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GAI REPORT NO. 1729



TOPICAL REPORT

# DYNAMIC ANALYSES OF VITAL PIPING SYSTEMS SUBJECTED TO SEISMIC MOTION



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ENGINEERS/CONSULTANTS
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CC:JD

Abstract:

This report deals with the approach adopted by Gilbert Associates in relation to the aseismic design of vital piping systems. The "Dynamic Analyses of Vital Piping Systems Subjected To Seismic Motion" is based upon a multi-degree of freedom lumped parameter model. Classical normal modes are presumed to exist for the slightly damped systems; linear behavior is also assumed. A modal analysis employing the response spectrum method and the approach developed by Biggs and Roesset for coupling the effect of the building are used to determine the total response of the piping. The maximum inertial forces for each mode thus developed are applied as static loads on the system in order to obtain the internal stresses and support reactions using the PIPE STRESS PROGRAM. The most probable maximum values are obtained by taking the square root of the sum of the squares of the stresses and reactions resulting from all contributing modes.

For the Primary Coolant Loop, the building and the loop are coupled in the same model to account for their interaction. In all other respects the analytical approach for this system follows the pattern described above.

## TABLE OF CONTENTS

# INTRODUCTION

This report deals with the approach adopted by Gilbert Associates in relation to the aseismic design of vital piping systems. These systems come under classification I and are defined as follows:

> Those systems whose failure might cause, or increase the severity of, a loss of coolant accident, or result in an uncontrolled release of excessive amount of radioactivity. Also included in this classification are systems vital to safe shutdown and isolation of the reactor.

Because the failure of any system defined above is regarded as unacceptable, the analytical approaches used to evaluate the behavior of the piping during an earthquake are conservative and are as consistent as possible with the accuracy of the assumptions that must be made regarding the earthquake characteristics.[1]

The aseismic design of the piping is complicated by the necessity to provide enough flexibility to satisfy thermal stress requirements; this results in run layouts which are much less than optimum for seismic conditions.

Percentages of critical damping selected follow the recommendations of N. M. Newmark,[2] except as specified in the appropriate safety analysis report; the increased damping that would result from the effects of the bolted and pinned connections of the restraints forming a part of the system is not considered.

Peak responses from earthquake motions in the horizontal and vertical directions are considered to act simultaneously. To get a reasonably accurate estimate of the behavior of the complete system, earthquake motions are applied in three mutually perpendicular directions corresponding to the global axes of each model. Stresses arising from the combination of each horizontal excitation with the vertical are compared, in order to arrive at the maximum values. Typical models and computer outputs are given in Appendices 1 and 2.

## THE MODEL

To obtain a model closely resembling the actual system the following factors are considered:

a. Lumped Masses

The magnitudes of the lumped masses are obtained as a proportion of the combined weights of the pipe, the insulation, and the contained fluid. The proportion used is the value which gives a frequency of approximately that which would be obtained from the uniform mass system. Heavy valves are also considered as masses lumped at their approximate centers of gravity. Three translational degrees of freedom are selected for each mass.

b. Pipe Properties

The outside diameter, wall thickness, Young's Modulus, and Poisson's Ratio are given for each section. Flexibility and Stress Intensification factors for elbows are given in accordance with the code.

c. Anchors (Not applicable to Primary Coolant Loop)

Anchors are assumed at connections to the following:

(1) structures,

(2) pieces of equipment, and

(3) pipes of much larger diameter than that in the model considered.

d. Supports

Spring hangers and vibration eliminators are modeled as double acting springs. Even though this may not be precisely correct in the case of the spring hanger, it makes little difference to the dynamic behavior of the model, since the spring rates are normally quite low.

Hanger rods and hydraulic shock suppressors, are considered as rigid along their longitudinal axes.

Restraining structures, such as steel frames, are also considered as rigid in a given direction if the movement permitted is of an order approximating the construction tolerances in the support system.

e. Coordinates

The global axes correspond as closely as possible to the directions of the axes of the majority of the legs of the model in order to resemble the principal axes.

## SEISMIC INPUT (NOT APPLICABLE TO PRIMARY COOLANT LOOP)

The input characteristics applied to the piping systems are a function of the anchor response to the ground motion. The ground motion is expressed by smoothed single degree response spectra applicable to the station site. When the dominant frequencies of the piping system and structure are coincident, or close to each other, the resulting tendency to resonate causes a sharp rise in the stress levels and reaction forces. Crandall and Mark[3] treated the general interaction problem by considering a two-degree-of-freedom system subjected to white noise input. Penzien and Chopra[4] treated the earthquake response of appendages on a structure by a time history approach applied to a two-degree-of-freedom model. Blume[5] used both floor response spectra and floor time-history to analyze the behavior of small equipment inside the reactor building. Since there appears to be no advantage in any of the above mentioned methods in comparison with that proposed by Biggs and Roesset[6], especially in view of the uncertainties associated with earthquake behavior, the last named method is selected as being the one that will give reasonable results, besides being the most practical to use.

In the approach of Biggs and Roesset the equipment is assumed to be very small in relation to the mass of the building. For equipment that is very stiff in comparison to that of the building, the input acceleration is essentially the same as the acceleration of the building at the point of attachment. If, on the other hand, the equipment is relatively very flexible it behaves as though it is supported directly upon the ground and experiences the ground response only. Between these two limits a resonance effect is experienced between the equipment and the structure. In this region, it is hypothesized that where the ratio of equipment to structure periods is less than 1.25 the input to the equipment consists of a series of damped harmonics, each of which corresponds to one of the normal modes of the structure. For equipment to structure period ratios greater than 1.25, the input to the equipment is assumed to be the ground motion as magnified by the structure; the magnification factor is assumed to be the ratio of maximum structural response to ground motion input, when the ground motion input is a pure harmonic with a frequency equal to that of the equipment. This is based upon the fact that most significant harmonic components of the earthquake motion are in near resonance with the equipment. The theoretical amplification curves thus derived are modified to provide closer agreement with the El Centro results based on a two-degree-of-freedom model. The curves apply only for the damping values noted.

The amplification curves for the specific damping values of this report are shown in Figures 1 and 2.

## PRIMARY COOLANT LOOP

Several differences exist between this and the other Class I systems namely:

a. The reactor, reactor coolant pumps, and steam generator are included in the loop.

b. The building is coupled in the model.

c. The loop/building mass ratio is much larger.

d. A large variation in seismic input exists between the uppermost and lowest support elevations.

For the above reasons a different method from that used for the other Class I systems is adopted. The flexibility matrix for the building is obtained by the STRESS PROGRAM and that for the piping by the PIPE STRESS PROGRAM.[7,8,9] These two matrices are then combined into an overall matrix by considering rigid connections at the restraint locations. The reactions at these points are then derived as redundant forces by the condition of compatibility of displacements[10,11]. The remainder of the analysis is as described in the Theory. For conservatism the piping damping ratio is used for the entire model.

THEORY

A glossary of the terms for the following equations has been established in Appendix 3.

The equations of motion of a three dimensional piping system subjected to seismic input, may be written as:

$$[\ulcorner m \lrcorner] \{\ddot{x}\} + [C] \{\dot{x}\} + [K] \{x\} = - [\ulcorner m \lrcorner] \{\ddot{y}\}. \qquad (1)$$

In deriving the above equation and in the following analysis, three assumptions are made as follows:[12]

a. The system can be treated as a lumped parameter model.

b. The system is linear.

c. Classical normal modes exist.

The mass matrix $[\ulcorner m \lrcorner]$ is diagonal and may include mass inertia terms. $\{x\}$ is the relative displacement vector and may include rotations. The dots over the variable indicates time derivatives. $[C]$ and $[K]$ are the symmetric damping matrix and stiffness matrix respectively, and $\{\ddot{y}\}$ is the input support acceleration vector.

The undamped natural frequencies and mode shapes are obtained from the free vibrational, homogeneous equations

$$[\ulcorner m \lrcorner] \{\ddot{x}\} + [K] \{x\} = \{0\} \qquad (2)$$

or

$$[F] [\ulcorner m \lrcorner] \{\ddot{x}\} + [\ulcorner I \lrcorner] \{x\} = \{0\}, \qquad (3)$$

where $[F]$ is the symmetric flexibility matrix of the system and $[\ulcorner I \lrcorner]$ is the identity matrix. The technique of Jacobian diagonalization is used to obtain all the eigenvalue and eigenvectors simultaneously.

Since this technique demands a symmetric matrix operator[13], and our operator $[F]\,[\ulcorner m \lrcorner]$ is not in general symmetric, a transformation is required. Let

$$\{x\} = [\ulcorner m \lrcorner]^{-\frac{1}{2}}\,\{\eta\}. \tag{4}$$

Substituting equations (4) into equations (3) and pre-multiplying with $[\ulcorner m \lrcorner]^{\frac{1}{2}}$, we have

$$[\tilde{F}]\,\{\ddot{\eta}\} + [\ulcorner I \lrcorner]\,\{\eta\} = 0, \tag{5}$$

where $[\tilde{F}]$ represents $[\ulcorner m \lrcorner]^{\frac{1}{2}}\,[F]\,[\ulcorner m \lrcorner]^{\frac{1}{2}}$. $[F]$ is symmetric, so is $[\tilde{F}]$. Applying the orthogonal transformation[13,14]

$$\{\eta\} = [\phi]\,\{\lambda\} \tag{6}$$

to equation (5) and pre-multiplying with $[\phi]^T$, we have

$$\left[\ulcorner \frac{1}{\omega_i^2} \lrcorner\right]\,\{\ddot{\lambda}\} + [\ulcorner I \lrcorner]\,\{\lambda\} = \{0\}, \tag{7}$$

where $\left[\ulcorner \frac{1}{\omega_i^2} \lrcorner\right]$ is $[\phi]^T\,[\tilde{F}]\,[\phi]$, and $[\phi]^T$ is the transpose of $[\phi]$.

Elements of $\left[\ulcorner \frac{1}{\omega_i^2} \lrcorner\right]$ are eigenvalues of $[\tilde{F}]$; columns of $[\phi]$ are the eigenvectors of $[\tilde{F}]$. The eigenvectors of the original system of equations (3) are obtained from equations (4)

$$[\psi] = [\ulcorner m \lrcorner]^{-\frac{1}{2}}\,[\phi]. \tag{8}$$

Rewriting equations (8) as

$$[\phi] = [\ulcorner m \lrcorner]^{\frac{1}{2}}\,[\psi], \tag{9}$$

then the orthogonal conditions are

$$[\phi]^T [\phi] = [\psi]^T \lceil m \rfloor [\psi] = \lceil I \rfloor, \tag{10}$$

where the eigenvectors are normalized. The eigenvalues are

$$\left\lceil \frac{1}{\omega_i^2} \right\rfloor = [\phi]^T [\tilde{F}] [\phi] = [\psi] \lceil m \rfloor [F] \lceil m \rfloor [\psi]. \tag{11}$$

Let

$$\{x\} = [\psi] \{\lambda\} \tag{12}$$

We can uncouple equations (3) directly by pre-multiplying it with $[\psi]^T \lceil m \rfloor$,

$$[\psi]^T \lceil m \rfloor [F] \lceil m \rfloor [\psi] \{\ddot{\lambda}\} + \lceil I \rfloor [\psi]^T \lceil m \rfloor [\psi] \{\lambda\} = \{0\}$$

or

$$\left\lceil \frac{1}{\omega_i^2} \right\rfloor \{\ddot{\lambda}\} + \lceil I \rfloor \{\lambda\} = \{0\}. \tag{13}$$

Raleigh[15] showed that the sufficient condition for a damped system to possess classical normal modes is that the damping matrix is a linear combination of the mass matrix and the stiffness matrix. Caughey[16] pointed out that the necessary and sufficient conditions for the existence of classical normal modes is that the damping matrix be diagonalized by the same transformation that uncouples the undamped system. With the method of superposition of normal modes, we apply the coordinate transformation (12) to equation (1) and pre-multiply it by $[\psi]^T$, obtaining

$$[\psi]^T \lceil m \rfloor [\psi] \{\ddot{\lambda}\} + [\psi]^T [C] [\psi] \{\dot{\lambda}\} + [\psi]^T [K] [\psi] \{\lambda\} = - [\psi]^T \lceil m \rfloor \{\ddot{y}\}. \tag{14}$$

Considering equations (10), and the orthogonality conditions[10]

$$[\psi]^T\ [K]\ [\psi] = [\ulcorner \omega_i^2 \lrcorner]\ [\ulcorner I \lrcorner] = [\ulcorner K_i \lrcorner] \qquad (15)$$

and proportional damping[10]

$$[C] = \xi[\ulcorner m \lrcorner] + \alpha[K], \qquad (16)$$

equations (14) are uncoupled as

$$[\ulcorner I \lrcorner]\ \{\ddot{\lambda}\} + (\xi[\ulcorner I \lrcorner] + \alpha[\ulcorner K_i \lrcorner])\ \{\dot{\lambda}\} + [\ulcorner K_i \lrcorner]\ \{\lambda\} =$$
$$-[\psi]^T\ [\ulcorner m \lrcorner]\ \{\ddot{y}\}. \qquad (17)$$

The $i^{th}$ component has the form

$$\ddot{\lambda}_i + (\xi + \alpha K_i)\ \dot{\lambda}_i + K_i\ \lambda_i = -\{\psi_i\}T\ [\ulcorner m \lrcorner]\ \{\ddot{y}\} \qquad (18)$$

where $\{\psi_i\}^T$ is the transpose of the $i^{th}$ column of $[\psi]$. Instead of specifying the proportional constants $\xi$ and $\alpha$, we use the percentage of critical damping which is defined as

$$\beta = \frac{C}{C_{cr}} = \frac{\xi + \alpha K_i}{2\omega_i}\ ; \qquad (19)$$

equation (18) becomes

$$\ddot{\lambda}_i + 2\beta\omega_i\lambda_i + \omega_i^2\lambda_i = -\{\psi_i\}\ [\ulcorner m \lrcorner]\ \{\ddot{y}\} \qquad (20)$$

furthermore let

$$\{\ddot{y}\} = \ddot{y}_o\ \{d\}\ f(t) \qquad (21)$$

where $\ddot{y}_o$ is the maximum support acceleration, $\{d\}$ is the earthquake direction vector, and f(t) is the time function for support acceleration. Define the participation factor $\gamma_i$ as

$$\gamma_i = \{\psi_i\}^T \left[\ulcorner m \lrcorner\right] \{d\}, \tag{22}$$

which can be thought as a measure of the extent to which the $i^{th}$ normal mode participates in synthesizing the total loads on the system[10]. With the initial conditions as

$$\dot{\lambda}(0) = \lambda(0) = 0, \tag{23}$$

the solution of equation (20) is[10]

$$\lambda_i\ (t) = + \frac{\gamma_i \ddot{y}_o}{\omega_i^2} \int_o^t \frac{\omega_i{}^2}{\omega_i \sqrt{1 - \beta^2}}\, e^{-\beta\omega_i(t-\tau)}$$

$$f(\tau)\mathrm{Sin}[\omega_i \sqrt{1 - \beta^2}\ (t-\tau)]d\tau \tag{24}$$

For small damping ratios $\omega_i \sqrt{1 - \beta^2} \to \omega_i$. Let the response spectrum value be[17,18]

$$Sa(\omega_i) = [\ddot{y}_o \int_o^\tau \omega_i\ e^{-\beta\omega_i(t-\tau)}\ f(\tau)\mathrm{Sin}\omega_i(t-\tau)\ d\tau]_{max}. \tag{25}$$

In this analysis, the value of Sa is taken directly from the response spectrum curve. Then the maximum response will be

$$(\lambda_i)max = \frac{\gamma_i\ \ Sa}{\omega_i^2}\ . \tag{26}$$

Comparing equation (20) with the equation of motion of a single-degree-of-freedom system, the equivalent maximum modal absolute accelerations is[19]

$$[\ddot{\lambda}_i + \gamma_i \ddot{y}_o f(t)] = \gamma_i Sa. \qquad (27)$$

Hence the equivalent maximum modal force will be[10,19]

$$\{F_i\} = \gamma_i Sa[\ulcorner m \lrcorner] \{\psi_i\} \qquad (28)$$

or

$$\{F_i\} = (\lambda_i)_{max}[K] \{\psi_i\}. \qquad (29)$$

## DESIGN SEQUENCE

The steps to do an analysis of the behavior of a system under earthquake loading and to complete an aseismic design are as follows:

a. The system is modeled as described previously, the locations of seismic restraints being established from experience.

b. The free vibration frequencies and mode shapes are obtained from equations (3).

c. Participation factors are calculated from equations (22).

d. Modal accelerations are obtained by reading the response spectrum curve ordinates corresponding to the modal period. This value is then modified by the amplification curves of Figures 1 and 2 as described briefly in the Seismic Input and more completely in reference 6.

e. The modal accelerations are multiplied by the participation factors for the mode, the mode shape, and the mass at each node, to obtain the inertial forces as given in equations (28).

f. The inertial forces for each mode are applied to the piping system to obtain the internal stresses and reactions at each support joint by the PIPE STRESS PROGRAM. The effects of shear, axial, torsional, and flexural deformations are included in the generation of the flexibility matrix. Since the maximum stresses and reactions of all modes do not occur at the same time, the most probable maximum stresses and reactions are obtained by taking the square root of the sum of the squares of the stresses and reactions produced by all the contributing modes. For conservatism this analysis considers all the modes in which the modal acceleration values in equation (27) are greater than 1 percent of the maximum modal acceleration among all the modes.

g. The seismic stresses are combined with other stresses in accordance with the codes and compared with code allowables. Modifications are made to the seismic restraints if the resultant stress levels indicate such a need, and a rerun is performed.

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# F I G U R E S

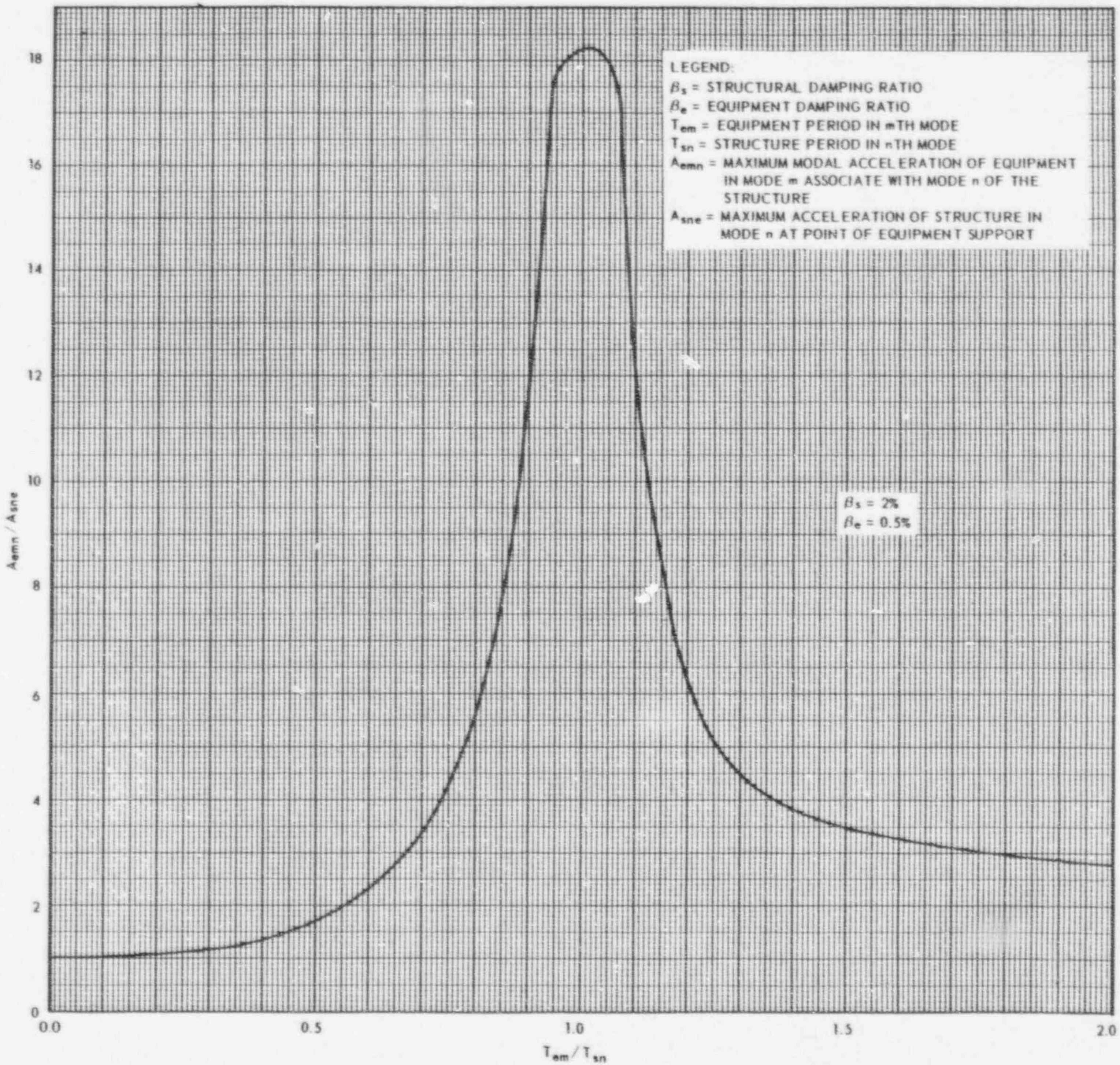


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FIGURE 1
AMPLIFICATION CURVE 1
FOR CLASS I PIPING SYSTEMS

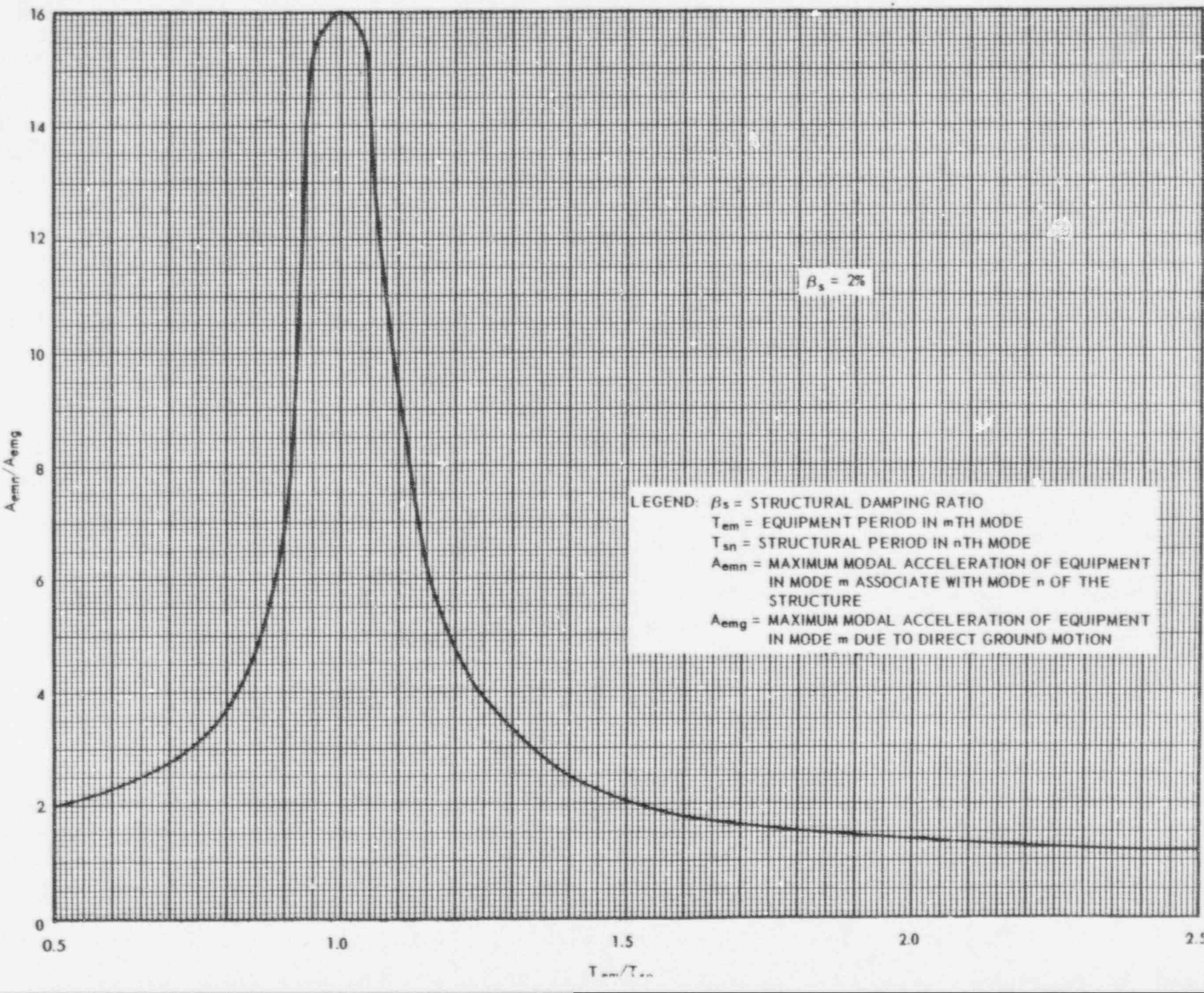


FIGURE 2
AMPLIFICATION CURVE 2
FOR CLASS I PIPING SYSTEMS

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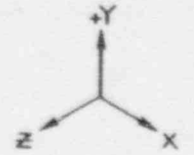
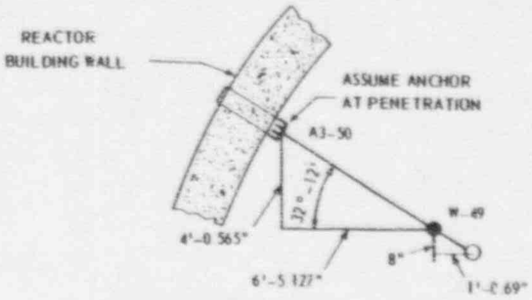
# A P P E N D I C E S




COORDINATE ORIENTATION
(RIGHT HAND CARTESIAN SYSTEM)




DETAIL A

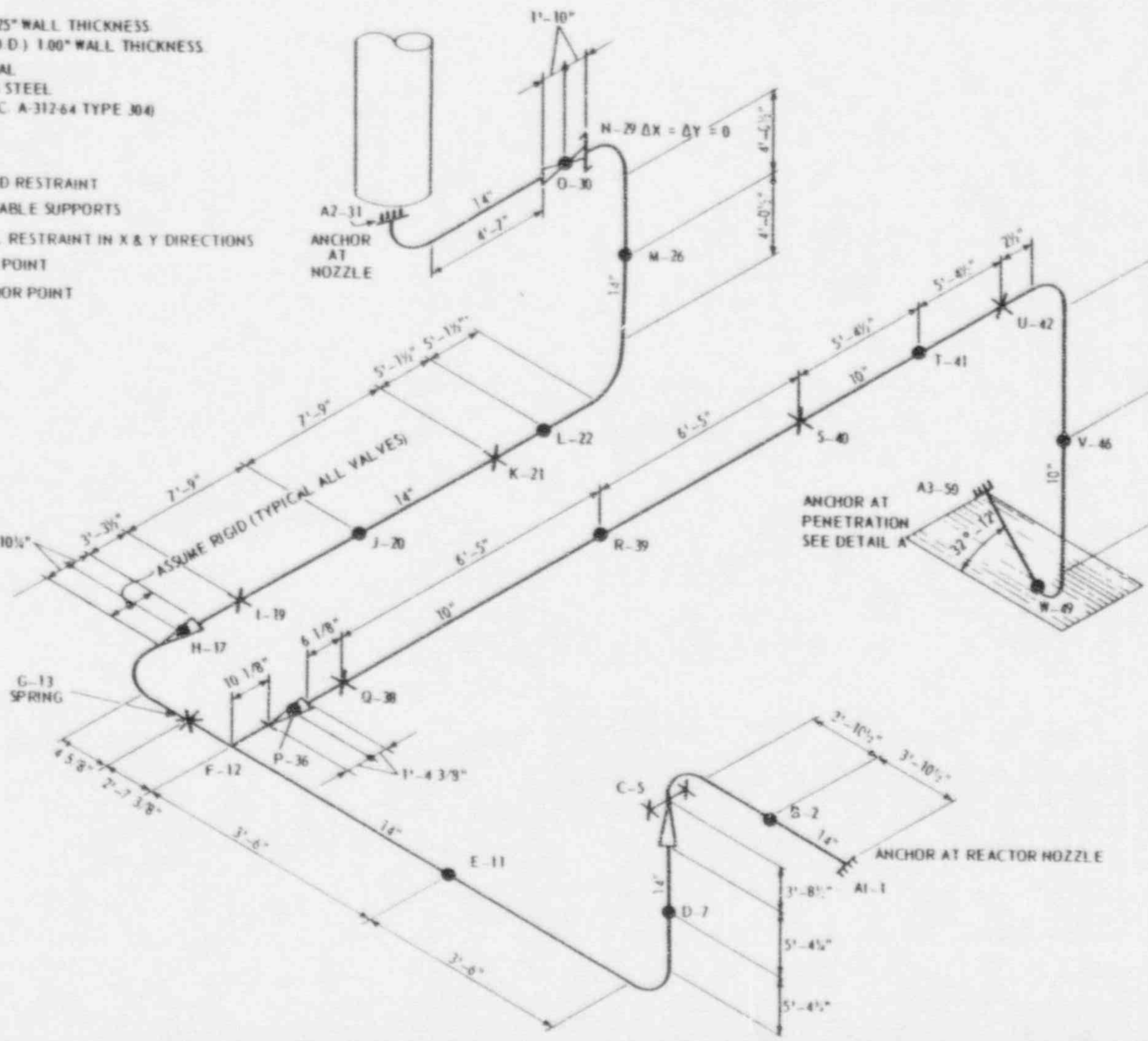
NOTES:

PIPE SIZE
14" O.D. 1.25" WALL THICKNESS
10" (10.75" O.D.) 1.00" WALL THICKNESS

PIPE MATERIAL
STAINLESS STEEL
(ASTM SPEC. A-312-64 TYPE 304)

LEGEND:

- ⟷ – RIGID RESTRAINT
- X – VARIABLE SUPPORTS
- ΔX = ΔY = 0 – FULL RESTRAINT IN X & Y DIRECTIONS
- ● – MASS POINT
- ⊥⊥⊥⊥ – ANCHOR POINT

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TYPICAL SEISMIC MODEL
CLASS I PIPING SYSTEM

LUMPED MASS POINTS - LBS

| POINT | X | Y | Z |
|---|---|---|---|
| B | 1363.000 | 681.000 | 1363.000 |
| D | 2921.000 | 2921.000 | 2921.000 |
| E | 1605.000 | 1605.000 | 1605.000 |
| H | 2354.000 | 1177.000 | 2354.000 |
| J | 2012.000 | 1006.000 | 2012.000 |
| L | 1509.000 | 1509.000 | 1509.000 |
| M | 1584.000 | 1584.000 | 1584.000 |
| O | 2001.000 | 2001.000 | 4002.000 |
| P | 2212.000 | 1106.000 | 2212.000 |
| R | 1061.000 | 531.000 | 1061.000 |
| T | 875.000 | 438.000 | 875.000 |
| V | 509.000 | 509.000 | 509.000 |
| W | 792.000 | 792.000 | 792.000 |

| MODE | EIGENVALUES | NATURAL FREQUENCY |
|---|---|---|
| 1 | 0.35121342-02 | 0.26855583 01 |
| 2 | 0.74681226-03 | 0.58239067 01 |
| 3 | 0.54488323-03 | 0.68181792 01 |
| 4 | 0.36800859-03 | 0.82964281 01 |
| 5 | 0.25749790-03 | 0.99182098 01 |
| 6 | 0.13737954-03 | 0.13578728 02 |
| 7 | 0.98402446-04 | 0.16044167 02 |
| 8 | 0.81032622-04 | 0.17680323 02 |
| 9 | 0.66115681-04 | 0.19573473 02 |
| 10 | 0.59214032-04 | 0.20682728 02 |
| 11 | 0.40219800-04 | 0.25095750 02 |
| 12 | 0.35402093-04 | 0.26748884 02 |
| 13 | 0.22253902-04 | 0.33737822 02 |
| 14 | 0.20484111-04 | 0.35165077 02 |
| 15 | 0.17395401-04 | 0.38159520 02 |
| 16 | 0.12619535-04 | 0.44802110 02 |
| 17 | 0.11632377-04 | 0.46664423 02 |
| 18 | 0.70514977-05 | 0.59934854 02 |
| 19 | 0.54397723-05 | 0.68238547 02 |
| 20 | 0.47404368-05 | 0.73098919 02 |
| 21 | 0.44165724-05 | 0.75731656 02 |
| 22 | 0.41576185-05 | 0.78054476 02 |
| 23 | 0.34676584-05 | 0.85467692 02 |
| 24 | 0.27366780-05 | 0.96207356 02 |
| 25 | 0.21587734-05 | 0.10832198 03 |
| 26 | 0.14405237-05 | 0.13260501 03 |
| 27 | 0.10181078-05 | 0.15773325 03 |
| 28 | 0.93194922-06 | 0.16486331 03 |
| 29 | 0.79616484-06 | 0.17836869 03 |
| 30 | 0.77633096-06 | 0.18063283 03 |
| 31 | 0.72435110-06 | 0.18700171 03 |
| 32 | 0.45347366-06 | 0.23634374 03 |
| 33 | 0.40799379-06 | 0.24916862 03 |
| 34 | 0.36709935-06 | 0.26268080 03 |
| 35 | 0.24818207-06 | 0.31947356 03 |
| 36 | 0.18007323-06 | 0.37505551 03 |
| 37 | 0.16564499-06 | 0.39104882 03 |
| 38 | 0.12756259-06 | 0.44561362 03 |
| 39 | 0.11746171-06 | 0.46437836 03 |

RESPCNSE TO EARTHQUAKE FOR MODE 1*

| MASS POINT | DIR | MODE SHAPE | X QUAKE ACCELERATION FT/SEC/SEC | X QUAKE DISPLACEMENT FEET | Y QUAKE ACCELERATION FT/SEC/SEC | Y QUAKE DISPLACEMENT FEET | Z QUAKE ACCELERATION FT/SEC/SEC | Z QUAKE DISPLACEMENT FEET |
|---|---|---|---|---|---|---|---|---|
| B | X | 1.0863314-05 | 1.6408764-03 | 5.7629782-06 | -3.5492330-04 | -1.2465383-06 | -2.1282007-04 | -7.4745266-07 |
| | Y | -1.4099092-03 | -2.1296326-01 | -7.4795556-04 | 4.6064178-02 | 1.6178357-04 | 2.7621127-02 | 9.7009107-05 |
| | Z | 1.1393979-04 | 1.7210320-02 | 6.0444955-05 | -3.7226104-03 | -1.3074307-05 | -2.2321618-03 | -7.8396517-06 |
| D | X | 3.3079772-02 | 4.9966170-00 | 1.7548790-02 | -1.0807735-00 | -3.7958217-03 | -6.4805635-01 | -2.2760609-03 |
| | Y | -9.5075115-03 | -1.4360859-00 | -5.0437263-03 | 3.1062689-01 | 1.0909633-03 | 1.8625894-01 | 6.5416639-04 |
| | Z | -6.3835933-03 | -9.6422584-01 | -3.3864906-03 | 2.0856306-01 | 7.3250147-04 | 1.2505915-01 | 4.3922452-04 |
| E | X | 5.6095707-02 | 8.4731164-00 | 2.9758722-02 | -1.8327440-00 | -6.4368429-03 | -1.0989549-00 | -3.8596773-03 |
| | Y | -2.3034260-02 | -3.4792674-00 | -1.2219654-02 | 7.5256920-01 | 2.6431240-03 | 4.5125759-01 | 1.5848772-03 |
| | Z | -9.1919850-03 | -1.3884264-00 | -4.8763398-03 | 3.0031809-01 | 1.0547574-03 | 1.8007755-01 | 6.3245652-04 |
| H | X | 5.2882456-02 | 7.9877629-00 | 2.8054096-02 | -1.7277615-00 | -6.0681304-03 | -1.0360051-00 | -3.6385888-03 |
| | Y | -3.5779386-02 | -5.4043870-00 | -1.8980933-02 | 1.1689746-00 | 4.1055957-03 | 7.0094372-01 | 2.4618084-03 |
| | Z | -2.2999538-03 | -3.4740229-01 | -1.2201235-03 | 7.5143480-02 | 2.6391399-04 | 4.5057738-02 | 1.5824882-04 |
| J | X | 3.9459797-02 | 5.9603038-00 | 2.0933387-02 | -1.2892200-00 | -4.5279136-0[illegible] | -7.7304559-01 | -2.7150399-03 |
| | Y | -1.8469375-02 | -2.7897531-00 | -9.7979872-03 | 6.0342652-01 | 2.1193149-03 | 3.6182825-01 | 1.2707894-03 |
| | Z | -2.3055027-03 | -3.4824043-01 | -1.2230671-03 | 7.5324772-02 | 2.6455071-04 | 4.5166444-02 | 1.5863061-04 |
| L | X | 2.2878945-02 | 3.4558076-00 | 1.2137260-02 | -7.4749482-01 | -2.6253021-03 | -4.4821487-01 | -1.5741908-03 |
| | Y | -4.6559654-03 | -7.0327195-01 | -2.4699855-03 | 1.5211846-01 | 5.3426046-04 | 9.1213686-02 | 3.2035471-04 |
| | Z | -2.3116086-03 | -3.4916271-01 | -1.2263063-03 | 7.5524262-02 | 2.6525135-04 | 4.5286063-02 | 1.5905073-04 |
| M | X | 6.6723047-03 | 1.0078350-00 | 3.5396517-03 | -2.1799576-01 | -7.6563039-04 | -1.3071521-01 | -4.5908937-04 |
| | Y | 5.0946016-05 | 7.6952685-03 | 2.7026816-05 | -1.6644947-03 | -5.8459288-06 | -9.9806883-04 | -3.5053517-06 |
| | Z | -5.9013895-04 | -8.9139016-02 | -3.1306819-04 | 1.9280863-02 | 6.7716979-05 | 1.1561243-02 | 4.0604639-05 |
| O | X | 1.3875668-04 | 2.0958850-02 | 7.3610295-05 | -4.5334213-03 | -1.5921984-05 | -2.7183424-03 | -9.5471835-06 |
| | Y | -1.3930262-05 | -2.1041313-03 | -7.3899916-06 | 4.5512582-04 | 1.5984630-06 | 2.7290378-04 | 9.5847471-07 |
| | Z | 1.8793217-05 | 2.8386685-03 | 9.9697850-06 | -6.1400699-04 | -2.1564750-06 | -3.6817254-04 | -1.2930714-06 |
| P | X | 5.4061513-02 | 8.1658565-00 | 2.8679584-02 | -1.7662834-00 | -6.2034242-03 | -1.0591036-00 | -3.7197141-03 |
| | Y | -2.7973311-02 | -4.2252988-00 | -1.4839817-02 | 9.1393658-01 | 3.2098680-03 | 5.4801714-01 | 1.9247097-03 |
| | Z | -6.3368637-03 | -9.5716745-01 | -3.3617006-03 | 2.0703633-01 | 7.2713937-04 | 1.2414368-01 | 4.3600928-04 |
| R | X | 4.3609344-02 | 6.5870825-00 | 2.3134718-02 | -1.4247929-00 | -5.0040639-03 | -8.5433818-01 | -3.0005504-03 |
| | Y | -1.7187249-02 | -2.5960911-00 | -9.1178204-03 | 5.6153724-01 | 1.9721941-03 | 3.3671048-01 | 1.1825724-03 |
| | Z | -6.3293669-03 | -9.5603508-01 | -3.3577235-03 | 2.0679139-01 | 7.2627913-04 | 1.2399682-01 | 4.3549347-04 |
| T | X | 1.9405287-02 | 2.9311201-00 | 1.0294487-02 | -6.3400436-01 | -2.2267084-03 | -3.8016342-01 | -1.3351850-03 |
| | Y | -4.4486919-03 | -6.7196381-01 | -2.3600271-03 | 1.4534648-01 | 5.1047634-04 | 8.7153051-02 | 3.0609321-04 |
| | Z | -6.3159124-03 | -9.5400280-01 | -3.3505859-03 | 2.0635181-01 | 7.2473525-04 | 1.2373323-01 | 4.3456772-04 |
| V | X | 4.4537618-03 | 6.7272960-01 | 2.3627167-03 | -1.4551212-01 | -5.1105810-04 | -8.7252373-02 | -3.0644205-04 |
| | Y | -6.9018063-04 | -1.0425006-01 | -3.6614021-04 | 2.2549398-02 | 7.9196512-05 | 1.3521131-02 | 4.7488028-05 |
| | Z | -6.4399525-03 | -9.7273875-01 | -3.4163891-03 | 2.1040441-01 | 7.3896855-04 | 1.2616327-01 | 4.4310233-04 |
| W | X | 2.9134978-03 | 4.4007657-01 | 1.5456080-03 | -9.5189025-02 | -3.3431663-04 | -5.7077502-02 | -2.0046385-04 |
| | Y | -5.5024498-04 | -8.3113131-02 | -2.9190447-04 | 1.7977458-02 | 6.3139244-05 | 1.0779692-02 | 3.7859725-05 |
| | Z | -4.6258264-03 | -6.9871953-01 | -2.4539968-03 | 1.5113377-01 | 5.3080209-04 | 9.0623242-02 | 3.1828099-04 |

| | X QUAKE | Y QUAKE | Z QUAKE |
|---|---|---|---|
| PARTICIPATION FACTOR | 1.9373764-01 | -5.4754673-00 | -2.5127583-00 |
| AMPLITUDE, G'S | 2.4232292-01 | 2.7818584-01 | 2.4232292-01 |
| KINETIC ENERGY, FT-LBS | 4.0065283-01 | 1.8745001-00 | 6.7397166-01 |

* Results given are for a 0.06 g earthquake.

DEFLECTIONS IN INCHES DUE TO EARTHQUAKE FOR ALL 39 MODES *

| MASS POINT | DIR. | X QUAKE | Y QUAKE | Z QUAKE |
|---|---|---|---|---|
| B | X | 0.0001 | 0.0000 | 0.0000 |
| | Y | 0.0124 | 0.0028 | 0.0023 |
| | Z | 0.0014 | 0.0003 | 0.0042 |
| D | X | 0.2740 | 0.0465 | 0.0441 |
| | Y | 0.0794 | 0.0141 | 0.0123 |
| | Z | 0.0573 | 0.0105 | 0.1073 |
| E | X | 0.4632 | 0.0775 | 0.0682 |
| | Y | 0.1965 | 0.0390 | 0.0310 |
| | Z | 0.0792 | 0.0136 | 0.1625 |
| H | X | 0.4364 | 0.0733 | 0.0647 |
| | Y | 0.3189 | 0.0732 | 0.0687 |
| | Z | 0.0304 | 0.0071 | 0.1671 |
| J | X | 0.3293 | 0.0556 | 0.0509 |
| | Y | 0.1736 | 0.0450 | 0.0726 |
| | Z | 0.0304 | 0.0071 | 0.1670 |
| L | X | 0.2006 | 0.0324 | 0.0333 |
| | Y | 0.0451 | 0.0121 | 0.0487 |
| | Z | 0.0304 | 0.0071 | 0.1667 |
| M | X | 0.0643 | 0.0098 | 0.0134 |
| | Y | 0.0019 | 0.0007 | 0.0100 |
| | Z | 0.0138 | 0.0043 | 0.0777 |
| O | X | 0.0012 | 0.0002 | 0.0002 |
| | Y | 0.0004 | 0.0001 | 0.0020 |
| | Z | 0.0002 | 0.0000 | 0.0003 |
| P | X | 0.4463 | 0.0748 | 0.0649 |
| | Y | 0.2442 | 0.0527 | 0.0423 |
| | Z | 0.0557 | 0.0097 | 0.1646 |
| R | X | 0.3607 | 0.0619 | 0.0534 |
| | Y | 0.1555 | 0.0371 | 0.0459 |
| | Z | 0.0556 | 0.0097 | 0.1644 |
| T | X | 0.1639 | 0.0324 | 0.0537 |
| | Y | 0.0443 | 0.0119 | 0.0711 |
| | Z | 0.0555 | 0.0097 | 0.1641 |
| V | X | 0.0399 | 0.0093 | 0.0385 |
| | Y | 0.0170 | 0.0062 | 0.0307 |
| | Z | 0.0545 | 0.0091 | 0.1120 |
| W | X | 0.0243 | 0.0042 | 0.0300 |
| | Y | 0.0130 | 0.0046 | 0.0213 |
| | Z | 0.0386 | 0.0066 | 0.0479 |

* Results given are for a 0.06 g earthquake

RESULTS FROM EARTHQUAKE** IN X-Y* DIRECTION USING MODES
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
27 28 29 30 31 33 35 36 38

PARTIAL OUTPUT FOR REACTIONS AND STRESS RANGE
RESTRAINING REACTIONS AT "TO" END ARE REFERRED TO AT EACH POINT IN BRANCH

| | | | MOMENTS IN FOOT POUNDS | | | FORCES IN POUNDS | | | STRESS |
|---|---|---|---|---|---|---|---|---|---|
| | BRANCH | POINT | ABOUT X | ABOUT Y | ABOUT Z | X | Y | Z | PSI |
| BRANCH 1, FROM A1 TO B | 1 | 1 | 6797. | 3505. | 30902. | 3642.2 | 3162.7 | 518.2 | 2603. |
| | 1 | 2 | 6797. | 3097. | 29345. | 3642.2 | 3162.7 | 518.2 | 2476. |
| BRANCH 2, FROM B TO C | 2 | 2 | 6797. | 3097. | 29345. | 3634.3 | 3133.3 | 496.8 | 2476. |
| | 2 | 3 | 6797. | 3855. | 32671. | 3634.3 | 3133.3 | 496.8 | 3309. |
| | 2 | 4 | 6797. | 4435. | 35457. | 3634.3 | 3133.3 | 496.8 | 3583. |
| | 2 | 5 | 6261. | 4435. | 29335. | 3634.3 | 3133.3 | 496.8 | 2987. |
| BRANCH 3, FROM C TO D | 3 | 5 | 6261. | 4435. | 29335. | 3634.5 | 3133.2 | 496.8 | 2480. |
| | 3 | 6 | 5418. | 4435. | 16950. | 3634.3 | 3133.2 | 496.8 | 1500. |
| | 3 | 7 | 5211. | 4435. | 10101. | 3634.3 | 3133.2 | 496.8 | 998. |
| BRANCH 4, FROM D TO E | 4 | 7 | 5211. | 4435. | 10101. | 2704.8 | 2835.2 | 363.1 | 998. |
| | 4 | 8 | 4311. | 4435. | 21186. | 2704.8 | 2835.2 | 363.1 | 2174. |
| | 4 | 9 | 4178. | 4435. | 25551. | 2704.8 | 2835.2 | 363.1 | 2587. |
| | 4 | 10 | 4178. | 4347. | 21015. | 2704.8 | 2835.2 | 363.1 | 2153. |
| | 4 | 11 | 4178. | 4446. | 12920. | 2704.8 | 2835.2 | 363.1 | 1168. |
| BRANCH 5, FROM E TO F | 5 | 11 | 4178. | 4446. | 12920. | 2064.5 | 2145.1 | 538.9 | 1168. |
| | 5 | 12 | 4178. | 4654. | 7966. | 2064.5 | 2145.1 | 538.9 | 828. |
| BRANCH 6, FROM F TO G | 6 | 12 | 2714. | 4519. | 4632. | 1177.7 | 1294.2 | 1076.7 | 574. |
| | 6 | 13 | 2714. | 3497. | 3631. | 1177.7 | 1294.2 | 1076.7 | 468. |

* Results from Earthquake in X-Z directions are of similar form

** Results given are for a 0.06 g earthquake

RESULTS FROM EARTHQUAKE** IN X-Y* DIRECTION USING MODES 1 2 3 4 5 6 7 8 9 10 11 13 14 15 16 17 18 19 20 21 27 28 29 30 31 33 35 36 38

SUM OF RESTRAINING REACTIONS AT EACH BRANCH POINT

| | MOMENTS IN FOOT POUNDS | | | FORCES IN POUNDS | | |
|---|---|---|---|---|---|---|
| POINT | ABOUT X | ABOUT Y | ABOUT Z | X | Y | Z |
| A1 | 6797. | 3505. | 30902. | 3642.2 | 3162.7 | 518.2 |
| B | 0. | 0. | 0. | 232.3 | 41.4 | 48.5 |
| C | 0. | 0. | 0. | 0.0 | 149.0 | 0.0 |
| D | 0. | 0. | 0. | 1015.9 | 473.4 | 782.9 |
| E | 0. | 0. | 0. | 702.1 | 873.6 | 272.4 |
| F | 0. | 0. | 0. | 0.0 | 0.0 | 0.0 |
| G | 0. | 0. | 0. | 0.0 | 459.7 | 0.0 |
| H | 0. | 0. | 0. | 995.9 | 1486.7 | 419.3 |
| I | 0. | 0. | 0. | 0.0 | 381.9 | 0.0 |
| J | 0. | 0. | 0. | 952.6 | 869.1 | 358.4 |
| K | 0. | 0. | 0. | 0.0 | 245.7 | 0.0 |
| L | 0. | 0. | 0. | 648.6 | 389.7 | 268.1 |
| M | 0. | 0. | 0. | 401.3 | 54.3 | 179.7 |
| N | 0. | 0. | 0. | 1275.0 | 2018.6 | 0.0 |
| O | 0. | 0. | 0. | 344.2 | 95.6 | 31.1 |
| A2 | 1038. | 2092. | 14221. | 676.5 | 1044.2 | 1688.0 |
| P | 0. | 0. | 0. | 954.4 | 934.1 | 249.6 |
| Q | 0. | 0. | 0. | 0.0 | 324.4 | 0.0 |
| R | 0. | 0. | 0. | 491.5 | 367.0 | 120.1 |
| S | 0. | 0. | 0. | 0.0 | 98.6 | 0.0 |
| T | 0. | 0. | 0. | 456.9 | 174.8 | 99.4 |
| U | 0. | 0. | 0. | 0.0 | 20.7 | 0.0 |
| V | 0. | 0. | 0. | 143.2 | 180.3 | 60.8 |
| W | 0. | 0. | 0. | 99.8 | 220.4 | 123.9 |
| A3 | 2289. | 14131. | 4392. | 799.8 | 566.2 | 1109.1 |

MAXIMUM STRESS = 3583. PSI AT POINT 4

* Results from Earthquake in X-Z directions are of similar form

** Results given are for a 0.06 g earthquake

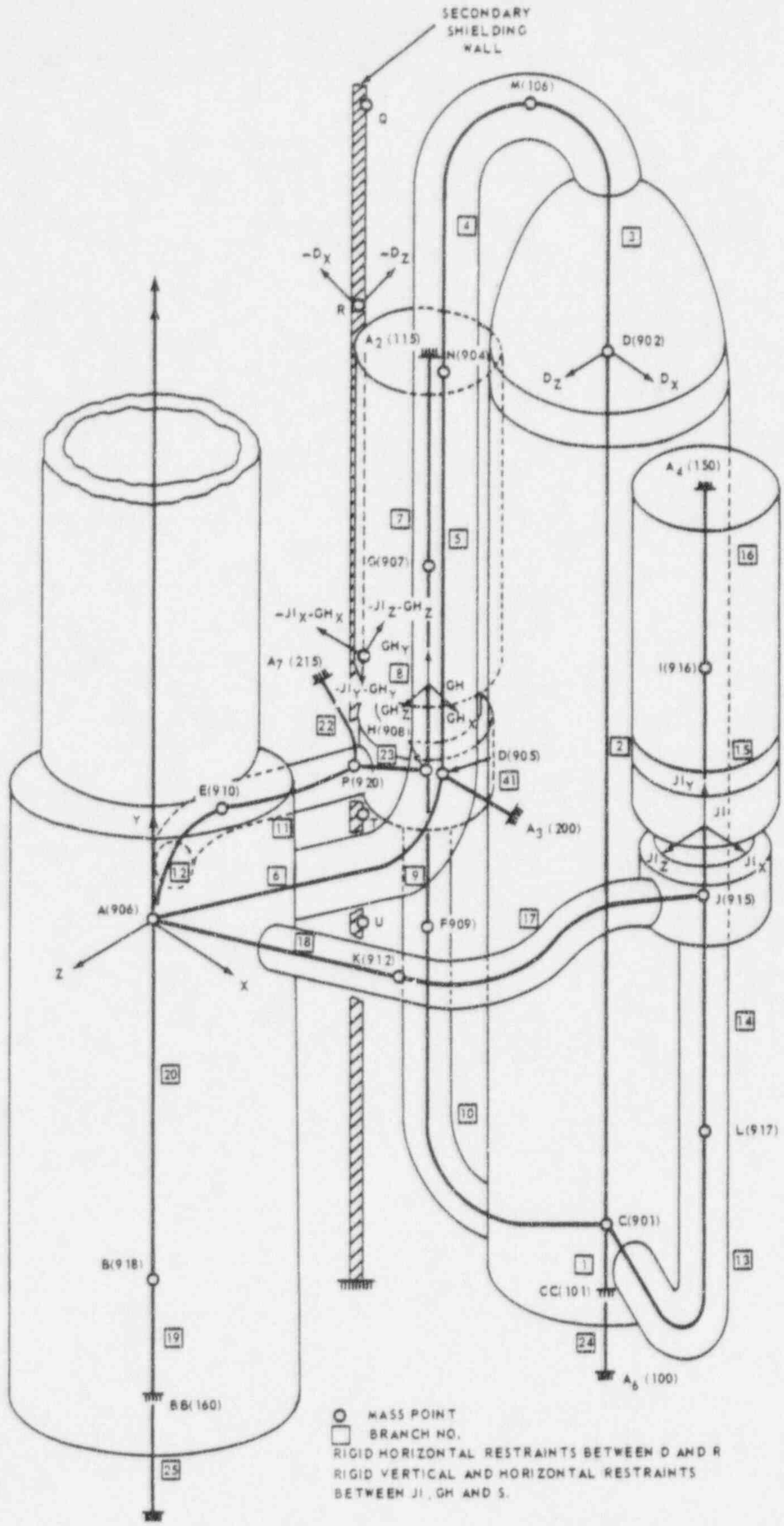
APPENDIX 2

Supplementary Data for

Primary Coolant Loop*

1. Model For Primary Coolant Loop and Secondary Shielding Wall (Figure)
2. Masses (lb $Sec^2/in$)
3. Eigenvalues and Natural Frequencies (CPS)

* In other respects the primary coolant loop output will be similar to that given in Appendix 1.




○ MASS POINT

□ BRANCH NO.

RIGID HORIZONTAL RESTRAINTS BETWEEN D AND R

RIGID VERTICAL AND HORIZONTAL RESTRAINTS BETWEEN JI, GH AND S.

THE BUILDING IS REPRESENTED BY A CANTILEVER BEAM WITH 5 LUMPED MASSES. THE LOOP IS REPRESENTED BY A THREE DIMENSIONAL PIPING SYSTEM WITH 16 LUMPED MASSES. [24] AND [25] REPRESENT ROTATIONAL SPRINGS AT THE BUSES OF THE EQUIPMENT.

GILBERT ASSOCIATES, INC.

**MODEL FOR PRIMARY COOLANT LOOP AND SECONDARY SHIELDING WALL**

Masses (lb $Sec^2$/in)

| Mass pt. | X | Y | Z |
|---|---|---|---|
| F | 108.2 | 108.2 | 108.2 |
| G | 246.0 | 246.0 | 246.0 |
| S(GH,JI) | 13050.0 | | 13050.0 |
| H | 167.0 | 167.0 | 167.0 |
| P | 172.8 | 172.8 | 172.8 |
| E | 43.4 | 43.4 | 43.4 |
| B | 2245.0 | 2245.0 | 2245.0 |
| D and R | 19255.0 | 2255.0 | 19255.0 |
| M | 103.5 | 103.5 | 103.5 |
| N | 97.0 | 97.0 | 97.0 |
| O | 113.0 | 113.0 | 113.0 |
| A | 2245.0 | 2245.0 | 2245.0 |
| K | 45.0 | 45.0 | 45.0 |
| C | 752.0 | 752.0 | 752.0 |
| L | 104.3 | 104.3 | 104.3 |
| J | 340.0 | 340.0 | 340.0 |
| I | 247.5 | 247.5 | 247.5 |
| Q | 4230.0 | | 4230.0 |
| T | 9950.0 | | 9950.0 |
| U | 11850.0 | | 11850.0 |

| MODE | EIGENVALUES | NATURAL FREQUENCY (CPS) |
|---|---|---|
| 1 | 0.18082017-02 | 0.37428006 01 |
| 2 | 0.17680265-02 | 0.37872286 01 |
| 3 | 0.16227307-02 | 0.39509079 01 |
| 4 | 0.15504531-02 | 0.40419489 01 |
| 5 | 0.33682745-03 | 0.86719426 01 |
| 6 | 0.21345109-03 | 0.10893588 02 |
| 7 | 0.20608512-03 | 0.11086560 02 |
| 8 | 0.19124061-03 | 0.11508801 02 |
| 9 | 0.18036737-03 | 0.11850622 02 |
| 10 | 0.17349764-03 | 0.12082960 02 |
| 11 | 0.17120118-03 | 0.12163730 02 |
| 12 | 0.15730647-03 | 0.12689568 02 |
| 13 | 0.14950265-03 | 0.13016544 02 |
| 14 | 0.13615374-03 | 0.13639717 02 |
| 15 | 0.85077956-04 | 0.17254867 02 |
| 16 | 0.67941388-04 | 0.19308695 02 |
| 17 | 0.60565678-04 | 0.20450637 02 |
| 18 | 0.55659914-04 | 0.21332849 02 |
| 19 | 0.49914218-04 | 0.22527241 02 |
| 20 | 0.45717065-04 | 0.23538618 02 |
| 21 | 0.41569301-04 | 0.24685036 02 |
| 22 | 0.40278640-04 | 0.25077413 02 |
| 23 | 0.33093244-04 | 0.27666261 02 |
| 24 | 0.31111653-04 | 0.28533732 02 |
| 25 | 0.29711660-04 | 0.29198240 02 |
| 26 | 0.27800679-04 | 0.30185087 02 |
| 27 | 0.26147129-04 | 0.31124911 02 |
| 28 | 0.25708560-04 | 0.31389273 02 |
| 29 | 0.23568303-04 | 0.32783550 02 |
| 30 | 0.23020612-04 | 0.33171240 02 |
| 31 | 0.12204617-04 | 0.45557307 02 |
| 32 | 0.12197266-04 | 0.45571035 02 |
| 33 | 0.91766650-05 | 0.52538503 02 |
| 34 | 0.85242439-05 | 0.54512010 02 |
| 35 | 0.85056264-05 | 0.54571637 02 |
| 36 | 0.81652667-05 | 0.55697403 02 |
| 37 | 0.72874413-05 | 0.58956628 02 |
| 38 | 0.65912323-05 | 0.61992168 02 |
| 39 | 0.62577622-05 | 0.63622481 02 |
| 40 | 0.62198364-05 | 0.63816158 02 |
| 41 | 0.60974023-05 | 0.64453678 02 |
| 42 | 0.51900669-05 | 0.69860816 02 |
| 43 | 0.40207818-05 | 0.79371553 02 |
| 44 | 0.38766981-05 | 0.80833083 02 |
| 45 | 0.37203326-05 | 0.82514306 02 |
| 46 | 0.22441892-05 | 0.10624057 03 |
| 47 | 0.19303857-05 | 0.11455079 03 |
| 48 | 0.17458766-05 | 0.12045182 03 |
| 49 | 0.16220839-05 | 0.12496358 03 |
| 50 | 0.14233549-05 | 0.13340237 03 |
| 51 | 0.12422443-05 | 0.14279619 03 |
| 52 | 0.11698022-05 | 0.14715124 03 |
| 53 | 0.91684789-06 | 0.16621549 03 |
| 54 | 0.85282656-06 | 0.17234148 03 |
| 55 | 0.78275799-06 | 0.17988973 03 |
| 56 | 0.76297859-06 | 0.18220654 03 |

APPENDIX 3

Glossary of Terms

1. Glossary of Terms

Glossary of Terms:

| | |
|---|---|
| $[\sim m \sim]$ | Mass Matrix |
| $[C]$ | Symmetric Damping Matrix |
| $[K]$ | Stiffness Matrix |
| $\{x\}$ | Relative Displacement Vector |
| $\{\dot{x}\}$ | Relative Velocity Vector |
| $\{\ddot{x}\}$ | Relative acceleration Vector |
| $\{\ddot{y}\}$ | Input acceleration Vector |
| $t$ | Time |
| $[\sim I \sim]$ | Identity Matrix |
| $\{\eta\}$ | Transformed Displacement Vector |
| $[F]$ | Flexibility Matrix |
| $[\tilde{F}]$ | Modified Flexibility Matrix |
| $[\sim \frac{1}{\omega_i^2} \sim]$ | Eigenvalue Matrix |
| $[\phi]$ | Modified Eigenvector Matrix |
| $[\psi]$ | Eigenvector Matrix |
| $\{d\}$ | Earthquake Direction Vector |
| $f(t)$ | Time Function for Support Acceleration |
| $\gamma i$ | Participation Factor |
| $\{\lambda\}$ | Normal Coordinates |
| $\beta$ | Critical Damping Ratio |
| $Sa$ | Response Spectrum Acceleration |
| $\tau$ | Time |

PRC# 178



# Crystal River Unit 3

## Operability Concern Resolution Evaluation Report

| Tag Number | Description of SSC |
|---|---|
| MSH-13B<br>MSH-27B | Piping / Pipe Supports |

| OCR Number MS-96-MSH-13B/27B | Revision 1 | Date 6/11/96 |
|---|---|---|
| Problem Report Number 96-0180 | Resp Dept | Date |

Personnel Involved with Preparations

| Print Name and Title | Signature |
|---|---|
| C. Glenn Pugh, Senior Structural Engineer - NED | C. Glenn Pugh |
| | |
| | |
| | |

Concurrence

Operations

| Signature Carl W. Bergstrom | Title [illegible] | Date 6-1?-96 |
|---|---|---|

Engineering

| Signature [illegible] | Title Supervisor NED | Date 6/11/96 |
|---|---|---|

Licensing

| Signature [illegible] | Title Sr. Nuc Lic Engr | Date 6/12/96 |
|---|---|---|

Plant Review Committee

PRC Mtg Number: 96-23  Date: 6/20/96

PRC Chairman: [signature] Robinson

## Operability Concern Resolution

| Tag Number | Description of SSC |
|---|---|
| MSH-13B<br>MSH-27B | NON-SAFETY RELATED, NON-SIESMIC VERTICAL ROD HANGERS ON RESPECTIVE MS LINES DOWNSTREAM OF MSV-413 AND MSV-414 |

| OCR Number | Revision | Date |
|---|---|---|
| ~~SSC~~ MS-96-MSH-13B/27B | Ø | 5/15/96 |
| **Problem Report Number** | **Resp Dept** NED | **Date** |

| | | |
|---|---|---|
| Operations<br><br>Immediate<br><br>Disposition | [✓]<br><br><br><br>[ ] | Conditionally Operable/ Potentially Inoperable<br><br><br>Inoperable |
| Risk Level | [ ]<br>[ ]<br>[ ]<br>[✓] | Level 1<br>Level 2<br>level 3<br>level 4 |

Basis for Immediate Disposition: SEE ATTACHED CC MAIL W/INITIAL
If applicable, provide reasoning for decision regarding safest action for the plant
Attach log entry if desired
ENG RESPONSE. Provide responses to items [illegible] 1, 2, AS WELL AS DOCUMENT THE RESPONSE TO THE ORIGINAL Precursor card reporting the bent hangers

Basis for Risk Level and Target Date/Time: NON-SAFETY RELATED NON-SIESMIC

SSOD Desired Target Date/Time: 5/23/96 PSAM Color: GREEN *

| SSOD | Date/Time |
|---|---|
| [signature] | 5/15/96 2108 |

| Person(s) Providing Information | Phone |
|---|---|
| SAME | 3133 |

Risk Level 1: Evaluation is to proceed continuously until the OCR is delivered to the SSOD.

Risk Level 2: Evaluation is to proceed on day shift continuously through the weekends and holidays.

Risk Level 3: Evaluation is to proceed as top priority on day shift of weekdays only.

Risk Level 4: Evaluation is to be controlled by the Problem Report Corrective Action Plan. Managers should review the timing of the CAP step for the OCR completion and ensure it is timely and prompt.

* PER D. MISKIEVICZ, HANGERS ARE NOT PART OF THE PSAM DATA BASE

# Operability Concerns Resolution Report Checklist

| OCR Number | Revision | Date |
|---|---|---|
| MS-96-MSH-10B/27B | 1 | 6/11/96 |

Checklist:

1.0 <u>Description and Purpose</u>
- [x] Abstract of the concern
- [x] Circumstances of discovery described
- [x] Component clearly described

2.0 <u>Safety Classification</u>
- [x] Safety class described with basis document identified

3.0 <u>Current Licensing Basis</u>
- [x] Source document(s) identified where design basis is extracted
- [n/a] If applicable, use NDCS and FULTEXT
- [n/a] Applicable active OCRs are considered
- [n/a] Current licensing basis is clearly understood

4.0 <u>Description of Identified Concern</u>
- [x] Concern fully explained
- [x] Impact on the operation and component function described
- [n/a] Diagrams/figures attached if applicable

5.0 <u>Impact Analysis and Reliability Considerations</u>
- 5.1 Impact on Current Licensing Basis Accidents
  - [n/a] Impact of concern in Section 4.0 compared against each accident identified in Section 3.0
- 5.2 Reliability Considerations of Component
  - [n/a] Mission time explained and analyzed

6.0 <u>PSA Evaluation</u>
- [n/a] PSA numbers included (if applicable)

7.0 Operability Evaluation

Answer: [x] "Can it still perform its function and how"?
[n/a] "What additional measures are required to enable this component to perform its function"?

Extent of qualification described.
- [x] operable, fully qualified
- [n/a] operable but degraded
- [n/a] inoperable

8.0 Justification for Continued Operation
- [n/a] Mode of plant operation
- [n/a] Required compensatory measures
- [n/a] Reasons justifying above

9.0 Corrective Action to Obtain Full Qualification
- [x] What has to be done to obtain full qualification?
- [x] When will it be accomplished?

10.0 References

11.0 Attachments and Figures

| Report writer | | Date/Time |
|---|---|---|
| C. Glenn Pugh | C. Glenn Pugh | 6/11/96 1020 |

| NSM | | Date/Time |
|---|---|---|
| | [signature] | 6/17/96 |

Operability Concerns Resolution Report
OCR Number: MS-96-MSH-13B/27B, Rev. 1

## 1.0 Purpose:

This OCR report is to document the condition and operability status of two Main Steam Hangers. These hangers are tagged MSH-13B and MSH-27B. The concern is that these two hangers were observed to have bent hanger rods. This concern is documented on Precursor Card 96-2535 and Problem Report 96-0180. This concern also is documented in the Nuclear Shift Supervisors' Log.

The circumstances of discovery are detailed on Precursor Card 96-2535. The hangers were found with bent rods on a routine walkdown by Operations.

## 2.0 Safety Classification:

The hangers are located on sections of pipe that are classified by the flow diagrams and analysis isometrics (see Attachments) as Non-safety related, ISI Class 4, and non-seismic (S-III). However, it is recognized that these hangers should be treated as seismic hangers to insure the integrity of the class break. The class break is currently shown at the isolation valves (MSV-413 and MSV-414).

## 3.0 Current Licensing Basis:

Per the drawings listed above, these two hangers are on piping qualified to B31.1-1967 piping code. This is required per FSAR Section 1.3.2.12.

## 4.0 Description of Identified Concern:

Two Main Steam Hangers, MSH-13B, and MSH-27B were found on a routine walkdown to have bent rods. Both pipe supports are classified as rod hangers. That is, they are designed only to resist the vertical down load of the piping they are supporting. This type of pipe support is not designed for supporting vertical up load, lateral load, or axial pipe load. Pipe support drawings for these hangers show the rods to be 2" in diameter.

## 5.0 Impact Analysis and Reliability Considerations:

These hangers are downstream of isolation valves. Failure of these hangers might lead to a Main Steam line break downstream of these valves. Main Steam line failures are discussed in detail in Chapter 14 of the FSAR. This analysis assumes several break locations and the worst scenario is failure of all steam lines outside the

Reactor Building. As discussed in FSAR Section 14.2.2.1.5, Case III, this scenario does not result in unacceptable challenges to the safety of the plant.

## 6.0 PSA Evaluation:

The low frequency associated with a seismic event in Florida reduces any concern associated with a seismically induced Main Steam line break caused by failure of these rod hangers. Furthermore, a seismically, or non-seismically, induced Main Steam line break is not considered a significant risk contributor to the core damage frequency at CR3.

## 7.0 Operability Evaluation:

These two pipe supports are rod hangers. This type of pipe support transfers the vertical down pipe loads using a clamp around the pipe, tied to the supporting structure using round rod tension member.

A review of the loads associated with these two supports (piping analyses CR-5 and CR-6) and a check of the support members and their associated capacities has been done (Reference 10.6). It is engineering's position that the hangers will perform their intended vertical load function in their current condition.

As stated above, these two supports are designed to withstand the vertical down load from the pipe. The bend in the rod does not affect this function. The bend will not affect the capacity of the rod. If the hanger rods see their design load, then this load would only serve to "straighten out" the rod to its normal position. This is based on the ductile nature of the rod material.

The bent rods are fabricated from carbon steel. The hanger drawings show the rods to be made with ASTM A575 material. The exact grade of A575 material is not specified on the hanger bill-of-material. An inspection of the ASTM shows the majority of A575 grades (8 out of 10) to have a carbon content of less than 0.30%. Generally, a carbon content of less than 0.30% is considered mild steel and the material can be considered ductile. The two grades of A575 that have carbon content between 0.30% and 0.50% fall outside of the mild steel classification but are still ductile. Reference 10.8 states that steel with higher levels of carbon will see some decrease in ductility. Per, Reference 10.8, the percent ductility at a carbon content of 0.30% is around 30%. At a carbon content of 0.50% the percent ductility drops to around 20%. This approximate 10% drop is ductility (for the higher carbon content grades) is still considered acceptable.

Based on the above, cold bending at the radius shown by the bent bars does not reduce the load carrying capacity of these rods.

In addition to the above discussion on the rod hangers, a review of the piping and adjacent supports was also done. This review/walkdown found no evidence of damaged pipe supports. No damage to support base plates or grout pads. No indications of anchor bolts slippage or damage. No indication of damaged or overstressed welds.

Adjacent snubbers and spring can components all appeared adequate. The snubber struts appeared acceptable. No evidence could be found of snubber fluid leaks. The spring cans appeared to have all the travel stops removed. The springs all appeared to have adequate travel clearance in both directions.

There were some areas were insulation was damaged, missing, or not sealed completely. Engineering considers this to be due more to lack of good housekeeping or normal pipe vibrations than to any sort of system failure.

The walkdown showed no significant damage to piping, pipe supports, or other attached smaller piping. Whatever the cause of the bent hanger rods (MSH-13B and MSH-27B) there is no evidence of collateral damage to other components.

## 8.0 Justification for Continued Operation:

As stated above, the rod hangers are considered operable for all plant modes. There is no loss of strength in the rods and the rods can perform their design function.

## 9.0 Corrective Action to Obtain Full Qualification:

The bent rods have been determined to be operable. However, the rods should be replaced simply because it is good work practice to do so.

## 10.0 References:

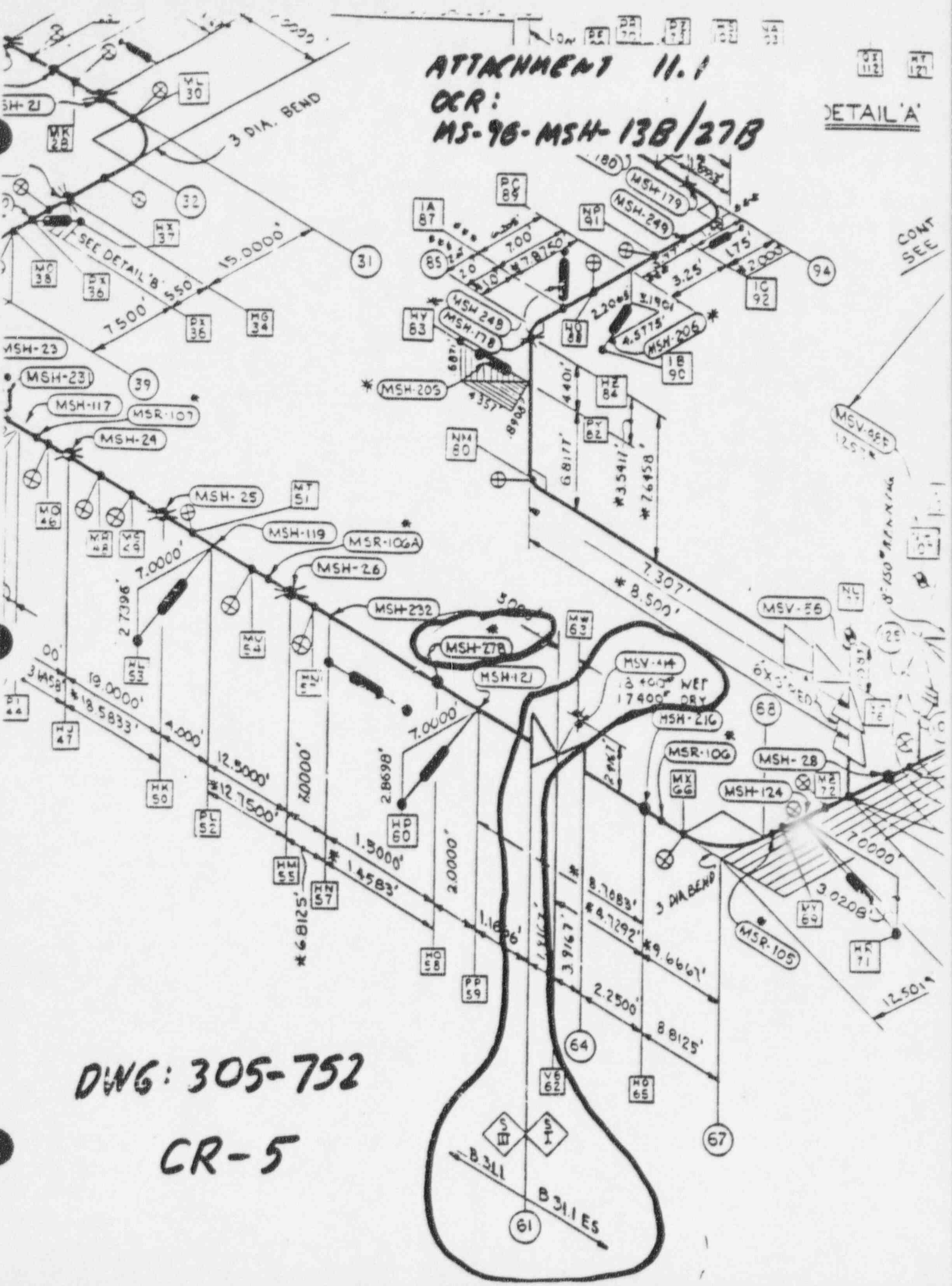
10.1 Precursor Card 96-2535
10.2 Problem Report 96-0180
10.3 302-011, Sheet 1, Revision 57
10.4 305-752, Revision 2
10.5 305-753, Revision 1
10.6 CC:Mail's from Joe Lese, dated 5/13/96

10.7 CC:Mail from Ed Morea, dated 5/15/96
10.8 "Element of Material Science and Engineering," by Van Vlack, Pages 354 and 355

## 11.0 Attachments and Figures:

11.1 Partial Copy of Drawing 305-752
11.2 Partial Copy of Drawing 305-753
11.3 Photographs of two hangers in the as-found condition

ATTACHMENT 11.1
OCR:
MS-96-MSH-13B/27B

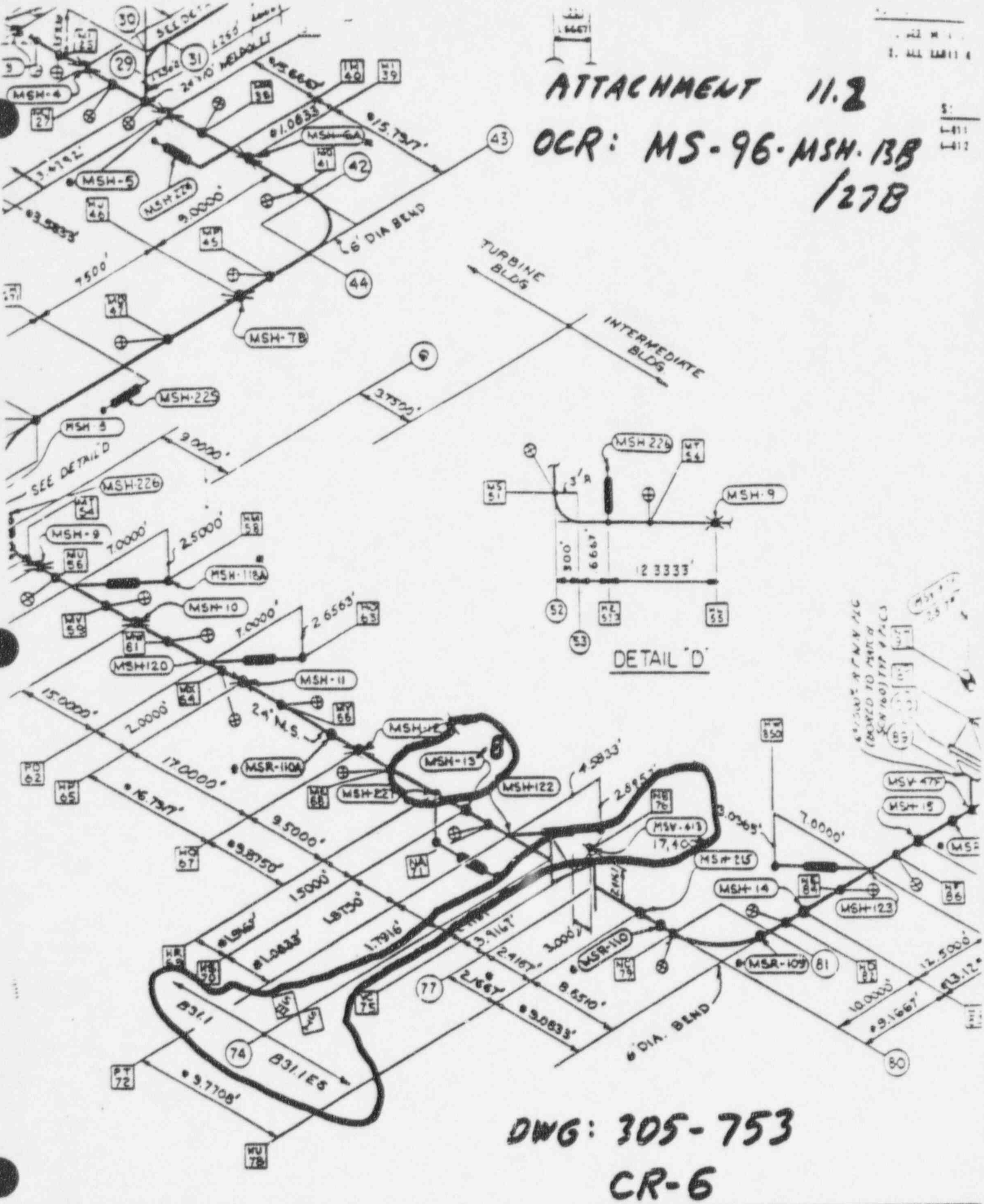



DWG: 305-752

CR-5

ATTACHMENT 11.2

OCR: MS-96-MSH-13B /27B

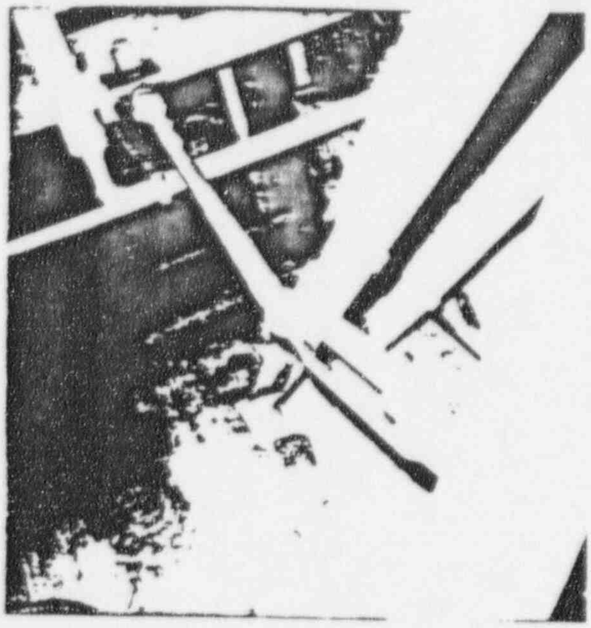



DWG: 305-753

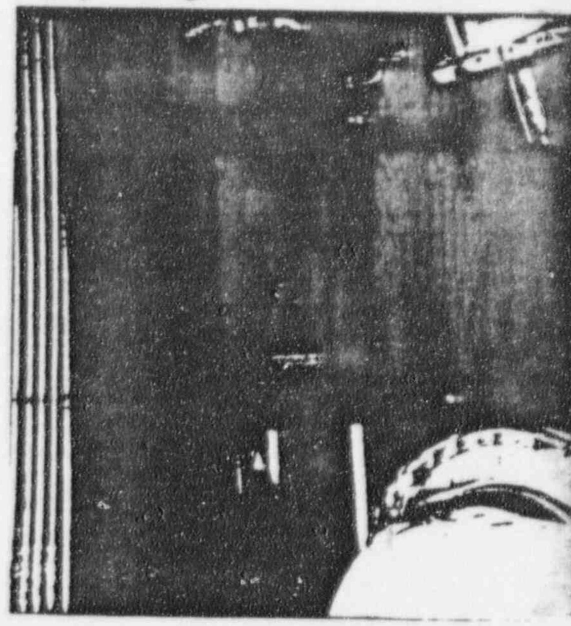
CR-6

ATTACHMENT 11.3

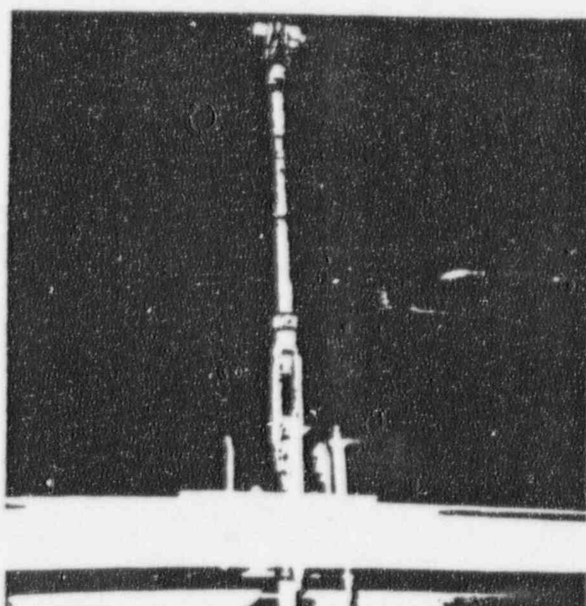
OCR: MS-96-MSH-13B/27B



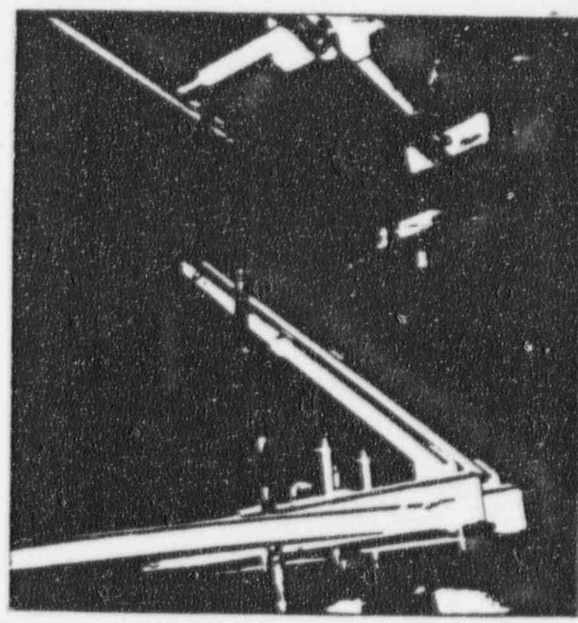
MSH - 13B



MSH-13B (ON LEFT)



MSH - 27B



MSH- 13B

# PROBLEM REPORT PR 96 -0180



**PART 1A: INITIATION**

**Title: HANGERS MSH-13B AND MSH-27B BENT**

| covery Method: VISUAL OBSERVATION | Discovery Date: 5/10/96 | Occurrence Date & Time: UNKNOWN | Precursor Card Number 96-2535 |
|---|---|---|---|

| Plant Condition: MODE 3, OTSG-LLL, NORMAL SYSTEM PRESSURE AND TEMP | Equipment Tag Number(s): HANGERS MSH-13B AND MSH-27B |
|---|---|

| Plant Location: [Building] INTERMEDIATE BUILDING 119' | [Elevation] 119' | [Area/Room] |
|---|---|---|

Description of the Condition/Event: WHILE IN THE INTERMEDIATE BUILDING, AN OPERATOR NOTICED A VERTICAL HANGER ROD ON THE B-1 STEAM LINE, DOWNSTREAM OF THE MSIV THAT APPEARED TO BE BENT, POSSIBLE FROM IMPACT AGAINST A HORIZONTAL SUPPORT. FURTHER INVESTIGATION REVEALED THAT THE IDENTICAL SUPPORT ON THE B-2 STEAM LINE DOWNSTREAM OF MSV-414 WAS ALSO BENT, BUT NOT TO THE SAME EXTENT. A PRECURSOR CARD WAS WRITTEN AND OCR WAS GENERATED (OCR MS-96-MSH-13B/27B)

Is this problem a Radiological Safety Concern?
[ X ] NO [ ] YES Immediately contact HP Supervisor for proper documentation.

Requirement(s) Violated: NONE

sociated/Related Documents: N/A

Immediate Actions Taken: NOTIFIED SHIFT MANAGEMENT AND DESIGN ENGINEERING

| Originator: RAWLS, R.E | Date: 5/29/96 |
|---|---|

**PART 1B: EVALUATION**

| This PR has been evaluated for operability **[SSOD Signature]:** [signature] | System/Train Safety Function Lost: N/A |
|---|---|
| [ ] **KNOWN DBI** [ ] **SUSPECTED DBI** [ X ] **Not a DBI** | **Severity Level:** Ø |

| | NO | YES | |
|---|---|---|---|
| **REPORTABLE:** | X | | Part 2 required if YES |
| **TECHNICAL SPECIFICATION VIOLATION:** | X | | |
| **UNPLANNED RELEASE:** | X | | |

**Recommendations for Resolving the Problem:** MODIFY OR REPLACE HANGER

| **Recommended Responsible Organization:** NED | **Responsible Manager: MASEDA** |
|---|---|
| **Shift Manager:** [signature] | **PR Issue Date:** 5-29-96 |

**PROBLEM REPORT** PR 96-0180 Page: ___

## PART 3 - SECTION A: PROBLEM INVESTIGATION AND CAUSE ANALYSIS

(1) Method of Performing Cause Analysis: [ ] Structured Analysis [X] Deductive Logic

(2) CHECK ALL CAUSES THAT APPLY, AND FILL IN CAUSE CODES:

**Human Performance**

| | | | | | |
|---|---|---|---|---|---|
| [ ] Verbal Communication | | [ ] Work Organization/ Planning | | [ ] Change Management | |
| [ ] Written Communication | | [X] Work Practices | F5Z** | [ ] Resource Management | |
| [ ] Training/Qualification | | [ ] Supervisory Methods | | [ ] Environmental Conditions | |
| [ ] Work Schedule | | [ ] Managerial Methods | | [ ] Interface Design or Equipment Condition | |

**Equipment Performance**

| | | | | | |
|---|---|---|---|---|---|
| [X] Plant/System Operation | P2Z** | [ ] Maintenance/Testing | | [ ] Design Config/Analysis | |
| [ ] Equipment Spec/Mfg and Construction | | [ ] External | | | |

** Bending of existing structural component due to unanticipated loading

(3a) Primary Cause(s):

The primary cause of the two bent hanger rods is buckling or bending in the rods due to excessive, or inappropriate, loads. The hanger rods are primarily designed to withstand only vertical dead load. They are not designed to withstand vertical up loading, or lateral loads.

The exact cause of the bent rods cannot be determined at this point. Engineering believes the primary cause of the rods bending is from uplift on the pipe, or by some sort of rigging off of the rod hangers that caused bending in the rods. These items are discussed further on the continuation page.

The piping analysis shows these two hangers to be basically deadweight rod hangers. The current analysis load sheets show dead weight, thermal, and seismic loads existing on these supports. There is a an uplift seismic load component in the analysis. However, this is due to an abnormality in the analysis technique used. Any uplift load that caused the bent rods would be due o an unanalyzed load case.

Continued:

(3b) Secondary Cause(s):
See Section 3a.

(3c) Contributing Factor(s) :
See Section 3a.

(4) SUPPORTING INFORMATION (IF APPLICABLE):

| | | |
|---|---|---|
| LER No: | PROCEDURE No: | WR No: |
| OTHER: | | |

(5) Previous Similar Events/Conditions
None

(6) Manufacturer/Nameplate Data:
n/a

(7) Nonconforming Equipment/Material Disposition:
[ ] N/A (no nonconforming equipment or material involved) [ ] Accept-As-Is* [ ] Repair* [X] Rework
[ ] Other (describe): ______
* Engineering Justification and Approval Required for these Dispositions (obtain documentation and attach)

(8) Maintenance Preventable Functional Failure (MPFF):
[ ] No [ ] INITIAL [ ] REPETITIVE

PROBLEM REPORT PR 95 - 0180

PART 3a: CONTINUATION SHEET

There are two main possibilities for the bent rods. The first possibility considered is that some sort of system transient caused a large vertical up load that then caused the rod to buckle in compression. This system transient may have been the result of a waterhammer, steamhammer, cycling of the MSIV's, cycling the governor valves, or even a turbine trip.

Any one of the load sources mentioned above might have caused the pipe to jump up. However, an inspection of adjacent pipe supports, attached piping, and other components show no other collateral damage. Also, no reports of recent waterhammer or steamhammer events have been reported to NED on this section of piping. A section of this piping was subjected to waterhammer several years ago. The piping and supports were inspected at that time. These hangers were not damaged by that past event. The results of a transient load due to valve cycling is considered to have less of an impact of the supports than a transient due to waterhammers or a turbine trip.

One of the steps taken to verify if the rods bent due to a transient load was to examine the adjacent piping, pipe supports, and other attached components. A walkdown was done that found no evidence of damaged pipe support.. No damage to support base plates or grout pads. No indications of anchor bolts slippage or damage. No indication of damaged or overstressed welds.

Snubbers and Spring Can components of supports near the bent rods all appeared adequate. The snubber struts appeared acceptable. No evidence could be found of snubber fluid leaks. The spring cans appeared to have all the travel stops removed. The springs all appeared to have adequate travel clearance in both directions.

There were some areas were insulation was damaged, missing, or not sealed completely. Engineering considers this to be due more to lack of good housekeeping or normal pipe vibrations than to any sort of system failure.

Therefore, if the cause of the bent rods was due to some sort of transient load, no evidence could be found that would indicate a concern for the remainder of the system.

The other main possibility for the bent rods is related to some sort of maintenance activity. Such as vertical uplift loads being placed on the pipe during maintenance activities on the adjacent isolation valves. If sufficient force was applied while trying to remove the operator, and the operator stuck, then the force would apply uplift to the pipe. This uplift might have been enough to buckle to rods.

Related to maintenance activities causing the bent rods is that some lateral, or bending, load was applied to the rods. This load may be due to some type of temporary "rigging" load applied to the rod, just above the turnbuckle. The exact source of the rigging load cannot be determined.

Bending of these hanger rods is considered an isolated case. There is no evidence this is a generic concern or that other hangers require investigation.

It should be noted; that the Safety Class and ISI Class of these supports is not currently specified in the CR3 Configuration Management System (CMIS). The Seismic Class is established as Class III, or non seismic (this is in agreement with the piping classification). The safety classification and the ISI classification needs to be better established to insure proper evaluation of the significance of these and similar supports during maintenance activities. A CMIS code key should be developed. It would identify pipe supports, supporting nonsafety piping, that are required to ensure the integrity of safety related piping.

# PROBLEM REPORT

PR 96-0180

Page ___

PART 3 - SECTION B: Corrective Action Plan (CAP)

(1) Corrective Action Plan:

| ACTIONS | SCHEDULED COMPLETION | ASSIGNED ORGANIZATION/INDIVIDUAL |
|---|---|---|
| 1. Complete Operability Concern Resolution (OCR) | Completed | NED - Structural, A. Petrowsky |
| 2. Replace bent hanger rods on MSH-13B and MSH-27B. ~~Hanger rods may be replaced when piping is not in service (11R).~~ | ~~12/1/98~~ ~~7/1/96~~ AP Completed AP | Maintenance, & Scheduling Jerry Campbell/ H. Koon FMC |
| 3. Complete piping class break review and revision of support safety, ISI, and seismic classifications. This is necessary to assure that supports in vicinity of class breaks are correctly classified to preserve the integrity of the class break. | 12/1/96 | NED - Structural, A. Petrowsky |
| 4. Structural Design Supervisor to review current training program for rigging and provide comments to training. This will be accomplished by auditing training class on rigging. | 10/1/96 | NED - Structural Design Supervisor, A. Petrowsky |
| 5. Maintenance to develop appropriate "Study Books" on rigging practices. This is to ensure rigging off of piping, conduits, and supports is done so no damage results from the rigging. Reference Problem Reports recently issued that indicate damage to plant components might have been due to rigging. For example, this Problem Report (96-0180); Problem Report 96-0155, "RWH-66A Embedded Plate Concrete Spalling;" Problem Report 96-0101, "RW Spool Piece (RW-56) Lower Flange Alignment Rejection." | 12/1/96 | Maintenance, Jerry Campbell FMC |

(2) ADDITIONAL CAP INFORMATION: None

(3) Developed by (print & sign): C. Glenn Pugh C Glenn Pugh AP 6/13/96

(4) Responsible Organization Approval by (print & sign): JOE R. MASCOA [signature] Date: 6/14/96

(5) NSM CAP Concurrence: (print & sign): L. MOFFATT [signature] Date: 6/27/96

PART 3C: FINAL REVIEW OF COMPLETED CORRECTIVE ACTIONS BY THE TTG

Comments:

(2) TTG Final Package Review (print & sign): Date:

WHEN COMPLETE, TRANSMIT TO TTG.

PRC Addition to PR 96-0180

The normal process for processing operability concerns was not followed in this case. The normal process is to write a problem report, develop a CP-150 OCR, and then make an operability determination. In this case, the operability determination was made first, then the OCR, and now the problem report. An investigation needs to be performed on the use of this process and ensure th individuals involved understand the process. The NSS involved has already been coached on the use of the process.

G.H. Halnon 5/3-96
PRC Chairman

NEW STEP #6 Follow up with G. Halnon indicates a step should be added to the PR to: "Determine why the process was not followed and establish appropriate corrective actions." Due Date 7-31-96 Responsibility: ~~G. J. Hickle~~ D. Demontfort

I Concur.

for FX Sullivan