WESTINGHOUSE PROPRIETARY CLASS 3

PRESSURIZER SAFETY AND RELIEF LINE EVALUATION

SUMMARY REPORT

ROCHESTER GAS AND ELECTRIC CORPORATION

GINNA STATION

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SECTION 1

INTRODUCTION

The pressurizer safety and relief valve (PSARV) discharge piping system for pressurized water reactors, located on top of the pressurizer, provides overpressure protection for the reactor coolant system. A water seal is maintained upstream of each pressurizer safety valve to prevent a steam interface at the valve seat. This water seal reduces the possibility of valve leakage. While this arrangement maximizes the plant availability, the water slug, driven by high system pressure upon actuation of the valves, generates severe hydraulic shock loads on the piping and supports.

Under NUREG 0737, Section II.D.1, "Performance Testing of BWR and PWR Relief and Safety Valves", all operating plant licensees and applicants are required to conduct testing to qualify the reactor coolant system relief and safety valves under expected operating conditions for design-basis transients and accidents. In addition to the qualification of valves, the functionability and structural integrity of the as-built discharge piping and supports must also be demonstrated on a plant specific basis.

In response to these requirements, a program for the performance testing of PWR safety and relief valves was formulated by EPRI. The primary objective of the Test Program was to provide full scale test data confirming the functionability of the reactor coolant system power operated relief valves and safety valves for expected operating and accident conditions. The second objective of the program was to obtain sufficient piping thermal hydraulic load data to permit confirmation of models which may be utilized for plant unique analysis of safety and relief valve discharge piping systems.

This report is the response of the Rochester Gas and Electric Corporation to the US NRC plant-specific submittal request for piping evaluation and is applicable to the Ginna pressurizer safety and relief valve discharge piping system.

SECTION 2
PIPE STRESS CRITERIA

2.1 PIPE STRESS CALCULATION

The piping between the pressurizer nozzles and the pressurizer relief tank was analyzed according to the requirements of the appropriate equations of the ANSI B31.1-1973 Code up to and including 1973 addenda (hereafter referred to as the Code). These equations establish limits for stresses from sustained loads, sustained plus occasional loads (including earthquake), thermal expansion loads, and sustained plus thermal expansion loads. The allowable stresses for use with the equations were determined in accordance with the requirements of the Code.

2.2 LOAD COMBINATIONS

In order to evaluate the pressurizer safety and relief valve piping, appropriate load combinations and acceptance criteria were developed. The load combinations and acceptance criteria are identical to those recommended by the piping subcommittee of the PWR PSARV test program and are outlined in Tables 2-1 and 2-2. Definitions of the load abbreviations are provided in Table 2-3. The PSARV test program allows the option of using either the design basis load combinations or the load combinations as defined in Table 2-1 and 2-2. The load combinations and acceptance criteria defined in Table 2-1 and Table 2-2 were used in the Ginna analysis.

TABLE 2-1

LOAD COMBINATIONS AND ACCEPTANCE CRITERIA FOR PRESSURIZER SAFETY AND RELIEF VALVE PIPING AND SUPPORTS - UPSTREAM OF VALVES

Combination	Plant/System Operating Condition	Load Combination	Piping Allowable Stress Intensity
1	Normal	N	1.0 S_h
2	Upset	N + OBE + SOT_U	1.2 S_h
3	Emergency	N + SOT_E	1.8 S_h
4	Faulted	N + MS/FWPB or DBPB + SSE + SOT_F	2.4 S_h
5	Faulted	N + LOCA + SSE + SOT_F	2.4 S_h

NOTES:
(1) Plants with an FSAR may use their original design basis in conjunction with the appropriate system operating transient definitions in Table 2-3; or they may use the proposed criteria contained in Tables 2-1 to 2-3.

(2) See Table 2-3 for SOT definitions and other load abbreviations.

(3) The bounding number of valves (and discharge sequence if setpoints are significantly different) for the applicable system operating transient defined in Table 2-3 should be used.

(4) Verification of functional capability is not required, but allowable loads and accelerations for the safety-relief valves must be met.

(5) Use SRSS for combining dynamic load responses.

TABLE 2-2

LOAD COMBINATIONS AND ACCEPTANCE CRITERIA
FOR PRESSURIZER SAFETY AND RELIEF VALVE PIPING
AND SUPPORTS - SEISMICALLY DESIGNED DOWNSTREAM PORTION

Combination	Plant/System Operating Condition	Load Combination	Piping Allowable Stress Intensity
1	Normal	N	1.0 S_h
2	Upset	N + SOT_U	1.2 S_h
3	Upset	N + OBE + SOT_U	1.8 S_h
4	Emergency	N + SOT_E	1.8 S_h
5	Faulted	N + MS/FWPB or DBPB + SSE + SOT_F	2.4 S_h
6	Faulted	N + LOCA + SSE + SOT_F	2.4 S_h

NOTES: (1) Plants with an FSAR may use their original design basis in conjunction with the appropriate system operating transient definitions in Table 2-3; or they may use the proposed criteria contained in Tables 2-1 to 2-3.

(2) This table is applicable to the seismically designed portion of downstream non-Category I piping (and supports) necessary to isolate the Category I portion from the non-seismically designed piping response, and to assure acceptable valve loading on the discharge nozzle.

(3) See Table 2-3 for SOT definitions and other load abbreviations.

(4) The bounding number of valves (and discharge sequence if setpoints are significantly different) for the applicable system operating transient defined in Table 2-3 should be used.

(4) Verification of functional capability is not required, but allowable loads and accelerations for the safety-relief valves must be met.

(5) Use SRSS for combining dynamic load responses.

TABLE 2-3

DEFINITIONS OF LOAD ABBREVIATIONS

N	=	Sustained loads during normal plant operation
SOT	=	System operating transient
SOT_U	=	Relief valve discharge transient(1)
SOT_E	=	Safety valve discharge transient(1), (2)
SOT_F	=	Maximum of SOT_U and SOT_E; or transition flow
OBE	=	Operating basis earthquake
SSE	=	Safe shutdown earthquake
MS/FWPB	=	Main steam or feedwater pipe break
DBPB	=	Design basis pipe break
LOCA	=	Loss-of-coolant accident
S_h	=	Basic material allowable stress at maximum (hot) temperature

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(1) May also include transition flow, if determined that required operating procedures could lead to this condition.

(2) Although certain nuclear steam supply systems design transients (for example, loss of load) which are classified as upset conditions may actuate the safety valves, the extremely low number of actual safety valve actuations in operating pressurizer water reactors justifies the emergency condition from the ASME design philosophy and a stress analysis viewpoint. However, if actuation of safety valves would occur, a limitation must be placed to shut down the plant for examination of system integrity after an appropriate number of actuations. This number can be determined on a plant specific basis.

NOTE: Plants with an FSAR may use their original design basis in conjunction with the appropriate system operating transient definitions in Table 2-3; or they may use the proposed criteria contained in Tables 2-1 to 2-3.

SECTION 3
LOADING CONDITIONS ANALYZED

3.1 LOADING

The piping stress analyses described in this section consider all pertinent loadings. These loadings result from thermal expansion, pressure, weight, earthquake, and safety valve and relief valve operation.

3.1.1 THERMAL EXPANSION

The thermal growth of the reactor coolant loop equipment and all connected piping is considered in the thermal analysis of this system.

The modulus of elasticity (E), the coefficient of thermal expansion at the metal temperature (α), the external movements transmitted to the piping as described above, and the temperature rise above the ambient temperature (ΔT for various operating modes), define the required input data to perform the flexibility analysis for thermal expansion.

Because of the many possible operating modes, the system may experience many different thermal loadings. The temperatures used in the expansion analysis are based on all available information and include pertinent valve opening cases.

To provide the necessary high degree of integrity for the piping, the transient conditions selected for secondary stress evaluation are based on conservative estimates of the magnitude and anticipated frequency of occurrence of the temperature and pressure transients resulting from the possible operating conditions.

The transients selected are conservative representations of transients for design purposes, and are used as a basis for piping secondary stress evaluation to provide assurance that the piping is acceptable for its application over the design life of the plant.

For purposes of piping evaluation, the number of transient occurrences is based on a plant design life of 40 years.

3.1.2 PRESSURE

Pressure loading in this report is either design pressure or operating pressure. The design pressure is used in the calculation of longitudinal pressure stress in accordance with the Code. The range of operating pressure is used in calculating various stress intensities, as applicable.

3.1.3 WEIGHT

To meet the requirements of the Code, a weight analysis is performed by applying a 1.0 g uniformly distributed load downward on the complete piping system. The distributed weight characteristics of the piping system are specified as a function of its properties. This method provides a distributed loading to the piping system as a function of the weight of the pipe, insulation, and contained fluid during normal operating conditions.

3.1.4 SEISMIC

Seismic motion of the earth is treated as a random process. Certain assumptions reflecting the characteristics of typical earthquakes are made so these characteristics can be readily employed in a dynamic response spectrum analysis.

Piping rarely experiences the actual seismic motion at ground elevation, since it is supported by components attached to the containment building. Although a band of frequencies is associated with the ground earthquake motion, the building itself acts as a filter to this environment and will effectively transmit those frequencies corresponding to its own natural modes of vibration.

The forcing functions for the piping seismic analyses are derived from dynamic response analyses of the containment building when subjected to seismic ground motion. These forcing functions are in the form of floor response spectra. Response spectra are obtained by determining the maximum response of a single mass-spring-damper oscillator to a base motion time history. This single mass-spring-damper oscillator system represents a single natural vibration mode of the piping system. A plot of the maximum responses versus the natural frequencies of the oscillator forms the response spectrum for that particular base motion.

The intensity and character of the earthquake motion producing forced vibration of the equipment mounted within the containment building are specified in terms of the floor response spectrum curves at various elevations within the containment building.

The seismic floor response spectrum curves corresponding to the highest elevation at which the component or piping is attached to the containment building are used in the piping analysis.

Seismic loads must be known to calculate the resultant moment (Mi_3) used in the design equations The plant operating condition (full load) is the condition under which the specified earthquake is assumed to occur.

3.1.5 SAFETY AND RELIEF VALVE THRUST

The pressurizer safety and relief valve discharge piping system provides overpressure protection for the RCS. The two spring-loaded safety valves and two power-operated relief valves, located on top of the pressurizer, are designed to prevent system pressure from exceeding design pressure by more than 10 percent and 100 psi, respectively. A water seal is maintained upstream of each safety valve to minimize leakage. Condensate accumulation on the inlet side of each valve prevents any leakage of hydrogen gas or steam through the valves.

If the pressure exceeds the set point and the valves open, the water slug from the loop seal discharges. The water slug, driven by high system pressure, generates transient thrust forces at each location where a change in flow direction occurs.

The safety and relief lines are analyzed for various cases of thrust loadings to ensure the primary and secondary stress limits are not exceeded.

3.2 DESIGN CONDITIONS

The design conditions are the pressures, temperatures, and various mechanical loads applicable to the design of nuclear power plant piping.

3.2.1 DESIGN PRESSURE

The specified internal and external design pressures are not less than the maximum difference in pressure between the inside and outside of the component, which exists under the specified normal operating conditions. The design pressures are used in the computations made to show compliance with the Code. The design pressure of the pressurizer safety and relief valve piping between the pressurizer and the valves is 2485 psig. The downstream design pressure from the valve discharge to the pressurizer relief tank is 600 psig.

3.2.2 DESIGN TEMPERATURE

The specified design temperature is not less than the actual maximum metal temperature existing under the specified normal operating conditions for each area of the component considered. It is used in computations involving the design pressure and coincidental design mechanical loads. The design temperature of the pressurizer safety and relief valve piping between the pressurizer and the relief tank is 650°F.

3.3 PLANT OPERATING CONDITIONS

3.3.1 NORMAL CONDITIONS

A normal condition is any condition in the course of system startup, design power range operation, hot standby, and system shutdown, other than upset, faulted, emergency, or testing conditions. Normal occurrences are operations that are expected to occur frequently or regularly in the course of power operation, refueling or maintenance of the plant.

3.3.2 UPSET CONDITIONS

An upset condition is any deviation from normal conditions anticipated to occur often enough that design should include a capability to withstand the condition without operational impairment. Upset conditions include those transients resulting from any single operator error or control malfunction, transients caused by a fault in a system component requiring its isolation from the system, and transients due to loss of load or power. Upset conditions include any abnormal incidents not resulting in a forced outage and also forced outages for which the corrective action does not include any repair of mechanical damage. Upset occurrences include incidents, any one of which may occur during a calendar year for a particular plant.

3.3.3 EMERGENCY CONDITIONS

Emergency conditions are defined as those deviations from normal conditions which require shutdown for correction of the conditions or repair of damage in the system. The conditions have a low probability of occurrence but are included to provide assurance that no gross loss of structural integrity will result as a concomitant effect of any damage developed in the system. The total number of postulated occurrences for such events shall not cause more than 25 stress cycles. Emergency occurrences include incidents, any one of which may occur during the lifetime of a particular plant.

3.3.4 FAULTED CONDITIONS

Faulted conditions are those combinations of conditions associated with extremely low probability - postulated events whose consequences are such that the integrity and operability of the nuclear energy system may be impaired to the extent that considerations of public health and safety are involved. Faulted occurrences are faults that are not expected to occur, but are postulated because their consequences would include the potential for the release of significant amounts of radioactive material.

SECTION 4
ANALYTICAL METHODS AND MODELS

4.1 INTRODUCTION

The analytical methods used to obtain a piping deflection solution consist of the transfer matrix method and stiffness matrix formulation.

The complexity of the piping system requires the use of a computer to obtain the displacements, forces, and stresses in the piping and support members. To obtain these results, accurate and adequate mathematical representations (analytical models) of the systems are required. The modeling considerations depend upon the degree of accuracy desired and the manner in which the results will subsequently be interpreted and evaluated. All static and dynamic analyses are performed using the WESTDYN computer program. This program, described in WCAP-8252, was reviewed and approved by the U.S. NRC (NRC letter, April 7, 1981 from R. L. Tedesco to T. M. Anderson).

The integrated piping/supports system model is the basic system model used to compute loadings on components, component and piping supports, and piping. The system model includes the stiffness and mass characteristics of the piping system. The deflection solution of the entire system is obtained and then internal member forces and piping stresses are calculated.

4.2 STATIC ANALYSIS

The piping system models, constructed for the WESTDYN computer program, are represented by an ordered set of data which numerically describes the physical system.

The spatial geometric description of the piping model is based upon the isometric piping drawings and equipment drawings. Node point coordinates and incremental lengths of the members are determined from these drawings. Node point coordinates are put on network cards. Incremental member lengths are put on element cards. The geometrical properties along with the modulus of elasticity, E, the coefficient of thermal expansion, α, the average temperature change from the ambient temperature, ΔT, and the weight per unit length, w, are specified for each element. The supports are represented by stiffness matrices which define restraint characteristics of the supports. Plotted models for various parts of the safety and relief valve discharge piping are shown in figures in Section 6.

The static solutions for deadweight and thermal loading conditions are obtained by using the WESTDYN computer program. The WESTDYN computer program is based on the use of transfer matrices which relate a twelve-element vector [B] consisting of deflections (three displacements and three rotations) and loads (three forces and three moments) at one location to a similar vector at another location. The fundamental transfer matrix for an element is determined from its geometric and elastic properties. If thermal effects and boundary forces are included, a modified transfer relationship is defined as follows:

$$\begin{bmatrix} T_{11} & T_{12} \\ T_{21} & T_{22} \end{bmatrix} \begin{bmatrix} \Delta_o \\ F_o \end{bmatrix} + \begin{bmatrix} \delta_t \\ f_t \end{bmatrix} = \begin{bmatrix} \Delta_i \\ F_i \end{bmatrix}$$

or

$$T_1 B_o + R_1 = B_1$$

where the T matrix is the fundamental transfer matrix as described above, and the R vector includes thermal effects and body forces. This B vector for the element is a function of geometry, temperature, coefficient of thermal expansion, weight per unit length, lumped masses, and externally applied loads.

The overall transfer relationship for a series of elements (a section) can be written as follows:

$$B_1 = T_1B_o + R_1$$

$$B_2 = T_2B_1 + R_2 = T_2T_1B_o + T_2R_1 + R_2$$

$$B_3 = T_3B_2 + R_3 = T_3T_2T_1B_o + T_3T_2R_1 + T_3R_2 + R_3$$

or

$$B_n = \left(\prod_{1}^{n} T_r\right) \cdot B_o + \sum_{r=2}^{n} \left[\left(\prod_{r}^{n} T_r\right) \cdot R_{r-1}\right] + R_n$$

A network model is made up of a number of sections, each having an overall transfer relationship formed from its group of elements. The linear elastic properties of a section are used to define the characteristic stiffness matrix for the section. Using the transfer relationship for a section, the loads required to suppress all deflections at the ends of the section arising from the thermal and boundary forces for the section are obtained. These loads are incorporated in the overall load vector.

After all the sections have been defined in this manner, the overall stiffness matrix, K, and associated load vector needed to suppress the deflection of all the network points is determined. By inverting the stiffness matrix, the flexibility matrix is determined. The flexibility matrix is multiplied by the negative of the load vector to determine the network point deflections due to the thermal and boundary force effects. Using the general transfer relationship, the deflections and internal forces are then determined at all node points in the system. The support loads, F, are also computed by multiplying the stiffness matrix, K, by the displacement vector, δ, at the support point.

4.3 DYNAMIC ANALYSIS

The models used in the static analyses are modified for use in the dynamic analyses by including the mass characteristics of the piping and equipment.

4.4 SEISMIC ANALYSIS

The lumping of the distributed mass of the piping systems is accomplished by locating the total mass at points in the system which will appropriately represent the response of the distributed system. Effects of the equipment motion, that is, the pressurizer, on the piping system are obtained by modeling the mass and the stiffness characteristics of the equipment in the overall system model.

The supports are again represented by stiffness matrices in the system model for the dynamic analysis. Mechanical shock suppressors which resist rapid motions are now considered in the analysis. The solution for the seismic disturbance employs the response spectra method. This method employs the lumped mass technique, linear elastic properties, and the principle of modal superposition.

From the mathematical description of the system, an overall stiffness matrix [K] is developed from the individual element stiffness matrices using the transfer matric $[K_R]$ associated with mass degrees-of-freedom only. From the mass matrix and the reduced stiffness matrix, the natural frequencies and the normal modes are determined. The modal participation factor matrix is computed and combined with the appropriate response spectra value to give the modal amplitude for each mode. Since the modal amplitude is shock direction dependent, the total modal amplitude is obtained conservatively by the absolute sum of the contributions for each direction of shock. The modal amplitudes are then converted to displacements in the global coordinate system and applied to the corresponding mass point. From these data the forces, moments, deflections, rotation, support reactions, and piping stresses are calculated for all significant modes.

The seismic response from each earthquake component is computed by combining the contributions of the significant modes.

4.5 PRESSURIZER SAFETY AND RELIEF LINE ANALYSIS

4.5.1 PLANT HYDRAULIC MODEL

When the pressurizer pressure reaches the safety valve set pressure of 2,500 psia and the valve opens, the high pressure steam in the pressurizer forces the water in the water loop seal through the valve and down the piping system to the pressurizer relief tank. Additionally, when the relief valve set pressure of 2350 psia is reached and the valve opens high pressure steam is discharged to the downstream piping. For the pressurizer safety and relief piping system, analytical hydraulic models, as shown in Figures 4-1 and 4-2, were developed to represent the conditions described above.

The computer code ITCHVALVE was used to perform the transient hydraulic analysis for the system. This program uses the Method of Characteristics approach to generate fluid parameters as a function of time. One-dimensional fluid flow calculations applying both the implicit and explicit characteristic methods are performed. Using this approach the piping network is input as a series of single pipes. The network is generally joined together at one or more places by two or three-way junctions. Each of the single pipes has associated with it friction factors, angles of elevation, and flow areas.

Conservation equations can be converted to the following characterisitic equations:

$$\frac{dz}{dt} = V+c$$

$$\frac{dP}{dt} + \rho c \frac{dV}{dt} = c(F + \rho g\cos\theta) - \frac{q'''c^2}{\rho \frac{\partial h}{\partial \rho}}$$

$$\frac{dz}{dt} = V - c$$

$$\frac{dP}{dt} - \rho c \frac{dV}{dt} = -c(F + \rho g\cos\theta) - \frac{q'''c^2}{\rho \frac{\partial h}{\partial \rho}}$$

$$c^2 = \frac{-\,\partial h/\partial \rho}{\frac{\partial h}{\partial \rho} - \frac{1}{\rho J}}$$

z = variable of length measurement
t = time
V = fluid velocity
c = sonic velocity
p = pressure
ρ = fluid density
F = flow resistance
g = gravity
θ = angle off vertical
J = conversion factor for converting pressure units to equivalent heat units
h = enthalpy
q''' = rate of heat generation per unit pipe length

The computer program possesses special provisions to allow analysis of valve opening and closing situations.

Fluid acceleration inside the pipe generates reaction forces on all segments of the line that are bounded at either end by an elbow or bend. Reaction forces resulting from fluid pressure and momentum variations are calculated. These forces can be expressed in terms of the fluid properties available from the transient hydraulic analysis performed using program ITCHVALVE. The momentum equation can be expressed in vector form as:

$$\vec{F}_{cv} = \frac{1}{g_c} \frac{\partial}{\partial t} \int_V \rho \vec{V} dv + \frac{1}{g_c} \int_A \rho V(\vec{V} \cdot ndA)$$

From this equation, the total force on the pipe can be derived:

$$F_{pipe} = \frac{r_1}{g_c} \frac{(1 - \cos \alpha_1)}{\sin \alpha_1} \frac{\partial W}{\partial t} \Bigg|_{Bend\ 1} + \frac{r_2}{g_c} \frac{(1 - \cos \alpha_2)}{\sin \alpha_2} \frac{\partial W}{\partial t} \Bigg|_{Bend\ 2}$$

$$+ \frac{1}{g_c} \int_{\substack{straight \\ pipe}} \frac{\partial W}{\partial t} dl$$

A = piping flow area
v = volume
F = force
r = radius of curvature of appropriate elbow
α = angle of appropriate elbow
W = mass acceleration
g_c = gravitational conversion constant

All other terms are previously defined.

Unbalanced forces are calculated for each straight segment of pipe from the pressurizer to the relief tank using program FORFUN. The time-histories of these forces are stored on tape to be used for the subsequent structural analysis of the pressurizer safety and relief lines.

4.5.2 COMPARISON TO EPRI TEST RESULTS

Piping load data has been generated from the tests conducted by EPRI at the Combustion Engineering Test Facility. Pertinent tests simulating dynamic opening of the safety valves for representative commercial upstream environments were carried out. The resulting downstream piping loadings and responses were measured. Upstream environments for particular valve opening cases of importance, which envelope the commercial scenarios, are:

A. Cold water discharge followed by steam - steam between the pressure source and the loop seal - cold loop seal between the steam and the valve,

B. Hot water discharge followed by steam - steam between the pressure source and the loop seal - hot loop seal between the steam and the valve.

C. Steam discharge - steam between the pressure source and the valve,

Specific thermal hydraulic and structural analyses have been completed for the Combustion Engineering Test Configuration. Figure 4-3 illustrates the placement of force measurement sensors at the test site. Figures 4-4, 4-5 and 4-6 illustrate a comparison of the thermal hydraulically calculated results using the ITCHVALVE and FORFUN computer programs versus experimental results for Test 908, the cold water discharge followed by steam case. Figure 4-4 shows the pressure time histories for PT9, which is located just downstream of the valve. Figures 4-5 and 4-6 illustrate, respectively, the force time histories of the horizontal run (WE28/WE29) and the long vertical run (WE32/WE33) immediately downstream of the safety valve. Significant structural damping in the third segment after the valve was noticed at the test and was verified by structural analyses. Consequently, a comparison of force WE30/WE31 was not presented here. No useable test data for sensor WE34/WE35 was available for Test 908.

Figures 4-7 through 4-11 illustrate a comparison of calculated versus experimental results for Test 917, the hot water discharge followed by steam case. Figure 4-7 shows the pressure time histories for PT9. Figures 4-8, 4-9, 4-10 and 4-11 illustrate, respectively, the thermal hydraulically calculated and the experimentally determined force time histories for (WE28/WE29), (WE32/WE33), (WE30/WE31) and (WE34/WE35). Blowdown forces were included in the total analytically calculated force for WE34/WE35 as this section of piping vents to the atmosphere. Although not presented here, comparisons were also made to the test data available for safety valve discharge without a loop seal (steam discharge).

The application of the ITCHVALVE and FORFUN computer programs for calculating the fluid-induced loads on the piping downstream of the safety and relief valves has been demonstrated. Although not presented here, the capability has also been shown by direct comparison to the solutions of classical problems.

The application of the structural computer programs (discussed in Section 4.6.3) for calculating the system response has also been demonstrated. Structural models representative of the Combustion Engineering Test Configuration were developed. Figures 4-12, 4-13 and 4-14 illustrate, respectively, a comparison of the structural analysis results and the experimental results for locations (WE28/WE29), (WE32/WE33) and (WE30/WE31) for test 908. No useable test data for sensor (WE34/WE35) was available. Figures 4-15, 4-16, 4-17 and 4-18 show for test 917, respectively, the structural analysis results versus the test results for locations (WE28/WE29), (WE32/WE33), (WE30/WE31) and (WE34/WE35).

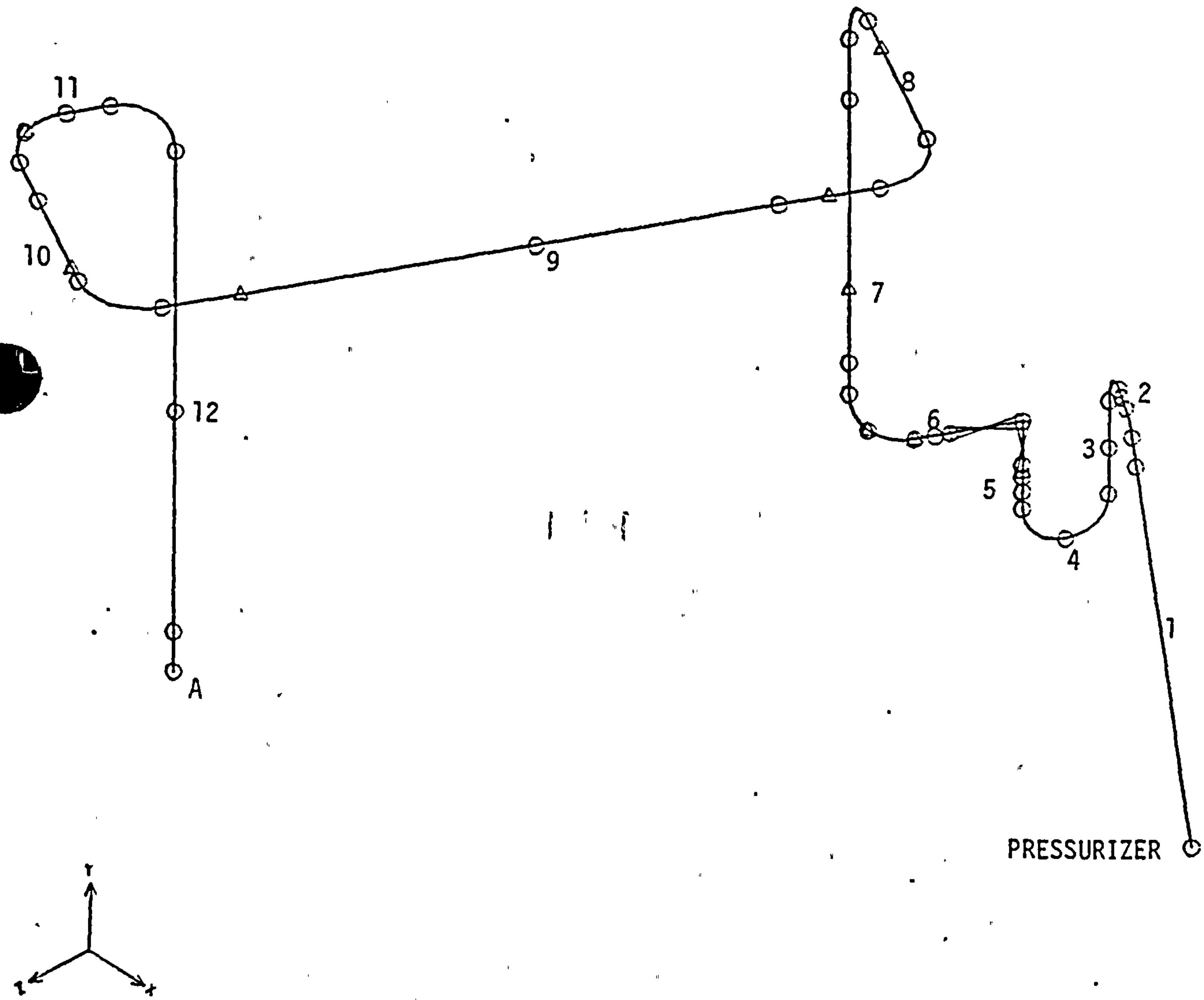
4.5.3 VALVE THRUST ANALYSIS

The safety and relief lines were modeled statically and dynamically as described in Sections 4.1 through 4.3. The mathematical model used for dynamic analyses was modified for the valve thrust analysis to represent the safety and relief valve discharge. The time-history hydraulic

forces determined by FORFUN were applied to the piping system lump mass points. The dynamic solution for the valve thrust was obtained by using a modified-predictor-corrector-integration technique and normal mode theory.

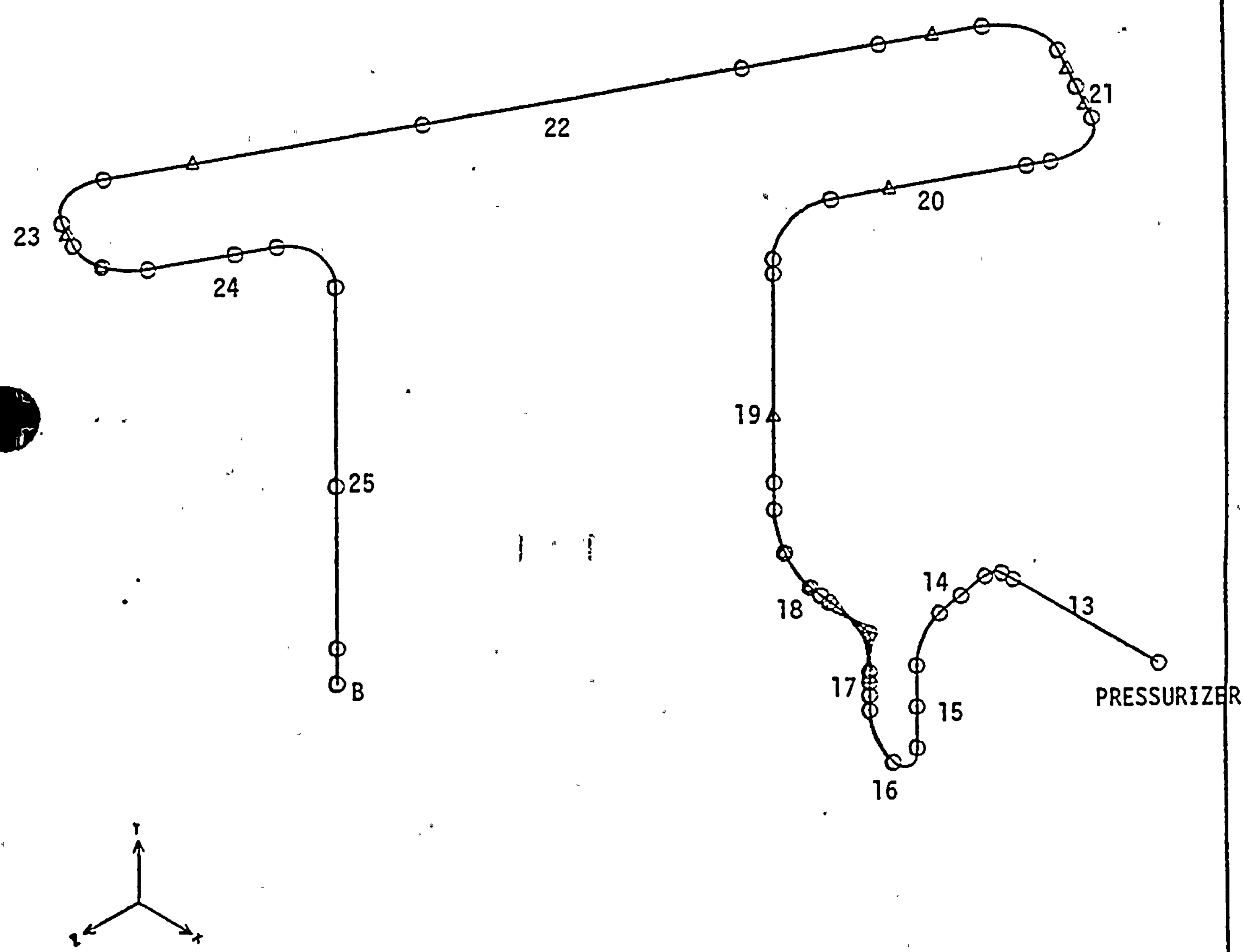
The time-history solution was found using program FIXFM3. The input to this program consists of natural frequencies, normal modes, and applied forces. The natural frequencies and normal modes for the modified pressurizer safety and relief line dynamic model were determined with the WESTDYN program. The time-history displacement response was stored on magnetic tape for later use in computing the total system response due to the valve thrust conditions. The time-history displacements of the FIXFM3 program were used as input to the WESDYN2 program to determine the time-history internal forces and deflections at each end of the piping elements. For this calculation, the displacements were treated as imposed deflections on the pressurizer safety and relief line masses. The solution was stored on tape for later use in the piping stress evaluation and piping support load determination.

The time-history internal forces and displacements of the WESDYN2 program were used as input to the POSDYN2 program to determine the maximum forces, moments, and displacements that exist at each end of the piping elements and the maximum loads for piping supports. The results from program POSDYN2 are saved on TAPE14 for future use in piping stress analysis and support load determination.



NOTE: The numbers correspond to the force numbers in Table 6-1.

FIGURE 4-1: HYDRAULIC MODEL, SAFETY LINE



Note: The numbers correspond to the force numbers in Table 6-1.

FIGURE 4-1: (CONT.) HYDRAULIC MODEL, SAFETY LINE

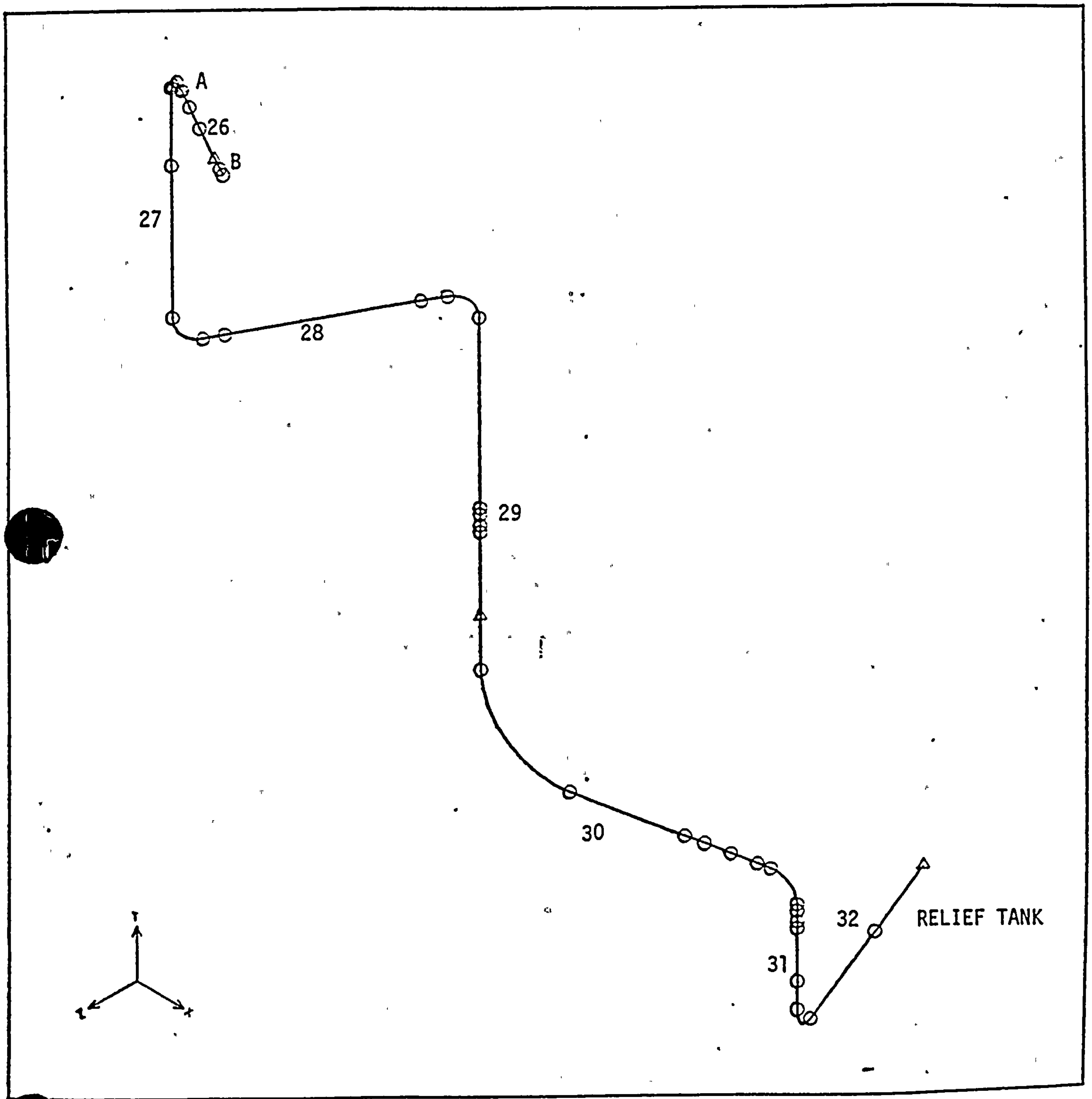
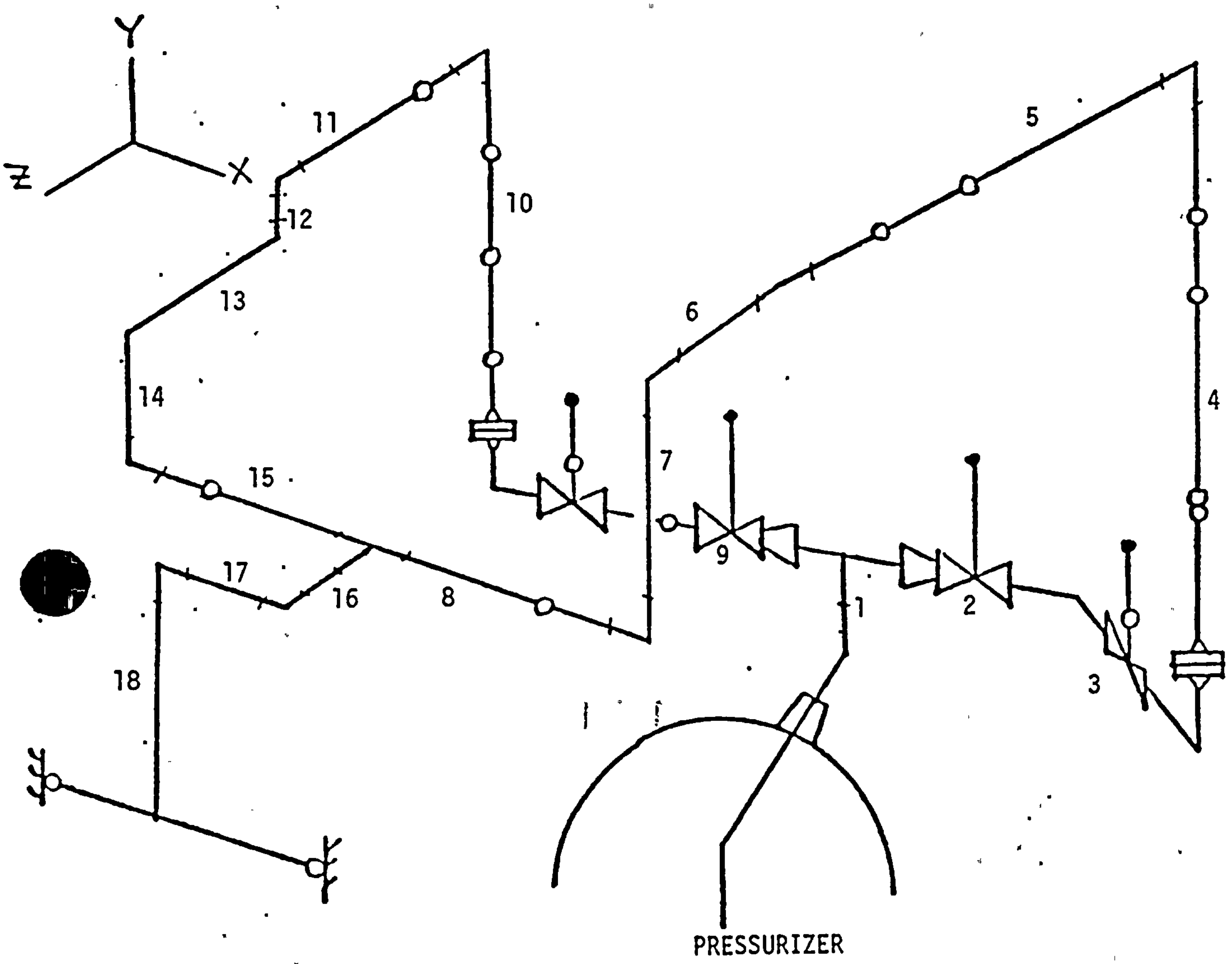


FIGURE 4-1: (CONT.) HYDRAULIC MODEL, SAFETY LINE



NOTE: The numbers correspond to the force numbers in Table 6-2.

FIGURE 4-2: HYDRAULIC MODEL, RELIEF LINE

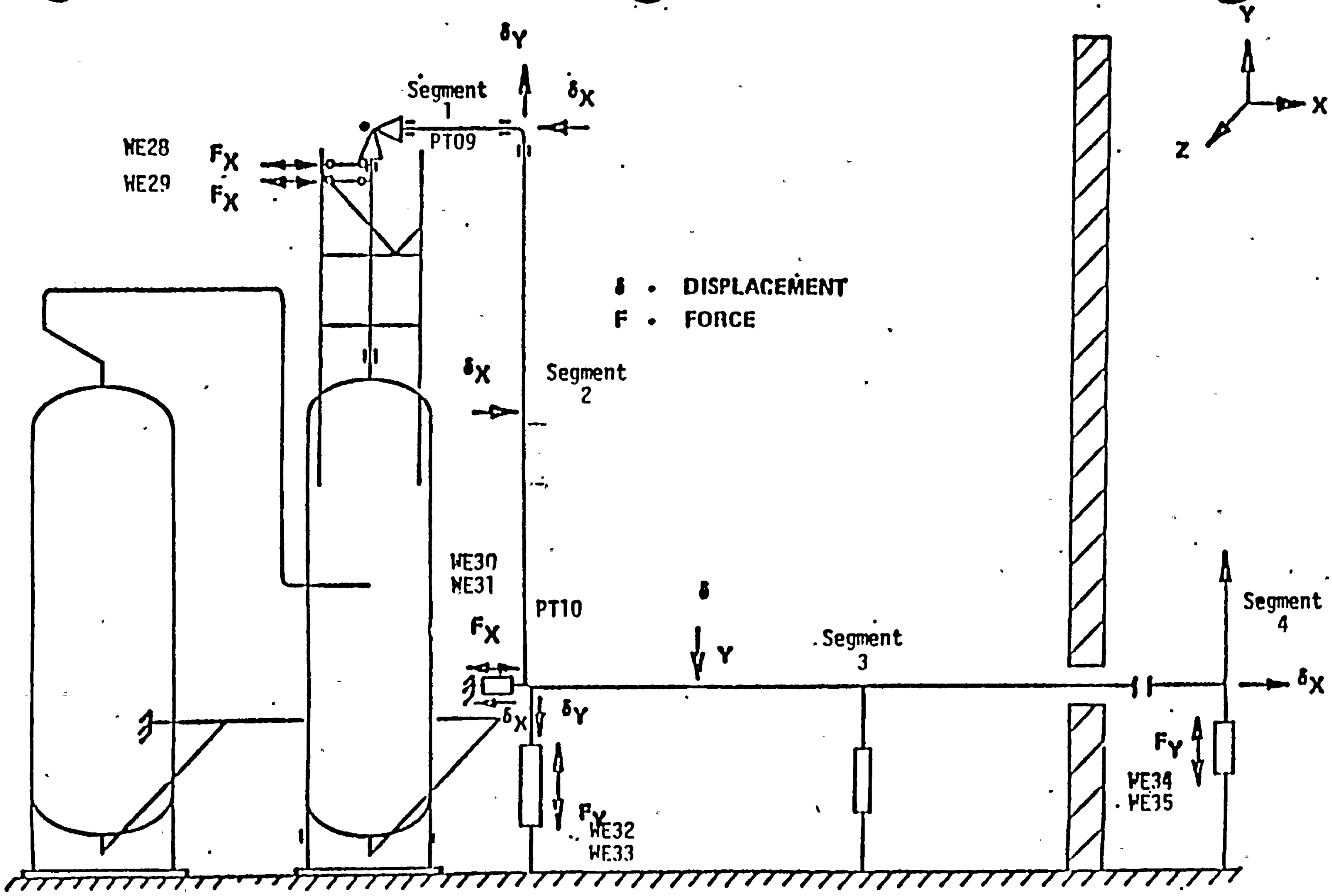


FIGURE 4-3: STRUCTURAL RESPONSE - FORCE MEASUREMENT LOCATIONS - EPRI TESTS

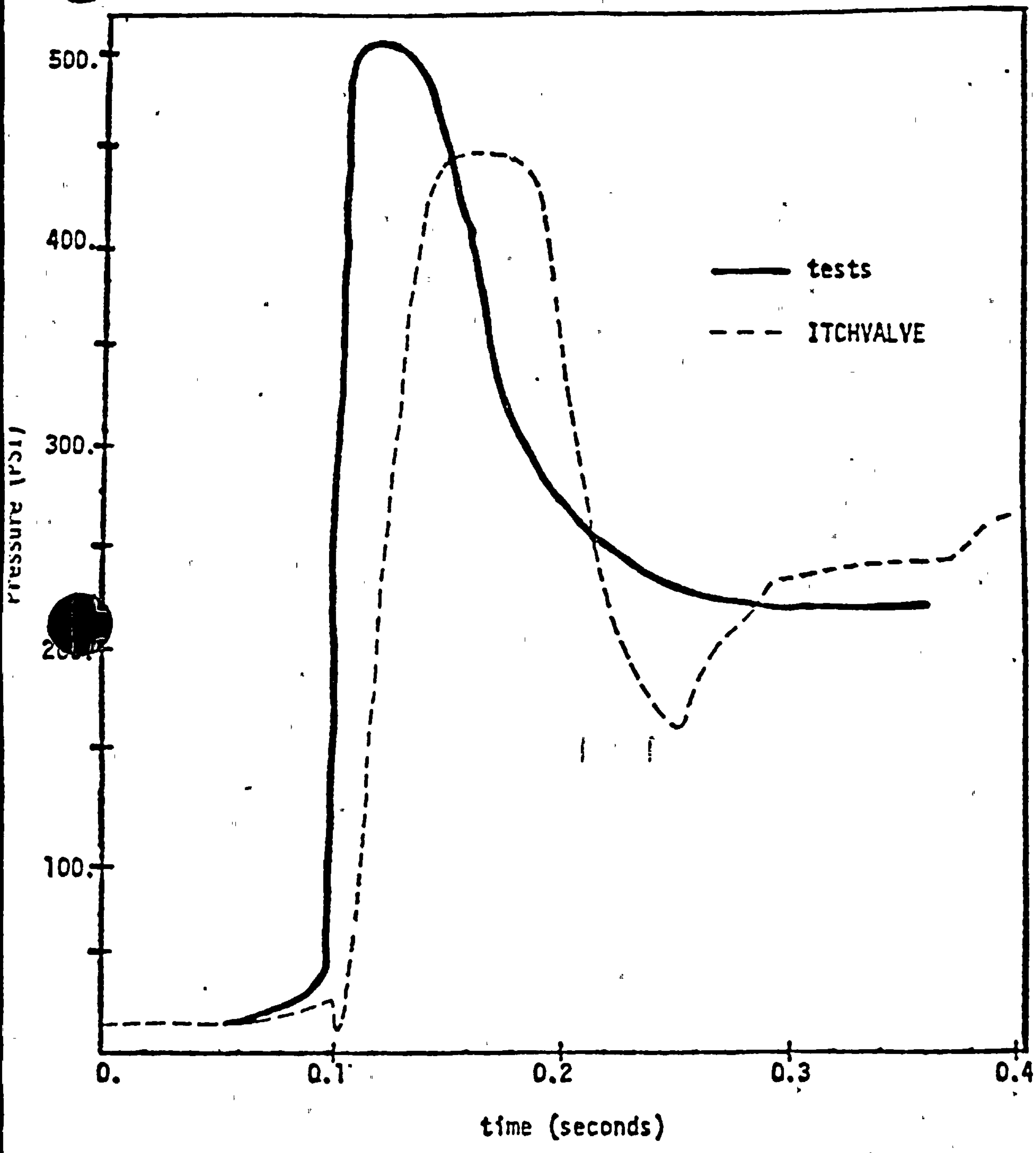


FIGURE 4-4 : Comparison of the EPRI Pressure Time-History for PT09 from Test 908 with the ITCHVALVE Predicted Pressure Time-History

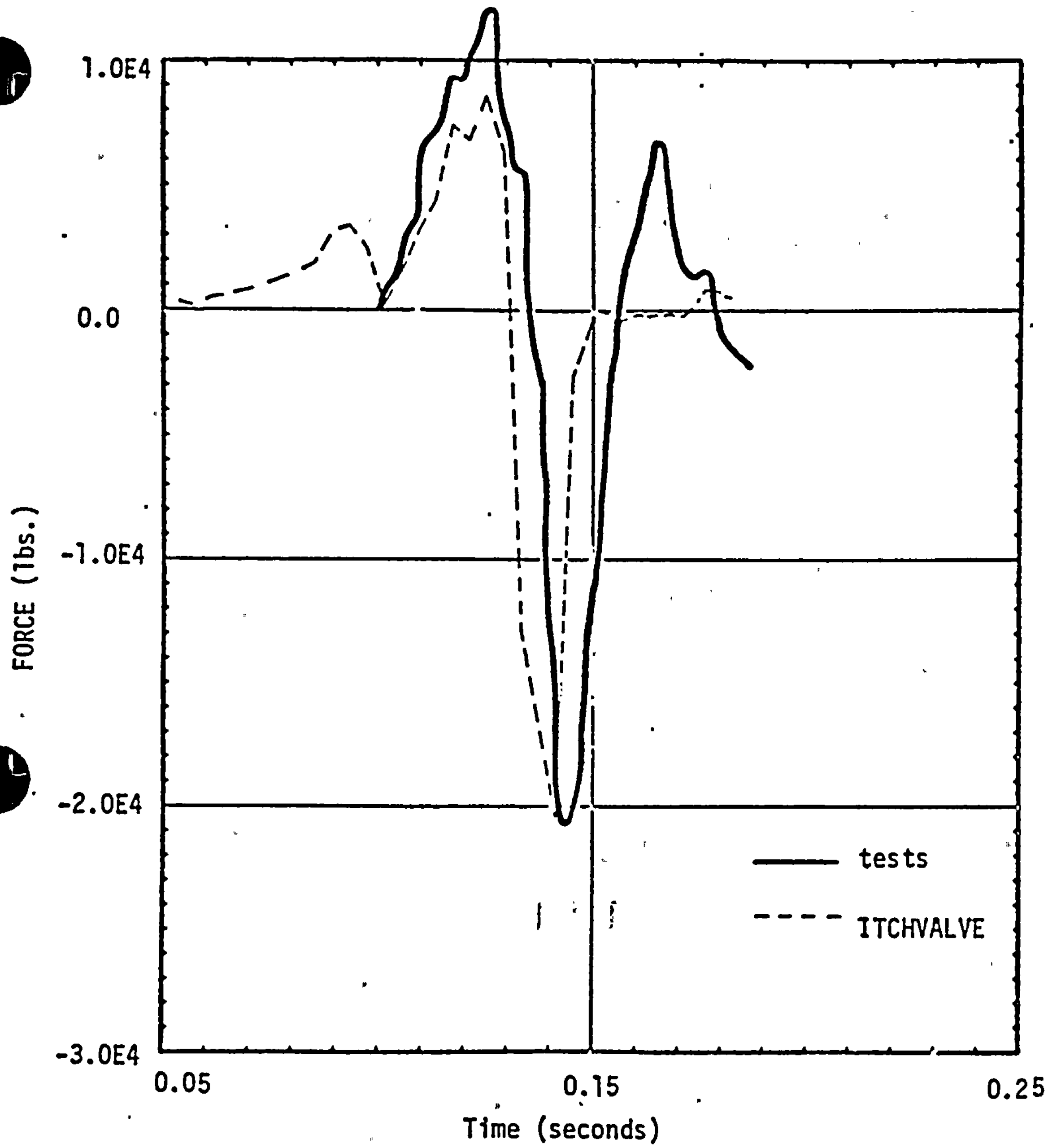


FIGURE 4-5: COMPARISON OF THE EPRI FORCE TIME-HISTORY FOR WE28 and WE29 FROM TEST 908 WITH THE ITCHVALVE PREDICTED FORCE TIME-HISTORY

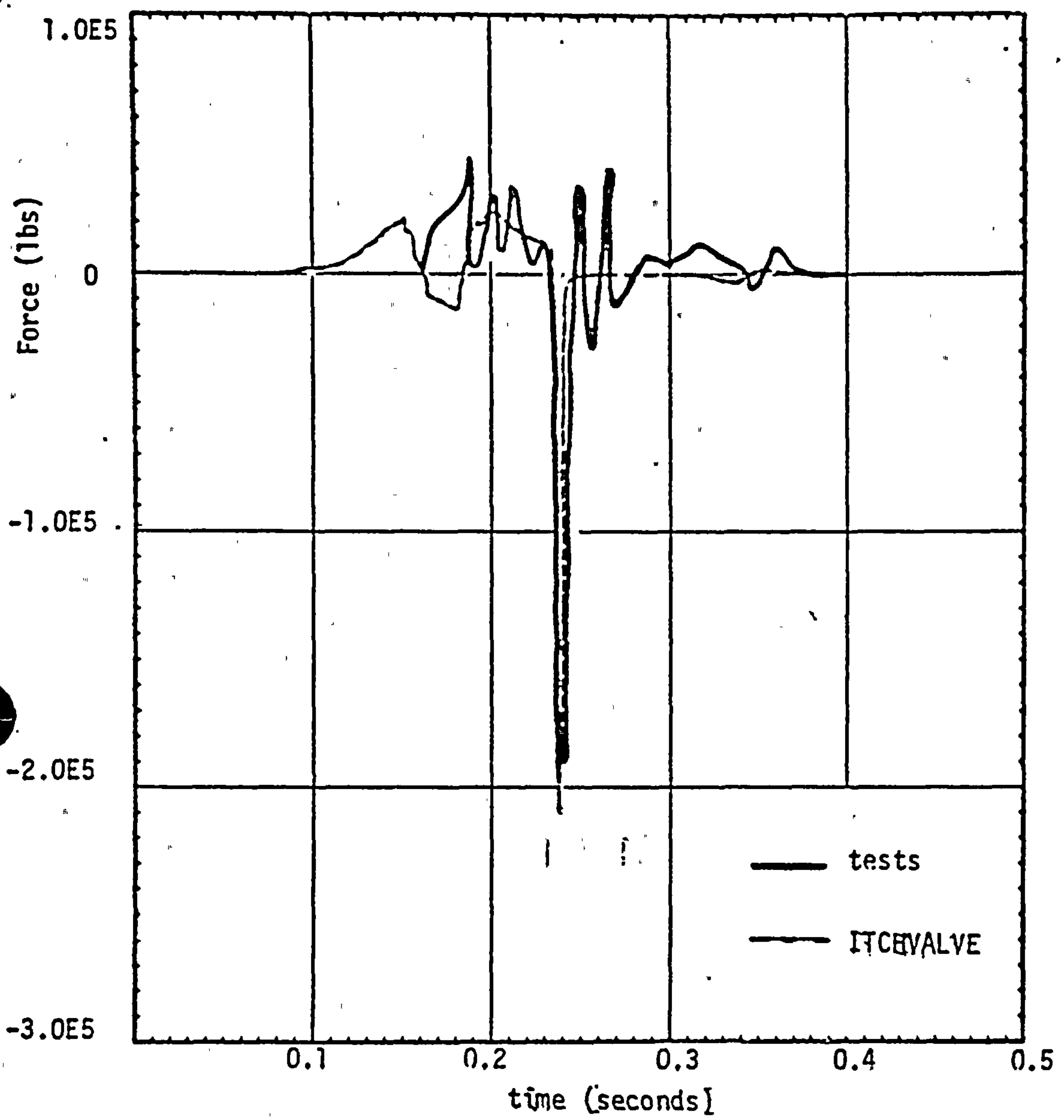


FIGURE 4-6: COMPARISON OF THE EPRI FORCE TIME-HISTORY FOR WE32 AND WE33 FROM TEST 908 WITH THE ITCHVALVE PREDICTED FORCE TIME-HISTORY

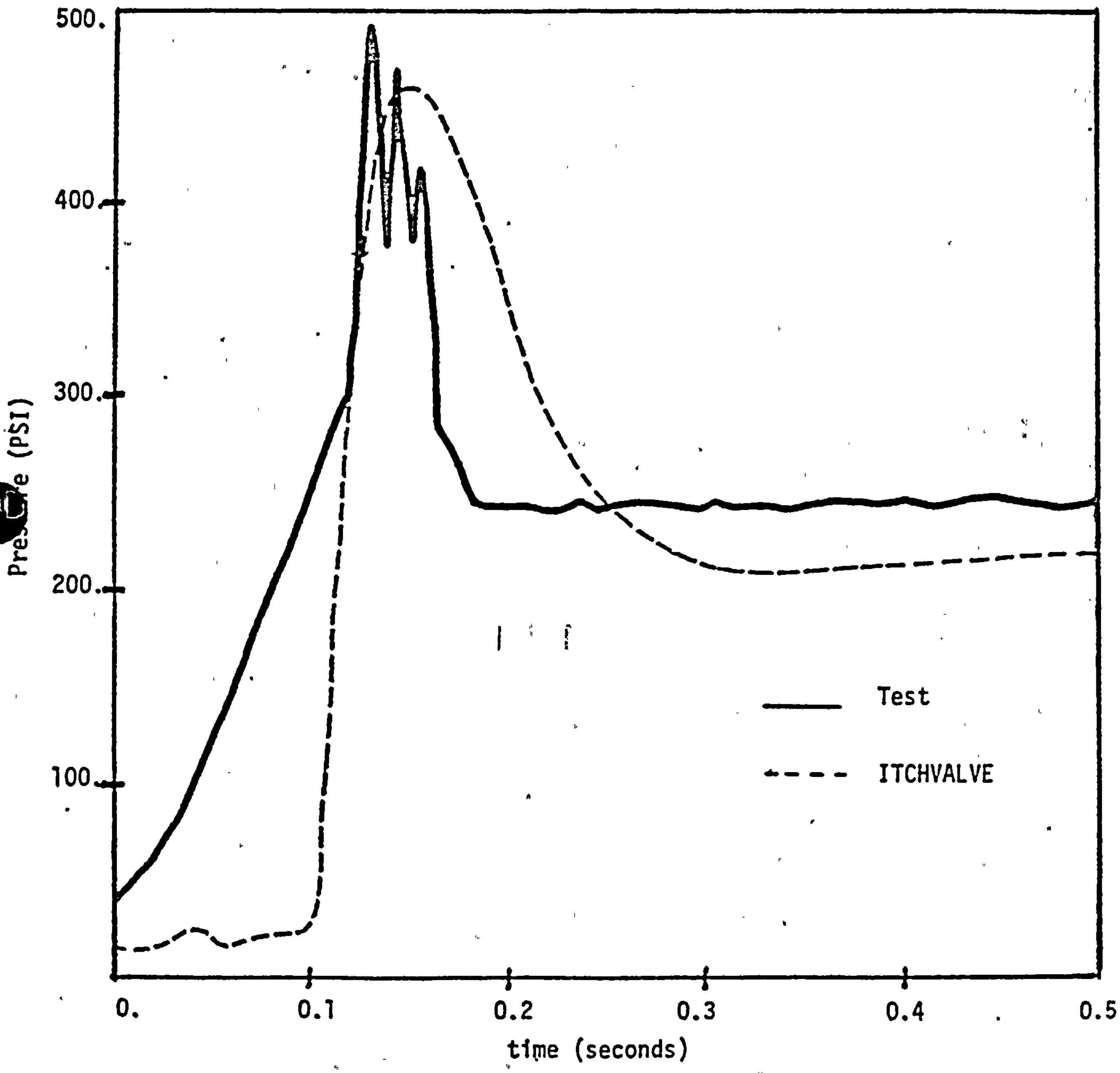


FIGURE 4-7 : Comparison of the EPRI Pressure Time-History from PT09 from Test 917 with the ITCHVALVE Predicted Pressure Time-History

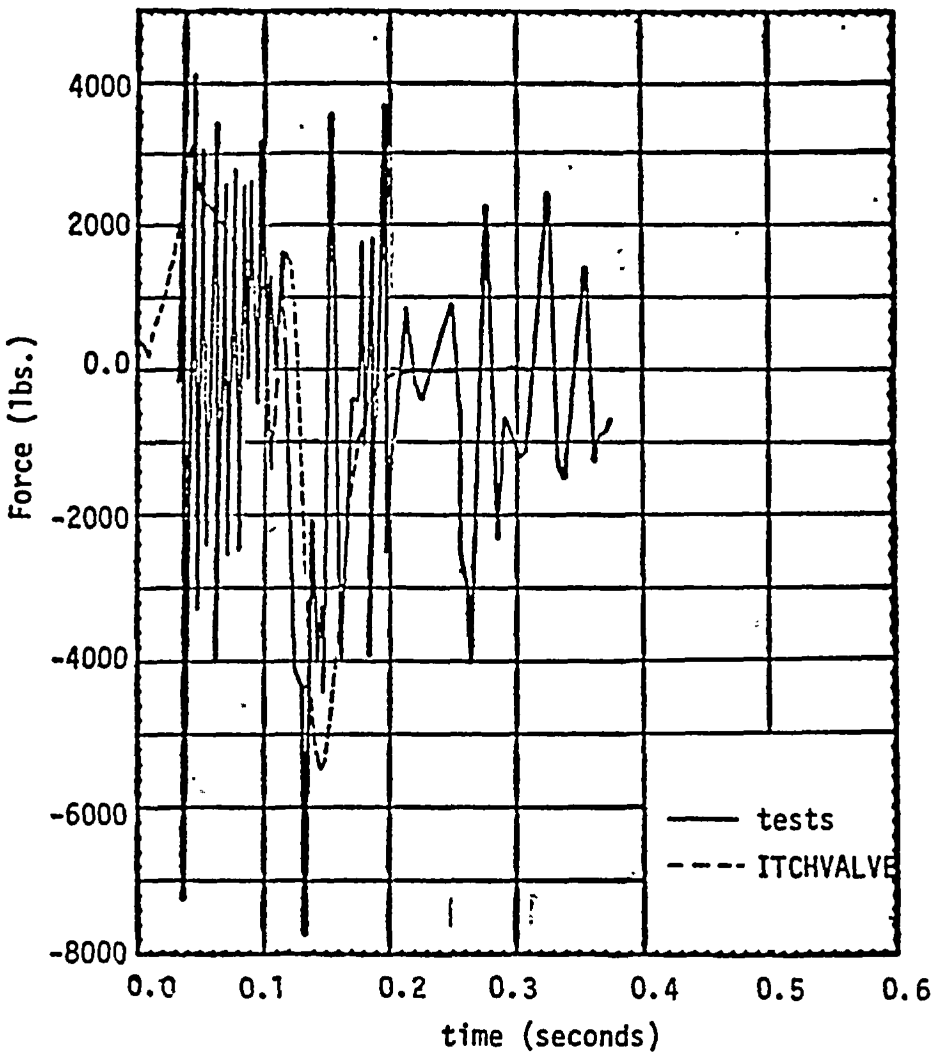


FIGURE 4-8 : Comparison of the EPRI Force Time-History for WE28 and WE29 from Test 917 with the ITCHVALVE Predicted Force Time-History

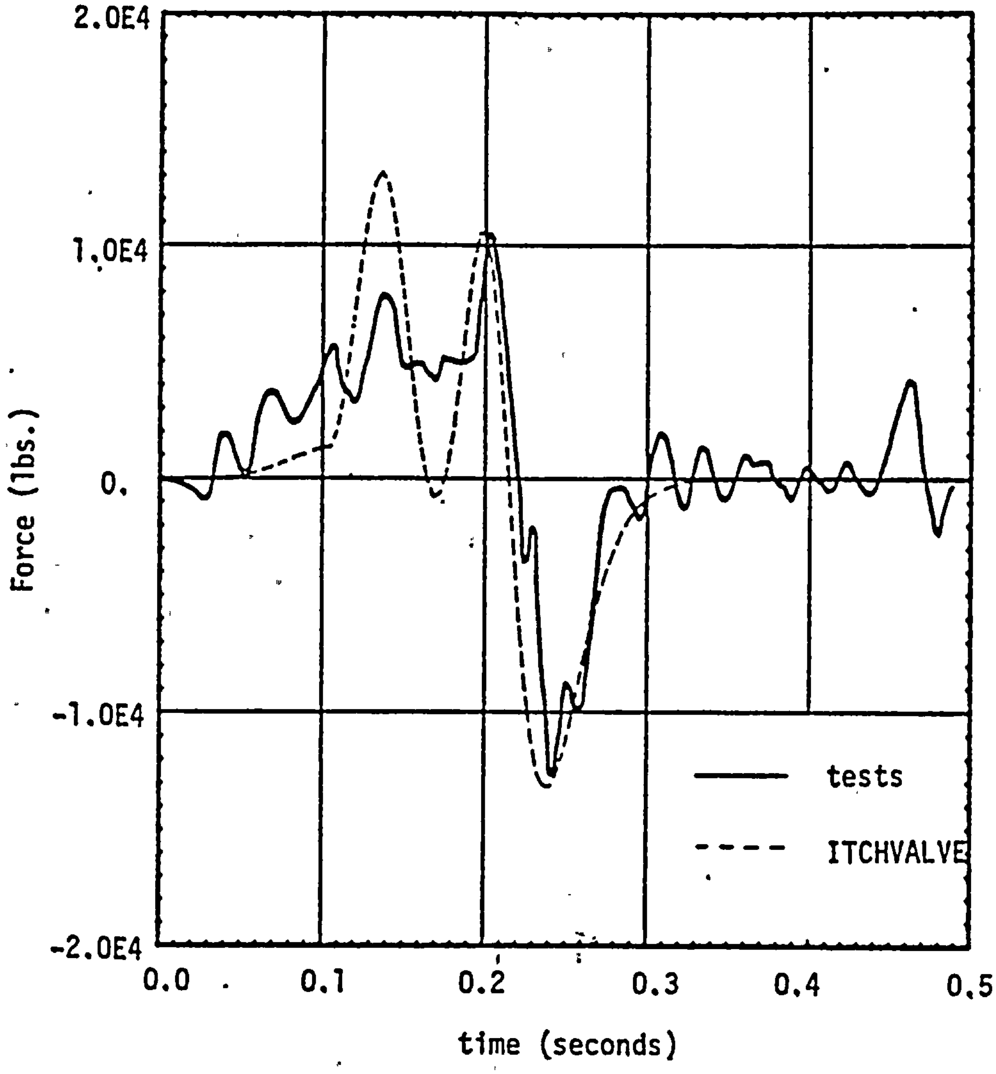


FIGURE 4-9 : Comparison of the EPRI Force Time-History for WE32 and WE33 from Test 917 with the ITCHVALVE Predicted Force Time-History

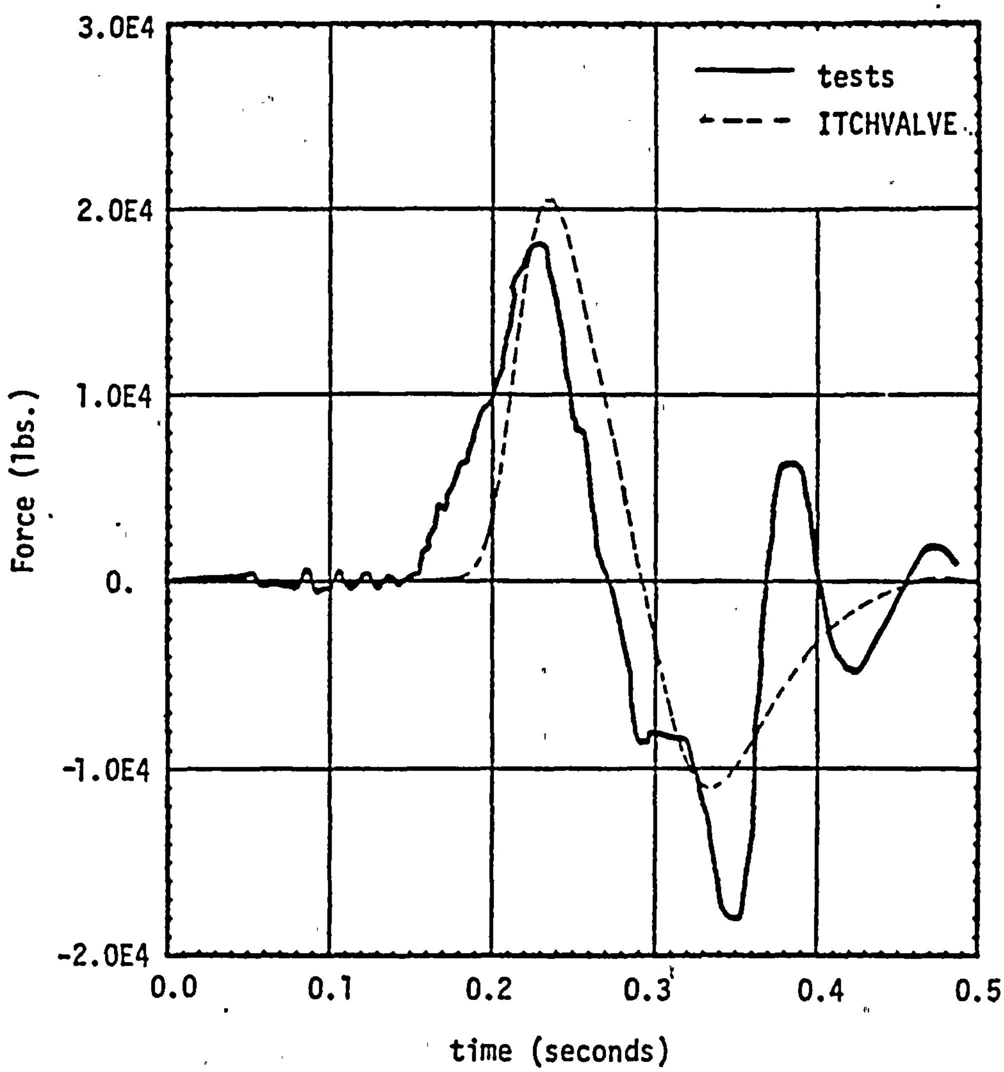


FIGURE 4-10: Comparison of the EPRI Force Time-History For WE30 and WE31 From Test 917 with the ITCHVALVE Predicted Force Time-History

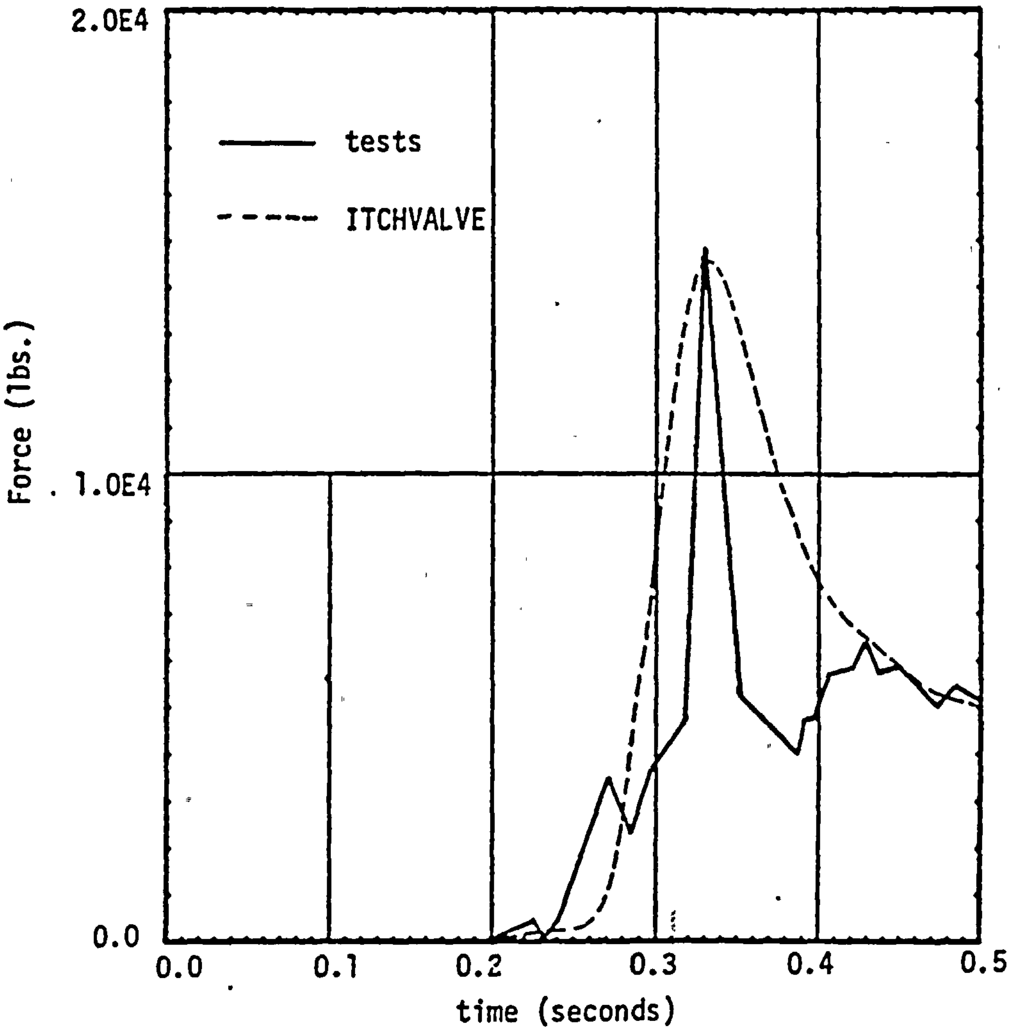


FIGURE 4-11: Comparison of the EPRI Force Time-History For WE34 and WE35 from Test 917 with the ITCHVALVE Predicted Force Time-History

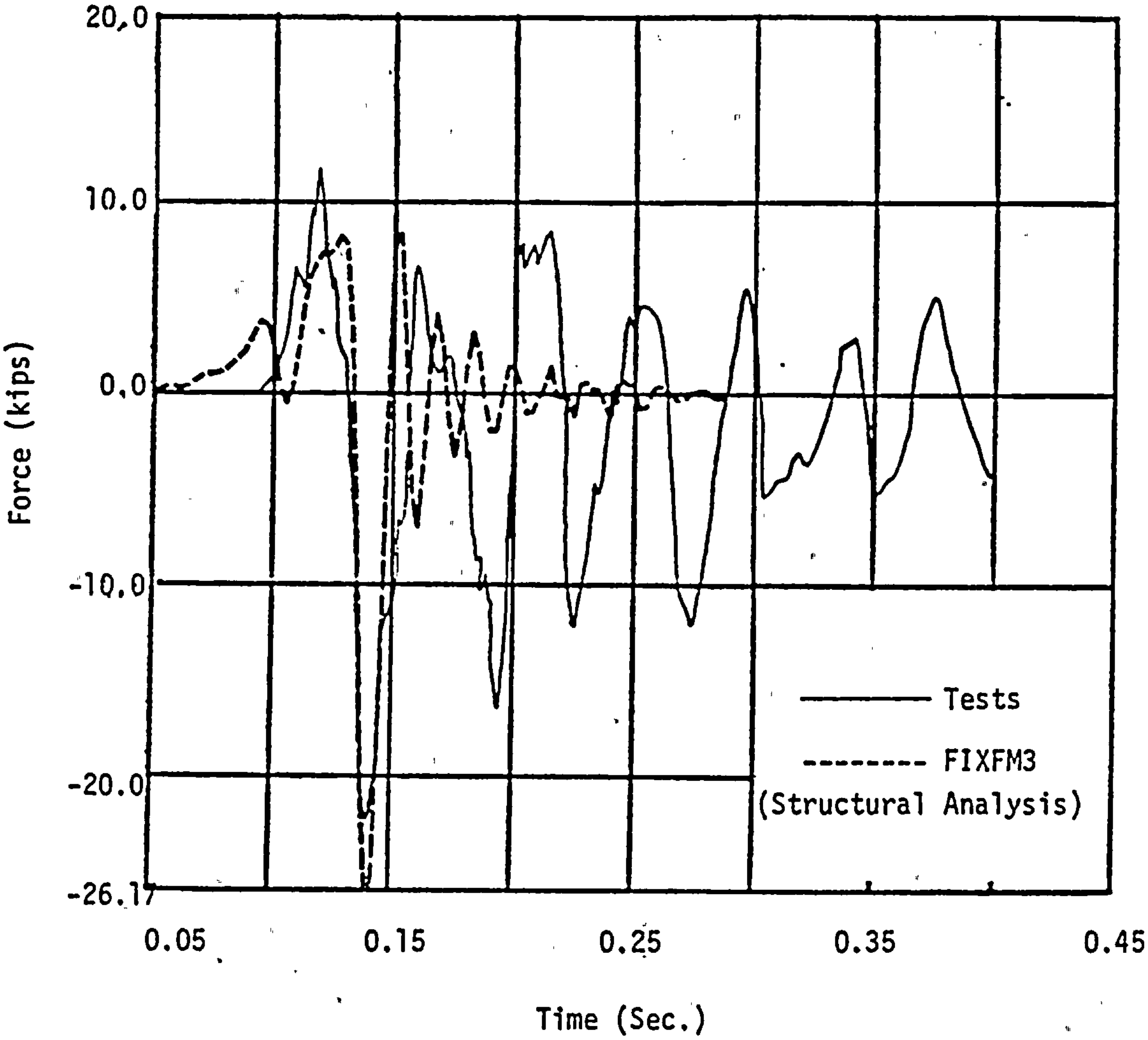


FIGURE 4-12: Comparison of the EPRI Force Time-History for WE28 and WE29 from Test 908 with the FIXFM3 Predicted Force Time-History

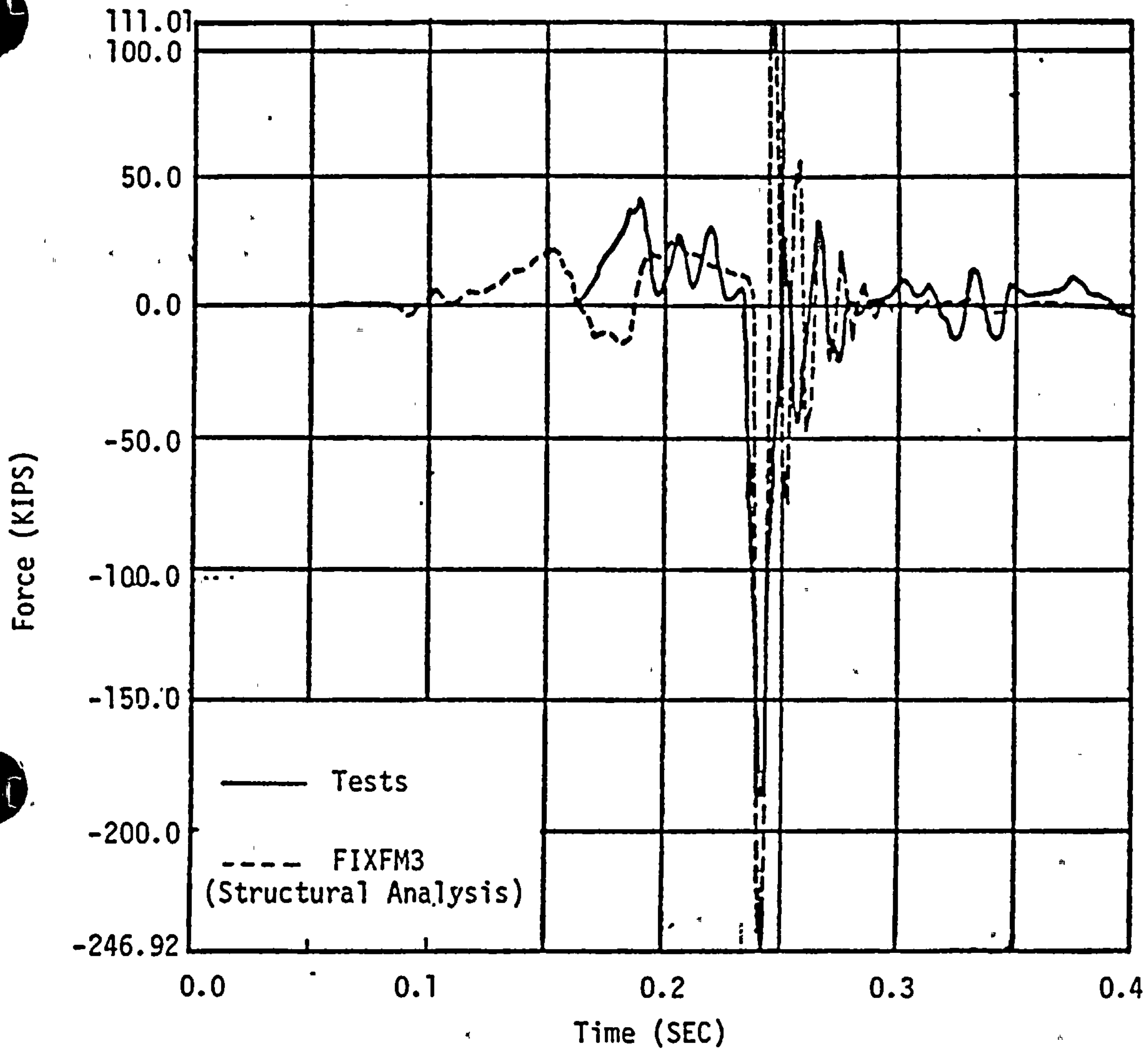


Figure 4-13: Comparison of the EPRI Force Time-History For WE32 and WE33 From Test 908 With the FIXFM3 Predicted Force Time-History

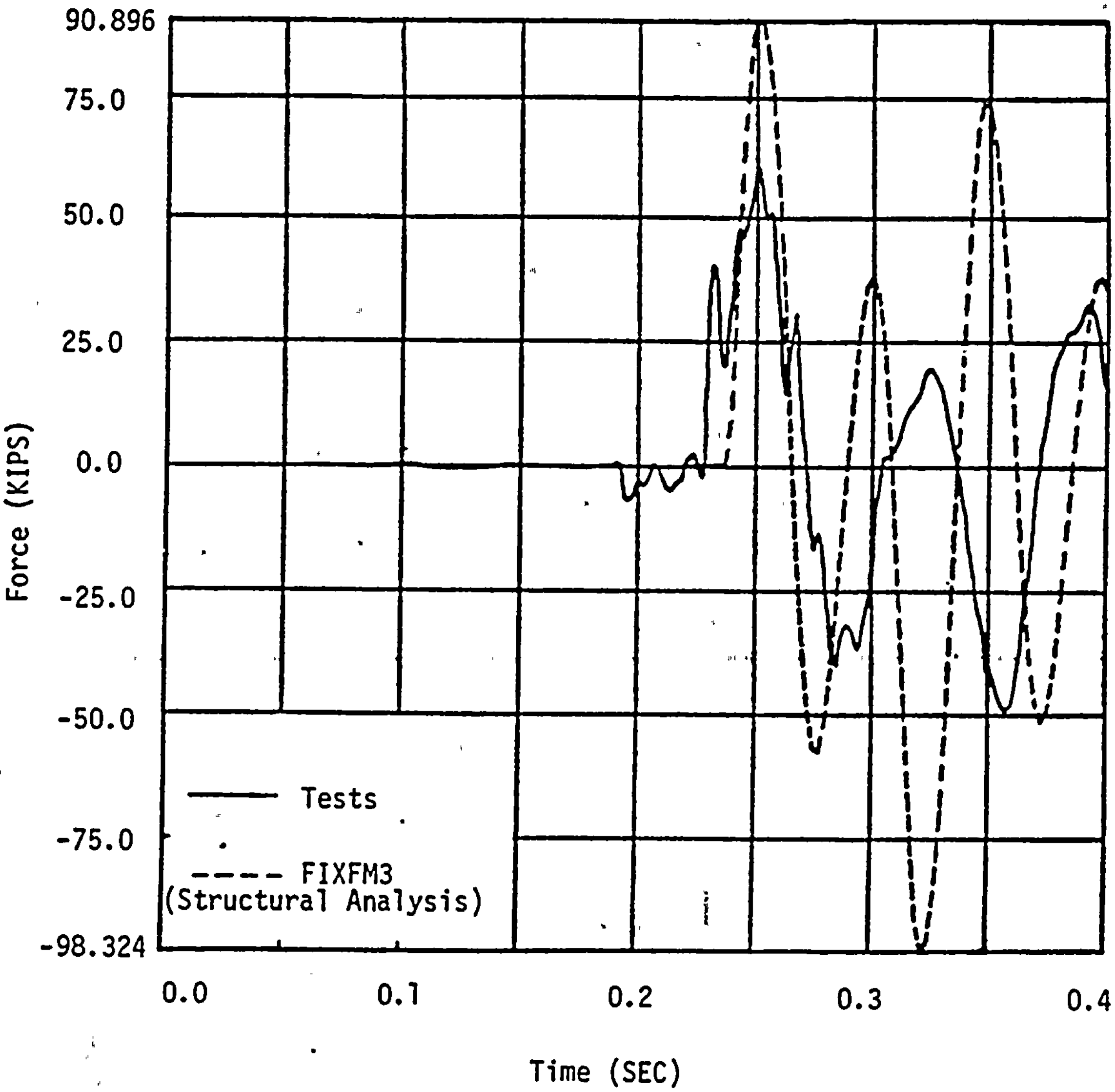


Figure 4-14: Comparison of the EPRI Force Time-History For WE30 and WE31 From Test 908 With the FIXFM3 Predicted Force Time-History

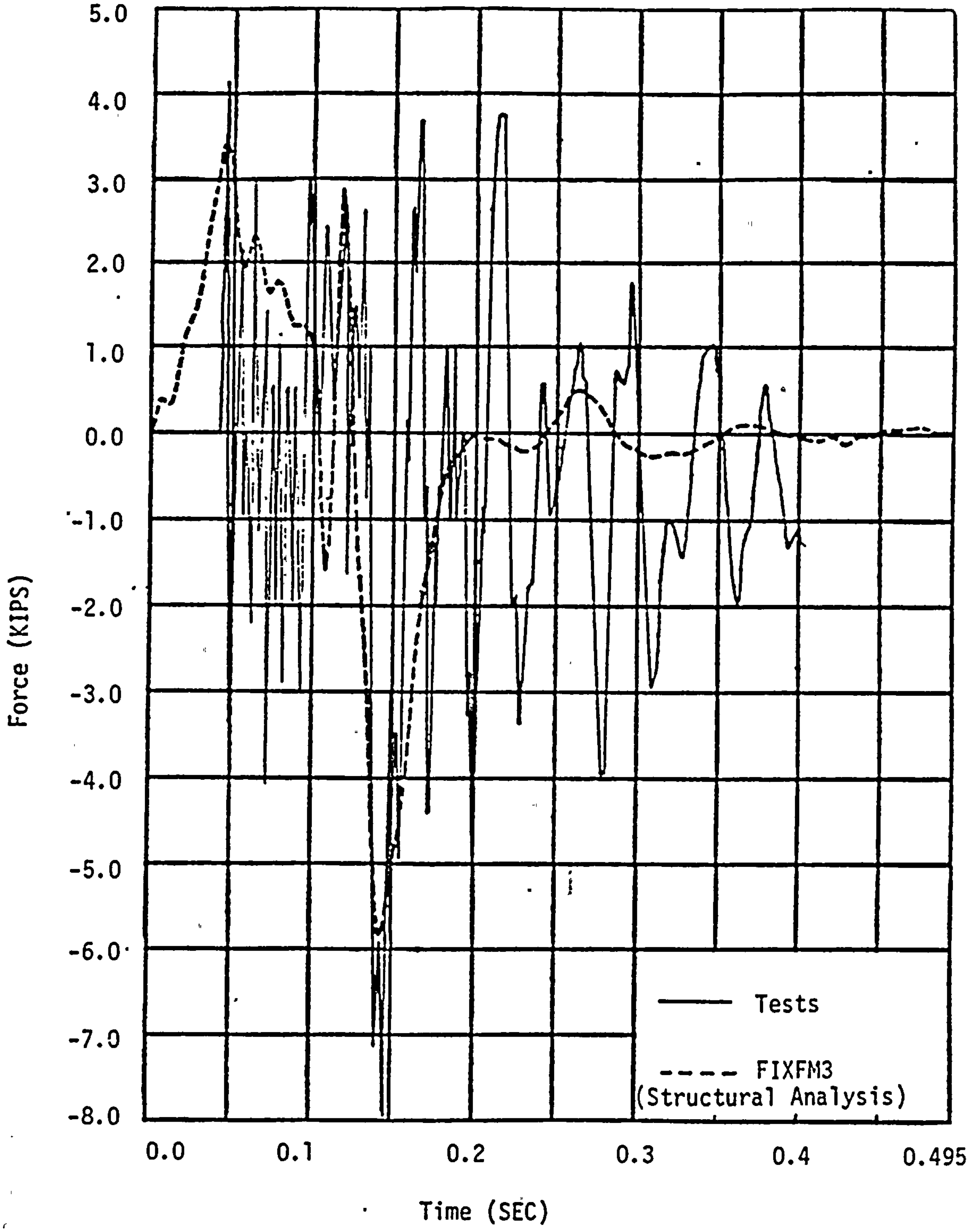


Figure 4-15: Comparison of the EPRI Force Time-History For WE28 and WE29 From Test 917 With the FIXFM3 Predicted Force Time-History

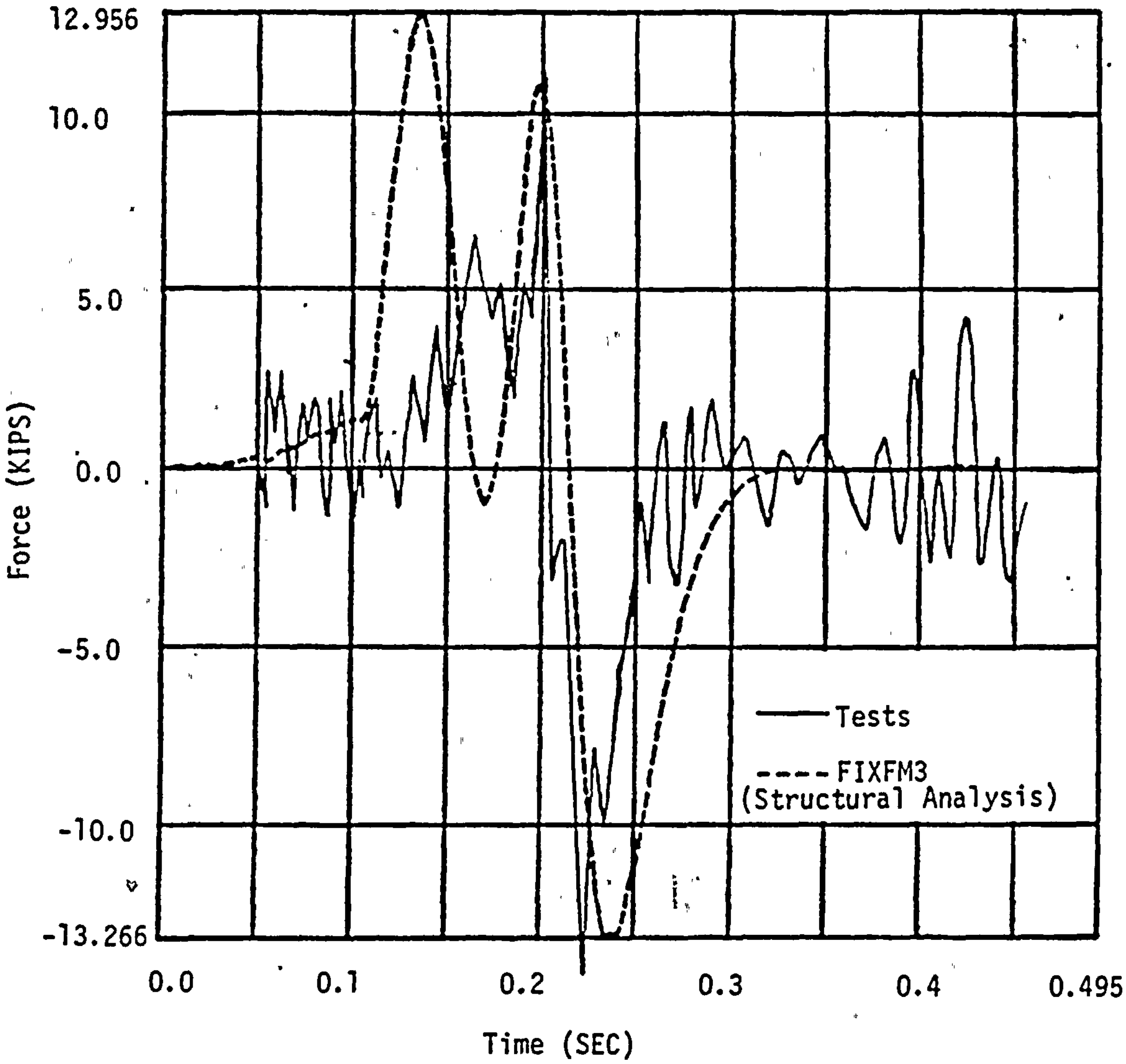


Figure 4-16: Comparison of the EPRI Force Time-History For WE32 and WE33 From Test 917 With the FIXFM3 Predicted Force Time-History

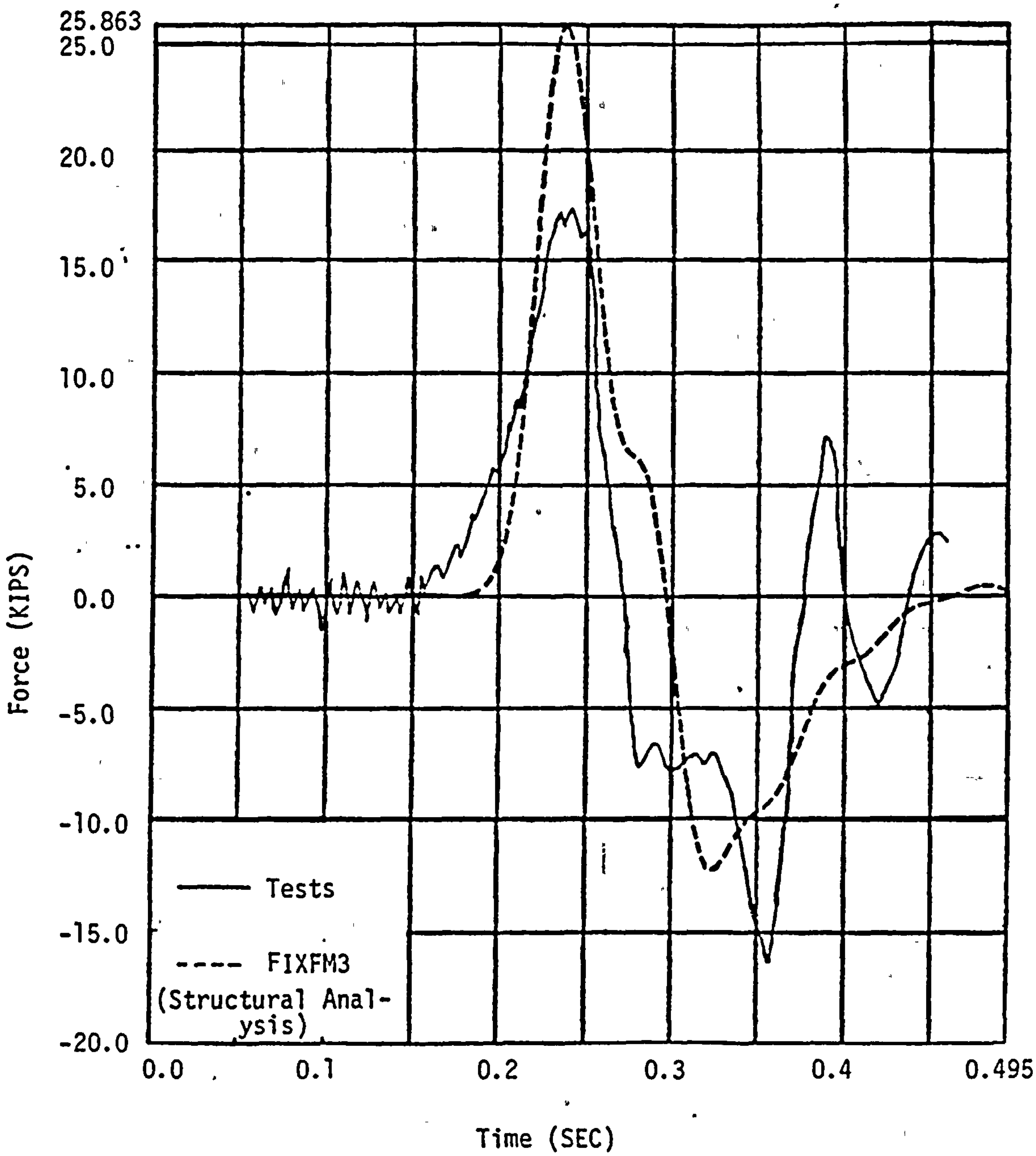


Figure 4-17: Comparison of the EPRI Force Time-History For WE30 and WE31 From Test 917 With the FIXFM3 Predicted Force Time-History

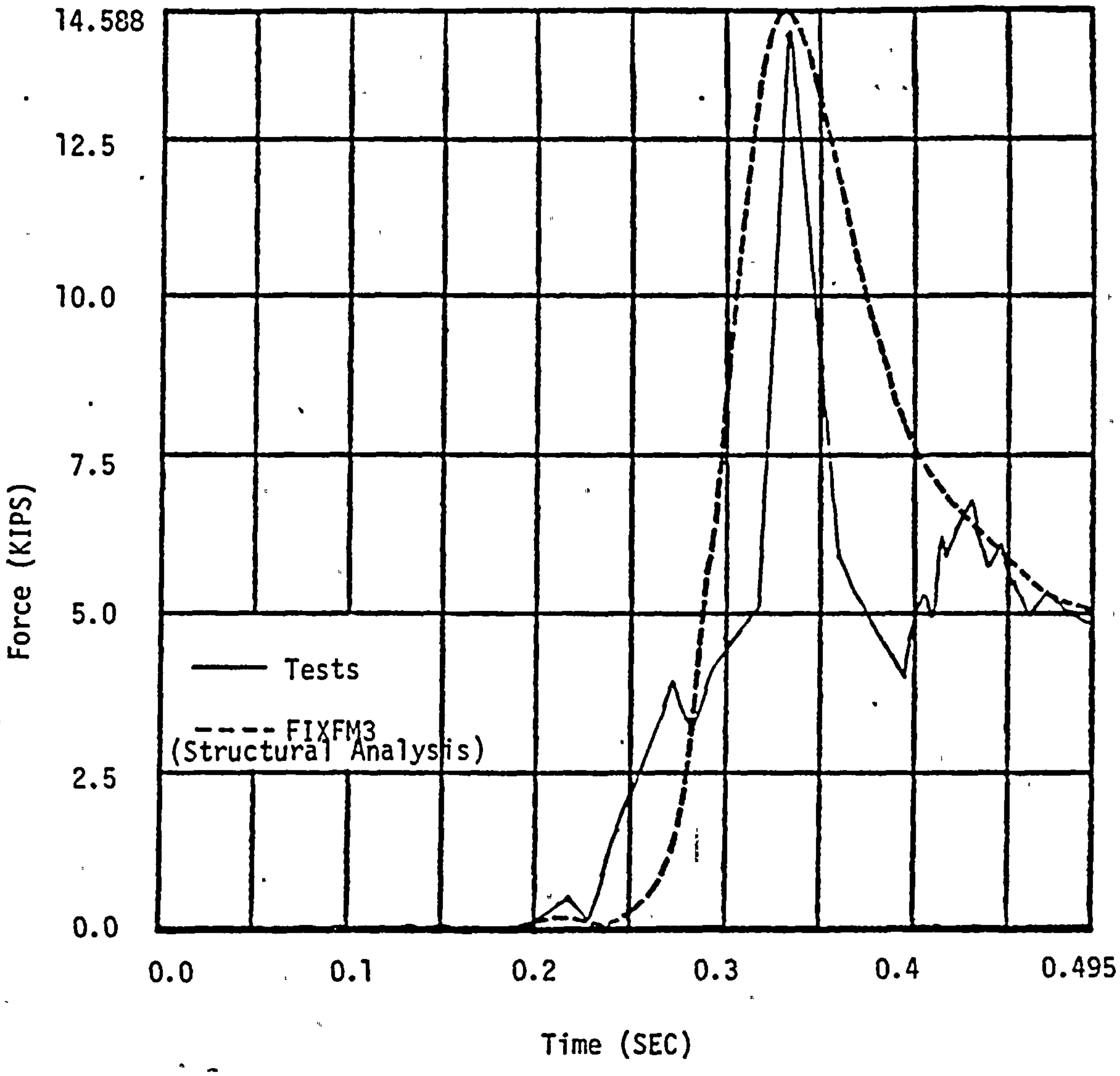


Figure 4-18: Comparison of the EPRI Force Time-History For WE34 and WE35 From Test 917 With the FIXFM3 Predicted Force Time-History

SECTION 5
METHOD OF STRESS EVALUATION

5.1 INTRODUCTION

The method used to combine the primary loads to evaluate the adequacy of the piping system is described in this section.

5.2 PRIMARY STRESS EVALUATION

In order to perform a primary stress evaluation in accordance with the rules of the Code, definitions of stress combinations are required for the normal, upset, emergency, and faulted plant conditions as defined in Section 3. Tables 2-1 and 2-2 illustrate the allowable stress intensities for the appropriate combinations as discussed in Section 2.2. Table 2-3 defines all pertinent terms.

5.2.1 DESIGN CONDITIONS

The piping minimum wall thickness, t_m, is calculated in accordance with the Code. The actual pipe minimum wall thickness meets the Code requirement.

The combined stresses due to primary loadings of pressure, weight, and any other design mechanical loads, calculated using applicable stress intensity factors, must not exceed the allowable limit. The resultant moment, M_i, is calculated using the following equation:

$$M_i = \left[\left(M_{x_{wt}} + M_{x_{DML}}\right)^2 + \left(M_{y_{wt}} + M_{y_{DML}}\right)^2 + \left(M_{z_{wt}} + M_{z_{DML}}\right)^2\right]^{1/2}$$

where

$M_{x_{wt}}, M_{y_{wt}}, M_{z_{wt}}$ = deadweight moment components

$M_{x_{DML}}, M_{y_{DML}}, M_{z_{DML}}$ = design mechanical load moment components

5.2.2 UPSET CONDITIONS

The combined stresses due to the primary loadings of pressure, weight, operating basis earthquake (OBE), and relief valve thrust, calculated using the applicable stress intensity factors, must not exceed the allowables. The resultant moment, M_i, is calculated as shown below.

For seismic and relief valve thrust loading:

$$M_i = \left[\left(\left|M_{x_{wt}}\right| + \left(M_{x_{OBE}}^2 + M_{x_{SOT_U}}^2\right)^{1/2}\right)^2 + \left(\left|M_{y_{wt}}\right| + \left(M_{y_{OBE}}^2 + M_{y_{SOT_U}}^2\right)^{1/2}\right)^2 + \left(\left|M_{z_{wt}}\right| + \left(M_{z_{OBE}}^2 + M_{z_{SOT_U}}^2\right)^{1/2}\right)^2\right]^{1/2}$$

where

$M_{x_{wt}}, M_{y_{wt}}, M_{z_{wt}}$ = deadweight moment components

$M_{x_{OBE}}, M_{y_{OBE}}, M_{z_{OBE}}$ = OBE moment components

$M_{x_{SOT_U}}, M_{y_{SOT_U}}, M_{z_{SOT_U}}$ = relief line operation moment components

to primary loadings of pressure, weight, and
ng applicable stress intensification factors,
owable limits. The magnitude of the resultant
ed from the moment components as shown below:

$$\ldots \left|M_{x_{wt}}\right|\Big)^2 + \left(M_{y_{SOT_E}} + \left|M_{y_{wt}}\right|\right)^2 + \left(M_{z_{SOT_E}} + \left|M_{z_{wt}}\right|\right)^2 \Bigg]^{1/2}$$

$\ldots M_{z_{wt}}$ = deadweight moment components

$\ldots y_{SOT_E}, M_{z_{SOT_E}}$ = safety line operation moment components

LTED CONDITIONS

ined stresses due to the primary loadings of pressure, weight,
utdown earthquake (SSE), and SOT_F, using applicable stress
ification factors, must not exceed the allowable limits. The
tude of the resultant moment, M_i, is calculated from the three
nt components as shown below:

$$M_i = \Bigg[\left(\left(M_{x_{SOT_F}}{}^2 + M_{x_{SSE}}{}^2\right)^{1/2} + \left|M_{x_{wt}}\right|\right)^2 + \left(\left(M_{y_{SOT_F}}{}^2 + M_{y_{SSE}}{}^2\right)^{1/2} + \left|M_{y_{wt}}\right|\right)^2 + \ldots$$

$$\ldots \Big)^2 \Big]^{1/2}$$

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6.2.1 THERMAL HYDRAULIC RESULTS

The thermal hydraulic analysis used computer programs which have been shown to match the results of the EPRI Test Program (Section 4.5.2). Hydraulic forcing functions were generated assuming the simultaneous opening of either the safety valves or the relief valves since these represent the worst applicable loading cases for the piping and supports of this specific layout. No design condition or operating procedure would result in a transition flow condition through either the safety or relief valves.

Table 6-1 shows the maximum forces on each straight run of pipe for the simultaneous opening of both safety valves while Table 6-2 shows the maximum forces for the simultaneous opening of both relief valves. To account for uncertainties in the valve flow capacities due to tolerances and deviations, a conservative factor of over 1.20 was included in the maximum rated valve mass flow rate for these cases. This results in conservative forcing functions.

For the relief valves opening case, small cold loop seals were assumed to exist upstream of the valves. This is conservative as the piping layout is such that no or very little condensate will remain in the upstream relief valve line piping.

For the safety valves opening case, hot loop seals were assumed to exist upstream of the valves. This assumption was made because the piping is insulated. The loop seal temperature distribution for this case was presumed to be consistent with the distribution in EPRI test 917. That is, the loop seal temperature at the valve inlet was about 300°F, and approximately eight feet upstream, the loop seal liquid temperature was near the system saturation temperature of 655°F. Based upon engineering judgement, significant flashing of hot water near the valve occurred for test 917, thus reducing the downstream loads significantly.

Based on analytical work and tests to date, all acoustic pressures in the upstream piping calculated or observed prior to and during safety valve hot or cold loop seal discharge are below the maximum permissable pressure. The piping between the pressurizer nozzle and the inlet of the safety valves is 4-inch schedule 160. The calculated maximum upstream pressure for this size of piping is below the maximum permissable pressure. A similar evaluation of this inlet piping phenomenon, applicable for temperatures below 300°F, was conducted and the results are documented in a report entitled "Review of Pressurizer Safety Valve Performance as Observed in the EPRI Safety and Relief Valve Test Program", WCAP-10105, dated June 1982.

6.2.2 STRUCTURAL RESULTS

Stress summaries for the valve discharge loading cases considered are provided in Tables 6-3 through 6-20. Plots of the structural models are shown in Figures 6-1 and 6-2.

For purposes of providing stress summaries, the system was broken up into the following three sets of sections:

Section 1: Piping between the pressurizer and the safety valve outlet nozzles (upstream of valves).

Section 2: Piping between the pressurizer and the relief valve outlet nozzles (upstream of valves).

Section 3: Piping between the safety and relief valve outlet nozzles and the pressurizer relief tank (seismically designed downstream portion).

The evaluation conducted prior to the completion of the structural analysis and based on the thermal hydraulic loadings for the simultaneous discharge of both safety valves or both relief valves indicated that the piping could be qualified. The structural analyses have been completed and have confirmed and quantified this as shown in Tables 6-3 through 6-20.

The piping supports were analyzed in accordance with Section III, subsection NF and no modifications were required to ensure the operability of the relief and safety valve system. Three modifications will be made to the supports for relief piping leading to the pressurizer relief tank, however, these modifications are not required for the relief and safety valves to function properly. The modifications will be made to ensure that analysis assumptions are valid for downstream piping, although not required for valve operability, and to assure that fluid relieved from the pressurizer will be directed to the relief tank. With the inclusion of these support modifications, all supports were found to be adequate to withstand all pertinent loadings.

In addition, the acceptability of the valve nozzles, valve accelerations, and equipment nozzles was assured for the applied loads.

6.3 SUMMARY OF RESULTS AND CONCLUSIONS

The thermal hydraulic analysis and structural evaluation of the R.E. Ginna pressurizer safety and relief valve discharge piping system have been completed. In summary the operability and structural integrity of the system have been ensured for all applicable loadings and load combinations including all pertinent safety and relief valve discharge cases.

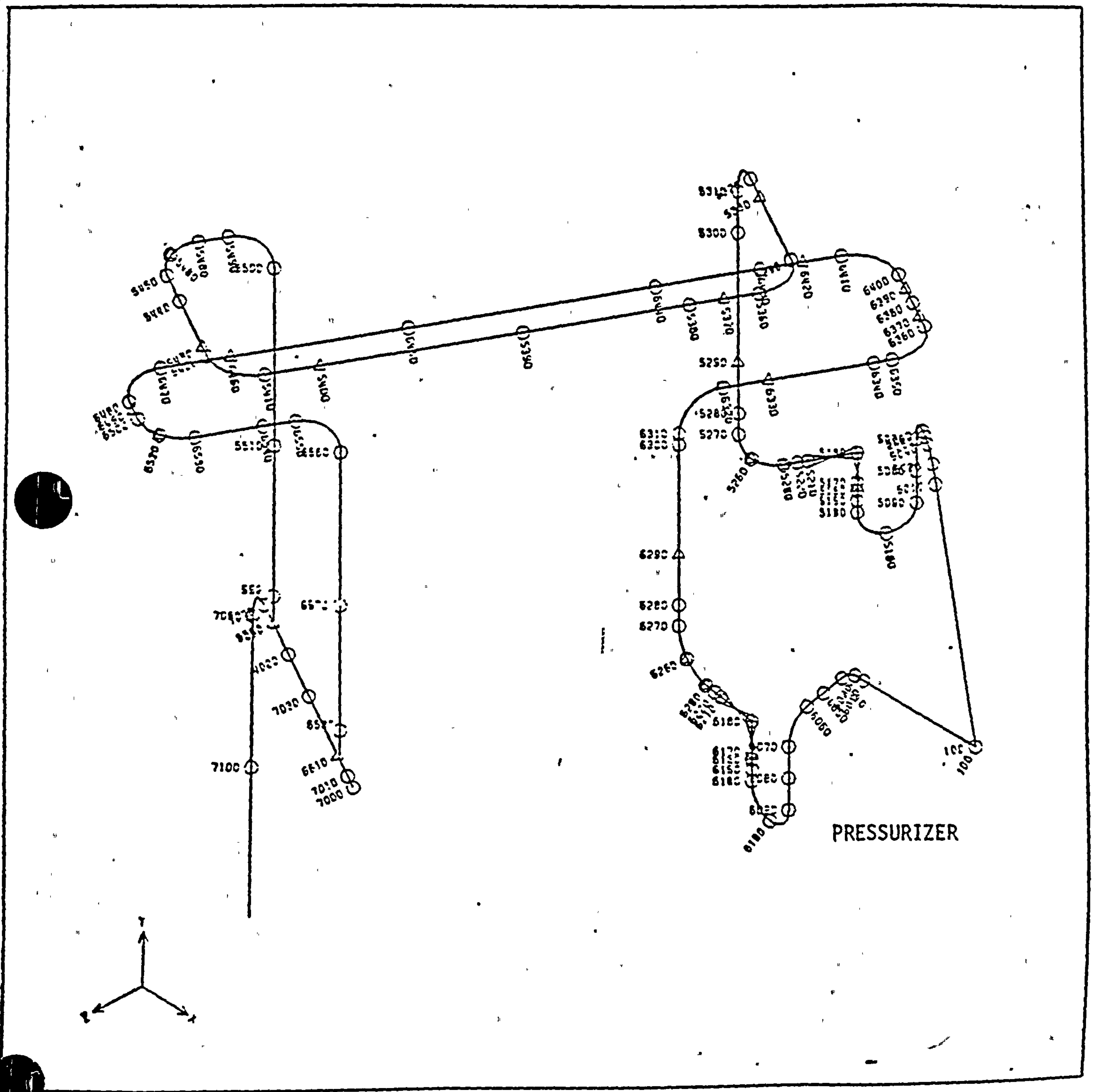

FIGURE 6-1: STRUCTURAL MODEL, SAFETY LINE

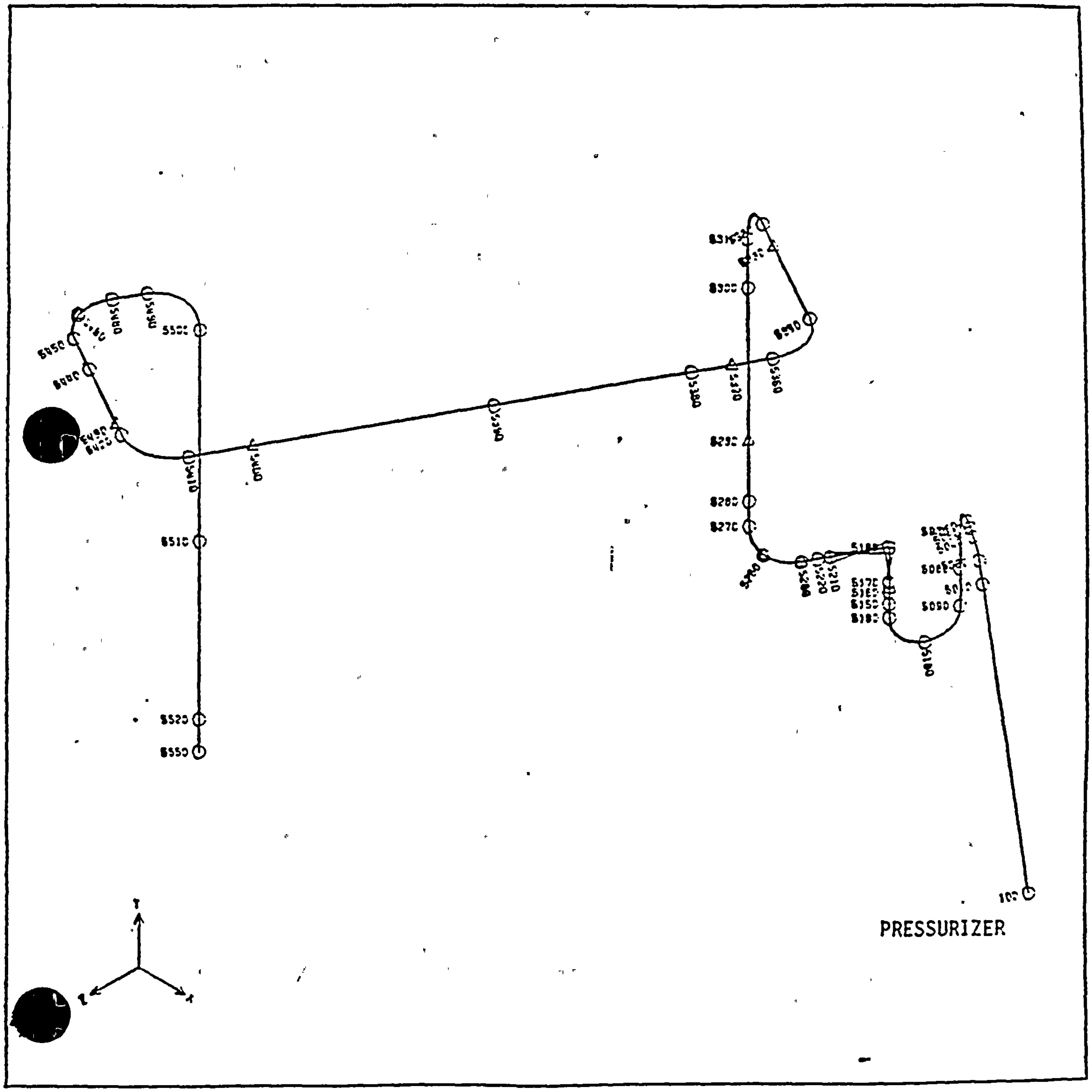

FIGURE 6-1: (CONT.) STRUCTURAL MODEL, SAFETY LINE

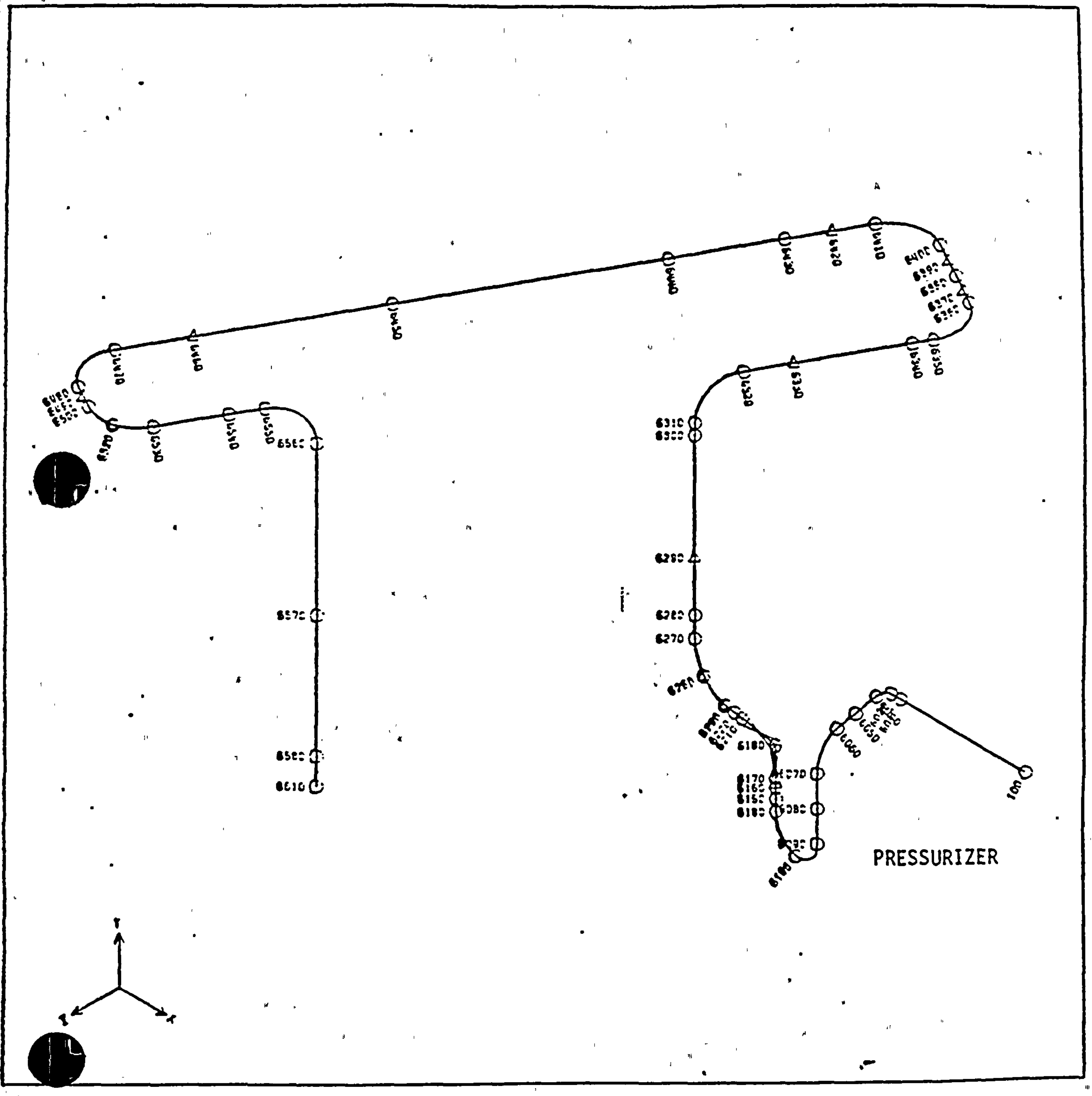

FIGURE 6-1: (CONT.) STRUCTURAL MODEL, SAFETY LINE

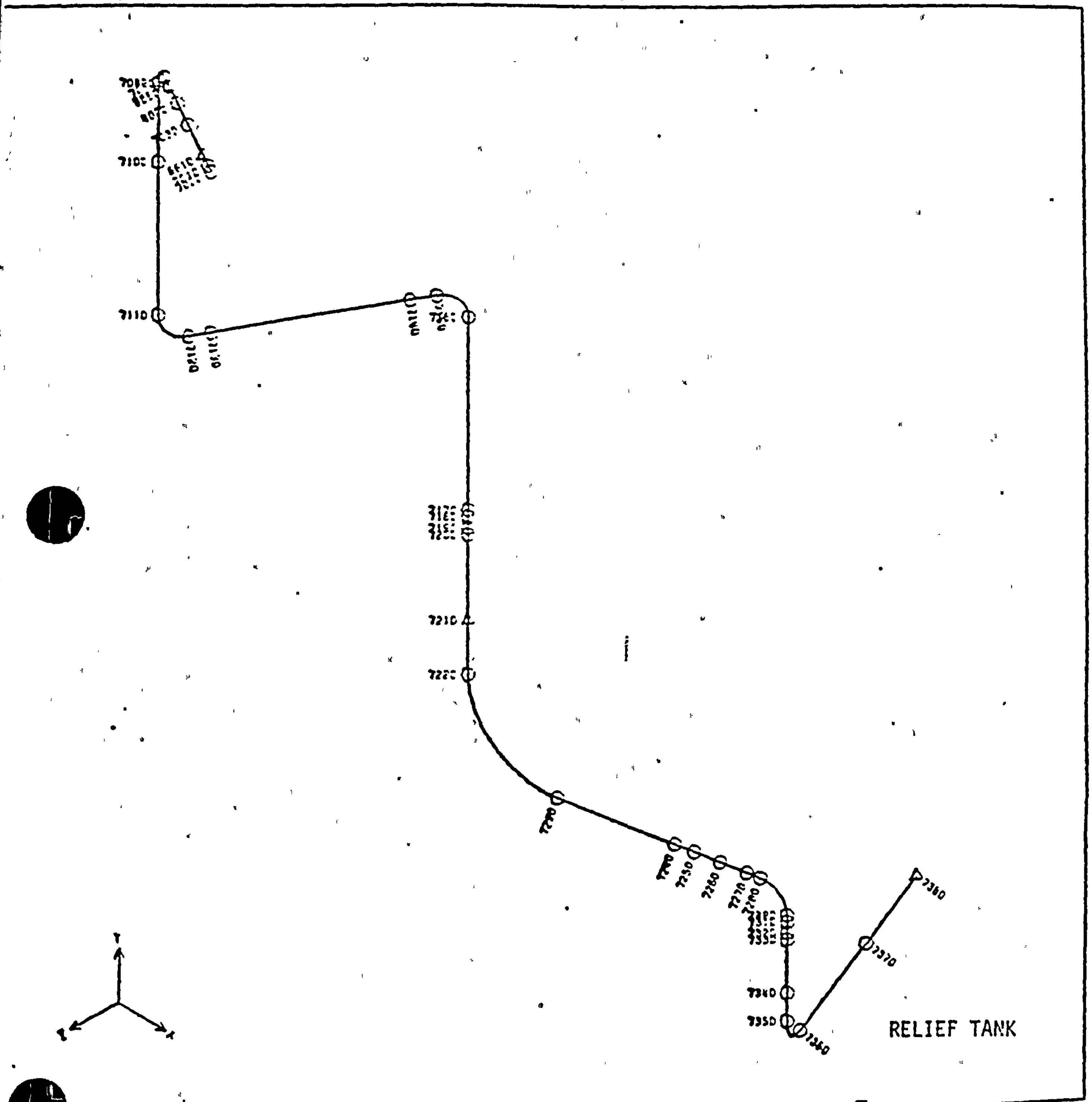

FIGURE 6-1: (CONT.) STRUCTURAL MODEL, COMMON HEADER

TABLE 6-1

HYDRAULIC FORCES - SAFETY LINE

Force No.	Force (LBF)	Force No.	Force (LBF)
1	115	17	4240
2	80	18	2525
3	1870	19	8140
4	2970	20	5640
5	4250	21	3195
6	2505	22	7650
7	8840	23	1130
8	4780	24	1655
9	7675	25	2865
10	2515	26	2450
11	1175	27	5815
12	3695	28	4835
13	120	29	5785
14	125	30	4640
15	1865	31	2500
16	2965	32	3360

The force numbers correspond to the segment numbers on Figure 4-1.

TABLE 6-3

PRIMARY STRESS SUMMARY

PIPING COMPONENTS - UPSTREAM OF VALVES

Piping System: Pressurizer Relief Line

Maximum Values for Combination 1 - N

Node Point	Piping Component	Maximum Stress (ksi)	Allowable Stress (ksi)
2045	Straight run	3.8	16.4
2000	Butt weld	4.5	16.4
120	Elbow	3.8	16.4
2000	Reducer	4.5	16.4
150	Tee	4.9	16.4

See Tables 2-1 through 2-3 for load combinations and definitions.

TABLE 6-4

PRIMARY STRESS SUMMARY

PIPING COMPONENTS - UPSTREAM OF VALVES

Piping System: Pressurizer Relief Line

Maximum Values for Combination 2 - N + OBE + SOT_U

Node Point	Piping Component	Maximum Stress (ksi)	Allowable Stress (ksi)
2045	Straight run	15.3	19.7
2040	Butt weld	19.3	19.7
120	Elbow	15.0	19.7
1100	Reducer	17.7	19.7
150	Tee	12.3	19.7

See Tables 2-1 through 2-3 for load combinations and definitions.

TABLE 6-5

PRIMARY STRESS SUMMARY

PIPING COMPONENTS - UPSTREAM OF VALVES

Piping System: Pressurizer Relief Line

Maximum Values for Combination 3 - N + SOT_E

Node Point	Piping Component	Maximum Stress (ksi)	Allowable Stress (ksi)
2045	Straight run	4.5	29.6
1000	Butt weld	4.9	29.6
120	Elbow	4.7	29.6
1100	Reducer	5.3	29.6
150	Tee	5.3	29.6

See Tables 2-1 through 2-3 for load combinations and definitions.

TABLE 6-5

PRIMARY STRESS SUMMARY
PIPING COMPONENTS - UPSTREAM OF VALVES

Piping System: Pressurizer Relief Line

Maximum Values for Combination 3 - N + SOT_E

Node Point	Piping Component	Maximum Stress (ksi)	Allowable Stress (ksi)
2045	Straight run	4.5	29.6
1000	Butt weld	4.9	29.6
120	Elbow	4.7	29.6
1100	Reducer	5.3	29.6
150	Tee	5.3	29.6

See Tables 2-1 through 2-3 for load combinations and definitions.

TABLE 6-6

PRIMARY STRESS SUMMARY

PIPING COMPONENTS – UPSTREAM OF VALVES

Piping System: Pressurizer Relief Line

Maximum Values for Combinations 4 and 5 – N + SSE + SOT_F

Node Point	Piping Component	Maximum Stress (ksi)	Allowable Stress (ksi)
2045	Straight run	17.8	39.4
2040	Butt weld	22.5	39.4
120	Elbow	16.4	39.4
1100	Reducer	20.2	39.4
150	Tee	13.6	39.4

See Tables 2-1 through 2-3 for load combinations and definitions.

TABLE 6-7

PRIMARY STRESS SUMMARY

PIPING COMPONENTS - SEISMICALLY DESIGNED DOWNSTREAM PORTION

Piping System: Pressurizer Relief Line

Maximum Values for Combination 1 - N

Node Point	Piping Component	Maximum Stress (ksi)	Allowable Stress (ksi)
2135	Straight run	3.6	15.0
3100	Butt weld	4.2	15.0
3020	Elbow	2.5	15.0
4020	Tee	4.3	15.0

See Tables 2-1 through 2-3 for load combinations and definitions.

TABLE 6-8

PRIMARY STRESS SUMMARY

PIPING COMPONENTS - SEISMICALLY DESIGNED DOWNSTREAM PORTION

Piping System: Pressurizer Relief Line

Maximum Values for Combination 2 - N + SOT_U

Node Point	Piping Component	Maximum Stress (ksi)	Allowable Stress (ksi)
2105	Straight run	13.2	18.0
3100	Butt weld	11.1	18.0
3020	Elbow	13.6	18.0
4020	Tee	10.3	18.0

See Tables 2-1 through 2-3 for load combinations and definitions.

TABLE 6-9

PRIMARY STRESS SUMMARY

PIPING COMPONENTS - SEISMICALLY DESIGNED DOWNSTREAM PORTION

Piping System: Pressurizer Relief Line

Maximum Values for Combination 3 - N + OBE + SOT_U

Node Point	Piping Component	Maximum Stress (ksi)	Allowable Stress (ksi)
2105	Straight run	16.4	27.0
3100	Butt weld	15.4	27.0
2190	Elbow	15.7	27.0
4020	Tee	13.3	27.0

See Tables 2-1 through 2-3 for load combinations and definitions.

TABLE 6-10

PRIMARY STRESS SUMMARY

PIPING COMPONENTS – SEISMICALLY DESIGNED DOWNSTREAM PORTION

Piping System: Pressurizer Relief Line

Maximum Values for Combination 4 – N + SOT_E

Node Point	Piping Component	Maximum Stress (ksi)	Allowable Stress (ksi)
2135	Straight run	4.3	27.0
3100	Butt weld	4.4	27.0
3070	Elbow	3.9	27.0
4020	Tee	13.7	27.0

See Tables 2-1 through 2-3 for load combinations and definitions.

TABLE 6-11

PRIMARY STRESS SUMMARY

PIPING COMPONENTS - SEISMICALLY DESIGNED DOWNSTREAM PORTION

Piping System: Pressurizer Relief Line

Maximum Values for Combinations 5 and 6 - N + SSE + SOT_F

Node Point	Piping Component	Maximum Stress (ksi)	Allowable Stress (ksi)
2105	Straight run	18.0	36.0
3100	Butt weld	17.8	36.0
2190	Elbow	17.1	36.0
4020	Tee	14.9	36.0

See Tables 2-1 through 2-3 for load combinations and definitions.

TABLE 6-12

PRIMARY STRESS SUMMARY

PIPING COMPONENTS - UPSTREAM OF VALVES

Piping System: Pressurizer Safety Line

Maximum Values for Combination 1 - N

Node Point	Piping Component	Maximum Stress (ksi)	Allowable Stress (ksi)
6050	Straight run	3.9	16.4
6010	Butt weld	4.9	16.4
6030	Elbow	4.3	16.4
6010	Reducer	5.9	16.4

See Tables 2-1 through 2-3 for load combinations and definitions.

TABLE 6-13

PRIMARY STRESS SUMMARY

PIPING COMPONENTS – UPSTREAM OF VALVES

Piping System: Pressurizer Safety Line

Maximum Values for Combination 2 – N + OBE + SOT_U

Node Point	Piping Component	Maximum Stress (ksi)	Allowable Stress (ksi)
6110	Straight run	6.2	19.7
6010	Butt weld	11.1	19.7
6130	Elbow	6.2	19.7
6010	Reducer	15.3	19.7

See Tables 2-1 through 2-3 for load combinations and definitions.

TABLE 6-14

PRIMARY STRESS SUMMARY

PIPING COMPONENTS - UPSTREAM OF VALVES

Piping System: Pressurizer Safety Line

Maximum Values for Combination 3 - N + SOT_E

Node Point	Piping Component	Maximum Stress (ksi)	Allowable Stress (ksi)
6110	Straight run	10.8	29.6
5010	Butt weld	19.5	29.6
6120	Elbow	10.9	29.6
5010	Reducer	28.1	29.6

See Tables 2-1 through 2-3 for load combinations and definitions.

TABLE 6-15

PRIMARY STRESS SUMMARY

PIPING COMPONENTS - UPSTREAM OF VALVES

Piping System: Pressurizer Safety Line

Maximum Values for Combinations 4 and 5 - N + SSE + SOT_F

Node Point	Piping Component	Maximum Stress (ksi)	Allowable Stress (ksi)
6110	Straight run	11.6	39.4
6010	Butt weld	21.7	39.4
6120	Elbow	11.6	39.4
6010	Reducer	31.3	39.4

See Tables 2-1 through 2-3 for load combinations and definitions.

TABLE 6-16

PRIMARY STRESS SUMMARY

PIPING COMPONENTS - SEISMICALLY DESIGNED DOWNSTREAM PORTION

Piping System: Pressurizer Safety Line

Maximum Values for Combination 1 - N

Node Point	Piping Component	Maximum Stress (ksi)	Allowable Stress (ksi)
7220	Straight run	4.2	15.0
7280	Butt weld	4.2	15.0
7280	Elbow	4.4	15.0
5550	Tee	4.8	15.0

See Tables 2-1 through 2-3 for load combinations and definitions.

TABLE 6-17

PRIMARY STRESS SUMMARY

PIPING COMPONENTS - SEISMICALLY DESIGNED DOWNSTREAM PORTION

Piping System: Pressurizer Safety Line

Maximum Values for Combination 2 - N + SOT_U

Node Point	Piping Component	Maximum Stress (ksi)	Allowable Stress (ksi)
7090	Straight run	4.2	18.0
7070	Butt weld	4.2	18.0
7080	Elbow	4.4	18.0
5550	Tee	4.8	18.0

See Tables 2-1 through 2-3 for load combinations and definitions.

TABLE 6-18

PRIMARY STRESS SUMMARY

PIPING COMPONENTS - SEISMICALLY DESIGNED DOWNSTREAM PORTION

Piping System: Pressurizer Safety Line

Maximum Values for Combination 3 - N + OBE + SOT_U

Node Point	Piping Component	Maximum Stress (ksi)	Allowable Stress (ksi)
7090	Straight run	7.2	27.0
7070	Butt weld	7.9	27.0
7080	Elbow	12.4	27.0
5550	Tee	17.0	27.0

See Tables 2-1 through 2-3 for load combinations and definitions.

TABLE 6-19

PRIMARY STRESS SUMMARY
PIPING COMPONENTS - SEISMICALLY DESIGNED DOWNSTREAM PORTION

Piping System: Pressurizer Safety Line

Maximum Values for Combination 4 - $N + SOT_E$

Node Point	Piping Component	Maximum Stress (ksi)	Allowable Stress (ksi)
7100	Straight run	27.0	27.0
7110	Butt weld	23.6	27.0
7110	Elbow	26.6	27.0
5550	Tee	26.4	27.0

See Tables 2-1 through 2-3 for load combinations and definitions.

TABLE 6-20

PRIMARY STRESS SUMMARY

PIPING COMPONENTS - SEISMICALLY DESIGNED DOWNSTREAM PORTION

Piping System: Pressurizer Safety Line

Maximum Values for Combinations 5 and 6 - N + SSE + SOT_F

Node Point	Piping Component	Maximum Stress (ksi)	Allowable Stress (ksi)
7100	Straight run	29.4	36.0
7110	Butt weld	24.1	36.0
7110	Elbow	30.9	36.0
5550	Tee	28.3	36.0

See Tables 2-1 through 2-3 for load combinations and definitions.