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TECHNICAL REPORT

TELEDYNE ENGINEERING SERVICES

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MARK I CONTAINMENT PROGRAM

PLANT-UNIQUE ANALYSIS REPORT
OF THE
TORUS SUPPRESSION CHAMBER
FOR
PILGRIM STATION - UNIT 1

SEPTEMBER 14, 1984

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BOSTON EDISON COMPANY
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BRAINTREE, MASSACHUSETTS 02184

TECHNICAL REPORT TR-5310-1
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 TELEDYNE ENGINEERING SERVICES

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RECORD OF REVISIONS

<u>REVISION</u>	<u>PAGE</u>	<u>DESCRIPTION</u>
1	Cover	Changed Revision 0 to Revision 1 and date from October 27, 1982 to April 21, 1983
	Title	Changed Revision 0 to Revision 1 and date from October 27, 1982 to April 21, 1983
	ix	Added Table 4
	1	Changed Reference 9 to Reference 1
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	35	Deleted Reference 9
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vi		Added Appendix 4.
17		Correct saddle configuration on Figure 2-5 for Pilgrim.
51		Correct Figure 3-4 missing beams.
84		Figure 5-1: 20.50 dimension should be 23.5.
70		Seismic and Thermal result for Main Vent/Drywell Intersection supplied by BECO.
85		Figure 5-2: Correct saddle configuration and note "similar plant".

ABSTRACT

The work summarized in this report was undertaken as a part of the Mark 1 Containment Long-Term Program. It includes a summary of the analysis that was performed, the results of the analysis and a description of 19 significant modifications that were made to the structure and internals to increase safety margins.

In all cases, the stresses reported in this document meet the allowable levels as defined in the structural acceptance criteria (Reference 3). The methods and assumptions used in this analysis are in accordance with USNRC NUREG 0661 (Reference 2), except as noted in the text. The modifications described in this report are also in compliance with NUREG 0661, unless otherwise noted.

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1.0 GENERAL INFORMATION

The purpose of the Mark 1 Torus Program is to evaluate the effects of hydrodynamic loads resulting from a loss of coolant accident and/or an SRV discharge to the torus structure. This report summarizes the results of extensive analysis on the Pilgrim torus structure and reports safety margins against established criteria. The content of this report deals with the torus shell, external support system, vent header system and internal structures. Analysis and results for piping attached to the torus (including shell penetrations and internal piping), for the SRV line (except the submerged portion and tee-quencher), and for the SRV line vent pipe penetration will be presented in a separate piping report, TR-5310-2.

The criteria used to evaluate the torus structure is the ASME Boiler & Pressure Vessel Code, Section III, Division 1, with addenda through Summer 1977 (Reference 11) and Code Case N-197. Modifications were done under Section XI of the ASME Code and meet the Summer 1978 edition of Section III for design, materials and fabrication.

A great many technical reports have been written and issued as a part of this program. These reports provide detailed descriptions of the phenomena, the physics controlling the phenomena, calculational methods and detailed procedures for plant unique load calculations. Several of these documents are listed as references in this report. The approach of this report will be to reference these documents, wherever possible, and to avoid a re-statement of the same information.

A major part of this program has dealt with providing plant-unique load calculation procedures (Reference 1 is an example of this). In most cases, the loads used to support the analysis were calculated in strict accordance with those procedures, as amended by NUREG 0661 (Reference 2). In some cases, optional methods have been used; these methods are specifically referenced in

Program documentation. Examples of these are the use of plant-unique SRV test data to calibrate SRV analysis, and use of plant unique quarter scale pool swell movies to refine certain water impact and froth loads. In a few cases, analysis assumptions have been made that do not appear in Program documentation; these are identified in the text.

Extensive structural analysis was performed as a part of this evaluation. The major analysis was for dynamic response to time-varying loads. Analysis for static and thermal conditions was also done. The computer code used to perform almost all of this analysis was the STARDYNE code, as marketed by Control Data Corporation. STARDYNE is a fully qualified and accepted code in this industry; details of the code are available through CDC. Cases where a computer code other than STARDYNE is used will be identified in the text. All dynamic analysis used damping equal to 2% of critical, unless stated otherwise.

As an aid in processing the large amounts of calculated data, post-processors for the STARDYNE program were written and used. These programs were limited in function to data format manipulations and simple combinations of load or stress data; no difficult computational methods were included.

The loads and load combinations considered in this program required special consideration to determine the appropriate levels of ASME Code application. Reference 3 was developed to provide this standard. Table 5-1 of Reference 3 is the basis for all the evaluation work in this report; it is reproduced in this report as Table 1 and shows 27 load combinations that must be considered for each structure. The number actually becomes several times that when we consider the many different values associated with various SRV discharge conditions. The approach used in the final evaluation of structures is to reduce this large number to a smaller number of cases by conservative bounding. For example, load combinations including SSE seismic, have a higher allowable than the same combination with OBE seismic. For these cases, our first evaluation attempt is to consider the SSE combination against the OBE allowables. If this produces an acceptable result, those numbers are reported as final. This procedure results in many cases where safety margins are understated; this is the case for most of the results.

As an aid in correlating discussion of particular load analyses to detailed program documentation, most analysis described in this report has been referenced directly to a paragraph in the Load Definition Report (Reference 1). This has been done by identifying the applicable LDR paragraph in parenthesis immediately following the title of the load. This referencing directs the reader to a more detailed description of the load than can be included in this report.

2.0 PLANT DESCRIPTION

2.1 General Arrangement

The configuration of the Pilgrim torus structure is shown in Figures 2-1 and 2-2.

Figure 2-1 shows a plan view of the torus. It is made up of the sixteen (16) mitred sections, connected to the drywell by eight (8) equally spaced vent pipes. It is supported by two external columns and an intermediate saddle at each of sixteen places, as shown. The saddles and columns are connected to the basemat with eight anchor bolts per saddle. Four earthquake restraints, spaced equally around the torus, connect the belly of the torus to the basemat (Figure 3-10).

Figure 2-2 shows some of the inside arrangement. Ring girders reinforce the outer shell at each of the sixteen planes defined by the external support system. The vent header system is supported off of the ring girders and is directly connected to the drywell via the vent pipes. Openings where the vent pipes penetrate the torus shell are sealed by bellows. The ring girder also supports the catwalk, spray header and SRV tee-quenchers. Figures 2-3 to 2-21 show several details of the torus structure. Table 2.0 lists several of the plant specific dimensions.

2.2 Recent Modifications

Over the period of the past few years, many modifications have been made to the Pilgrim torus, both to increase its strength and also to mitigate the hydrodynamic loads. The modifications are illustrated and listed in the composite sections of Figures 2-3 and 2-4, along with their installation dates. A description and illustration of each individual modification follows:

2.2.1 Modifications to Reduce Hydrodynamic Loads

Drywell Pressurization System (ΔP System)

Installation of a system to maintain a pressure differential between torus and drywell was the first modification of this Program. The system is illustrated in Figure 2-5. It is designed to maintain a minimum positive pressure difference of 1.17 psi between the vent system (drywell) and the airspace inside the torus. The result of this pressure difference (ΔP) is to depress the water leg in the downcomers and reduce the water slug that must be cleared, if rapid pressurization of the drywell occurs. Early generic testing in the Program demonstrated that this was an effective means to reduce shell pressures related to DBA pool swell. The 1.17 psi pressure difference was selected as the basis for the Pilgrim plant unique quarter-scale pool swell tests and is intended to be the normal operating condition of the plant. The system complies with NUREG 0661, which requires two narrow range instrument channels with less than ± 0.1 psid error. Pilgrim Station uses a narrow range instrument for drywell-to-wetwell ΔP and backup instruments to measure drywell and wetwell pressures separately. The maximum error for the above instruments is $\pm .08$ psid.

Downcomer Shortening

Downcomer shortening is an additional means of reducing the water slug that must be cleared from the downcomers during rapid drywell pressurization. Its primary advantage is to reduce pool swell loads during those periods of time when the ΔP system may be inoperative. It also allows for a very small water leg during normal operation, without the problems associated with higher drywell pressures. The downcomers at Pilgrim were cut to provide a minimum submergence of 3.0 feet (distance from bottom of downcomer to minimum torus water level).

Vent Header Deflector

The vent header deflector at Pilgrim is illustrated in Figures 2-6 and 2-7. It is a 16-inch schedule 120 pipe with $\frac{1}{2}$ -inch plate welded to the sides.

The deflector extends under the belly of the vent header to protect the vent header from direct water impact during pool swell. It shields the most sensitive part of the vent header by separating and diverting the rising pool before it can reach the vent header. This deflector was included in the plant unique pool swell tests for Pilgrim to provide accurate vent header loading for detailed analysis.

SRV Tee-Quencher

A tee-quencher has been installed at the discharge end of each main steam relief line to replace the existing ramsheads. A typical quencher and its support are illustrated in Figure 2-8. The quencher serves to divide the SRV discharge bubble into hundreds of smaller bubbles and to distribute them over an entire bay. This division and distribution of SRV discharge has been shown in generic testing to reduce torus shell pressure by factors of two or more when compared to ramshead pressures. The plant-unique characteristics of these devices at Pilgrim were determined by in-plant testing after their installation. End cap holes in the tee-quencher were also provided to promote suppression pool mixing and minimize temperature gradients.

The quencher support is also illustrated in Figure 2-8. It is a 20-inch schedule 120 pipe welded to the ring girder, as shown.

Temperature Monitoring System & RHR Return Lines

The addition of a pool temperature monitoring system and an elbow to the discharge end of the RHR return lines are both intended to assure proper operation of the SRV quencher. These modifications are illustrated in Figures 2-9, 2-10, 2-17 and 2-20.

The temperature monitoring system senses pool temperature through a set of 26 sensors set in thermowells around the torus shell (Figures 2-17 and 2-20). Of these 26, 12 are mounted in redundant pairs (6 locations)

to sense local pool temperature*. The remaining 14 are mounted in seven redundant pairs and are used along with the local sensors to determine bulk pool temperature. The system is hard wired to a console in the control room.

The elbows on the RHR return lines were added to improve pool circulation during periods of extended SRV blowdown. Circulation of the pool with these lines assures that local-to-bulk temperature differences will be minimized and that SRV quencher performance will be maintained for the maximum possible time during extended discharge. These two RHR return lines were further modified by re-routing them to the ring girders. The ring girders react drag loads on these lines and also provide for reactions due to elbow discharge loads (see Figure 2-10).

Additional SRV Vacuum Breakers

Each of the four SRV discharge lines at Pilgrim has been fitted with two, ten-inch vacuum breakers, in addition to the original one-inch vacuum breakers. This modification minimizes the temporary formation of the high water leg in the SRV line which could occur due to steam condensation oscillation after an initial actuation; and thereby prevents the high clearing loads which could occur if a second actuation occurred at that time. The location of these devices is different on each SRV line due to space constraints, and is not illustrated.

Removal of Submerged Piping

Some of the piping inside the torus extended to greater depths than was necessary for its proper functioning. This additional submergence resulted in drag loads on the piping that was unnecessary. In order to reduce the loads, these piping systems were cut off to provide a three-foot

*The six local pairs are located in the six SRV tee-quencher bays. Only four of these quenchers are operative; the other two are not connected to the steam relief lines and have been installed for possible future use.

submergence at minimum torus water level. The five lines affected were the HPCI exhaust, RCIC exhaust, HPCI drain, RCIC drain and a 18-inch diameter spare line.

In addition, the eight vent drain lines (one-inch diameter) were cut off and capped above the pool. In the future, any condensation in the vent system will be manually drained, as required.

Removal of Monorail

The monorail originally installed at Pilgrim was a low capacity unit of relatively light design. Modification of the unit to withstand worst-case froth loads was judged impractical. The monorail was removed, and not replaced.

2.2.2 Modifications to Strengthen the Structure

Torus Support Saddles and Anchor Bolts

Support saddles were added under each ring girder as shown in Figure 2-11. The saddles, support columns and ring girder all lie in the same plane and react all vertical loads on the torus - most of the load is reacted by the saddle.

Each saddle is constructed of 1½-inch type SA 516 GR 70 steel web plates, which are welded to the torus shell at the top, and to a clevis/sole plate assembly on the bottom. Anchor bolt attachments are welded to the web plates and clevis sole plates, and eight anchor bolts per saddle restrain upward motion. A total of 128, two-inch diameter Williams Rock Bolts were installed, with a 24-inch minimum embedment into the basemat.

The anchor bolt restraints are set with a small clearance, and the sole plates rest on lubrite plates, to allow for normal radial growth of the torus due to temperature changes. The lubrite plates rest on a bed plate which is grouted to the basemat.

Installation of the saddles required relocation of the 18-inch core spray lines, to eliminate interference problems.

Torus Support Columns and Bases

The torus columns were welded to the saddle webs and the bases will be held down by using the existing "J" bolts (two per column). Figure 2-12 shows one of the two beams that bridge the base holding down the column. There is a gap between the beam and base that will allow for thermal growth, radial movement of the column sliding on the lubrite plate.

Downcomer Tie-Rods and Vent Header Gussets

The downcomer tie-rods and vent header gussets are illustrated in Figure 2-13.

The tie-rods are constructed from 2½-inch schedule 40 pipe and provide greatly increased capacity to downcomer lateral loads than the original tie bars. They are attached to the downcomers with specially fabricated 24-inch pipe clamps, constructed from ¾-inch steel. The clamps are prevented from sliding on the downcomers by welded steel clips both above and below the clamp.

The gussets between the downcomers and vent header are to reduce local intersection stresses due to chugging lateral loads on the downcomers. They are constructed from ½-inch thick SA 516 GR 70 steel plate, and are welded to the vent header and downcomers.

Ring Girder Weld Modification

The weld between the ring girder and the torus shell will be increased in the area of the tee-quencher as illustrated in Figure 2-21. The existing 5/16-inch fillet weld was increased to ½-inch, as shown, to help react and distribute the lateral tee-quencher reaction loads due to SRV discharge.

Catwalk and Handrail

The catwalk and handrail at Pilgrim required substantial modification, as illustrated in Figures 2-14 and 2-15. The planned or completed modifications included the following:

- Replacement of original catwalk extension support columns with four-inch diameter pipe columns.
- Addition of bracing between catwalk channels.
- Addition of lateral supports.
- Addition of grating restraints.
- Replacement of handrails.

Electrical Junction Box Modification

There are two large, barrel-shaped, electrical junction boxes inside the Pilgrim torus. These boxes are mounted at the top of the torus, in the path of both froth 1 and froth 2 impingement loads. They are constructed with sheet metal covers which could deform under these loads.

The junction box covers were strengthened by the addition of external reinforcement as shown in Figure 2-19. The reinforcement consists of three longitudinal struts connected to two rings which encircle the box and prevent buckling from occurring.

Drywell-Wetwell Vacuum Breaker Support

The attachment between the wetwell vacuum breaker mounting stub and the end cap of the vent pipe was strengthened by the addition of three gussets as illustrated in Figure 2-18. This modification assures

acceptable stress levels in the intersection, during postulated pool swell impact. There are ten vacuum breakers at the Pilgrim Plant.

Spray Header Support Modification

The spray header piping inside the torus is hung from the ring girder at the top of the torus, as illustrated in Figure 2-3. The original supports for this line was a "U" shaped rest support which could not react upward loads. These were modified as shown in Figure 2-16 to react the upward loads associated with pool swell and froth.

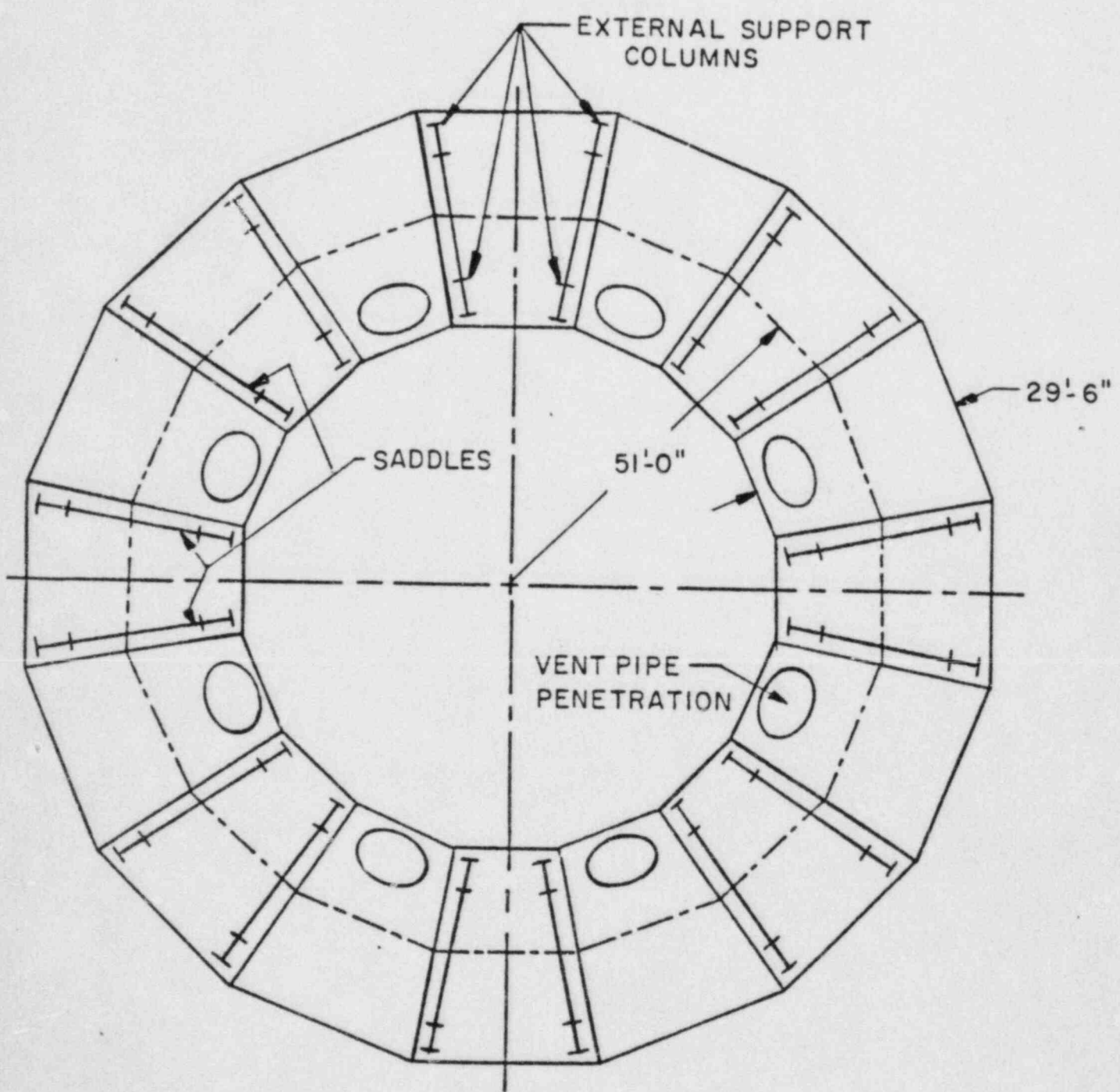


FIG. 2-1
TORUS PLAN VIEW

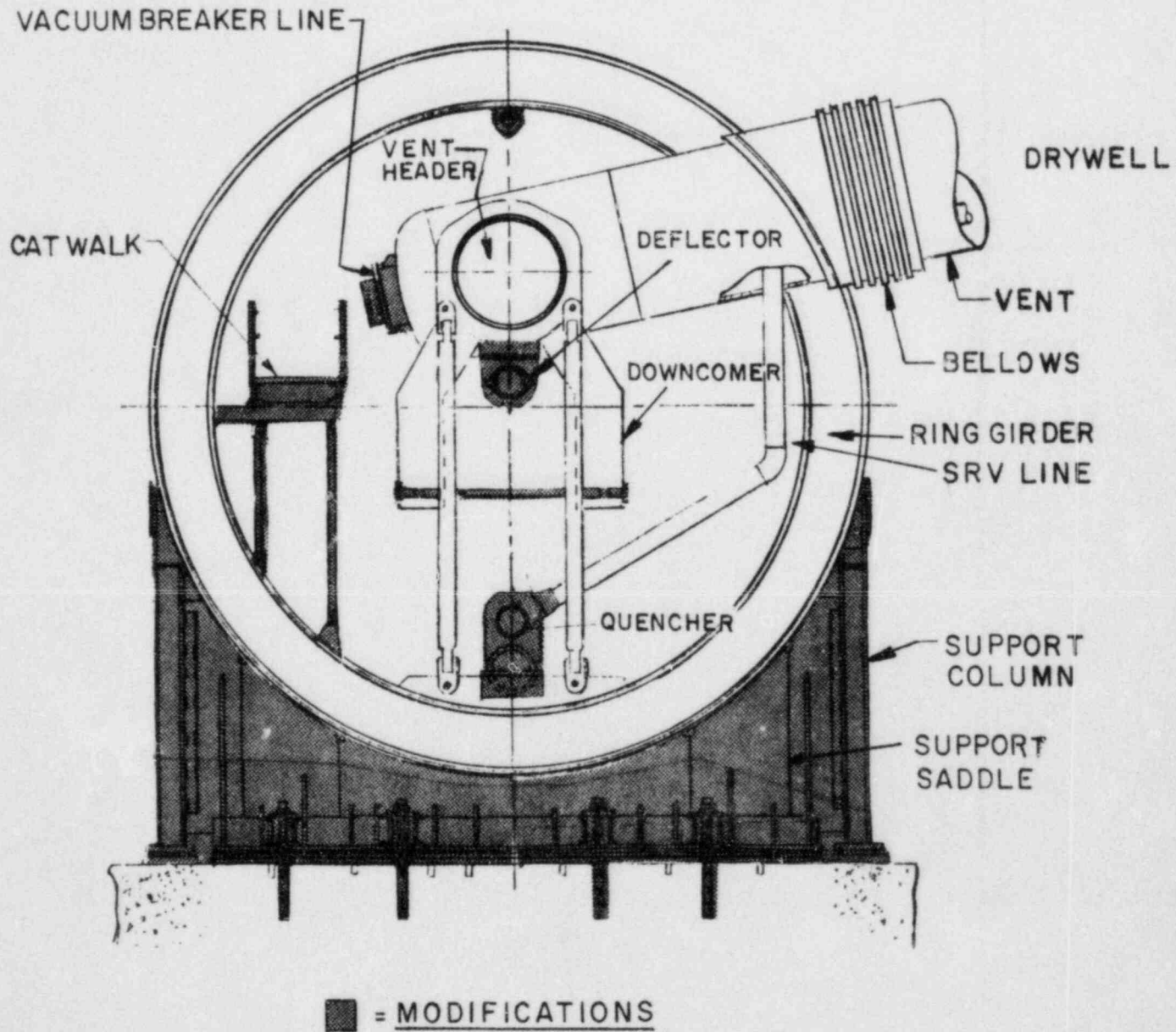
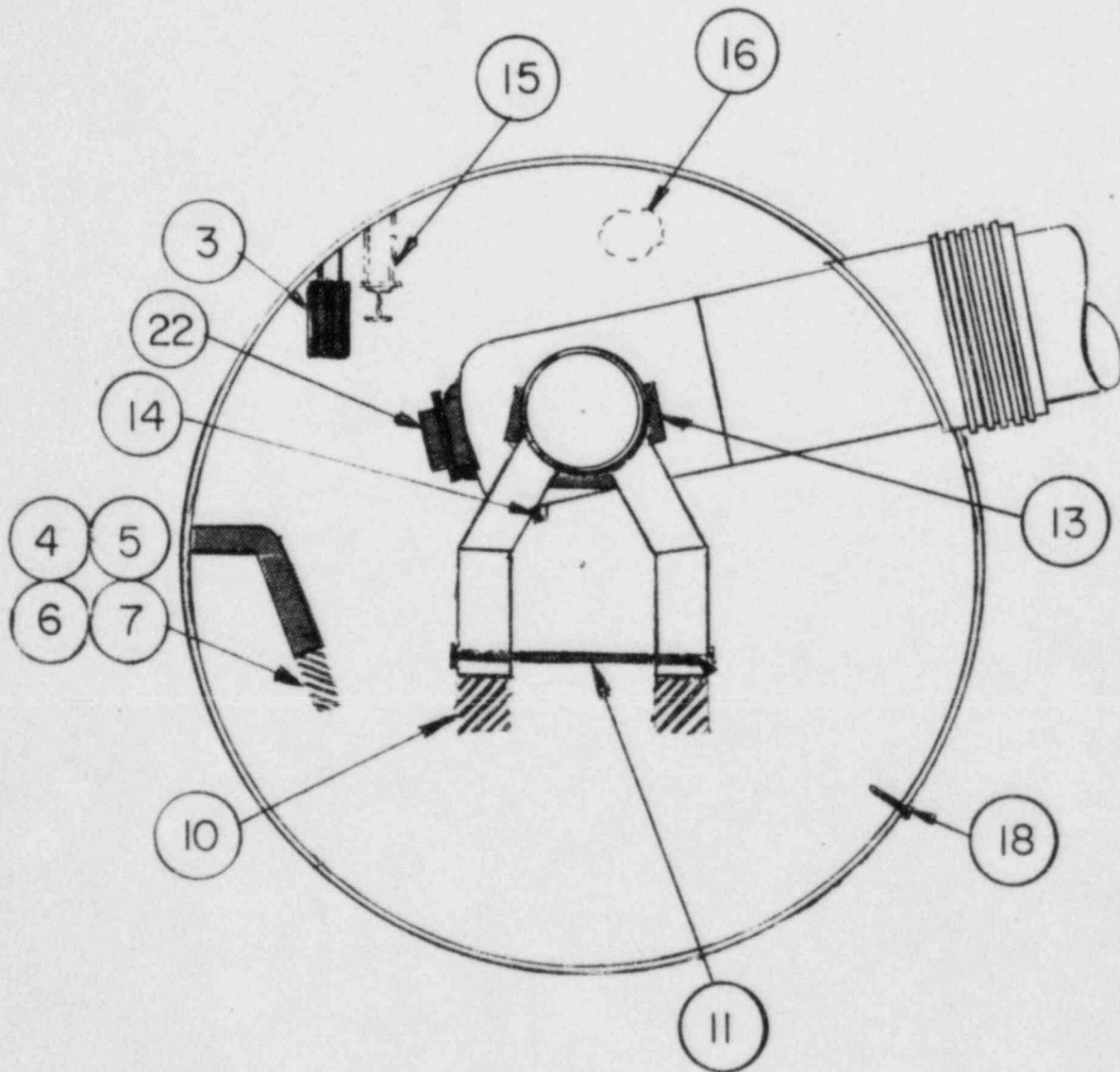


FIG. 2-2

TORUS COMPOSITE CROSS SECTION - PILGRIM

KEY FOR FIGURES 2-3 AND 2-4

<u>Modification</u>	<u>Completion Date</u>
1. Reenforce Supports on 4" Spray Header	12/81
2. RHR Elbow Return	5/80
3. Strengthen Electrical Penetrations	12/81
4. Shorten HPCI Exhaust Line	12/81
5. Shorten RCIC Exhaust Line	12/81
6. Shorten HPCI & RCIC Drain Lines	12/81
7. Shorten 18" Spare Line	12/81
8. Mitred Joint Saddle	5/80
9. Saddle Anchor Bolts	4/82
10. Shorten Downcomers	12/81
11. Downcomer Ties	5/80
12. Vent Header Deflector	5/80
13. Vent Header Downcomer Stiffening	12/81
14. Vent and Drain Cut and Cap	12/81
15. Monorail - Remove	12/81
16. Drywell to Wetwell P Control	1976
17. Add Temperature Monitoring System (Except Thermowell) Prior to fuel cycle #7	
18. Thermowells	5/80
19. Add Larger Vacuum Breakers to the SRV Line in Drywell and Support Lines	5/80 & 12/81
20. Add Tee-Quenchers	5/80
21. Tee-Quencher Supports	5/80 & 12/81
22. Wetwell Vacuum Breaker Penetration Modification	12/81
23. Catwalk Modifications	12/81 & prior to fuel cycle #7
24. Increase Ring Girder Weld	Prior to fuel cycle #7
25. Column Base Holddown	Prior to fuel cycle #7



■ = MODIFICATIONS

FIG. 2-4
TORUS MODIFICATIONS - CROSS SECTION AT MID BAY

1.17 PSIG - PRESSURE MAINTAINED BY N₂
INERTING SYSTEM

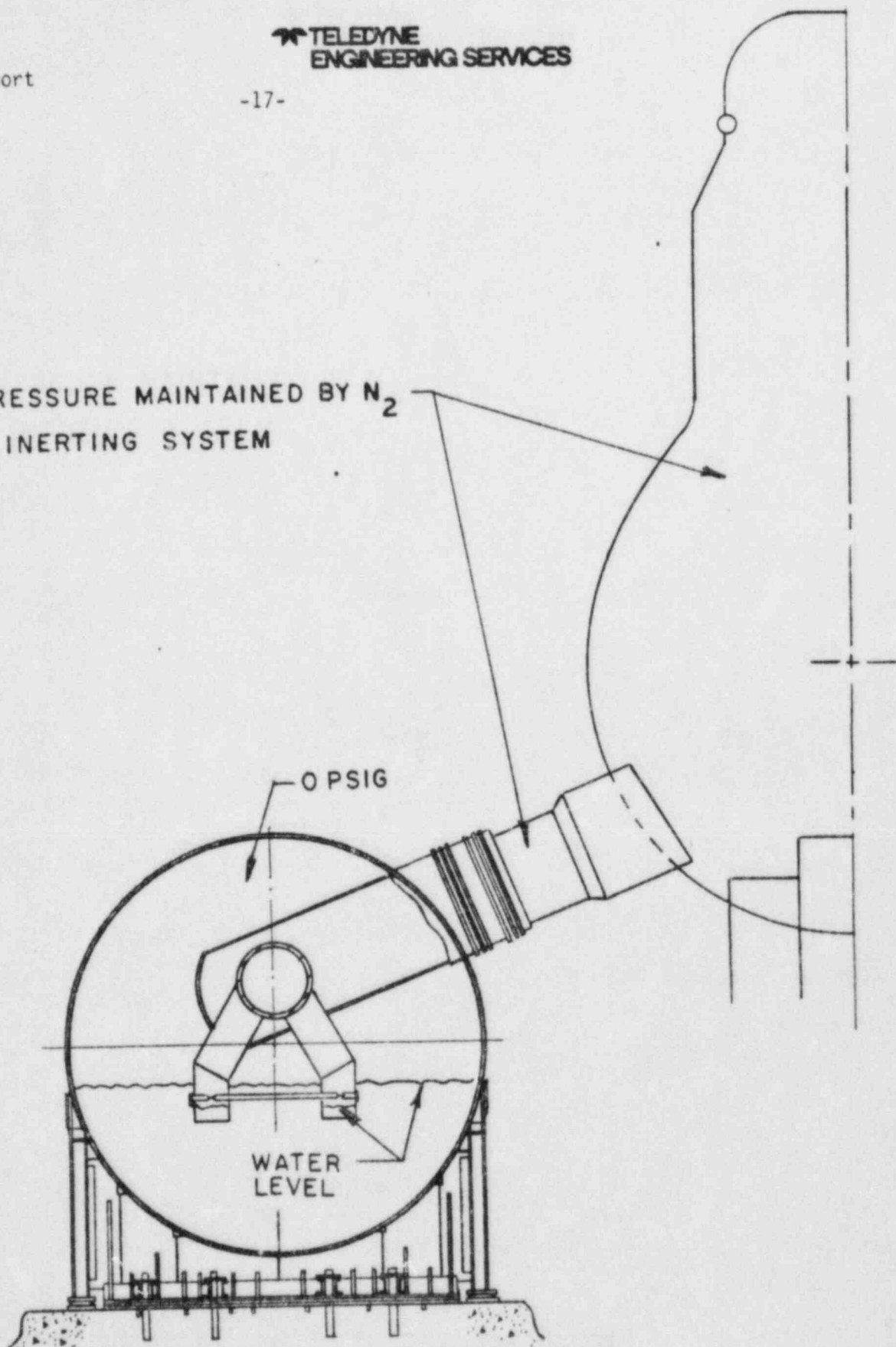


FIG.2-5
ΔP PRESSURIZATION SYSTEM

-18-

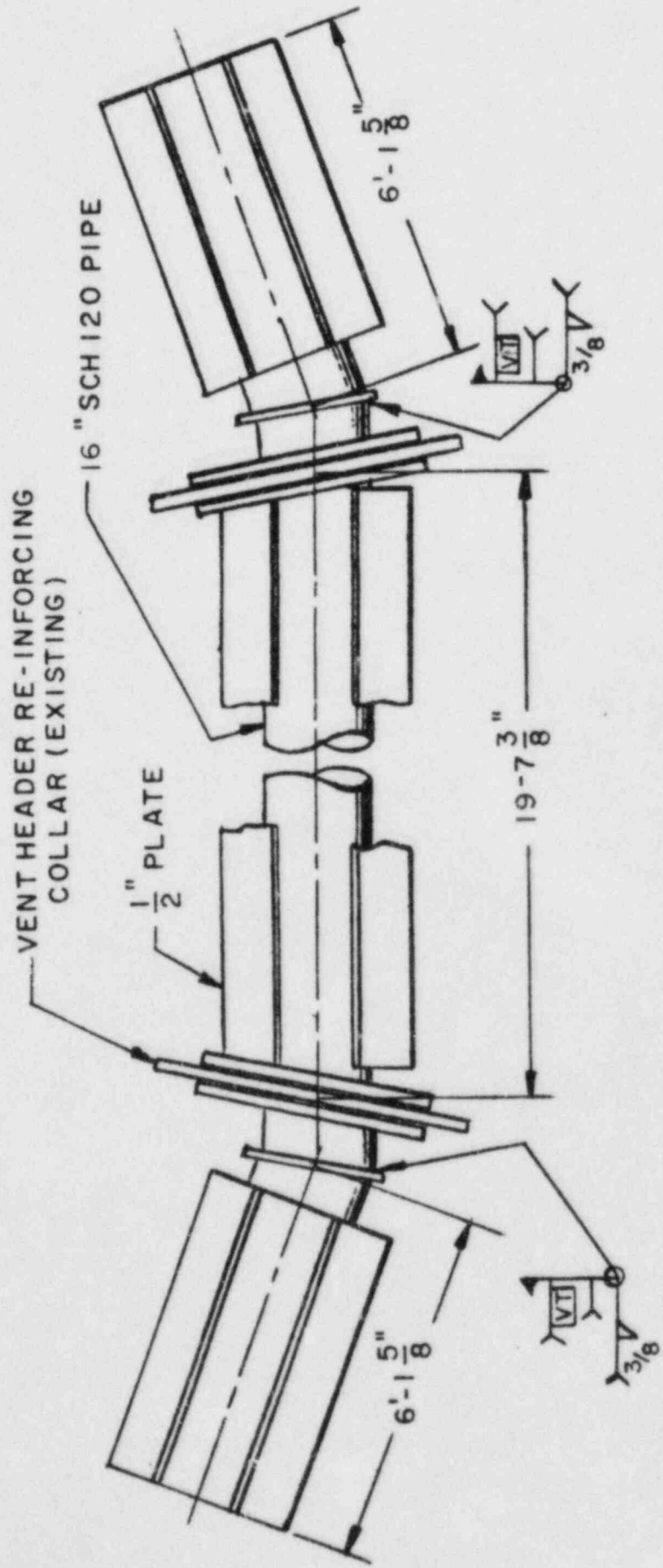


FIG. 2-6
VENT HEADER DEFLECTOR

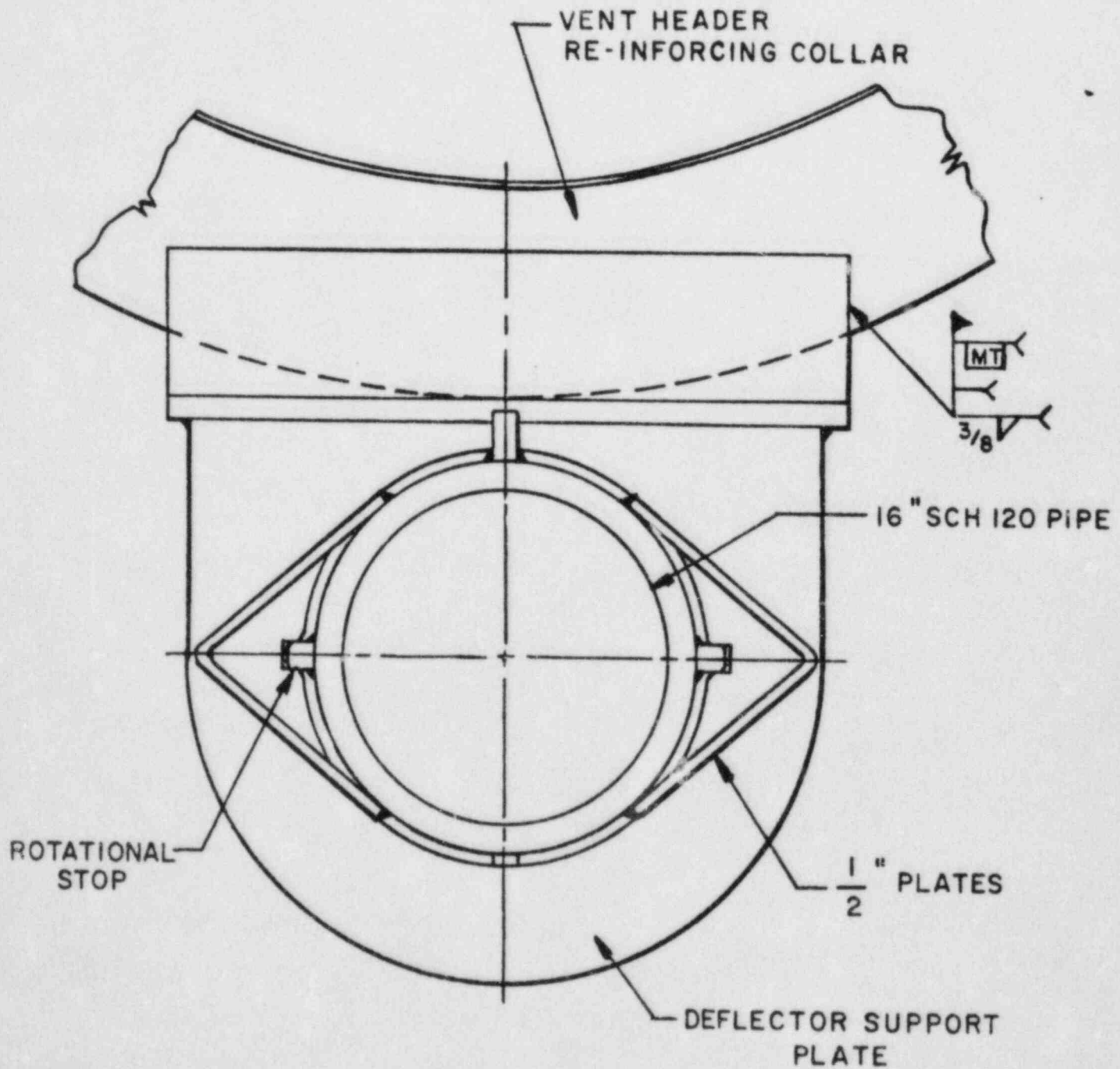
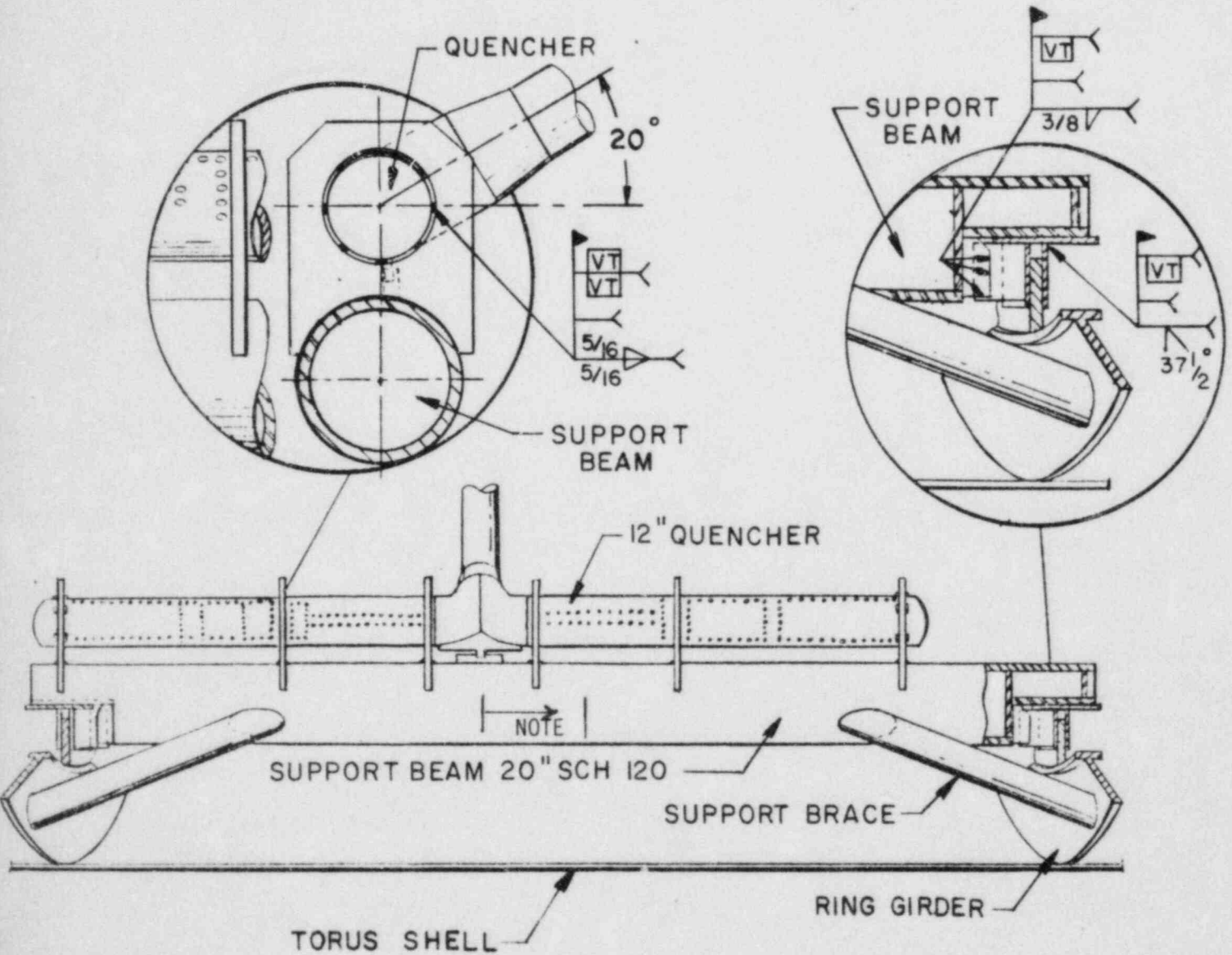
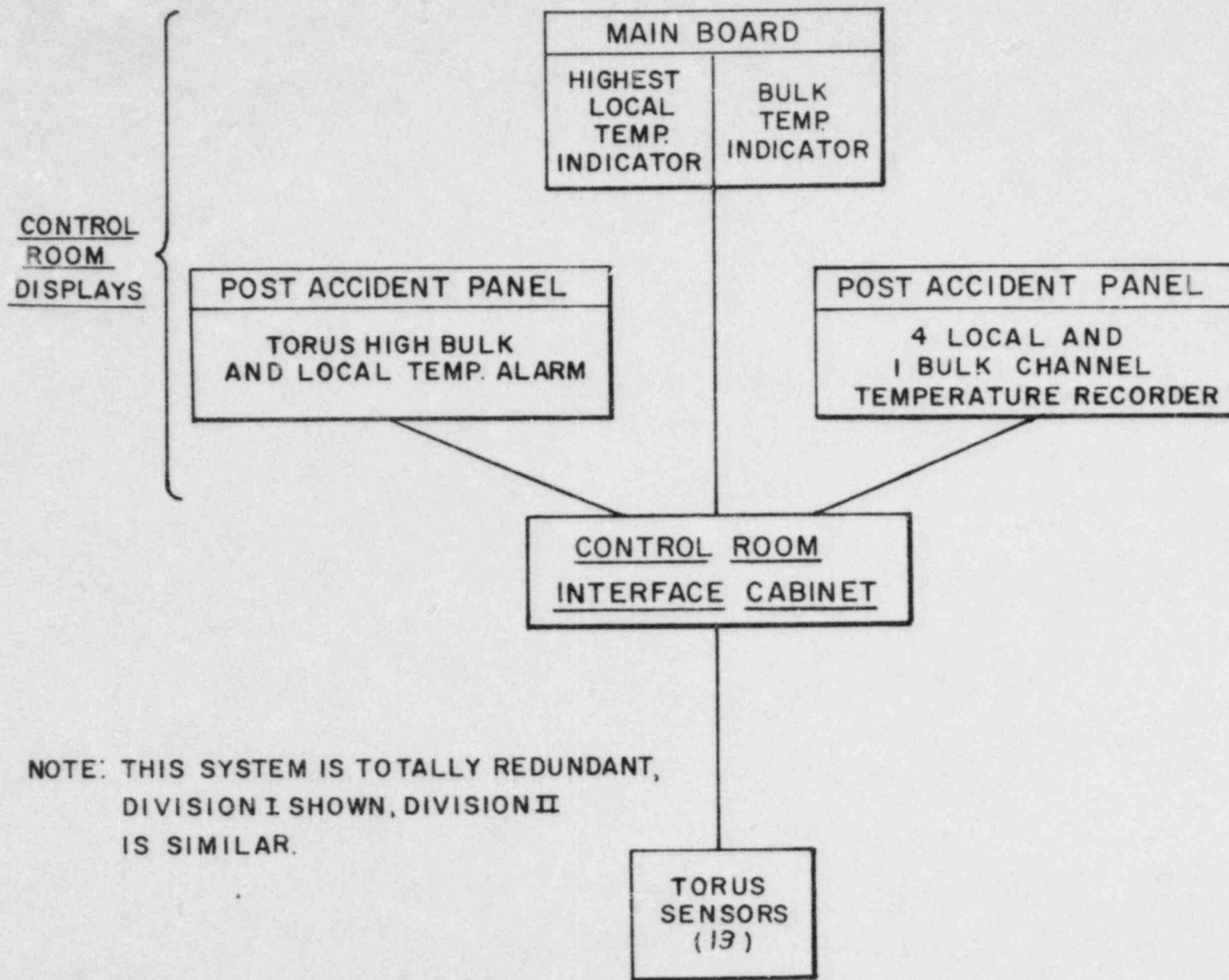


FIG. 2-7
VENT HEADER DEFLECTOR ATTACHMENT



NOTE: QUENCHER IS CENTERED ON
SUPPORT BEAM FOR PILGRIM

FIG. 2-8
SRV TEE-QUENCHER & SUPPORT
PILGRIM



NOTE: THIS SYSTEM IS TOTALLY REDUNDANT,
DIVISION I SHOWN, DIVISION II
IS SIMILAR.

FIG. 2-9
POOL TEMPERATURE MONITORING SYSTEM

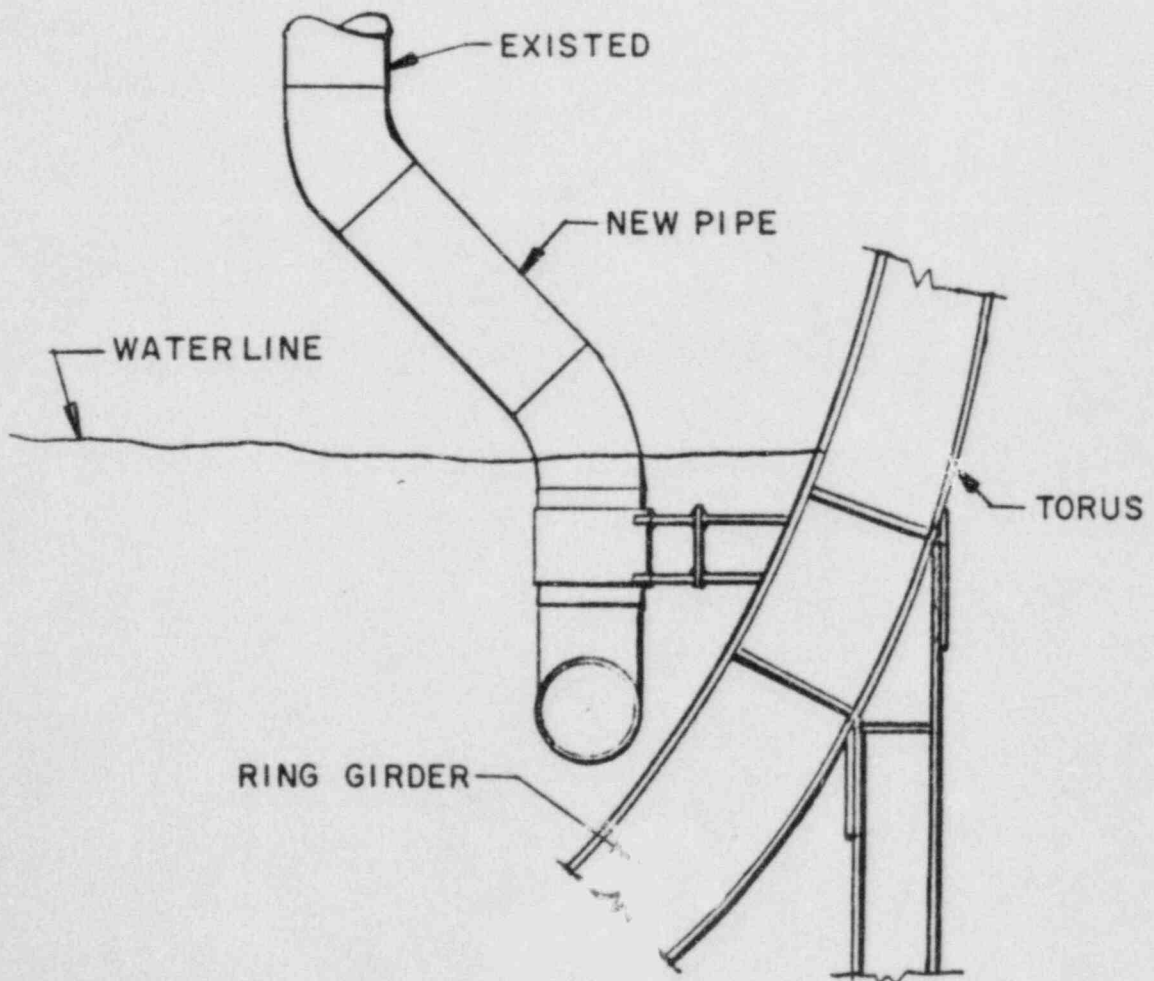
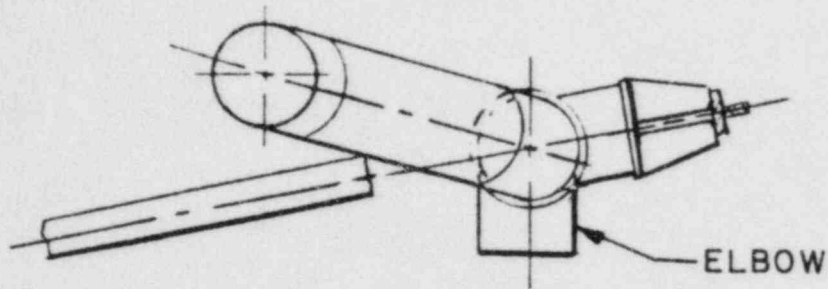


FIG.2-10
RHR RETURN LINE ELBOW & SUPPORT

-23-

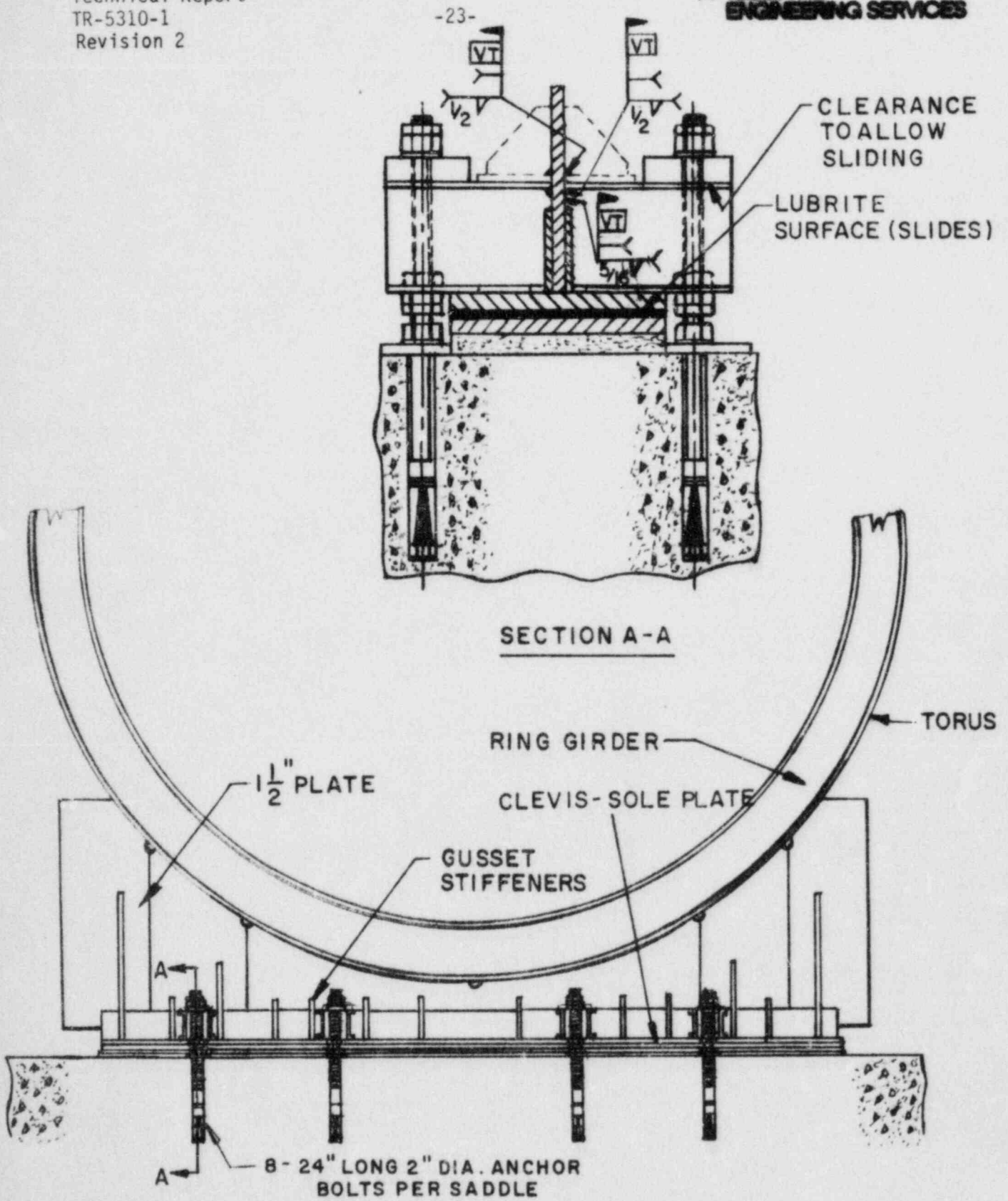


FIG. 2-II

TORUS SUPPORT SADDLES & SADDLE ANCHORS

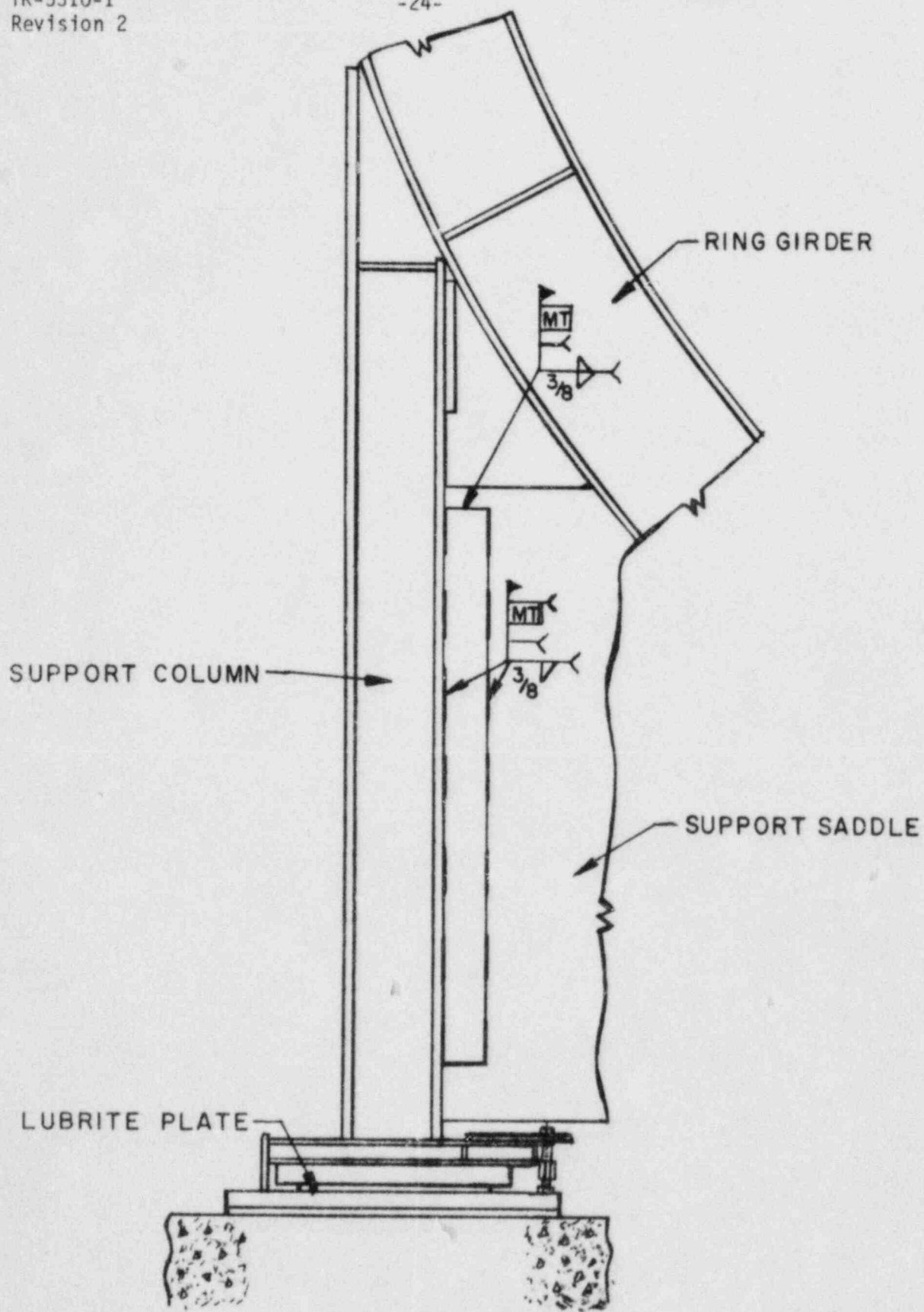


FIG. 2-12
TORUS SUPPORT COLUMNS

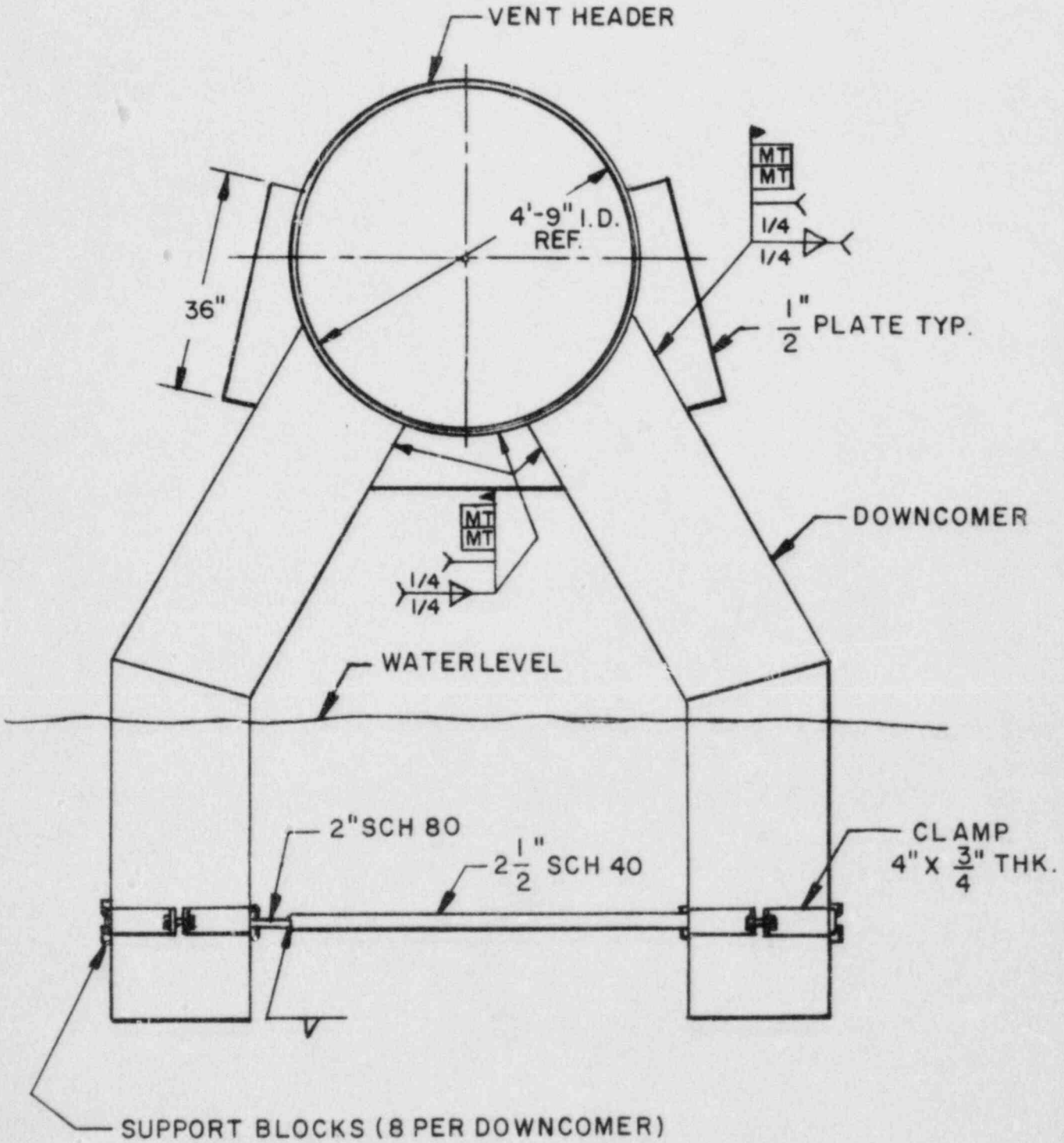
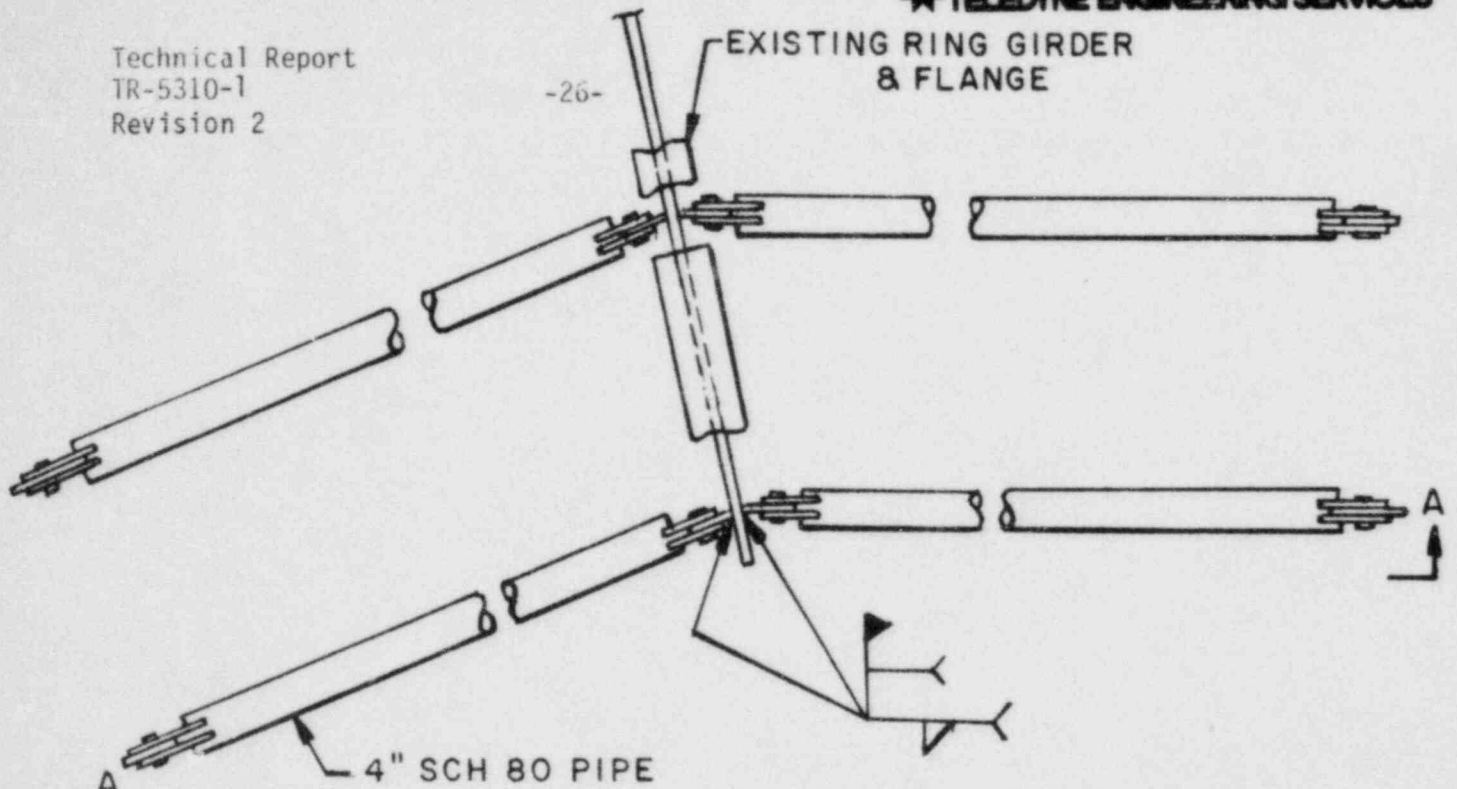


FIG. 2-13
DOWNCOMER TIE-ROD & GUSSET MODIFICATION

Technical Report
TR-5310-1
Revision 2

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EXISTING RING GIRDER
& FLANGE



RING GIRDER

EXISTING WALKWAY

EXISTING
LEG 4 X 4
ANGLE

4" SCH 80 PIPE

EXISTING RING GIRDER

ELEV. A-A

FIG. 2-14
CATWALK & HANDRAIL MODIFICATION

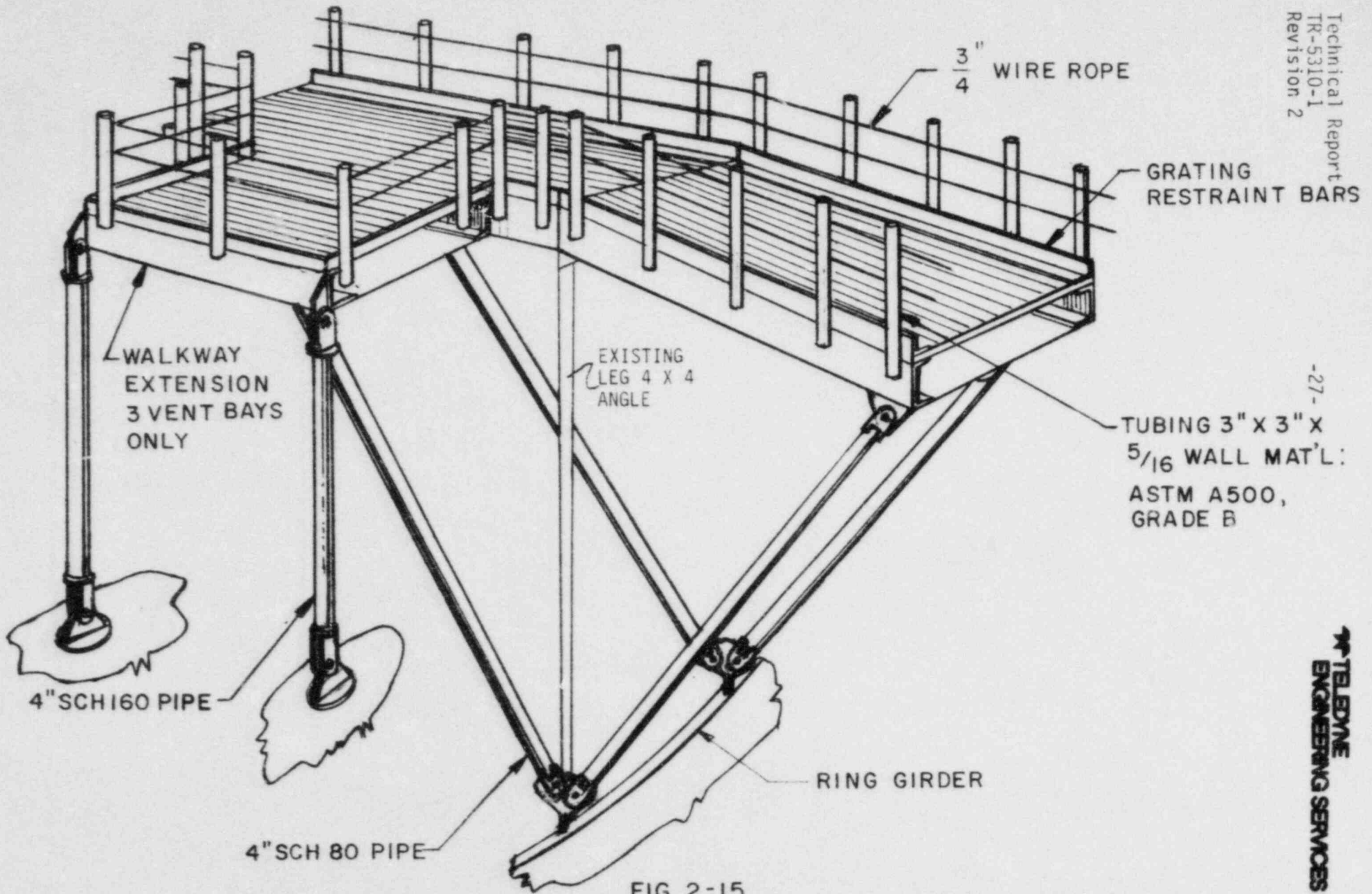


FIG. 2-15
CATWALK & HANDRAIL MODIFICATION

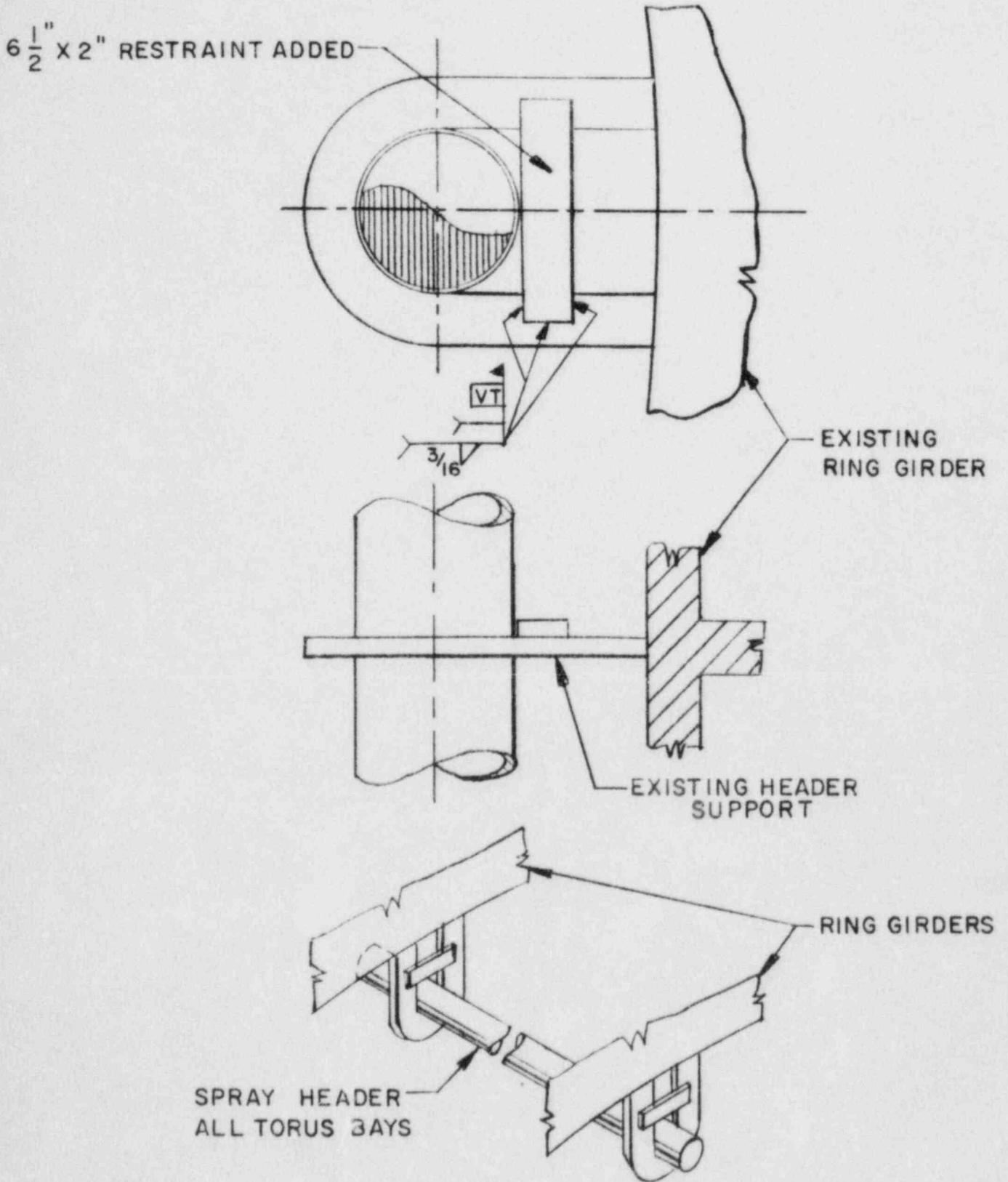


FIG. 2-16

TORUS SPRAY HEADER SUPPORT MODIFICATIONS

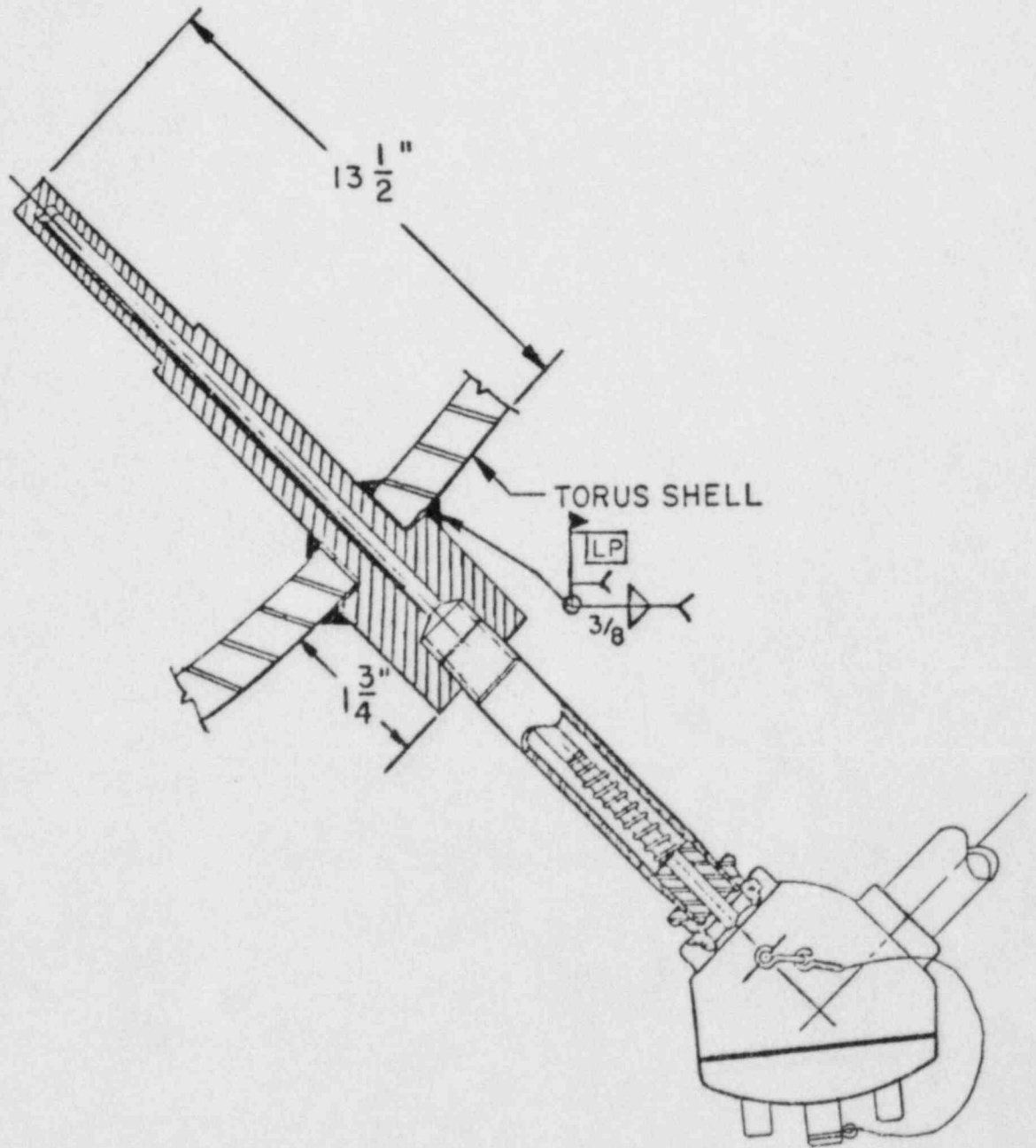


FIG. 2-17
THERMOWELL DETAIL

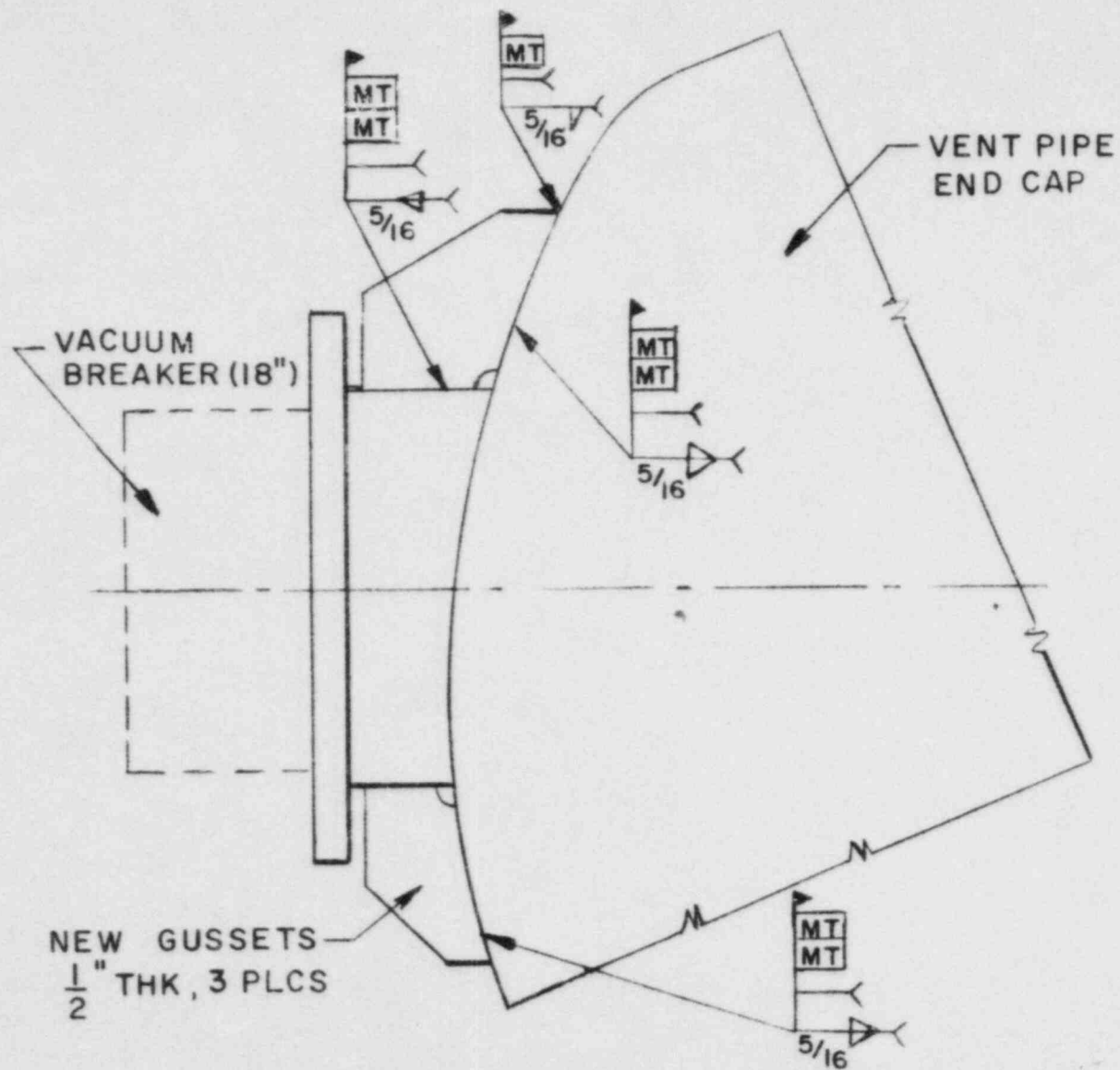


FIG 2-18

VACUUM BREAKER-VENT INTERSECTION MODIFICATION

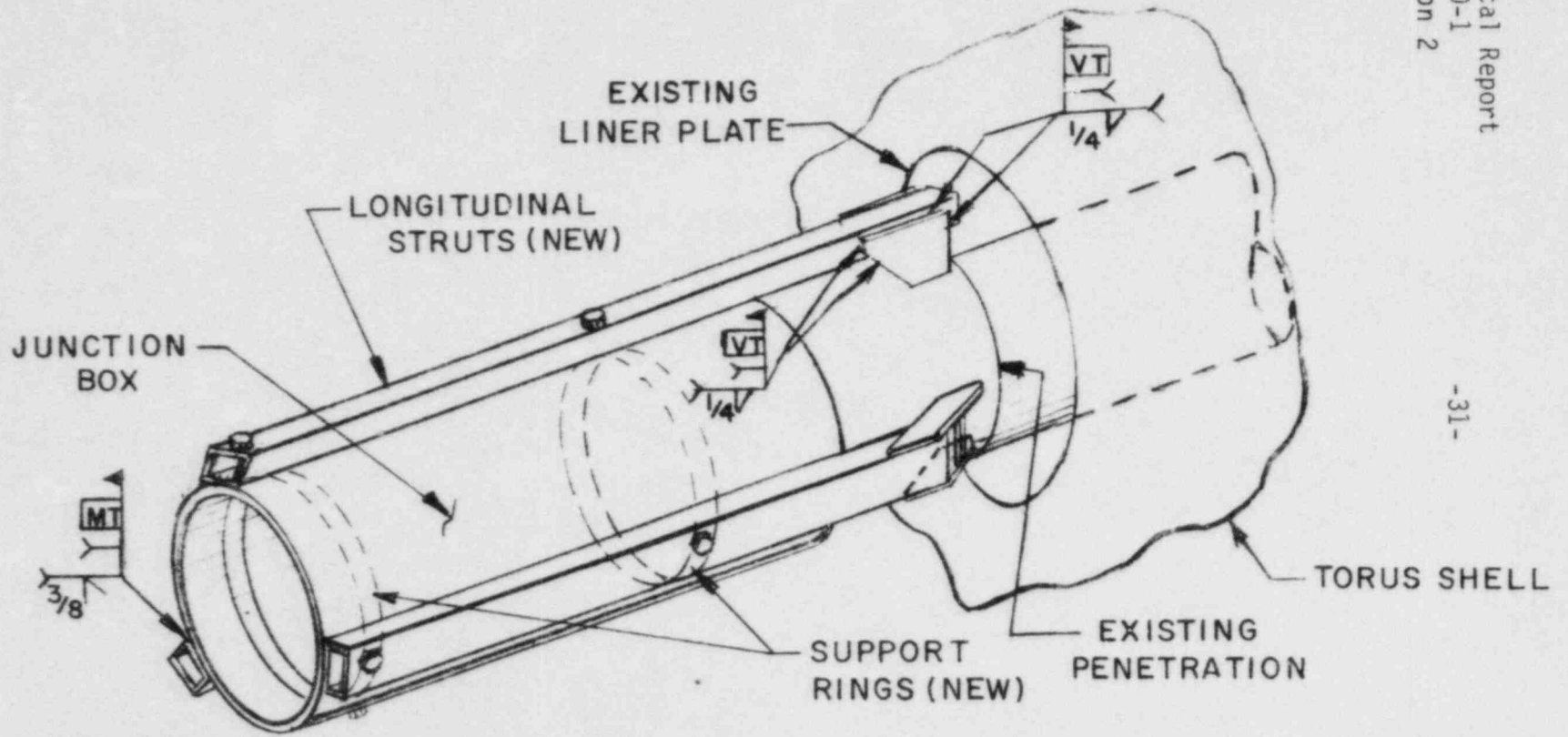


FIG. 2-19
ELECTRICAL JUNCTION BOX MODIFICATION

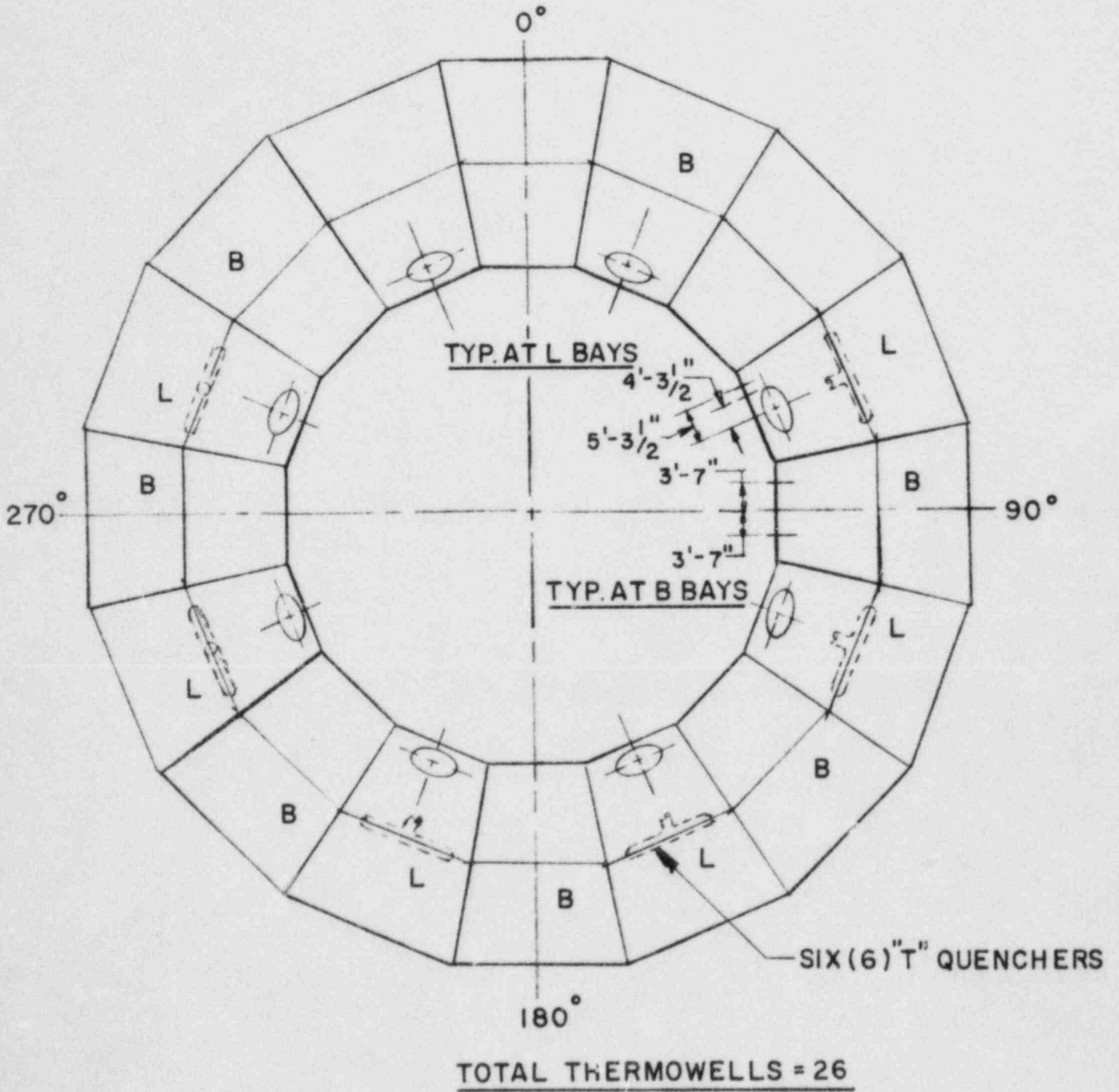


FIG. 2-20
THERMOWELL LOCATIONS - PILGRIM

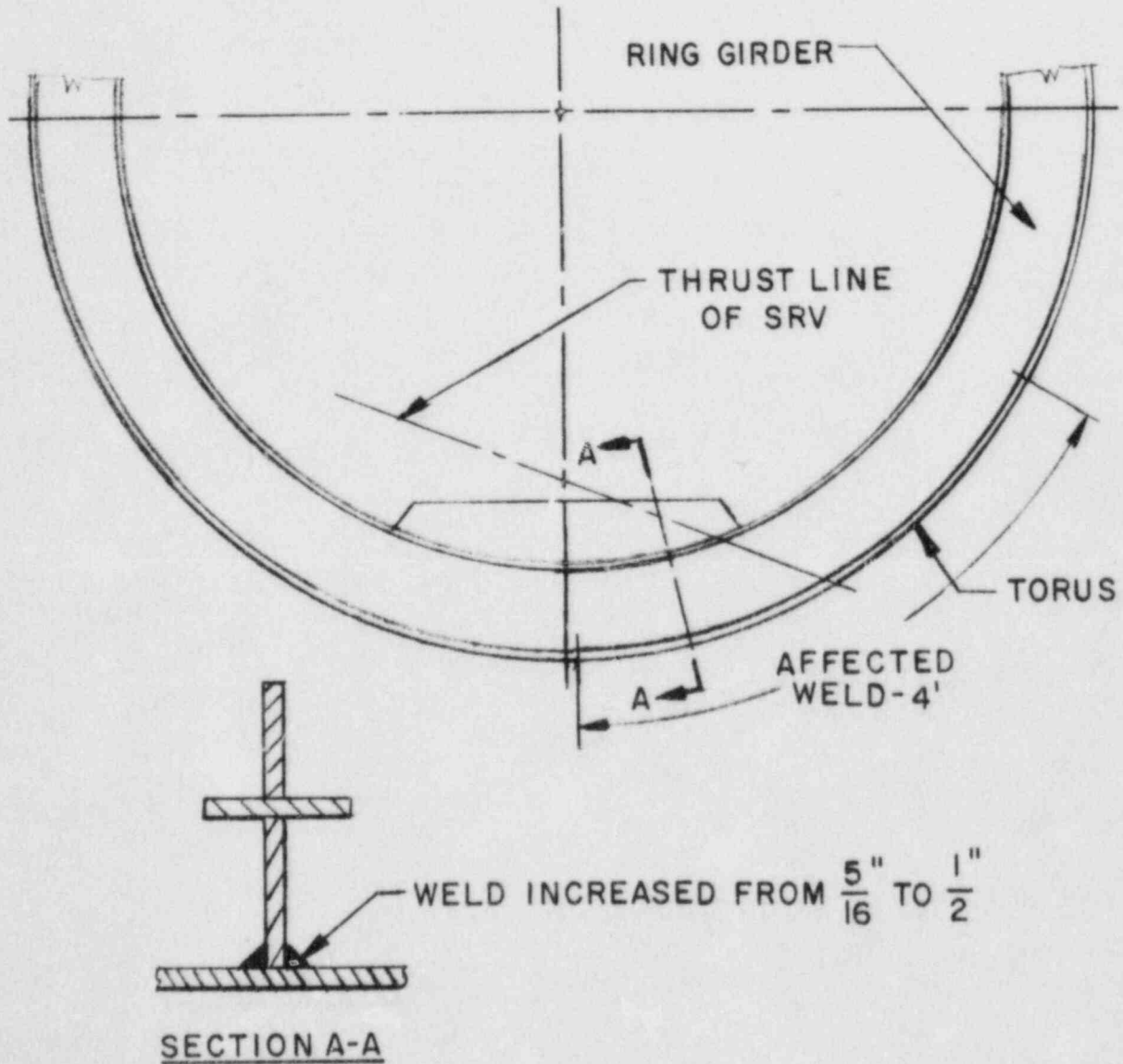


FIG. 2-21
RING GIRDER WELD MODIFICATION

3.0 CONTAINMENT STRUCTURE ANALYSIS - OUTER SHELL & EXTERNAL SUPPORT SYSTEM (INCLUDING ANCHORS)

The containment structure section of this report includes the analysis and evaluation of the following structures:

- Torus Shell
- Support Columns
- Column-To-Torus Weld
- Support Saddles
- Saddle-to-Torus Weld
- Earthquake Restraints & Attachment
- Anchor (Tie-Down) System

3.1 Computer Models

Analysis of the containment structures was accomplished using the computer models shown in Figure 3-1 to Figure 3-4. The detailed shell model shown in Figure 3-1 was used to calculate the effects of all loads on shell stress, as well as all symmetric loads on the support and anchor system. The beam model shown in Figure 3-4 was used to determine the effects of asymmetric loads on the support system. Asymmetric loads on the torus structure are horizontal earthquake, SRV and chugging. Evaluation of the support system considered the combined effect of symmetric and asymmetric loads in accordance with the load combination table (Table 1).

The detailed finite element model shown in Figure 3-1 simulates one-half of the non-vent bay. It is bounded by the ring girder on one end and the mid-bay point on the other. The vent header system is assumed to be dynamically uncoupled from the shell by the support saddles and is not included in this model. This model was constructed with the assumption that the small offset that exists between the ring girder and mitre joint will not affect results; accordingly, the offset is not included in the model.

This model includes 513 structural nodes, 518 plate elements, 2242 static degrees and 364 dynamic degrees of freedom. Symmetric boundary conditions were used at both ends of the model.

The model was modified for various load calculations to account for differences in the percent of the water mass that is effective for that load event. In all cases, modeling of the water mass was accomplished using a 3-D virtual mass simulation as an integral part of the structural analysis. The percent of water mass used is identified in the discussion of each load calculation that follows.

The 360⁰ beam model of the torus is shown in Figure 3-4. This model was used to evaluate the effects of lateral loads on the support system and earthquake restraint system. The beam element properties were selected to simulate combined bending and shear stiffness of the sections. Water mass was lumped with the structure weight on the wetted nodes.

3.2 Loads Analysis

3.2.1 Pool Swell Loads (4.3.1 & 4.3.2)

Analysis for pool swell loads was done using the finite element model shown in Figure 3-1. This was a dynamic analysis performed in the time domain by applying a force time history, to simulate the pressure-time histories of the pool swell event to each node on the computer model. Input pressure-time histories were varied in both the longitudinal and radial directions in accordance with the information in References 1, 2 and 10. Typical pressure-time history curves are shown in Figures 3-5 through 3-7. (These pressure-time histories are taken directly from Reference 10, before adjustment, as required by Reference 2. Therefore, the amplitudes shown are slightly different than the loads used in the analysis).

The computer analysis was run for two different pool swell conditions, full ΔP and zero ΔP . Figures 3-5 through 3-7 show comparative values and time histories for the two cases. The only difference between the analyses was the input loads; the models were identical. Details of the full load distribution can be found in References 1 and 10.

Plant-unique quarter scale pool swell tests showed that the effective water mass was less than 100% after bubble breakthrough and was different for both zero and full ΔP conditions (Reference 4). The water mass used in the computer simulation was constant throughout the analysis and was set at the average of the two reduced masses identified in the quarter scale tests. The reduced and average mass values are given in Table 3. This simplification in water mass analysis is consistent with the relatively slow (pseudo-static) nature of the pool swell load. This simplification only affects the inertial (frequency) calculation; the effects of weight are accurately calculated for each load and time in the deadweight analysis.

3.2.2 Condensation Oscillation - DBA (4.4.1)

Analysis for condensation oscillation (CO) was also done with the structural model shown in Figure 3-1.

The condensation oscillation shell load is specified as a spectrum of pressures in 1 Hz bands (Reference 1). The analysis for this load was performed by considering the effects of unit loads at each load frequency (harmonic analysis) and then scaling and combining the individual frequency effects to determine total stress at selected elements. The three variations in the CO spectrum (Reference 1) were evaluated by re-scaling the results of the unit load analysis. 100% of the water mass was used for all CO analysis. A plant-unique factor was applied to the nominal condensation oscillation pressures as discussed in Reference 1; the factor is listed in Table 3.

The combination of individual harmonic stresses into total element stress was done by considering frequency contributions at 31 Hz and

below. The actual combination was done by adding the absolute value of the four highest harmonic contributors to the SRSS combination of the others for shell stress. Loads on the support and anchor system were determined by adding the absolute value of the three highest harmonic contributors to the SRSS of the others. These combination methods and use of the 31 Hz cutoff are the result of extensive numerical evaluation of full scale test data, which is reported and discussed in References 6 and 14, and in Appendix 2 of this report.

3.2.3 Chugging

3.2.3.1 Pre-Chugging & IBA/CO (4.5.1.2 & 4.4.1)

The pre-chug load was evaluated for both the symmetric and asymmetric distribution described in Reference 1. Results for the symmetric pre-chug analysis were also used for IBA/CO as described in paragraph 4.4 of Reference 1.

Results for symmetric pre-chug were developed directly from the unit-load harmonic analysis done for CO. The results of that analysis were scaled to two psi (the pre-chug pressure) and all frequencies in the pre-chug range were scanned to determine the highest possible stresses.

Analysis for asymmetric pre-chug was performed using the beam model in Figure 3-4 by applying the unbalanced lateral load through the prescribed frequency range.

3.2.3.2 Post Chugging (4.5.1.2)

Post chugging is defined as a spectral load across a wide band, similar in nature to the CO, but much lower in amplitude. Analysis done on one of the TES plants produced very low stresses and loads that were bounded by pre-chug values. The analyses for pre- and post chug produced these results for maximum shell stress:

Maximum Shell Stress

Shell Membrane Stress

Pre-Chug	1284 psi
Post Chug	774 psi ¹

1. Based on frequencies to 30 Hz - sum of 4 maximum + SRSS of others.

Additional work published in Reference 12 showed that pre-chug bounded post chug (to 50 Hz) for column and saddle loads (Table 5-1, Ref. 12). It also showed that $P_L + P_b$ stress due to post chug exceeded pre-chug by 53%.

TES analysis for post chug used the pre-chug stress values. The pre-chug stress may be increased by 53% to account for the 30 to 50 Hz contribution and they will still meet allowable stress.

No further post chug analysis was done for the shell. This position was also influenced by the fact that post chug stresses were very small.

3.2.4 SRV Discharge

Calculation of stresses due to SRV line discharge pressures, were also done using the finite element model in Figure 3-1. The loading function used for this analysis was based on data collected from in-plant SRV testing in this facility. Testing was done in general accordance with the guidelines given in Reference 2. In these tests, pressure amplitude and frequency were recorded and compared to calculated values for the test conditions. Factors were developed that related test to calculated values for both amplitude and frequency (see Appendix 1). These factors were then applied to calculated load values for other SRV conditions; the structural analyses were

performed using these adjusted values. Appendix 1 discusses the in-plant test and analysis in more detail. A typical set of SRV shell pressures is shown in Figure 3-8.

The method of modeling the water mass in the SRV computer model was the subject of extensive study in this program. Initial attempts to reproduce measured stresses by applying measured pressures to the computer models failed badly. After considerable study of the nature of the SRV phenomena itself, and the differences between it, and the pool swell related loads, it appeared that a dry structure analysis should produce acceptable correlation. The method was tested and correlation of calculated-to-measured shell stress was excellent. The dry structure analysis method was subsequently used as a basis for all SRV analysis.

3.2.5 Deadweight, Thermal & Internal Pressure

Deadweight, thermal and internal pressure analyses were done using the computer model shown in Figure 3-1. Resulting stresses were calculated and considered for all elements on the model.

For the thermal analysis, conduction into the columns and saddles from the torus was considered. Convection from the columns and saddles to ambient produced a calculated temperature gradient in these elements. The torus water, internals and shell were all assumed at the same temperature.

3.2.6 Seismic

Seismic analysis for shell stress was done by applying static G levels to the model in Figure 3-1. Load orientation and values were adjusted for vertical and horizontal earthquakes in accordance with Table 3.

The effects of lateral seismic loads on the support system were determined using the model in Figure 3-4. The effective water mass used in this (lateral) analysis was adjusted in line with test results which showed

that net dynamic reaction loads due to the water mass were substantially less than those obtained from static application of the seismic acceleration. A discussion of this fact can be found in Reference 7; the effective water mass used can be found in Table 3 of this report.

3.2.7 Fatigue Analysis

Fatigue analysis of the torus shell and external support system is described here. Analysis of the shell at piping penetrations will be described in TES report TR-5310-2, when the piping analysis is complete.

The fatigue analysis of the shell and support system was a conservative one, which was based on applying a stress concentration factor of 4.0 on the most highly stressed elements for each load case. In the case of the support system, only the column-to-torus and saddle web-to-torus welds were considered, since they have higher stresses than the rest of the support system. The process is conservative because:

- It applies the maximum stress concentration (4.0), recognized by Section III of the ASME Code to all elements (Reference 11).
- and
- It adds the maximum absolute stress for each load case even though they do not usually occur at the same element.

The procedure used in this analysis consists of the following steps.

1. For a given load, locate the maximum component-level stresses (S_x , S_y , S_{xy}) for the free shell, local shell, and the supports.
2. For these locations, establish the stress intensity ranges and the approximate number of cycles.

3. Repeat the process for all other loads in the load combination.
4. Add the stress ranges for all loads, independent of sign.
5. Multiply these total stress ranges by 4.0 (the SIF).
6. Calculate the alternating stress intensity and complete the fatigue analysis in compliance with Reference 11.

Fatigue analysis resulting from chugging was done assuming that the operator would depressurize the system within 15 minutes after chugging begins. Plant procedures are presently under study to provide for this action.

3.3 Results and Evaluation

Results are reported for each structural component of the containment system for the controlling load combination. Controlling load combinations are the ones that produce the smallest margins against the allowable stress - not necessarily the highest stress.

All load combinations listed in Table 1 have been considered. As stated previously, most results include some level of bounding analysis and, therefore, understate the margins which actually exist.

3.3.1 Torus Shell

Results of shell stress due to individually applied loads were calculated and maintained on a component stress level until all the load combinations were formed. Stress intensities were then calculated from these total component-level values.

The controlling load combinations for the shell at Pilgrim are cases 14 and 20 in Table 1; these are:

Case 14 - IBA.CO + SRV + Seismic (SSE Used) + Pressure + Weight

Case 20 - DBA.CO + Seismic (SSE) + Pressure + Weight

These load combinations control all categories of shell stress, although the location of the elements is different for the different types of stress. The following table summarizes the controlling stresses. Approximate locations of the controlling stresses are shown in Figure 3-9.

CONTROLLING SHELL STRESSES - PILGRIM

<u>TYPE OF STRESS & LOAD CASE</u>	<u>LOCATION</u>	<u>ACTUAL STRESS (psi)</u>	<u>ALLOWABLE STRESS (psi)</u>
Membrane (Pm) (Case 14)	Free Shell Element 17	13,324	19,300
Local (P1) (Case 14)	Local Shell Element 125	8,365	28,950
Membrane + Bending (Case 20)	Free Shell Element 19	17,258	28,950
Stress Range (Case 14)	Local Shell Element 147	26,399	69,900

Compressive Buckling - Acceptable (see below)

Compressive Buckling Reference 13 discusses the results of analytical studies and tests on Mark 1 torus structures to determine their compressive buckling capabilities. The report concludes that SRV is the dynamic load which presents the maximum chance of com-

pressive buckling failure; but, that a safety factor of 7 still exists for an applied SRV pressure of +29.3/-22.6 psi. The maximum worst-case SRV shell pressures for Pilgrim are +12.6 psi and -9.6 psi, which are lower than those used in the referenced study. Based on this, compressive buckling stresses are considered to be acceptable for the Pilgrim torus.

FATIGUE EVALUATION - PILGRIM

CUMULATIVE USAGE FACTOR SUMMARY
 (STRESS INTENSIFICATION FACTOR = 4.0)

<u>ELEMENT</u>	<u>NORMAL OPERATION</u>	<u>EVENT TYPE</u>	
		<u>SBA/IBA</u>	<u>DBA</u>
19	.005	.001	.015
147	.164	.003	.026

3.3.2 Support Columns & Attachments

The controlling load case for the support column and attachment weld to the torus shell is load case 16 in Table 1. Controlling stresses are associated with the downward loads. Case 16 includes:

Pool Swell ($0\Delta P$) + Pressure + Weight

For this load case, the following controlling stresses were identified:

SUPPORT COLUMN - CONTROLLING AXIAL CONDITION

<u>COLUMN</u>	<u>LOAD DIRECTION</u>	<u>CONTROLLING STRESS</u>	<u>ACTUAL FACTOR</u>	<u>ALLOWABLE FACTOR</u>
Inner	Down	Axial + Bending	.307	1.0
Outer	Down	Axial + Bending	.352	1.0

COLUMN-TO-SHELL WELD

<u>LOCATION</u>	<u>LOAD DIRECTION</u>	<u>CONTROLLING STRESS</u>	<u>ACTUAL STRESS</u>	<u>ALLOWABLE STRESS</u>
Inner	Down	Shear	12.32 K/in	28.9 K/in
Outer	Down	Shear	10.99 K/in	28.9 K/in

3.3.3 Support Saddles & Shell Weld

The controlling load case for the weld between the saddle and the torus shell, and for down loads on the saddle is load case 16 in Table 1. This case includes:

Pool Swell ($0\Delta P$) + Weight

The resulting stresses are:

SADDLE STRESSES

<u>LOCATION</u>	<u>LOAD DIRECTION</u>	<u>TYPE STRESS</u>	<u>ACTUAL STRESS</u>	<u>ALLOWABLE STRESS</u>
Sole Plate	Down	Bending	19.65 K/in	28.5 K/in

SADDLE-TO-SHELL WELD

<u>LOCATION</u>	<u>LOAD DIRECTION</u>	<u>TYPE STRESS</u>	<u>ACTUAL STRESS</u>	<u>ALLOWABLE STRESS</u>
Outside End	Down	Shear	11.93 K/in	13.64 K/in

The controlling case for the saddle associated with up load is case 21, which includes:

DBA.CO + Seismic (SSE) + Weight

Loads for this case are:

<u>LOCATION</u>	<u>LOAD DIRECTION</u>	<u>TYPE STRESS</u>	<u>ACTUAL LOAD</u>	<u>ALLOWABLE LOAD</u>
Clamping Plate	Up	Bending	95 kips	103.2 kips

3.3.4 Earthquake Restraints & Attachments

The earthquake restraint system is illustrated in Figure 3-10. The controlling load case for this system is the one that produces the largest lateral load. This is case 15 which includes:

Chugging + SRV + SSE

All three of these loads have been selected to produce the highest lateral load on one earthquake restraint; contributions from the individual loads were added directly.

The controlling stress results follow:

<u>EARTHQUAKE RESTRAINT</u>			
<u>STRESS LOCATION</u>	<u>STRESS TYPE</u>	<u>ACTUAL STRESS</u>	<u>ALLOWABLE STRESS</u>
Tie Plate at Slot	Pin Bearing	4,879 psi	27,000 psi

ATTACHMENT WELD

<u>STRESS LOCATION</u>	<u>STRESS TYPE</u>	<u>ACTUAL STRESS</u>	<u>ALLOWABLE STRESS</u>
Weld at Tie Plate - Base Plate Connection	Shear	3,668 psi	21,000 psi

3.3.5 Anchor System

The torus at Pilgrim is restrained against upward loads by two-inch diameter anchor bolts in the support saddle and 1½-inch anchor bolts in the column bases that were part of the original plant design.

The original 1½-inch column base bolts did not restrain upward movement because they were used only to hold a base plate which was not attached to the column. The tiedown fix will use the original bolts with clamping plates to tie down the torus columns.

The controlling load case for these anchor bolts is case 21 in Table 1. This case includes:

DBA.CO + Seismic (SSE) + Weight

The loads are:

SADDLE ANCHOR BOLTS (PER SADDLE)

<u>ACTUAL MAXIMUM LOAD</u>	<u>MAXIMUM CAPACITY</u>	<u>FACTOR OF SAFETY</u>
76.6 K/bolt	264 K/bolt	3.45

The original column anchor bolts are a "J" bolt embedded in the concrete and constructed from structural steel. The capacity of these bolts will be determined by the stresses in the steel bolt rather than concrete pull out capacity. Accordingly, they are evaluated against stress:

COLUMN ANCHOR BOLTS - ORIGINAL

<u>COLUMN LOCATION</u>	<u>ACTUAL MAXIMUM LOAD</u>	<u>MAXIMUM CAPACITY</u>	<u>FACTOR OF SAFETY</u>
Inner	47.5 kips	60 kips	1.26
Outer	40.3 kips	60 kips	1.49

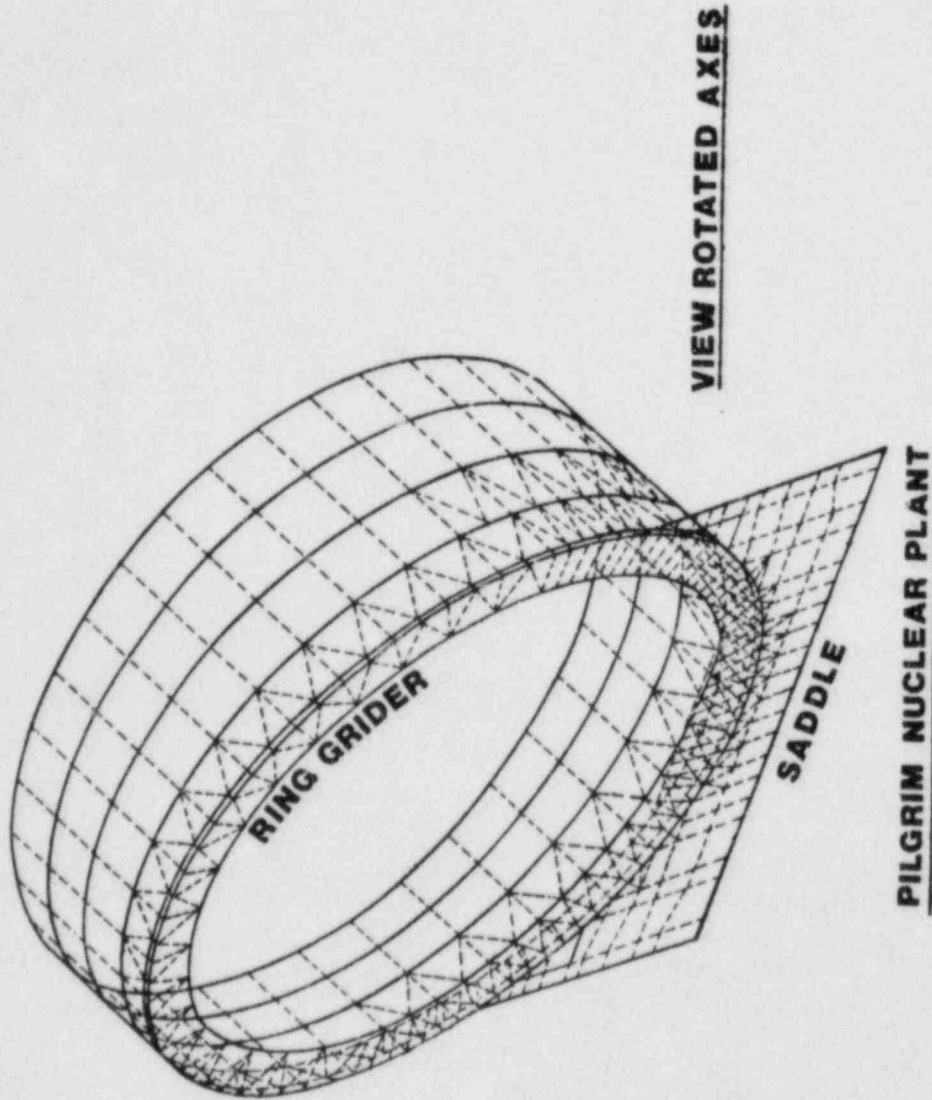


FIGURE 3.1 DETAILED SHELL MODEL

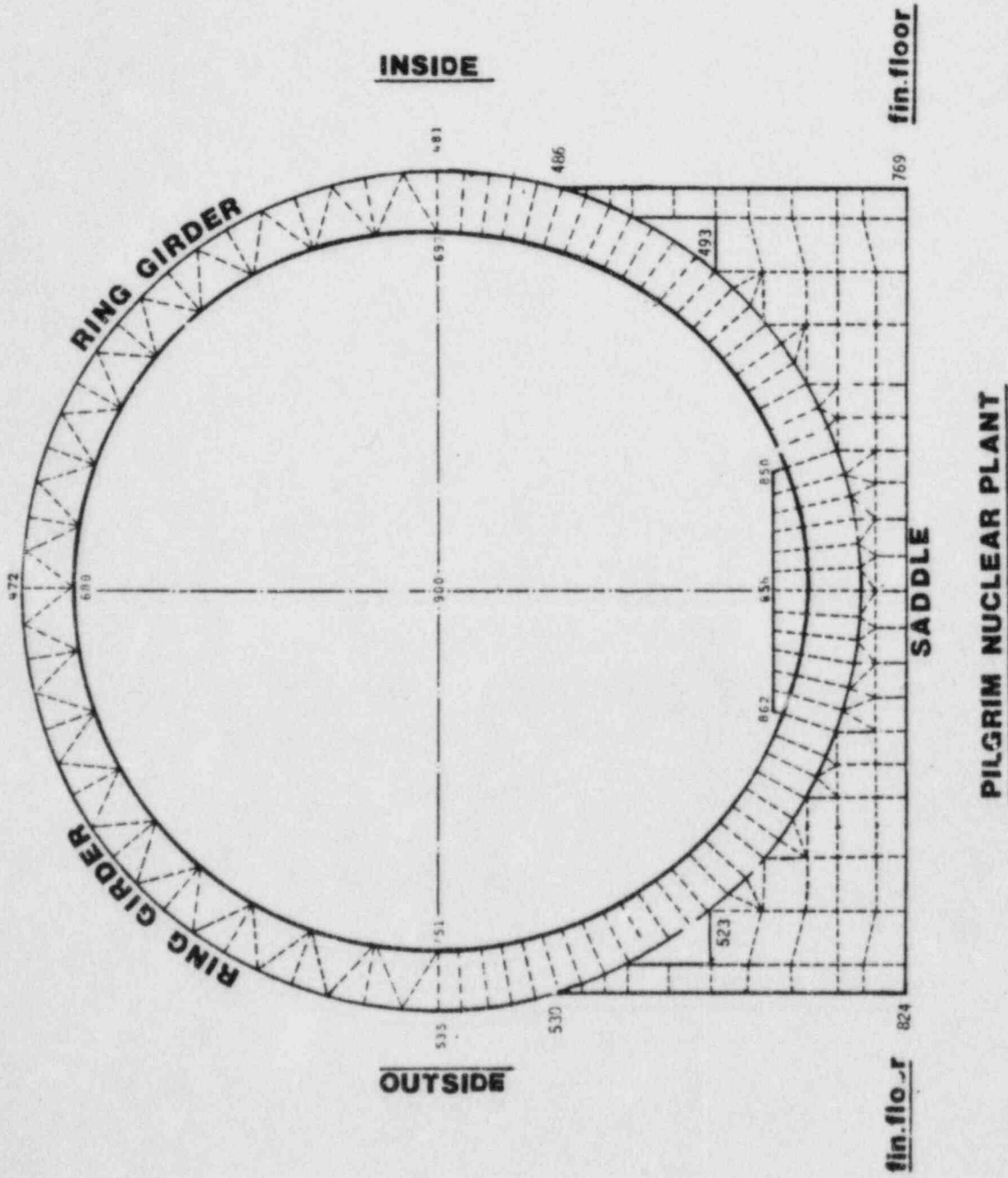
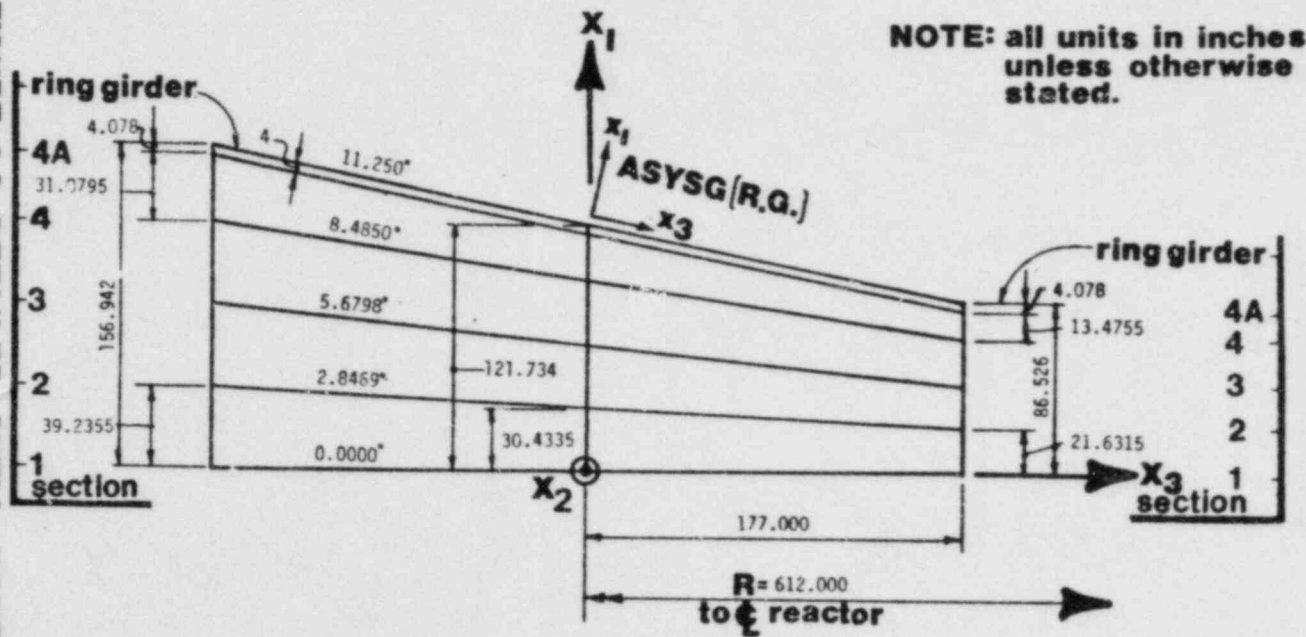


FIGURE 3.2 DETAILED SHELL MODEL

1/32nd
TORUS MODEL WITH
SADDLE

FIGURE 3.3 DETAILED SHELL MODEL



PILGRIM NUCLEAR PLANT

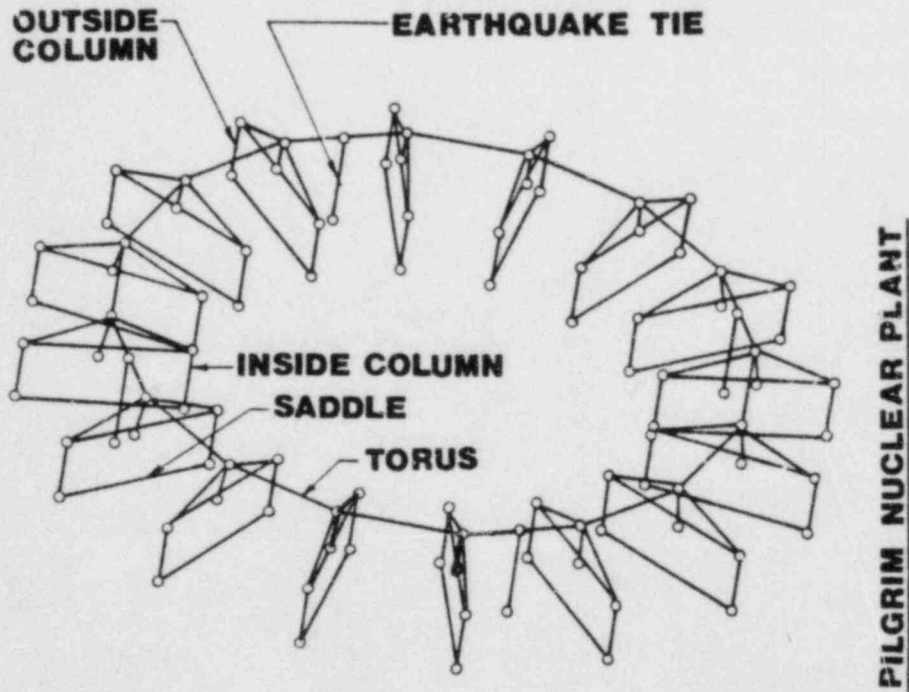


FIGURE 3.4 360°TORUS BEAM MODEL

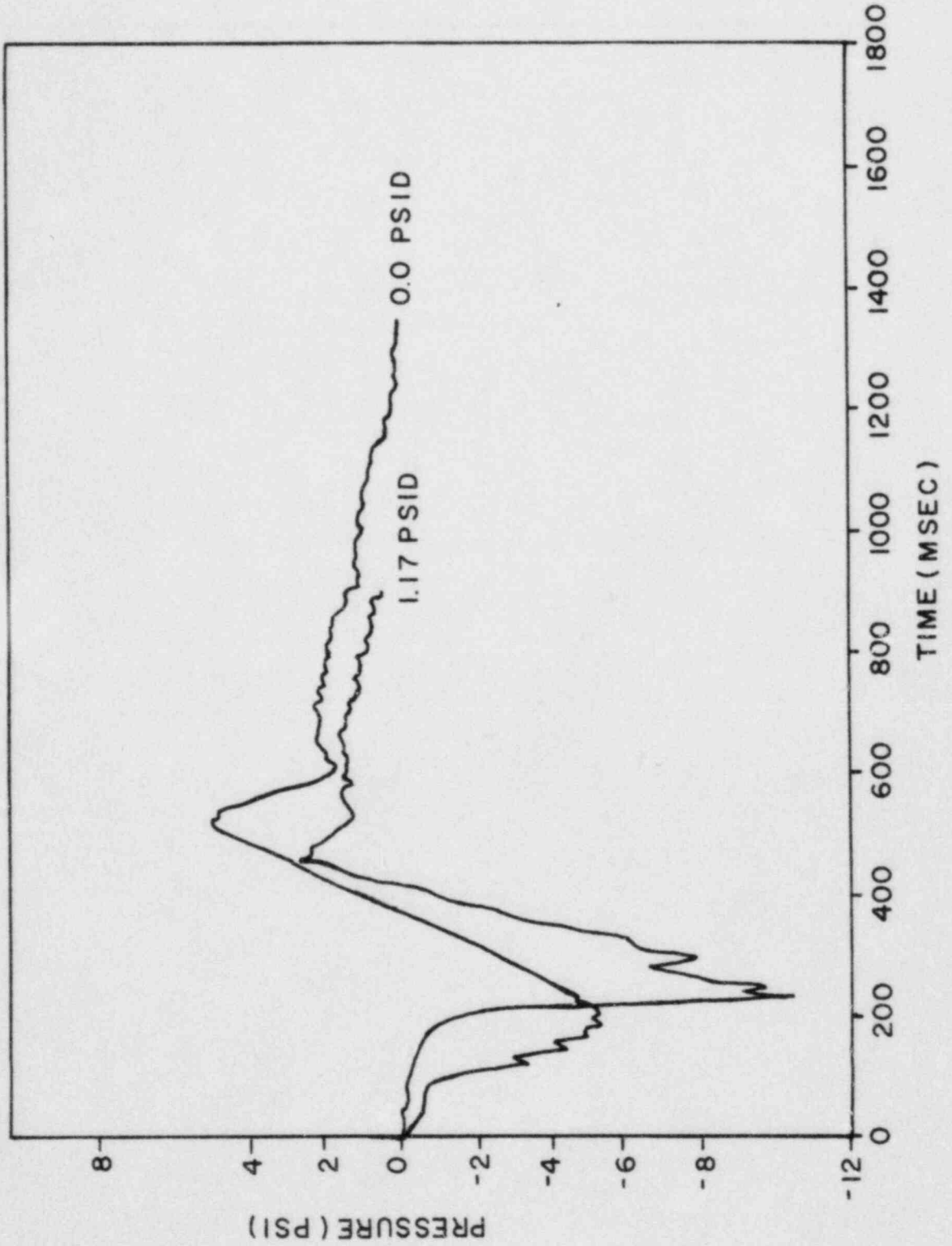


FIG. 3-5
POOL SWELL-NET VERTICAL LOAD

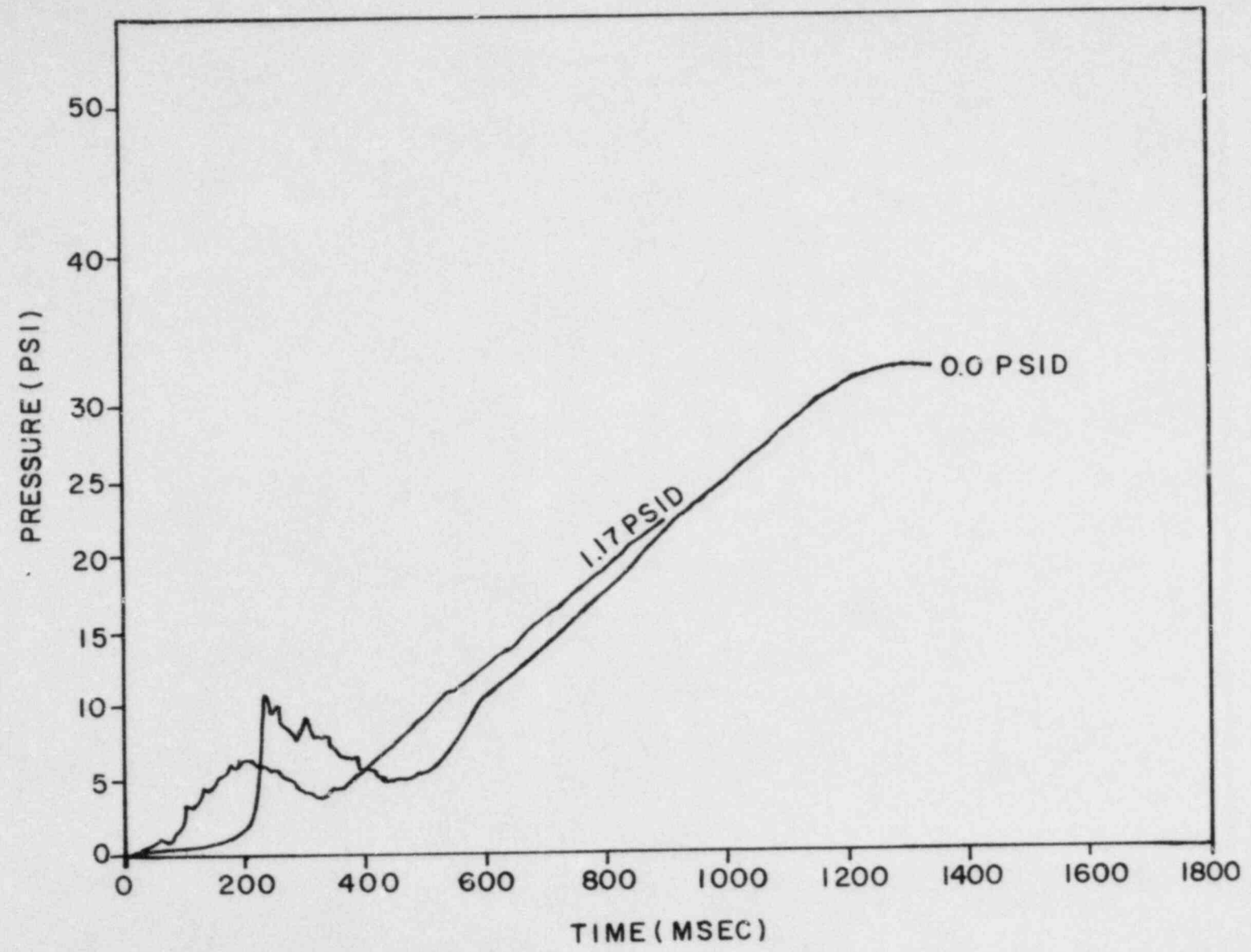


FIG. 3-6
POOL SWELL - AVERAGE SUBMERGED PRESSURE

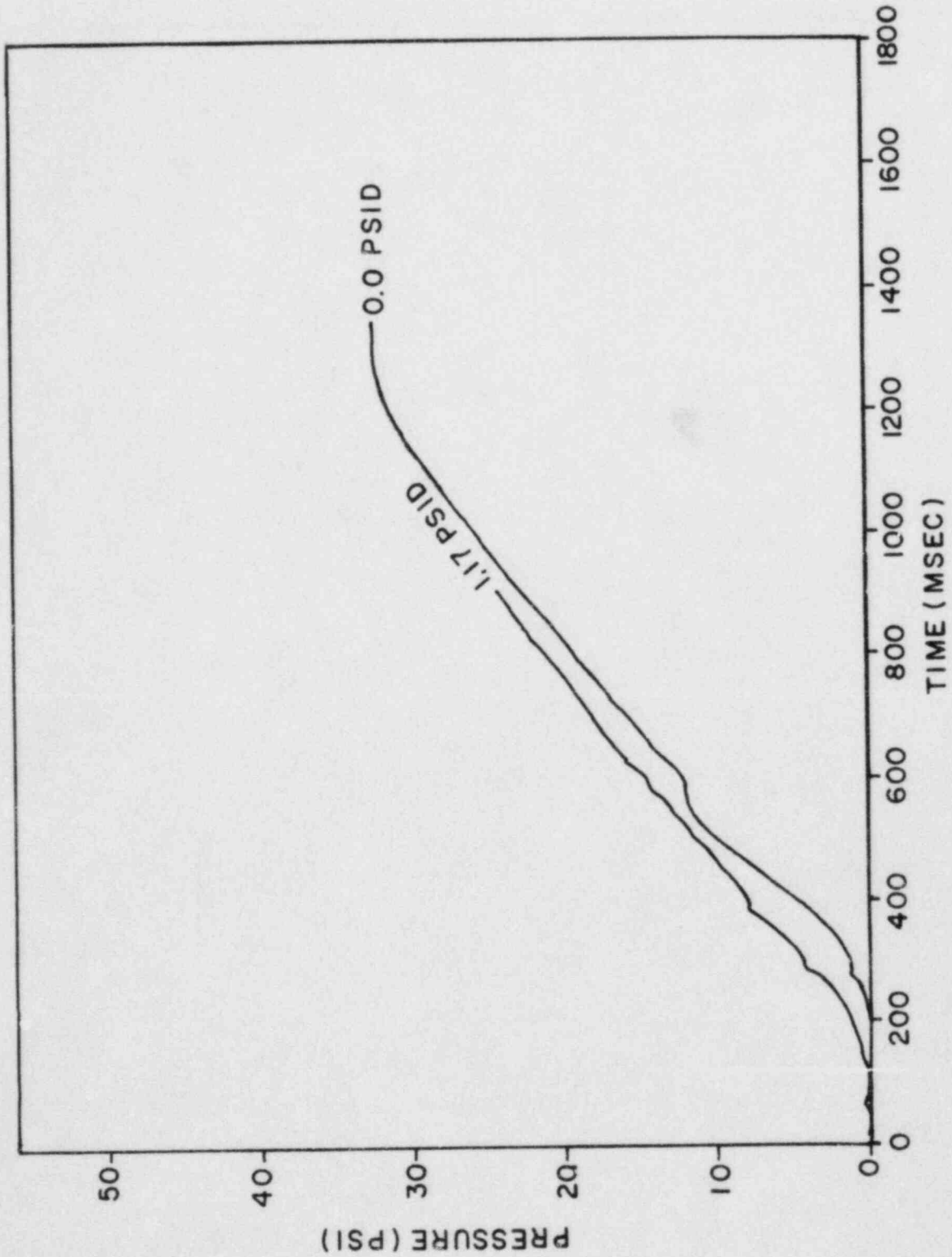


FIG. 3-7
POOL SWELL - TORUS AIR PRESSURE

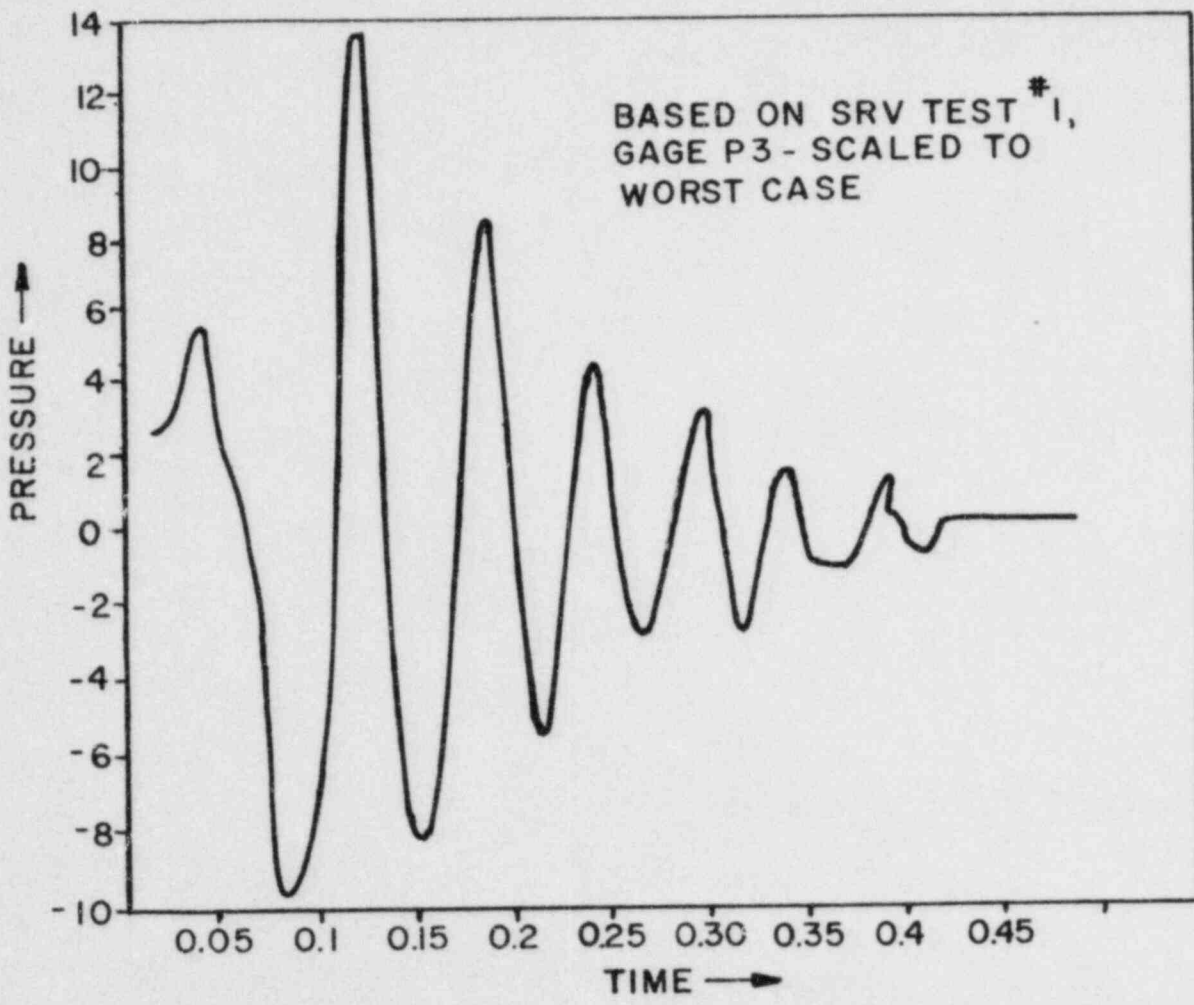


FIG. 3-8
TYPICAL SRV SHELL PRESSURE -PILGRIM

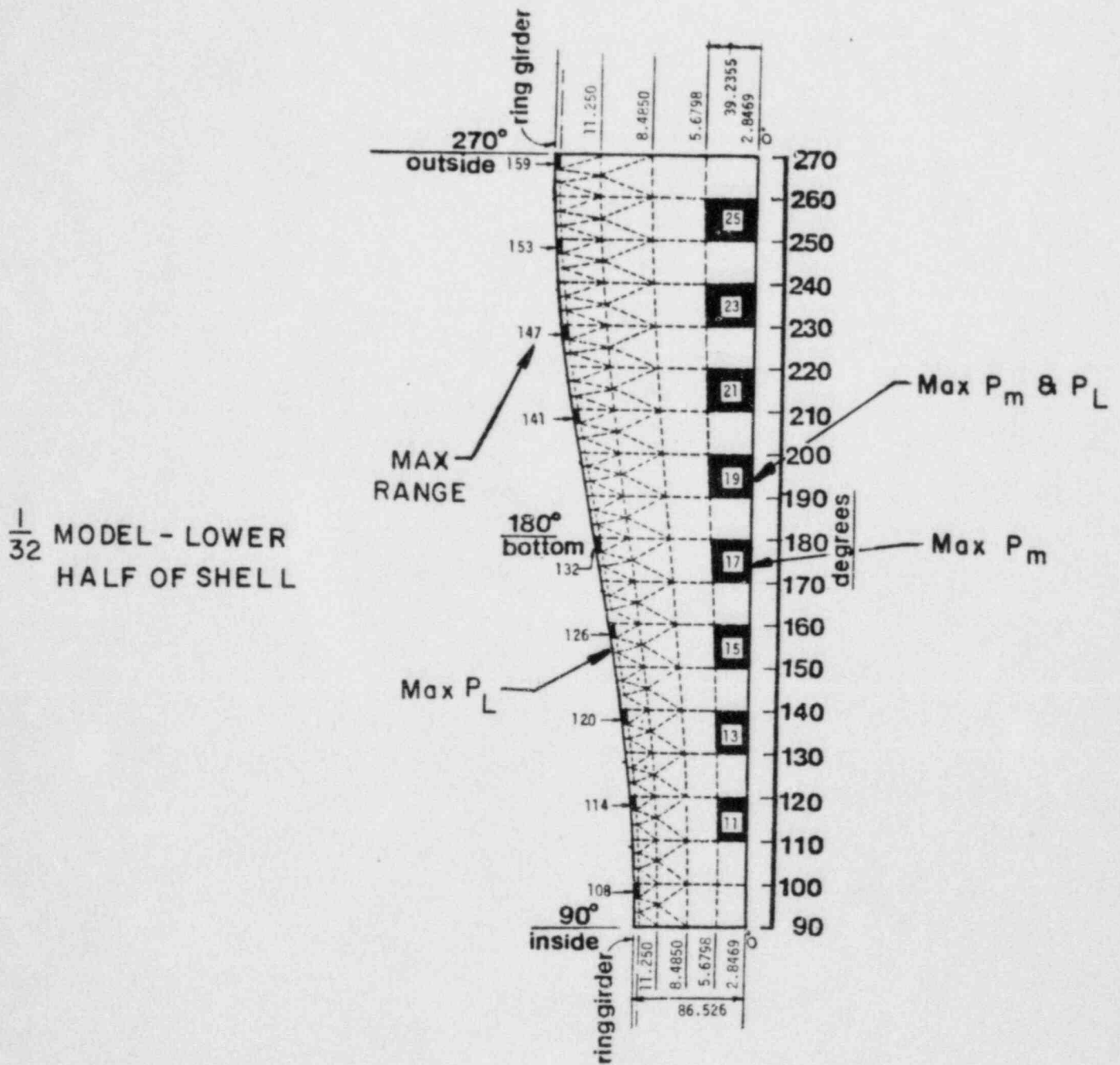


FIG. 3-9

MAXIMUM SHELL STRESS LOCATIONS - PILGRIM

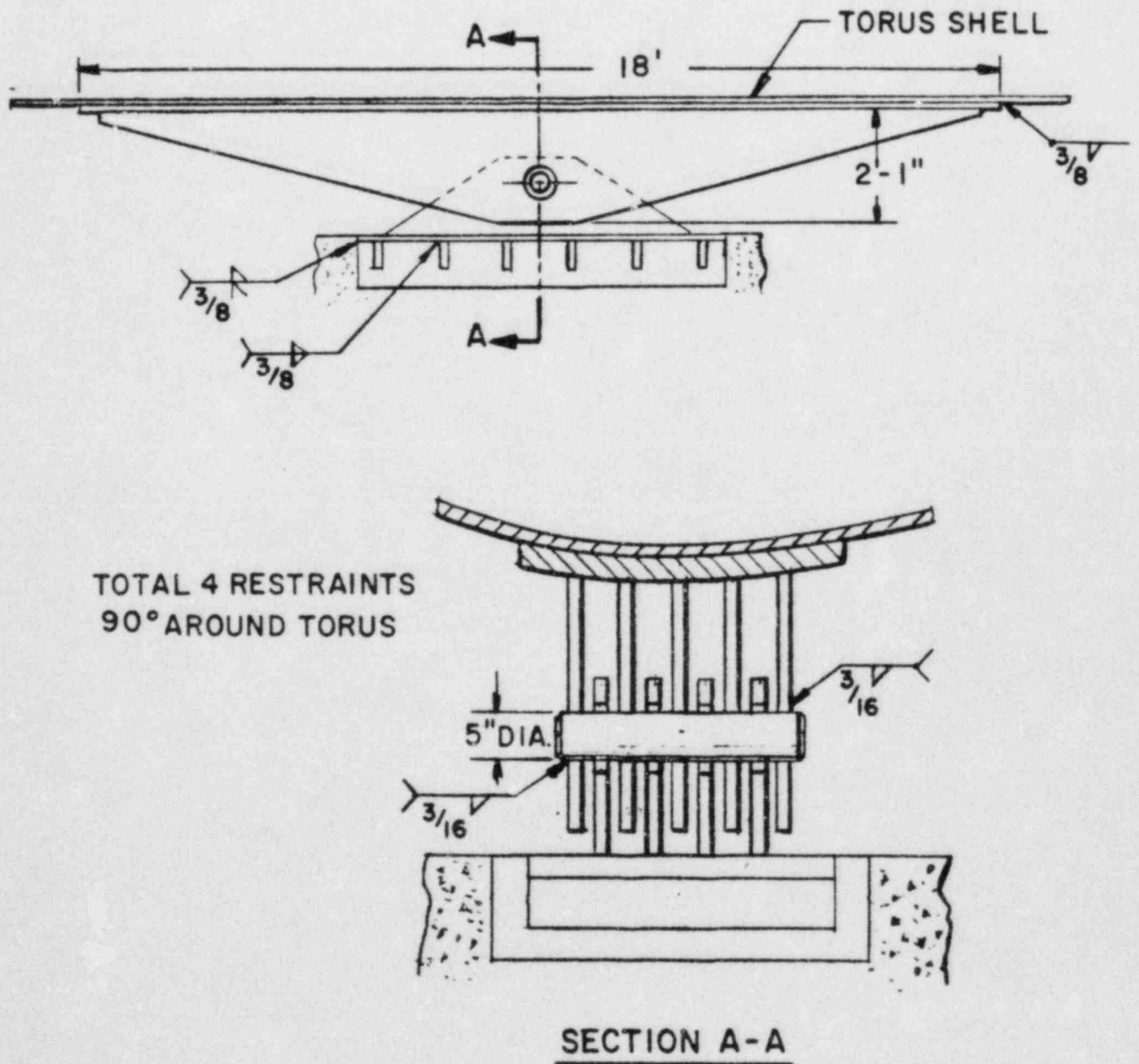


FIG. 3-10
EARTHQUAKE RESTRAINT SYSTEM

4.0 VENT HEADER SYSTEM

4.1 Structural Elements Considered

The vent header system, as defined in this section, includes the following structural components:

- a. Vent Header (V.H.)
- b. Main Vent Pipe (V.P.)
- c. Downcomers (D.C.)
- d. Downcomer Tie Bars
- e. Deflector
- f. Vent Header Support Columns & Attachments
- g. VH/DC Intersection
- h. VH/VP Intersection
- i. VP/Drywell Intersection
- j. Vent Header Mitre Joint

The main vent bellows are considered in Section 7.0.

4.2 Computer Models

Two computer models provided the means to analyze the vent header system, they are shown in Figures 4-1 through 4-4.

The first of these is a detailed shell model, (Figures 4-1 to 4-3), which includes a highly detailed representation of one-half of the header in a non vent bay, complete with four downcomers.

The model also includes an approximate representation of one-half of the vent bay; this was intended to provide the proper boundary conditions and stiffness transition near the non-vent bay. The vent bay half of the model was not used for stress determination. This large finite element model was used primarily to determine shell stresses in the non-vent bay; some other

uses are discussed in the following text. It was used for both static and dynamic analysis and provided detailed stress gradient information in the downcomer/vent header intersection region.

The second vent header model is the beam model shown in Figure 4-4. This model represents a full vent bay, complete with vent pipe and downcomers; as well as a half non-vent bay on either side. It was used to determine boundary loads on the vent system components to support a more detailed stress analysis of those components. This model was used to define loads on the following elements:

- Vent Header Support Columns
- Vent Pipe/Vent Header Intersection
- Vent Pipe/Drywell Intersection
- Vent Header Mitre Joint
- Main Vent Pipe

The loads and moments taken from the beam model were used in further analysis to determine stresses. The calculation methods used for these stresses are:

- VH support columns - hand analysis
- VP/VH intersection - applied stress multipliers (stress intensification factors) from Reference 7
- VP/drywell intersection - used stress multipliers from - Reference 16 (Bijlaard)
- Mitre joint - used stress multipliers from detailed shell model (Figure 4-1)
- Main vent pipe - hand analysis

The beam model used a stiffness representation of the VP/VH intersection taken from Reference 8. Attachment stiffness between the vent pipe and drywell was calculated using References 17 and 18.

Pool swell water impact on the vent header deflector was calculated with a hand analysis. The impact forces were applied statically to a beam model and a dynamic load factor was applied (see Figure 4-5).

4.3 Loads Analysis

4.3.1 Pool Swell Loads

4.3.1.1 Pool Swell Water Impact

Analysis for stresses due to pool impact and drag was done using both computer models.

Determination of shell stresses was done with the detailed model in Figure 4-1. For this analysis, force time histories based on QSTF test data were used (References 4 and 10). These time histories were applied at 100 nodal points on the shell model and the dynamic response of the structure was calculated. Relative timing between loadings (Reference 1) was maintained to preserve accurate representation of longitudinal and circumferential wave sweep. Stresses in the vent header/downcomer intersection, as well as in the free shell areas, were taken directly from this model. Stresses in the downcomer tie bars were also taken from this model. Analysis was done for both full and zero ΔP impacts.

The beam model (Figure 4-4) was also used to determine stress from pool swell impact and drag. This was done with a time history dynamic analysis using loads developed by integrating the impact pressures over small areas and reducing them to nodal forces. Approximately 95 nodes along the length of the beam model were dynamically loaded in this analysis, including loads on the VP/VH intersection and vent pipe. The results of this analysis were used to define boundary loads on VP/VH intersection, mitre joint and other elements as listed in Section 4.2. Stress analysis for these elements was performed using the methods indicated in Section 4.2.

4.3.1.2 Pool Swell Thrust (4.2)

Pool swell thrust forces are defined as dynamic forces at each bend or mitre in the vent system, and are a consequence of the flowing internal fluids. Analysis for these loads was done using the beam model and applying the loads statically. This is consistent with the slow nature of the applied pressure forces.

The calculation was performed with the maximum value of all thrust forces applied simultaneously; this is a conservative condition.

4.3.1.3 Pool Swell Drag Loads (4.3.7 & 4.3.8)

The vent header support columns are loaded by forces from LOCA-jet and LOCA bubble drag. By inspection, it was concluded that LOCA-jet loads would not combine with water impact on the vent system due to differences in timing and, therefore, would not contribute to the maximum stress calculations - LOCA jet forces were not considered further.

LOCA bubble forces were calculated and the maximum normal components (radial and longitudinal) were applied simultaneously to conservatively bound the bending moments on the support column. These peak values were applied statically at the midpoint of the column. Stress calculations were done by hand.

4.3.2 Chugging Loads

4.3.2.1 Downcomer Lateral Loads (4.5.3)

Reference 1 identifies downcomer lateral loads as static equivalents with random orientation in the horizontal plane. The major consequence of this loading is to produce high local stress in the VH/

downcomer intersection. The detailed shell model (Figure 4-1) was used to identify stresses in the downcomer intersection due to static loads applied at the base of the downcomer. Frequencies of the first downcomer response mode were taken from a dynamic analysis on the same model (Figure 4-1) with the downcomers full of water to the operating level. This frequency was necessary to determine the proper dynamic scale factor to apply to the static load.

The stress results from the statically applied load were used as a basis for a fatigue evaluation of the intersection in accordance with Reference 1.

4.3.2.2 Chugging - Synchronized Lateral Loads

The random nature of the downcomer lateral chugging load provides for all combinations of alternate force orientations on adjacent pairs of downcomers. Various load combinations were examined to determine stress levels in the vent header and mitre joint as a result of these loads. The cases considered are shown in Figure 4-6.

These cases were considered by applying static loads to the beam model (Figure 4-4) and determining final stresses as described in Section 4.2.

4.3.2.3 Internal Pressure (4.5.4)

Three vent system internal pressures exist during chugging. They are:

- Gross vent system pressure - a .7 Hz oscillating pressure with a maximum value of 5.0 psi. This pressure acts on the entire vent system.
- Acoustic vent system pressure - a sinusoidal pressure varying from 6.9 to 9.5 Hz at a maximum value of 3.5 psi. This pressure affects the entire vent system.

- Acoustic downcomer pressure oscillation - a 40-50 Hz pressure at 13 psi that produces only hoop stress in the downcomers.

Responses to these pressures were estimated using hand analysis and were determined to be substantially less than those resulting from internal vent system pressures during pool swell. The values associated with pool swell pressures were used in all combined load cases involving chugging pressures; this produces conservative results.

4.3.2.4 Submerged Structure Drag (Support Columns only)

Examination of the load combinations that include chugging makes it clear that these cannot control maximum stress level in the support columns; combinations that include vent header water impact will produce much higher stresses. For this reason, stresses in the vent header support columns were not calculated for chugging drag.

Drag forces on the downcomers and downcomer tie bars are already included in the Downcomer Lateral Loads, which were based directly on test data.

4.3.3 Condensation Oscillation - DBA

4.3.3.1 Downcomer Dynamic Load (4.4.3.2)

The downcomer dynamic load, due to condensation oscillation, is a sinusoidal pressure variation that can be equal or unequal in the two downcomers forming a pair.

The unequal pressure case produces a net lateral load on the downcomer much like chugging. The major considerations for this load are stresses in the downcomer intersection due to a net lateral load on

one pair of downcomers and a more general stress case where loads on adjacent downcomer pairs are phased to produce gross lateral loads on the vent system or torsion in the vent header.

The horizontal component of the CO downcomer load produces the same type of loading on the vent system as the CH lateral load, in terms of the stress analysis. A comparison of the magnitudes and frequencies of these two loads shows that stresses resulting from CH horizontal loads will bound CO horizontal loads.

The CO downcomer load also produces a vertical component of load, which is not present during CH. The effects of this load were evaluated by static analysis of the detailed vent header model (Figure 4-1) and consideration of dynamic amplification effects, using the beam model (Figure 4-4). This evaluation showed that the combined effects of the CO downcomer load (horizontal and vertical components) would still be bounded by CH lateral loads.

Based on this, CH lateral load results were conservatively used in all load cases in place of CO downcomer loads.

4.3.3.2 Vent System Loads (4.4.4)

Vent system loads consist of a sinusoidal pressure in the vent header and downcomers superimposed on a static pressure. The dynamic pressure in the downcomers is used to calculate hoop stress only.

Stresses for all pressure loads were based on hand analysis using static analysis. The static analysis assumption is consistent with the low frequency of the applied pressure and the fact that the ring modes of the structure are very high.

4.3.3.3 Thrust Forces (4.2)

Stresses resulting from CO thrust forces were conservatively taken from the pool swell thrust calculations and applied to all CO load cases (para. 4.3.1.2).

4.3.3.4 Drag Forces on Support Columns

Inspection of approximate total loads on support columns due to CO, CH, and pool swell showed that condensation oscillation would not contribute to the maximum column load, due to differences in timing. No detailed analysis was performed.

4.3.4 Condensation Oscillation - IBA

Stresses and loads resulting from IBA condensation oscillation are bounded in all cases by either DBA condensation oscillation or chugging. No detailed analysis was performed for IBA condensation oscillation.

4.3.5 SRV Loads

4.3.5.1 SRV Drag Loads

An SRV discharge produces drag loads which act on the vent header support columns, downcomers, and downcomer tie bars. Analysis for drag loads on these structures was based on data collected during in-plant SRV tests.

Data collected during these tests was scaled to correct it for the appropriate SRV conditions and then applied to the structural model to determine the resulting stress. A more detailed discussion of this procedure is provided in Appendix 1.

4.3.6 Other Loads

Deadweight and seismic stresses in the vent system were calculated using the beam model of Figure 4-4.

Seismic stresses were calculated by statically applying the acceleration values in Table 3.

Thermal stresses were determined for the steady state application of maximum vent system temperature, using hand analysis.

4.4 Results and Evaluation

Results are reported for each structural element of the vent system for the controlling load combination. Controlling load combinations are the ones that produce the smallest margins against the allowable stress - not necessarily the highest stress. All load combinations listed in Table 1 have been considered.

As stated previously, most results include some level of bounding analysis and, therefore, understate the margins which actually exist.

4.4.1 Vent Header - Downcomer Intersection

The controlling load on the vent header-downcomer intersection, both for maximum stress and fatigue, is the downcomer lateral load due to chugging. The worst load combination in which this load appears is case 27 of Table 1. This cases consists of:

Chugging (DBA) + Seismic (SSE) + Weight + Presssure + Thrust
+ SRV

For this case, the following stress occurs at a point 90° from the plane of a downcomer pair. It is primarily the result of a longitudinal chugging force on the downcomer.

<u>TYPE OF STRESS</u>	<u>ACTUAL STRESS</u>	<u>ALLOWABLE STRESS</u>
Combined Maximum Stress	36, 719 psi	37,635 psi

4.4.2 Vent Header - Vent Pipe Intersection

The controlling load on the vent header/vent pipe intersection occurs as a result of pool swell water impact. The controlling load condition is case 25 in Table 1 which includes:

Pool Swell (full Δ P) + Thrust + Seismic (SSE) + Weight + SRV Pressure

<u>TYPE OF STRESS</u>	<u>ACTUAL STRESS</u>	<u>ALLOWABLE STRESS</u>
Combined Maximum Stress	28,930 psi	28,950 psi

This load case was formed using a 0 P load, and was evaluated to a level A allowable. This conservative evaluation was performed to eliminate the need to evaluate several other vent header load cases.

4.4.3 Vent Header Support Columns and Attachments

The controlling load combination for the vent header support columns and the clevis joints at each end is case 25, Table 1. This case includes:

Pool Swell (full Δ P) + Seismic (SSE) + Weight + Thrust + SRV Pressure

As before, the evaluation was conservatively performed using 0 Δ P loads and a level A allowable.

Controlling stress in the support column is:

<u>TYPE OF STRESS</u>	<u>ACTUAL STRESS</u>	<u>ALLOWABLE STRESS</u>
Axial in Column (tension)	17,420 psi	18,000 psi

Controlling stress in the clevis joint at the end of the support column is:

<u>LOCATION</u>	<u>STRESS TYPE</u>	<u>ACTUAL STRESS</u>	<u>ALLOWABLE STRESS</u>
Clevis Plate	Shear	13,015 psi	15,200 psi

4.4.4 Downcomer Tie-Bars and Attachments

The controlling load combination for stresses in the downcomer tie bar and attachments is case 25, in Table 1. The major load is associated with pool swell impact on the crotch region of the downcomers which produces tensile loads in the tie bar.

The controlling case includes:

Pool Swell Impact (full ΔP) + SSE Seismic + SRV + Weight + Pressure + Thrust

Zero ΔP pool swell loads and service level allowables were conservatively used in this analysis.

The controlling stress is:

<u>LOCATION</u>	<u>STRESS TYPE</u>	<u>ACTUAL STRESS</u>	<u>ALLOWABLE STRESS</u>
Tie Bar Clamp	Bending	16,800 psi	22,240 psi

4.4.5 Vent Header Deflector and Attachments

The major load on the vent header deflector occurs as a result of pool swell water impact. The controlling load condition is case 19 in Table 1 which includes:

Pool Swell (full Δ P) + SSE Seismic + Weight + Thrust

The controlling stress in the deflector is:

<u>LOCATION</u>	<u>STRESS TYPE</u>	<u>ACTUAL VALUE</u>	<u>ALLOWABLE VALUE</u>
Center of the Long Span	Bending	21,000 psi	23,700 psi

The controlling stress for the attachments is:

<u>LOCATION</u>	<u>STRESS TYPE</u>	<u>ACTUAL VALUE</u>	<u>ALLOWABLE VALUE</u>
Fillet Weld	Shear	15,800 psi	17,100 psi

4.4.6 Main Vent/Drywell Intersection

The major load on the drywell penetration occurs as a result of chugging. The controlling load condition is case 21 in Table 1 which includes:

Chugging + Seismic (SSE) + Weight + Pressure (Drywell)

The controlling stress is:

<u>TYPE OF STRESS</u>	<u>ACTUAL STRESS</u>	<u>ALLOWABLE STRESS</u>
Primary and Secondary	39,970 psi	69,900 psi

The effects of all loads from the vent system, and the pressure load were considered using Reference 16. Information regarding stresses due to seismic and thermal response of the drywell was supplied by BECO and is included in the analysis.

4.4.7 Vent Header, Main Vent & Downcomers - Free Shell Stresses

It was established by inspection of the computer results that large safety margins existed in free shell regions and that minimum safety margins would be controlled by local shell stresses. No further work was done for free shell stress in these structures.

4.4.8 Vent Header - Mitre Joint

The controlling load on the vent header mitre joint occurs as a result of pool swell water impact. The controlling load condition is case 25 in Table 1 which includes:

Pool Swell (full Δ P) + Thrust + Seismic (SSE) + Weight + SRV
+ Pressure

<u>TYPE OF STRESS</u>	<u>ACTUAL STRESS</u>	<u>ALLOWABLE STRESS</u>
Combined Maximum Stress	27,137 psi	28,950 psi

4.4.9 Fatigue Evaluation

The fatigue analysis of the vent system is a conservative one which assumes that all maximum stresses occur simultaneously, and that all cycles reach these maximum values. The duration of the major loads in this analysis is 900 seconds, the length of chugging associated with an SBA/IBA event.

The procedure used in this analysis consists of the following steps:

- For a given load and component, locate the highest stress.
- For this location, establish the stress range.
- Repeat this process for all other loads in the load combination.
- Add the stress ranges for all loads.
- Multiply this total stress range by the appropriate stress intensification factor.
- Calculate stress intensity and determine the allowable number of stress cycles.
- Determine the usage factor, using the methods of Reference 11.

The fatigue evaluation was performed for all high stress areas in the vent system. The major load, contributing to the fatigue evaluation, is chugging following a DBA. The controlling load case is case 21 in Table 1, which includes:

Chugging (DBA) + Seismic (SSE) + Weight

The controlling usage factor for the vent system is:

VENT SYSTEM FATIGUE RESULTS

<u>LOCATION</u>	<u>ACTUAL USAGE FACTOR</u>	<u>ALLOWABLE USAGE FACTOR</u>
VH Support	.76	1.0

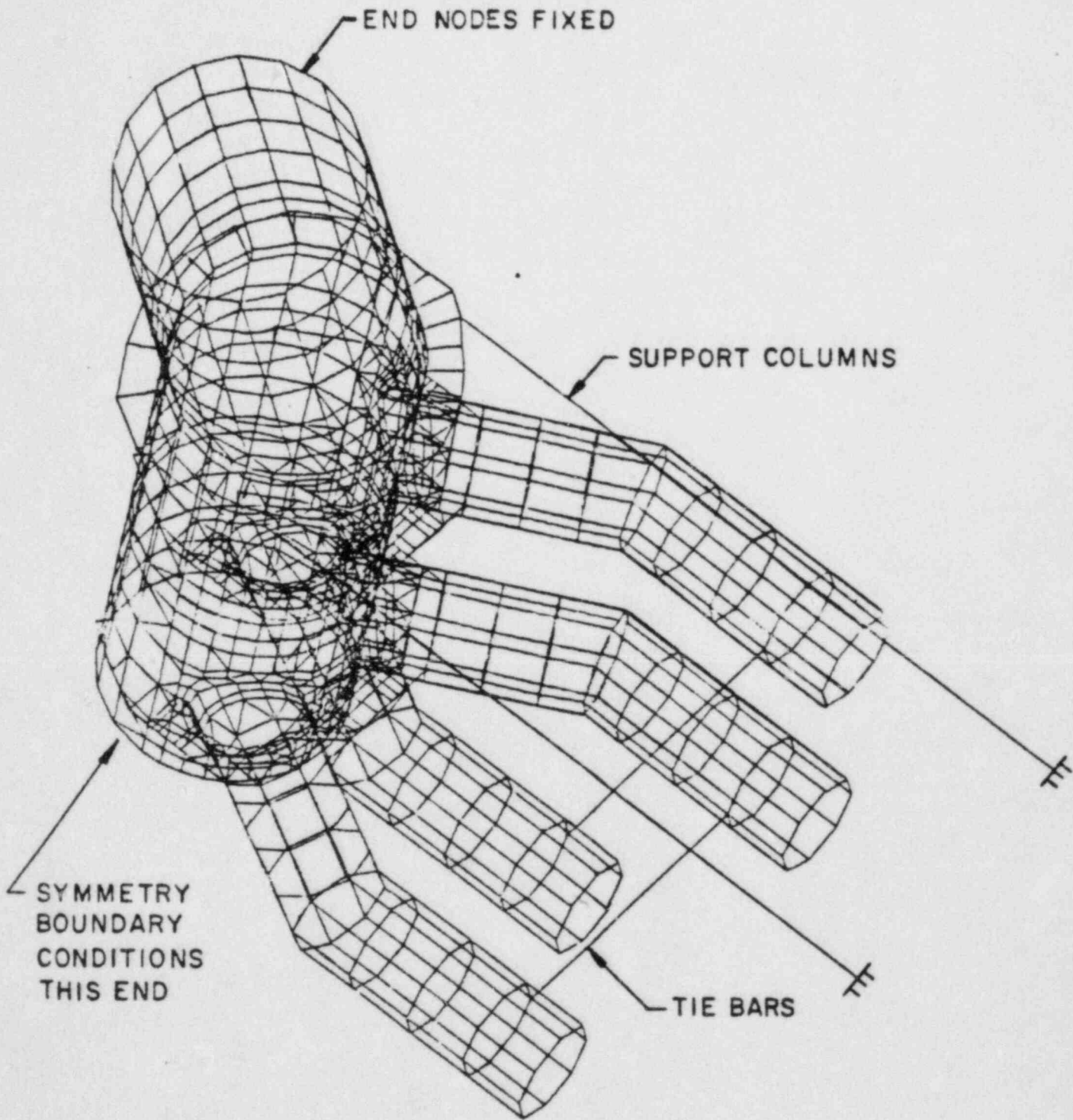


FIG. 4-1
VENT HEADER MODEL

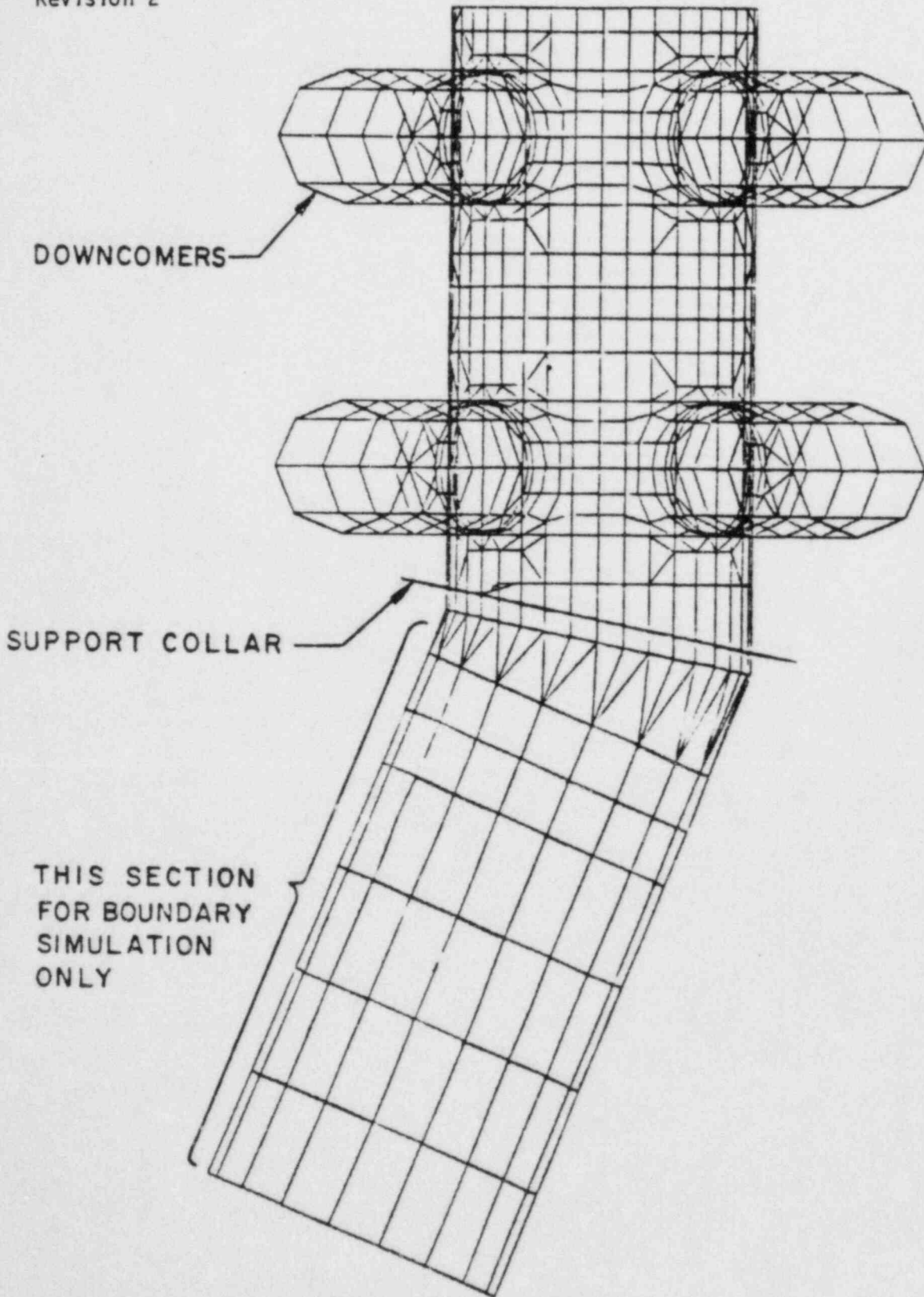


FIG. 4-2
DETAILED VENT HEADER MODEL

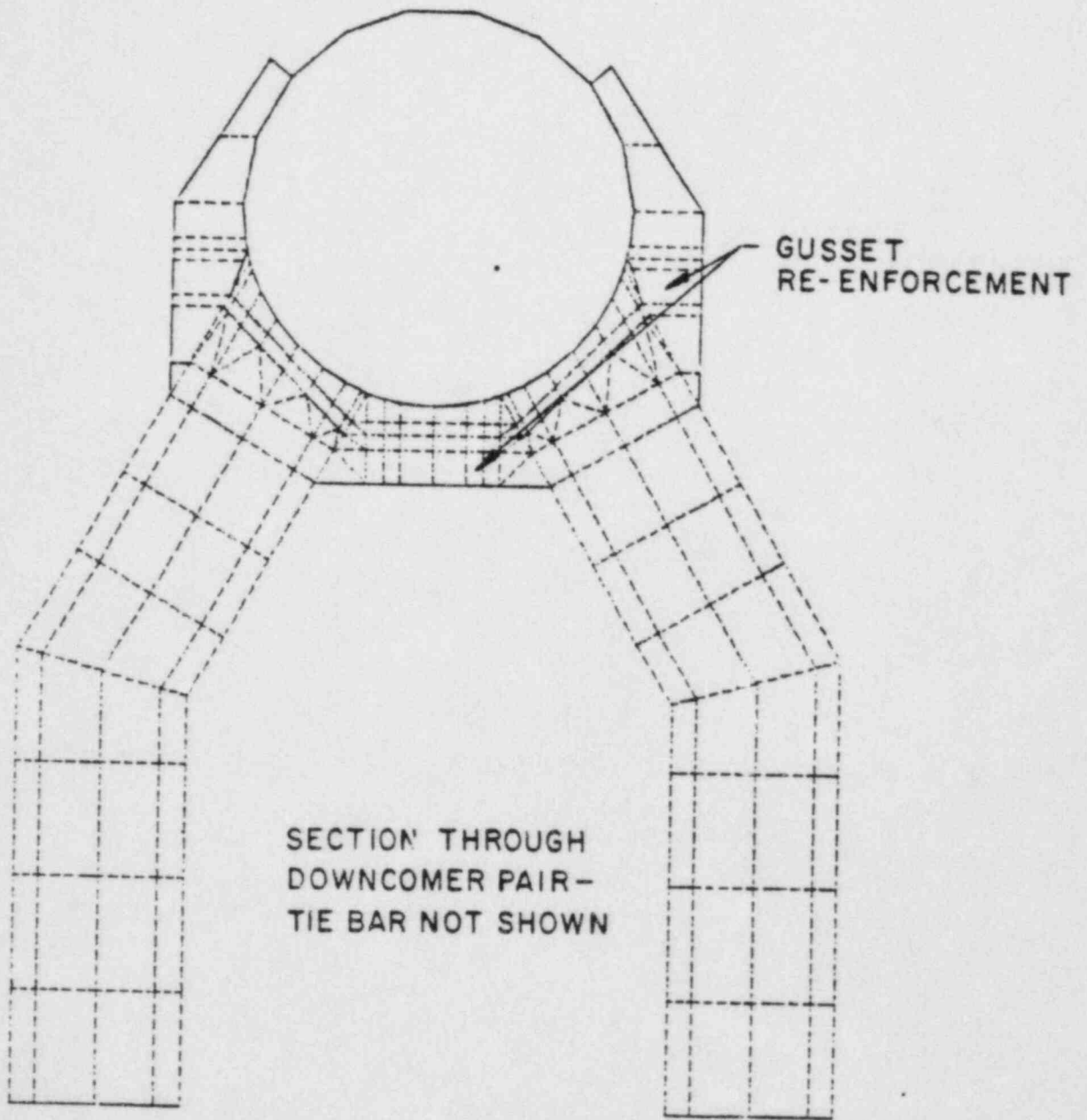


FIG. 4-3
DETAILED VENT HEADER MODEL

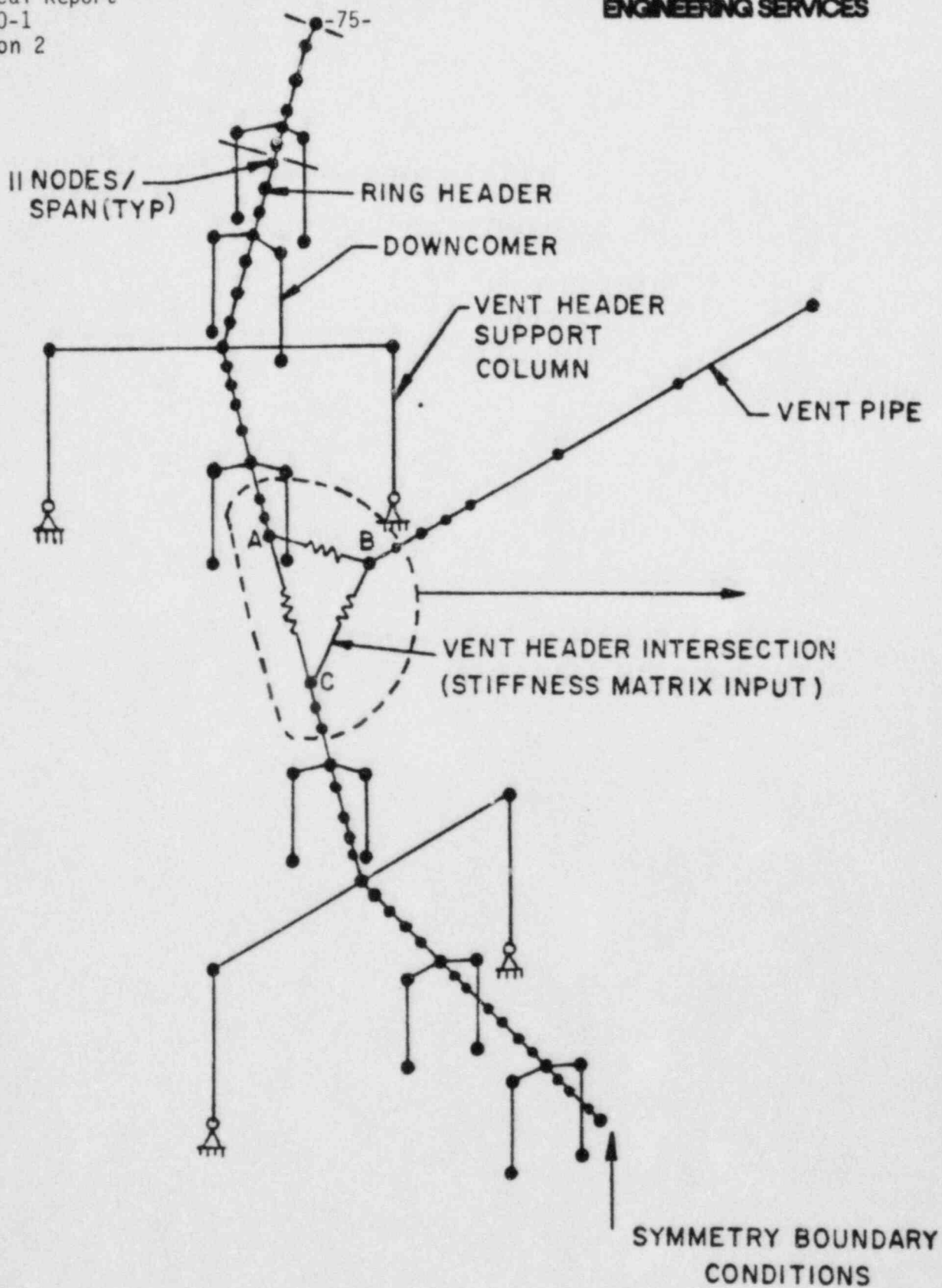


FIG. 4-4
VENT SYSTEM BEAM MODEL

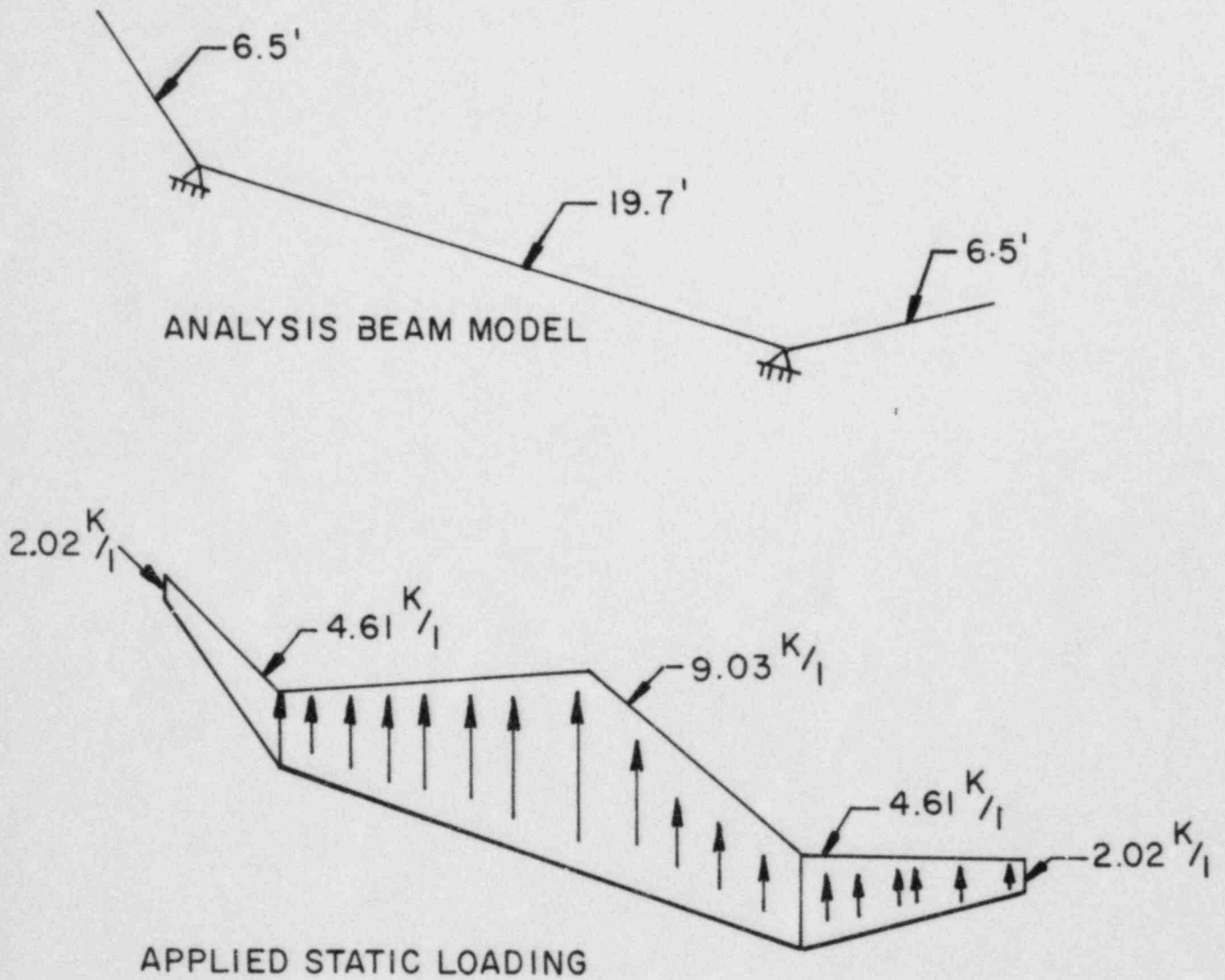
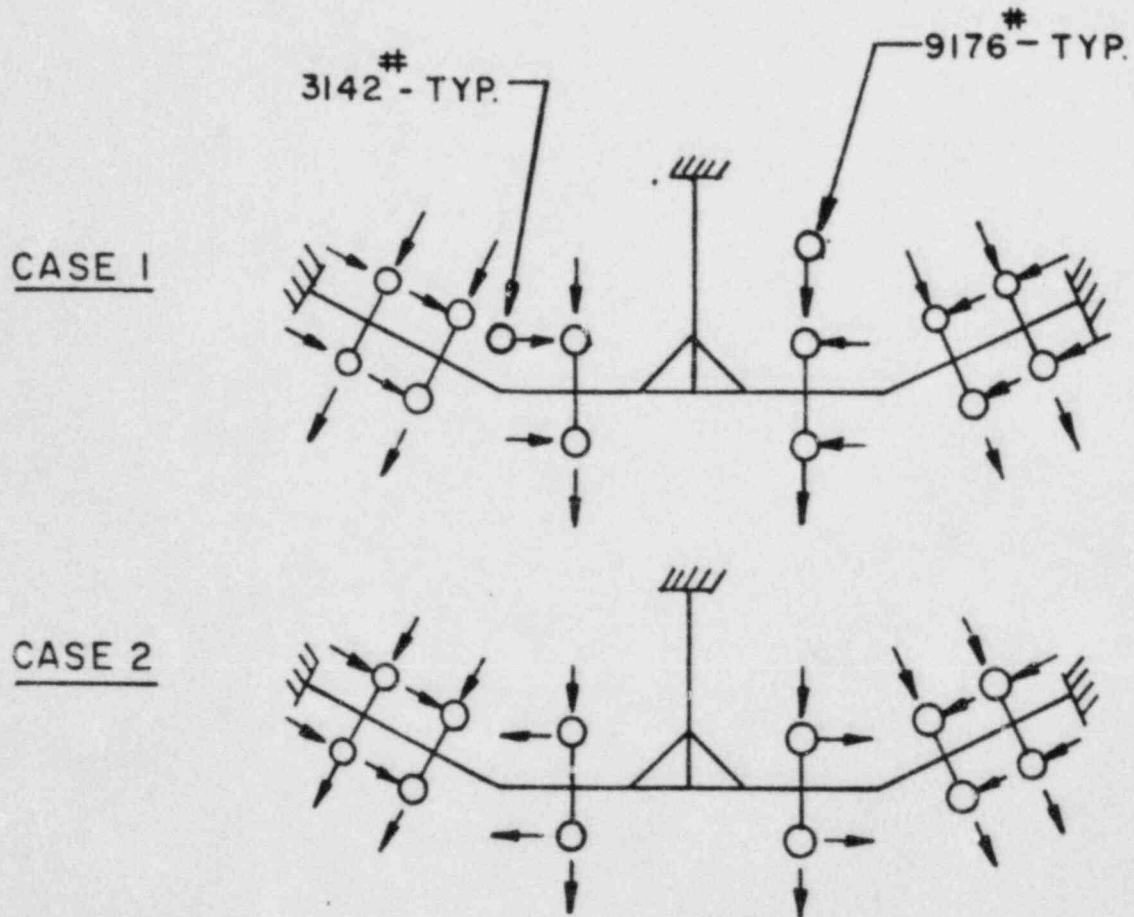


FIG. 4-5

VENT HEADER DEFLECTOR ANALYSIS - PILGRIM



ANALYSIS CASES FOR SYNCHRONIZED LATERAL CHUGGING

FIG 4-6

5.0 RING GIRDER ANALYSIS

The ring girder for Pilgrim is shown in Figure 5-1. It is mounted in a vertical plane that passes through the support saddles and the support columns. Because all major internal structures are supported by the ring girders, the ring girders that must react to the largest number of individual loads.

5.1 Structural Elements Considered

Elements considered in this section are:

- (a) The ring girder web and flange
- (b) The attachment weld to the shell

Local stresses at attachments have also been considered and added, i.e., vent header support columns, catwalk, etc.

5.2 Computer Models

Two computer models were used as a part of the ring girder analyses; both are detailed models which also include the shell and external supports.

The first model is shown in Figure 5-2. This is a detailed model, which represents one-sixteenth of the torus structure; one half bay on each side of the mitre joint. It accurately simulates the ring girder offset (four-inches from the mitre joint) as well as structural differences between the vent and non-vent bays. Because the ring girder is not at the boundary of this model, out-of-plane motion of the ring girder can be accurately determined. This model was used to evaluate all direct loads on the ring girder; these include loads from attached structures such as the tee-quencher supports, catwalk and vent header system, as well as all drag loads. The one-

sixteenth model used for the Pilgrim ring girder analysis was one that had been constructed for one of the other Mark 1 plants analyzed by TES. The dimensions of this other plant are very similar to Pilgrim; the diameter of the torus, shell thickness and distance between the ring girder and mitre joint are all similar. The ring girder flange in this model is slightly smaller than Pilgrim and, therefore, produces conservative results since lateral loads control ring girder stresses. The comparison is:

Ring Girder Flange Dimensions (inches)

Pilgrim: 1.5 x 7
Model Used: 1.5 x 6

The second model used to determine ring girder loads is the Pilgrim 1/32 finite element model shown in Figure 3-1. This model was used previously to evaluate shell stresses of all symmetric loads that act on the shell. These same computer analyses produce information on ring girder stress for symmetric loads. Loads evaluated with this model include weight, internal pressure and all shell dynamic loads. The boundary conditions on this model restrict the ring girder to in-plane motion.

5.3 Loads Analysis

5.3.1 Loads Applied to Shell

As stated, the ring girder stresses for all symmetric loads applied to the shell were taken from the appropriate analyses described in Section 3.0; these include:

- (a) Pool Swell Shell Load (Paragraph 3.2.1)
- (b) Condensation Oscillation (3.2.2)
- (c) Chugging (3.2.3)

- (d) SRV Discharge*
- (e) Seismic
- (f) Deadweight, Thermal and Pressure

*SRV discharge is conservatively assumed to be a symmetrically applied load for shell analysis.

5.3.2 Drag Loads

The ring girder is subject to drag loads from each of the dynamic shell loads as well as Fluid Structure Interaction (FSI) effects from CO and CH. All these loads were evaluated by using the 1/16 model and applying static loads on the wetted nodes of the ring girder. The use of static analysis was based on the assumption that the stiffening effect of the saddle, columns and column gussets would make the ring girder very stiff and would prevent frequency interaction with the dynamic loads. Because of this, no dynamic amplification was applied to the static analysis results (DLF = 1.0). Drag loads considered were:

- (a) Pool Swell Bubble
- (b) Pool Swell Jet (bounded by a)
- (c) SRV Jet
- (d) SRV Bubble
- (e) CO including FSI (bounded by g)
- (f) Pre-chug including FSI (bounded by g)
- (g) Post Chug including FSI

The effects of SRV jet (c) and SRV drag (d) were evaluated based on data collected from in-plant tests. A discussion of the in-plant tests and the use of drag data from these tests is given in Appendix 1.

Calculation of ring girder drag loads due to condensation oscillation and post chug FSI was not in accordance with NUREG 0661 (Reference 2). An alternate method of calculating drag volume was used in this load

calculation. It produced drag volumes for the ring girder of about half of those that the NUREG 0661 procedure would have produced. A discussion of this is included in Appendix 3. The FSI drag calculation was based on local pool accelerations at the ring girder due to the response of the entire shell. The post chug and FSI analysis considered frequencies to 31 Hz, which were combined by adding the values of the five maximum components to the SRSS sum of the others.

5.3.3 Loads Due to Attached Structure

Loads applied to the ring girder by structures attached to it were evaluated by equivalent static analysis, using the 1/16 model (Figure 5-2). The important loads are applied in the area of the support saddle and columns which make the ring girder very stiff and minimizes dynamic interaction. Because of this, dynamic amplification of the static ring girder stresses was not done (DLF = 1.0). The load input to the ring girder was a result of a dynamic analysis of the attached system (or had an appropriate DLF applied) and, therefore, included the effects of dynamic amplification on load.

The following loads are applied to the ring girder and were considered:

- Tee-quencher support beam thrust due to SRV discharge.
- Tee-quencher and support drag loads.
- Vent header support column reaction loads during pool swell.
- Vent header support column drag loads.
- Catwalk support column reactions and drag.

As stated in Section 5.1, stresses resulting from attached structure have been included in the following results.

5.4 Results & Evaluations

5.4.1 Ring Girder Web & Flange

The controlling load combination for the ring girder web and flange is load case 16 of Table 1; this includes:

Pool Swell ($0\Delta P$) + Internal Pressure + Weight

The controlling stress is:

<u>LOCATION</u>	<u>LOAD DIRECTION</u>	<u>STRESS TYPE</u>	<u>ACTUAL STRESS</u>	<u>ALLOWABLE STRESS</u>
Web	Down	Membrane + Bending	16.6 ksi	28.95 ksi
Flange	Down	Membrane	15.0 ksi	19.3 ksi

5.4.2 Weld to Torus Shell

The controlling load combinations for the shell weld are load cases 21 and 25 as indicated below. These cases include:

Load Case 21

DBA.CO + Seismic (SSE) + Pressure + Weight

Load Case 25

Pool Swell ($full\Delta P$) + Seismic (SSE) + Pressure +
Weight

For these cases, the controlling loads are:

RING GIRDER/SHELL WELD LOADS

<u>LOCATION</u>	<u>LOAD CASE</u>	<u>STRESS TYPE</u>	<u>ACTUAL LOAD</u>	<u>ALLOWABLE LOAD</u>
Inner Column Region	21	Shear	7.46 K/in	8.53 K/in
Outer Column Region	21	Shear	8.34 K/in	8.53 K/in
Saddle Region	25	Shear	8.29 K/in	8.53 K/in

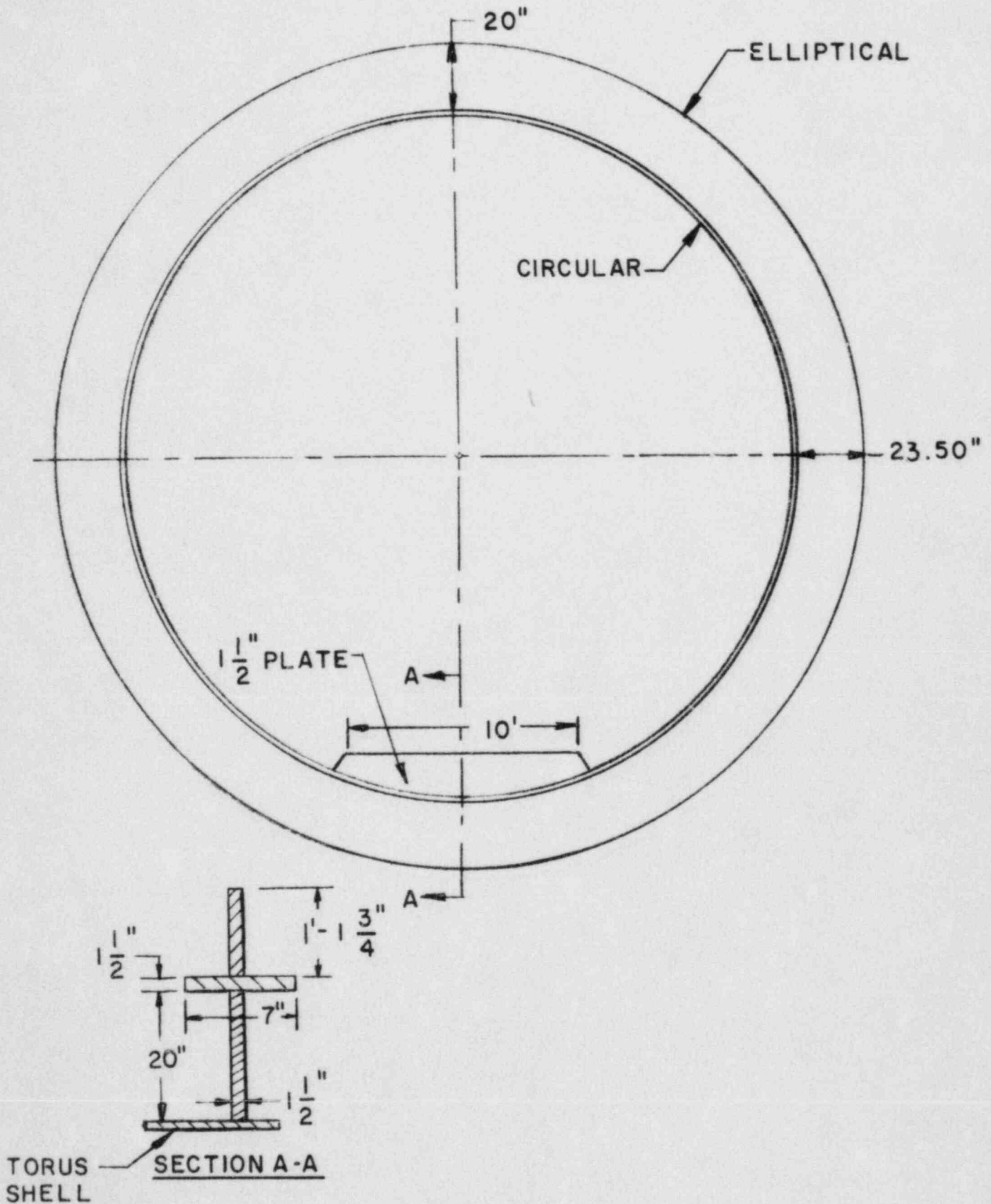


FIG. 5-1
RING GIRDER - PILGRIM

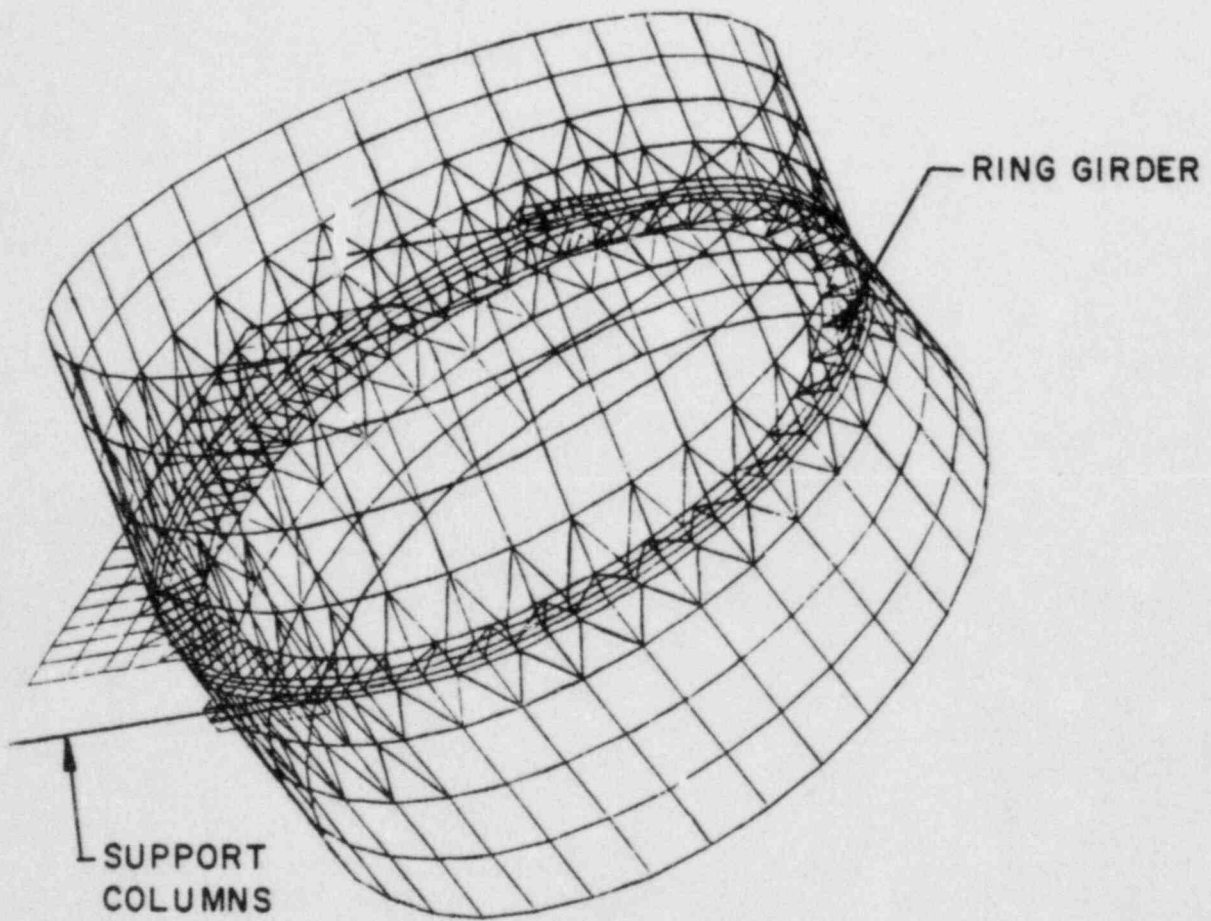


FIG. 5-2
DETAILED RING GIRDER - SHELL MODEL
(SIMILAR PLANT)

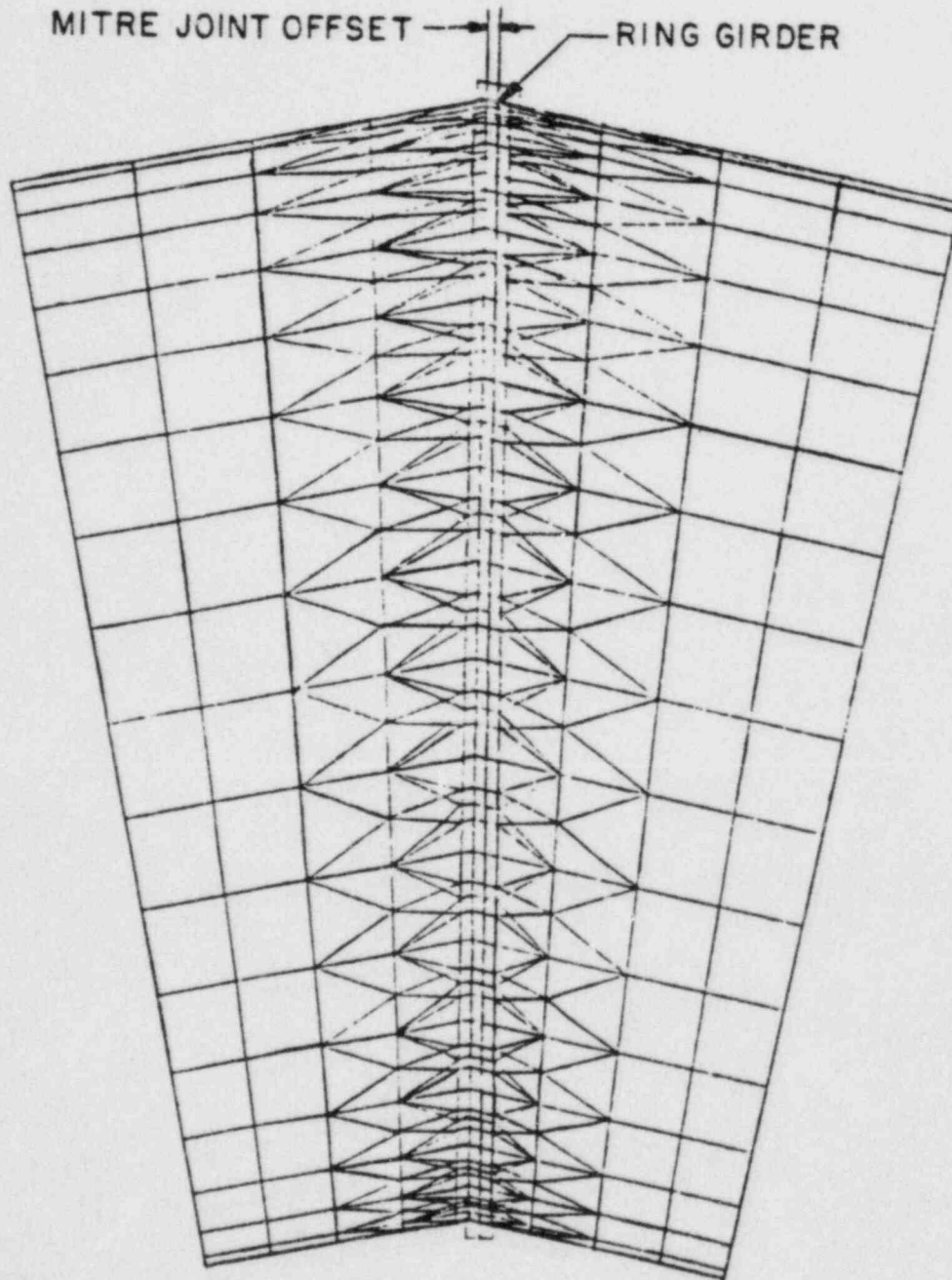


FIG. 5-3
DETAILED RING GIRDER - SHELL MODEL

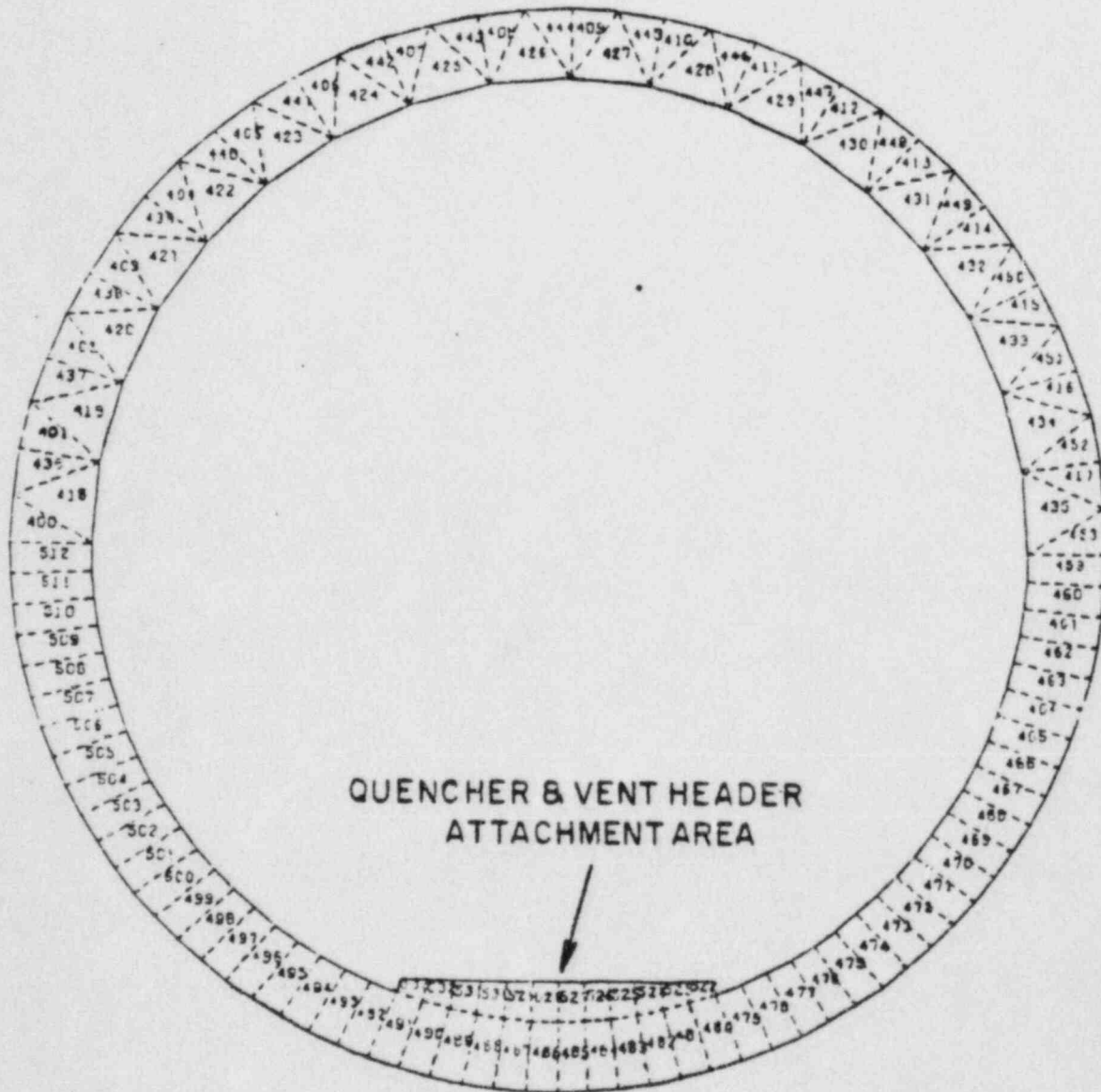


FIG. 5-4
DETAILED RING GIRDER - SHELL MODEL
RING GIRDER ELEMENTS

6.0 TEE-QUENCHER AND SUPPORT

The following results for the tee-quencher and support are conservative due to the combined effect of several factors, three of which are:

- The calculational methods to determine applied loads improved after this analysis was complete, and would provide reduced stresses.
- Some loads were intentionally bounded by conservative values from other plants so a single calculation could be used for more than one plant.
- For submerged drag loads, individual frequency components were added to produce maximum stress without regard to load direction.

The effect of these conservatisms vary among stresses, but can be significant in some cases.

6.1 Structural Elements Considered

The configuration of the quencher and support is shown in Figure 2-8. Pilgrim has four discharge lines, each enters the pool at a 20⁰ angle.

The structural elements considered in this section include:

- The quencher,
- The submerged portion of the SRV line.
- The quencher support beam and attachments.

6.2 Computer Models

The computer model used in this analysis is shown in Figure 6-1.

This is a STARDYNE beam model which represents all piping and structure between the drywell jet deflector and the ring girder. For these analyses, the ring girder was assumed rigid and the vent pipe penetration was represented by a stiffness matrix which was developed from a finite element model of the penetration. Releases were modeled between the quencher and support plates to allow for free rotation of the quencher arms in the supports.

This model was used for both static and dynamic analysis.

6.3 Loads Analysis

6.3.1 SRV - Load

The calculation of stress due to SRV blowdown was done by applying the dynamic loads to the computer model and calculating the time-history response of the system. The applied loads included both the blowdown forces on the piping and the water clearing loads at the quencher. The controlling condition was for a second, multiple valve actuation after an IBA/SBA break, with steam in the drywell (SRV case C3.3). This case produces a high reflood level at the time of the second actuation and produces maximum load on the support system. Loads for this analysis were developed using G.E. computer program RVFOR-05.

6.3.2 Pool Swell Loads

The effects of pool swell jet and bubble loads on the quencher and support system were conservatively estimated by static analysis and a dynamic load factor of 2. It was clear from this analysis that combined pool swell events would not control stresses - no further analysis was done.

6.3.3 Chugging Loads

Dynamic analysis of the quencher and support system was done for drag loads due to pre-chug, post chug and chugging FSI. All these analyses were based on a set of harmonic analysis which provided results for all steady-state frequency excitations from 1-31 Hz. Results for individual load conditions were determined by scaling individual frequency results of the computer analysis by the appropriate pressure amplitude.

The mass of the structure used in the computer analysis was adjusted to account for the "added mass" effect of the surrounding water. For FSI and post-chugging analyses, individual frequency components were combined by adding the five maximum frequency contributors to the SRSS sum of the others (see Reference 12 for discussion). The maximum value of each frequency component was used in the combination, regardless of vector direction or time of instantaneous response. FSI loads were calculated by considering the calculated local accelerations in the pool due to response of the entire shell.

6.3.4 Condensation Oscillation Loads

The quencher and support system are subjected to condensation oscillation drag and CO-FSI drag. Analysis for these loads was based on the same harmonic analysis discussed in paragraph 6.3.3, scaled to the CO amplitudes. Each of the three CO spectra shown in Figure 4.4.1-1 of Reference 1 were considered.

All other discussion from paragraph 6.3.3 for chugging applies to the condensation oscillation analysis, except that the final load was determined by adding the four maximum frequency contributors to the SRSS sum of the others.

6.3.5 Other Loads

Calculations of stress due to weight, thermal and seismic loads was done by using the computer model in Figure 6-1 and static analysis. Pressure stresses for the piping and quencher were calculated by hand.

6.4 Results and Evaluation

The results reported in this section may be conservative depending on the effect of factors discussed in Sections 1.0 and 6.0 of this report.

6.4.1 Tee-Quencher

The controlling stress in the tee-quencher itself occurs in the ramshead between the quencher arms. It is the result of a second SRV actuation after an SBA accident - load case 15 of Table 1. It includes:

SRV blowdown (case C3.3) + Chugging Drag + Weight + Seismic + Internal Pressure + Thermal

The controlling stress is:

<u>STRESS LOCATION</u>	<u>STRESS TYPE</u>	<u>ACTUAL STRESS</u>	<u>ALLOWABLE STRESS</u>
Bifurcated Elbow	Bending	18,671 psi	24,705 psi

6.4.2 Submerged SRV Line

The controlling stress for the submerged portion of the SRV line occurs in the inclined lines and is a result of load case 15 in Table 1. This case includes:

SRV Blowdown (case C3.3) + Chugging Drag + Weight + Seismic +
Internal Pressure + Thermal

The controlling stress is:

<u>STRESS LOCATION</u>	<u>STRESS TYPE</u>	<u>ACTUAL STRESS</u>	<u>ALLOWABLE STRESS</u>
Vertical Section Above First Elbow	Bending	9,094 psi	27,000 psi

6.4.3 Tee-Quencher Support

The controlling stress that was calculated for the tee-
quencher support is the result of load case 15 of Table 1. This case
includes:

SRV Blowdown (case C3.3) + Chugging Drag + Weight + Seismic +
Thermal

The controlling stress for the beam is:

<u>STRESS LOCATION</u>	<u>STRESS TYPE</u>	<u>ACTUAL STRESS</u>	<u>ALLOWABLE STRESS</u>
At the Brace Connection	Bending	17,361 psi	27,000 psi

6.4.4 Tee-Quencher Support Brace

The controlling stress that was calculated for the tee-
quencher support diagonal brace is the result of load case 15 of Table 1.
This case includes:

SRV 3lowdown (case C3.3) + Chugging Drag + Weight + Seismic +
Thermal

The controlling stress is:

<u>STRESS LOCATION</u>	<u>STRESS TYPE</u>	<u>ACTUAL STRESS</u>	<u>ALLOWABLE STRESS</u>
In Brace	Bending	12,719 psi	27,000 psi

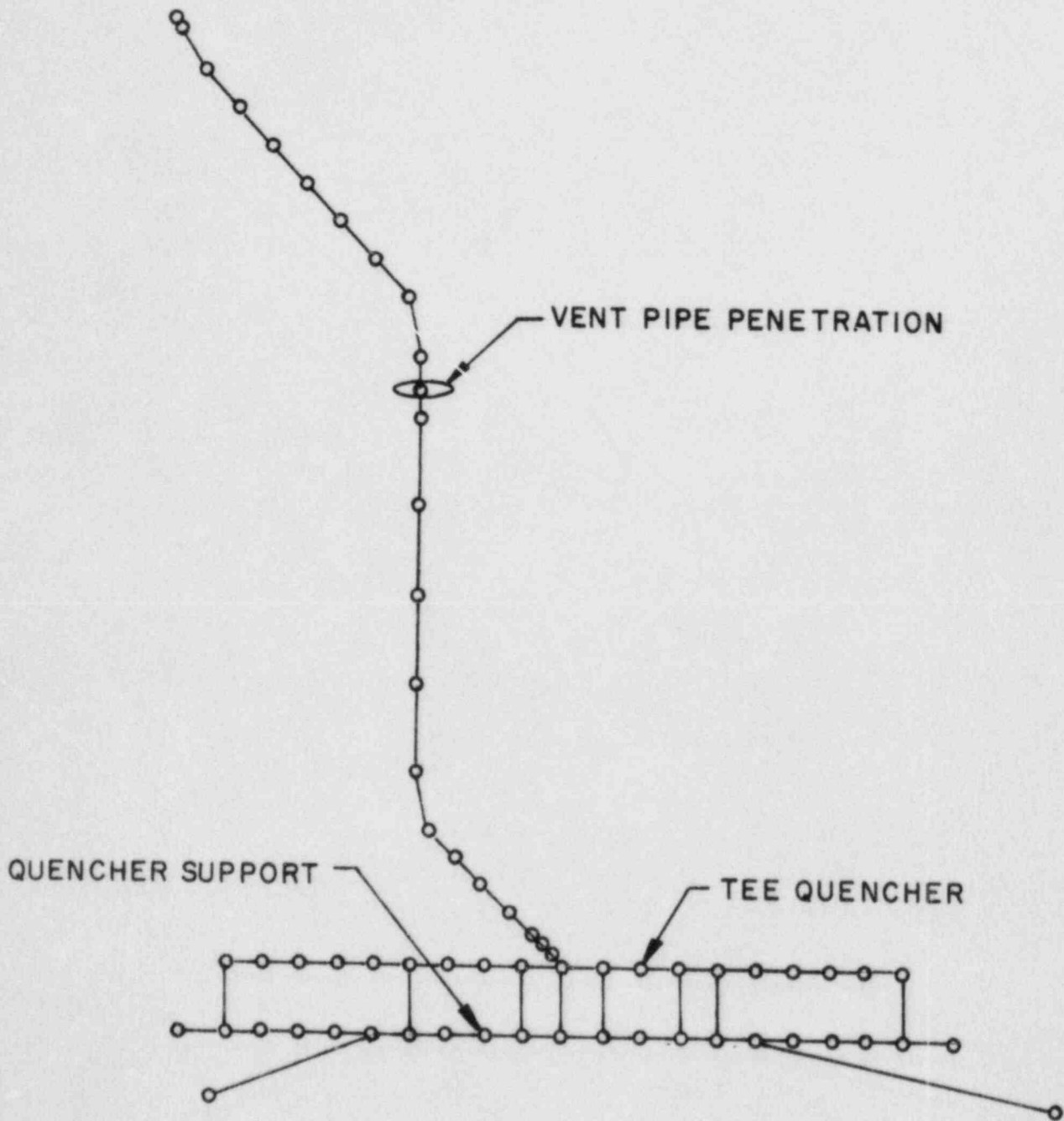


FIG.6-1
PILGRIM ANALYTIC MODEL

7.1 Catwalk

The catwalk structure is attached to the ring girders and provides 360⁰ access to the inside of the torus. It consists of a horizontal frame structure which supports sections of open grating. At each ring girder, one side of the frame is attached directly to the ring girder by a short horizontal member; the far side of the catwalk is supported by vertical columns which connect to the ring girder below the water line. Additional pipe column supports were added and the hand rail is wire rope as shown on Figures 2-14 and 2-15.

7.1.1 Computer Model

The computer models of the catwalk are shown in Figures 7-1 and 7-2 for the original and modified catwalk. It represents the structure for one full bay, beginning at mid-bay. They include all of the load carrying structural members, but do not include the grating or handrails. Loads from these elements are calculated and applied to the frame as forces at the points of attachment.

All catwalk analysis was performed on these linear models. All analysis used static application of loads, increased to account for dynamic amplification, where appropriate.

7.1.2 Loads Analysis

Loads analysis for the catwalk was performed for the direct effects of the following loads. Indirect effects due to motion of the ring girder at the attachments points were considered, but judged to be negligible.

7.1.2.1 Pool Swell Drag (4.3.4)

Pool swell drag loads are produced as the rising pool envelops the main frame, grating and handrails. Loads on the frame were

calculated based on velocities taken from plant unique QSTF movies and the methods in Reference 1. These were multiplied by two to account for the dynamic effect. Loads on the grating were taken from Section 4.3.4 of Reference 1; these loads already include a dynamic factor, since they are based on test data.

7.1.2.2 Pool Swell Fallback (4.3.6)

Pool fallback loads were calculated and applied in accordance with Reference 1, except in unusual cases where fallback loads exceeded upward loads. In these cases, the maximum values of upward load were used for fallback also. Fallback affects the main frame and grating as well as the handrails.

7.1.2.3 Froth Load (4.3.5)

Froth loads have their major effect on the catwalk handrails; and, when applied horizontally, can produce high bending stresses in the vertical handrail members. Froth loads were calculated in accordance with Reference 1, except that the froth 1 influence region was redefined using plant-unique QSTF movies. These movies show clearly that froth 1 loads do not reach the catwalk railing; the analysis was therefore performed with froth 2 loads only.

Except for the handrails, the entire catwalk is submerged before froth loads reach this part of the torus; because of this, froth was only considered on the handrails.

7.1.2.4 Drag Loads (Support Columns)

The submerged portion of the catwalk support columns are subject to loading from drag forces from the following sources:

- (a) Pool Swell
- (b) SRV Discharge

- (c) Condensation Oscillation
- (d) Chugging

Loads from these sources were calculated and applied to the support columns as static loads. The natural frequency of the support was calculated using hand calculations and compared to the frequency(s) of each source. The statically determined stress was then multiplied by a dynamic amplification factor, developed by considering the worst case frequency ratio and the fact that this is a harmonic loading.

7.1.2.5 Weight and Seismic Loads

Stresses due to weight loads were analyzed using static analysis and the computer model shown in Figure 7-2. Seismic loads are small and were considered using hand analysis and scaling static stresses.

7.1.3 Results and Evaluation

Table 1 allows stresses in the catwalk structure (excluding attachments) to exceed yield; and, in certain cases, to exceed ultimate. Our analysis was based on a linear model and all stresses were maintained below the stress at which a plastic hinge would form. Controlling stress and load combination for various catwalk elements are listed here.

7.1.3.1 Main Frame

The controlling stress in the catwalk frame occurs in the inboard supporting channel, Point A in Figure 7-2. It is a result of the combined condition that includes:

Pool Swell + SRV + Seismic + Weight (case 25)

The maximum stress value is:

<u>TYPE OF STRESS</u>	<u>ACTUAL STRESS</u>	<u>ALLOWABLE STRESS</u>
Bending + Axial	24,700 psi	40,600 psi

7.1.3.2 Support Columns, Support Diagonal Braces & End Joints

The controlling load case for the support system and end joints includes:

SRV + Seismic + Weight (case 3)

Resulting stresses are:

<u>TYPE OF STRESS</u>	<u>STRESS LOCATION</u>	<u>ACTUAL STRESS</u>	<u>ALLOWABLE STRESS</u>
Axial + Bending	Column to Ring Girder	8,415 psi	12,600 psi

7.1.3.3 Welds to Ring Girder

The controlling load combination for this stress is also case 25:

Pool Swell + SRV + Seismic + Weight

For this condition, stresses are:

<u>TYPE OF STRESS</u>	<u>ACTUAL STRESS</u>	<u>ALLOWABLE STRESS</u>
Shear	8,007 psi	42,000 psi

7. Internal Spray Header

The internal spray header is attached to the ring girders and to a penetration on the shell. It is located at the top of the torus, above the vent header (Figure 2-3).

7.2.1 Computer Model

The computer model used to analyze the spray header is shown in Figure 7-3. It was constructed to allow determination of stresses in a typical multi-span area as well as at branch connections. This is part of a piping system and piping elements were used in the model. All results were obtained through the use of static analysis, with factors applied to account for dynamic response.

7.2.2 Loads Analysis

The spray header is high enough in the torus so it does not experience direct water impact-froth in the only pool swell related load that is applied.

The motion of the ring girder that results from pool swell loads on the shell was considered but judged to be a negligible input to the spray header. Shell displacement at the nozzle connections was input to the computer analysis.

7.2.2.1 Froth Load (4.3.5)

Froth loads on the spray header were calculated as outlined in Reference 1. The worst stress condition existed for a vertically applied load. The loads were applied statically to the system (DLF = 1.3).

7.2.2.2 Weight, Seismic & Ring Girder Displacement

The effects of weight, seismic and shell displacement were all considered by using the model shown in Figure 7-3 and applying loads and displacements statically.

7.2.3 Results and Evaluation

The controlling stress for the spray header piping is a result of load case 19 in Table 1.

This case includes:

Froth, Weight, Seismic and Shell Motion

The controlling stress is:

SPRAY HEADER PIPING

<u>STRESS LOCATION</u>	<u>STRESS TYPE</u>	<u>ACTUAL STRESS</u>	<u>ALLOWABLE STRESS</u>
Mid-bay	Bending	22,784 psi	32,880 psi

ATTACHMENTS TO RING GIRDER

<u>STRESS LOCATION</u>	<u>STRESS TYPE</u>	<u>ACTUAL STRESS</u>	<u>ALLOWABLE STRESS</u>
Support Hold Down Plate	Bearing	17,298 psi	34,200 psi

WELDS TO RING GIRDER

<u>STRESS LOCATION</u>	<u>STRESS TYPE</u>	<u>ACTUAL STRESS</u>	<u>ALLOWABLE STRESS</u>
At Ring Girder	Tension + Shear	1,868 psi	18,000 psi

7.3 Vent Pipe Bellows

The vent pipe bellows forms the pressure seal between the vent pipe and torus and allows for relative motion between these parts. It is illustrated in Figure 7-4.

7.3.1 Analysis Method

The bellows are rated by the manufacturer for differential motion both axially and radially. These ratings are intended to define static differences which occur over a long enough time so that dynamic response of the bellows itself can be ignored.

In the present analysis, both ends of the bellows are experiencing dynamic motion; one end is controlled by the vent pipe, the other by the torus shell. We expect that the dynamic characteristics of the convoluted bellows should increase stresses over their static equivalents. We also expect that the convolutions will produce complex modes and stress patterns that will not couple efficiently with specific input frequencies; i.e., high dynamic response is not expected. Further, the "pogo" and "roiling" modes of the convolutions are non-linear, highly cross-coupled modes that would not be predicted by ordinary structural codes.

Our approach to the bellows evaluation is to compare the maximum calculated difference in dynamic response (displacement) across the bellows to the manufacturers' allowable. We accept the bellows as adequate for all cases where a large margin exists between predicted input motion and the static capacity, as stated by the manufacturer.

7.3.2 Loads Analysis

Calculation of vent pipe motion and torus shell motion was done as a part of the analysis work discussed in Sections 3.0 and 4.0 of this report. The analysis of the torus shell in Section 3.0 was based on a

computer model of the non-vent bay and therefore did not account for the presence of the vent pipe hole, or the heavy shell reinforcement in that area.

7.3.3 Results and Evaluation

The maximum differential motion across the bellows occurs as a result of case 25 in Table 1; this case includes:

Pool Swell Pressure on Shell + Water Impact on the Vent System + Vent System Thrust + Pressure + Weight + SRV + Seismic

For this case, the following deflections occurred:

	<u>MAXIMUM DIFFERENTIAL MOTION</u>	<u>MANUFACTURERS' STATIC ALLOWABLE</u>
Axial Compression (in.)	.038	.875
Axial Extension (in.)	.038	.375
Lateral Motion (in.)	.062	.625

All calculated values are less than 11% of the manufacturer's allowables. We consider that this large difference demonstrates the acceptability of the bellows, especially if we consider that much of the load is either static or a single-pulse transient (maximum amplification of 2).

7.4 Vacuum Breaker Penetration Reinforcement

The vent header penetration for the drywell-to-wetwell vacuum breakers required modification as a result of load case 19 of Table 1.

This case includes:

Pool Swell + Seismic + Weight

PENETRATION STRESS

<u>STRESS TYPE</u>	<u>ACTUAL STRESS</u>	<u>ALLOWABLE STRESS</u>
Primary + Secondary	46,013 psi	57,900 psi

The modification was to add three stiffener plates to each penetration as shown in Figure 2-18.

7.5 Electrical Junction Canister

The electrical canisters (2) near the top of the wetwell required modification as a result of load case 19 of Table 1. The canisters are subject to Level D service limits which allows for yielding of the material. The stress reported is compared to yield.

This case includes:

Pool Swell (froth) + Seismic + Weight

MAXIMUM CANISTER STRESS

<u>LOCATION</u>	<u>STRESS TYPE</u>	<u>ACTUAL STRESS</u>	<u>ALLOWABLE STRESS</u>
Canister Support Arm	Bending	46,000 psi	46,000 psi (yield)

The modification support arm and ring to each penetration is shown in Figure 2-19.

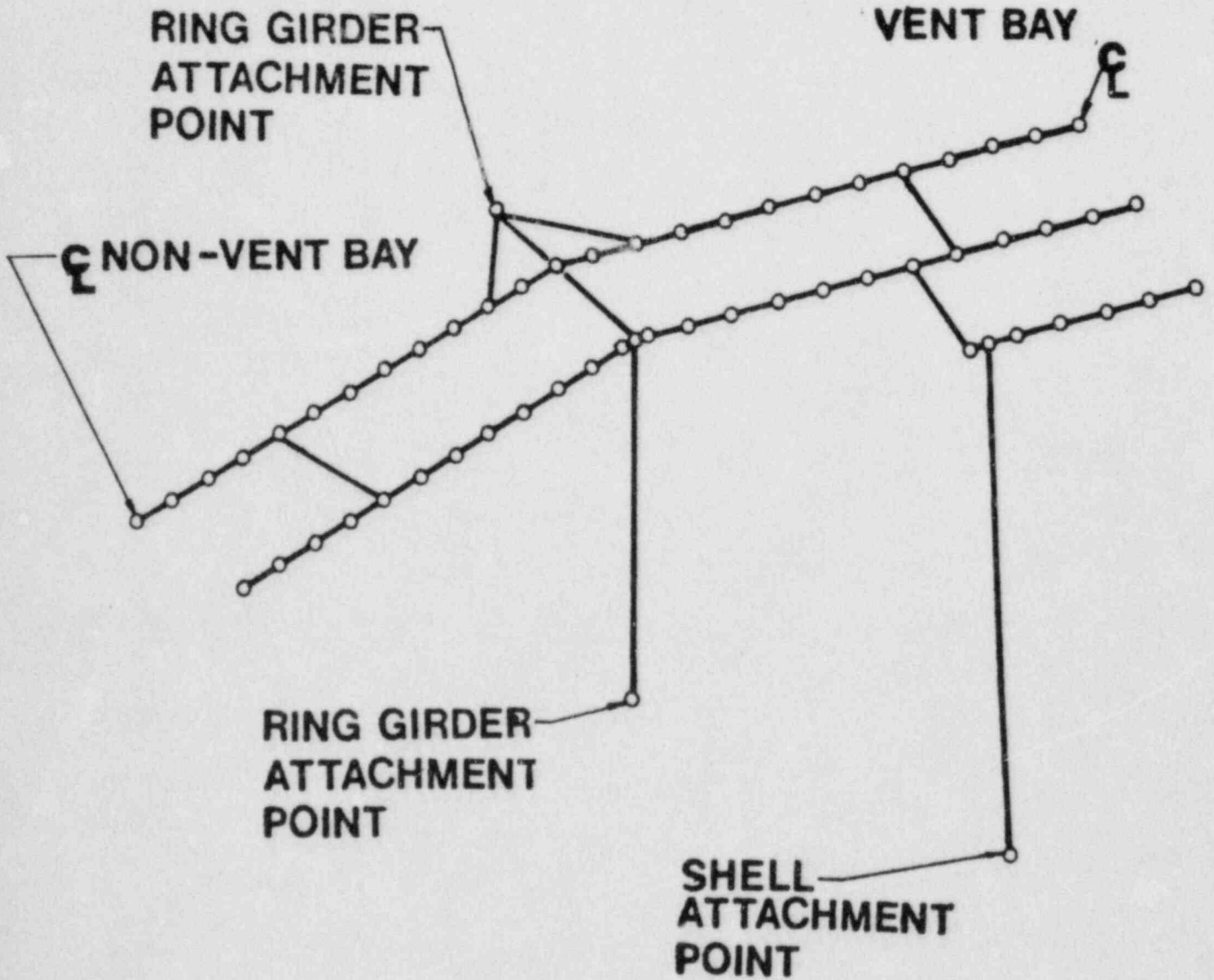


FIG.7-1

UNMODIFIED CATWALK COMPUTER MODEL - PILGRIM

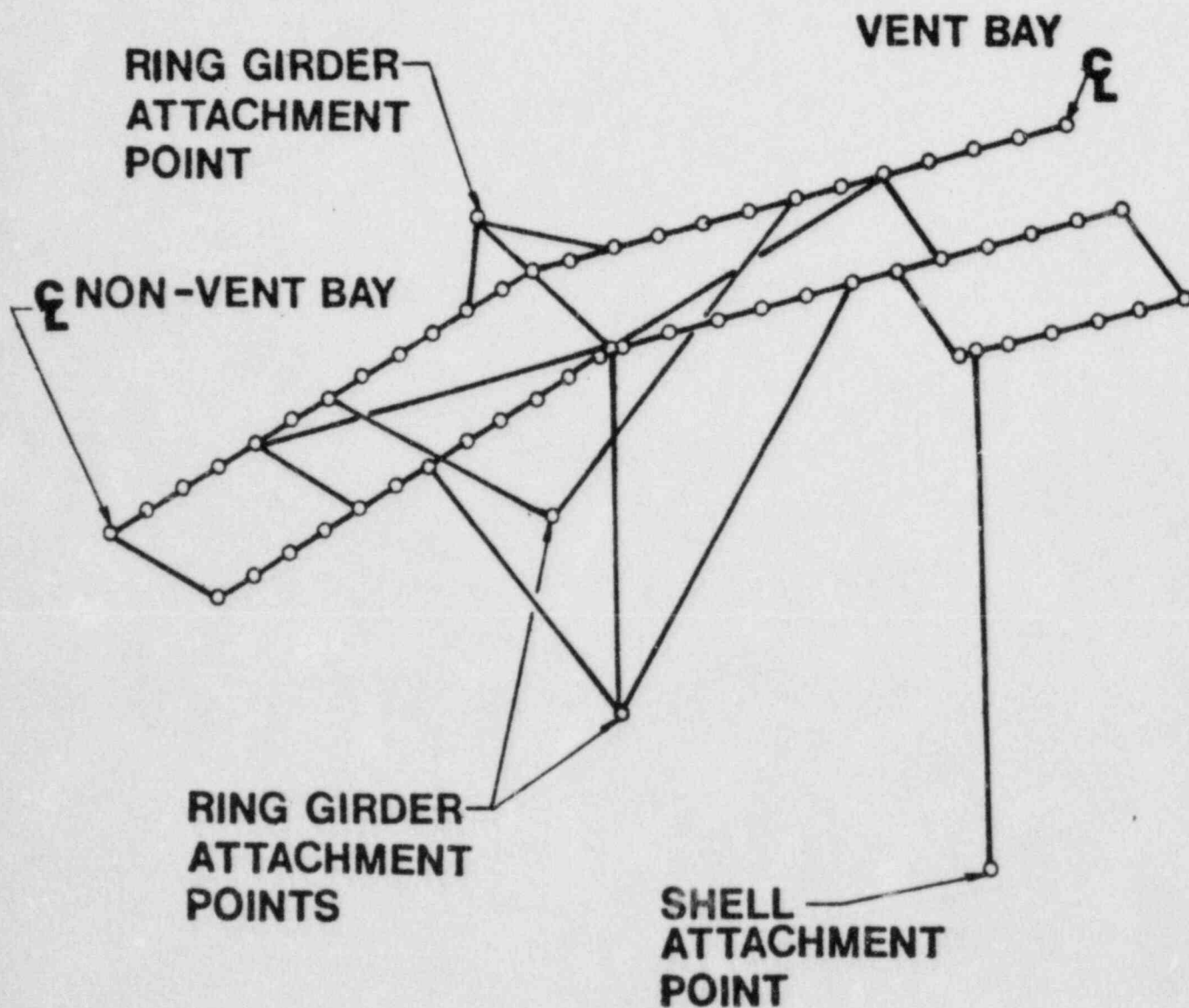


FIG. 7-2
MODIFIED CATWALK COMPUTER MODEL - PILGRIM

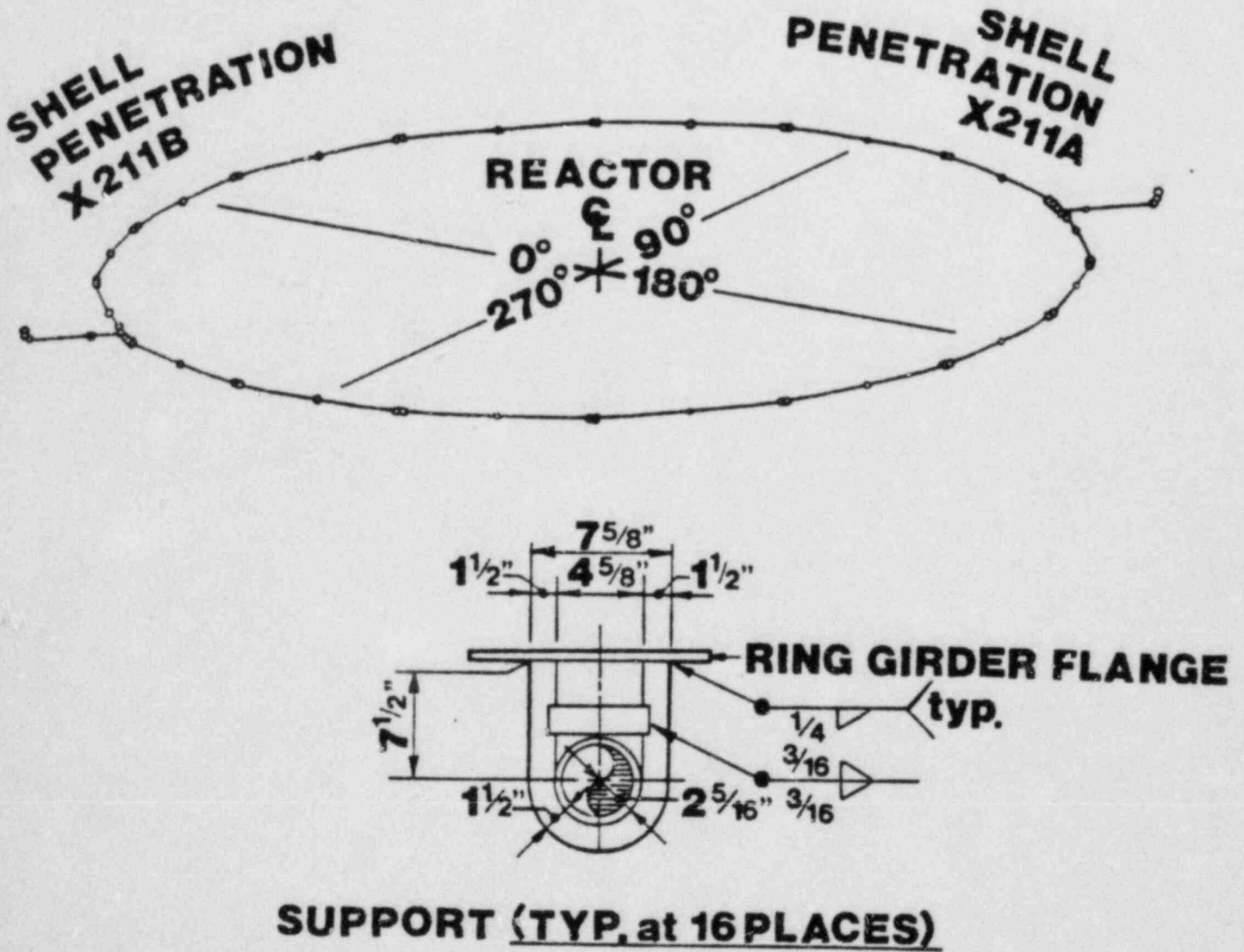


FIG. 7-3

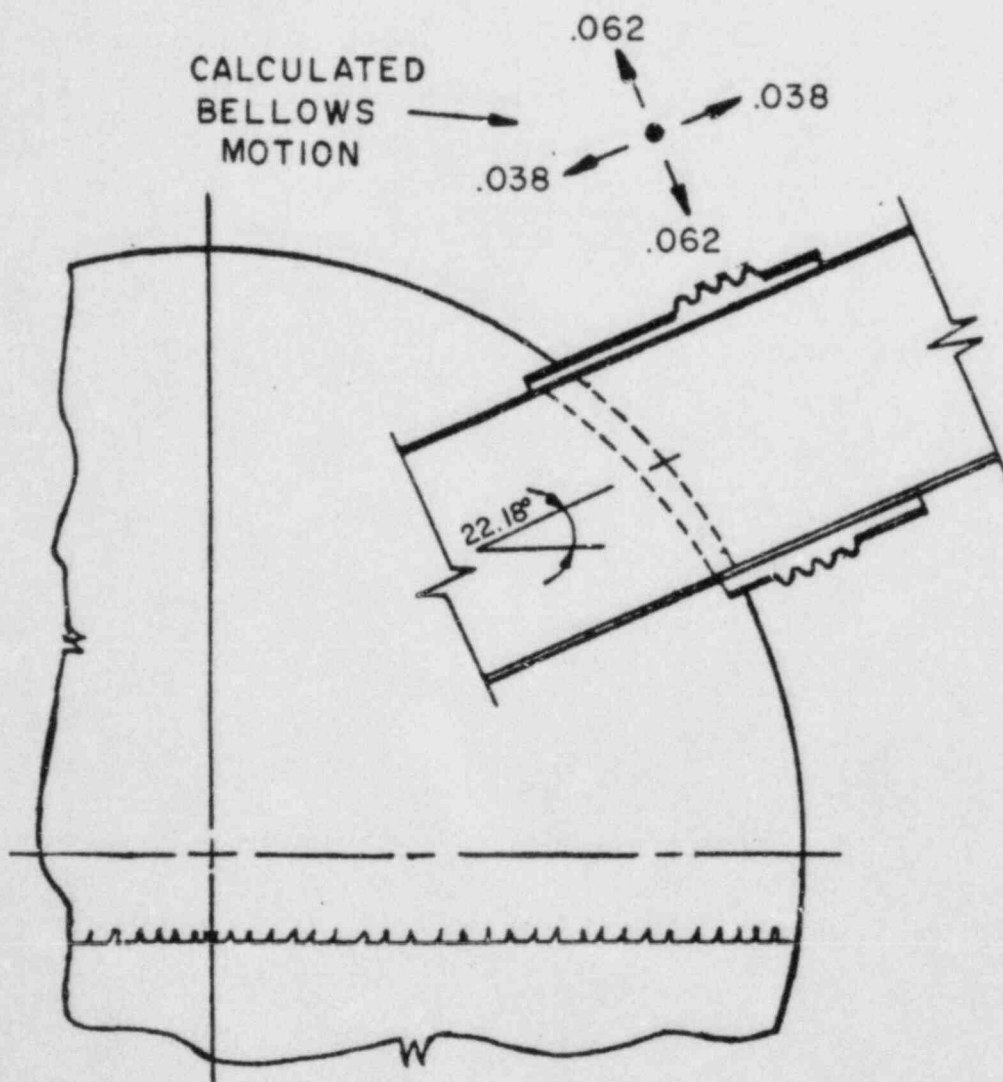


FIG. 7-4
MAXIMUM VENT PIPE - TORUS SHELL RELATIVE MOTION
ZERO- ΔP POOL SWELL- PILGRIM

8.0 SUPPRESSION POOL TEMPERATURE EVALUATION

The Mark 1 modification which added tee-quenchers at the discharge end of the SRV lines required that we consider the high temperature performance characteristics of these devices. Several meetings took place where the high temperature effectiveness and condensation stability of the devices was discussed. An important consideration in high temperature performance is the mixing characteristics of the device and the attendant local-to-bulk temperature difference (Δt).

In response to these concerns and to assure reliable operation of these devices, the NRC has set limits on maximum pool temperatures for tee-quencher operation, as well as guidelines for a temperature monitoring system for the suppression pool. These requirements are stated in NUREG 0661 (Reference 2) and NUREG 0783.

8.1 Maximum Suppression Pool Temperature

NUREG 0783 presents maximum pool temperature limits for tee-quencher operation at different flow rates, and for several different plant conditions. Evaluation of the Pilgrim Plant for these conditions was done by General Electric Company under contract to Boston Edison. The results of that work are reported here.

The local pool temperature limits for the Pilgrim Plant and in accordance with NUREG 0783 are given in Figure 8-1. These correspond to a minimum quencher submergence of 7.0 feet.

General Electric evaluated the Pilgrim Plant for the following seven conditions that bound those specified in NUREG 0783. This analysis was performed using an initial pool temperature of 90°F.

- 1A Stuck-open SRV during power operation with one RHR loop available.
- 1B Stuck-open SRV during power operation assuming reactor isolation due to MSIV closure.
- 2A Isolation/scram and manual depressurization with one RHR loop available.
- 2B Isolation/scram and manual depressurization with the failure of an SRV to reclose (SORV).
- 2C Isolation/scram and manual depressurization with two RHR loops available. This case demonstrates the pool temperature responses when an isolation/scram event occurs under normal power operation, i.e., when all systems are operating in normal mode.
- 3A Small-break accident (SBA) with manual depressurization; accident mode with one RHR loop available.
- 3B Small-break accident (SBA) with manual depressurization and failure of the shutdown cooling system.

The result of the G.E. analysis showed that the pool temperature remained below the limiting values shown in Figure 8-1 for all seven cases and is therefore acceptable. The results of the analysis for the seven cases are listed in Table 8-1.

8.2 Pool Temperature Monitoring System

The NRC criteria also presents guidelines for a monitoring system to constantly monitor pool temperature. A monitoring system will be installed at Pilgrim which uses a network of RTDs set in thermowells in the torus wall, hard wired to a display console in the control room. The system is described more fully in Section 2.2.1 of this report and is illustrated in Figures 2-9, 2-17 and 2-20.

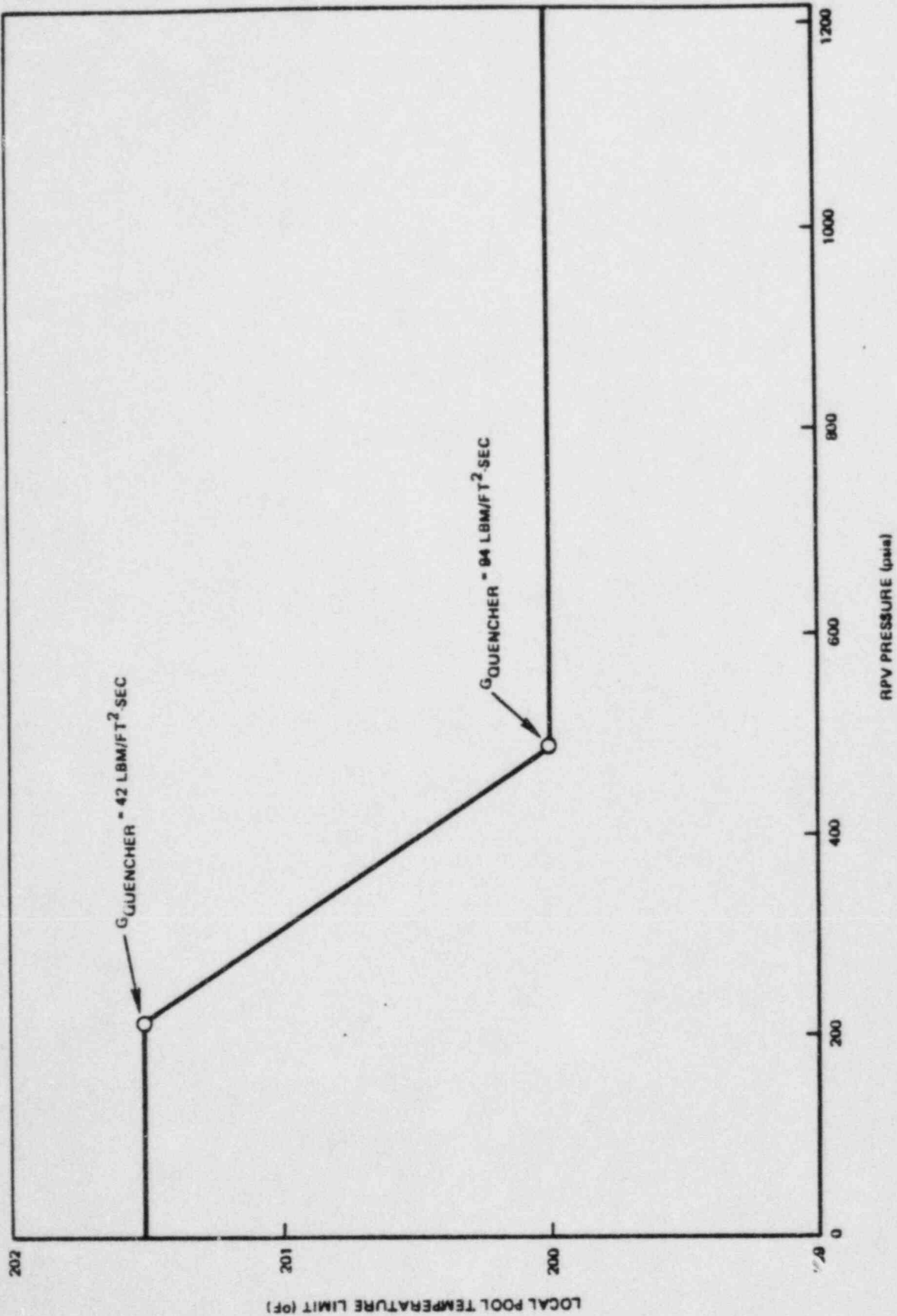


Figure 8-1 NRC Specified Local Pool Temperature Limit Based on NUREG-0783 for Pilgrim

TABLE 8-1
 RESULT SUMMARY OF PILGRIM POOL TEMPERATURE RESPONSES

Case No.	Event	Number of SRVs Manually Opened	Maximum Cooldown Rate (°F/hr)	Maximum Bulk Pool Temperature (°F)	Maximum Local Pool Temperature (°F)
1A	SORV at Power, 1 RHR Loop	0	880*	148	182
1B	SORV at Power, Spurious Isolation, 2 RHR Loops	0	710	152	195
2A	Rapid Depressurization at Isolated Hot Shutdown, 1 RHR Loop	4	1000	157	196
2B	SORV at Isolated Hot Shutdown, 2 RHR Loops	0	710	140	182
2C	Normal Depressurization at Isolated Hot Shutdown, 2 RHR Loops	4	100	147	176
3A	SBA-Accident Mode, 1 RHR Loop	4 (ADS)**	4400	156	190
3B	SBA-Failure of Shutdown Cooling Mode, 2 RHR Loops	4	100	148	174

*When the main condenser becomes available.

**ADS = Automatic Depressurization System

REFERENCES

1. G.E. Report NEDO-21888, Rev. 2, "Mark 1 Containment Program Load Definition Report", dated November 1981.
2. NRC "Safety Evaluation Report, Mark 1 Containment Long-Term Program", NUREG 0661, dated July 1980.
3. G.E. Report NEDO-24583-1 "Mark 1 Containment Program Structural Acceptance Criteria Plant Unique Analysis Application Guide" dated October 1979.
4. G.E. Report NEDO-21944 "... $\frac{1}{4}$ Scale 2-D Plant Unique Pool Swell Test Report" dated August 1979.
5. G.E. Report NEDO-24615 "... $\frac{1}{4}$ Scale Suppression Pool Swell Test Program: Supplemental Plant Unique Test", dated June 1980.
6. G.E. Report NEDE-24840 "Mark 1 Containment Program - Evaluation of Harmonic Phasing for Mark 1 Torus Shell Condensation Oscillation Loads" October 1980.
7. G.E. Report NEDE-24519-P "Mark 1 Torus Program Seismic Slosh Evaluation" dated March 1978.
8. G.E. Report NEDE-21968 "Analysis of Vent Pipe - Ring Header Intersection" dated April 1979.
9. Deleted.
10. G.E. Report NEDO-24565, Rev. 2, "Mark 1 Containment Program - Plant Unique Load Definition - Pilgrim Station: Unit 1," dated May 1982.

REFERENCES (CONTINUED)

11. ASME B&PV Code, Section III, Division 1, through Summer 1977.
12. 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.
13. Mark 1 Containment Program Report WE8109.31 "Buckling Evaluation of a Mark 1 Torus", dated January, 1982.
14. Structural Mechanics Assoc. Report SMA-12101.04-R003D, "Response Factors Appropriate for Use with CO Harmonic Response Combination Design Rules", dated March, 1982, pg. 3.
15. Intentionally Blank
16. Welding Research Council Bulletin No. 107, "Local Stresses in Spherical & Cylindrical Shells due to External Loadings", dated August 1965 with March 1979 revision.
17. Welding Research Supplement, "Local Stresses in Spherical Shells from Radial and Moment Loadings", P.P. Bijlaard, dated May 1957.
18. "On the Effects of Tangential Loads on Cylindrical & Spherical Shells", P.P. Bijlaard, Unpublished, Available from PVRC, Welding Research Council.

CLASS NC COMPONENTS AND INTERNAL STRUCTURES

TABLE I

EVENT COMBINATIONS	SRV	SRV + EQ	SBA		SBA + EQ		SBA + SRV		SBA + SRV + EQ		SBA + SRV + EQ		DBA		DBA + EQ			DBA + SRV		DBA + EQ + SRV		
			IBA	CO, CH	IBA	CO, CH	IBA	CO, CH	IBA	CO, CH	IBA	CO, CH	PS	CO, CH	PS	CO, CH	PS	CO, CH	PS	CO, CH	PS	CO, CH
TYPE OF EARTHQUAKE		0 5			0 5	0 5			0 5	0 5					0 5	0 5					0 5	0 5
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)	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Earthquake		X		X		X		X		X		X		X		X		X		X		X
SRV Discharge	X	X		X		X		X		X		X		X		X		X		X		X
LOCA Thermal			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
LOCA Reactions			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
LOCA Quasi-Static Pressure			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
LOCA Pool Swell			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
LOCA Condensation Oscillation			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
LOCA Chugging			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
STRUCTURAL ELEMENT																						
External Class NC																						
Torus, External Vent Pipe, Bellows, Drywell (at Vent), Attachment Welds, Torus Supports, Seismic Restraints	1	A B C	A A	B C B C A	A A	B C B C	A A	B C B C	A A	B C B C	A A	B C B C	A A	(3, 6)	A B C	B C B C	A A	B C B C	A A	B C B C	A A	B C B C
Internal Vent Pipe																						
General and Attachment Welds	2	A B C	A A	B C B C A	A A	B C B C	A A	B C B C	A A	B C B C	A A	B C B C	A A	(3, 5)	A B C	B C B C	A A	B C B C	A A	B C B C	A A	B C B C
At Penetrations (e.g., Header)	3	A B C	A A	B C B C A	A A	B C B C	A A	B C B C	A A	B C B C	A A	B C B C	A A	(3)	A B C	B C B C	A A	B C B C	A A	B C B C	A A	B C B C
Vent Header																						
General and Attachment Welds	4	A B C	A A	B C B C A	A A	B C B C	A A	B C B C	A A	B C B C	A A	B C B C	A A	(3, 5)	A B C	B C B C	A A	B C B C	A A	B C B C	A A	B C B C
At Penetrations (e.g., Downcomers)	5	A B C	A A	B C B C A	A A	B C B C	A A	B C B C	A A	B C B C	A A	B C B C	A A	(3, 4, 5)	A B C	B C B C	A A	B C B C	A A	B C B C	A A	B C B C
Downcomers																						
General and Attachment Welds	6	A B C	A A	B C B C A	A A	B C B C	A A	B C B C	A A	B C B C	A A	B C B C	A A	(3, 5)	A B C	B C B C	A A	B C B C	A A	B C B C	A A	B C B C
Internal Supports	7	A B C	A A	B C B C A	A A	B C B C	A A	B C B C	A A	B C B C	A A	B C B C	A A	(3, 5)	A B C	B C B C	A A	B C B C	A A	B C B C	A A	B C B C
Internal Structures																						
General	8	A B C	A A	B C B C A	A A	B C B C	A A	B C B C	A A	B C B C	A A	B C B C	A A	(3, 5)	A B C	B C B C	A A	B C B C	A A	B C B C	A A	B C B C
Vent Deflector	9	A B C	A A	B C B C A	A A	B C B C	A A	B C B C	A A	B C B C	A A	B C B C	A A	(3, 5)	A B C	B C B C	A A	B C B C	A A	B C B C	A A	B C B C

TABLE 2
PLANT PHYSICAL DIMENSIONS
PILGRIM

TORUS

Inner Diameter	29'6"
Number of Sections	16
Shell Plate Thickness	
Vent Pipe Penetration	1.125"
Top Half	.568"
Bottom Half	.629"

SUPPORT COLUMNS

	<u>Quantity</u>	<u>Size</u>
Outer	16	I-Beam (12.5" x 1.25" Flange & 10" x 1.125 Web)
Inner	16	I-Beam (12.5" x 1.25" Flange & 10" x 1.125 Web)
Base Assembly	Sliding	

RING GIRDER

Quantity	16
Size	T-Beam (7" x 1.5" Flange, 1.5" x 20" (Average) Web)

EARTHQUAKE RESTRAINT SYSTEM

Quantity	4
Type	Support Saddles

DRYWELL VENT SYSTEM

	<u>Quantity</u>	<u>Size</u>
Vent Pipe	8	6'9" I.D.
Vacuum Breakers (Internal)	10	18" I.D.
Vent Header Support Columns	16 pairs	6" Sch. 80
Downcomers	96	24"
Minimum Submergence	3'0"	

TABLE 3
PLANT ANALYSIS INFORMATION
PILGRIM

Seismic Acceleration Values (G's)

	<u>OBE</u>	<u>SSE</u>
Vertical	.06	.10
Horizontal	.08	.15

Effective Water Mass for Horizontal Seismic Load (Reference 7)

25.3%

Effective Water Mass during Pool Swell Uplift (Reference 4)

Full ΔP - 50%

Zero ΔP - 30%

Plant Unique C.O. Multiplier (Reference 1)

.917

TABLE 4
SRV LOAD CASE/INITIAL CONDITIONS

<u>Design Initial Condition</u>	<u>Any One Valve</u>	<u>ADS* Valves</u>	<u>Multiple Valves</u>
	1	2	3
1 NOC*., First Act.	A1.1		A3.1
A 2 SBA/IBA,* First Act.	A1.2	A2.2	A3.2
3 DBA,* First Act. ¹	A1.3		
1 NOC, Subsequent Act.			C3.1
C 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 coincidentally 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

APPENDIX 1

Use of SRV In-Plant Test Data for Analysis

Test Data

The in-plant SRV tests used to support structural analysis were run at Pilgrim in August, 1980. The data was collected in a series of four tests, each consisting of one actuation with a cold line and a second about one minute later (hot line). The test sets were about three hours apart to allow for SRV line cool down.

The torus shell was instrumented with a combination of strain and pressure transducers as shown in Figure A1-1. Strain gages were mounted in pairs on both sides of the shell to allow separation of bending and membrane stresses. Additional gages were located on the columns (Figure A1-2), the SRV quencher (Figure A1-3) and an attached piping system (Figure A1-4).

Two independent data collection systems were used to provide a check on system accuracy. The major system was a multiplexed FM tape system on which all data was collected. The second system was a hard wired oscillograph to produce direct, quick-look readout on several channels.

In all, 84 transducers were used during the testing. Some difficulty was experienced with the shell pressure gages and some gages did not work properly; however, the remaining gages provided sufficient data to fulfill test objectives.

Use of Data - Applications

The SRV test data was used to calibrate computer analysis of the shell and support systems and also to establish actual numbers for SRV drag loads on submerged structures.

Use of Data - Shell & Support System Analysis

Evaluation of shell stress and support system loads due to SRV actuation was done with a large detailed computer model as discussed in para. 3.2.4 of the report. Data collected from the in-plant tests was used to define the actual shell pressures and decay time for a benchmark (test) condition and to develop correction factors between these measured results and values predicted by generic analytical methods. The steps involved are these:

1. Determine maximum average shell pressure, average frequency and waveform for the four cold tests.
2. Calculate these same quantities for the test conditions using the generic computer programs (QBUBS 02).
3. Calculate calibration factors relating predicted-to-actual pressure and predicted-to-actual frequency.
4. Calculate predicted pressures and frequencies using the generic computer program, for other SRV conditions.
5. Apply the calibration factors calculated in step (3) to all other predictions for pressure and frequency. The duration of the pressure transient, as measured in the test, is affected proportionally by the frequency correction and used as the basis for all computer model loading.

Verification of Computer Model

The test data was also used to verify the accuracy of the computer model. This was done by the following method:

1. The computer model was loaded with the measured shell pressures.
2. The model was run and stresses at all strain gage locations were calculated.
3. Comparisons were made between computer predicted shell stress and measured shell stress at the same points.

Correlations for shell stress were excellent - generally within 5%. Correlations to column loads were not so good - generally off by about 50%. This difference in computer results for test conditions was handled by developing a second calibration factor for supports only, and combining it with the previous pressure calibration factor. The results were two different calibration factors to be applied to final analysis - one for the shell and one for the columns. The factors developed and used are:

Shell pressure = $.62 \times$ predicted

Support load = $.4 \times$ predicted

Multiple Valve Contributions

For cases where more than one valve actuates, the contributions from other valves were added directly (same signs). The maximum value used was $1.65 \times$ the pressure from a single valve (Reference 2).

SRV Test Data for Drag Loads

In the period after the Pilgrim SRV test and May, 1982, TES ran in-plant SRV tests in four plants, and collected SRV drag information on submerged structures in accordance with the following table:

	<u>Catwalk Supports</u>	<u>Vent Column</u>	<u>Downcomer</u>	<u>Ring Girder</u>
Millstone	X	X	X	
Nine Mile Point		X	X	
Vermont Yankee	X	X		
Fitzpatrick	X	X	X	X

Data collected in these tests was evaluated, analyzed and used to develop loads for SRV drag on submerged structures for these four plants, as well as for Pilgrim. (The Pilgrim in-plant SRV test pre-dated this period, at a time when the very conservative nature of calculated SRV drag loads had not been established).

During these tests, strains were measured on the structures indicated (except for the ring girder, which was a pressure measurement). The strain gages were positioned to show bending stress due to the combined effect of SRV jet and bubble drag. Figures A1-5 and A1-6 show typical test instrumentation on these structures.

Evaluation of the test data for the four plants showed these important results:

1. Structural response occurred at the natural frequency of the structure only.
2. Responses were much less than would be predicted by program analysis methods - generally less than one-tenth of predicted loads.

An important consideration in the application of this data was the possibility that resonant structural response might occur at some other SRV condition. This was considered and dismissed based on two separate arguments; they are:

1. If a major frequency component existed in the drag force, it would be detectable on each of the structural responses for a given test. This did not occur.
2. The response frequencies of the structures tested (structural natural frequencies) ranged from 8.1 to 38 Hz.* If any single strong frequency existed in the drag load, one of the structural responses should have demonstrated some degree of resonant response - none did.

We conclude from this that the structures involved are responding to a fairly uniform random field and that the test data represents useable data for all SRV conditions.

The next step in the process was to calculate an equivalent static load for each structure. This is the static load that produces the same bending stresses measured in the test, when applied uniformly to the submerged area. These static pressure values were plotted against distance from the quencher and Figure A1-7 was developed. This curve represents the equivalent static drag pressures, including quencher jet loads. It is scaled upward from test conditions to more severe SRV cases by the ratio of the calculated shell pressures for the two cases, for application to structures under different loading conditions.

*Actual values were 8.1, 8.2, 14.5, 15, 21, 23, 24, 25, 29, 30, 34 and 38 Hz.

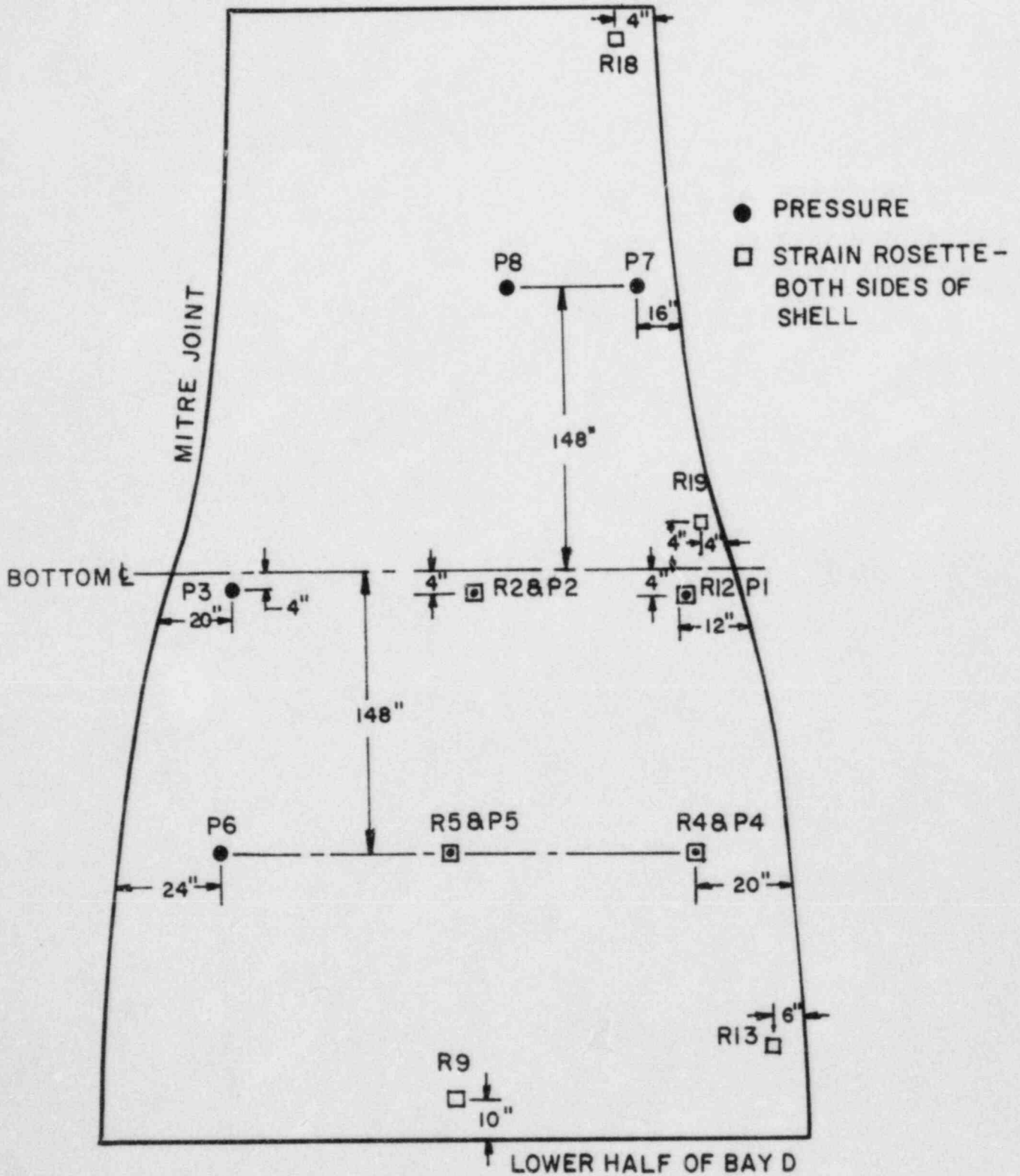


FIG. A1-1
SRV TEST INSTRUMENTATION - PILGRIM
SHELL GAGES

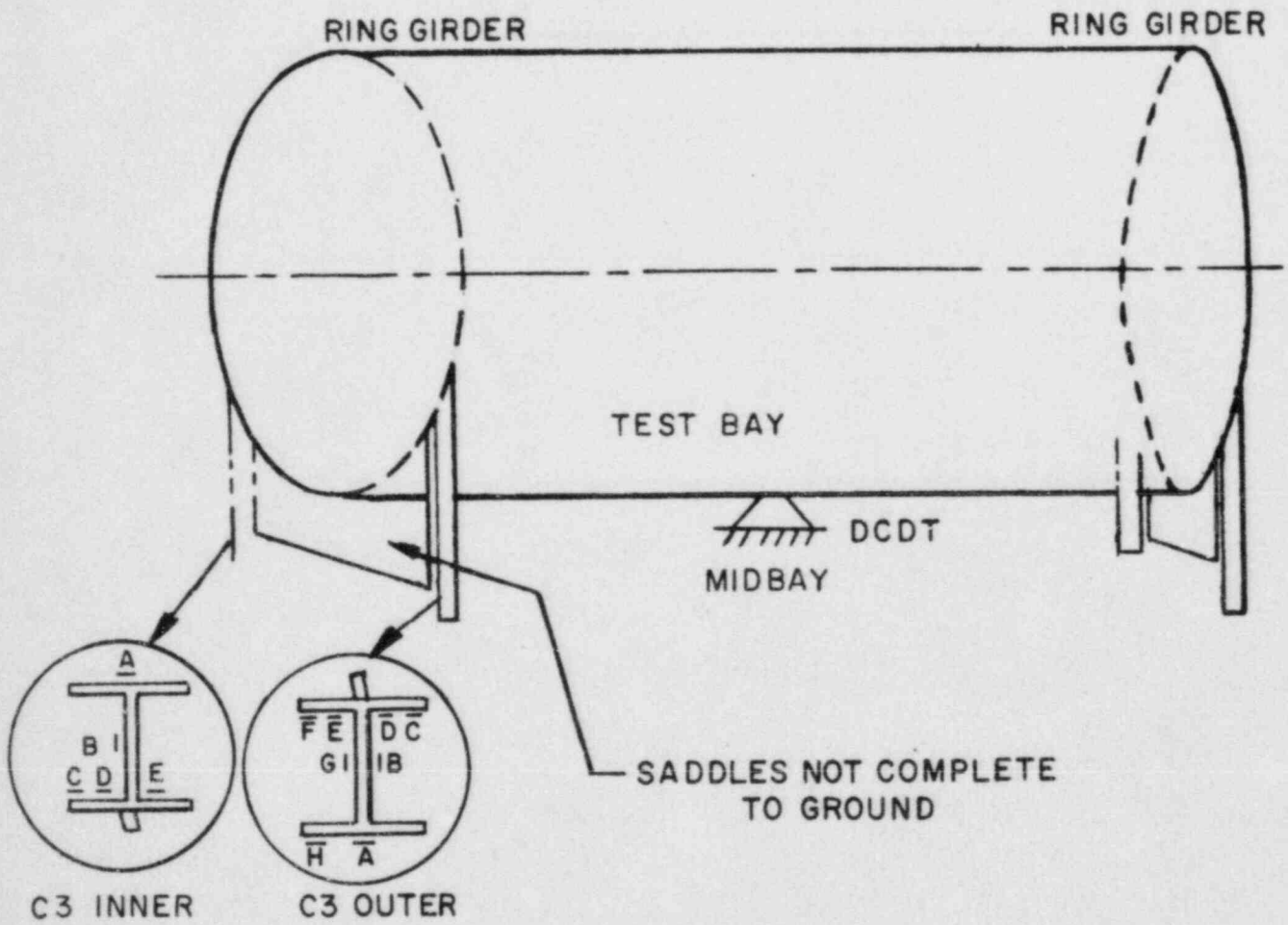
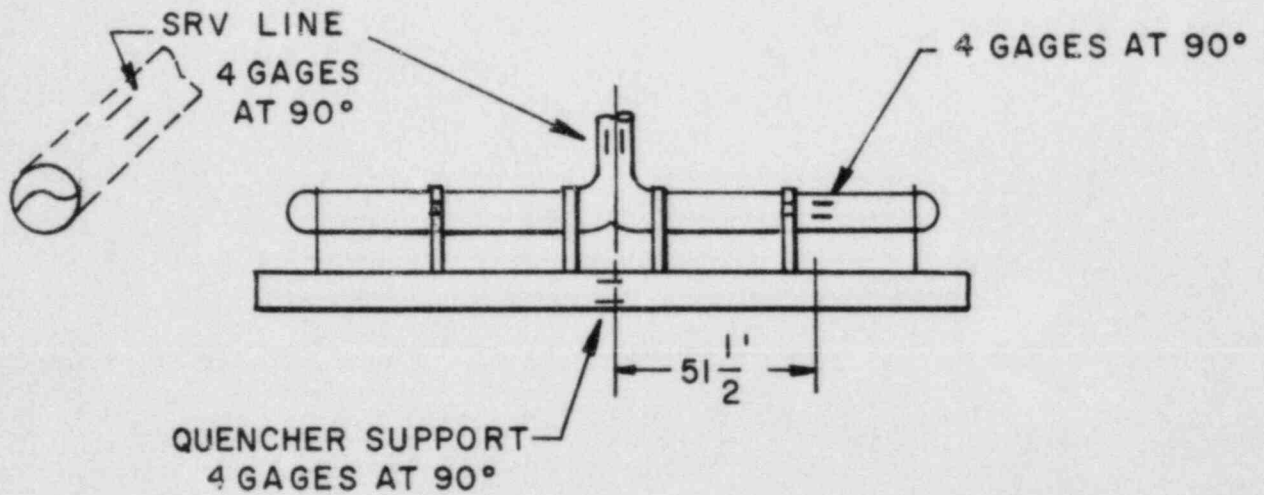


FIG. A1-2
SRV TEST INSTRUMENTATION - PILGRIM
COLUMN GAGES



I STRAIN GAGES

FIG. A1-3
SRV TEST INSTRUMENTATION - PILGRIM
SRV QUENCHER & SUPPORT

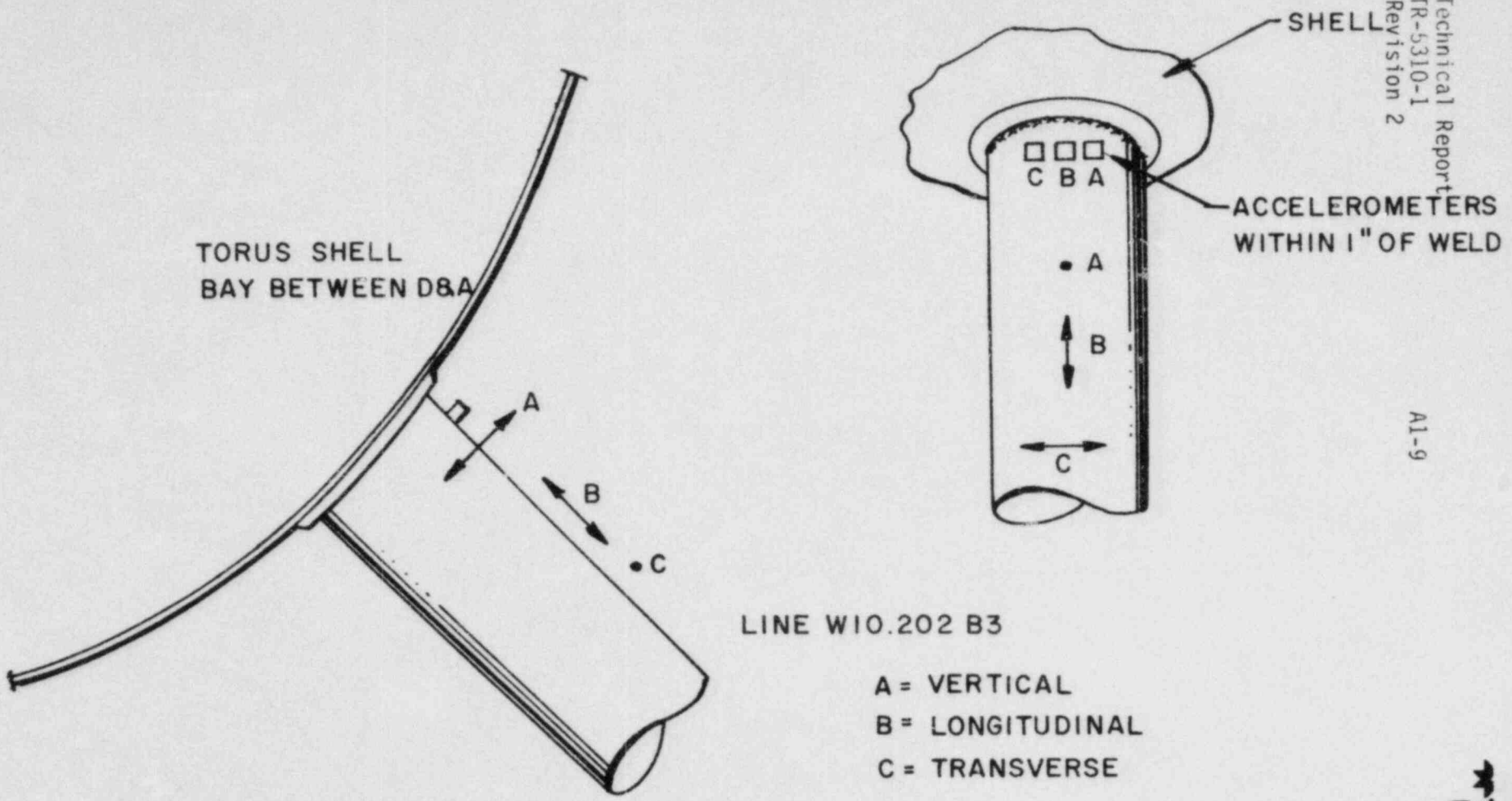


FIG. AI-4
SRV TEST INSTRUMENTATION - PILGRIM
ATTACHED PIPING

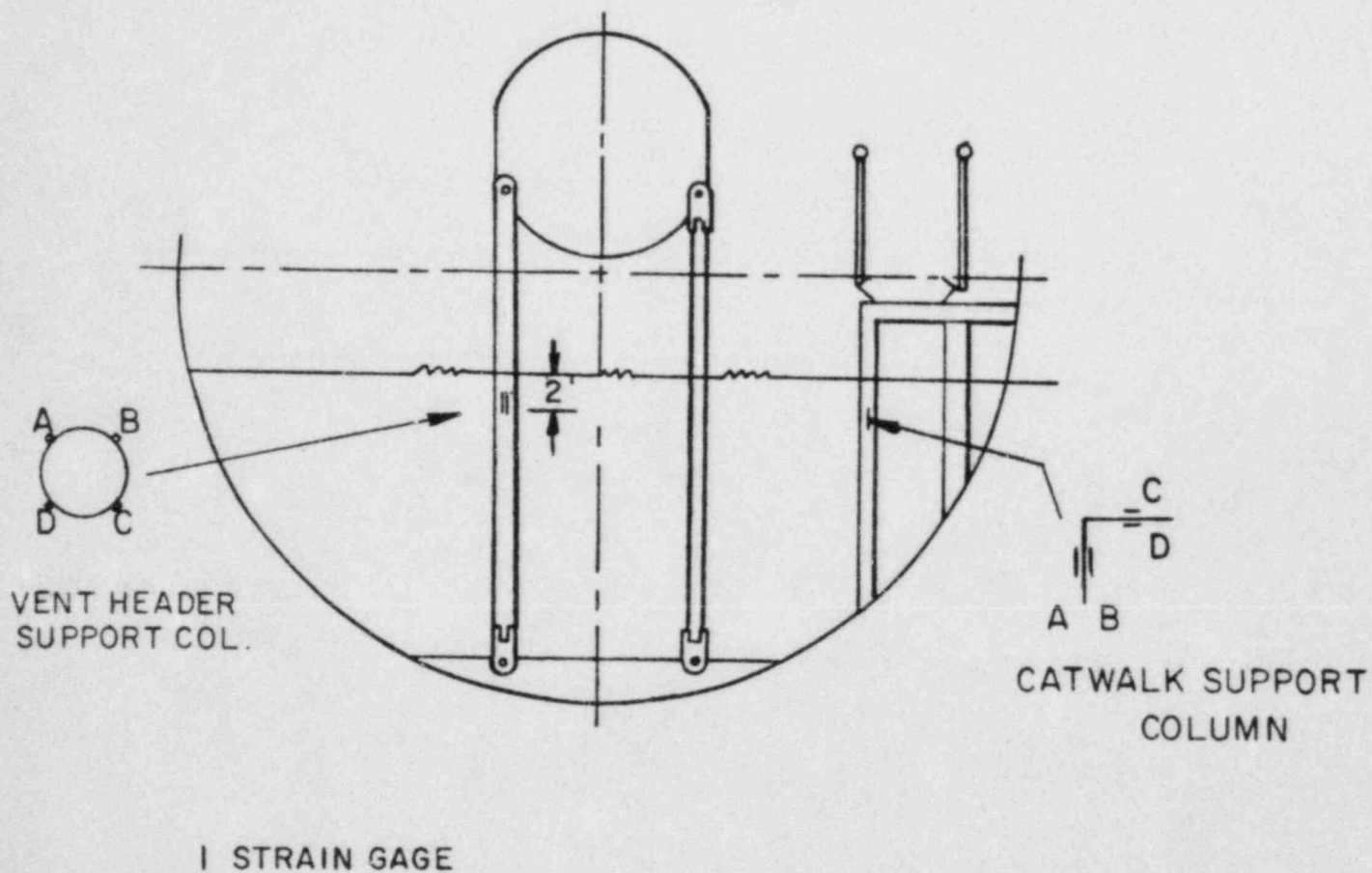
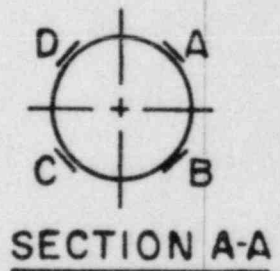
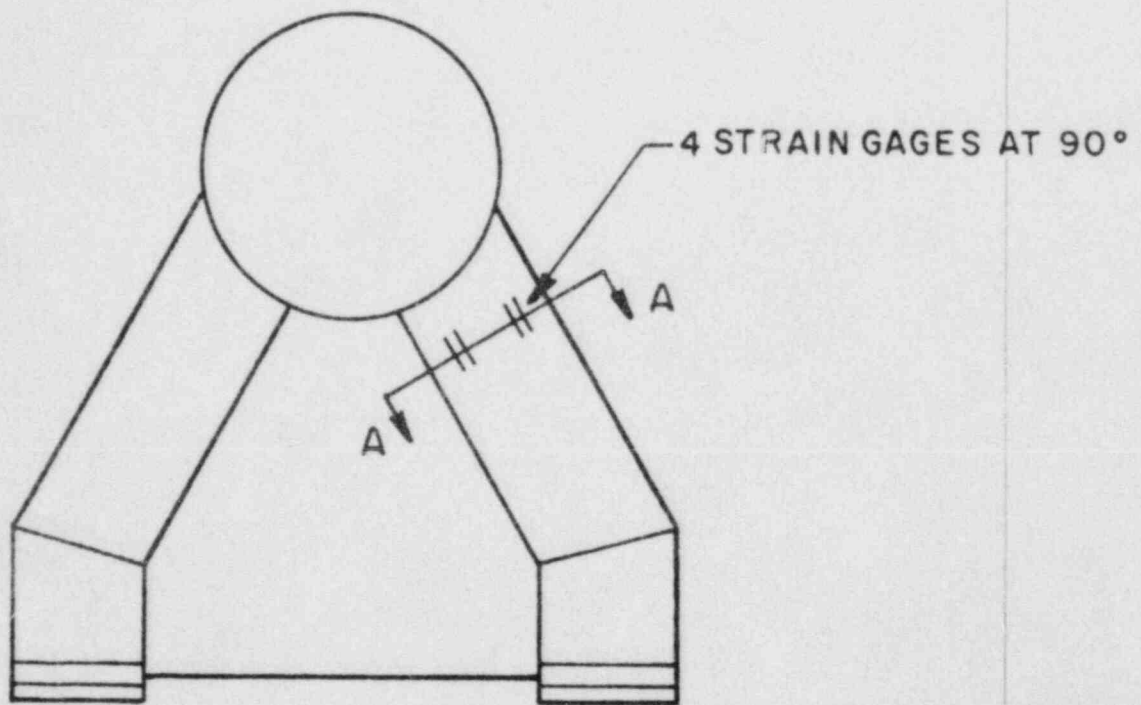
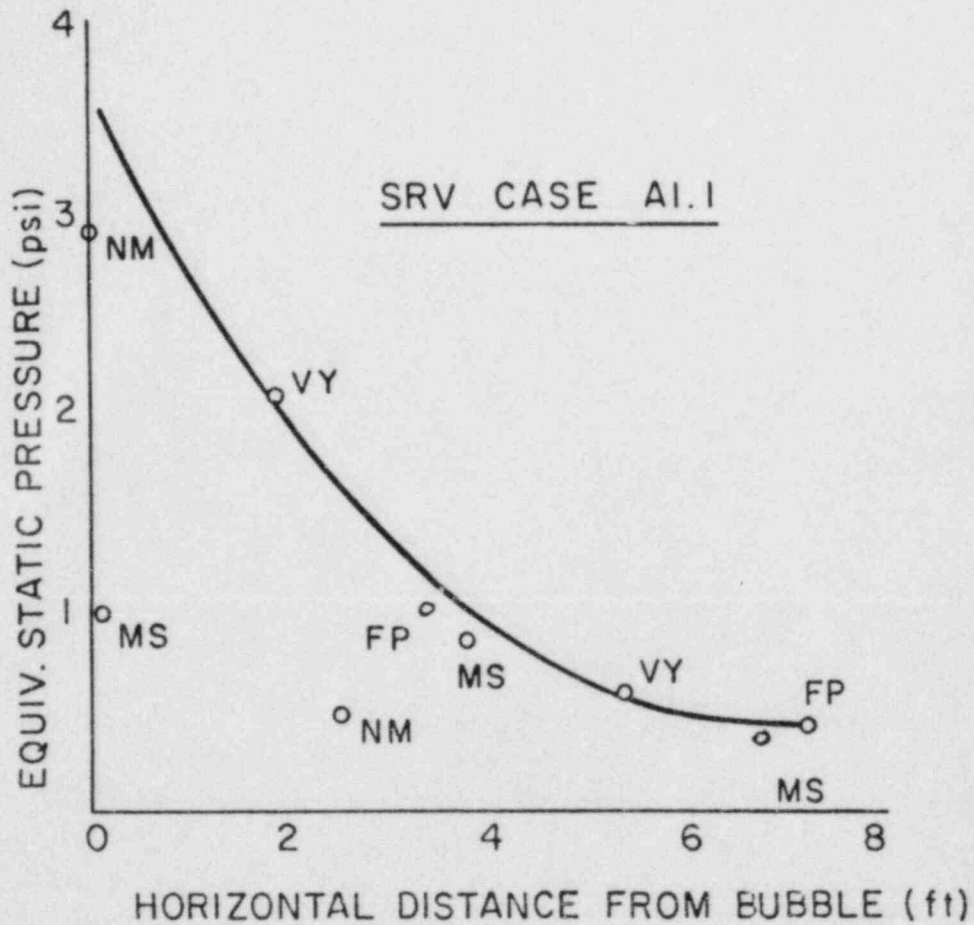


FIG. A1-5
SRV TEST INSTRUMENTATION-TYPICAL
INTERNAL STRUCTURES



SRV TEST INSTRUMENTATION-TYPICAL DOWNCOMER
FIG. A1-6



EQUIVALENT SRV DRAG FROM IN PLANT TESTING
FIG A1-7

APPENDIX 2

Discussion of 32 Hz Frequency Cut-off for
Condensation Oscillation and Post Chug Analysis

TES made the decision to limit CO and Post Chug response analysis to frequencies below 32 Hz early in the program. The decision was the result of several considerations that led to the conclusion that the 32 Hz cut-off would produce realistic results.

The basis for use of a 32 Hz cut-off involved strong fundamental arguments, both in the loads used for the analysis, and in the stress analysis itself. The primary arguments are different for CO, and for Post Chug, and are given here:

For condensation analysis.

1. Load Definition - A PSD study of the CO pressure data showed that frequencies above 25 Hz accounted for only 10% of total power (Reference 1, page 4.4.1-10). This means that a system with flat frequency response to 50 Hz would suffer a 10% unconservative stress error if a 25 Hz cut-off was used. Since we are using a 32 Hz cut-off and our system is highly responsive at low frequencies (not flat), we should expect a much smaller error.
2. Structural Response Analysis - The relative importance of loads below and above 32 Hz can be judged based on examination of the modal frequencies and generalized coordinates of the structure in both frequency ranges. If we consider the characteristics of a typical torus model in these ranges, we find:

	Number of Frequencies	Number of* $GX\phi^2$ > 1000	Number of $CX\phi^2$ > 2000	Max. Value $GX\phi^2$
Below 32 Hz	44	25	14	167,858
32-50 Hz	34	5	1	4,594

*Product of generalized weight and the square of the participation factor - used as an indicator of modal response strength.

These figures show that for condensation oscillation, frequencies below 32 Hz clearly dominate the response and frequencies above 32 Hz are relatively insignificant. They provide a strong indication that the 10% worst-case unconservatism discussed above will be greatly reduced by the selective nature of the structural response. We should logically expect the structural response characteristics, and the fact that we are using a 32 Hz cut-off, instead of 25, to reduce the 10% maximum error to less than 5%. An error of this magnitude is consistent with other assumptions which must be made in the analysis and is considered acceptable.

A further statement regarding the validity of this approach may be found in References 11 and 14.

For the post chug load, the second consideration of structural response is also valid, but the load definition is not as heavily skewed toward the low frequency end as is C0. The decision for handling post chug was heavily influenced by the fact that it produced very low stress and, in fact, that shell membrane stresses would be bounded by pre-chug. This is discussed further in Section 3.2.3.2 of this report.

CO/CH Drag Loads for Ring Girder Analysis

TES did not follow the calculational methods of NUREG 0661 (Reference 2) for calculation of CO/CH drag loads on the ring girder. This appendix describes the method that was used, the differences with the NUREG method and the basis for the change.

The NUREG analysis method specifies that acceleration drag forces (and effective hydrodynamic mass) for flat plates be based on an equivalent cylinder with radius equal to $\sqrt{2}$ times the radius of the circumscribed circle. It also specifies that the drag forces be increased by an additional factor of 2 for structures attached to the torus shell, to account for wall interference.

Application of the NUREG criteria produces a factor of 4 multiplier for drag force for flat plate structures in the fluid; and a factor of 8 multiplier for flat plate structures in the fluid and attached to the shell. These values are referenced to a drag force equal to 1.0 for flat plate calculations based on potential flow theory and neglecting interference effects.

These increases in loads are supported by data available in Reference A3-1 and A3-2. Keolegan and Carpenter show in Reference A3-1 that the drag forces on a plate in an oscillating flow may be a factor of 4 higher than the theoretical force based on potential flow. Sarpkaya shows in Reference A3-2 that forces on a cylinder near a boundary, may be twice as high as forces away from the boundary.

Both References 1 and 2 present results as a function of the V_T/D ratio where:

V = maximum velocity

T = period of flow oscillation

D = diameter

Keolegan and Carpenter show the effective hydrodynamic mass coefficient for a plate varies from a maximum of 4 at $\frac{VT}{D} = 125$ to 1 at $VT/D = 0$. (pure potential flow). Sarpkaya shows an increase in the hydrodynamic mass coefficient for a cylinder near a boundary that varies from a maximum factor of 2 at $\frac{VT}{D} = 15$ to a minimum of 1.65 at $VT/D = 0$.

NUREG 0661 appears to use the bounding values from both of these references to formulate its' analysis method. It implies by this that large values of $\frac{VT}{D}$ will exist in the torus. In fact, this is not true for C_0 and C_H drag loads on the ring girder. For this structure, under this load, $\frac{VT}{D}$ ratios are near zero and the use of maximum multipliers should not be necessary. It is on this basis that we have used an alternate method to calculate C_0 and C_H drag loads on the ring girder.

The TES method to calculate these drag loads on the ring girder used the same references as above (A3-1 and A3-2), but accounted for calculated values of $\frac{VT}{D}$, rather than the values corresponding to the maximum increases. Consideration of the actual $\frac{VT}{D}$ ratio for wall interference led to an interference factor of 1.65 (instead of 2).

Low values of $\frac{VT}{D}$ suggest that the theoretical hydrodynamic mass coefficient for the ring girder is appropriate. The theoretical coefficient for this structure is estimated by an equivalent cylinder with a radius equal to the circumscribing radius. Use of this cylinder results in a hydrodynamic mass coefficient equal to two. The total factor used was related to the NUREG multiplier by:

$$\frac{2.0}{4.0} \times \frac{1.65}{2.0} = .41$$

The factor used by TES was .41 x the NUREG 0661 factor.

REFERENCES

A3-1 Keolegan and Carpenter, "Forces on Cylinders and Plates in a Oscillating Fluid," National Bureau of Standards, Vol. 60, No. 5, May 1959.

A3-2 Sarpkaya, "Forces on Cylinders near a Plane Boundary in a Sinusoidally Oscillating Fluid", Journal of Fluids Engineering, September 1976.

APPENDIX 4

NRC REVIEW COMMENTS AND RESPONSES

This report was reviewed by NRC consultants during 1983 and 1984. As a result of these reviews, meetings were held and additional information was exchanged. This appendix summarizes the review process and includes copies of all relevant information resulting from the review.

Part of the review process included questions on torus attached piping systems, including main steam safety relief lines. These analyses were not reported in this 5310-1 report but the questions are included in this appendix, along with the other information. TES report 5310-2 documents the piping analysis.

The event sequence that made up the review process is as follows:

Review by Franklin Institute

1. April 14, 1983 - Questions were received from Franklin Institute. These are included in Section A4.1 of this appendix.
2. July 13, 1983 - A written response was provided to the Franklin Institute questions. These are included in Section A4.2 of this appendix.
3. August 9, 1983 - A meeting was held at the Yankee Atomic offices in Framingham, Massachusetts, with representatives from Franklin Institute, the NRC, TES, Boston Edison Company and Yankee Atomic. The meeting was to review the TES generic methods used for attached piping analysis. The presentation handout used at the meeting is included in Section A4.3.
4. August 18, 1983 - At the August 9 meeting, a request was made for

additional information on the calculation of usage factors for fatigue analysis. This request was answered by a TES letter on August 18, 1983; it is included in Section A4.4.

5. July 19, 1984 - Questions on TR-5310-2 were received from Franklin Institute. These are included in Section A4.5 of this appendix.
6. August 23, 1984 - A meeting was held at the TES offices in Waltham, Massachusetts, with representatives from Franklin Institute, the NRC, TES and Boston Edison Company. The meeting was to discuss the responses to the July 19, 1984 questions. A copy of the presentation handout from the meeting is included as Section A4.6.

This completed the review process by Franklin Institute.

Review by Brookhaven National Laboratories

1. June 21, 1984 - Questions were received from Brookhaven National Laboratories. These are included in Section A4.7 of this appendix.
2. August 23, 1984 - A meeting was held at the Teledyne Engineering Services offices in Waltham, Massachusetts, with representatives from Brookhaven, the NRC, TES and Boston Edison Company. The meeting was held to discuss responses to the June 21, 1984 questions above. A copy of the presentation handout from the meeting is included as Section A4.8.

This concluded the Brookhaven review, as well as the NRC review of the document.

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TR-5310-1
Revision 2

A4.1-1

REVIEW BY FRANKLIN INSTITUTE (FRC)

A4.1 Review questions received in April 14, 1983.



APR 14 1983

Docket No. 50-293

Mr. A. Victor Morisi
Manager, Nuclear Operations
Support Department
Boston Edison Company
25 Braintree Hill Park
Rockdale Street
Braintree, MA 02184

RECEIVED
APR 20 1983
LICENSING

Dear Mr. Morisi:

SUBJECT: MARK I CONTAINMENT LONG TERM PROGRAM - PLANT UNIQUE ANALYSIS REPORT
STRUCTURAL EVALUATION

Re: Pilgrim Nuclear Power Station

The NRC staff and its consultant Franklin Research Center (FRC) are reviewing the structural aspects of your plant unique analysis report. As a result of our review to date we have prepared the enclosed request for additional information.

It is requested that you provide a response within 45 days of receipt of this letter. If you determine there is a need to meet with or to have a conference call with the staff and FRC to discuss this request prior to responding, please contact your project manager. In addition, if you cannot meet this response date, please notify your project manager within seven days of receipt of this letter.

This request for information was approved by the Office of Management and Budget under clearance number 3150-0091 which expires October 31, 1985.

Sincerely,

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

Enclosure: As stated _____

cc w/enclosure
See next page


REQUEST FOR INFORMATION
PILGRIM NUCLEAR POWER STATION

- Item 1: Provide a summary of the analysis with regard to the vacuum breaker piping systems and the vacuum breaker valves; indicate whether they are considered Class 2 components as required by the criteria [1].
- Item 2: Provide a summary of the analysis of torus attached piping systems consisting of analytical models which represent piping and supports from torus to first rigid anchor (or where the effect of torus motion is insignificant), and classification of piping systems as essential or non-essential for each load combination. Also, indicate whether a response spectrum or time history analysis for dynamic effect of torus motion at the attachment points has been considered.
- Item 3: 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 the nozzle at the main steam line to discharge in the suppression pool, and the discharge device and its supports. Also, the information should indicate that 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.
- Item 4: Provide a summary of the analysis with regard to the active containment system piping systems, piping systems which provide a drywell-to-wetwell pressure differential, and other internal piping systems.
- Item 5: Provide a list indicating whether all the piping systems and their supports have been classified as Class 2 or Class 3 piping, or essential or non-essential piping systems, and whether a pump or valve associated with the piping is an active or inactive component, and is considered operable.
- Item 6: Provide justification for determining the load combinations indicated throughout the PUA report [2] to be the governing load combinations.
- Item 7: Indicate whether the fatigue usage factors for the SRV piping and the torus attached piping are sufficiently small that a plant-unique fatigue analysis is not warranted for piping. The NRC is expected to review the conclusions of a generic presentation [3] and determine whether it is sufficient for each plant-unique analysis to establish that the expected usage factors for piping are small enough to obviate a plant-unique fatigue analysis of the piping.

- Item 8: With regard to the finite element model of the torus, including the shell, ring girders, and supports, it is not clear whether the saddle webs and the torus columns were welded together as shown in Figures 2-5, 2-11, 2-12, 3-1, and 3-2 [2]. Provide information showing the as-built configuration of the torus and its supports.
- Item 9: With regard to the 360° torus beam model, provide information showing the finite element model actually used in the analysis, which should not have missing members as shown in Figure 3.4 in the PUA report [2].
- Item 10: With regard to the ring girder model, the dimensions shown in Figure 3.3 [2] seem inconsistent with the dimensions shown in Figure 5-2 [2]. Provide information showing the dimensions of the ring girder.
- Item 11: 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.
- Item 12: Provide and justify the reasons for not considering a 180° segment of the vent system in order to determine the effects of seismic and other nonsymmetric loads as required by the criteria [1].
- Item 13: Provide and justify the reasons for not considering the superposition of reactions from the vent deflectors and ring headers in evaluating the vent support columns for pool swell.
- Item 14: With reference to the computer model for the 1/32 segment of the torus shown in Figure 3-1 of Reference 2 and the analysis performed using only symmetric boundary conditions, provide justification for not considering skew symmetric boundary conditions in order to evaluate the effect of the resulting modes.
- Item 15: Confirm that structural responses from any two dynamic phenomena have been combined using either their absolute sum or the cumulative distribution function method and provide justification for using any alternative methods to combine responses.
- Item 16: Indicate the present status of the proposed study of plant procedures to ensure that the operator would depressurize the system within 15 minutes after chugging begins, since this is assumed for fatigue analysis with regard to chugging.
- Item 17: With reference to page 70 of Reference 2, provide justification for not considering stresses due to seismic and thermal response of the drywell in analyzing the main vent drywell intersection.

- Item 18: With reference to the 1/16 model used for the ring girder analysis, provide more details to justify the assumption that the dimensions of the torus at the Pilgrim plant are similar to the dimensions of the torus at the plant which was actually analyzed. Compare the boundary conditions and the support systems of these torus structures.
- Item 19: Justify the assumption, with regard to drag loads, that the columns, column gussets, and saddle would make the ring girder very stiff and prevent frequency interaction with dynamic loads.
- Item 20: With reference to the high values of actual loads in the ring girder-shell welds in the outer column and saddle regions, indicate any conservatism in the analysis which would ensure that the allowables will not be exceeded.
- Item 21: Provide the fatigue evaluation of the bellows.
- Item 22: The ASME Code provides an acceptance 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 of the stress-range amplitudes considered and of the associated number of cycles in order to account for the interspersed 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.

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 **TELEDYNE
ENGINEERING SERVICES**

A4.2-1

REVIEW BY FRANKLIN INSTITUTE (cont.)

A4.2 TES Response to FRC Questions - July 1983

Technical Report
TR-5310-1
Revision 2

A4.2-2

July 13, 1983
5310-143

Mr. George M. McHugh, Jr.
Deputy Director
Nuclear Engineering Department
Boston Edison Company
25 Braintree Hill Park
Braintree, MA 02184

Subject: Responses to NRC Request for Information Mark 1 Torus Program
5310-9

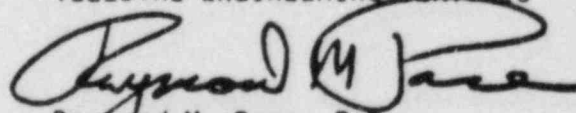
Dear Mr. McHugh:

I have enclosed the final copy of the subject TES responses for your review.

If you have any questions, please call Mr. Nicholas Celia, Project Manager, or me.

Very truly yours,

TELEDYNE ENGINEERING SERVICES



Raymond M. Pace, P.E.
Manager, Projects

RMP:alt

enclosures

cc: G. V. Mileris (BECO)
R. V. Fairbanks (BECO)
D. F. Landers
N. S. Celia
R. H. Berks
R. A. Enos
G. E. O'Connor

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TR-5310-1
Revision 2

A4.2-3

RESPONSES TO NRC REQUEST FOR INFORMATION

MARK 1 TORUS PROGRAM PLANT UNIQUE REPORT

BOSTON EDISON COMPANY

PILGRIM NUCLEAR STATION UNIT 1

JULY 13, 1983

Technical Report
TR-5310-1
Revision 2

A4.2-4

ITEM 1

QUESTION

Provide a summary of the analysis with regard to the vacuum breaker piping system and the vacuum breaker valves, indicate whether they are considered Class 2 component as required by the criteria (1).

ANSWER

The Pilgrim vacuum breakers are internal to the torus and do not have any piping associated with them. The Pilgrim vacuum breaker valves are considered to be Class 2 for analysis purposes.

The NRC is in the process of reviewing the loading function used to complete the vacuum breaker valve analysis. A preliminary analysis has been completed indicating areas for potential improvement of the valve components.

The analysis techniques used, and the vacuum breaker components analyzed, will be summarized within TES Technical Report TR-5310-2, which is scheduled for completion later this year.

ITEM 2

QUESTION

Provide a summary of the analysis of torus attached piping systems consisting of analytical models which represent piping and supports from torus to first rigid anchor (or where the effect of torus motion is insignificant), and classification of piping systems as essential or non-essential for each load combination. Also, indicate whether a response spectrum or time history analysis for dynamic effect of torus motion at the attachment points has been considered.

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ANSWER

A4.2-5

For purposes of these evaluations, all torus attached piping systems have been considered to be essential to plant operation for each load combination. The torus motion for all dynamic loads was applied to the piping system as a time history. The excited attachment points are the torus penetration nozzle and any supports attached to the torus shell, as applicable.

The analysis techniques used, piping stresses, support loads and required modifications will be summarized within TES Technical Report TR-5310-2, which is scheduled for completion later this year.

ITEM 3

QUESTION

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 the nozzle at the main steam line to discharge in the suppression pool, and the discharge device and its supports. Also, the information should indicate that 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.

ANSWER

Analysis of the SRV discharge line has been done and will be reported as two separate analyses. Analysis of the quencher, quencher supports and piping in the torus is reported in TES Technical Report TR-5310-1. Analysis of the vent pipe penetration and all upstream piping and supports will be reported in TR-5310-2, scheduled for release later this year.

This separation is possible because stresses in the piping and structure in the torus are controlled by water clearing and pool drag loads alone.

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A4.2-6

Stresses in the penetration and the drywell are affected by all loads, including gas clearing. The separation of analysis was made to provide early results for torus wetwell piping, which previously had been identified by the NRC as an area of concern.

A summary of the analysis for the quencher, quencher supports and torus piping is given here. Load combinations considered were cases 3, 15 and 25 from the PUA report, Table 1. These cases bound all others. The loads considered in combination for each event are:

Case 3: SRV discharge, seismic, LOCA thermal, deadweight and internal pressure.

Case 15: SRV discharge, seismic, LOCA thermal, deadweight, internal pressure and post chug/CO.

Case 25: SRV discharge, seismic, LOCA thermal, deadweight, internal pressure and LOCA Bubble/LOCA Jet.

Stress analysis was performed using STARDYNE 3.0 with static and dynamic analysis for the following applications:

SRV Water Clearing Thrust:	SRV water clearing loads vary for each SRV line depending on the height of water reflood after a first actuation. Maximum reflood will occur in line C (162 ⁰ azimuth) which therefore will produce the highest loads and stresses for SRV piping and supports inside the torus. (All lines are identical inside the torus). Water thrust loads were calculated for line C for SRV case C3.3 (maximum reflood case) using the G.E. computer code RVFOR-04. Second actuation was assumed to occur at the point of maximum line reflood.
----------------------------------	---

The bounding thrust loads, calculated for line C, were applied to all four SRV lines in a time history dynamic analysis.

- Post Chug/CO: This is a force-frequency spectral input using STARDYNE, DYNRE 2. Maximum values of post chugging and condensation oscillation (whichever pressure amplitude was largest at each frequency from 0 to 31 Hz) were used at various locations on the tee-quencher, support beam and submerged portion of the SRV line. These values provided a bounding spectrum which was conservative since maximum values were combined without consideration of direction or time phasing. The application of the resulting spectral vectors was in the three local coordinate directions.
- LOCA Bubble/
LOCA Jet: The greater of these forces, (generally LOCA/Jet), was applied uniformly to the submerged portion of the SRV line, the tee-quencher and supports as a static loading with an included dynamic load factor of 2.
- LOCA Thermal: This was a static analysis.
- Deadweight: A static analysis.
- Seismic: A static analysis with original plant design load factors.

ITEM 4

QUESTION

Provide a summary of the analysis with regard to the active containment system piping systems, piping systems which provide a drywell-to-wetwell pressure differential, and other internal piping systems.

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TR-5310-1
Revision 2

A4.2-8

ANSWER

The piping involved with the pressurization of the drywell will be considered in Torus Attached Piping (TAP) Technical Report (TR-5310-2)

ITEM 5

QUESTION

Provide a list indicating whether all the piping systems and their supports have been classified as Class 2 or Class 3 piping, or essential or non-essential piping systems, and whether a pump or valve associated with the piping is an active or inactive component, and is considered operable.

ANSWER

All Pilgrim Torus Attached Piping systems have been classified as essential Class 2 piping systems and all components associated with these systems are considered active for purposes of these evaluations.

ITEM 6

QUESTION

Provide justification for determining the load combinations indicated throughout the PUA reports (2) to be the governing load combinations.

ANSWER

Five load combinations were chosen as governing using the following criteria:

NOC Event Combinations

Event combination 3 evaluated to service level A allowables bounds event combinations 1 and 2 with the greater of OBE or SSE seismic loads.

SBA/IBA Event Combinations

Event combination 15 evaluated to service level A allowables bounds event combinations 4 through 14 with the greater of OBE or SSE seismic loads.

DBA Pressurized Pool Swell Event Combination

Event combination 25 evaluated to service level A allowables bounds event combinations 16, 18, 19, 22 and 24 with the greater of OBE or SSE seismic loads.

DBA O Δ P Pool Swell Event Combination

Event combination 16 was evaluated to service level D allowables.

DBA Condensation Oscillation and Chugging Event Combinations

Event combinations 23, 26 and 27 were not considered because CO, CH cannot occur in combination with SRV. Therefore, event combination 21 evaluated to service level A allowables bounds event combinations 17 and 20 with the greater of OBE or SSE seismic loads.

The five cases analyzed, as described above, for Class MC components and internal structures as listed in Appendix B of the PUA report on Table I were cases:

A4.2-10

ITEM 7

QUESTION

Indicate whether the fatigue usage factors for the SRV piping and the torus attached piping are sufficiently small that a plant-unique fatigue analysis is not warranted for piping. The NRC is expected to review the conclusions of a generic presentation (3) and determine whether it is sufficient for each plant-unique analysis to establish that the expected usage factors for piping are small enough to obviate a plant-unique fatigue analysis of the piping.

ANSWER

TES has provided typical fatigue information to the Mark 1 Owners' Group generic study for all five of the plants for which we are analyzing torus attached piping. Therefore, the conclusion of the generic presentation to the NRC, which established that the fatigue usage factors are small enough to obviate a plant-unique fatigue analysis, applies. We anticipate NRC agreement with the generic results, shortly.

ITEM 8

QUESTION

With regard to the finite element model of the torus, including the shell, ring girders and supports, it is not clear whether the saddle webs and the torus columns were welded together as shown in Figures 2-5, 2-11, 2-12, 3.1, and 3.2 (2). Provide information showing the as-built configuration of the torus and its supports.

ANSWER

The referenced figures contain illustration errors and do not accurately represent the analysis models. These illustrations will be corrected in future revisions of the report. TES has included the as-designed Saddle

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A4.2-11

Assembly Drawing E-5110, Rev. 4 (Sheet 1 of 2) which shows the actual saddle web and column support geometry.

ITEM 9

QUESTION

With regard to the 360^o torus beam model, provide information showing the finite element model actually used in the analysis, which should not have missing members as shown in Figure 3.4 in the PUA report (2).

ANSWER

The referenced figure contains illustration errors and does not accurately represent the analysis models. This illustration will be corrected in future revisions of the report. Copies of the actual FEM computer plots (five views) are included to verify the accuracy of the geometry.

ITEM 10

QUESTION

With regard to the ring girder model, the dimensions shown in Figure 3.3 (2) seem inconsistent with the dimensions shown in Figure 5-2 (2). Provide information showing the dimensions of the ring girder.

ANSWER

Figure 5-1 contains the ring girder dimensions, one of which is in error. The 20.50 inch ring girder web dimension should be 23.5 inches. We are including an uncontrolled copy of the Pilgrim CB&I drawing, numbers 50 and 52, which contains the dimensions in question. This is an illustration error that does not affect analysis.

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A4.2-12

ITEM 11

QUESTION

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.

ANSWER

All loads shown on Table 1 of Appendix B in the PUA report have been considered in the analysis, except those that were specifically identified and discussed in the report; these are:

3.0 CONTAINMENT STRUCTURE ANALYSIS

All loads were analyzed on the torus shell with the exception of the post chugging load. Analysis done on one of the TES plants produced very low stresses and loads that were bounded by pre-chug values. Additional work published (Ref. 12 PUA Report) showed that pre-chug bounded post chug (to 50 Hz) for column and saddle loads. It also showed that $P_1 + P_b$ stress, due to post chug, exceeded pre-chug by 53%. TES analysis for post chug used the pre-chug stress values which may be increased by 53% and still meet allowable stress.

The attached piping reaction loads on the torus shell will be considered in the Torus Attached Piping (TAP) Technical Report (TR-5310-2). These loads are a function of the final piping configuration. The local stresses will be added to the existing state of stress for the appropriate region of the torus shell.

4.0 VENT HEADER SYSTEM

The following vent system loads were not analyzed:

- Pool Swell Drag LOCA Jet Forces

The vent header support columns are loaded by forces from LOCA-Jet and LOCA-Bubble drag. By inspection, it was concluded that LOCA-Jet loads would not combine with water impact on the vent system due to differences in timing and, therefore, would not contribute to the maximum stress calculations.

- Submerged Structure Drag (Support Columns Only)

Examination of the load combinations that include chugging makes it clear that these cannot control maximum stress level in the support columns; combinations that include vent header water impact will produce much higher stresses. For this reason, stresses in the vent header support columns were not calculated for chugging drag.

- Drag Forces on Support Columns

Inspection of approximate total loads on support columns, due to CO, CH and pool swell, showed that condensation oscillation would not contribute to the maximum column load, due to differences in timing.

- Condensation Oscillation - IBA

Stresses and loads resulting from IBA condensation oscillation are bounded in all cases by either DBA condensation oscillation or chugging.

7.0 OTHER STRUCTURES

All direct loads were applied to the torus catwalk. Indirect effects, due to motion of the ring girder at attachment points were considered,

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A4.2-14

but judged to be negligible. Except for the handrails, the entire catwalk is submerged before froth loads reach this part of the torus; because of this, froth was only considered on the handrails.

The internal spray header is attached to the ring girders and to a penetration on the shell. The motion of the ring girder that results from pool swell loads on the shell was considered but judged to be a negligible input to the spray header. Shell displacement at the nozzle connections was input to the computer analysis. The spray header is high enough in the torus so it does not experience any direct water impact.

The vent pipe bellows analysis was done as a part of the analysis work discussed in Sections 3.0 and 4.0, above.

ITEM 12

QUESTION

Provide and justify the reasons for not considering a 180° segment of the vent system in order to determine the effects of seismic and other nonsymmetric loads as required by the criteria (1).

ANSWER

A generic analysis was performed using a 180° segment vent system beam model with symmetric boundary conditions for the appropriate asymmetric loading cases. The two loading cases considered are synchronized chugging and static seismic.

The static seismic values of 0.17g horizontal and 0.1g vertical used, envelope the original plant design seismic spectra for the five TES plants analyzed (Nine Mile Point, Millstone, Vermont Yankee, Fitzpatrick and Pilgrim).

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A4.2-15

The combined seismic and chugging stresses of the 180° segment model are less than the combined stresses of the 45° segment model because of the conservative assumptions used to apply the anti-symmetric chugging load on the 45° model.

The ratios of the combined seismic and chugging stress of the 180°/45° models are:

970 psi/7851 psi = 0.13 for the downcomers

3630 psi/6020 psi = 0.6 for the vent headers

Therefore, the combined stress analysis reported in the PUAR using the results from the 45° model is conservative.

ITEM 13

QUESTION

Provide and justify the reasons for not considering the superposition of reactions from the vent deflectors and ring headers in evaluating the vent support columns for pool swell.

ANSWER

The reactions from the vent deflectors and ring headers were superpositioned to evaluate the vent support columns for pool swell. The term "Pool Swell (full ΔP)" is meant to include all pool swell loads superpositioned on the structure to be analyzed.

ITEM 14

QUESTION

With reference to the computer model for the 1/32 segment of the torus shown in Figure 3-1 of Reference 2, and the analysis performed using only

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TR-5310-1

Revision 2, ^{A4.2-16} symmetric boundary conditions, provide justification for not considering skew symmetric boundary conditions in order to evaluate the effect of the resulting modes.

ANSWER

It has been our position that the geometry of the torus structure, the nature of the loads imposed, and the constraints imposed by the support saddles and ring girder will force the symmetric modes to dominate shell response to the extent that asymmetric modes can be omitted; the logic follows:

The nature of the loading was considered first. For both vertical and horizontal loadings, shell forces in adjacent bays are in phase and differ by no more than 40 percent. We expect such a load to react almost entirely with the symmetric modes of the structure, to produce deflections that are in phase on both sides of the support saddle. We believe that the response of asymmetric modes which contain out-of-phase deflections will be negligible.

Next we considered the consequences of an error in our assumption. If asymmetric modes were important, but were not considered, what would be the effect? Our symmetric boundary conditions "fixed" the ring girder from rotation. Asymmetric modes would allow the ring girder to rotate slightly under load. The effect of this ring girder flexibility would be to reduce local shell stresses that would accompany the fixed boundary assumption. Admittedly, the two conditions (fixed and flexible) are associated with different frequencies, but we are dealing with loads that are essentially single-frequency harmonics. These loads can exist anywhere within a range, but only at a single frequency. We conclude that the highest shell stresses will occur at load frequencies that are highly coupled to fixed ring girders (symmetric modes), not modes where the ring girder can move. Based on this, we have concluded that any error introduced by using symmetric boundary conditions will be conservative.

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A4.2-17
ITEM 15

QUESTION

Confirm that structural responses from any two dynamic phenomena have been combined using either their absolute sum or the cumulative distribution function method and provide justification for using any alternative methods to combine responses.

ANSWER

The cumulative distribution function method of combining any two structural responses has not been used for any analysis. All combinations of two separate dynamic loads were done by absolute sum.

ITEM 16

QUESTION

Indicate the present status of the proposed study of plant procedures to ensure that the operator would depressurize the system within 15 minutes after chugging begins, since this is assumed for fatigue analysis with regard to chugging.

ANSWER

The G.E. Supplementary Support Effort (SSE) response to question number 324, dated February 22, 1983, addresses this issue as it is affected by the Emergency Procedure Guidelines (EPG's) to stop chugging for a postulated SBA.

The response states that "By following the EPG's, chugging would never be expected to occur in a Mark 1 plant" during an SBA.

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A4.2-18

Pilgrim Station EPG Step PC/P-3 indicates:

If suppression pool pressure exceeds (14 psig (Suppression Pool Spray Initiation Pressure)), but only if (suppression pool temperature and pressure are below the Drywell Spray Initiation Pressure Limit and drywell temperature and pressure are below the Drywell Spray Initiation Pressure Limit) (shut down recirculation pumps and drywell cooling fans and) initiate drywell sprays.

It, therefore, appears that Pilgrim will not experience SBA Chugging.

The EPG requirement that the operators spray down the containment if the pressure exceeds the 14 psig will also stop chugging for an IBA event.

ITEM 17

QUESTION

With reference to page 70 of Reference 2, provide justification for not considering stresses due to seismic and thermal responses of the drywell in analyzing the main vent/drywell intersection.

ANSWER

TES has obtained the original stress analysis from Boston Edison Company for the Pilgrim Vent Pipe/Drywell Intersection. This analysis contains the deadweight, thermal and seismic stress evaluation of the penetration.

Addition of the thermal stress has not increased the value reported for total stress. The seismic analysis which TES completed for the penetration was more conservative than the original analysis results reviewed. The TES seismic analysis was not replaced by the original penetration seismic analysis results.

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A4.2-19

All allowable values of stress are met for the combined original and Mark 1 stresses. The PUA Torus Technical Report will be revised to reflect the combined stress results.

ITEM 18

QUESTION

With reference to the 1/16 model used for the ring girder analysis, provide more details to justify the assumption that the dimensions of the torus at the Pilgrim plant are similar to the dimensions of the torus at the plant which was actually analyzed. Compare the boundary conditions and the support systems of these torus structures.

ANSWER

The dimensions of the model used are identical to the Pilgrim Torus; the diameter of the torus, shell thickness and distance between the ring girder and mitre joint are identical. The ring girder flange in this model is slightly smaller than Pilgrim and, therefore, produces conservative results since lateral loads control ring girder stresses. The comparison is:

Pilgrim: 1.5 x 7

Model Used: 1.5 x 6

The saddle in the 1/16 ring girder model is the abbreviated design used at Millstone and not the full saddle design of Pilgrim. This difference in saddle geometry will conservatively result in a concentration of the load over the smaller saddle area.

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A4.2-20

ITEM 19

QUESTION

Justify the assumption, with regard to drag loads, that the columns, column gussets, and saddle would make the ring girder very stiff and prevent frequency interaction with dynamic loads.

ANSWER

The natural frequency of the ring girder resulting from lateral loading has been shown to be much greater than the loading frequency of the drag loads thereby substantiating the assumption of no load amplification.

The estimated ring girder frequency, $w = 122$ Hz.

The maximum loading frequency (Drag Loads), $\omega = 26.5$ Hz.

$$\omega/w = 26.5/122 = .21 \longrightarrow \text{DLF} = 1.0$$

ITEM 20

QUESTION

With reference to the high values of actual loads in the ring girder shell welds in the outer column and saddle regions, indicate any conservatism in the analysis which would ensure that the allowables will not be exceeded.

ANSWER

The controlling loads in question conservatively contain peak stresses which were not separated from the membrane portion of the loading. In addition, a review of Table 1 reveals that the controlling load combinations 21 and 25 are to be compared to level C allowables. The allowable loads used for

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Revision 2

A4.2-21

comparison are level A, to bound any additional cases. This bounding technique is discussed in detail in Section 1.0 INTRODUCTION AND GENERAL INFORMATION of the PUA report.

ITEM 21

QUESTION

Provide the fatigue evaluation of the bellows.

ANSWER

TES has reported that the maximum calculated differential motion across the bellows is less than 10% of the rated movements for the rated cycles (~ 1000). Based on EJMA (*) fatigue data of unreinforced austenitic bellows, the permissible cycles for the present condition are well in excess of the endurance limit ($\sim (10)^6$ cycles). Therefore, the condition does not impact the fatigue acceptability of the bellows.

(*) Standard of the Expansion Joint Manufacturers Assoc., Inc.
Fifth Edition, 1980.

ITEM 22

QUESTION

The ASME Code provides an acceptance 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 of the stress-range amplitudes considered and of the associated number of cycles in order to account for the interspersions 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.

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A4.2-22

ANSWER

The fatigue analysis of the torus shell does correct the stress-range amplitudes and associated number of cycles to account for the interspersions of stress cycles of unlike character. The reported usage factors do reflect the use of this method.

It should be pointed out, however, that the usage factors reported do not contain the fatigue usage factors at the Torus Attached Piping Penetrations. The fatigue analysis for the TAP penetrations will be discussed in detail in TES Technical Report TR-5310-2, which will be issued later this year.

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 **TELEDYNE
ENGINEERING SERVICES**


A4.3-1

REVIEW BY FRANKLIN INSTITUTE (cont.)

A4.3 Presentation Handout at FRC/NRC/TEB/BECO/YAEC Meeting
on August 9, 1983

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A4.3-2

 **TELEDYNE**
ENGINEERING SERVICES

MARK 1 CONTAINMENT PROGRAM

REVIEW OF THE

PLANT UNIQUE ANALYSES REPORTS

OF THE

TORUS ATTACHED PIPING

Technical Report
TR-5310-1
Revision 2

A4.3-3

 **TELEDYNE**
ENGINEERING SERVICES

FOR

PILGRIM UNIT 1

VERMONT YANKEE AND

MILLSTONE POINT UNIT 1

NUCLEAR POWER STATIONS

AUGUST 1983

GENERAL

- TORUS ATTACHED PIPING SYSTEMS (TAP)
- MAIN STEAM SAFETY RELIEF VALVE DISCHARGE PIPING
- PIPING
- PENETRATIONS
- SUPPORTS
- ACTIVE COMPONENTS
- MODIFICATIONS

SRV PIPING ANALYSIS

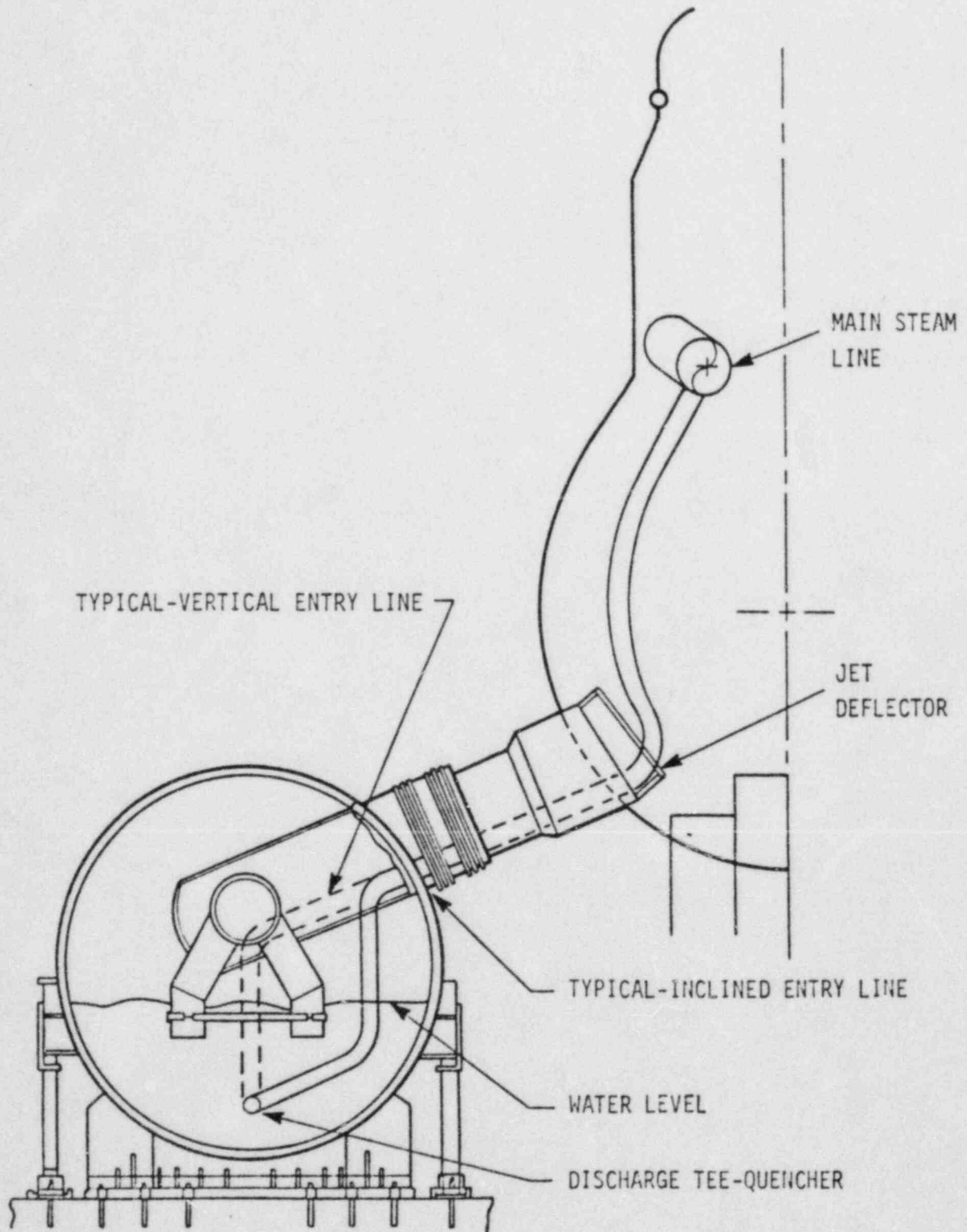
- SRVDL'S PER PLANT (4-6)
 - DISCHARGE END (PUAR-1)
- TORUS SRV PIPING
- TEE-QUENCHERS
- QUENCHER SUPPORT BEAM- MAIN STEAM TO MAIN VENT PENETRATION

PIPING

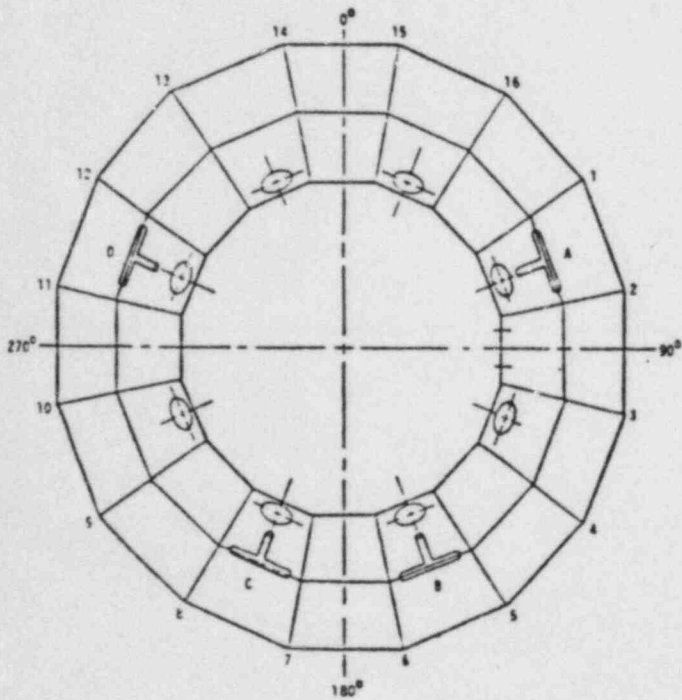
SUPPORTS

ACTIVE COMPONENTS

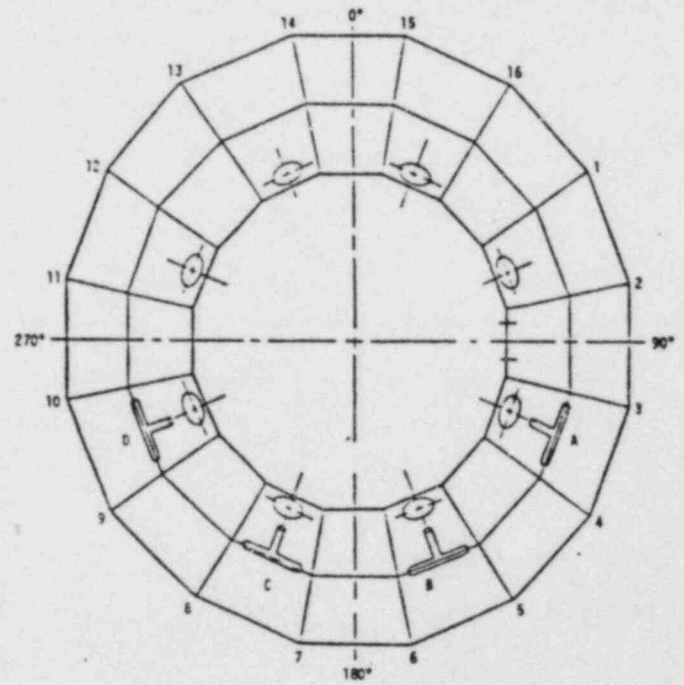
MAIN VENT PENETRATION



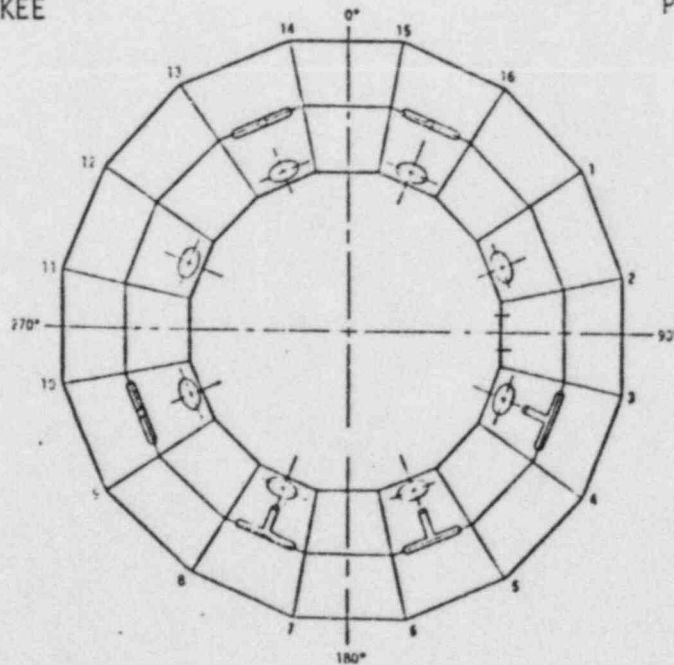
SRV LINE ROUTING-TYPICAL



VERMONT YANKEE



PILGRIM



MILLSTONE

SRV LINE ARRANGEMENT TORUS

APPLICABLE CODES AND CRITERIA

- ANALYSIS OF PIPING AND SUPPORTS

SECTION III ASME BOILER AND PRESSURE VESSEL CODE, 1977 EDITION,
INCLUDING SUMMER 1977 ADDENDA

- DESIGN AND FABRICATION OF SUPPORTS

ASME BPVC SECTION XI

- LOAD COMBINATIONS AND STRESS LEVELS

MARK 1 CONTAINMENT PROGRAM STRUCTURAL ACCEPTANCE CRITERIA PLANT
UNIQUE ANALYSIS APPLICATION GUIDE (PUAAG)

SRV PIPING LOADS

• GAS CLEARING

SUDDEN PRESSURIZATION DUE TO RAPID SRV OPENING

UNBALANCED DYNAMIC FORCES

G.E. COMPUTER CODE RVFOR-04

A1.2 BOUNDING ANALYSIS OF EACH LINE

• WATER CLEARING DISCHARGE

WATER ACCELERATION UNDER SRV DISCHARGE LINE PRESSURE

C3.3 BOUNDING ANALYSIS, MAXIMUM REFLOOD (G.E. RVRIZ)

• SUBMERGED STRUCTURE DRAG (POOL MOTION) ON TEE-QUENCHER, SRV PIPING,
SUPPORT BEAM, AND MAIN VENT PENETRATION

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

LOADS REPORTED IN PUAR-1

SRV PIPING LOADS (CONTINUED)

- WEIGHT, THERMAL AND SEISMIC ANALYSES ARE BASED ON EXISTING FSAR AND ESTABLISHED SYSTEMATIC EVALUATION PROGRAM DATA

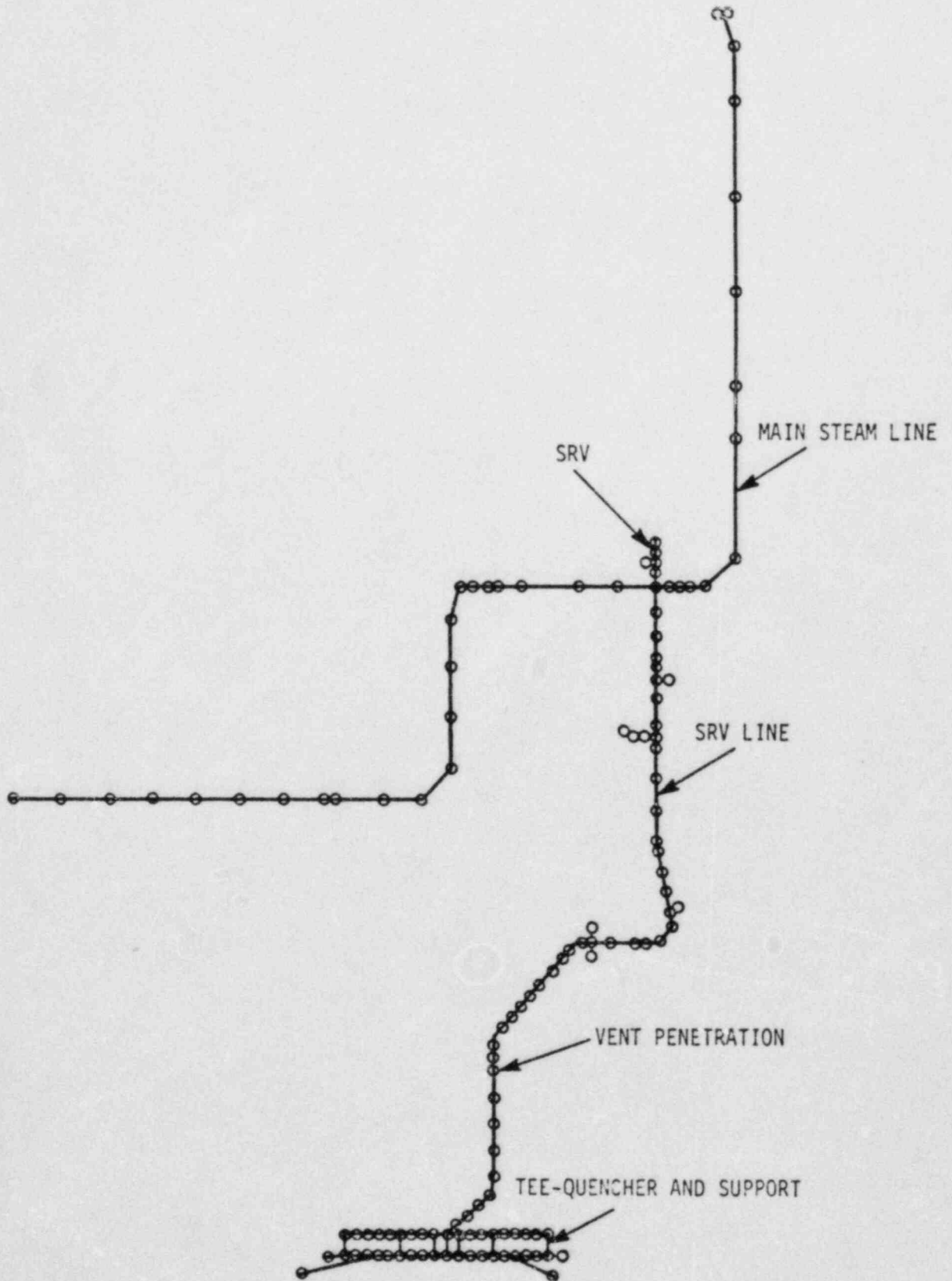
- THERMAL EXPANSION

SRVDL

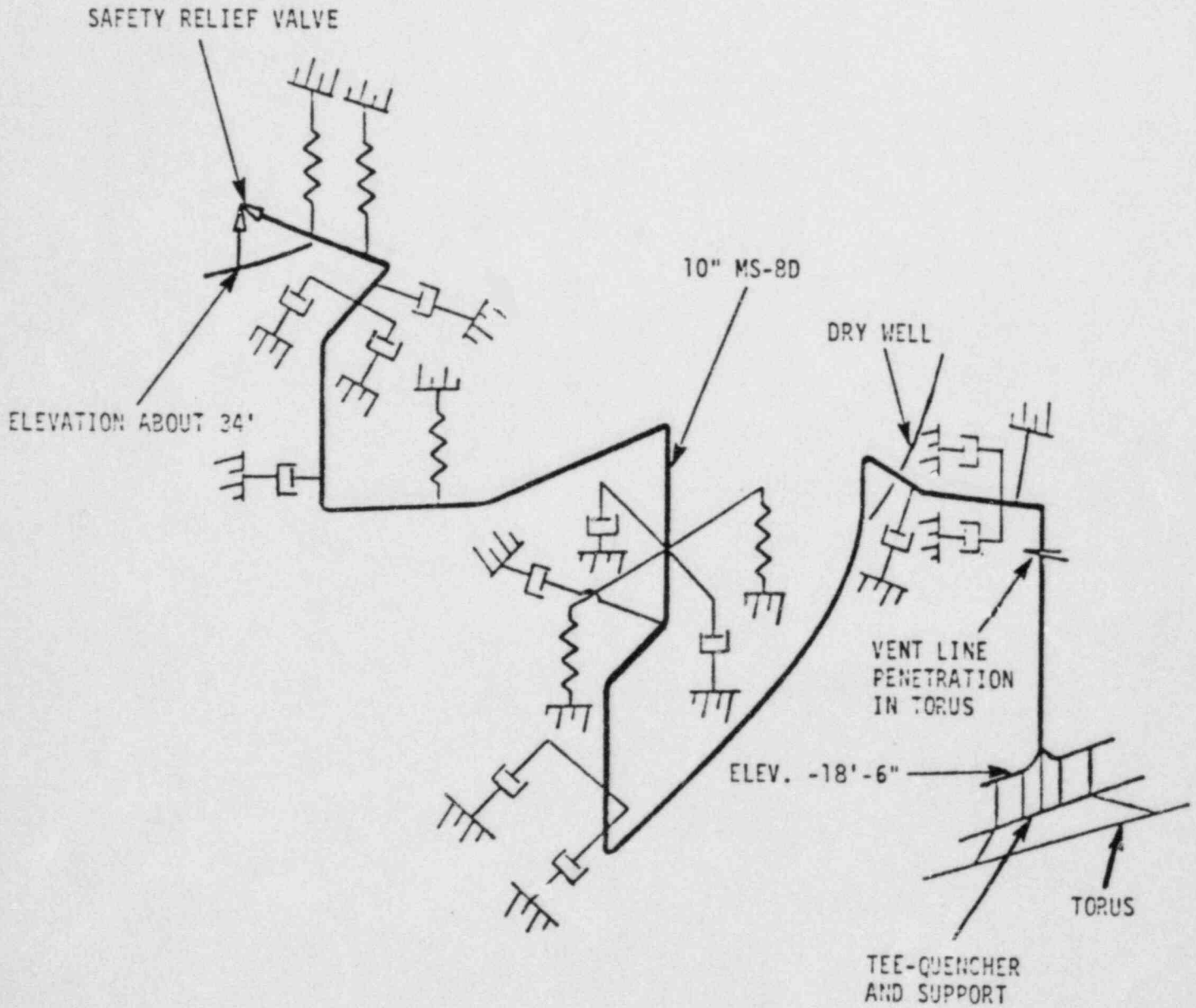
CONTAINMENT

SRV PIPING ANALYSIS COMPUTER MODEL

- STARDYNE COMPUTER CODE
- REPRESENTATION OF THE MAIN STEAM LINE BY A FULL 6 X 6 STIFFNESS MATRIX DEVELOPED FROM A STATIC ANALYSIS OF THE MAIN STEAM LINE OR MODELING OF THE MAIN STEAM LINE WITH EACH SRVDL
- REPRESENTATION OF THE STIFFNESS OF THE MAIN VENT PENETRATION BY A SET OF SIX 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 ALLOWS FREE TORSIONAL ROTATION TO THE QUENCHER ARMS
- DAMPING AT 2% OF CRITICAL FOR ALL TIME HISTORY ANALYSIS



PIPING MODEL, TYPICAL

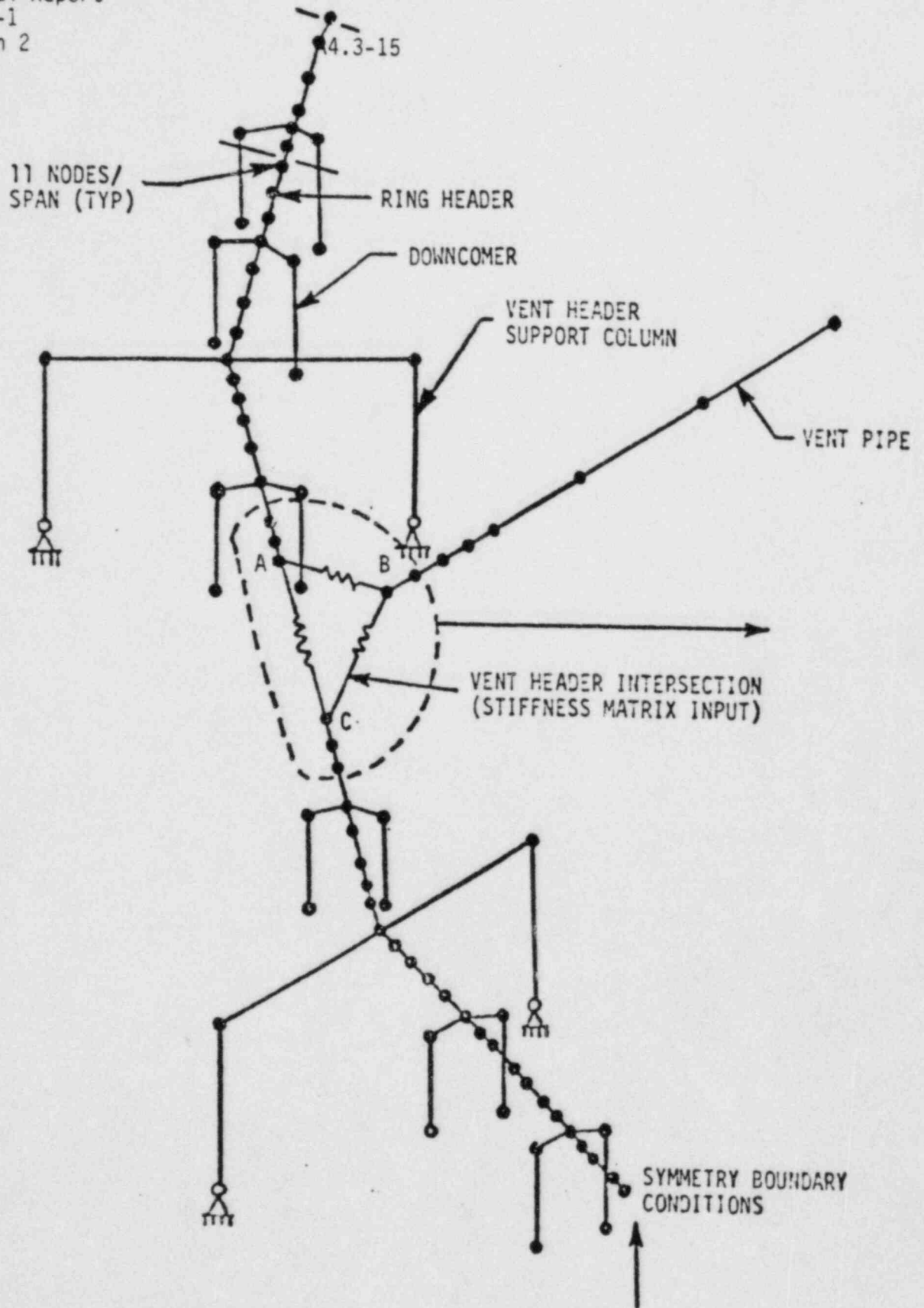


SRV PIPING MODEL, TYPICAL

SRV PIPING ANALYSIS METHOD

- INDIVIDUAL TIME HISTORIES FOR WATER AND GAS CLEARING LOADS APPLIED AT EACH BEND AND ELBOW
- DYNAMIC ANALYSIS
- LINE UNIQUE LOADS
- BOUNDING ANALYSIS WITH WORST CASE GAS AND WATER CLEARING LOADS
- DAMPING 2% OF CRITICAL
- CALCULATIONAL TIME INCREMENTS FOR SOLUTION MONITORING AT .0025 SEC
- RESPONSE FREQUENCIES TO 50 HZ
- INTERNAL PRESSURE BY HAND
- THERMAL, WEIGHT AND SEISMIC ANALYSIS USING THE SAME MODEL

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VENT SYSTEM MODEL

SRV PIPE SUPPORT ANALYSIS

- ANALYSIS BY HAND AND COMPUTER
- STAAD COMPUTER PROGRAM USED FOR ANALYSIS OF COMPLEX SUPPORTS
- ANALYSIS EXTENDED TO INCLUDE THE ATTACHMENT WELD TO SUPPORTING STEEL
- SUPPORTING STEEL WAS INCLUDED IF LOAD CAPACITY WAS SUSPECT
- MAIN VENT PIPE SUPPORTS:

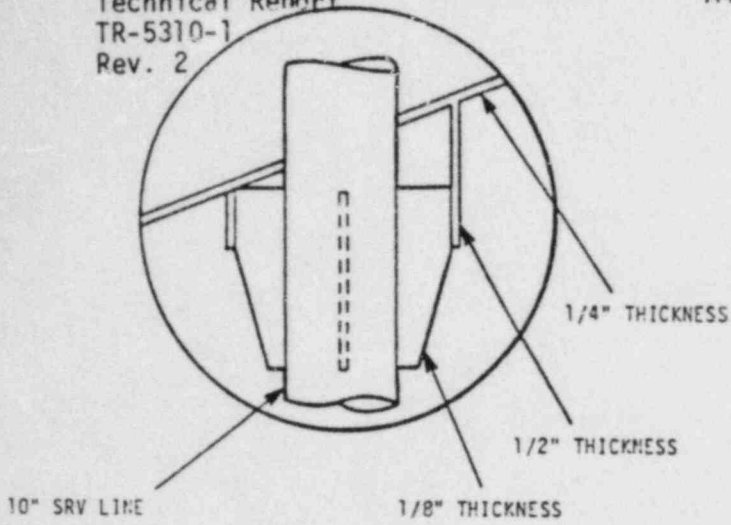
DETAILED EVALUATION OF STRESSES IN THE MAIN VENT WALL

BIJLAARD ANALYSIS IN COMBINATION WITH INTENSIFIED FREE SHELL STRESSES DUE TO VENT HEADER LOADING

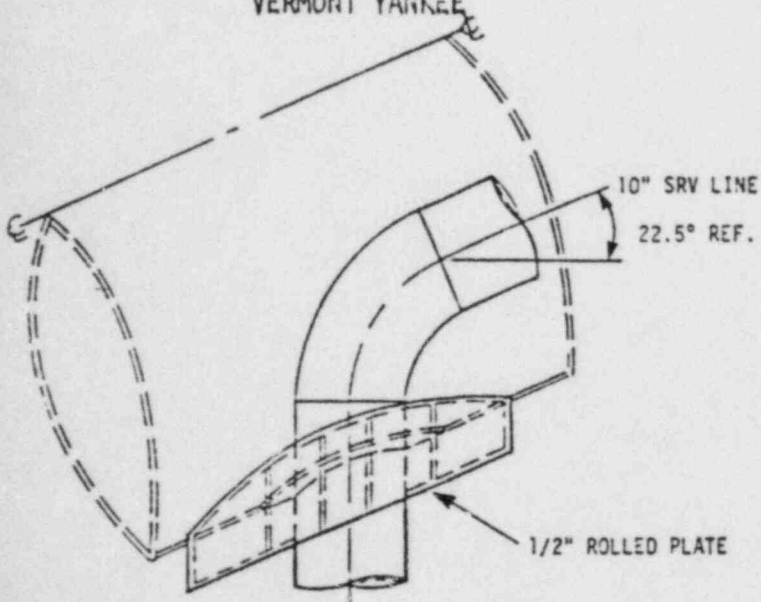
SRV MAIN VENT PENETRATION ANALYSIS

- BIJLAARD ANALYSIS TO DETERMINE LOCAL PENETRATION STRESSES DUE TO SRV DISCHARGE LINE LOADS
- LOCAL STRESSES ADDED TO INTENSIFIED FREE SHELL STRESSES
- VERTICAL ENTRY LINES HAVE A COMPLEX PENETRATION REINFORCEMENT REQUIRING A DETAILED FINITE ELEMENT ANALYSIS (ANSYS COMPUTER CODE)

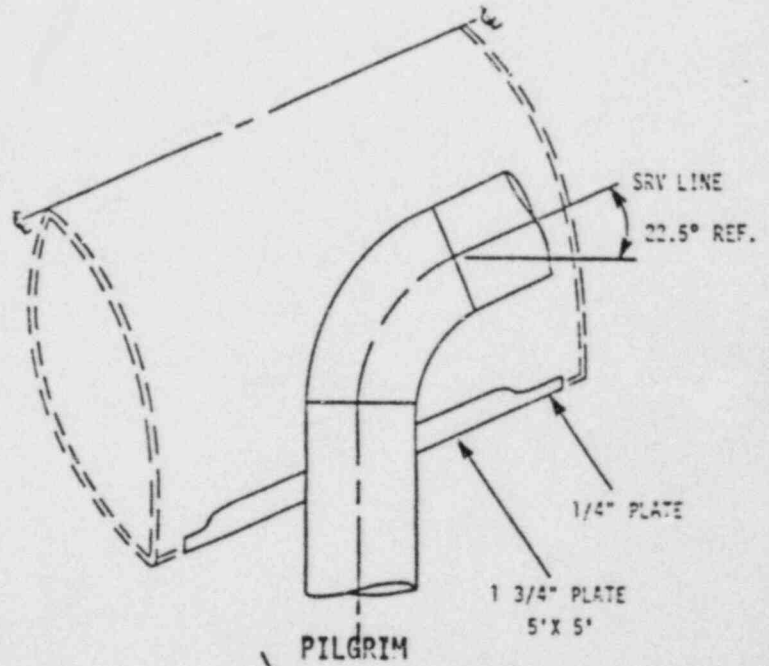
TYPICAL SRV LINE ROUTING
INCLINED ENTRY



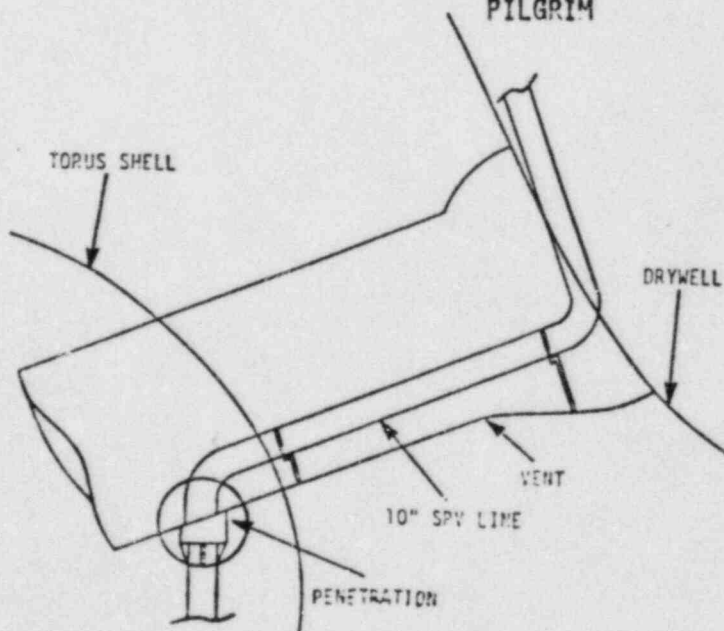
VERMONT YANKEE



MILLSTONE

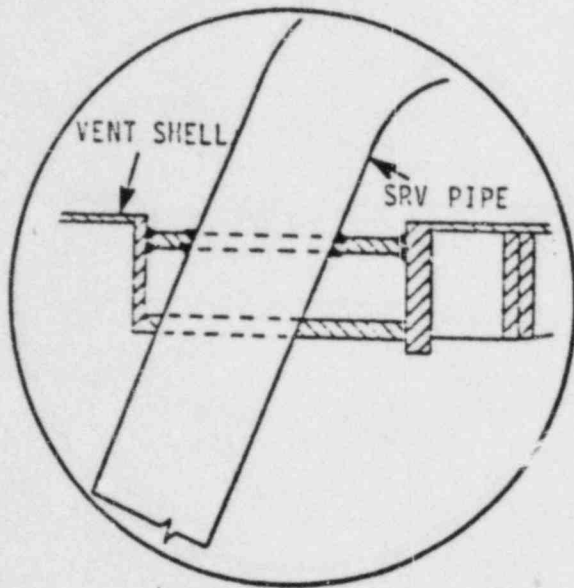


PILGRIM

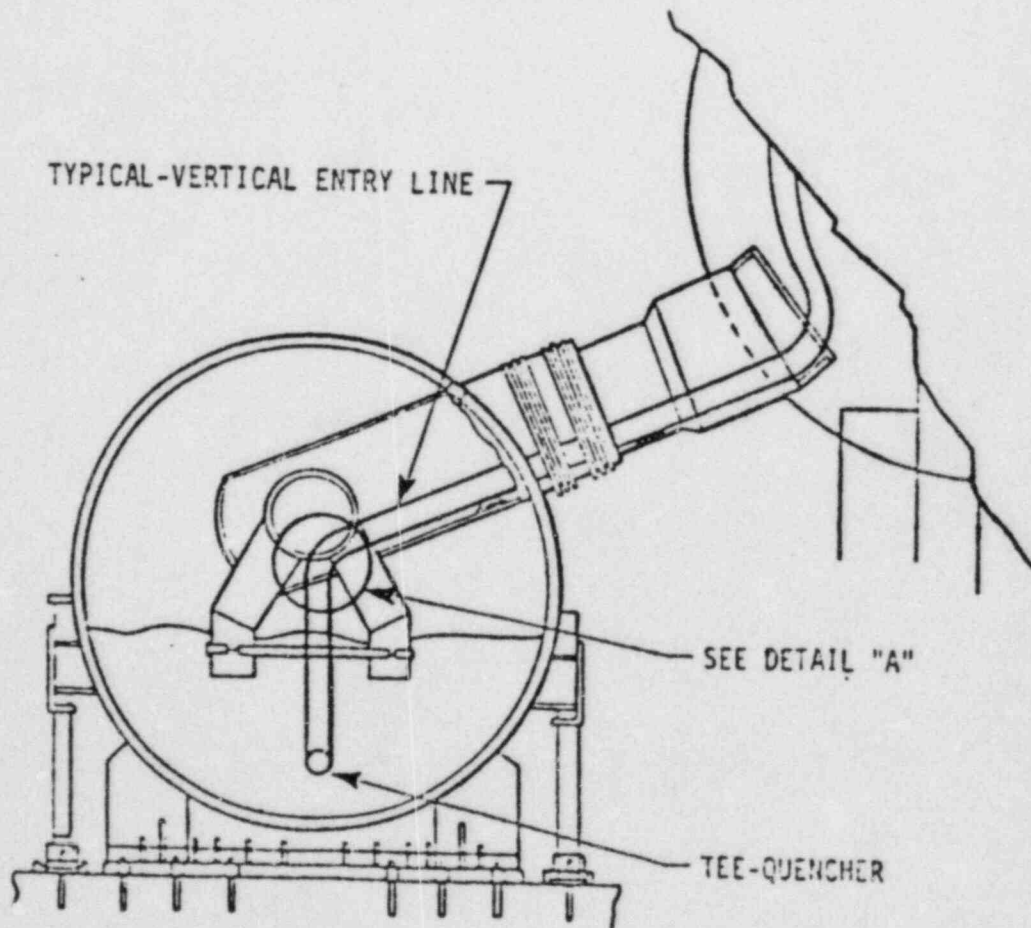


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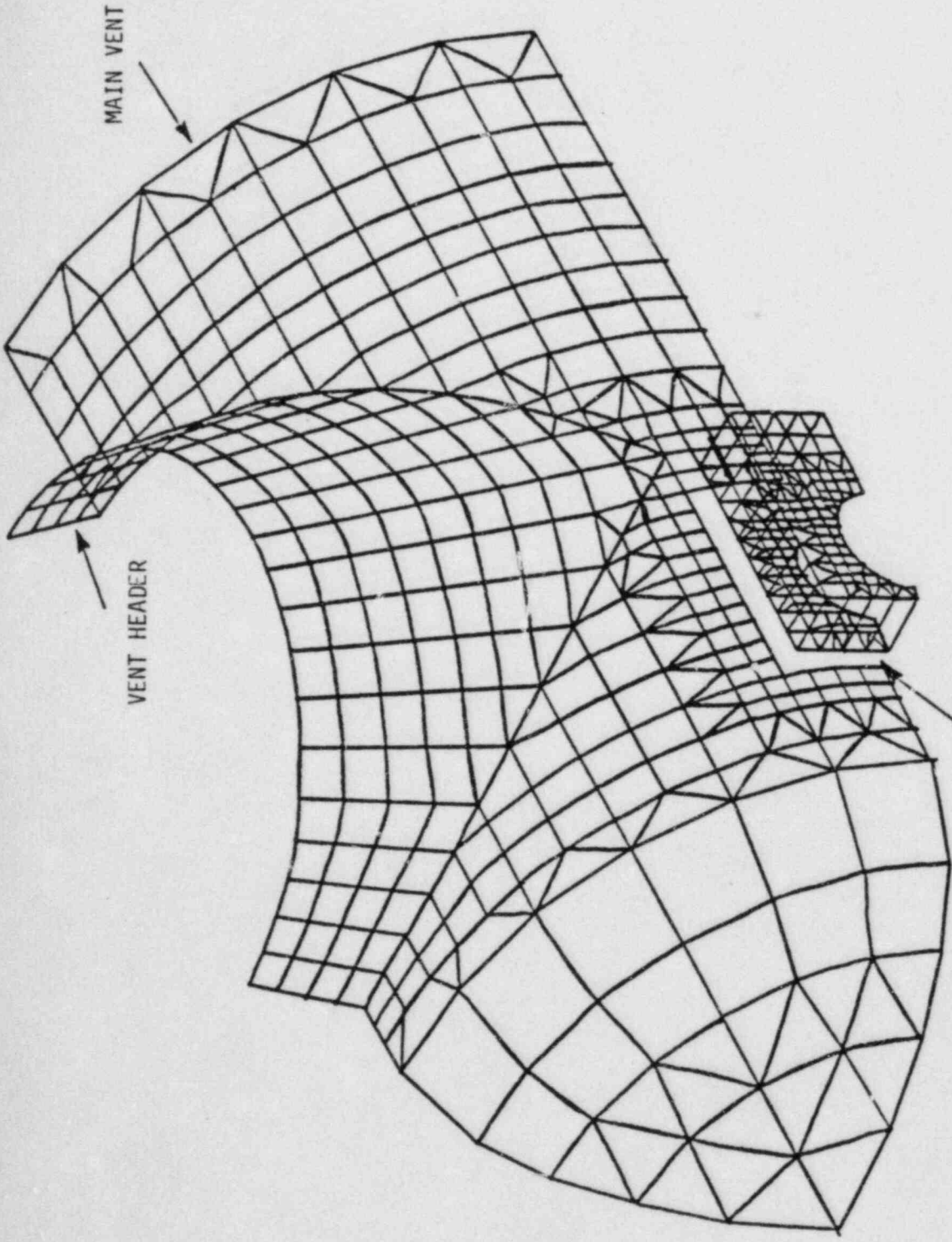
A4.3-18



DETATIL "A"



VERTICAL SRV LINE ROUTING - TYPICAL



NOTE: PLOTTING OF SECTION OFFSET FOR CLARITY
ELEMENTS ARE CONNECTED

SRV PENETRATION COMPUTER MODEL

SRVDL EVALUATION

- 27 LOAD COMBINATIONS (PUAAG)
- 13 COMBINATIONS INCLUDE SRV
- CONSERVATIVE (BOUNDING) LOAD CASE EVALUATED AGAINST LEVEL B ALLOWABLES

$$DW + \sqrt{(SSE)^2 + (BLOWDOWN)^2} = 1.2 Sh$$

- LESS CONSERVATIVE COMBINATIONS EVALUATED WHERE REQUIRED

$$DW + \sqrt{(SSE)^2 + (BLOWDOWN)^2} = 1.8 Sh$$

$$DW + OBE = 1.2 Sh$$

$$DW + BLOWDOWN = 1.2 Sh$$

(THESE CASES REPRESENT LOAD COMBINATIONS 15, 1 AND 2)

- FATIGUE EVALUATION OF SRV LINES WAS UNDERTAKEN AS A GENERIC MARK 1 PROGRAM EFFORT USING BOUNDING ASSUMPTIONS

THE EFFORT CONCLUDES THAT FATIGUE WILL NOT BE A PROBLEM

SRV DISCHARGE PIPING DATA PROVIDED TO GENERIC EFFORT

SRV SUPPORTS AND STRUCTURAL STEEL

- PIPE SUPPORTS AND STRUCTURAL STEEL WERE EVALUATED USING A WORST CASE LOAD CONDITION

CONSERVATIVE BLOWDOWN CASE

SSE SEISMIC (SRSS'D WITH BLOWDOWN)

WORST CASE THERMAL LOAD

DEADWEIGHT

SRV MAIN VENT PENETRATION

- LOADS FROM THE TORUS AND DRYWELL PORTIONS OF THE PIPING WERE COMBINED TO PERFORM THE ANALYSIS IN ACCORDANCE WITH ASME BPVC SUBSECTION NE
- ANALYSIS INDICATES THAT THE MAXIMUM LOAD CAN BE CYCLED FOR A MINIMUM OF 7500 CYCLES

MAJOR LOAD 50 CYCLES MAXIMUM

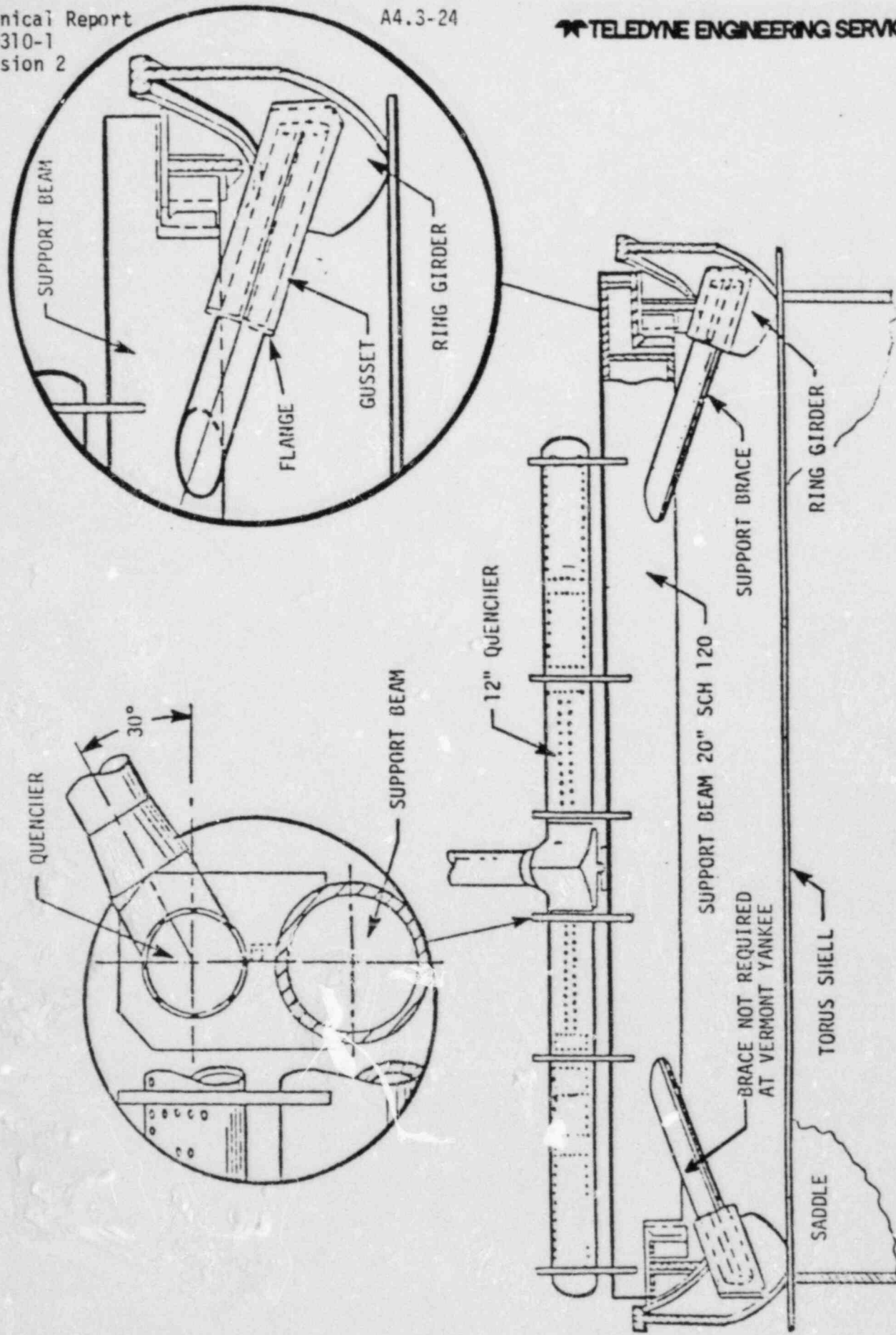
NORMAL SRV ACTUATIONS PRODUCE LESS THAN 4500 CYCLES AT SIGNIFICANTLY LESS LOAD

SAFETY RELIEF VALVES AND VACUUM BREAKERS

- STRESSES IN ADJACENT PIPING MEET LEVEL B CRITERIA TO INSURE PROPER OPERATION OF VALVES

SUMMARY OF SRV LINE MODIFICATIONS

- INSTALLATION OF TEE-QUENCHER DISCHARGE DEVICES AND QUENCHER SUPPORTS
- INSTALLATION OF TWO TEN-INCH VACUUM BREAKERS ON EACH SRVDL
- MODIFICATION OF MAIN VENT PIPE PENETRATIONS AS REQUIRED
- MODIFICATION TO SRVDL SUPPORTS AS REQUIRED
- MODIFICATION TO SUPPORT STEEL IN THE DRYWELL AS REQUIRED



SRV TEE-QUENCHER & SUPPORT

TORUS ATTACHED PIPING (TAP)

- APPROXIMATELY 15 LARGE BORE PIPING SYSTEMS (> 4 IN. DIA.) PER PLANT
- ANALYSIS OF LARGE BORE PIPING SYSTEMS IS FROM THE TORUS TO THE FIRST ANCHOR
- SMALL BORE PIPING (≤ 4 IN. DIA.) WAS ANALYZED TO THE FIRST ANCHOR OR A DISTANCE WHERE THE TORUS LOADS COULD BE CONSIDERED NEGLIGIBLE
- 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

APPLICABLE CODES AND CRITERIA

- TAP PIPING ANALYSIS

ASME BPVC SECTION III, 1977

- BRANCH PIPING ANALYSIS

ASME BPVC SECTION III, 1977

ORIGINAL DESIGN CODE FROM FSAR

- SUPPORT ANALYSIS

ALL TAP AND BRANCH SUPPORTS WERE ANALYZED IN ACCORDANCE WITH THE AISC CODE AND INCLUDING NRC BULLETIN 79-02 REQUIREMENTS

ALL STRUCTURAL SUPPORT STEEL -- AISC

- LOAD COMBINATIONS AND STRESS LEVELS

MARK 1 CONTAINMENT STRUCTURAL ACCEPTANCE CRITERIA PLANT UNIQUE ANALYSIS APPLICATION GUIDE

TAP LOADS

- THE ORIGINAL DESIGN LOADS WHICH INCLUDE WEIGHT, THERMAL AND SEISMIC BASED ON EXISTING FSAR AND ESTABLISHED SYSTEMATIC EVALUATION PROGRAM DATA
- SHELL MOTION LOADS WERE OBTAINED FROM PLANT UNIQUE SHELL RESPONSE DATA DEVELOPED AND REPORTED IN PUAR-1
- SHELL ANALYSIS PROVIDES A TIME HISTORY RESPONSE IN 5 DDOF
- POOL SWELL
- SRV DISCHARGE
- CONDENSATION OSCILLATION
- POOL DRAG AND IMPACT LOADS ON TORUS INTERNAL PIPING WERE CALCULATED IN ACCORDANCE WITH THE LOAD DEFINITION REPORT
- SUBMERGED PIPING LOADS:
 - CO SOURCE AND FSI DRAG
 - POST CHUG SOURCE AND FSI DRAG
 - PRE-CHUG DRAG
 - SRV BUBBLE AND JET LOADS
 - POOL SWELL BUBBLE DRAG AND FALLBACK

TAP LOADS (CONTINUED)

- STRUCTURES ABOVE THE POOL:

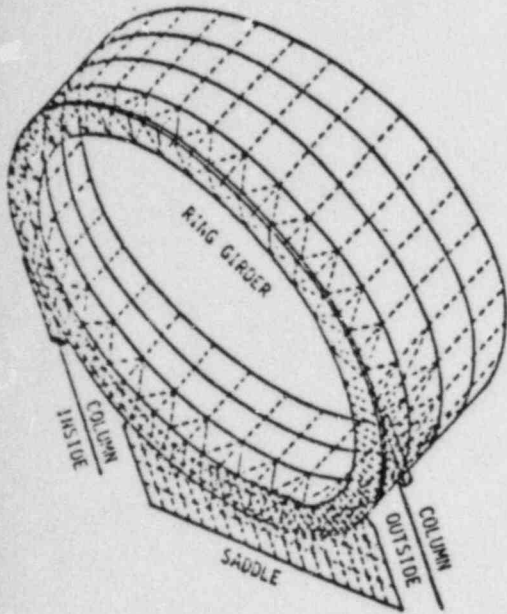
POOL SWELL WATER IMPACT AND DRAG
FROTH
FALLBACK

- SUBMERGED STRUCTURE LOAD SPECTRUM WAS DYNAMICALLY ANALYZED FOR PIPING SYSTEMS. THE SPECTRUM INCLUDES CO AND CH SOURCE AND FSI DRAG

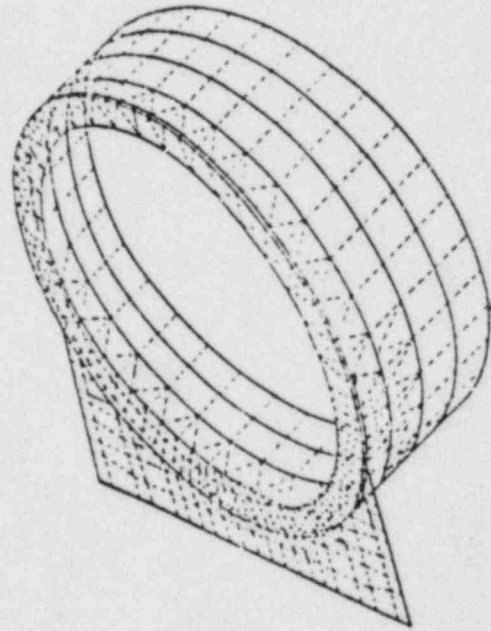
- REMAINING SUBMERGED STRUCTURE LOADS WERE APPLIED AS SEPARATE STATIC CASES WITH WORST CASE ORIENTATIONS

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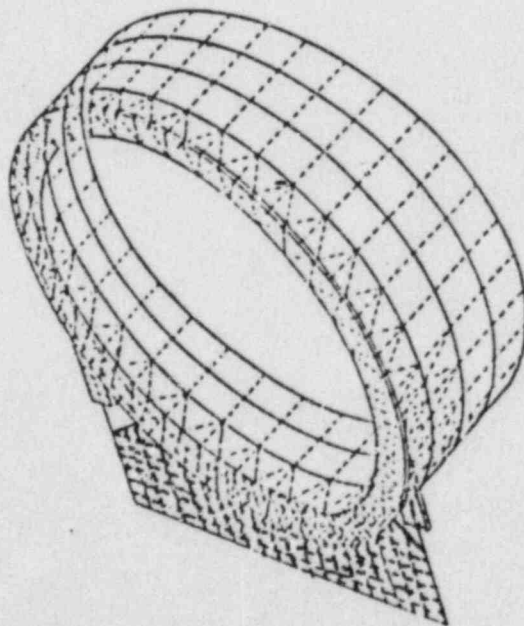
A4.3-29



MILLSTONE



PILGRIM

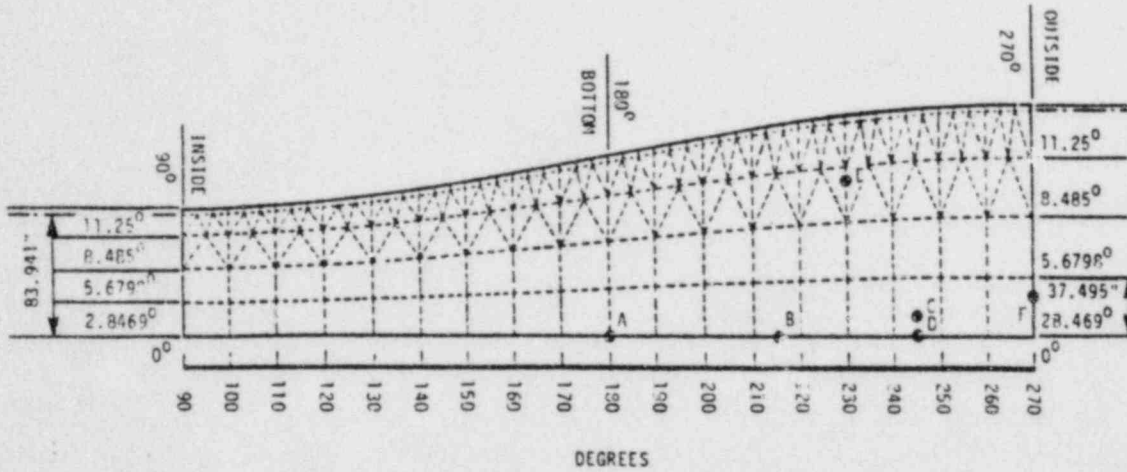


VERMONT YANKEE

DETAILED SHELL MODELS

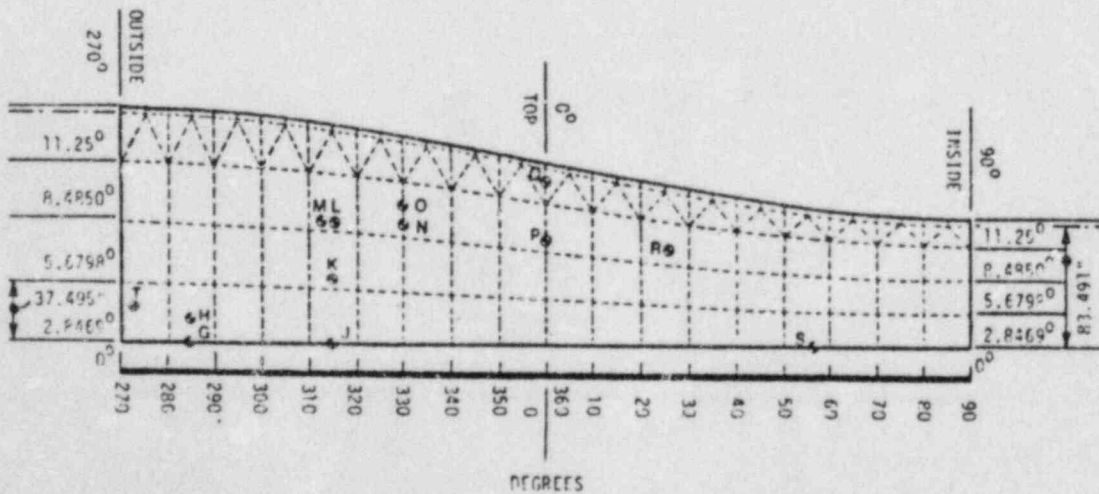
TORUS PENETRATIONS

NODE NO.	LOCATION	PENETRATION NO.	ANGLE
19	A	x213a-h	180°
23	B	x224a-b	217.50°
25	C	x209b-c	245.00°
26	D	x206b-c	245.00°
146	E	x225,226a-b	230.00°
--	F	x227	269.00°
--		x222,223	269.00°



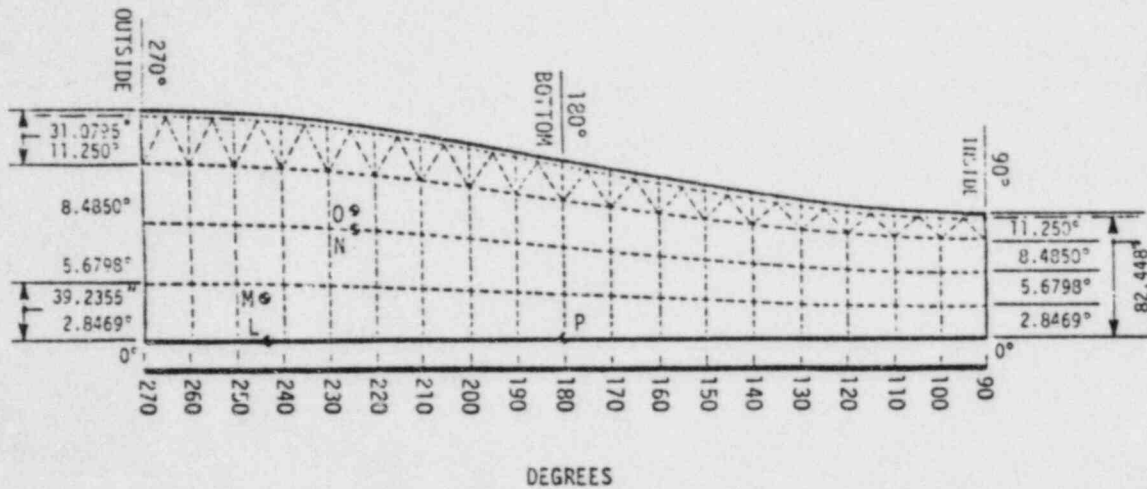
TORUS PENETRATIONS

NODE NO.	LOCATION	PENETRATION NO.	ANGLE
29	G	x206a,d	285.00°
30	H	x209a,d	285.00°
33	J	x202a-h	319.40°
69	K	x202j-k	319.40°
--	L	x200a-b	319.40°
104	M	x205	316.60°
106	N	x215-x219	330.00°
--	O	x214spare	330.00°
73	P	x211a-b	000.00°
109	Q	x220	0.00°
111	R	x210a-b	25.70°
--	S	x201a-h	57.60°
64	T	x212,x221	272.40°



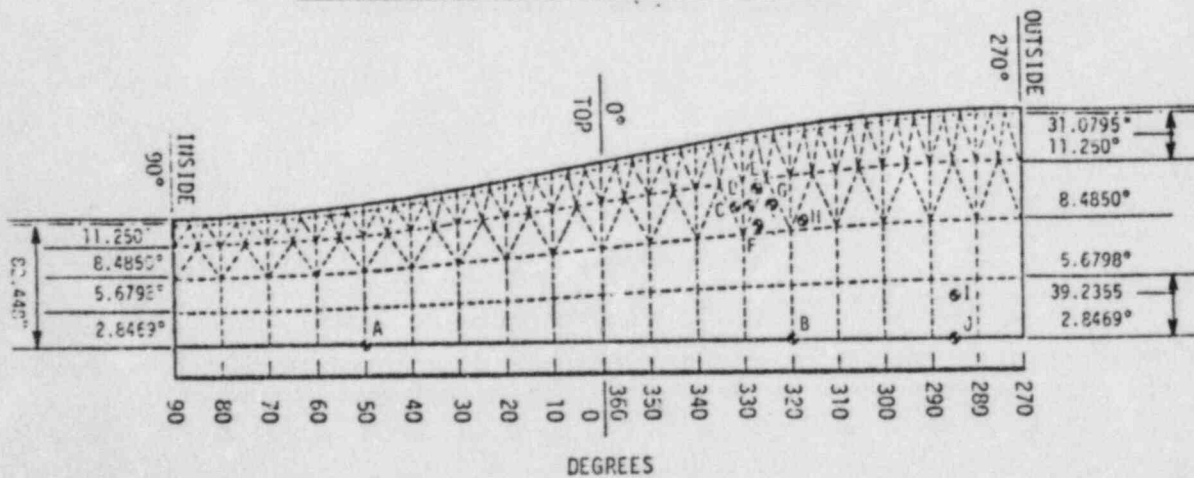
TORUS PENETRATIONS

NODE NO.	LOCATION	PENETRATION NO.	ANGLE
-	L	209b-c	244.70°
-	M	206b-c	244.70°
96	N	204a-c	226.90°
96	O	204b	226.90°
19	P	213a-b	180.00°



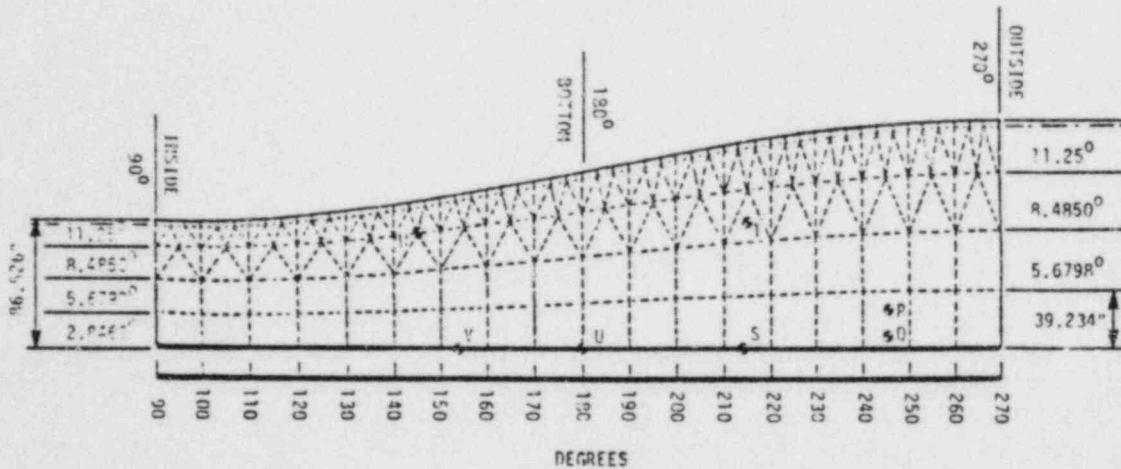
TORUS PENETRATIONS

NODE NO.	LOCATION	PENETRATION NO.	ANGLE
-	A	201a-h	50.00°
33	B	202a-h	319.00°
106	C	211a-b	332.80°
106	D	212	330.00°
-	E	214-219	330.40°
-	F	200a-b	327.10°
105	G	210a-b	325.50°
105	H	205	319.90°
-	I	206a-d	285.00°
-	J	209a-d	285.00°



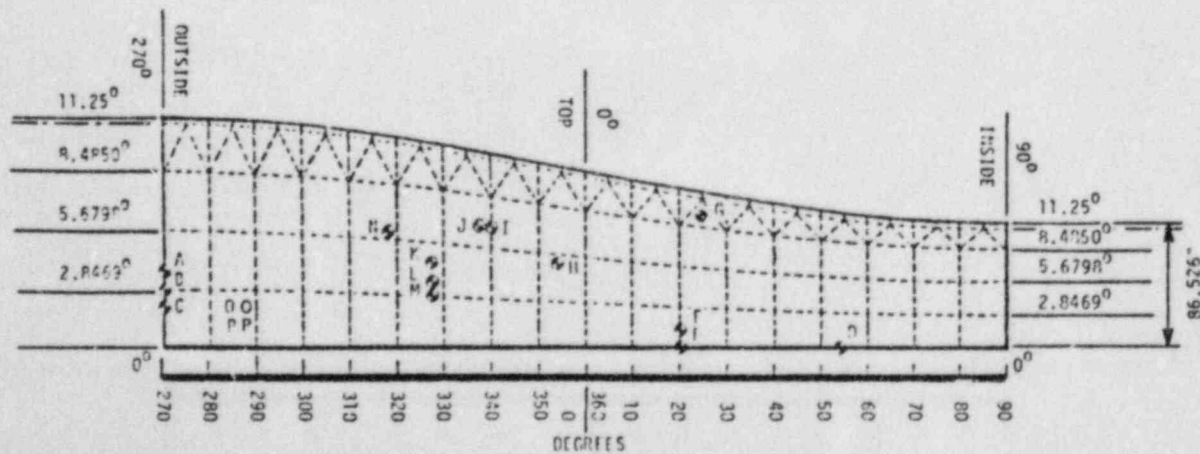
TORUS PENETRATIONS

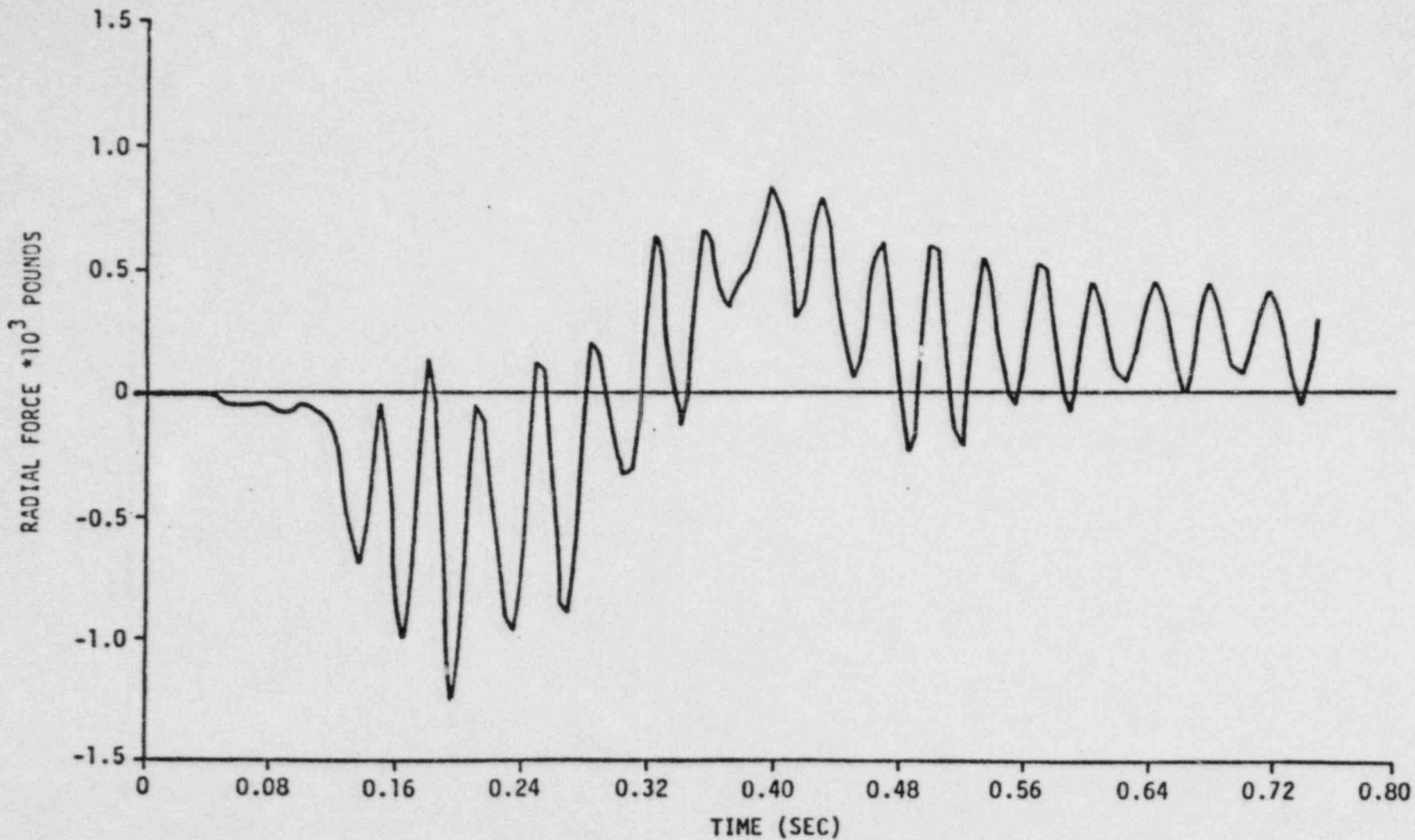
NODE NO.	LOCATION	PENETRATION NO.	ANGLE
25	Q	x206b-c	245.00°
61	R	x209b-c	215.00°
22	S	x220	213.70°
94	T	x22b/d	213.70°
19	U	x213a-b	180.00°
16	V	x221,x22a/c	154.30°
129	W	x229a-b	146.20°



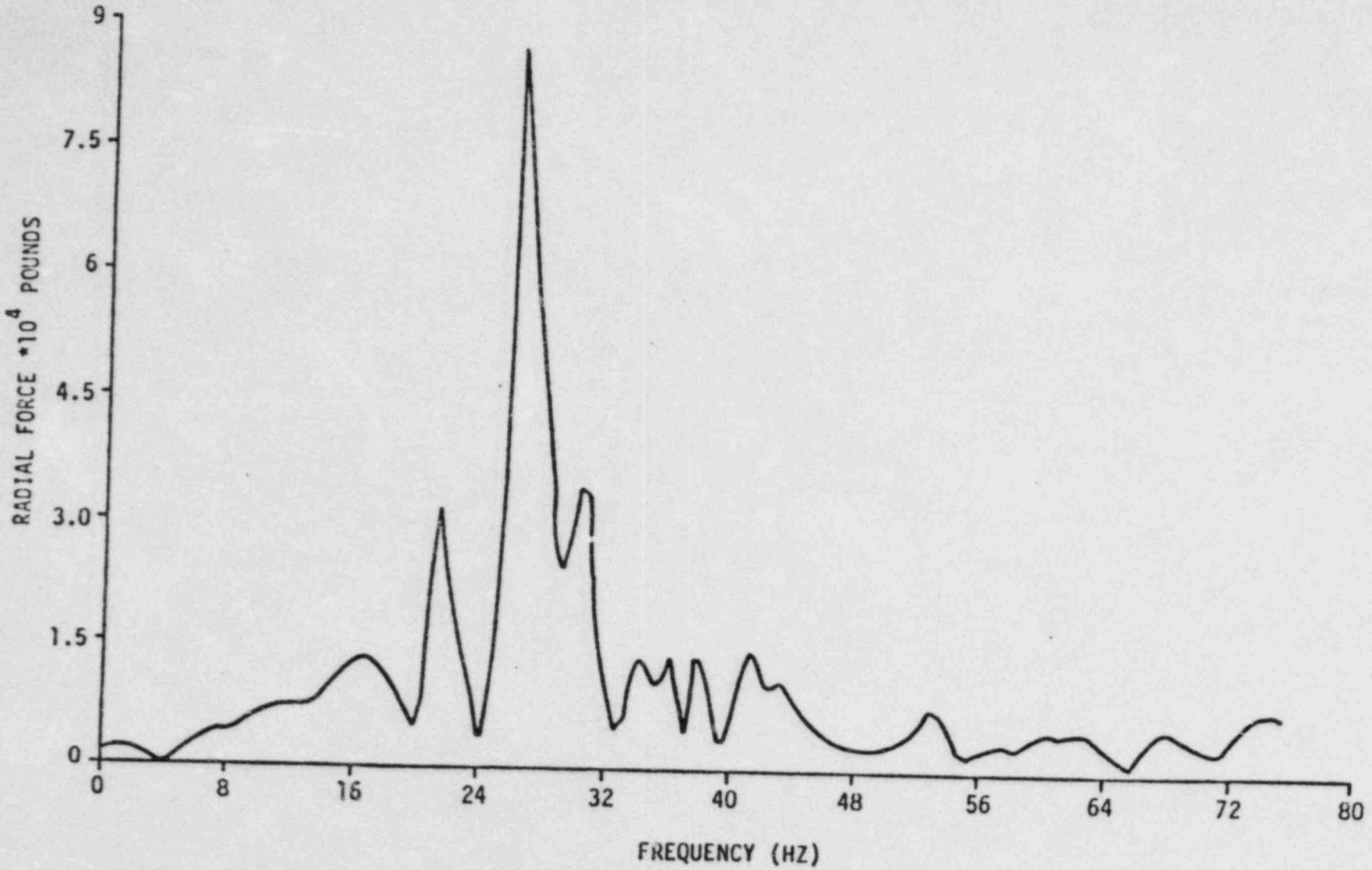
TORUS PENETRATIONS

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	x229c-e,h,j,k	20.00°
3	F	x229a,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°

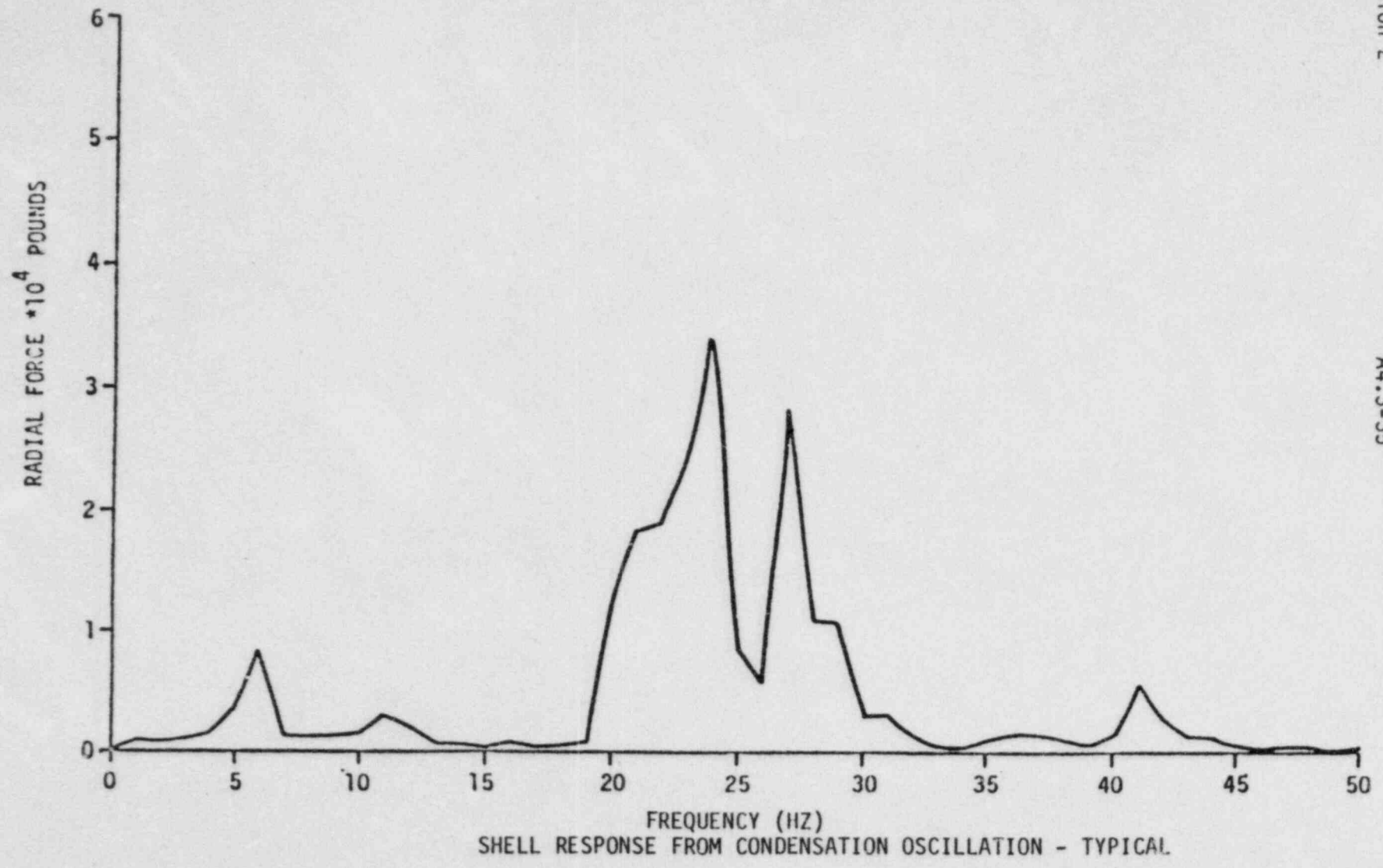




SHELL RESPONSE FROM POOL SWELL TYPICAL

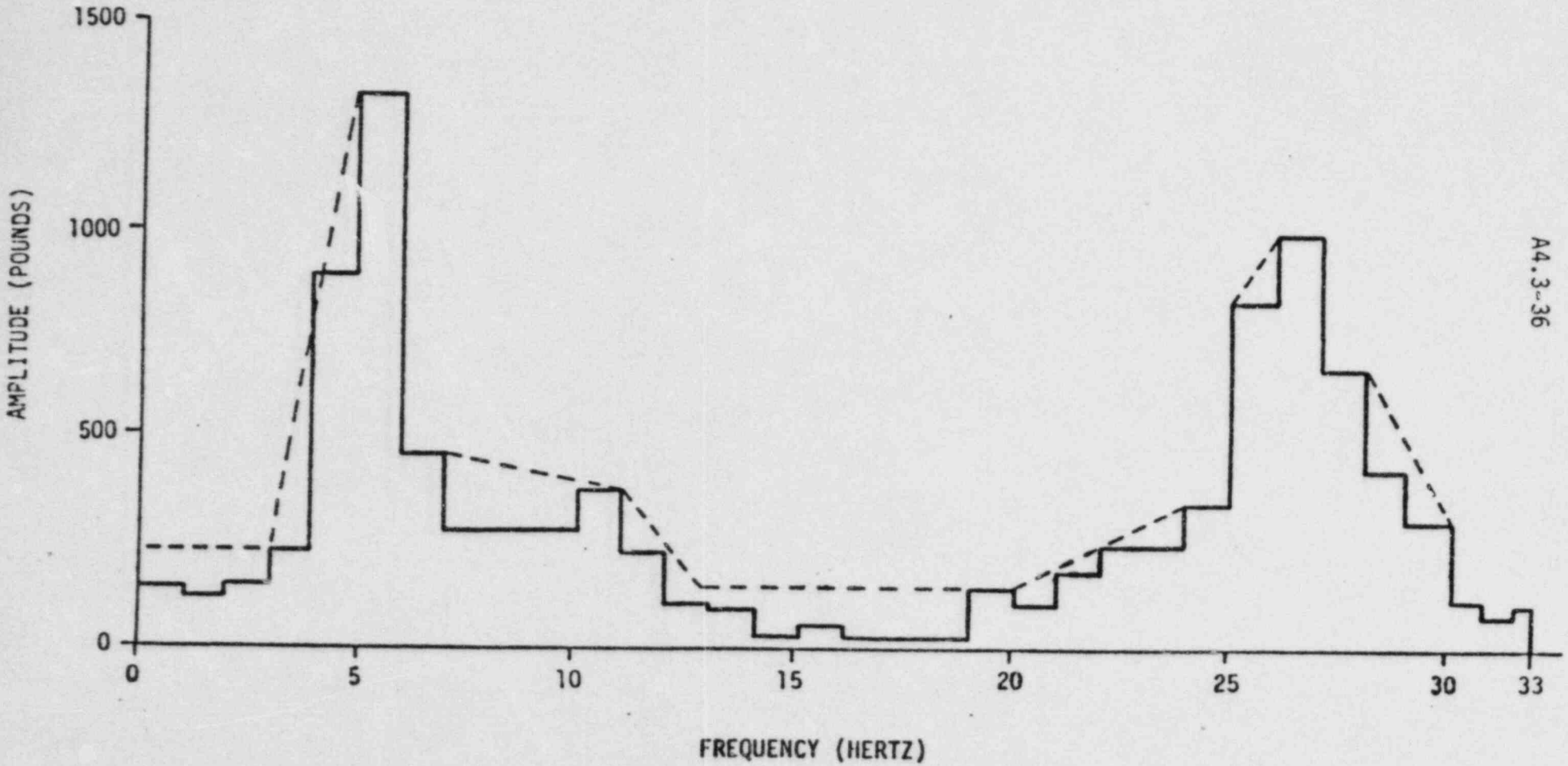


SHELL RESPONSE FROM SRV-TYPICAL



CONDENSATION OSCILLATION AND POST CHUG

A4.3-36



DRAG LOAD ON INTERNAL PIPING

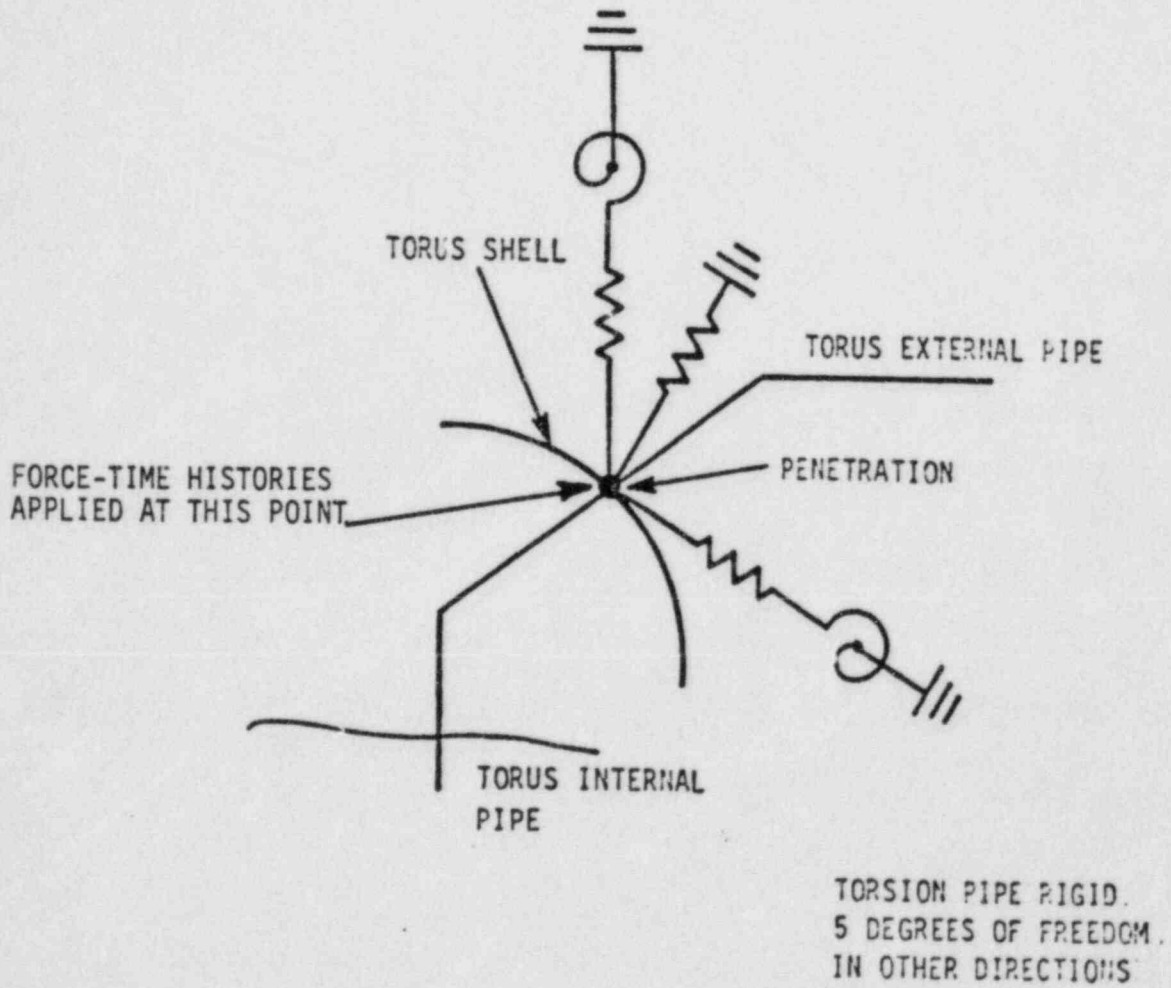
REPRESENTATION OF TORUS SHELL FOR PIPING ANALYSIS

- DYNAMIC INTERACTION BETWEEN THE PIPING AND THE TORUS
- GROUND SPRINGS IN THE PIPING MODEL REPRESENT THE TORUS CONNECTION
- STIFFNESS VALUES CALCULATED BY APPLYING UNIT LOADS AND MOMENTS TO THE 1/32ND FEM. THE IN-PLANE (TORSION) MOTION OF THE SHELL IS CONSIDERED NEGLIGIBLE

LARGE BORE TAP (>4 IN. DIA.)

- FINITE ELEMENT MODEL OF EACH TAP SYSTEM INCLUDING PIPING INSIDE THE TORUS, AND GROUND SPRINGS TO REPRESENT THE TORUS SHELL
- STARDYNE COMPUTER CODE DYNAMIC TIME HISTORY ANALYSIS
- DAMPING VALUES OF 2% IS CRITICAL
- PRE-CHUG LOAD WAS NOT RUN FOR EACH TAP SYSTEM AS IT IS ALWAYS BOUNDED BY DBA CO
- DRAG LOADS DUE TO INTERNAL PIPING WERE CALCULATED BY HARMONIC ANALYSIS FOR THE SPECTRAL LOADS
- PIPE STRESSES DUE TO WELDED ATTCHMENTS WERE ANALYZED

A4.3-38



TAP PENETRATION REPRESENTATION (TYPICAL)

SMALL BORE TAP (≤ 4 IN. DIA)

- COMPLEX SYSTEMS TREATED IDENTICALLY TO LARGE BORE SYSTEMS
- MARK 1 DYNAMIC LOADS LIMITED TO DBA CO
- SIMPLE SMALL BORE SYSTEMS COULD BE REDUCED TO SINGLE MASS APPROXIMATIONS AND ANALYZED BY HAND

BRANCH PIPING

- GENERALLY MODELLED WITH TAP SYSTEMS (APPROXIMATELY 1/6 DIAMETER RATIO)
- BRANCH PIPING CONSIDERED FLEXIBLE IN COMPARISON TO THE MAIN RUN PIPE WAS GENERALLY DECOUPLED AND EVALUATED BY STATIC COMPUTER ANALYSIS UTILIZING TOTAL THERMAL AND DYNAMIC DISPLACEMENTS AT THE BRANCH CONNECTION
- SOME SMALL BORE BRANCH PIPING WAS REVIEWED AND JUDGED ACCEPTABLE WITHOUT RIGOROUS ANALYSIS

TAP PENETRATION ANALYSIS

- LOADS FROM PIPING RESPONSE DUE TO SHELL MOTION
- LOADS DUE TO SUBMERGED DRAG AND/OR POOL IMPACT ON INTERNAL TAP
- WEIGHT, THERMAL AND SEISMIC PIPING LOADS
- MARK 1 EVENT COMBINATION TORUS SHELL LOADING
- BIJLAARD ANALYSIS TO ACCOUNT FOR LOCAL PENETRATION STRESS DUE TO PIPING LOADS
- FREE SHELL STRESSES WERE INTENSIFIED TO ACCOUNT FOR THE DISCONTINUITY

ANALYSIS METHOD FOR PIPING SUPPORTS

- ALL PIPING SUPPORTS FOR THE TAP AND BRANCH PIPING ANALYZED
- STAAD AND STRUDL COMPUTER PROGRAMS USED IN COMBINATION WITH HAND ANALYSIS
- BASEPLATES AND ANCHOR BOLTS ANALYZED USING NRC BULLETIN 79-02
- LOCAL TORUS SHELL STRESSES WERE EVALUATED FOR LOAD FROM TAP SUPPORTS CONNECTED TO THE TORUS SHELL

VACUUM BREAKER ANALYSIS

- WETWELL-TO-DRYWELL VACUUM BREAKERS NOT A PART OF THE MARK 1 PROGRAM
- SEPARATE TRANSMITTAL TO NRC
- MILLSTONE VALVE DISC IMPACT VELOCITIES FROM MARK 1 LOADS ARE LESS THAN NORMAL CLOSURE DUE TO WEIGHT ALONE
- VERMONT YANKEE VALVES DO NOT ACTUATE DUE TO MARK 1 LOADS
- PILGRIM VALVE ANALYSIS IS INCOMPLETE PENDING NRC REVIEW OF CONTINUUM DYNAMICS DATA

EVALUATION

- FOR PURPOSES OF THIS EVALUATION, ALL TAP SYSTEMS ARE CLASSIFIED AS ESSENTIAL
- CONSERVATIVE BOUNDING OF 27 (PUAAG) EVENT COMBINATIONS:

<u>CASE NO.</u>	<u>MAJOR LOAD(S)</u>	<u>ALLOWABLE</u>
3	SRV + SSE	LEVEL B (1.2 Sh)
16	ZERO DELTA P	LEVEL B AS MODIFIED BY FOOTNOTE
21	DBA CO/CH + SSE	SAME AS 16
25	POOL SWELL + SRV	SAME AS 16
15	SSE + SRV + CH	SAME AS 16

- SEISMIC STRESSES WERE COMBINED WITH THE MARK 1 LOADS BY SRSS METHOD
- EVALUATION OF VALVES WAS BASED ON STRESSES IN THE ADJACENT PIPING. PIPE STRESSES MEETING LEVEL B CRITERIA WERE CONSIDERED ADEQUATE TO ASSURE PROPER OPERATION OF THE VALVE
- PIPING SUPPORTS WERE EVALUATED FOR THE SAME LOAD COMBINATIONS AS THE PIPING

FATIGUE EVALUATION

- MARK 1 GENERIC STUDY CONCLUDES THAT THE STRESS LEVELS AND CYCLES INVOLVED IN THESE SYSTEMS WILL NOT PRODUCE A FATIGUE PROBLEM
- ALL TES PLANTS CONTRIBUTED TO THE MARK 1 FATIGUE DATA BASE
- THE FATIGUE EVALUATION OF THE PENETRATION SHOWED THAT THE MAXIMUM LOAD COULD BE CYCLED ON EACH PENETRATION FOR AT LEAST 10,000 CYCLES
- MAJOR LOADS PRODUCE LESS THAN 1,000 CYCLES

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 **TELEDYNE**
ENGINEERING SERVICES

A4.4-1

REVIEW BY FRANKLIN INSTITUTE (cont.)

A4.4 Response to FRC Request for Additional Data

August 18, 1983

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A4.4-2

**TELEDYNE
ENGINEERING SERVICES**

130 SECOND AVENUE

WALTHAM, MASSACHUSETTS 02254

(617) 890-3350 TWX (710) 324-7505

August 18, 1983
5960-6

Mr. Nat Subramonian
Franklin Research Center
20th and Race Streets
Philadelphia, PA 19103

Subject: SRVDL/Vent Pipe Penetration Fatigue Usage Factors

Dear Nat:

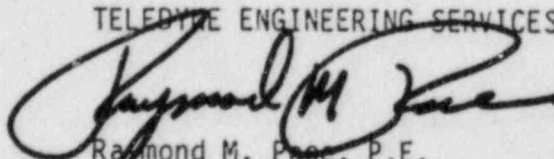
I have enclosed the subject data for your review per our August 9, 1983 meeting at Yankee Atomic Electric Company.

Please note that the fatigue usage factors presented are bounding cases which were conservatively calculated assuming 10,000 cycles of loading at the maximum alternating stress intensity amplitude.

If you have any questions, please call Mr. Nicholas Celia, Manager, Engineering Projects or me.

Very truly yours,

TELEDYNE ENGINEERING SERVICES



Raymond M. Pace, P.E.
Manager, Projects

RMP:alt


enclosure

cc: N. S. Celia
R. H. Berks
R. A. Enos
R. White (YEAC)
M. Franceschina (NUSCO)
G. Mileris (BECO)
M. Lenhart (BECO)

SRVDL/VENT PIPE PENETRATION FATIGUE USAGE FACTOR SUMMARY

Plant	Maximum Alternating Stress (KSI)	Cycles		Usage Factor
		Assumed n	Allowable N	
Vermont Yankee	29.5	10,000	20,500	.49
Pilgrim	21.1	10,000	65,000	.15
Millstone - Inclined	37.6	10,000	10,000	1.0
Vertical	36.5	10,000	10,400	.36

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 **TELEDYNE
ENGINEERING SERVICES**

A4.5-1

REVIEW BY FRANKLIN INSTITUTE (cont.)

A4.5 Review questions received on July 19, 1984.

Request for Information
Pilgrim Nuclear Power Station
SRV and Torus Attached Piping Systems

1. With respect to Section 2.3.2 of the PUA report, TR-5310-2 [2], indicate whether any SRV piping supports are located in the main vent pipe. If so, explain how the stresses in the main vent wall, near the supports, were calculated.
2. With respect to Section 2.4.2 of the PUA report, TR-5310-2 [2], indicate whether pressure (P) was considered in the SRV load cases.
3. With respect to Section 3.3.5 of the PUA report, TR-5310-2 [2], provide calculations demonstrating conformance to the 10% rule of Section 6.2 d [1] that may have exempted some branch piping at the Pilgrim plant from analysis.
4. Regarding the controlling load cases for torus attached piping given in Section 3.4.1 of the PUA report, TR-5310-2 [2], indicate whether seismic loads were considered in load case 25 (Table 1).
5. With respect to Section 3.4.7 of the PUA report, TR-5310-2 [2], provide the analytical results of the fatigue evaluation of torus shell penetrations.
6. With respect to Tables 3-1 and 3-2 of the PUA report, TR-5310-2 [2], indicate whether the lines in each of the following sets are identical and explain why only one result appears for each set: X-222A and X-222B, X-222C and X-222D, X-206C and X-206D, X-209A and X-209D, X-214 and X-215, X-216 and X-217, X-218 and X-219, X-228D and X-228F, and X-240A, X-240B, X-241A, and X-241B.
7. Provide the analytical results for the small bore lines associated with penetrations X-218 and X-219.

References

1. NEDO-24583-1
"Mark I Containment Program Structural Acceptance Criteria
Plant-Unique Analysis Application Guide"
General Electric Company, San Jose, CA
October 1979
2. Pilgrim Nuclear Power Station
Plant-Unique Analysis Report of the Torus Attached Piping, Mark I
Containment Program
Boston Edison Company
October 1983, TR-5310-2

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 **TELEDYNE
ENGINEERING SERVICES**

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REVIEW BY FRANKLIN INSTITUTE (cont.)

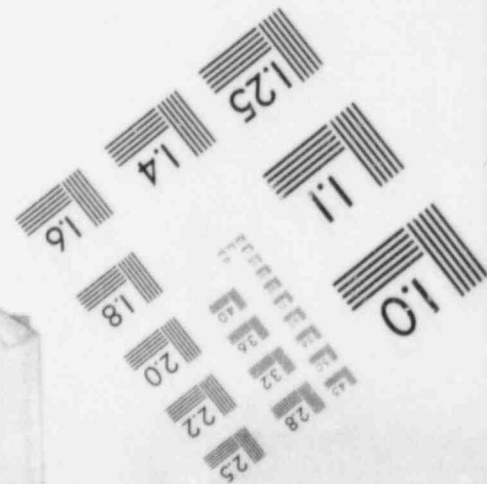
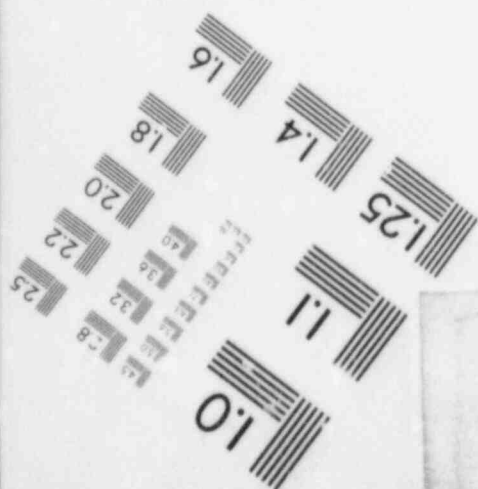
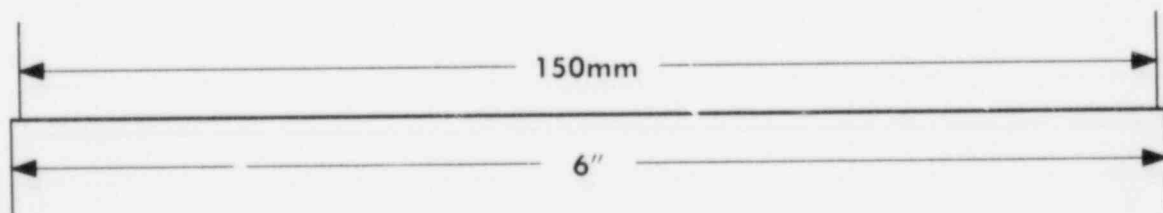
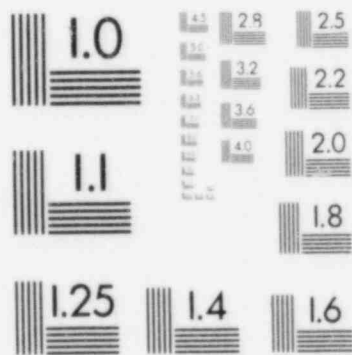
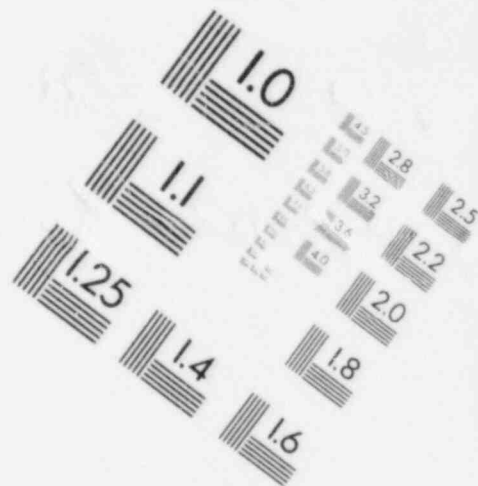
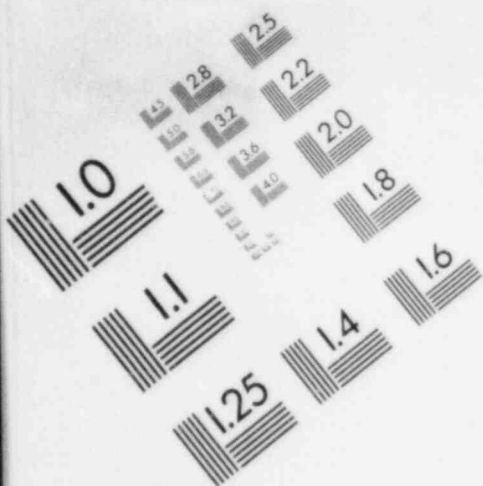
A4.6 Presentation Handout at FRC/NRC/TES/DECO Meeting on August 23, 1984

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A4.6-2

REQUEST FOR INFORMATION
PILGRIM NUCLEAR POWER STATION
SRV AND TORUS ATTACHED PIPING SYSTEMS

IMAGE EVALUATION
TEST TARGET (MT-3)



Item 1:

With respect to Section 2.3.2 of the PUA report, TR-5310-2 (2), indicate whether any SRV piping supports are located in the main vent pipe. If so, explain how the stresses in the main vent wall, near the supports, were calculated.

- o There are no SRV piping supports located in the main vent pipe.

Item 2:

With respect to Section 2.4.2 of the PUA report, TR-5310-1 (2), indicate whether pressure (P) was considered in the SRV load cases.

- o Pressure was considered as a sustained load and is included in the DW term of the equations in Section 2.4.2.

Item 3:

With respect to Section 3.3.5 of the PUA report, TR-5310-2 (2), provide calculations demonstrating conformance to the 10 rule of Section 6.2 d (1) that may have exempted some branch piping at the Pilgrim plant from analysis.

- o Five branch lines are analyzed separately using the 10% rule. These lines are reported in Table 3-3 of the PUA report.
- o The maximum deflections for all loading conditions at the branch connection point of the main run pipe are determined.
- o The deflections are combined per the PUAAG for the controlling load cases.
- o The maximum deflection is doubled and applied to the branch piping conservatively assuming a cantilevered beam to the first branch support.
- o In each branch analysis, the resulting stresses are less than 10% of the allowable.

Item 4:

Regarding the controlling load cases for torus attached piping given in Section 3.4.1 of the PUA report, TR-5310-2 (2), indicate whether seismic loads were considered in load case 25 (Table 1).

- o The SSE seismic load is included in the evaluation of load case 25.

Item 5:

With respect to Section 3.4.7 of the PUA report TR-5310-2 (2), provide the analytical results of the fatigue evaluation of torus shell penetrations.

- o Usage factor determines fatigue acceptability. This is calculated as

$$\frac{\text{Maximum Number Cycles Possible}}{\text{Number Allowable Cycles at } S_a}$$

- o Maximum number of cycles always used is 10,000. As referenced in the PUAR-2, the major loads are pool swell (one cycle), DBACO (about 900 cycles), SRV Case A1.2 (about 50 cycles). Other loads, such as IBACO and chugging, can produce about 10,000 cycles.
- o All cycles assumed at maximum amplitude with full stress reversal.
- o IBACO and chugging are at greatly reduced stress levels.
- o Allowable number of cycles at S_a is calculated according to ASME Section III, NE-3221.5, and uses Table I-9.1 in the Appendices.
- o Using Table 3-6 (Page 61) of the PUAR-2, the three penetrations with the highest usage factors are:

- Small Bore Piping

- 1) X-218 = 0.222 Usage Factor
- 2) X-219 = 0.200
- 3) Remaining = 0

- Large Bore Piping

- 1) X-225 = 0.556 Usage Factor
- 2) X-223 = 0.530
- 3) X-229B = 0.500

Item 6:

With respect to Tables 3-1 and 3-2 of the PUA report, TR-5310-2 (2), indicate whether the lines in each of the following sets are identical and explain why only one result appears for each set: X-222A and X-222B, X-222C and X-222D, X-206C and X-206D, X-209A and X-209D, X-214 and X-215, X-216 and X-217, X-218 and X-219, X-228D and X-228F, and X-240A, X-240B, X-241A, and X-241B.

- o Lines X-222 A&B - Both lines are connected by a cross-over system. This analytical model included both lines and the cross-over system in a single analysis. Only the maximum stress results are reported.
- o Lines X-222 C&D - Similar configuration and analysis as performed for X-222 A&B.

Item 6 (Continued)

- o Lines X-206 C&D - The original configuration of this analysis includes a header system that connects the two lines. Only the maximum stress results are reported. Subsequent to issuing the report, the support system was changed to separate these lines into two separate systems. This change eliminates the need for extensive support modifications. The separate results for lines X-206C and X-206D will be reported in Revision 1 of the PUA report, Table 3-2, as follows:

X-206C	1" SCH80	Dynamic	34,300.	37,500.	Anchor.
X-206D	1" SCH80	Dynamic	29,870.	37,500.	Anchor.

- o Remaining line groupings are of very similar or identical designs. Worst case analysis is reported in each case.

Item 7:

Provide the analytical results for the small bore lines associated with penetrations X-218 and X-219.

- o The analysis of lines X-218 and X-219 have been completed and the results will be presented in Revision 1 of the PUA report, Table 3-2.

X-218	4" SCH40	Dynamic	15,695.	43,752.	Floor Penet.
X-219	4" SCH40	Dynamic	17,656.	43,752.	Floor Penet.

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A4.7-1

REVIEW BY BROOKHAVEN NATIONAL LABORATORIES (BNL)

A4.7 Review Questions Received on June 21, 1984

ITEM 1: PUAR Section 3.1-3.2

During pool swell, the water mass was modeled "using a 3D virtual mass simulation as an integral part of the structural analysis", and the total water mass used was taken as the average of the effective masses for the full and zero delta-p cases.

How was the water mass distributed in the computer simulation? How sensitive were the controlling stresses to the distribution and magnitude of the water mass?

ITEM 2: PUAR Section 4.3.2.1

In the computation of the downcomer first lateral response frequency, what virtual mass of water was used? (At what level was the water assumed to be inside the downcomer, and how was the displacement of the outside water accounted for?).

How sensitive was the controlling stress (e.g., at the vent-header/downcomer intersection) to what was assumed about the water mass in the downcomer frequency calculation?

ITEM 3: PUAR Section 4.3.3.1

It is stated that "the combined effects of the CO downcomer loads (are) bounded by CH lateral loads".

Does this apply to the entire vent-header/downcomer system as well as the individual downcomer pairs? The LDR specifies the CO loading on the entire vent-header/downcomer system as the worst of eight different phasing combinations of the loads on the various downcomer pairs in the system. Were these considered, and was the worst of them bounded by the chugging load?

ITEM 4: PUAR Sections 3.2.4, Appendix 1

Provide the following additional information regarding the in-plant SRV tests conducted at Pilgrim and the SRV design loads extrapolated from the tests:

1.0 Description of the tested Quencher Device

- 1.1 Drawings showing details of the quencher geometry - plan, elevation, arm length, arm diameter, hole arrangement, spacing, size, etc.
- 1.2 Location of quencher device relative to suppression pool boundaries and suppression pool surface.

- 1.3 Any difference between the tested quencher configuration and the Monticello version (as described in GE NEDE-24542-P) highlighted and quantified.
- 2.0 A description of the loads observed during testing -
 - 2.1 Peak overpressure (POP) and underpressure (PUP) recorded on the torus shell during each relevant SRV actuation.
 - 2.2 A measure of the frequency content of each pressure signature.
- 3.0 A description of the test conditions -
 - 3.1 Geometry of the tested SRVDL (diameter, length, free volume, and routing below pool surface).
 - 3.2 Geometry of any SRVDLs in the plant that differ significantly from the tested SRVDL.
 - 3.3 SRV steam flow rate (MS), pool temperature (TPL), pipe temperature (TP), water leg length (LW) and pressure differential (P), if any, for each test.
 - 3.4 Minimum P permitted by NRC Technical Specification and corresponding LW for all SRVDLs.
- 4.0 A description of the design conditions for each load case used for design -
 - 4.1 Geometry of all SRVDLs involved and their azimuthal location in the torus.
 - 4.2 TP, TPL, MS, P and LW for all SRVDLs involved.
- 5.0 A description of the design loads for each load case -
 - 5.1 Normalized pressure signature.
 - 5.2 Single valve POP/PUP values.
 - 5.3 Spatial attenuation of the POP/PUP values (if this differs from the LDR methodology, sufficient additional torus shell pressure data must be supplied to justify such deviation).
 - 5.4 Frequency range considered.
 - 5.5 Procedure used to combine loads for multiple values.

ITEM 5: PUAR Appendix 1

With regard to the Table on page A1-4 and Figure A1-7, justify the inclusion of data from Nine Mile Point which uses a quencher device radically different from the other three plants included in the data base.

Identify any structures for which SRV drag allowable margins are less than 3.0 and state what the margins are. In other words, list those structures which would be stressed beyond allowable limits if SRV drag loads were increased 3.0 times in Pilgrim and provide the margins for these structures.

ITEM 6: PUAR Section 2.2.1

The footnote on page 7 of the PUAR states that only 4 of the 6 SRV quenchers installed in Pilgrim are operative, with the other two not connected to steam relief lines. Is all the wetwell piping in place for the non-functioning quencher devices? How were multiple valve SRV loads computed for Pilgrim - based on four or on six quenchers?

ITEM 7: PUAR Section 2.2.1

What is the vertical location of the pool temperature sensors with respect to the centerline of the T-quenchers?

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REVIEW BY BROOKHAVEN NATIONAL LABORATORIES (BNL) (cont.)

A4.8 Presentation Handout for BNL/NRC/TES/BECO Meeting on August 23, 1984

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 **TELEDYNE
ENGINEERING SERVICES**

MARK I TORUS PROGRAM
REVIEW OF PLANT UNIQUE ANALYSIS REPORT FOR
PILGRIM I NUCLEAR POWER PLANT

August 23, 1984

ITEM 1: PUAR Section 3.1-3.2

During pool swell, the water mass was modeled "using a 3D virtual mass simulation as an integral part of the structural analysis", and the total water mass used was taken as the average of the effective masses for the full and zero delta-p cases.

How was the water mass distributed in the computer simulation?
How sensitive were the controlling stresses to the distribution and magnitude of the water mass?

- 3D virtual mass modeled with the same procedure used by most AE's.

1/32nd model fluid representation.

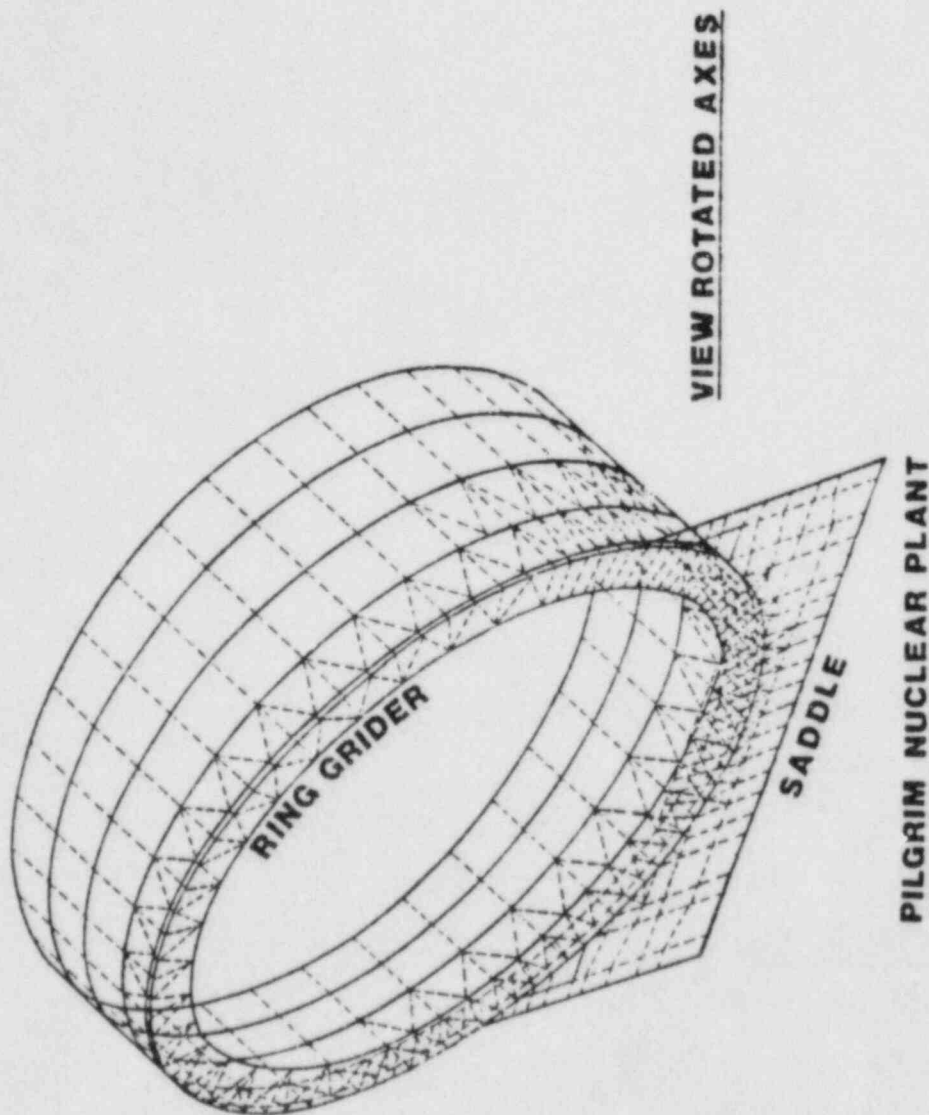
Full 3D mass matrix developed.

Mass matrix terms lumped to structural model at fluid/
structure interface.

- Effective pool swell water mass:

ΔP	57%
$0\Delta P$	47%
Avg	52%

- The resulting 10% mass discrepancy will shift the first structural frequency 5% or $\pm .63$ Hz.
- Pool swell is a quasi-static phenomenon (approximately 2 Hz) and therefore the structural response (first frequency = 11.9 Hz) is not sensitive to the small frequency shift.
- Actual pool swell loading function is applied as a shell pressure independent with respect to the 3D mass.



DETAILED SHELL MODEL

ITEM 2: PUAR Section 4.3.2.1

In the computation of the downcomer first lateral response frequency, what virtual mass of water was used? (At what level was the water assumed to be inside the downcomer, and how was the displacement of the outside water accounted for?)

How sensitive was the controlling stress (e.g., at the vent-header/downcomer intersection) to what was assumed about the water mass in the downcomer frequency calculation?

- A virtual mass of water was used for the submerged portion of the downcomer per the LDR, assuming minimum submergence

$$\text{Virtual Mass} = \rho \pi R^2 L \text{ (cylinder)}$$

- Displacement of the water outside the downcomer is accounted for by the virtual mass. The downcomer was assumed empty to maximize frequency and provide conservative results.
- Chugging controls downcomer loads and stress. The LDR method specifies the following relationship for chugging response:

$$DLF = \pi f t_d$$

- Use of minimum submergence and no internal water mass provides the maximum frequency and therefore maximum DLF.
- In general, calculated stress is proportional to the square root of a mass change ($DLF \propto f$).

ITEM 3: PUAR Section 4.3.3.1

It is stated that "the combined effects of the CO downcomer loads (are) bounded by CH lateral loads".

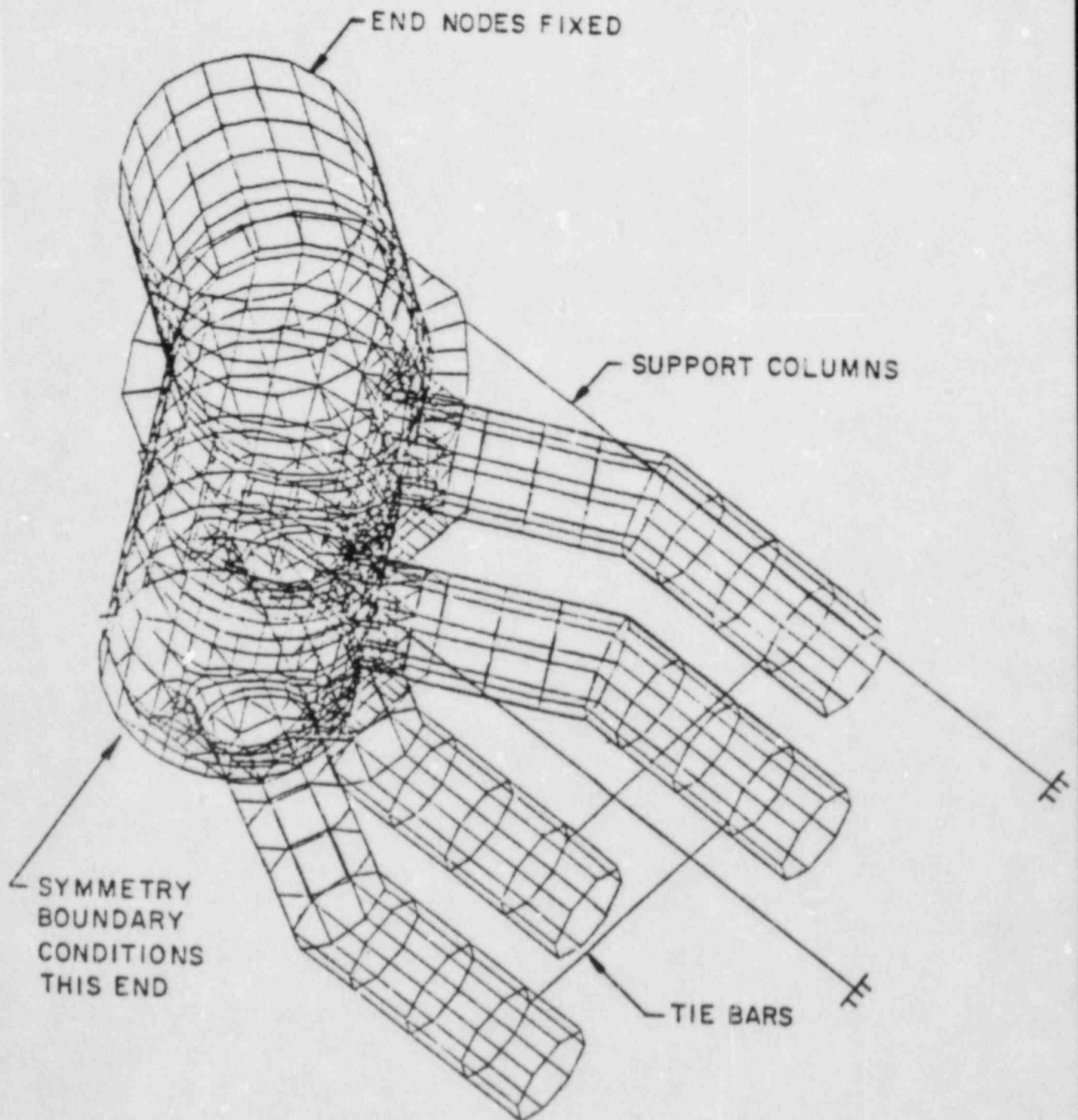
Does this apply to the entire vent-header/downcomer system as well as the individual downcomer pairs? The LDR specifies the CO loading on the entire vent-header/downcomer system as the worst of eight different phasing combinations of the loads on the various downcomer pairs in the system. Were these considered, and was the worst of them bounded by the chugging load?

For the individual downcomers:

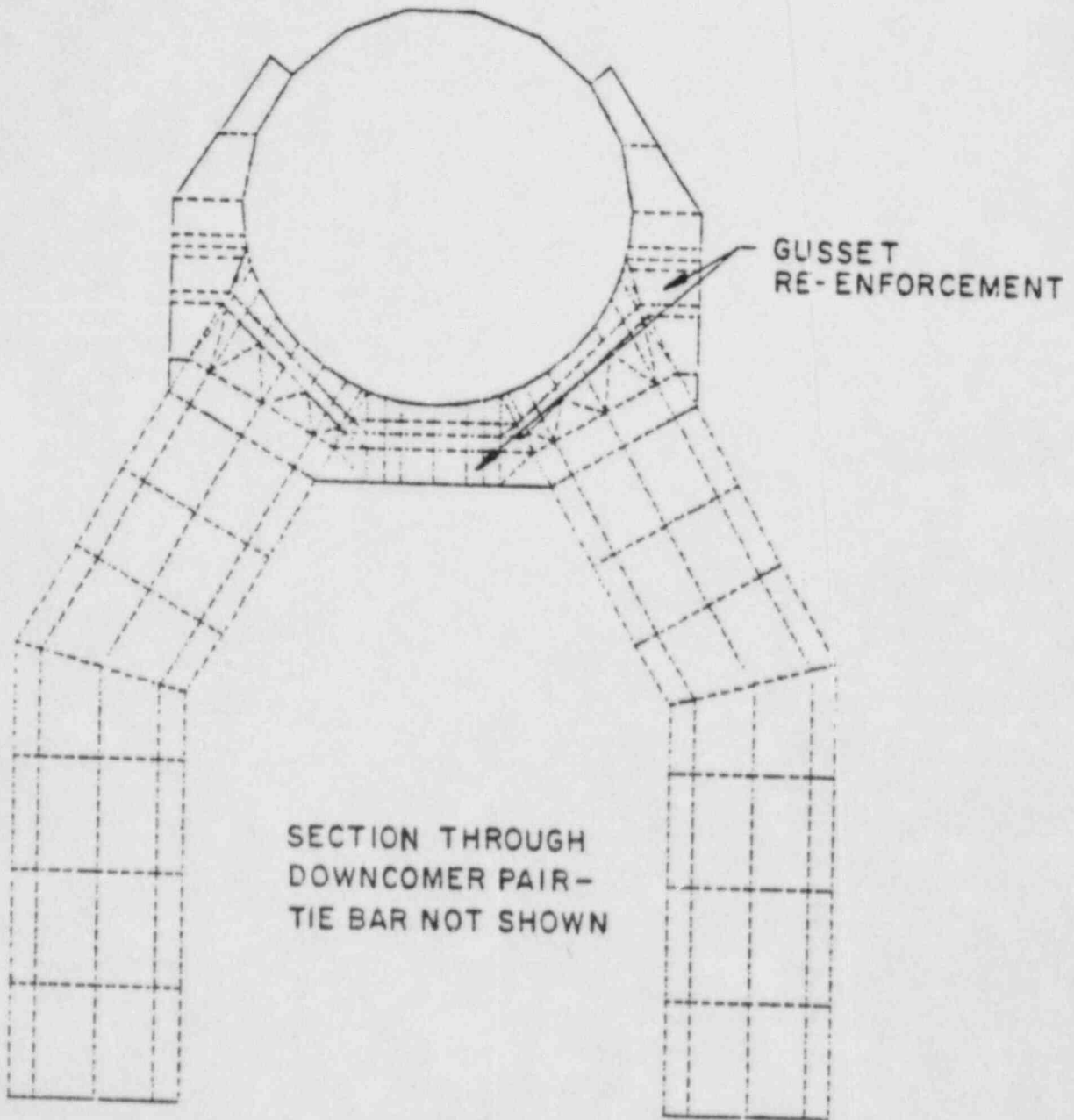
- Downcomer stresses due to CO loads were calculated by assuming structural resonance would occur and applying a dynamic amplification factor of 25 (2% damping) to static analysis.
- The above process produced stresses that were only 35% of CH stresses. CH stresses were conservatively used for all evaluations.
- A full dynamic analysis for CO downcomer loads was done for the unmodified downcomer. It showed a DLF = 15. After modification, the dynamic analysis was replaced by the conservative static equivalent, described above.

For the downcomer system:

- The eight/CO phasing combinations on various downcomer pairs were considered and bounded by the chugging load.



VENT HEADER MODEL



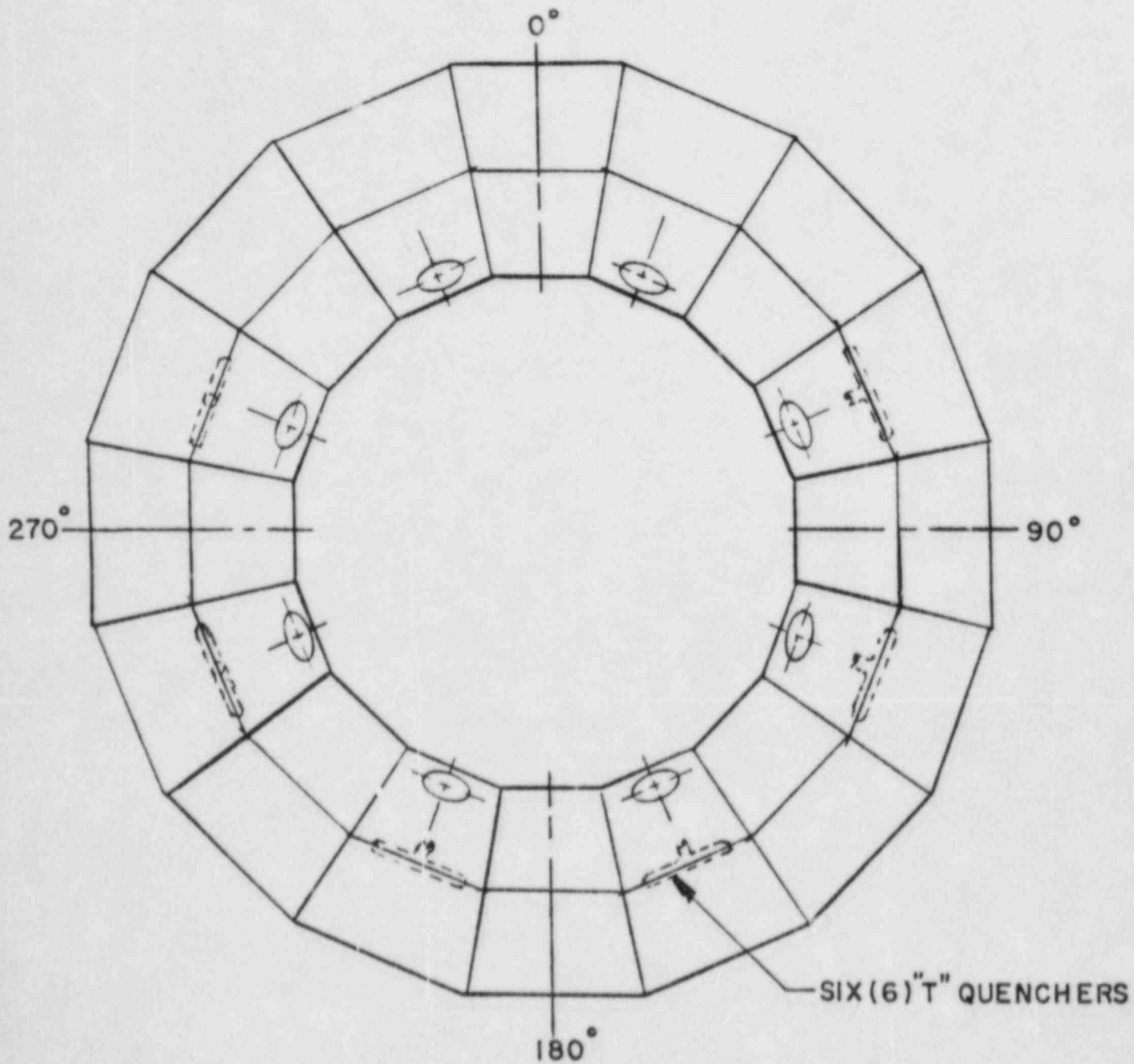
DETAILED VENT HEADER MODEL

ITEM 4: PUAR Sections 3.2.4, Appendix 1

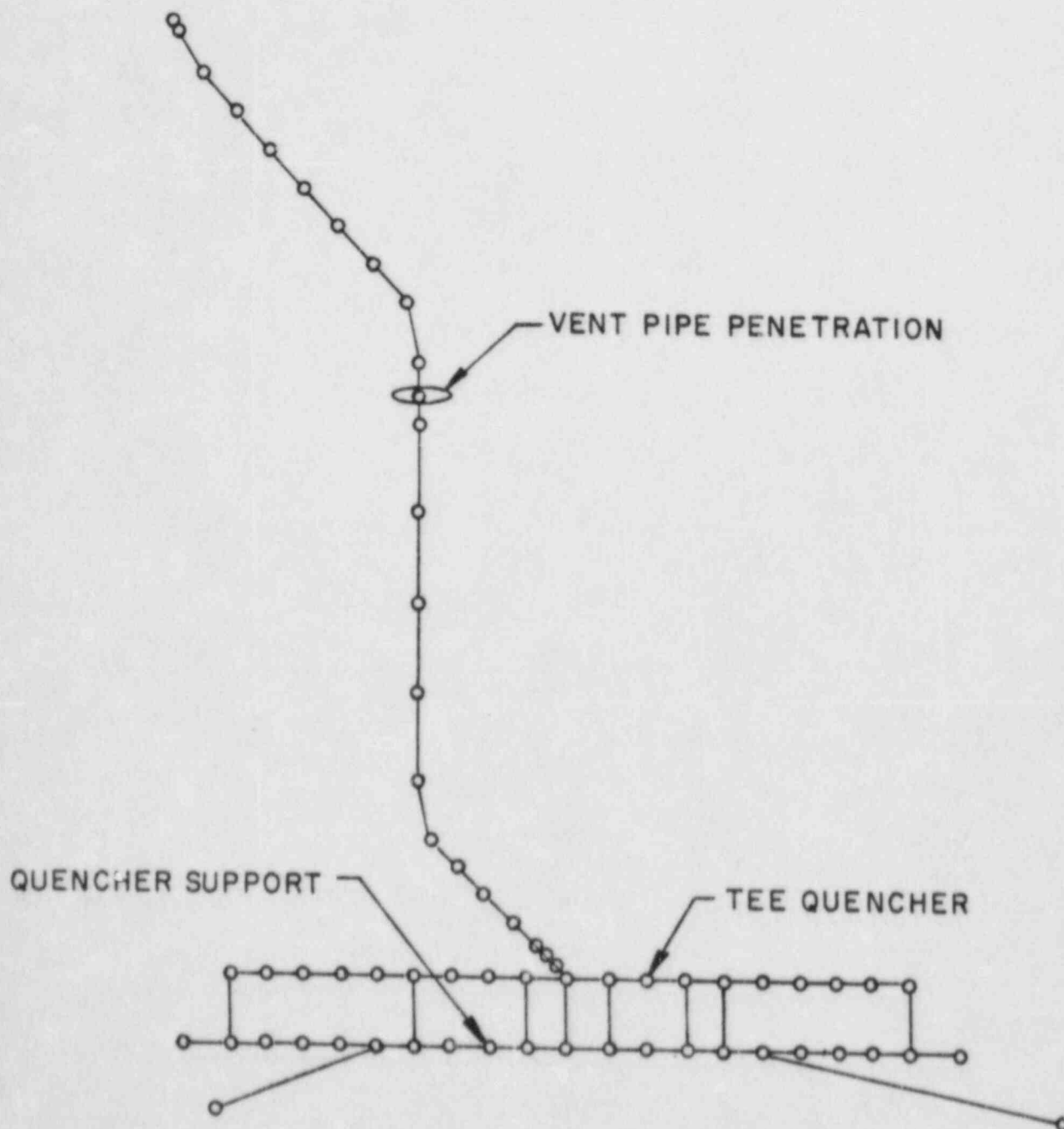
Provide the following additional information regarding the in-plant SRV tests conducted at Pilgrim and the SRV design loads extrapolated from the tests:

1.0 Description of the Tested Quencher Device

- 1.1 Drawings showing details of the quencher geometry -plan, elevation, arm length, arm diameter, hole arrangement, spacing, size, etc.
- 1.2 Location of quencher device relative to suppression pool boundaries and suppression pool surface.
- 1.3 Any difference between the tested quencher configuration and the Monticello version (as described in GE NEDE-24542-P) should be identified.
 - The Pilgrim T-quencher device is identical to the Monticello device (Standard GE Mark I Device).
 - Pilgrim entry angle is 20° compared to 30° for Monticello.
 - The vertical distance from the quencher to the water surface is 6.5' (at maximum submergence).
 - The quencher location from the bottom of the torus is 5'-0".
 - Plan view of torus with quencher locations is included.



"T"-QUENCHER LOCATIONS - PILGRIM



PILGRIM ANALYTIC MODEL

ITEM 4 (cont.)

2.0 A Description of the Loads Observed During Testing

2.1 Peak overpressure (POP) and underpressure (PUP) recorded on the torus shell during each relevant SRV actuation.

2.2 A measure of the frequency content of each pressure signature.

- Four tests completed at Pilgrim
- Frequencies obtained by scaling the second and third half-cycles of response.
- The two cycles represent the maximum positive and negative pressures.

<u>Test No.</u>	<u>Max. Press. (psi)</u>	<u>Min. Press. (psi)</u>	<u>Frequencies (Hz)</u>
1C	7.8	0.9	4.2, 7.1
2C	6.4	0.5	4.5, 7.1
3C	6.1	0.3	4.3, 7.3
4C	6.8	0.4	4.5, 7.1

ITEM 4 (cont.)

3.0 A Description of the Test Conditions

3.1 Geometry of the tested SRVDL (diameter, length, free volume, and routing below pool surface).

- The SRV test was performed on line D. For this line:

Diameter - 12.75" O.D., 12.00" ID and 12.75 O.D, 11.938 ID.

Quencher arm diameter - 12.75" O.D., 11.38" ID.

Length from SRV valve to top of quencher (12" above centerline of quencher arms) - 93.12 feet.

Air volume at test condition ($\Delta P = 1.6$ psi).
64.5 ft³

Routing below pool. See attached figure.

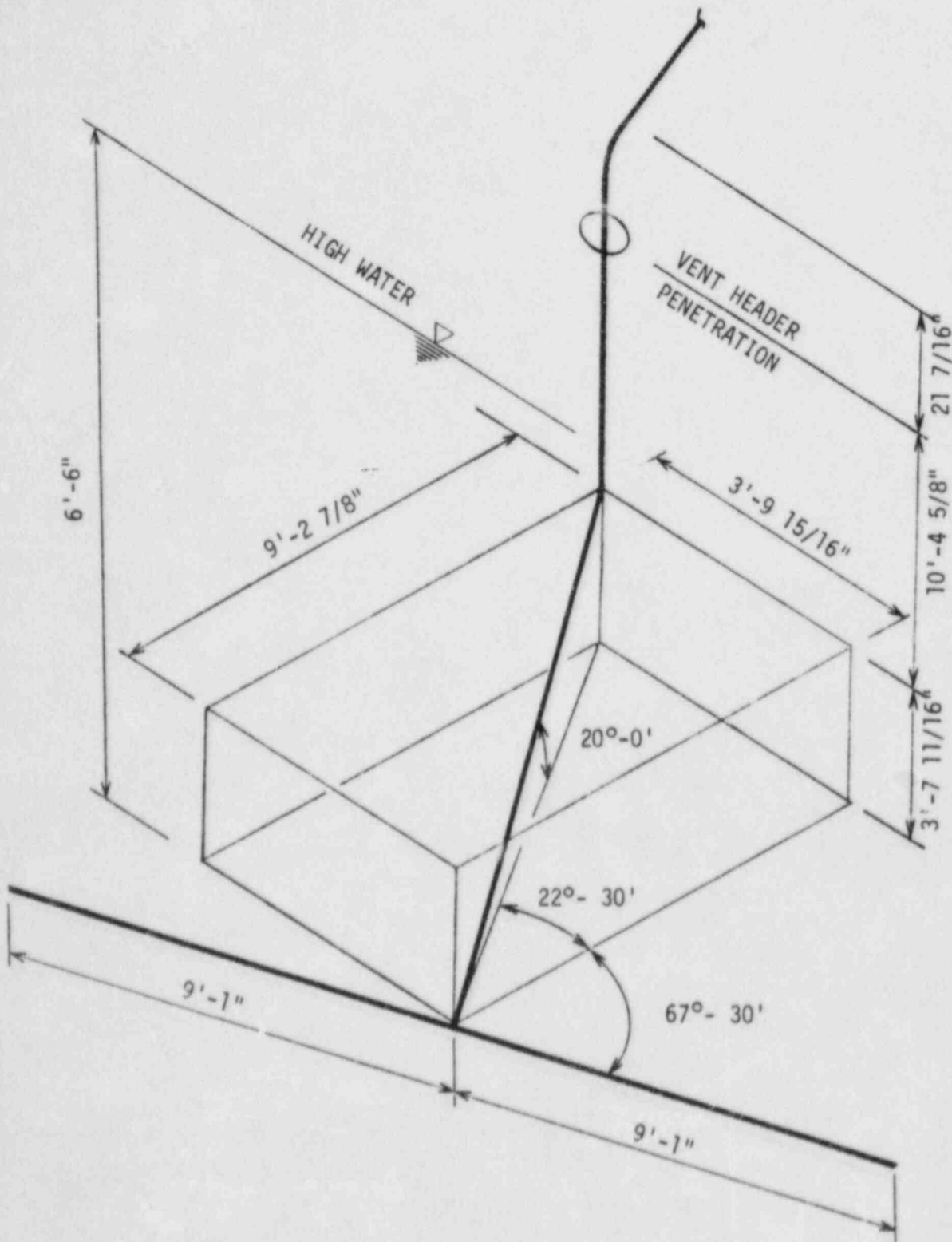
3.2 Geometry of any SRVDL's in the plant that differ significantly from the tested SRVDL.

- Diameters - all lines identical.

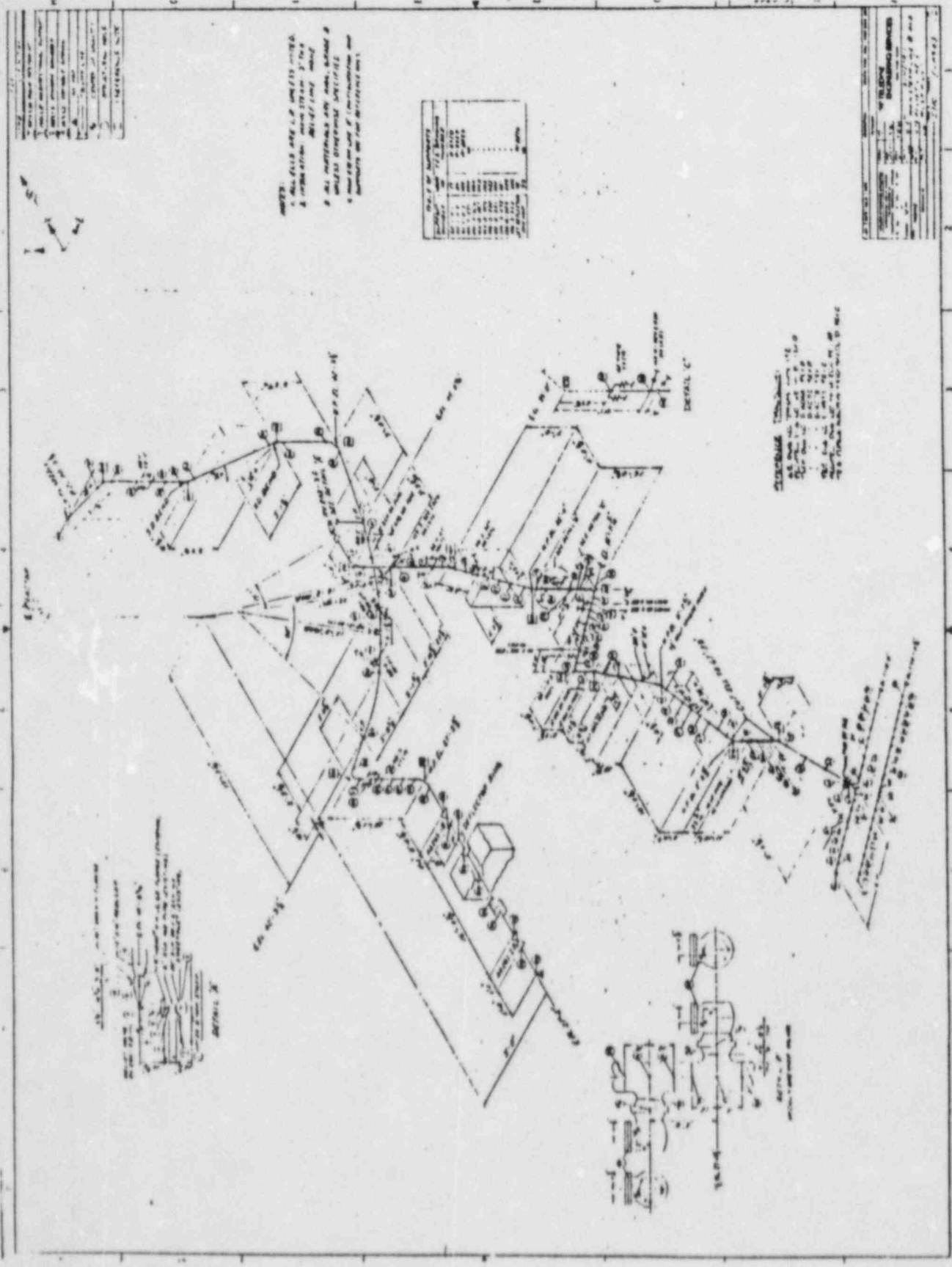
Lengths - vary from 88.06 to 93.12 feet.

4 lines at 88.06, 88.16, 93.06, 93.12.

Air Volumes - vary 60.31 ft³ to 64.77 ft³



TYPICAL PILGRIM SRV LINE ROUTING IN POOL



ITEM 4 (cont.)

3.3 SRV steam flow rate (MS), pool temperature (TPL), pipe temperature (TP), water leg length (LW) and pressure differential (ΔP), if any, for each test.

- Steam flow rates for the test were not recorded and, therefore, are not available. Steam pressure in the main steam line was recorded and ranges from 966.0 to 973.0 psi for the four tests.

Cold Tests

TPL	80 ⁰ F
TP ¹	115 ⁰ F
LW ²	10.18'
ΔP	1.56 psi

3.4 The water leg length for all SRVDL's corresponding to the previously provided minimum ΔP permitted by NRC technical staff.

- The water leg² inside the SRV line for minimum ΔP ($\Delta P = 1.2$)³ is: 11.97' for all lines (Case A1.1).

¹Plant Operating Conditions (in the drywell).

²This dimension is referenced to the centerline of the quencher arms.

³The effective minimum ΔP is 1.0 psi, since 0.2 psi is required to open the SRV vacuum breaker.

ITEM 4 (cont.)

4.0 A Description of the Design Conditions for Each Load Case Used for Design

4.1 Geometry of all SRVDL's involved and their azimuthal location in the torus.


4.2 Pipe temperature, pool temperature, steam flow rate, pressure differential and water leg length for all SRVDL's involved.

- Load Case A1.2 used to define SRV shell loads.
- Provides maximum shell pressure for line (SRVDL-C).
- The maximum pressure load frequency calculated for Case C3.2 for shortest line (SRVDL-B).
- Calculated frequencies increased by 40% per LDR.
- Higher frequencies produce maximum DLF.
- Combined A1.2/C3.2 case is bounding.

	<u>A1.2</u>	<u>C3.2</u>
Pool Temperature	123°F	123°F
Pipe Temperature	260°F	430°F
Steam Flow Rate	290 $\frac{\text{LB-M}}{\text{sec}}$	290 $\frac{\text{LB-M}}{\text{sec}}$
ΔP	1.9 psi	1.9 psi
Water Leg	8.36 ft	11.52 ft
Gas Volume	67.3 ft ³	63.65 ft ³

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 **TELEDYNE
ENGINEERING SERVICES**

ITEM 4 (cont.)

- Allowable multiplier on SRV test pressure to meet code allowable for shell stress is 2.63.

ITEM 4 (cont.)

5.0 A Description of the Design Loads for Each Load Case .

5.1 Normalized pressure signature.

5.2 Single valve POP/PUP values.

5.3 Spatial attenuation of the POP/PUP values (if this differs from the LDR methodology, sufficient additional torus shell pressure data must be supplied to justify such deviation).

5.4 Frequency range considered.

5.5 Procedure used to combine loads for multiple valves.

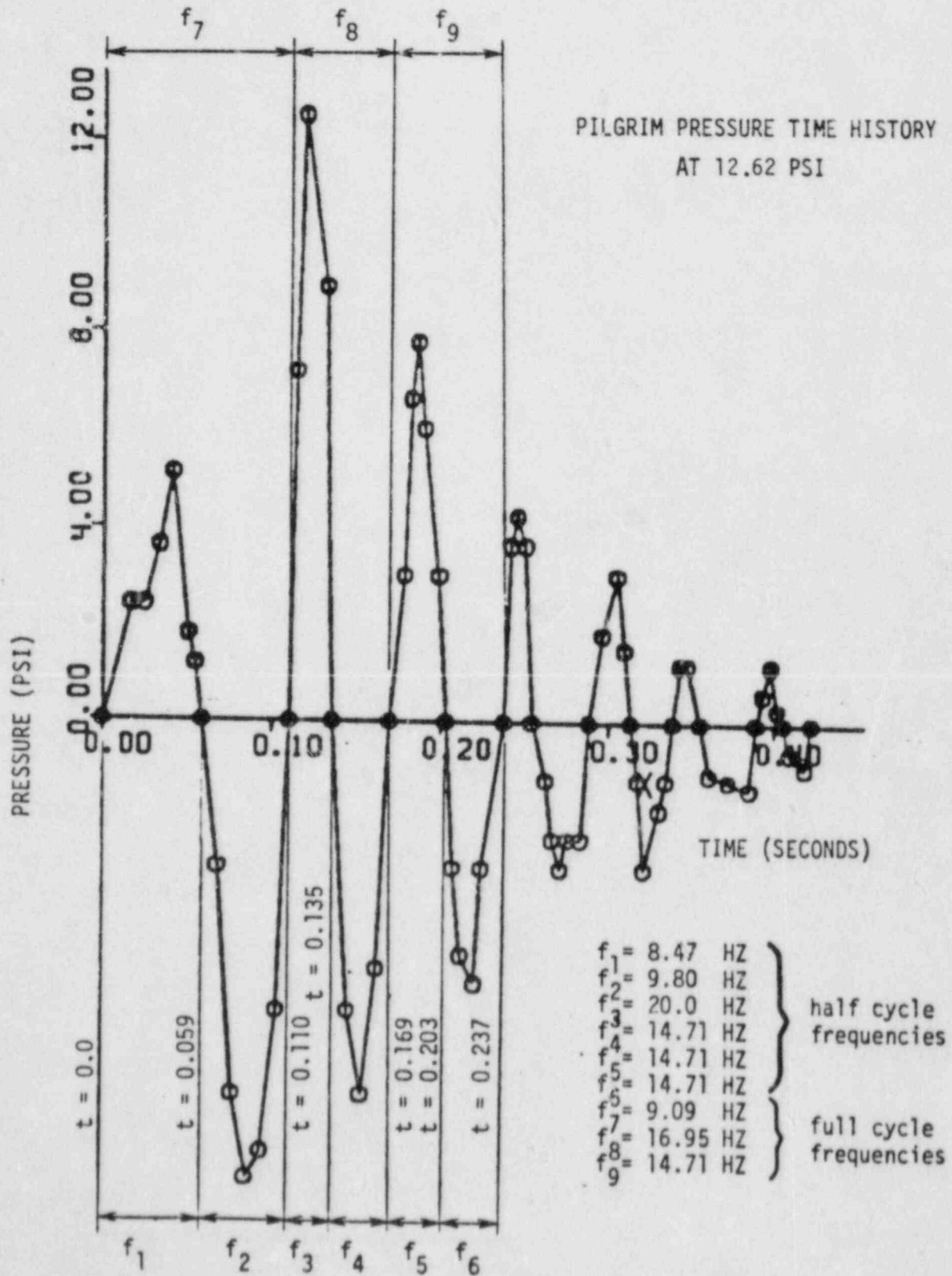
- Pressure profile used as input to shell analysis computer model included for mid-bay BDC.
- Pressure profile is based directly on test results.
- Pressure amplitude scaled to represent the worst case A1.2.
- Forcing function frequency is scaled to C3.2 frequency including 40% increase per LDR.

• Shell pressures used for analysis:

Maximum 12.62 psi

Minimum -9.62 psi

- A factor of 1.65 was used for analysis of multiple valve actuation load conditions per LDR.



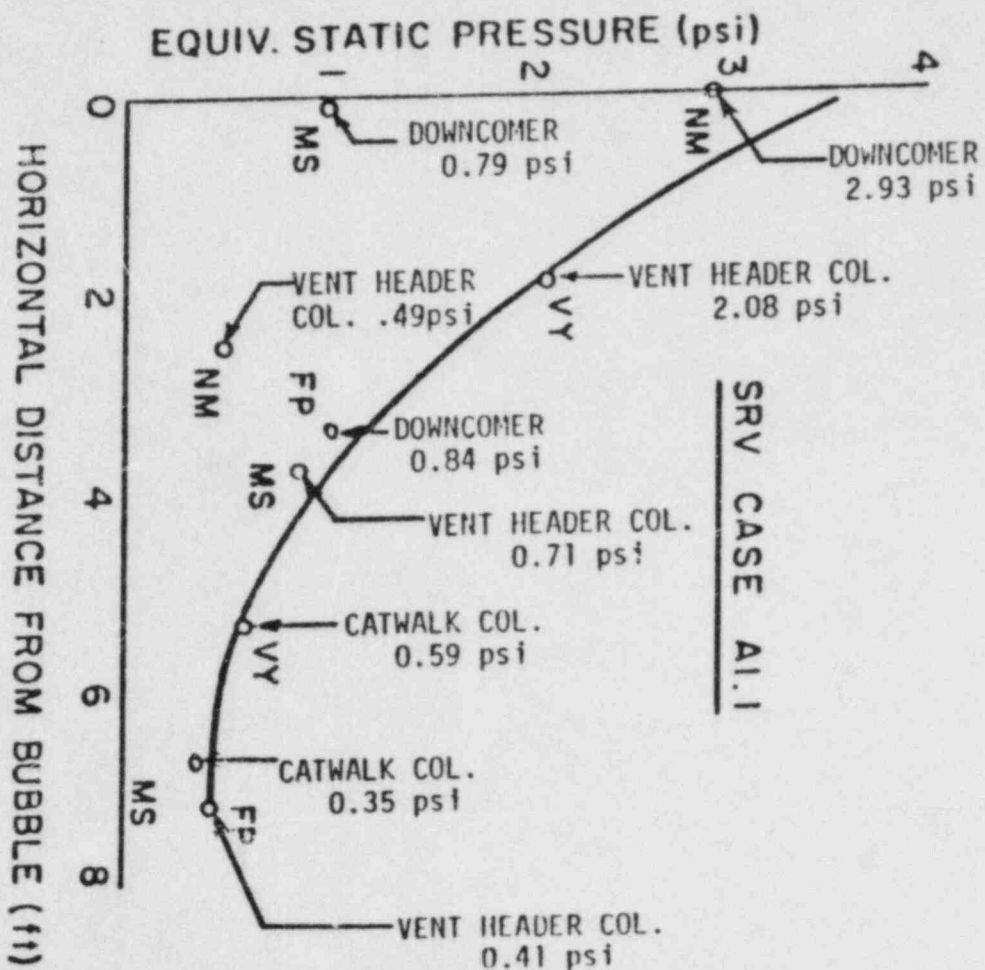
ITEM 5: PUAR Appendix 1

With regard to the Table on page A1-4 and Figure A1-7, justify the inclusion of data from Nine Mile Point which uses a quencher device radically different from the other three plants included in the data base.

Identify any structures for which SRV drag allowable margins are less than 3.0 and state what the margins are. In other words, list those structures which would be stressed beyond allowable limits if SRV drag loads were increased 3.0 times in Pilgrim and provide the margins for these structures.

- Inclusion of Nine Mile Point data in Figure A1-5 was done to illustrate the comparative results for the two devices. This data did not affect the resulting curve used in analysis.

- See attached table for safety margins.



EQUIVALENT SRV DRAG FROM IN PLANT TESTING

SUMMARY PILGRIM SRV BUBBLE DRAG MARGIN

Controlling Condition

<u>Item</u>	<u>Location</u>	<u>Type</u>	<u>Load Case</u>	<u>SRV Stress</u>	<u>Total Stress</u>	<u>Allowable Stress</u>	<u>SRV Drag Mult.</u>
Downcomers	Vent Header/DC Intersection	Bending	14	16547 psi	26729 psi	37635 psi	2.12
Downcomer Tie Bar	Clamp	Bending	25	1000 psi	16800 psi	22240 psi	6.44
Vent Header Support System	Pin	Bearing	25	293 psi	26453 psi	27000 psi	40.09
	Column	Comp. & Bending	25	.129 f/F	.565 f/F	1.0 f/F	4.37
Ring Girder	Flange	Memb. & Bending	25	889 psi	15027 psi	19300 psi	5.81
Ring Girder Weld	Column Region	Shear	15	.51 K/in	7.25 K/in	8.53 K/in	3.51
Catwalk	Platform Column	Bending	25	9955 psi	32937 psi	66912 psi	4.41

A4.8-23

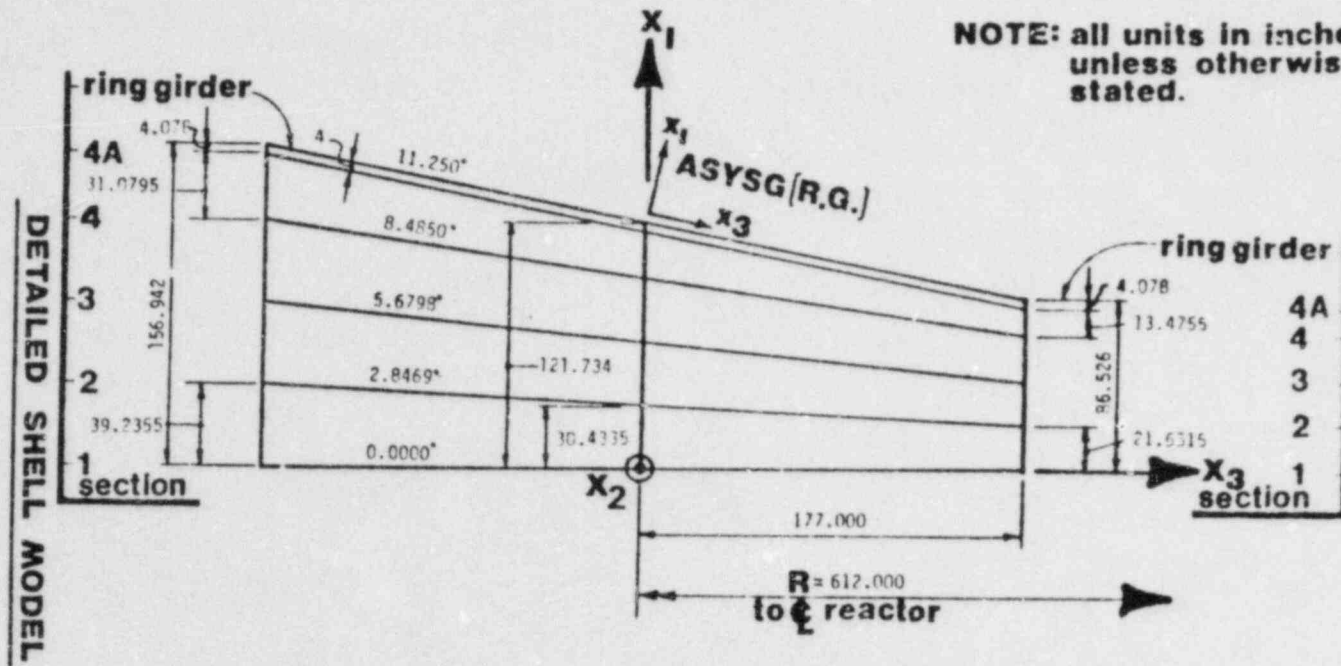
ITEM 6: PUAR Sction 2.2.1

The footnote on page 7 of the PUAR states that only four of the six SRV quenchers installed in Pilgrim are operative, with the other two not connected to steam relief lines. Is all the wetwell piping in place for the nonfunctioning quencher devices? How were multiple valve SRV loads computed for Pilgrim - based on four or on six quenchers?

- The wetwell piping for the nonfunctioning quencher devices is not in place.
- 1/32nd model used to analyze the torus and support structures.
- Symmetric boundary conditions on model mirrors SRV load as if applied in every bay.
- A 1.65 factor was used to simulate multiple actuations.
- Therefore, stresses in shell and supports are based on six quenchers.

1/32nd
TORUS MODEL WITH
SADDLE

NOTE: all units in inches
 unless otherwise
 stated.



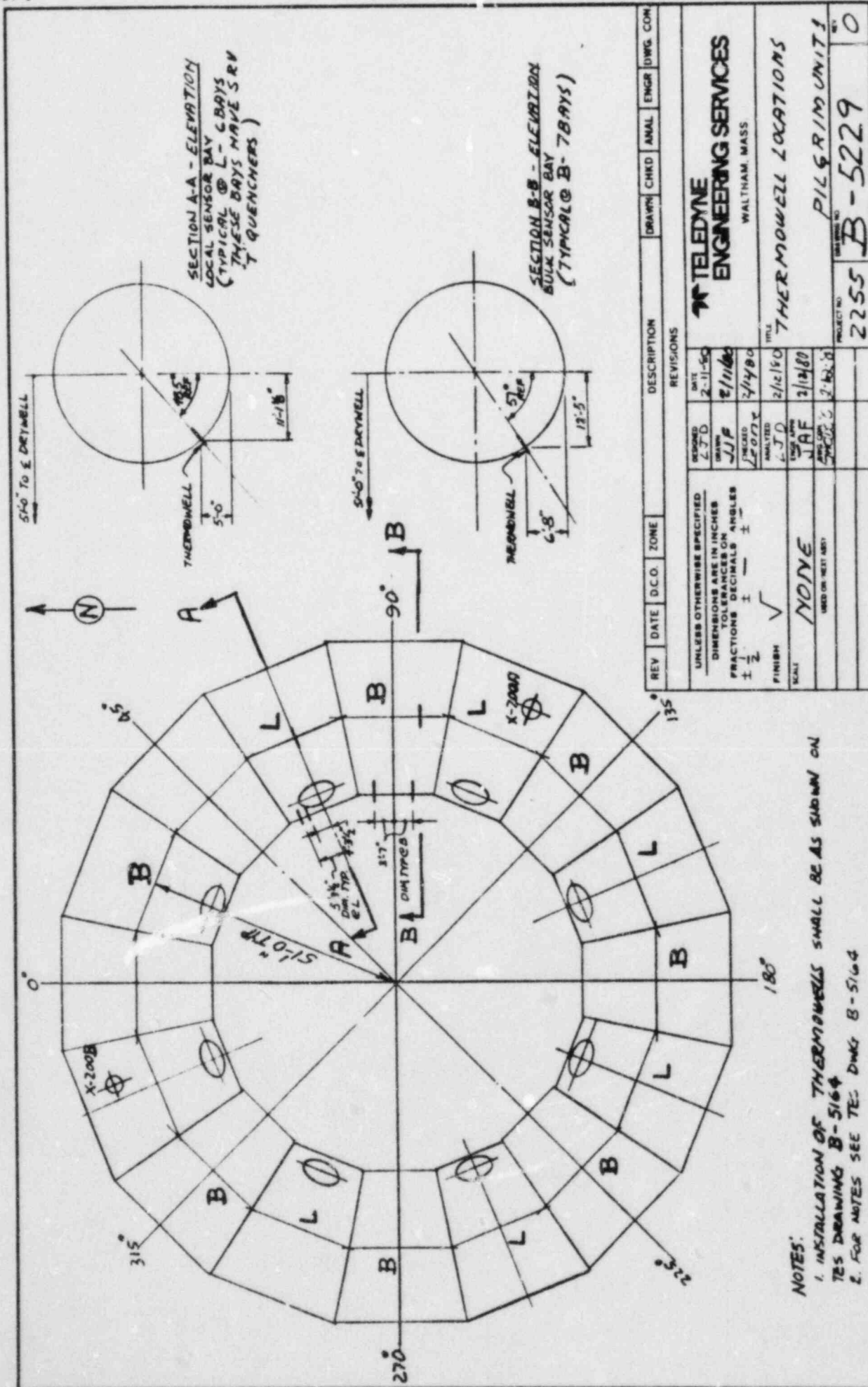
A4.8-25

PILGRIM NUCLEAR PLANT

ITEM 7: PUAR Sction 2.2.1

What is the vertical location of the pool temperature sensors with respect to the centerline of the T-quenchers?

- Sensor locations are shown on the following drawings.
- The centerline of the T-quenchers is 5'-0" from torus bottom.



SECTION A-A - ELEVATION
 LOCAL SENSOR BAY
 (TYPICAL @ L - 6 BAYS
 THESE BAYS HAVE S RV
 QUENCHERS)

SECTION B-B - ELEVATION
 BULK SENSOR BAY
 (TYPICAL @ B - 7 BAYS)

REV	DATE	D.C.O.	ZONE	DESCRIPTION	DRAWN	CHKD	ANAL	ENGR	DWG CON
2	11/80	JJP							
1	4/80	Forn							
1	12/70	LJD							
1	11/60	JJP							
1	2/60	JJP							

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES FRACTIONS DECIMALS $\pm \frac{1}{2}$ \pm \pm	DATE 2-11-80	REVISIONS
FINISH <input checked="" type="checkbox"/> NONE SCALE <input checked="" type="checkbox"/> NONE USED OR NOT USED	DESIGNED 2-7-80	DATE 2/11/80
	DRAWN JJP	DATE 2/11/80
	CHECKED Forn	DATE 2/11/80
	ANALYZED LJD	DATE 2/12/80
	APPROVED JJP	DATE 2/12/80
TITLE THERMOWELL LOCATIONS		
PROJECT NO 2255		
DRAWN BY B-5229		
UNIT PILEGRIM UNIT		
WALTHAM, MASS TELEDYNE ENGINEERING SERVICES		

NOTES:
 1. INSTALLATION OF THERMOWELLS SHALL BE AS SHOWN ON
 THIS DRAWING B-5164
 2. FOR NOTES SEE THE DWG B-5164