Enclosure 1

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November 1979

SUMMARY OF THE DRESDEN UNIT 2 PIPING CALCULATIONS PERFORMED FOR THE SYSTEMATIC EVALUATION PROGRAM

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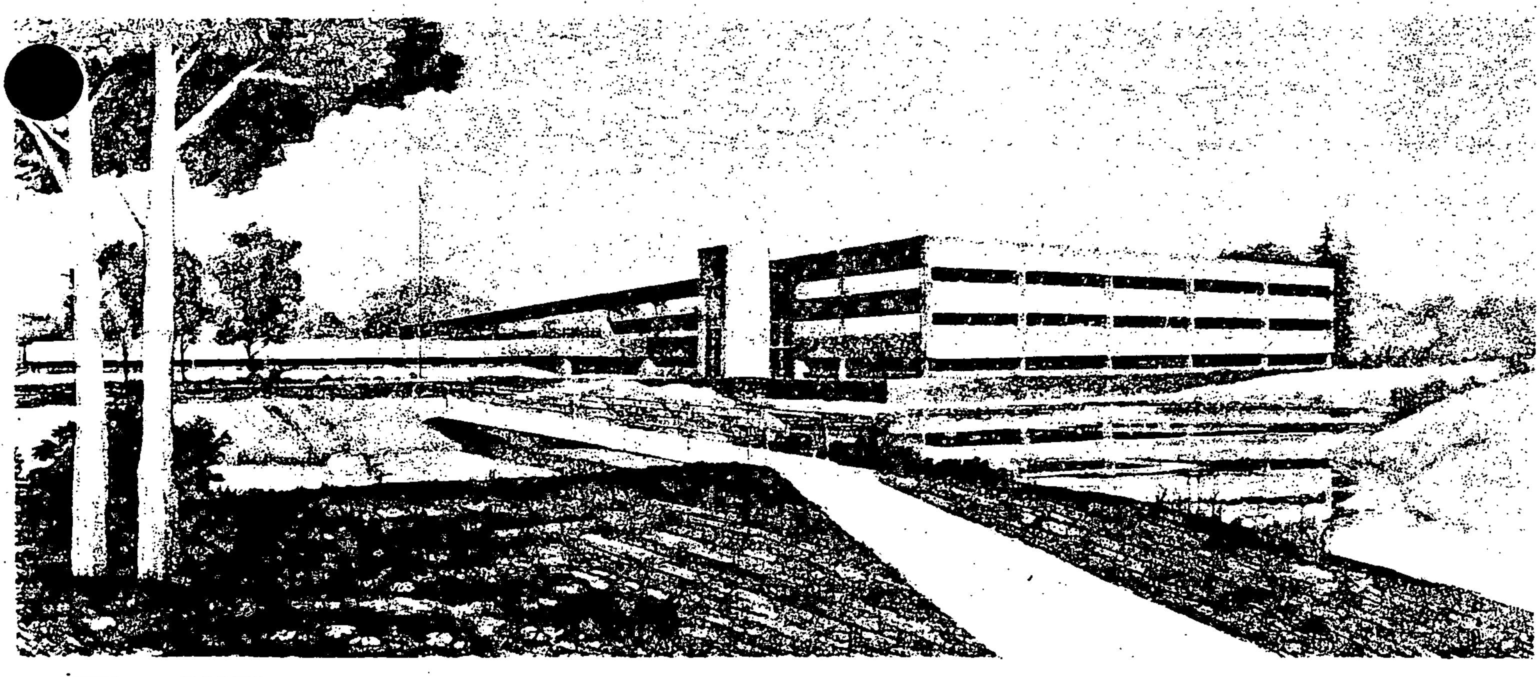
U.S. Department of Energy
Idaho Operations Office • Idaho National Engineering Laboratory



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INTERIM REPORT

ABSTRACT

The Dresden Unit 2 recirculation loop and low pressure coolant injection piping systems were analyzed in support of the Nuclear Regulatory Commission's Systematic Evaluation Program. Audit calculations to verify the original analyses and new calculations incorporating current regulations and standards were performed. In addition, a piping system composed of small diameter piping was analyzed to verify design charts used to locate seismic supports. Pertinent details concerning each analysis are contained within the report.

SUMMARY

This report describes the analyses performed on the Dresden Nuclear Power Station, Unit 2, piping in support of the Nuclear Regulatory Commission's Systematic Evaluation Program (SEP). Calculations were performed on the recirculation and Low Pressure Coolant Injection (LPCI) pipelines to verify the original analyses. New calculations were also performed on these systems to investigate the effects of certain modeling techniques and to obtain analyses which incorporate current ASME Code and Regulatory Guide criteria. A representative piping system was also analyzed to provide verification to design charts which are used to locate seismic supports on small diameter piping. Results of these analyses were compared to ASME Code requirements for Class 2 piping systems at the appropriate service conditions. All pertinent assumptions and methodology employed are discussed in the report.

The analyzed piping systems were chosen to be representative of the various piping size ranges and analysis methods used in the design of the plant. The results from these analyses are intended to be used as information to aid in the assessment of piping structural adequacy under Safe Shutdown Earthquake (SSE) loading when considering current seismic requirements.

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I. INTRODUCTION

The U.S. Nuclear Regulatory Commission (NRC) is conducting the Systematic Evaluation Program (SEP). This program includes a plant-by-plant reassessment of the safety of 11 older operating reactors. Unit 2 of the Dresden Nuclear Power Station is an 800 MWe Boiling Water Reactor (BWR) located at Morris, Illinois. This reactor began commercial operation in August of 1970 and has been included for review within the SEP.

Briefly, SEP goals will be accomplished by reviewing typical components and systems with the objective of assessing their integrity and capability of achieving and maintaining a safe shutdown condition in the reactor during and after a postulated seismic event. The assessment of this subgroup of equipment will then be used to infer similar capabilities in other safety related systems. Judgment would indicate that a positive finding with respect to a carefully chosen subgroup of systems would imply assurance of the adequacy of similarly designed systems.

This report describes the analyses performed on the Dresden Unit 2 recirculation loop and Low Pressure Coolant Injection (LPCI) piping systems. A representative piping system was also analyzed to provide verification to design charts which were used to locate seismic supports on small diameter piping.

The recirculation loop piping was originally analyzed for seismic loading conditions using the finite element methods and procedures described in the Reference 1 report. The LPCI pump suction piping was originally qualified for seismic loading by performing a "seismic coefficient" type analysis. This means that acceleration values are used to determine a set of "equivalent" loads which are then applied statically to the piping mathematical model. Piping design charts were originally developed to be used for the seismic qualification of piping of eight-inch nominal size and below. The small diameter piping seismic example is used to verify the acceptability of these charts.

The three types of analyses described above have been identified as being typical of the methods used to seismically qualify Dresden Unit 2 piping systems. The purposes of these analyses are to simulate and thus verify the methodology used in the original analyses and to analyze the subject piping using current ASME Code and Regulatory Guide guidelines. Enough information will be produced such that the accuracy and adequacy of the modeling techniques used in the original analysis may be assessed. The results of these analyses may then be used to develop a level of confidence in the seismic qualification of the piping under currently accepted criteria.

The ASME Boiler and Pressure Vessel Code[2] (elsewhere referred to as the ASME Code) was used as the criterion for evaluating piping structural adequacy. The governing conditions, engineering assumptions, and analytical techniques used in completing the analyses are described herein. The report is organized such that each major section contains a subsection pertinent to each piping system analyzed.

This work was performed for and funded by the United States Nuclear Regulatory Commission.

II. PIPING SYSTEM DESCRIPTION

1. STRUCTURAL DESCRIPTION

1.1 Recirculation Loop

The recirculation loop consists of 28-inch piping which discharges fluid from each pump into a 22-inch manifold. Riser piping of 12-inch nominal size carries the fluid from the manifold to nozzles distributed around the circumference of the reactor vessel. Pump suction piping of 28-inch nominal size and a 20-inch shutdown line are also included. The general layout of the piping is shown in Figure 1.

Three separate finite element models corresponding to the Reference 1 designations of P1, P2, and P3 were developed for the recirculation loop piping. Plots of these models are shown in Figures 2 through 4. Nodes, masspoints, and restraint locations are indicated. The P1 model includes the 28-inch pump discharge lines, 22-inch manifold and the 12-inch riser piping. The P2 model includes the loop two 28-inch pump suction line and the 20-inch shutdown line. The P3 model is comprised of the loop one 28-inch pump suction line.

1.2 LPCI Suction Piping

The LPCI suction line consists of 24-inch piping which carries fluid from a 24-inch ring header. The piping changes diameter at a tee

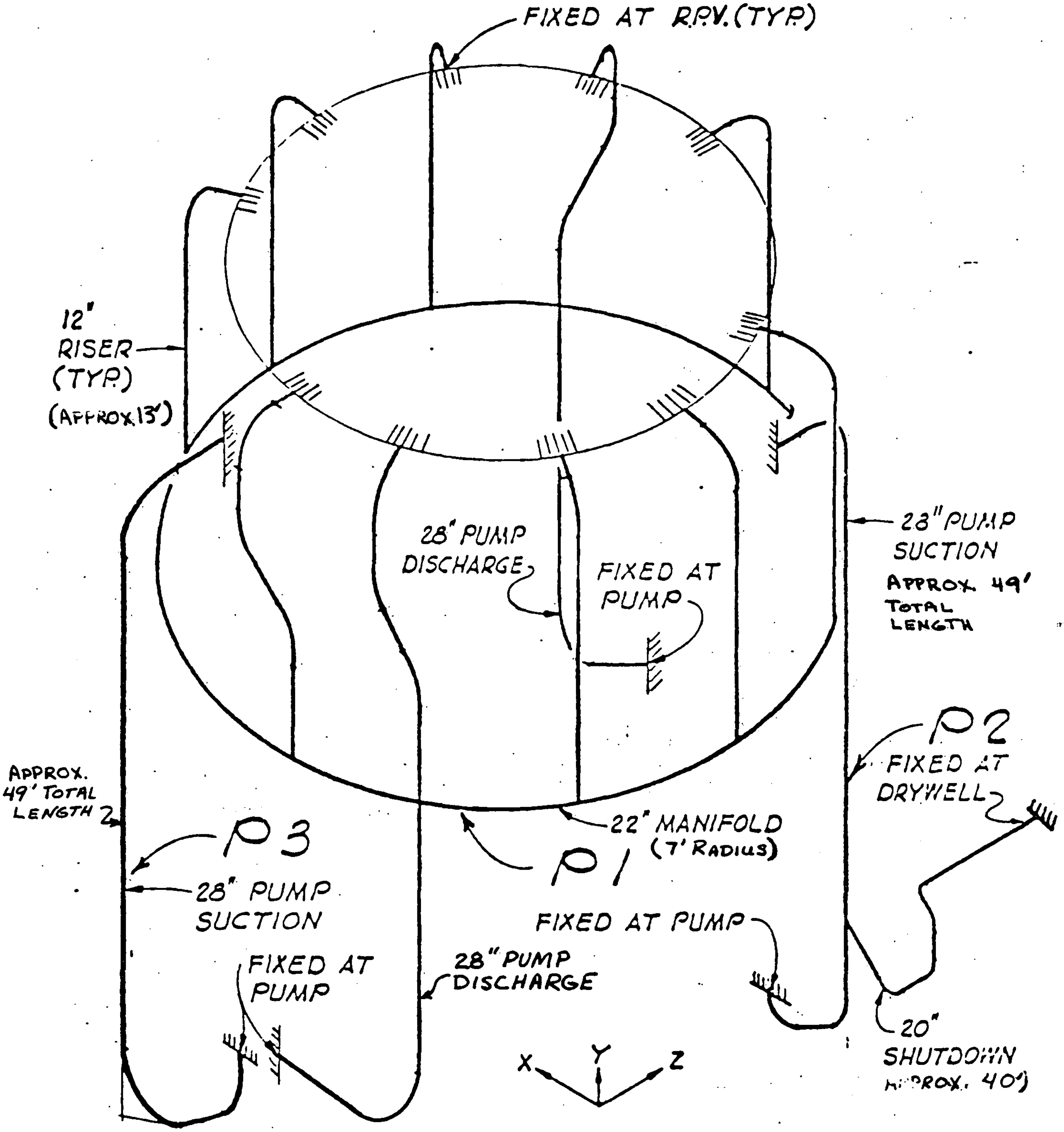
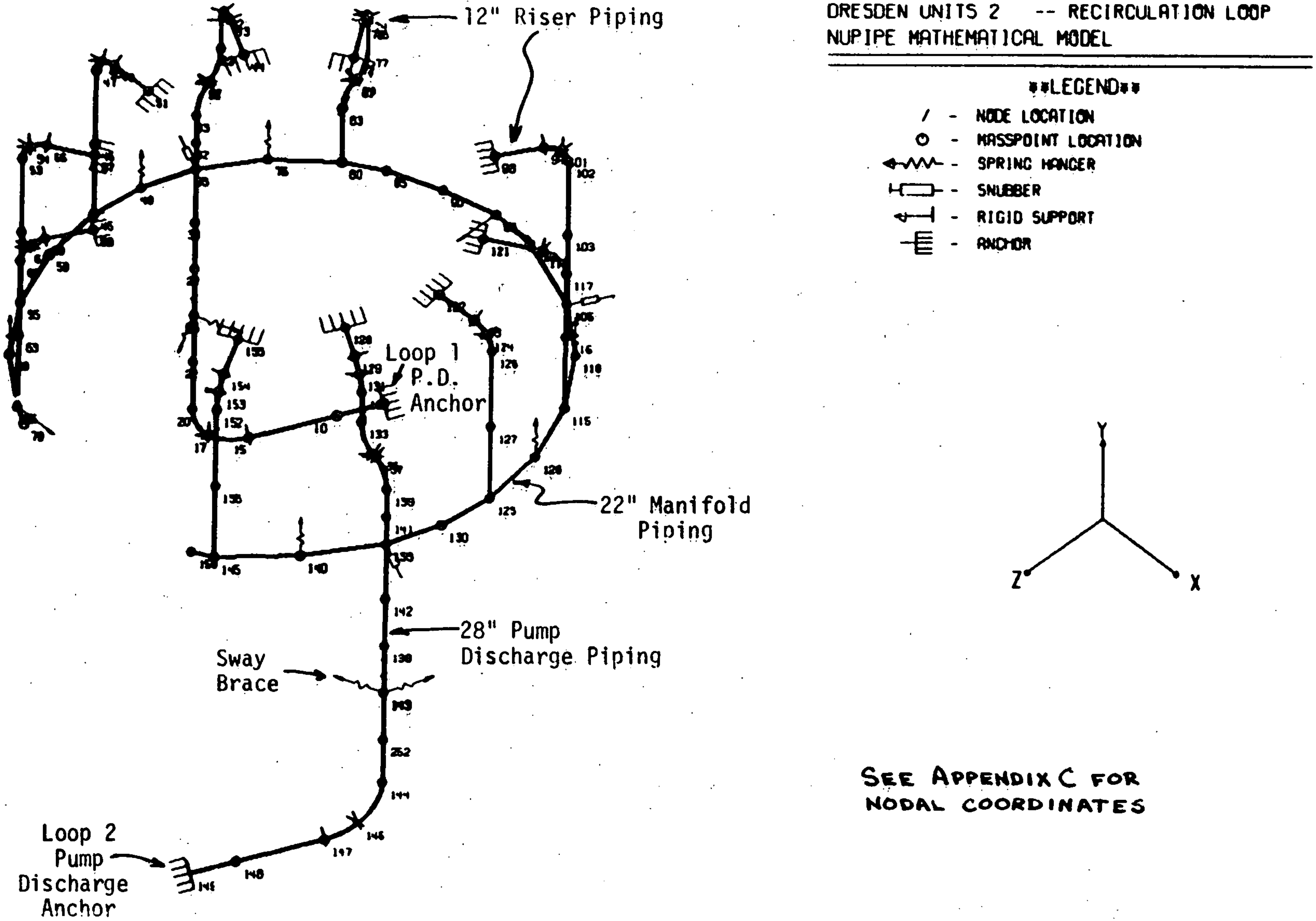


Figure 1

General Layout of Dresden Unit 2
Recirculation Loop Piping
(NOTE: Not to Scale)



SEE APPENDIX C FOR NODAL COORDINATES

Figure 2

Computer Model Plot - Dresden Recirculation Loop Piping - P1 Model

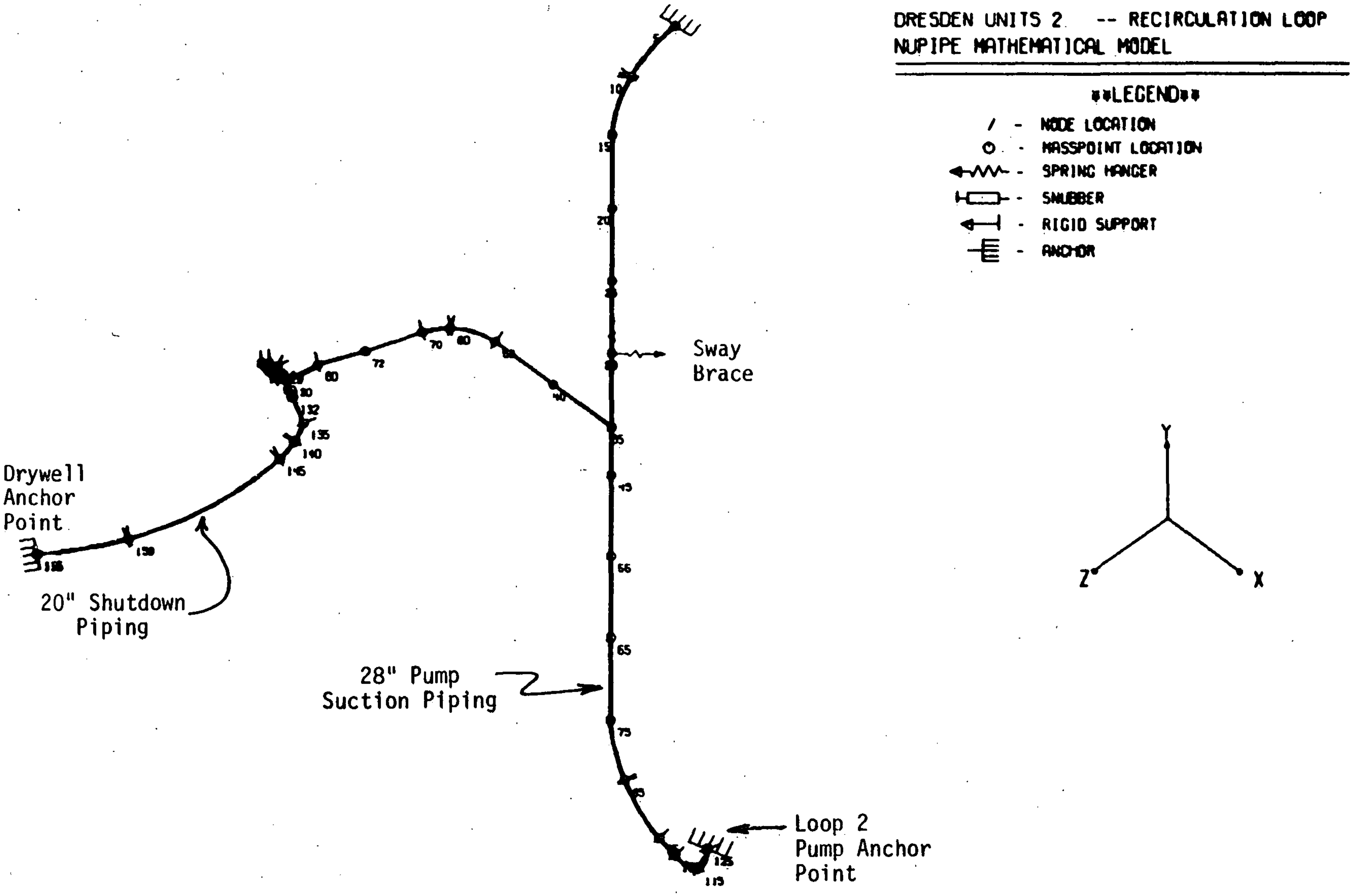


Figure 3
Computer Model Plot - Dresden Recirculation Loop Piping - P2 Model

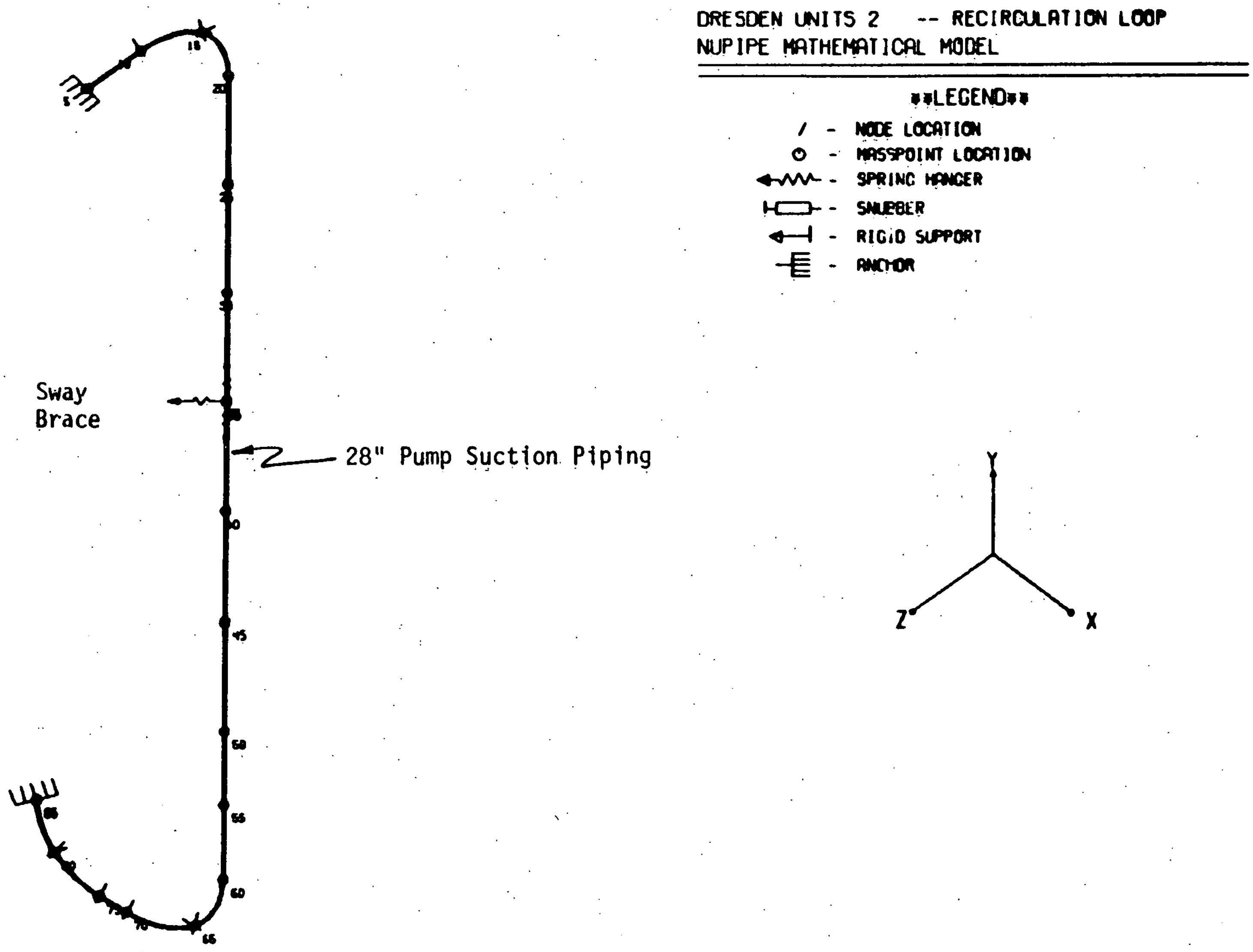


Figure 4

Computer Model Plot - Dresden Recirculation Loop Piping - P3 Model

and a reducer such that two 14-inch lines are used to carry fluid to the two LPCI pumps. A portion of the 24-inch ring header piping was also included in this model for purposes of continuity. The LPCI mathematical model is shown in Figure 5. Nodes, element types, masspoints, and restraint locations are indicated.

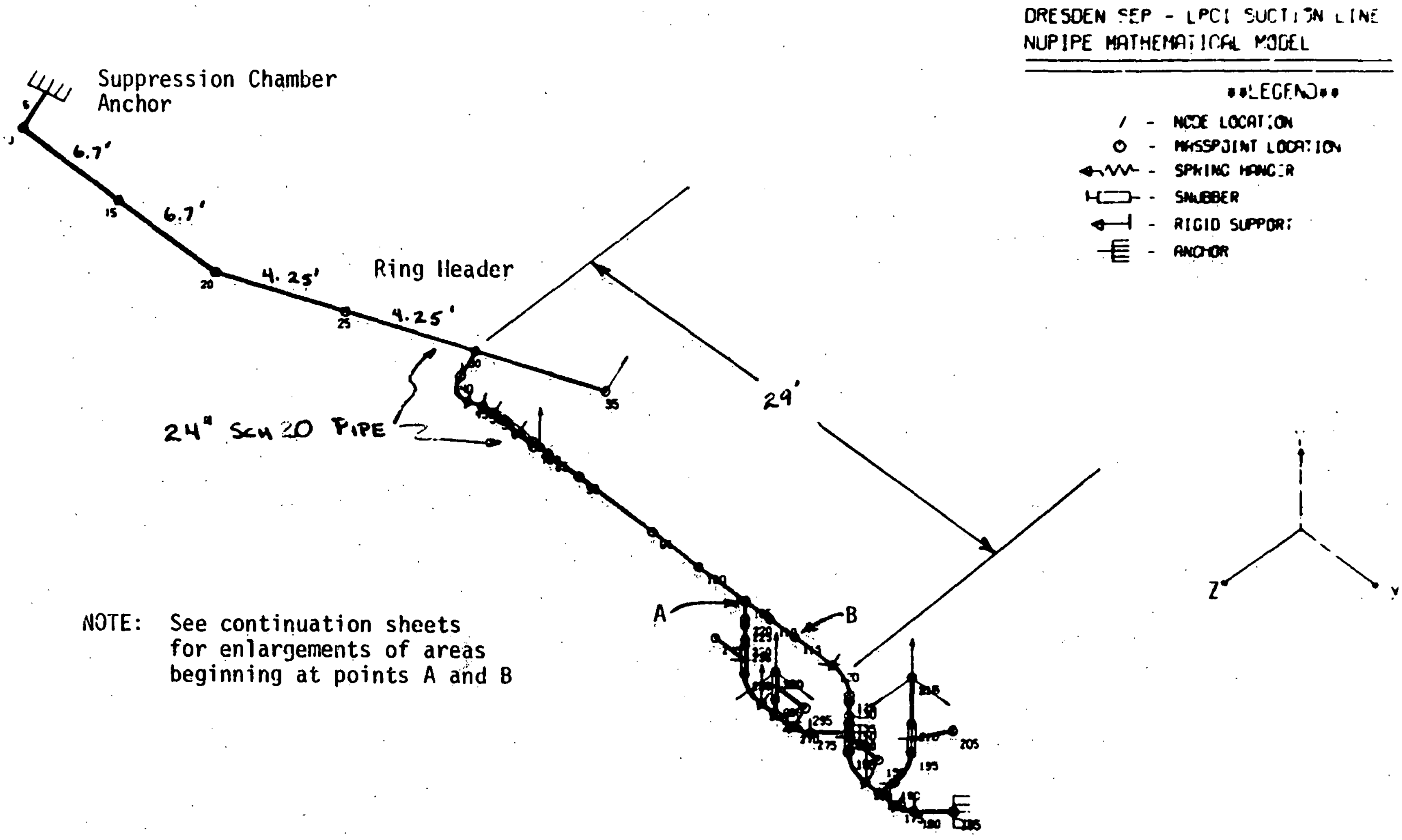
1.3 Small Piping Seismic Example

The small piping seismic example consists of eight-inch piping extending from a tank anchor through a long radius elbow and a pipe bend to arrive at the terminating anchor. Figure 6 contains the finite element model including vertical supports while Figure 7 contains the finite element model which results when the vertical supports are assumed not effective during seismic loading.

Listings of geometric and structural data used in the analyses of all piping models are included in the computer output contained in Appendix C.

2. MATERIAL AND GEOMETRIC DATA

Tables I, II, and III list the significant material and geometric data used in the recirculation loop, LPCI pump suction, and small piping seismic example analyses, respectively.



NOTE: See continuation sheets for enlargements of areas beginning at points A and B

Figure 5

Dresden Unit 2 LPCI Suction Piping Model

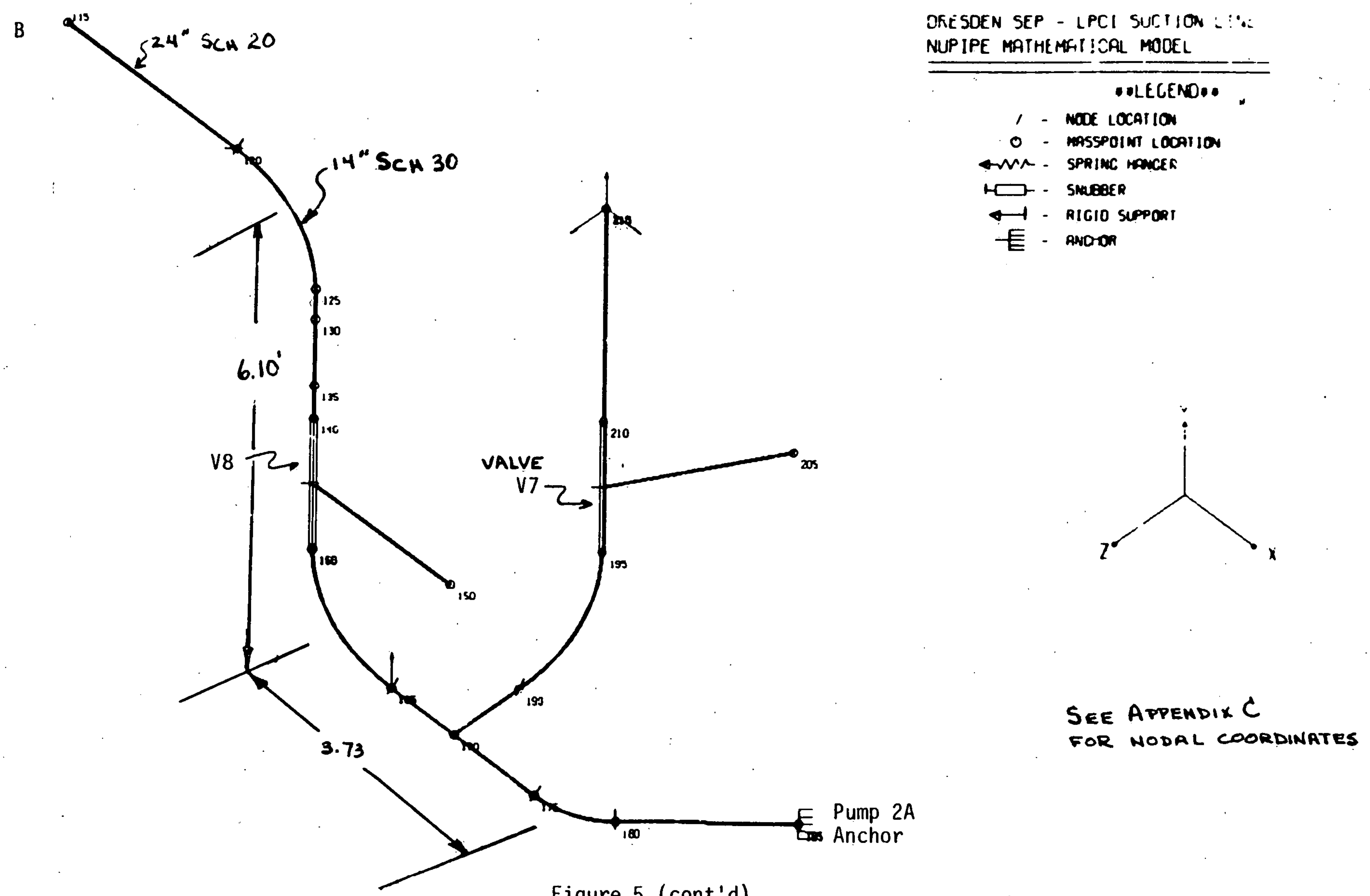
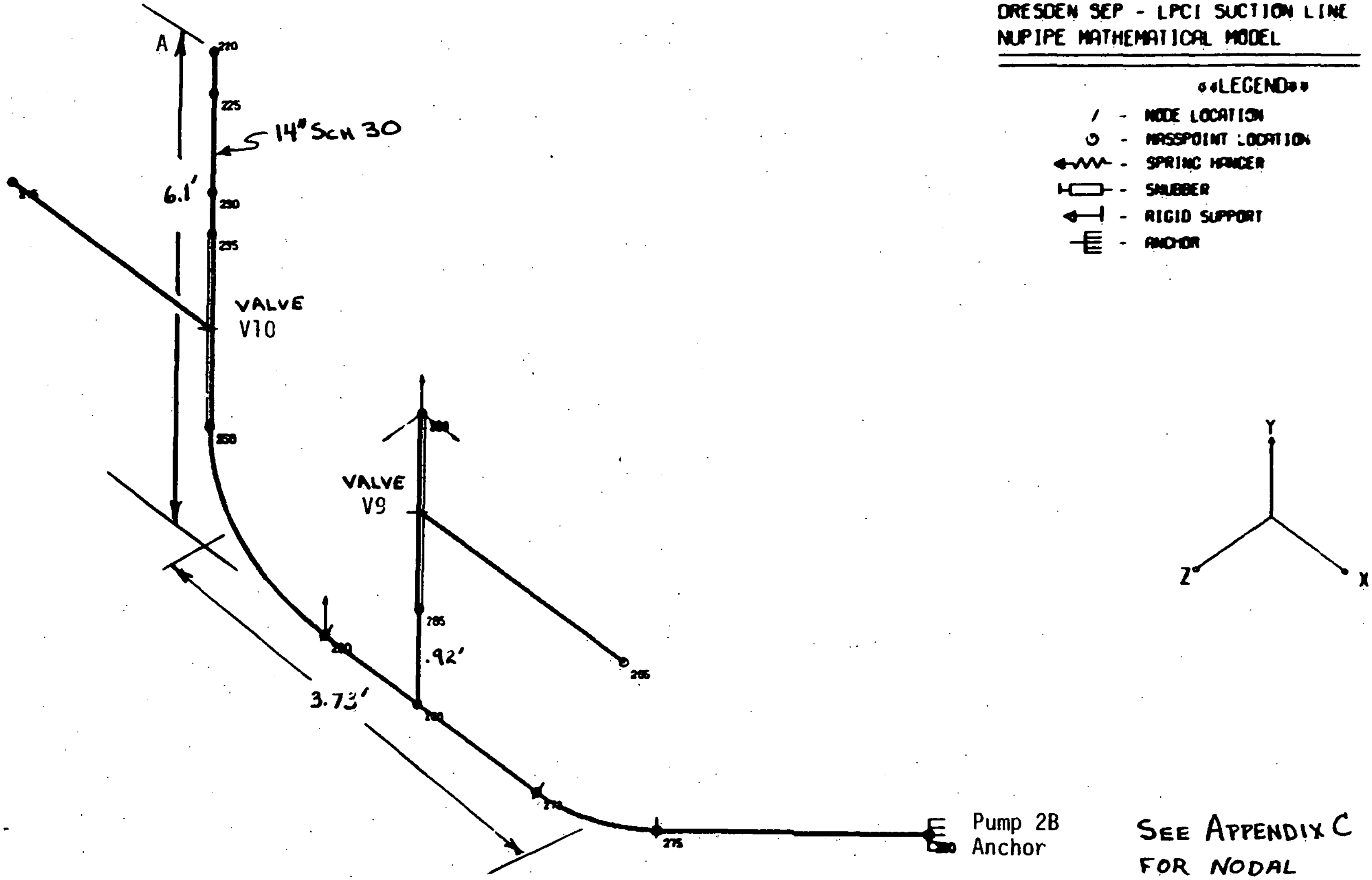


Figure 5 (cont'd)

Dresden Unit 2 - LPCI Suction Piping Model
(Isolated Portion to Pump 2A Anchor)



See Appendix C
for Nodal
Coordinates

Figure 5 (cont'd)

Dresden Unit 2 - LPCI Suction Piping Model
(Isolated Portion to Pump 2B Anchor)

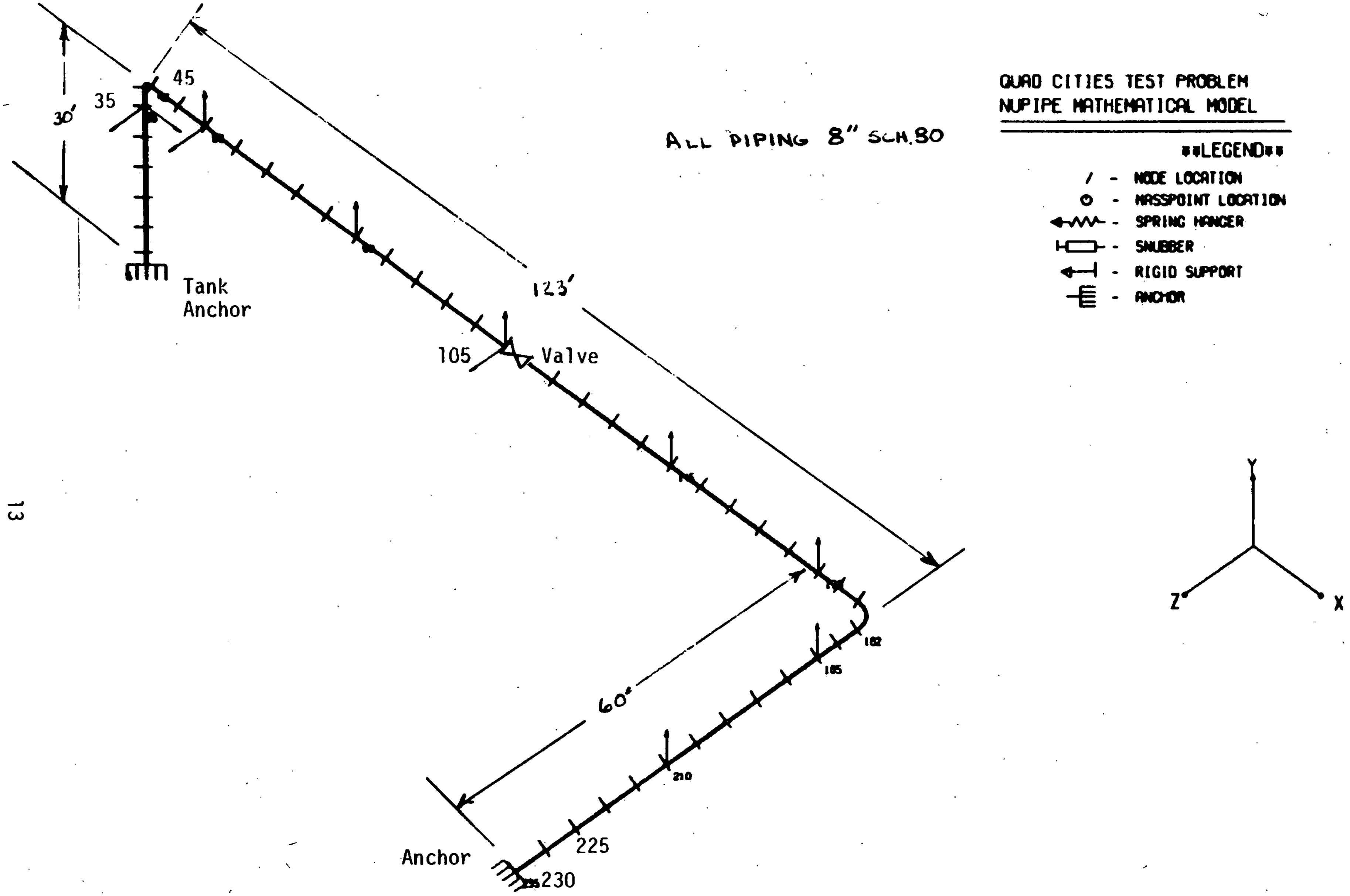


Figure 6

Small Piping Example Problem
Finite Element Model Including Vertical Supports

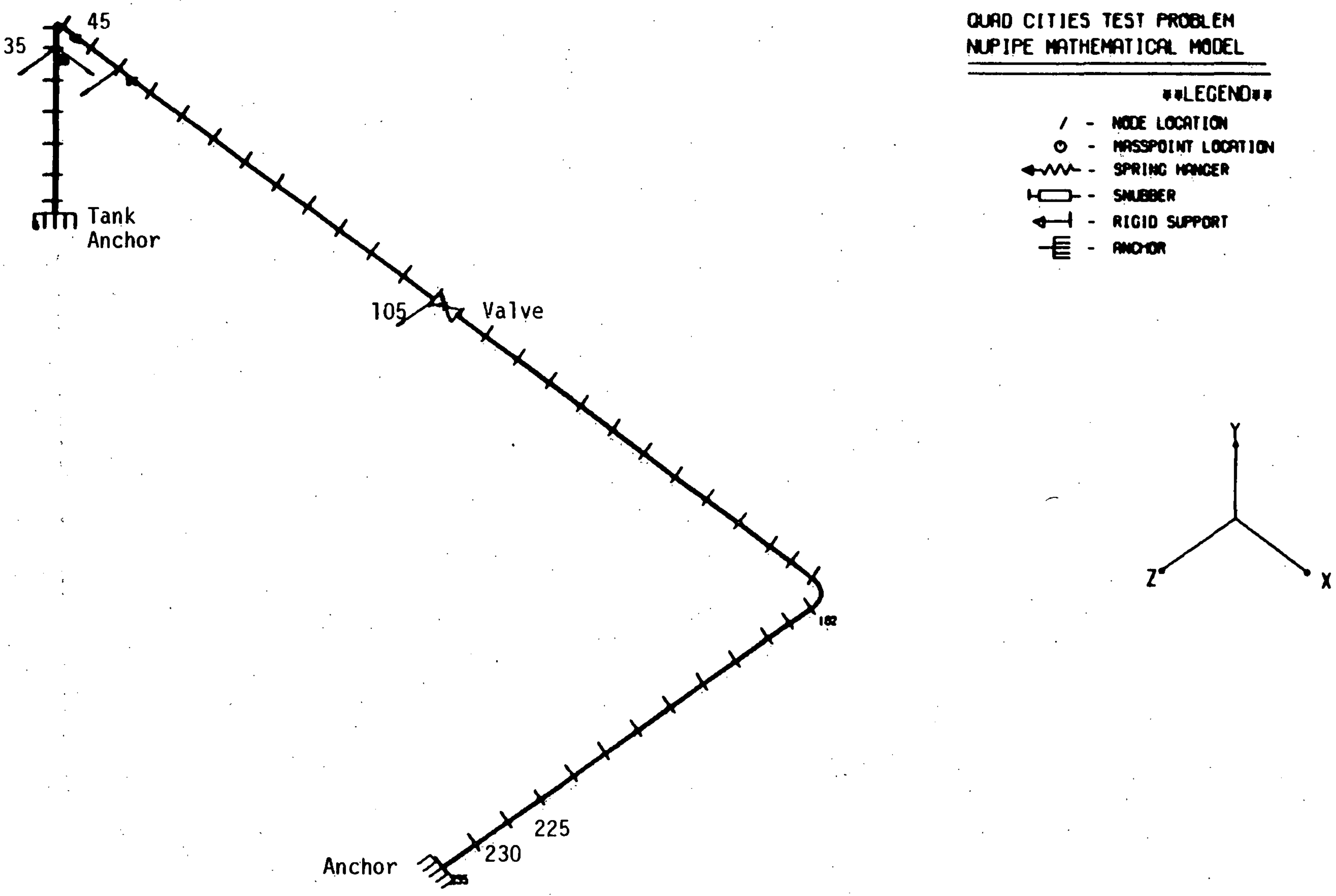


Figure 7

Small Piping Example Problem
Finite Element Model Omitting Vertical Supports

TABLE I

MATERIAL AND GEOMETRIC DATA FOR RECIRCULATION LOOP

O.D. (inches)	28.3	21.3	20.0	12.8
Thickness (inches)	1.20	1.09	1.03	.687
Weight (lbs/inch)	51.3	33.5	28.7	12.7
Material	All Piping - SA 358, TP 304 Stainless Steel			
E_{cold} (10^6 psi)	28.3	28.3	28.3	28.3
S (575°F) (psi)	15900	15900	15900	15900
S_Y (psi)	30000	30000	30000	30000
$\alpha\overline{T}$ (in./ft)	0.0568	0.0568	0.0568	0.0568

TABLE II

MATERIAL AND GEOMETRIC DATA FOR LPCI SUCTION PIPING

O.D. (inches)	24.0	14.0
Thickness (inches)	0.375	0.375
Weight (lbs/inch)	23.2	9.52
Material	A106 GRB	A106 GRB
E_{cold} (10^6 psi)	27.9	27.9
S (165°F) (psi)	15000	15000
S_Y (psi)	35000	35000
$\alpha\overline{T}$ (in./ft)	0.0023	0.0023

TABLE III

MATERIAL AND GEOMETRIC DATA FOR SMALL PIPING SEISMIC EXAMPLE

O.D. (inches)	8.63
Thickness (inches)	0.375
Weight (lbs/inch)	5.27
Material	A106, GR.B.
E_{cold} (10^6 psi)	29.0
S (100°F) (psi)	15000
S_Y (psi)	35000
$\alpha\overline{T}$ (in./ft)	0.0023

As used in the previous tables, $\alpha\overline{T}$ is the overall thermal growth parameter of the pipe. α is the average thermal coefficient of expansion and $\overline{T}$ is the average temperature of the pipe. Insulation weight is not included in the above tables.

III. DESIGN AND SERVICE CONDITIONS

The following sections list the various design and operating conditions utilized in the analyses. It is emphasized that all systems were analyzed as ASME Code Class 2.

1. DESIGN CONDITIONS

3.1.1 Recirculation Loop

Design Pressure - 1250 PSI

Design Temperature - 575°F

3.1.2 LPCI Suction

Design Pressure - 70 PSI

Design Temperature - 165°F

3.1.3 Small Piping Seismic Example

Design Pressure - 0 PSI

Design Temperature - 70°F

2. SERVICE LEVEL A

Service Level A was referred to as the normal operating condition in previous versions of the ASME code. Operating temperature and pressures are listed below.

3.2.1 Recirculation Loop

Operating Pressure - 1250 PSI

Operating Temperature - 575°F

3.2.2 LPCI Suction

Operating Pressure - 70 PSI

Operating Temperature - 100°F

3.2.3 Small Piping Seismic Example

Operating Pressure - 0 PSI

Operating Temperature - 70°F

It should be noted that the temperatures and pressures listed for design conditions and Service Level A are those quantities used in the analyses described herein. In most cases, only one value was available and was therefore used for both the design and operating values. Since no pressure or temperature information was obtained for the small piping example problem, the values listed above were assumed. While the values shown above may not be exactly correct, they do represent the best available information and are sufficiently accurate to achieve the main objective of the SEP - assessing plant safety relative to current criteria.

3. SERVICE LEVEL B

Service Level B was referred to as the upset operating condition in previous versions of the ASME Code. The only Service Level B loading condition considered was the Operating Basis Earthquake (OBE). The OBE loading case was considered in the simulation of the original analyses of the recirculation and LPCI systems.

4. SERVICE LEVEL C

Service Level C was referred to as the emergency condition in former versions of the ASME Code. No Service Level C load cases were considered for the analyses described herein.

5. SERVICE LEVEL D

Service Level D was referred to as the faulted condition in former versions of the ASME Code. Safe Shutdown Earthquake (SSE) was considered as the Service Level D loading for the analyses described in this report.

IV. PIPING SYSTEM STRUCTURAL ANALYSES

The piping systems were analyzed for the various structural load cases using the computer program NUPIPE-II, a proprietary program developed by Nuclear Services Corporation. NUPIPE-II capabilities are briefly described in Appendix A. Idaho National Engineering Laboratory (INEL) program modules LCPIP6L and C0059001 were used for the analyses.

1. RECIRCULATION LOOP ANALYSES

Three separate finite element models corresponding to the Reference 1 designations of P1, P2, and P3 were developed for the recirculation loop. These models are as shown in Figures 2 through 4. Certain pipe and valve weight data used in these calculations were obtained from the Reference 1 report. Additional information and piping drawings were provided by NRC-DOR.

Important assumptions used for the recirculation loop analyses are listed below:

1. Valves were simulated by placing concentrated weights at appropriate node points. This approach was used to verify the original finite element model. The valve weights and node locations are shown in Table IV.

2. No account was taken for interaction of the shutdown line on the P3 model. This shutdown line is indicated on drawings

provided by D0R; however, little detail is provided. No attempt was made to simulate any shutdown line interaction in the audit calculation P3 model; thus, similarity to the original analysis P3 model was maintained.

3. Some values of spring hanger hot loads, spring stiffnesses of spring hangers and sway braces, and snubber stiffnesses were assumed. This was due to the poor quality of reproduction on the drawings used. As much information as possible was taken from the drawings; however, when unreadable, assumptions of necessary values were based on the known information coupled with analytical experience and engineering judgment. All stiffness and applied load values used are listed with the NUPIPE-II input data contained in Appendix C.

4. No pipe supports are shown mounted to the 20-inch shutdown line in the P2 model. Insufficient detail exists on the drawings provided to determine if supports are present; thus, none were assumed.

5. The drawings used for the audit calculations indicated three snubbers which, apparently, were not included in the original (Reference 1) analysis of the P1 model. These snubbers were included in the P1 model for the "current criteria" calculations but were omitted in other runs required to verify the original analyses.

6. It was uncertain whether the two piping crosses on the 22-inch manifold piping were forged or fabricated components. Thus, forged tee stress intensification factors were used as an estimate of the stress intensification at these two points.

7. Further assumptions made for the audit calculations were:

   a. All components were forged and butt welded (flush).

   b. All components meet ANSI B16.9 and B16.28 standards.

   c. The requirements of the ASME Code, Section III, Subarticle NC-3640 are satisfied.

TABLE IV

PIPING SYSTEM VALVE WEIGHTS AND CENTERS OF GRAVITY RECIRCULATION LOOP PIPING

Model	Node	Weight (lb)	C.G. Distance From Pipe Axis (in.)
P1	10	17220	0
P1	85	6280	0
P1	100	6280	0
P1	148	17220	0
P2	45	17000	0
P2	70	5720	0
P3	50	17220	0

The recirculation system was analyzed for the following loads:

1. Deadweight
2. North-south plus vertical OBE (Square Root Sum of the Squares (SRSS) combination technique "stiff" restraints).
3. North-south plus vertical OBE (absolute sum combination technique "stiff" restraints).
4. East-west plus vertical OBE (SRSS combination technique "stiff" restraints).
5. East-west plus vertical OBE (absolute sum combination technique "stiff" restraints).
6. Repeat of load Case 2 using "reasonable" restraint stiffnesses.
7. Repeat of load Case 3 using "reasonable" restraint stiffnesses.
8. Repeat of load Case 4 using "reasonable" restraint stiffnesses.
9. Repeat of load Case 5 using "reasonable" restraint stiffnesses.
10. SSE using SRSS combination of modal response from "current criteria" three directional earthquake and "reasonable" support stiffnesses.

The response spectrum shown in Figure 8 was used to verify the original analysis OBE response. The data contained in Figure 8 have been normalized to a 0.1 g Zero Period Ground Acceleration (ZPGA). Mass point seven data were used because the elevations of the 12-inch riser anchors were at approximately the same elevation as this masspoint. Since the north-south and east-west OBE response spectra are nearly identical, the plot contained in Figure 8 was used to represent both of the response directions. Vertical spectra were taken to be 2/3 times the horizontal spectrum.

The many variations of OBE loading listed above were considered in order to satisfy several objectives. The original analysis (References 1) was performed using two directional earthquakes and high (rigid) stiffness values for beam type seismic supports. The SRSS method was used to combine modal results in the original analysis. The maximum stresses reported in Reference 1 are without regard to the direction of the earthquake used for loading. The original analysis was simulated by the north-south plus vertical and east-west plus vertical load cases using the SRSS method of combining modal results and "rigid' restraint stiffnesses for beam-type seismic supports. The absolute sum method of combining dynamic analysis results was also commonly used during the time period in which the original analysis was performed. Computer runs using this method were made in order to assess the resulting differences in calculated stress levels. The version of NUPIPE-II used throughout these analyses performs absolute summations only on a resultant level. Therefore, the technique employed on the absolute sum computer runs was to perform single directional response spectra analyses and then combine the resultants by absolute summation.

This was done for both X+Y (north-south + vertical) and Z+Y (east-west + vertical) combinations. This technique will indicate an upper bound to be expected on the results of an analysis using the SRSS combination method. A further discussion of various combination methods and test problems run at the INEL is presented in Appendix B. Restraint stiffnesses of 1.0 X 10^{12} lb/in. were used to simulate the "rigid" stiffnesses of beam-type seismic supports. Values of 1.0 X 10^{6} lb/in. were chosen as being a better representation of the actual beam stiffnesses and were used in the loading cases as listed above to determine if any significant differences in system response would occur due to the resulting increase in flexibility. It should be noted that the P2 and P3 models did not contain any beam-type seismic supports. Thus, the computer runs containing restraint stiffness variations apply only to the P1 model. The purposes of the analyses described above are to simulate the original analysis and to produce enough information such that the accuracy and adequacy of the modeling techniques used in the original analysis may be assessed.

Analyses using the P1, P2, and P3 recirculation loop models were also performed using the response spectra shown in Figures 9 and 10. These spectra were taken from Reference 2 for mass point seven at three-percent damping for the SSE load case. Modal responses were combined using the SRSS method. These runs were made using current ASME Code (Reference 3) criteria and are in compliance with Regulatory Guide 1.92. The results of "current criteria" analysis will be used to assess the margin of safety under current standards and regulations.

Microfiche copies of all computer runs are contained in Appendix C. Paper copies of the computer output were not included because of the large volume.

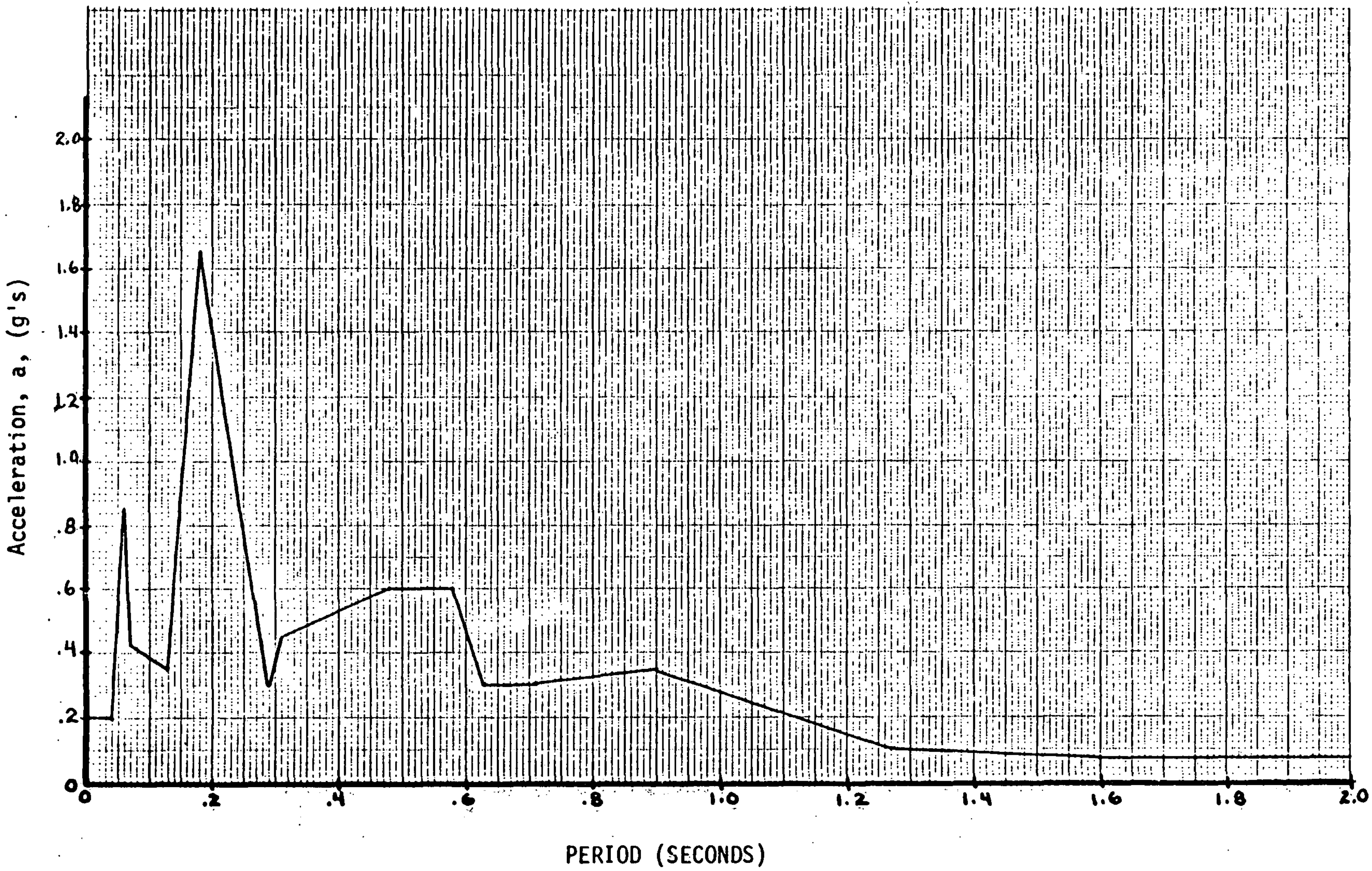


Figure 8
Response Spectrum, Mass Point 7, 0.5% Damping, Dresden Recirculation Loop Piping
(This curve replotted from original John A. Blume & Assoc., Engineers, data)

2. LPCI SUCTION PIPING ANALYSES

The finite element model representing the LPCI suction piping is shown in Figure 5. The required physical data were provided by NRC-DOR. In addition, it was assumed that all components were forged and butt welded, that all components met ANSI B 16.9 and B16.28 standards, and that the requirements of the ASME Code, Section III, Subarticle NC-3640 are satisfied. The valve weights and centers-of-gravity for this system are shown in Table V.

TABLE V

PIPING SYSTEM VALVE WEIGHTS AND CENTERS OF GRAVITY - LPCI SUCTION PIPING

Valve	Weight (lb)	C.G. Distance From Pipe Axis (in.)
V7	1120	24
V8	1299	24
V9	1120	24
V10	1299	24
V11	3284	24

The LPCI system was analyzed for the following loads:

1. Deadweight
2. Seismic coefficient
3. "Current criteria" SSE

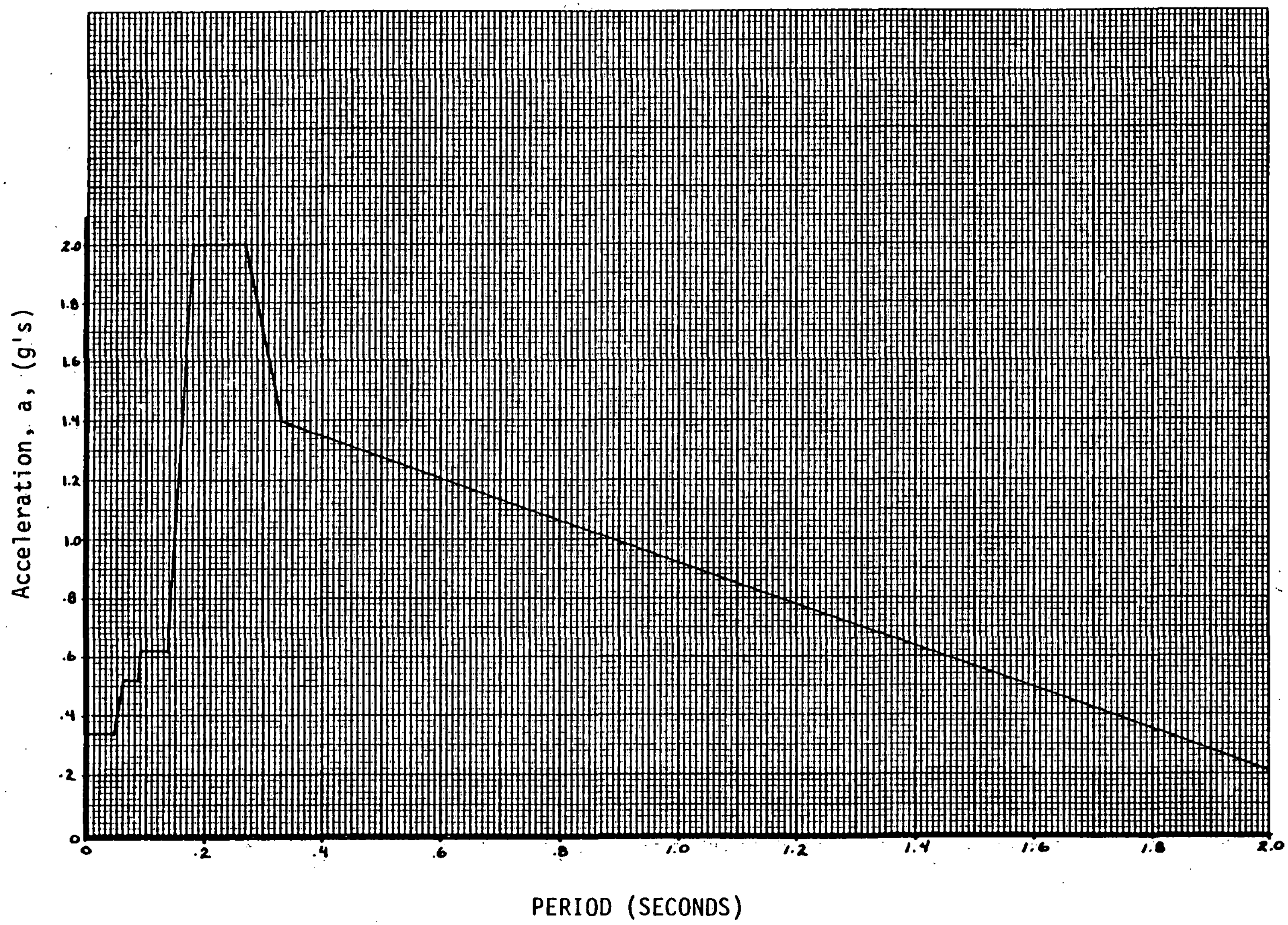


Figure 9
Response Spectrum, Mass Point 7, East-West, 3% Damping

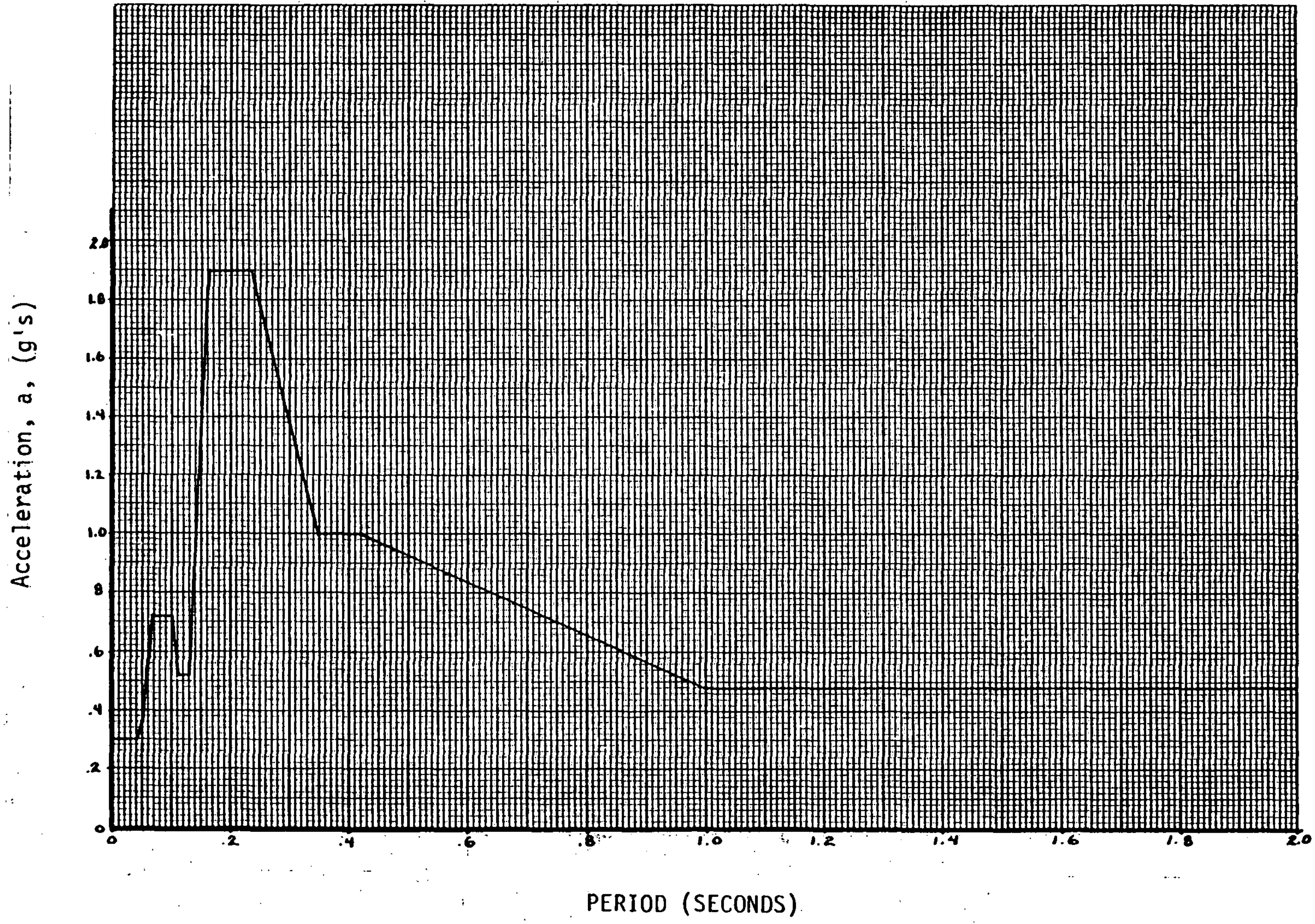


Figure 10
Response Spectrum, Mass Point 7, North-South, 3% Damping

The seismic coefficient analysis was performed to simulate the original analysis of the LPCI suction piping. The procedure followed was to use acceleration values to determine a set of "equivalent" loads which were then applied statically to the piping mathematical model. A horizontal acceleration of 0.7 g applied perpendicular to the pipe axis and a vertical acceleration of 0.067 g were used for the seismic coefficient load case. The response spectra data contained in Figures 11 and 12 were used in the horizontal directions to perform the SSE analysis using current modeling practice, standards, and regulations. These spectra were obtained from Reference 2. The spectral accelerations of Figure 12 were also used as the vertical direction data after a scaling factor of 2/3 was applied. The modal responses of the response spectra run were combined using the SRSS method. Support stiffnesses of 1.0 X 10^7 lb/in. were considered reasonable estimates and, thus, were used at all support locations. This stiffness is slightly higher than the values used on the Recirculation Loop Piping. Exact support Geometries were not known; however, from the available information it appeared likely that these supports were somewhat shorter and, thus, possibly stiffer than the other beam type supports. It is reiterated that these are assumed values and are considered to be reasonable for the pipe size under consideration. Stiffnesses of 2.0 X 10^5 lb/in. were used to simulate the stiffness of the adjacent piping at nodes 215 and 300. Continuance of the piping at these points was indicated by dashed lines on the system isometric drawings, however, no further detail was obtainable.

Microfiche copies of all LPCI computer runs are contained in Appendix C.

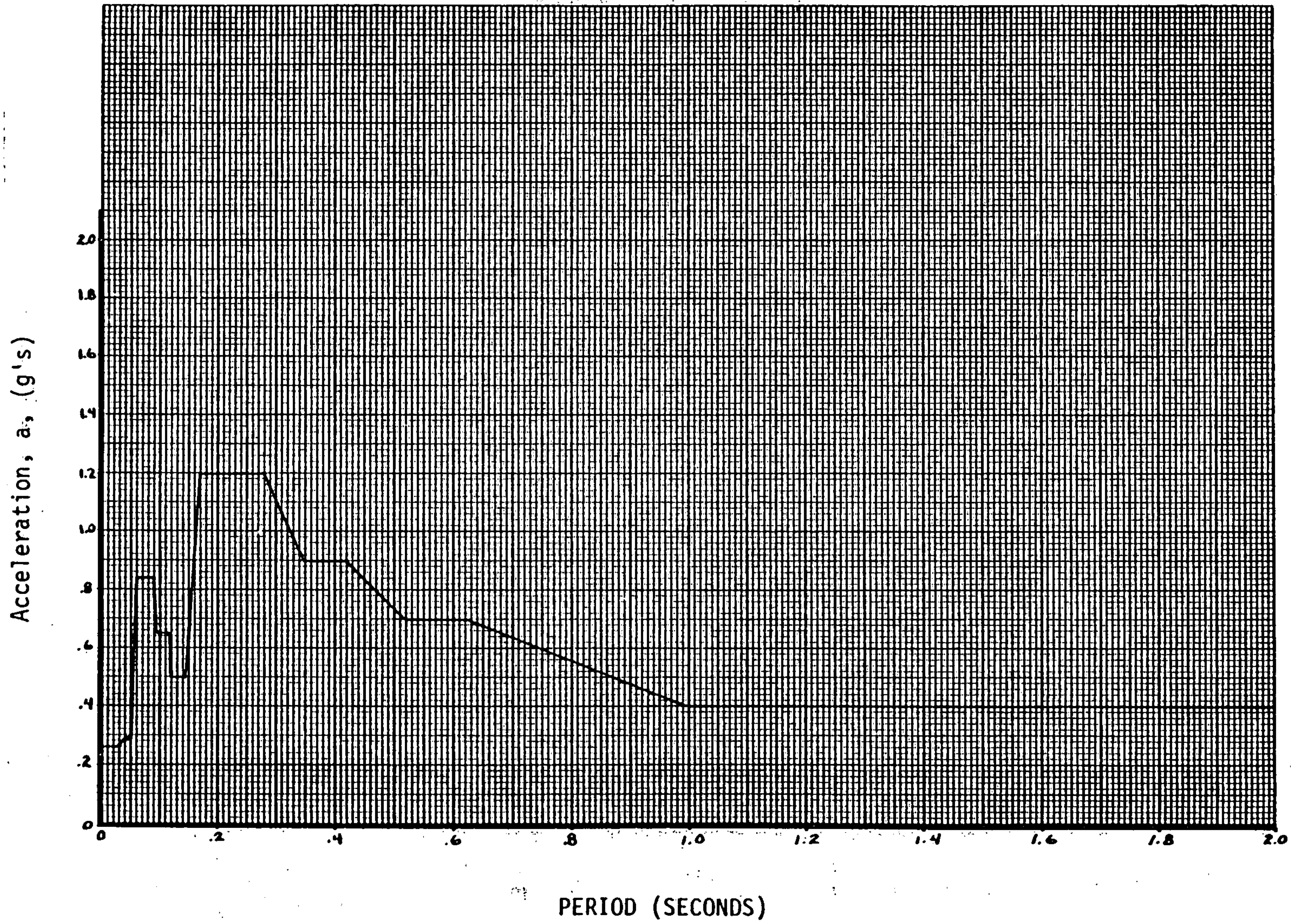


Figure 11
Response Spectrum, Mass Point 8, North-South, 3% Damping

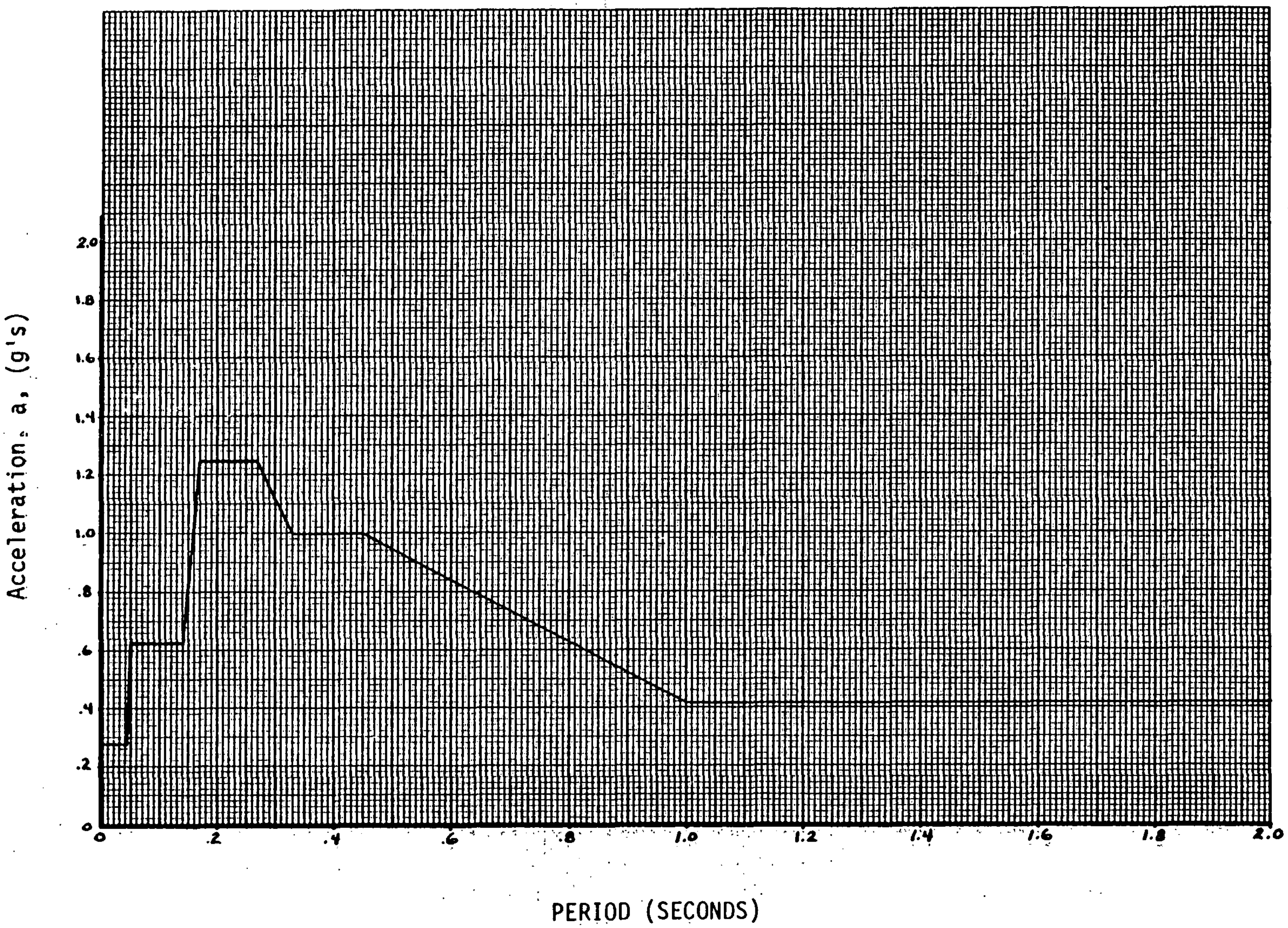


Figure 12
Response Spectrum, Mass Point 8, East-West, 3% Damping

3. SMALL PIPING SEISMIC EXAMPLE ANALYSES

Two configurations of the small piping seismic example problem were analyzed. Figure 6 contains the finite element model including vertical supports while Figure 7 contains the finite element model which results when the vertical supports are assumed not effective during seismic loading. Required physical data were provided by NRC-DOR. It was assumed that all components were forged and butt welded, that all components met ANSI B16.9 and B16.28 standards, and that the requirements of the ASME Code, Section III, Subarticle NC-3640 are satisfied. The only valve included in this system weighed 1000 pounds and was assumed to have its center of gravity 15 inches from the axis of the pipe. Both models were analyzed using currently acceptable modeling practice and reasonable (2.0 X 10^5 lb/in.) values of support stiffness. Additional computer runs were made using support stiffness values of 10 times the bending stiffness of a typical pipe section spanning two adjacent supports. This stiffness value was 6.8 X 10^6 lb/in. The response spectrum shown in Figure 13 was used in all small piping example problem computer runs. This spectrum was also taken from Reference 2. A scaling factor of 2/3 was applied to the Figure 13 spectrum to obtain vertical spectral data. Modal responses were combined using the SRSS method. The small piping example problem was analyzed to provide information which would help determine the degree of conservatism in the original design charts.

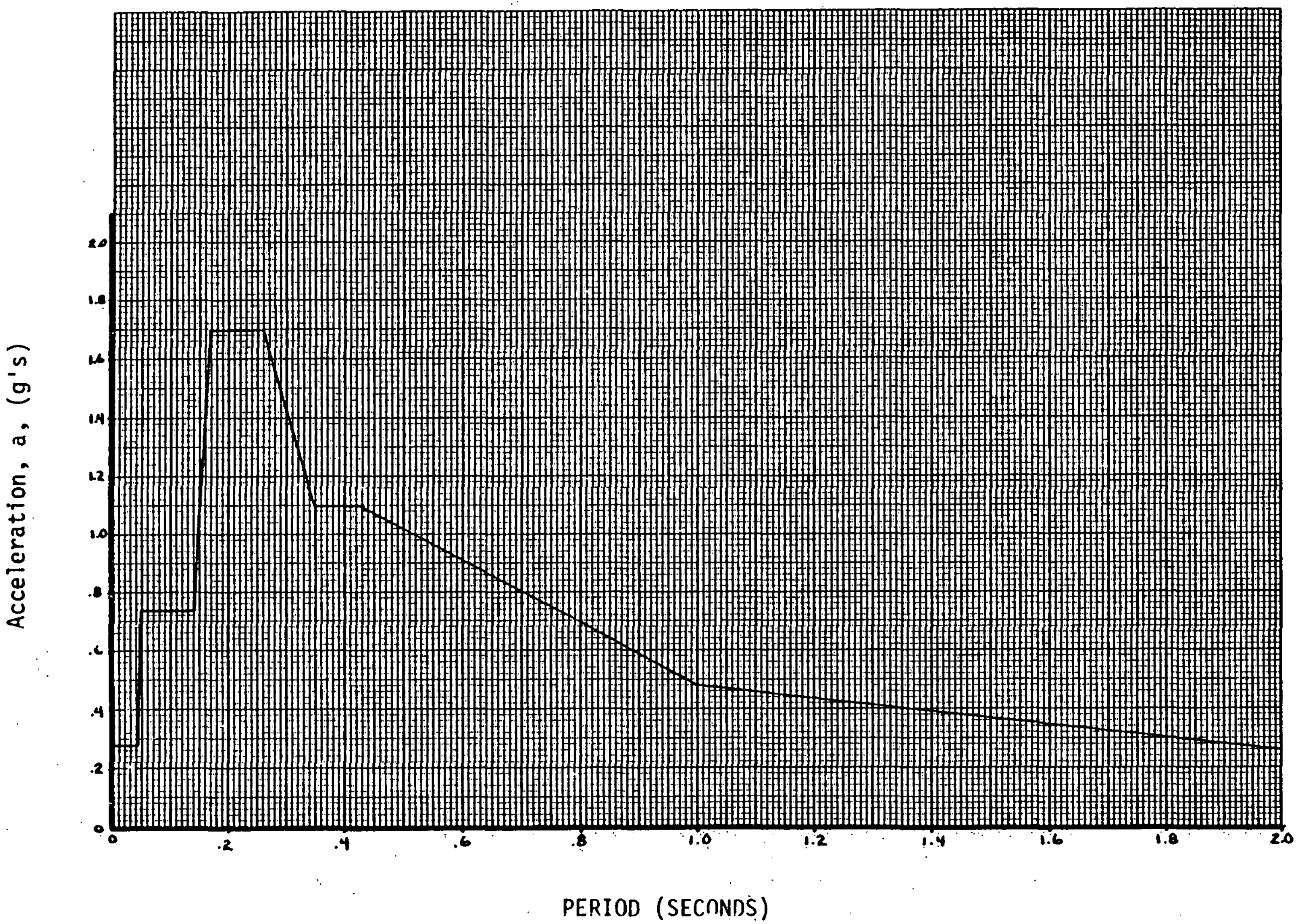


Figure 13
Response Spectrum, Mass Point 8, East-West, 2% Damping

V. ASME BOILER AND PRESSURE VESSEL CODE, SECTION III, STRESS ANALYSES

Stress analyses of the recirculation loop, LPCI, and small piping seismic example were performed per the requirements of Subarticle NC-3600 of the ASME Code. The 1977 edition of the ASME Code including the Winter, 1978, addenda was used throughout the analyses described herein. The results obtained from the structural analyses described in Section IV of this report were used to evaluate stress levels.

1. MINIMUM THICKNESS CHECK

The Code requires verification that the piping minimum wall thickness is satisfactory. The thickness was checked against Equation (3) of NC-3641.1:

$$t_m = \frac{P\,D_o}{2\,(S + PY)} + A$$

where:

t_m = Minimum required wall thickness, in.

P = Internal design pressure, PSI

D_o = Outside diameter, in.

S = Allowable stress, PSI

y = .4 or $\frac{d}{d + D_o}$ if $D_o/t_m < 6$ (per Code)

A = Corrosion allowance (.08 in.).

Results of this calculation are contained in Tables VI and VII for the recirculation loop and LPCI suction piping, respectively. This calculation was not performed for the small piping seismic example because a design pressure of zero was used.

TABLE VI

MINIMUM THICKNESS PARAMETERS - RECIRCULATION LOOP PIPING

Pressure (psi)	O.D. (in.)	S (psi)	t_m (in.)	t_{Actual} (in.)
1250	28.3	15900	1.16	1.20
1250	21.3	15900	0.892	1.09
1250	20.0	15900	0.842	1.03
1250	12.8	15900	0.568	0.687

TABLE VII

MINIMUM THICKNESS PARAMETERS - LPCI SUCTION PIPING

Pressure (psi)	O.D. (in.)	S (psi)	t_m (in.)	t_{Actual} (in.)
70	24.0	15000	0.136	0.375
70	14.0	15000	0.113	0.375

Since the actual thicknesses are all greater than the t_m calculated, the system meets the requirements of NC-3641.1. It has been assumed that all intersections are standard fittings and therefore meet the requirements of NC-3643.2 for branch connections not requiring reinforcement.

2. NC-3650 PIPING STRESS ANALYSES RESULTS

The stress results of the computer runs described above were calculated using Equation 9 in Subparagraph NC-3652.2. This is the Class 2 equation which must be satisfied for occasional loads. The equation is:

$$S_{OL} = \frac{P_{MAX} D_o}{4t_n} + 0.75i \quad \frac{M_A + M_B}{Z} < 1.2 \ S_H$$

where:

P_{MAX} = Peak pressure, psi

D_o = Outside diameter of pipe, in.

t_n = Nominal wall thickness, in.

i = Stress intensification factor

Z = Section modulus of pipe, $in.^3$

M_A = Resultant moment loading due to weight and other sustained loads, in.-lb

M_B = Resultant moment loading due to occassional loads such as relief valve thrusts, flow transients and earthquake, in.-lb

S_H = Basic material allowable stress at design temperatue, psi

It is very important to note that the 1.2 S_H limit is for design and service level A and B loading conditions. The Equation 9 stress limits for service levels C and D are 1.8 S_H and 2.4 S_H, respectively. The OBE load cases included in these calculations are considered as service level B (upset) loads; therefore, Equation 9 stress limits of 1.2 S_H are used. Equation 9 stress limits of 2.4 S_H were used for the SSE load cases because they were defined as service level D (faulted) loads.

5.2.1 Recirculation Loop Piping

Individual modal frequencies and periods of vibration for the P1, P2, and P3 models are contained in Tables VIII and IX. Guidelines contained in Reference 4 indicate that structures with natural frequencies of 33 hertz or higher may be considered rigid. For this reason, a cut-off frequency limit of 33 hertz was specified for all seismic analyses.

ASME Code Class 2 stress summaries for all models are included in the computer output contained in Appendix C. Equation 9 stress values for the anchor points and the three highest stressed points on the piping are listed for the P1, P2, and P3 models in Tables X through XII. It should be remembered that Equation 9 combines the effects of pressure, sustained loads (such as deadweight) and occasional loads (such as OBE or SSE). A stress comparison at identical points in the P1, P2, and P3 models for the original analysis seismic stresses and the audit calculation OBE seismic stresses is contained in Table XIII. Seismic support loads for the recirculation loop models are summarized in Tables XIV and XV. The Reference 1 support loads for the beam-type seismic supports on the P1 model are also included in Table XIV. The global forces on the piping system anchors are summarized and compared to the original analysis loads in Tables XVI and XVII.

As shown in Tables VIII and IX the calculations performed using NUPIPE-II resulted in slightly different natural frequencies. This was expected in the P1 model which included the three snubbers as noted in Table VIII. It should emphasized that the recirculation models as described in this report were developed with a more uniform mass distribution than that shown in the original (Reference 1) analysis. This difference in mass distribution will influence natural frequency calculations and is probably the main contributor to the differences noted above. Analyses previously performed at the INEL have shown that differences in support stiffness can also influence natural frequency results. The exact stiffnesses used in the original analysis were not known and, thus, could not be exactly duplicated. Table VIII shows that the changes in support stiffness did produce frequency changes as expected. The frequency changes were relatively minor in this case.

The summaries contained in Tables X through XII indicate that the ASME Code, Equation 9 stresses were well below the allowable limits for all analyses described in this report. The seismic stresses compared in Table XIII also indicate low stress magnitudes. The support and anchor load summaries presented in Tables XIV through XVII indicate that, in general, support loads are lower while anchor loads are similar or of higher absolute value. The differences in the stresses compared in Table XIII and the support and anchor loads compared in Tables XIV through XVII are at least partially dependent upon the mass distribution of the finite element models. Since the mass of the P1 model shown in Figure 2 is more evenly distributed than is the original analysis, it follows that the inertia effects will be reduced due to the smaller mass concentration at node 30.

Similarly, it follows that the support loads would be altered. Because mass points were more accurately defined throughout the recirculation loop models, the changes in anchor loads were not surprising. The changes in stresses and loads will also be partially caused by the previously discussed variations in natural frequency. The natural frequencies are used to determine the accelerations needed to calculate the inertial forces in a response spectrum analysis. Thus variations in frequency may cause significant changes in the results.

The results of the recirculation loop analyses described in the preceeding sections show that the variations in support stiffness and modal response combination method had a greater effect on support and anchor loads than on stress levels. However, the reader is cautioned to remember that these results are specific for the subject piping and may not represent general trends.

TABLE VIII

DRESDEN RECIRCULATION LOOP PIPING - P1 MODEL - SUMMARY OF NATURAL FREQUENCIES AND PERIODS OF VIBRATION

	Configuration 1		Configuration 2		Configuration 3		Original Analysis
Mode	f(Hz)	T(sec.)	f(Hz)	T(sec.)	f(Hz)	T(sec.)	T(sec.)
1	7.09	.141	7.12	.140	9.09	.110	.148
2	8.27	.121	8.33	.120	10.3	.097	.124
3	9.37	.107	9.86	.101	13.1	.077	.095
4	13.4	.075	13.4	.075	13.4	.075	.065
5	14.8	.068	17.4	.057	15.6	.064	.063
6	17.1	.058	19.4	.052	17.6	.057	.051
7	19.4	.052	19.7	.051	19.6	.051	
8	20.1	.050	20.7	.048	20.4	.049	
9	20.9	.048	21.8	.046	21.6	.047	
10	21.7	.046	25.4	.039	21.8	.046	
11	23.4	.043	25.8	.039	25.4	.039	
12	25.5	.039	26.8	.037	25.5	.039	
13	26.8	.037	31.2	.032	26.7	.037	
14	31.2	.032	34.2	.029	31.2	.032	
15	31.7	.032			32.8	.030	
16	34.7	.029			34.3	.029	

NOTES:

1. Configuration 1 - "Reasonable" seismic support stiffnesses (K = 1.0 x 10^6 lb/in)
2. Configuration 2 - "Stiff" seismic support stiffneses (1.0 x 10^{12} lb/in)
3. Configuration 3 - "Reasonable" seismic support stiffnesses (1.0 x 10^6) plus model included 3 snubbers as shown on drawings provided.

TABLE IX

DRESDEN RECIRCULATION LOOP PIPING - P2 AND P3 MODELS - SUMMARY OF NATURAL FREQUENCIES AND PERIODS OF VIBRATION

P2 Model

Mode	Frequency (Hertz)	Period (sec.)	Period (sec.) Original Analysis
1	7.66	0.130	0.117
2	8.93	0.112	0.113
3	11.4	0.088	0.083
4	17.3	0.058	0.066
5	22.1	0.045	
6	24.1	0.041	
7	27.1	0.037	
8	31.1	0.032	
9	38.3	0.026	

P3 Model

Mode	Frequency (Hertz)	Period (sec.)	Period (sec.) Original Analysis
1	8.50	0.118	0.098
2	10.5	0.096	0.077
3	19.6	0.051	
4	27.8	0.036	
5	28.4	0.035	
6	50.4	0.020	

NOTE

The P2 And P3 models contained seismic supports whose stiffness values were well established. Therefore, only one configuration of these models was analyzed using the known values of support stiffness.

TABLE X

SUMMARY OF ASME CODE, CLASS 2, EQUATION 9 STRESS VALUES - P1 MODEL CONSIDERING RESTRAINT STIFFNESS VARIATIONS, OBE LOAD CASE (P + DW + OBE)

	Stresses (KSI)					
	AB SUM		2-D SRSS		Allowable	
Node	Stiff[1]	REAS[2]	Stiff	REAS	(1.2 S_H)	Comments
5	8.24	8.37	8.09	8.20	19.1	Loop 1 Pump Anchor
58	7.50	7.50	7.27	7.28	19.1	Riser Anchor
57	7.07	7.09	6.89	6.91	19.1	" "
51	7.74	7.80	7.48	7.53	19.1	" "
44	8.53	8.66	8.12	8.23	19.1	" "
72	12.8	12.9	12.5	12.5	19.1	" "
98	13.2	13.4	12.6	12.6	19.1	" "
121	6.92	6.98	6.69	6.66	19.1	" "
122	7.10	7.34	6.80	6.87	19.1	" "
128	9.52	10.1	8.56	8.78	19.1	" "
155	8.49	8.76	7.83	7.86	19.1	" "
149	8.45	8.59	8.08	8.08	19.1	Loop 2 Pump Anchor
95	8.46	8.54	8.05	8.11	19.1	Manifold Intersection
76	8.28	8.30	8.04	8.04	19.1	Riser Elbow
102	8.06	8.23	7.94	7.90	19.1	" "

NOTES

1. "Stiff" → Seismic Restraint Stiffness = 1.0×10^{12} lb/in
2. "REAS" → Reasonable Seismic Restraint Stiffness = 1.0×10^{6} lb./in.
3. Numbers shown for P1 Model only. P2 and P3 models did not have "beam" type seismic supports.
4. Allowable based on S_H = 15.9 KSI for ASTM A358, TP304 stainless steel at 575°F.
5. Equation 9 includes the effects of pressure, sustained loads (deadweight), and occasional loads (OBE).
6. "AB SUM" Denotes 2-D absolute sum combination as defined on Page 24.
7. 2-D SRSS → Only 2 Directions (one horizontal and vertical) combined. Both north-south horizontal plus vertical and east-west horizontal plus vertical cases were analyzed. Loads shown are maximum values regardless of directions.

TABLE XI

SUMMARY OF ASME CODE, CLASS 2, EQUATION 9 STRESS VALUES - P2 and P3 MODELS, TWO METHODS, OBE LOAD CASE (P + DW + OBE)

		STRESSES (KSI)			
Model	Node	AB SUM	2-D SRSS	1.2 S_H	Comment
P2	5	10.6	10.4	19.1	Reactor Vessel Anchor
	125	9.48	9.32	19.1	Pump Anchor
	155	9.78	9.63	19.1	Shutdown Line Anchor
	35	11.9	11.5	19.1	Tee Intersection
	45	10.7	10.6	19.1	Concentrated Weight (valve)
	30	9.86	9.69	19.1	Run (Support Point)
P3	5	8.64	8.43	19.1	Reactor Vessel Anchor
	85	10.3	9.99	19.1	Pump Anchor
	70	9.03	8.86	19.1	Elbow
	75	9.79	9.53	19.1	"
	80	10.2	9.91	19.1	"

NOTES

1. 0.5% Damping, 0.1 ZPGA J. A. Blume Spectra Used.
2. AB Sum → Absolute Sum method of combination.
3. 2-D SRSS → Only 2 Directions (one horizontal and vertical) combined. Both north-south horizontal plus vertical and east-west horizontal plus vertical cases were analyzed. Stresses shown are maximum values regardless of directions.
4. Allowable based on S_H = 15.9 KSI for ASTM A358, TP304 stainless steel at 575°F.
5. Equation 9 includes the effects of pressure, sustained loads (deadweight), and occasional loads (OBE).

TABLE XII

SUMMARY OF ASME CODE, CLASS 2, EQUATION 9, STRESS VALUES - CURRENT CRITERIA ANALYSIS, SSE LOADING (P + DW + SSE)

Model	Node	Eq. 9 Stress (KSI)	Allow. Stress (KSI)	Comment
P1	5	8.85	38.2	Loop 1 Pump Anchor
	58	7.74	38.2	Riser Anchor
	57	7.25	38.2	" "
	51	8.00	38.2	" "
	44	9.14	38.2	" "
	72	14.5	38.2	" "
	98	14.7	38.2	" "
	121	7.16	38.2	" "
	122	7.30	38.2	" "
	128	9.18	38.2	" "
	155	8.58	38.2	" "
	149	8.61	38.2	Loop 2 Pump Anchor
	95	8.86	38.2	Manifold Intersection
	76	8.57	38.2	Riser Elbow
	102	8.60	38.2	" "
P2	5	10.6	38.2	Reactor Vessel Anchor
	125	10.1	38.2	Pump Anchor
	155	9.87	38.2	Shutdown Line Anchor
	35	12.0	38.2	Tee Intersection
	45	11.1	38.2	Concentrated Weight (valve)
	30	10.0	38.2	Run (Support Point)
P3	5	9.17	38.2	Reactor Vessel Anchor
	85	11.0	38.2	Pump Anchor
	70	9.53	38.2	Elbow
	75	10.4	38.2	"
	80	10.7	38.2	"

NOTES

1. 3% damping used in all cases.

2. Allowable stress based on S_H = 15.9 KSI for ASTM A358, TP304 Stainless Steel at 575°F.

3. Equation 9 includes the effects of pressure, sustained loads (deadweight), and occasional loads (SSE).

TABLE XIII

STRESS COMPARISON AT IDENTICAL POINTS - OBE LOADING[1], .1g ZPGA

	Model P1	P2	P3
Original Analysis Node	30	150	10
Orig. Anal. Max. Stress (KSI)	3.4	3.00	2.00
Current Model Node	145	5	75
Stress (KSI) - AB Sum, "Stiff"[2]	.535	N.A	N.A
" - AB Sum, "REAS"[3]	.437	2.41	2.40
" - 2-D SRSS, Stiff	.378	N.A	N.A
" - 2-D SRSS, "REAS"	.385	2.21	2.14

NOTES

1. Seismic stresses only are shown above.

2. "Stiff" → Seismic Restraint Stiffness = 1.0 x 10^{12} lb./in.

3. "REAS" → " " " = 1.0 x 10^{6} lb./in.

TABLE XIV

SUPPORT LOAD SUMMARY - RECIRCULATION LOOP P1 MODEL - SEISMIC LOADS ONLY

		Load (K)					Original
Node	Dir.	Config. 1	Config. 2	Config. 3	Config. 4	Curr.	Analysis
25	H	.041	.042	.038	.039	.046	
143	H	.042	.051	.032	.032		
65	X	1.39	2.18	1.21	1.88	3.40	-3.27
95	X	2.99	12.7	2.34	10.3	19.5	-8.73
95	Z	8.44	9.52	4.79	7.47	16.5	-25.6
135	Z	N.A.	N.A.	N.A.	N.A.	9.03	
105	X	N.A.	N.A.	N.A.	N.A.	5.75	
35	Z	N.A.	N.A.	N.A.	N.A.	13.0	

NOTES

1. H implies horizontal. This is the maximum load on either one of two sway braces which are oriented at 90 degrees to each other in the horizontal plane.

2. X or Z imply restraint in the indicated global direction.

Configuration 1 = Absolute summation run with "stiff" support stiffness (1×10^{12} lb/in.)
Configuration 2 = Absolute summation run with "reasonable" support stiffness (1×10^{6} lb/in.)
Configuration 3 = 2-D SRSS run with "stiff" support stiffness (1×10^{12} lb/in.)
Configuration 4 = 2-D SRSS run with "reasonable" support stiffness (1×10^{6} lb/in.)
Curr. = "Current Criteria" analysis using reasonable restraint stiffness.

4. Config. 1 → Config. 4 loads are OBE seismic loads. Current criteria seismic loads are for an SSE load case.

5. N.A. = Not Applicable. Restraints at these nodes are for snubbers which were not included in OBE analyses.

6. Original analysis loads taken from Reference 1.

TABLE XV

SUPPORT LOAD SUMMARY - RECIRCULATION LOOP P2 and P3 MODELS - SEISMIC LOADS ONLY

P2 Model

Node	Direction	Load (K) AB. Sum (OBE)	2-D SRSS (OBE)	Current (SSE)
30	H	.082	.080	.087

P3 Model

Node	Direction	Load (K) AB. Sum (OBE)	2-D SRSS (OBE)	Current (SSE)
35	H	.074	.066	.091

NOTES

1. H implies horizontal. This is the maximum load on either one of two sway braces which are oriented at 90 degrees to each other in the horizontal plane.

TABLE XVI

ANCHOR LOAD SUMMARY - RECIRCULATION LOOP P1 MODEL - SEISMIC LOADS ONLY

Node	Dir.	Config. 1	Config. 2	Load (K) Config. 3	Config. 4	Curr.	Original Analysis
5	X	2.83	4.00	2.29	3.41	7.61	-4.35
	Y	2.24	3.75	1.88	2.66	5.58	-3.02
	Z	3.23	3.40	2.90	3.04	4.96	-4.38
44	X	.549	.690	.443	.555	.63	-.776
	Y	2.07	2.40	1.49	1.70	3.34	-.232
	Z	1.20	1.28	1.11	1.18	1.55	-1.34
51	X	.555	.628	.500	.575	.763	-.877
	Y	1.58	1.72	1.14	1.24	2.17	.906
	Z	1.04	1.08	.950	.985	1.23	-1.53
57	X	.427	.477	.389	.430	.627	-.697
	Y	.836	.719	.610	.550	1.26	.186
	Z	.965	.994	.885	.910	1.13	-1.46
58	X	.220	.242	.196	.220	.281	-.358
	Y	1.52	1.48	1.16	1.13	1.91	-1.84
	Z	1.02	1.03	.935	.945	1.24	-1.56
72	X	.655	.724	.470	.515	.900	-1.45
	Y	3.65	3.84	3.21	3.22	6.83	-7.18
	Z	.802	.885	.645	.720	1.07	-.842
98	X	.089	.265	.065	.196	.366	.077
	Y	4.53	4.76	3.58	3.56	7.62	-6.39
	Z	.699	.753	.505	.500	.878	-.825
[illegible]1	X	.466	.540	.335	.363	.566	-.152
	Y	1.12	1.00	.860	.765	1.63	-.779
	Z	.800	1.04	.680	.715	.765	-.388
122	X	1.01	1.18	.750	.750	.838	-.840
	Y	2.22	2.53	1.53	1.55	2.41	.969
	Z	.851	1.08	.725	.760	.818	.275
128	X	2.74	2.29	1.98	1.97	1.88	-1.95
	Y	6.39	5.79	4.50	4.50	5.13	3.26
	Z	1.22	1.20	1.04	1.08	1.21	.217
149	X	5.72	6.6	4.04	3.92	7.06	-6.84
	Y	8.12	9.42	5.55	5.55	7.16	-4.48
	Z	4.12	4.86	3.19	3.33	4.86	-3.47
155	X	1.68	1.90	1.12	1.13	1.61	-2.07
	Y	1.76	1.99	1.19	1.26	2.38	-.548
	Z	1.02	1.22	.775	.833	1.22	-1.04

NOTES

1. Original analysis loads taken from Reference 1. Moment loads were not included because the original loads were not readily available.
2. Directions listed are in the model global coordinate system.
3. Configuration 1 = Absolute summation run with "stiff" support stiffness (1 X 10^{12} lb/in.)
   Configuration 2 = Absolute summation run with "reasonable" support stiffness (1 x 10^6 lb/in.
   Configuration 3 = 2-D SRSS run with "stiff" support stiffness (1 x 10^{12} lb/in.)
   Configuration 4 = 2-D SRSS run with "reasonable" support stiffness (1 x 10^6 lb/in.)
   Curr. = "Current Criteria" analysis using reasonable restraint stiffness.
   Config. 1 → Config. 4 loads are OBE seismic loads. Current criteria seismic loads are for an SSE load case. These loads are from response spectra output and, thus, carry no sign in the computer output.

TABLE XVII

ANCHOR LOAD SUMMARY - RECIRCULATION LOOP P2 AND P3 MODELS - SEISMIC LOADS ONLY

Model	Node	Dir.	Ab. Sum	2-D SRSS	Curr.	Orig.
P2	5	X	13.3	12.4	11.5	-9.87
		Y	13.6	10.5	11.6	-12.7
		Z	6.23	5.78	8.39	-7.82
	125	X	14.7	14.0	13.1	-9.60
		Y	10.4	9.74	9.01	5.63
		Z	8.60	7.67	11.1	-11.7
	155	X	2.99	2.83	3.03	-3.37
		Y	2.44	1.73	2.74	-3.51
		Z	7.01	6.44	9.30	-11.0
P3	5	X	4.70	4.20	9.24	-5.07
		Y	8.06	5.80	12.3	-2.83
		Z	5.89	2.82	7.40	-4.59
	85	X	8.05	7.41	16.2	-14.2
		Y	5.14	4.36	9.28	-5.32
		Z	12.9	6.00	16.1	-15.6

NOTES

1. Original analysis loads taken from Reference 1. Moment loads were not included because the original loads were not readily available.

2. Directions listed are in the model global coordinate systems.

3. Ab Sum → Absolute Sum method of combination.

4. 2-D SRSS → Only 2 Directions (one horizontal and vertical) combined. Both north-south horizontal plus vertical and east-west horizontal plus vertical cases were analyzed. Loads shown are maximum values regardless of directions.

5. Ab Sum and 2-D SRSS are OBE load cases. Current criteria (Curr.) load case is for an SSE. These loads are all from response spectra analyses and, thus, carry no sign in the computer output.

5.2.2 LPCI Pump Suction Piping

Individual modal frequencies and periods of vibration for the LPCI model are contained in Table XVIII.

ASME Code Class 2, Equation 9 stresses are summarized at the anchors and the four highest stressed points on the piping. This summary is contained in Table XIX. Support loads are summarized in Table XX. Support load information from the original analysis was not readily available and, thus, was not compared to the loads shown in Table XX. The global forces on the piping system anchors are summarized and compared to the original analysis loads in Table XXI. Original analysis loads at the suppression chamber anchor (see Figure 5) were not included because they were not readily available. Moment loading was not included in Table XXI because the original analysis moment loads were not readily available for comparison.

TABLE XVIII

DRESDEN UNIT 2 LPCI SUCTION PIPING MODEL - NATURAL FREQUENCIES AND PERIODS OF VIBRATION

Mode	Frequency (Hertz)	Period (sec.)
1	7.55	0.132
2	10.1	0.099
3	12.5	0.080
4	15.5	0.065
5	16.6	0.060
6	16.9	0.059
7	19.9	0.050
8	23.8	0.042
9	26.8	0.037
10	37.8	0.026

TABLE XIX

SUMMARY OF ASME CODE, CLASS 2, EQUATION 9, STRESS VALUES - LPCI MODEL, TWO METHODS, SSE LOAD CASE

	Stresses (KSI)			
Node	"Static g"[1]	Resp. Spect[2]	Allowable[3]	Comment
5	5.97	5.88	36.0	Supp. Chamber Anchor
185	3.55	2.79	36.0	Pump 2A Anchor
280	2.77	2.43	36.0	Pump 2B Anchor
10	13.2	12.0	36.0	Ring Header Tee
30	10.3	9.37	36.0	Suct Line/Header Tee
105	12.1	12.5	36.0	Pump 2B Branch Intersection
260	11.1	7.67	36.0	Elbow

NOTES

1. Horizontal Acceleration = 0.7 g perpendicular to piping.
   Vertical Acceleration = 0.067 g.

2. Spectra shown in Figures 11 and 12 used.

3. Allowable stress based on S_H = 15.0 KSI for A106, Gr. B carbon steel.
   Allowable = 2.4 S_H for Service Level D.

4. Numbers given at anchor points and 4 highest stress points.
   Equation 9 (NC-3652.2) used to calculate all stresses.

5. Equation 9 combines effects of pressure, sustained loads (deadweight), and occasional loads (SSE).

TABLE XX

SUPPORT LOAD SUMMARY - LPCI MODEL - SEISMIC LOADS ONLY

		Load (K)	
Node	Global Direction	Static g	Response Spectra
35	R	7.10	2.30
80	Y	-1.33	3.90
165	Y	.854	1.90
260	Y	.647	3.60

NOTES

1. R implies radial direction. This is a support attached to the ring header.

2. All supports listed were assumed active during seismic events.

TABLE XXI

ANCHOR LOAD SUMMARY - LPCI MODEL - SEISMIC LOADS ONLY

		LOAD (K)		
Node	Dir.	"Static g"	Resp. Spect.	Orig. Anal.
5	X	2.94	10.6	
	Y	-.289	4.12	
	Z	-6.06	2.28	
185	X	-.049	2.11	4.42
	Y	-.207	1.11	1.70
	Z	-3.20	1.48	3.30
280	X	.178	2.00	9.78
	Y	-.850	.990	2.72
	Z	-2.14	.745	4.18

NOTE

1. Original analysis loads taken from Appendix D. Moment loads were not included because the original loads were not readily available.

5.2.3 Small Piping Seismic Example

Individual modal frequencies and periods of vibration for the different configurations of the small piping seismic example problem are shown in Table XXII.

ASME Code Class 2, Equation 9 stresses are summarized in Table XXIII. This table contains stress results at the system anchors and the three highest stressed points on the piping. Support loads and global forces and moments on the system anchors are summarized in Tables XXIV and XXV, respectively. Original analysis loads were not included in Tables XXIV and XXV because they were not available.

TABLE XXII

SUMMARY OF NATURAL FREQUENCIES AND PERIODS OF VIBRATION FOR SMALL PIPING TEST PROBLEM

	Configuration 1		Configuration 2		Configuration 3		Configuration 4	
Mode	f(Hz)	T(sec.)	f(Hz)	T(sec.)	f(Hz)	T(sec.)	f(Hz)	T(sec.)
1	1.79	.558	.290	3.45	1.80	.557	.290	3.45
2	2.81	.356	.657	1.52	2.82	.354	.657	1.52
3	3.65	.274	1.72	.583	3.69	.271	1.72	.583
4	5.04	.198	1.79	.558	5.40	.185	1.80	.557
5	6.35	.157	2.64	.379	6.39	.157	2.64	.378
6	7.58	.132	2.82	.354	7.62	.131	2.83	.353
7	8.47	.118	3.50	.286	8.49	.118	3.51	.285
8	9.05	.110	3.67	.272	9.17	.109	3.70	.270
9	10.2	.098	4.65	.215	10.3	.097	4.83	.207
10	11.2	.089	6.33	.158	11.6	.087	6.36	.157
11	11.6	.086	6.40	.156	11.8	.085	6.46	.155
12	12.6	.080	8.00	.125	13.0	.077	8.02	.125
13	13.2	.076	8.48	.118	13.7	.073	8.50	.118
14	14.7	.068	9.57	.104	15.1	.066	9.60	.104
15	14.8	.067	10.2	.098	16.0	.063	10.3	.097
16	15.3	.065	11.6	.086	16.1	.062	11.8	.085
17	15.9	.063	13.2	.076	17.0	.059	13.3	.075
18	17.0	.059	13.2	.075	17.1	.058	13.7	.073
19	18.1	.055	14.6	.068	19.6	.051	15.0	.067
20	20.6	.049	14.8	.067	21.2	.047	15.9	.063
21	23.4	.043	16.0	.063	23.9	.042	16.2	.062
22	26.2	.038	17.0	.059	27.8	.036	17.1	.058
23	27.4	.037	18.4	.054	29.4	.034	18.5	.054
24	28.2	.035	20.6	.049	30.0	.034	21.2	.047
25	33.9	.030	22.9	.044	34.5	.029	23.0	.043
26	34.1	.029	23.4	.043			23.8	.042
27			26.3	.038			26.4	.038
28			27.4	.037			27.8	.036
29			28.2	.034			29.8	.034
30			29.9	.033			29.9	.033
31			34.1	.029			34.5	.029

NOTES

1. Configuration 1 → Restraint Stiffness (R.S.) = 2×10^5 lb./in. and vert. supports active

2. Configuration 2 → R. S. = 2×10^5, vert. supports not active

3. Configuration 3 → R. S. = 6.8×10^6 (10X bending stiffness of pipe between adjacent supports), vert. supports active

4. Configuration 4 → R. S. = 6.8×10^6, vert. supports not active

TABLE XXIII

SUMMARY OF ASME CODE, CLASS 2, EQUATION 9, STRESS VALUES - SMALL PIPING EXAMPLE PROBLEM, SSE LOAD CASE (P + DW + SSE)

	Stresses (KSI)					
Node	Configuration 1 Eq. 9	Configuration 2 Eq. 9	Configuration 3 Eq. 9	Configuration 4 Eq. 9	Allow- able	Comments
5	7.53	8.5	7.86	8.57	36.0	Tank Anchor
235	13.0	26.8	12.6	26.2	36.0	Anchor
35	11.98		11.5		36.0	Run
45	14.1		13.6		36.0	Elbow
105	12.3	16.3	12.1	15.8	36.0	Valve Weld
225		16.8		16.8	36.0	Run
230		20.2		20.0	36.0	Run

NOTES

1. Configuration 1 → Restraint Stiffness = 2 x 10^5 lb/in. and vert. supports active
   Configuration 2 → R. S. = 2 x 10^5, vert. supports <u>not</u> active
   Configuration 3 → R. S. = 6.8 x 10^6 (10X bending stiffness of pipe between adjacent supports), vert. supports active
   Configuration 4 → R. S. = 6.8 x 10^6, vert. supports <u>not</u> active

2. Allowable stress based on S_H = 15.0 KSI for A106, Gr. B carbon steel.
   Allowable = 2.4 S_H for Service Level D.

3. Equation 9 includes the effects of pressure, sustained loads (deadweight) and occasional loads (SSE).

   Note that zero, pressure was assumed. Thus, no pressure effects are included in the results shown above.

TABLE XXIV

SUPPORT LOAD SUMMARY - SMALL PIPING TEST PROBLEM - SEISMIC LOADS ONLY

Node	Global Dir.	Load (K)			
		Config. 1	Config. 2	Config. 3	Config. 4
35	X	13.7	10.2	13.0	9.57
35	Z	2.56	2.74	2.58	2.74
55	Y	3.17		3.01	
55	Z	4.32	4.59	4.31	4.55
80	Y	.989		.749	
105	Y	.718		.421	
105	Z	3.41	3.53	3.21	3.39
145	Y	.586		.492	
170	Y	.898		.781	
185	Y	.747		.648	
210	Y	.830		.718	

NOTES

1. Configuration 1 → Restraint Stiffness (R.S.) = 2 x 10^5 lb/in. and vert. supports active
   Configuration 2 → R. S. = 2 x 10^5, vert. supports not active
   Configuration 3 → R. S. = 6.8 x 10^6 (10X bending stiffness of pipe between adjacent supports), vert. supports active
   Configuration 4 → R. S. = 6.8 x 10^6, vert. supports not active

TABLE XXV

ANCHOR LOAD SUMMARY - SMALL PIPING SEISMIC EXAMPLE MODEL - SEISMIC LOADS ONLY

Node	Dir.	Config. 1	Config. 2	Config. 3	Config. 4
5	X	2.00	2.15	2.08	2.15
	Y	2.90	1.52	2.79	1.42
	Z	.626	.735	.602	.724
	XX	58.4	70.8	58.3	71.2
	YY	1.14	8.62	2.58	8.96
	ZZ	186.	208.	195.	210.
235	X	1.87	1.90	1.82	1.84
	Y	.529	2.01	.464	1.90
	Z	1.61	1.70	1.60	1.67
	XX	37.1	576.	31.7	566.
	YY	297.	310.	289.	301.
	ZZ	2.14	39.9	1.96	37.8

NOTES

1. Configuration 1 → Restraint Stiffness = 2 x 10^5 lb/in. and vert. supports active.
   Configuration 2 → R. S. = 2 x 10^5, vert. supports not active.
   Configuration 3 → R. S. = 6.8 x 10^6 (10X bending stiffness of pipe between adjacent supports), vert. supports active.
   Configuration 4 → R. S. = 6.8 x 10^6, vert. supports not active.

2. X implies load in pounds in global X direction.
   XX implies moment in inch-kips about the global X direction.

VI. CONCLUSIONS

The recirculation loop, LPCI suction and small piping seismic example piping systems have been analyzed using independently developed finite element models. Original analyses have been simulated and new analyses incorporating current ASME Code and Regulatory Guide requirements have been performed. Specific comments regarding each piping system follow.

1. RECIRCULATION LOOP

From the information described in the previous report sections it can be concluded that recirculation loop piping stresses are within acceptable limits during an OBE or SSE event. Since the support loads determined by the analyses described herein are of lower magnitude than the original analysis loads, it can be concluded that the recirculation loop piping is adequately supported for OBE and SSE events. Detailed drawings of the seismic support members were not provided. It is therefore obvious that any conclusions regarding support structural adequacy are based on the assumption that suitable stress analysis of the pertinent supports has been previously performed. In certain cases, the anchor loads discussed above are higher than those found by the original analysis. However, the piping stresses at the anchor points have all been shown to be well within allowable limits. Thus, it can be concluded that the nozzles will not be overstressed due to imposed piping seismic loads.

As a final suggestion, points of high stress may be considered as possible locations for postulating pipe breaks if future efforts address the effects of pipe breaks inside containment.

2. LPCI SUCTION

As shown in Table XIX, the maximum stresses for the LPCI suction piping were well within allowable limits for both methods used. From the information contained in this table it can be concluded that the piping stresses should be within allowable limits during OBE or SSE loading.

Support configuration or load information was not readily available for this system. Thus, no comparison of support loads or conclusions concerning support structural adequacy will be made.

The anchor load summary contained in Table XXI indicates that the loads determined by the analyses described in this report were of similar magnitude to those found by the original analysis. Therefore, it can be concluded that the pump suction nozzles will not be overstressed due to imposed piping seismic loads.

The reader is again reminded that these results and conclusions are dependent upon the engineering assumptions utilized.

3. SMALL PIPING SEISMIC EXAMPLE

The purpose of analyzing the small piping seismic example problem was to verify design charts which were developed for piping of eight-inch nominal size or less. Since there are no original analysis results no comparisons to the results of the analyses described herein are possible. The stress summary contained in Table XXIII indicates that the piping stresses will be within allowable limits when subjected to SSE loading. This also indicates that the support configuration resulting from use of the design charts will provide sufficient seismic support. It can be concluded that for this particular case use of the design charts would provide for the structural adequacy of the piping. No conclusions can be drawn concerning structural adequacy of supports or nozzles.

VII. REFERENCES

1. John A. Blume & Associates, Engineers, "Dresden Units 2 & 3 Nuclear Plant Earthquake Analysis: Recirculation Loop Piping", Report to General Electric Company, December 1968.

2. Senior Seismic Review Team, "Seismic Review of Dresden Nuclear Power Station Unit 2 for the Systematic Evaluation Program" NUREG/CR-0891, July 1979.

3. American Society of Mechanical Engineers, ASME Boiler and Pressure Vessel Code, Section III, Division I, "Nuclear Power Plant Components", Subsection NC, 1977 Edition plus Winter 1979 Addenda.

4. U.S. Department of Energy Division of Nuclear Power Development, "Seismic Requirements for Design of Nuclear Power Plants and Test Facilities", RDT Standard F9-2, Draft Version, August 1979.

APPENDIX A

NUPIPE-II COMPUTER PROGRAM DESCRIPTION

COMPUTER PROGRAM DESCRIPTION

The NUPIPE-II computer program performs linear elastic analysis of three-dimensional piping systems subject to thermal, deadweight, seismic, and other static and dynamic loads. The NUPIPE-II program is also designed to perform stress and fatigue analyses in accordance with the ASME Boiler and Pressure Vessel Code, Section III, Nuclear Power Plant Components, 1974 Edition through the Summer 1975 Addenda; and the ANSI B31.1 Code, 1967 and Summer 1973 versions. NUPIPE-II may also be utilized to assure compliance with later piping code requirements provided the analyst takes into consideration any possible changes. Piping systems of more than one classification can be analyzed.

NUPIPE-II utilizes the finite element method of analysis with special features incorporated to accommodate specific requirements of piping system analysis. In accordance with the finite element method, the continuous piping is mathematically idealized as an assembly of elastic structural members connecting discrete nodal points. Nodal points are placed in such a manner as to isolate particular types of piping elements, such as straight runs of pipe, elbows, valves, etc., for which force-deformation characteristics can be categorized. Nodal points are also placed at all discontinuities, such as piping supports, concentrated weights, branch lines, and changes in cross-section. System loads such as weights, equivalent thermal forces, and earthquake inertia forces are applied at the nodal points. For the deadweight and dynamic time-history and response spectra analyses, distributed weight properties of the piping as well as concentrated weights, such as valves, pumps, or snubbers, can be considered. A lumped mass model of the piping system is used for all dynamic analyses. Both translational and rotational degrees-of-freedom may be considered.

For further information concerning NUPIPE-II capabilities or analytical procedures, contact Applied Mechanics Branch of EG&G Idaho, Inc.

APPENDIX B

BENCHMARK PROBLEM TO ASSESS SPATIAL COMBINATION METHOD FOR RESPONSE SPECTRUM ANALYSIS

ME Nitzel

April 19, 1979

Mr. R. E. Tiller, Director
Reactor Operations and Programs Division
Idaho Operations Office - DOE
Idaho Falls, ID 83401

SEISMIC REEVALUATION OF PIPING ASSOCIATED WITH THE NRC SHOW CAUSE ORDER OF MARCH 13, 1979 - JAD-96-79

Dear Mr. Tiller:

A benchmark problem which permits assessment of intermodel spatial combination methodology for response spectrum analysis has been formulated and analyzed at the request of Mr. V. S. Noonan, NRC-DOR. The attachment describes the problem and the results generated from hand calculations and the SAP-IV, NUPIPE, and ADLPIPE computer codes. The costs incurred in doing this benchmark problem were charged against the task of reviewing five plants currently undergoing piping seismic reevaluation.

Very truly yours,

J. A. Dearien, Manager
Code Assessment and
Applications Program

vjd

Attachment:
As stated

cc: V. S. Noonan, NRC-DOR
K. R. Wichman, NRC-EE
R. W. Kiehn, EG&G Idaho, w/o Attach.

bcc: J. A. Dearien
R. C. Guenzler
C. A. Moore
C. F. Obenchain CFO
P. H. Vander Hyde
Applied Mechanics Branch personnel
Central File
J. A. Dearien File

BENCHMARK PROBLEM TO ASSESS SPATIAL COMBINATION METHOD FOR RESPONSE SPECTRUM ANALYSIS

by

R. L. Grubb

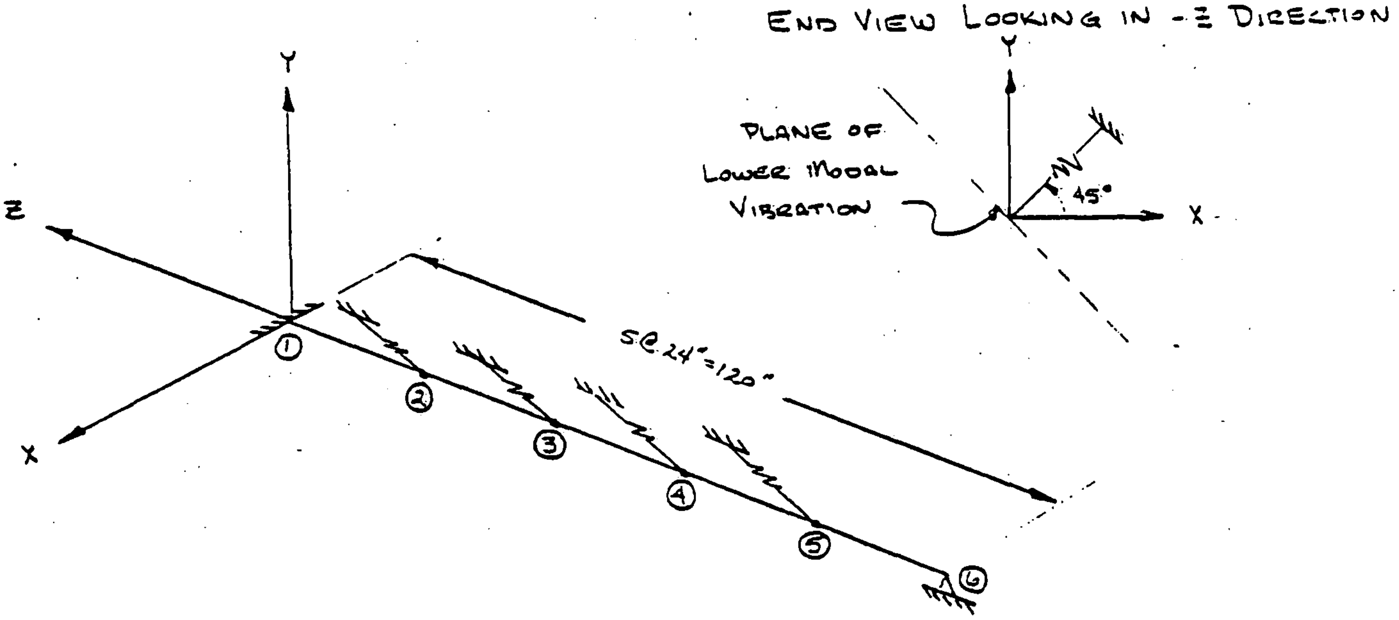
R. W. Macek

G. L. Thinnes

A mathematical problem has been designed to exercise the spatial combination of motion components which may be used in a seismic modal response spectrum analysis. Specifications for the finite element model include:

1. The capability to exercise all known schemes of spatial combination, i.e. SRSS, absolute sum, and algebraic sum methods.
2. A simplicity affording manual calculation of eigenvectors, modal participation factors, eigenvalues and displacements for the purposes of verifying the original computer code solutions.
3. A solution which will quickly and easily reflect the method of spatial combination in the total deflections calculated by the tested computer code.

With this in mind, the following problem has been constructed:



It consists of a uniform beam with all degrees of freedom (D.O.F.) fixed at Node ① and all translational D.O.F. fixed at Node ⑥ . Intermediate support is provided by boundary or truss elements of equal stiffness directed perpendicularly to the Z axis oriented as shown in the end view and attached to the beam at Nodes ② - ⑤. The mass of the system is uniformly distributed.

In the finite element models, however, the mass is lumped at nodes with mass moments of inertia assumed equal to zero. It is, therefore, expected that small variations in frequencies will exist between the theoretical and model calculations.

Specific mass and stiffness data includes:

Typical Boundary Stiffness: $1.0(10^5)$lbs/in.

Typical Lumped Mass: $\frac{100}{386.4} = .259\ \text{lb}_{\text{mass}}$

Beam Modulus of Elasticity: $1.0(10^6)\text{lbs/in}^2$

All Beam Moments of Inertia: $1.0\ \text{in}^4$

(No Shear Deflections Considered)

Axial Area: $1.0\ \text{in}^2$

The boundary elements are skewed 45° off the X-Z and Y-Z planes to force the beam to respond in the plane perpendicular to the boundary elements' direction. With the support conditions shown, the beam modes under 33 Hz are bending modes of a propped cantilever in a plane rotated 45° about its neutral axis. This arrangement forces the modal participation factors in the X and Y directions for at least the first four modes to be of opposite sign. This is of importance since this sign difference may cause unconservative spatial combination. As an example:

$$\{U_{re}\} = S_{re}(W_r)\ \Gamma_{re}\{\phi_r\} \qquad (1)$$

where:

$\{U_{re}\}$ A vector of displacements caused by excitation in the e direction for mode r.

$S_{re}(W_r)$ The spectral displacement corresponding to circular frequency W_r for mode r in direction e = X, Y, Z. (This is equal to spectral acceleration divided by W_r^2)

Γ_{re} The modal participation factor for mode r in direction e.

$\{\phi_r\}$ The eigenvector for mode r.

Since the scalar quantity $S_{re}(W_r)$ always has a positive sign and the spatial combination is performed at each mode (ϕ is the same for all three components), the modal participation factor governs the summation. For mode r:

$$U_x = S_x(W)\Gamma_x\phi \qquad (2)$$

$$U_y = S_y(W)\Gamma_y\phi \qquad (3)$$

$$U_z = S_z(W)\Gamma_z\phi \qquad (4)$$

and the components can be combined as:

$$U = \sqrt{U_x^{\ 2} + U_y^{\ 2} + U_z^{\ 2}} \qquad (5)$$

or $$U = U_x + U_y + U_z \qquad (6)$$

or $$U = |U_x| + |U_y| + |U_z| \qquad (7)$$

For this test problem a spectrum is applied to the model to excite only the second mode. (See Table I for all calculated periods.) The applied acceleration spectrum is:

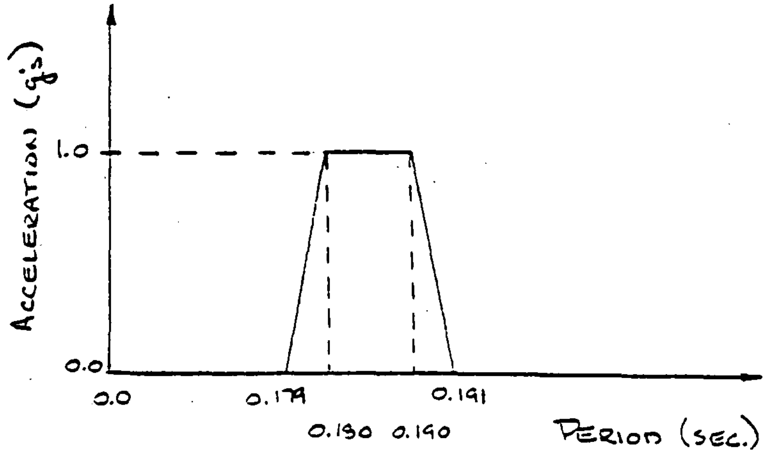


TABLE I

CALCULATED MODAL PERIODS

Method	T_1	T_2	T_3	T_4
Manual	.610	.188	.090	.053
SAP IV	.610	.189	.094	.062
NUPIPE	.599	.187	.093	.062
ADLPIPE	.599	.187	.093	.062

This spectrum is applied in the X and Y directions only. Therefore, U_z in Equation (4) is zero and there are only two non zero components in Equations (5), (6), or (7). Since only one mode is excited, this test removes any form of intermodal combination, e.g. closely spaced modal methods.

Manual Calculations

Calculations for this problem consisted of, first determining the first four frequencies of the uniformly loaded propped cantilevered beam. All hand calculations are included in the attachment. Then the eigenvectors and modal participation factors for the second mode were calculated. The X and Y modal displacements (for the second mode) are listed in Table II for all methods of calculation. Finally, the displacements for Node 2 of the model were calculated using the three spatial combinations discussed. The modal participation factors for the second mode and the displacements are tabulated in Tables III and IV respectively for all calculations.

SAP IV

The spatial combination employed with this code is that of Equation (7). It is noted that care must be taken to insure correct combination by using positive factors to designate direction of spectral excitation.

NUPIPE

The NUPIPE computer code performed the spectral analysis spatial component combination in accordance with the NRC's Reg. Guide 1.92. The combination approach is equivalent to that shown in Equation (5) if all modes are considered equally.

ADLPIPE

The computer code ADLPIPE allows for three spatial component combination procedures. The Reg. Guide 1.92 approach is included in the code and can be reduced to yield the standard SRSS approach shown in Equation (5). Combination

TABLE II

MODE SHAPES FOR MODE 2 NORMALIZED TO A MAXIMUM VALUE OF UNITY

Node	Method	Δx	θy
1	A	0	0
	B	0	0
	C	0	0
2	A	-.771	.638
	B	.778	.630
	C	-.774	.634
3	A	-.947	-.496
	B	.944	-.504
	C	-.946	-.449
4	A	.303	-.962
	B	-.307	-.963
	C	.305	-.962
5	A	1.0	.154
	B	-1.0	.155
	C	1.0	.155
6	A	0	1.0
	B	0	1.0
	C	0	1.0

A-Hand Calculations
B-NUPIPE
C-SAP IV

Note 1: No eigenvectors supplied in ADLPIPE output

Note 2: $\Delta x = -\Delta y$ and $\theta x = \theta y$ and $\Delta z = \theta z = 0$

Note 3: In NUPIPE the beam is modeled in positive z coordinates.

TABLE III

MODAL PARTICIPATION FACTORS FOR THE SECOND MODE

Method	Frequency (Hz)	Γ_x	Γ_y
Manual	5.32	-.0927	.0927
NUPIPE	5.36	.0928	.0928
SAP IV	5.29	-.0927	.0927
ADLPIPE	5.36	.09	-.09

TABLE IV

COMPARISON OF RESULTANT DISPLACEMENTS OF MODEL NODE 2 CALCULATED BY VARIOUS METHODS

Method	Δx	Δy	θx	θy
Manual (SRSS)	.0302	.0302	.0015	.0015
Manual (Algebraic Sum)	0	0	0	0
Manual (Absolute Sum)	.0428	.0428	.00211	.00211
NUPIPE	.030	.030	.0014	.0014
SAP IV	.0435	.0435	.00207	.00207
ADLPIPE (SRSS)	.0300	.0300	.0014	.0014
ADLPIPE (Algebraic Sum)	0	0	0	0

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by the algebraic summation method presented in Equation (6) is also available in the code. The combination procedures available prior to the 1978 version of ADLPIPE are not clearly defined in the input manual.

Conclusions

The result of this exercise shows the following:

1. NUPIPE combines spatially by the SRSS method.
2. SAP IV uses the absolute sum method which is more conservative than NUPIPE. Any code using this method will calculate displacements for this given problem which will be larger than the SRSS method calculations by a factor of $\sqrt{2}$.
3. ADLPIPE allows spatial combination by either the SRSS method or the algebraic sum method. Any code using the algebraic sum method and calculating displacements for this given problem will calculate zero values for all displacements.
4. The version of ADLPIPE used was dated 1978. The schemes of spatial combination in ADLPIPE before this date are not known at this time.
5. It appears that, while the algebraic sum method may be valid for excitation in a single direction, spatial combination does not appear to be required for this special case. If spatial combination is required unconservative deflections and forces could result using the algebraic sum method. (It is noted that if individual runs are made for each direction using any of the methods discussed and then those results are combined by SRSS, the final result would be the same as the SRSS spatial combination.)

ATTACHMENT A

HAND CALCULATIONS FOR CHECKING SPECTRAL ANALYSIS SPATIAL COMPONENT COMBINATION PROCEDURES

B11

The following piping system is analyzed to determine the effect of three spatial component combination procedures:

Modulus of elasticity = $E=1x10^6$ psi

The moment of inertia = $I=1.0$ in.^{4}

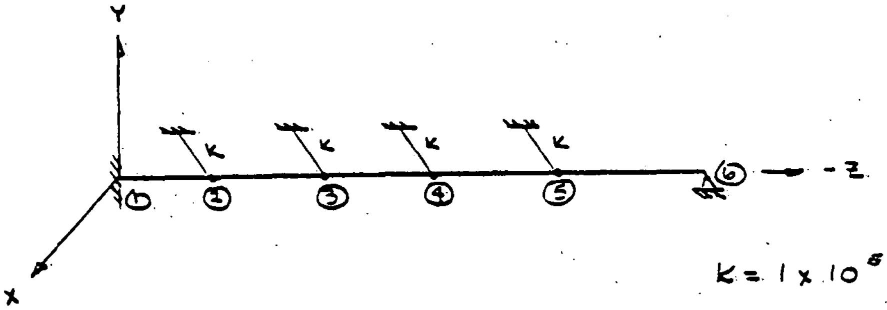
The weight of the system = $W=500$ lb

The weight/unit length = $w=4.1667$ lb/in.

The length = $\ell=120$ in.

The acceleration of gravity = $g=386.1$ in./sec^2

The piping configuration



$K = 1 \times 10^6$ LB/IN.

The three combination procedures considered are:

(1) $U = \sqrt{U_x^2 + U_y^2 = U_z^2}$ SRSS

(2) $U = U_x + U_y + U_z$ Algebraic Sum

(3) $U = |U_x| + |U_y| + |U_z|$ Absolute Sum

The frequencies for the system may be derived from Table 36 of Reference 1.

$$f_n = \frac{\kappa_n}{2\pi}\sqrt{\frac{EIg}{w\ell^4}}$$ where

Mode	κ_n
1	15.4
2	50.0
3	104
4	178

f_1 = 1.6385 cps

f_2 = 5.3197 cps

f_3 = 11.0649 cps

f_4 = 18.9380 cps

The mode shape for the second mode of vibration can be derived from Table 3 of Reference 1 by a simple rotation of 45^0 and by multiplication of the curvature by the factor β_2 = .0589 based on a length of 120 inches. The mode shape values for z and θ_z are identically zero.

The modal participation factor for x input or y input is

$$\frac{\{\phi\}^T[M]\{I\}}{\{\phi\}^T[M]\{\phi\}} = \Gamma$$ where {I} selects either x or y degrees of freedom

If a lumped mass matrix is assumed and further the mass inertias are assumed to be equal to zero, the following mass matrix can be formed for the x, y, θ_x, and θ_y degrees of freedom.

$$\begin{array}{cc|cccccccccccccccccccccccc|}
 & & \multicolumn{4}{c}{1} & \multicolumn{4}{c}{2} & \multicolumn{4}{c}{3} & \multicolumn{4}{c}{4} & \multicolumn{4}{c}{5} & \multicolumn{4}{c}{6} \\
 & & X & Y & \Theta_x & \Theta_y & X & Y & \Theta_x & \Theta_y & X & Y & \Theta_x & \Theta_y & X & Y & \Theta_x & \Theta_y & X & Y & \Theta_x & \Theta_y & X & Y & \Theta_x & \Theta_y \\
\hline
1 & X & M_E \\
 & Y & & M_E \\
 & \Theta_x & & & 0 \\
 & \Theta_y & & & & 0 \\
2 & X & & & & & M_I \\
 & Y & & & & & & M_I \\
 & \Theta_x & & & & & & & 0 \\
 & \Theta_y & & & & & & & & 0 \\
3 & X & & & & & & & & & M_I \\
 & Y & & & & & & & & & & M_I \\
 & \Theta_x & & & & & & & & & & & 0 \\
 & \Theta_y & & & & & & & & & & & & 0 \\
4 & X & & & & & & & & & & & & & M_I \\
 & Y & & & & & & & & & & & & & & M_I \\
 & \Theta_x & & & & & & & & & & & & & & & 0 \\
 & \Theta_y & & & & & & & & & & & & & & & & 0 \\
5 & X & & & & & & & & & & & & & & & & & M_I \\
 & Y & & & & & & & & & & & & & & & & & & M_I \\
 & \Theta_x & & & & & & & & & & & & & & & & & & & 0 \\
 & \Theta_y & & & & & & & & & & & & & & & & & & & & 0 \\
6 & X & & & & & & & & & & & & & & & & & & & & & M_E \\
 & Y & & & & & & & & & & & & & & & & & & & & & & M_E \\
 & \Theta_x & & & & & & & & & & & & & & & & & & & & & & & 0 \\
 & \Theta_y & & & & & & & & & & & & & & & & & & & & & & & & 0 \\
\hline
\end{array}$$

$M_I = .259$

$M_E = .1295$

$$\Phi_2 = \left\{\begin{array}{r} 0 \\ 0 \\ 0 \\ 0 \\ -.7598 \\ .7598 \\ .03752 \\ .03752 \\ -.93284 \\ .93284 \\ -.02920 \\ -.02920 \\ .29888 \\ -.29888 \\ -.05662 \\ -.05662 \\ .98536 \\ -.98536 \\ .00906 \\ .00906 \\ 0 \\ 0 \\ .05883 \\ .05883 \end{array}\right\}
\begin{array}{lc} X & \\ Y & 1 \\ \Theta_x & \\ \Theta_y & \\ X & \\ Y & 2 \\ \Theta_x & \\ \Theta_y & \\ X & \\ Y & 3 \\ \Theta_x & \\ \Theta_y & \\ X & \\ Y & 4 \\ \Theta_x & \\ \Theta_y & \\ X & \\ Y & 5 \\ \Theta_x & \\ \Theta_y & \\ X & \\ Y & 6 \\ \Theta_x & \\ \Theta_y & \end{array}
\qquad
\underset{\text{(NORMALIZED TO UNITY)}}{\Phi_2} = \left\{\begin{array}{r} 0 \\ 0 \\ 0 \\ 0 \\ -.7711 \\ .7711 \\ .6378 \\ .6378 \\ -.9467 \\ .9467 \\ -.4964 \\ -.4964 \\ .3303 \\ -.3303 \\ -.9624 \\ -.9624 \\ 1.0 \\ 1.0 \\ .1540 \\ .1540 \\ 0 \\ 0 \\ 1.0 \\ 1.0 \end{array}\right\}$$

The modal participation factors become

$$\Gamma x = -\Gamma y = \frac{M_E(o)+M_I(-.75978)+M_I(-.93284)+M_I(.29888)+M_I(.98536)+M_E(o)}{2(M_e(o)^2=M_I(-.93284)^2+M_I(.29888)^2+M_I(.98536)^2+M_E(o)^2)}$$

$$\Gamma x = -\Gamma y = \frac{-.40838}{5.01544} = -.81425 \qquad \Gamma x = -.081425$$

$$\Gamma y = .081425$$

$$w_2{}^2 = (2\pi(5.3197))^2 = 1117.208\ \frac{\text{rad}}{\text{sec}^2}$$

If x and y are nonmalized to the mass for comparison purposes the values become

$$\frac{\Gamma x}{\sqrt{\frac{500}{386.1}}} = -\Gamma y = -.0927 \qquad \Gamma x = -.0927$$

$$\Gamma y = .0927$$

The spectral displacement must be specified in inches. The spectral acceleration for the second mode is defined to be 1.0 g's or 386.1 in./sec^2. The spectral displacement becomes

$$S_d = \frac{386.1}{1117.308} = .34559 \text{ in.}$$

For Node 2 the discrete displacements and rotations become

$$\begin{array}{c|c|c} & \Gamma x & \Gamma y \\ x & .02138 & -.02138 \\ y & -.02138 & .02138 \\ \theta x & -.00105 & .00105 \\ \theta y & -.00105 & .00105 \end{array}$$

The combined displacements and rotations become

$$\text{Absolute Sum} \qquad \begin{matrix} x \\ y \\ \theta x \\ \theta y \end{matrix} \left\{ \begin{matrix} .04276 \\ .04276 \\ .00211 \\ .00211 \end{matrix} \right.$$

$$\text{Algebraic Sum} \qquad \begin{matrix} x \\ y \\ \theta x \\ \theta y \end{matrix} \left\{ \begin{matrix} 0 \\ 0 \\ 0 \\ 0 \end{matrix} \right.$$

$$\text{SRSS} \qquad \begin{matrix} x \\ y \\ \theta x \\ \theta y \end{matrix} \left\{ \begin{matrix} .03024 \\ .03024 \\ .00148 \\ .00148 \end{matrix} \right.$$

$$\frac{\text{Absolute Sum}}{\text{SRSS}} = \sqrt{2}$$

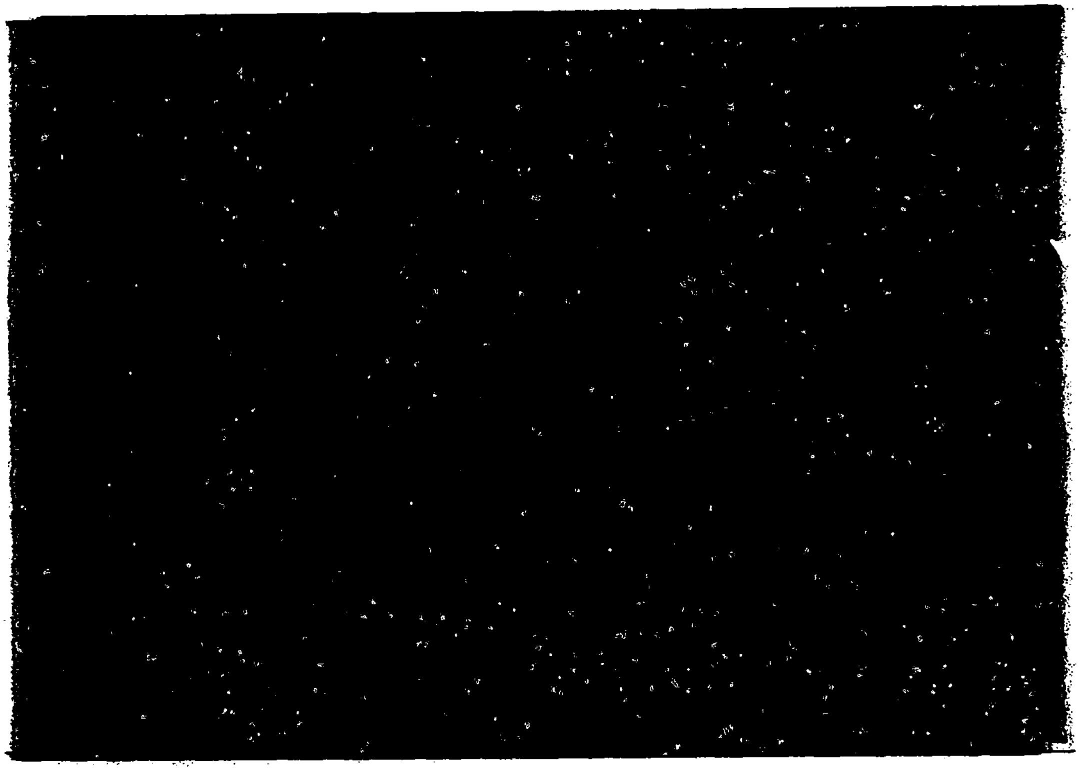
REFERENCES

1. R. J. Roak and W. C. Young, Formulas for Stress and Strain, Fifth Edition, McGraw Hill, 1965.

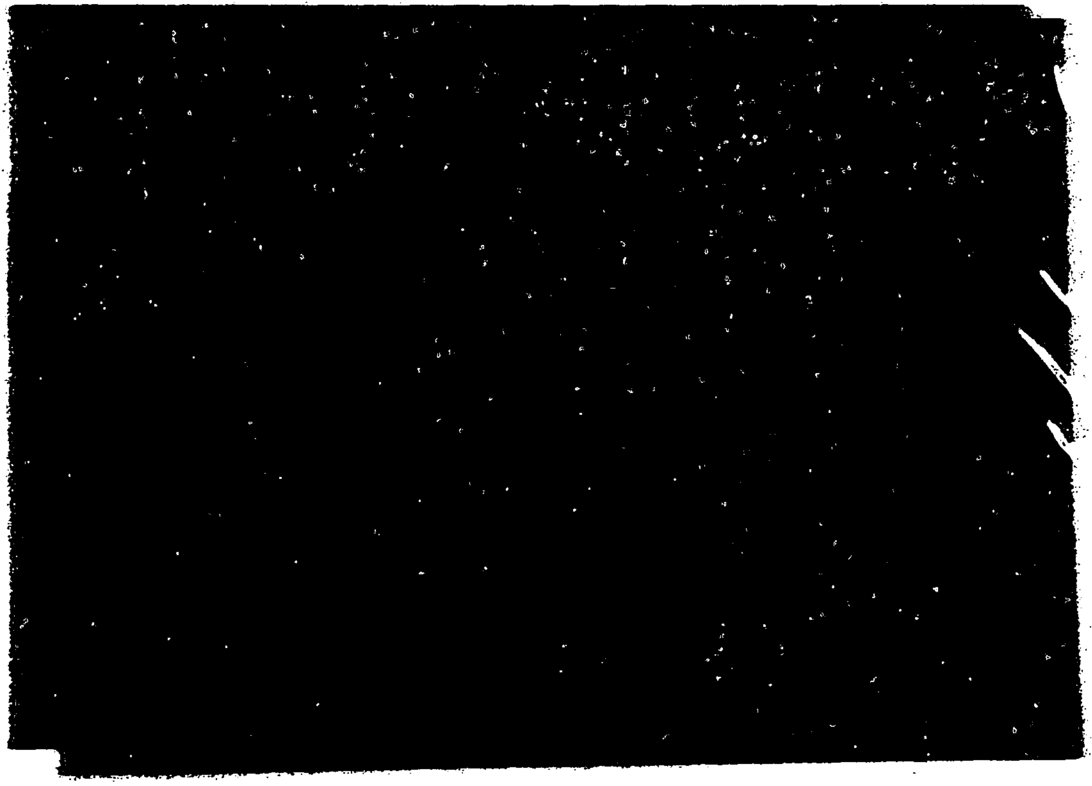
2. D. Young and R. P. Felgar, Jr., "Tables of Characteristic Functions Representing Normal Mode of Vebration of a Beam", The University of Texas Publication No. 4913, July 1, 1949.

APPENDIX C

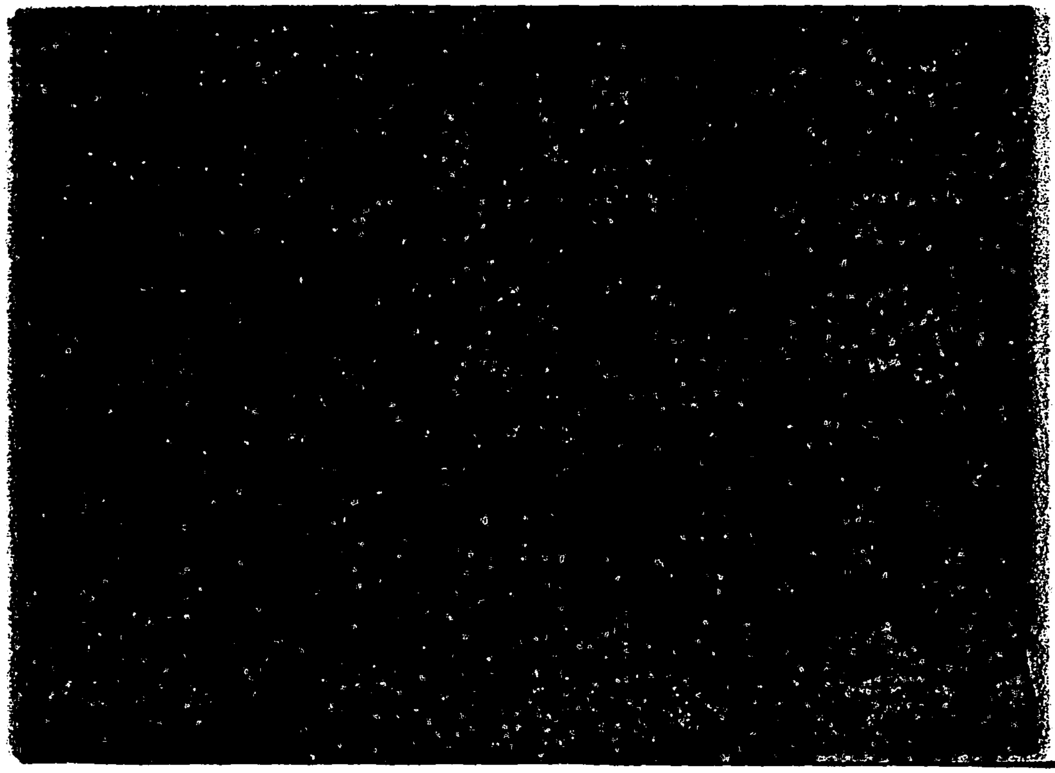
MICROFICHE COPIES OF NUPIPE-II COMPUTER RUNS



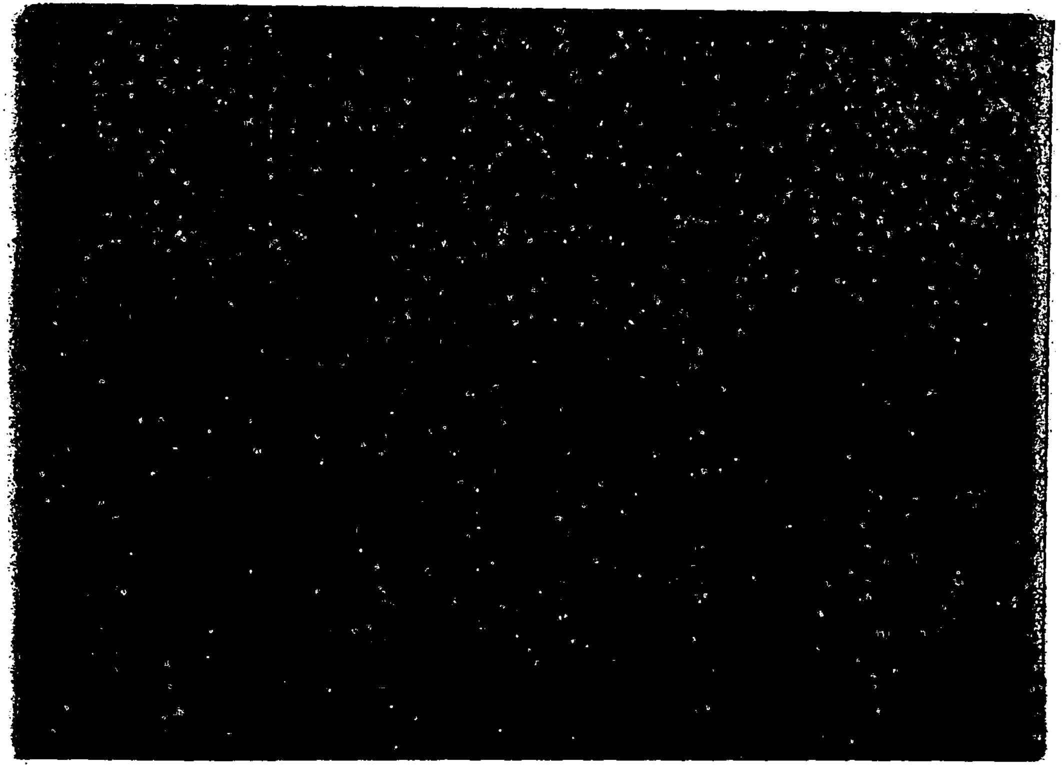
Dresden Unit 2, P1 Model, X+Y (N-S+Vert.) OBE, SRSS, Reasonable Stiffnesses



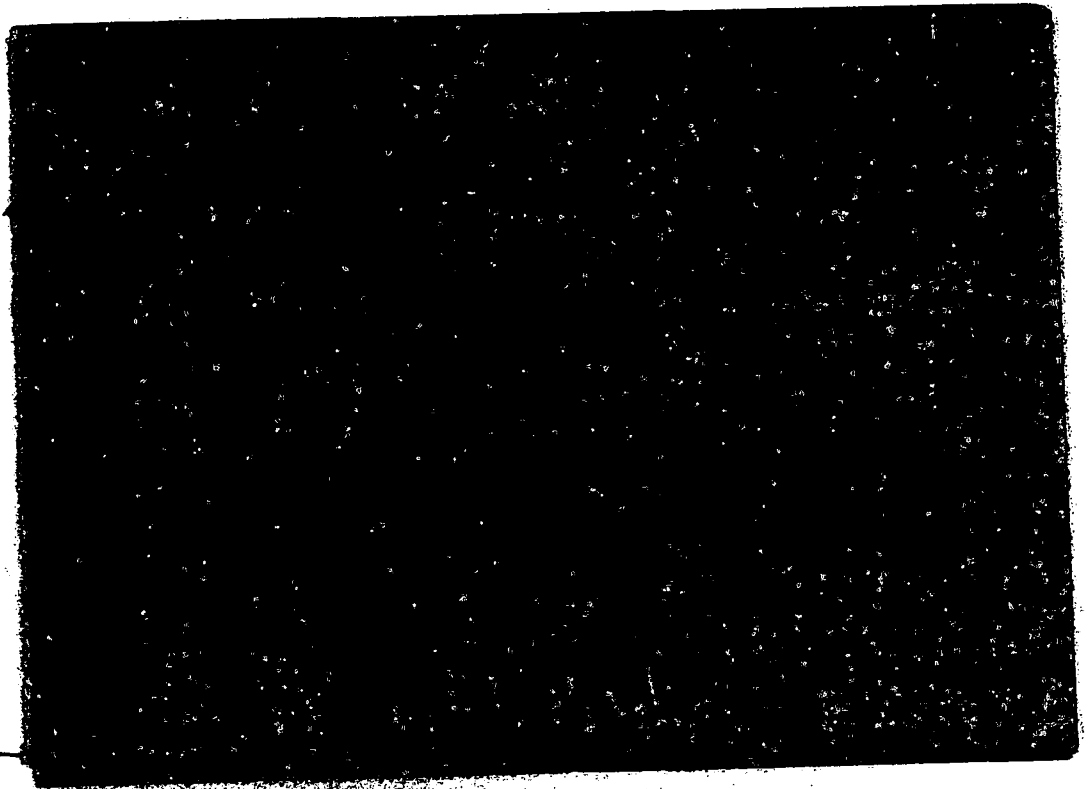
D2 P1 Model, Z+Y (E-W+Vert.) OBE, SRSS, Reasonable Stiffnesses



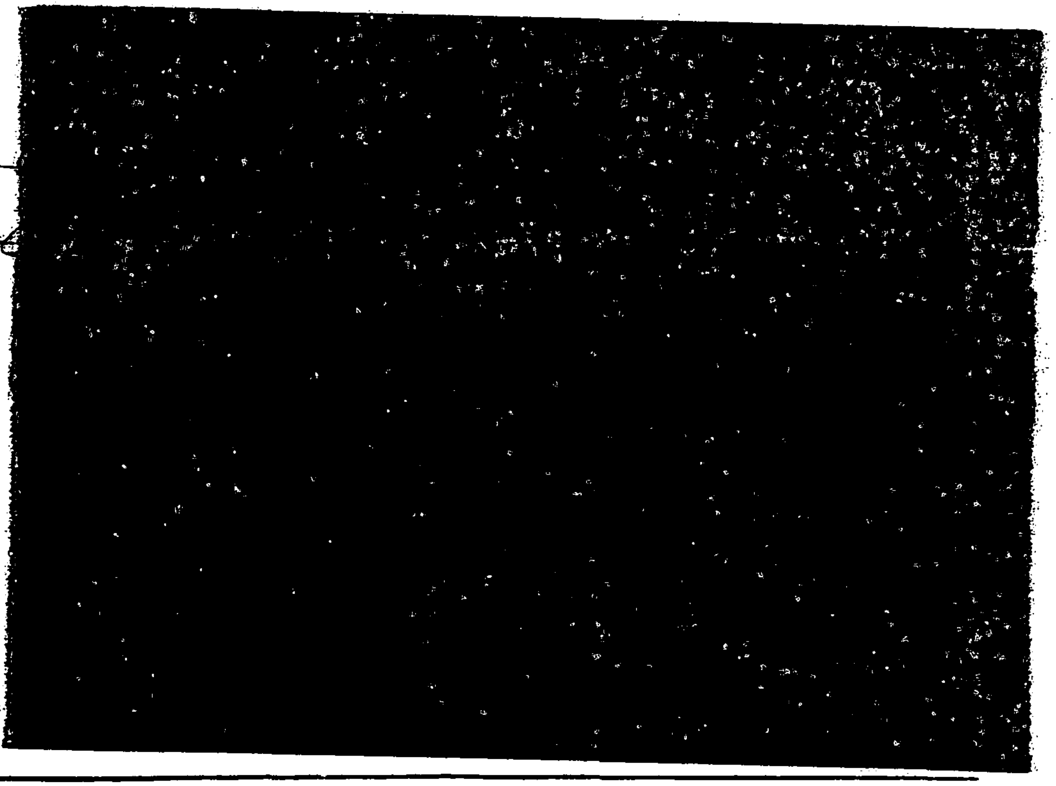
D2 P1 Model, X+Y (N-S+Vert.) OBE, SRSS, "Stiff" Restraints



D2 P1 Model, Z+Y (E-W+Vert.) OBE, SRSS, "Stiff" Restraints



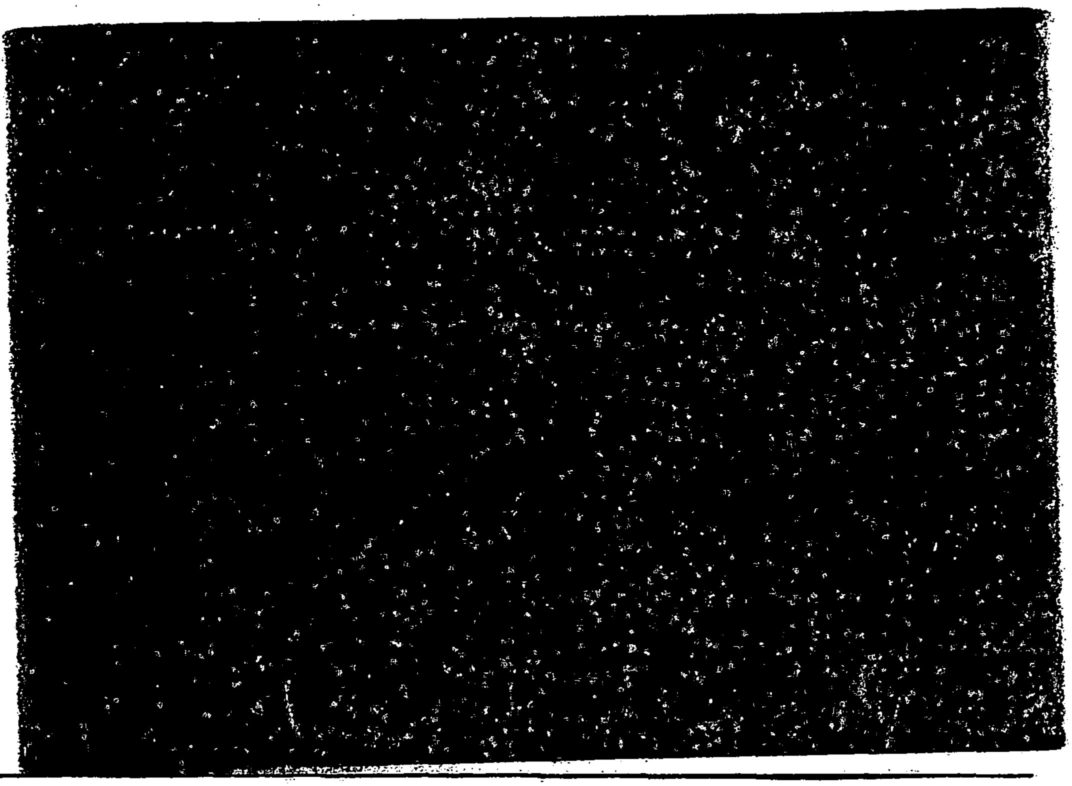
D2 P1 Model, X+Y (N-S+Vert.) OBE, Ab. Sum, Reasonable Restraint Stiffnesses



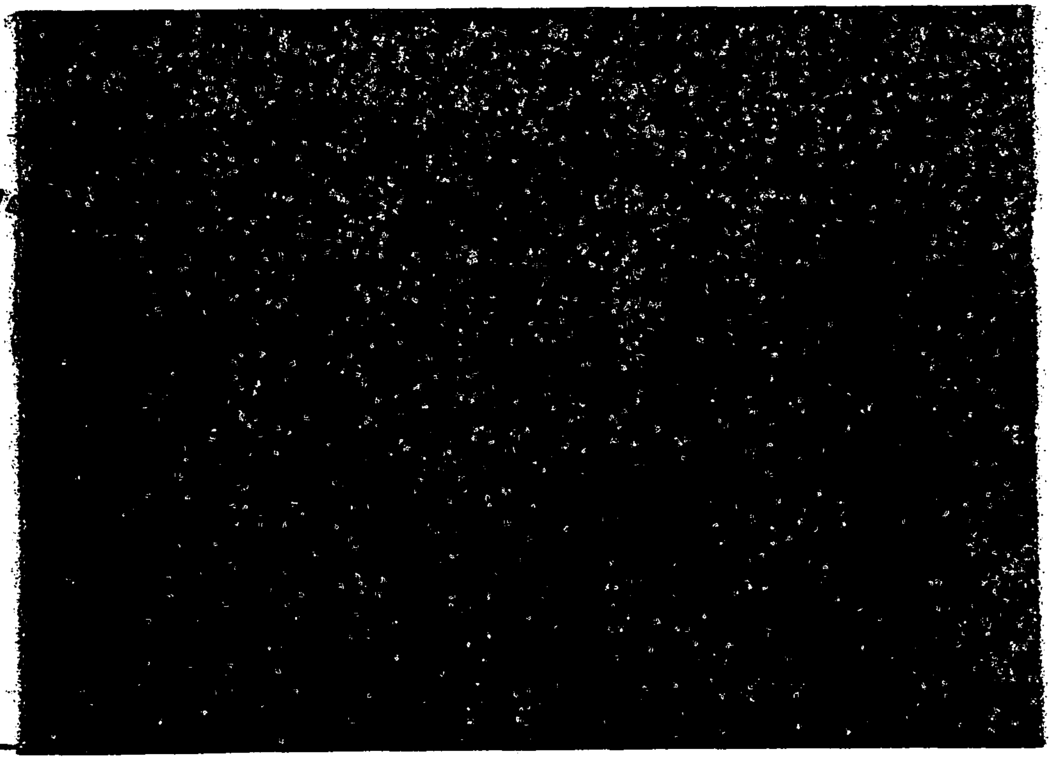
me

①

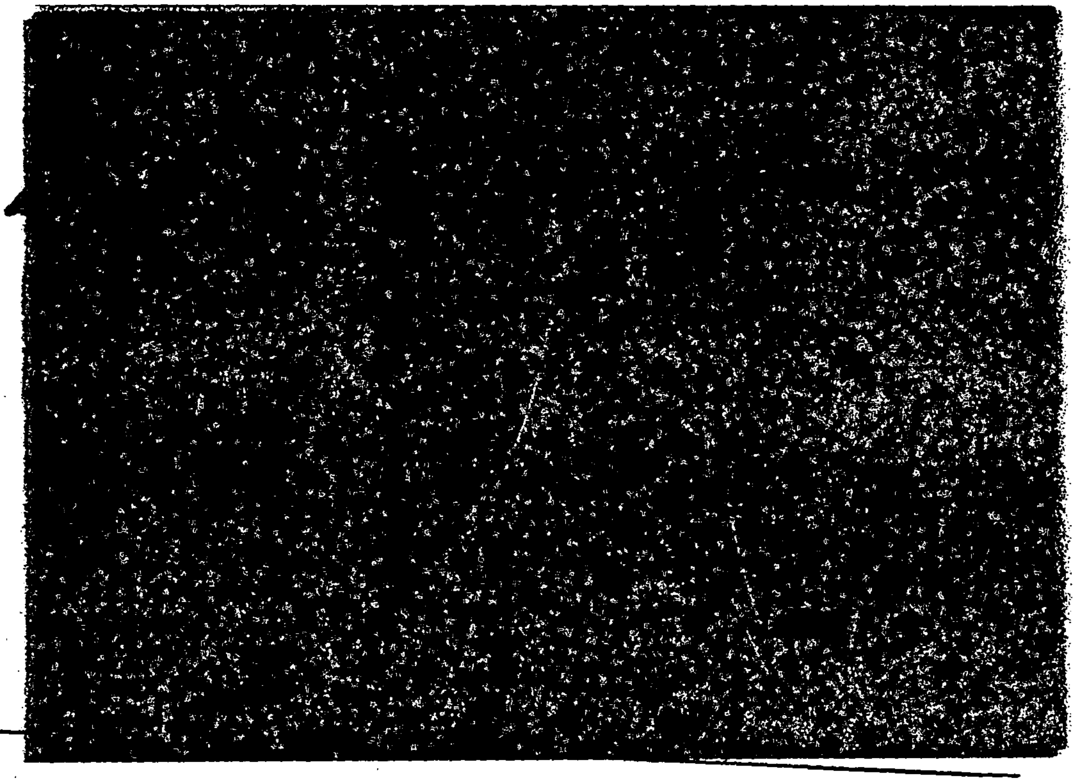
D2 P1 Model, Z+Y (E-W+Vert.) OBE, Ab. Sum, Reasonable Restraint Stiffnesses



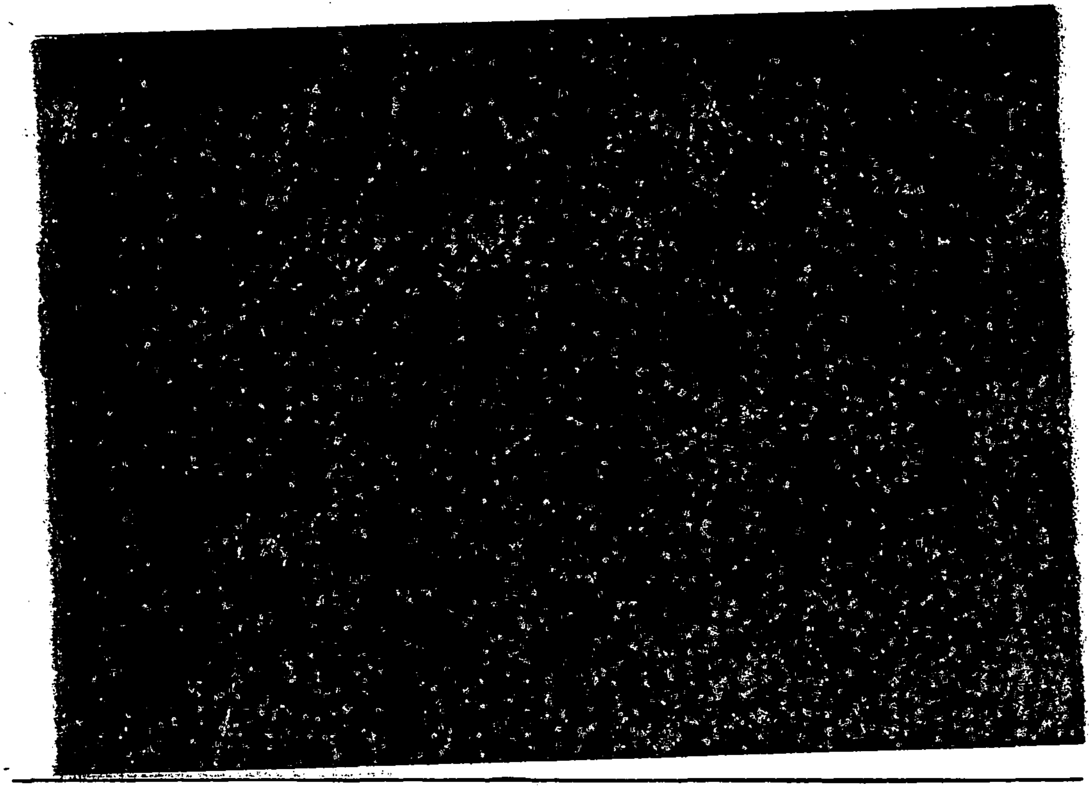
D2 P1 Model, X+Y (N-S+Vert.) OBE, Ab. Sum, "Stiff" Restraints



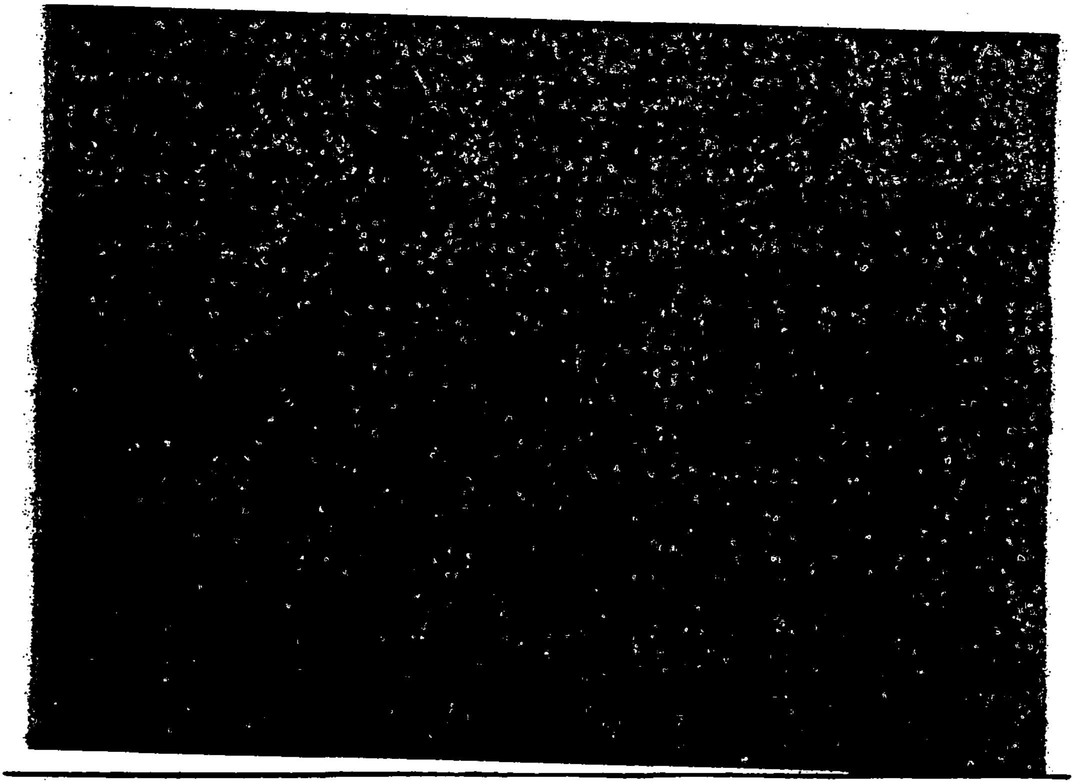
D2 P1 Model, Z+Y (E-W+Vert.) OBE, Ab. Sum, "Stiff" Restraints



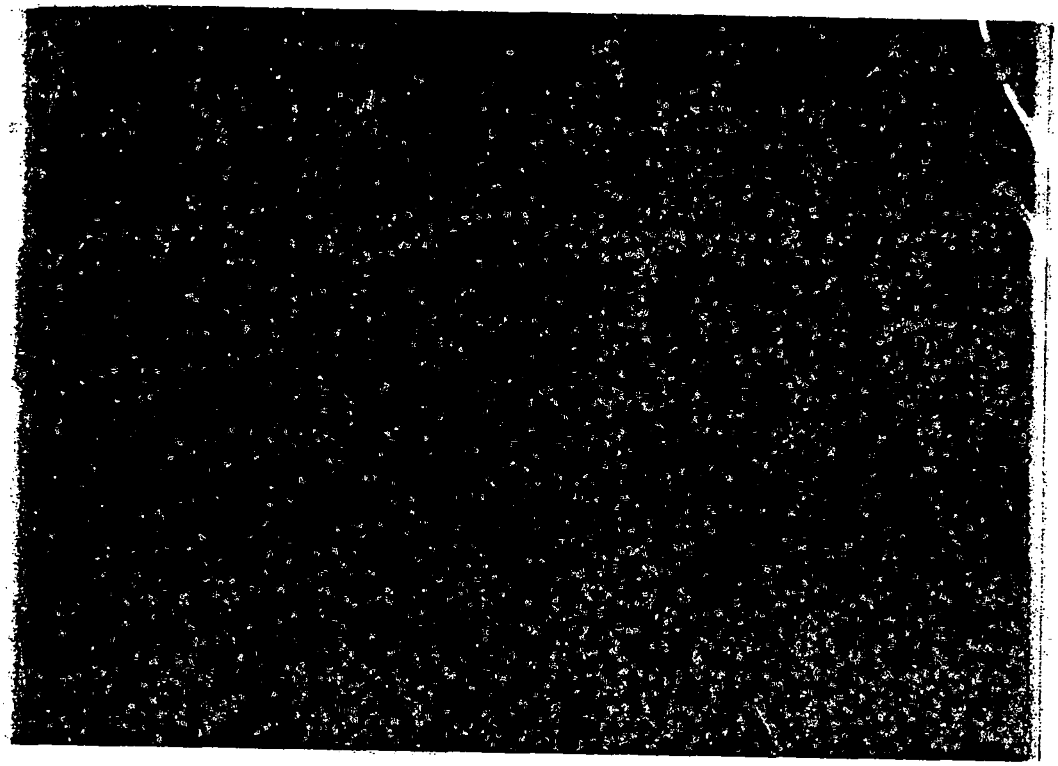
D2 P1 Model, Current Criteria SSE



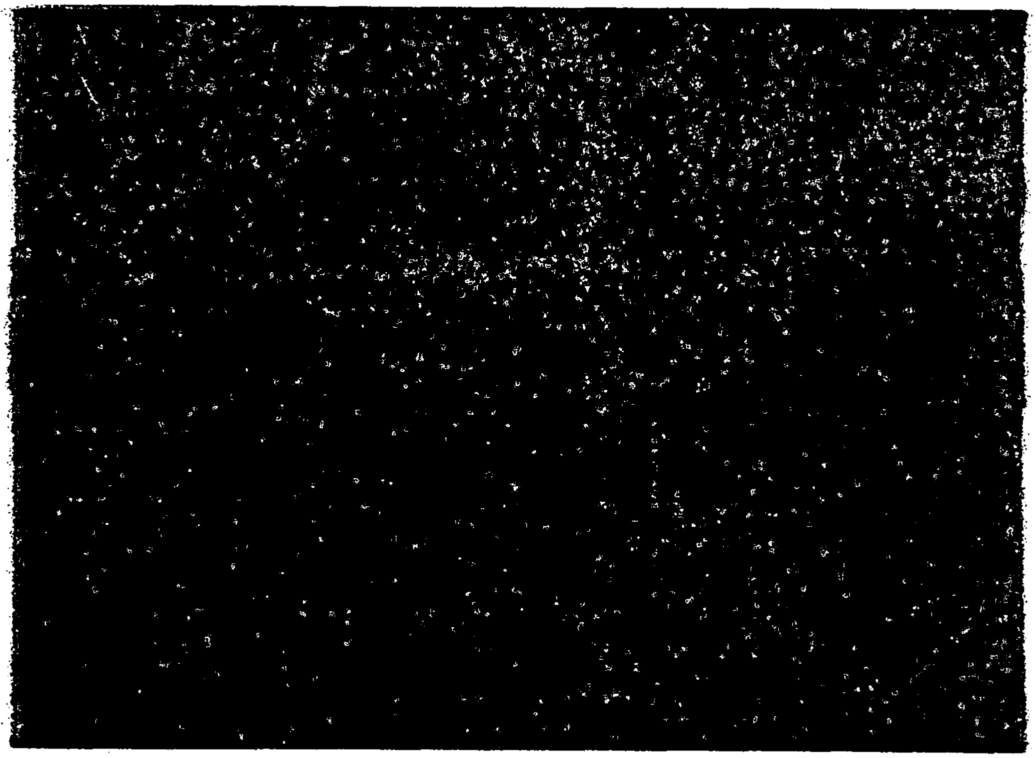
D2 P2 Model, X+Y (N-S+Vert.) OBE, SRSS



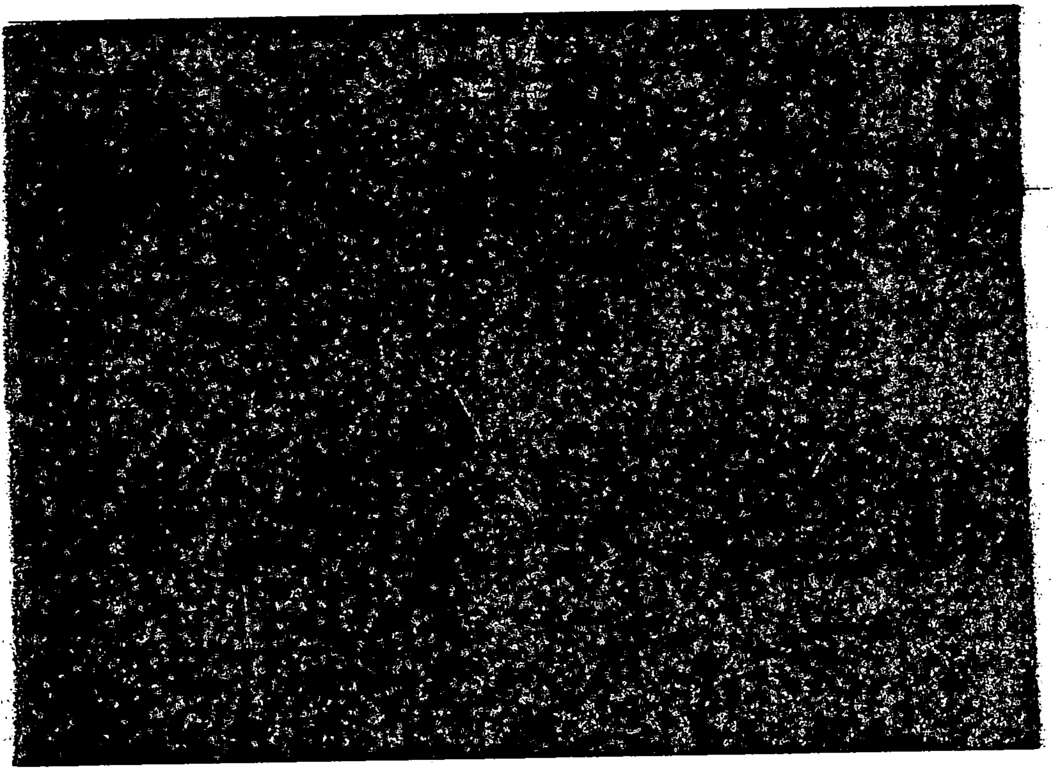
D2 P2 Model, Z+Y (E-W+Vert.) OBE, SRSS



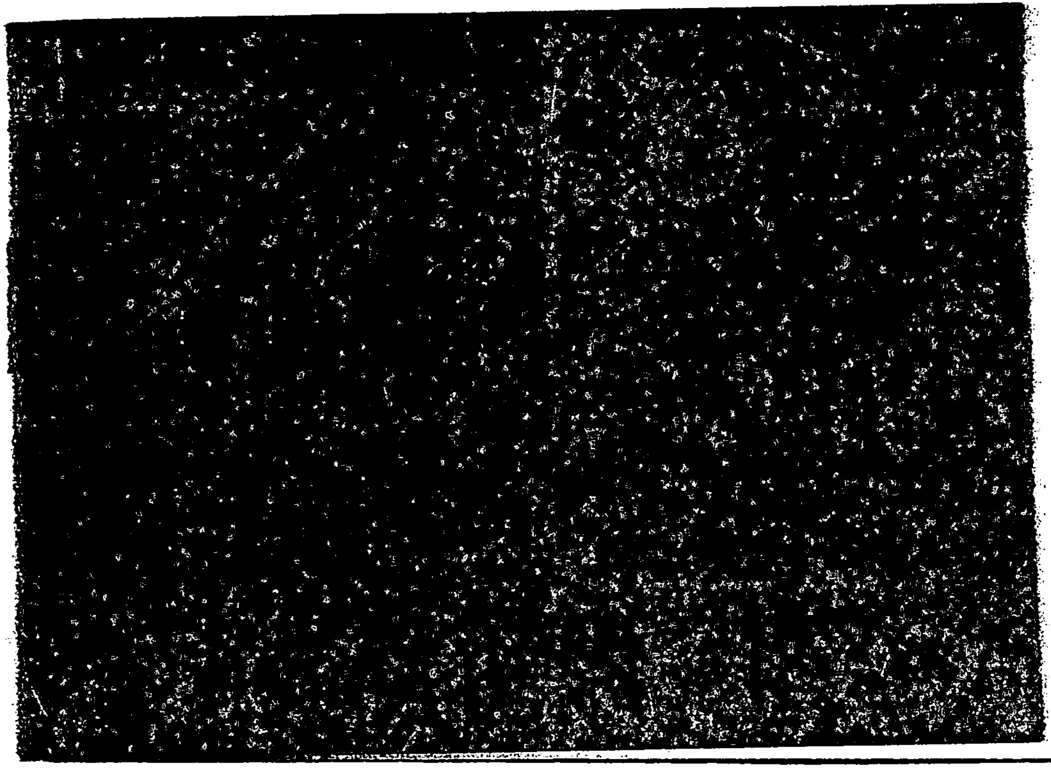
D2 P2 Model, X+Y (N-S+Vert.) OBE, Ab. Sum



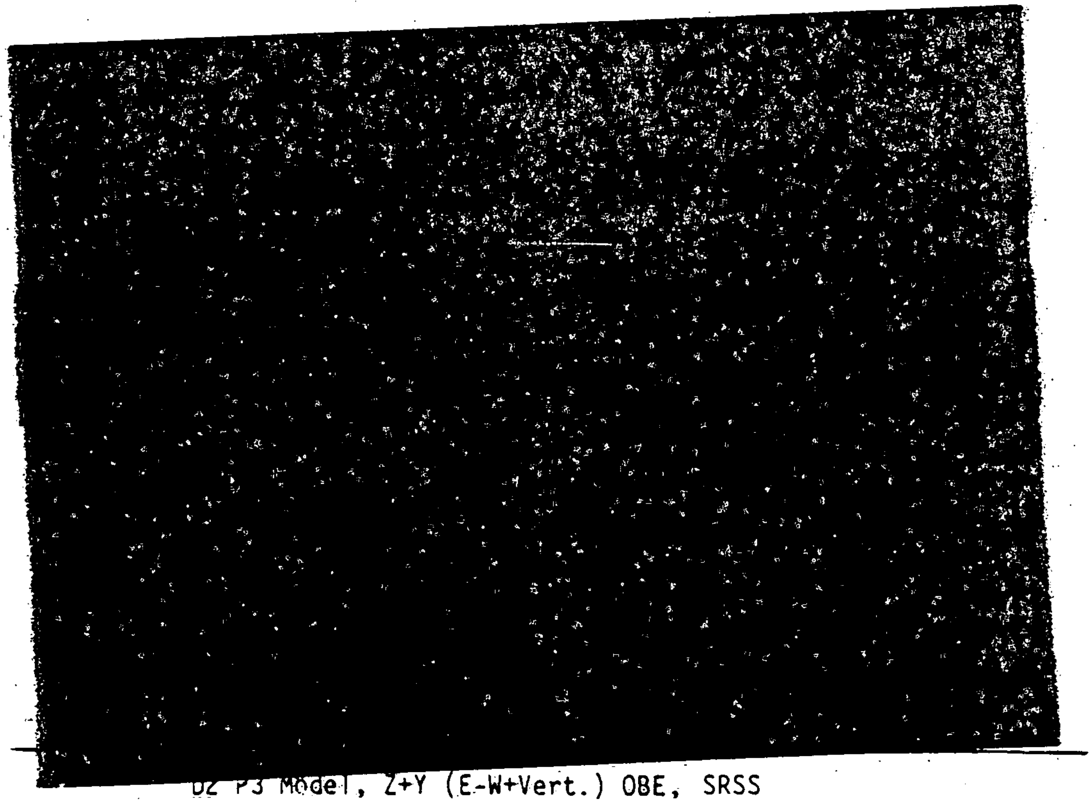
D2 P2 Model, Z+Y (E-W+Vert.) OBE, Ab. Sum



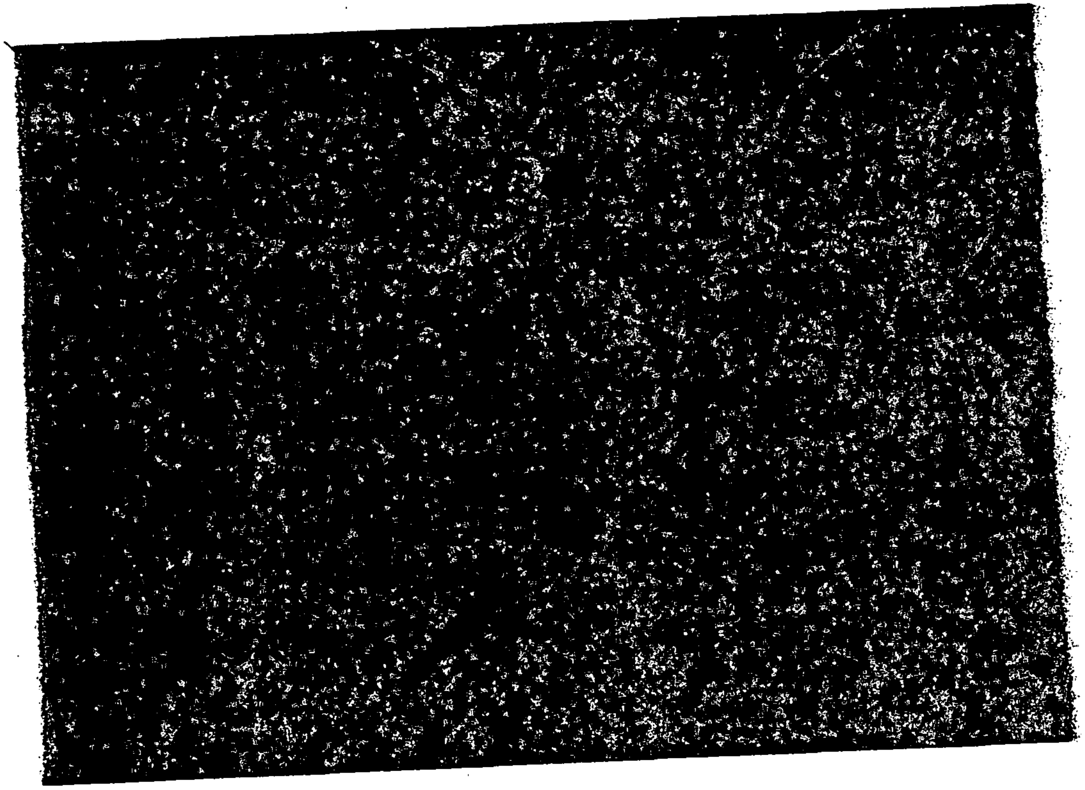
D2 P2 Model, Current Criteria SSE



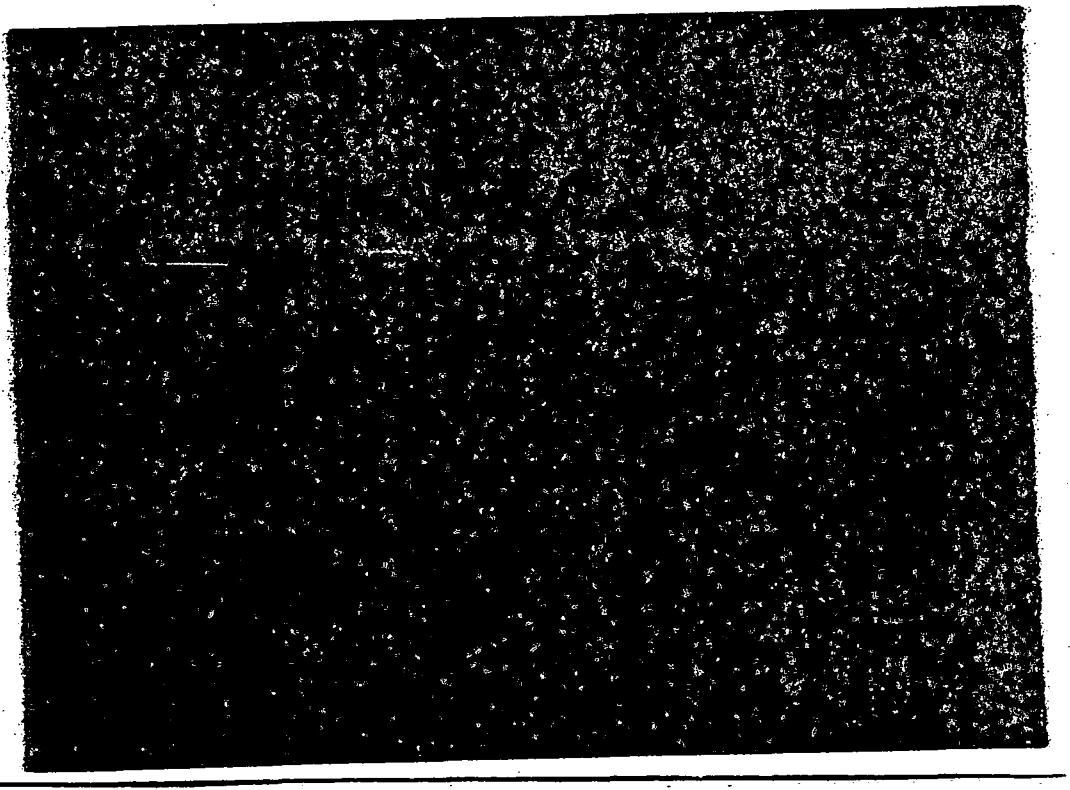
D2 P3 Model, X+Y (N-S+Vert.) OBE, SRSS



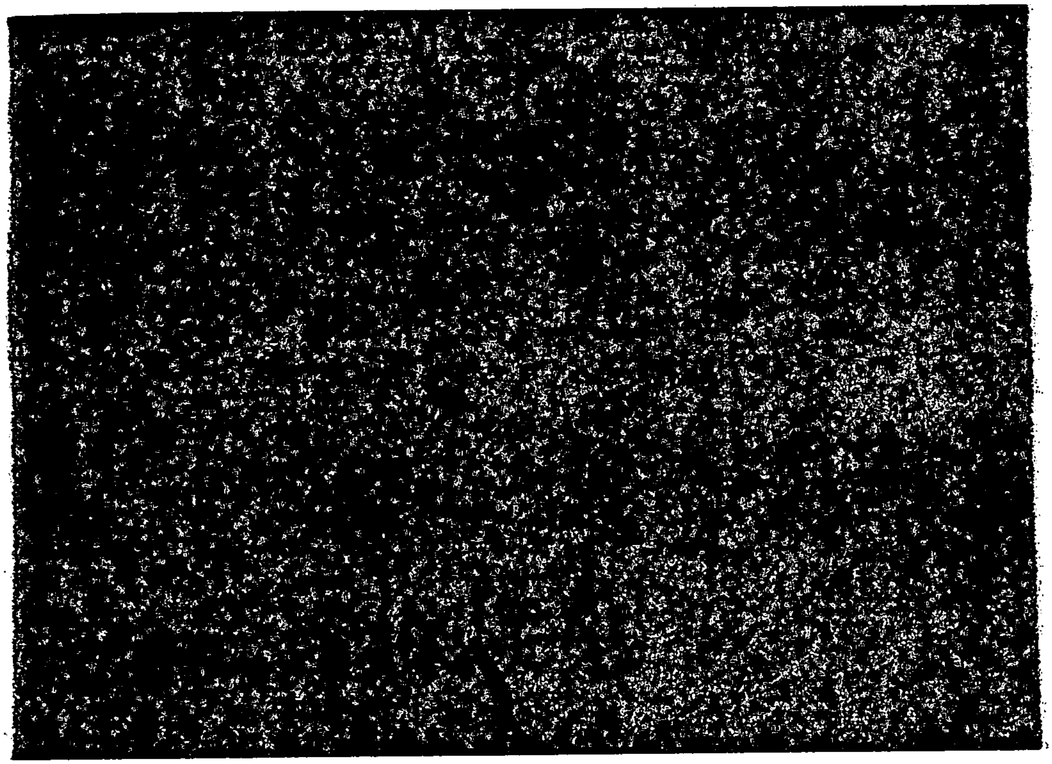
D2 P3 Model, Z+Y (E-W+Vert.) OBE, SRSS



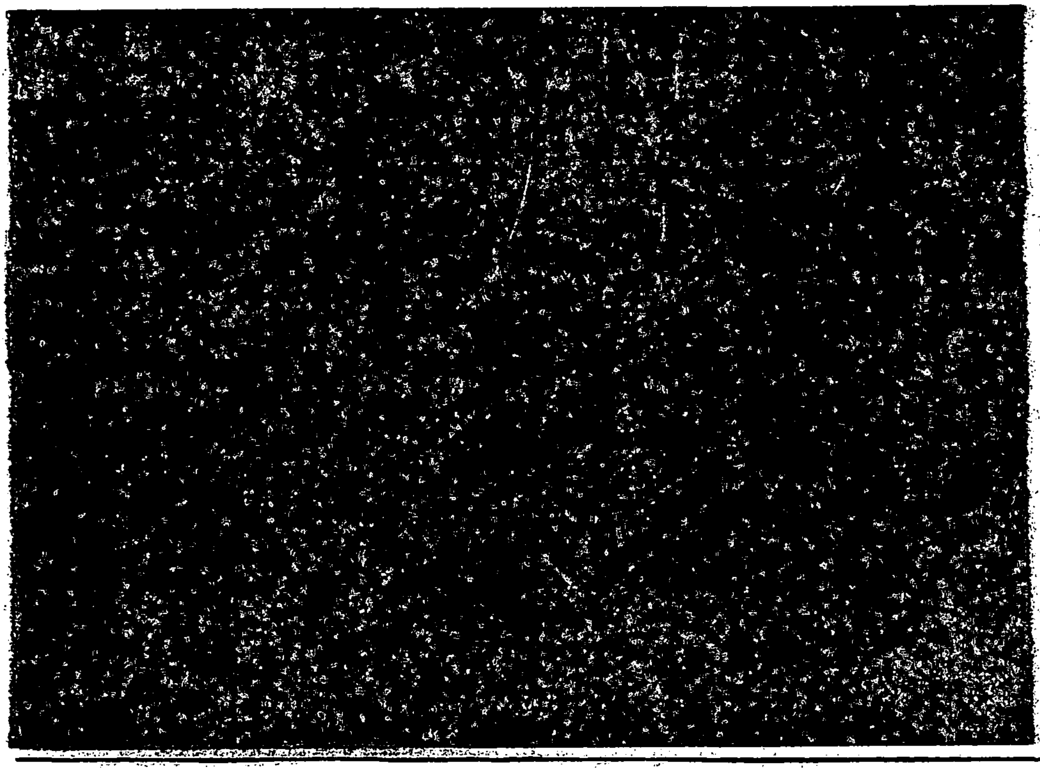
D2 P3 Model, X+Y (N-S+Vert.) OBE, Ab. Sum



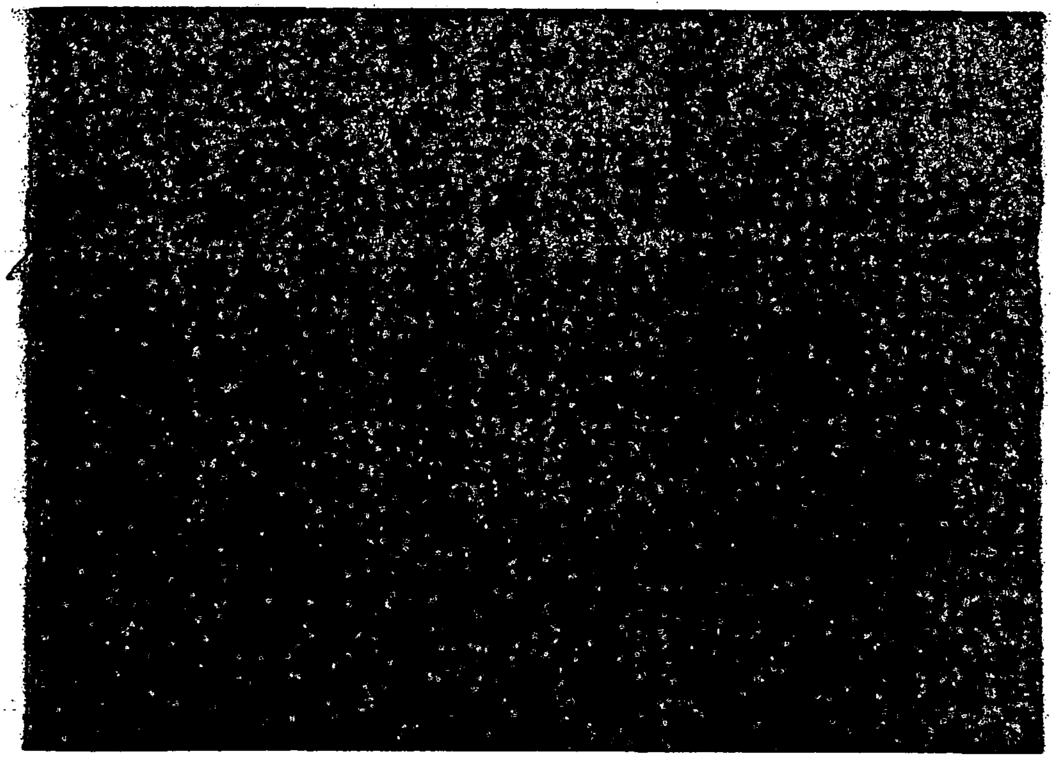
D2 P3 Model, Z+Y (E-W+Vert.) OBE, Ab. Sum



D2 P3 Model, Current Criteria SSE

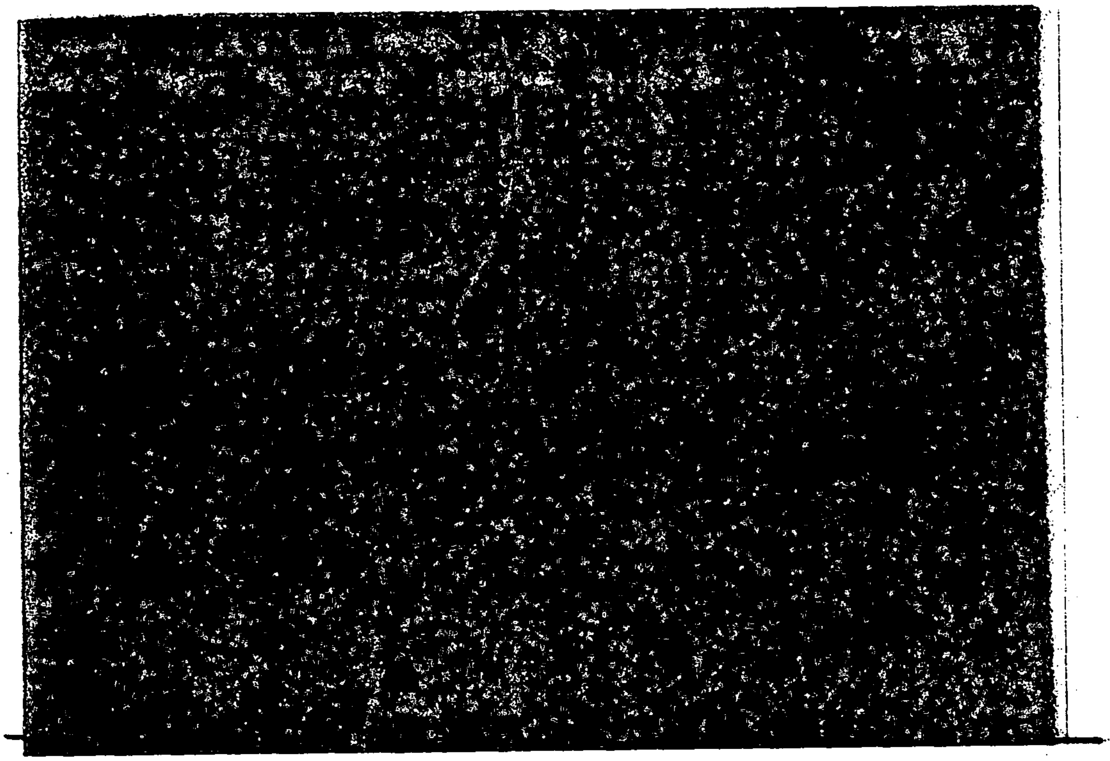


D2 LPCI Suction, Original Analysis Simulation

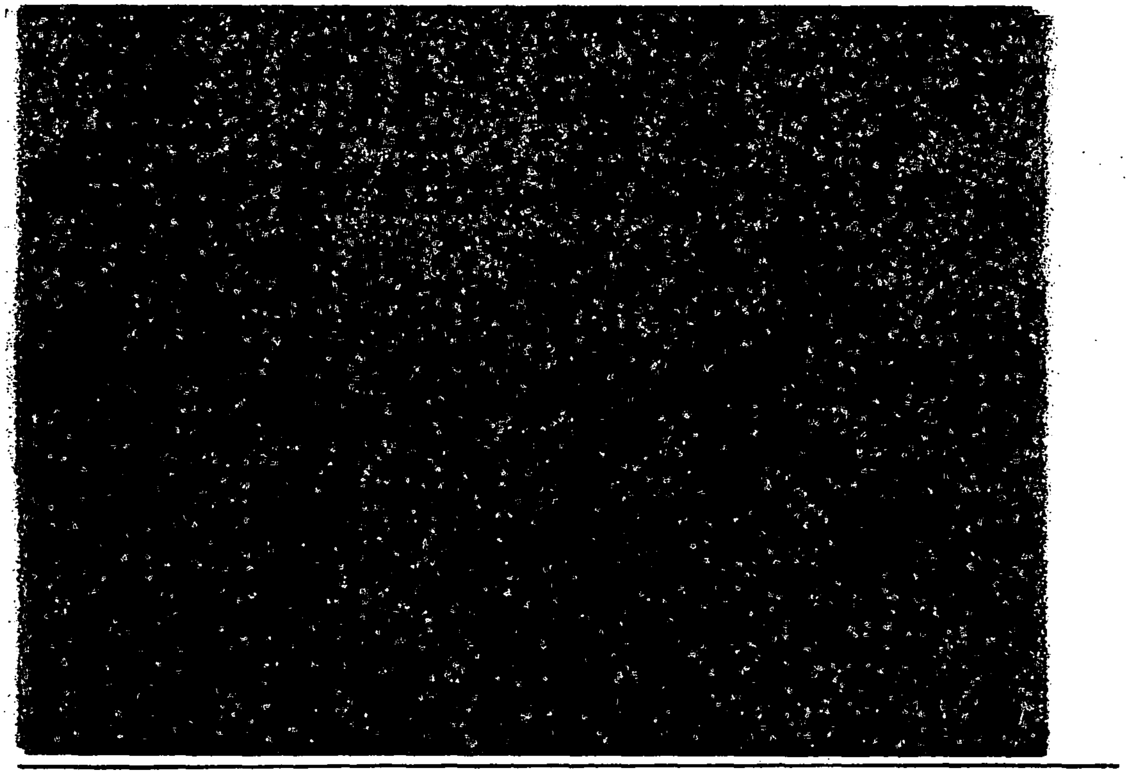


D2 LPCI Suction, Current Criteria SSE

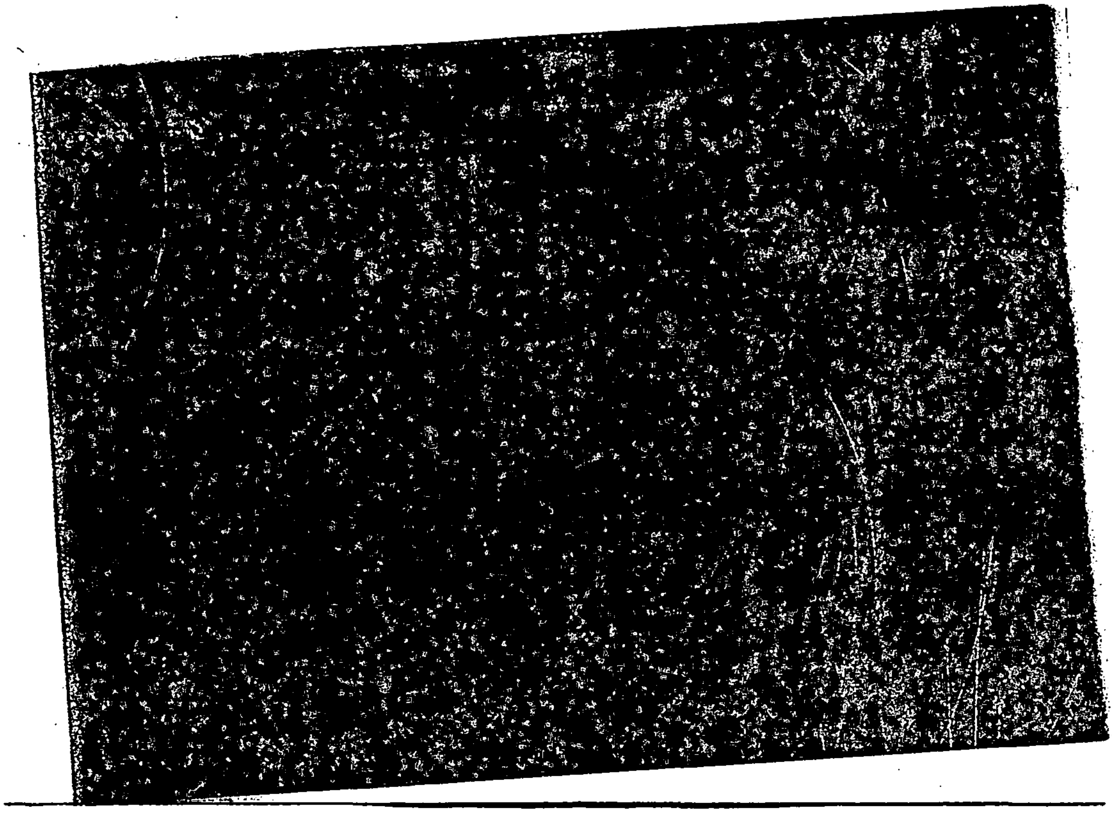
Information provided for the small piping seismic example problem consisted of a representative small diameter (eight inch nominal size) system from the Quad Cities Nuclear Power Station. Therefore, the following computer output is labeled as "Quad Cities Test Problem". While the system analyzed is not from the Dresden Unit 2 reactor, the analysis does serve the purpose of verifying the design charts.



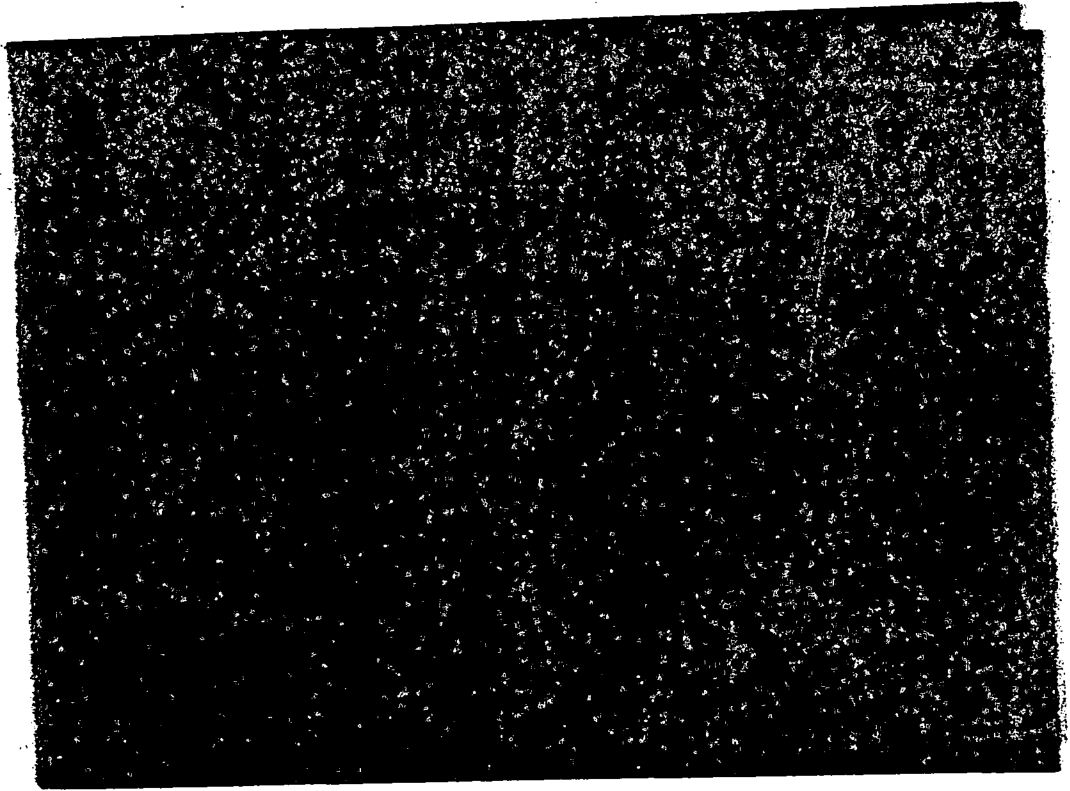
Quad Cities Test Problem, SSE, Vert. Restraints In, Reasonable Support Stiffness



Quad Cities Test Problem, SSE, No Vert. Restraints, Reasonable Stiffness



Quad Cities Test Problem, SSE, Vert. Restraints In,
Restraint Stiffness = 10 x Pipe Span Stiffness



Quad Cities Test Problem, SSE, No Vert. Restraints,
Restraint Stiffness = 10 x Pipe Span Stiffness

APPENDIX D

ORIGINAL ANALYSIS LPCI SUCTION PIPING NOZZLE LOADS

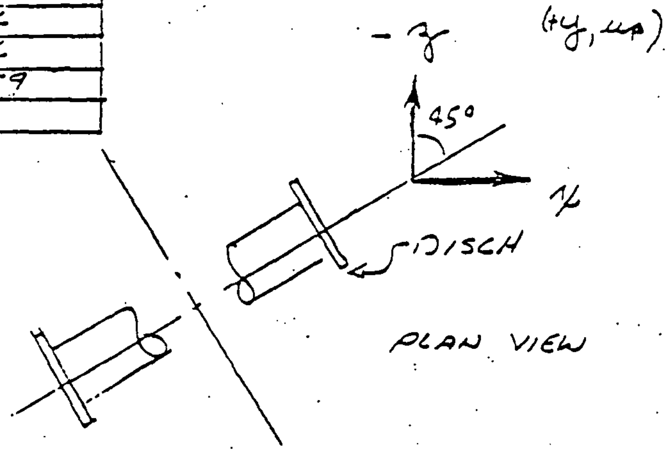
6-30-69

NOTE: FORCES (LBS) AND MOMENTS (FT-LBS) ARE APPLIED TO ANCHOR POINTS

PIPING: LPCI PUMP A AND B SUCTION AND DISCH NOZZLE LOADS

~~OPERATING CONDITIONS:~~ SEE DWG M-547

POINT		LOADS CAN BE ~~HOT~~ FOR ~~NO CUT-SHORTS~~ SEISMIC (1)	☐ SEE CUT-SHORTS SUMMARY ☐ 67% CUT-SHORT		
			HOT, Σ_h	COLD, Σ_c	
5 "B" PUMP DISCH	Fx	335			
	Fy	3153			
	Fz	2460			
	Mx	6172			
	My	406			
	Mz	3036			
45 "A" PUMP DISCH	Fx	4364			
	Fy	7223			
	Fz	395			
	Mx	2753			
	My	1316			
	Mz	9320			
5 "A" PUMP SUCT	Fx	4413			
	Fy	1697			
	Fz	3297			
	Mx	10 507			
	My	6725			
	Mz	2734			
85 "B" PUMP SUCT	Fx	9779			
	Fy	2722			
	Fz	4122			
	Mx	11 556			
	My	10059			
	Mz	2512			
	Fx				
	Fy				
	Fz				
	Mx				
	My				
	Mz				
	Fx				
	Fy				
	Fz				
	Mx				
	My				
	Mz				
	Fx				
	Fy				
	Fz				
	Mx				
	My				
	Mz				



ORIENTATION OF SUCT AND DISCH

(1) 1.00X HORIZ + 0.067X VERT