August 18, 1973

ROC-01-01

PRELIMINARY REPORT
DYNAMIC ANALYSIS OF FEEDWATER PIPING
FOR WATER HAMMER LOAD
ROBERT E. GINNA PLANT

Prepared for

Rochester Gas & Electric Corp.

by

Nuclear Services Corporation

CAMPBELL, CALIFORNIA

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1.0 INTRODUCTION

This report, prepared for Rochester Gas and Electric Company, describes results of dynamic response analyses of the main and auxiliary feedwater piping systems to steam generator 1B at Robert E. Ginna Nuclear Generating Station. Isometric drawings of the piping analyzed are given in Figures 1-1, 1-2 and 1-3.

The feedwater piping system was subjected to an abnormal transient loading condition on July 22, 1973, when a failure occurred in the stem to disc connection within Feedwater Control Valve 476 causing a sudden decrease in feedwater flow to steam generator 1B. Following the incident, the plant was brought to a shutdown conditions, and an inspection of the piping was made. Evidence was seen indicating that significant deflections had taken place in the main feedwater line to steam generator 1B and in the line from motor driven auxiliary feedwater pump 1B to this main feedwater line. A decision was made to continue with a more detailed examination of the piping and to perform dynamic analyses to determine the magnitude of stresses resulting from the transient.

The analyses have been made based on a time history water hammer forcing function computed by (conservatively) assuming an instantaneous and complete closure of the valve. The results of the analyses report herein include maximum values of stresses, deflections and support loads during the transient.

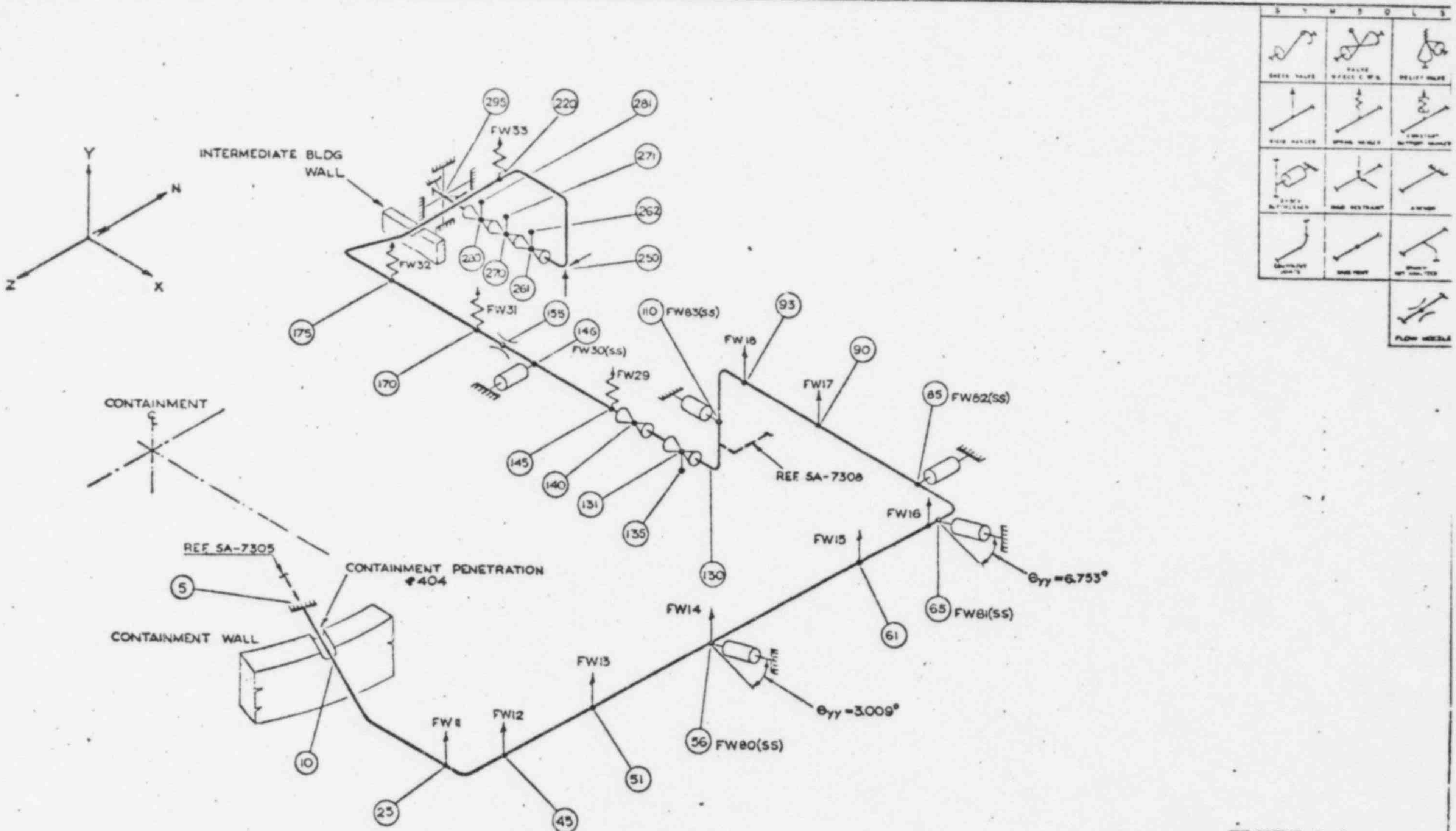

FIGURE 1-1

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R.E. GINNA PLANT - UNIT 1
MATHEMATICAL MODEL
FEEDWATER PIPING

SA-7309

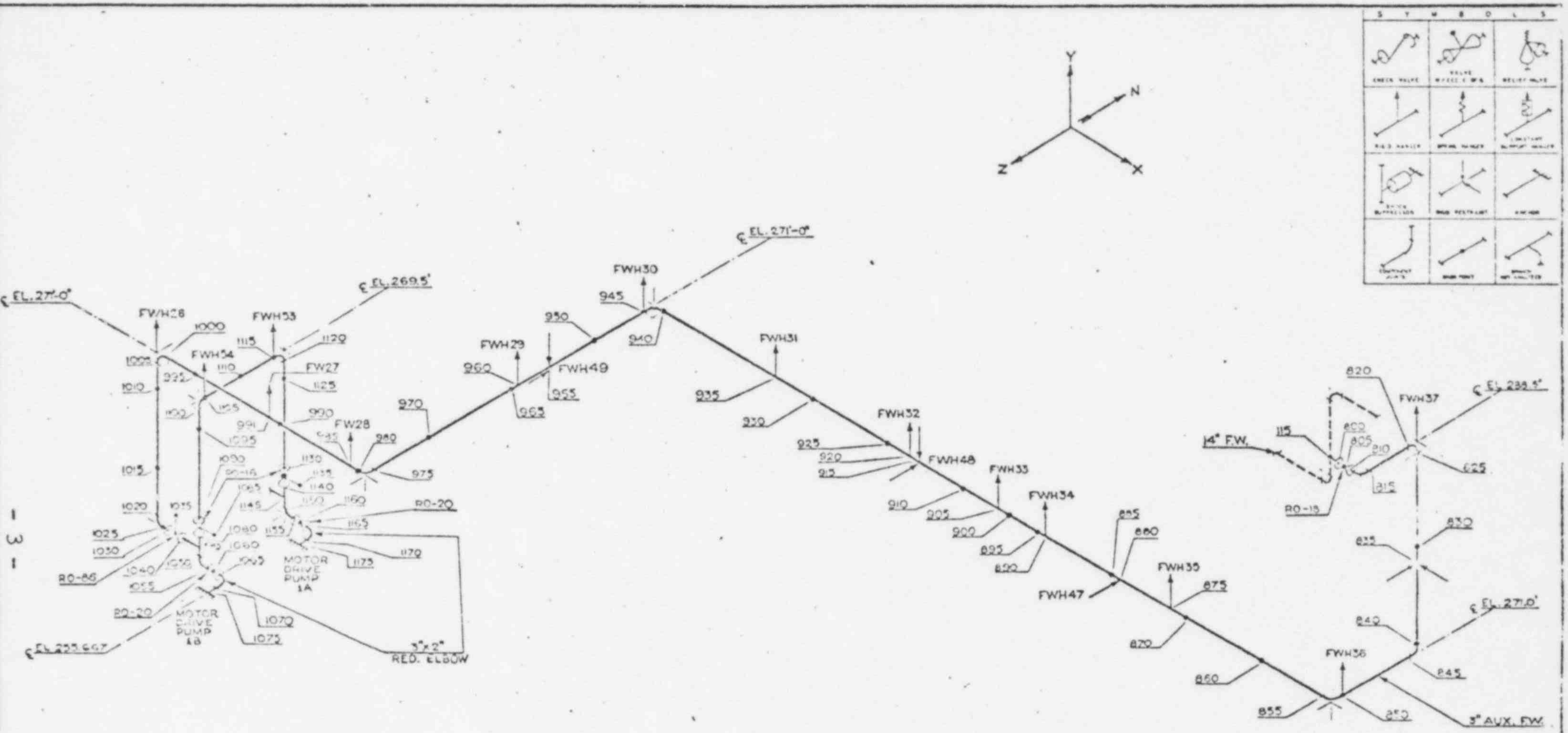

FIGURE 1-2

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GINNA
AUXILIARY FEEDWATER LINE
MATHEMATICAL MODEL

SA-7308

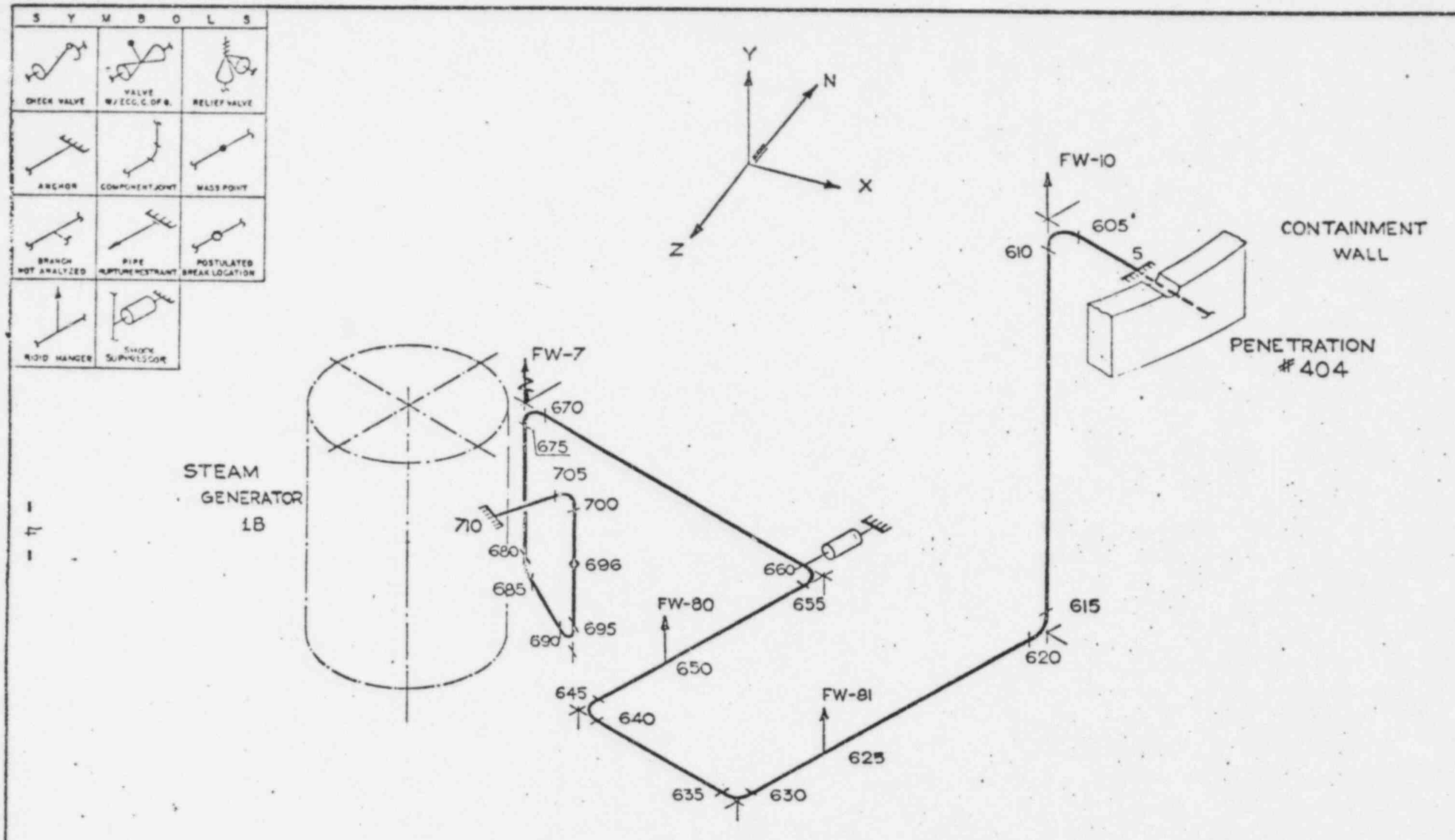

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FIGURE 1-3

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GINNA - FEEDWATER LINE INSIDE CONTAINMENT MATHEMATICAL MODEL

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2.0 PIPING SYSTEM DESCRIPTION

The main feedwater system carries water from the condensate system to the steam generators. In the Ginna plant the feedwater leaving the two high pressure feedwater heaters is joined in a single line. This line terminates at an anchor to the turbine building intermediate floor just outside the intermediate building. From this anchor individual lines branch, leading to the two steam generators inside containment. The main feedwater piping included in this analysis runs from the turbine building anchor, through portions of the turbine, intermediate, and containment buildings, to steam generator 1B. Configuration of the piping and support system was taken from reference 4, and is shown on the isometric drawings Figures 1-1 and 1-2.

The auxiliary feedwater system supplies water to the steam generators in the event of a loss of normal feedwater. The system consists of one steam turbine driven and two motor driven pumps, and piping connecting these pumps to the main feedwater lines. The auxiliary feedwater piping included in this analysis runs from motor driven auxiliary feedwater pump 1B, located on the basement floor of the intermediate building, to a connection to the main feedwater line to steam generator 1B. Configuration of the piping and support system was taken from marked copies of reference 1 supplied by Rochester Gas & Electric, and is shown on the isometric drawing Figure 1-3.

The main feedwater piping is 14" schedule 100, and the auxiliary feedwater piping is 3" schedule 80. Both main and auxiliary feedwater piping are made from A106 Grade C material. Piping properties are summarized in Table A-1 of this report.

3.0 DESIGN CRITERIA

The design specification for this piping is given in reference 5. The main feedwater piping is safety Class 1 between the steam generators and isolation check valves RO-6, and has no safety classification beyond these valves. The main feedwater piping has been designed to meet Class 1 seismic requirements not only in the Class 1 portion itself, but also from the valves RO-6 to the common anchor in the turbine building. The auxiliary feedwater piping is safety Class 1 throughout.

Code requirements for the piping are given by the ANSI B31.1.0 Code for Power Piping (Reference 2).

4.0 LOADING CONDITIONS

4.1 Temperature and Pressure Conditions

The main feedwater is supplied at 432°F and 905 psia in the full load operating condition (Reference 5). The auxiliary feedwater is supplied at 100°F (maximum) and 1250 psia (Reference 5).

4.2 Weight Data

The deadweight and dynamic analyses have considered the distributed weight of piping, insulation and contained water, as well as concentrated weights of valves and flow elements. Eccentric weight of valve operators has been considered where appropriate. Distributed weight data is summarized in Table A-1 and concentrated weight values are given in Table A-2.

4.3 Time History Dynamic Forcing Function

For the time history dynamic analyses, the forcing function has been derived using formulas for water hammer effects and assuming instantaneous and complete closure of the feedwater control valve 476.

Following the valve closure, there is a sudden decrease in flow downstream of the valve, and an expansion wave moves from the valve toward the steam generator at acoustic velocity. The pressure change across this wave is given by,

$$\Delta P = \frac{\dot{\omega} C}{g_c A}$$ (Reference 8)

where

$\dot{\omega}$ = Initial flow rate = 913 lb/sec

C = Acoustic velocity for water at 432°F and 905 psia

= 3500 ft/sec

g_c = 32.2 ft/sec^2

A = Feedwater pipe flow area

= 115.5 in^2

applying the formula, we find

$$\Delta P = 859.2 \text{ psi}$$

As the wave passes in the main feedwater piping from the valve to the steam generator, unbalanced forces exist successively in each straight run of piping during traversal of the wave from beginning to end of the straight run. The forcing function for each straight run has the form of a square pulse, with an instantaneous rise as the wave passes the beginning of the run, a maximum value as the wave traverses the run and an instantaneous decrease to zero as the wave passes the end of the run. The maximum value of the unbalanced force for the main feedwater is given by

$$F = \Delta PA = 859.2\ (115.5) = 99{,}000 \text{ lbs}$$

and traversal time for each run is given by

$$\Delta t = \ell / c$$

where

ℓ = Length of run

c = Acoustic velocity = 3500 ft/sec

When the wave passes the auxiliary feedwater connection, a similar wave with the same pressure drop will begin traveling back toward the auxiliary feedwater pumps, causing transient forces in the auxiliary feedwater piping similar to those in the main feedwater. The maximum value for these forces is given by

$$F = \Delta P A$$

where

ΔP = 859.2 psi

A = Flow area of auxiliary feedwater pipe
= 6.6 in^2

thus

$$F = (859.2)(6.6) = 5671 \text{ lbs}$$

The procedure for computing wave transit times for auxiliary feedwater is similar to that for main feedwater, except that acoustic velocity for water at 100°F is 4987 ft/sec (Reference 9).

The maximum forces and times thus computed were applied to the piping in a time history dynamic response analysis. The forcing functions input in this analysis are summarized in Table A-3. It should be noted that the point of application of a force pulse along a given straight run of pipe is arbitrary, since axial response of the piping is negligible.

5.0 ANALYTICAL PROCEDURES

The method of analysis used was the finite element stiffness approach. In accordance with this, the continuous piping is mathematically idealized as an assembly of elastic structural members connecting discrete nodal points. Nodal points were placed in such a manner as to isolate particular types of piping elements, such as straight runs or pipe, elbows, valves, etc., for which force-deformation characteristics could be categorized. Also, nodal points were placed at discontinuities, such as piping supports, concentrated weights, branch lines, and changes in cross section.

System loads such as weights, equivalent thermal forces, and dynamic inertia forces were applied at the nodal points. Stiffness characteristics of the interconnecting members are related to the effective shear area and moment of inertia of the pipe. The stiffness of piping elbows was modified to account for local deformation effects by the flexibility factors suggested in the ANSI B31.1.0 Code for Power Piping (Reference 2)

The equation of equilibrium for this idealized system may be written, in matrix form, as follows:

$$MU + CU + KU = P - Q + F_g \qquad (1)$$

where:

U = Nodal acceleration vector = U (t)

U = Nodal velocity vector = U (t)

U = Nodal displacement vector = U (t)

M = Mass matrix for assembled system

C = Damping matrix for assembled system

K = Stiffness matrix for assembled system

P = External forces, weights, etc.

Q = Equivalent thermal forces = $\int E\alpha T dV$

F = Dynamic Forces

5.1 Static Analysis

The static equation of equilibrium for the idealized system may be written in matrix form, as follows:

$$KU = P - Q \qquad (2)$$

The nodal unknown displacements can be obtained by solving these simultaneous equations using the Gauss-Siedel method. The nodal displacements are then applied to the individual members, and member stiffnesses used to find internal forces. The nodal displacements at support locations can be used along with the support stiffnesses to determine support reactions.

5.2 Dynamic Analysis

A. Mathematical Model

For the dynamic analysis, the mathematical model is described as a lumped mass, multi-degree of freedom model. The distributed piping mass is lumped at the system nodal points. For the dynamic analysis the equation of equilibrium for the system is:

$$M\ddot{U} + C\dot{U} + KU = F \qquad (3)$$

where

M = Mass matrix for assembled system

C = Damping matrix for assembled system

$\ddot{U}$ = Nodal acceleration vector = $\ddot{U}(t)$

$\dot{U}$ = Nodal velocity vector = $\dot{U}(t)$

F = Applied dynamic forces = $F(t)$

= $M\ddot{U}_g$ For earthquake

$\ddot{U}_g$ = Ground acceleration = $\ddot{U}_g(t)$

This equation is solved for the system dynamic response as follows. First, the frequency equation, obtained by removing the forcing and damping terms from equation (3), is solved for the system natural frequencies and mode shapes. Next, the natural mode shapes are used to affect an orthogonal transformation of equation (3), yielding a series of independent equations of motion uncoupled in the system modes. Then, the uncoupled equations are solved by step-by-step integration to obtain system response in each mode, and the individual modal results are combined to determine the total system dynamic response. The mathematical formulation of these steps is as follows:

B. Natural Frequencies and Mode Shapes

The eigenvalues (natural angular frequencies ω_n) and the eigenvectors (mode shapes Φ_n) for each of the natural modes are calculated by solving the frequency equation:

$$[K - \omega_n^2 M] \{\phi_n\} = \{0\} \qquad (4)$$

where

ω_n = Natural frequency in n^{th} mode

K = Stiffness matrix

M = Mass matrix

ϕ_n = Mode shape vector in n^{th} mode

0 = Null vector

The eigenvalues and eigenvectors are obtained using the Householder - QR algorithm.

C. Dynamic Response

Pre-/and post-multiplication of equation (3) by $[\phi]$, the square matrix of mode shape vectors, constitutes an orthogonal transformation, from which the uncoupled equations of motion shown below are obtained.

$$\ddot{Y}_n + 2\omega_n \lambda_n \dot{Y}_n + \omega_n^2 Y_n = P_n \qquad (5)$$

where

Y_n = Generalized (modal) displacement coordinate for the n^{th} mode ($U = \phi_n Y$)

λ_n = Damping ratio for the n^{th} mode expressed as percent of critical damping

K_n = Generalized stiffness for the n^{th} mode

= $\phi_n^T K \phi_n$

P_n = Generalized force for the n^{th} mode

= $\phi_n^T F$

Solution to these differential equations may be obtained by direct integration, as follows:

D. Time History Integration

To determine dynamic response using direct time history integration, equation (5) is written for finite time increments, for each normal mode, as follows.

$$\Delta\ddot{Y}_n + 2\omega_n\lambda_n\Delta\dot{Y}_n + \omega_n^2\Delta Y_n = \Delta P_n \qquad (6)$$

By assuming linear variation of accelerations during a time step, and making use of kinematic relationships between accelerations, velocities and displacements, equations can be written for the generalized acceleration and velocity increments within a time step, as follows.

$$\Delta\ddot{Y}_n = \frac{6\Delta Y}{\Delta t^2} - \frac{6\dot{Y}no}{\Delta t} - 3\ddot{Y}_{no} \qquad (7)$$

$$\Delta\dot{Y}_n = \frac{3\Delta Y}{\Delta t} - 3\dot{Y}_{no} - \frac{\Delta t\ddot{Y}_{no}}{2} \qquad (8)$$

Where the zero subscript refers to conditions at the beginning of the time step. Substituting these equations into equation (6) we obtain

$$\left\{\frac{6}{\Delta t^2} + \frac{6\omega_n\lambda_n}{\Delta t} + \omega_n^2\right\} \Delta Y_n = \Delta P_n + \frac{6Y_{no}}{\Delta t} + 3\ddot{Y}_{no} + 2\omega_n\lambda_n \left\{3\dot{Y}_{no} + \frac{\Delta t\ddot{Y}_{no}}{2}\right\} \qquad (9)$$

This equation can be solved directly for the generalized displacement, which can in turn be used to find the generalized velocity and acceleration increments using equations (7) and (8). The increments can then be added to the initial

conditions for the current time step to find initial conditions for the next time step.

The total generalized displacement, which is maintained as a running sum of the increments, is expanded using the mode shape vector to form the system total displacement vector. This expansion is performed for each mode for each time step. These modal displacements are then applied to the system to determine internal forces, moments and reactions for each mode for each time step. Finally, the modal responses at each time step are combined directly to form total response for each time step.

5.3 Stress Analysis

The results of the static and dynamic analyses were used, along with input pressure and temperature information, to calculate stresses at the system nodal points. The stresses were calculated in accordance with the requirements of the ANSI B31.1.0 Code for Power Piping (Reference 2).

Stresses in the piping due to bending and twisting are computed by the formula:

$$S_E = \sqrt{S_b^{\,2} + 4S_t^{\,2}}$$

where

S_E = Resultant stress in piping

S_b = Resultant bending stress

$$= \frac{\sqrt{(iM_{bp})^2 + (iM_{bt})^2}}{Z}$$

S_t = Torsional stress = $\frac{M_t}{2Z}$

M_{bp} = Bending moment in plane of member

M_t = Torsional moment

Z = Sectional modulus of pipe

i = Stress intensification factor for elbows, tees and certain other piping elements

Stresses due to internal pressure are given by (See page 10, Reference 2):

$$S_{1p} = \frac{Pd^2}{D_o^2 - d^2}$$

where

S_{1p} = Longitudinal pressure stress, psi

P = Internal design pressure, psi

d = Nominal inside dia. of the pipe, in.

D_o = Nominal outside dia. of the pipe, in.

All the required static, dynamic and stress analyses were conducted using Nuclear Services Corporation computer code NUPIPE, Reference 7.

6.0 CONCLUSIONS AND RECOMMENDATIONS

In accordance with the ANSI B31.1.0 Code for Power Piping (Reference 2) the allowable primary stress for the piping material at operating temperature is 21,000 psi (1.2 S_{hot}) and the yield stress at operating temperature is 40,000 psi.

During the week following the incident, preliminary analyses were made for the main feedwater piping, which indicated that this piping exceeded allowable stress, but not yield, at the containment penetration and at hydraulic snubbers FW-82 and FW-83. These results were reported to Rochester Gas and Electric on July 26, 1973, so that they could begin examination of the highly stressed areas of the piping. Subsequently, the analytical model was expanded to include the auxiliary feedwater piping, and additional analyses were performed. The latter analyses, reported herein, indicate high stresses in the auxiliary feedwater line near its intersection with main feedwater, in addition to the locations on main feedwater summarized above. It is recommended that piping be examined for damage in the highly stressed areas mentioned. A complete summary of calculated stresses is given in Table A-4.

Substantial loads were calculated for the piping anchors in the turbine building, at the containment penetration #404, and at the steam generators. These anchors should also be inspected. Calculated anchor loads are summarized in Table A-5.

Reaction forces calculated in the analyses indicated an overload on hydraulic snubbers FW-82 and FW-83, and significant loads on hydraulic snubbers FW-30 and FW-80. These snubbers should also be inspected. A summary of calculated piping support loads is given in Table A-6.

Peak deflections calculated were about 2-1/2 inches for the main feedwater line and 5 inches for the auxiliary feedwater line. A summary of calculated deflections is given in Table A-7 and a comparison of calculated deflections with some deflections observed by inspecting the piping after the transient (Reference 6) is given in Table A-8. The observed deflections were taken with the pipe in its hot position, were estimated by noting crushing of piping insulation caused by pipe contact with adjacent structure, and are, of course, approximate.

7.0 REFERENCES

1. Westinghouse Electric Corporation, Drawing D-304-086, Rev. VII "Auxiliary Feedwater Pump Discharge, Plan and Sections, Intermediate Building".

2. American Society for Mechanical Engineers "Power Piping Code", ANSI B31.1.0--1967.

3. Flow Diagram--Westinghouse Electric Corporation, D302-192I.

4. Westinghouse Electric Corporation, Drawings D-304-083, Rev. VII and D-304-084, Rev. IV, "Feedwater Pump Suction and Discharge".

5. Gilbert Associates, Inc. Technical Specifications, "Fabricated Piping and Supports", SP5291, revision dated October 2, 1967.

6. Telecon R. E. Smith (Rochester Gas & Electric) to R. Broman (Nuclear Services Corporation) July 23, 1973.

7. Nuclear Services Corporation, "NUPIPE: Computer Code for Stress Analysis of Nuclear Piping", revision dated June 1, 1972.

8. Streeter, V. L., "Fluid Mechanics", 1962.

9. Zemansky, "Heat Transmission".

APPENDIX A

TABULATED DATA

TABLE	DESCRIPTION
A-1	PIPE DATA
A-2	CONCENTRATED WEIGHTS
A-3	TIME HISTORY FORCING FUNCTIONS
A-4	PIPING STRESS SUMMARY
A-5	ANCHOR LOADING SUMMARY
A-6	PIPING SUPPORT LOADS
A-7	PIPE DEFLECTION SUMMARY
A-8	DEFLECTION COMPARISON

TABLE A-1: PIPE DATA

Line No.	From Point	To Point	O.D. (In.)	Wall Thick (In.)	Matl. ASTM Spec.	Fluid	Wt. Of Pipe & Fluid (Lb./Ft.)	Wt. Of Insul. (Lb./Ft.)	Design Temp. (Deg. F)	Design Press. (PSIG)
	5	295	14.0	0.937	A106 GR C	Water	180.7	10.7	450	1,550
	115	1,065	3.5	0.3	A106 GR C	Water	13.1	1.25	100	2,065
	1,065	1,075	2.375	0.218	A106 GR C	Water	6.3	1.10	100	2,065
	1,045	1,165	3.5	0.3	A106 GR C	Water	13.1	1.25	100	2,065
	1,165	1,175	2.375	0.218	A106 GR C	Water	6.3	1.10	100	2,065
	5	696	14.0	0.937	A106 GR C	Water	180.7	10.7	450	1,550
	696	710	18.0	1.157	A106 GR C	Water	291.7	12.3	450	1,550

TABLE A-2: CONCENTRATED WEIGHTS

Point No.	Description	Weight (Lbs.)	Eccentricity (In.) From ℄ Pipe
135	Valve, RO-1	3,300	27.0
140	Valve, RO-6	2,400	——
155	Flow Meter	70	——
262	Valve, RO-2	4,170	25.5
271	Valve, FCV 476	3,400	27.996
281	Valve, RO-2	4,170	25.5
805	Valve, RO-18	145	——
1035	Valve, RO-86	355	27.0
1060	Valve, RO-20	145	——
1085	Valve, RO-16	220	15.0
1135	Valve, RO-16	220	15.0
1160	Valve, RO-20	145	——
1145	Line Section - Tee	157	——
115	Line Section - Tee	191	——

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PROJECT ROBERT E. GINNA NUCLEAR STATION

SHEET__________ **OF**______

SUBJECT FEEDWATER LINE FROM STEAM GENERATOR 1B TO MAIN HEADER AND AUXILIARY FEEDWATER LINE FROM EL 288.5' TO MOTOR DRIVE PUMPS 1A & 1B

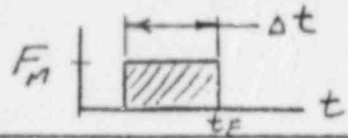

TABLE A-3: TIME HISTORY FORCING FUNCTIONS

Node Point	L (ft)	Δt (sec)	t_{final} (sec)	Maximum Force (lb)	REMARKS
256	7.6	.002	.002	99,000	
246	12.0	.00342	.00542	99,000	
235	5.0	.00142	.00684	99,000	
190	15.0	.00428	.01112	99,000	
146	52.0	.01485	.02597	99,000	
110	17.94	.00512	.0313	99,000	
90	31.0	.00885	.0402	99,000	
56	93.0	.0265	.667	99,000	
25	6.5	.0019	.0686	99,000	
15	12.0	.0034	.0720	99,000	
805	2.7	.00054	.0273	5,671	
820	5.5	.0011	.0284	5,671	
830	17.5	.0036	.0320	5,671	
850	8.0	.0016	.0336	5,671	
910	76.1	.0152	.0488	5,671	
965	28.2	.0057	.0545	5,671	
990	20.0	.004	.0585	5,671	
1015	14.0	.0028	.0613	5,671	
1040	3.8	.0008	.0621	5,671	

PROJECT ROBERT E. GINNA NUCLEAR STATION

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TO MAIN HEADER AND AUXILIARY FEEDWATER LINE
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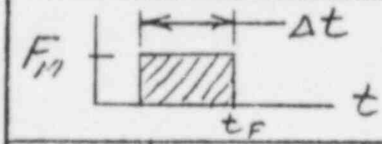

TABLE A-3: TIME HISTORY FORCING FUNCTIONS
(continued)

Node Point	L (ft)	Δt (sec)	t_{final} (sec)	Maximum Force (lb)	REMARKS
1050	1.5	.0003	.0624	5,671	
1060	1.5	.0003	.0627	5,671	
1070	1.2	.0003	.0630	5,671	
1095	12.5	.0025	.0646	5,671	
1110	8.25	.0017	.0663	5,671	
1130	13.8	.0027	.0690	5,671	
1160	1.8	.0004	.0694	5,671	
1170	1.2	.0002	.0696	5,671	
605	18.0	.0051	.0737	99,000	
615	16.0	.00457	.0785	99,000	
630	14.0	.004	.0823	99,000	
640	7.0	.002	.0843	99,000	
655	11.0	.0031	.0874	99,000	
670	13.0	.0037	.0911	99,000	
680	6.0	.0017	.0928	99,000	
690	6.0	.0017	.1045	99,000	

PROJECT ROBERT E. GINNA NUCLEAR STATION

SHEET________ OF________

SUBJECT FEEDWATER LINE FROM STEAM GENERATOR 1B
TO MAIN HEADER AND AUXILIARY FEEDWATER LINE
FROM EL 288.5' TO MOTOR DRIVE PUMPS 1A and 1B

TABLE A-4

PIPING STRESS SUMMARY

Piping System Feedwater

Allowable Stresses (PSI): S_{cold} = 17.5 ksi S_{hot} = 17.5 ksi S_A = 26.25 ksi

1.2 S_{hot} = 21.0 ksi S_{yield} = 40.0 ksi

Node No.	Thermal Stress	Pressure Stress	Deadweight Stress	Water Hammer Stress	Press. + Wt. + Water Hammer Stress	COMMENTS
5	1,253	2,718	333	5,749	8,800	
10	1,745	2,718	106	23,507	26,331	
15	2,451	2,718	276	14,227	17,221	
20	2,389	2,718	262	11,169	14,149	
25	2,013	2,718	137	8,955	11,810	
40	1,759	2,718	97	13,396	16,211	
41	1,031	2,718	53	8,154	10,925	
45	896	2,718	263	6,477	9,458	
46	588	2,718	389	6,315	9,422	
49	285	2,718	429	6,598	9,745	
51	238	2,718	684	6,991	10,393	
50	41	2,718	293	8,677	11,688	
53	371	2,718	338	5,916	8,972	
54	570	2,718	596	10,049	13,462	
56	617	2,718	906	11,058	14,682	
55	815	2,718	187	6,551	9,456	
58	1,226	2,718	460	10,321	13,499	
59	1,441	2,718	456	9,767	12,941	

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1.2 S_{hot} = 21.0 ksi S_{yield} = 40.0 ksi

Node No.	Thermal Stress	Pressure Stress	Deadweight Stress	Water Hammer Stress	Press. + Wt. + Water Hammer Stress	COMMENTS
61	1,456	2,718	544	9,749	13,011	
62	1,688	2,718	56	9,666	12,440	
65	1,943	2,718	192	12,380	15,290	
70	2,971	2,718	106	14,018	16,842	
80	2,908	2,718	512	8,239	11,469	
85	1,663	2,718	670	26,617	30,005	
86	1,309	2,718	562	18,198	21,478	
90	972	2,718	470	10,207	13,332	
91	747	2,718	654	7,176	10,548	
95	729	2,718	1,374	8,633	12,725	
100	963	2,718	1,311	10,321	14,350	
116	630	2,718	544	8,243	11,505	
110	441	2,718	372	31,077	34,167	
111	463	2,718	372	28,939	32,029	
115	1,065	2,718	387	10,621	13,723	14" run
115	15,122	2,738	2,026	35,984	40,748	3" branch
115	1,096	2,718	364	10,873	13,955	14" run
120	1,378	2,718	549	13,133	16,400	

PROJECT ROBERT E. GINNA NUCLEAR STATION

SHEET ________ OF ____

SUBJECT FEEDWATER LINE FROM STEAM GENERATOR 1B
TO MAIN HEADER AND AUXILIARY FEEDWATER LINE
FROM EL 288.5' TO MOTOR DRIVE PUMPS 1A and 1B

TABLE A-4

PIPING STRESS SUMMARY

Piping System Feedwater

Allowable Stresses (PSI): S_{cold} = 17.5 ksi S_{hot} = 17.5 ksi S_A = 26.25 ksi

1.2 S_{hot} = 21.0 ksi S_{yield} = 40.0 ksi

Node No.	Thermal Stress	Pressure Stress	Deadweight Stress	Water Hammer Stress	Press. + Wt. + Water Hammer Stress	COMMENTS
130	1,369	2,718	1,132	16,513	20,363	
136	709	2,718	434	11,335	14,487	
139	633	2,718	296	9,781	12,795	
141	492	2,718	916	7,358	10,992	
145	491	2,718	933	7,346	10,997	
147	478	2,718	277	9,146	12,141	
146	531	2,718	325	11,918	14,961	
150	561	2,718	297	11,198	14,213	
155	582	2,718	276	11,109	14,103	
160	605	2,718	275	10,501	13,494	
170	653	2,718	421	9,409	12,548	
171	872	2,718	482	9,715	12,915	
175	1,114	2,718	612	6,193	9,523	
180	1,816	2,718	440	7,640	10,798	
190	1,767	2,718	200	7,612	10,530	
200	1,503	2,718	292	7,393	10,403	
210	1,467	2,718	310	7,446	10,474	
215	863	2,718	217	7,168	10,103	

PROJECT ROBERT E. GINNA NUCLEAR STATION SHEET______OF_____

SUBJECT FEEDWATER LINE FROM STEAM GENERATOR 1B
TO MAIN HEADER AND AUXILIARY FEEDWATER LINE
FROM EL 288.5' TO MOTOR DRIVE PUMPS 1A and 1B

TABLE A-4

PIPING STRESS SUMMARY

Piping System Feedwater

Allowable Stresses (PSI): S_{cold} = 17.5 ksi S_{hot} = 17.5 ksi S_A = 26.25 ksi

1.2 S_{hot} = 21.0 ksi S_{yield} = 40.0 ksi

Node No.	Thermal Stress	Pressure Stress	Deadweight Stress	Water Hammer Stress	Press. + Wt. + Water Hammer Stress	COMMENTS
220	999	2,718	356	12,349	15,423	
230	810	2,718	141	12,619	15,478	
235	697	2,718	296	11,608	14,622	
245	456	2,718	354	9,461	12,533	
246	240	2,718	233	5,780	8,731	
250	571	2,718	348	16,037	19,103	
256	369	2,718	1,140	17,004	20,862	
260	243	2,718	762	15,026	18,506	
285	1,390	2,718	522	10,790	14,030	
290	1,613	2,718	1,805	11,031	15,554	
295	612	2,869	874	4,010	7,753	
800	10,215	2,738	678	32,344	35,760	
810	15,456	2,738	592	33,142	36,472	
815	14,625	2,738	535	30,515	33,788	
820	19,761	2,738	677	18,928	22,343	
825	20,868	2,738	745	21,243	24,726	
830	2,530	2,738	215	13,602	16,555	
835	5,965	2,738	300	16,248	19,286	

PROJECT ROBERT E. GINNA NUCLEAR STATION SHEET______OF______

SUBJECT FEEDWATER LINE FROM STEAM GENERATOR 1B
TO MAIN HEADER AND AUXILIARY FEEDWATER LINE
FROM EL 288.5' TO MOTOR DRIVE PUMPS 1A and 1B

TABLE A-4

PIPING STRESS SUMMARY

Piping System Feedwater

Allowable Stresses (PSI): S_{cold} = 17.5 ksi S_{hot} = 17.5 ksi S_A = 26.25 ksi

1.2 S_{hot} = 21.0 ksi S_{yield} = 40.0 ksi

Node No.	Thermal Stress	Pressure Stress	Deadweight Stress	Water Hammer Stress	Press. + Wt. + Water Hammer Stress	COMMENTS
840	7,124	2,738	380	10,112	13,230	
845	6,807	2,738	289	9,932	12,959	
850	3,656	2,738	307	14,546	17,591	
855	3,570	2,738	99	14,985	17,822	
860	1,267	2,738	1,556	13,214	17,508	
870	467	2,738	1,053	7,122	10,913	
875	624	2,738	1,563	5,879	10,180	
880	928	2,738	983	9,132	12,853	
885	976	2,738	982	10,436	14,156	
890	701	2,738	844	3,399	6,981	
895	683	2,738	609	3,451	6,798	
900	404	2,738	688	5,284	8,710	
905	260	2,738	653	2,474	5,865	
910	133	2,738	283	1,453	4,474	
915	80	2,738	194	6,294	9,226	
920	90	2,738	673	5,861	9,272	
925	202	2,738	340	3,111	6,189	
930	566	2,738	94	3,017	5,849	

TABLE A-4

PIPING STRESS SUMMARY

Piping System Feedwater

Allowable Stresses (PSI): S_{cold} = 17.5 ksi S_{hot} = 17.5 ksi S_A = 26.25 ksi

1.2 S_{hot} = 21.0 ksi S_{yield} = 40.0 ksi

Node No.	Thermal Stress	Pressure Stress	Deadweight Stress	Water Hammer Stress	Press. + Wt. + Water Hammer Stress	COMMENTS
935	578	2,738	202	3,003	5,943	
940	1,312	2,738	228	4,838	7,804	
945	1,301	2,738	165	4,906	7,809	
950	585	2,738	595	3,518	6,851	
955	314	2,738	371	4,019	7,128	
960	188	2,738	1,475	4,608	8,821	
965	93	2,738	597	5,057	8,392	
970	441	2,738	1,411	2,385	6,534	
975	1,131	2,738	105	5,682	8,525	
980	1,145	2,738	247	5,856	8,841	
985	785	2,738	718	5,219	8,675	
990	523	2,738	131	3,434	6,303	
991	469	2,738	[illegible]	3,431	9,247	
995	315	2,738	735	4,288	7,761	
1000	571	2,738	260	6,561	9,559	
1005	556	2,738	184	6,494	9,416	
1010	208	2,738	127	3,836	6,701	
1015	297	2,738	112	4,869	7,719	

PROJECT ROBERT E. GINNA NUCLEAR STATION

SHEET________ OF______

SUBJECT FEEDWATER LINE FROM STEAM GENERATOR 1B
TO MAIN HEADER AND AUXILIARY FEEDWATER LINE
FROM EL 288.5' TO MOTOR DRIVE PUMPS 1A and 1B

TABLE A-4

PIPING STRESS SUMMARY

Piping System Feedwater

Allowable Stresses (PSI): S_{cold} = 17.5 ksi S_{hot} = 17.5 ksi S_A = 26.25 ksi

1.2 S_{hot} = 21.0 ksi S_{yield} = 40.0 ksi

Node No.	Thermal Stress	Pressure Stress	Deadweight Stress	Water Hammer Stress	Press. + Wt. + Water Hammer Stress	COMMENTS
1020	836	2,738	144	9,601	12,483	
1025	669	2,738	476	9,135	12,349	
1030	399	2,738	938	7,489	11,165	
1040	875	2,738	710	5,039	8,487	
1045	1,721	2,738	1,337	5,154	9,229	
1050	1,718	2,738	792	2,690	6,220	
1055	1,051	2,738	809	2,967	6,514	
1065	841	2,738	369	3,098	6,205	
1070	3,227	2,499	823	9,843	13,165	
1075	4,851	2,499	2,557	9,444	14,500	
1080	607	2,738	1,832	4,105	8,675	
1090	533	2,738	295	3,248	6,281	
1095	179	2,738	354	2,807	5,899	
1100	446	2,738	540	3,655	6,933	
1105	495	2,738	1,384	3,801	7,923	
1110	111	2,738	316	979	4,033	
1115	244	2,738	850	2,971	6,559	
1120	651	2,738	596	3,109	6,443	

Nuclear Services Corporation

PROJECT ROBERT E. GINNA NUCLEAR STATION

SHEET ______ OF ______

SUBJECT FEEDWATER LINE FROM STEAM GENERATOR 1B TO MAIN HEADER AND AUXILIARY FEEDWATER LINE FROM EL 288.5' TO MOTOR DRIVE PUMPS 1A and 1B

TABLE A-4

PIPING STRESS SUMMARY

Piping System Feedwater

Allowable Stresses (PSI): S_{cold} = 17.5 ksi S_{hot} = 17.5 ksi S_A = 26.25 ksi

1.2 S_{hot} = 21.0 ksi S_{yield} = 40.0 ksi

Node No.	Thermal Stress	Pressure Stress	Deadweight Stress	Water Hammer Stress	Press. + Wt. + Water Hammer Stress	COMMENTS
1125	312	2,738	395	2,914	6,047	
1130	415	2,738	325	2,142	5,205	
1140	486	2,738	1,403	2,391	6,532	
1145	539	2,738	1,387	2,437	6,562	
1150	841	2,738	1,886	3,797	8,421	
1155	726	2,738	1,702	4,153	8,593	
1165	1,488	2,738	615	4,214	7,567	
1170	3,960	2,499	869	12,755	16,123	
1175	4,253	2,499	3,857	11,792	18,148	
5	1,253	2,718	45	13,881	16,644	
605	2,508	2,718	59	16,336	19,113	
610	2,470	2,718	44	15,226	17,988	
615	2,623	2,718	70	10,686	13,474	
620	2,317	2,718	184	9,676	12,578	
625	2,018	2,718	194	5,883	8,795	
630	3,538	2,718	128	9,589	12,435	
635	3,846	2,718	274	9,937	12,929	
640	2,915	2,718	227	10,380	13,325	

Nuclear Services Corporation

PROJECT ROBERT E. GINNA NUCLEAR STATION

SHEET________ OF_____

SUBJECT FEEDWATER LINE FROM STEAM GENERATOR 1B
TO MAIN HEADER AND AUXILIARY FEEDWATER LINE
FROM EL 288.5' TO MOTOR DRIVE PUMPS 1A and 1B

TABLE A-4

PIPING STRESS SUMMARY

Piping System Feedwater

Allowable Stresses (PSI): S_{cold} = 17.5 ksi S_{hot} = 17.5 ksi S_A = 26.25 ksi

1.2 S_{hot} = 21.0 ksi S_{yield} = 40.0 ksi

Node No.	Thermal Stress	Pressure Stress	Deadweight Stress	Water Hammer Stress	Press. + Wt. + Water Hammer Stress	COMMENTS
645	2,127	2,718	461	10,250	13,429	
650	647	2,718	695	7,998	11,411	
655	540	2,718	290	11,219	14,227	
660	1,453	2,718	233	14,781	17,732	
670	2,520	2,718	259	11,006	13,983	
675	2,080	2,718	227	10,268	13,213	
680	1,560	2,718	218	10,583	13,519	
685	1,320	2,718	184	13,334	16,236	
690	764	2,718	189	15,366	18,273	
695	329	2,718	191	17,158	20,067	
696	221	2,718	130	15,453	18,301	
700	582	2,858	135	13,906	16,899	
705	1,184	2,358	388	16,792	20,038	
710	677	2,858	326	11,230	14,414	

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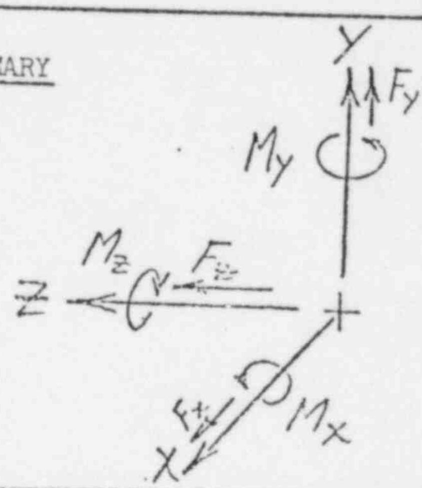
PROJECT ROBERT E. GINNA NUCLEAR STATION

SUBJECT FEEDWATER LINE FROM STEAM GENERATOR 1B
TO MAIN HEADER AND AUXILIARY FEEDWATER LINE
FROM EL 288.5' TO MOTOR DRIVE PUMPS 1A and 1B

SHEET________ OF________

TABLE A-5: ANCHOR LOADING SUMMARY

WATER HAMMER ANALYSIS



Node Point	Location	Force (lb)			Moment (in-lb)		
		F_x	F_y	F_z	M_x	M_y	M_z
5	Outside containment Pen. #404	27,707	1,143	31,170	1,913	56,268	3,768
5	Inside containment Pen. #404	6,628	11,226	11,343	130,303	30,758	25,233
295	Pipe header	16,892	14,054	3,983	99,011	19,656	45,641
1075	Motor Drive Pump 1B	275	224	273	142	556	36
1175	Motor Drive Pump 1A	127	209	370	536	424	220
710	Steam Generator 1B	48,358	22,597	27,766	53,553	137,833	171,897

Nuclear Services Corporation

PROJECT ROBERT E. GINNA NUCLEAR STATION SHEET ______ OF ______

SUBJECT FEEDWATER LINE FROM STEAM GENERATOR 1B
TO MAIN HEADER AND AUXILIARY FEEDWATER LINE
FROM EL 288.5' TO MOTOR DRIVE PUMPS 1A and 1B

TABLE A-6:

PIPING SUPPORT LOADS

NODE PT.	CUSTOMER MARK NO.	SUPPORT TYPE	DIRECTION	SPRING CONSTANT #/IN	REACTION TO WATER HAMMER (LBS)
10	PEN-404	Penetration	Lateral	Rigid	75,518
25	FW-11	Hanger	Y	Rigid	3,151
45	FW-12	Hanger	Y	Rigid	4,640
56	FW-80	Snubber	Inclined	--	22,130
65	FW-16	Hanger	Y	Rigid	5,661
65	FW-81	Snubber	Inclined	--	24,938
85	FW-82	Snubber	Z	--	74,372
110	FW-83	Snubber	X	--	78,622
145	FW-29	Spring Hanger	Y	1,080	2,450
146	FW-30	Snubber	Z	--	13,488
170	FW-31	Spring Hanger	Y	1,600	3,951
175	FW-32	Spring Hanger	Y	800	1,253
220	FW-33	Spring Hanger	Y	600	370
250 Vertical	--	Hanger	Y	Rigid	17,584
250 Lateral	--	Hanger	Z	Rigid	18,951
825	FW-37	Hanger	Y	Rigid	1,445
835 West	--	Hanger	X	Rigid	853
835 North	--	Hanger	Z	Rigid	804
850	FW-36	Hanger	Y	Rigid	249
875	FW-35	Hanger	Y	Rigid	166

TABLE A-6:

PIPING SUPPORT LOADS

NODE PT.	CUSTOMER MARK NO.	SUPPORT TYPE	DIRECTION	SPRING CONSTANT #/IN	REACTION TO WATER HAMMER (LBS)
880	FW-47	Lateral	Z	Rigid	491
890	FW-34	Hanger	Y	Rigid	94
905	FW-33	Hanger	Y	Rigid	52
915 Vertical	FW-48	Built-up	Y	Rigid	134
915 Horizontal	FW-48	Built-up	Z	3.8×10^3	398
920	FW-32	Hanger	Y	Rigid	115
935	FW-31	Hanger	Y	Rigid	2
945	FW-30	Hanger	Y	Rigid	5
955 Vertical	FW-49	Built-up	Y	9×10^4	104
955 North	FW-49	Built-up	Z	2.1×10^6	60
960	FW-29	Hanger	Y	Rigid	90
985	FW-28	Hanger	Y	Rigid	66
991	FW-27	Hanger	Y	Rigid	199
1005	FW-26	Hanger	Y	Rigid	700
1115	FW-53	Hanger	Y	Rigid	152
610	FW-10	Hanger	Y	Rigid	88
625	FW-81	Hanger	Y	Rigid	1,326
650	FW-80	Hanger	Y	Rigid	267
660 Lateral	--	Snubber	Lateral	--	19,550

Nuclear Services Corporation

PROJECT ROBERT E. GINNA NUCLEAR STATION

SHEET________ OF________

SUBJECT FEEDWATER LINE FROM STEAM GENERATOR 1B
TO MAIN HEADER AND AUXILIARY FEEDWATER
LINE FROM EL 288.5' TO MOTOR DRIVE PUMPS 1A and 1B

TABLE A-6:

PIPING SUPPORT LOADS

NODE PT.	CUSTOMER MARK NO.	SUPPORT TYPE	DIRECTION	SPRING CONSTANT #/IN	REACTION TO WATER HAMMER (LBS)
675	FW-7	Spring Hanger	Y	241	149

SUBJECT FEEDWATER LINE FROM STEAM GENERATOR 1B
TO MAIN HEADER AND AUXILIARY FEEDWATER LINE
FROM #L 288.5' TO MOTOR DRIVE PUMPS 1A & 1B

TABLE A-7

PIPE DEFLECTION SUMMARY

Node Point	Deflection (in)					
	Thermal Expansion			Water Hammer Response		
	ΔX	ΔY	ΔZ	ΔX*	ΔY*	ΔZ*
25	.324	.0	.180	.148	.003	.863
45	.626	.0	-.06	.404	.005	1.055
51	1.292	.0	-.602	1.136	.279	1.058
56	2.225	.0	-1.305	.051	.339	1.056
61	2.872	.0	-1.995	.781	.211	1.047
65	2.982	.0	-2.351	.117	.006	1.040
90	2.438	-.001	-2.001	.412	1.686	1.031
95	2.155	.002	-1.665	.412	2.041	2.420
Vert 250	.467	.001	.0	.121	.018	.019
Lat'l 250	.467	.001	.0	.121	.018	.019
825	1.581	.0	-1.391	1.680	.0	1.984
West 835	.0	-.03	.0	.0	.0	.0
North 835	.0	-.03	.0	.0	.0	.0
850	-.913	.0	.796	4.961	.0	1.139
875	-.965	.0	.256	5.025	.0	1.244

* - All Values are ±

TABLE A-7

PIPE DEFLECTION SUMMARY

Node Point	Deflection (in)					
	Thermal Expansion			Water Hammer Response		
	ΔX	ΔY	ΔZ	ΔX*	ΔY*	ΔZ*
North 880	-.986	-.025	.0	5.025	.154	.0
890	-.988	.0	-.142	5.077	.0	.699
905	-1.028	.0	-.111	5.077	.0	.775
Vert 915	-1.056	.0	.0	5.077	.0	.105
Lat'l 915	-1.056	.0	.0	5.077	.0	.105
920	-1.057	.0	.006	5.077	.0	.092
935	-1.092	.0	.105	5.077	.0	.335
945	-1.112	.0	.03	5.054	.0	.0
Vert 955	-.776	.0	.0	4.099	-.001	.0
North 955	-.776	.0	.0	4.099	-.001	.0
960	-.680	.0	-.007	3.900	.0	.0
985	-.066	.0	-.09	1.603	.0	.215
991	-.091	.0	-.209	1.603	.0	1.061
1005	-.120	.0	-.235	1.577	.0	1.522
1105	-.199	.0	-.03	.078	.0	.786

* - All Values are ±

Nuclear Services Corporation

PROJECT ROBERT E. GINNA NUCLEAR STATION SHEET________ OF________

SUBJECT FEEDWATER LINE FROM STEAM GENERATOR 1B
TO MAIN HEADER AND AUXILIARY FEEDWATER LINE
FROM EL 288.5' TO MOTOR DRIVE PUMPS 1A & 1B

TABLE A-7
PIPE DEFLECTION SUMMARY

Node Point	Deflection (in)					
	Thermal Expansion			Water Hammer Response		
	ΔX	ΔY	ΔZ	ΔX*	ΔY*	ΔZ*
1115	-.246	.0	-.053	.229	.0	.786
610	-0.079	-0.062	-0.040	0.053	0.052	0.073
625	0.093	-0.350	0.335	1.794	1.376	0.878
650	0.094	-0.210	0.212	1.304	1.107	0.216
675	-0.009	-0.054	-0.139	0.936	0.617	0.485

* - All values are ±

Nuclear Services Corporation

PROJECT ROBERT E. GINNA NUCLEAR STATION

SUBJECT FEEDWATER LINE FROM STEAM GENERATOR 1B
TO MAIN HEADER & AUXILIARY FEEDWATER LINE
FROM EL 288.5 TO MOTOR DRIVE PUMPS 1A & 1B

SHEET________ OF________

TABLE A-8: PIPING DEFLECTION COMPARISON

Location	Deflection (Inches)					
	Field Observation (Hot Condition)			Calculated Water Hammer		
	ΔX	ΔY	ΔZ	ΔX	ΔY	ΔZ
11 feet south of FWH-14	-1.25	----	----	±1.089	±.349	±1.059
Near FWH-15	-----	+.937	----	±.181	±.211	±1.047
Int. Bldg. Penetration (near node 90)	-----	-----	-1.375	±.412	±1.686	±1.031
At FWH-7	±1.0	±0.5	-----	±.936	±.617	±.485

Trans w/ Ltr dtd 8/21/73

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