SEISMIC REANALYSIS OF THE BURIED EMERGENCY SERVICE WATER LINES OYSTER CREEK NUCLEAR GENERATING STATION

prepared for

Jersey Central Power and Light Company
Morristown, New Jersey

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SEISMIC REANALYSIS OF THE BURIED EMERGENCY SERVICE WATER LINES

Introduction

This report summarizes the results of the seismic reanalysis by URS/John A. Blume & Associates, Engineers, of the buried emergency service water lines at the Oyster Creek Nuclear Generating Station. The seismic analysis of these pipes by John A. Blume & Associates in 1967[1] was based on the prevailing state of the art at the time. Currently acceptable procedures are used in the reanalysis to calculate the seismic stresses induced in the pipes by the Safe Shutdown Earthquake SSE). These calculated stresses are below allowables except at one bend location. There, however, they are localized, and the conservative inelastic analyses presented herein show that they are not high enough to impair the safety of the pipes during an SSE.

Description of Pipes

The two 14-in.-diameter buried emergency service water lines extending from the intake structure to the turbine building[2] are shown schematically in Figures 1 and 2. The two pipes emerge from the intake structure at elevation 1 ft 6 in. and following a series of vertical and horizontal bends (see Figures 1 and 2), enter the turbine building at elevations 15 ft 9 in. and 17 ft 0 in., respectively. The pipes are assumed fixed to the intake structure, which is the case that would produce maximum stresses in the pipe, and are assumed free at the turbine building. The structural drawings[2] show the pipes entering the turbine building through sleeves set in the concrete walls below grade, and an on-site inspection[3] confirmed that the pipes are not fixed to the turbine building walls at the point of entry. The pipes are 1/2 in. thick and made of ASTM A-53 steel grade A or B[4] which has a minimum yield strength of 30 ksi and an ultimate strength of 48 ksi.[5] The allowable design stress intensity (3 S_m for SSE) is 48 ksi[5] and the modulus of elasticity (E_s) is taken to be 29,900 ksi.

Analysis Procedures

The seismic analysis of the buried service water lines closely follows the procedures outlined in References 6 and 7. This approach assumes that the soil surrounding the pipes consists of a homogenous elastic material, that a wave motion propagates in one direction without interference from other waves in other directions, and that the variation in the shape of the wave between the two points considered along the pipe is relatively small. The procedure used calculates stresses in the pipe for the case where the total seismic input propagates through the soil in the form of either S, P, or surface (Rayleigh) waves.

The pipe is analyzed as a series of bends and straight segments. Normal stresses are calculated for all three wave types with angles of incidence that produce maximum stresses in the pipe. The normal stresses are due to moment and axial force at the elbows, while only axial stresses are considered in the straight segments since bending stresses in long straight segments are generally very small.

The seismic input used is based on the earthquake design criteria[8] used to qualify the plant seismically. A peak ground acceleration (A_m) of 0.22g is used, and the peak ground velocity (V_m) is estimated, as recommended in Reference 6, to be:

$$V_m = (48 \text{ in./sec})\, A_m \tag{1}$$

The soil properties used in the analysis are:

Dry weight density of soil (γ_α)	=	103 pcf
Wet weight density of soil (γ_ω)	=	122 pcf
Poisson ratio (ν)	=	0.39
Soil/pipe friction factor (μ)	=	0.25
Shear wave velocity (C_s)	=	600 fps

Discussion of Results

The maximum combined normal stresses in each pipe segment of the two buried emergency service water lines are given in Table 1 and 2. The tables show the total normal stresses, and also the component parts of these stresses due to moment and axial force.

The normal stresses in the pipe are less than the 48 ksi allowable except at bend D, where the stresses go up to a maximum of 59.7 ksi in line 1 and 62.5 ksi in line 2 when calculated on an elastic basis. Since the analysis gives moments at bend D that are higher than yield moments, estimates of curvature and displacement ductilities associated with these moments were calculated.

The calculation of curvature ductilities was based on reserve energy procedures,[9, 10] and assumed an elastic-perfectly plastic moment-curvature relationship for the steel pipe. This is a simplified procedure for estimating ductilities from results of elastic analyses and, in general, gives conservative estimates of ductility.

Displacement ductilities were calculated by dividing the maximum relative displacement between points E and D by the relative displacement that produces a yield moment at bend D. The elastic analyses used to calculate the relative displacements were based on the procedures described above. A yield stress of 30 ksi was used to calculate the yield moment. Redistribution of forces to the rest of the pipe system because of yielding at bend D was neglected in the ductility calculation. This resulted in more conservative value for the ductility demands on the pipe.

Using these procedures, curvature ductilies at bend D of 2.00 and 2.14, and displacement ductilities of 1.72 and 1.80, were calculated for lines 1 and 2, respectively. These low ductility demands would not cause distress in the pipes.

In our judgment high stresses at bend D do not pose a hazard to the safe operation of the pipes. The following mitigating facts:

1. Because of the complexity of the problem, the analytical procedure developed to solve it uses simplified assumptions that produce exaggerated stress levels in the pipes.

2. The high stresses occur only in the case of the idealization that segment EDC of the pipe is a bend with free ends at E and C and that the seismic motion arrives in the form of surface body waves and at an angle of incidence that produces maximum stresses. By neglecting the partial restraint due to segment EF, this analysis produces higher moments at bend D than would a more rigorous analysis, in which the restraint was accounted for.

3. The stresses considered will be effective for only a short time--the duration of the highest pulses of an SSE.

4. According to the analytical procedure used, the highest moments in buried pipes occur as a result of soil/pipe differential motion at bends or elbows. These moments reduce away from the bend because of soil bearing pressure against the pipe. The bearing pressures are calculated on the assumption that the pipe is a beam on an elastic foundation. The distance from the bend at which the moment becomes negligible, which is normally short, is a function of the pipe stiffness and the soil coefficient of subgrade reaction.

   Axial force in the pipe due to friction between the soil and the pipe's circumference increases away from the bend until it reaches its limiting value. After that there is slippage between the soil and the pipe. Hence, the normal stresses in the pipe are due primarily to moment at the bends and axial force along the straight segments away from the bends. Given this assumed behavior of buried pipes, the following comments could be made about the high stresses calculated at bend D:

   a. The high stresses are localized at bend D and the normal stresses due to moment get smaller away from the bend. The maximum normal stress in segment DE away from bend D reduces from 59.72 ksi to 10.20 ksi in line 1 and from 62.52 ksi to 10.70 ksi in line 2.

   b. According to the computed high stresses, the pipe material may yield at bend D. However, since the high stresses are localized and the steel pipe is highly ductile, the stresses will redistribute themselves quickly over some length near the bend without any distress.

5. If we make the very conservative assumption that the strains in the pipe at bend D that have been calculated actually occur and that no redistribution of forces takes place to relieve them, in this case the pipe could still maintain its integrity if it had enough ductility to undergo these plastic deformations. The ductility demands on the pipe in this case have been estimated at a maximum of 2.14 curvature ductility and 1.80 displacement ductility. These low values would not interfere with the safe operation of the pipe.

Conclusion

The buried emergency service water lines 1 and 2 were analyzed and their response to SSE motions calculated. The analytical procedure used is in keeping with the current state of the art, but is conservative nonetheless. The stresses calculated are below code allowables for all segments of the lines except at bend D (see Figures 1 and 2). The higher stresses at this bend are not expected to impair the safety of the pipes or their safe operation during an SSE.

REFERENCES

1. *Jersey Central Reactor Project, Earthquake Analysis: Buried Emergency Service Water Lines,* for General Electric Co., November 20, 1967.

2. Burns and Roe, Inc., Jersey Central Power and Light Co., Oyster Creek Station - Unit #1, Drawings:

2117-6	2192	2194-6	2196-6
2120-6	2193-7	2195-5	4087-7

3. Record of Telephone Conversation with William Schmidt of MPR Associates, August 24, 1979.

4. Oyster Creek Specification (W.O.2299) #60-C for the Emergency Service Water System, pp. II-47 and II-48.

5. American Society of Mechanical Engineers, *ASME Boiler and Pressure Vessel Code, Section III, Division I - Nuclear Power Plant Components, Subsection NB - Class 1 Components,* New York, 1977.

6. Goodling, E. C., "Flexibility Analysis of Buried Piping", *Proceedings,* Joint ASME/CSME Pressure Vessels and Piping Conference, Montreal, June 1978.

7. Shah, H. H., and Chu, S.L., "Seismic Analysis of Underground Structural Elements", *Journal of the Power Division,* vol. 100, no. PO1, July 1974.

8. Housner, G. W., *Recommended Earthquake Design Criteria for the Jersey Central Nuclear Reactor Project,* March 4, 1964.

9. Blume, J. A., "A Reserve Energy Technique for the Earthquake Design and Rating of Structures in the Inelastic Range," *Proceedings,* Second World Conference on Earthquake Engineering, Tokyo, 1960, vol. 2, pp. 1061-1084.

10. Blume, J. A., Newmark, N. M., and Corning, L. H., *Design of Reinforced Buildings for Earthquake Motion,* Portland Cement Association, 1961.

TABLE 1

MAXIMUM NORMAL STRESSES IN BURIED EMERGENCY SERVICE WATER LINE 1

Pipe* Segment	Normal Stress (ksi)		
	Due to Moment	Due to Axial Force	Total
AB	26.94	8.51	35.45
BC	26.94	2.84	29.78
CD	51.80	7.92	59.72
DE	51.80	2.64	54.44
EF	28.43	4.35	32.78
FG	27.91	1.45	29.36
GH	15.33	2.34	17.67
HI	15.33	0.78	16.11

*See Figure 1

TABLE 2

MAXIMUM NORMAL STRESSES IN BURIED EMERGENCY SERVICE WATER LINE 2

Pipe* Segment	Normal Stress (ksi)		
	Due to Moment	Due to Axial Force	Total
AB	30.12	9.51	39.63
BC	30.12	3.17	33.29
CD	54.23	8.29	62.52
DE	54.23	2.76	56.99
EF	28.43	4.35	32.78
FG	27.91	1.45	29.36
GH	13.85	2.13	15.98
HI	13.85	0.71	14.56

*See Figure 2

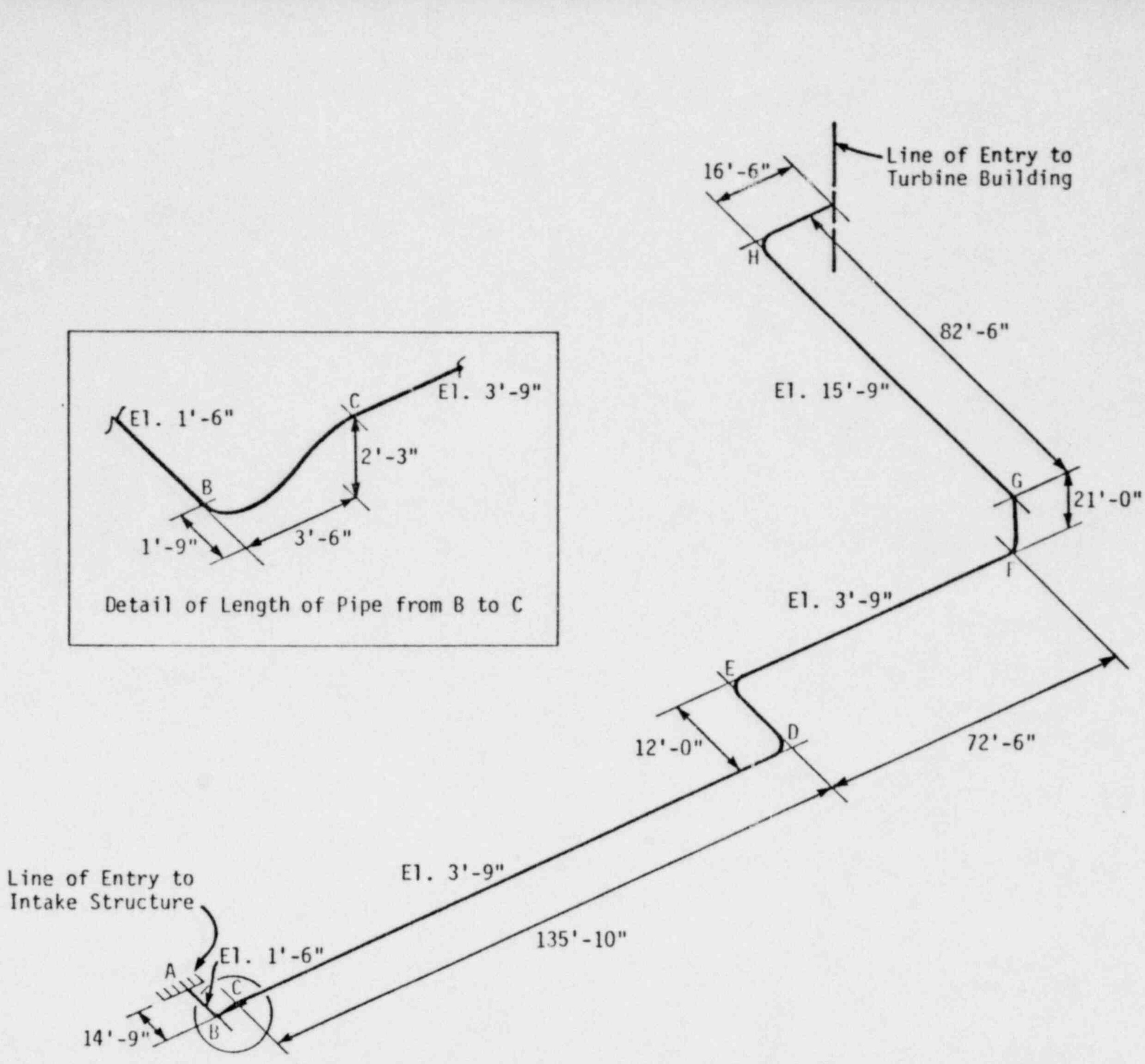

FIGURE 1 BURIED EMERGENCY SERVICE WATER LINE NO. 1

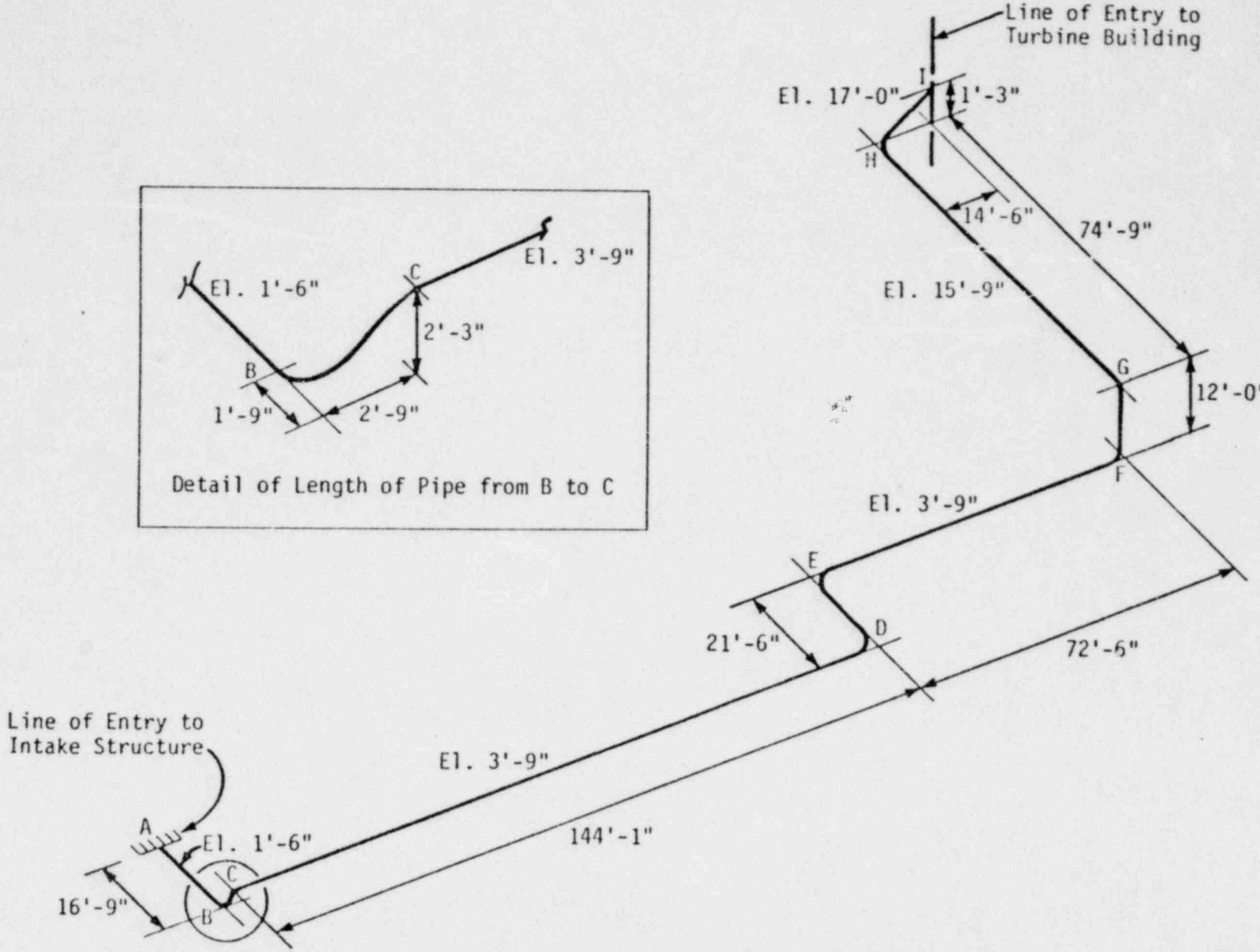

FIGURE 2 BURIED EMERGENCY SERVICE WATER LINE NO. 2

EVALUATION OF VALVE ECCENTRICITY ON PIPING SEISMIC STRESSES

As part of JCP&L's review of the seismic design of Oyster Creek, approximate analyses of the effect of eccentric masses due to valve operators on seismic stresses in the attached piping were made. Results of these analyses for typical 6-, 8- and 10-inch motor operated valves were transmitted to the USNRC (Mr. T. V. Wambach) by JCP&L (Mr. T. E. Tipton) letter dated August 24, 1979. Subsequently, USNRC (T. V. Wambach) letter dated September 4, 1979 to JCP&L requested additional information on the effect of the eccentric mass of valve operators in smaller (1" to 4") lines.

JCP&L has identified two applications of valves with operators in safety related piping systems less than 4" in size. These are the 2" motor-operated recirculation system bypass valves and a 1-1/2" air operated valve in the CRD hydraulic system. The 2" motor-operated valve has been selected for evaluation on the basis that the motor operator represents the worst-case eccentric mass in these small lines.

Results of analyses which are attached show that the effect of the valve operator eccentric mass on piping stresses is small (less than 1100 psi) and has no significant effect (i.e., less than 10% effect) on the total piping stress.

Title: Evaluation of Effect of Eccentric Mass on Piping Seismic Stress

Project: OCNGS

Calculated by: WRS Date: 12/6/79
Checked by: J. Tohmeon Date: 6-11-80
Reviewed by: J. Tohmeon Date: 6-11-80
P 1-4

Purpose:

To determine the effect of eccentric mass due to valve operator weight on piping seismic and total stresses.

Analytical Model and Data:

2" Motor gate valves used as recirc isolation valve bypass valves. The valves are shown on Crane Co. Drawing PA-129691 and according to Crane Co. letter dated December 4, 1979, attached, the total valve and operator weight is 155 lbs. The valve center-of-gravity is located 7" from the inlet centerline. The attached piping is 2" schedule 80 with the following properties:

Material: Type 316 Stainless Steel

Outside Diameter: $D_o = 2.375$ in.

Section Moment of Inertia, $I = 0.8679 \text{ in}^4$

Section Modulus, $Z = 0.7307 \text{ in}^3$

Allowable Stress for OBE:

- Pressure, dead weight, seismic loads: $1.2S_h = 20{,}500$ psi
- The above plus thermal expansion: $1.2S_h + S_a = 48{,}000$ psi

Calculations

The maximum stresses in the Oyster Creek recirc bypass piping are reported in Table 16 of MPR Report "Oyster Creek Nuclear Generating Station, Unit No. 1, High Energy Piping Systems Inside Containment, Stress Summary" dated February 6, 1979, as follows:

- Seismic stress (not considering eccentric mass effect) - 3860 psi
- Gravity stress — Included in Thermal
- Pressure — 2970 psi
- Thermal — 6780 psi

13610 psi

The additional seismic stresses due to the valve eccentricity are calculated below.

- Equivalent Static Seismic Load - The equivalent static force to be applied for the worst horizontal component of seismic acceleration is given in the Burns and Roe general piping specifications as 0.43g (This corresponds to 1/2% damping, 0.11g OBE). The maximum vertical seismic force is 2/3 of the horizontal, or 0.29g. Accordingly, the maximum combined horizontal and vertical load on an absolute basis is 0.43g + 0.29g = 0.72g.

- Equivalent Movements on Piping

  The worst-case valve orientation would be one that subjects the piping to a direct bending moment and a torsional moment of the seismic force x distance of valve c.g. to piping centerline. These moments are:

Bending Moment, M_b = 0.72g·(valve weight)·(eccentricity)

= 0.72g (155 lbs) (7")

= 781 lbs-in, and also

Torsional Moment, M_t = 781 lbs-in

- <u>Additional Stress in Piping</u>

The additional stresses are due to the bending and torsional moments carried by the piping at each end of the valve. The amount carried by either end is dependent on the piping stiffnesses. Conservatively assuming that one end of the valve applies 100% of the moments to the piping, the resulting stresses are:

$$\text{Bending Stress} = \frac{M_b}{Z} = \frac{781 \text{ in-lbs}}{0.7307 \text{ in}^3} = 1069 \text{ psi}$$

$$\text{Torsional Stress} = \frac{M_t}{2Z} = \frac{781}{2(.7307)} = 534 \text{ psi}$$

These additional seismic stresses may be combined with pressure, thermal, gravity and seismic stresses (not including eccentric mass effects) as follows.

° Maximum total direct and bending stresses (from above)	13,610 psi
° Additional bending stress due to eccentric mass	1,069
Total bending and direct stress	14,679 psi

- Maximum additional torsional stress - 534 psi
- Combined maximum total stress = $\sqrt{\sigma_b^2 + 4\sigma_t^2}$ - 14718 psi

It is concluded that the additional stresses due to valve operator eccentricity are small and amount to approximately $\frac{14718-13610}{13610}$ x 100, or 8% of the total stress. The allowable stresses are 20,500 psi (excluding thermal stresses) and 48000 psi (including thermal stresses), which are both well above the calculated maximum of 14718 psi.

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CRANE INDIAN ORCHARD PLANT

CRANE CO. • 203 HAMPSHIRE STREET • INDIAN ORCHARD, MASSACHUSETTS 01151

December 4, 1979

MPR Associates, Inc.
1140 Connecticut Avenue, N. W.
Washington, D. C. 20036

Attention: Mr. W. R. Schmidt

Subject: 2" List 608 Motor Operated Gate Valve
Oyster Creek Nuclear Generating Station
G.E. P.O. 205-50679
Crane Order No. CV-07003-5

Gentlemen:

With reference to your letter of November 30, 1979, the subject 2" 600# motor operated gate valve should have a weight of 155#. The approximate location of center of gravity is 7" from center of valve port.

We are attaching drawing PA-129691 covering the valve in question.

If you need further assitance, please do not hesitate to contact us.

Very truly yours,

CRANE CO., INDIAN ORCHARD PLANT

W. F. Lemire, Engineering Services

WFL:db
Enc. PA-129691