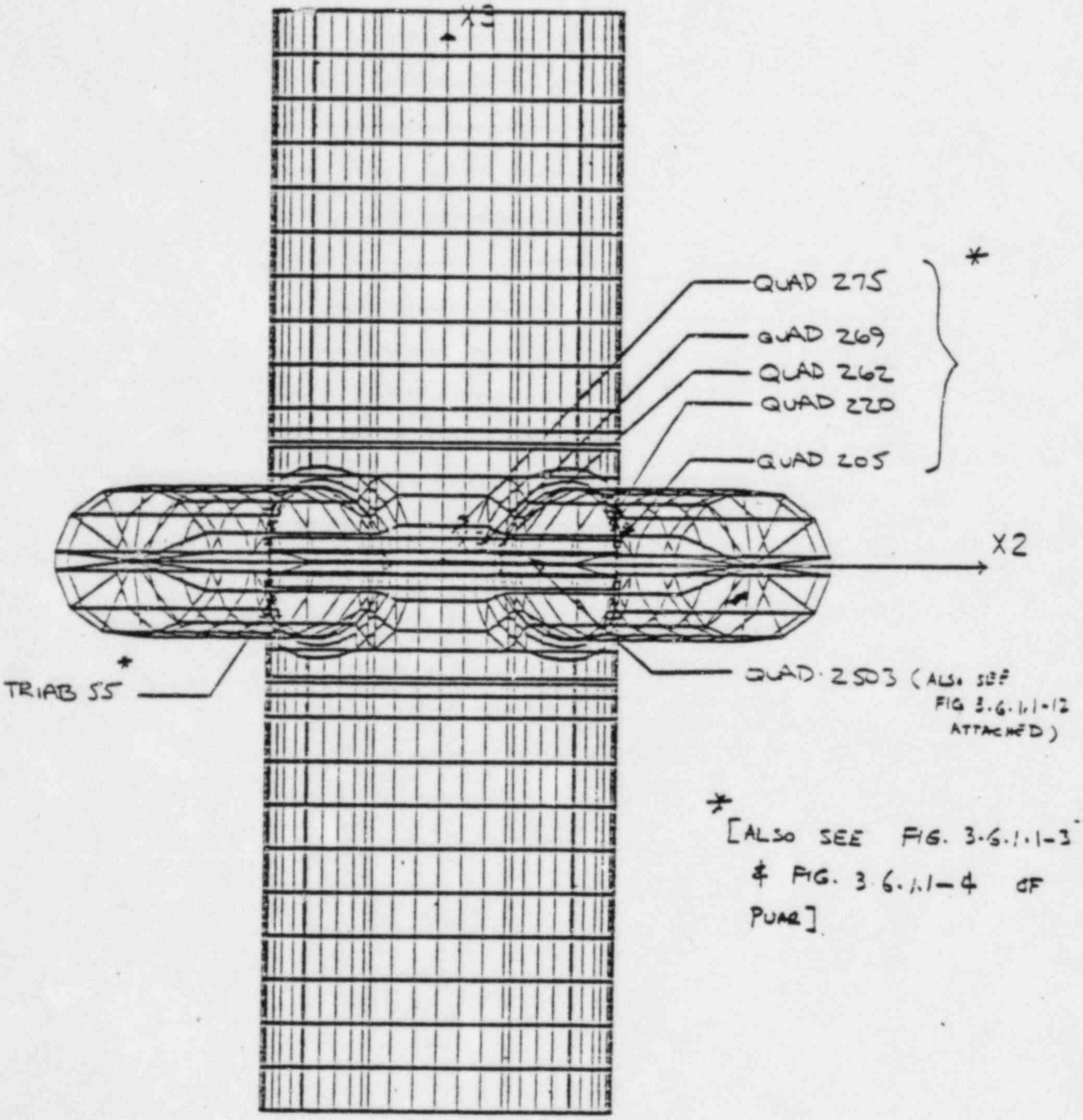


Figure 3.6.1.1-12 Downcomer/Vent Header Finite Element Projection on X_1 - X_2 Plane

FRC - RAI 258-2

LOCATIONS CORRESPONDING TO HIGH STRESS INTENSITY VALUES GIVEN IN TABLE 3.8.4.3-1



*[ALSO SEE FIG. 3.6.1.1-3 & FIG. 3.6.1.1-4 OF PUAR]

Figure 3.6.1.1-13 Downcomer/Vent Header Finite Element Projection on X_2 - X_3 Plane

RAI 26 Provide a justification for using a stress concentration factor of 2, stated on page 3-48 (4).

RESPONSE

Justification for using a stress concentration factor of 2 for the weld at the downcomer/ring header intersection is provided in Welding Researech Council Bulletin 256, "Review of Data Relevant to the Design of Tubular Joints for Use in Fixed Offshore Platforms", by E. C. Rodabaugh, January 1980.

RAI G1 With reference to Section 1.5 in the PUA report (4), justify the assumption that the fluid structure interaction and dynamic load factors for post-chugging are the same as those for condensation oscillation.

RESPONSE

The condensation oscillation load is an oscillatory pressure on the submerged portion of the torus shell. The load is symmetric, having the same value and distribution at all vertical cross sections of the torus along the circumference. The pressure distribution on the wetted perimeter of the torus changes from zero at the water surface to the maximum possible value of 15.37 psi at the bottom dead center of the torus. The load is defined in the frequency domain for the frequency range of 1 to 50 Hz. This load is applied to the torus for a duration of 30 or 900 seconds depending on the type of break.

The post-chugging load is also an oscillatory pressure on the submerged portion of the torus shell. The post-chugging load distribution is similar to the condensation oscillation load along the torus circumference and the wetted perimeter of the torus cross-section. The maximum possible pressure at the bottom dead center of the torus shell is 3.7 psi. This load is applied to the torus for 30 or 900 seconds depending on the type of break. The cycle duration of the post-chugging load is 0.5 seconds every 1.4 seconds for the total duration of the load. This load is

RESPONSE (Continued)

defined in the frequency domain for frequencies of 1 to 50 Hz.

Table G-1 shows the frequency versus pressure amplitude for condensation oscillation and post-chugging loads. The amplitudes are normalized to the absolute sum of the amplitude of each load for better comparison.

The fluid-structure interaction (FSI) factor for the torus depends on the ratio of water mass to torus mass, which is constant for both condensation oscillation loads and post-chugging loads. The variation in these two loads has minimal effect on the FSI factor. Due to very low ratio of water to torus mass the maximum FSI factor obtained for condensation oscillation load is 1.13.
The dynamic load factor (DLF) for post chugging load may be different from the dynamic load factor obtained for condensation oscillation load. Since the post-chugging load appears to have relatively higher amplitudes at higher frequencies than the condensation oscillation load and the structural natural frequencies starts from 27 Hz., the dynamic load factor for post-chugging load may be higher than 1.5. A simplified conservative approach using the natural frequencies of the torus and assuming the torus as a single degree of freedom system results in an upper bound DLF for post-chugging load. A DLF of less than 3 was obtained from the analysis.

RAI G1 (Continued)

RESPONSE (Continued)

In light of this conclusion, the DLF used for hydrodynamic loads was increased to 3 and the stresses calculated. A discussion of the results are given on Page 1-34 of the PUAR. The stresses are all below allowables. It was concluded that the hydrodynamic loads are not appreciable loads in the concrete torus.

For additional information see RAI G3.

FRC RAI G1

Table G-1

Comparison of Condensation Oscillation and Post-Chugging Loads Frequency Versus Pressure Amplitude (Normalized to the Absolute Sum of Amplitude of Each Load*)

Frequency Hz.	Amplitude			Frequency Hz.	Amplitude		
	C.O	P.C	Ratio(CO/PC)		C.O	P.C	Ratio
1	0.019	0.011	1.73	26	0.016	0.011	1.45
2	0.016	0.011	1.45	27	0.037	0.077	0.48
3	0.021	0.014	1.50	28	0.008	0.047	0.17
4	0.031	0.014	2.21	29	0.012	0.032	0.38
5	0.077	0.016	4.81	30	0.009	0.024	0.38
6	0.174	0.014	12.42	31	0.005	0.008	0.63
7	0.027	0.027	1.0	32	0.002	0.005	0.40
8	0.025	0.027	0.93	33	0.002	0.005	0.40
9	0.025	0.027	0.93	34	0.002	0.005	0.40
10	0.025	0.027	0.93	35	0.003	0.005	0.60
11	0.051	0.016	3.19	36	0.005	0.008	0.63
12	0.029	0.014	2.07	37	0.007	0.014	0.50
13	0.008	0.008	1.0	38	0.005	0.008	0.63
14	0.005	0.008	0.63	39	0.004	0.011	0.36
15	0.005	0.005	1.0	40	0.006	0.011	0.55
16	0.007	0.005	1.40	41	0.021	0.041	0.51
17	0.003	0.003	1.0	42	0.021	0.041	0.51
18	0.003	0.003	1.0	43	0.021	0.041	0.51
19	0.003	0.003	1.0	44	0.021	0.041	0.51
20	0.018	0.011	1.64	45	0.021	0.041	0.51
21	0.013	0.008	1.63	46	0.021	0.041	0.51
22	0.020	0.014	1.43	47	0.021	0.041	0.51
23	0.022	0.014	1.57	48	0.021	0.041	0.51
24	0.021	0.014	1.50	49	0.021	0.041	0.51
25	0.010	0.011	0.91	50	0.021	0.041	0.51

---

*Absolute sum of C.O. load amplitude = 15.37 psi
Absolute sum of P.C. load amplitude = 3.75 psi

RAI G2 Provide information indicated that the water mass has been included in the seismic analysis of the Torus. Provide justification if it has not been considered.

RESPONSE

The water mass, about 16 percent of the total weight of the torus, is located at the bottom portion of the torus. It was included in the original response spectra seismic analysis of the torus and dry well. The actual distribution of the acceleration is linear, with maximum acceleration at the top of the torus decreasing to a smaller value at the bottom of the torus. The maximum horizontal and vertical accelerations at the top of the torus were applied to the entire torus in the quasi-static seismic analysis to account for the actual distribution of the seismic loads.

The calculated shearing stresses due to seismic and other loads are far below the allowable stresses and inclusion of the water mass, though not justified, does not impair the integrity of the torus.

RAI G3a With reference to Section A-1.2.5 of the PUA report (4), provide information on the stress results for condensation oscillation load at modal points listed in Table A-1-10 (4).

RESPONSE

The stress results for the condensation oscillation load applied statically to the torus shell are shown in Attachment RAI G3a. The maximum radial stress is 34 psi, the maximum azimuth (circumferential) stress is 9.8 psi, the maximum axial (meridional) stress is 15 psi and the maximum shear stress is 13 psi. The very high dynamic load factor, listed in Table A.1-10 corresponds to stresses having a value less than 1 psi and were not used. Dynamic load factors in the range of 1.5 to 3 occur at a few nodes. The remaining nodes have a dynamic load factor of 1.5 which was considered typical and used in the analysis for all the stress components with insignificant error.

Stress levels in the concrete torus due to the condensation oscillation and other hydrodynamic loads are low when compared with a steel torus. This is due to the continuous support at the bottom of the concrete torus and the very low ratio of water mass to total mass of the torus. To study the effect of hydrodynamic loads on the stresses in the torus for various load combinations given in Table 1.4-1 of the PUAR, hydrodynamic load factors were increased to 3 and stresses for various load combinations obtained. The stresses were increased between 0 to 40 percent (see page 1-34

RAI G3a (Continued)

RESPONSE

of the PUAR for more information). The maximum stresses remain below allowables. Those limited areas of the torus and loadings which show a dynamic load factor between 1.5 and 3 are enveloped by these results.

REFERENCES

1. NEDO-24583-1 (79NED125)
   "Mark I Containment Program, Structural Acceptance Criteria, Plant Unique Analysis Application Guide".
   General Electric Company, San Jose, California
   October 1979

2. NEDO-21888
   "Mark I Containment Program Load Definition Report"
   General Electric Company, San Jose, California
   November 1981, Revision 2

COMPUTER PRINTOUT
STATIC ANALYSIS
STRESS RECOVERY PHASE
FOR
C.O. LOADS

(Total 2 pages)

CAROLINA POWER & LIGHT COMPANY
BRUNSWICK STEAM ELECTRIC PLANT

UNITS 1 & 2

Attachment RAI G3a

- = ERC RAI G 3A

Stres. in PSI

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1     STATIC ANALYSIS ANALYSIS OF THE STRUCTURE ONLY                                                              PAGE     1
      STRESS RECOVERY PHASE FOR C. O. LOADS
                                                                                                              SUBCASE  1
0                                  S T R E S S E S   I N   T R I A X 6   E L E M E N T S
0     GRID                                 STRESS  IN  MATERIAL  COORD  SYSTEM
       ID              RADIAL                AZIMUTH                     AXIAL                       SHEAR
        1          5.225637E-01          1.387771E+00                2.591616E+00                5.679495E-01
        3          1.323674E-01          1.062930E+00                4.554790E-01                5.940844E-02
        5          9.294149E-02          6.942310E-01                2.128920E+00                1.529623E-01
       11          2.844396E+00          1.152408E+00                1.964620E+00                5.278292E-01
       13          8.861746E-01          4.625260E-01                1.084490E+00                1.499095E+00
       15          1.821027E-01          1.127520E-01                6.144008E-01                1.220665E-01
       21          3.464891E+00          2.331902E-01                5.479317E-01                3.955376E+00
       23          4.130962E-01          4.169407E-01                3.445716E+00                3.667288E+00
       25          2.125854E-01          6.763395E-01                6.333787E+00                4.952159E-01
       31          1.579539E+00          9.917255E-01                8.946444E-01                7.964580E+00
       33          6.593912E-01          1.417642E+00                5.678531E+00                4.385339E+00
       35          2.122885E-01          1.076577E+00                1.252701E+01                3.831552E-01
       41          2.885403E+00          2.191131E+00                1.270652E+00                1.105489E+01
       43          2.304793E+00          2.272904E+00                7.170174E+00                3.286446E+00
       45          4.167235E-01          1.242134E+00                1.466305E+01                4.106932E-01
       51          3.821136E+00          3.506945E+00                5.435822E+00                1.279752E+01
       53          6.797293E+00          3.294875E+00                6.886390E+00                4.305611E+00
       55          2.809120E+00          2.546211E+00                8.431485E+00                1.981779E-01
       61          1.940835E+01          5.343297E+00                9.864787E+00                1.193852E+01
       63          1.407550E+01          4.757365E+00                8.627442E+00                4.933579E+00
       65          9.755188E+00          4.002120E+00                7.862745E+00                1.266846E-01
       71          2.955612E+01          7.564635E+00                1.357240E+01                7.480150E+00
       73          2.316466E+01          6.851352E+00                1.101460E+01                3.720179E+00
       75          2.004084E+01          6.228838E+00                1.017451E+01                1.484458E-01
       81          3.403780E+01          9.351757E+00                1.505249E+01                2.567807E-01
       83          2.809597E+01          8.824928E+00                1.194584E+01                4.619387E-01
       85          2.647261E+01          9.642224E+00                1.111127E+01                4.762943E-01
       91          2.773761E+01          9.768146E+00                1.372572E+01                7.098040E+00
       93          2.238694E+01          9.263906E+00                1.127440E+01                3.228756E+00
       95          1.997678E+01          9.095986E+00                1.055954E+01                1.322296E-01
      101          1.660253E+01          9.421907E+00                1.026357E+01                1.092345E+01
      103          1.270656E+01          8.732532E+00                9.152415E+00                4.466595E+00
      105          9.402495E+00          8.315500E+00                8.362357E+00                1.595282E-01
      111          6.958446E+00          8.939131E+00                6.509202E+00                1.110096E+01
      113          5.680123E+00          8.052911E+00                7.249625E+00                3.901921E+00
      115          2.592560E+00          7.308204E+00                7.201947E+00                1.351772E-01
      121          5.894350E-01          8.587668E+00                3.645528E+00                8.818447E+00
      123          1.747614E+00          7.448619E+00                6.386958E+00                3.262665E+00
      125          3.865393E-01          5.941523E+00                1.051463E+01                4.047930E-01
      131          3.616984E+00          9.202395E+00                3.435419E+00                5.135512E+00
      133          5.122184E-01          7.722492E+00                5.034573E+00                4.476329E+00
      135          2.316688E-01          5.589744E+00                7.883978E+00                4.450140E-01
      141          5.187616E+00          7.417602E+00                6.706284E+00                7.391302E-01
      143          6.329753E-01          9.193003E+00                2.757694E+00                3.772502E+00
      145          3.485439E-01          4.218600E+00                6.261550E-01                6.726735E-01
      151          3.773108E+00          6.694682E+00                1.021609E+01                1.937009E+00
      153          1.371030E+00          8.363577E+00                3.253014E-01                9.211014E-01
      155          3.997217E-01          9.694535E+00                8.661324E+00                2.339859E-01
      161          4.293762E-01          5.558057E+00                8.178920E+00                1.795907E+00
      163          6.091980E-01          7.651263E+00                6.715338E-01                1.926819E+00
1     STATIC ANALYSIS ANALYSIS OF THE STRUCTURE ONLY                                                              PAGE     2
      STRESS RECOVERY PHASE FOR C. O. LOADS
                                                                                                              SUBCASE  1
0                                  S T R E S S E S   I N   T R I A X 6   E L E M E N T S
0     GRID                                 STRESS  IN  MATERIAL  COORD  SYSTEM
       ID              RADIAL                AZIMUTH                     AXIAL                       SHEAR
      169          3.806322E-01          8.61933[illegible]E+00          7.828737E+00                5.390341E-01
      171          1.973067E-01          5.150718E+00                1.756124E+00                4.184902E-01
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FRC RAIG3A

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              3.374543E-01          5.355943E+00          1.050551E+00          3.777110E-01
      181     4.244153E-01          5.519962E+00          3.971959E+00          8.528146E-01
      183     2.931644E-01          4.198280E+00          1.710759E-01          5.807171E-01
      185     1.454611E-01          2.982972E+00          4.024528E+00          4.166475E-02
      191     7.436967E-01          4.425889E+00          4.361212E+00          1.644233E+00
      193     1.056920E-01          2.843925E+00          1.362950E-01          2.514242E-01
      195     1.922954E-01          1.747745E+00          2.877698E+00          1.495166E-01
      201     9.504785E-01          3.323925E+00          2.757790E+00          1.512040E+00
      203     1.019079E-01          1.827975E+00          5.356016E-02          5.797440E-01
      205     6.350530E-02          8.879379E-01          1.104027E+00          2.121707E-01
      211     1.434271E+00          2.938512E+00          1.400959E+00          1.216003E+00
      213     1.651536E-01          9.435535E-01          8.986043E-02          7.881070E-01
      215     1.585873E-01          1.753937E-02          1.890071E-01          9.549292E-02
      221     2.794103E+00          2.393988E+00          8.551637E-01          1.468409E+00
      223     1.542244E-01          7.731853E-01          8.727468E-02          5.032736E-01
      225     1.466396E+00          2.360200E-01          1.033397E-01          2.031232E-01
      231     4.764950E+00          1.911630E+00          6.242183E-01          1.618879E+00
      233     1.863584E-01          6.778881E-01          1.673837E-01          2.913405E-01
      235     3.708739E+00          3.556754E-01          1.887273E-01          1.584975E-01
      241     5.828896E+00          1.595670E+00          1.969058E-01          1.083520E+00
      243     1.609325E-01          7.242871E-01          2.712080E-01          2.802783E-01
      245     5.445207E+00          1.892267E-01          2.915164E-01          2.198281E-01
      251     4.522531E+00          1.259671E+00          1.420310E-01          2.341461E-01
      253     1.431078E-01          7.714938E-01          3.012464E-01          9.049120E-01
      255     2.477336E+00          7.273573E-01          3.388450E-01          2.053157E-01
      261     1.035686E+00          5.749115E-01          2.253672E-01          1.111272E-01
      263     7.299545E-02          7.955179E-01          3.609367E-01          6.160020E-01
      265     7.362399E-01          1.378413E+00          2.655990E-01          5.198557E-02
      271     8.813372E-01          5.533307E-02          2.433136E-01          4.716893E-01
      273     1.690063E-01          7.863818E-01          1.191250E-01          1.516324E-01
      275     9.214801E-01          1.461139E+00          2.886604E-02          7.991367E-02
      281     1.137294E+00          2.915660E-01          5.278395E-01          7.181812E-01
      283     2.165294E-01          6.827054E-01          1.222796E-01          2.771883E-01
      285     3.478382E-02          1.490001E+00          9.698149E-02          2.136768E-02
      291     9.121711E-01          6.878777E-01          9.683151E-01          8.612726E-01
      293     7.192895E-02          1.643867E-01          1.926238E-01          2.248189E-01
      295     3.485641E-02          9.420838E-01          2.953804E-01          1.503553E-01
      301     7.435339E-01          1.218699E+00          1.839765E+00          1.136281E+00
      303     5.771675E-02          3.610399E-01          2.098862E-01          1.387087E-01
      305     3.979859E-02          4.636229E-01          8.812423E-01          2.426291E-01
      311     4.971699E-01          1.739136E+00          2.824550E+00          1.146063E+00
      313     6.220624E-02          1.099279E+00          2.852238E-01          3.860010E-02
      315     8.984234E-02          4.943677E-01          1.655491E+00          3.667020E-01
      321     1.802196E-01          1.933377E+00          3.369261E+00          7.080918E-01
      323     1.216875E-01          1.519940E+00          3.783158E-01          5.952160E-02
      325     8.683118E-02          1.136537E+00          2.214396E+00          4.308083E-01
      331     1.054050E-01          1.777958E+00          3.253912E+00          1.014874E-01
1   STATIC ANALYSIS ANALYSIS OF THE STRUCTURE ONLY                                                      PAGE    3
    STRESS RECOVERY PHASE FOR C. O. LOADS
                                                                                               SUBCASE  1
0                                   S T R E S S E S   I N   T R I A X 6   E L E M E N T S
0   GRID                                       STRESS  IN  MATERIAL  COORD  SYSTEM
     ID            RADIAL                 AZIMUTH               AXIAL                 SHEAR
     333      1.412565E-01          1.459396E+00          3.059694E-01          6.689495E-02
     335      4.287764E-02          1.163868E+00          2.992972E+00          2.371881E-01
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RAI G3b Also, provide justification for considering those stresses which yielded dynamic load factors greater than 1.45 not reliable or typical.

RESPONSE

See Response to RAI G3a.

RAI G4 Provide details and schedules for the relocation of the electric penetration box which was found to be overstressed as indicated in Section 2.3.2.9 of the PUA report (4).

RESPONSE

Suppression pool electrical penetrations X-232-B and X-232-C, presently equipped with 24" x 24" x 24" termination boxes at the inboard end, have been modified by Plant Modifications PM 81-251 and PM 81-252.

Plant Modifications have provided necessary design and qualification documentation for:

a. Removal of the termination boxes from inboard end of the above electrical penetrations.

b. Substitution of the termination points by environmentally and seismically qualified cable splices, manufactured by Raychem Corporation.

RAI G5 With reference to Table 2.3.2-3 of the PUA report (4), indicate the schedule for modifications of the platform structure.

RESPONSE

The modifications to the platform structures are to be accomplished for Unit 2 during the maintenance outage scheduled to start in November 1983 and for Unit 1 during the refueling outage scheduled to start in July 1985.