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May 7, 1984

United States Nuclear Regulatory Commission
Washington, DC 20555

ATTENTION: Mr. George W. Knighton, Chief
Licensing Branch 3
Office of Nuclear Reactor Regulation

SUBJECT: Beaver Valley Power Station - Unit No. 2
Docket No. 50-412
NRC - Mechanical Engineering Branch Audit

Gentlemen:

The Mechanical Engineering Branch Audit was held on April 3-5, 1984, at the offices of Stone & Webster Engineering Corporation in Boston, MA.

In this audit, our responses to your "Request for Additional Information" contained in your letter dated February 9, 1984, were discussed along with the associated draft SER open items and the majority were closed. In addition, design documentation was reviewed with you and your consultants. Finally, we presented the results of our oversized fittings study; and this item will be closed pending your receipt and review of a written report.

Enclosed is a documentation which summarizes our understanding of the results of this audit. Please inform us of any comments you have on this material. Upon your concurrance, the responses to the MEB questions will be incorporated in FSAR Amendment 7, presently scheduled for July 3, 1984.

DUQUESNE LIGHT COMPANY

By E. J. Woolever
E. J. Woolever
Vice President

SUBSCRIBED AND SWORN TO BEFORE ME THIS 7th DAY OF May, 1984.

Anita Elaine Reiter
Notary Public

ANITA ELAINE REITER, NOTARY PUBLIC
ROBINSON TOWNSHIP, ALLEGHENY COUNTY
MY COMMISSION EXPIRES OCTOBER 20, 1986

JJS/wjs
Enclosure

cc: Mr. M. Lacitra, Project Manager (w/enclosure)

B001
1/1

COMMONWEALTH OF PENNSYLVANIA)
) SS
COUNTY OF ALLEGHENY)

On this 7th day of May, 1984, before me, a Notary Public in and for said Commonwealth and County, personally appeared E. J. Woolever, who being duly sworn, deposed and said that (1) he is Vice President of Duquesne Light, (2) he is duly authorized to execute and file the foregoing Submittal on behalf of said Company, and (3) the statements set forth in the Submittal are true and correct to the best of his knowledge.

Anita Elaine Reiter
Notary Public

ANITA ELAINE REITER, NOTARY PUBLIC
ROBINSON TOWNSHIP, ALLEGHENY COUNTY
MY COMMISSION EXPIRES OCTOBER 20, 1986

NOTES OF CONFERENCE
NRC MECHANICAL EQUIPMENT BRANCH (MEB) AUDIT
BEAVER VALLEY POWER STATION - UNIT NO.2
DUQUESNE LIGHT COMPANY

Held in the Offices of
Stone & Webster Engineering Corporation
Boston, Massachusetts
April 3 - April 5, 1984

Participants: See Attachment A

PURPOSE

The NRC's Mechanical Equipment Branch Audit is a regularly scheduled activity in the safety review of an application for an Operating License. Major subjects addressed in this audit included:

i.) Duquesne Light Company's (DLC) proposed responses to the MEB's request for additional information, i.e., the 210 series of NRC Staff questions. These questions were transmitted to DLC in a letter from George W. Knighton to Earl J. Woolever dated February 9, 1984;

ii.) review of design documentation for BVPS-2; and

iii.) the generic influences of heavy wall pipe fittings.

The meeting agenda is provided as Attachment B.

DISCUSSION

i.) MEB Request for Additional Information

The NRC's letter of February 9, 1984 transmitted 38 questions numbered 210.4 through 210.41. A number of these questions are directly related to issues identified in the BVPS-2 Draft Safety Evaluation Report (SER) as Open Items. (A cross reference of SER Open Items and the related MEB questions is provided as Attachment C). Proposed responses to the 38 questions were presented to the MEB auditors and their consultants. Discussion of the responses resulted in 11 remaining as open items and two being classified as confirmatory issues. Four of the 11 open items do not require any further action by DLC at this time in that the NRC Staff indicated the need for further internal discussion and review of the response as provided. The status of each of the 38 questions is tabulated in Attachment D, and the proposed responses are provided in Attachment E.

ii.) Design Documentation Review

During the NRC MEB audit of BVPS-2 design specifications, the following specifications were discussed: Service Water Pump (2BVS-224), Motor-Operated Butterfly Valve (2BVS-76A), and Piping and Engineering Design Specification (2BVS-939).

The pump and valve specifications and their supporting documentation were presented and general questions were discussed with the NRC. The NRC asked that the following documents be transmitted to them for a detailed review:

Pump

1.) Service Water (SWS) Pump Specification 2BVS-224, Revision 3 and addenda up to and including Addendum No. 4.

2.) SWS Pump Seismic Analysis - SWEC File No. 2602.540-224-001C.

3.) SWS Pump Seismic Analysis Addendum No. 1 SWEC File No. 2602.540-224-036A

4.) SWS Pump Outline Drawings - 2002.540-224-0024
2002.540-224-003I

Valve

1.) Motor-Operated Butterfly Valve Specification 2BVS-76A, Revision 2 and Addendum No. 1

2.) Seismic Calculation for 2SWS*MOV107 SWEC File No. 2602.450-76A-111B

3.) Seismic Functional Test Procedure SWEC File No. 2606.450-76A-114F

For the Piping Design Specification, a description of the method of how system information is prepared and used in developing design conditions and performing pipe stress analyses was discussed with the NRC. The following documents were requested to be sent to the NRC for their detailed review:

Piping

1.) Piping Engineering and Design Specification 2BVS-939, Revision 3 and Addenda up to and including Addendum No. 5

2.) Shop Fabricated Piping Specification 2BVS-58, Revision 4

3.) Design and Fabrication of Piping Supports 2BVS-50, Revision 2 and Addenda up to and including Addendum No. 6

4.) SWEC Pipe Classes Specification 2BVS-939A, Revision 4 and Addendum No.1

5.) Field Fabrication and Erection of Piping Specification 2BVS-920, Revision 7 and Addenda up to and including Addemdum No. 5

6.) Procedure for Preparation of System Design Information Required for Pipe Stress Analysis - 2BVM-45, dated June 6, 1983

7.) Typical Power Piping Co. purchase order for materials

8.) Typical Power Piping Co. pipe spool documentation package

9.) Memo describing how maximum Design Condition are determined for Pipe Classes

10.) Stress Analysis Data Package for Steam Generator Blowdown System (BDG) SI-RM-100A, Rev. 1

11.) Flow Diagram RM-100A-13

12.) Piping Drawings, RP-99A-6D, RP-99D-5B, RP-99F-3F

13.) Pipe Stress Calculation NP(N) - X99K,Revision 2

Copies of all of the above noted documents will be provided to the NRC consultants under separate cover.

iii.) Heavy Wall Pipe Fittings

In a letter dated July 26, 1983, the Director of the Division of Project and Resident Programs, Region I USNRC requested that the Office of Nuclear Reactor Regulation (NRR) review and evaluate the significance of using heavier walled pipe fittings in safety-related systems at BVPS-2. On October 25, 1983, DLC provided the NRC with a study prepared by Stone & Webster Engineering Corporation (SWEC) which indicated that the piping analyses employed for BVPS-2 include sufficient conservatisms to offset any potential effects due to heavy fittings. In a letter dated January 27, 1984 from George W. Knighton of the NRC to Earl Woolever of DLC, the NRC staff indicated that the DLC study adequately demonstrated that the effect of heavy wall (or oversized) fittings on seismic loadings is insignificant. However, the staff requested additional analyses to address; (1) the impact of thermal expansion loads on equipment nozzles, and (2) the impact of the effect of oversized fittings on thermal expansion stresses for restraints and piping other than tees and elbows.

SWEC, acting as DLC's agent, performed the requested analyses and presented the results to the MEB auditors and their participating consulttants. Copies of the slides employed in this presentation are provided in Attachment F. The study again concluded that there is sufficient conservatism in the design analyses to offset any potential effects due to heavy fittings.

The NRC representative agreed with the above conclusion and indicated that they would consider this item closed pending their receipt and review of a written report documenting the presentation. This report is to include also the effects on stress levels in straight piping section when the stress intensification factor for a heavy elbow does not exceed 1.0.

It was agreed that submittal of this report should be attempted by June 30, 1984 but is secondary in priority to submittal of the final response to the MEB question concerning functional capability (Question 210.32). Therefore, the June 30 date is tentative and may be extended.

BVPS-2 AUDIT
NRC MECHANICAL ENGINEERING BRANCH
SWEC, BOSTON
APRIL 3-5, 1984

ATTENDANCE LIST

	NAME	ORGANIZATION	4/3	4/4	4/5
1.	D. Terao	NRC/MED	X	X	X
2.	H. L. Brammer	NRC/DE/MEB	X	X	X
3.	E. A. Licitra	NRC-DL-LB3		X	X
4.	E. Rodabaugh	Consultant/ORNL		X	X
5.	J. L. Alzheiman	PNL	X	X	
6.	S. E. Moore	NRC/ORNL		X	X
7.	M. Ley	NRC/DL		X	X
8.	E. F. Kurtz, Jr.	DLC/NCD	X	X	X
9.	J. Szy Slow Ski	DLC/NCD	X	X	X
10.	P. A. Cadena, Jr.	DLC/NCD	X	X	X
11.	C. L. Hill	DLC/NCD	X	X	
12.	W. V. Pfrommer	DLC/NCD	X	X	X
13.	K. A. Troxler	DLC/NCD	X	X	
14.	S. K. Mukherjee	DLC/NCD	X		
15.	G. L. Beatty	DLC/NCD	X	X	X
16.	J. Sutton	SWEC/Licensing	X	X	X
17.	J. Spizuoco	SWEC/EMD	X	X	
18.	F. Gharahl	SWEC/Licensing	X	X	
19.	R. A. Loranger	SWEC/EMD	X	X	X
20.	D. A. VanDuyne	SWEC/EMD	X	X	X
21.	R. Obadiah	SWEC	X		
22.	J. J. Elder	SWEC	X	X	
23.	N. P. Sacco	SWEC/EMD	X	X	
24.	N. A. Gocostein	SWEC	X		
25.	J. P. Camobreco	SWEC	X	X	
26.	K. L. Polk	SWEC/EMD	X		X
27.	R. F. Hankinson	SWEC/EMD	X		X
28.	R. J. Spahl	SWEC/EMD	X		
29.	R. S. Benson	SWEC		X	
30.	G. H. East	SWEC	X	X	
31.	P. RaySircar	SWEC		X	
32.	A. L. VanSickle	SWEC/EMD			X
33.	C. O. Richardson	SWEC			X
34.	P. J. Quinlan	NUSCO/EMD			X
35.	J. L. Majewski	Northeast Utilities			X
36.	S. L. Stamin	SWEC			X
37.	W. F. Emerson	SWEC			X
38.	C. W. Lin	Westinghouse	X	X	
39.	R. Orr	Westinghouse	X	X	
40.	F. Scapellato	Westinghouse	X	X	
41.	A. M. Sicari	Westinghouse	X		
42.	S. D. Phillips	Westinghouse/Licensing	X	X	X
43.	J. McInerney	Westinghouse	X	X	

Attachment B

MEB AUDIT AGENDA

Tuesday 4/3/84	8:00 a.m.	Introductions
	8:30 a.m. - 5:00 p.m.	Question 210.9 through 210.41; 210.4 - 210.8 and SER Open Items
Wednesday 4/4/84	8:00 a.m. - 12:00 noon	Completion of 210 questions and SER Open Items
	1:00 p.m. - 5:00 p.m.	Design Documentation Review
Thursday 4/5/84	8:00 a.m. - noon	Completion of Design Documentation Review
	1:00 p.m. - 5:00 p.m.	Presenation and discussion of Oversized Fittings

Attachment C

BVPS-2 DRAFT SER OPEN ITEM NUMBER	MEB QUESTION
24	210.6
25	210.4
26	210.12
27	210.5
28	210.10
29	210.13
30	210.14
31	210.16, 210.9
32	210.18
33	210.23
34	210.21
35	210.22
36	210.27
37	210.29
38	210.25
39	210.32
40	210.31
41	210.33
42	210.34
43	210.41

STATUS OF NRC MEB QUESTIONS

210.4: Closed.

210.5: Confirmation required. Partial response provided; schedule for submittal of balance of requested information provided in proposed response (Attachment E).

210.6: Closed.

210.7: Closed.

210.8: Closed.

210.9: Confirmation required. Partial response provided; schedule for submittal of balance or requested information provided in proposed response (Attachemnt E).

210.10: Open. The question asks for a discussion regarding pipe-to-pipe impact. This issue has been addressed in the proposed response. In the audit, the question of the effects of jet impingement arose. This issue is addressed in Question 210.12.

210.11: Closed.

210.12: Open. Schedule for requested information provided in proposed response (Attachment E). The acceptance criteria for jet impinged targets will be summarized. Jet impingement loads will be incorporated into the load combination tables.

210.13: Closed.

210.14: Closed.

210.15: Closed.

210.16: Closed.

210.17: Closed.

210.18: Closed.

210.19: Closed.

210.20: Closed.

210.21: Closed. Acceptable stress levels for steady state vibrations have been included in the response.

210.22: Closed.

210.23: Closed.

210.24: Closed.

210.25: Closed.

210.26: Closed.

210.27: Open. NRC indicated need to review the proposed response. No further DLC action required at this time.

210.28: Open. NRC indicated need to review the proposed response. No further DLC action required at this time.

210.29: Closed.

210.30: Closed.

210.31: Open. Schedule for requested information provided in proposed response (Attachment E).

210.32: Open. Proposed response is provided in Attachment E. A study will be prepared to determine if the pipe stress analysis procedures used by SWEC on BVPS-2 inherently provide sufficient design margin to ensure performance of required safety functions under all plant conditions. The results of this study will be submitted to the NRC on June 30, 1984.

210.33: Closed.

210.34: Open. NRC indicated need to review the proposed response. No further DLC action required at this time. The buckling criteria employed by Westinghouse for linear type auxiliary equipment supports has been clarified in the response.

210.35: Closed.

210.36: Closed.

210.37: Open. Schedule for submittal of requested informatio is provided in proposed response (Attachment E).

210.38: Closed.

210.39: Open. NRC indicated need to review the proposed response. No further DLC action required at this time.

210.40: Open. Schedule for submittal of requested information is provided in proposed response (Attachment E).

210.41: Open. Schedule for submittal of requested information is provided in proposed response (Attachment E). An earlier submittal will be attempted.

Proposed Responses to NRC Mechanical Equipment Branch Questions

NRC Letter: February 9, 1984

Question 210.4 (Section 3.6.2)

BTP MEB 3-1 requires that if two intermediate break locations are not determined by applying the criteria of B.1.C.(1).(b) and (c) the two highest stress locations based upon Eq. (10) should be used. FSAR Section 3.6B.2.1.1.1.C states that the selection will be based on the highest cumulative usage factor or stress intensity range. Provide justification for the use of cumulative usage factor in this instance.

Response:

The words "cumulative usage factor" have been deleted from Section 3.6B.2.1.1.1.2.c, Amendment 7, of the FSAR in compliance with SRP 3.6.2.

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3.6B.2.1.1.1 Break Locations - ASME Section III Class 1 Piping

Breaks in high-energy ASME Section III, Code Class 1 piping are postulated to occur at the following locations in each piping run or branch run:

1. At terminal ends of the pressurized portions of the runs.

   (Terminal ends are extremities of piping runs that connect to structures, components (for example, vessels, pumps), or pipe anchors. A branch connection to a main piping run is a terminal end of the branch run. However, if the branch is included in the structural model with the main run and if the branch has a significant influence on the behavior of the main run (that is, similar piping sizes), the branch is considered part of the main run.

2. At intermediate location between terminal ends selected by the following criteria:

   a. At any intermediate location between terminal ends where the maximum stress intensity range, for normal and upset plant conditions and for an operating basis earthquake (OBE) event transient, exceeds 2.4S , calculated by Equation 10 and by either Equation 12 or Equation 13 in Paragraph NB-3653 of the ASME Code, Section III.

      (S_m is the design stress intensity as specified in Section III of the ASME Boiler and Pressure Vessel Code).

   b. At any intermediate locations between terminal ends where the cumulative usage factor U, derived from the piping fatigue analysis under the loadings associated with OBE and operational plant conditions, exceeds 0.1.

      (U is the cumulative usage factor as specified in Section III of the ASME Boiler and Pressure Vessel Code).

   c. When fewer than two breaks are required to be postulated by application of the preceding stress and usage factor criteria (items a and b), at least two breaks are postulated at separate locations selected on the basis of highest cumulative usage factor or stress intensity range. These breaks are separated from each other by a change in direction of the piping run and are not located on the same fitting.

      , AS CALCULATED BY EQUATION 10 IN PARAGRAPH NB-3653 OF ASME CODE SECTION III.

NRC Letter: February 9, 1984

Question 210.5 (Section 3.6.2)

The criteria in the FSAR for designating the break exclusion zones on piping in the containment penetration areas require further justification. Additional information is required for our evaluation regarding the extended boundaries of the break exclusion zones. Provide drawing and/or other information quantifying the lengths of pipe for all systems defined by criteria of Section 3.6B.2.1.2.1.2.b and c.

Response:

There is no piping break exclusion zone defined by the criteria of Section 3.6b.2.1.2.1.2.c.

The piping defined by the Criteria of Section 3.6B.2.1.2.1.2.b and the lengths of pipe are provided in Table 210.5-1 and shown for the feedwater and main steam systems on Figures 3.6B-13a and 3.6B-14a respectively. For those lengths of piping identified as not available, the information, including figures, is scheduled to be provided by March, 1985. (Also refer to Question 210.9.)

TABLE 210.5-1

LENGTHS OF BREAK EXCLUSION ZONE
IN MAIN STEAM SYSTEM (MSS) AND
FEEDWATER SYSTEM (FWS)

Point A (From)	Point B (To)	Length Between Points A & B
MSS Isolation Vlv. (2MSS*HYV101A)	Break Exclusion Zone (BEZ) Boundary in 32" MSS Piping	10'-3"
MSS Isolation Vlv. (2MSS*HYV101B)	BEZ Boundary in 32" MSS Piping	10'-2"
MSS Isolation Vlv. (2MSS*HYV101C)	BEZ Boundary in 32" MSS Piping	10'-3"
Steam Drains System (SDS) Isol'n Vlv. (2SDS*AOV111A2)	BEZ Boundary in SDS Ppg.	Later
SDS Isol'n Vlv. (2SDS*AOV111B2)	BEZ Boundary in SDS Ppg.	Later
SDS Isol'n Vlv. (2SDS*AOV111C2)	BEZ Boundary in SDS Ppg.	Later
SDS Isol'n Vlv. (2SDS*AOV111A2)	BEZ Boundary in GNS Ppg.	Later
SDS Isol'n Vlv. (2SDS*AOV111B2)	BEZ Boundary in GNS Ppg.	Later
SDS Isol'n Vlv. (2SDS*AOV111C2)	BEZ Boundary in GNS Ppg.	Later
MSS Warm Up Line Isol'n Vlv. (2MSS*AOV102A)	BEZ Boundary in 32" MSS Piping	Later
MSS Warm Up Line Isol'n Vlv. (2MSS*AOV102B)	BEZ Boundary in 32" MSS Piping	Later
MSS Warm Up Line Isol'n Vlv. (2MSS*AOV102C)	BEZ Boundary in 32" MSS Piping	Later
FWS Isol'n Vlv. (2FNS*HVY157A)	BEZ Boundary in 16" FWS Piping	31'-10"
FWS Isol'n Vlv. (2FNS*HVY157B)	BEZ Boundary in 16" FWS Piping	31'-10"
FWS Isol'n Vlv. (2FNS*HVY157C)	BEZ Boundary in 16" FWS Piping	31'-10"

NRC Letter: February 9, 1984

Question 210.6 (Section 3.6.2)

SRP 3.6.2 requires the postulation of through-wall leakage cracks in moderate energy lines both inside and outside of containment. In FSAR Section 3.6.1.1.2 through-wall leakage cracks in moderate energy systems located outside containment are discussed. Discuss how through-wa.l leakage cracks in moderate energy systems located inside containment are considered.

Response:

Containment environmental zones (pressure, temperature, humidity) are defined by high energy line breaks which envelope moderate energy crack environmental effects. Worst case internal containment flood effects are based on the maximum water volumes from the RWST, reactor coolant system, and CAT being sprayed and/or injected into the containment post-LOCA. This volume of water and resulting flood level also envelopes any effects due to moderate energy leakage cracks.

NRC Letter: February 9, 1984

Question 210.7 (Section 3.6.2)

Discuss how high energy leakage cracks were considered.

Response:

High energy line cracks are not postulated; however, high energy breaks are postulated in accordance with BTP MEB 3-1. Building environmental zones are defined by high energy line breaks, which also envelope high energy crack environmental effects. These environments are identified for all areas containing safety-related equipment and are used in the environmental qualification program described in Section 3.11. Information concerning the consideration of environmental effects of postulated piping failures is provided in Section 3.6B.1.3.2.4.

NRC Letter: February 9, 1984

Question 210.8 (Section 3.6.2)

No discussion could be found in the FSAR regarding design stress limits for Class 1 piping in the break exclusion zone. If there are any Class 1 lines in the break exclusion zone, provide the required desi · limits.

Response:

There are no Class 1 lines in the break exclusion zones.

NRC Letter: February 9, 1984

Question 210.9 (Section 3.6.2)

In order to assure the pipe break criteria have been properly implemented, the SRP requires the review of sketches showing the postulated rupture locations and of summaries of the data developed to select postulated break locations including, for each point: the calculated stress intensity, the calculated cumulative usage factor, and the calculated primary plus secondary stress range. Sketches showing break locations for only a limited number of lines could be found in the FSAR. No tables containing the above data could be found in the FSAR. Provide this information for our review.

Response:

Amendment 3 provided the appropriate technical information for the following lines:

1. Feedwater lines inside containment (Figure 3.6B-12a, 12b, 12c)

2. Feedwater lines outside containment (Figure 3.6B-13a, 13b) and

3. Main steam lines outside containment (Figure 3.6B-14a, 14b).

Information for the remainder of the high energy lines will be submitted as shown on the following schedule:

1. Containment building, March 1985.
2. Main steam valve house and cable vault building, March 1985.
3. Auxiliary building, April 1985.
4. Service building, May 1985.
5. Pipe tunnel, July 1985.

The submittals of data for all high energy lines are scheduled to be completed by July 1985.

NRC Letter: February 9, 1984

Question 210.10 (Section 3.6.2)

No discussion could be found regarding pipe-to-pipe impact. Have the criteria from SRP 3.6.2 regarding pipe-to-pipe impact been used? If so, include a discussion in the FSAR.

Response:

Refer to revised Section 3.6B.1.3.2.3, Amendment 4, which provides a discussion on pipe-to-pipe impacts.

Jet impingement is addressed in Question 210.12.

NRC Letter: February 9, 1984

Question 210.11 (Section 3.6B.2.3.4)

In FSAR Section 3.6B.2.3.4 a shape factor for reducing the jet impingement load is discussed. Provide justification for the use of a shape factor.

Response:

Shape factors, as defined in Appendix D of ANSI/ANS 58.2-1980, "Design Basis for Protection of Light Water Nuclear Power Plants Against Effects of Postulated Pipe Ruptures," are used in the calculation of the jet force acting on a target.

NRC Letter: February 9, 1984

Question 210.12

Tables concerning jet impingement effects could not be found. Provide these tables.

Response:

The required information concerning jet impingement effects will be provided with the assessment of other jet impingement effects for all high energy systems where breaks are postulated, which is scheduled to be submitted by July 1985.

The submittal dates for the various buildings are the same as those provided in the response to Question 210.9, Amendment 7.

The tables for jet impingement effects will be integrated with those for pipe whip effects (refer to Question 210.9) and the table format will be included in Amendment 7 of the FSAR.

NRC Letter: February 9, 1984

Question 210.13

Have limited area circumferential or longitudinal break areas been considered? If so, provide a list of limited break area locations and justify their use.

Response:

No limited area longitudinal breaks have been considered. Limited area circumferential breaks have been considered only for the reactor coolant system primary coolant piping. Limited area breaks at these locations are assured by use of rigid bumpers and the stiffness of the primary coolant system/supports as described in Section 5.4.14. Use of limited area breaks minimizes cubicle pressurization effects and nozzle loads subsequent to very low probability primary coolant system pipe breaks. Section 5.4.14 and Figure 5.4-25 provide break locations on primary coolant piping. All primary loop breaks except numbers 7, 9, 10, and 11 are limited area breaks. Restraints on other piping systems may effectively limit break area, but no credit has been taken for reduced effects.

NRC Letter: February 9, 1984

Question 210.14

It is the staff's position that jet expansion is not acceptable when used to evaluate jet impingement forces due to saturated water or subcooled water blowdown. If jet expansion has been used for these instances, justify its use.

Response:

Refer to revised Section 3.6B.2.3, Amendment 7.

CN 509

any target is calculated assuming the jet force is constant in any plane normal to the jet stream and assuming that the jet stream diverges conically at a solid angle of 20 degrees. However, for those cases where the 20-degree divergence assumption is shown to be unnecessarily conservative for the blowdown of steam or steam-water mixtures, Moody's (1973) asymptotic jet expansion model is adopted.

INSERT A →

4. The proportion of the total jet force acting on the target is determined from the fraction of the jet intercepted and by the shape factor of the target. For a target with its flat surface area normal to the center of the jet stream, the impingement load is the product of the pressure and the intercepted jet area. For those cases where the target area is such that the intercepted jet stream is deflected rather than totally stopped, a shape factor which is less than unity and which is a function of the target geometry is used in calculating the total jet impingement load.

Since the jet impingement force is a dynamically applied load, the target will be analyzed either by static methods using an appropriate dynamic load factor, or dynamically using elastic or inelastic structural response codes (Appendix 3A). The load combinations and design allowables are given in Sections 3.8.3 and 3.9.

3.6B.2.3.1 Pipe Rupture Restraints

Two basic restraint types are used: elastic and energy-absorbing. The elastic restraints are generally used where displacements subsequent to a postulated pipe rupture must be minimized to either restrict the break opening area or limit loads in the broken piping run. Energy-absorbing restraints are used where the primary objective is to dissipate the energy of a ruptured pipe.

3.6B.2.3.1.1 Elastic Restraints

Since elastic restraints are used to minimize displacements of the broken pipe, they are close-gapped. For some applications, this requires that they contact the pipe during conditions other than a postulated rupture, in which case they are designed as a pipe support in accordance with the applicable code (Section 3.9.3). If an elastic restraint will only contact the pipe following a rupture, it is designed according to the criteria for structural steel (Section 3.8.3).

3.6B.2.3.1.2 Energy-Absorbing Restraints

Several approaches are used for energy absorption in pipe rupture restraints. In tension, stainless steel studs or straps are used, with a design limit of 50 percent of uniform ultimate strain. In compression, honeycomb panels or pipe sections are used. Compressive

Insert A

for steam or water-steam mixtures. Jet expansion is not used for cases involving saturated water or subcooled water blowdown that are below the saturation temperature of the corresponding ambient pressure beyond the break (Moody 1969).

Whipping in bending of a broken stainless steel pipe section such as used in the RCS does not cause this section to become a missile. This design basis has been demonstrated by Westinghouse Nuclear Energy Systems bending tests on large and small diameter, heavy and thin walled stainless steel pipes.

3.6N.2.3.4 Pipe Restraints and Locations

Refer to Section 3.6B.2.5.

3.6N.2.3.5 Design Loading Combinations

Refer to Section 3.6B.2.3.

3.6N.2.4 Guard Pipe Assembly Design Criteria

Refer to Section 3.6B.2.4.

3.6N.2.5 Material to be Submitted at the Operating License Review

Refer to Section 3.6B.2.5.

3.6.3 References for Section 3.6

Bordelon, F.M. 1971. A Comprehensive Space-Time Dependent Analysis of Loss of Coolant (SATAN-IV Digital Code). WCAP-7263, (Proprietary) and WCAP-7750, (Non-Proprietary).

De Haller, P. 1945. The Application of Graphical Method to Some Dynamic Problems in Gases. Sulzer Technical Review No. 1, p 6-24.

Fauske, H.K. 1962. Contribution to the Theory of Two Phase, One-Component Critical Flow, ANL-6633, Argone National Laboratory.

Gerber T.L. 1974. Plastic Deformation of Piping Due to Pipe Whip Loading. ASME Paper 74-NE-1.

Hartree, D.R. 1952. Some Practical Methods of Using Characteristics in the Calculation of Non-Steady Compressible Flow. Los Alamos Report LA-HU-1.

Henry, R.E. and Fauske, H.K. 1971. Two Phase Critical Flow of One-Component Mixtures in Nozzles, Orifices, and Short Tubes. Journal of Heat Transfer, ASME.

Jonssen, V.K.; Matthews, L.; and Spalding, D.B. 1973. Numerical Solution Procedure for Calculating the Unsteady, One-Dimensional Flow of Compressible Fluid with Allowance for the Effect of Heat Transfer and Friction. ASME Paper 73-FE-30.

Moody, J.F. 1969. Prediction of Blowdown Thrust and Jet Forces. ASME Paper 69-HT-31.

Moody, J.F. 1973. Time Dependent Pipe Forces Caused by Blowdown and Flow Stoppage. ASME Paper 73-FE-23.

NRC Letter: February 29, 1984

Question 210.15

Provide the loads, load combinations, and stress limits that were used in the design of pipe rupture restraints. Include a discussion of the design methods applicable to the auxiliary steel used to support the pipe rupture restraint. Provide assurance that the pipe rupture restraint and supporting structure cannot fail during a seismic event.

Response:

The auxiliary steel consists of the steel connecting a pipe rupture restraint to building structural steel or building embedments. The auxiliary steel and the elastic components of pipe rupture restraints are designed to the load combinations and stress limits specified for steel structures in Sections 3.8.3 and 3.8.4, as applicable. Energy absorbing components are designed to the strain limits specified in Section 3.6B.2.2.1 rather than limits on stress.

Seismic loads are considered in the design of the pipe rupture restraints and the auxiliary steel. The auxiliary steel is typically seismically rigid and the seismic effects are small compared to pipe rupture effects. Rupture loads for auxiliary steel are factored by an appropriate dynamic load factor, or this steel is included in the dynamic analysis of the restrained system.

Application of the above procedures assure that the rupture restraint and supporting structure cannot fail during a seismic event.

NRC Letter: February 9, 1984

Question 210.16

Provide the design criteria used for pipe rupture restraints that also support piping.

Response:

The criteria for dual purpose restraints are as follows:

1. For the pipe support function, the restraint is designed to the loading conditions and stress allowables as indicated in the response to Question 210.34.

2. For the pipe rupture function, the restraint is designed in accordance with AISC 7th Edition, as amended by Sections 3.8.3 and 3.8.4.

NRC Letter: February 9, 1984

Question 210.17

Is there any unrestrained whipping pipe inside containment? If so, discuss how pipe whip and jet impingement effects were determined for those postulated breaks in high energy piping that are not restrained (unrestrained whipping pipe). Provide the acceptance criteria for the impacted safety-related structures, systems, and components.

Response:

Unrestrained pipe whip and jet impingement are permitted in containment when either:

1. The high energy piping is located in zones where separation, enclosure, or adequate shielding is demonstrated,

2. Targeted structures, systems, and components are assessed as non-essential for the postulated initiating event and its consequences, or

3. Targeted structure, systems, and components are assessed as essential and meet the evaluation/acceptance criteria as discussed in Sections 3.6B.1.3, 3.6B.2.2, and 3.6B.2.3.

The determination of whether a target is essential or non-essential (items 2. and 3. above) includes an evaluation of break propogation criteria as discussed in Section 3.6N.2.3.2.

Where unrestrained pipe whip or jet impingement cause interactions unacceptable under the above criteria, the whipping pipe will be restrained, the target shielded from the jet source, or the hazard source/target relocated to preclude the unacceptable interaction.

NRC Letter: February 9, 1984

Question 210.18 (Section 3.9.1)

Justify not considering the following reactor coolant system design transients:

Normal
1) Feedwater cycling at hot shutdown
2) Loop out of service
3) Unit loading and unloading between 0 and 15 percent of full power
4) Boron concentration equalization
5) Refueling
6) Reduced temperature return to power
7) Reactor coolant pumps starting/shutdown
8) Turbine roll test
9) Primary side leak test
10) Secondary side leak test
11) Tube leakage test

Upset
1) Inadvertent reactor coolant depressurization
2) Inadvertent start-up of an inactive loop
3) Control rod drop

Emergency
1) Small LOCA
2) Small steam break
3) Complete loss of flow

Faulted
1) Feedwater line break
2) Reactor coolant pump locked rotor
3) Control rod ejection

Response:

The design transients for the BVPS-2 reactor coolant system are based upon Westinghouse internal design criteria for a plant using Model 51 steam generators. These transients are different than those identified for other Westinghouse plants which have Model D or Model F steam generators and the information contained in FSAR Section 3.9.1 is correct.

The design transients in the FSAR have been supplemented by Westinghouse design documents SS1.3X, Rev. 0 for the Class 1 auxiliary nozzles and related piping. This reference, SS1.3X, Rev. 0, will be added to FSAR Section 3.9.B.1 in Amendment 7. The transients listed above are included in the SS1.3X, Rev. 0, document were applicable. The transients in the SS1.3, Rev. 1, and SS1.3X, Rev. 0 documents are consistent and are combined at the reactor coolant system/auxiliary line interface.

It should also be noted that emergency conditions are not incorporated in the design because such conditions were not included

in the applicable ASME Code and internal Westinghouse design document at the time that design criteria for BVPS-2 were established. However, the emergency conditions transients identified in this question are enveloped by the defined faulted condition transients.

Plants with Model 51 Steam Generators

Farley 1&2
Cook 1&2
Zion 1&2
Beaver Valley 1&2
Prairie Island 1&2
Diablo Canyon 1&2
Salem 1&2
Trojan
Sequoyah 1&2
North Anna 1&2
Surrey 1&2
Kewaunee

NRC Letter: February 9, 1984

Question 210.19

Provide a commitment that, in the event any experimental stress analysis is used in lieu of analytical methods for the design of equipment, components or piping systems, the NRC will be notified and provided with the needed justification.

Response:

As stated in Sections 3.9B.1.3 and 3.9N.1.3, no experimental stress analysis has been employed in lieu of analytical methods for the design of equipment, components, or piping systems. However, the NRC will be notified and provided with the needed justification should this approach be used.

NRC Letter: February 9, 1984

Question 210.20 (Section 3.9.2)

On page 3.9-4 of the FSAR, near the middle of the second full paragraph, reference is made to "items 1 thru 4." Clarify what items 1 thru 4 are.

Response:

Items 1 through 4 refer to the four numbered items mentioned in the beginning of Section 3.9B.2.1. For clarity, the words: "Items 1 through 4 previously" will be replaced by the words: "Table 3.9B-1."

Refer to revised Section 3.9B.2.1, Amendment 7.

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during service and to confirm that normal thermal motion is not restrained.

The preoperational tests will be performed to verify, as nearly as possible, the performance of the systems under actual operating conditions. Where required, simulated signals or inputs are used to demonstrate the full operating range of the systems that are used during normal operation, and verify and calibrate as close as possible to actual operating conditions. Systems that are not used during normal plant operation but must be in a state of readiness to perform safety functions, are checked under various modes and test conditions prior to initial BVPS-2 start-up. Whenever practical, these tests are performed under the conditions expected when the systems would be required to function. When these conditions cannot be attained or appropriately simulated at the time of the test, the system is tested to the extent practical under the given conditions, with additional testing completed at a time when appropriate conditions are attained.

A list of the systems and the types of tests being conducted is contained in Table 3.9B-1. The different flow modes of operation and transients to which each system will be subjected during the tests are contained in Chapter 14. The test titles, test prerequisites, test objectives, and summary of testing are also described in Chapter 14. For each system defined in Items 1 thru 4 previously, all flow modes of operation that the systems are subjected to during the tests will be visually observed, where accessible. In addition, systems that were stress analyzed for fluid flow instabilities will have instrumented measurements at selected locations for the specific flow modes analyzed.

TABLE 3.9B-1

3.9B.2.1.1 PIPING VIBRATION AND DYNAMIC EFFECTS TESTING

The measured results will be compared to the analytically predicted values and determined acceptable if they are equal to or less than the predicted values. If they exceed predicted values, acceptability will depend on the analytically predicted stress levels and the magnitude of the measured displacements. Since both of these parameters are variables dependent on specific locations in the systems, the acceptance tolerance for movements exceeding the predicted values will be established as a percentage allowable deviation for each individual location. These tolerances will be established and documented in the appropriate system test procedures after completion of the stress analysis and prior to preoperational testing for vibration and/or dynamic effects. If measured displacements exceed the acceptance tolerance, the analysis will be reviewed to explain the anomaly, an evaluation of the effects on stress and loads will be performed, and the total results and evaluation documented to ensure that piping and pipe support criteria still satisfy the applicable code requirements.

Instrumented measurements will also be conducted (as needed) for other systems and conditions. For ASME Code Class 1, 2, and 3 piping systems, design and supervision of the tests, definition of

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acceptance criteria, evaluations of tests results, and the making of any changes in the piping system necessary to ensure that the piping is adequately designed and supported, are performed as required by Section III of the ASME code.

The selected locations in the piping systems at which visual inspections and measurements (as needed) will be performed are AND identified in Table 3.9B-2. Isometrics depicting the locations of these points will be contained in the appropriate test procedures. If vibrations are observed which from visual examination appear to be excessive in the opinion of experienced engineers who will supervise, conduct, and witness the various tests, then either: 1) an instrumented test program will be conducted and the system reanalyzed (or compared to existing analysis) to demonstrate that the observed levels do not cause ASME code stress and fatigue limits to be exceeded; 2) the cause of the vibration will be eliminated; or 3) a corrective support system will be designed and installed and the effect of the modification will be incorporated in the pipe stress analysis. Special attention will be paid to piping sections between supports; connections to instruments, vents, and drains; other free end connections; and motor or diaphragm operators for valves.

Instrumented measurement of vibration is generally limited to those systems subject to potential fluid transient loads. The selection of monitoring points will be based upon calculated results and accessibility. Locations for monitoring thermal expansion are chosen based on 1) expected large movements, 2) areas with tight clearances, and 3) all snubber locations to verify unrestricted motion. Snubbers are listed in Table 3.9B-3.

3.9B.2.1.2 THERMAL EXPANSION TESTING

The purpose of the thermal expansion monitoring program is to verify that the piping systems are free from interferences and unexpected restraints on thermal expansion, and that the pipe supports are functioning as intended. During hot functional testing, the piping systems will be raised to their operating temperatures in discrete temperature step increments. Displacement instrumentation and visual observations will be utilized to monitor the thermal expansions at selected temperatures and predetermined locations which are tabulated in Table 3.9B-2. WILL BE CONTAINED IN THE APPROPRIATE TEST PROCEDURES The types of instruments to be used for thermal expansion measurements, requirements that instruments be calibrated, installation details, etc, will ALSO be contained in the specific test procedures for each system.

If the measured thermal motion is not as predicted, system heatup will be terminated and the system will be examined to verify that thermal expansion is not being restricted by any type of interference, and the pipe support system will be examined to verify that all support components are functioning properly or to locate points of binding of restraints. If improper function of supports are found, adjustments or other corrective actions will be made to eliminate the unacceptable condition. If binding of restraints is found, the restraints will be adjusted to eliminate the unacceptable

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NRC Letter: February 9, 1984

Question 210.21 (Section 3.9.2)

Provide the acceptance criteria that will be used to determine if the vibration levels observed or measured during the preoperational testing are acceptable. Specifically address how the vibration amplitudes will be related to a stress level and what stress levels will be used for both steady-state and transient vibration.

Response:

Vibration levels are observed or measured during preoperational testing for both steady state and transient vibration conditions. The programs used to monitor these conditions are described below.

Steady State Vibrations

Visual observations are used for judging acceptability of steady state vibration. Visual observations may be aided by hand-held instruments (e.g., vibrometers) when considered appropriate by engineers experienced in piping design.

A screening velocity or displacement will be established for use with hand held instrument results. If the measurement indicates that the velocity or displacement limit is exceeded, the measured values are reconciled with the respective analyses by considering the specific piping configuration, velocity or displacement amplitude measured, stress indices, and the endurance strength of the material properly accounting for high cycle effects. If system modifications are required, the applicable ASME design calculations are reconciled to assure acceptable system characteristics for all applicable design conditions.

For steady state vibrations, the acceptable stress levels are as follows:

For carbon steel,

Endurance limit = S_{el} = 0.61 $S_{alternating}$ at 10^6 cycles from the applicable fatigue curves of ASME III Code.

For stainless steel,

Endurance limit = S_{el} = $S_{alternating}$ at 10^{11} cycles from the applicable fatigue curves of ASME III Code.

Transient Vibrations

Transient vibration conditions are subjected to visual and instrumented observations as defined in Table 3.9B-1. When instrumented observations are taken, the acceptance criteria are based on the applicable fluid system transient analysis (stress, deflection, etc) results. Instrumented observations are considered acceptable if they are within the transient analysis results acceptance criteria. If instrumented results exceed the acceptance criteria, the results are reconciled with the design analysis. When system modifications are required to achieve acceptable levels of transient vibration, the ASME design calculations are reviewed and modified as necessary to assure acceptable system characteristics.

NRC Letter: February 9, 1984

Question 210.22 (Section 3.9.2)

It is the staff's position that all essential safety-related instrumentation lines should be included in the vibration monitoring program during preoperational or start-up testing. We require that either a visual or instrumented inspection (as appropriate) be conducted to identify any excessive vibration that will result in fatigue failure.

Provide a list of all safety-related small bore piping and instrumentation lines that will be included in the initial test vibration monitoring program.

Response:

Small bore piping and instrument lines potentially affected by steady state vibrations of large bore piping and components are monitored visually. Generally, this includes the portion up to and including the first support away from the connection to large bore piping or component. If observations suggest that other spans are being excited, further inspection would be conducted on a case by case basis.

The safety-related small bore piping and instrument lines that are included in the vibration test program will be identified in the detailed test procedures as required by Section 14.2.3.2. The list will be available as part of the test procedures for all systems no later than 2 months prior to hot functional testing.

NRC Letter: February 9, 1984

Question 210.23 (Section 3.9.2)

Provide a schedule for completion of Table 3.9B-2.

Response:

Table 3.9B-2 has been deleted in Amendment 7 of the FSAR. The information concerning Table 3.9B-2 will be included in detailed test procedures as required by Section 14.2.3.2 and will be available for all systems no later than 2 months prior to hot functional testing.

NRC Letter: February 9, 1984

Question 210.24 (Section 3.9.2)

The second full paragraph on page 3.9-5 of the FSAR implies that all snubber locations will be instrumented. It is also stated that snubbers are listed in Table 3.9B-3. Will all snubber locations be instrumented and are all entries in Table 3.9B-3 snubbers?

Response:

All snubbers on piping will be inspected prior to and during preoperational testing.

All entries in Table 3.9B-3 are snubbers.

NRC Letter: February 9, 1984

Question 210.25 (Section 3.9.2)

In the fourth full paragraph on FSAR page 3.7-18, alternates to single and multifrequency testing programs are mentioned. Provide a more detailed description of these methods, a list of when they are used and justification for their use.

Response:

Test results based on methods other than single or multifrequency are potentially useful as supplemental qualification information and are not employed as the primary method of qualification. To date, no supplemental testing data beyond single or multifrequency testing procedures have been employed.

NRC Letter: February 9, 1984

Question 210.26 (Section 3.9.2)

FSAR Section 3.7B.3.2.1 states that fewer than 10 maximum stress cycles per earthquake may be used if justified by review of the applicable structural time history. Provide a discussion of how this would be done.

Response:

This criterion has not been employed on BVPS-2 and therefore has been deleted in Amendment 7 of the FSAR.

NRC Letter: February 9, 1984

Question 210.27 (Section 3.9.2)

SRP Section 3.9.2.II.2.d.(1) states that the maximum structural responses due to each of the three components of earthquake motion should be combined by SRSS. Justify the method described in the first paragraph of FSAR Section 3.7B.3.6 for combining the three components of earthquake motion for equipment and components.

Response:

FSAR Section 3.7B.3.6 reflects a 2-D analysis approach to equipment qualification. Based on the NRC's input to this subject, and in accordance with the referenced telecon below, it is believed that applicable licensing commitments for combining the components of earthquake motion have been employed.

The applicability dates for three-component earthquake analysis were discussed in telephone conversations between M. J. Ray of Stone & Webster Engineering Corporation (SWEC) and D. Jeng of the AEC on August 21, 1974, and between M. J. Ray and Dr. Shao, AEC Structural Branch Chief, on September 16, 1974. These telephone conversations were documented in a memorandum, Licensing Note 27, from H. L. Vener to distribution, dated September 18, 1974. The memorandum states, in part, the "The AEC has recently clarified its position with regard to the applicability dates for three-component earthquake analysis. For all nuclear stations docketed since November 1, 1972, the effects of three components of earthquake motion (two horizontal, one vertical) must be combined."

NRC Letter: February 9, 1984

Question 210.28 (Section 3.9.2)

Provide a more detailed explanation of Equation 3.7B-18.

Response:

When piping is routed between structures, the total relative displacement affecting the pipe includes the effect of the seismic inertial displacements of the individual structures as well as the relative displacement between the structures caused by the movement of the ground surface resulting from the passage of seismic waves. Total relative seismic displacements are obtained by combining the relative structural displacements and the relative inertial ground surface displacements by Equation 3.7B-18 in Section 3.7B.3.9.

To provide clarity, the designation for relative ground surface displacements in Equation 3.7B-18 has been changed from $X(ORB_{1-2})$ to $X(REL_{1-2})$, definitions have been revised, and the discussion of seismic anchor displacements has been more appropriately relocated from Section 3.7B.3.8 to Section 3.7B.3.9.

Refer to revised Sections 3.7B.3.8 and 3.7B.3.9, Amendment 7.

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j = 1,2,3 corresponds to response in X,Y, or Z global coordinate direction, respectively.

where:

$\{\ddot{X}\}_n$ = Maximum acceleration vector of mode n, in the j direction,

$\ddot{\eta}_{njmax}$ = Maximum generalized coordinate acceleration of mode n, in the j direction

Γ_{nj} = Modal participation factor for the nth mode in jth global coordinate direction,

$= \{\phi\}_n^T \ [M] \ \{e\}_j,$

$\{e\}_j$ = A vector with components of unity in all directions parallel to jth global coordinate direction and zero otherwise,

$(S_a)_{nj}$ = Spectral acceleration for the nth mode, in jth global coordinate direction (from enveloped and peak broadened ARS),

and the maximum inertia force vector for the nth mode is given by

$$\{F\}_{njmax} = M_n \{\phi\}_n \ \ddot{\eta}_{njmax} \qquad (3.7B\text{-}17)$$

These inertia forces are calculated for each of the system natural modes and applied as static forces in the same manner as the weight or thermal forces, to find internal moments and forces in each mode. The total maximum member forces and moments due to seismic excitation are then obtained by combining the modal responses described in Section 3.7B.3.7. The seismic anchor displacement effect is considered separately from seismic inertial effect. When piping is routed between different structures, total relative distortion affecting the pipe includes the effects of seismic displacements obtained from a dynamic analysis of the structures, as well as the relative displacements ground motion due to the passage of seismic waves at or near the ground surface. AS DESCRIBED IN SECTION 3.7B.3.9

Total relative seismic displacements are obtained by combining these two conditions as input for piping analysis by SRSS method which is given by:

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$$\bar{X} = \sqrt{(X_1 + X_2)^2 + [X(ORB_{1-2})]^2} \qquad (3.7B\text{-}18)$$

where:

$\bar{X}$ = Total relative seismic displacement,

X_1 = Structural dynamic displacement for first structure,

X_2 = Structural dynamic displacement for second structure,

$X(ORB_{1-2})$ = Ground motion displacement between the centroids of the two structures.

Each maximum relative directional component of seismic anchor displacement is treated individually as input and a static analysis is performed. The resulting member forces and moments from all three directions of seismic anchor displacement input are combined by the SRSS method. Total seismic response is developed by summing absolutely the inertia and anchor displacement effects for 1/2 SSE. For SSE, anchor displacement effects are considered for the piping in Table 3.9B-9, QA Category I equipment, and containment penetrations.

These seismic member moments and forces are then combined with loads from deadweight, pressure, other mechanical or thermal loads, to complete the stress analysis of all Seismic Category I, and some nonseismic Category I piping. For ASME Code Class 1 piping, the formulation specified in Subarticle NB-3600, ASME Section III, is employed. For ASME Code Class 2 and 3 pipings, the formulations in Subarticle NC-3600 and ND-3600, respectively, are used.

non-Seismic

Piping systems are also evaluated to assess the potential for significant flow induced dynamic loadings that could result from various modes of system operation as defined in the design specification. These dynamic force loadings are included as occasional mechanical loadings in piping analysis.

The plant design criteria, applicable to BOP Seismic Category I piping systems are tabulated in Tables 3.7B-32 and 3.9B-8 thru 3.9B-11.

3.7B.3.9 Multiply-Supported Equipment and Components with Distinct Inputs

To calculate the maximum inertial response of multiply-supported subsystems, an upper bound envelope of all the individual response spectra for the support locations is used. In addition, the relative displacements at the support points are considered. Support

displacements are imposed statically on the subsystem in the most conservative combinations. For support locations within a Seismic Category I structure, relative displacements are defined algebraically and imposed. Displacements between Seismic Category I structures are considered to be out-of-phase, and the maximum relative displacements between Seismic Category I structures are thus determined from absolute sums of the support displacements. The stresses due to seismic inertia and relative displacements are added to those due to other appropriate loadings such as deadweight, pressure, etc, and the resulting stresses are limited by allowable stresses defined in applicable codes.

3.7B.3.10 Use of Constant Vertical Static Factors

3.7B.3.10.1 Equipment and Components

Constant load factors are not utilized for vertical floor response in the design of Seismic Category I equipment and components.

3.7B.3.10.2 Piping Systems

The method of applying constant static factors as vertical response loads, based on the assumption of vertically rigid structures, for the seismic design of Seismic Category I piping is not used. However, a simplifed analysis (equivalent static load method), using constant load factors for both the vertical and horizontal directions based on the peaks of applicable ARS, is used for some small bore piping systems, as described in Section 3.7B.3.5.2.

3.7B.3.11 Torsional Effects of Eccentric Masses

The effect of eccentric masses, such as valves and valve operators, is considered in the seismic piping analysis described in Section 3.7B.3.1.2. These eccentric masses are included in the mathematical model for the system analysis and the torsional effects caused by them are evaluated and included in the total system response. The total response must meet the limits of the criteria applicable to the Safety Class of the piping for ASME III piping, and the criteria described in Section 3.7B.3.13 for non-ASME III piping which is seismically analyzed.

3.7B.3.12 Buried Seismic Category I Piping Systems

In performing stress analysis of buried Seismic Category I piping systems, the following loadings are considered:

1. Internal pressure,

2. Soil pressure (includes dead load and live loads due to traffic when applicable),

3. Thermal expansion,

When Seismic Category I structures are not attached to the same mat foundation, additional displacements caused by the movement of the ground surface resulting from the passage of seismic waves are combined with the structural dynamic displacements as shown in equation 3.7B-18

$$\bar{X} = \sqrt{(X_1 + X_2)^2 + [X(REL_{1-2})]^2} \qquad (3.7B-18)$$

WHERE: $\bar{X}$ = TOTAL RELATIVE DYNAMIC DISPLACEMENT (X, Y, OR Z DIRECTION)

X_1 = MAX RELATIVE STRUCTURAL DYNAMIC DISPLACEMENT FOR FIRST STRUCTURE RELATIVE TO BASE (X, Y, OR Z DIRECTION)

X_2 = MAX RELATIVE STRUCTURAL DYNAMIC DISPLACEMENT FOR SECOND STRUCTURE RELATIVE TO BASE (X, Y, OR Z DIRECTION)

$X(REL_{1-2})$ = MAX RELATIVE GROUND SURFACE DISPLACEMENT BETWEEN STRUCTURES (X, Y, OR Z DIRECTION)

THE PROCEDURES USED TO COMPUTE STRUCTURAL DISPLACEMENTS AND THE RELATIVE GROUND SURFACE DISPLACEMENTS ARE DESCRIBED IN SECTIONS 3.7B.2 AND 2.5.4.7.4, RESPECTIVELY.

Each maximum relative directional component of seismic anchor displacement is treated individually as input and a static analysis is performed. The resulting member forces and moments from all three directions of seismic anchor displacement input are combined by the SRSS method. Total seismic response is developed by summing absolutely the inertia and anchor displacement effects for 1/2 SSE. For SSE, anchor displacement effects are considered for the piping in Table 3.9B-9, QA Category I equipment, and containment penetrations.

These seismic member moments and forces are then combined with loads from deadweight, pressure, other mechanical or thermal loads, to complete the stress analysis of all Seismic Category I, and some non-Seismic ~~nonseismic~~ Category I piping. For ASME Code Class 1 piping, the formulation specified in Subarticle NB-3600, ASME Section III, is employed. For ASME Code Class 2 and 3 pipings, the formulations in Subarticle NC-3600 and ND-3600, respectively, are used.

NRC Letter: February 9, 1984

Question 210.29 (Section 3.9.2)

On page 3.7-21 of the FSAR, it is stated that all significant dynamic modes of responses under seismic excitation with frequencies less than 50 cps or modes less than 50, whichever is reached first, are included in the dynamic analysis. Provide assurance that all modes less than or equal to 33 Hz have been included.

Response:

The seismic analyses of Westinghouse supplied components considered all modes less than or equal to 33 Hz. This is true for the three dimensional dynamic analyses of the Westinghouse supplied primary equipment and also the two dimensional equivalent static analyses of the Westinghouse supplied Class 2 and 3 auxiliary equipment.

Application of this criteria ensures that all significant system responses less than or equal to 33 Hz have been included.

NRC Letter: February 9, 1984

Question 210.30 (Section 3.9.2)

Provide the basis used for the design o. piping supports and anchors which separate seismically designed piping and non-seismic Category I piping. Include in your discussion, the loads and load combinations used and how the local pipe wall stresses are considered.

Response:

To maintain the integrity of the seismic portion of seismic/nonseismic interface, BVPS-2 design basis is to comply with Regulatory Guide 1.29. This is accomplished as follows:

For piping sizes 12 inches NPS and smaller, the next anchor beyond the seismic/nonseismic boundary is designed to accommodate the maximum loads (plastic hinge) for which the piping on the nonseismic side of the anchor can transmit. An anchor may be a series of restraints which effectively act as an anchor.

Pipe sizes over 12 inches NPS are analyzed for seismic effects on both sides of the seismic/nonseismic boundary. In utilizing this criteria, the nonseismic side is reviewed to assure that it is adequately supported for the operational loads: thermal, deadweight, fluid transient loads where applicable, and seismic loads.

The seismic/nonseismic anchor is evaluated to assure adequate structural design. The integrity of the pressure boundary beyond the interface anchor is not of concern, including local pipe wall stresses, since piping beyond that interface anchor may have the pressure boundary compromised because it provides no safety function.

NRC Letter: February 9, 1984

Question 210.31 (Section 3.9.3)

The staff finds that there is insufficient information describing the design of safety-related HVAC ductwork and supports. Provide the design basis used for qualifying the HVAC ductwork and support structural integrity.

Response:

Response to be provided by June 1, 1984.

NRC Letter: February 9, 1984

Question 210.32 (Section 3.9.3)

Provide the basis for assuring that ASME Code Class 1, 2, and 3 piping systems are capable of performing their safety function under all plant conditions. Describe the methodology used to assure the functional capability of essential piping systems when service limits C or D are specified.

Response:

ASME III Classes 1, 2 and 3 piping systems are designed for all plant conditions in accordance with the ASME III code requirements as shown in Tables 3.9B-5, 3.9B-8, 3.9B-9, 3.9B-11, and 3.9B-14.

Numerous operating fluid transient events have occurred in operating nuclear power plants (NUREG-0582 and NUREG/CR-2059). Many of these events caused code allowable stresses to be exceeded, and some were severe enough to significantly damage piping and pipe supports. None of these events resulted in a loss of functional capability where the integrity of the pressure boundary was maintained. Other experiences, such as the effects of the 1979 Imperial Valley earthquake on the El Centro Steam Plant (NUREG/CR-1665), which did not cause any loss of functional capability although design to withstand earthquake was minimal and the earthquake was of high intensity, indicate that functional capability is, again, not a practical concern.

The difference between operating experience and academic concern is in part explained by a study of seismic design margins for piping (NUREG/CR-2137) where lower bound margins of 1.4 or greater indicated significant reserve strength when designed to ASME III rules. In addition, stresses are dominated by stress intensification factors which address fatigue strength of local areas, but are not indicative of the general state of stress in the piping system. Although ASME Level D stress limits theoretically permit gross yielding of piping while only protecting the pressure boundary, practical experience indicates otherwise. Failures of the pressure boundary have occurred due to unanticipated loads (e.g., waterhammer, vibration, etc) or corrosion/erosion, but gross yielding of an intact pressure boundary has not led to a loss of functional capability.

The practice of reducing code allowable stresses to preclude theoretical gross yielding for very low probability loads may in fact reduce the overall safety and reliability of the piping system. Lower allowable stresses are achieved by additional pipe supports, and usually snubbers (which reduce dynamic stresses without increasing thermal or deadweight stresses), resulting in a stiffer system with higher stresses during normal plant operation, but theoretically lower stresses for the low probability design events

applicable to Level D stress limits which are dynamic in nature. Additional pipe supports, particularly snubbers, and increased piping stiffness are often cited (e.g., NUREG/CR-2136 and S. H. Bush letter to N. J. Palladino of August 20, 1981) as sources of potential failures due to limiting access for maintenance and inservice inspection, difficulty in installation and proper adjustment, and higher stresses during normal plant operation.

NRC Letter: February 9, 1984

Question 210.33 (Section 3.9.3)

Provide a discussion of the design considerations used for safety and relief valve loads and piping reactions. Include in your discussion (1) the basis for assuring that the valve end loads are acceptable, (2) the support arrangement for the affected piping, and (3) the methodology used to calculate the hydraulic transient forces in the piping due to valve blowdown.

Response:

The design considerations used for safety and relief valve loads and piping reactions are described in Section 3.9B.3.3. Response to the three specific items noted above follows:

1) Acceptability of valve end loads is assured through a combination of both testing and analyses. Section 3.9B.3.3 states, "The design of these valves takes into consideration the reaction force when the valve opens. The design criteria for all pressure-relieving devices are in accordance with the rules of ASME Boiler and Pressure Vessel Code, Section III." Further assurance of acceptable valve end loads is provided under the "Valve Operability Assurance Program" described in Section 3.9B.3.2.2, which demonstrates overpressurization safety capabilities during a seismic event through successful valve actuation within design requirements. Supplemental assurance is provided through qualification of the attached piping since the valve is inherently stronger than the piping. For piping qualification, Section 3.9B.3.3 states, "In addition, relief and safety valve discharge events are considered as occasional loads and classified as upset, emergency, or faulted, depending upon the expected frequency of occurrence, with the exception that safety valve discharge events in the RCS are classified as either emergency or faulted only. These loads are combined with other service loadings and maintained within the appropriate stress limits as indicated in Section 3.9B.3.1."

   Maximum nozzle loads for safety and relief valves are defined in the valve equipment specifications. These nozzle loads take into account all loads on the valve including fluid discharge loads. These nozzle loads are provided to the piping designer (SWEC) as interface criteria. If the specified nozzle loads are exceeded by the piping designer, the loads are sent to Westinghouse for evaluation to determine their acceptability.

2) The support arrangement for the affected piping is a function of the piping stress analysis and is governed by the requirement to maintain pipe stress levels within the appropriate limits as indicated in Section 3.9B.3.1.

3) The methodology used to calculate the hydraulic transient forces in the piping due to valve blowdown is described in Section 3.9B.3.3.2.

4) For large bore computer analyzed piping, calculated piping reactions on the safety valve outlet nozzle will be reconciled for acceptability with the valve vendors.

NRC Letter: February 9, 1984

Question 210.34 (Section 3.9.3)

The staff review of FSAR Section 3.9B.3.4 and 3.9N.3.4 finds that there is insufficient information regarding the design of component supports. Per SRP Section 3.9.3, our review includes an assessment of design and structural integrity of the supports. The review addresses three types of supports: (1) plate and shell, (2) linear, and (3) component standard types. For each of the above three types of supports, provide the following information (as applicable) for our review.

(a) Describe (for typical support details) which part of the support is designed and constructed as component supports and which part is designed and constructed as building steel (NF vs. AISC jurisdictional boundaries).

(b) Provide the complete basis used for the design and construction of both the component support and the building steel up to the building structure. Include the applicable codes and standards used in the design, procurement, installation, examination, and inspection.

(c) Provide the loads, load combinations, and stress limits used for the component support up to the building structure.

(d) Provide the deformation limits used for the component support.

(e) Describe the buckling criteria used for the design of component support.

Response:

The BVPS-2 is a non-ASME III, NF plant when addressing design and construction of component supports. A very small percentage of components have supports designed and constructed to ASME III, NF requirements, but this is due to the purchase order date for the components. The vast majority of component supports are not designed to ASME III, NF requirements and are not required to be.

The specific responses to the questions are provided in three separate parts. Part 1 addresses Westinghouse supplied component supports, Part 2 addresses SWEC designed/supplied component supports, and Part 3 addresses piping component supports.

Part I - Westinghouse Supplied Component Supports

Westinghouse has supplied supports only for those Class 2 and 3 components also supplied by Westinghouse to which the supports are attached. This equipment is divided into two groups.

The first group consists of auxiliary tanks and heat exchangers. The supports for these components are of two types; linear and, for the most part, plate and shell type supports. The supports for the tanks and heat exchangers meet either the requirements of Subsection NF of the ASME Code or the requirements of the AISC Code depending on the procurement date of the component. Components procured prior to the inclusion of Subsection NF into the ASME Code were designed to the AISC Code requirements. A listing of the tanks and heat exchangers and the codes to which the respective supports were designed is available if needed.

The second group consists of Class 2 and 3 auxiliary pumps. The supports for these pumps are plate and shell and, for the most part, linear-type supports. The auxiliary pump supports are designed by the pump manufacturer to pressure boundary stress limits, with the exception of the boric acid transfer pumps, the supports for which are designed to the limits of the AISC Code.

The loads and loading combinations of the supports for the auxiliary equipment supplied by Westinghouse are the same as those of the supported component. These loads and combinations are given in FSAR Table 3.9N-4.

Deformation of the tanks and heat exchangers is accounted for through the use of the stress limits of AISC or ASME, NF. These limits ensure the supports remain elastic, thereby preventing permanent deformation. Additionally, the supports for active pumps must not deform such that specified critical clearances are maintained so that the pump remains operable. These clearances are specified in the pump specification.

Buckling is prevented by limiting compressive stresses for linear-type auxiliary equipment supports under loadings from all service conditions to the limits of AISC Section 1.5 or ASME Appendix XVII-2210. These limits, which are identical, are based on the Column Research Council (CRC) buckling curve for centrally loaded columns. A variable factor of safety, based on column length and section material properties, provides adequate margin to the critical buckling values of the CRC curve. A discussion of the buckling criteria for plate and shell type supports is as follows.

Buckling Criteria for Plate and Shell Type Supports

Plate and shell type supports for Class 2 and 3 auxiliary equipment are evaluated for buckling and instability through selective use of the criteria of Appendix XVII, Subarticle XVII-2200 and Subsection NC, Subparagraph NC-3133.6 of Section III of ASME Code.

Subparagraph NC-3133.6 gives methods for calculating the maximum allowable compressive stress in cylindrical shells subjected to axial and loading that produce longitudinal compression stresses in the shell.

Subarticle XVII-2200 gives requirements for structural steel members including allowable compressive loads based on slenderness ratios and interaction equations for combined stresses.

Use of the above requirements, in addition to those of Subsection NF, in the design of plate and shell type supports for Westinghouse supplied auxiliary equipment, ensures the dimensional stability of the support throughout the range of applied loadings.

In accordance with the request of the MEB staff, a discussion on how allowable buckling stresses are calculated for linear-type supports are included in this response. In addition, FSAR Section 3.9N.3.4, Component Supports, has been revised to reflect the discussion on Class 2 and 3 auxiliary equipment support types and design criteria.

Component Supports (Section 3.9N.3.4)

Westinghouse has supplied supports only for those Class 2 and 3 components also supplied by Westinghouse to which the supports are attached. The loads and loading combinations of the supports are the same as those of the supported component. These loads and combinations are given in FSAR Talbe 3.9N-4.

The Class 2 and 3 auxiliary equipment supplied by Westinghouse is grouped into two general categories. One group consists of tanks and heat exchangers. The other group is auxiliary pumps. Design criteria for the supports for these components are discussed below.

Tanks and Heat Exchangers (Section 3.9N.3.4.1)

The supports for auxiliary tanks and heat exchangers are of two types: linear and, for the most part, plate and shell type supports. The supports meet either the requirements of Subsection NF of the ASME Code or the requirements of the AISC Code, depending on the procurement date of the component. Components procured prior to the inclusion of Subsection NF into the ASME Code were designed to the AISC Code requirements.

Auxiliary Pumps (Section 3.9N.3.4.2)

The supports for Class 2 and 3 auxiliary pumps are plate and shell and, for the most part, linear-type supports. The supports are designed by the pump manufacturer to pressure boundary stress limits, with the exception of the boric acid transfer pumps, the supports for which are designed to the limits of the AISC Code.

Part II - SWEC Supplied/Designed Component Supports

(a) The SWEC supplied component supports are for the most part supplied with its component. Component supports supplied with the equipment are designed and constructed in accordance with AISC Code or ASME III, NF requirements. ASME III components

constructed to ASME III, 1971 Edition through Summer 1973 Addenda or earlier have supports designed to AISC. After Summer 1973, supports are in accordance with NF requirements.

The loads, load combinations, and stress limits for the SWEC supplied component supports are identified in Table 3.9B-16, Amendment 7.

All equipment supports are designed to elastic limits. Deformation limits are not used.

AISC jurisdiction is assigned to embedments or building steel to which the supports are attached. The anchorage design criteria is described in the response provided for Question 210.35.

(b) The SWEC designed equipment component supports are designed using AISC Code allowables or the allowables of ASME III, NF as guidance, even though the requirements of ASME III, NF were not mandatory for these supports due to the procurement date of the components.

The loads, load combinations, and stress limits for the primary equipment supports are identified in Table 5.4-21 and the remaining equipment supports in Table 3.9B-16, Amendment 7.

All equipment supports are designed to elastic limits. Deformation limits are not used.

The buckling criteria for the equipment supports are in accordance with the AISC Code.

AISC jurisdiction is assigned to the embedments or building steel to which the supports are attached. The anchorage design is described in the response provided for Question 210.35.

Part III - Piping Component Supports

Except for integral welded attachments defined in Section 3.9B.3.4.2, pipe supports are not designed or constructed to ASME III requirements because their design and procurement proceeded ASME III, NF. Therefore, plate and shell type designations are not applicable.

The response to items (a) through (e) of Question 210.34, as applicable to pipe supports, are:

(1) All pipe supports are designed as described in Tables 3.9B-14 and 3.9B-15, Amendment 7. AISC jurisdiction is assigned to embedments or building steel to which the pipe supports are attached.

(2) Pipe supports meet the criteria of the AISC Code ANSI B31.1 Code and Tables 3.9B-14 and 3.9B-15, Amendment 7. When pipe

supports include integral attachments to pressure retaining boundaries, the integral welded attachments are designed, fabricated, installed, and inspected in accordance with the criteria stated in Section 3.9B.3.4.2.1.

(3) Loads and load combinations used to design pipe supports are described in Tables 3.9B-14 and 3.9B-15, Amendment 7. The allowables are based on the AISC Code. The loads, load combinations and the corresponding allowables for designing integral attachments to the pressure boundary are described in Section 3.9B.3.4.2.1.

(4) All pipe supports are designed to elastic limits. Deformation limits are not used.

(5) Buckling criteria for pipe supports are in accordance with the AISC Code.

<u>Summary</u>

Component supports for BVPS-2 are not designed or constructed to ASME III, NF requirements for the majority of components. SWEC will specifically identify supports designed and constructed to NF requirements in the ASME Code Baseline Document which is due to be issued in June 1984. This ASME Code Baseline Document will be referenced in and become part of the FSAR.

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3.9B.3.4.1 Equipment Component Supports

IN GENERAL, None of the equipment component supports were [are not] considered to be within the jurisdiction of ASME III since Subsection NF was not in effect at the time the various [THAT MOST] equipment component support systems were purchased. However, Subsection NF [ASME] criteria was used extensively as guidance in terms of both design and fabrication. Equipment component supports for the RCS, which were considered to be on the level of ASME III, Class 1, are described in Section 5.4.14. All remaining supports, which were considered to be within a classification of ASME III, Class 2 and 3, are described in Section 3.9B.2. A SMALL NUMBER OF ASME III CLASS 2 AND 3 COMPONENTS HOWEVER, HAVE BEEN SUPPLIED FOR WHICH THE SUPPORT STRUCTURES ARE TO ASME III, NF REQUIREMENTS, DUE TO THE PROCUREMENT DATE OF THE COMPONENT(S).

3.9B.3.4.1.1 LOADS, LOAD COMBINATIONS & STRESS LIMITS

LOADS, LOAD COMBINATIONS, AND STRESS LIMITS FOR EQUIPMENT COMPONENT SUPPORTS ARE IDENTIFIED IN TABLE 3.9B-16.

3.9B.3.4.2 Piping Component Supports

3.9B.3.4.2.1 Loading Combinations, System Operating Transients, and Stress Limits

Loading combinations, system operating transients, and stress limits for piping component supports fall into two categories:

a. That part of the support which transmits loads from the pressure retaining boundary to the building structure (welded attachment) is considered locally as an extension of the piping and falls under the jurisdiction of ASME III outlined in Sections 3.9B.3.1.1 and 3.9B.3.1.2.

b. **That part of the support other than the pressure boundary interface is evaluated as a piping component support structure as outlined in Section 3.9B.3.4.2.2.**

3.9B.3.4.2.2 Piping Component Support Structures

a. Piping component support structures are defined as that part of the support structure other than the pressure boundary interface. This includes snubbers, struts, structural steel, etc. [SUPPLEMENTAL MATERIAL SUCH AS STEEL, STRUCTURAL BOLTS, ETC. IT ALSO INCLUDES PRE-FABRICATED VENDOR COMPONENTS SUCH AS STRUTS, SNUBBERS, SPRING HANGERS, ...]

b. The load combinations used for the analysis of piping component support structures are combined in a conservative manner consistent with the requirements of ANSI B31.7-1969, Division 1-720 and 1-721, and ANSI B31.1.0-1967, Paragraphs 120 and 121. [USA Standard Code for Pressure Piping, Nuclear Power Piping ANSI B31.7-1969 and USA Standard Code for Pressure Piping, Power Piping ANSI B31.1.0-1967.]

c. Piping component support structure design loads are arrived at by the summation of the resultant forces and moments for sustained loads, occasional loads (including building settlement and hydrotest loads), dynamic loads, and thermal

expansion loads. The summation of these loads include a maximum positive design load and a maximum negative design load. (Earthquake and other cyclic loads are combined by SRSS).

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d. Stress levels — on supplemental material — generated by the design loads are compared to the permissible stress limits for pipe component support structures consistent with those in the AISC Manual of Steel Construction - Seventh Edition - 1969 1970 to assure the adequacy of the support. the ANSI (B31.1) Code, and Table 3.9B-14 and Table 3.9B-15

3.9B.3.4.2.3 Standard Prefabricated Piping (Hanger) Supports

The design of all hanger supports conforms to the requirements of the Manufacturers Standardization Society Standard Practices SP58 and SP69, and the requirements of ASME III (use of code cases are in accordance with Regulatory Guides 1.84 and 1.85 unless otherwise stated herein).

3.9B.3.4.2.4 Snubbers

1. Mechanical Properties

   Mechanical and hydraulic snubbers are utilized to limit piping movements resulting from dynamic loadings while permitting normal thermal expansion. Snubbers are not provided for use as vibration arrestors.

2. Structural Analysis and System Evaluation

   a. The entire piping system is mathematically modeled for complete structural analysis. In the mathematical model, the snubbers are modeled as struts with spring stiffness dependent on snubber size. The analysis determines the forces and moments acting on each component and the forces acting on the snubbers due to all the dynamic loading conditions defined in the piping design specification. The design load on snubbers includes those loads caused by seismic forces (OBE, SSE, seismic anchor movements), and reaction forces caused by relief valve discharge, turbine stop valve closure, etc.

   b. The flexibility of support components is considered in the support designs. The assigned stiffness values are adequate for determining pipe stress and pipe support loads from Nupipe (as described in Appendix 3A).

   c. Snubber end fitting clearance and lost motion are minimized in the design and [illegible] of the piping component supports.

e Prefabricated vendor components are qualified by comparing the support design loads to the rated loads of the component(s) as specified by the vendor(s).

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TABLE 3.9B-14

LOAD COMBINATIONS FOR PIPE SUPPORTS EXCEPT QSS, RSS, AND SIS (4)(5) (6)

Plant Operating Condition	Load Condition (3)	Allowable Tensile Stress (2)(7)
Normal/Upset	D + T + R + R" + W + S (1)	0.6 Sy
	D + E + H + T + R + A	0.8 Sy
Emergency/ Faulted	D + E' + H	0.8 Sy

NOTES:

1. For definition of terms, see Table 3.9B-11.
2. Buckling criterion for pipe supports is in accordance with the AISC Code.
3. Generally, an enveloped design load is used thus producing a more conservative load combination. The above load combination and limits may be used when specific loading methods are needed.
4. See Table 3.9B-15 for allowable tensile stress values for QSS, RSS, and SIS systems.
5. QSS, RSS, and SIS systems correspond to:
   QSS- Quench spray system
   RSS- Recirculation spray system
   SIS- Safety injection system
6. For pipe support designs on instrumentation tubing, thermal loads, and seismic loads are evaluated separately if the instrument line is normally dead-ended (i.e., no flow).
7. The above allowables are the basic tensile stress allowables. All other requirements of the AISC code related to member stresses are satisfied.

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TABLE 3.9B-15

LOAD COMBINATIONS FOR PIPE SUPPORTS FOR QSS, RSS, AND SIS (4)(5) (6) 1.13

Plant Operating Condition	Load Combinations (3)	Allowable Tensile Stress (2)(7)	
			1.16 1.17
Normal/Upset	D + T + R + R" + W + S (1)	0.6 Sy	1.19
	D + T + R + E + A + H	0.8 Sy	1.21
			1.23
Emergency/ Faulted	D + E' + H	0.8 Sy	1.25
	T + R' + A' + X	0.8 Sy	1.27

NOTES: 1.29

1. For definition of terms, see Table 3.9B-11. 1.32
2. Buckling criterion for pipe supports is in accordance with the AISC code. 1.33
3. Generally, an enveloped design load is used thus producing a more conservative load combination. The above load combination and limits may be used when specific loading methods are needed. 1.34 1.35
4. For pipe support designs on instrumentation tubing, thermal loads and seismic loads are evaluated separately if the instrument line is normally dead-ended (i.e., no flow). .36 .37
5. QSS, RSS, and SIS systems correspond to:
   QSS- quench spray system .40
   RSS- recirculation spray system
   SIS- safety injection system
6. The above allowables are the basic tensile stress allowables. All other requirements of the AISC code related to member stresses are satisfied. .42

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TABLE 3.9B-16

LOADS, LOAD COMBINATIONS, & STRESS LIMITS FOR S/W DESIGNED/EXP COMPONENTS/SUPPORTS

PLANT DESIGN OR OPERATING CONDITION	LOADS & LOADING COMBINATIONS	STRESS LIMITS	REFERENCE SOURCE
NORMAL	DEADWEIGHT OF COMPONENT & SUPPORTS TEMPERATURE PRESSURE MECHANICAL(PIPING) LOADS***	STRUCTURAL MEMBERS TENSION & BENDING(F_t) 0.6 Sy SHEAR (F_v) 0.4 Sy BOLTS (EITHER ABOVE OR:) TENSION (F_t) Su/2 SHEAR (F_v) 0.62 Su/3	ASME III SUBSECTION NF SUBART. NF-3100 NF-3230 ARTICLE XVII-2000 TABLE NF-3225.1 ABOVE USED AS A GUIDE
UPSET	NORMAL + OBE	SAME AS NORMAL	SAME AS NORMAL
EMERGENCY	NOT APPLICABLE *	—	
FAULTED	NORMAL + SSE	STRUCTURAL MEMBERS LESSER OF: 1.2 (S_Y/F_t) or .7 (S_u/F_t) ** BOLTS .7 S_u/F_t < S_Y	ASME III SUBSECTION NF APPENDIX F SUBART. F-1370 ABOVE USED AS A GUIDE

NOTES:

* AS STATED IN SECTION 3.9B.1-1

** USED ONLY WHEN FAULTED STRESSES EXCEED NORMAL/UPSET ALLOWABLES (CONSERVATIVE)

Sy IS SPECIFIED MINIMUM MATERIAL YIELD STRENGTH AT TEMPERATURE

Su IS SPECIFIED MINIMUM MATERIAL ULTIMATE STRENGTH AT TEMPERATURE

For Bolting materials, [illegible] Su [illegible] than Sy.

*** INCLUDES THERMAL EXPANSION & ANCHOR POINT MOTION LOADS

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loads due to maximum seismic excitation will not affect the functional ability of the valve, since the valve disc is designed to be isolated from the body wall. The clearance supplied by the design around the disc will prevent the disc from becoming bound or restricted due to any body distortions caused by nozzle loads. Therefore, the design of these valves is such that once the structural integrity of the valve is assured using standard methods, the ability of the valve to operate is assured by the design features. The valve will also undergo: 1) in-shop hydrostatic tests; 2) in-shop seat leakage test; and 3) periodic in situ valve exercising and inspection to assure the functional ability of the valve.

The pressurizer safety valves are qualified by the following procedures (these valves are also subjected to tests and analysis similar to check valves): stress and deformation analyses for SSE loads, in-shop hydrostatic and seat leakage tests, and periodic in situ valve inspection. In addition to these tests, a static load equivalent to the SSE is applied at the top of the bonnet, and the pressure is increased until the valve mechanism actuates. Successful actuation within the design requirements of the valve assures its overpressurization safety capabilities during a seismic event.

Using the methods described, all the safety-related valves in the systems are qualified for operability during a seismic event. These methods conservatively simulate the seismic event and ensure that the active valves will perform their safety-related function when necessary.

This testing program for valves is conservative. Alternate valve operability testing, such as dynamic vibration testing, will be allowed if it is shown to adequately assure the faulted condition functional ability of the valve system.

3.9N.3.2.2 Pump Motor and Valve Electric Motor Operator Qualification

Active pump motors (and vital pump appurtenances) and active valve electric motor operators (and limit switches and pilot solenoid valves), are seismically qualified by meeting the requirements of IEEE Standard 344-1971, as described in Section 3.10N.

3.9N.3.3 Design and Installation Details in Mounting of Pressure Relief Devices

This is discussed in 3.9B.3.3.

3.9N.3.4 Component Supports

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The criteria for Westinghouse-supplied supports for ASME Code Class 2 and Class 3 mechanical equipment are as follows:

Linear Supports for Tanks and Heat Exchangers

1. Normal - The allowable stresses of the American Institute of Steel Construction (AISC-69) Part 1 are employed for normal condition allowables.

2. Upset - Stress limits for upset conditions are 33 percent higher than those specified for normal conditions. This is consistent with Paragraph 1.5.6 of AISC-69 Part 1 which permits a 1/3 increase in allowable stresses for wind or seismic loads.

3. Emergency - Not applicable.

4. Faulted - Stress limits for faulted conditions are the same as for the upset condition.

Plate and Shell Supports for Tanks and Heat Exchangers

1. Normal - Normal condition limits are those specified in ASME Section VIII Division 1 or AISC-69 Part 1.

2. Upset - Stress limits for upset condition are 33 percent higher than those specified for normal conditions. This is consistent with Paragraph 1.5.6 of AISC Part 1 which permits a 1/3 increase in allowable stresses for wind or seismic loads.

3. Emergency - Not applicable.

4. Faulted - Stress limits for faulted condition are the same as for the upset condition.

Plate and Shell Supports for Pumps

The stress limits used for ASME Code Class 2 and Class 3 plate and shell component supports are identical to those used for the supported component. These allowable stresses are such that the design requirements for the components and system structural integrity are maintained.

3.9N.4 Control Rod Drive Systems

3.9N.4.1 Descriptive Information of Control Rod Drive System

Control Rod Drive Mechanism

Control rod drive mechanisms (CRDMs) are located on the dome of the reactor vessel. They are coupled to rod control clusters which have absorber material over the entire length of the control rods. The CRDM is shown on Figure 3.9N-3 and schematically on Figure 3.9N-4.

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3.9N.3.4 COMPONENT SUPPORTS

Westinghouse has supplied supports only for those Class 2 and 3 components also supplied by Westinghouse to which the supports are attached. The loads and loading combinations of the supports are the same as those of the supported component. These loads and combinations are given in Table 3.9N-4.

The Class 2 and 3 auxiliary equipment supplied by Westinghouse is grouped into two general categories. One group consists of tanks and heat exchangers. The other group is auxiliary pumps. Design criteria for the supports for these components are discussed below.

3.9N.3.4.1 Tanks and Heat Exchangers

The supports for auxiliary tanks and heat exchangers are of two types: linear and, for the most part, plate and shell type supports. The supports meet either the requirements of Subsection NF of the ASME Code or the requirements of the AISC Code, depending on the procurement date of the component. Components procured prior to the inclusion of Subsection NF into the ASME Code were designed to the AISC Code requirements.

3.9N.3.4.2 Auxiliary Pumps

The supports for Class 2 and 3 auxiliary pumps are plate and shell and, for the most part, linear-type supports. The supports are designed by the pump manufacturer to pressure boundary stress limits, with the exception of the boric acid transfer pumps, the supports for which are designed to the limits of the AISC Code.

NRC Letter: February 9, 1984

Question 210.35

The staff's review of your component support design finds that additional information is required regarding the design basis used for bolts.

(a) Describe the allowable stress limits used for bolts in equipment anchorage, component supports, and flanged connections.

(b) Provide a discussion of the design methods used for expansion anchor bolts used in component supports.

Response:

(a) The stress limits for ASME III, Classes 1, 2, and 3 equipment and equipment support anchors follow:

1. When threaded studs in embedments provide the anchorage, the allowable stress limits are in accordance with the AISC Manual of Steel Construction (7th Edition, 1969).

2. When the anchorage is provided by bolting into embedments, the allowables of ASME III NF are used as indicated in FSAR Amendment 7, Table 3.9B-16 (refer to Question 210.34).

3. When the anchorage is bolting and is through intermediate support structure, the allowables of ASME III NF or AISC are used as a guideline.

4. For tanks and heat exchangers supplied by Westinghouse, the only bolting for supports is on the regenerative heat exchanger. These bolts meet the requirements of Subsection NF and Code Case 1644. Any bolting on supports for Westinghouse supplied Class 2 and 3 pumps are to pressure boundary stress limits.

5. Bolts for flange connections are designed in accordance with ASME III. All other bolts are in accordance with the AISC Manual of Steel Construction (7th Edition, 1969) specifications.

(b) Basic allowable values of shear and tension, including consideration of interaction, are based on manufacturer's test data, onsite test data, and SWEC analysis.

Performance specifications and testing assure that anchor failure is a minimum of four times the basic allowable value for expansion type drilled-in anchors, and three times the basic allowable value for drilled-in bearing type anchors.

The criteria for determining design load on anchor bolts consider base plate flexibility effects where applicable.

For tanks and heat exchangers supplied by Westinghouse, the only bolting for supports provided by Westinghouse is on the regenerative heat exchanger. These bolts meet the requirements of Subsection NF and Code Case 1644. Any bolting on supports for Westinghouse supplied Class 2 and 3 pumps are to pressure boundary stress limits.

NRC Letter: February 9, 1984

Question 210.36

Valve discs are considered part of the pressure boundary and as such should have allowable stress limits. Provide these limits for our review.

Response:

ASME Class 2 and 3 valves are designed to ASME III requirements. The integrity of the Class 2 and 3 valve discs is assured through disc hydrostatic testing. There are no Class 1 BOP valves.

Valve discs in Westinghouse-supplied Class 1, 2, and 3 valves are considered as part of the pressure boundary and are evaluated to the same pressure boundary stress limits as the valves in which they are contained.

Stress limits for Class 1 valve discs are limited, for all operating conditions, to the normal condition stress limits of the valve. The stress limits for Class 1 valves are given in FSAR Table 3.9N-3.

Stress limits for Class 2 and 3 valve discs are the same as the stress limits for the valve for each operating condition. The stress limits for Class 2 and 3 valves are given in FSAR Table 3.9N-8.

Additionally, the leak tightness for Class 1, 2, and 3 valve discs is assured through hydrostatic testing.

TABLE 3.9N-3

ALLOWABLE STRESSES FOR ASME SECTION III CLASS 1 COMPONENTS*

Operating Condition Classification	Vessels/Tanks	Pumps	Valves
Normal	ASME Section III	ASME Section III	ASME Section III
Upset	ASME Section III	ASME Section III	ASME Section III
Faulted	Section 3.9N.1.4.4	Section 3.9N.1.4.4	**

NOTES:

*A test of the components may be performed in lieu of analysis.
**Class 1 Valve Faulted Condition Criteria:

Active

a) Calculate P with Internal Pressure P = 1.25 P
P ≤ 1.5 S

b) Calculate S with
C = 1.5
P = 1.25 P
Q = 0
P = 1.3 x value of P from ASME B+PV Code, Section III
S ≤ 3 S

Inactive

a) Calculate P with Internal Pressure P = 1.50 P
P ≤ 2.4 S

b) Calculate S with
C = 1.5
P = 1.50 P
Q = 0
P = 1.3 x value of P from ASME B+PV Code, Section III
S ≤ 3 S

P , P , Q , C , S , and S as defined by Section III, ASME Code.

REPLACE WITH INSERT A

TABLE 3.9N-3

INSERT A

ACTIVE	INACTIVE
a) Calculate Pm from para. NB3545.1 with Internal Pressure Ps = 1.25Ps Pm ≤ 1.5Sm	a) Calculate Pm from para. NB3545.1 with Internal Pressure Ps = 1.50 Ps Pm ≤ 2.4Sm or 0.7 Su
b) Calculate Sn from para. NB3545.2 with Cp = 1.5 Ps = 1.25Ps Qt2 = 0 Ped = 1.3X value of Ped from equations of 3545.2(b)(1) Sn ≤ 3Sm	b) Calculate Sn from para. NB3545.2 with Cp = 1.5 Ps = 1.50Ps Qt2 = 0 Ped = 1.3X value of Ped from equations of NB3545.2(b)(1) Sn ≤ 3Sm

P_e, P_m, P_b, Q_t, C_p, S_n & S_m as defined by Section III, ASME Code

NRC Letter: February 9, 1984

Question 210.37

Due to a long history of problems dealing with inoperable and incorrectly installed snubbers, and due to the potential safety significance of failed snubbers in safety-related systems and components, it is requested that maintenance records for snubbers be documented as follows:

Preservice Examination

A preservice examination should be made on all snubbers listed in Tables 3.7-4a and 3.7-4b of Standard Technical Specification 3/4.7.9. This examination should be made after snubber installation but not more than six months prior to initial system preoperational testing, and should as a minimum verify the following:

(1) There are no visible signs of damage or impaired operability as a result of storage, handling, or installation.

(2) The snubber location, orientation, position setting, and configuration (attachments, extensions, etc.) are according to design drawings and specifications.

(3) Snubbers are not seized, frozen, or jammed.

(4) Adequate swing clearance is provided to allow snubber movement.

(5) If applicable, fluid is to the recommended level and is not leaking from the snubber system.

(6) Structural connections such as pins, fasteners and other connecting hardware such as lock nuts, tabs, wire, and cotter pins are installed correctly.

If the period between the initial preservice examination and initial system preoperational test exceeds six months due to unexpected situations, reexamination of items 1, 4, and 5 shall be performed. Snubbers which are installed incorrectly or otherwise fail to meet the above requirements must be repaired or replaced and reexamined in accordance with the above criteria.

Preoperational Testing

During preoperational testing, snubber thermal movements for systems whose operating temperature exceeds 250°F should be verified as follows:

(a) During initial system heatup and cooldown, at specified temperature intervals for any system which attains operating temperature, verify the snubber expected thermal movement.

(b) For those systems which do not attain operating temperature, verify via observation and/or calculation that the snubber will accommodate the projected thermal movement.

(c) Verify the snubber swing clearance at specified heatup and cooldown intervals. Any discrepancies or inconsistencies shall be evaluated for cause and corrected prior to proceeding to the next specified interval.

The above described operability program for snubbers should be included and documented by the preservice inspection and preoperational test programs.

The preservice inspection must be a prerequisite for the preoperational testing of snubber thermal motion. This test program should be specified in Chapter 14 of the FSAR.

Response:

Duquesne Light Company is developing a Preservice Inspection (PSI) Program which will include snubber inspection criteria. The PSI Program will be submitted to the NRC in June 1984.

NRC Letter: February 9, 1984

Question 210.38

Provide the stress categories and limits for core support/structures and include the applicable codes used for evaluation of the faulted condition.

Response:

The BVPS-2 core support structures are similar to those of other Westinghouse plants recently reviewed by the NRC. The design and construction of the BVPS-2 core support structures conforms to the requirements of Subsection NG of Section III of the ASME Code, except that the internals were not Code stamped and a plant specific stress report has not been written. This is because procurement of the BVPS-2 core support structures predated the inclusion of Subsection NG into the ASME Code. The FSAR has been amended to reflect this.

The BVPS-2 FSAR outlines the Code stress limits and loading combinations used in evaluating the core support structures and internal structures in Tables 3.9N-12, 3.9N-13, and 3.9N-14 and FSAR Section 3.9N-5.

to assure that the core is intact with acceptable heat transfer geometry following transients arising from abnormal operating conditions.

6. Following the DBA, BVPS-2 shall be capable of being shut down and cooled in an orderly fashion so that fuel cladding temperatures are kept within specified limits. This implies that the deformation of certain critical reactor internals must be kept sufficiently small to allow core cooling.

The functional limitations for the core structures during the design basis accident are shown in Table 3.9N-11. To ensure no column loading of rod cluster control guide tubes, the upper core plate deflection shall not exceed the value shown in Table 3.9N-11.

Details of the dynamic analyses, input forcing functions, and response loadings are presented in Section 3.9B.2.

The following identifies the basis for the design stress and deflection criteria:

Allowable Stresses

For normal operating conditions Section III of the ASME Boiler and Pressure Vessel Code is used as a basis for evaluating acceptability of calculating stresses. Both static and alternating stress intensities are considered. It should be noted that the allowable stresses in Section III of the ASME Code are based on unirradiated material properties. The strength of Type 304 stainless steel used for internals is not changed when exposed to an irradiation level of less than 1 x 10^{21} neutron per sq cm and increases when exposed to high levels; thus, it is considered that use of the allowable stresses in Section III is appropriate and conservative for irradiated internal structures.

The allowable stress limits during the DBA used for the core support structures are defined in the 1974 edition of the ASME Code for Core Support Structure, Subsection NG, and the Criteria for Faulted Conditions. Stress limits for reactor vessel internal structures are presented in Table 3.9N-12. Design and construction for core support structures meet Subsection NG in full.

INSERT C

3.9N.6 References for Section 3.9

Biggs, J. M. 1964. Introduction to Structural Dynamics. McGraw-Hill Book Company, New York, N.Y.

Bloyd, C.N. and Singleton, N.R. 1975. UHI Plant Internals Vibration Measurement Program and Pre- and Post- Hot Functional Examinations, WCAP-8516-P (Proprietary) and WCAP-8517 (Non-Proprietary).

Section 3.9N.5.4

INSERT C

The design and construction of the BVPS-2 core support structures conforms to the requirements of Subsection NG, except that the core support structures are not Code stamped and a plant specific stress report has not been written. This is because procurement of the BVPS-2 core support structures predated the inclusion of Subsection NG into the ASME Code.

NRC Letter: February 9, 1984

Question 210.39

Does the design criteria for component supports in Beaver Valley 2 systems categorize the stresses produced by seismic anchor point motion of piping and the thermal expansion of piping as primary or secondary? It is the staff's position that for the design of component supports, and stresses produced by seismic anchor point motion of piping and the thermal expansion of piping should be categorized as primary stresses.

Response:

The design criteria for the component supports in BVPS-2 systems do not categorize the stresses produced by seismic anchor point motion of piping and the thermal expansion of piping as primary or secondary.

Mechanical loads and thermal expansion loads produced by piping are combined and imposed upon the piping supports. Combined load effects on the supports are maintained within the limits provided, as addressed in the response provided for Question 210.34, Amendment 6.

The design criteria used by Westinghouse for the design of supports for Class 2 and 3 auxiliary equipment categorizes the stresses produced by seismic anchor point motion and the thermal expansion of piping as primary stresses.

NRC Letter: February 29, 1984

Question 210.40 (Section 3.9.6)

There are several safety systems connected to the reactor coolant pressure boundary that have design pressure below the rated reactor coolant system (RCS) pressure. There are also some systems which are rated at full reactor pressure on the discharge side of pumps but have pump suction below RCS pressure. In order to protect these systems from RCS pressure, two or more isolation valves are placed in series to form the interface between the high pressure RCS and the low pressure systems. The leak tight integrity of these valves must be ensured by periodic leak testing to prevent exceeding the design pressure of the low pressure systems.

Pressure isolation valves are required to be Category A or AC per IWV-2000 and to meet the appropriate requirements of IWV-3420 of Section XI of the ASME Code except as discussed below.

Limiting Conditions for Operation (LCO) are required to be added to the Technical Specifications which will require corrective action; i.e., shutdown or system isolation when the final approved leakage limits are not met. Also, surveillance requirements which will state the acceptable leak rate testing frequency shall be provided in the Technical Specifications.

Periodic leak testing of each pressure isolation valve is required to be performed at least once per each refueling outage, after valve maintenance prior to return to service, and for systems rated at less than 50 percent of RCS design pressure each time the valve has moved from its fully closed position unless justification is given. The testing interval should average to be approximately one year. Leak testing should also be performed after all disturbances to the valves are complete, prior to reaching power operation following a refueling outage, maintenance, etc.

The staff's present position on leak rate limiting conditions for operation must be equal to or less than 1 gallon per minute (gpm) for each valve to ensure the integrity of the valve, demonstrate the adequacy of the redundant pressure isolation function and give an indication of valve degradation over a finite period of time. Significant increases over this limiting value would be an indication of valve degradation from one test to another.

The Class 1 to Class 2 boundary will be considered the isolation point which must be protected by redundant isolation valves.

In cases where pressure isolation is provided by two valves, both will be independently leak tested. When three or more valves provide isolation, only two of the valves need to be leak tested.

Provide a list of all pressure isolation valves included in your testing program along with four sets of Piping and Instrument Diagrams which describe your reactor coolant system pressure isolation valves. Also discuss in detail how your leak testing program will conform to the above staff position.

Response:

Duquesne Light Company is developing a Preservice Inspection (PSI) Program for submittal to the NRC in June 1984. This program will include inservice testing of valves in accordance with ASME Section XI, Subsection IWV, 1980 Edition through Winter 1980 Addenda.

In the section of the PSI Program addressing IWV, Duquesne Light Company will identify the criteria, valve categroization and applicable relief requests. It will also identify the procedure(s) utilized for valve Leak Rate Test (IWV-3420), which will include the address of reactor coolant system isolation valves.

As the valve inservice inspection procedures will follow the PSI Program development and submittal to the NRC, the specific valve listing is presently estimated to be completed within six months after the submittal of the PSI Program.

NRC Letter: February 9, 1984

Question 210.41

Provide a schedule for completion of your program for inservice testing of pumps and valves including any request relief from ASME Section XI requirements.

Response:

The Inservice Inspection (ISI) Program submittal is presently scheduled for June 1985. Detailed procedures establishing frequency of testing for specific pumps and valves will be developed concurrent with the ISI Program submittal to the NRC and will be available for review at that time.

Duquesne Light Company

Beaver Valley Power Station - Unit 2

Effects of Oversized Pipe Fittings - Slide Presentation

PRELIMINARY

OBJECTIVE OF PRESENTATION

- TO RESOLVE NRC'S CONCERN REGARDING POTENTIAL
  - THERMAL LOAD INCREASE AT EQUIPMENT NOZZLES, RESTRAINTS AND ANCHORS
  - SHIFT IN THERMAL STRESSES FROM FITTINGS TO STRAIGHT PIPE
- THESE OBJECTIVES WILL BE ACCOMPLISHED BY
  - REVIEW OF PREVIOUS PRESENTATION TO HIGHLIGHT SOME OF THE MISSED POINTS
  - REBUTTAL OF SOME NRC STATEMENTS
  - ADDITIONAL ANALYSIS OF GENERIC MODELS 3 AND 7
  - ADDITIONAL ANALYSIS OF SPECIFIC RHS PIPING PROBLEMS
- IN THE END WE WILL SHOW THAT THE CONCERN FOR THERMAL LOADS AND STRESSES IS NOT WARRANTED WHEN THE ENTIRE DESIGN PROCESS AND LOAD FORMULATION IS CONSIDERED

LOADS APPLIED TO PIPING

- STATIC
  - PRESSURE
  - THERMAL EXPANSION
  - LOCAL THERMAL EFFECTS
  - DEADWEIGHT
  - EARTHQUAKE DISPLACEMENTS
  - BUILDING SETTLEMENT
- DYNAMIC
  - FLUID TRANSIENTS
  - EARTHQUAKE INERTIAL
  - HYDRODYNAMIC

FIGURE 1.1

PRELIMINARY

PIPING DESIGN PROCESS

- FACTORS THAT EFFECT PIPING RESPONSE
- CODE REQUIREMENTS
- U.S. REGULATORY REQUIREMENTS
- LOADING CONDITIONS
- ANALYTICAL METHODS
- EARTHQUAKE MOTION DEFINITION
- DAMPING
- RESULTS OF PARAMETRIC STUDIES

FIGURE 1.2

PRELIMINARY

FACTORS THAT EFFECT PIPING RESPONSE

- INHERENT FLEXIBILITY
- LOCATION AND TYPES OF SUPPORTS
- COMPONENT DIMENSIONAL VARIATIONS/TOLERANCES
- DAMPING CHARACTERISTICS OF PIPING & SUPPORTS
- MASS DISTRIBUTION
- SMALL GAPS & FREEPLAY IN SUPPORT SYSTEMS
- PIPING GEOMETRY

FIGURE 1.3

CODE REQUIREMENTS

- CODE EVOLUTION
- FAILURE MODES
- STRESS CATEGORIES
- STRESS COMBINATIONS & LIMITS
- DESIGN MARGINS
- CODE APPROACH TO PIPING ANALYSIS

FIGURE 2.1

CODE DEVELOPMENT

1935 - ASA B31.1 "CODE FOR PRESSURE PIPING"

1967 - ANSI B31.1 "POWER PIPING CODE"

1969 - ANSI B31.7 "NUCLEAR POWER PIPING CODE"

1971 - "ASME BOILER AND PRESSURE VESSEL CODE SECTION III"

FIGURE 2.2

FIGURE 2.3

STRUCTURAL FAILURE MODES CONSIDERED BY ASME SECTION III

BURSTING, GROSS DISTORTION, AND ELASTIC INSTABILITY

PROGRESSIVE DISTORTION

FATIGUE FAILURE

PRELIMINARY

80-17980

STRESS CATEGORIES

FIGURE 2.4

PRIMARY STRESS

CAUSES BURSTING, OR TENSILE IN-
STABILITY NOT SELF LIMITING

SECONDARY STRESS

CAUSE RATCHETTING OR INCREMENTAL
COLLAPSE IS SELF LIMITING

PEAK STRESS

CONTRIBUTES TO FATIGUE FAILURE

CODE STRESS ALLOWABLES

ASME CLASS 1

$$S_M = \text{THE SMALLER OF } \begin{cases} 2/3\ S_y \\ 1/3\ S_u \end{cases}$$

ASME CLASS 2/3 & B 31.1

$$S = \text{THE SMALLER OF } \begin{cases} 5/8\ S_y \\ 1/4\ S_u \end{cases}$$

FIGURE 2.5

PRELIMINARY

ASME III CLASS 1

STRESS & FATIGUE ANALYSIS REQUIREMENTS PER NB3650

	NORMAL AND UPSET CONDITIONS	EMERGENCY CONDITIONS	FAULTED CONDITIONS
PRIMARY STRESS INTENSITY (EQUATION 9)	$B_1(\frac{PD_o}{2t}) + B_2(\frac{D_o}{2I})M_i \quad \le 1.5 S_m$	$\le 2.25 S_m$	$\le 3.0 S_m$
PRIMARY + SECONDARY STRESS RANGE (EQUATION 10)	$S_n = C_1(\frac{P_o D_o}{2t}) + C_2(\frac{D_o}{2I})M_i + \frac{1}{2(1-\nu)}E\alpha\lvert\Delta T_1\rvert + C_3 E_{ab}\lvert\alpha_a T_a - \alpha_b T_b\rvert \quad \le 3S_m$	N/R	N/R
PEAK STRESS RANGE (EQUATION 11)	$S_p = K_1 C_1(\frac{P_o D_o}{2t}) + K_2 C_2(\frac{D_o}{2I})M_i + \frac{1}{2(1-\nu)}K_3 E\alpha\lvert\Delta T_1\rvert + K_3 C_3 E_{ab}\lvert\alpha_a T_a - \alpha_b T_b\rvert + \frac{1}{1-\nu}E\alpha\lvert\Delta T_2\rvert$	N/R	N/R
THERMAL EXPANSION RANGE (EQUATION 12)	$S_e = C_2(\frac{D_o}{2I})M_i \quad \le 3S_m$	N/R	N/R
PRIMARY + SECONDARY MEMBRANE, + BENDING STRESS (EQUATION 13)	$C_1(\frac{P_o D_o}{2t}) + C_2(\frac{D_o}{2I})M_i + C_3' E_{ab}\lvert\alpha_a T_a - \alpha_b T_b\rvert \le 3S_m$	N/R	N/R
ALTERNATING STRESS (EQUATION 14)	$S_{alt} = \frac{1}{2} K_e S_p$	N/R	N/R
USAGE FACTOR	$U = \frac{\text{ACTUAL NO. CYCLES}}{\text{ALLOWABLE NO. CYCLES}} \qquad \Sigma U \le 1.0$	N/R	N/R

FIGURE 2.6

FIGURE 2.7

ASME III CLASS 2 & 3

STRESS ANALYSIS REQUIREMENTS PER NC3650 & ND3650

	NORMAL AND UPSET CONDITIONS	EMERGENCY CONDITIONS	FAULTED CONDITIONS
SUSTAINED LOADS (EQUATION 8)	$\frac{PD_o}{4t} + \frac{(0.75i)M_A}{Z} \leq S_h$	N/R	N/R
OCCASIONAL LOADS (EQUATION 9)	$\frac{PD_o}{4t} + \frac{(0.75i)M_A}{Z} + \frac{(0.75i)M_B}{Z} \leq 1.2\,S_h$	$\leq 1.8\,S_h$	$\leq 2.4\,S_h$
THERMAL EXPANSION LOADS (EQUATION 10)	$\frac{iM_C}{Z} \leq S_A$ $\leq f(1.25S_C + 0.25S_h)$	N/R	N/R
SUSTAINED + THERMAL EXPANSION LOADS (EQUATION 11)	$\frac{PD_o}{4t} + \frac{(0.75i)M_A}{Z} + \frac{(i)M_C}{Z} \leq S_A + S_h$	N/R	N/R

PRELIMINARY

FIGURE 2.8

CODE APPROACH TO PIPING ANALYSIS

- DEVELOP COMPUTER MODEL
- INCLUDE FLEXIBILITY OF VARIOUS PIPING COMPONENTS
- CALCULATE FORCES, MOMENTS, DEFLECTIONS & ROTATIONS
- CALCULATE NOMINAL STRESS AND MODIFY BY USING STRESS INTENSIFICATION FACTORS OR STRESS INDICES

ASME SECTION III, 1971 ED. TO WINTER 1972

SELECTED CODE REQUIREMENTS RELATING TO ELBOWS

CODE PARAGRAPH	DESCRIPTION OF ITEM
NB/NC-3641.1	Requires that manufacturer's tolerances be considered in calculating minimum wall thickness.
NB/NC-3642.1	Thickness after bending curved segments of pipe must meot minimum wall thickness requirements.
NB-3642.2	Elbows manufactured in accordance with ANSI B16.9 and B16.28 are acceptable for the same nominal thickness of pipe except the crotch region of short radius elbows (B16.28) must be 20% thicker than minimum wall thickness.
NB/NC-3650	Stress evaluation equations use nominal wall thickness.
NB-3672.5 & NC-3672.9	States that expansion stress calculations shall be based upon the least cross-sectional area of the pipe or fitting, using nominal dimensions.
NC-3673.2(e)	States that nominal dimensions shall be used for flexibility calculations.
NB-3683.1	States in part that for ANSI B16.9 and B16.28 piping products nominal dimensions for the equivalent pipe are used for diameter and wall thickness terms.

FIGURE 2.9

PRELIMINARY

PIPING DESIGN PROCESS

- PIPING COMPONENTS MANUFACTURED IN ACCORDANCE WITH ASME REQUIREMENTS.
- PIPING ANALYSIS PROCEDURES FOLLOW ALL ASME DESIGN REQUIREMENTS.
- PIPING FABRICATED AND ERECTED IN ACCORDANCE WITH ASME REQUIREMENTS.

FIGURE 2.10

PRELIMINARY

ANSI STANDARD B16.9

- INCLUDES DESIGN AND DIMENSIONAL REQUIREMENTS FOR STEEL BUTTWELDING FITTINGS.
- STIPULATES DIMENSIONS FOR THE INSIDE DIAMETER AND OUTSIDE DIAMETERS AT THE WELDED ENDS ONLY.
- STIPULATES MINIMUM WALL THICKNESS REQUIREMENTS FOR THE ENTIRE FITTING.
- EXCLUDED ARE ANY:
  - MAXIMUM WALL THICKNESSES BETWEEN WELDED ENDS.
  - MAXIMUM PIPE OUTSIDE DIAMETER BETWEEN WELDED ENDS.

FIGURE 2.11

PRELIMINARY

MSS-SP-87 STANDARD *

- LIMITED TO CLASS I NUCLEAR PIPING APPLICATIONS.
- SHORT RADIUS ELBOW WALL THICKNESS MAY BE 1.5 TIMES NOMINAL.
- ELBOWS WITH A COUNTERBORE MAY USE NEXT HIGHER SCHEDULE, OR MAY BE 1.33 TIMES NOMINAL WALL.
- BODY THICKNESS OF TEES AWAY FROM CROTCH REGION MAY BE 2.5 TIMES NOMINAL WALL THICKNESS OF ATTACHED RUN PIPE.

* ISSUED IN 1977 AND IS NON-MANDATORY

FIGURE 2.12

ANALYTICAL METHODS

LINEAR ANALYSIS METHODS

- STATIC
- DYNAMIC
  - RESPONSE SPECTRA MODAL ANALYSIS
  - TIME HISTORY MODAL SUPPERPOSITION
  - DIRECT TIME HISTORY INTEGRATION

NON-LINEAR ANALYSIS METHODS

FIGURE 3.1

GENERATION OF ARS

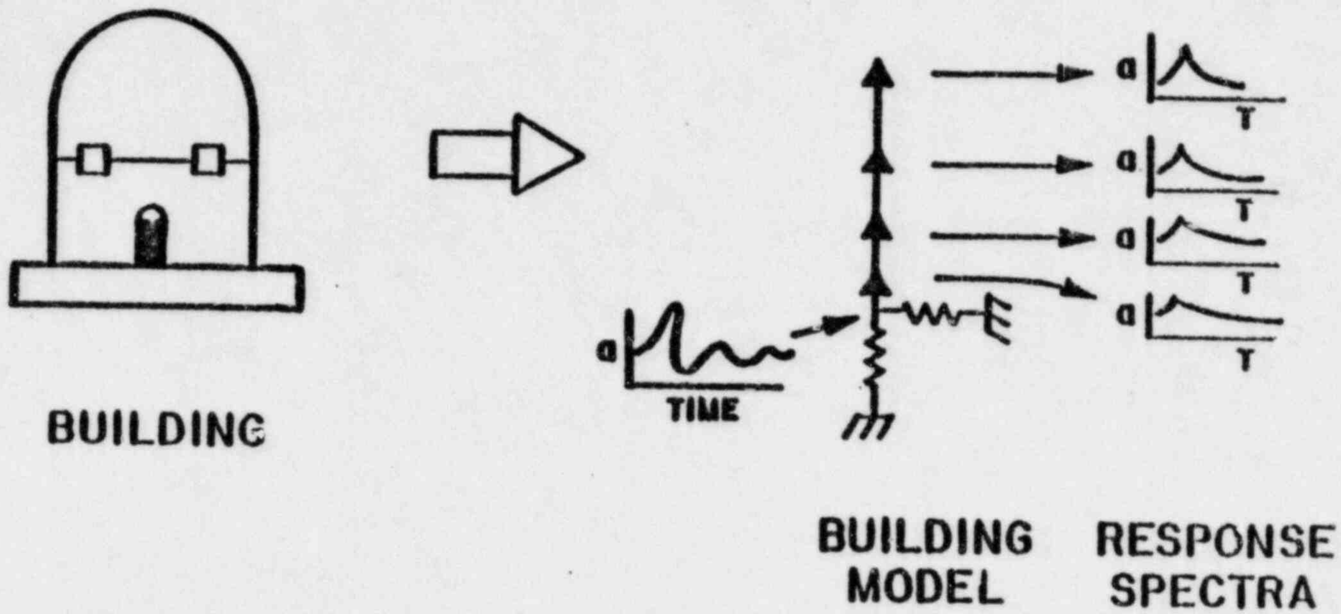


FIGURE 4.1

PRELIMINARY

GENERATION OF AN AMPLIFIED RESPONSE SPECTRUM

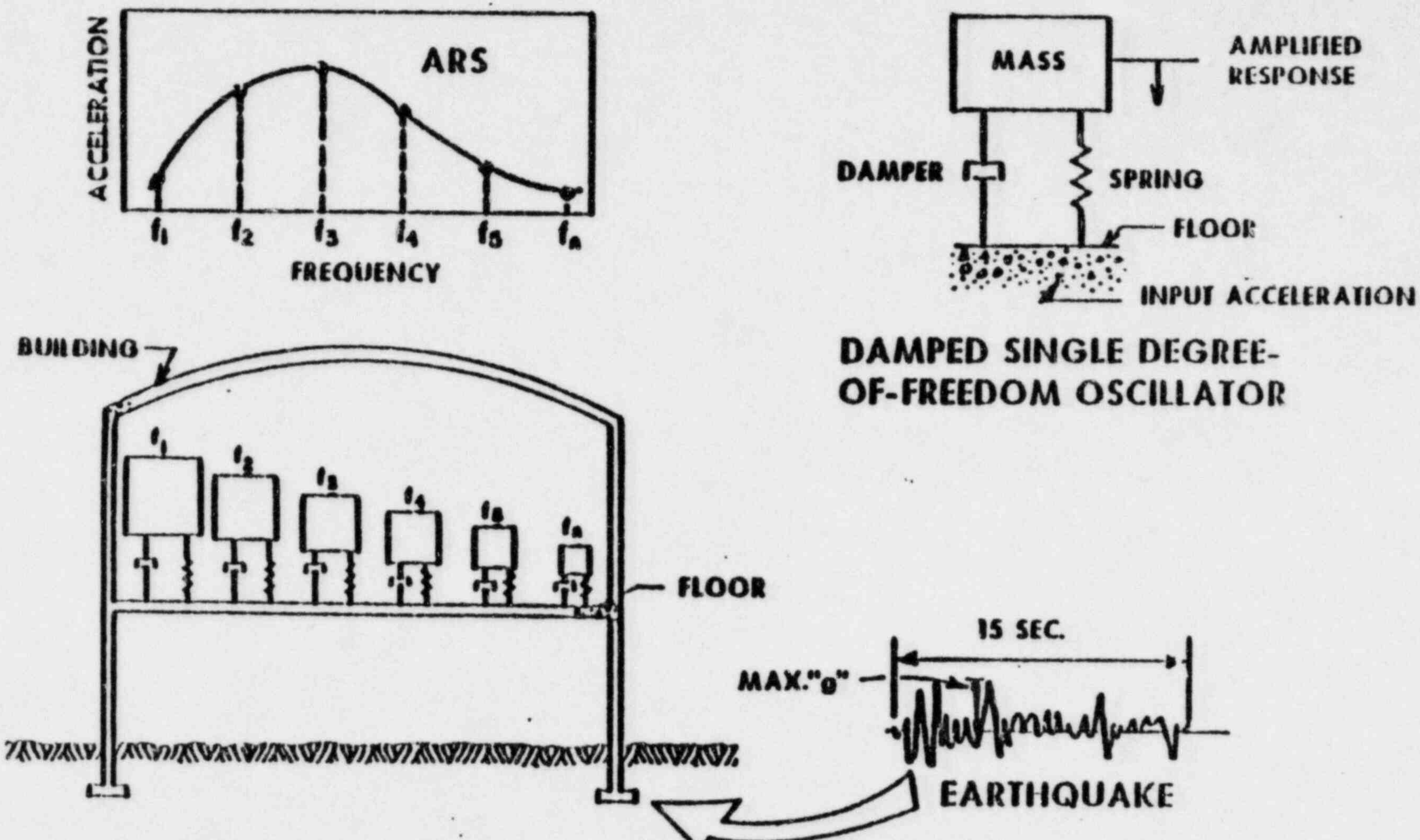
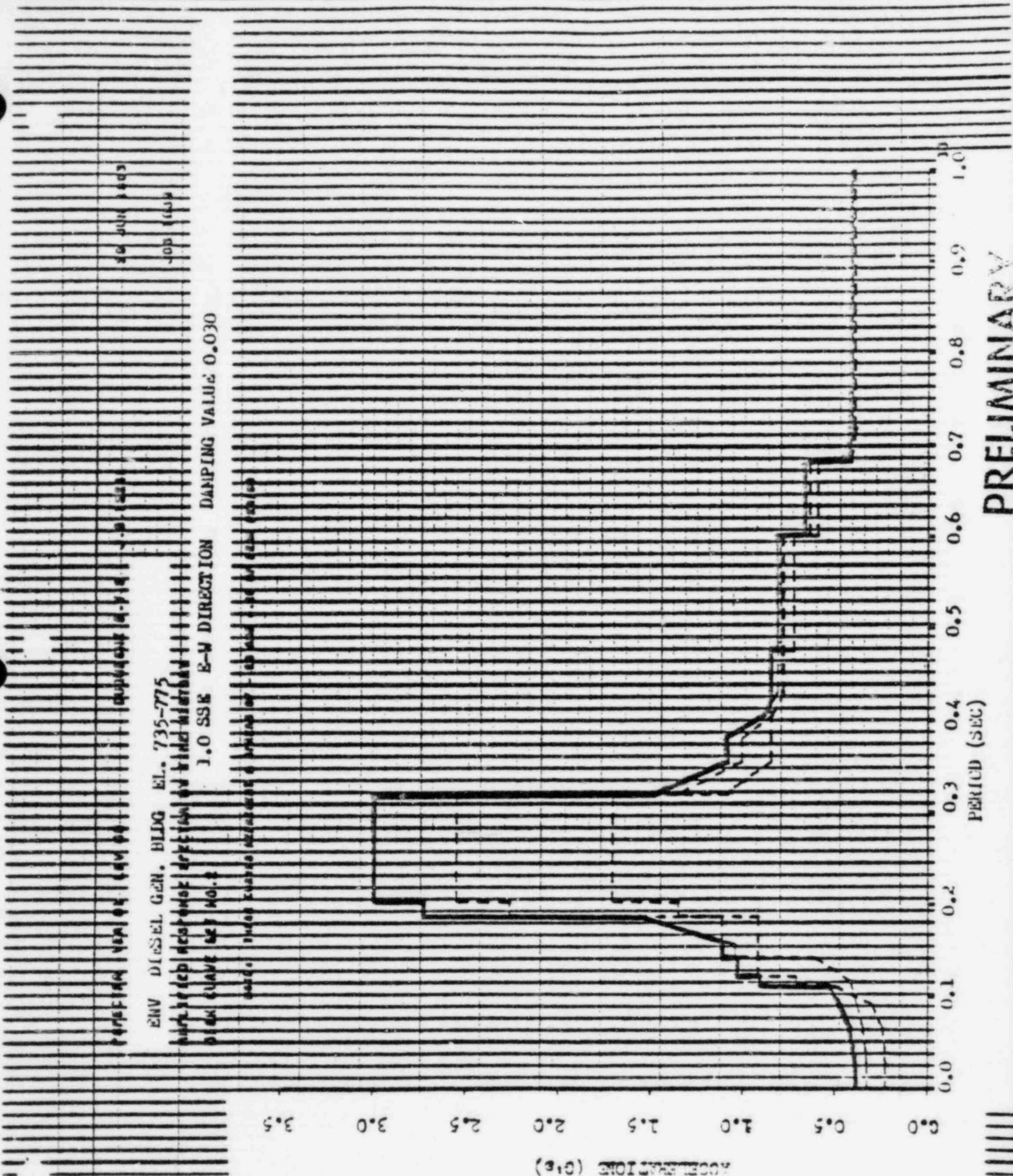


FIGURE 4.2



ENV DIESEL GEN. BLDG EL. 735-775
1.0 SSE E-W DIRECTION DAMPING VALUE 0.030
ACCELERATIONS (G's)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
PERIOD (SEC)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
PRELIMINARY

FIGURE 4.3

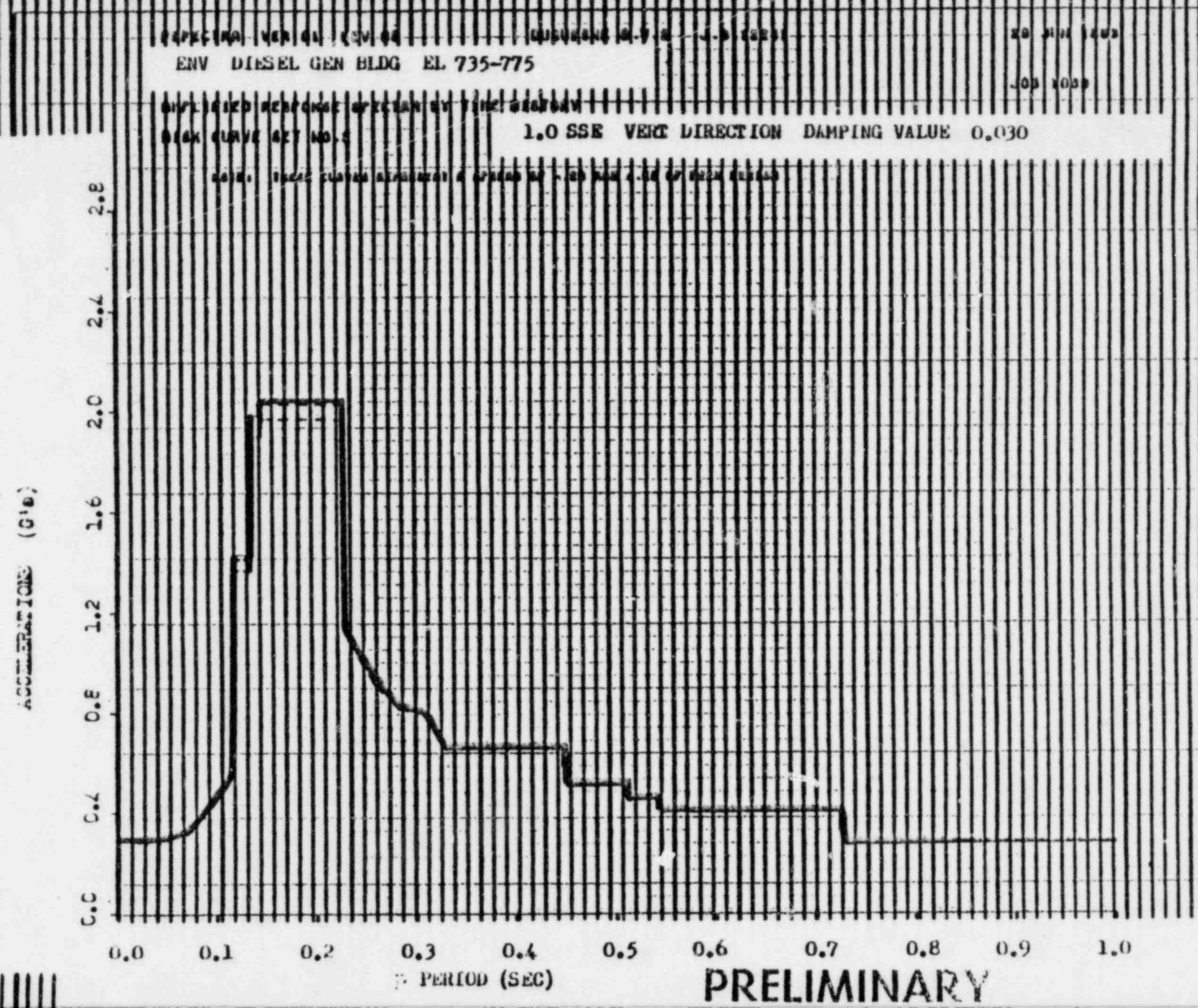

ENV DIESEL GEN BLDG EL 735-775
1.0 SSE VERT DIRECTION DAMPING VALUE 0.030
ACCELERATIONS (G's)
0.0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
PERIOD (SEC)
PRELIMINARY

FIGURE 4.4

PRELIMINARY

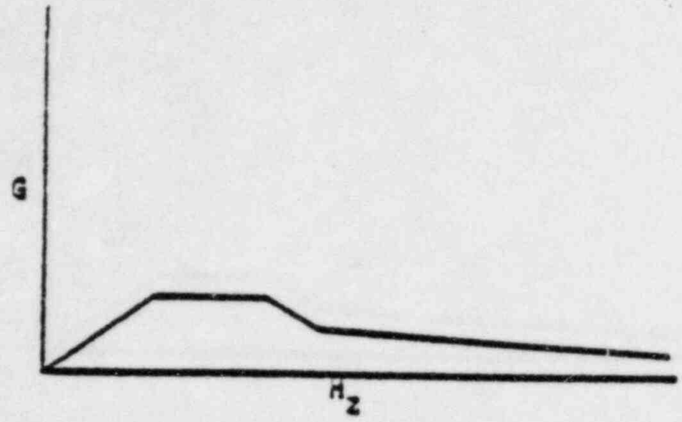
MAXIMUM SSE SEISMIC RESPONSE

SPECTRA FOR DIESEL GENERATOR BUILDING

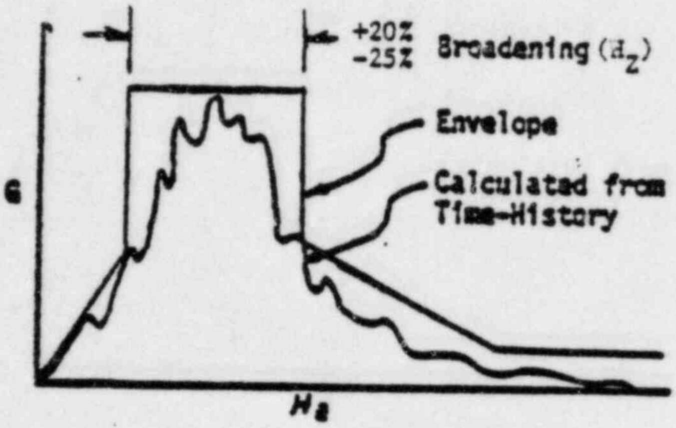
ELEVATION 733-775

EQUIPMENT DAMPING	EAST-WEST (X-AXIS)	VERTICAL (Y-AXIS)	NORTH-SOUTH (Z-AXIS)
1/2 %	6.64 g	4.70 g	6.22 g
1 %	4.93 g	3.54 g	5.23 g
3 %	3.00 g	2.05 g	3.17 g
4 %	2.49 g	1.75 g	2.71 g

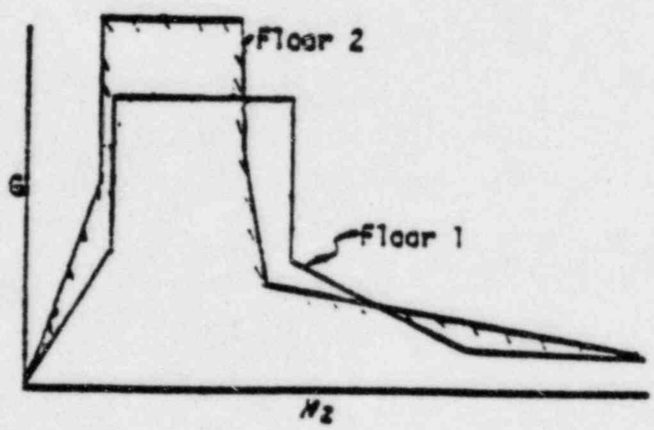
FIGURE 4.5



Base Spectra Horizontal North-South



Floor 1 Spectra Horizontal North-South



Envelope Spectra Horizontal North-South

CONSERVATISM IN SEISMIC RESPONSE SPECTRA

FIGURE 4.6

PRELIMINARY

TYPES OF DAMPING

- STRUCTURAL DAMPING (5 - 10% CRITICAL)
  SLIPPAGE ON SUPPORTS, JOINT SLIPPAGE AND FRICTIONAL EFFECTS.

- IMPACT DAMPING (5 - 10% CRITICAL)
  IMPACT OR BANGING IN THE CLOSING OF GAPS IN SUPPORTS.

- MATERIAL DAMPING (0.04 - C.2% CRITICAL)
  HYSTERSIS ENERGY LOSS

FIGURE 5.1

PRELIMINARY

HISTORIC DEVELOPMENT OF DAMPING

SOURCE	YEAR	PERCENT OF CRITICAL DAMPING	LIMIT
HOUSNER	1963	0.5	-
NEWMARK	1969	0.5	$< 1/4\ S_Y$
		0.5 TO 1.0	$< 1/2\ S_Y$
		2.0	$< S_Y$
		5.0	$> S_Y$
REG. GUIDE 1.61 (INTERIM LOWER BOUND)	1973	1.0	OBE - PIPE ≤ 12"
		2.0	OBE- > 12"
		2.0	SSE - PIPE ≤ 12"
		3.0	SSE > 12"
NEWMARK AND HALL	1978	1.0 TO 2.0	$\leq 1/2\ S_Y$
		2.0 TO 3.0	$\leq S_Y$

FIGURE 5.2

FIGURE 5.3

COMPARISON OF DAMPING VALUES IN PIPING SYSTEMS

SOURCE	PERCENT OF CRITICAL DAMPING	
	OBE (.67 YIELD)	SSE (.9 YIELD)
BEAVER VALLEY 2 ANALYSIS	0.5	1.0
REG. GUIDE 1.61		
LARGE PIPING (>12")	2.0	3.0
SMALL PIPING	1.0	2.0
MEASURED + NORMALIZED REF. 2 - STEVENSON'S PAPER	10.0	12.7
MEASURED REF. 11 - JOYO TEST	3.3 TO 23.6	---
MEASURED REF. 9 - SMALL BORE TEST	10 TO 20	---
MEASURED REF. 10 - SNAPBACK TEST	5 to 11	---

PRELIMINARY

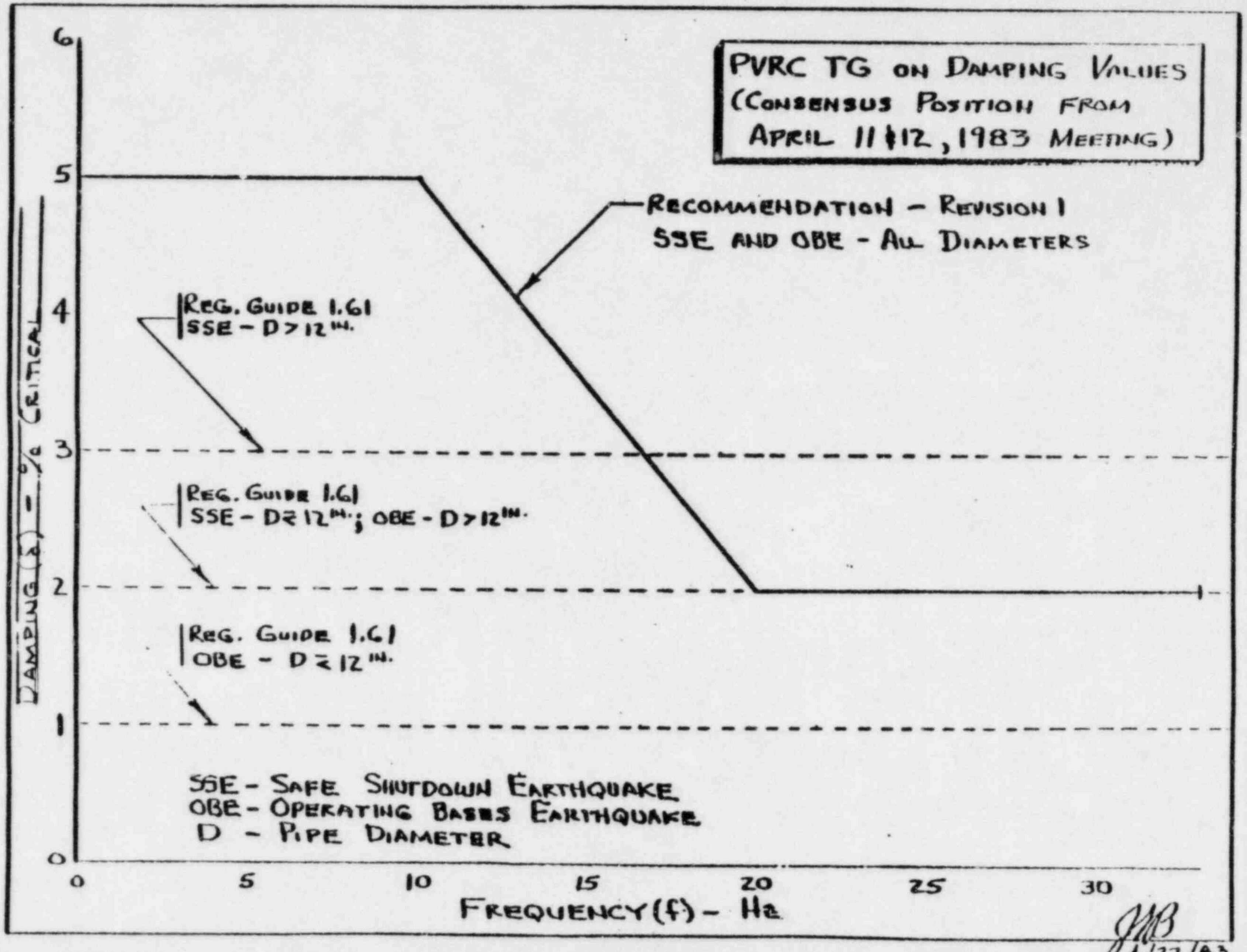


FIGURE 5.4

ATTACHMENT 2

PRELIMINARY

SKETCH SHEET

PRELIMINARY

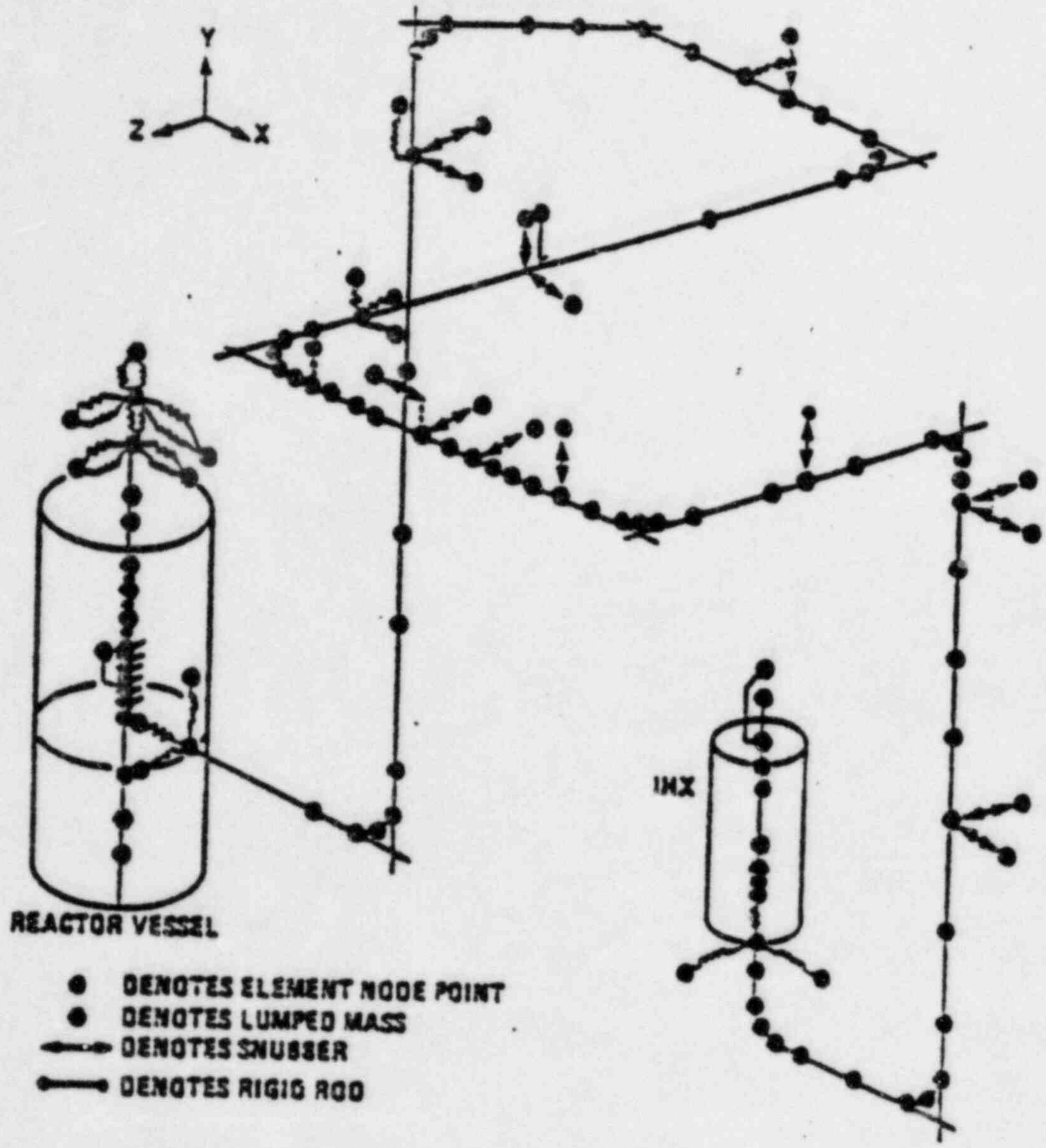


FIGURE I — IDEALIZATION OF PROTOTYPIC PIPING LEG

G. M. Hubert - LMFBR Study Ref. (11)

FIGURE 6.1

TABLE 1. MAXIMUM REACTOR VESSEL NOZZLE LOADS CALCULATED USING TWO ANALYTICAL METHODS

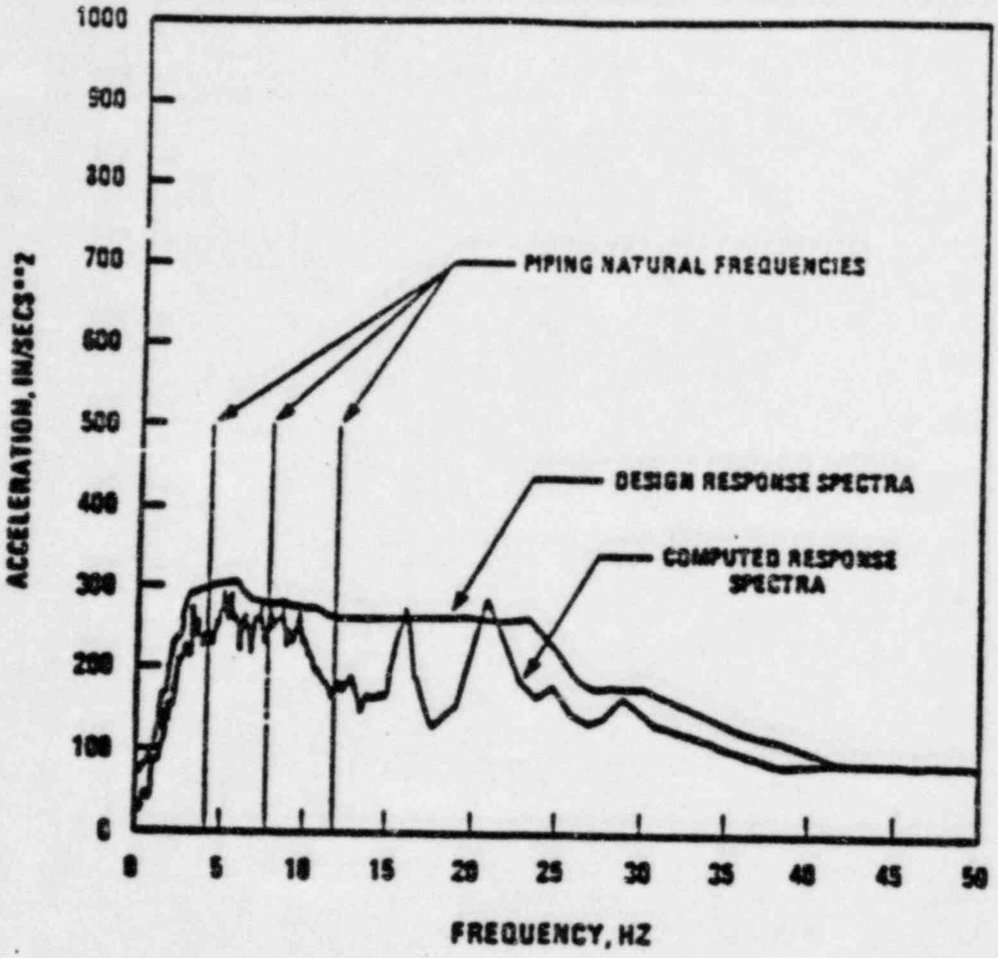
Analytical Method	Nozzle Load F_x Kg	F_y Kg	F_z Kg	M_x Kg-m	M_y Kg-m	M_z Kg-m
Response Spectrum Analysis	8740	8470	8130	38500	94300	89100
Modal Superposition Time History Analysis	5080	6940	4720	32700	54400	73800
% Difference Between Methods	42	18	42	15	42	11

Response spectra for response spectrum analysis are smoothened and peak broadened.

Time histories for modal superposition time history analysis include 10% expansion and contraction.

G. M. Hubert - LMFBR Study Ref. (11)

FIGURE 6.2



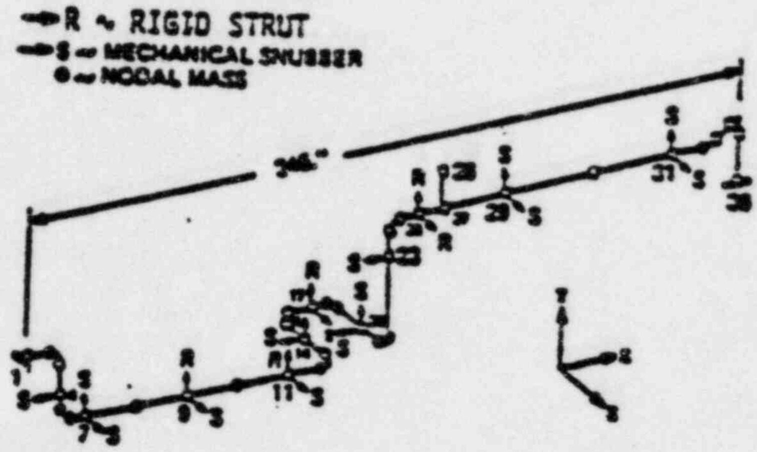
—COMPARISON OF DESIGN RESPONSE SPECTRA AND COMPUTED RESPONSE SPECTRA OF VERTICAL EARTHQUAKE SHOCK

FIGURE 6.3

MODAL CONTRIBUTION FROM 12.31 Hz MODE TO REACTOR VESSEL NOZZLE RESPONSE

Analytical Method	Nozzle Load F. Kg	F, Kg	F, Kg	M. Kg-m	M, Kg-m	M. Kg-m
Response Spectrum Analysis	1880	4420	99	990	900	39900
Modal Superposition Time History Analysis	1410	3330	75	750	680	30000
% Difference Between Methods	25	25	24	24	24	25

FIGURE 6.4



SMALL BORE PIPING SEISMIC TEST FINDINGS

- L. K. SEVERUD ET AL REF. (7)

FIGURE 6.5

PRELIMINARY

Table 3: Seismic Support Loads with Snubbers, LBS

HANGER	NODE	RESPONSE SPECTRA			TIME DOMAIN ANALYSIS				TEST
NO.	NO.	RUN 1	2	3	4	5	6	7	8
H - 11	4 - X	109.7	29.7	55.0	9.0	18.3	18.9	18.6	6.8
10	7 - Y	44.7	24.1	17.9	.0	5.7	6.5	6.0	4.6
10	7 - Z	270.5	262.4	236.1	115.9	117.5	114.7	123.8	33.3
9	9 - Z	233.2	222.6	212.8	96.3	98.4	103.2	103.6	45.0
8	11 - Z	537.7	320.8	228.9	123.8	132.7	152.8	142.5	58.8
7	14 - X	337.1	187.8	147.3	19.1	31.6	47.6	34.7	1.5
6	17 - Z	671.7	455.1	389.7	246.3	241.7	227.7	245.9	115.6
5	20 - X	286.5	231.5	101.4	9.6	12.0	21.0	12.6	8.4
5	20 - Y	318.9	230.5	146.1	.0	8.4	19.9	10.1	3.2
4	23 - X	112.9	72.7	45.3	.0	25.5	51.5	31.3	19.1
2	29 - Y	213.5	145.7	79.9	15.8	13.8	16.3	14.4	2.5
2	29 - Z	489.3	344.4	201.8	122.7	120.0	129.4	126.5	50.0
1	31 - Y	215.8	174.7	75.7	18.0	22.2	28.1	23.9	118.5*
H - 1	31 - Z	325.5	223.8	145.5	143.6	145.6	160.6	152.3	74.1

1. Response spectra analysis - summation of absolute values of modal responses.
2. Response spectra analysis - modal responses combined according to U. S. NRC Regulatory Guide 1.92.
3. Response spectra analysis - modal responses combined by SRSS method.
4. Time domain analysis - 2% system damping, snubber damping, snubber gaps = .015 inch.
5. Same as Run 4 except snubber gaps = 0.
6. Time domain analysis - snubber gaps = 0. 2% system damping, snubber damping = 5% of total.
7. Time domain analysis - snubber gaps = 0. 2% system damping, snubber damping = 50% of total.
8. Test results (with snubbers).

*Sole response underpredicted by analyses. Cause unknown, to be investigated in future testing and analyses.

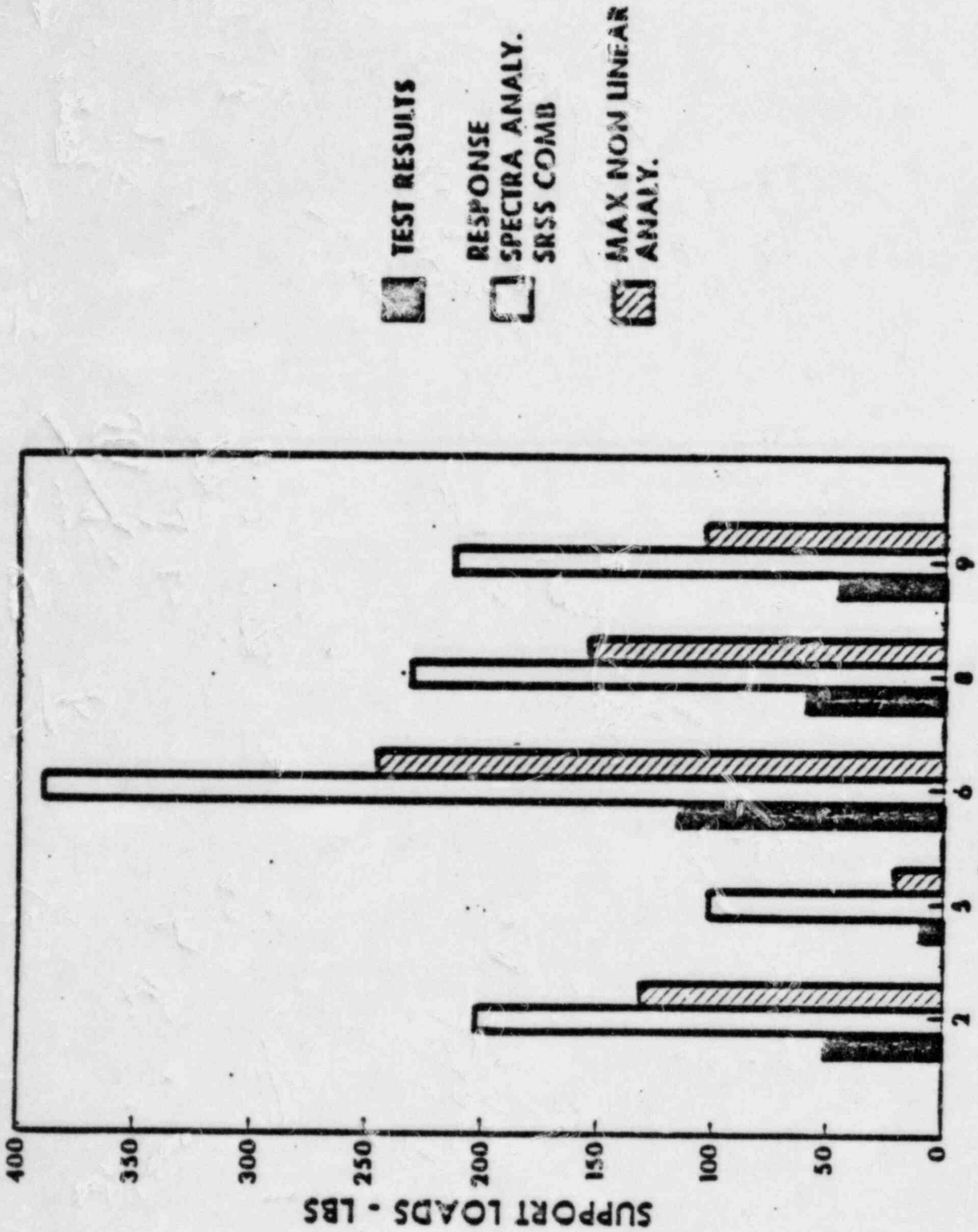
1 LB = 0.22481 N

SMALL BORE PIPING SEISMIC TEST FINDINGS

- L. K. SEVERUD ET AL · REF. (7)

FIGURE 6.6

PRELIMINARY



SMALL BORE PIPING SEISMIC TEST FINDINGS
- L. K. SEVERUD ET AL REF. (7)

FIGURE 6.7

83-29,603

PRELIMINARY

PIPING SYSTEMS ANALYZED

Three sizes of piping systems were analyzed:

- 4 in. (10 cm) pipeline, see Figure 4
- 16 in. (41 cm) pipeline, see Figure 5
- 28 in. (71 cm) pipeline, see Figure 6.

The 4 in. (10 cm) pipe system has 14 seismic supports; 7 rigid vertical supports and 7 horizontal restraints using small snubbers. The 16 in. (41 cm) pipe system has a total of 19 seismic supports with medium to large size mechanical snubbers. At some locations, two snubbers are used to provide restraint in a single direction. The 28 in. (71 cm) piping has 13 seismic supports and the snubbers range from medium to large in size.

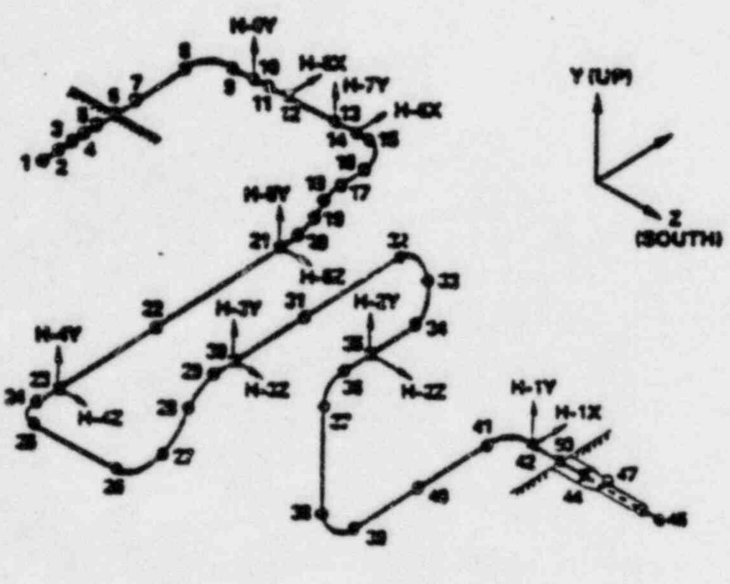


Figure 4. 4 Inch Pipeline Model

Seismic analysis of piping with non-linear supports

(D. A. Barta et al Ref. 6)

FIGURE 6.8

PRELIMINARY

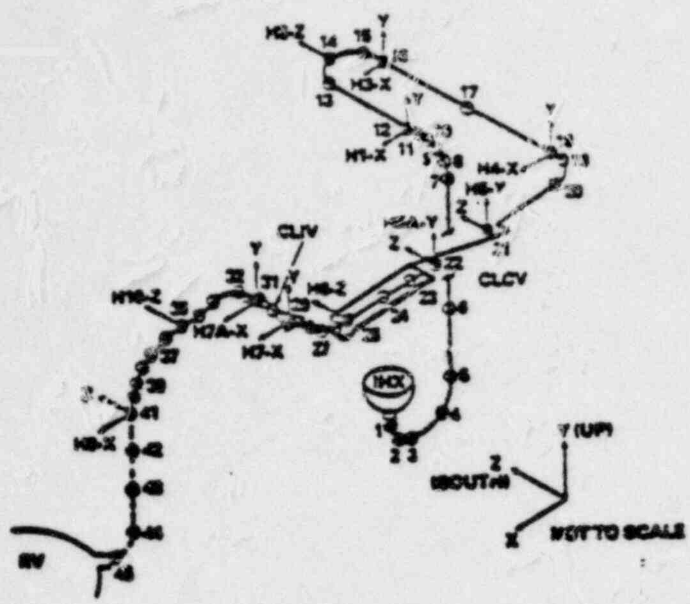
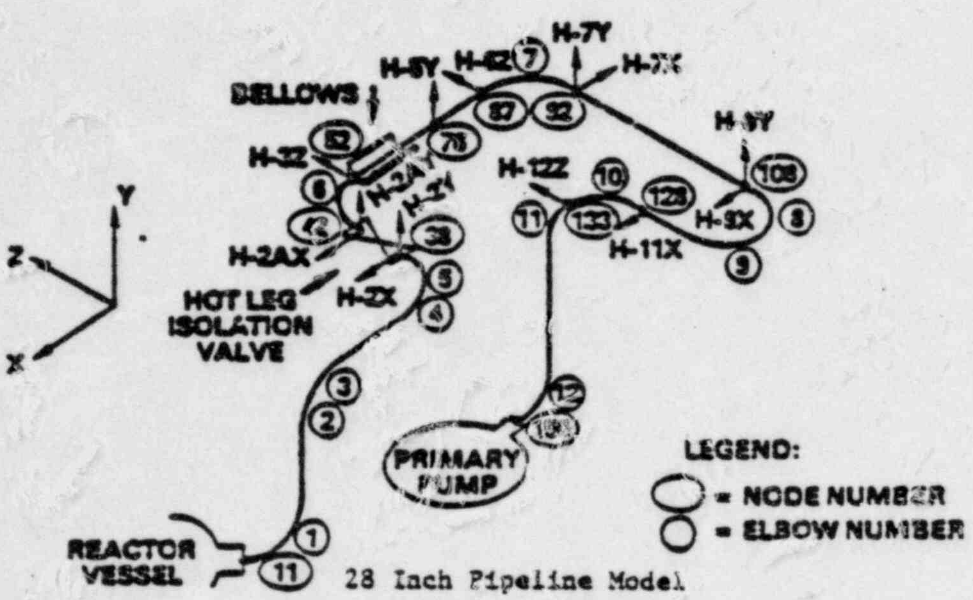


FIGURE 6.9

Figure 5. 16 Inch Pipeline Model



28 Inch Pipeline Model

Seismic analysis of piping with non-linear supports

(D. A. Barta et al Ref. 6)

FIGURE 6.10

TABLE 3. 4 INCH PIPELINE

HANGER NO.	HANGER LOAD ~ LB. (1 LBF = 4.448 N)												
	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7	RUN 8	RUN 9	RUN 10	RUN 11	RUN 12	RUN 13
H - 9Y	94	134	107	39	39	39	38	39	39	39	38	39	28
H - 8X	62	168	105	0	16	0	0	0	0	0	0	72	109
H - 7Y	77	192	144	51	51	51	50	51	51	50	51	53	44
H - 6X	529	946	431	70	107	89	151	70	70	65	79	480	518
H - 5Y	105	125	91	33	33	33	33	26	39	30	33	34	43
H - 5Z	439	448	200	0	42	23	33	0	0	0	0	198	199
H - 4Y	67	152	113	23	22	22	22	19	25	22	22	25	35
H - 4X	191	269	156	0	13	0	0	0	0	0	0	128	214
H - 3Y	73	175	115	31	31	31	31	25	36	29	31	31	36
H - 3X	52	176	99	0	22	9	13	0	0	0	0	97	94
H - 2Y	36	270	211	48	48	48	48	38	55	48	47	55	43
H - 2X	79	183	142	0	13	0	0	0	0	0	0	84	113
H - 1X	142	359	180	20	60	40	65	15	23	14	26	210	241
H - 1Y	54	131	88	22	22	22	22	18	25	22	21	21	45
LOCATION					MAXIMUM PIPING STRESS ~ PSI (1 KSI = 6.89 MPa)								
NOZ.' 1		12.1										3.3	

NOTES: 1. PIPESD analysis with rigid supports and using enveloping design seismic spectra of Figures 10 and 11.
2. PIPESD analysis with support and clamp flexibility and using enveloping seismic spectra.
3. ANSYS model with support and clamp flexibility same as in RUN 2 but using calculated seismic spectra.
4. Nonlinear, time domain analysis with support and clamp flexibility same as in RUN 3 and combined with snubber stiffness and damping characteristics.
Snubber gaps = .030 in. (.076 cm).
5. Same as RUN 4 but with snubber gaps = .005 in. (.013 cm).
6. Same as Run 4 but with snubber gaps = .015 in. (.038 cm).
7. Same as RUN 4 but with snubber damping reduced 50%.
8. Same as RUN 4 but with clamp stiffness decreased 30%.
9. Same as RUN 4 but with clamp stiffness increased 30%
10. Same as RUN 4 but with time history compressed 10%.
11. Same as RUN 4 but with time history expanded 10%.
12. Same as RUN 4 but with snubber damping scaled in proportion to the energy across the snubber.
13. Structural parameters same as in RUN 3 but with spatial components of seismic motion applied separately and spatial responses combined according to Regulatory Guide 1.92, Article 2.2.

Seismic analysis of piping with non-linear supports

(D. A. Barta et al Ref. 6)

FIGURE 6.11

PRELIMINARY

TABLE 4. 16 INCH PIPELINE

SEISMIC SUPPORT NO.	SEISMIC SUPPORT LOAD ~ LB. (1 LBF = 4.448 N)						
	LINEAR ANALYSIS	NONLINEAR ANALYSIS					
	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7
H - 1 X	6083	91	95	87	99	133	1390
H - 1 Y	3347	104	154	113	153	135	726
H - 2 X	5076	949	1200	965	1207	1224	1224
H - 3 X	10786	569	634	557	629	684	907
H - 3 Y	2645	396	403	317	334	395	812
H - 4 X	29512	3165	3170	3044	2826	2082	3579
H - 4 Y	25496	352	394	408	364	394	580
H - 5 Y	2083	0	0	0	0	0	942
H - 5 X	12566	2139	2178	2062	2172	2190	2262
H - 5AY	6986	0	0	12	6	15	880
H - 5AX	9357	3837	3862	3736	3989	3999	3262
H - 6 X	36525	3986	3986	3719	4157	4150	4160
H - 7 X	77212	1526	1613	1408	1707	1672	4378
H - 7 Y	10441	1983	2219	2189	2341	2232	3818
H - 7AX	85086	3275	3304	3156	3212	3209	5048
H - 7AY	14840	2240	2187	2153	2303	2209	4472
H - 10X	31668	6278	9945	6804	6168	6167	6981
PIPING ELBOW NO.	PIPING STRESS ~ PSI (1 PSI = 6.89 KPa)						
1	16185	3867	5736	3843	5767	5718	6832
6	15084	3567	3888	3573	3739	3714	4098
8	36963	13536	15353	14876	15460	15451	15666
9	36089	23831	22644	21310	22131	22182	23076
11	63906	7831	8196	7779	7965	8087	9189
13	57404	35037	35737	34283	35357	35378	36058

NOTES: RUN 1 - PIPESD analysis with support flexibility, using 2% damped SSE seismic spectra and 10% method modal summation.
RUN 2 - Nonlinear, time history analysis with snubber stiffness and damping characteristics, snubber gap = .030 in (.076 cm). Average clamp stiffness. Normal time history.
RUN 3 - Same as RUN 2 but with time history compressed 10%.
RUN 4 - Same as RUN 2 but with time history expanded 10%.
RUN 5 - Same as RUN 3 but with minimum clamp stiffness.
RUN 6 - Same as RUN 3 but with maximum clamp stiffness.
RUN 7 - Maximum responses from RUNS 2-6 due to x-axis loading combined with responses due to z-axis and y-axis loadings according to Regulatory Guide 1.92, Article 2.2.

Seismic analysis of piping with non-linear supports

(D. A. Barta et al Ref. 6)

FIGURE 6.12

PRELIMINARY

TABLE 5. 18 INCH PIPELINE

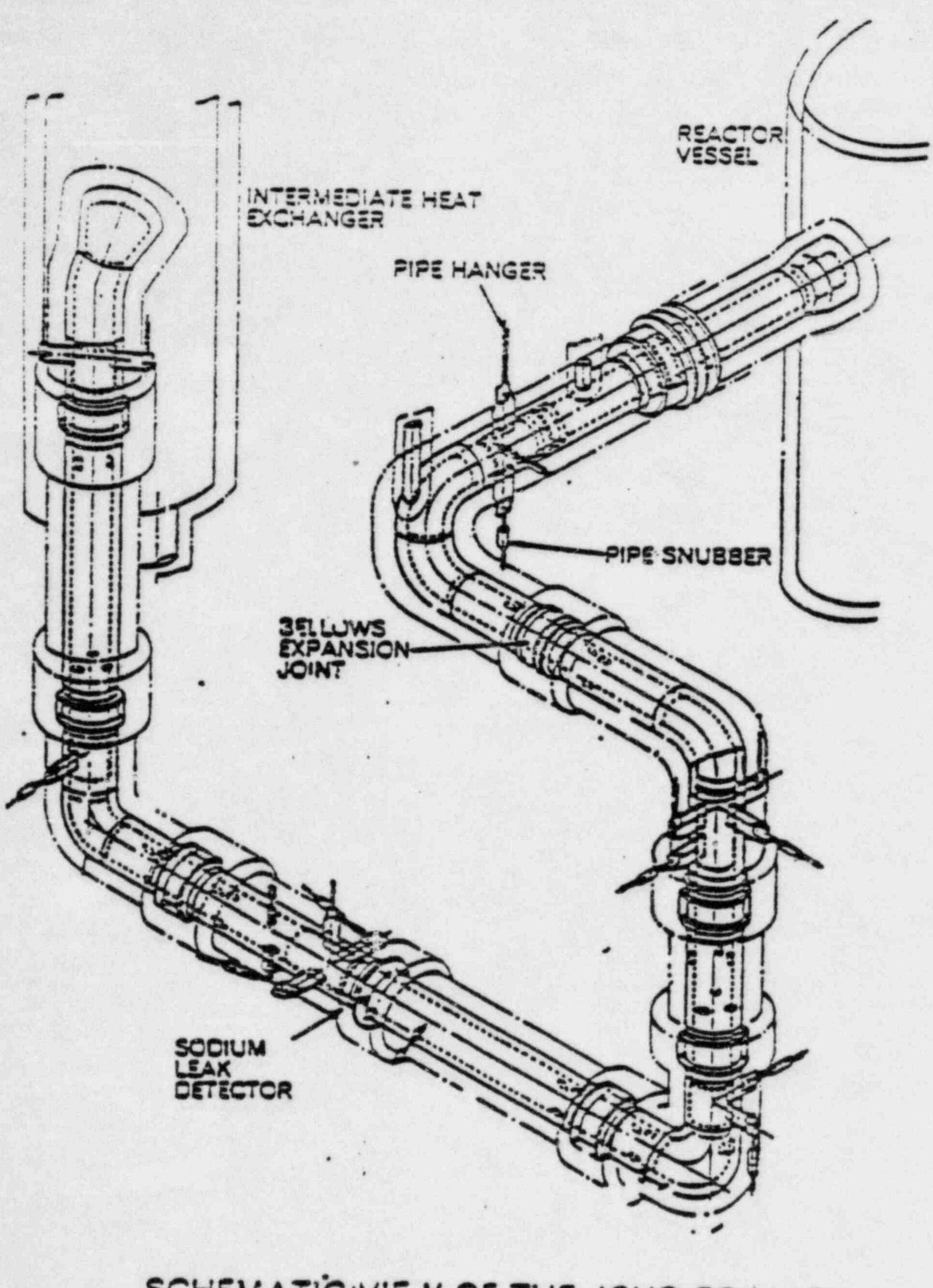
HANGER NO.	LINEAR ANALYSIS		NONLINEAR ANALYSIS									
	HANGER LOAD ~ LBS. (1 LBF = 4.448 N)											
	RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6	RUN 7	RUN 8	RUN 9	RUN 10	RUN 11	RUN 12
H - 2 X	33944	16041	5826	5854	8299	5816	5831	5502	6108	11387	11584	10266
H - 2 Y	9406	9749	4593	4667	6119	4583	4602	4376	4689	15752	8336	7042
H - 2AX	24016	13271	5040	5001	5927	5079	5021	5039	5133	14563	10773	11074
H - 2AY	8599	13247	3439	3496	7486	3438	3440	3368	3502	10419	6776	6594
H - 3 X	11100	30095	5475	5647	13221	5475	5476	5217	5666	32725	23603	24862
H - 5 Y	4949	8976	2657	2688	4491	2665	2646	2953	2081	8602	5945	5676
H - 6 X	7919	27628	5534	5685	11743	5538	5530	5244	5783	29380	22729	22216
H - 7 X	5596	17521	2371	2376	4772	2266	2419	2152	2465	16095	5962	8070
H - 7 Y	7580	7486	1739	1770	3758	1667	1808	1584	1821	5849	4460	4281
H - 9 X	4654	20374	1722	1846	2860	1719	1718	1604	1811	19917	5815	7924
H - 9 Y	6501	26646	1523	1674	7804	1525	1530	1402	1697	18368	9033	8492
H - 11X	4876	14215	2051	2995	6318	2090	2082	2669	3034	14155	11180	8866
H - 12X	9540	20670	3585	3671	6073	3579	3607	3416	3754	15809	12332	11534
ELBOW NO.	PIPING ELBOW STRESS ~ PSI (1 PSI = 6.89 KPa)											
1	7898	20598	7513	7500	—	7310	7315	7748	7451	28320	15163	16712
5	16814	17521	8617	8564	—	86[illegible]	8608	8274	8774	21053	14720	10631
6	10745	16779	6376	6318	—	8362	6380	5892	6565	29304	16305	15338
7	8745	26512	5380	5315	—	5335	5380	5608	5162	25104	13388	10861
10	13068	28703	6865	7058	—	6866	6861	7642	7442	24536	15974	12403
12	8894	19306	5037	4988	—	5033	5037	4895	5814	16959	12354	10648

NOTES: RUN 1 - PIPESD linear analysis with reactor vessel ledge flexibility but with rigid pipe supports.
RUN 2 - PIPESD linear analysis with reactor vessel ledge flexibility and with flexible pipe supports.
RUN 3 - ANSYS nonlinear analysis with reactor vessel ledge flexibility, average clamp stiffness, snubber test data of stiffness and damping characteristics, snubber gaps = 0.030 in (0.076 cm).
RUN 4 - Same as RUN 3 but with snubber gaps = 0.015 in (0.038 cm).
RUN 5 - Same as RUN 3 but with RUN 2 support stiffnesses and snubber dampings = 200 lb-sec/in (350 N-sec/cm).
RUN 6 - Same as RUN 3 but with minimum biaxial clamp stiffnesses at H-7 and H-9.
RUN 7 - Same as RUN 3 but with maximum biaxial clamp stiffnesses at H-7 and H-9.
RUN 8 - Same as RUN 3 but with time history compressed 10%.
RUN 9 - Same as RUN 3 but with time history expanded 10%.
RUN 10- Same as RUN 3 but with mass damping and 1.8 times the horizontal acceleration/time history.
RUN 11- Same as RUN 10 but with snubber damping scaled down in proportion to the energy across the snubber.
RUN 12- Same as RUN 11 but with spatial components of seismic motion applied separately and spatial responses combined according to Regulatory Guide 1.92 Article 2.2.

Seismic analysis of piping with non-linear supports

(D. A. Barta et al Ref. 6)

FIGURE 6.13



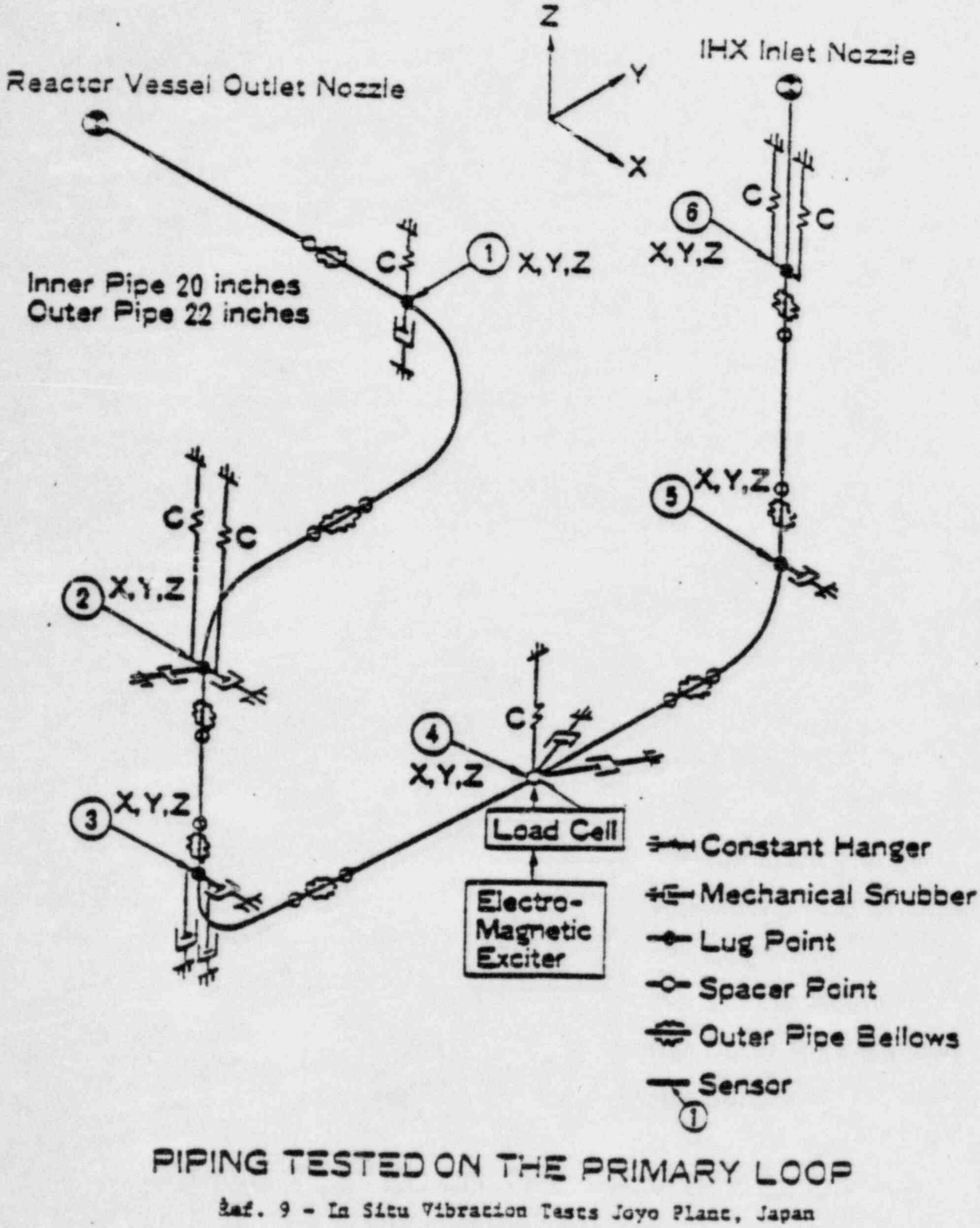
PRELIMINARY

SCHEMATIC VIEW OF THE JOYO PRIMARY
HOT-LEG PIPING SYSTEM

Ref. 9 - In Situ Vibration Tests Joyo Plant, Japan

FIGURE 6.14

PRELIMINARY



PIPING TESTED ON THE PRIMARY LOOP

Ref. 9 - In Situ Vibration Tests Joyo Plant, Japan

FIGURE 6.15

Test Result Summary of PHTS In-situ Vibration Test With Analytical Data

	Eigenfrequency Hz									Damping Factor, %		
		Analytical Result *1										
			Dynamic Spring Constant of Snubber. kg/mm									
Mode	Test Result *1	No Struts	K=500	K=1000	K=2000	K=3000	K=4000	Rigid	Design Value *2	Test Result	Design Value	Serial #
–	8.4	0.83	5.03	6.26	7.40	7.94	8.27	13.45	—	—	1.0	1
–	8.8	0.93	5.08	6.89	8.77	9.52	9.85	14.42	—	—		2
–	9.2	2.01	5.46	7.22	9.68	11.29	12.32	15.98	—	10.5～15.9		3
–	10.0	2.59	7.07	8.69	10.76	12.05	12.88	16.90	—	5.4～23.6		4
–	10.8	4.52	8.43	10.87	12.21	13.53	14.72	18.68	—	8.9～15.9		5
1	12.8	6.10	9.14	11.16	13.85	15.00	15.62	19.11	10.79	4.6～ 9.2		6
2	13.6	7.01	9.70	11.89	15.02	16.11	17.07	26.05	13.90	5.7～ 9.3		7
–	14.4	11.08	11.49	12.51	15.27	17.08	17.97	27.56	—	4.4～10.1		8
3	14.8	14.01	14.63	14.98	16.14	17.95	19.46	35.85	16.17	4.9～ 8.8		9
4	16.8	15.42	16.13	17.03	18.70	20.71	22.03	39.16	16.34	5.6～ 7.4		10
–	18.8	18.24	18.57	18.94	19.79	20.83	22.69	39.86	—	—		11
5	19.2	18.65	19.00	19.52	21.13	23.07	24.12	42.38	19.28	3.3～ 4.7		12
	20.4	19.88	20.29	20.81	22.06	23.31	25.27	48.79	—	—	1.0	13

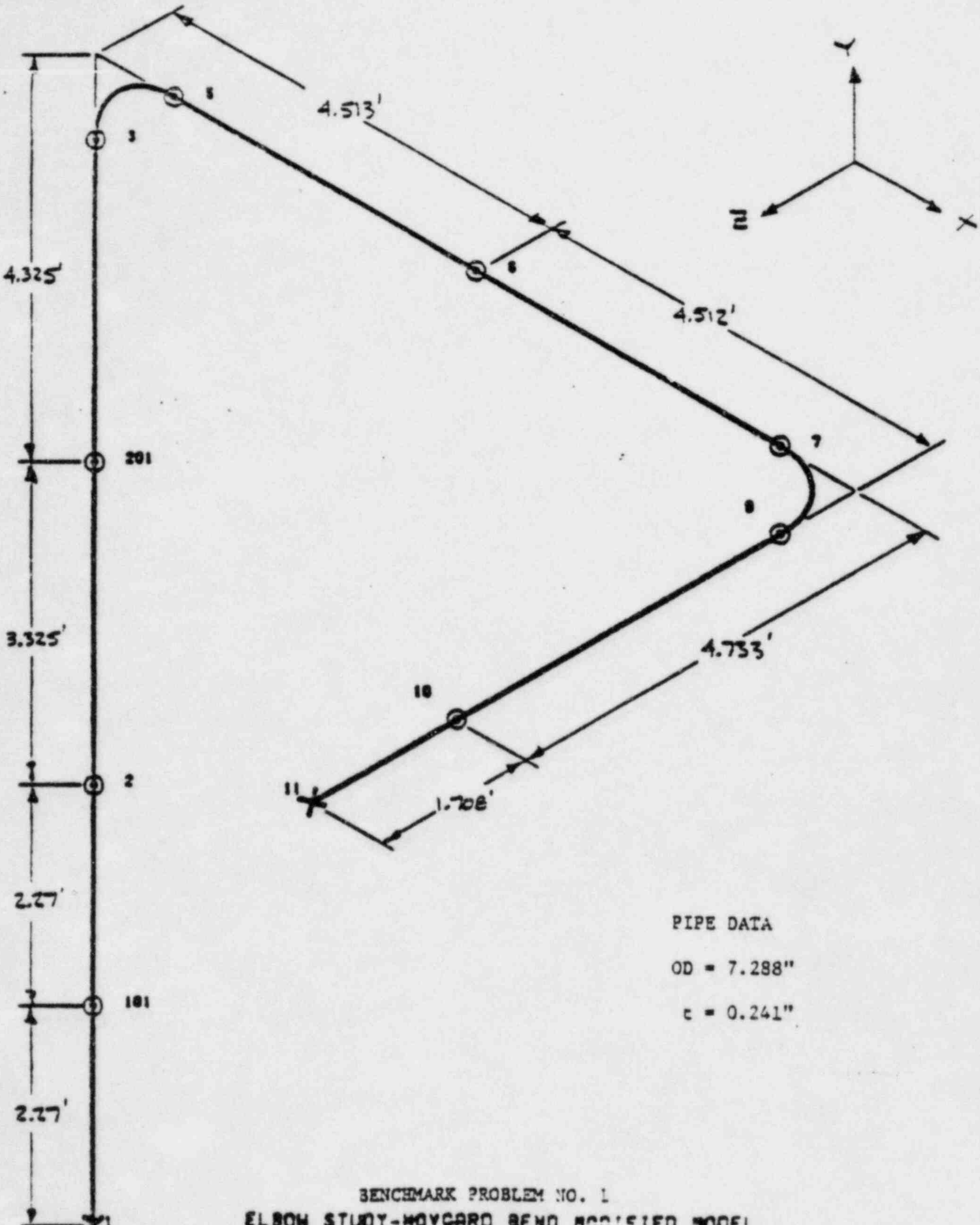
Note) ※1 220°C, RUN 10, ※2 500°C

Ref. 9 - In Situ Vibration Tests Joyo Plant, Japan

FIGURE 6.16

PRELIMINARY

PRELIMINARY



PIPE DATA

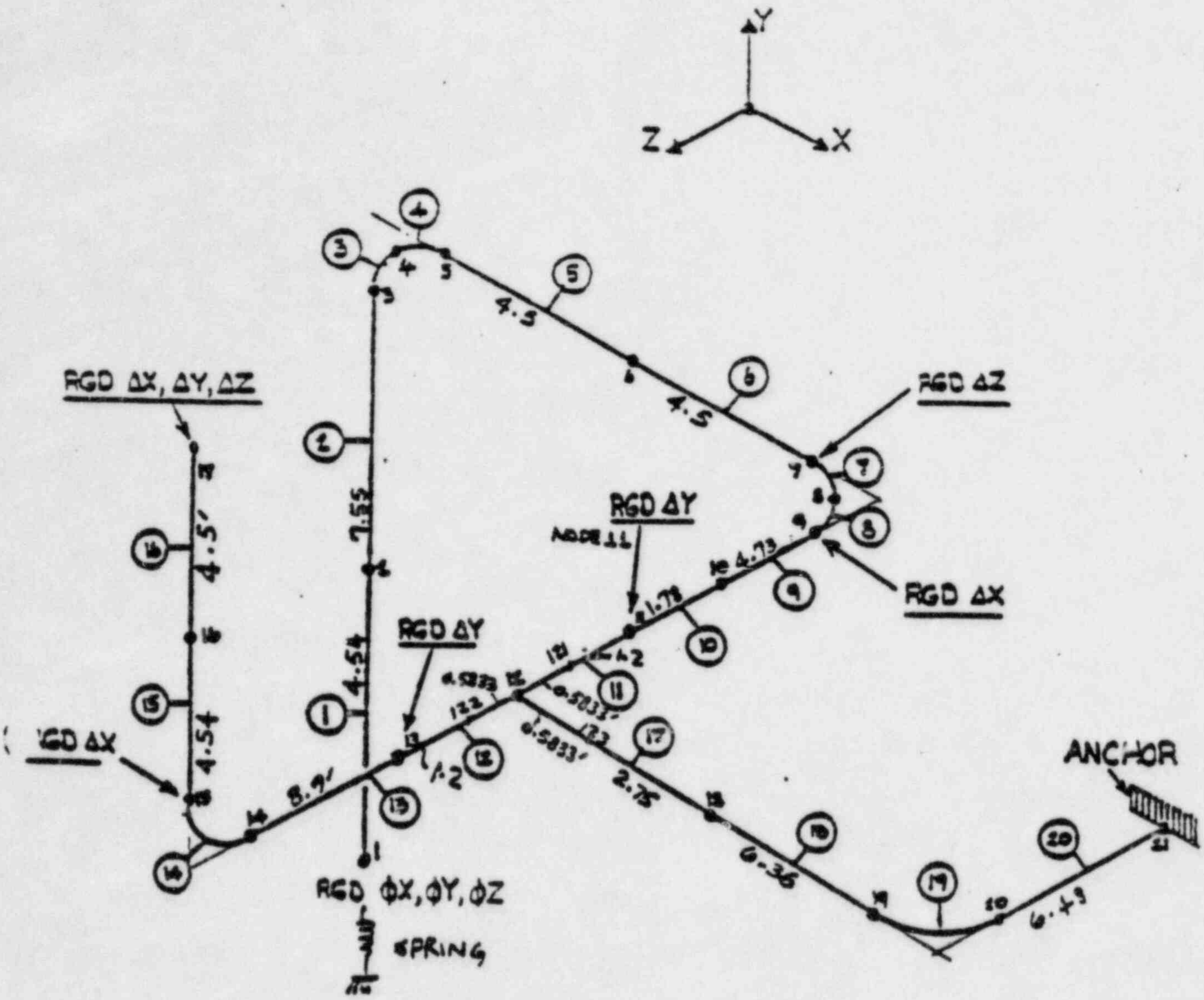
OD = 7.288"

t = 0.241"

BENCHMARK PROBLEM NO. 1
ELBOW STUDY-HOVGARD BEND MODIFIED MODEL

FIGURE 7.1

PRELIMINARY



DIMENSIONS IN FEET

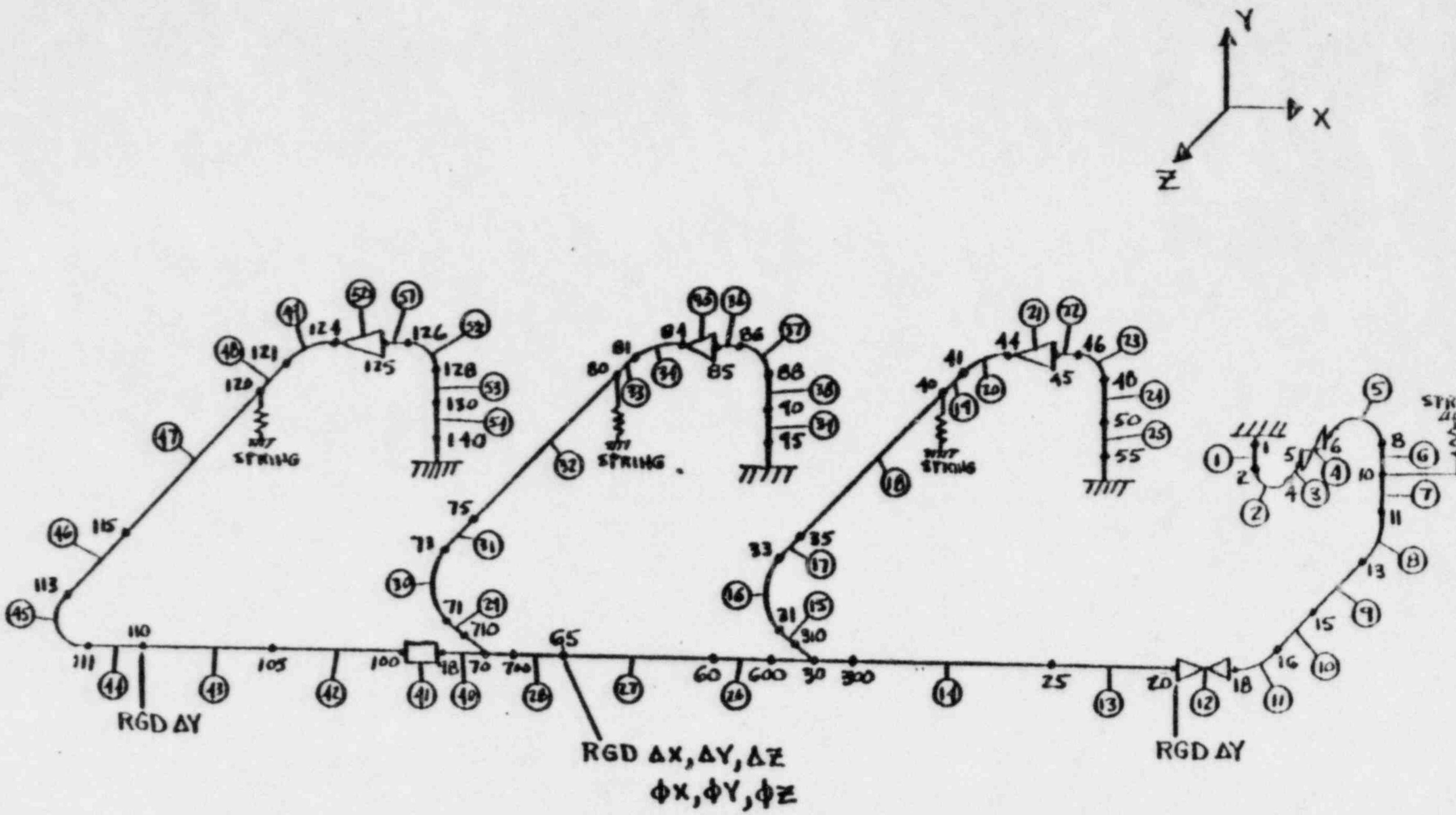
MODIFIED MODEL NO. 3

FIGURE 7.2

PIPE DATA

OD = 7.288"

t = 0.241"



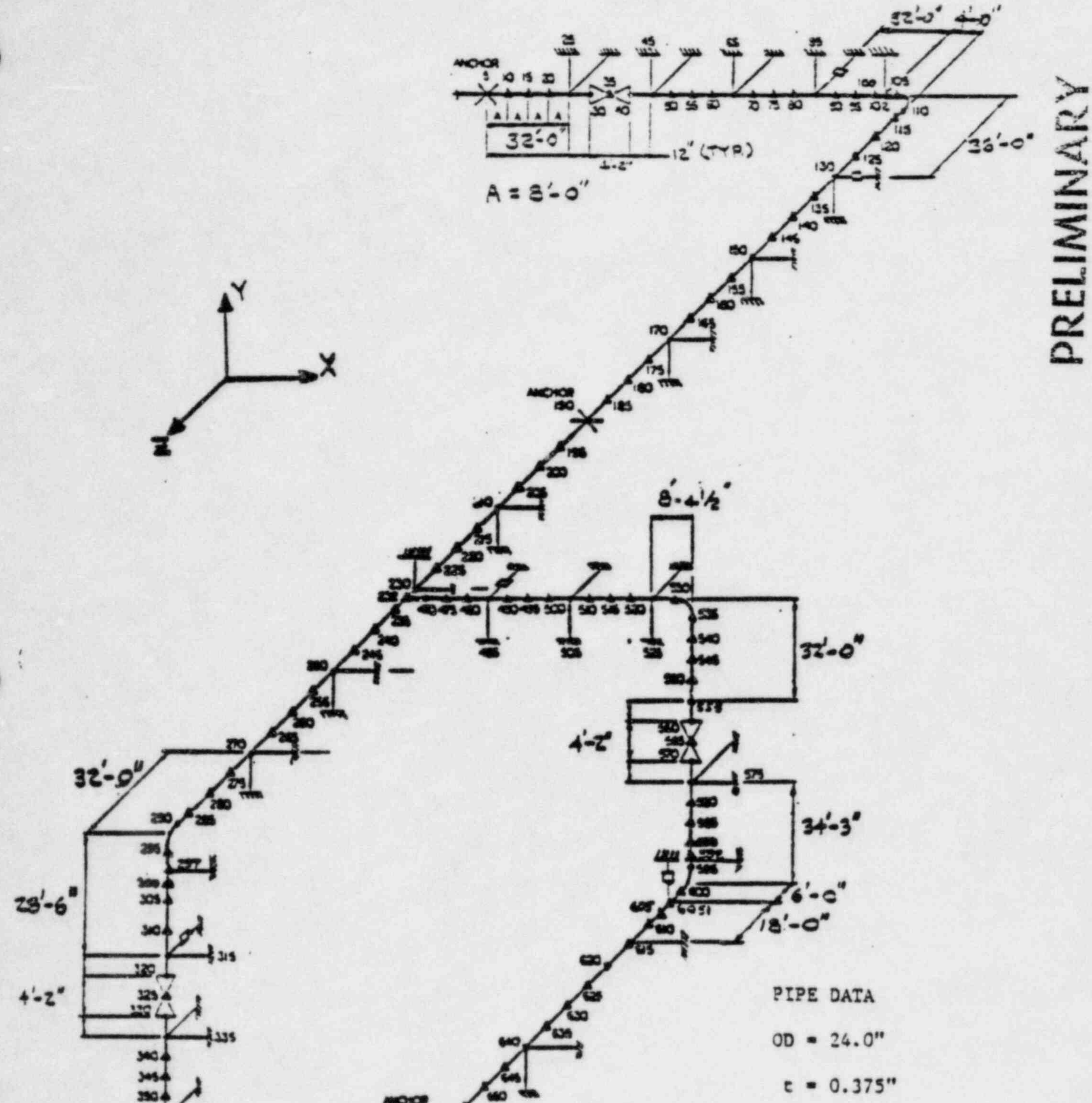
BENCHMARK PROBLEM Nº 7

PIPE DATA

OD = 3.5"/4.5"

t = 0.300"/0.337"

FIGURE 7.3



PIPE DATA

OD = 24.0"

t = 0.375"

24" PIPING STUDY MODEL

FIGURE 7.4

PRELIMINARY

COMPARISON OF NATURAL FREQUENCIES (HZ)

MODIFIED BENCHMARK MODEL NO. 1

MODE	STANDARD FITTINGS	HEAVY FITTINGS	EXTRA HEAVY
1	11.58	11.59	11.09
2	19.25	21.10	21.33
3	27.18	27.07	26.07
4	59.44	60.91	61.17
5	60.05	62.73	63.35
6	90.37	93.43	94.63
7	90.59	96.61	99.69

NOTES: Heavy fittings are twice as thick as standard fittings.

Extra heavy fittings are three times as thick as standard fittings.

Figure 7.5

PRELIMINARY

COMPARISON OF NATURAL FREQUENCIES (HZ)

MODIFIED MODEL NO. 3

MODE	STANDARD FITTINGS	HEAVY FITTINGS	EXTRA HEAVY
1	3.38	3.69	3.71
2	4.19	5.02	5.26
3	9.55	10.71	10.97
4	13.59	14.33	14.45
5	15.01	17.10	17.47
6	17.90	17.96	17.87
7	19.78	22.19	22.68
8	38.73	42.24	42.91
9	48.32	48.02	48.22

NOTES: Heavy fittings are twice as thick as standard fittings.

Extra heavy fittings are three times as thick as standard fittings.

FIGURE 7.6

PRELIMINARY

COMPARISON OF NATURAL FREQUENCIES (HZ)

BENCHMARK MODEL NO. 7

MODE	STANDARD FITTINGS	HEAVY FITTINGS	EXTRA HEAVY
1	5.02	6.05	6.22
2	7.80	8.44	8.46
3	8.18	8.92	8.96
4	8.96	9.99	10.04
5	9.30	10.20	10.25
6	9.88	10.77	10.80
7	13.19	15.16	15.35
8	14.90	15.91	15.79
9	15.03	16.02	16.06
10	17.72	18.30	18.23
11	18.05	21.94	22.74
12	22.83	24.05	24.03
13	24.96	26.17	26.00
14	25.62	26.77	26.80
15	26.82	28.73	28.83
16	28.05	30.58	30.61
17	30.10	32.25	32.42
18	35.11	36.59	36.44
19	36.99	38.34	38.20
20	42.49	44.70	44.42
21	44.24	48.25	48.95
22	48.00	49.72	49.58

NOTES: Heavy fittings are twice as thick as standard fittings.

Extra heavy fittings are three times as thick as standard fittings.

FIGURE 7.7

PRELIMINARY

24" PIPING STUDY

COMPARISON OF NATURAL FREQUENCIES (HZ)

MODE	STANDARD FITTINGS	HEAVY FITTINGS	EXTRA HEAVY
1	6.816	7.294	7.544
2	9.838	10.666	10.598
3	10.415	11.191	11.510
4	11.362	11.739	11.788
5	13.282	13.372	13.231
6	13.525	13.545	13.435
7	13.719	13.790	13.708
8	14.866	15.466	15.576
9	15.570	15.736	15.678
10	15.634	15.912	15.888

NOTES: Heavy fittings are twice as thick as standard fittings.

Extra heavy fittings are three times as thick as standard fittings.

Figure 7.8

PRELIMINARY

COMPARISON OF SELECTED THERMAL AND DEADWEIGHT STRESSES (PSI)

MODIFIED BENCHMARK MODEL NO. 1

LOADING	NODE	MEMBER TYPE	STANDARD FITTINGS	HEAVY FITTINGS	EXTRA HEAVY
THERMAL	1	ANCHOR	10547	13260	14466
	201	RUN	1504	3996	5223
	5	ELBOW	15237	9367	6053
	5	RUN	6020	11133	13412
	9	ELBOW	11669	5619	3401
DEAD WEIGHT	1	ANCHOR	66	101	126
	201	RUN	107	174	217
	5	ELBOW	179	105	88
	5	RUN	94	166	216
	9	ELBOW	64	56	49

NOTES: Heavy fittings are twice as thick as standard fittings.

Extra heavy fittings are three times as thick as standard fittings.

Figure 7.9

COMPARISON OF SELECTED SEISMIC STRESSES (PSI)

MODIFIED BENCHMARK MODEL NO. 1

FLAT ARS

NODE	MEMBER TYPE	EQUIPMENT DAMPING	STANDARD FITTINGS	HEAVY FITTINGS	EXTRA HEAVY
1	ANCHOR		9093	9073	9671
201	RUN		1955	2360	2691
5	ELBOW	1%	3943	1752	1330
5	RUN	(5G)	2077	2777	3261
9	ELBOW		5029	2718	2146
1	ANCHOR		5456	5444	5803
201	RUN	3%	1173	1416	1614
5	ELBOW	(3g)	2366	1051	798
5	RUN		1246	1666	1957
9	ELBOW		3017	1631	1288

NOTES: Heavy fittings are twice as thick as standard fittings.

Extra heavy fittings are three times as thick as standard fittings.

Figure 7.10

PRELIMINAR

COMPARISON OF SELECTED SEISMIC STRESSES (PSI)
MODIFIED BENCHMARK MODEL 1
BVPS-2 ARS (FIG. 4.3 & 4.4)

NODE	MEMBER TYPE	EQUIPMENT DAMPING	STANDARD FITTINGS	HEAVY FITTINGS	EXTRA HEAVY
1	ANCHOR	1%	848	841	908
201	RUN		175	205	234
5	ELBOW		362	157	119
5	RUN		191	248	292
9	ELBOW		467	242	190
1	ANCHOR	3%	815	808	877
201	RUN		169	198	227
5	ELBOW		348	151	115
5	RUN		183	239	283
9	ELBOW		449	235	185

NOTES: Heavy fittings are twice as thick as standard fittings.

Extra heavy fittings are three times as thick as standard fittings.

Figure 7.11

PRELIMINARY

COMPARISON OF ANCHOR THERMAL & DEAD WEIGHT LOADS

MODIFIED BENCHMARK MODEL NO. 1, NODE 1

LOADING CONDITION	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
THERMAL	STANDARD	-1044	-924	-338	-2593	902	7512
	HEAVY	-1544	-1517	-527	-3922	793	9224
	EXTRA HEAVY	-1763	-1762	-612	-4483	724	9986
DEAD WEIGHT	STANDARD	-12	-309	3	-27	-23	36
	HEAVY	-21	-347	4	-42	-28	58
	EXTRA HEAVY	-27	-377	4	-52	-32	74

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

Figure 7.12 (1 of 2)

PRELIMINARY

COMPARISON OF ANCHOR THERMAL & DEAD WEIGHT LOADS

MODIFIED BENCHMARK MODEL NO. 1, NODE 11

LOADING CONDITION	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
THERMAL	STANDARD	1044	924	338	4458	-4577	-3221
	HEAVY	1544	1517	527	7320	-5981	-4239
	EXTRA HEAVY	1763	1762	612	8430	-6559	-4555
DEAD WEIGHT	STANDARD	12	-177	-3	-697	-82	-20
	HEAVY	21	-188	-4	-732	-141	-56
	EXTRA HEAVY	27	-202	-4	-798	-177	-77

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

Figure 7.12 (2 of 2)

COMPARISON SEISMIC ANCHOR LOADS

MODIFIED BENCHMARK MODEL NO. 1, NODE 1

FLAT ARS

EQUIPMENT DAMPING	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
1% (5G)	STANDARD	482	288	798	6217	1099	2774
	HEAVY	544	359	815	6001	1399	3061
	EXTRA HEAVY	595	419	858	6318	1590	3367
3% (3g)	STANDARD	289	173	479	3730	659	1664
	HEAVY	327	216	489	3600	839	1837
	EXTRA HEAVY	357	251	515	3791	954	2020

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

Figure 7.13 (1 of 2)

PRELIMINARY

COMPARISON OF SEISMIC ANCHOR LOADS

MODIFIED BENCHMARK MODEL NO. 1, NODE 11

FLAT ARS

EQUIPMENT DAMPING	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
1% (5G)	STANDARD	1289	658	535	3546	6681	305
	HEAVY	1432	727	707	3980	7010	424
	EXTRA HEAVY	1579	808	809	4475	7619	526
3% (3g)	STANDARD	774	395	321	2128	4009	183
	HEAVY	859	436	424	2388	4206	254
	EXTRA HEAVY	947	485	486	2685	4571	316

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.
EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

Figure 7.13 (2 of 2)

COMPARISON OF ANCHOR DESIGN LOADS

MODIFIED BENCHMARK MODEL NO. 1, NODE 1

(DL + THER + FLAT ARS)

EQUIPMENT DAMPING	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
1% (5g)	STANDARD	-1538	-1521	-1133	-8837	1978	10322
	HEAVY	-2109	-2223	-1338	-9965	2164	12343
	EXTRA HEAVY	-2385	-2558	-1466	-10853	2282	13427
3% (3g)	STANDARD	-1345	-1406	-814	-6350	1538	9212
	HEAVY	-1892	-2080	-1012	-7564	1604	11119
	EXTRA HEAVY	-2147	-2390	-1123	-8326	1646	12080

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

Figure 7.14 (1 of 2)

PRELIMINARY

COMPARISON OF ANCHOR DESIGN LOADS

MODIFIED BENCHMARK MODEL NO. 1, NODE 11

(DL + THER + FLAT ARS)

EQUIPMENT DAMPING	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
1% (5G)	STANDARD	2345	1405	870	7307	-11340	-3546
	HEAVY	2997	2056	1230	10568	-13132	-4719
	EXTRA HEAVY	3369	2368	1417	12107	-14355	-5158
3% (3g)	STANDARD	1830	1142	656	5889	-8668	-3424
	HEAVY	2424	1765	947	8976	-10328	-4559
	EXTRA HEAVY	2737	2045	1094	10317	-11307	-4948

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

Figure 7.14 (2 of 2)

COMPARISON OF SELECTED THERMAL AND DEADWEIGHT STRESSES (PSI)
MODIFIED MODEL NO. 3

LOADING	NODE	MEMBER TYPE	STANDARD FITTINGS	HEAVY FITTINGS	EXTRA HEAVY
THERMAL	1	ANCHOR	303	464	521
	3	ELBOW	355	261	213
	11	RUN	2965	3159	3233
	19	ELBOW	2382	1391	903
DEAD WEIGHT	1	ANCHOR	163	250	305
	3	ELBOW	767	416	274
	11	RUN	1306	1283	1338
	19	ELBOW	423	236	171

NOTES: Heavy fittings are twice as thick as standard fittings.

Extra heavy fittings are three times as thick as standard fittings.

FIGURE 7.15

PRELIMINARY

COMPARISON OF SELECTED SSE SEISMIC STRESSES (PSI)
MODIFIED MODEL NO. 3
FLAT ARS

NODE	MEMBER TYPE	EQUIPMENT DAMPING	STANDARD FITTINGS	HEAVY FITTINGS	EXTRA HEAVY
1	ANCHOR		20491	20338	23548
3	ELBOW	1%	30906	11269	7889
11	RUN	(5g)	23068	23705	23506
19	ELBOW		8155	4711	3664
1	ANCHOR		12295	12203	14129
3	ELBOW	3%	18544	6761	4733
11	RUN	(3g)	13841	14223	14103
19	ELBOW		4893	2826	2199

NOTES: Heavy fittings are twice as thick as standard fittings.
Extra heavy fittings are three times as thick as standard fittings

FIGURE 7.16A

RESTRAINT THERMAL & DEAD WEIGHT LOADS [lbs.]
FOR MODIFIED MODEL NO. 3

LOADING	FITTING TYPE	NODE 7	NODE 9	NODE 11	NODE 13	NODE 15
		F_z	F_x	F_y	F_y	F_x
THERMAL	STANDARD	-396	-505	1172	-2004	-220
	HEAVY	-721	-606	+1496	-2850	-252
	EXTRA HEAVY	-881	-651	1655	-3268	-268
DEAD WEIGHT	STANDARD	-6	33	-627	27	-14
	HEAVY	-10	60	-625	-20	-20
	EXTRA HEAVY	-13	75	-653	-36	-23

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7.17

PRELIMINARY

COMPARISON OF SEISMIC (SSE)
RESTRAINT LOADS (LBS) MODIFIED MODEL NO. 3
FLAT ARS

EQUIPMENT DAMPING	FITTING TYPE	NODE 7	NODE 9	NODE 11	NODE 13	NODE 15	
		F_z	F_x	F_y	F_y	F_x	
1% (5g)	STANDARD	3680	2074	7248	4143	438	
	HEAVY	3465	2305	7500	4349	431	
	EXTRA HEAVY	4616	2403	7557	4417	503	
1% (3g)	STANDARD	2208	1244	4349	2486	263	
	HEAVY	2079	1383	4500	2609	259	
	EXTRA HEAVY	2770	1442	4534	2650	302	

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7.18A

RESTRAINT DESIGN LOADS (LBS)
FOR MODIFIED MODEL NO. 3 WITH FLAT ARS
(DL + THER + SSEI)

EQUIPMENT DAMPING	FITTING TYPE	NODE 7	NODE 9	NODE 11	NODE 13	NODE 15	
		F_z	F_x	F_y	F_y	F_z	
1% (5g)	STANDARD	4076	2579	8420	6147	658	
	HEAVY	4907	2911	8996	7199	683	
	EXTRA HEAVY	5497	3054	9212	7685	771	
1% (3g)	STANDARD	2714	1277	4976	2513	277	
	HEAVY	2089	1443	5125	2629	279	
	EXTRA HEAVY	2783	1517	5187	2686	325	

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7.19A

PRELIMINARY

COMPARISON OF ANCHOR THERMAL & DEAD WEIGHT LOADS

MODIFIED MODEL NO 3 NODE 1

LOADING CONDITION	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
THERMAL	STANDARD	-	-	-	-60	-221	-12
	HEAVY	-	-	-	-57	-347	-12
	EXTRA HEAVY				-53	-392	-12
DEAD WEIGHT	STANDARD				-29	-47	111
	HEAVY				-20	-44	183
	EXTRA HEAVY				-16	-45	226

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7.20 (1 OF 3)

COMPARISON OF ANCHOR THERMAL & DEAD WEIGHT LOADS

MODIFIED MODEL NO. 3 NODE 17

LOADING CONDITION	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
THERMAL	STANDARD	19	831	362	-	-	-
	HEAVY	23	1353	747	-	-	-
	EXTRA HEAVY	25	1612	939			
DEAD WEIGHT	STANDARD	16	-354	-7			
	HEAVY	22	-375	-7			
	EXTRA HEAVY	24	-396	7			

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7.20 (2 OF 3)

PRELIMINARY

COMPARISON OF ANCHOR THERMAL & DEAD WEIGHT LOADS

MODIFIED MODEL NO. 3 NODE 21

LOADING CONDITION	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
THERMAL	STANDARD	705	1	34	4	3890	-20
	HEAVY	836	2	-26	4	4143	-26
	EXTRA HEAVY	894	2	-58	7	4227	-27
DEAD WEIGHT	STANDARD	-9	-271	3	1046	-41	-13
	HEAVY	-14	-288	5	1094	-57	-61
	EXTRA HEAVY	-18	-306	7	1173	-67	-83

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7.20 (3 OF 3)

PRELIMINARY

COMPARISON OF (SSE) SEISMIC ANCHOR LOADS
MODIFIED MODEL NO. 3 MOD 1
FLAT ARS

EQUIPMENT DAMPING	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
1% (5g)	STANDARD	-	-	-	7859	6362	11799
	HEAVY	-	-	-	7412	4957	12583
	EXTRA HEAVY	-	-	-	7565	7630	14263
3% (3g)	STANDARD	-	-	-	4715	3817	7079
	HEAVY	-	-	-	4447	2974	7550
	EXTRA HEAVY	-	-	-	4539	4573	8558

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

Figure 7.21A (1 of 3)

PRELIMINARY

COMPARISON OF (SSE) SEISMIC ANCHOR LOADS
MODIFIED MODEL NO. 3 NODE 17
FLAT ARS

EQUIPMENT DAMPING	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
1% (5g)	STANDARD	305	200	623	-	-	-
	HEAVY	335	195	573	-	-	-
	EXTRA HEAVY	314	290	504	-	-	-
3% (3g)	STANDARD	183	120	374	-	-	-
	HEAVY	201	117	344	-	-	-
	EXTRA HEAVY	188	174	303	-	-	-

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7.21A (2 of 3)

PRELIMINARY

COMPARISON OF (SSE) SEISMIC ANCHOR LOADS
MODIFIED MODEL NO. 3 NODE 21
FLAT ARS

EQUIPMENT DAMPING	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
1% (5g)	STANDARD	1774	1834	559	9609	8419	802
	HEAVY	2024	1806	729	9154	8127	912
	EXTRA HEAVY	2619	1884	1083	9416	9689	995
3% (3g)	STANDARD	1064	1100	335	5765	5051	481
	HEAVY	1215	1083	438	5493	4876	547
	EXTRA HEAVY	1571	1130	650	5650	5813	597

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7.21A (3 of 3)

PRELIMINARY

COMPARISON OF ANCHOR DESIGN LOADS
MODIFIED MODEL NO. 3 NODE 1 WITH FLAT ARS
(DL + THER + SSEI)

EQUIPMENT DAMPING	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
1% (5g)	STANDARD	-	-	-	7919	6583	11811
	HEAVY	-	-	-	7469	5304	12595
	EXTRA HEAVY	-	-	-	7618	8022	14275
3% (3g)	STANDARD	-	-	-	4744	3864	7190
	HEAVY	-	-	-	4467	3018	7733
	EXTRA HEAVY	-	-	-	4555	4623	8784

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7.22A (1 OF 3)

COMPARISON OF ANCHOR DESIGN LOADS
MODIFIED MODEL NO. 3 NODE 17 WITH FLAT ARS
(DL + THER + SSEI)

EQUIPMENT DAMPING	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
1% (5g)	STANDARD	324	1031	985			
	HEAVY	358	1548	1320			
	EXTRA HEAVY	339	1902	1443			
3% (3g)	STANDARD	199	474	381			
	HEAVY	223	492	351			
	EXTRA HEAVY	212	570	310			

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7.22A (2 OF 3)

PRELIMINARY

COMPARISON OF ANCHOR DESIGN LOADS
MODIFIED MODEL NO. 3 NODE 21 WITH FLAT ARS
(DL + THER + SSEI)

EQUIPMENT DAMPING	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
1% (5g)	STANDARD	2479	1835	593	9613	12309	822
	HEAVY	2860	1808	755	9158	12270	938
	EXTRA HEAVY	3513	1886	1141	9423	13916	1022
3% (3g)	STANDARD	1073	1371	338	6811	5092	494
	HEAVY	1229	1371	443	6587	4933	608
	EXTRA HEAVY	1589	1436	687	6823	5880	680

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7.22A (3 OF 3)

COMPARISON OF SELECTED THERMAL AND DEAD WEIGHT STRESSES (PSI), BENCHMARK MODEL NO. 7

LOADING	NODE	MEMBER TYPE	STANDARD FITTINGS	HEAVY FITTINGS	EXTRA HEAVY
THERMAL	2	ELBOW	4995	3189	2873
	11	ELBOW	4297	2783	2474
	41	ELBOW	6212	3675	3276
	60	RUN	173	202	212
	81	ELBOW	3155	1786	1578
	121	ELBOW	1533	925	828
DEAD WEIGHT	2	ELBOW	225	157	154
	11	ELBOW	307	162	145
	41	ELBOW	295	147	131
	60	RUN	166	188	194
	81	ELBOW	185	113	102
	121	ELBOW	71	45	42

NOTES: Heavy fittings are twice as thick as standard fittings.

Extra heavy fittings are three times as thick as standard fittings.

FIGURE 7.23

PRELIMINARY

COMPARISON OF SELECTED SSE SEISMIC STRESSES (PSI)
BENCHMARK MODEL NO. 7
FLAT ARS

NODE	MEMBER TYPE	EQUIPMENT SAMPING	STANDARD FITTINGS	HEAVY FITTINGS	EXTRA HEAVY
2	ELBOW		50512	26178	23354
11	ELBOW	1%	14975	7221	6415
41	ELBOW		11353	6059	5402
60	RUN	(5g)	8814	6695	6499
81	ELBOW		8867	4891	4348
121	ELBOW		21263	10637	9381
2	ELBOW		30307	15707	14012
11	ELBOW	3%	8985	4333	3849
41	ELBOW		6812	3635	3241
60	RUN	(3g)	5288	4017	3899
81	ELBOW		5320	2935	2609
121	ELBOW		12758	6382	5629

NOTES: Heavy fittings are twice as thick as standard fittings.

Extra heavy fittings are three times as thick as standard fittings.

FIGURE 7.24A

PRELIMINARY

COMPARISON OF SEISMIC (SSE)
RESTRAINT LOADS (LBS) BENCHMARK MODEL 7
FLAT ARS

EQUIPMENT DAMPING	FITTING TYPE	NODE 20	NODE 110				
		F_Y	F_Y				
1% (5g)	STANDARD	1072	826				
	HEAVY	1105	854				
	EXTRA HEAVY	1156	882				
3% (3g)	STANDARD	643	495				
	HEAVY	663	513				
	EXTRA HEAVY	694	529				

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7.25A

PRELIMINARY

RESTRAINT DESIGN LOADS
FOR BENCHMARK MODEL 7 WITH FLAT ARS
(DL + THER + SSE)

EQUIPMENT DAMPING	FITTING TYPE	NODE 20	NODE 110				
		F_Y	F_Y				
1% (5g)	STANDARD	1556	1004				
	HEAVY	1686	1039				
	EXTRA HEAVY	1771	1071				
3% (3g)	STANDARD	1127	673				
	HEAVY	1244	698				
	EXTRA HEAVY	1309	718				

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7.25B

COMPARISON OF ANCHOR THERMAL & DEAD WEIGHT LOADS

MODEL NO. 7 NODE 1

LOADING CONDITION	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
THERMAL	STANDARD	308	187	-48	565	-668	1113
	HEAVY	404	271	-79	806	-988	1504
	EXTRA HEAVY	429	293	-87	871	-1075	1608
DEAD WEIGHT	STANDARD	-11	-69	3	-50	28	6
	HEAVY	-13	-76	4	-82	36	7
	EXTRA HEAVY	-14	-82	4	-97	39	7

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7.26 (1 OF 5)

PRELIMINARY

COMPARISON OF ANCHOR THERMAL & DEAD WEIGHT LOADS

MODEL NO. 7 NODE 55

LOADING CONDITION	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
THERMAL	STANDARD	169	-47	-317	-768	-388	-360
	HEAVY	215	-58	-364	-872	-349	-449
	EXTRA HEAVY	225	-60	-372	-886	-340	-466
DEAD WEIGHT	STANDARD	0	-92	-2	7	-5	3
	HEAVY	0	-97	-3	7	-6	5
	EXTRA HEAVY	0	-100	-3	7	-6	6

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7.26 (2 OF 5)

COMPARISON OF ANCHOR THERMAL & DEAD WEIGHT LOADS

MODEL NO. 7 NODE 65

LOADING CONDITION	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
THERMAL	STANDARD	-419	25	648	74	-233	-110
	HEAVY	-547	34	772	81	-392	-101
	EXTRA HEAVY	-580	36	796	82	-430	-99
DEAD WEIGHT	STANDARD	10	-378	-1	46	5	-188
	HEAVY	12	-385	-1	51	7	-172
	EXTRA HEAVY	13	-397	-2	54	8	-168

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7.26 (3 OF 5)

PRELIMINARY

COMPARISON OF ANCHOR THERMAL & DEAD WEIGHT LOADS

MODEL NO. 7 NODE 95

LOADING CONDITION	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
THERMAL	STANDARD	10	-27	-251	-611	-598	45
	HEAVY	12	-30	-291	-720	-674	54
	EXTRA HEAVY	12	-31	-298	-736	-687	56
DEAD WEIGHT	STANDARD	0	-91	0	-8	2	18
	HEAVY	0	-96	0	-9	2	25
	EXTRA HEAVY	0	-99	0	-9	2	26

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7.26 (4 OF 5)

PRELIMINARY

COMPARISON OF ANCHOR THERMAL & DEAD WEIGHT LOADS

MODEL NO. 7 NODE 140

LOADING CONDITION	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
THERMAL	STANDARD	-68	-9	-33	-31	-352	222
	HEAVY	-83	-9	-38	-48	-439	268
	EXTRA HEAVY	-86	-9	-39	-50	-454	276
DEAD WEIGHT	STANDARD	1	-104	0	-30	4	46
	HEAVY	1	-111	0	-33	3	59
	EXTRA HEAVY	1	-116	0	-34	4	63

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7.26 (5 OF 5)

PRELIMINARY

COMPARISON OF (SSE) SEISMIC ANCHOR LOADS
BENCHMARK MODEL NO. 7 NODE 1
FLAT ARS

EQUIPMENT DAMPING	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
1% (5g)	STANDARD	1316	1880	1926	12132	5710	1806
	HEAVY	1343	2229	2199	14525	5726	2090
	EXTRA HEAVY	1406	2382	2326	15560	5955	2222
3% (3g)	STANDARD	789	1128	1156	7279	3426	1084
	HEAVY	806	1337	1319	8715	3435	1254
	EXTRA HEAVY	844	1429	1395	9336	3573	1333

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7.27 A (1 OF 3)

PRELIMINARY

COMPARISON OF (SSE) SEISMIC ANCHOR LOADS
BENCHMARK MODEL NO. 7 NODE 35
FLAT ARS

EQUIPMENT DAMPING	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
1% (5g)	STANDARD	737	1057	974	2766	2078	3545
	HEAVY	797	1071	1048	2952	2075	3891
	EXTRA HEAVY	823	1097	1084	3042	2124	4028
3% (3g)	STANDARD	442	634	585	1660	1247	2127
	HEAVY	478	643	629	1771	1245	2335
	EXTRA HEAVY	494	658	651	1825	1274	2417

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7.27A (2 OF 5)

COMPARISON OF (SSE) SEISMIC ANCHOR LOADS
BENCHMARK MODEL NO. 7 NODE 65
FLAT ARS

EQUIPMENT DAMPING	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
1% (5g)	STANDARD	1324	1128	1473	2208	7368	4604
	HEAVY	1282	1082	1407	1900	6542	4401
	EXTRA HEAVY	1302	1122	1434	1896	6605	4530
3% (3g)	STANDARD	794	677	844	1325	4421	2762
	HEAVY	769	649	844	1140	3925	2641
	EXTRA HEAVY	781	673	861	1138	3963	2713

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7.27A (3 OF 5)

PRELIMINARY

COMPARISON OF (SSE) SEISMIC ANCHOR LOADS
BENCHMARK MODEL NO. 7 NODE 95
FLAT ARS

EQUIPMENT DAMPING	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
1% (5g)	STANDARD	922	1199	576	1498	729	4377
	HEAVY	896	1238	641	1631	750	4776
	EXTRA HEAVY	908	1269	663	1682	771	4934
3% (3g)	STANDARD	553	720	346	899	438	2626
	HEAVY	538	743	385	979	450	2866
	EXTRA HEAVY	545	761	398	1009	463	2960

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7.27A (4 OF 5)

COMPARISON OF (SSE) SEISMIC ANCHOR LOADS
BENCHMARK MODEL NO. 7 NODE 140
FLAT ARS

EQUIPMENT DAMPING	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
1% (5g)	STANDARD	840	871	1720	4671	3235	3795
	HEAVY	961	919	1749	4841	3124	4214
	EXTRA HEAVY	1000	946	1784	4947	3167	4370
3% (3g)	STANDARD	504	523	1032	2803	1941	2277
	HEAVY	577	551	1049	2905	1874	2528
	EXTRA HEAVY	600	567	1071	2968	1900	2622

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7.27A (5 OF 5)

PRELIMINARY

COMPARISON OF ANCHOR DESIGN LOADS
BENCHMARK MODEL NO. 7 NODE 1 WITH FLAT ARS
(DL + THER + SSEI)

EQUIPMENT DAMPING	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
1% (5g)	STANDARD	1624	2067	1974	12697	6378	2919
	HEAVY	1747	2500	2278	15331	6714	3594
	EXTRA HEAVY	1835	2675	2413	16431	7030	3830
3% (3g)	STANDARD	800	1197	1159	7329	3454	1090
	HEAVY	819	1413	1323	8797	3471	1261
	EXTRA HEAVY	858	1511	1399	9433	3612	1340

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7.28A (1 OF 5)

PRELIMINARY

COMPARISON OF ANCHOR DESIGN LOADS
BENCHMARK MODEL NO. 7 NODE 35 WITH FLAT ARS
(DL + THER + SSEI)

EQUIPMENT DAMPING	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
1% (5g)	STANDARD	906	1104	1291	3534	2466	3905
	HEAVY	1012	1129	1412	3824	2424	4340
	EXTRA HEAVY	1048	1157	1456	3928	2464	4492
3% (3g)	STANDARD	442	726	587	1667	1252	2130
	HEAVY	478	740	632	1778	1251	2340
	EXTRA HEAVY	494	758	654	1832	1280	2423

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7.28A (2 OF 5)

PRELIMINARY

COMPARISON OF ANCHOR DESIGN LOADS
BENCHMARK MODEL NO. 7 NODE 65 WITH FLAT ARS
(DL + THER + SSEI)

EQUIPMENT DAMPING	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
1% (5g)	STANDARD	1743	1153	2121	2282	7601	4714
	HEAVY	1829	1116	2179	1981	6934	4502
	EXTRA HEAVY	1882	1158	2230	1978	7035	4629
1% (3g)	STANDARD	804	1055	885	1371	4426	2950
	HEAVY	781	1034	845	1191	3932	2813
	EXTRA HEAVY	794	1070	863	1192	3971	2886

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7.28A (3 OF 5)

PRELIMINARY

COMPARISON OF ANCHOR DESIGN LOADS
BENCHMARK MODEL NO. 7 NODE 05 WITH FLAT ARS
(DL + THER + SSEI)

EQUIPMENT DAMPING	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
1% (5g)	STANDARD	932	1226	827	2109	1327	4422
	HEAVY	908	1268	932	2351	1424	4830
	EXTRA HEAVY	920	1300	961	2418	1458	4990
3% (3g)	STANDARD	553	811	346	907	440	2644
	HEAVY	538	839	385	988	452	2891
	EXTRA HEAVY	545	860	398	1018	465	2986

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7.28A (4 OF 5)

PRELIMINARY

COMPARISON OF ANCHOR DESIGN LOADS
BENCHMARK MODEL NO. 7 NODE 140 WITH FLAT ARS
(DL + THER + SSEI)

EQUIPMENT SAMPLING	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
1% (5g)	STANDARD	908	880	1753	4702	3578	4017
	HEAVY	1044	928	1787	4889	3563	4482
	EXTRA HEAVY	1086	955	1823	4997	3621	4646
3% (3g)	STANDARD	505	617	1032	2833	1945	2323
	HEAVY	578	662	1049	2938	1877	2587
	EXTRA HEAVY	601	683	1071	3002	1904	2685

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7.28A (5 OF 5)

PRELIMINARY

24" PIPING STUDY
COMPARISON OF SELECTED THERMAL AND DEAD WEIGHT STRESSES (PSI)

LOADING	NODE	MEMBER TYPE	STANDARD FITTINGS	HEAVY FITTINGS	EXTRA HEAVY
THERMAL	290	ELBOW	22,181	19,053	14,261
	335	RUN	15,742	18,410	20,241
	380	ELBOW	1,844	1,938	1,436
	469	TEE	10,291	3,509	1,878
	575	RUN	11,395	12,582	13,277
	600	ELBOW	12,070	8,821	6,110
DEAD WEIGHT	290	ELBOW	627	258	159
	335	RUN	718	778	843
	380	ELBOW	6,652	2,077	1,070
	469	TEE	156	61	35
	575	RUN	894	1,235	1,508
	600	ELBOW	174	361	317

NOTES: **Heavy fittings are twice as thick as standard fittings.**

Extra heavy fittings are three times as thick as standard fittings.

Figure 7.29

PRELIMINARY

24" PIPING STUDY

COMPARISON OF SELECTED SEISMIC* STRESSES (PSI) - FLAT ARS

NODE	MEMBER TYPE	EQUIPMENT DAMPING	STANDARD FITTINGS	HEAVY FITTINGS	EXTRA HEAVY
290	ELBOW		4,167	1,544	912
335	RUN		5,316	5,604	5,616
380	ELBOW	1%	24,291	5,796	2,551
469	TEE	(5G)	9,279	3,491	1,992
575	RUN		7,534	7,864	8,151
600	ELBOW		11,879	3,417	2,115
290	ELBOW		2,500	926	547
335	RUN		3,189	3,363	3,370
380	ELBOW	3%	14,575	3,478	1,530
469	TEE	(3g)	5,568	2,094	1,195
575	RUN		4,520	4,719	4,890
600	ELBOW		7,128	2,050	1,269

NOTES: Heavy fittings are twice as thick as standard fittings.

Extra heavy fittings are three times as thick as standard fittings.

Figure 7.30

24" PIPING STUDY
COMPARISON OF SELECTED SEISMIC STRESSES (PSI)
BVPS-2 ARS (FIG. 4.3 & 4.4)

NODE	MEMBER TYPE	EQUIPMENT DAMPING	STANDARD FITTINGS	HEAVY FITTINGS	EXTRA HEAVY
290	Elbow	1%	379	130	74
335	Run		450	453	456
380	Elbow		2,996	566	238
469	Tee		755	283	161
575	Run		697	716	750
600	Elbow		1,298	356	230
290	Elbow	3%	349	124	72
335	Run		429	439	441
380	Elbow		2,388	486	208
469	Tee		742	279	159
575	Run		637	651	678
600	Elbow		1,085	303	190

NOTES: Heavy fittings are twice as thick as standard fittings.

Extra heavy fittings are three times as thick as standard fittings.

Figure 7.31

PRELIMINARY

24" PIPING STUDY

RESTRAINT THERMAL & DEAD WEIGHT LOADS [lbs.]

LOADING	FITTING TYPE	SUPPORT TYPE - RIGID					
		NODE	NODE	NODE	NODE	NODE	NODE
		25	45	65	150	170	230
		F_z	F_z	F_z	F_x	F_x	F_x
THERMAL	STANDARD	-3,794	6,368	-3,932	3,785	-3,070	-4,325
	HEAVY	-4,662	7,827	-5,270	5,051	-3,728	-5,648
	EXTRA HEAVY	-5,087	8,539	-5,924	5,669	-4,050	-6,442
DEAD WEIGHT	STANDARD	0	0	0	0	0	1,066
	HEAVY	0	0	0	0	0	1,664
	EXTRA HEAVY	0	0	0	0	0	2,090

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7.32 (1 OF 3)

24" PIPING STUDY

RESTRAINT THERMAL & DEAD WEIGHT LOADS [lbs.]

LOADING	FITTING TYPE	SUPPORT TYPE - RIGID					
		NODE	NODE	NODE	NODE	NODE	NODE
		230	250	270	315	335	335
		F_y	F_y	F_y	F_x	F_x	F_z
THERMAL	STANDARD	2,215	-7,480	13,087	9,633	-11,039	16,424
	HEAVY	2,784	-9,082	19,310	11,659	13,735	22,501
	EXTRA HEAVY	3,164	-10,181	23,627	12,952	-15,450	26,716
DEAD WEIGHT	STANDARD	-3,978	-2,431	-3,813	1,545	-2,015	19
	HEAVY	-4,395	-2,492	-3,754	1,663	-2,197	17
	EXTRA HEAVY	-4,786	-2,505	-3,770	1,802	-2,386	16

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7.32 (2 OF 3)

PRELIMINARY

24" PIPING STUDY

RESTRAINT THERMAL & DEAD WEIGHT LOADS [lbs.]

LOADING	FITTING TYPE	SUPPORT TYPE - RIGID					
		NODE	NODE	NODE	NODE	NODE	NODE
		355	385	505	525	525	640
		F_z	F_y	F_y	F_y	F_z	F_y
THERMAL	STANDARD	-9,493	-7,497	987	567	2,329	-3,255
	HEAVY	-11,086	-12,163	2,469	476	2,698	-5,119
	EXTRA HEAVY	-12,182	-15,477	3,381	390	2,915	-6,215
DEAD WEIGHT	STANDARD	-5	-19,092	1,495	-20,579	-76	-6,543
	HEAVY	-4	-19,963	946	-21,137	-122	-6,273
	EXTRA HEAVY	-4	-20,797	651	-21,815	-152	-6,124

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7. 32 (3 OF 3)

PRELIMINARY

24" PIPING STUDY
COMPARISON OF SEISMIC
RESTRAINT LOADS (lbs.)
FLAT ARS

EQUIPMENT DAMPING	FITTING TYPE	SUPPORT TYPE - RIGID					
		NODE	NODE	NODE	NODE	NODE	NODE
		25	45	65	150	170	230
		F_z	F_z	F_z	F_x	F_x	F_x
1% (5G)	STANDARD	11,695	16,203	13,833	10,361	9,547	17,381
	HEAVY	12,439	17,343	13,766	12,154	10,686	16,902
	EXTRA HEAVY	12,109	17,354	12,307	12,406	10,614	18,834
3% (3g)	STANDARD	7,071	9,722	8,300	6,216	5,728	10,429
	HEAVY	7,463	10,406	8,260	7,292	6,412	10,141
	EXTRA HEAVY	7,266	10,412	7,384	7,444	6,368	11,300

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7.33 (1 OF 3)

PRELIMINARY

24" PIPING STUDY
COMPARISON OF SEISMIC
RESTRAINT LOADS (lbs.)
FLAT ARS

EQUIPMENT DAMPING	FITTING TYPE	SUPPORT TYPE - RIGID					
		NODE	NODE	NODE	NODE	NODE	NODE
		230	250	270	315	335	335
		F_y	F_y	F_y	F_x	F_x	F_z
1% (5G)	STANDARD	8,823	6,878	14,490	10,664	17,899	11,906
	HEAVY	9,745	6,109	13,857	11,611	19,506	11,849
	EXTRA HEAVY	9,464	6,671	12,354	11,108	18,226	13,329
3% (3g)	STANDARD	5,294	4,127	8,694	6,399	10,740	7,143
	HEAVY	5,847	3,665	8,314	6,967	11,704	7,110
	EXTRA HEAVY	5,678	4,003	7,412	6,665	10,935	7,997

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.
EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7.33 (2 OF 3)

PRELIMINARY

24" PIPING STUDY
COMPARISON OF SEISMIC RESTRAINT LOADS (lbs.)
FLAT ARS

EQUIPMENT DAMPING	FITTING TYPE	SUPPORT TYPE - RIGID					
		NODE	NODE	NODE	NODE	NODE	NODE
		355	385	505	525	525	640
		F_z	F_y	F_y	F_y	F_z	F_y
1% (5G)	**STANDARD**	12,568	66,831	16,699	17,401	13,250	11,200
	HEAVY	13,022	61,365	17,718	20,034	14,795	10,072
	EXTRA HEAVY	14,935	60,121	17,933	21,569	16,262	10,978
3% (3g)	**STANDARD**	7,541	40,099	10,019	10,440	7,950	6,720
	HEAVY	7,813	36,819	10,631	12,021	8,877	6,043
	EXTRA HEAVY	8,961	36,073	10,760	12,941	9,757	6,587

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7.33 (3 OF 3)

PRELIMINARY

24" PIPING STUDY
COMPARISON OF DESIGN
RESTRAINT LOADS [lbs.]
(DW + THER + FLAT ARS)

EQUIPMENT DAMPING	FITTING TYPE	SUPPORT TYPE - RIGID					
		NODE 25	NODE 45	NODE 65	NODE 150	NODE 170	NODE 230
		F_z	F_z	F_z	F_x	F_x	F_x
1% (5G)	STANDARD	15,489	22,571	17,765	14,146	12,617	20,640
	HEAVY	17,101	25,170	19,036	17,205	14,414	20,886
	EXTRA HEAVY	17,196	25,893	18,231	18,075	14,664	23,186
3% (3g)	STANDARD	10,865	16,090	12,232	10,001	8,798	13,688
	HEAVY	12,125	18,233	13,530	12,343	10,140	14,125
	EXTRA HEAVY	12,355	18,951	13,308	13,113	10,418	15,652

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.
EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7.34 (1 OF 3)

PRELIMINARY

24" PIPING STUDY
COMPARISON OF DESIGN
RESTRAINT LOADS (lbs.)
(DL + THER + FLAT ARS)

EQUIPMENT DAMPING	FITTING TYPE	SUPPORT TYPE - RIGID					
		NODE	NODE	NODE	NODE	NODE	NODE
		230	250	270	315	335	335
		F_y	F_y	F_y	F_x	F_x	F_z
1% (3G)	STANDARD	12,801	16,789	23,764	21,842	30,953	28,349
	HEAVY	14,140	17,683	29,413	24,933	35,438	34,367
	EXTRA HEAVY	14,250	19,357	32,211	25,862	36,062	40,061
3% (3g)	STANDARD	9,272	14,038	17,968	17,577	23,794	23,586
	HEAVY	10,242	15,239	23,870	20,289	27,636	29,628
	EXTRA HEAVY	10,464	16,689	27,269	21,419	28,771	34,729

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7.34 (2 OF 3)

PRELIMINARY

24" PIPING STUDY COMPARISON OF DESIGN RESTRAINT LOADS (lbs.) (DL + THER + FLAT ARS)

EQUIPMENT DAMPING	FITTING TYPE	SUPPORT TYPE - RIGID					
		NODE	NODE	NODE	NODE	NODE	NODE
		355	385	505	525	525	640
		F_z	F_y	F_y	F_y	F_z	F_y
1% (5G)	STANDARD	22,066	93,420	19,181	37,980	15,503	20,998
	HEAVY	24,112	93,491	21,133	41,171	17,371	21,464
	EXTRA HEAVY	27,121	96,395	21,965	43,384	19,025	23,317
3% (3g)	STANDARD	17,039	66,688	12,501	31,019	10,203	16,518
	HEAVY	18,903	68,945	14,046	33,158	11,453	17,435
	EXTRA HEAVY	21,147	72,347	14,792	34,756	14,150	18,926

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7.34 (3 OF 3)

PRELIMINARY

24" PIPING STUDY
COMPARISON OF DESIGN/SEISMIC
RESTRAINT LOADS (lbs.) FOR SNUBBERS
(DL + THER + FLAT ARS)

EQUIPMENT DAMPING	FITTING TYPE	SUPPORT TYPE - SNUBBER					
		NODE	NODE	NODE	NODE	NODE	NODE
		85	130	315	355	485	6051
		F_z	F_x	F_z	F_x	F_z	F_y
1% (5G)	STANDARD	11,957	14,285	15,750	17,497	11,426	35,904
	HEAVY	13,439	15,086	14,792	18,686	11,486	36,837
	EXTRA HEAVY	14,420	14,880	14,626	18,262	11,718	38,375
3% (3g)	STANDARD	7,174	8,571	9,450	10,498	6,856	21,542
	HEAVY	8,063	9,052	8,875	11,212	6,892	22,102
	EXTRA HEAVY	8,652	8,928	8,775	10,957	7,031	23,025

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

FIGURE 7.35

PRELIMINAR

24" PIPING STUDY

COMPARISON OF ANCHOR THERMAL & DEAD WEIGHT LOADS

(TERMINAL ANCHOR, NODE 5)

LOADING CONDITION	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
THERMAL	STANDARD	-1421	0	-20	0	185	0
	HEAVY	-2178	0	-25	0	228	0
	EXTRA HEAVY	-2547	0	-27	0	249	0
DEAD WEIGHT	STANDARD	0	-1554	0	743	0	-7952
	HEAVY	0	-1554	0	651	0	-7952
	EXTRA HEAVY	0	-1554	0	643	0	-7952

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

Figure 7.36 (1 of 4)

PRELIMINARY

24" PIPING STUDY

COMPARISON OF ANCHOR THERMAL & DEAD WEIGHT LOADS

(INLINE ANCHOR, NODE 190)

LOADING CONDITION	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
THERMAL	STANDARD	942	137	-8274	-734	-3153	-7
	HEAVY	1107	171	-12,308	-916	-4044	89
	EXTRA HEAVY	1185	194	-15,255	-1037	-4489	142
DEAD WEIGHT	STANDARD	7	-3023	-11	121	75	-911
	HEAVY	11	-3030	-8	194	112	-795
	EXTRA HEAVY	13	-3034	-6	248	138	-844

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

Figure 7.36 (2 of 4)

PRELIMINARY

24" PIPING STUDY

COMPARISON OF ANCHOR THERMAL & DEAD WEIGHT LOADS

(TERMINAL ANCHOR, NODE 445)

LOADING CONDITION	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
THERMAL	STANDARD	1355	10	-16	1820	-129	-78
	HEAVY	2014	-17	-19	2069	-158	143
	EXTRA HEAVY	2430	-31	-22	2269	-176	252
DEAD WEIGHT	STANDARD	455	-1396	0	-4	-1	6301
	HEAVY	513	-1397	0	0	-1	6303
	EXTRA HEAVY	561	-1395	0	1	0	6287

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

Figure 7.36 (3 of 4)

PRELIMINARY

24" PIPING STUDY

COMPARISON OF ANCHOR THERMAL & DEAD WEIGHT LOADS

(TERMINAL ANCHOR, NODE 660)

LOADING CONDITION	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
THERMAL	STANDARD	80	1895	4165	15,509	-656	2960
	HEAVY	94	2668	5999	21,826	-768	3515
	EXTRA HEAVY	100	3123	7069	25,553	-819	3780
DEAD WEIGHT	STANDARD	-11	-48	-261	7,865	111	-252
	HEAVY	-15	-184	-486	6,444	158	-428
	EXTRA HEAVY	-18	-254	-630	5,701	193	-547

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

Figure 7.36 (4 of 4)

PRELIMINARY

24" PIPING STUDY

COMPARISON OF SEISMIC ANCHOR LOADS

(TERMINAL ANCHOR, NODE 5)

FLAT ARS

EQUIPMENT DAMPING	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
1% (5G)	STANDARD	65,682	5,940	4,759	2,046	23,368	29,208
	HEAVY	53,564	5,959	4,955	1,881	24,333	29,302
	EXTRA HEAVY	50,490	5,967	4,656	1,988	22,861	29,341
3% (3g)	STANDARD	39,409	3,564	2,855	1,228	14,021	17,525
	HEAVY	32,139	3,575	2,973	1,129	14,600	17,582
	EXTRA HEAVY	30,294	3,580	2,793	1,193	13,716	17,605

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

Figure 7.37 (1 of 4)

PRELIMINARY

24" PIPING STUDY

COMPARISON OF SEISMIC ANCHOR LOADS

(INLINE ANCHOR, NODE 190)

FLAT ARS

EQUIPMENT DAMPING	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
1% (5G)	STANDARD	9,312	8,594	54,715	31,413	48,850	4,798
	HEAVY	10,536	7,524	56,124	32,670	52,705	6,552
	EXTRA HEAVY	11,020	7,608	58,203	35,679	53,245	5,921
3% (3g)	STANDARD	5,587	5,156	32,829	18,848	29,310	2,879
	HEAVY	6,322	4,514	33,675	19,602	31,623	3,931
	EXTRA HEAVY	6,612	4,565	34,922	21,407	31,947	3.553

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

Figure 7.37 (2 of 4)

PRELIMINARY

24" PIPING STUDY

COMPARISON OF SEISMIC ANCHOR LOADS

(TERMINAL ANCHOR, NODE 445)

FLAT ARS

EQUIPMENT DAMPING	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
1% (5G)	STANDARD	9,937	5,434	6,993	3,120	35,962	30,725
	HEAVY	15,089	6,229	6,597	2,761	32,945	34,993
	EXTRA HEAVY	17,826	5,045	7,385	2,785	36,204	28,739
3% (3g)	STANDARD	5,962	3,261	4,196	1,872	21,577	18,435
	HEAVY	9,054	3,737	3,958	1,656	19,767	20,996
	EXTRA HEAVY	10,696	3,027	4,431	1,671	21,722	17,244

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

Figure 7.37 (3 of 4)

24" PIPING STUDY

COMPARISON OF SEISMIC ANCHOR LOADS

(TERMINAL ANCHOR, NODE 660)

FLAT ARS

EQUIPMENT DAMPING	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
1% (5G)	STANDARD	7,710	7,209	9,960	43,265	42,396	3,394
	HEAVY	7,731	7,283	13,351	42,542	41,616	4,241
	EXTRA HEAVY	8,087	8,265	16,429	47,372	44,509	6,143
3% (3g)	STANDARD	4,626	4,326	5,976	25,959	25,438	2,036
	HEAVY	4,639	4,370	8,010	25,525	24,970	2,544
	EXTRA HEAVY	4,582	4,959	9,857	28,423	26,705	3,686

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

Figure 7.37 (4 of 4)

PRELIMINARY

24" PIPING STUDY

COMPARISON OF ANCHOR DESIGN LOADS

(TERMINAL ANCHOR, NODE 5)

(DL + THER + FLAT ARS)

EQUIPMENT DAMPING	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
1% (5G)	STANDARD	67,103	7,494	4,779	2,789	23,553	37,160
	HEAVY	55,742	7,513	4,980	2,532	24,561	37,254
	EXTRA HEAVY	53,037	7,521	4,683	2,631	23,110	37,293
3% (3g)	STANDARD	40,830	5,118	2,875	1,971	14,206	25,477
	HEAVY	34,317	5,129	2,998	1,780	14,828	25,534
	EXTRA HEAVY	32,841	5,134	2,820	1,836	13,965	25,557

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

Figure 7.38 (1 of 4)

PRELIMINARY

24" PIPING STUDY

COMPARISON OF ANCHOR DESIGN LOADS

(INLINE ANCHOR, NODE 190)

(DL + THER + FLAT ARS)

EQUIPMENT DAMPING	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
1% (5G)	**STANDARD**	10,261	11,617	63,000	32,026	51,930	5,716
	HEAVY	11,654	10,554	68,440	33,392	56,637	7,347
	EXTRA HEAVY	12,218	10,642	73,464	36,465	57,596	6,765
3% (3g)	**STANDARD**	6,536	8,179	41,114	19,461	32,390	3,797
	HEAVY	7,440	7,544	45,991	20,324	35,555	4,726
	EXTRA HEAVY	7,810	7,599	50,183	22,193	36,298	4,397

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

Figure 7.38 (2 of 4)

PRELIMINARY

24" PIPING STUDY

COMPARISON OF ANCHOR DESIGN LOADS

(TERMINAL ANCHOR, NODE 445)

(DL + THER + FLAT ARS)

EQUIPMENT DAMPING	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
1% (5G)	STANDARD	11,747	6,830	7,009	4,936	36,092	37,026
	HEAVY	17,616	7,643	6,616	4,830	33,104	41,439
	EXTRA HEAVY	20,817	6,471	7,407	5,055	36,380	35,278
3% (3g)	STANDARD	7,772	4,657	4,212	3,688	21,707	24,736
	HEAVY	11,581	5,151	3,977	3,725	19,926	27,442
	EXTRA HEAVY	13,687	4,453	4,453	3,941	21,898	23,783

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

Figure 7.38 (3 of 4)

PRELIMINARY

24" PIPING STUDY

COMPARISON OF ANCHOR DESIGN LOADS

(TERMINAL ANCHOR, NODE 660)

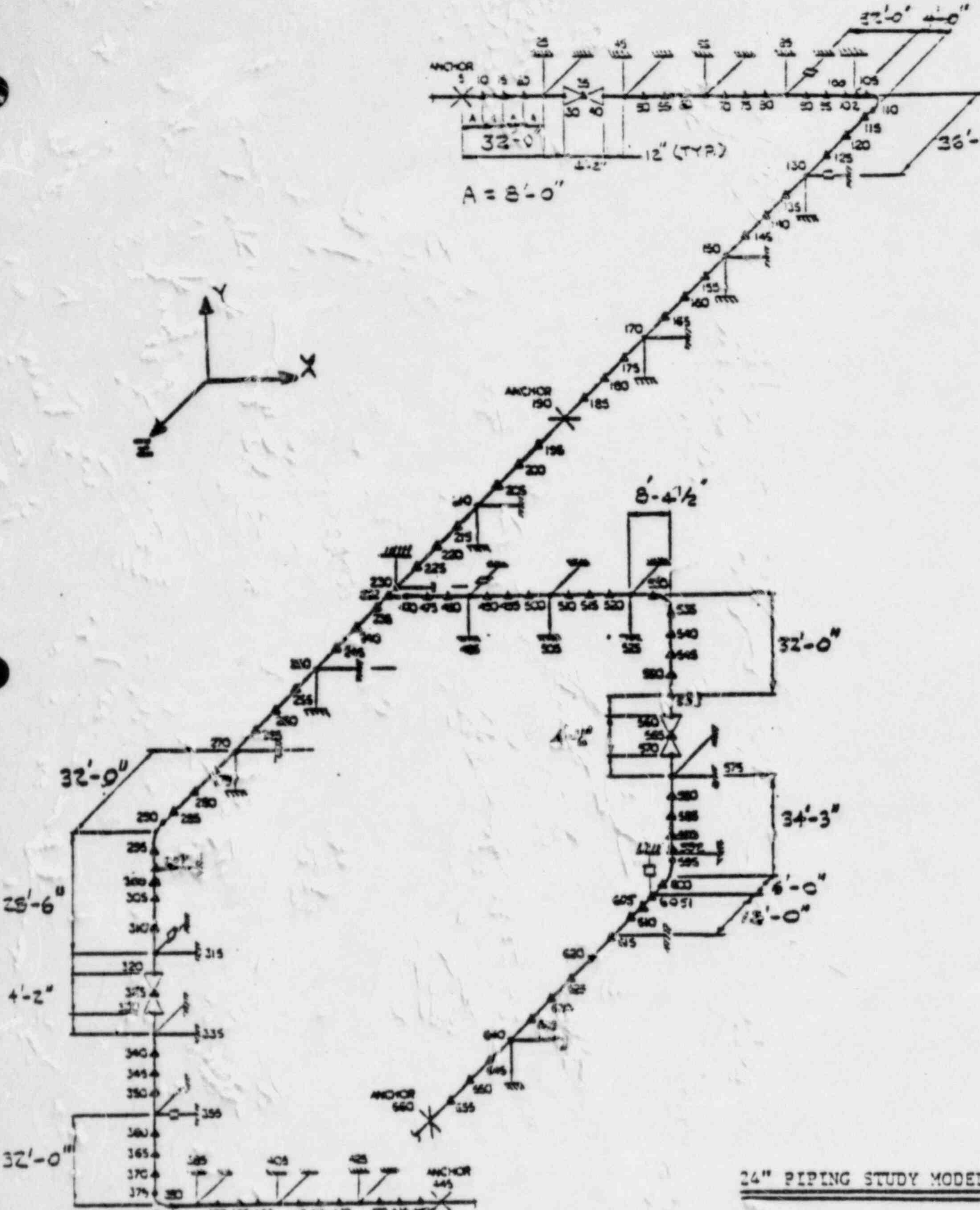
(DL + THER + FLAT ARS)

EQUIPMENT DAMPING	FITTING TYPE	FORCES, LBS.			MOMENTS, FT-LB		
		F_X	F_Y	F_Z	M_X	M_Y	M_Z
1% (5G)	STANDARD	7,779	9,056	13,864	66,639	42,941	6,102
	HEAVY	7,810	9,767	18,864	70,812	42,226	7,328
	EXTRA HEAVY	8,169	11,134	22,868	78,626	45,135	9,376
3% (3g)	STANDARD	4,695	6,173	9,880	49,333	25,983	4,744
	HEAVY	4,718	6,854	13,523	53,795	25,580	5,631
	EXTRA HEAVY	4,664	7,828	16,296	59,677	27,331	6,919

NOTES: HEAVY FITTINGS ARE TWICE AS THICK AS STANDARD FITTINGS.

EXTRA HEAVY FITTINGS ARE THREE TIMES AS THICK AS STANDARD FITTINGS.

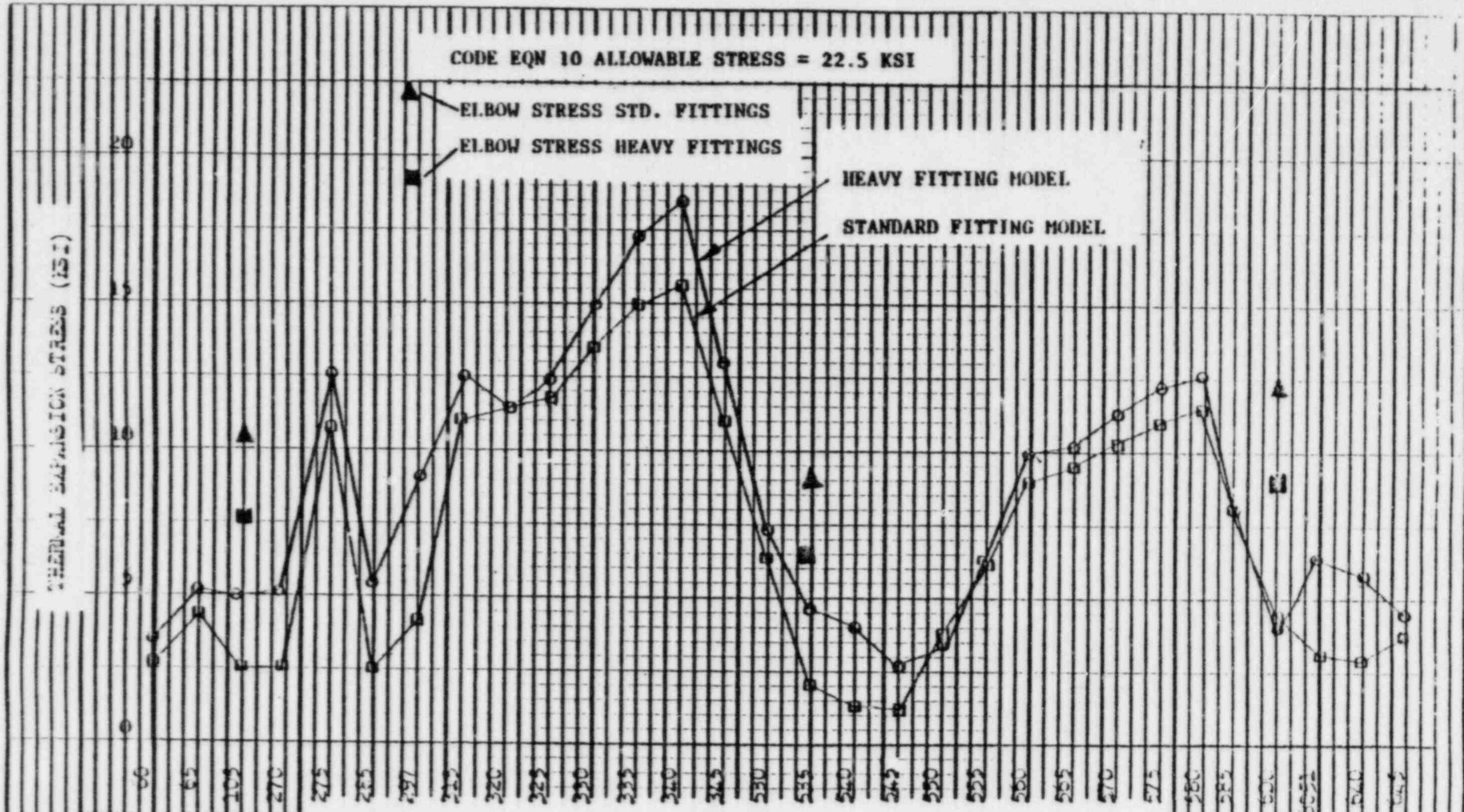
Figure 7.38 (4 of 4)



24" PIPING STUDY MODEL

PRELIMINARY

FIGURE 7.4



THERMAL EXPANSION STRESS CHANGES IN TYPICAL STRAIGHT PIPE RUN ELEMENTS CAUSED BY HEAVY FITTING SUBSTITUTION IN THE 24 IN. MODEL (FIG. 7.4)

FIGURE 7.39

PRELIMINARY

PRELIMINARY

THERMAL STRESS CHANGE IN STRAIGHT RUN ELEMENTS

AT SIGNIFICANT STRESS LOCATIONS ($S_e > 5000$ PSI)

24" MODEL (FIG. 7.4)

NODE	THERMAL STRESS		STRESS CHANGE
	HEAVY FITTINGS	STD. FITTINGS	
270	12850	10642	.21
275	5500	6274	-.12
297	12612	10969	.15
315	11518	11190	.03
320	12540	11849	.06
325	14813	13335	.11
330	17220	14939	.15
335	18410	15742	.17
340	12843	11038	.16
345	7322	6407	.14
550	6513	6477	.01
555	9906	9250	.07
560	10338	9598	.08
565	11240	10322	.09
570	12146	11047	.10
575	12582	11395	.10
580	7983	7698	.04

SUM	Σ	1.55
DATA	n	17
MEAN	$\bar{X}$	.09
STD. DEV.	σ^{n-1}	.08
VARIANCE	v^{n-1}	.006

FIGURE 7.40

PRELIMINARY

STRESS CHANGES FOR
MODELS 1, 3, 7 & 24

		THERMAL	DEADWEIGHT	SEISMIC
FITTINGS		0.05	-0.59	-0.78
		-0.66	-0.69	-0.86
		-0.14	-0.61	-0.77
		-0.39	-0.41	-0.73
		-0.52	-0.13	-0.83
		-0.26	-0.46	-0.68
		-0.42	-0.44	-0.78
		-0.36	-0.30	-0.65
		-0.35	-0.47	-0.69
		-0.41	-0.50	-0.71
		-0.43	0.13	-0.68
		-0.40	-0.39	-0.67
		-0.27	-0.37	-0.70
	n	13	13	13
	Σ	-4.56	-5.23	-9.53
	$\bar{X}$	-0.35	-0.40	-0.73
	σ^{n-1}	0.17	0.21	0.07

PRELIMINARY

LOAD CHANGES ON RESTRAINTS

MODEL	NODE	TYPE & DIRECTION	THERMAL LOAD	FIGURE NO.	DEADLOAD	FIGURE NO.
3	7	RGD (Z)	0.82	7.17	0.67	7.17
	9	RGD (X)	0.20		0.82	
	11	RGD (Y)	0.28		0	
	13	RGD (Y)	0.42		-0.26	
	15	RGD (X)	0.15		0.43	
7	20	RGD (Y)	0.57	7.25	0.05	7.25
	110	RGD (Y)	0.08		0.04	
24	25	RGD (Z)	0.23	7.32		7.32
	45	RGD (Z)	0.23			
	65	RGD (Z)	0.34			
	150	RGD (X)	0.33			
	170	RGD (X)	0.21			
	230	RGD (X)	0.31			
	230	RGD (Y)	0.26		0.56	
	250	RGD (Y)	0.21		0.03	
	270	RGD (Y)	0.48		-0.02	
	315	RGD (X)	0.21			
	335	RGD (X)	0.24			
	335	RGD (Z)	0.37			
	335	RGD (Z)	0.17			
	385	RGD (Y)	0.62		0.05	
	505	RGD (Y)	1.50		-0.37	
	525	RGD (Y)	-0.16		0.03	
	525	RGD (Z)	0.16			
	640	RGD (Y)	0.57		-0.04	
		n	25		14	
		Σ	8.75		1.96	
		$\bar{x}$	0.35		0.14	
		σ_{n-1}	0.31		0.35	

PRELIMINAR

LOAD CHANGES ON RESTRAINTS

MODEL	NODE	TYPE AND DIRECTION	SEISMIC LOAD	FIGURE NO.	DESIGN LOAD	FIGURE NO.
3	7	RGD (Z)	-.44	7.18A	-.49	7.19A
	9	RGD (X)	-.33		-.44	
	11	RGD (Y)	-.38		-.39	
	13	RGD (Y)	-.37		-.57	
	15	RGD (X)	-.41		-.58	
7	20	RGD (Y)	-.38	7.25A	-.20	7.25B
	110	RGD (Y)	-.38		-.30	
24	25	RGD (Z)	-.36	7.33 (1)	-.22	7.34 (1)
	45	RGD (Z)	-.36		-.19	
	65	RGD (Z)	-.40		-.24	
	150	RGD (X)	-.30		-.13	
	170	RGD (X)	-.33		-.20	
	230	RGD (X)	-.42		-.32	
	230	RGD (Y)	-.34	7.33 (2)	-.20	7.34 (2)
	250	RGD (Y)	-.47		-.09	
	270	RGD (Y)	-.43		+.004	
	315	RGD (X)	-.35		-.07	
	335	RGD (X)	-.35		-.11	
	335	RGD (Z)	-.40		+.05	
	355	RGD (Z)	-.38	7.33 (3)	-.14	7.34 (3)
	385	RGD (Y)	-.45		-.26	
	505	RGD (Y)	-.36		-.27	
	525	RGD (Y)	-.31		-.13	
	525	RGD (Z)	-.33		-.26	
	740	RGD (Y)	-.46		-.17	
	85	SNUB (Z)	-.33	7.35	-.33	7.35
	130	SNUB (X)	-.37		-.37	
	315	SNUB (Z)	-.44		-.44	
	355	SNUB (X)	-.36		-.36	
	485	SNUB (Z)	-.40		-.40	
	6051	SNUB (Y)	-.38		-.38	
TOTAL		Σ	-11.77		-8.196	
NO. DATA		n	31		31	
MEAN		$\bar{\bar{X}}$	-.38		-.26	
STD DEVIATION		σ_{n-1}	.044		.156	
VARIANCE		Vn	.002		.024	

$$\text{LOAD CHANGE} = \frac{\text{HEAVY FITTING (FLAT 3g) - STD FITTING (FLAT 5g)}}{\text{STD FITTING (FLAT 5g)}}$$

FIGURE 7.41

PRELIMINARY

THERMAL LOADS ON ANCHORS
SIGNIFICANT CHANGES

MODEL	FORCES	MOMENTS	FIGURE NO.
3	---- 0.65 1.06	---- 0.57 ----	7.20
3	0.19 ---- ----	---- 0.07 ----	7.20
7	0.31 0.45 ----	0.43 0.48 0.35	7.26
7	0.27 ---- 0.15	0.14 -0.10 0.25	7.26
7	0.31 ---- 0.19	---- 0.68 -0.08	7.26
7	---- ---- 0.16	0.18 0.13 ----	7.26
7	---- ---- ----	---- 0.25 0.21	7.26
24	0.53 ---- ----	---- 0.23 ----	7.36
24	0.18 0.25 0.49	0.25 0.28 ----	7.36
24	0.49 ---- ----	0.14 0.22 ----	7.36
24	---- 0.41 0.44	0.41 0.17 0.19	7.36
n *	17	22	
$\sum$	6.53	5.45	
$\bar{x}$	0.38	0.25	
σ^{n-1}	0.23	0.19	

* Number of significant data points

PRELIMINARY

DEADWEIGHT LOADS ON ANCHORS
SIGNIFICANT CHANGES

MODEL	FORCES	MOMENTS	FIGURE NO.
3	0.06 ——	—— 0.65	7.20
3.	0.06 ——	0.05 —— ——	7.20
7	—— —— ——	—— —— ——	7.26
7	0.05 ——	—— —— ——	7.26
7	0.02 ——	—— 0.09	7.26
7	0.05 ——	—— —— ——	7.26
7	0.07 ——	—— —— ——	7.26
24	0 ——	-0.12 0	7.36
24	0 ——	0.60 0.49 -0.13	7.36
24	0.13 0 ——	—— 0	7.36
24	—— 0.46	-0.18 0.42 0.70	7.36
n *	11	12	
Σ	0.90	2.39	
$\bar{x}$	0.08	0.20	
σ^{n-1}	0.13	0.34	

* Number of significant data points

SEISMIC LOADS ON ANCHORS-CHANGES

FIGURE 7.42

MODEL	FORCES	MOMENTS	FIGURE NO.
1	-.32 -.25 -.39	-.42 -.24 -.34	7.13 (1)
1	-.33 -.34 -.21	-.33 -.37 -.17	7.13 (2)
3	-.34 -.42 -.45	-.43 -.53 -.36	7.21A (1)(2)
3	-.32 -.41 -.22	-.43 -.42 -.32	7.21A (3)
7	-.39 -.29 -.32	-.28 -.40 -.31	7.27A (1)
7	-.35 -.39 -.35	-.36 -.40 -.34	7.27A (2)
7	-.42 -.42 -.43	-.48 -.47 -.43	7.27A (3)
7	-.42 -.38 -.33	-.35 -.38 -.35	7.27A (4)
7	-.31 -.37 -.39	-.38 -.42 -.33	7.27A (5)
24	-.51 -.40 -.37	-.45 -.38 -.40	7.37 (1)
24	-.32 -.47 -.38	-.38 -.35 -.18	7.37 (2)
24	-.09 -.31 -.43	-.47 -.45 -.32	7.37 (3)
24	-.40 -.39 -.20	-.41 -.41 -.25	7.37 (4)
Σ	-13.83	-14.49	TOTAL
n	39	39	NO. DATA
$\bar{x}$	-.35	-.37	MEAN
σ_{n-1}	.08	.08	STD. DEVIATION
V_n	.006	.006	VARIANCE

$$\text{LOAD CHANGE} = \frac{\text{HVY. FTG. (FLAT 3G) - STD. FTG. (FLAT 5G)}}{\text{STD. FTG. (FLAT 5G)}}$$

PRELIMINARY

DESIGN LOADS ON ANCHORS-CHANGES

MODEL	FORCES	MOMENTS	FIGURE NO.
1	+.23 +.37 -.11	-.14 -.19 -.08	7.14 (1)
1	+.03 +.26 +.09	+.23 -.09 +.29	7.14 (2)
3	-.31 -.52 -.64	-.44 -.54 -.35	7.22A (1)(2)
3	-.50 -.25 -.25	-.31 -.60 -.26	7.22A (3)
7	-.50 -.32 -.33	-.31 -.46 -.57	7.28A (1)
7	-.47 -.33 -.51	-.50 -.49 -.40	7.28A (2)
7	-.55 -.10 -.60	-.48 -.48 -.40	7.28A (3)
7	-.42 -.32 -.53	-.53 -.66 -.35	7.28A (4)
7	-.36 -.25 -.40	-.38 -.48 -.36	7.28A (5)
24	-.49 -.32 -.37	-.36 -.37 -.31	7.38 (1)
24	-.27 -.35 -.27	-.37 -.32 -.17	7.38 (2)
24	-.01 -.25 -.43	-.25 -.45 -.26	7.38 (3)
24	-.39 -.24 -.02	-.19 -.40 -.08	7.38 (4)
Σ	-11.00	-12.70	TOTAL
n	39	39	NO. DATA
$\bar{x}$	-.28	-.33	MEAN
σ_{n-1}	.24	.21	STD. DEVIATION
V_n	.057	.043	VARIANCE

$$\text{LOAD CHANGE} = \frac{\text{HEAVY FITTING (FLAT 3G) - STANDARD FITTING (FLAT 5G)}}{\text{STANDARD FITTING (FLAT 5G)}}$$

PRELIMINARY

PRELIMINARY

DESIGN LOADS ON ANCHORS-CHANGES
BASED ON REALISTIC PIPING MODELS

SWEC BELIEVES THAT THE RESULTS
OF MODEL ONE ARE NOT REPRESENTATIVE
OF ACTUAL PIPING SYSTEMS BECAUSE

- THERE ARE NO INTERMEDIATE SUPPORTS
- SIMPLISTIC GEOMETRY WITH LITTLE PIPING

STATISTICAL DATA SUMMATION FROM FIGURE 7.41
EXCLUDING MODEL 1 RESULTS

VARIABLE	FORCES	MOMENTS	DESCRIPTION
Σ	-11.87	-12.88	SUMMATION
n	33	33	NO. DATA
$\bar{X}$	-0.36	-0.39	MEAN
σ^{n-1}	0.150	0.127	DEVIATION
V^{n}	0.023	0.016	VARIANCE

FIGURE 7.44

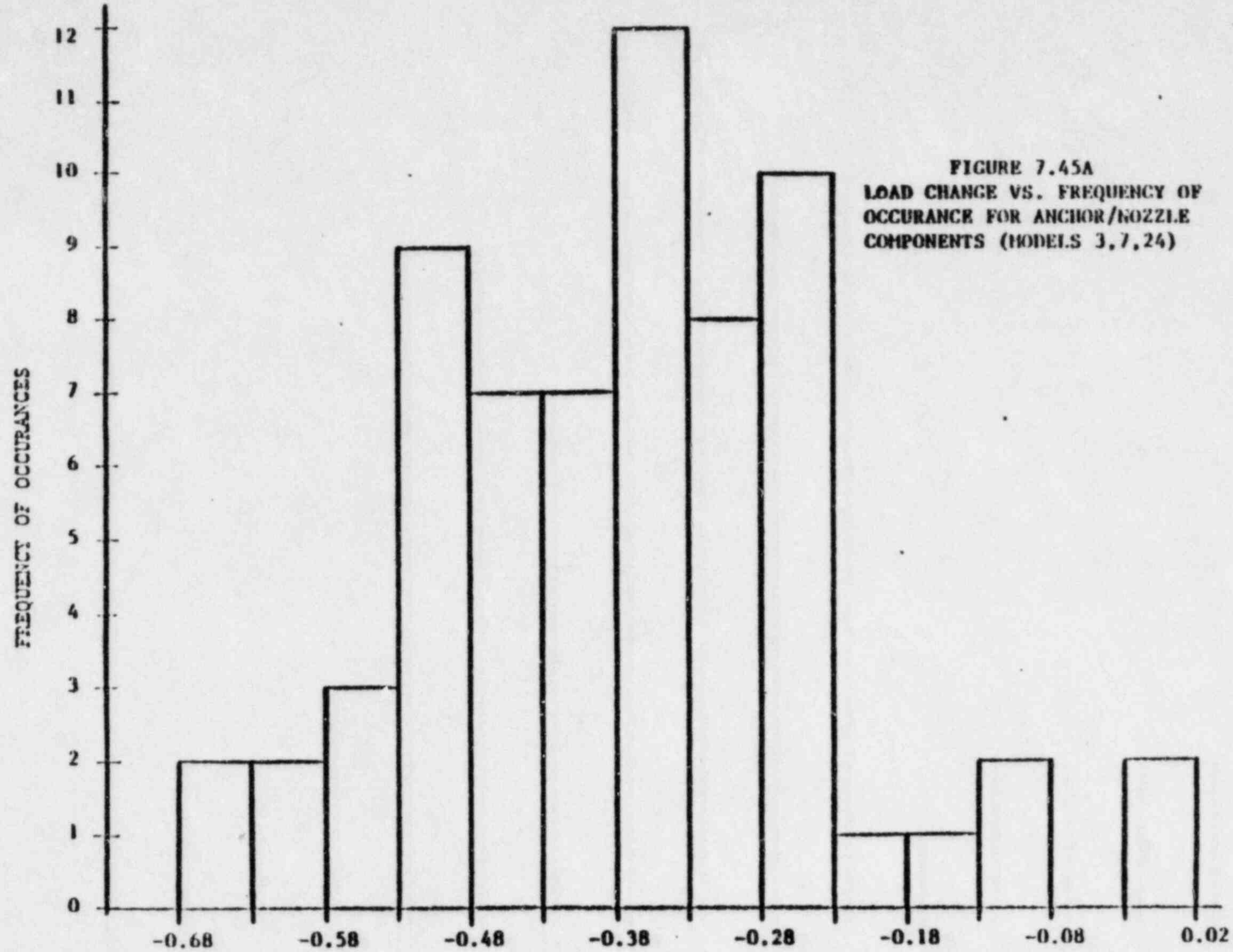


FIGURE 7.45A
LOAD CHANGE VS. FREQUENCY OF OCCURANCE FOR ANCHOR/NOZZLE COMPONENTS (MODELS 3,7,24)

LOAD CHANGE = HEAVY FITTINGS(FLAT 3g) - STD FITTINGS(FLAT 5g) / STD FITTINGS(FLAT 5g)

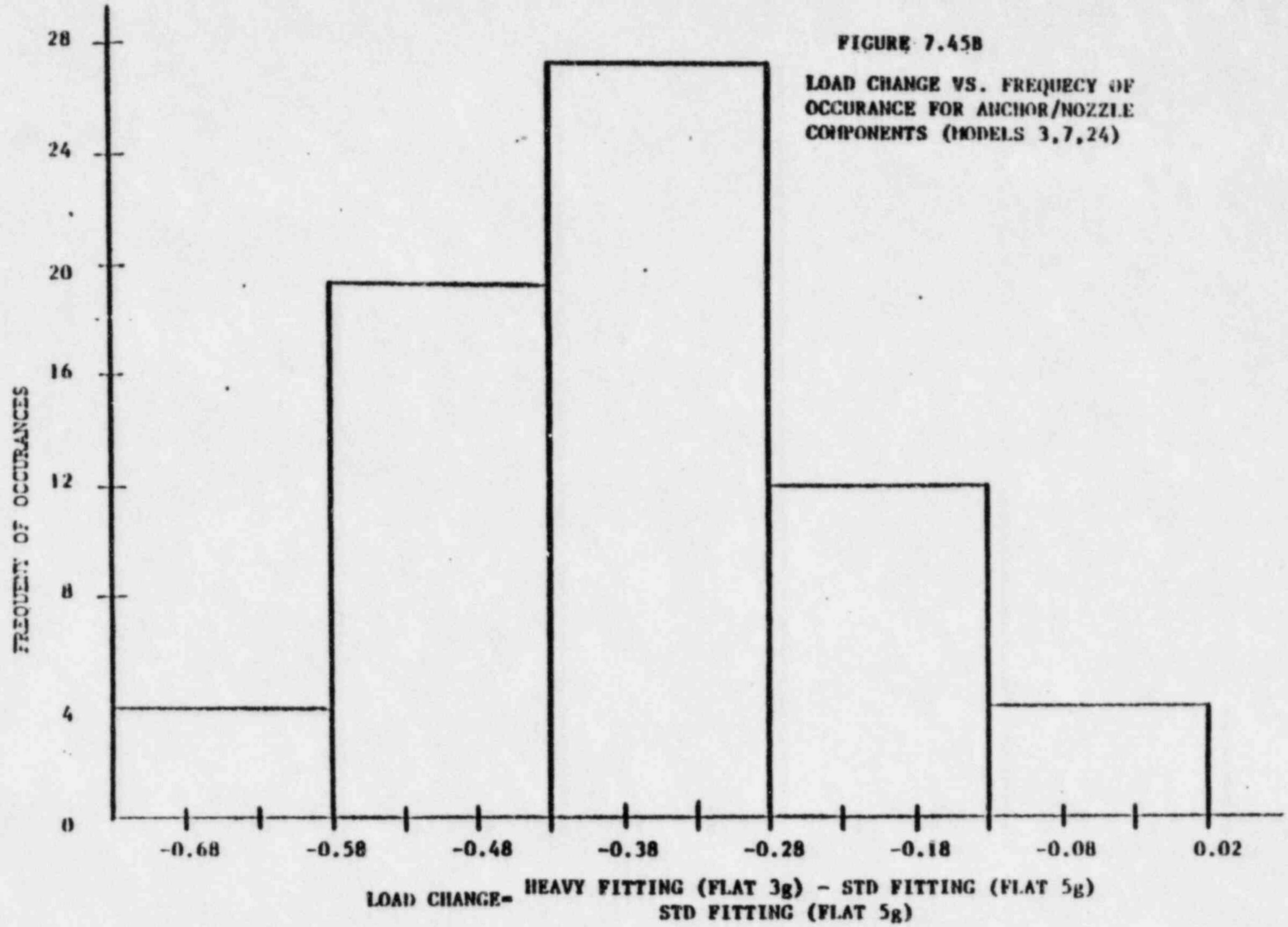


FIGURE 7.45B
LOAD CHANGE VS. FREQUECY OF OCCURANCE FOR ANCHOR/NOZZLE COMPONENTS (MODELS 3,7,24)
FREQUENCY OF OCCURANCES
28
24
20
16
12
8
4
0
-0.68
-0.58
-0.48
-0.38
-0.28
-0.18
-0.08
0.02
LOAD CHANGE= HEAVY FITTING (FLAT 3g) - STD FITTING (FLAT 5g)
STD FITTING (FLAT 5g)

SUMMARY OF CHANGES

STANDARD TO HEAVY FITTINGS

PARAMETER	THERMAL	DEADWEIGHT	SEISMIC
Stress In Fittings	-35%	-40%	-73%
Stress In Straight Runs	9% *	No Significant Change	-37%

* Based on 24" Piping Model

PRELIMINARY

SUMMARY OF LOAD CHANGES

STANDARD WEIGHT TO HEAVY WALL

GENERIC MODELS 3, 7, 24

VARIABLE	THERMAL	DEADWEIGHT	SEISMIC	DESIGN
RESTRAINTS	35%	14%	-38%	-26%
ANCHORS/ NOZZLES	38% FORCES 25% MOMENTS	8% FORCES 20% MOMENTS	-36% FORCES -38% MOMENTS	-36% FORCES -39% MOMENTS

PRELIMINARY

CONCLUSION GENERIC STUDY

GENERIC INVESTIGATION OF HEAVY FITTINGS AND THEIR EFFECTS INDICATE

- SYSTEM FREQUENCIES TEND TO INCREASE - MOVING AWAY FROM PEAK ACCELERATIONS
- THERMAL STRESSES
  - DECREASE AT FITTINGS
  - SLIGHT INCREASE IN STRAIGHT PIPE
  - FITTING STRESSES STILL CONTROL
- LOADS ON EQUIPMENT AND SUPPORTS
  - DECREASE IN SEISMIC LOADS
  - INCREASE IN THERMAL LOADS
  - OVERALL DECREASE IN TOTAL DESIGN LOADS

PRELIMINARY

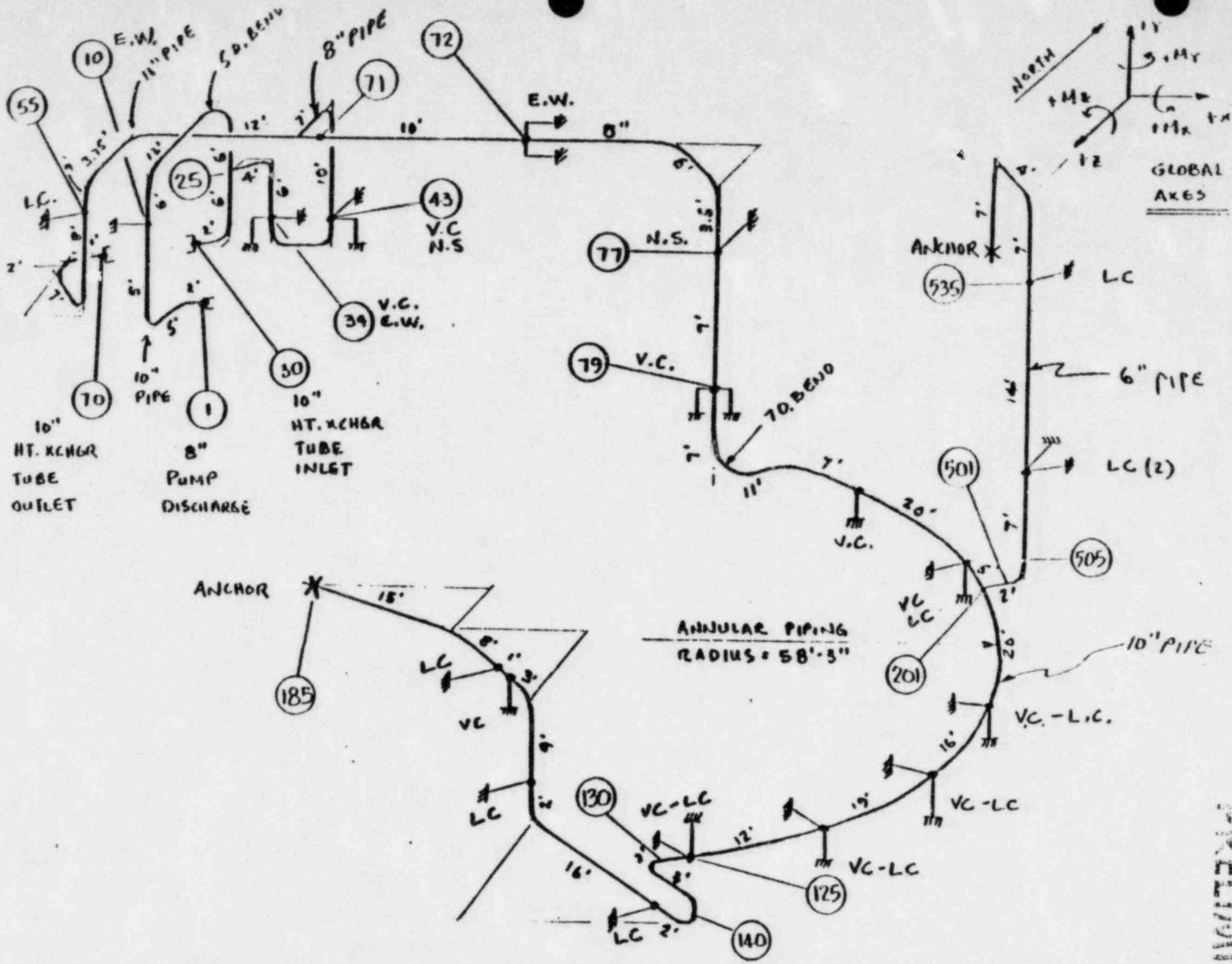
OBJECTIVE OF RHS ANALYSIS

- INVESTIGATE A SPECIFIC PIPING PROBLEM TO EVALUATE THE EFFECT OF HEAVY WALLED ELBOWS
- INCLUDE AS PART OF THIS INVESTIGATION A REFINED CALCULATION OF THE STATE OF STRESS EXISTING FROM THE VARIOUS LOADINGS

PRELIMINARY

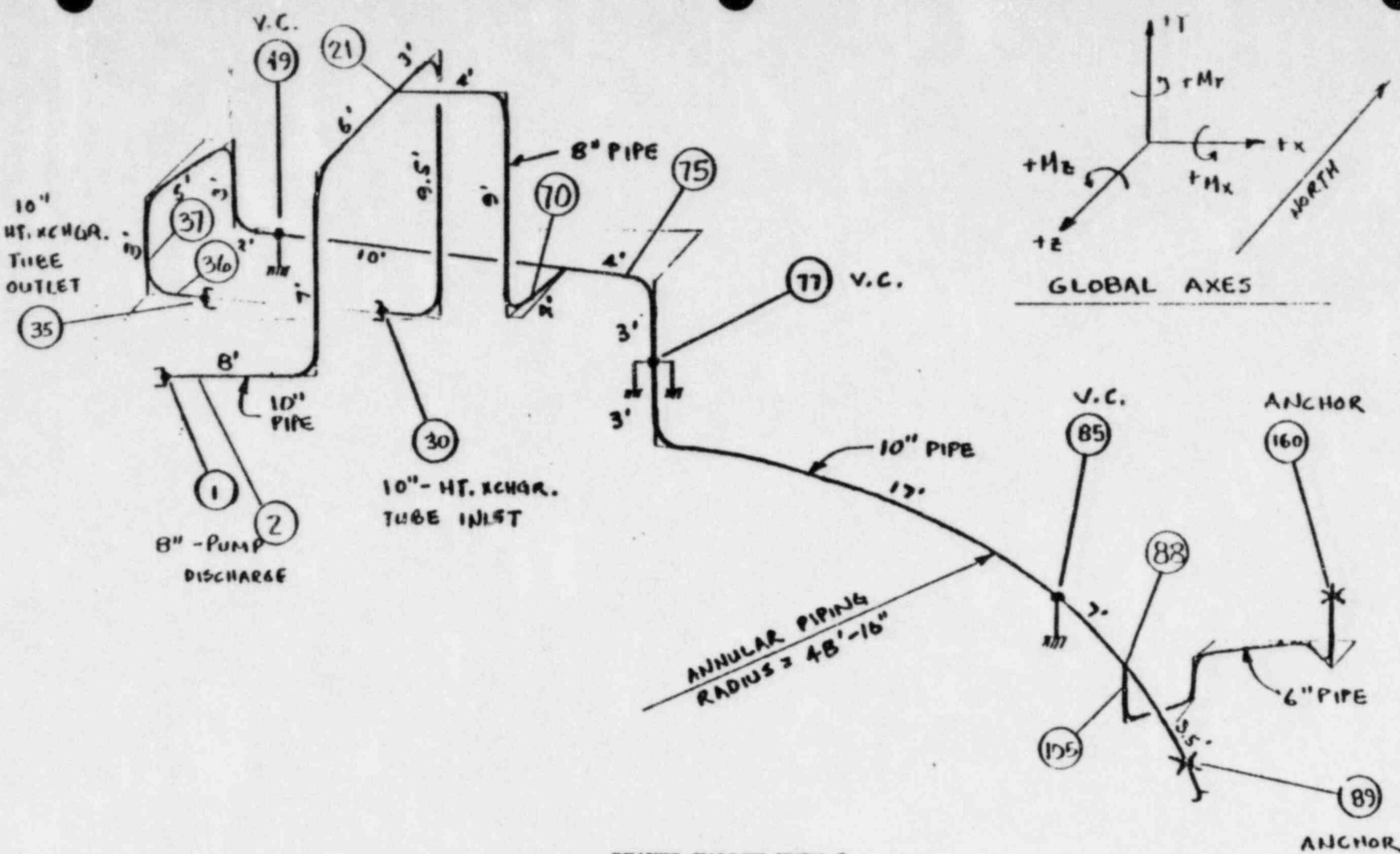
SELECTION PROCESS

- IS THE PIPING SUBJECT TO HIGH OPERATING TEMPERATURES? (300°F OR ABOVE)
- DO EQUIPMENT NOZZLES FORM A BOUNDARY FOR THE PIPING PROBLEM
- ARE THERMAL EXPANSION LOADS A SIGNIFICANT PORTION OF THE ALLOWABLE?
- DO ELBOWS CONTRIBUTE HIGHLY TO THERMAL FLEXIBILITY?



PRELIMINARY

BEAVER VALLEY UNIT 2
RHS PUMP "A" DESIGN BASIS
PIPING MODEL "A"
(NOMINAL WALL ELBOWS, GENERIC RESTRAINT STIFFNESS, DESIGN TEMP-350°F)
FIGURE 3



BEAVER VALLEY UNIT 2
RHS PUMP "B" DESIGN BASIS
PIPING MODEL "B"
(NOMINAL WALL ELBOWS, GENERIC RESTRAINT STIFFNESS, DESIGN TEMP-350°F)

FIGURE 4

PRELIMINARY

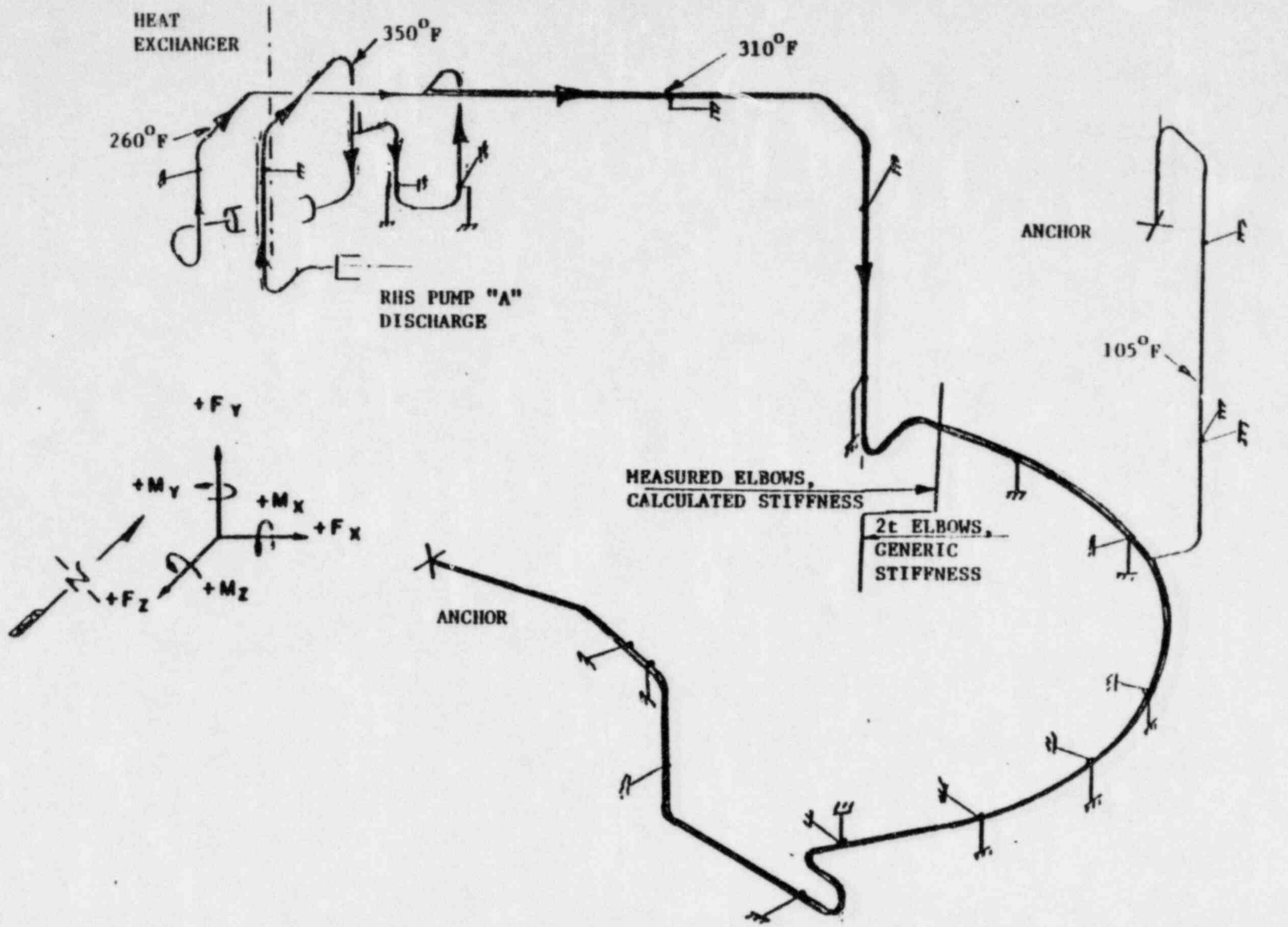
COMPARISON OF INPUT PARAMETERS

PARAMETER	DESIGN MODEL	REFINED PIPING MODEL
TEMPERATURE	350°F DESIGN	NORMAL OPERATING-310°F TYPICAL
FITTING THICKNESS	NOMINAL WALL	ACTUAL WALL (MEASURED AVERAGE)*
NOZZLE AND RESTRAINT STIFFNESS	GENERIC STIFFNESS	CALCULATED STIFFNESSES*
SEISMIC EQUIPMENT DAMPING	0.5%	2.0%

*2t FITTINGS AND GENERIC STIFFNESSES ARE USED BEYOND THE MEANINGFULL RANGE

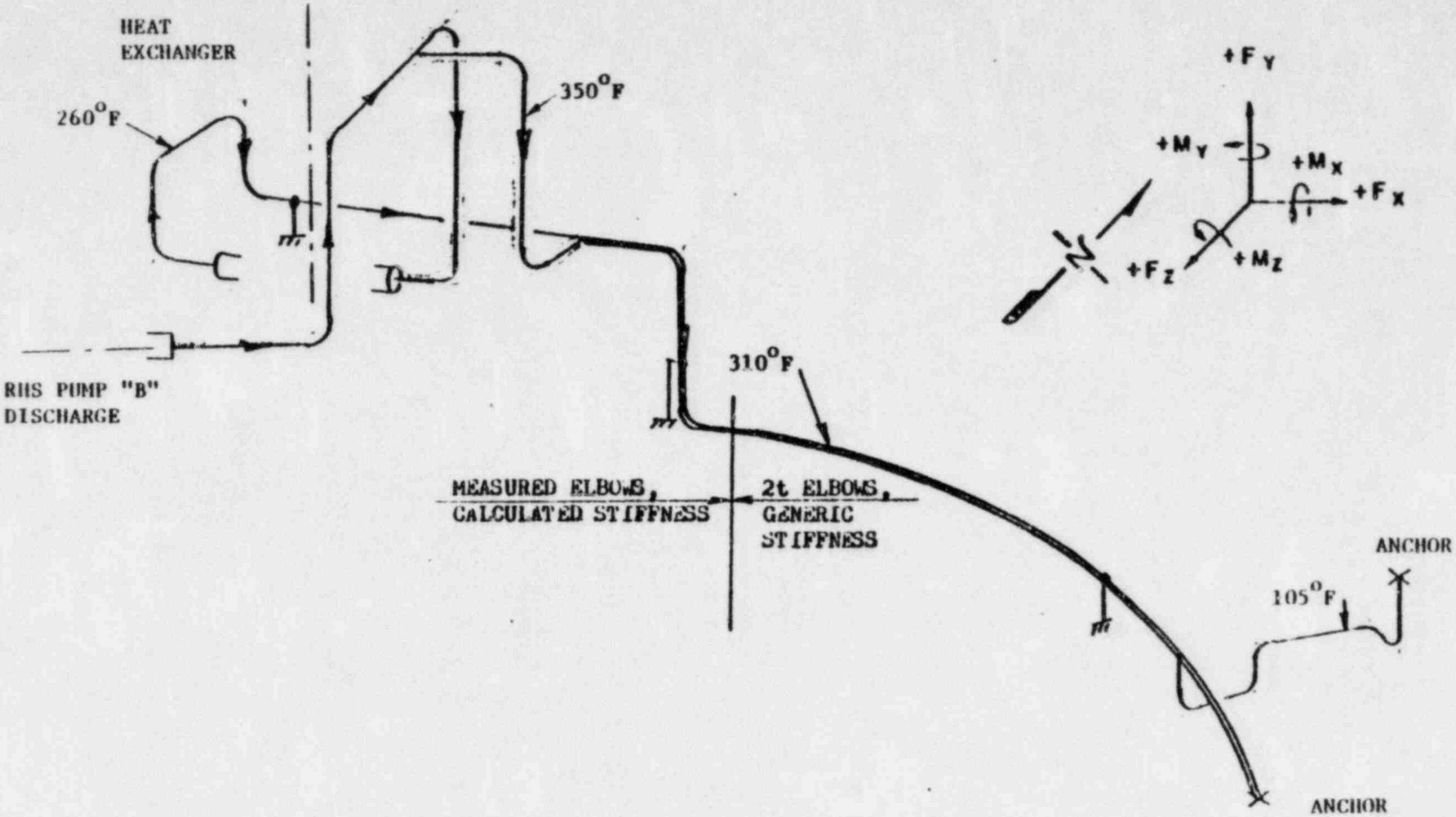
FIGURE 5

PRELIMINARY



BEAVER VALLEY UNIT 2
RHS PUMP "A" REFINED BASIS
PIPING MODEL "A" (MEASURED ELBOWS)
NORMAL OPERATING MODE
FIGURE 6

PRELIMINARY



BEAVER VALLEY UNIT 2
RHS PUMP "B" REFINED BASIS
PIPING MODEL "B" (MEASURED ELBOWS)
NORMAL OPERATING MODE

FIGURE 7

PRELIMINARY

MEASURED ELBOW DATA FOR MODELS A & B

ELBOW	NPS	NOM. WALL (IN)	MEASURED WALL (IN)				$\frac{t_{avg}}{t_{nom}}$
			1	2	3	4	
1	10"	.365	.594	.511	.523	.463	1.43
2	10"	.365	.623	.489	.542	.465	1.45
3	8"	.322	.439	.327	.364	.308	1.12
4	10"	.365	.568	.488	.476	.420	1.34
5	10"	.365	.569	.497	.498	.450	1.38
6	10"	.365	.549	.473	.448	.408	1.29
7	10"	.365	.570	.474	.487	.439	1.35
8	10"	.365	.632	.544	.574	.454	1.48
9	10"	.365	.561	.495	.499	.439	1.37
10	10"	.365	.564	.492	.496	.443	1.37
11	10"	.365	.586	.498	.512	.498	1.44
12	8"	.322	.444	.359	.341	.313	1.13
13 (red)	8"-10"	.365	.601	.513	.547	.466	1.44
14	10"	.365	.558	.469	.476	.420	1.32
15	10"	.365	.599	.520	.503	.455	1.42
16	10"	.365	.571	.480	.508	.445	1.37
17	8"	.322	.419	.337	.364	.340	1.13
18	8"	.322	.454	.354	.389	.348	1.20
19	8"	.322	.575	.506	.473	.476	1.58
20	8"	.322	.422	.347	.353	.320	1.12
21 (45)	10"	.365	.495	.472	.485	.465	1.31
22	10"	.365	.554	.471	.477	.419	1.32
23	10"	.365	.559	.470	.481	.421	1.32
24	10"	.365	.535	.482	.481	.426	1.32
25	10"	.365	.540	.477	.478	.417	1.31
26	10"	.365	.547	.464	.485	.437	1.32
27	10"	.365	.527	.454	.477	.423	1.29
28	10"	.365	.523	.478	.444	.479	1.32

TOTAL	Σ	37.24
NUMBER	n	28
MEAN	$\bar{X}$	1.33
STD.DEV.	σ_{n-1}	0.11

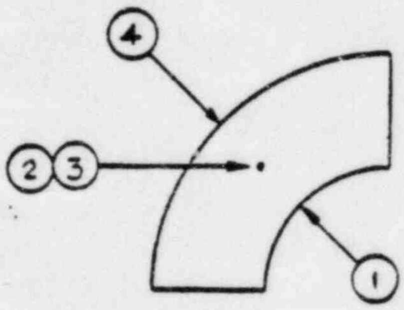


FIGURE 8

PRELIMINARY

RHS - MODEL "A" RESTRAINT STIFFNESS COMPARISON

	POINT NO.	STIFFNESS TYPE	SUPPORT STIFFNESS					
			K_{TRANS} (LB/IN)			K_{ROT} (IN-LB/RAD)		
			X	Y	Z	X	Y	Z
EQUIP. NOZZLE	1	GENERIC	1E9	1E9	1E9	1E11	1E11	1E11
		ACTUAL	2E6	1E6	1E6	1E8	2E8	2E8
	30	GENERIC	1E9	1E9	1E9	1E11	1E11	1E11
		ACTUAL	5.54E6	1.49E6	3.54E6	4.33E8	1.47E8	2.05E8
	70	GENERIC	1E9	1E9	1E9	1E11	1E11	1E11
		ACTUAL	5.54E6	1.49E6	3.54E6	4.33E8	1.47E8	2.05E8
RIGID RESTRAINT	10	GENERIC	1E6	-	-	-	-	-
		ACTUAL	3.01E5	-	-	-	-	-
	34	GENERIC	1E6	1E6	-	-	-	-
		ACTUAL	1.42E5	1.62E6	-	-	-	-
	43	GENERIC	-	1E6	1E6	-	-	-
		ACTUAL	-	1.94E5	1.95E4	-	-	-
	55	GENERIC	1E6 (SKEWED)			-	-	-
		ACTUAL	9.47E4			-	-	-
	72	GENERIC	1E6	-	-	-	-	-
		ACTUAL	3.63E5	-	-	-	-	-
	77	GENERIC	-	-	1E6	-	-	-
		ACTUAL	-	-	1.41E5	-	-	-
	79	GENERIC	-	1E6	-	-	-	-
		ACTUAL	-	2.87E5	-	-	-	-
		GENERIC						
		ACTUAL						

ALL REMAINING SUPPORTS USE GENERIC STIFFNESS VALUES

FIGURE 9A

PRELIMINARY

RHS - MODEL "B" RESTRAINT STIFFNESS COMPARISON

	POINT NO.	STIFFNESS TYPE	SUPPORT STIFFNESS					
			K_{TRANS} (LB/IN)			K_{ROT} (IN-LB/RAD)		
			X	Y	Z	X	Y	Z
EQUIPMENT NOZZLE	1	GENERIC	1E9	1E9	1E9	1E11	1E11	1E11
		ACTUAL	2E6	1E6	1E6	1E8	2E8	2E8
	30	GENERIC	1E9	1E9	1E9	1E11	1E11	1E11
		ACTUAL	5.54E6	1.49E6	3.54E6	4.33E8	1.47E8	2.05E8
	35	GENERIC	1E9	1E9	1E9	1E11	1E11	1E11
		ACTUAL	5.54E6	1.49E6	3.54E6	4.33E8	1.47E8	2.05E8
RIGID RESTRAINT	49	GENERIC	-	1E6	-	-	-	-
		ACTUAL	-	1.05E5	-	-	-	-
	77	GENERIC	-	1E6	-	-	-	-
		ACTUAL	-	4.75E5	-	-	-	-
	85	GENERIC		1E6				
		ACTUAL		1.31E5				
	89	GENERIC	1E8	1E8	1E8	1E10	1E10	1E10
		ACTUAL	2.18E5	2.03E5	2.43E5	2E8	1E8	1.96E8
	160	GENERIC	1E8	1E8	1E8	1E10	1E10	1E10
		ACTUAL	1.9E4	2.78E4	3.23E5	1.47E6	1.13E7	1.08E7
		GENERIC						
		ACTUAL						
		GENERIC						
		ACTUAL						
		GENERIC						
		ACTUAL						

FIGURE 9B

PRELIMINARY

RESIDUAL HEAT EXCHANGER
NOZZLE STIFNESS ANALYSIS
FINITE ELEMENT MODEL

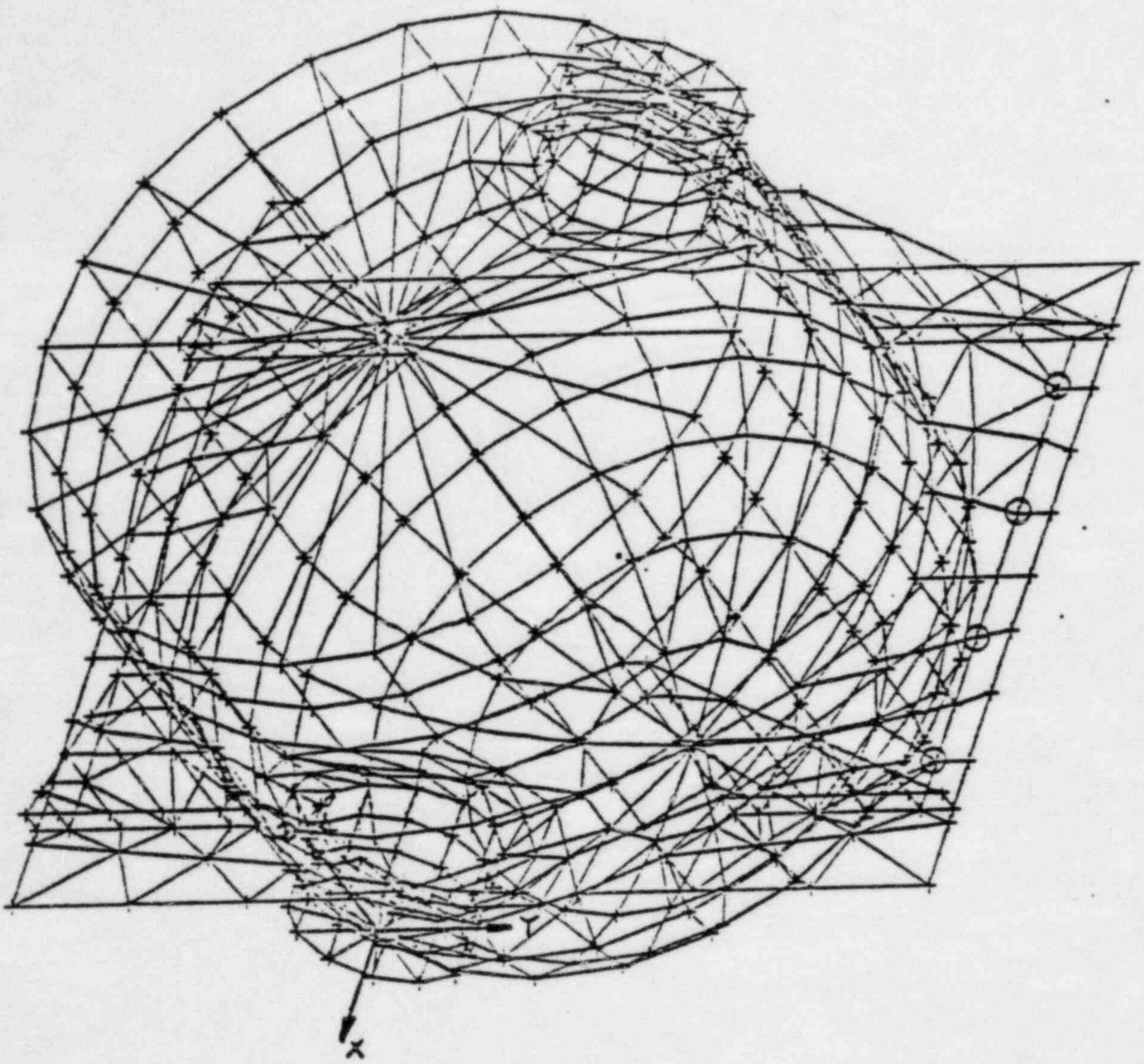


FIGURE 9C

46 0780

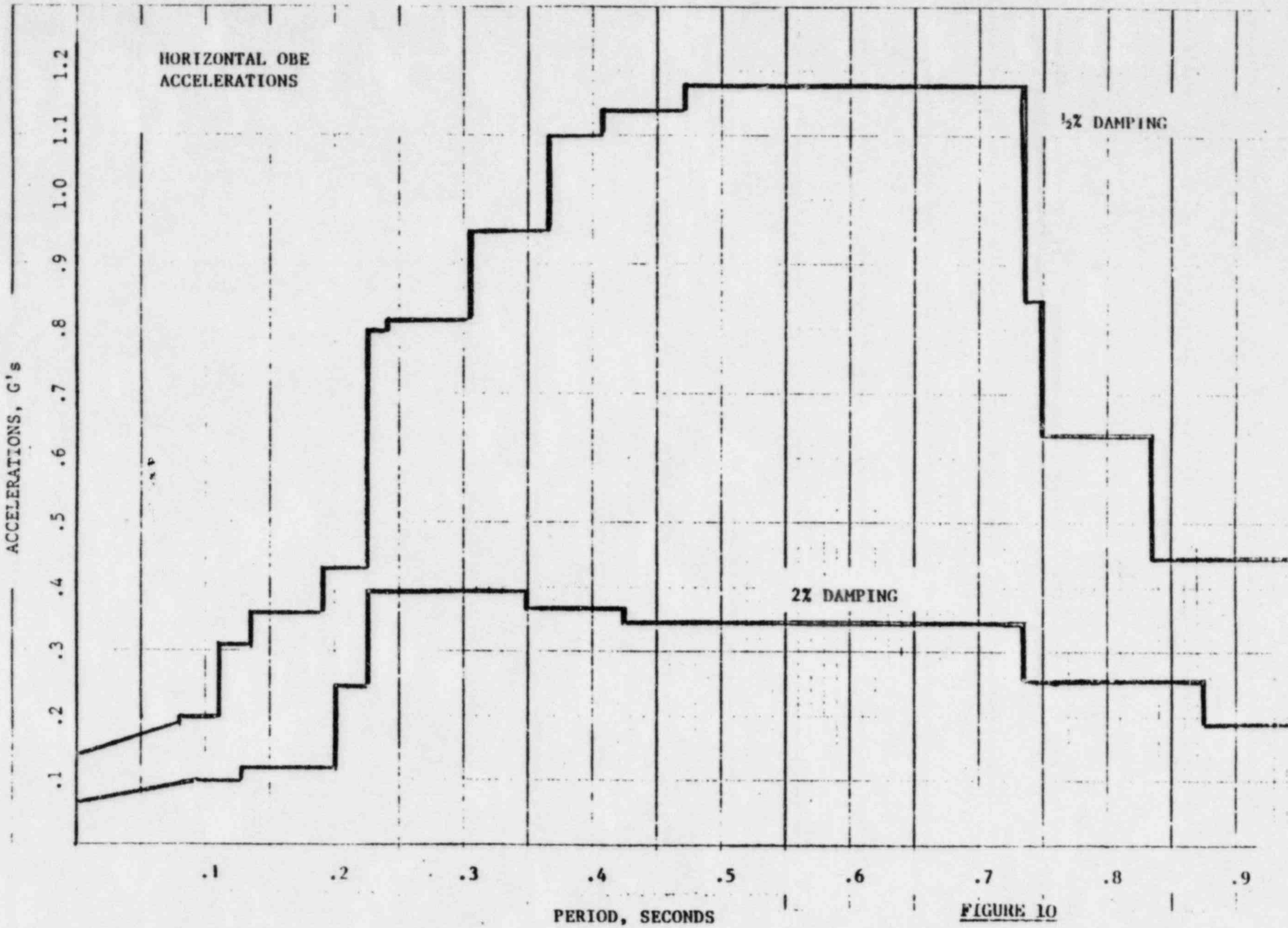
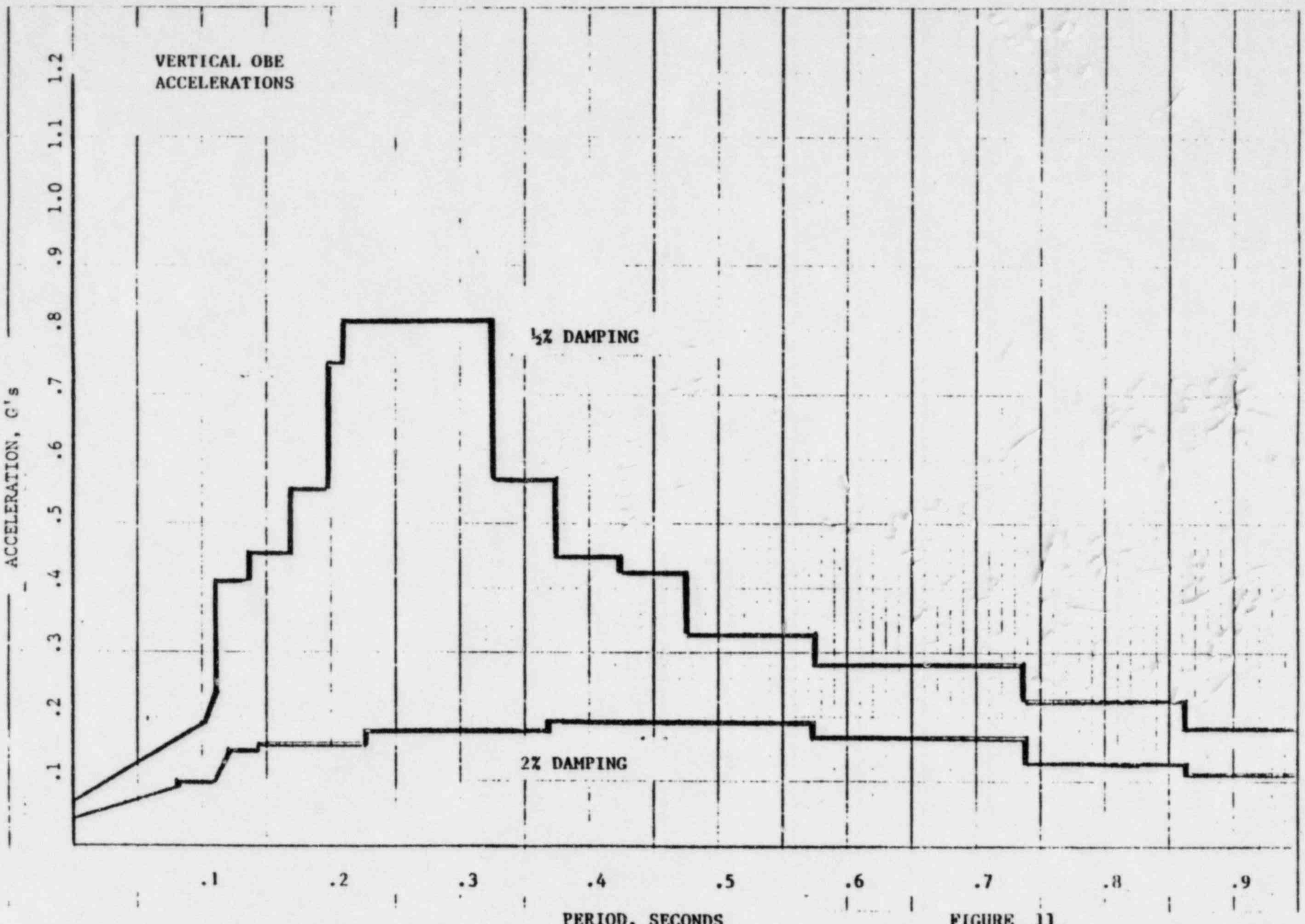


FIGURE 10

PRELIMINARY

46 0780



PRELIMINARY

FIGURE 11

COMPARISON OF INPUT PARAMETERS

PARAMETER	DESIGN MODEL	REFINED PIPING MODEL
TEMPERATURE	350°F DESIGN	NORMAL OPERATING-310°F TYPICAL
FITTING THICKNESS	NOMINAL WALL	ACTUAL WALL (MEASURED AVERAGE)*
NOZZLE AND RESTRAINT STIFFNESS	GENERIC STIFFNESS	CALCULATED STIFFNESSES *
SEISMIC EQUIPMENT DAMPING	0.5%	2.0%

*2t FITTINGS AND GENERIC STIFFNESSES ARE USED BEYOND THE MEANINGFULL RANGE

FIGURE 12

PRELIMINARY

PRELIMINARY

MODEL A

COMPARISON OF NATURAL FREQUENCIES (HZ)

RHS PUMP A DISCHARGE PPG

MODE	STANDARD FITTINGS	MEASURED FITTINGS
1	4.663	4.937
2	4.747	5.524
3	5.682	6.227
4	6.433	7.015
5	6.757	7.354
6	7.222	8.802
7	7.657	9.240
8	8.435	9.328
9	9.054	9.524
10	9.763	11.257
11	10.929	11.558
12	11.106	11.857
13	11.626	12.027
14	12.291	12.388
15	12.537	13.053
16	13.100	13.438
17	13.947	13.569
18	14.479	14.217
19	15.341	15.036
20	15.497	15.431
21	15.672	15.874
22	15.861	16.387

FIGURE 13

PRELIMINARY

MODEL B

COMPARISON OF NATURAL FREQUENCIES (HZ)

RHS PUMP B DISCHARGE PPG

MODE	STANDARD FITTING	MEASURED FITTINGS
1	8.318	8.054
2	10.768	10.384
3	11.489	11.631
4	13.293	12.298
5	14.375	12.616
6	16.631	15.235
7	17.253	16.457
8	17.896	18.073
9	18.882	18.432
10	21.510	19.004
11	22.493	21.405
12	23.586	22.452
13	24.627	22.639
14	23.002	23.362
15	25.538	24.258
16	28.115	24.956
17	28.864	26.728
18	30.987	27.773
19	33.499	28.769
20	35.091	31.928
21	38.415	33.347
22	41.011	35.308

FIGURE 14

COMPARISON OF MAXIMUM THERMAL STRESSES (PSI)

MODELS A & B

MODEL	NODE	FITTING TYPE	DESIGN BASIS	REFINED BASIS
PUMP B DISCHARGE	1	ANCHOR	1869.	2205.
	2	RUN	1856.	2148.
	21	TEE	6486.	6793.
	35	ANCHOR	6669.	6342.
	36	ELBOW	19213.	9818.
	37	ELBOW	18856.	9675.
	37	RUN	5519.	5290.
	70	ELBOW	5479.	4965.
	75	ELBOW	14278.	7610.
	75	RUN	5478.	5299.
	88	TEE	10744.	7083.
	89	ANCHOR	7558.	4858.
	105	RUN	976.	1836.
PUMP A DISCHARGE	25	TEE	4908.	5376.
	70	ANCHOR	3708.	3467.
	71	RUN	3094.	2903.
	125	RUN	3001.	3719.
	130	ELBOW	5958.	2271.
	140	ELBOW	3860.	1674.
	185	ANCHOR	3151.	4437.
	201	TEE	12561.	14712.
	501	ELBOW	17403.	7042.
	505	RUN	6950.	8399.
	505	ELBOW	15750.	6420.
	535	RUN	8692.	8243.

FIGURE 15

PRELIMINARY

COMPARISON OF MAXIMUM OBE SEISMIC STRESSES (PSI)

MODELS A & B

MODEL	NODE	FITTING TYPE	DESIGN BASIS	REFINED BASIS
PUMP B DISCHARGE	1	ANC	1937.	726.
	2	RUN	1753.	644.
	21	TEE	903.	439.
	35	ANCHOR	408.	206.
	36	ELBOW	843.	229.
	37	ELBOW	586.	164.
	37	RUN	229.	120.
	70	ELBOW	923.	386.
	75	ELBOW	973.	272.
	75	RUN	498.	253.
	88	TEE	1240.	691.
	89	ANCHOR	1200.	327.
	105	RUN	708.	389.
PUMP A DISCHARGE	25	TEE	3072.	1126.
	70	ANCHOR	1354.	442.
	71	RUN	2994.	1246.
	125	RUN	3060.	1016.
	130	ELBOW	5715.	639.
	140	ELBOW	5100.	599.
	185	ANCHOR	3035.	761.
	201	TEE	1188.	600.
	501	ELBOW	1289.	234.
	505	RUN	869.	400.
	505	ELBOW	1465.	228.
	535	RUN	1095.	422.

FIGURE 16

PRELIMINARY

RESTRAINT LOADS SUMMARY FOR MODELS A&B

Node (DIR)	Thermal		Deadweight		Seismic		Total	
	Design	Refined	Design	Refined	Design	Refined	Design	Refined
10-(X)	- 343	- 488	- 21	- 22	716	311	1080	821
34-(X)	+ 759	+ 876	+ 79	+ 84	434	251	1272	1202
34-(Y)	+ 343	+ 275	- 922	- 909	854	352	1776	1261
43-(Y)	+ 102	+ 162	-1723	-1749	464	192	2188	1941
43-(Z)	- 252	- 285	- 91	- 97	365	184	698	566
55-(X)	-2346	-2095	+ 11	+ 3	1533	679	3868	2781
55-(Z)	+1734	+1548	- 8	- 9	1133	502	2859	2041
72-(X)	+1653	+1249	- 75	- 68	1800	735	3379	1916
77-(Z)	- 953	- 886	- 42	- 45	1130	488	2125	1419
79-(Y)	+ 689	+ 527	-2198	-2258	387	196	2585	2454
89-(Y)	- 326	- 254	-2199	-2202	578	240	3103	2696
96-(X)	+1345	+1470	- 155	- 194	940	335	2130	1611
96-(Y)	-1425	-1192	-3145	-3100	492	239	5062	4531
96-(Z)	- 724	- 792	+ 83	+ 104	506	181	1147	869
104-(X)	+ 116	+ 150	- 11	- 25	866	337	971	462
104-(Y)	- 459	- 447	-2121	-2087	352	194	2932	2728
104-(Z)	- 8	- 11	+ 1	+ 2	61	24	68	33
110-(X)	+ 834	+ 859	+ 13	+ 9	1053	345	1900	1213
110-(Y)	+ 27	- 2	-1446	-1479	407	193	1853	1674
110-(Z)	+ 177	+ 183	+ 3	+ 2	224	73	404	258
115-(X)	- 241	- 353	+ 17	+ 21	514	206	738	538
115-(Y)	+ 716	+ 856	-1485	-1408	825	280	2310	1688
115-(Z)	- 143	- 209	+ 10	+ 12	305	122	438	319
125-(X)	+2556	+3653	- 91	- 147	1228	381	3693	3887
125-(Y)	-1270	-1811	-2241	-2515	660	256	4171	4582
125-(Z)	+2785	+4029	- 99	- 160	1338	415	4024	4244
147-(X)	-1869	-2093	- 4	+ 19	3181	991	5054	3065
147-(Z)	+1260	+1411	+ 3	- 13	2145	668	3408	2066
163-(X)	+ 364	+ 507	- 43	- 50	341	84	662	541
163-(Z)	- 246	- 342	+ 29	+ 34	230	57	447	299
173-(Y)	+ 74	+ 258	-2495	-3020	429	244	3374	3264
174-(X)	+ 871	+1367	+ 4	- 17	657	209	1532	1559
174-(Z)	- 588	- 922	- 2	+ 12	443	141	1033	1051
525-(X)	- 5	- 116	+ 196	+ 239	110	62	306	301
525-(Z)	+ 2	+ 51	- 86	- 105	48	27	134	132
535-(X)	- 515	- 532	- 32	- 32	265	140	812	704
535-(Z)	-1153	-1291	- 31	- 19	273	123	1457	1433
49-(Y)	+2899	+2512	-1613	-1675	157	156	1770	1831
77-(Y)	- 476	- 570	-2290	-2360	382	186	3148	3166
85-(Y)	-1942	-1409	-2046	-2014	233	214	4221	3643

FIGURE 17

PRELIMINARY

STATISTICAL COMPARISON OF RESTRAINT LOADS
MODELS A & B

Node -(DIR)	Thermal	Deadweight	Seismic	Total
10-(X)	+ .42	+ .05	- .57	- .24
34-(X)	+ .15	+ .06	- .42	- .06
34-(Y)	- .20	- .01	- .39	- .29
43-(Y)	+ .59	+ .02	- .59	- .11
43-(Z)	+ .13	+ .07	- .50	- .19
55-(X)	- .11	- .73	- .56	- .28
55-(Z)	- .11	+ .13	- .56	- .29
72-(X)	- .24	- .09	- .59	- .43
77-(Z)	- .07	+ .07	- .57	- .33
79-(Y)	- .24	+ .03	- .49	- .05
89-(Y)	- .22	+ .00	- .58	- .13
96-(X)	+ .09	+ .25	- .64	- .24
96-(Y)	- .16	- .01	- .51	- .10
96-(Z)	+ .09	+ .25	- .64	- .24
104-(X)	+ .29	+1.27*	- .61	- .52
104-(Y)	- .03	- .02	- .45	- .07
104-(Z)	+ .38	+1.00*	- .61	- .51
110-(X)	+ .03	- .31	- .67	- .36
110-(Y)	- .93	+ .02	- .53	- .10
110-(Z)	+ .03	- .33	- .67	- .36
115-(X)	+ .46	+ .24	- .60	- .27
115-(Y)	+ .20	- .05	- .66	- .27
115-(Z)	+ .46	+ .20	- .60	- .27
125-(X)	+ .43	+ .62	- .69	+ .05
125-(Y)	+ .43	+ .12	- .61	+ .10
125-(Z)	+ .45	+ .62	- .69	+ .05
147-(X)	+ .12	+3.75*	- .69	- .39
147-(Z)	+ .12	+3.33*	- .69	- .39
163-(X)	+ .39	+ .16	- .75	- .18
163-(Z)	+ .39	+ .17	- .75	- .33
173-(Y)	+ 2.49*	+ .21	- .43	- .03
174-(X)	+ .57	+3.25*	- .68	+ .02
174-(Z)	+ .57	+5.00*	- .68	+ .02
525-(X)	+22.20*	+ .22	- .44	- .02
525-(Z)	+24.50*	+ .22	- .44	- .01
535-(X)	+ .03	+ .00	- .47	- .13
535-(Z)	+ .12	- .39	- .55	- .02
49-(X)	- .13	+ .04	- .01	+ .03
77-(Y)	+ .20	+ .03	- .51	+ .01
85-(Y)	- .27	- .02	- .08	- .14
Sum Σ	+ 4.43	+1.03	-22.37	-7.07
No n	37	34	40	40
Mean $\overline{X}$	+ .12	+ .05	- .56	- .18
STD Dev δ^{n-1}	.31	.25	.15	.17

*Insignificant data points removed from statistical summary

FIGURE 18

PRELIMINARY

DESIGN LOADS ON ANCHORS & NOZZLES - CHANGES
SPECIFIC STUDY

Model	Forces	Moments	Figure Number
A	-0.05	0.06	19A
	-0.05	0.11	19A
	-0.08	-0.24	19A
A	0.03	0.07	19A
	-0.23	-0.07	19A
	-0.29	-0.01	19A
A	-0.49	-0.06	19A
	-0.22	-0.55	19A
	-0.19	-0.16	19A
A	0.36	0.39	19A
	-0.26	-0.16	19A
	0.13	-0.19	19A
A	-0.04	0.09	19A
	0.06	-0.23	19A
	0.04	0.04	19A
B	+0.01	0.04	19A
	-0.12	-0.24	
	-0.12	-0.26	
B	0.02	0.10	19B
	-0.18	0.09	19B
	0.11	0.10	19B
B	-0.16	-0.25	19B
	-0.17	-0.05	19B
	-0.13	-0.04	19B
B	-0.18	-0.05	19B
	0.01	-0.40	19B
	-0.05	-0.34	19B
B	0.07	0.01	19B
	0.13	-0.39	19B
	-0.39	+0.04	19B
NUMBER n	30	30	
MEAN $\bar{x}$	-0.08	-0.09	
STD. DEV σ_{n-1}	0.17	0.20	

FIGURE 20

PRELIMINARY

COMPARISON OF CALCULATED VS. ALLOWABLE LOADS

RHS PUMP A DISCHARGE PIPING - NODE 1

PUMP DISCHARGE NOZZLE

LOADING CONDITION	CASE	FORCES (LBS)			MOMENTS (FT-LB)		
		F_A	F_S	———	M_T	M_B	———
THERMAL PLUS DEADWEIGHT	DESIGN BASIS	THE NORMAL ALLOWABLE REQUIRES THE COMBINATION OF PUMP SUCTION & DISCHARGE LOADS. SINCE PUMP SUCTION IS NOT PART OF THIS STUDY, NO COMPARISON CAN BE MADE.					
	REFINED BASIS						
	ALLOWABLE						
THERMAL PLUS DEADWEIGHT PLUS SEISMIC	DESIGN BASIS ½% OBE	846	1041	-	1801	4094	-
	REFINED BASIS 2% OBE	807	1105	-	1907	6071	-
	ALLOWABLE	5510	5510	-	9194	9194	-

FIGURE 21(A)

F_A = TOTAL AXIAL FORCE

F_S = RESULTANT SHEAR FORCE

M_T = TORSIONAL MOMENT

M_B = RESULTANT BENDING MOMENT

PRELIMINARY

COMPARISON OF CALCULATED VS. ALLOWABLE LOADS

RHS PUMP A DISCHARGE PIPING - NODE 30

HEAT EXCHANGER NOZZLE INLET

LOADING CONDITION	CASE	FORCES (LBS)			MOMENTS (FT-LB)		
		F_A	F_S	——	M_T	M_B	——
THERMAL PLUS DEADWEIGHT	DESIGN BASIS	981	1648	-	2804	1971	-
	REFINED BASIS	1153	1673	-	3304	2211	-
	ALLOWABLE	1702	1739	-	4278	3016	-
THERMAL PLUS DEADWEIGHT PLUS SEISMIC	DESIGN BASIS ½% OBE	1322	2690	-	3209	2648	-
	REFINED BASIS 2% OBE	1284	2091	-	3053	2933	-
	ALLOWABLE	1872	2205	-	4485	3417	-

FIGURE 21(B)

F_A = TOTAL AXIAL FORCE

F_S = RESULTANT SHEAR FORCE

M_T = TORSIONAL MOMENT

M_B = RESULTANT BENDING MOMENT

PRELIMINARY

COMPARISON OF CALCULATED VS. ALLOWABLE LOADS

RHS PUMP A DISCHARGE PIPING - NODE 70

HEAT EXCHANGER NOZZLE OUTLET

LOADING CONDITION	CASE	FORCES (LBS)			MOMENTS (FT-LB)		
		F_A	F_S	——	M_T	M_B	——
THERMAL PLUS DEADWEIGHT	DESIGN BASIS	[illegible]68	1526	-	5259	5873	-
	REFINED BASIS	128	1394	-	5192	5102	-
	ALLOWABLE	309	2239	-	8381	7589	-
THERMAL PLUS DEADWEIGHT PLUS SEISMIC	DESIGN BASIS ½% OBE	770	2120	-	5890	7042	-
	REFINED BASIS 2% OBE	303	1226	-	5405	5416	-
	ALLOWABLE	559	2531	-	8637	8027	-

FIGURE 21(C)

F_A = TOTAL AXIAL FORCE

F_S = RESULTANT SHEAR FORCE

M_T = TORSIONAL MOMENT

M_B = RESULTANT BENDING MOMENT

PRELIMINARY

COMPARISON OF CALCULATED VS. ALLOWABLE LOADS

RHS PUMP B DISCHARGE PIPING - NODE 1

PUMP DISCHARGE NOZZLE

LOADING CONDITION	CASE	FORCES (LBS)			MOMENTS (FT-LB)		
		F_A	F_S	——	M_T	M_B	——
THERMAL PLUS DEADWEIGHT	DESIGN BASIS	NORMAL ALLOWABLE REQUIRES COMBINATION OF PUMP SUCTION & DISCHARGE LOADS. SINCE PUMP SUCTION IS NOT PART OF THIS STUDY, NO COMPARISON CAN BE MADE.					
	REFINED BASIS						
	ALLOWABLE						
THERMAL PLUS DEADWEIGHT PLUS SEISMIC	DESIGN BASIS ½% OBE	313	1527	-	2698	3613	-
	REFINED BASIS 2% OBE	316	1348	-	2814	2718	-
	ALLOWABLE	5510	5510	-	9194	9194	-

FIGURE 21(D)

F_A = TOTAL AXIAL FORCE

F_S = RESULTANT SHEAR FORCE

M_T = TORSIONAL MOMENT

M_B = RESULTANT BENDING MOMENT

PRELIMINARY

COMPARISON OF CALCULATED VS. ALLOWABLE LOADS

RHS PUMP B DISCHARGE PIPING - NODE 30

HEAT EXCHANGER NOZZLE INLET

LOADING CONDITION	CASE	FORCES (LBS)			MOMENTS (FT-LB)		
		F_A	F_S	———	M_T	M_B	———
THERMAL PLUS DEADWEIGHT	DESIGN BASIS	324	1112	-	4753	3400	-
	REFINED BASIS	408	1263	-	5309	3719	-
	ALLOWABLE	470	1696	-	7521	5101	-
THERMAL PLUS DEADWEIGHT PLUS SEISMIC	DESIGN BASIS ½% OBE	412	1306	-	5049	3768	-
	REFINED BASIS 2% OBE	452	1431	-	5514	4078	-
	ALLOWABLE	544	1835	-	7794	5503	-

FIGURE 21(E)

F_A = TOTAL AXIAL FORCE

F_S = RESULTANT SHEAR FORCE

M_T = TORSIONAL MOMENT

M_B = RESULTANT BENDING MOMENT

PRELIMINARY

COMPARISON OF CALCULATED VS. ALLOWABLE LOADS

RHS PUMP B DISCHARGE PIPING - NODE 35

HEAT EXCHANGER NOZZLE OUTLET

LOADING CONDITION	CASE	FORCES (LBS)			MOMENTS (FT-LB)		
		F_A	F_S	——	M_T	M_B	——
THERMAL PLUS DEADWEIGHT	DESIGN BASIS	3761	1904	-	3636	13545	-
	REFINED BASIS	3273	1673	-	2703	13043	-
	ALLOWABLE	4474	2215	-	4298	17973	-
THERMAL PLUS DEADWEIGHT PLUS SEISMIC	DESIGN BASIS ½% OBE	3956	2147	-	4351	13945	-
	REFINED BASIS 2% OBE	2681	1783	-	2992	13284	-
	ALLOWABLE	5362	2460	-	5022	20445	-

FIGURE 21(F)

F_A = TOTAL AXIAL FORCE

F_S = RESULTANT SHEAR FORCE

M_T = TORSIONAL MOMENT

M_B = RESULTANT BENDING MOMENT

PRELIMINARY

SUMMARY

RHS REFINED MODEL VS DESIGN MODEL

O REFINEMENTS

- ACTUAL OPERATING MODE
- CALCULATED RESTRAINT STIFFNESS
- CALCULATED EQUIPMENT NOZZLE STIFFNESS
- MEASURED FITTING DIMENSIONS
- MORE REALISTIC DAMPING VALUES

O CHANGE TO STRESS

- MAXIMUM THERMAL STRESS DECREASE 17408 TO 14712A
  19213 TO 4818B

- MAXIMUM SEISMIC STRESS DECREASE 5715 TO 1246A
  1937 TO 726B

O RESTRAINT LOADS

- THERMAL LOADS INCREASE	12%
- DEAD LOADS	SAME
- SEISMIC LOADS DECREASE	56%
- TOTAL SUPPORT DESIGN LOAD DECREASE	18%

O ANCHOR & NOZZLE LOADS

- TOTAL DESIGN LOADS DECREASE	8%
- WITHIN EQUIPMENT ALLOWABLES	

O OVERALL IMPACT OF HEAVY FITTINGS

- INSIGNIFICANT AND DOES NOT WARRANT FURTHER INVESTIGATION

PRELIMINARY

CONCLUSION

HEAVY FITTINGS ARE NOT A CONCERN BECAUSE

- CRITICAL (FITTING) STRESSES DECREASE
- SUPPORT DESIGN LOADS DECREASE USING MORE REFINED MODELING TECHNIQUES
- ANCHOR/NOZZLE LOADS DECREASE USING MORE REFINED MODELING TECHNIQUES
- NO KNOWN FAILURES ATTRIBUTABLE TO HEAVY FITTINGS
- SYSTEMS AND EQUIPMENT AT ARE TESTED AT OPERATING PRESSURES AND TEMPERATURES TO ASSURE EQUIPMENT OPERABILITY AND TO VERIFY PIPING BEHAVIOR