TELEDYNE
ENGINEERING SERVICES

TECHNICAL REPORT

TR-5310-2
REVISION 1

MARK I CONTAINMENT PROGRAM

**PLANT-UNIQUE ANALYSIS REPORT
OF THE
TORUS ATTACHED PIPING
FOR
PILGRIM NUCLEAR POWER STATION**

SEPTEMBER 1984

BOSTON EDISON COMPANY
25 BRAINTREE HILL PARK
BRAINTREE, MASSACHUSETTS 02184

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TELEDYNE ENGINEERING SERVICES
130 SECOND AVENUE
WALTHAM, MASSACHUSETTS 02254
617-890-3350

TELEDYNE ENGINEERING SERVICES

RECORD OF REVISIONS

REVISION	PAGE	DESCRIPTION
1	Cover Title	Add Revision 1 and change date to September 1984.
	7	Change "six" to "five attachment springs and a fixed torsional rotation of the pipe" at the second bullet.
	15	Change SRV stress and location to SRV Line A Elbow (Node 14) 16575 psi SRV Line B Elbow (Node 46) 17861 psi
	18	Change valve information. Line A / Line B SRV 16931 16857 1st Vac. Bkr. 10659 11450 2nd Vac, Bkr. 11624 13575
	44	Change maximum stress and location. X-205 26297 Floor Penet. X-227 18602 Reducer
	45	Remove Note (*) at bottom of page. Modify: Liq. Lvl. Indicator X206C 1" Sch. 80 Dynamic 34300 37500 Anchor Liq. Lvl. Indicator X206D 1" Sch. 80 Dynamic 29870 37500 Anchor CACS X218 4" Sch. 80 Dynamic 15695 43752 Floor Penetration CACS X219 4" Sch. 80 Dynamic 17656 43752 Floor Penetration
	47	Change maximum and allowable stresses. X205 2249 36000 (4.0 Sch. 40) X205 869 36000 (1.0 Sch. 40) X222A & B 1675 36000 (P-203A) X222A & B 2318 36000 (P-203C)

RECORD OF REVISIONS (cont.)

REVISION	PAGE	DESCRIPTION		
	47 (cont.)	Make note on bottom of page singular and remove "*" at X205.		
	48	Change stresses and allowable.		
			Pipe Stress	Allowable
		AO-5036/A	9243/11860	18000
		AO-5036/B	391/5123	
	49	20"-N238	5096/5404	
		20"-N294M4K	3771/7902	
	50	8"N294M4K	5537/4346	
		8"N238	9079/9071	
		AO-5042-A	2599/767	
		AO-5040-A	1247/1016	18000
		AO-5042-B	7246/5506	
		AO-5040-B	754/638	18000
	55	Change X-22A and B to X-222A and B		

Note: Revision 1 changes are a result of incorporating NRC review comments which are documented in TR-5310-1, Revision 1, and reanalysis of piping due to replacement of valves under the Pilgrim Valve Betterment Program.

ABSTRACT

The work summarized in this report was undertaken as part of the Mark 1 Containment Long Term Program. It includes the evaluation of all piping systems that are attached to the suppression pool (torus).

These piping systems include both Main Steam Safety Relief lines and piping attached to the torus shell.

Mark 1 induced loads, as well as original design loads, are included in the evaluation. Necessary modifications are summarized.

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FIGURES AND TABLES

1.0 GENERAL

The purpose of the Mark 1 Containment Program is to evaluate the effects of hydrodynamic loads resulting from a loss of coolant accident and/or an SRV discharge on the torus structure.

Teledyne report TR-5310-1 (Reference 1) reported the effects of Mark 1 loads on the Pilgrim torus structure, support system and internals. This second report completes the work on the program by considering the effects of the Mark 1 loads on the piping systems attached to the torus. Both the main steam relief lines and the piping connected to the torus shell are considered. Also included is the evaluation of piping penetrations, supports and active components.

A summary of modifications made as a result of this analysis is included.

The report is separated into two major categories, one that deals with main steam relief lines (SRV piping) and one that deals with piping attached to the torus shell (TAP). Each of these sections is written to stand alone and includes a discussion of methods and results.

2.0 SRV PIPING ANALYSIS

There are four main steam relief (SRV) lines at Pilgrim. These lines connect to the main steam lines in the drywell, extend down the main vents and penetrate the main vent into the torus (Figures 2-1 and 2-2). These lines penetrate the main vent pipe near the outer torus shell and enter the pool vertically; they then enter the discharge quencher at a 20° angle (Figures 2-3 and 2-4).

Analysis results for the discharge end of the SRV lines were previously reported in Reference 1. This referenced report includes SRV piping in the torus airspace, the submerged part of the SRV line, the tee-quencher and the quencher support beam. This report will cover the remaining portion of the line, which includes:

- The main vent penetration.
- The SRV piping between the penetration and the main steam line.
- SRV pipe supports between the penetration and main steam line.

The analysis of SRV piping in this report accounts for the fact that some modifications have previously been made to these lines. These modifications are described in the Reference 1 report and consist of the addition of tee-quenchers and support beams (Figure 2-4) and the addition of two ten-inch vacuum breakers on each SRV line.

2.1 Applicable Codes and Criteria

The SRV piping analysis was performed in accordance with Section III of the ASME Code, 1977 Edition, including Summer 1977 addenda (Reference 2). Pipe support analysis was done to Section III of the ASME Code, Subsection NF (Reference 2).

In cases where modifications to SRV line supports were required, they were designed in accordance with Section III of the ASME Code, (Reference 2).

Load combinations and stress levels were evaluated in accordance with Table 5-5 of the Mark 1 Containment Program Structural Acceptance Criteria Plant Unique Analysis Application Guide (Reference 5). Table 5-5 is reproduced in this report as Table 1.

2.2 SRV Loads

The Mark 1 Program defined several new SRV line conditions. These conditions resulted from different drywell and torus conditions and produced several different reflood heights and discharge pressures. The load cases considered are listed in Table 2-1.

The analysis and evaluation in this report considers all these SRV cases, as well as seismic, weight, thermal and pressure effects.

The specific loads considered in this analysis include:

- Gas clearing (blowdown) loads.
- Water clearing discharge loads.
- Submerged structure drag on the SRV line, quencher and support due to pool motion.
- Thermal expansion of SRV line.
- Thermal expansion of containment structure.
- Seismic.
- Weight.
- Internal pressure.

Calculational methods developed as a part of the Mark 1 generic program were used to the extent that they apply.

2.2.1 SRV Gas Clearing Loads

Sudden pressurization of the SRV line, due to rapid opening of the safety relief valve, causes unbalanced dynamic forces on the SRV

piping. These forces progress through the system as pressure waves, whose speed and amplitude depend upon the particular line conditions being considered; the various SRV cases as listed in Table 2-1.

TES has evaluated the stresses resulting in various SRV piping systems, due to the cases listed in Table 2-1, and has concluded that SRV Case A1.2 is the bounding case for gas clearing loads. Case A1.2 is a first actuation after an SBA/IBA break and is characterized by increased gas density in the line before valve actuation. This increased density is a consequence of increased drywell pressure which affects the internal line pressure and density through the vacuum breakers. This increased density produces higher thrust forces than the lower density cases. This load case was run for each of the four SRV lines.

The calculation of loads resulting from Case A1.2, as well as all other SRV cases, was based upon use of the Computer Code RVFOR-05 (Reference 7), which is the property of General Electric Company.

Case A1.2 was run for each of the four SRV lines at Pilgrim. Gas clearing loads associated with this case were used for all SRV cases and, therefore, produced conservative results for normal actuation as well as other cases.

2.2.2 SRV Water Clearing Loads

Water clearing loads are produced in the SRV line as water accelerates under line pressure and is forced around the elbows at the quencher end of the line. These forces are very sensitive to reflood height which varies for several of the second actuation cases.

Maximum line reflood and water clearing are clearly associated with SRV Case C3.3. Case C3.3 is the second actuation after an IBA/SBA break with steam in the drywell. The high reflood is a consequence of

additional steam entering the line through the vacuum breaker after the first actuation (rather than air).

The high water clearing loads that result from this condition affect the torus end of the SRV line, including the piping in the main vent. It has a negligible effect on piping loads in the drywell.

Water clearing for Pilgrim was calculated for SRV Case C3.3, using G.E. programs RVRIZ and RVFOR-04 (Reference 7). It was concluded, based on inspection and analysis, that line C would produce the highest reflood heights for case C3.3 (lines C and D were analyzed; lines A and B are practically identical to C & D). Values for line C represent the worst case for water clearing loads and were used for all four SRV lines; these lines are identical inside the torus. The second valve actuation was assumed to occur at the point of maximum reflood.

Water clearing loads associated with SRV Case C3.3 bound all other cases and were used for all SRV analysis conditions.

2.2.3 Pool Drag Loads

The torus end of the SRV line, including the tee-quencher and quencher support beam, are submerged in the torus pool. These components are subject to drag loads due to pool motion from the following loads:

Pool Swell - Jet Loads
- Bubble Loads

Condensation Oscillation -
- Source induced drag
- Fluid Structure Interaction (FSI) Drag

Chugging - Source Induced Drag
- FSI Drag

SRV Discharge - Drag from Adjacent Quenchers (as applicable)

The drag loads associated with these events were calculated in the earlier part of the program and the methods are reported in Reference 1. At that time, these drag loads were used to determine stresses in the SRV piping in the torus, the quencher and the support beam; these were all reported in Reference 1. The same drag load information was used as a part of this analysis to help determine stress in the penetration, and the SRV line and supports in the main vent pipe.

2.2.4 Thermal Expansion

Two different load conditions were considered for thermal expansion stress.

The first assumed that the entire SRV line was at its design temperature (340^{0}F). It included maximum thermal motion of the connection at the main steam line and assumed the drywell and torus were at ambient.

The second case was like the first except the main vent pipe was also assumed to be at 340^{0}F. This has the effect of moving the penetration in the main vent pipe relative to the torus and quencher.

2.2.5 Weight, Pressure and Seismic

Weight, pressure and seismic loads were also considered in the analysis. The seismic analysis was based on the existing FSAR seismic response spectra for the OBE event. A multiplier of 1.875 was applied to OBE results for the SSE event, in accordance with the FSAR.

Seismic end effects were considered for this analysis, but judged to be negligible.

A typical horizontal spectra is illustrated in Figure 2-6; all spectra were taken from Reference 15.

2.3 SRV Analysis Method

2.3.1 Piping Analysis

2.3.1.1 Computer Model

Analysis of all SRV load cases was performed using computer models of the piping systems and the STARDYNE computer code (Reference 16). A typical computer model is illustrated in Figure 2-5.

Features of the model include:

- Modeling of the main steam line with each SRV line.
- Representation of the stiffness of the main vent penetration by a set of five attachment springs, developed by computer analysis of the penetration area.
- Full representation of the tee-quencher and quencher support beam in the piping model.
- Full representation of the brackets between the quencher and support beam which allow free torsional rotation of the quencher arms.
- Two percent damping used for time history analysis - ½% spectra used for OBE seismic.

2.3.1.2 Piping Analysis Method

Analysis for SRV discharge cases was done by imposing individual time histories for water and gas clearing loads at each bend

and elbow in the system and performing the dynamic analysis. Bounding analysis was performed for these cases by combining gas clearing loads from SRV Case A1.2 with water clearing loads from SRV Case C3.3 into a single load condition. This conservative combination was used to bound all discharge cases, including normal actuations. Different line-unique loads were applied to each of the four SRV lines for gas clearing; water clearing is the same for all lines and equals the maximum load for the longest line.

Damping for these time history analyses was taken at two percent of critical and calculational time increments for the solution were taken at .0025 seconds. All response frequencies to 50 Hz were considered in the solution.

Seismic analysis was done using the same model and computer program by performing response spectrum analysis for the ½% damped spectra in the FSAR. Figure 2-6 is a typical horizontal OBE spectra used as a part of this input. The full seismic response was formed by an SRSS combination of the higher horizontal response with the vertical. This is in accordance with the FSAR. The SSE multiplier is given in paragraph 2.2.5.

Analysis for thermal and weight conditions was done using static analysis. Calculations for internal pressure were done by hand.

2.3.2 Pipe Supports Analysis

Analysis for SRV piping supports was done using both hand and computer analysis. The STAAD computer program was used for the analysis of complex supports (Reference 17).

The support analysis extended to include the attachment weld to the supporting steel. In all cases, the supporting steel was reviewed and a judgement was made regarding the ability of the support steel to carry the new loads. In all cases, the existing support steel was judged acceptable.

Support analysis was done to the ASME Code, Section III, Subsection NF (Reference 2).

2.3.3 SRV Main Vent Penetration Analysis

The SRV line penetrations of the vent pipe are illustrated in Figure 2-3. Analysis of these penetrations was done using a Bijlaard analysis (Reference 9), to determine local penetration stresses due to SRV line loads. These local stresses were added to intensified free shell stresses which occur in the vent pipe due to vent header loads. These were calculated using the finite element model illustrated in Figure 2-7. Development of these free shell stresses and a description of the model are given in Reference 1, Section 4.

2.4 Evaluation and Results (SRV)

2.4.1 General

Combinations of the previous analysis cases were done to allow evaluation of the results in accordance with Table 1. This table lists a total of 27 different load combinations; of these, 13 include an SRV event.

This evaluation is concerned with piping and supports from the main steam line to the vent pipe penetration; evaluation of piping and supports inside the torus is reported in Reference 1. This separation is important to the selection of the controlling load combinations that follow.

The results of a conservative load case (described below) were evaluated against level B allowables, without use of increased allowables, as allowed in Table 1. Where this load combination produced unacceptable results, less conservative combinations were evaluated, as described below.

Thermal loads were considered differently for piping and supports as discussed below.

2.4.2 SRV Pipe Stresses

Initial evaluation of SRV pipe stress was done as described in Section 2.4.1 above; that is:

$$DW \pm \sqrt{(SSE)^2 + (Blowdown)^2} \leq 1.2\ S_h$$

In cases where this conservative condition could not be met, the following three cases were evaluated:

(1) $DW \pm \sqrt{(SSE)^2 + (Blowdown)^2} \leq 1.8\ S_h$

(2) $DW + OBE = 1.2\ S_h$

(3) $DW + Blowdown = 1.2\ S_h$

These three cases represent load combinations (15), (1) and (2) in Table 1, and are still conservative. No further reduction in conservatism was necessary to qualify the SRV piping.

Thermal expansion stresses were evaluated for piping as a separate load condition, using ASME Code Equation 10.

Results of SRV pipe stress evaluation are listed in Table 2-2.

2.4.3 SRV Pipe Supports

SRV pipe supports were evaluated in accordance with the ASME Code, Section III, Subsection NF (Reference 2).

A worst-case load condition was developed to include:

1. The conservative A1.2/C3.3 blowdown case.

2. SSE seismic.
3. Worst case thermal load.
4. Deadweight.

Seismic and blowdown were combined by SRSS and added to the other loads. Allowable stress for this condition was maintained below yield to assure that pipe stress would not be effected by support motion. This stress criteria is consistent with the case 15 allowables from Table 1.

Results of pipe support analysis are listed in Table 2-3.

2.4.4 Support Steel for SRV Supports

Evaluation of drywell support steel for SRV supports was done in accordance with Subsection NF of the ASME Code, (Reference 2), as required.

2.4.5 SRV Penetration

Stresses in the main vent pipe penetration area were evaluated in accordance with subsection NE of The ASME code, using the following paragraphs:

NE-3221.2	Local Membrane Stress Intensity
NE-3221.3	Primary General or Local Membrane plus Primary Bending Stress Intensity
NE-3221.4	Primary plus Secondary Stress Intensity
NE-3221.5	Analysis for Cyclic Operation
NE-3227.5	Nozzle Piping Transition (for vertical lines only)

Fatigue evaluation of the penetration (paragraph NE-3221.5) showed that the maximum load could be cycled on the penetrations for at least 7500 cycles without exceeding code allowables. The major load component in this case is SRV case C3.3, which can only occur for a few cycles (less than 50). Normal SRV actuations produce substantially less load for up to 4500 effective stress cycles (Reference 10). Since the 7500 cycles of maximum load bounds both of these by such a large margin and since no other significant loads are imposed on the line, the penetration was assumed acceptable for fatigue without further evaluation.

Controlling stresses in the SRV penetration follow:

PRIMARY STRESS
(Local Membrane Shell Stress Intensity)

CONTROLLING LOAD CASE	CALCULATED STRESS	ALLOWABLE STRESS
Case 15 (Table 1)	12,264	15,100

SECONDARY STRESS
(Primary plus Secondary Stress Intensity)

Case 15	21,137	69,900 (3.0 S_{mi})

2.4.6 Valves

Evaluation of the SRV valves and vacuum breakers was done on the basis of stresses in the adjacent piping for the combined load cases. Pipe stresses meeting level B criteria were considered adequate to insure proper operation of the device (Reference 5, Section 5.5).

Results of the valve evaluation are listed in Table 2-4.

2.4.7 Fatigue Evaluation

Fatigue evaluation of SRV lines was undertaken as a generic Mark 1 Program effort, using bounding assumptions. This effort is described and reported in Reference 10, and concludes that fatigue will not be a problem for Mark 1 SRV lines; this includes the SRV lines at Pilgrim. No further plant-unique analysis is necessary.

Fatigue evaluation of the SRV penetration is discussed in Paragraph 2.4.5.

2.5 Summary of SRV Line Modifications

Modification to the SRV lines at Pilgrim included the following changes:

- Installation of tee-quencher discharge devices and quencher supports on all four lines (Figure 2-4).
- Installation of two ten-inch vacuum breakers on each SRV line.
- Modification to supports in the drywell as listed in Table 2-3.

TABLE 2-1

PILGRIM

SRV LOAD CASE/INITIAL CONDITIONS

	Design Initial Condition	Any One Valve	ADS* Valves	Multiple Valves
A	1 NOC*., First Act.	A1.1		A3.1
	2 SBA/IBA,* First Act.	A1.2	A2.2	A3.2
	3 DBA,* First Act.[1]	A1.3		
C	1 NOC, Subsequent Act.			C3.1
	2 SBA/IBA, Sub. Act. Air in SRV/DL			C3.2
	3 SBA/IBA, Sub. Act. Steam in SRV/DL			C3.3

(1) This actuation is assumed to occur coincidently with the pool swell event. Although SRV actuations can occur later in the DBA accident, the resulting air loading on the torus shell is negligible since the air and water initially in the line will be cleared as the drywell to wetwell ΔP increases during the DBA transient.

* ADS = Automatic Depressurization System

NOC = Normal Operating Condition

SBA = Small Break Accident

IBA = Intermediate Break Accident

DBA = Design Basis Accident

TABLE 2-2

PILGRIM

SRV PIPE STRESS

SRV Line	Max. Stress Location	Line Size & Sch. @ Max. Stress Pt.	Maximum Stress	Allowable Stress
Line A	Elbow (Node 14)	12" Sch. 40	16,575 psi	18,000 psi
Line B	Elbow (Node 46)	12" Sch. 40	17,861 psi	18,000 psi
Line C	Elbow (Node 164)	12" Sch. 40	33,008 psi	37,500 psi
Line D	Elbow (Node 60)	12" Sch. 40	35,258 psi	37,500 psi

TABLE 2-3

PILGRIM

SRV PIPE SUPPORT MODIFICATIONS

SRV Line Number	Support Tag	Support Type	Modification
A	MS-S-500	Snubber	None
	MS-S-501	Snubber	None
	MS-S-502	Snubber	Extend Lugs
	MS-S-503	Snubber	Extend Lugs
	MS-S-504	Snubber	Replace Pipe Clamp and Relocate Lugs
	MS-S-505	Snubber	Replace Pipe Clamp and Relocate Lugs
	MS-S-506	Snubber	None
	MS-S-507	Snubber	None
	H-1-1-122	Spring	Replace Spring
	H-1-1-123	Spring	Replace Spring
	GE-1-H6	Spring	Removed
	Jet Deflector	Y-Z Rigid	Added Plates
B	H-1-1-124	Spring	Replace Spring
	H-1-1-125	Spring	Replace Spring
	MS-S-508	Snubber	Replace Pipe Clamp and Relocate Lugs
	MS-S-509	Snubber	None
	MS-S-510	Snubber	None
	MS-S-511	Snubber	None
	MS-S-512	Snubber	Replace Pipe Clamp
	MS-S-513	Snubber	Replace Pipe Clamp
	MS-S-514	Snubber	Replace Base Plate and Add Side Brace
	MS-S-515	Snubber	Replace Base Plate and Add Side Brace
	Jet Deflector	Y-Z Rigid	Added Plates

TABLE 2-3 (CONTINUED)

SRV Line Number	Support Tag	Support Type	Modification
C	MS-S-516	Snubber	None
	MS-S-517	Snubber	None
	MS-S-518	Snubber	None
	MS-S-519	Snubber	None
	MS-S-520	Snubber	None
	MS-S-521	Snubber	None
	MS-S-522	Snubber	None
	MS-S-523	Snubber	None
	MS-S-524	Snubber	None
	H-1-1-126	Spring	Replace Spring
	H-1-1-127	Spring	Adjust Spring
	GE-1-4-11	Spring	Readjust Spring
	Jet Deflector	Y-Z Rigid	Added Plates
D	MS-S-525	Snubber	None
	MS-S-526	Snubber	None
	MS-S-527	Snubber	None
	MS-S-529	Snubber	None
	MS-S-530	Snubber	None
	MS-S-531	Snubber	None
	MS-S-532	Snubber	None
	MS-S-533	Snubber	None
	MS-S-534	Snubber	None
	GE-1-H-1	Spring	Replace Springs
	GE-1-H-2	Spring	Replace Springs
	GE-1-H-3	Spring	Adjust Spring
	Jet Deflector	Y-Z Rigid	Added Plates

TABLE 2-4

PILGRIM

SRV VALVE EVALUATION

Component Designation	Component Type	SRV TAP System	Max. Total Pipe Stress At Valve	Level B Allowable Pipe Stress
RV-203-3A	SRV Valve	Relief Line A	16,931	18,000
	1st Vac. Bkr.		10,659	
	2nd Vac. Bkr.		11,624	
RV-203-3B	SRV Valve	Relief Line B	16,857	18,000
	1st Vac. Bkr.		11,450	
	2nd Vac. Bkr.		13,575	
RV-203-3C	SRV Valve	Relief Line C	16,909	18,000
	1st Vac. Bkr.		5,718	
	2nd Vac. Bkr.		5,840	
RV-203-3D	SRV Valve	Relief Line D	16,354	18,000
	1st Vac. Bkr.		7,018	
	2nd Vac. Bkr.		6,660	

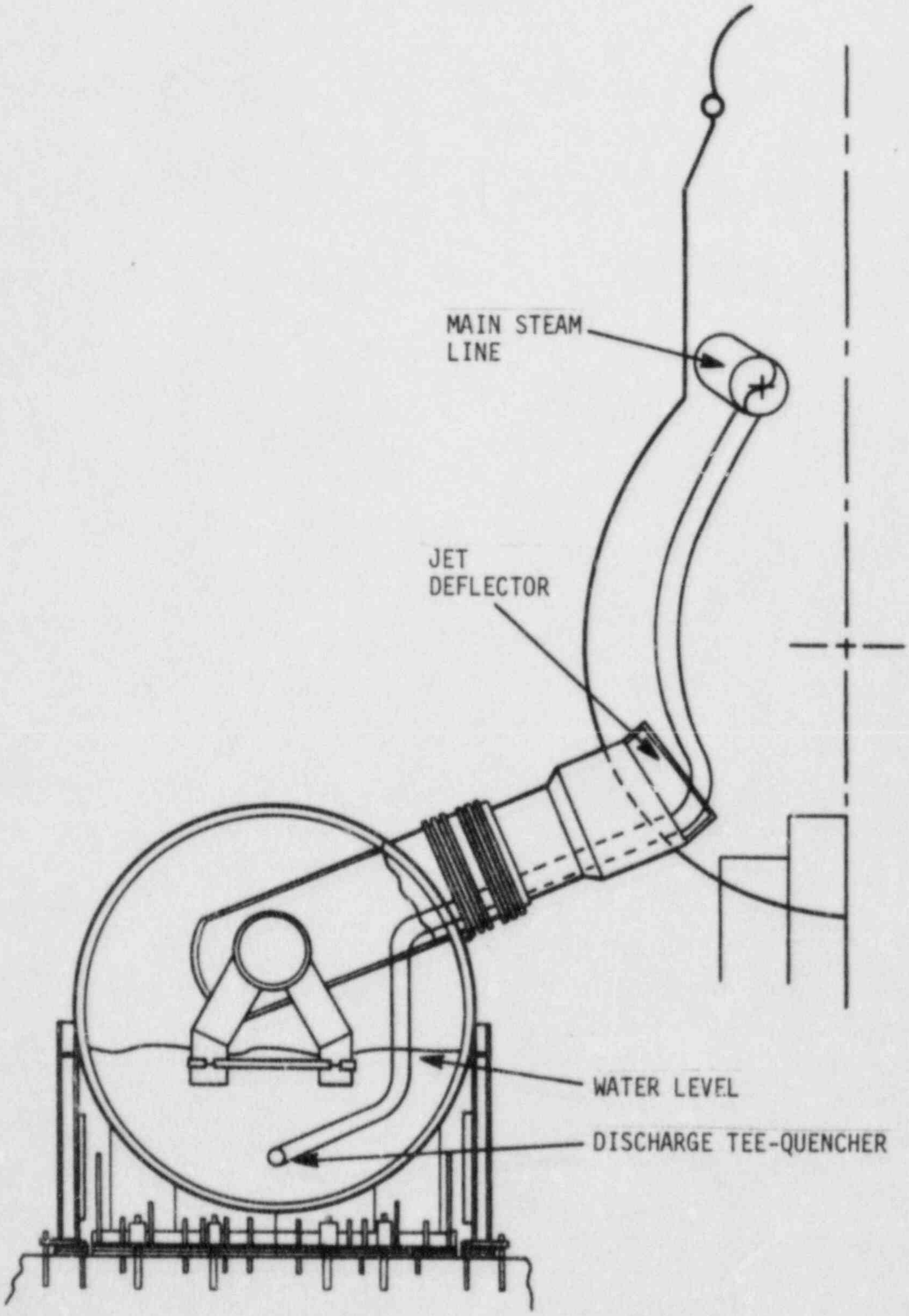


FIGURE 2-1 SRV LINE ROUTING-TYPICAL

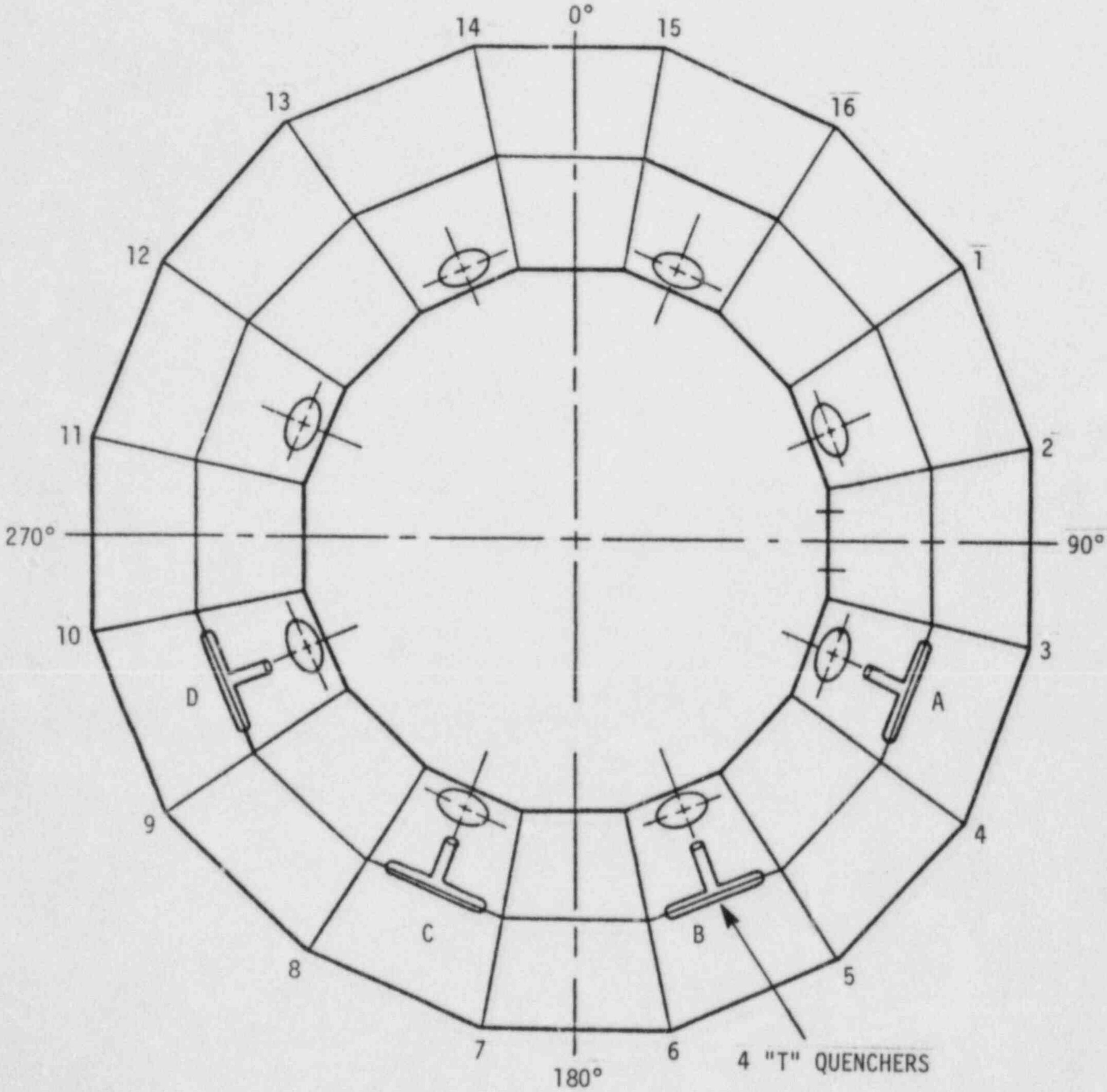


FIGURE 2-2 SRV LINE ARRANGEMENT-TORUS

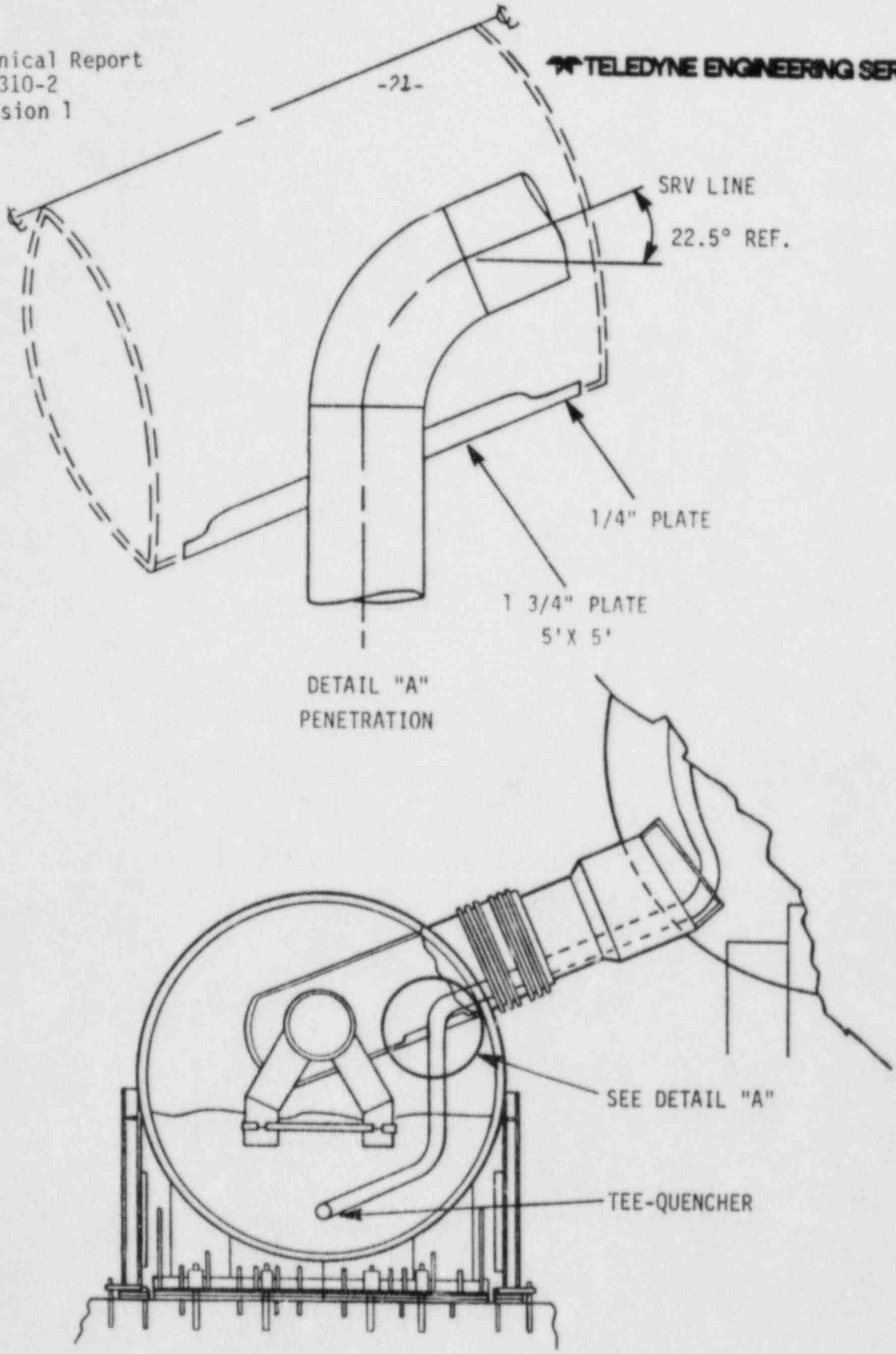


FIGURE 2-3 SRV LINE ROUTING-TYPICAL

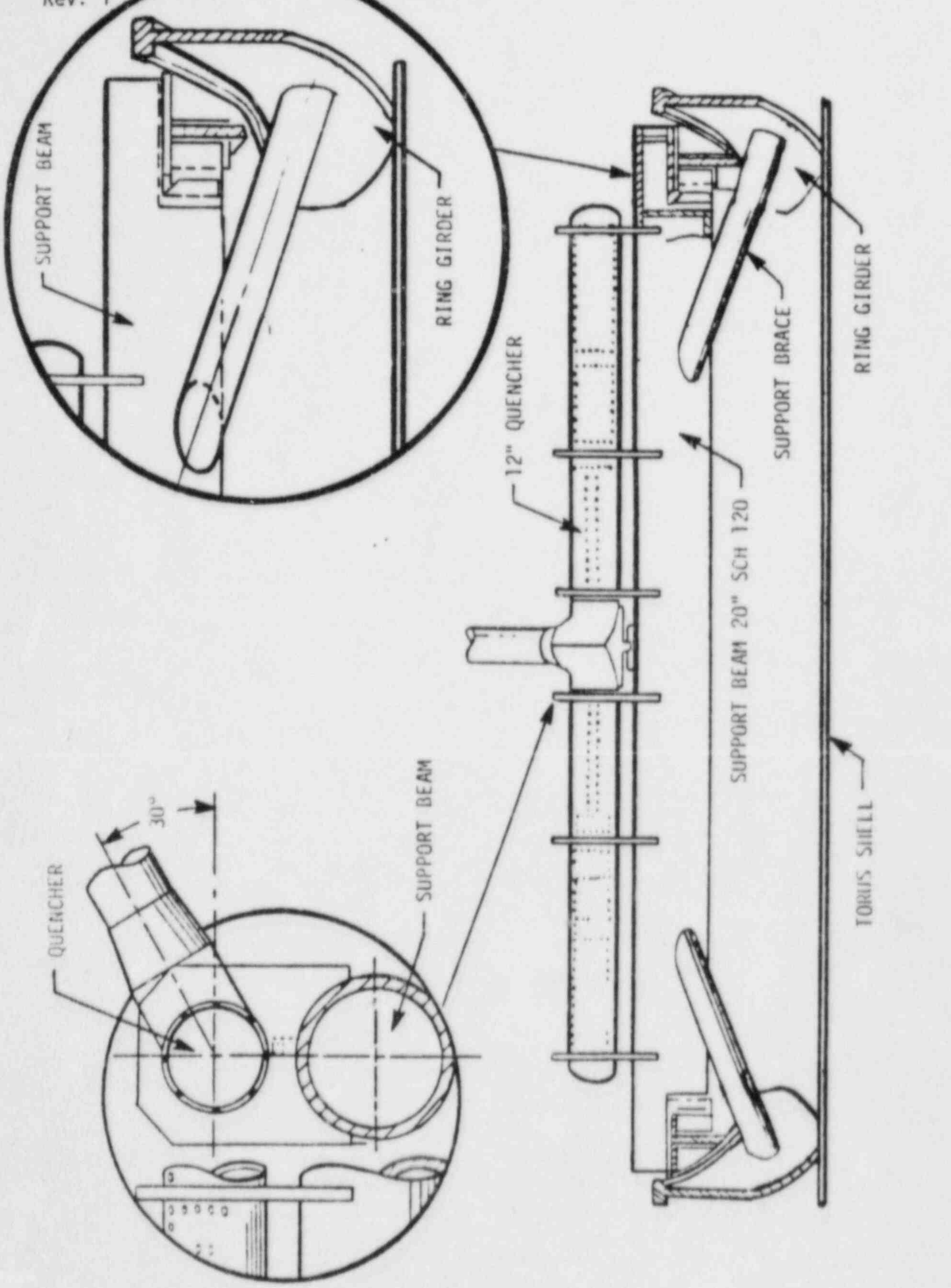


FIGURE 2-4 SRV TEE-QUENCHER & SUPPORT INCLINED ENTRY LINE

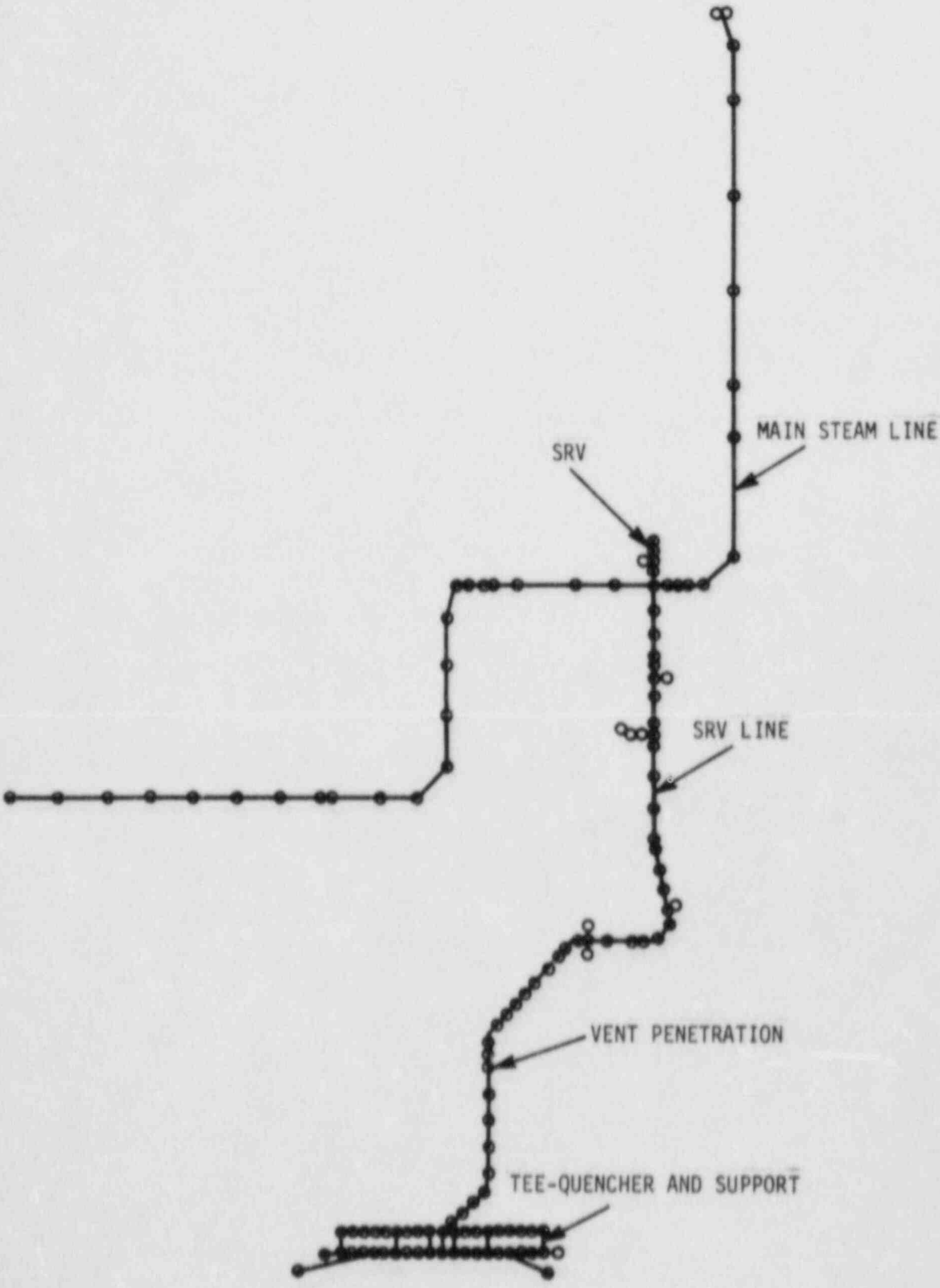


FIGURE 2-5 SRV PIPING MODEL, TYPICAL

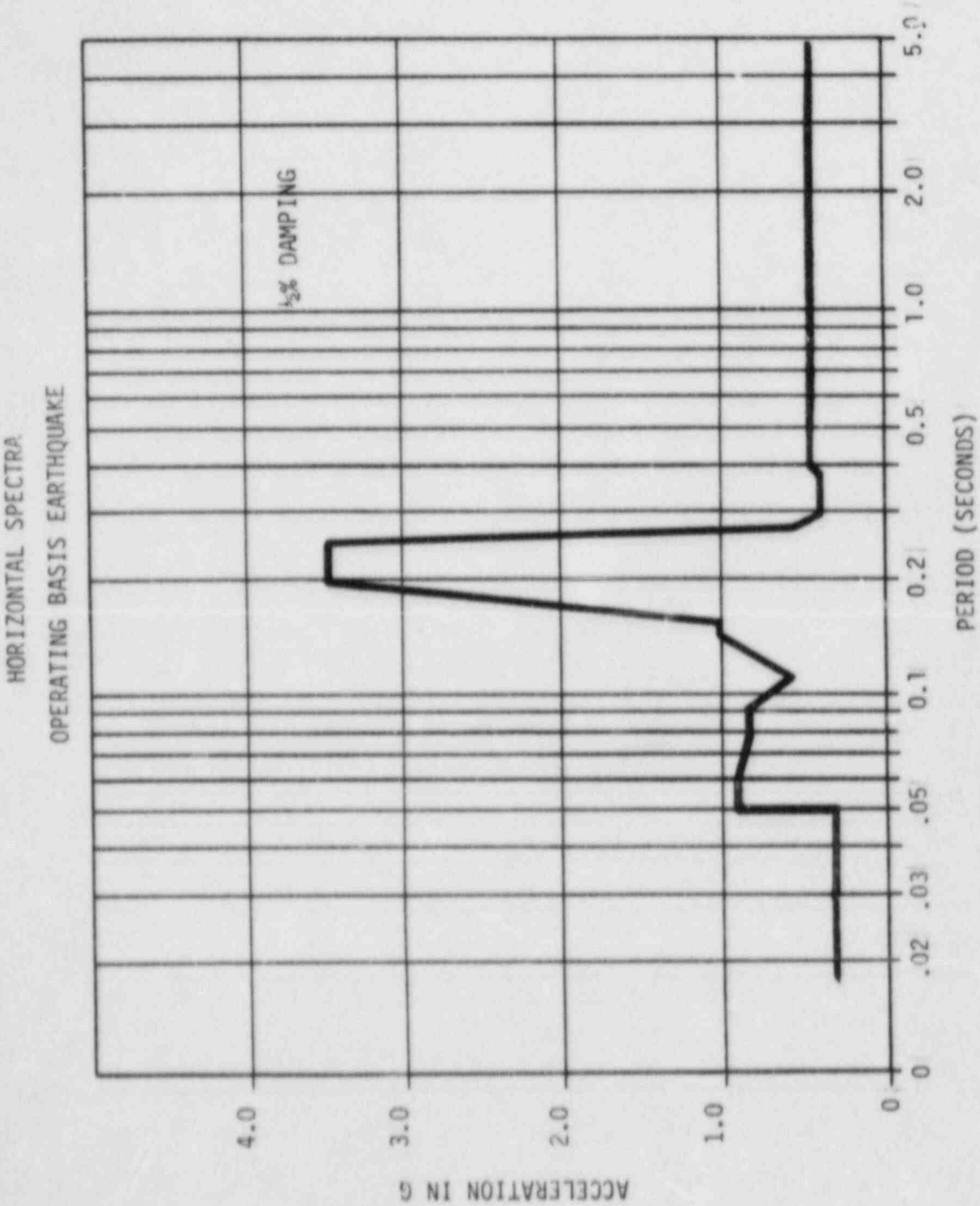


FIGURE 2-6 SRV SEISMIC SPECTRA

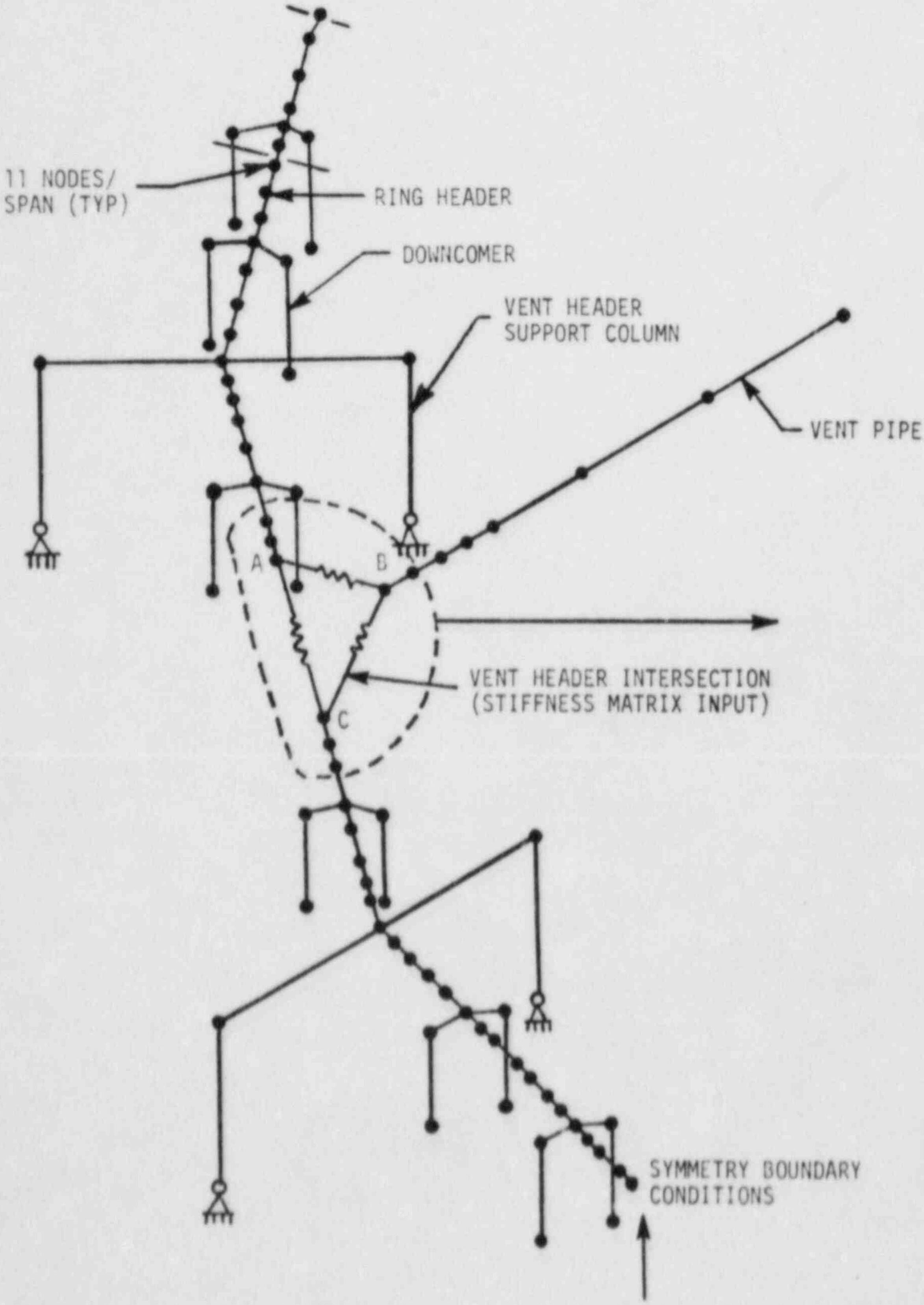


FIGURE 2-7 VENT SYSTEM MODEL

3.0 TORUS ATTACHED PIPING (TAP)

The torus at Pilgrim has 19 piping systems attached to its outer shell. These systems connect to 40 penetrations and are listed in Tables 3-1 and 3-2. Analysis of the large diameter attached piping systems included all piping from the torus to the first anchor. Small diameter piping was analyzed to the first anchor or a distance where the torus loads could be considered negligible.

Also considered in this analysis are:

- Branch piping connected to TAP systems.
- Torus penetration stresses.
- Piping inside the torus attached to TAP systems.
- Pump and valve loads.
- All pipe support and anchor loads.

The analysis method is different for large bore TAP systems (above four-inch diameter) and small bore systems (four-inch and below), as discussed in the following text.

3.1 Applicable Codes and Criteria

Analysis and modifications to TAP piping and supports were in accordance with the following codes:

Piping Analysis

All TAP systems and branch lines - ASME, Section III, 1977 (Reference 2).

Support Analysis

All TAP and branch supports - ASME, Section III, Subsection NF, and including NRC Bulletin 79-02 requirements (Reference 3).

Load combinations and stress levels were evaluated in accordance with Table 5-5 of the Mark 1 Containment Program Structural Acceptance Criteria Plant Unique Analysis Application Guide (Reference 5). Table 5-5 is reproduced in this report as Table 1.

Damping of all time history piping analysis was taken at 2% of critical. Seismic analysis used a 0.5% damped spectra.

3.2 TAP Loads

Loads applied to TAP systems include:

Mark 1 Loads

Shell motion due to pool swell.
Shell motion due to SRV line discharge.
Shell motion due to condensation oscillation.
Shell motion due to chugging.
Pool drag loads on internal piping.

and

Original Design Loads

Deadweight.
Thermal expansion.
Seismic.
Pressure.

The Mark 1 loads, due to shell motion, were calculated based on plant unique shell response data developed during an earlier phase of this program and reported in the PUA report, Reference 1. Drag loads on internal piping were developed using generic methods from the Mark 1 Program as a part of this piping analysis work. These loads are described more fully in the Mark 1 Load Definition Report (Reference 11).

Analysis for seismic response was based on FSAR spectra.

3.2.1 Shell Motion Due to Pool Swell

TAP input loads, due to shell motion during pool swell, were based on data developed during the Plant Unique Analysis for the shell (Reference 1). The PUA shell analysis provided time history response information in five degrees of freedom for every point on the shell where large bore TAP was connected. This data consisted of three translations and two out of plane rotations (no torsion). Data for small bore piping was based on conservative bounding of the large bore data. Attachment points for large bore piping are illustrated in Figures 3-8a and 3-8b.

Data available from the plant unique shell analysis consists of time history displacements and rotations. These were converted to equivalent time history forces as described in paragraph 3.3.1.

A typical pool swell force time history is illustrated in Figure 3-1.

3.2.2 Shell Motion Due to DBA Condensation Oscillation

The DBA condensation oscillation load definition is given in Reference 11 as a set of spectral pressures, from 1-50 Hz. Shell response due to this loading was calculated by applying each frequency in this band to the torus shell model shown in Figure 3-7 and calculating response for each sinusoidal excitation. (This work was done earlier to allow calculation of shell stress for Reference 1). Shell response was calculated for frequencies up to 32 Hz; frequencies above 32 Hz were considered negligible as discussed in Appendix 2.

Shell responses for each of these frequency components were combined into an equivalent time history using random phasing of the indivi-

dual components. Amplitudes of this equivalent time history were then increased by a factor of 1.15 to allow for the in-phase response of the four peak frequency components. See Reference 6 for a further discussion of the factor and component phasing.

This method of combining frequency components and generating an equivalent shell response time history was repeated for each TAP penetration for large bore piping. Responses for small bore piping were based on conservative bounding of the large bore data.

A typical DBA CO shell response is illustrated in Figure 3-2.

3.2.3 Shell Motion Due to Chugging

Shell response during chugging was defined separately for pre-chug and post chug loads.

Pre-chug is a sinusoidal pressure load equal to ± 2 psi on the torus shell; this load can occur at any frequency between 6.9 and 9.5 Hz (Reference 11). Shell response for pre-chug was calculated by applying a continuous ± 2 psi sine pressure to the large torus model (Figure 3-7) in the specified frequency range. Maximum shell response in this range occurred at 9.5 Hz. This was considered as one of the inputs to TAP.

Post chug is specified as a spectrum of pressures from 1-50 Hz. Shell response was calculated for each 1 Hz component in this spectrum, then all 50 components were combined into an equivalent time history using random phasing of all components. Amplitudes of this time history loading were multiplied by 1.15 to account for the fact that some elements of the spectrum are not randomly phased. Further discussion of this factor can be found in Reference 8. The resulting pressure time history was applied to the model in Figure 3-7 to calculate shell response.

3.2.4 Shell Motion Due to SRV Line Discharge

TAP input loads, due to shell motion during SRV line discharge, were based on data developed for the PUA shell analysis (Reference 1). This shell analysis was the result of a finite element analysis that was calibrated with in-plant SRV test data, as described in Reference 1. The data resulting from the shell analysis were time histories and were used to provide time history input functions for the TAP.

Section 5.2 in the Load Definition Report (Reference 11) requires that we allow for a ± 25 percent shift in the SRV frequency for discharge through a cold line, and a ± 40 percent shift for discharge through a hot line. This was considered by examining the response modes and frequencies of the TAP piping systems and then making adjustments within the specified ranges to force worst case input-response frequency pairing.

The strongest torus shell response during SRV actuation is the result of simultaneous actuation of several SRV lines. These cases were considered by adding the shell pressures due to the individual actuations by absolute summation.

A typical shell response due to SRV actuation is illustrated in Figure 3-3.

3.2.5 Loads on Internal Piping

Most of the large TAP systems extend into the torus. In the case of suction lines, the internal portions usually consist of a pipe fitting and strainer. For return lines, longer sections of pipe, up to approximately 20 feet, extend into the torus.

The internal portions of these systems are subjected to submerged structure drag if they are in the pool; or pool impact, if they are

above the water level. In either case, the appropriate Mark 1 loads were calculated and considered during the piping evaluation.

Loads for piping in the pool and above the pool were calculated in accordance with the methods of the Load Definition Report (Reference 11), NUREG 0661 (Reference 12) and Appendix 1 of Reference 1. All loads were considered, including:

For Submerged Piping:

- C.O. Source and FSI Drag
- Post Chug Source and FSI Drag
- Pre-chug Drag
- SRV Bubble and Jet Loads
- Pool Swell Bubble Drag
- Pool Swell Fallback

For Structures Above the Pool:

- Pool Swell Water Impact and Drag
- Froth
- Fallback

A typical submerged structure load spectrum is shown in Figure 3-4. This spectrum includes CO and CH source and FSI drag.

3.2.6 Deadweight, Thermal and Seismic Analysis

Analysis for all TAP systems was also done for deadweight, thermal and seismic conditions.

Thermal analysis was performed at maximum design thermal conditions as defined in Reference 14. Thermal displacement of the penetration was determined from the maximum operating temperature of the torus and applied for all cases.

Seismic analysis was done using the OBE spectra from the FSAR. A typical horizontal spectra is illustrated in Figure 3-5. Analysis for SSE was taken as 1.875 times the OBE results. Horizontal and vertical response were combined by an SRSS combination of the worst horizontal response with the vertical; also in accordance with the FSAR. The effect of the seismic response of the torus, at the penetration, was studied to determine if it would exceed the enveloped building spectra being used for the rest of the line. It was determined that the building spectra would control at all frequencies, so this same spectra was applied at the torus penetration.

3.3 TAP Analysis Method

The method for TAP pipe stress analysis varied for each of the following cases:

- Large bore piping (over 4" diameter).
- Small bore piping systems (4" and less), which could be reduced to single degree-of-freedom approximations.
- Small bore piping which could not be reduced to single dof systems.
- Branch piping off of TAP systems.

Analysis of supports, anchors and torus penetrations did not vary and was the same for all types of piping systems.

3.3.1 Representation of Torus Shell for Piping Analysis

Because the larger TAP systems are stiff and heavy when compared to the torus shell, it is important that the piping computer model allows for dynamic interaction between the piping and the torus. This was done for all TAP piping systems by including a set of ground springs in the piping model to represent the torus connection, as illustrated in Figure 3-6. Five ground springs were used to represent the torus shell; these represented stiffnesses associated with the three translations of the shell and the two out of plane moments on the shell. Torsional pipe loads were considered negligible.

The stiffness values of the ground springs were calculated by applying unit loads and moments to the large shell finite element model of the torus illustrated in Figure 3-7.. Different attachment stiffnesses were calculated for each pipe penetration location, and then applied to the appropriate piping system model.

3.3.2 Piping Analysis Method - Large Bore Systems

Analysis of all large bore piping systems was done using finite element models of each system. These models included ground springs to represent the torus and also included piping inside the torus.

All analysis on these models was done using the STARDYNE (Reference 16) computer code. Dynamic analysis used damping values of 2% of cricital for time history analysis; OBE seismic used a ½% damped spectra. Analysis on these models included:

- Zero and full Δ P pool swell shell motion and drag loads.
- Post chug shell motion and drag loads.
- DBA CO shell motion and drag loads.

- SRV Shell Motion and Drag Loads.
- Deadweight.
- Seismic.
- Thermal.

Pre-chug was considered as a separate load condition, but it was determined that it would always be bounded by DBA CO. On that basis, pre-chug loads were not run for each TAP system.

All TAP response due to shell motion was done using time history analysis. Response due to drag loads on internal piping was calculated by harmonic analysis for the spectral loads and hand analysis for transients. The effects of both shell motion and internal loadings were considered for all points in the piping system.

Pipe stress due to welded support attachments was considered by separate analysis and included in the pipe stress evaluation.

3.3.3 Piping Analysis Method - Complex Small Bore Systems

Analysis of small bore piping systems that could not be reduced to single degree of freedom systems were treated identically to large bore systems, except for the loads considered. For these systems, the loads considered included:

- DBA CO.
- Deadweight.
- Seismic.
- Thermal.

Consideration of Mark 1 dynamic loads was limited to DBA CO, based on experience with large bore piping analysis for five Mark 1 plants. This experience showed that all high stressed lines were controlled by DBA CO, except in a few special cases; Appendix 1 discusses this further.

3.3.4 Piping Analysis Method - Simple Small Bore Systems

Small bore piping systems that could be reduced to single mass approximations were analyzed using hand analysis. Torus shell stiffness was included in these models to the extent that it affected first mode response, as a minimum. Higher modes were considered if they fell within the range of the input load. Typically, these systems consisted of a short length of pipe, terminating in a valve or tubing.

Shell input to these systems (for Mark 1 loads) was formatted in the frequency domain to provide an input spectrum. This spectral data was used in combination with the hand analysis to calculate response levels.

Loads considered for simple small bore systems were the same as for the more complex small bore systems, including seismic, weight and thermal, if applicable.

3.3.5 Piping Analysis Method - Branch Piping

Branch piping connected to TAP systems was modeled with the TAP systems if the ratio of their bending stiffness was greater than 1:40 (approximately).

Branch piping too flexible to meet this ratio was considered by separate analysis. These systems were analyzed statically by placing a displacement at the connection point, equal to twice the TAP motion at the connection point. These analyses were carried to a point where Mark 1 loads produced less than 10% of the allowable stress.

3.3.6 Piping Analysis - Load Input for Computer Models

3.3.6.1 Mark 1 Loads Due to Shell Motion

Shell motion, due to internal Mark 1 loads, is due to pressures across broad areas of the shell, as opposed to concentrated

forces at the penetration. Because of this, the interactive effects of piping and shell should include allowance for local shell compliance in the force input to the piping system. The method of load input for TAP accounts for this. The method is illustrated in Figure 3-6.

The steps involved are:

- Extract displacement time history from large computer model for a shell without an attached TAP system. (Reference 1 and Figure 3-7).
- Determine local shell stiffness from large computer model (Reference 1 and Figure 3-7).
- Determine an equivalent force time history at the penetration by multiplying displacement by stiffness.
- Apply the force time history to the TAP as shown in Figure 3-6.

The use of forces, rather than displacements to drive the model, is necessary to accurately account for the inertial interaction of the piping, since the available shell response data is for an unloaded shell (no piping). Use of forces as input will allow displacements at the penetration to increase or decrease in reaction to the inertial forces from the piping.

3.3.6.2 Submerged Drag Loads on Internal TAP

Drag loads on internal piping during CO, CH, SRV and pool swell were evaluated using the same TAP piping models that were used for shell induced, seismic and other loads. Internal drag loadings were run as separate cases with worst-case orientations, and then combined with other

loadings to determine pipe stress, support loads and penetration stress. The effects of drag load on both internal and external parts of the TAP system were calculated and included in all evaluations.

Loads were applied to the piping and evaluated by the following methods:

- Pool Swell Drag - Static Analysis X2.
- Pool Swell Fallback - Static Analysis X1.
- Pool Swell Impact - Static Analysis X2.
- Pool Swell Froth - Static Analysis X2.
- CO Drag - Dynamic Analysis (spectrum).
- Post Chug Drag - Dynamic Analysis (spectrum).
- SRV Drag - Static Analysis X1.
- Pre-chug - Bounded by DBA CO.

Piping response to CO and post chug drag were evaluated using dynamic analysis. These spectra, including their FSI components, were then enveloped to form a single spectrum that was used in this analysis. Each frequency component in this spectrum was then applied to the CG of the submerged internal piping as a harmonic forcing function. The load in the pipe was calculated at a point just inside the penetration, in each of six degrees-of-freedom. These single-frequency piping loads were then combined into a single load at that point by absolute sum of the four largest components added to the SRSS of the balance. This was done for each degree-of-freedom. (The basis for this method of combining individual frequency components is discussed in Reference 6). The loads calculated in the pipe were then

applied to the system as static loads; and pipe stress, penetration stress, and support loads were determined. A typical combined spectrum is illustrated in Figure 3-4.

TAP analysis for other loads, noted above, was done by applying the appropriate load to the CG of the affected area and performing static analysis.

3.3.7 TAP Penetration Analysis

Analysis of torus penetrations included the following loads:

- Loads from piping response due to shell motion (Mark 1 loads).
- Loads due to submerged drag and/or pool impact, on internal sections of TAP, as applicable.
- Loads from weight, seismic and thermal conditions on the attached piping.
- Shell loads which exist due to the Mark 1 and other loads, independent of piping (from Reference 1).

The calculation of stress from the loads was done using a Bijlaard analysis (Reference 9) to account for local penetration stress due to piping loads. These stresses were combined with free shell stresses in that area, intensified to account for the discontinuity. Free shell stress was taken from earlier containment analysis, as reported in Reference 1. Penetration stresses were calculated for each load in each degree of freedom. Stresses resulting from this analysis were combined to form the load cases defined in the PUAAG (Reference 9 and Table 1).

Stress in the piping within the limits of reinforcement was calculated by combining the stress in the pipe with the local shell stresses by absolute summation. This was also evaluated for each degree of freedom and each of the PUAAG load cases (Table 1).

3.3.8 Analysis Method for Piping Supports

Analysis was done for all piping supports for all TAP and branch systems. Calculations were made using both hand and computer analysis, depending on the complexity of the individual support. Evaluation of baseplates and anchor bolts was included, using the current procedures developed in response to NRC Bulletin 79-02 (Reference 3). The STAAD computer program was used in most cases where computer analysis of supports was done (Reference 17).

In all cases, where applicable, the support analysis included a review of supporting steel for the new loads. Analysis was performed for those cases where supporting steel was judged questionable.

3.3.9 Vacuum Breaker Analysis

The wetwell-drywell vacuum breakers at Pilgrim are attached to the vent pipe-vent header intersection inside the torus and, therefore, are not included with any TAP analysis. Analysis of these vacuum breakers was not a part of the Mark 1 Containment Program, but is reported in Reference 13.

3.3.10 Active Components

Active components on TAP systems include seven pumps and 32 valves. Acceptability of these components was assured by limiting stresses at these locations, as described in the evaluation section. No analysis was necessary on these components.

3.4 Evaluation and Results

3.4.1 General

Combinations of the previous analysis cases were done to allow evaluation of results in accordance with Table 5-5 of Reference 5. (Table 1 in this report.) This table lists a total of 27 load cases for both

essential and non-essential piping systems. For purposes of this evaluation, all TAP systems are classified as essential.

The 27 load cases shown in Table 1 were reduced, by conservative bounding, to the cases listed below:

	CASE NO. (TABLE 1)	MAJOR LOAD(S)	ALLOWABLE (EQ. 9)
1	3	SRV (C3.1) + SSE	1.2 S_h
2	16	Zero $\triangle$P	2.4 S_h
3	21	DBA CO/CH + SSE	2.4 S_h
4	25	Pool Swell + SRV (A1.3)	2.4 S_h
5	15	SSE + SRV + Post Chug	2.4 S_h

In these cases, the seismic stresses were combined with the absolute sum of the Mark 1 dynamic loads by the the SRSS method.

3.4.2 Piping Stress - Large Bore Systems

Stress in all large bore TAP systems was combined and evaluated in accordance with Section III of the ASME code for the five cases listed in Paragraph 3.4.1. These evaluations included the effects of local pipe stresses due to welded attachments at supports. Fatigue was considered as explained in Paragraph 3.4.6.

The large bore TAP systems are listed in Table 3-1 along with the maximum stress for the controlling load combination.

3.4.3 Pipe Stress - Small Bore TAP Systems

Evaluation of small bore TAP systems was the same as for large bore systems, except that the only Mark 1 dynamic load considered was DBA CO. This approach was based on experience gained in large bore analysis and is discussed further in Appendix 1.

Small bore systems are listed in Table 3-2.

3.4.4 Pipe Stress - Branch Lines

Branch lines connected to TAP systems were evaluated for the load combination providing the maximum displacement at the branch point. Branch lines are listed in Table 3-3.

3.4.5 Pumps and Valves

Evaluation of pumps and valves was done based on stresses in the adjacent piping. Pipe stresses meeting Level B criteria were considered adequate to assure proper operation of the pumps or valve. (Reference 5, Section 5.5).

Results of the pump and valve evaluation are listed in Table 3-4.

3.4.6 Piping Fatigue Evaluation

Consideration of the fatigue effects of cyclic loading is reported in Reference 10 for bounding Mark I plants. This reference defines bounding conditions and concludes that the stress levels and cycles involved in these systems will not produce a fatigue problem. The conclusions are applicable to the Pilgrim Plant. No further plant unique evaluation was done to address fatigue considerations for piping. Fatigue analysis for the penetration is considered below.

3.4.7 Torus Shell Penetration Evaluation

Evaluation of torus penetration stresses considered loads from the external and internal piping, as well as the loads that exist in the shell, due to the same event(s). Shell stress away from penetrations is reported in Reference 1.

Stresses in the penetration area were evaluated in accordance with subsectin NE of The ASME code, using the following paragraphs:

NE-3221.2	Local Membrane Stress Intensity
NE-3221.3	Primary General or Local Membrane plus Primary Bending Stress Intensity
NE-3221.4	Primary plus Secondary Stress Intensity
NE-3221.5	Analysis for Cyclic Operation
NE-3227.5	Nozzle Piping Transition

Fatigue evaluation of the penetration (paragraph NE-3221.5) showed that the maximum load combination could be cycled on each penetration for at least 10,000 cycles without exceeding code allowables. The major loads that form these load combinations are pool swell (1 cycle), DBA CO (900 cycles), and SRV Case C3.3 (50 cycles). Other loads; normal SRV actuation, IBA CO, and chugging, can produce up to 10,000 cycles, but only at greatly reduced stress levels. Based on this, the 10,000 cycles at maximum stress represents a conservative level of evaluation and the TAP shell penetrations are considered acceptable for fatigue.

Controlling stresses in the TAP penetrations are listed in Table 3-6 Additional information on the number of cycles for each condition can be found in Reference 10.

3.4.8 Piping Supports

All piping supports on the TAP systems were evaluated for the same load combinations as the piping (Table 1).

Evaluation was done in accordance with the ASME Code, Section III, Subsection NF, and included the following criteria:

- Expansion type anchor bolts and baseplates were evaluated in accordance with Bulletin 79-02 criteria (Reference 3).
- No stresses in pipe supports were allowed to exceed yield, regardless of pipe stress allowables.

A listing of pipe supports and modifications for large bore piping is given in Table 3-5.

3.5 Summary of TAP Modifications

Modifications to torus attached piping systems consisted of support changes, as well as modifications to internal piping. Modifications to internal piping included shortening some lines to reduce submergence and drag loads; rerouting one line and supporting it from the ring girder and resupporting one other. The following modifications were made; these are illustrated in Reference 1:

- Reroute RHR line and support from ring girder.
- Reinforce spray header supports on the ring girders.
- Shorten HPCI exhaust line.
- Shorten RCIC exhaust line.
- Shorten RCIC and HPCI drain lines.
- Shorten 18-inch spare line.

Modifications to external piping consisted of support and support steel modifications. Table 3-5 summarizes these for large bore piping.

TABLE 3-1

PILGRIM

LARGE BORE TAP RESULTS

System Name	Penetration Number	Line Size & Schedule	Controlling Load Case	Maximum Stress	Allowable Stress	Max. Stress Location
Vacuum Relief from Bldg. & Purge Inlet	X-205	20" Std.	Case 21 (DBA CO)	26,297	32,880	Floor Penetration
Cont. Cooling & Core Spray Test Line	X-210A	12" Std.	21	9,929	32,880	16 x 12 Reducer near Pen.
	X-210B	12" Std.	15	18,253	32,880	Elbow near Pen.
Cont. Cooling to Spray Header	X-211A	6" Sch. 40	21	17,528	32,880	Spray Hdr. Pipe near Tee
	X-211B	6" Sch. 40	21	17,417	36,000	12" x 6" Weldolet
RCIC Pump Suction	X-220	6" Sch. 40	21	11,597	36,000	Elbow
HPCI	X-221	16" Std. 30	21	8,803	32,880	Elbow near Pen.
RHR	X-222A & B	18" Std. 30	21	11,148	36,000	Tee near Valve MOV/18"- N29M4
	X-222C & D	18" Std. 30	21	13,369	32,880	Elbow near Pen.
HPCI Turbine Exhaust	X-223	24" Std. 20	25	15,463	32,880	Elbow near Pen.
RCIC Turbine Exhaust	X-225	8" Std. 40	21	9,013	32,880	Elbow
Purge Exhaust	X-227	20" Std. 20	15	18,602	32,880	Reducer
Core Spray Pump Suction	X-229A	18" Std.	21	12,977	32,880	Elbow near Pen.
	X-229B	18" Std.	21	11,351	32,880	Elbow

TABLE 3-2

PILGRIM

SMALL BORE TAP RESULTS

System Name	Penetration Number	Line Size & Schedule	Type of Analysis	Maximum Stress	Allowable Stress	Max. Stress Location
Liq. Lvl. Indicator	X-206A	1"Sch. 80	Dynamic	32,593	36,000	Penetration
Liq. Lvl. Indicator	X-206B	1" Sch. 80	Dynamic	13,442	36,000	Penetration
Liq. Lvl. Indicator	X-206 C	1" Sch. 80	Dynamic	34,300	37,500	Anchor
Liq. Lvl. Indicator	X-206 D	1" Sch. 80	Dynamic	29,870	37,500	Anchor
Water Temp. & Spares	X-209 A-D	1" Sch. 80	Hand	1,472	36,000	Penetration
Spare	X-214-X-215	4" Sch. 80	Hand	1,396	36,000	Penetration
Spare	X-216-X-217	2" Sch. 80	Hand	1,396	36,000	Penetration
CACS	X-218	4" Sch. 40	Dynamic	15,695	43,752	Floor Penet.
CACS	X-219	4" Sch. 40	Dynamic	17,656	43,752	Floor Penet.
HPCI Cond. drain	X-224	2" Sch. 80	Dynamic	18,880	36,000	Penetration
RCIC Cond. Drain	X-226	2" Sch. 80	Dynamic	16,357	36,000	Penetration
Ref. Vessel Connect.	X-228A	1" Sch. 80	Dynamic	8,731	44,088	2nd Valve on Branch
Torus Pressure	X-228B	1" Sch. 80	Dynamic	7,285	44,088	Anchor
H_2O_2 Analyzer	X-228C	1" Sch. 80	Dynamic	21,400	37,680	Near Penetration
Spare	X-228 D&F	1" Sch. 80	Hand	130	36,000	Penetration
Vacuum Breaker	X-228E	1" Sch. 80	Dynamic	6,483	28,093	Elbow near Pen.
Post Accident Sampling	X-228G	1" Sch. 80	Dynamic	26,581	42,960	Elbow near Pen.

TABLE 3-2 (CONTINUED)

PILGRIM

SM.. L BORE TAP RESULTS

System Name	Penetration Number	Line Size & Schedule	Type of Analysis	Maximum Stress	Allowable Stress	Max. Stress Location
Post Accident Sampling	X-228H	1" Sch. 80	Dynamic	17,046	42,960	Elbow near Pen.
H_2O_2 Analyzer	X-228J	1" Sch. 80	Dynamic	18,236	37,680	Near Penetration
H_2O_2 Analyzer	X-228K	1" Sch. 80	Dynamic	36,748	37,680	Tee near Pen.
Torus Level Pressure	X-240 A&B X-241 A&B	1" Sch. 80	Hand	11,398	36,000	Penetration

TABLE 3-3

PILGRIM

BRANCH LINE PIPE STRESSES

Branch Line Designation	TAP System	TAP Penetration	Branch Line Dia./Sch.	Maximum Stress	Allowable Stress
4"-HE-9 1"-HM-9	Torus Purge Air	X-205	4.0 Sch. 40 1.0 Sch. 80	2,249 869	36,000 36,000
4"-HL-23	RHR & RCS Pump Discharge	X-210B	4.0 Sch. 40	*	32,880
4"-HE-26	RHR Pump P-203 A, Suction Piping	X-222A & B	4.0 Sch. 40	1,675	36,000
4"-HE-26	RHR Pump P-203C, Suction Piping	X-222A & B	4.0 Sch. 40	2,318	36,000

*This line experienced total displacements of less than 1/16 inch at the branch point and was judged acceptable without analysis.

TABLE 3-4

PILGRIM

PUMP AND VALVE EVALUATION

Component Designation	Component Type	TAP System/Penetration	Pipe Stress at Component	Allowable Pipe Stress
6"-238	Valve	RCIC Pump Suction/X-220	5894/6548	18,000
6"-N957M4K	Valve		4330/4355	18,000
6"-29K	Valve		5798/7367	18,000
6"-235	Valve		4619/5301	18,000
MO-1301-25	Valve		5778/3827	18,000
MO-1301-26	Valve		7819/7719	18,000
P-206	Pump		1171	36,000
N957MAK	Valve	HPCI/X221	1172/1225	16.440
H-1001-37B	Valve	Cont. Cooling Spray Hdr./ X-211B	8699/6323	18,000
AO-5036-A	Valve	Vacuum Relief from Bldg. & Purge Inlet/X-205	9243/11,860	18,000
AO/5036-B	Valve		391/5123	18,000
MO/1001-43A (A)	Valve	RHR/X-222A	3931/1992	18,000
A 18"-N29M4	Valve	"	2444/1149	16,440

TABLE 3-4 (CONTINUED)

PILGRIM

PUMP AND VALVE EVALUATION

Component Designation	Component Type	TAP System/Penetration	Pipe Stress at Component	Allowable Pipe Stress
A 18"-N957M4K	Valve	RHR/X-222A & B	3366/1934	16,440
B MO/1001-43C	Valve		3357/1691	18,000
B 18"-N29M4	Valve		2706/5215	16,440
B 18"-N957M4K	Valve		3007/4952	16,440
P-203A	Pump		1944	36,000
P-203C	Pump		5097	36,000
MOV-18"-N29M4	Valve	RHR/X-222C & D	3004/2383	16,440
MO-1001-43B7	Valve		1630/3488	18,000
MOV-18"-N29M4	Valve		4513/6593	16,400
None	Valve		2101/4254	18,000
P-203B	Pump		2873	36,000
P-203D	Valve		1621	36,000
20"-N238	Valve	HPCI Turbine Exh./X-223	5096/5404	18,000
20"-N294M4K	Valve		3771/7902	16,440

TABLE 3-4 (CONTINUED)

PILGRIM

PUMP AND VALVE EVALUATION

Component Designation	Component Type	TAP System/Penetration	Pipe Stress at Component	Allowable Pipe Stress
8"N294M4K	Valve	RCIC Turbine Exh./X-225	5537/4340	16,440
8"N238	Valve		9079/9071	18,000
AO-5042-A	Valve	Purge Exhaust/X-227	2599/767	18,000
AO-5040-A	Valve		1247/1016	18,000
AO-5042-B	Valve		7246/5506	16,440
AO-5040-B	Valve		754/638	18,000
12"-29K		Core Spray Pump/X-229A	1100/1426	18,000
MO-3A	Valve		3332/2170	16,440
P-215A	Pump		2309	18,000
12"-29K	Valve	Core Spray Pump Suct./ X-229B	1431/2053	18,000
MO-3B	Valve		3796/2397	16,440
P-215B	Pump		1717	18,000

TABLE 3-5

PILGRIM

TAP PIPE SUPPORTS (LARGE BORE)

Penetration	Line Number	Support Tag	Support Type	Modification
X-205	20"-HM-45	H-45-1-SG	X-Z Rigid	None
		H-45-1-1SG	Y Rigid	New installation
		H-45-1-2SR	Y Rigid	Replaced U-bolt with frame
X-210A	12"-HL-10	H-10-1-66	Y Spring	Reset spring
		H-10-1-67	Y Spring	Reset spring
		H-10-1-68	Y Spring	Replaced spring can
	16" Sch. 40 Internal	TES Lateral	X-Z Rigid	None
	12"-HL-10	H-10-1-89SA	Anchor	Added plates & anchor bolts
X-210B	12"-HL-10	H-10-1-75	Y Rigid	Replaced rod strut & pipe clamp
		H-10-1-76	Y Rigid	None
		H-10-1-77	Y Rigid	Modified support steel, replaced rod strut and pipe clamp
	12"-GB-10	H-10-1-89	X-Y Rigid	Replaced spring can with frame of structural tubing
	10"-GB-10	H-10-1-11	Y Rigid	Modified support steel, replaced spring with rigid strut
	12"-HL-10	TES Anchor	New Anchor	New installation

TABLE 3-5 (CONTINUED)

PILGRIM

TAP PIPE SUPPORTS (LARGE BORE)

Penetration	Line Number	Support Tag	Support Type	Modification
X-211A	6"-HL-10	H-10-1-51	Y Rigid	Replaced rod strut with adjustable rigid strut and pipe clamp
		H-10-1-52	Y Rigid	Modified support steel, replaced rod strut
		H-10-1-87SA	Anchor	Added plate & anchor bolts
X-211B	6"-GB-10	H-10-1-78	Y Rigid	Modified support steel, replaced rod strut
		H-10-1-79	Y Rigid	Modified support steel, replaced rod strut
		H-10-1-111	45^{o} Lateral	None
		H-10-1-40SA	Anchor	New installation
X-220	6"-HD-13	H-13-1-28	Y Spring	Reset spring can
		H-13-1-2SR	Y Rigid	Reorientated and replaced entire support
		H-13-1-27	Y Rigid	Added stanchion lugs for uplift
		H-13-1-26	Y Rigid	Added stanchion lugs for uplift
		H-13-1-1SG	Y Rigid	Replace angle frame
		H-13-1-25	Y Rigid	None
	6"-HL-13	H-13-1-1	Y Rigid	Added stanchion lugs for uplift
		H-13-1-2	Y Rigid	Added stanchion lugs for uplift

TABLE 3-5 (CONTINUED)

PILGRIM

TAP PIPE SUPPORTS (LARGE BORE)

Penetration	Line Number	Support Tag	Support Type	Modification
X-220	6"-HE-26	H-26-1-6	Y-Z Rigid	New installation
	6"-HE-13	H-26-1-1322SP	XYZ Rigid	None
X-221	16"-HL-23	H-23-1-21	Y Rigid	Added stanchion lugs for uplift
		H-23-1-22	Y Rigid	Added stanchion lugs for uplift
		TES New Support	X Rigid	New installation
		H-23-1-SH	Anchor	New installation except for stanchion
X-222A & B	18"-HB-10	HB-10-SG-18	Z Rigid	None
	18"-HL-10	H-10-1-19	Y Rigid	Added plate clamps to baseplate for uplift
		H-10-1-18SR	Y Rigid	Modified support steel & replaced adjustable rigid strut & pipe clamp
		H-10-1-20	Y Rigid	Added stanchion lugs for uplfit
		H-10-1-19SR	Y Rigid	None
		H-10-1-21	Y Rigid	Added stanchion lugs for uplift
		H-10-1-138	Y Rigid	Added stanchion lugs for uplift
		H-10-1-20SH	Y Rigid	None

TABLE 3-5 (CONTINUED)

PILGRIM

TAP PIPE SUPPORTS (LARGE BORE)

Penetration	Line Number	Support Tag	Support Type	Modification
X-222A & B	18"-HL-10	H-10-1-21SR	Y Rigid	None
	18"-HB-10	H-10-1-22SH	Y Spring	Replace spring can and add lubrite plate
	20"-HB-10	H-10-1-5	Y Spring	Reset spring cans
		H-10-1-45SR	X Rigid	None
		H-10-1-46SS	Y Spring	Reset spring can, add baseplate with gussets & anchor bolts
		H-10-1-47SH	Y Rigid	Added plate clamps to stanchion baseplate, added baseplate, gusset and anchor bolts to wall baseplate
	18"-HL-10	H-10-1-22	Y Rigid	Added stanchion lugs for uplift
		H-10-1-23SR	Y Rigid	None
		H-10-1-23	Y Rigid	Added stanchion lugs for uplift
		H-10-1-136	Y Rigid	None
	18"-HB-10	H-10-1-24SR	Y Rigid	Changed baseplate & anchors
		H-10-1-25SH	Y Spring	Reset spring can
		H-10-1-135	Y Spring	Reset spring can

TABLE 3-5 (CONTINUED)

PILGRIM

TAP PIPE SUPPORTS (LARGE BORE)

Penetration	Line Number	Support Tag	Support Type	Modification
X-222A & B	18"-HB-10	HB-10-SG-19	Z Rigid	None
		H-10-1-134	Y Spring	Reset spring can
	20"-HB-10	H-10-1-44SA	Anchor	Added gussets & steel
X-222C & D	18"-HL-10	H-10-1-29SR	45° Lateral	Modified support steel and baseplate, replaced adjustable rigid strut and pipe clamp
		H-10-1-30SR	45° Lateral	None
		H-10-1-31SH	Y Rigid	None
		H-10-1-32SR	45° Lateral	None
	18"-HB-10	H-10-1-33SH	Y Spring	Reset spring can
	18"-HL-10	H-10-1-53	Y Rigid	Replaced baseplate, added anchor bolts and plate clamps to new baseplate for uplift
		H-10-1-54	Y Rigid	None
		H-10-1-55	Y Rigid	None
		H-10-1-26SR	45° Lateral	Replaced adjustable rigid strut and clamp, added baseplates, gussets and anchor bolts

TABLE 3-5 (CONTINUED)

PILGRIM

TAP PIPE SUPPORTS (LARGE BORE)

Penetration	Line Number	Support Tag	Support Type	Modification
X-222C & D	18"-HG-10	H-10-1-27SR	45^{0} Lateral	Added baseplate and anchor bolts
	18"-HB-10	H-10-1-28SH	Y Spring	Reset spring can
	18"-HL-10	H-10-1-56	Y Rigid	Added plate clamps to baseplate for uplift
		H-10-1-57	Y Rigid	Added plate clamps to baseplate for uplift
		H-10-1-123	Y Rigid	None
	20"-HB-10	H-10-1-10	Y Spring	Replaced spring cans and rods
	18"-HL-10	H-10-1-121	Y Rigid	Added plate clamps to baseplate for uplift
	18"-HB-10	HB-10-1-SG-17	45^{0} Lateral	Replaced adjustable rigid strut
		H-10-1-119	Y Spring	Replaced spring can and all attachments
		H-10-1-120	Y Spring	Reset spring can
		HB-10-SG-16	45^{0} Lateral	Changed baseplate & bolts
	20"-HB-10	H-10-1-60SH	Y Rigid	Changed baseplate & bolts
		H-10-1-59SH	Y Spring	Reset spring
		H-10-1-58SR	X Lateral	None
		H-10-1-57SA	Anchor	None

TABLE 3-5 (CONTINUED)

PILGRIM

TAP PIPE SUPPORTS (LARGE BORE)

Penetration	Line Number	Support Tag	Support Type	Modification
X-223	20"-HB-23	H-23-1-15SS	Lateral Snubber	None
	24"-HL-23	H-23-1-18	Y Rigid	Replaced entire support with new installation
	20"-HB-23	H-23-1-17	Y Rigid	Replaced entire support with new installation
	20"-HB-23	H-23-1-16	Y Rigid	Replaced rigid rod strut with adjustable rigid strut and replaced pipe clamp, baseplate and anchor bolts
		H-23-1-14SS	X Snubber	None
		H-23-1-15	Y Spring	Reset spring can
		H-23-1-13SS	X Snubber	None
		H-23-1-14	Y Spring	Reset spring can
	16"-HB-23	H-23-1-19	Y Spring	Reset spring can, added plate and anchor bolts
		H-23-1-20	Y Spring	Replaced spring can, added plate and anchor bolts
		H-23-1-11SS	Z Snubber (skewed)	Added baseplate, gussets and anchor bolts

PILGRIM

TAP PIPE SUPPORTS (LARGE BORE)

Penetration	Line Number	Support Tag	Support Type	Modification
X-223	20"-HB-23	H-23-1-12SS	Z Snubber	None
	24"-HL-23	New	X Snubber	New installation
X-225	8"-HL-13	H-13-1-6	Y Spring	Replaced spring cans
		H-13-1-7	Y Spring	Replaced spring can, pipe clamp and attachments
		Two New Axial Snubbers (TES)	X Snubbers	New installation
		H-13-1-3SA	Anchor	None
X-227	20"-HM-45	H-45-1-3SG	Z Rigid	None
		H-45-1-4	Y Spring	Replaced spring
		H-45-1-4SG	X Rigid	New structural steel
	20"-HM-45	H-45-1-5	Z Rigid Y Spring	Added frame of tubular steel with baseplates and anchor bolts
		H-45-1-6	Y Spring	Remove bar stops for stanchion
X-229A	12"-HE-26	H-14-1-19S	Y Rigid	None
		H-14-1-23S	Z Rigid	None
	18"-HD-14	H-14-1-20S	Y-Z Rigid	Replaced rigid shock and sway arrestor and pipe clamp

TABLE 3-5 (CONTINUED)

PILGRIM

TAP PIPE SUPPORTS (LARGE BORE)

Penetration	Line Number	Support Tag	Support Type	Modification
X-229A	18"-HL-14	H-14-1-21S	X Rigid (skewed)	None
		H-14-1-22S	Z Rigid	None
		PS-450	Y Rigid	None
		H-14-1-5	Y Rigid	None
		H-14-1-4	Y Rigid	None
		H-14-1-6	Y Rigid	None
		H-14-1-20	Y Rigid	None
	16"-HE-26	H-14-1-24S	Anchor	
X-229B	12"-HE-26	H-14-1-26S	X Rigid	Added angles to stanchion baseplate for uplift
	12"-HE-26	H-14-1-30S	Y Rigid	None
	18"-HD-14	H-14-1-27S	Y Rigid	Replaced rigid shock and sway arrestor and pipe clamp, baseplate and anchor bolts
		H-14-1-12	X Rigid	Replace baseplate and anchor bolts
		H-14-1-13	Y Rigid	None
		H-14-1-28S	X Rigid	None

TABLE 3-5 (CONTINUED)

PILGRIM

TAP PIPE SUPPORTS (LARGE BORE)

Penetration	Line Number	Support Tag	Support Type	Modification
X-229B	18"-HL-14	H-14-1-9	Y Rigid	None
		H-14-1-29S	X Rigid	None
		H-14-1-7	Y Rigid	None
		H-14-1-8	Y Rigid	None
		PS-425	Y Rigid	None
	16"-HE-26	H-14-1-25G	Anchor	None

TABLE 3-6

PILGRIM

TAP PENETRATION STRESS RESULTS - PILGRIM

Penetration Number	Primary Stress: Calculated Max. Stress	Primary Stress: Allowable	Secondary Stress: Calculated Max. Stress	Secondary Stress: Allowable
X-205	13,419	19,300	67,059	69,900
X-210A	10,470	19,300	39,949	
X-210B	10,409	19,300	44,118	
X-211A	14,347	15,100	40,338	
X-211B	13,731	15,100	29,910	
X-220	12,807	15,100	29,761	
X-221	16,400	19,300	51,440	
X-222A X-222B	15,751	19,300	43,843	
X-222C X-222D	15,756	19,300	45,692	
X-223	15,041	19,300	58,570	
X-225	12,810	15,100	62,170	
X-227	13,447	19,300	36,367	
X-229A	15,830	19,300	56,334	
X-229B	15,767	19,300	60,433	

TABLE 1
STRUCTURAL ACCEPTANCE CRITERIA
CLASS 2 AND 3 PIPING SYSTEMS

EVENT COMBINATIONS		SRV	SRV + EQ		SBA IBA		SBA + EQ IBA + EQ				SBA + SRV IBA + SRV		SBA + SRV + EQ IBA + SRV + EQ				DBA		DBA + EQ				DBA + SRV		DBA + EQ + SRV			
						CO, CH			CO,CH			CO, CH			CO,CH		PS (1)	CO, CH	PS		CO,CH		PS	CO, CH	PS		CO,CH	
TYPE OF EARTHQUAKE			O	S			O	S	O	S			O	S	O	S			O	S	O	S			O	S	O	S
COMBINATION NUMBER		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
LOADS																												
Normal (2)	N	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Earthquake	EQ		X	X			X	X	X	X			X	X	X	X			X	X	X	X			X	X	X	X
SRV Discharge	SRV	X	X	X							X	X	X	X	X	X							X	X	X	X	X	X
Thermal	T_A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Pipe Pressure	P_A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
LOCA Pool Swell	P_{PS}																X		X	X			X		X	X		
LOCA Condensation Oscillation	P_{CO}					X			X	X		X			X	X		X			X			X			X	
LOCA Chugging	P_{CH}					X			X	X		X			X	X		X			X	X		X			X	X
STRUCTURAL ELEMENT	ROW																											
Essential Piping Systems																												
With IBA/DBA	10	B	B (3)	B (3)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)	B (4)
With SBA	11				B (3)	B (3)	B (4)	B (4)	B (4)	B (4)	B (3)	B (3)	B (4)	B (4)	B (4)	B (4)	-	-	-	-	-	-	-	-	-	-	-	-
Nonessential Piping Systems																												
With IBA/DBA	12	B	C (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)
With SBA	13				C (5)	C (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	D (5)	-	-	-	-	-	-	-	-	-	-	-	-

NOTES TO TABLE 1

1. Where drywell-to-wetwell pressure differential is normally utilized as a load mitigator, an additional evaluation shall be performed without SRV loadings, but assuming the loss of the pressure differential. Service Level D Limits shall apply for all structural elements of the piping system for this evaluation. The analysis need only be accomplished to the extent that integrity up to and including the first pressure boundary isolation valve is demonstrated, including operability of that valve. If the normal plant operating condition does not employ a drywell-to-wetwell pressure differential, the listed Service Level assignments shall be applicable.

2. Normal loads (N) consist of dead loads (D).

3. As an alternative, the 1.2 S_h limit in Equation 9 of NC-3652.2 may be replaced by Level C (1.8 S_h) provided that all other limits are satisfied. Fatigue requirements are applicable to all columns with the exception of 16, 18, 19, 22, 24 and 25.

4. Footnote 3 applies, except that instead of using Level C (1.8 S_h) in Equation 9 of NC-3652.2, Level D (2.4 S_h) may be used.

5. Equation 10 of NC or ND-3650 shall be satisfied, except that fatigue requirements are not applicable to columns 16, 18, 19, 22, 24 and 25, since pool swell loadings occur only once. In addition, if operability of an active component is required to ensure containment integrity, operability of that component must be demonstrated.

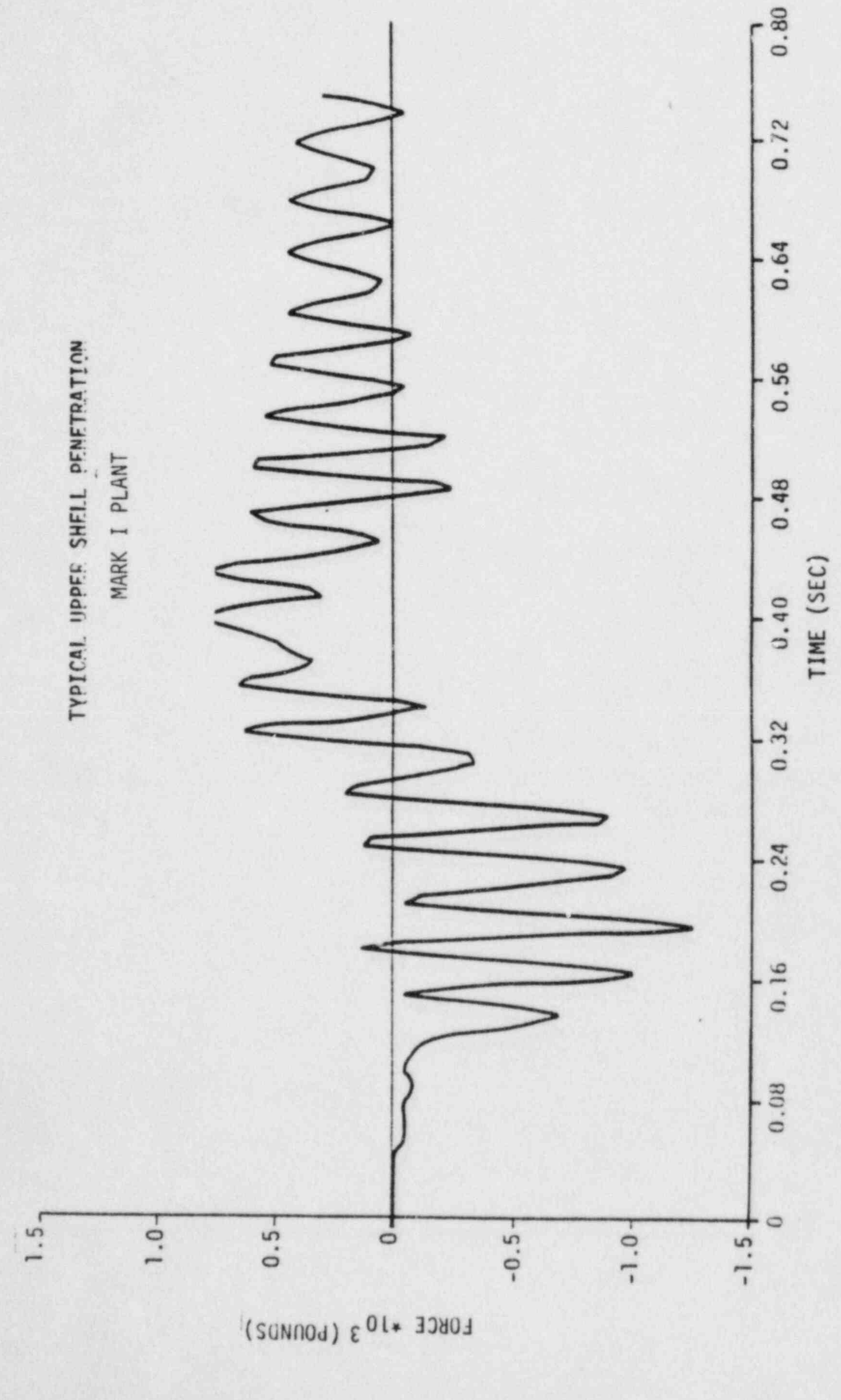


FIGURE 3-1 SHELL RESPONSE FROM POOL SWELL, TYPICAL

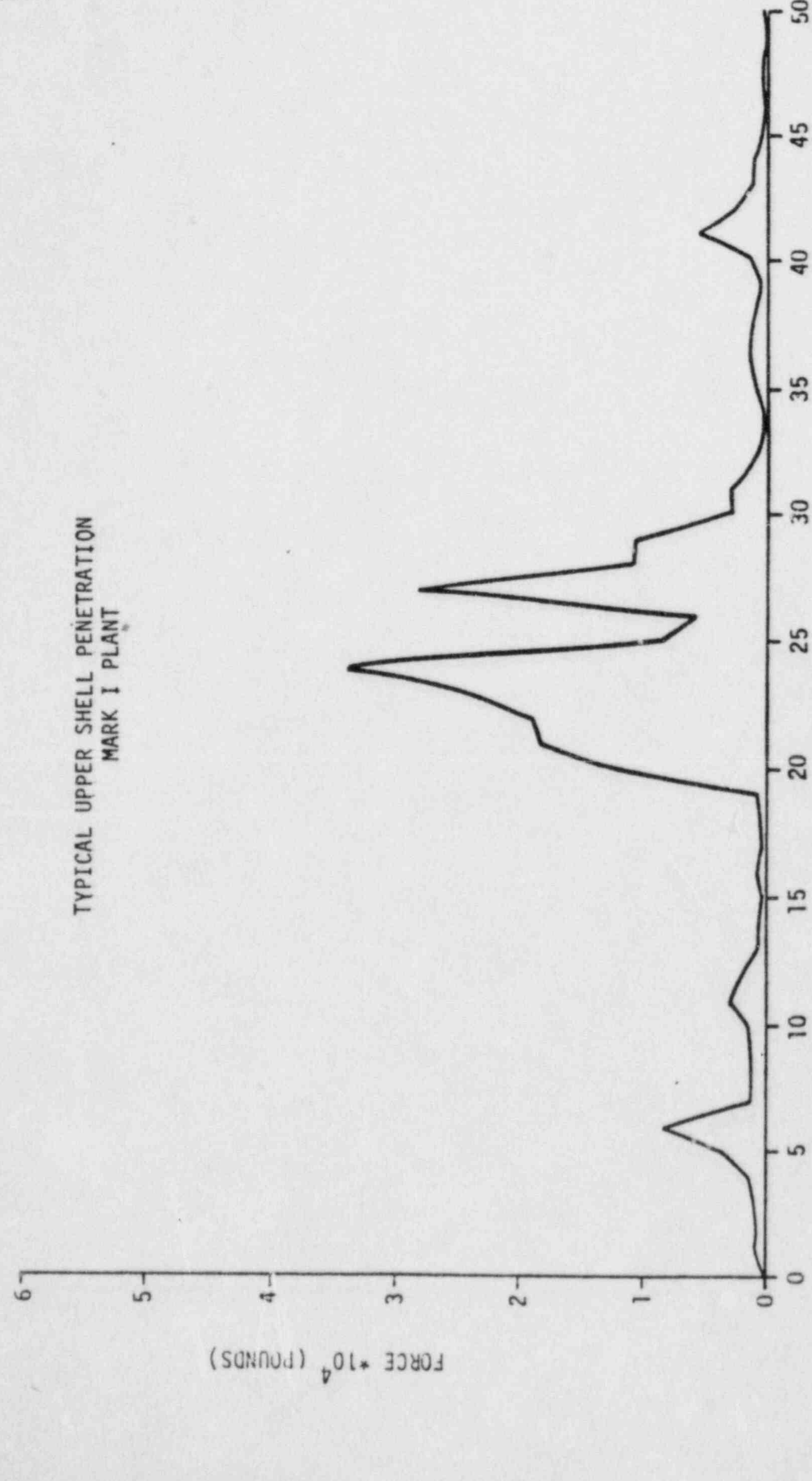


FIGURE 3-2 SHELL RESPONSE FROM CONDENSATION OSCILLATION-TYPICAL

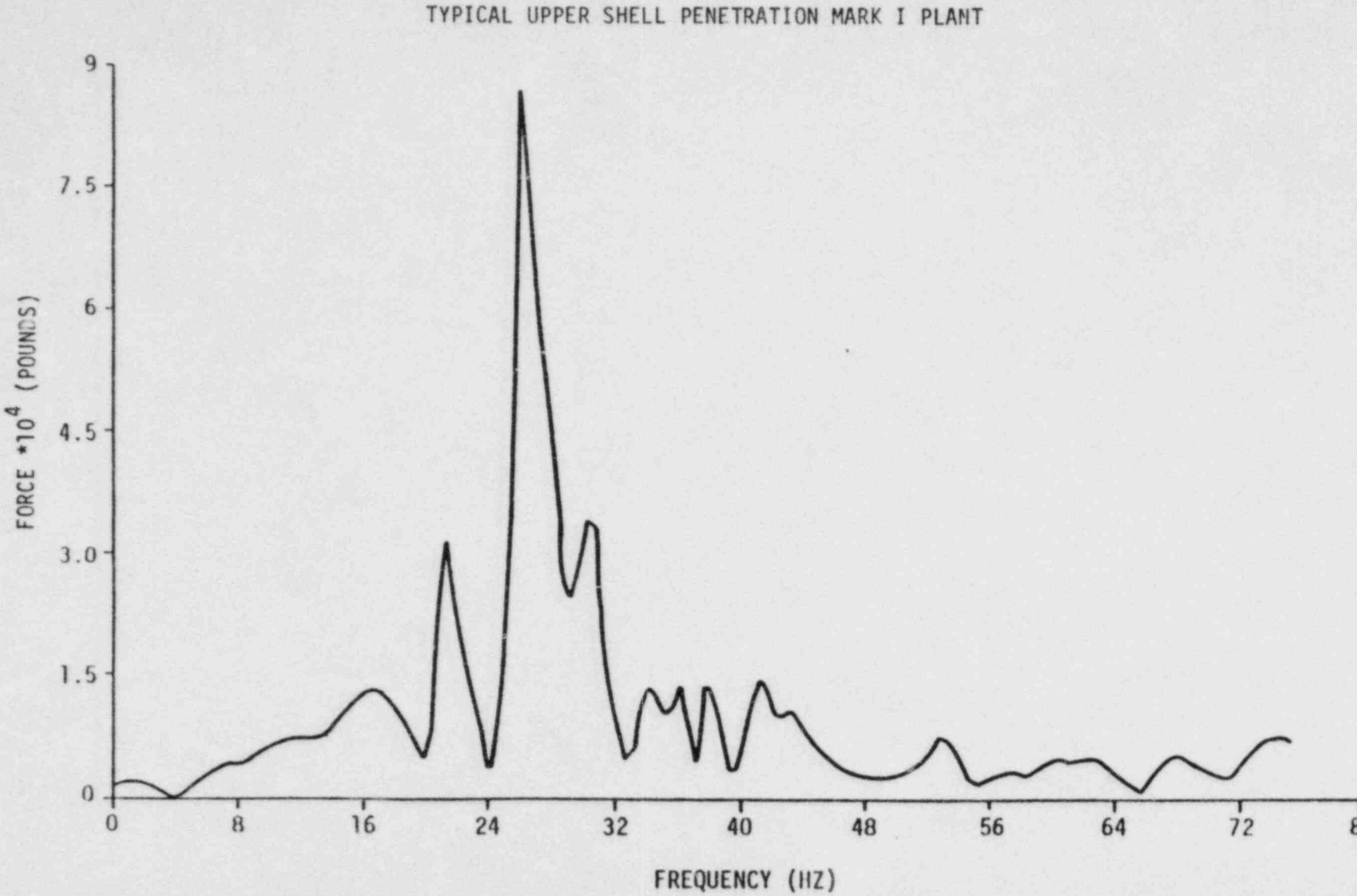


FIGURE 3-3 SHELL RESPONSE FROM SRV-TYPICAL

PENETRATION X-221
CONDENSATION OSCILLATION
AND POST CHUG

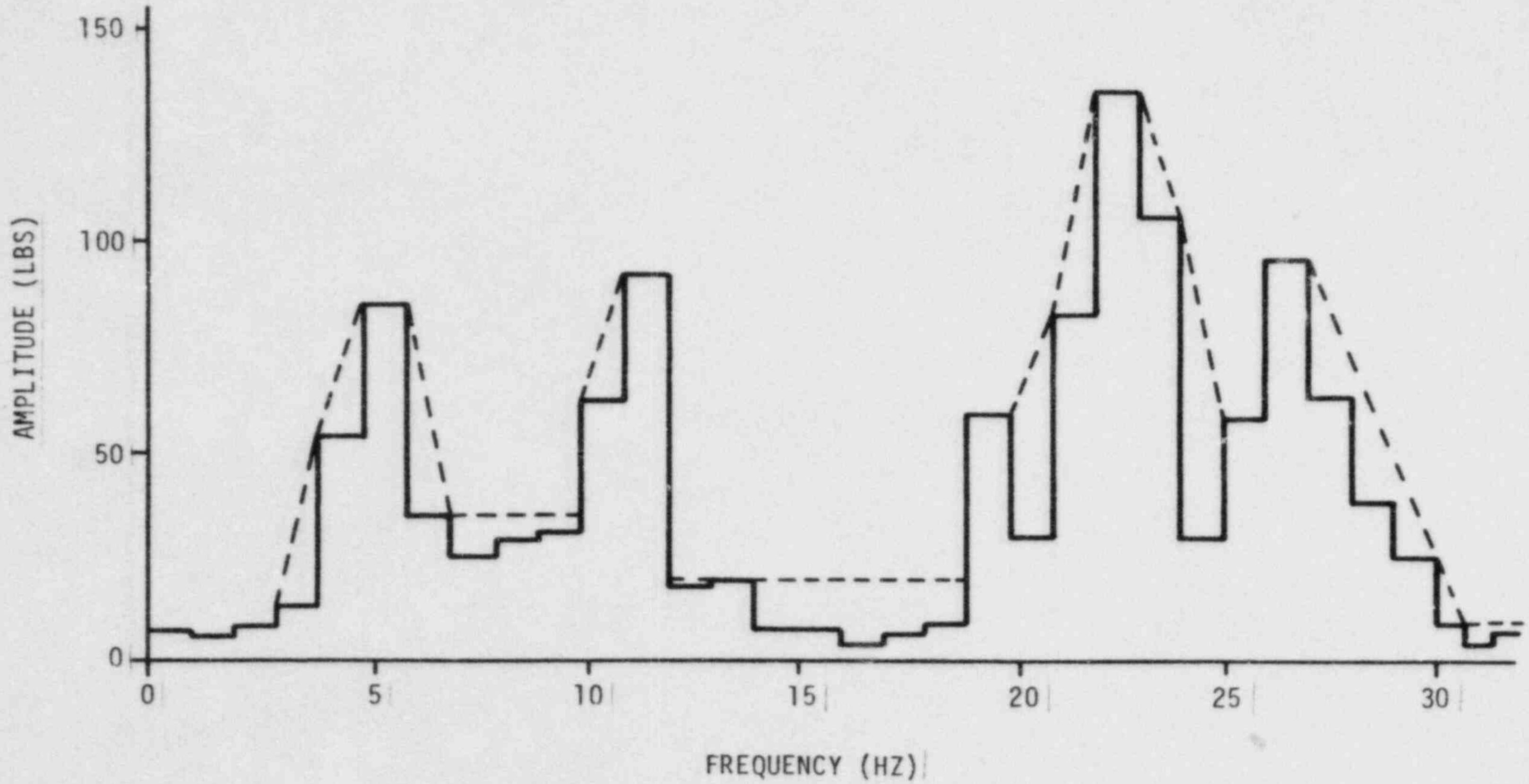


FIGURE 3-4 DRAG LOAD ON INTERNAL PIPING

HORIZONTAL SPECTRA

OPERATING BASIS EARTHQUAKE

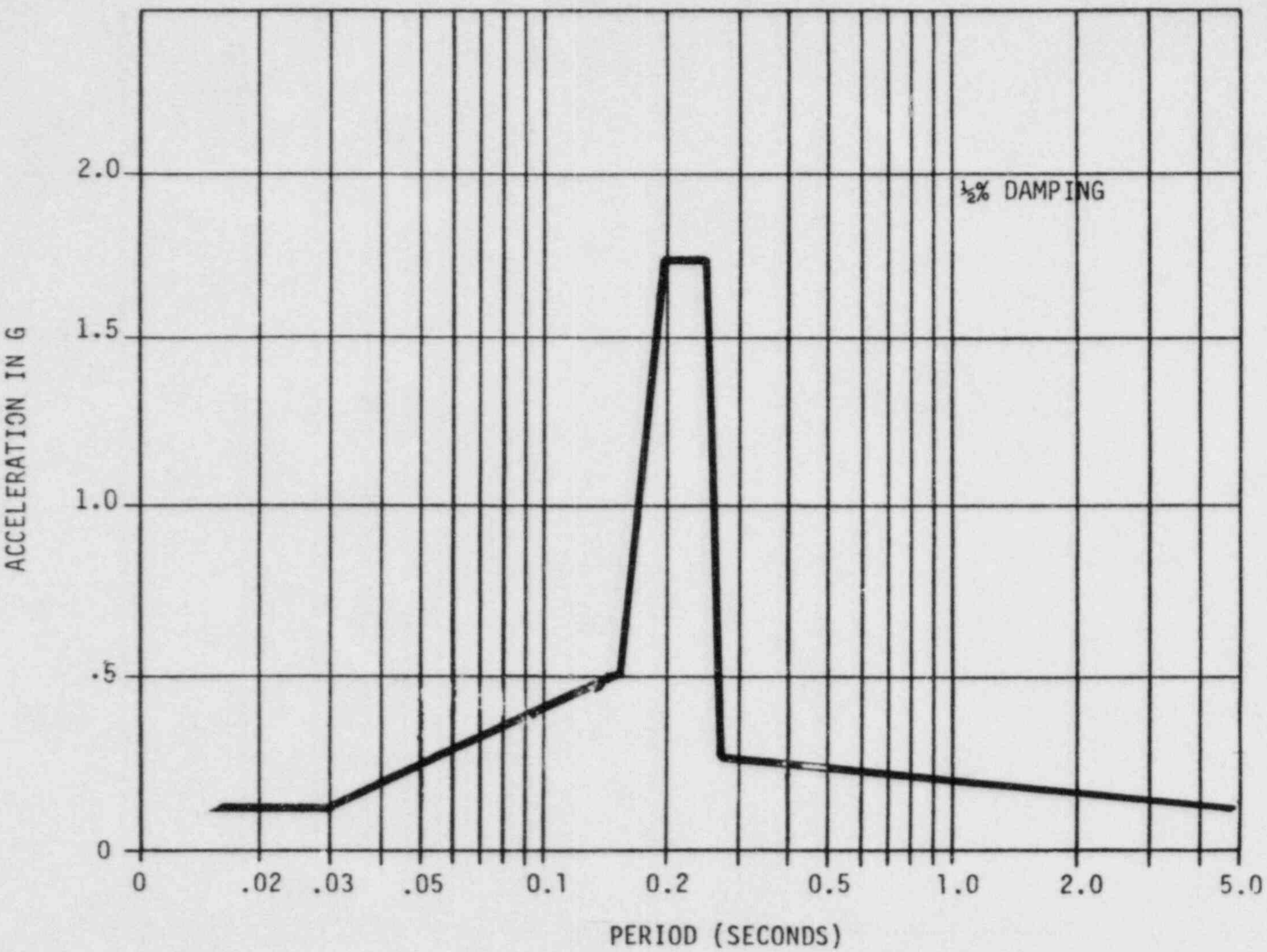


FIGURE 3-5 TAP SEISMIC SPECTRA

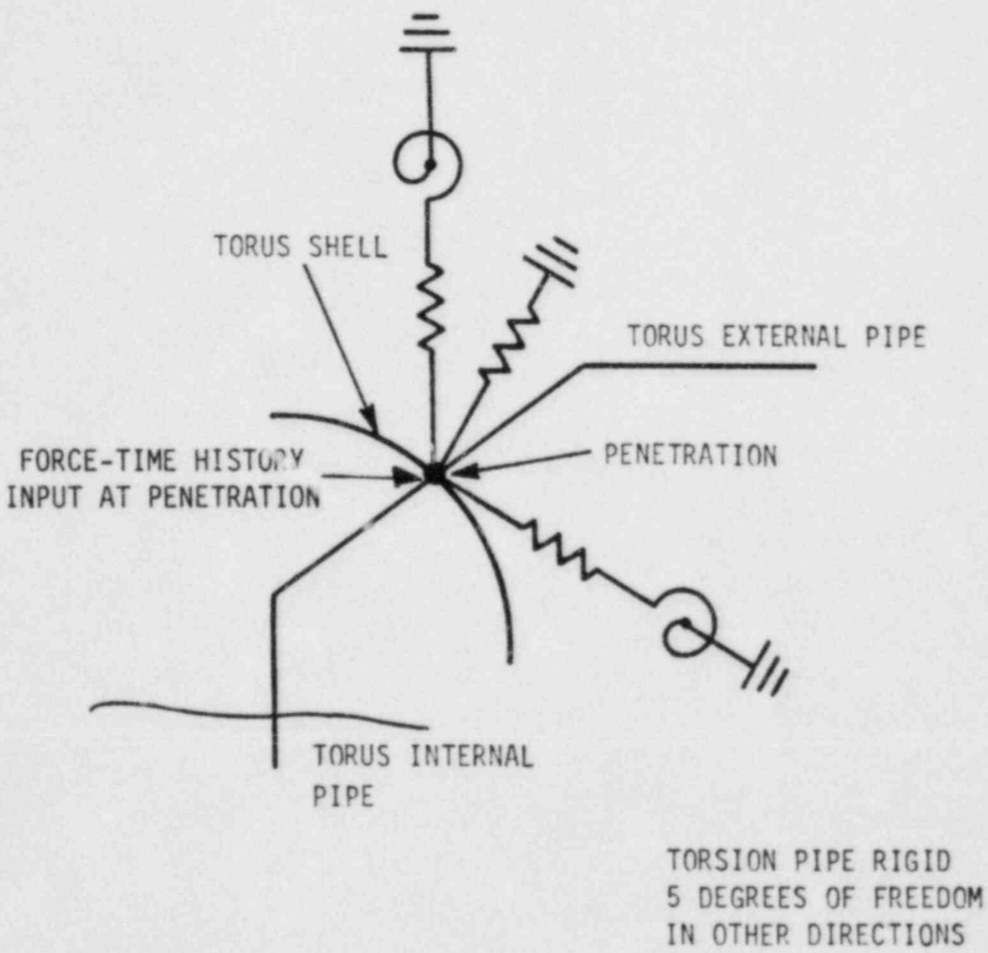


FIGURE 3-6 TAP PENETRATION REPRESENTATION (TYPICAL)

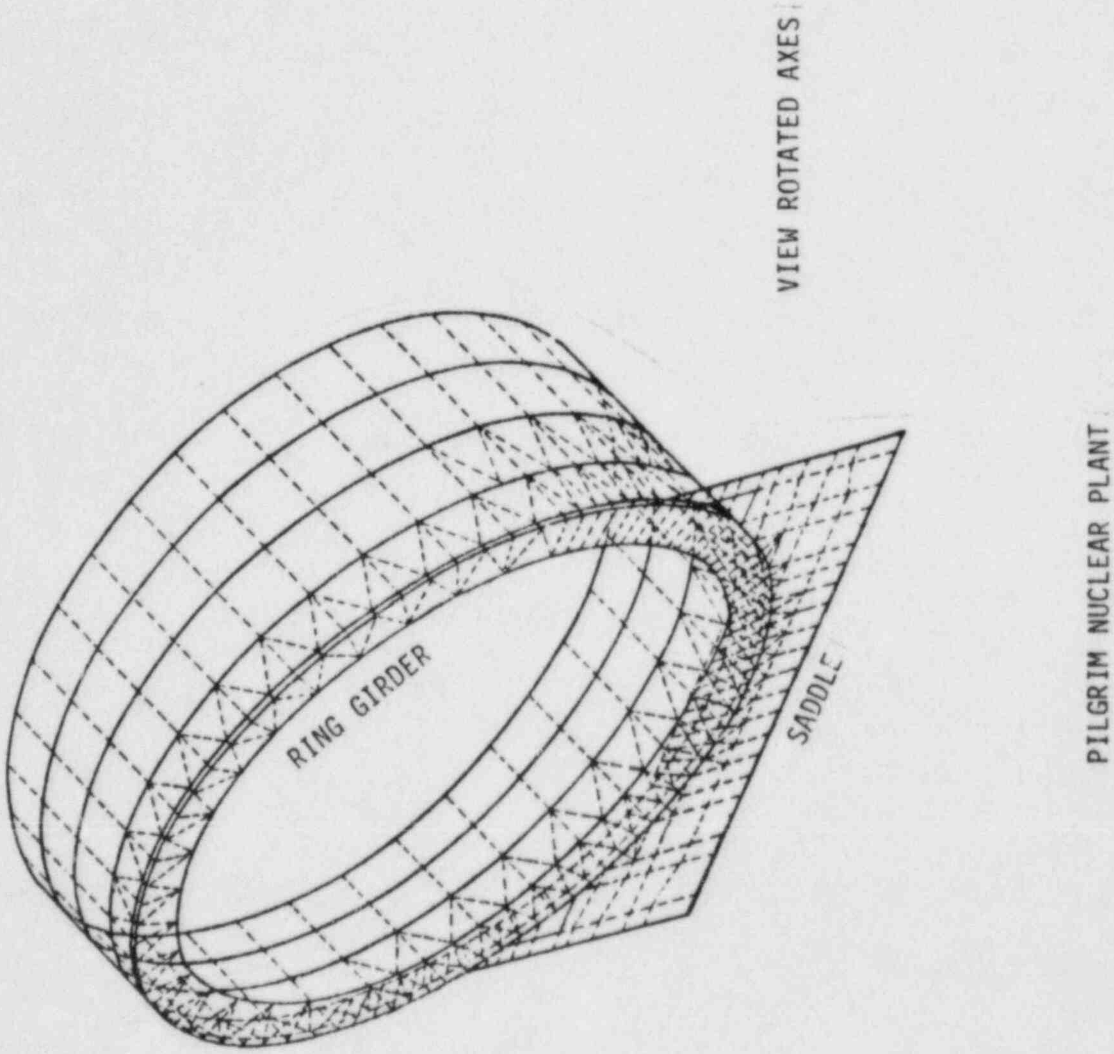
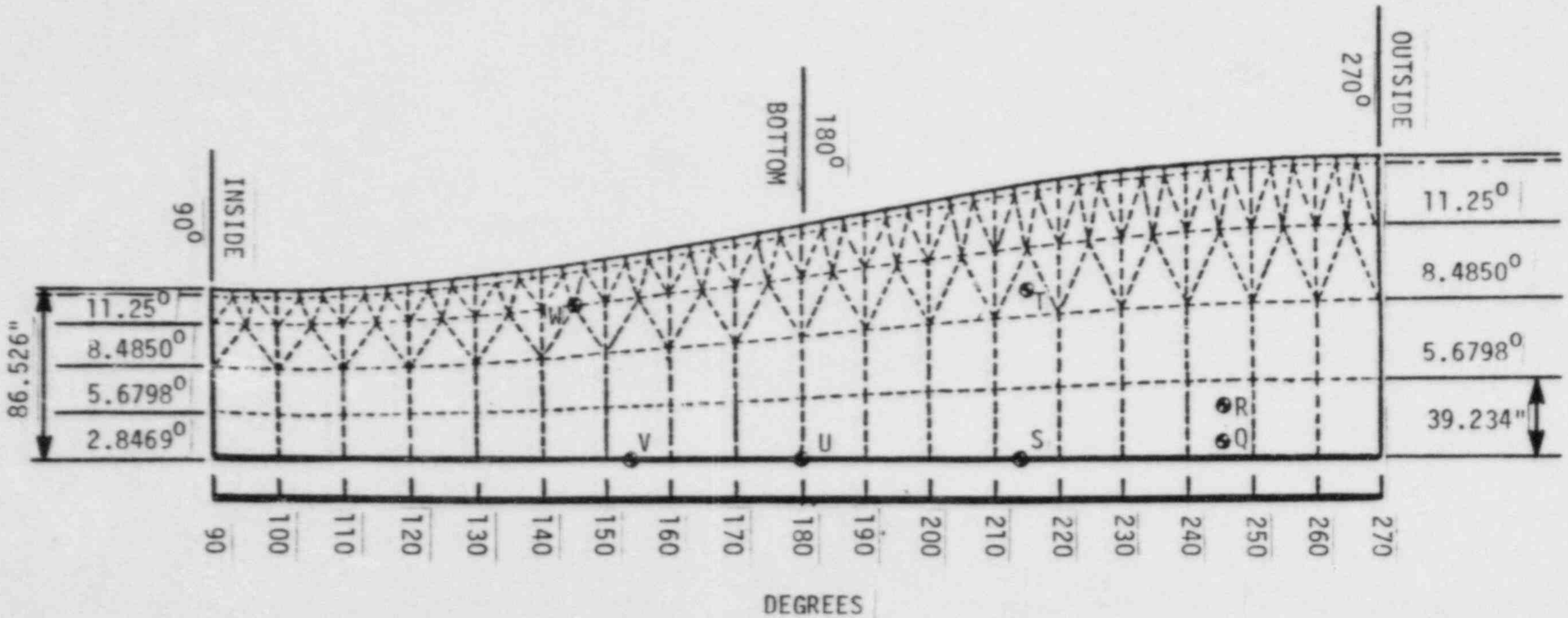


FIGURE 3-7 DETAILED SHELL MODEL

TORUS PENETRATIONS

NODE NO.	LOCATION	PENETRATION NO.	ANGLE
25	Q	x206b-c	245.00^{0}
61	R	x209b-c	245.00^{0}
22	S	x220	213.70^{0}
94	T	x22b/d	213.70^{0}
19	U	x213a-b	180.00^{0}
16	V	x221,x22a/c	154.30^{0}
129	W	x229a-b	146.20^{0}

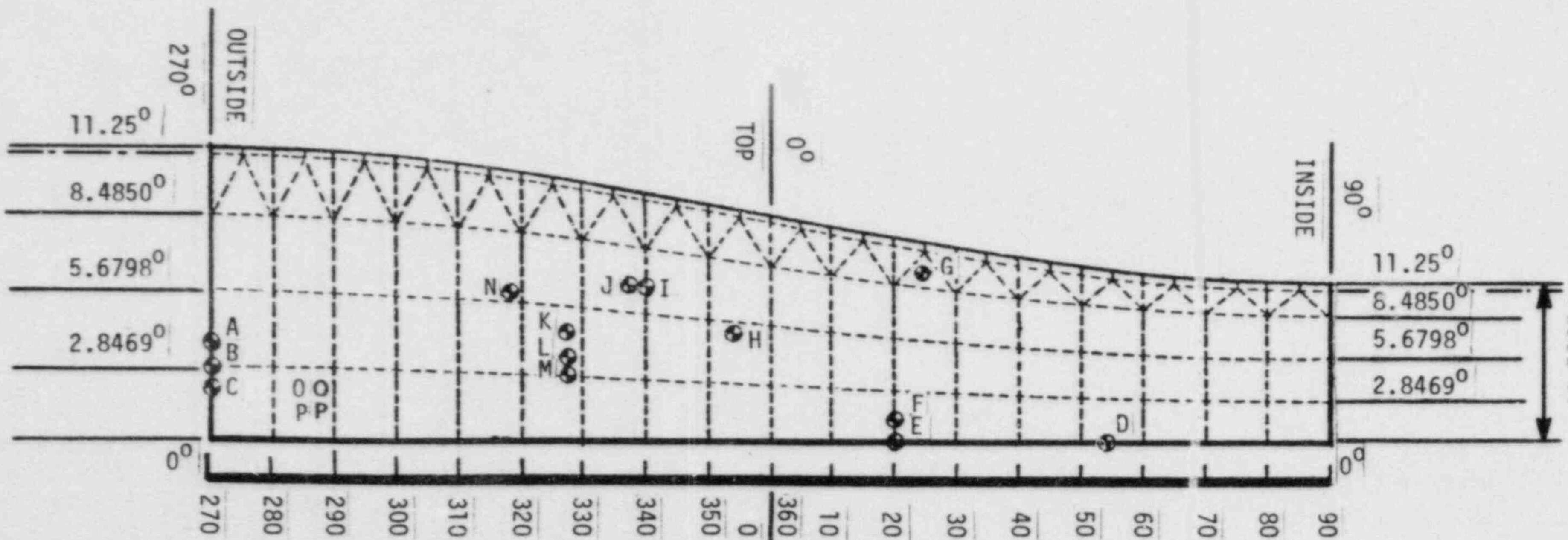


PILGIRM NUCLEAR PLANT UNIT 1

FIGURE 3-8a TAP PENETRATIONS UPPER SHELL

TORUS PENETRATIONS

NODE NO.	LOCATION	PENETRATION NO.	ANGLE
64	A	x224,x226	270.00°
64	B	x212	270.00°
64	C	x223,x225	270.00°
6	D	x201a-h	54.00°
3	E	x228c-e,h,j,k	20.00°
3	F	x228a,b,f,g	20.00°
111	G	x210a-b	25.10°
108	H	x230	354.20°
107	I	x214-219	340.00°
107-161	J	x211a-b	339.10°
--	K	x200a	327.20°
--	L	x200b	327.20°
--	M	x202a-b	327.20°
105	N	x205,x227	319.90°
65	O	x209a/d	285.00°
29	P	x206a/d	285.00°



PILGRIM NUCLEAR PLANT UNIT 1

FIGURE 3-8b TAP PENETRATIONS LOWER SHELL

REFERENCES

1. TES Report TR-5310-1, Rev. 1, "Mark 1 Containment Program, Plant Unique Analysis of the Torus Suppression Chamber for Pilgrim Station - Unit 1" dated April 21, 1983.

2. ASME B&PV Code, Section III, Division 1, through Summer 1977.

3. USNRC IE Bulletin 79-02, dated November 8, 1979, (Revision 2), Pipe Support Base Plate Designs Using Concrete Expansion Anchor Bolts.

4. ASME B&PV Code, Section XI, 1977 Edition, with 1978 Addenda.

5. G.E. Report NEDO-24583-1, "Mark 1 Containment Program Structural Acceptance Criteria Plant Unique Analysis Application Guide", dated October, 1979.

6. Structural Mechanics Assoc. Report SMA 12101.04-R002D "Response Factors Appropriate for use with CO Harmonic Response Combination Design Rules", dated March, 1982.

7. General Electric Computer Programs RVFOR-04 & RVFOR-05, Programs to Compute SRV Line Clearing Forces, General Electric Co., San Jose, CA.

8. Structural Mechanics Report SMA-12101.05-R001, "Design Approach for FSTF Data for Combining Harmonic Amplitudes for Mark 1 Post-Chug Response Calculations", dated May, 1982.

9. Welding Research Council Bulletin No. 107, "Local Stresses in Spherical and Cylindrical Shells due to External Loadings", dated March, 1979.

10. General Electric Report No. MPR-751 "Mark 1 Containment Program, Augmented Class 2/3 Fatigue Evaluation Method and Results for Typical Torus Attached and SRV Piping Analysis", dated November, 1982.

REFERENCES (CONTINUED

11. G.E. Report NEDO-21888, Rev. 2, "Mark 1 Containment Program Load Definition Report", dated November, 1981.

12. NRC "Safety Evaluation Report, Mark 1 Containment Long-Term Program", NUREG-0661, dated July, 1980.

13. BECO Letter 83-124, W. Harrington to D. G. Eisenhut, "Generic Letter 83-08 Modification of Vacuum Breakers on Mark 1 Containments", dated May 13, 1983.

14. BECO PNPS-1 Specification No. 6498-M-300 Piping Class Summary Sheets and Bechtel 79-14 Piping Analysis for PNPS-1.

15. BECO PNPS-1 Specification G505, Seismic Qualification of Safety Essential Equipment and Equipment Supports.

16. STARDYNE, A General Purpose Computer Program for Structural Analysis, System Development Corp., Santa Monica, Calif.

17. STAAD, A Computer Program for Frame-Structure Analysis, Research Engineers, Cherry Hill, NJ.

APPENDIX 1

USE OF CO LOAD FOR SMALL BORE PIPING

Experience with large bore piping analysis showed that DBA condensation oscillation was usually the most severe Mark 1 load for torus attached piping. This is consistent with the continuous nature of the CO load (as opposed to the transient nature of some other Mark 1 loads) and the frequency content of CO, which is in a range of typically high piping response.

Experience on large bore piping for the first two plants completed by TES follows:

	No. of Large Bore Systems	No. Controlled by CO
Pilgrim	14	11
Millstone	11	9
	25	20

Of the five cases not controlled by CO, CO loads were very close to the maximum, as follows:

Ratio of Controlling Stress Case to CO Case

Pilgrim - .999, .953, .958

Millstone - .89, .65*

*This is a atmospheric control (vacuum breaker) line that connects at three points at the top of the torus. The multiple connections and the penetration location make this line particularly susceptible to pool swell impact on the upper shell. There is no comparable small bore system. In addition, this is a relatively low stressed line. Maximum combined stress is less than half the allowable.

In addition, three of these five cases are controlled by pool swell and a significant contributor to total load was pool swell impact on internal piping. Small bore systems do not have internal piping so these loads will not exist, and stresses for pool swell cases would be less.

The decision to limit analysis of small bore piping to DBA CO as the only Mark 1 load was based on the foregoing. Seismic, thermal and weight were also considered, in addition to DBA CO.

APPENDIX 2

32 HZ CUTOFF FOR CONDENSATION OSCILLATION ANALYSIS

All condensation oscillation response of TAP systems due to torus shell motion used an input frequency cutoff of 32 Hz.

This practice began early in the TAP analysis work and was the result of a decision to cut off shell response frequencies at 32 Hz during the containment analysis. The 32 Hz cutoff for containment analysis is discussed in Appendix 2 of Reference 1, and was based on the fact that both high input energy and high modal responses occurred below that frequency. Use of the 32 Hz cutoff was shown to produce only a small error that was considered negligible. On this same basis, the 32 Hz cutoff was applied to CO analysis for TAP.

Later in the TAP analysis work, it became evident that the 32 Hz cutoff would not be realistic for post chug; input frequencies to 50 Hz were used for post chug. At this time, the decision to cut off CO frequencies at 32 Hz was reviewed. Spectra were generated for several penetrations showing the CO shell motion up to 50 Hz. Figures A4-1, A4-2, A4-3 and A4-4 illustrate typical spectra for rotation and displacement at TAP penetration points for a similar torus, analyzed by TES. These show clearly that shell response above 32 Hz is negligible for CO, and support the initial position.

FIGURE A4-1
DBA CO SHELL RESPONSE-RADIAL
(UNLOADED SHELL-NODE 37)

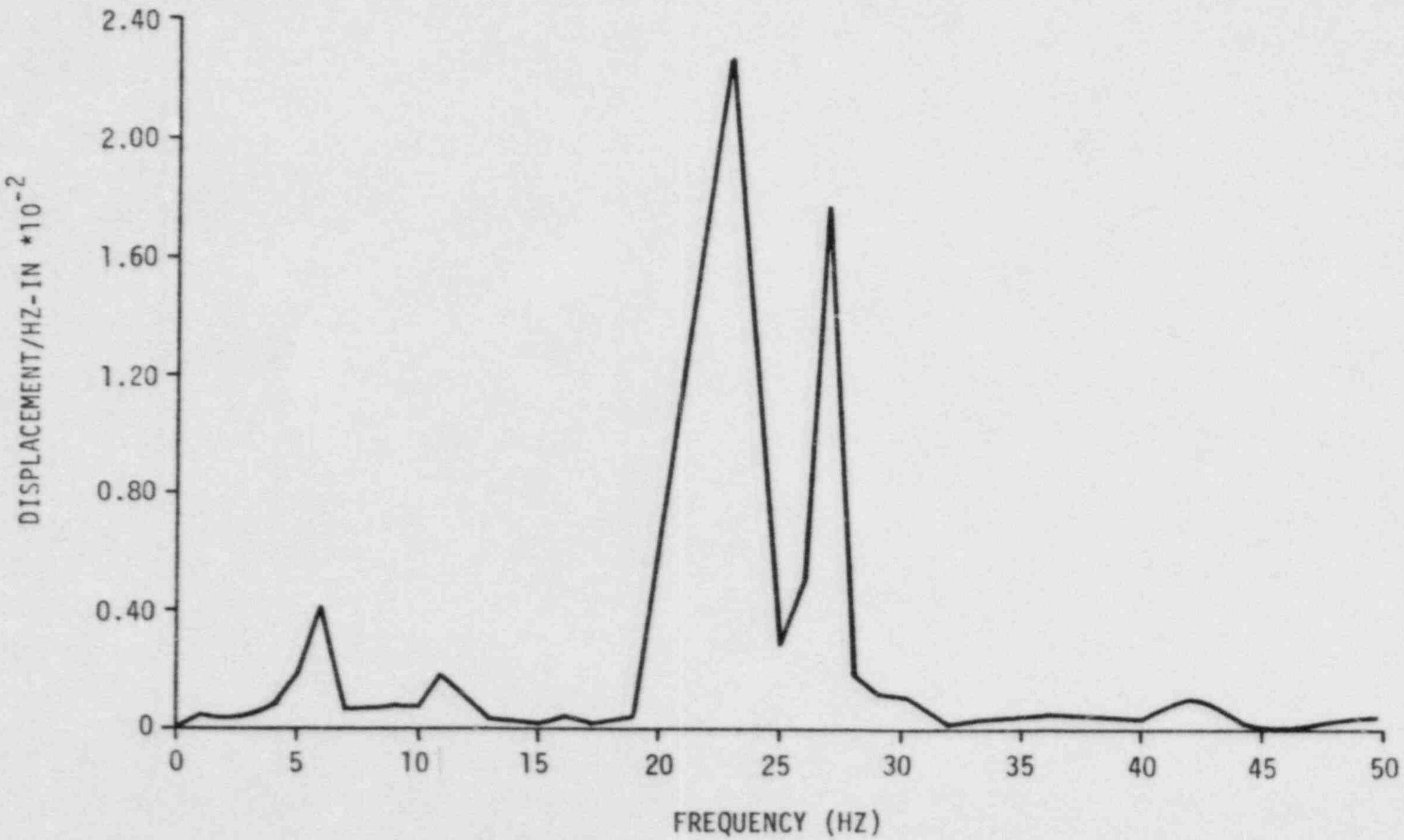


FIGURE A4-2

DBA CO SHELL RESPONSE-ROTATION

(UNLOADED SHELL-NODE 37)

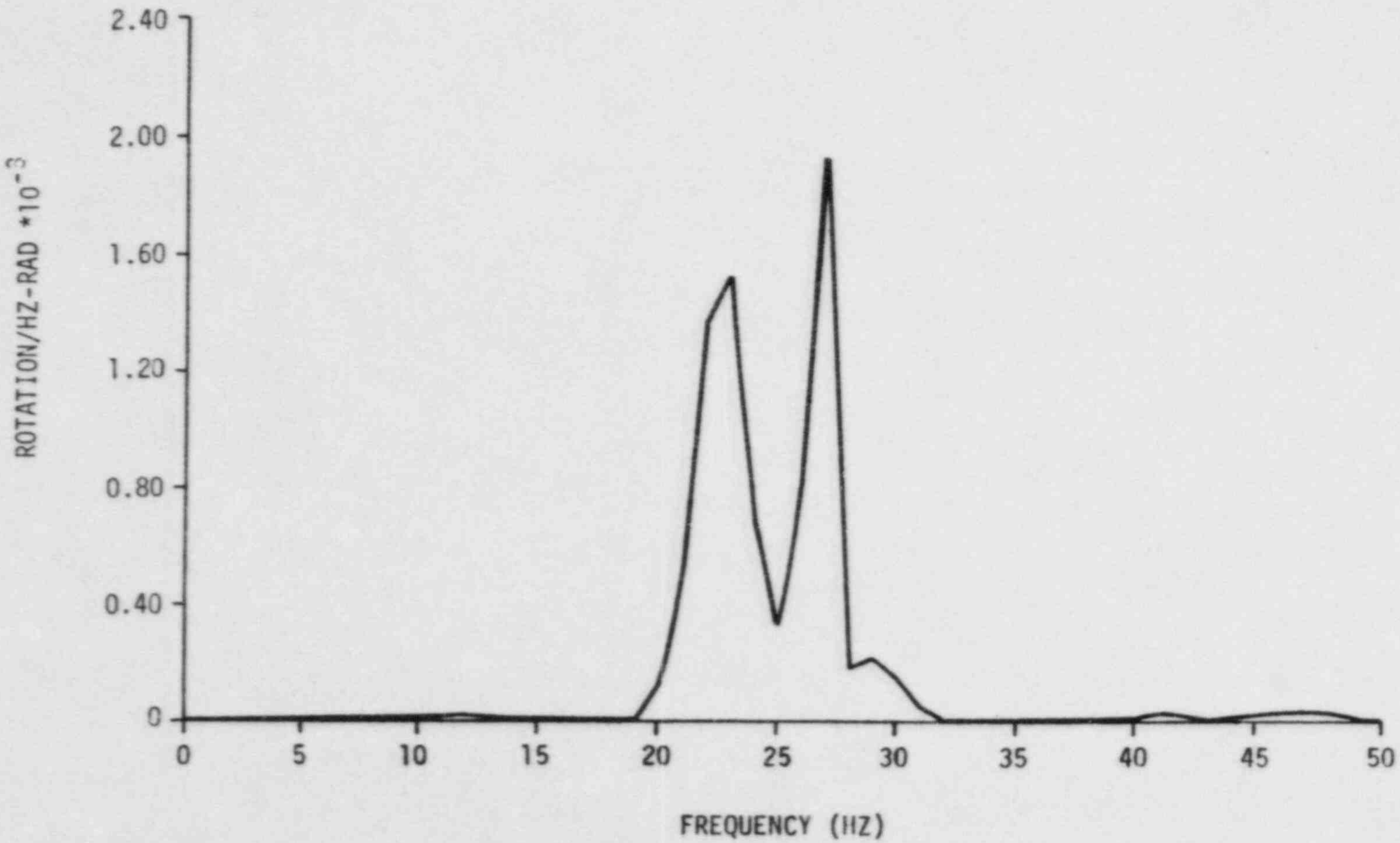


FIGURE A4-3

DBA CO SHELL RESPONSE-RADIAL

(UNLOADED SHELL-NODE 23)

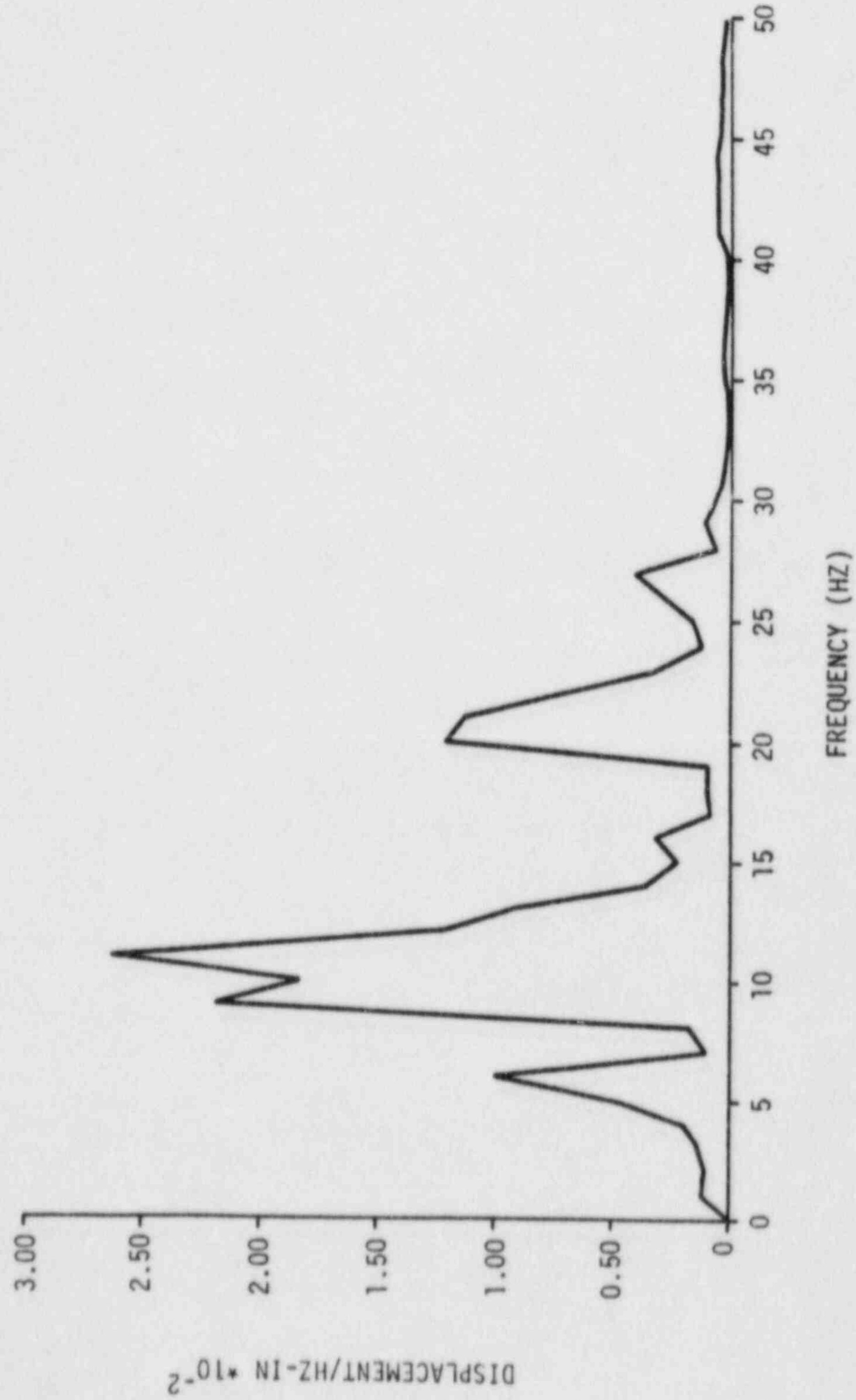


FIGURE A4-4

DBA CO SHELL RESPONSE-ROTATION

(UNLOADED SHELL-NODE 23)