WESTINGHOUSE PROPRIETARY CLASS 3

PRESSURIZER SAFETY AND RELIEF LINE
PIPING AND SUPPORT EVALUATION

ALABAMA POWER COMPANY

J. M. FARLEY UNIT 1 AND UNIT 2

L. C. Smith
D. R. Siddle

October 1982

Approved: ______________________
K. C. Chang, Manager
Systems Structural Analysis

This report is applicable to J. M. Farley Unit 1 and Unit 2 and contains the structural evaluation of ASME III Nuclear Class 1 piping analyzed to requirements of the ASME Boiler and Pressure Vessel Code, Section III, Nuclear Power Plant Components, 1971 Edition, including applicable addenda; as well as NNS piping done to requirements of ANSI B31.1 Code, 1967 Edition up to and including 1971 addenda. Results from the Safety and Relief Valve Test program, conducted by the Electric Power Research Institute (EPRI) and concluded on or before July 1, 1982, were factored into the analyses presented herein.

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SECTION 1
INTRODUCTION

The Pressurizer Safety and Relief Valve (PSARV) discharge piping system for pressurized water reactors, located on the top of the pressurizer, provides overpressure protection for the reactor coolant system. A water seal is maintained upstream of each pressurizer safety and relief valve to prevent a steam interface at the valve seat. This water seal practically eliminates 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. Based on the results of the aforementioned EPRI Safety and Relief Valve Test Program, additional thermal hydraulic analyses are required to adequately define the loads on the piping system due to valve actuation.

This report is the response of the Alabama Power Company to the US NRC plant specific submittal request for piping and support evaluation and is applicable to the J. M. Farley Unit 1 and Unit 2 PSARV piping system.

SECTION 2
PIPE STRESS CRITERIA

2.1 PIPE STRESS CALCULATION - CLASS 1 PORTION

In general, the criteria for the structural evaluation of the Class 1 components is based upon two categories of loading. These are self-limiting loads and non-self-limiting loads. A non-self-limiting load produces a primary stress while a self-limiting load produces a secondary stress. In order to prevent catastrophic failure of the system, primary stress criteria must be satisfied, which can be accomplished by applying Equation (9) of paragraph NB-3652 of the ASME Boiler and Pressure Vessel Code Section III, up to and including the Summer 1971 Addenda. Fatigue failure may occur if the maximum stress from all loadings is so concentrated at one location that continued cycling of the loads produces a crack, which may then propagate through the wall and result in leakage. For protection against fatigue failure, cyclic stresses from both self-limiting and non-self-limiting loads must be considered. The component will cycle within acceptable limits for each specified loading combination if Equation (10), subparagraph NB-3653.1 of the Code is satisfied. This requirement insures that incremental distortion will not occur. The peak stress intensity defined by Equation (11) is then used for calculating the alternating stress intensity, S_{alt}. The value of S_{alt} is then used to calculate the usage factor for the load set under consideration. The cumulative usage factor is then obtained using Miner's rule by considering all other load sets. However, if Equation (10) is not satisfied, which means some plastic deformation occurs with each application of load, the alternate analysis, "Simplified Elastic-Plastic Discontinuity Analysis", described in subparagraph NB-3653.6 of the Code must be considered. To avoid the posibility of fatigue failure, the cumulative usage factor should not exceed 1.0.

2.2 PIPE STRESS CALCULATION - CLASS NNS PORTION

The piping between the valves and the pressurizer relief tank shall be analyzed to satisfy the requirements of the appropriate equations of the ANSI B31.1 Code. These equations establish limits for stresses from sustained loads and occasional loads (including earthquake), thermal expansion loads, and sustained plus thermal expansion loads, respectively. The allowable stresses for use with the equations were determined in accordance with the requirements of the ANSI B31.1 Code.

2.3 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 with a definition of load abbreviation provided in Table 2-3.

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	1.5 S_m
2	Upset	N + OBE + SOT_U	1.8 S_m
3	Emergency	N + SOT_E	2.25 S_m
4	Faulted	N + MS/FWPB or DBPB + SSE + SOT_F	3.0 S_m
5	Faulted	N + LOCA + SSE + SOT_F	3.0 S_m

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	=	Max (SOT_U; 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
S_m	=	Allowable design stress intensity

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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 the loadings specified in the design specification. These loadings result from thermal expansion, pressure, weight, earthquake, design basis accident (DBA), plant operational thermal and pressure transients, 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), define the required input data to perform the flexibility analysis for thermal expansion.

Due to different operating modes, the system may experience multiple thermal loadings. The temperatures used in the expansion analysis of the piping are based upon the information presented in the design documents.

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 TRANSIENTS

To provide the necessary high degree of integrity for the NSSS, 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 are based on a plant design life of 40 years.

3.1.6 SAFETY AND RELIEF VALVE THRUST

The pressurizer safety and relief valve discharge piping system provide overpressure protection for the RCS. The three 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 valve to minimize leakage. Condensate accumulation on the inlet side of each valve prevents any leakage of hydrogen gas or steam through the valves. The valve outlet side is sloped to prevent the formation of additional water pockets.

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 (subparagraph 101.20 of the Code).

3.2.2 DESIGN TEMPERATURE

The specified design temperature is not less than the actual maximum metal temperature existing under the specified normal operating condi-

tions for each area of the component considered. It is used in computations involving the design pressure and coincidental design mechanical loads (subparagraph 101.3 of the Code).

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.

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.

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 (subparagraph NB-3113.3 of the code).

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.

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 for the static structural analysis. The response spectrum method is used for the seismic dynamic analysis.

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, attached equipment, and the stiffness of supports, which affects the system response. The deflection solution of the entire system is obtained for the various loading cases from which the 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 referenced in this report and equipment drawings referenced in the design specification. 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:

$$B_1 = T_1 B_o + R_1$$

$$B_2 = T_2 B_1 + R_2 = T_2 T_1 B_o + T_2 R_1 + R_2$$

$$B_3 = T_3 B_2 + R_3 = T_3 T_2 T_1 B_o + T_3 T_2 R_1 + T_3 R_2 + R_3$$

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 matrix $[K_R]$ 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 THERMAL TRANSIENTS

Operation of a nuclear power plant causes temperature and/or pressure fluctuations in the fluid of the piping system. The transients for this system are defined in "Westinghouse Systems Standard Design Criteria 1.3" and referenced in the Design Specification and were used to define the various operating modes used in the thermal expansion analyses.

4.6 PRESSURIZER SAFETY AND RELIEF LINE ANALYSIS

4.6.1 PLANT HYDRAULIC MODEL

When the pressurizer pressure reaches the set pressure (2,500 psia for a safety valve and 2,350 psia for a relief valve) and the valve opens, the high pressure steam in the pressurizer forces the water in the water seal loop through the valve and down the piping system to the pressurizer relief tank. 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:

$$F_{cv} = \frac{1}{g_c} \frac{\partial}{\partial t} \int_v \rho V dv + \frac{1}{gc} \int \rho V (V \cdot n dA)$$

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

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

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

A = piping flow area

v = volume

F = force

r = radius of curvature of appropriate elbow

α = angle of appropriate elbow

W = mass acceleration

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.

4.6.2 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).

4.6.3 VALVE THRUST ANALYSIS

The safety and relief lines were modeled statically and dynamically (seismically) as described in Sections 4.1 through 4.4. The mathematical model used in the seismic analysis 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 WESTDYN2 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 evaluation.

The time-history internal forces and displacements of the WESTDYN2 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 evaluation.

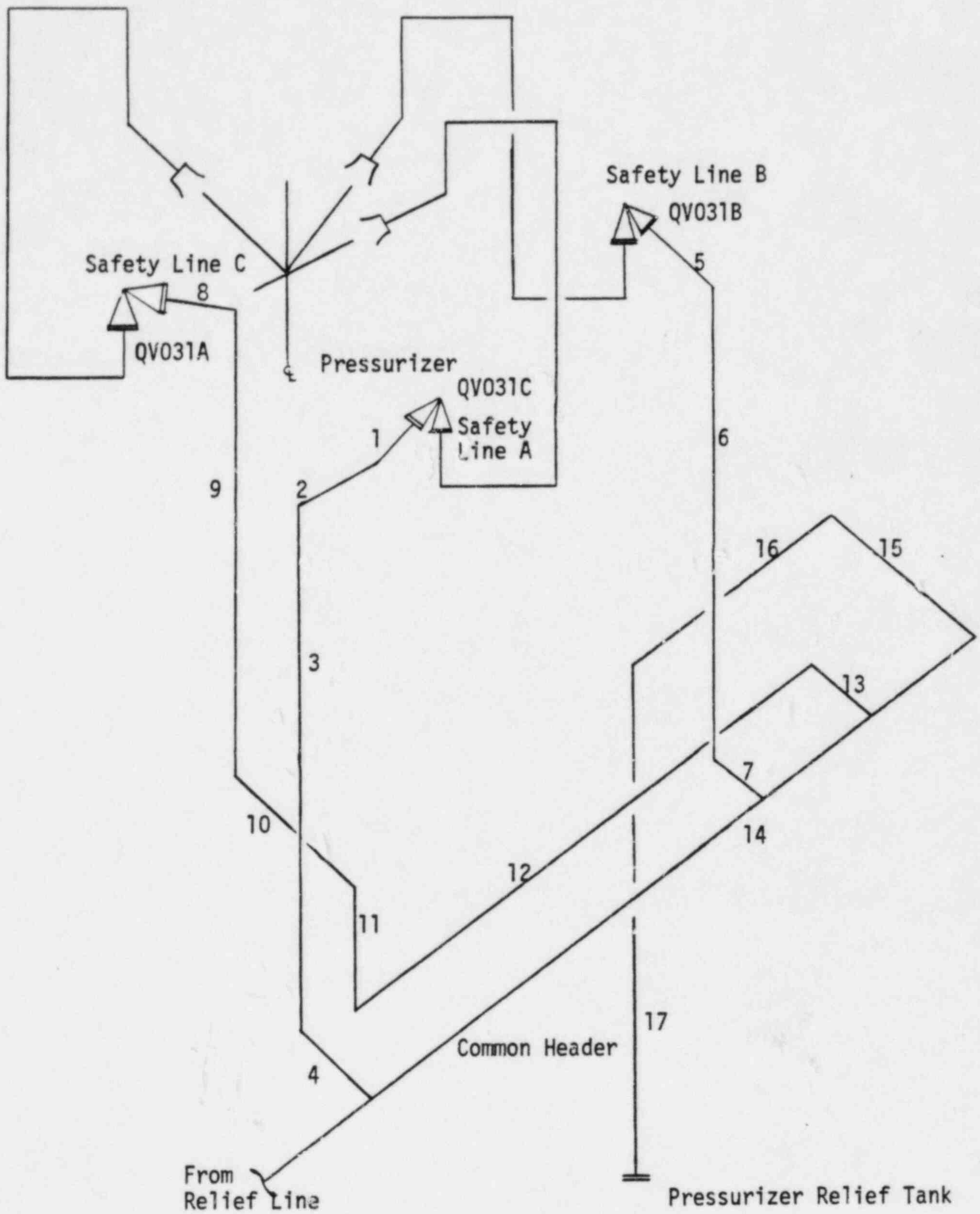

FIGURE 4-1
SAFETY LINES HYDRAULIC MODEL

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

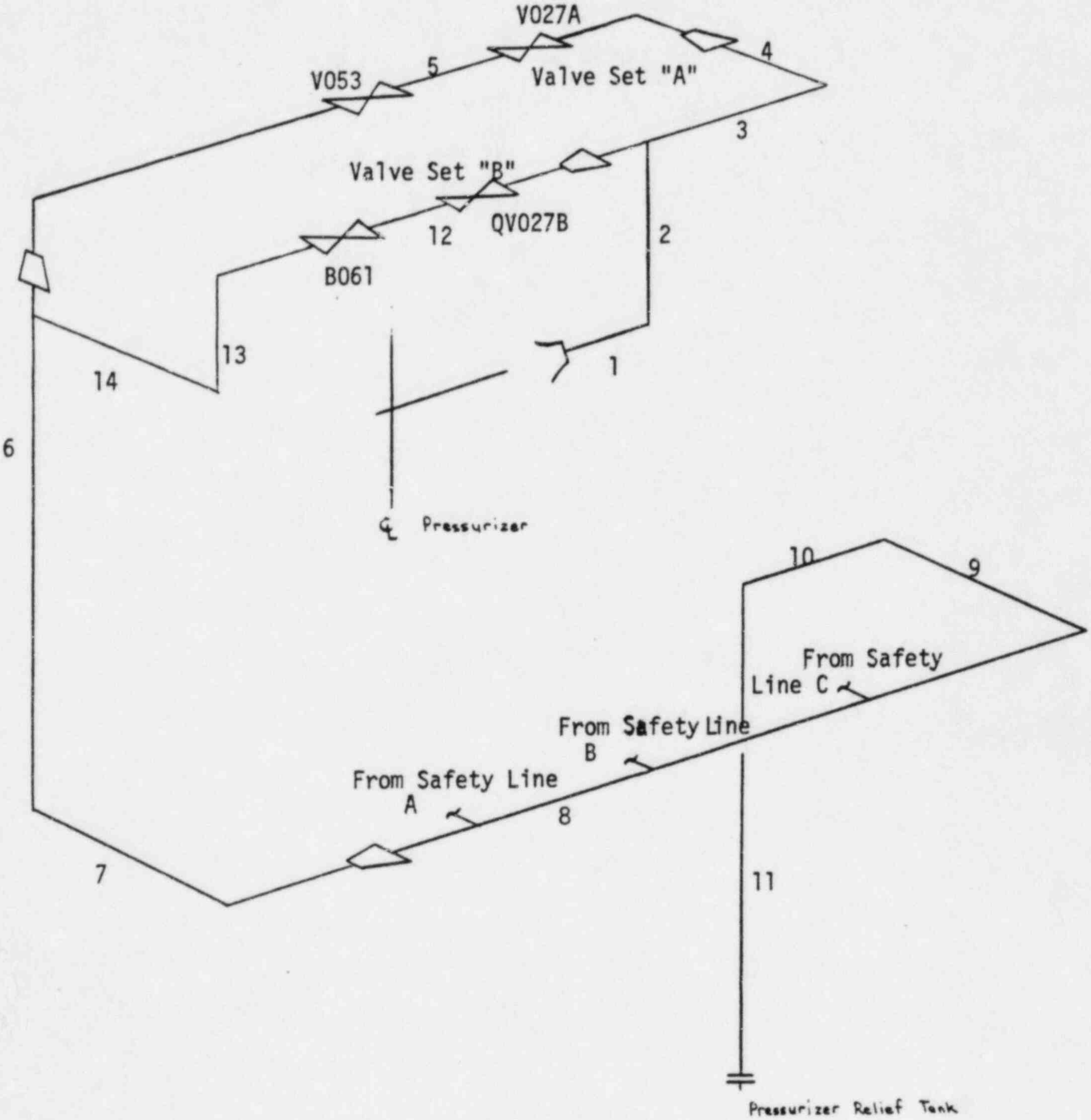

FIGURE 4-2

RELIEF LINF HYDRAULIC MODEL

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

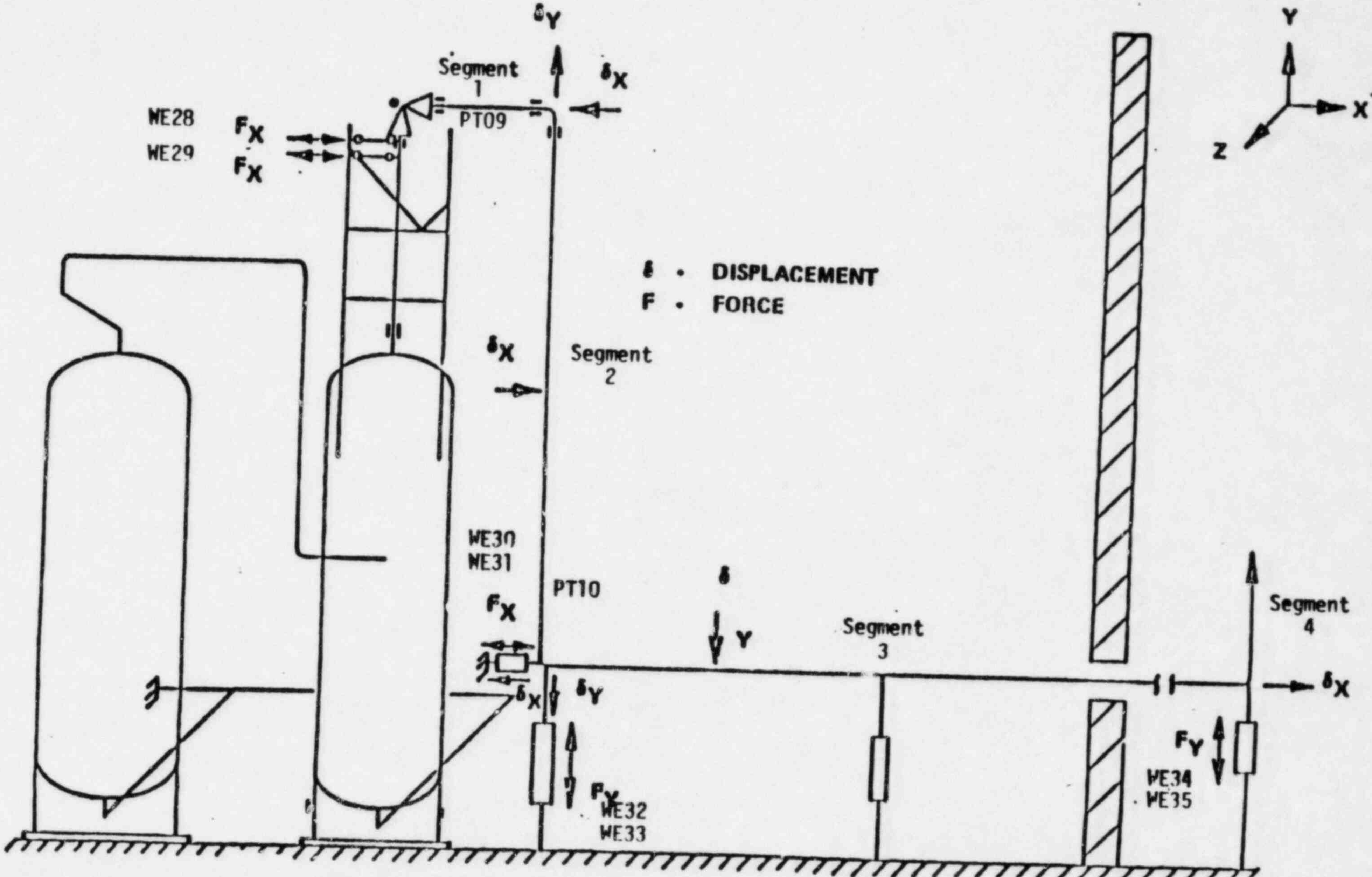

FIGURE 4-3: STRUCTURAL RESPONSE - FORCE MEASUREMENT LOCATIONS - EPRI TESTS

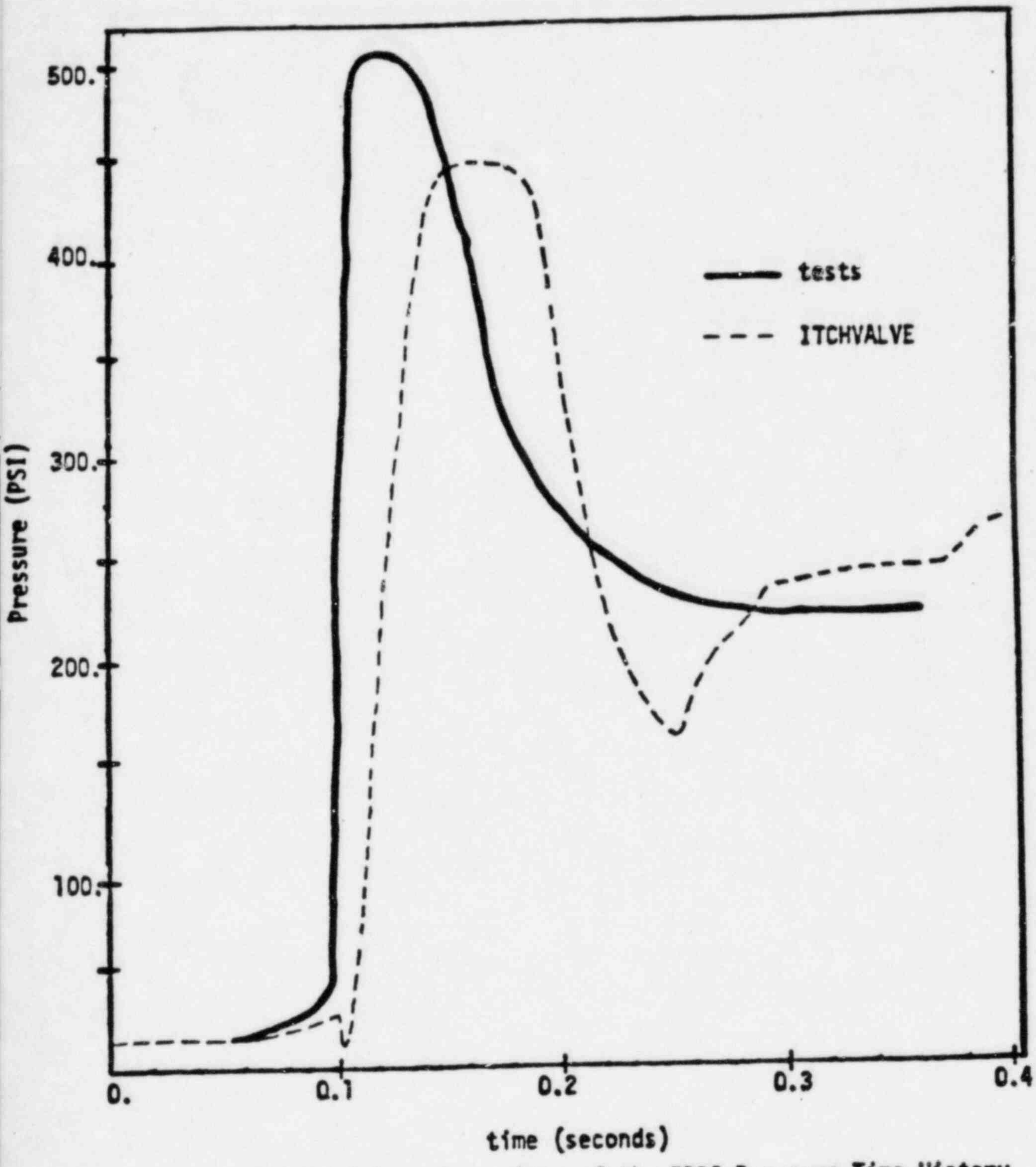

FIGURE 4-4 : Comparison of the EPRI Pressure Time-History for PT09 from Test 908 with the ITCHVALVE Predicted Pressure Time-History

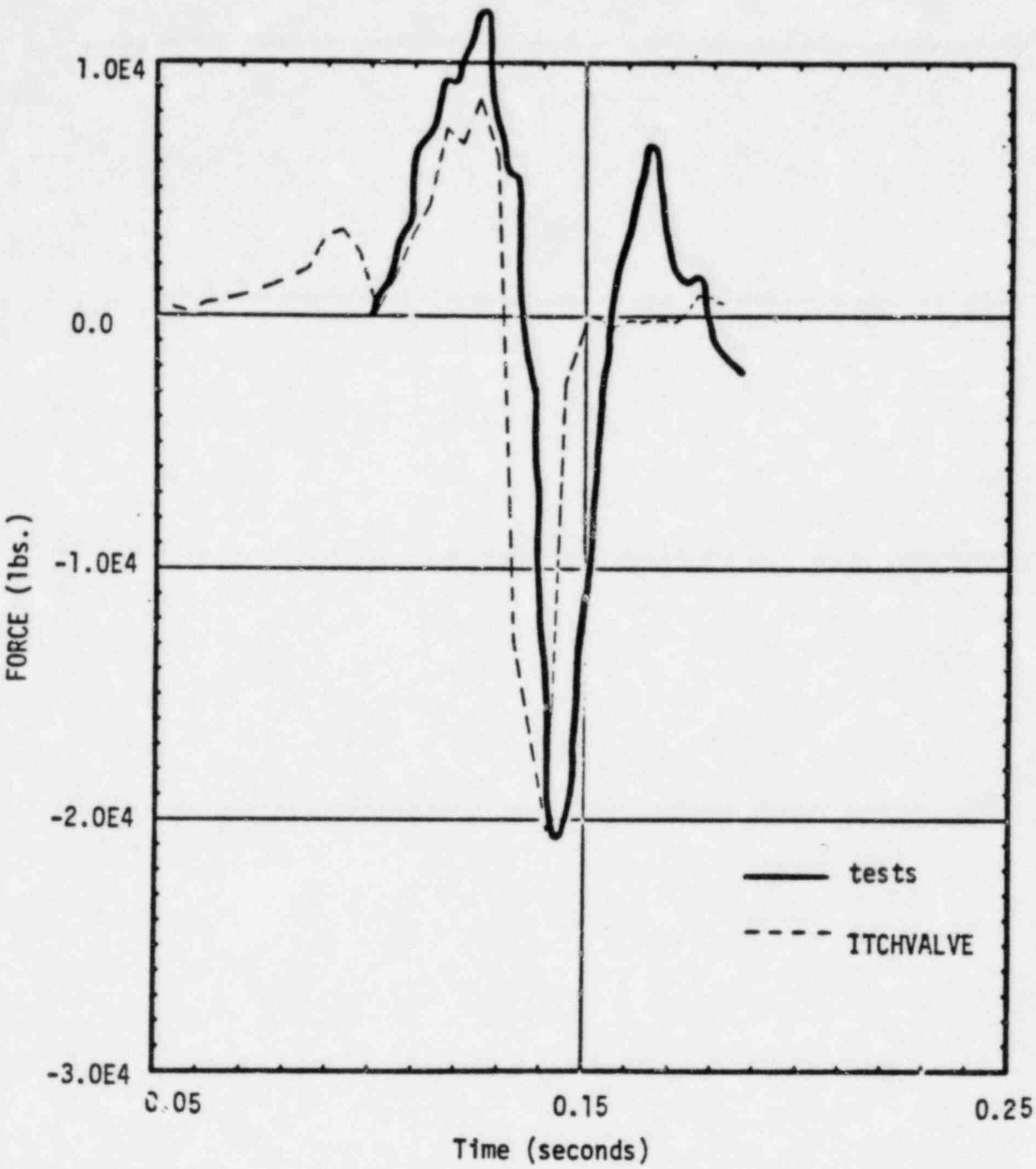

FIGURE 4-5: COMPARISON OF THE EPRI FORCE TIME-HISTORY FOR WE28 and WE29 FROM TEST 908 WITH THE ITCHVALVE PREDICTED FORCE TIME-HISTORY

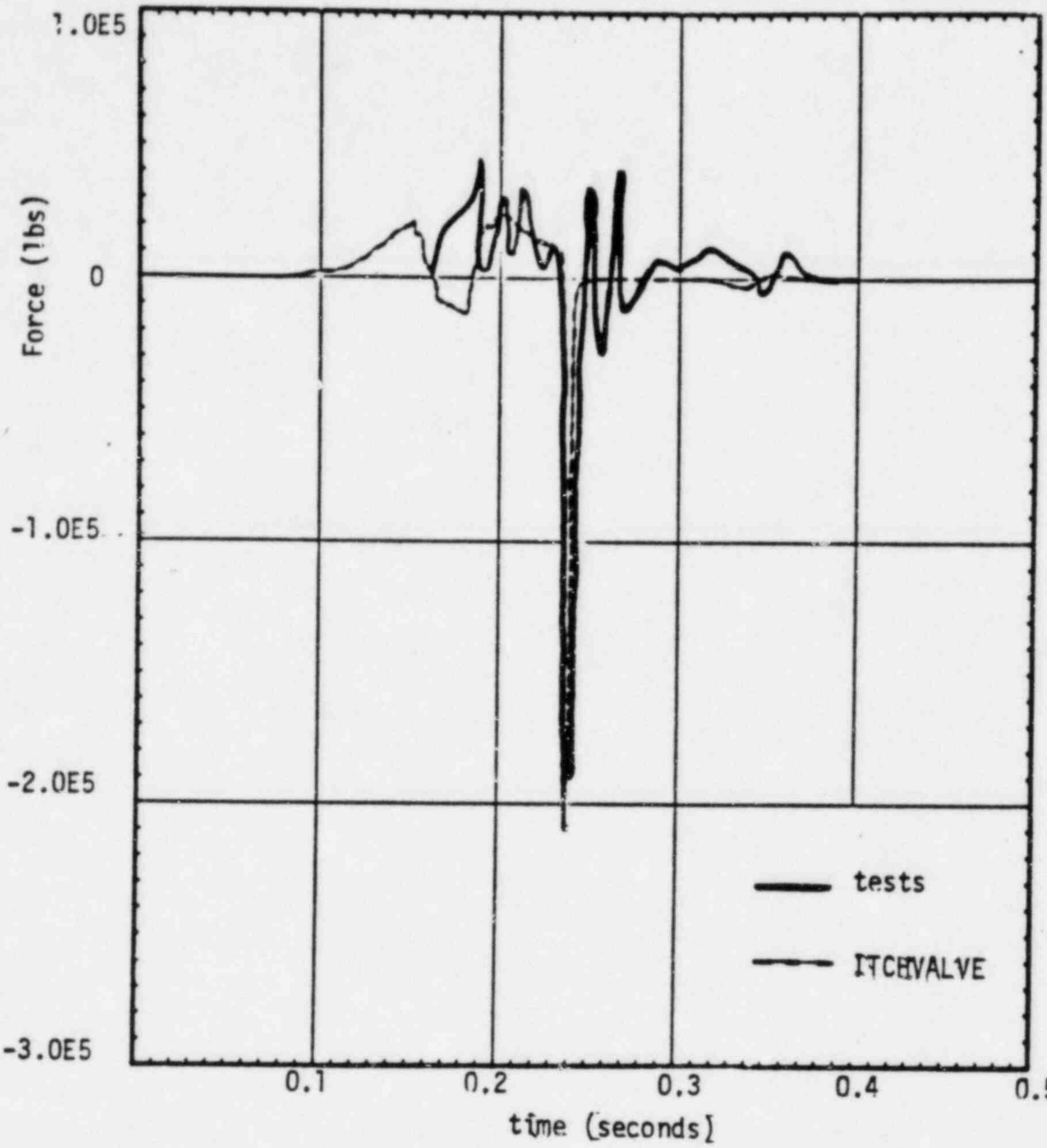

FIGURE 4-6: COMPARISON OF THE EPRI FORCE TIME-HISTORY FOR WE32 AND WE33 FROM TEST 908 WITH THE ITCHVALVE PREDICTED FORCE TIME-HISTORY

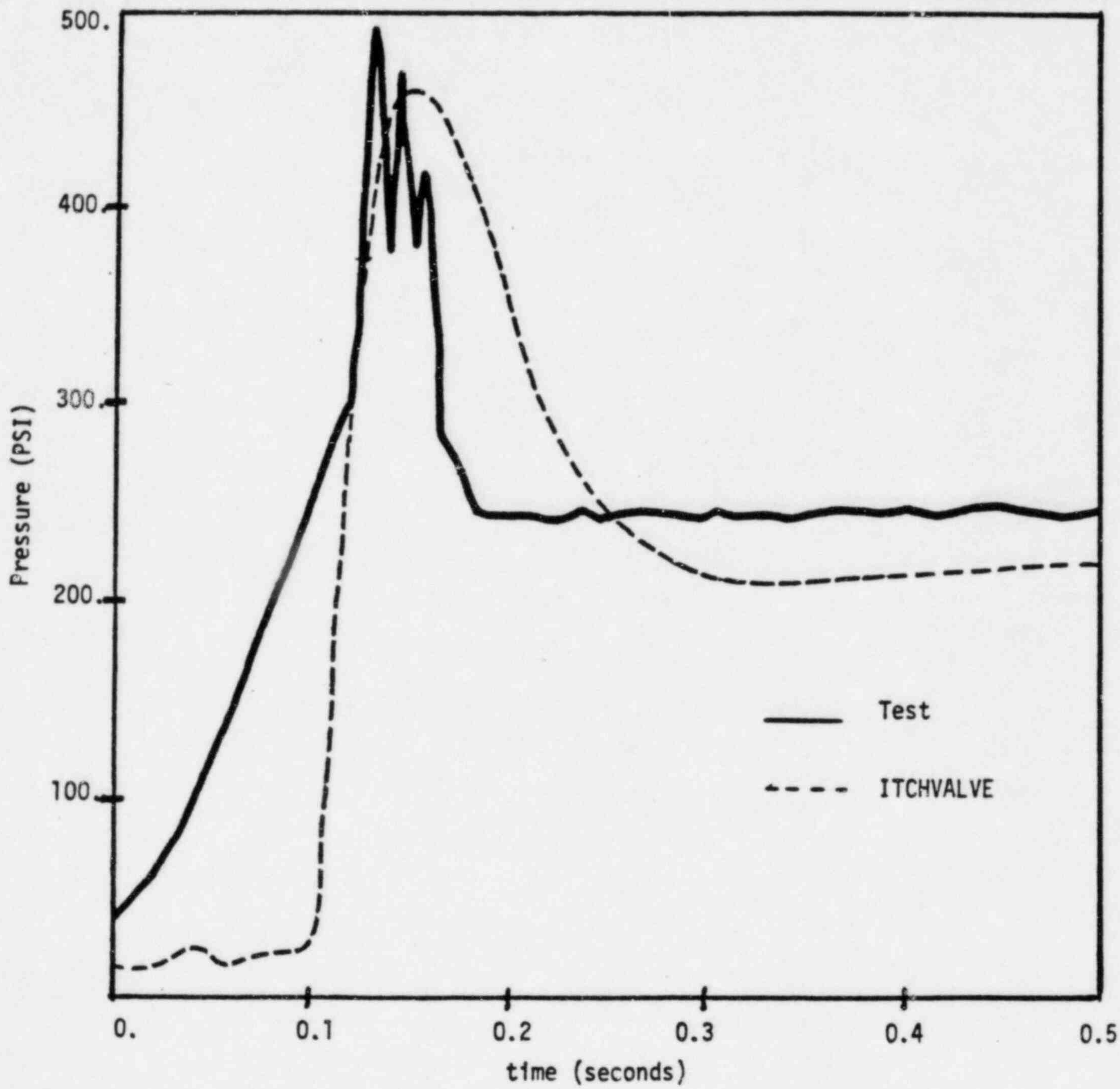

FIGURE 4-7 : Comparison of the EPRI Pressure Time-History from PT09 from Test 917 with the ITCHVALVE Predicted Pressure Time-History

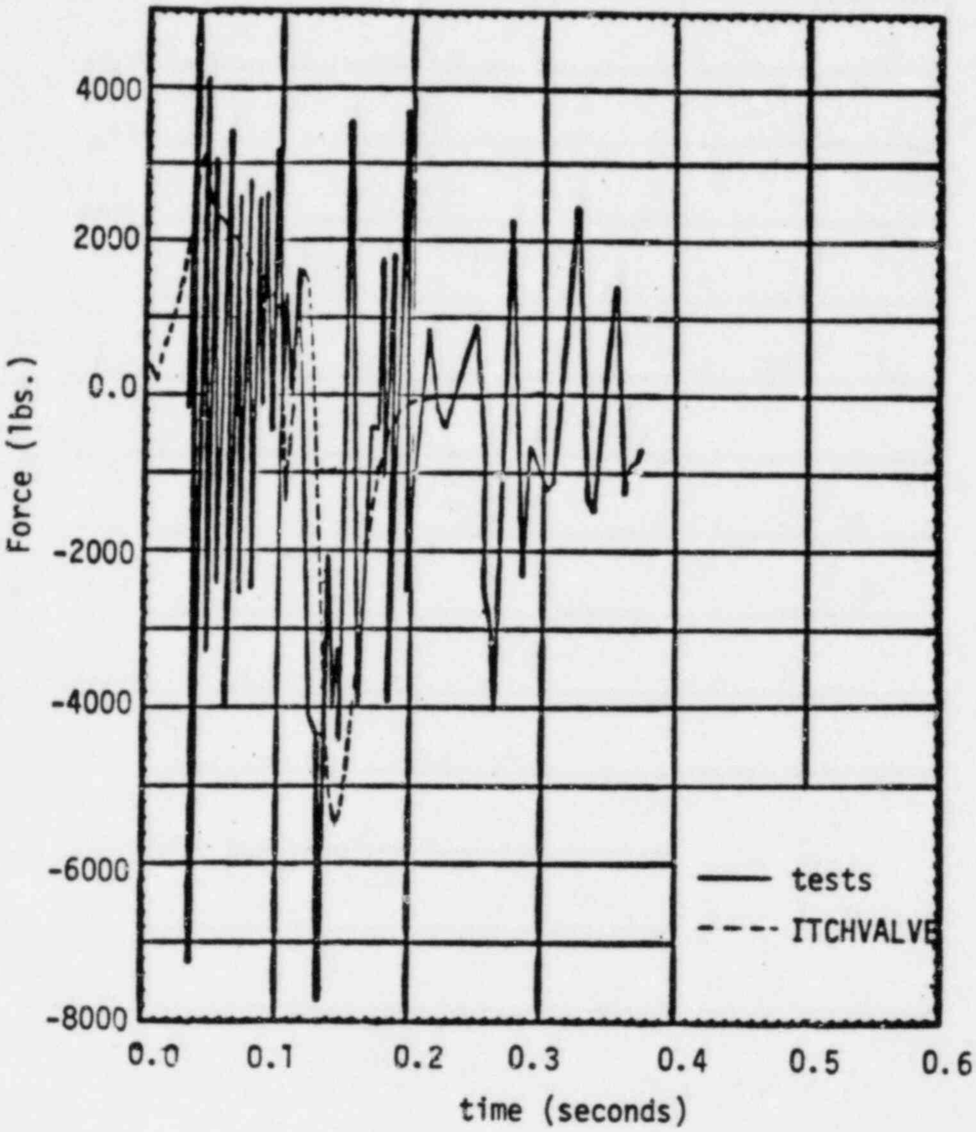

FIGURE 4-8 : Comparison of the EPRI Force Time-History for WE28 and WE29 from Test 917 with the ITCHVALVE Predicted Force Time-History

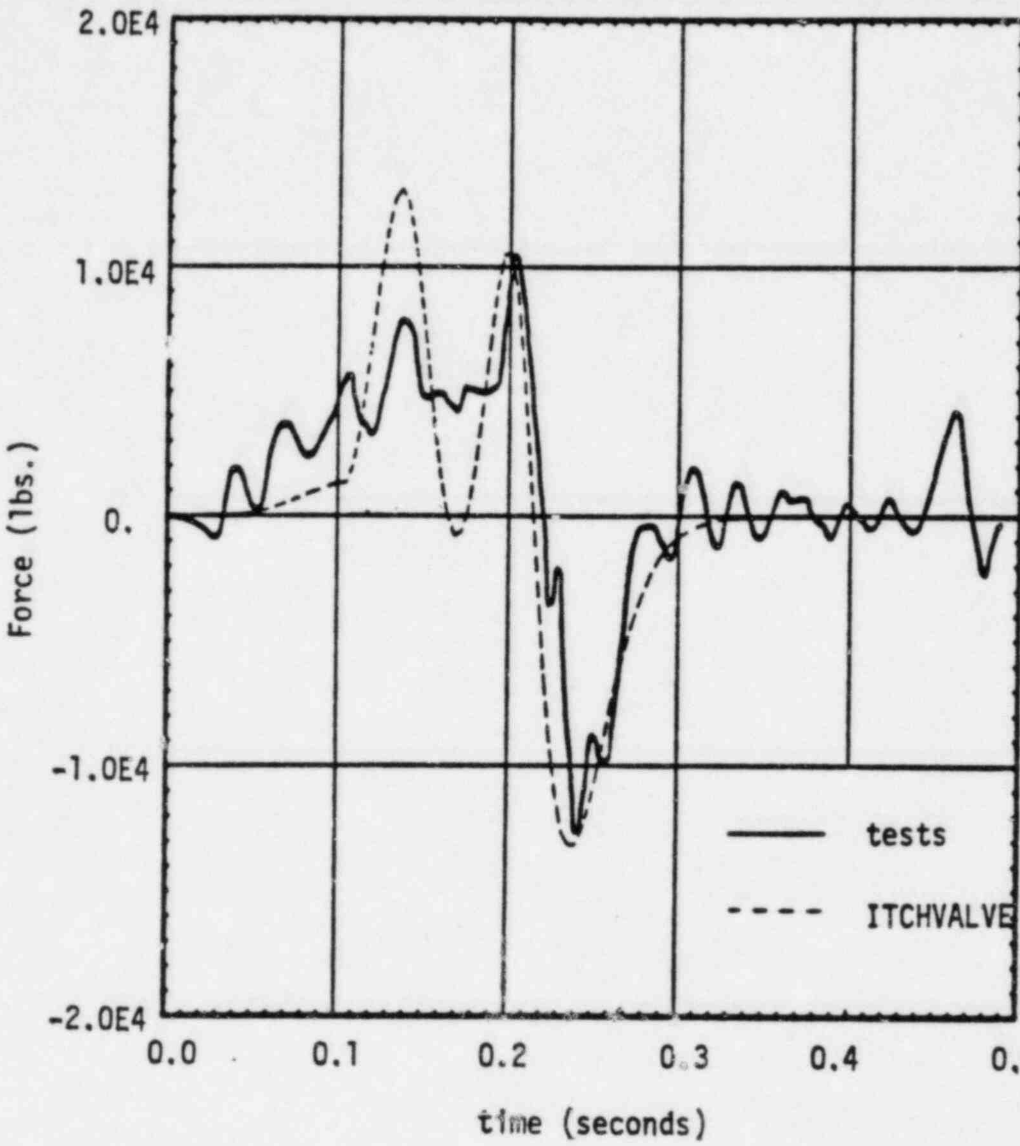

FIGURE 4-9 : Comparison of the EPRI Force Time-History for WE32 and WE33 from Test 917 with the ITCHVALVE Predicted Force Time-History

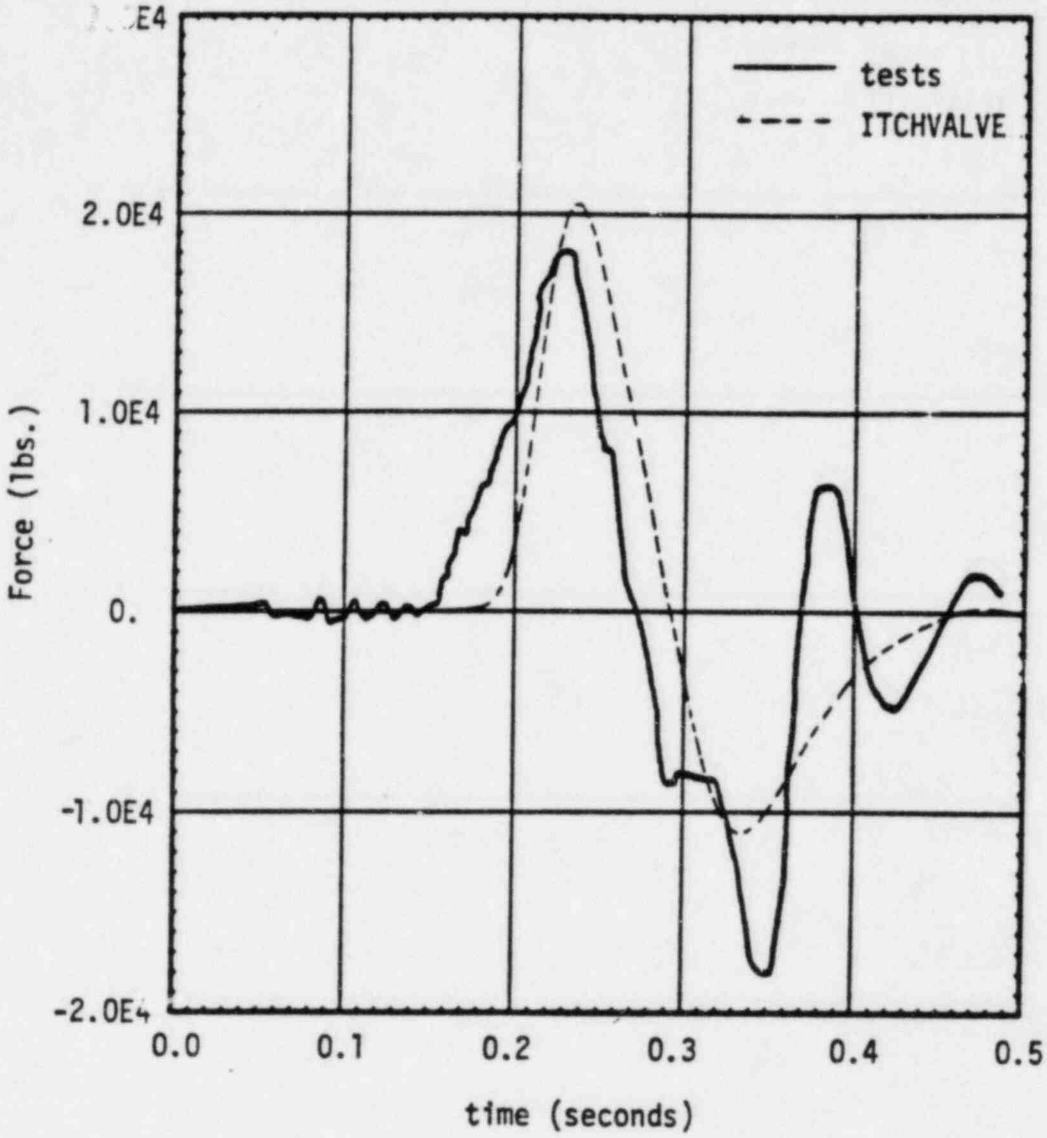

FIGURE 4-10: Comparison of the EPRI Force Time-History For WE30 and WE31 From Test 917 with the ITCHVALVE Predicted Force Time-History

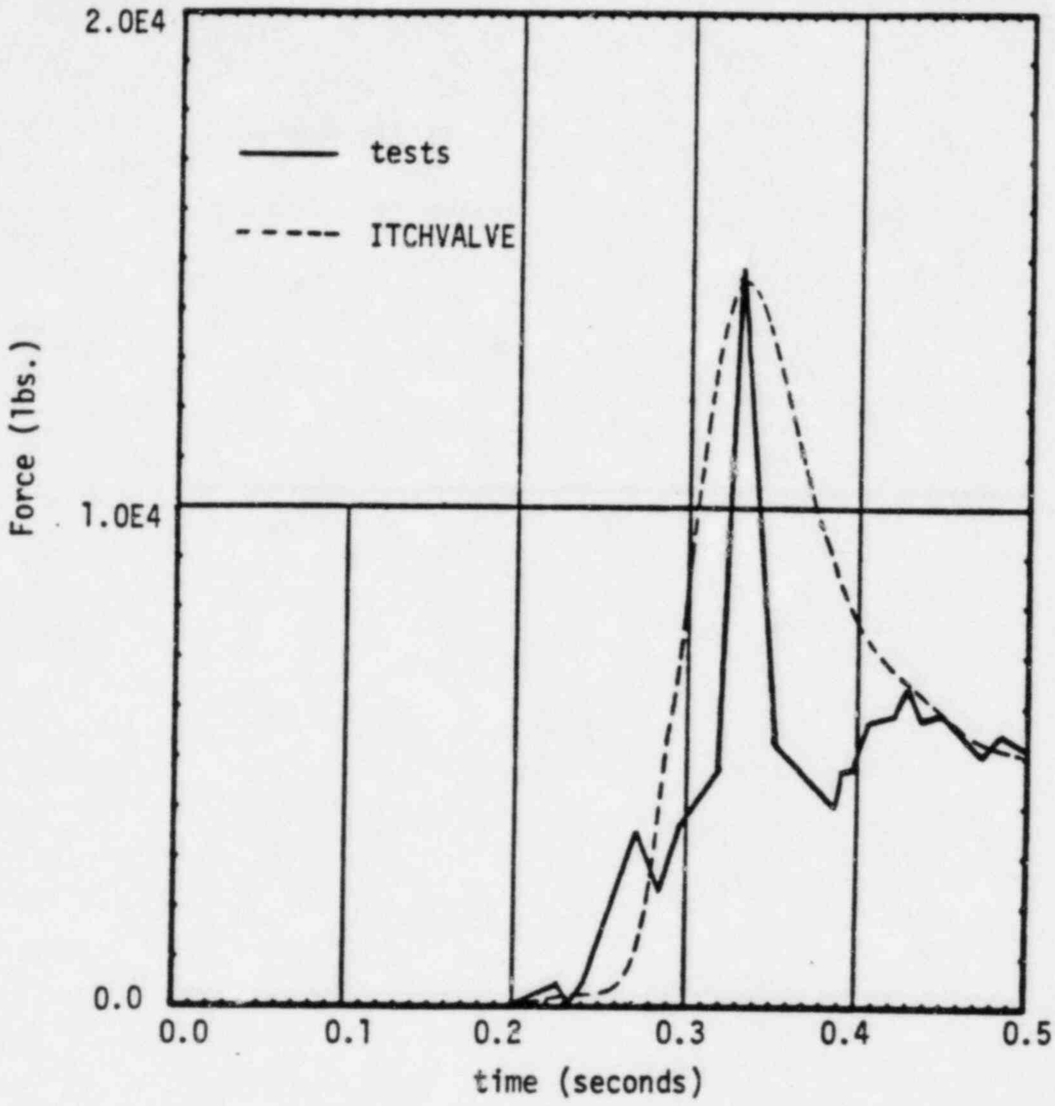

FIGURE 4-11: Comparison of the EPRI Force Time-History For WE34 and WE35 from Test 917 with the ITCHVALVE Predicted Force Time-History

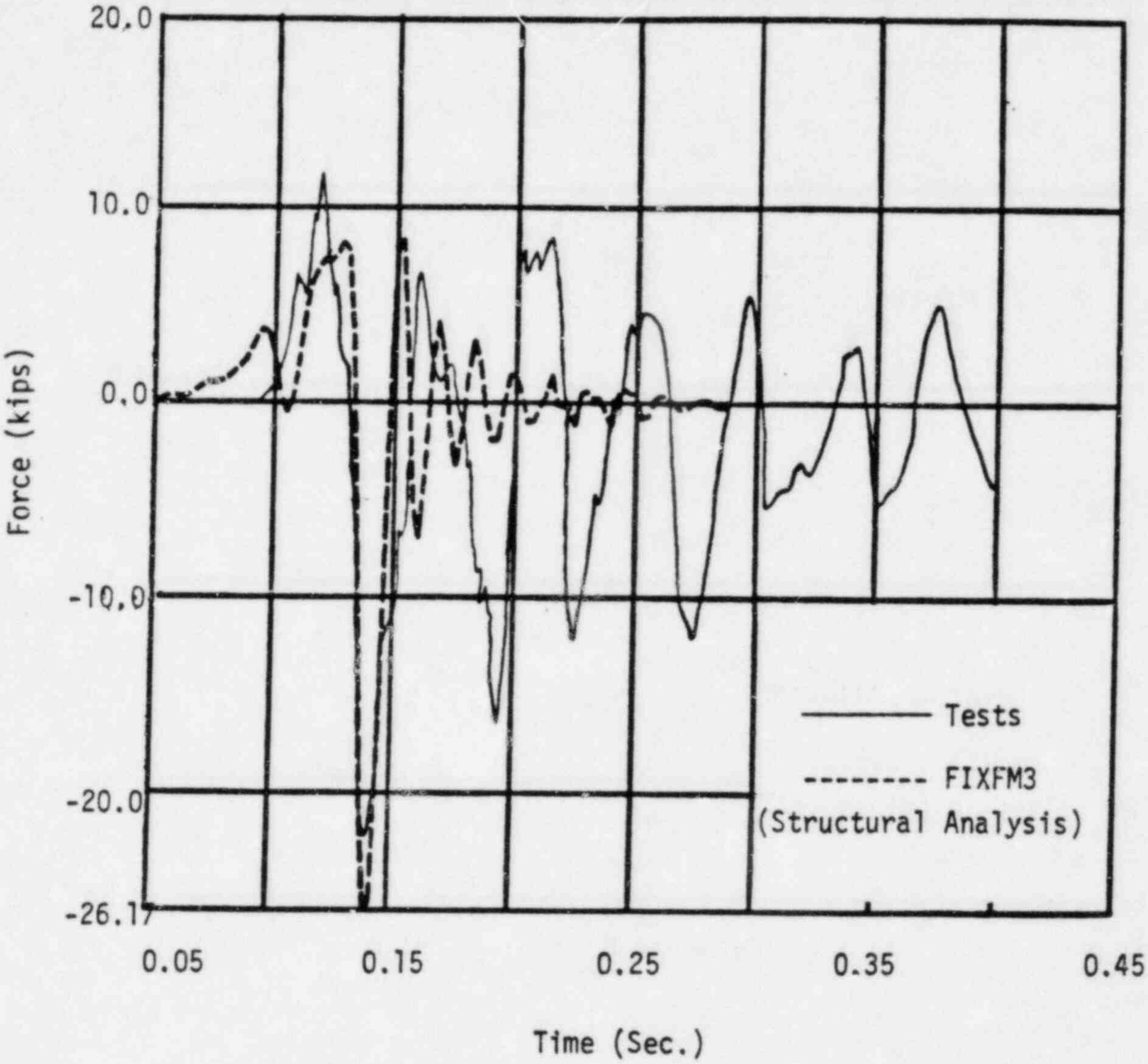

FIGURE 4-12: Comparison of the EPRI Force Time-History for WE28 and WE29 from Test 908 with the FIXFM3 Predicted Force Time-History

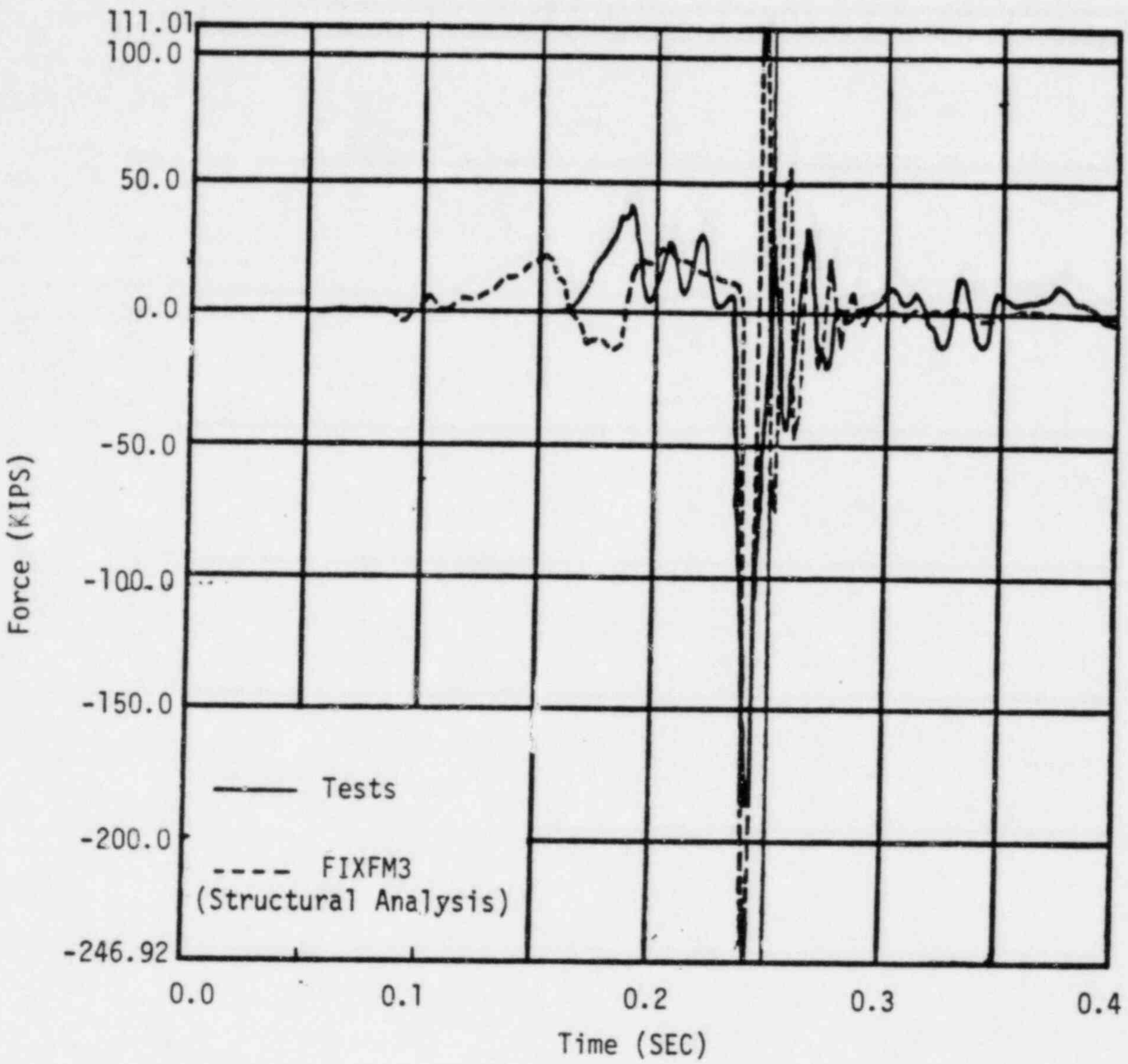

Figure 4-13: Comparison of the EPRI Force Time-History For WE32 and WE33 From Test 908 With the FIXFM3 Predicted Force Time-History

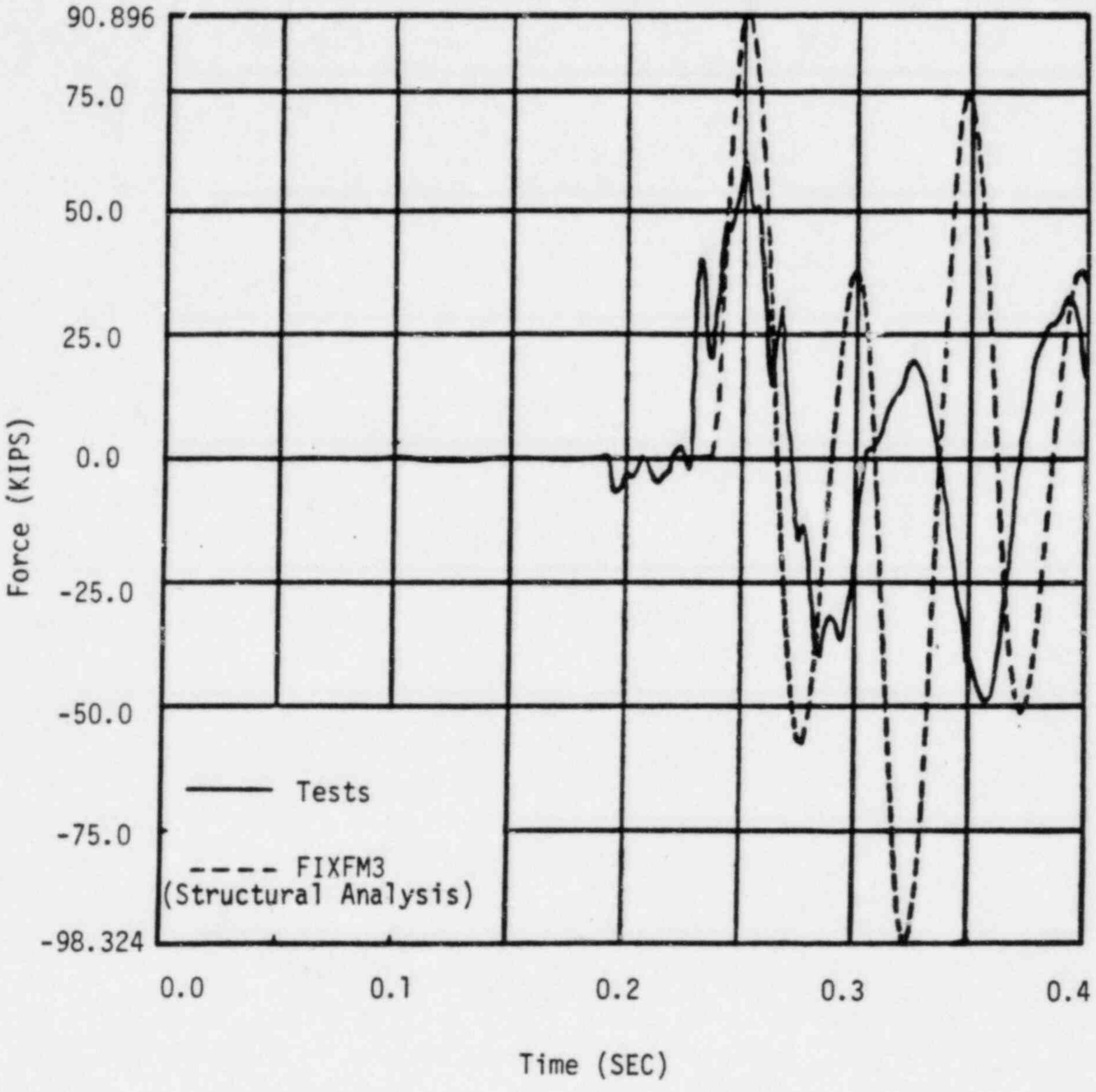

Figure 4-14: Comparison of the EPRI Force Time-History For WE30 and WE31 From Test 908 With the FIXFM3 Predicted Force Time-History

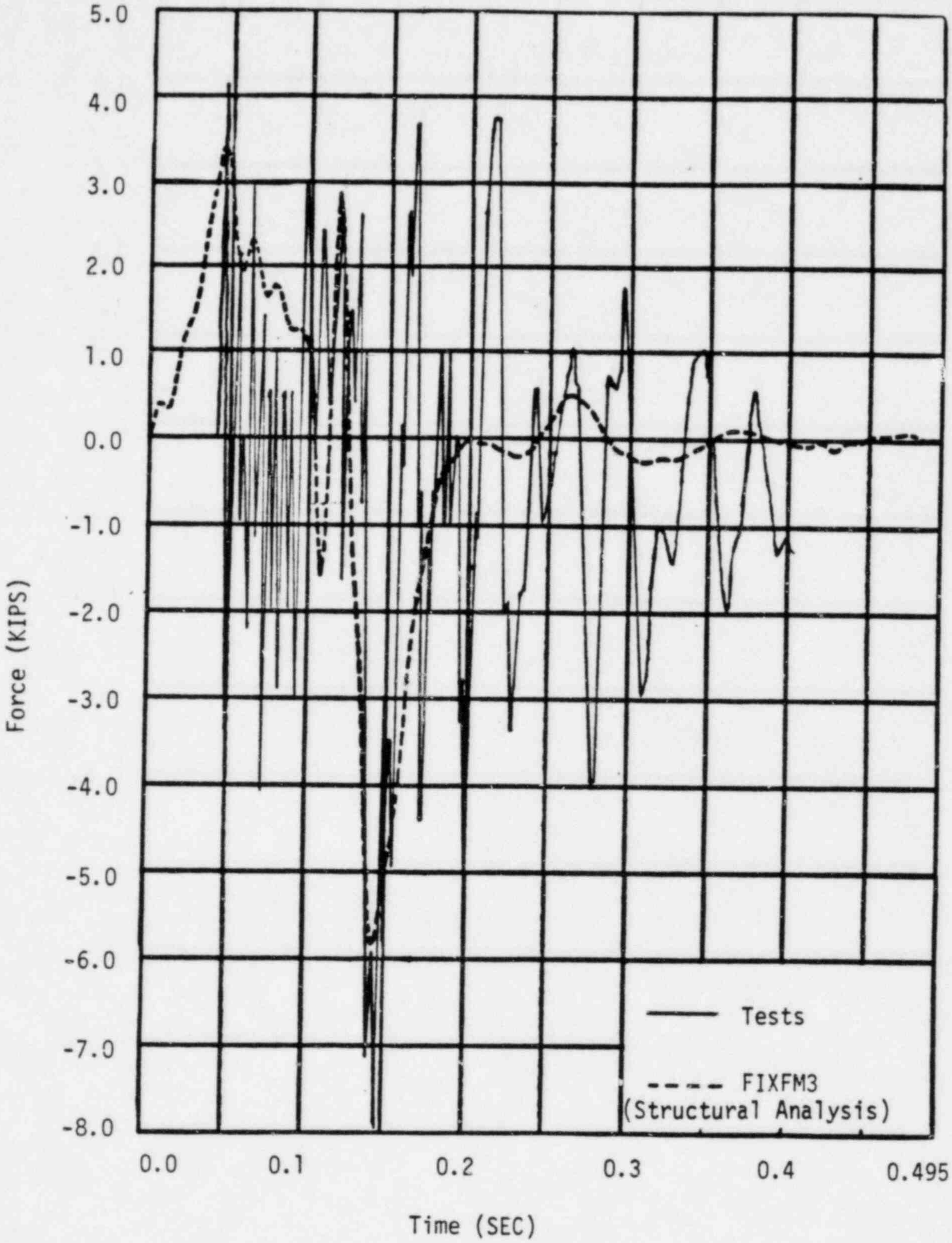

Figure 4-15: Comparison of the EPRI Force Time-History For WE28 and WE29 From Test 917 With the FIXFM3 Predicted Force Time-History

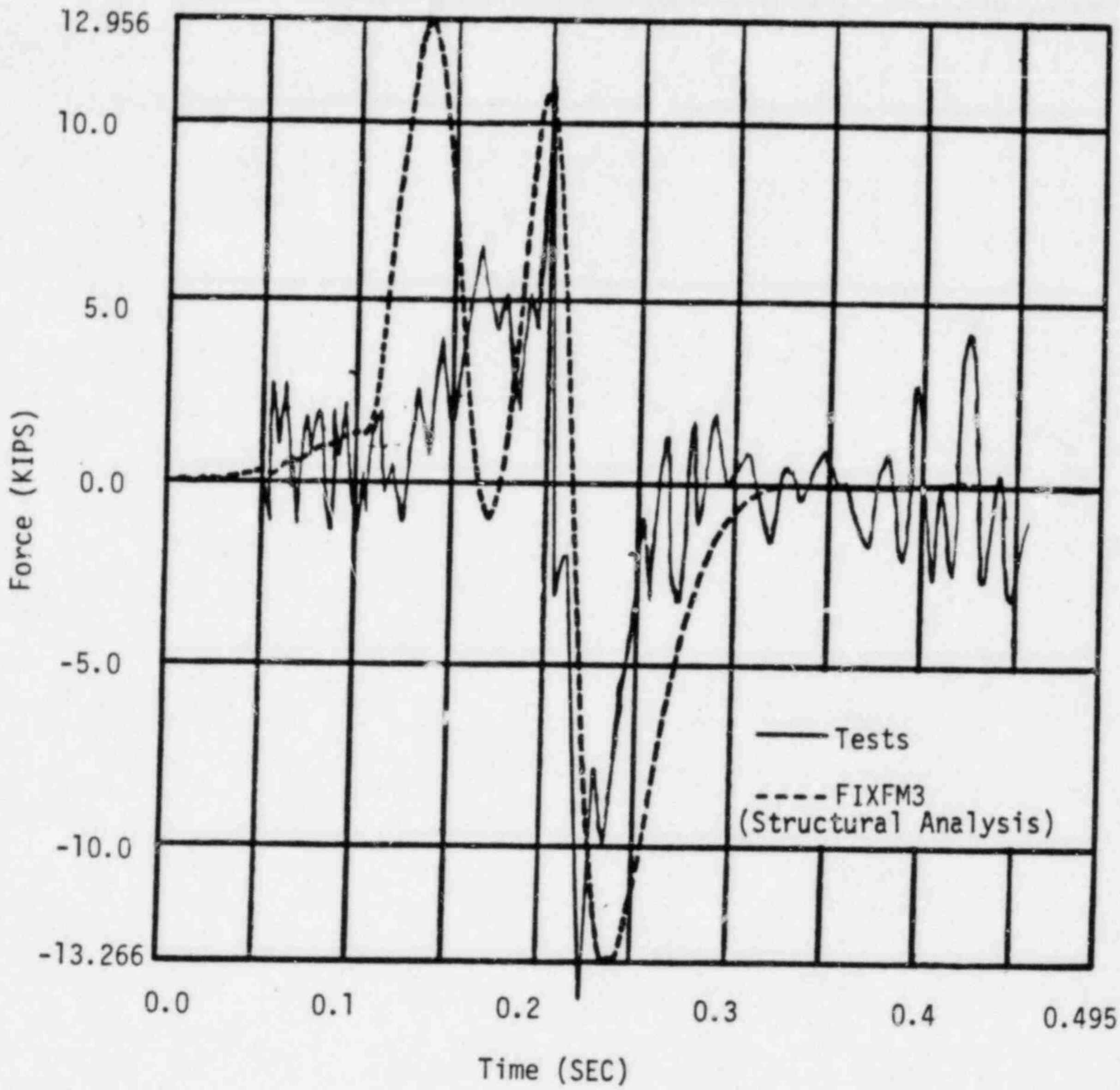

Figure 4-16: Comparison of the EPRI Force Time-History For WE32 and WE33 From Test 917 With the FIXFM3 Predicted Force Time-History

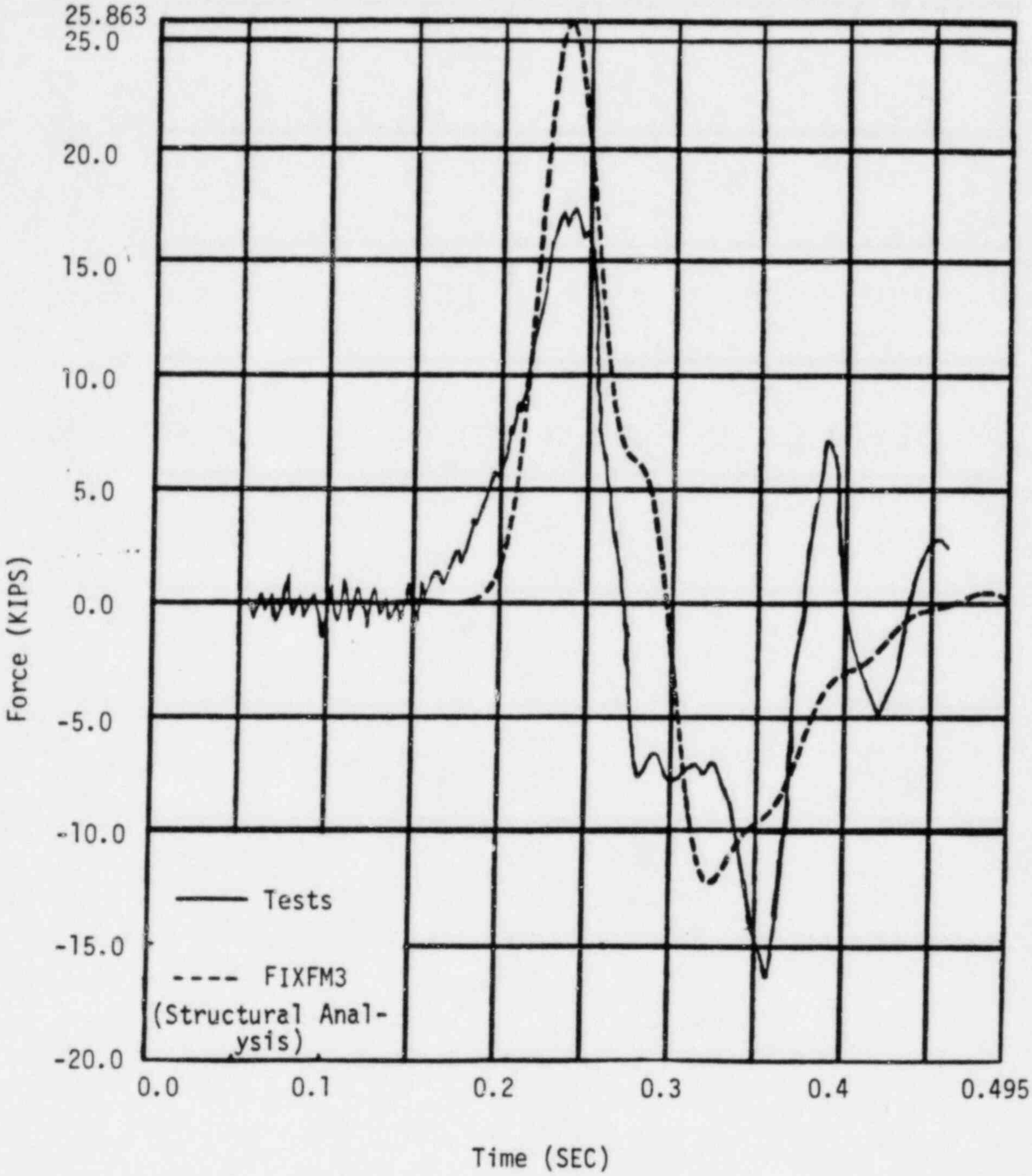

Figure 4-17: Comparison of the EPRI Force Time-History For WE30 and WE31 From Test 917 With the FIXFM3 Predicted Force Time-History

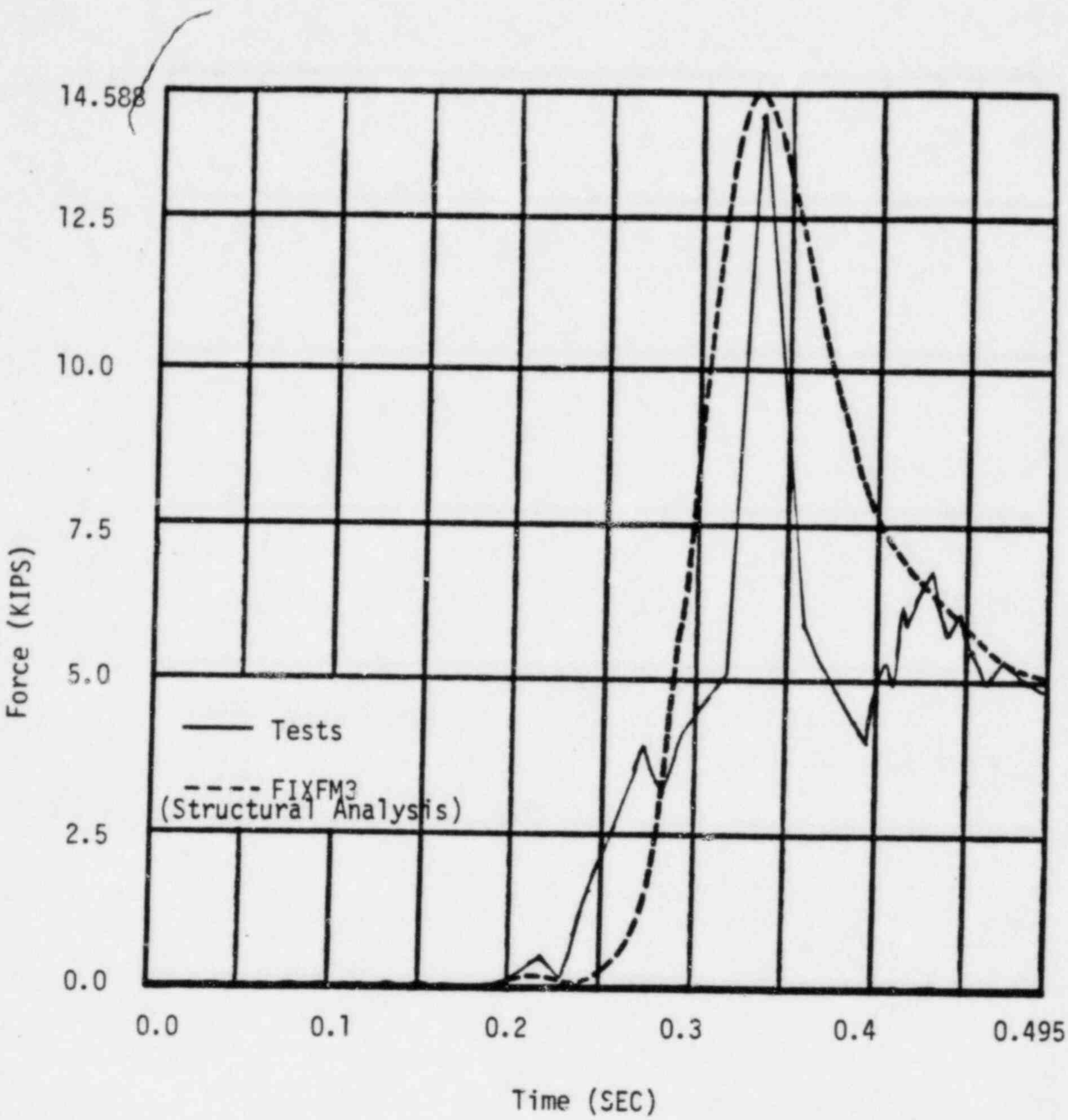

Figure 4-18: Comparison of the EPRI Force Time-History For WE34 and WE35 From Test 917 With the FIXFM3 Predicted Force Time-History

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 combination. 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 design mechanical loads calculated using applicable stress intensity factors must not exceed the allowable limit. The resultant moment, M_i, due to loads caused by weight and design mechanical loads 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

The maximum stresses due to pressure, weight, and DML in the piping system are reported on tables in Section 6.

5.2.2 UPSET CONDITIONS

The combined stresses due to the primary loadings of pressure, weight, OBE seismic, and relief valve thrust loadings calculated using the applicable stress intensity factors must not exceed the allowables. The resultant moments, M_i, due to loads caused by these loadings are calculated as shown below.

For seismic and relief valve thrust loading:

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

where

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

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

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

5.2.3 EMERGENCY CONDITIONS

The combined stresses due to primary loadings of pressure, weight and safety valve thrust, using applicable stress intensification factors, must not exceed the allowable limits. The magnitude of the resultant moment, M_i is calculated from the moment components as shown below:

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

where

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

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

5.2.4 FAULTED CONDITIONS

The combined stresses due to primary loadings of pressure, weight, SSE and SOT_F, using applicable stress intensification factors must not exceed the allowable limits. For the resultant moment loading, M_i, the SSE and SOT_F moments are combined using the square-root-of-the-sum-of-the-squares (SRSS) addition and added absolutely with deadweight for each moment component (M_x, M_y, M_z). The magnitude of the resultant moment, M_i, is calculated from the three moment components, as shown below:

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

$$+ \left[\left(M_{y_{SOT_F}}^{\ 2} + M_{y_{SSE}}^{\ 2}\right)^{1/2} + \left|M_{y_{wt}}\right|\right]^2$$

$$+ \left[\left(M_{z_{SOT_F}}^{\ 2} + M_{z_{SSE}}^{\ 2}\right)^{1/2} + \left|M_{z_{wt}}\right|\right]^2 \Bigg\}^{1/2}$$

where

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

$M_{x_{SSE}}, M_{y_{SSE}}, M_{z_{SSE}}$ = inertial SSE moment components

$M_{x_{SOT_F}}, M_{y_{SOT_F}}, M_{z_{SOT_F}}$ = maximum of SOT_U or SOT_E moment components

For the safety and relief piping, the faulted condition load combination of pressure, weight, and valve thrust is considered as given in Tables 2-1 and 2-2 and defined in Table 2-3. The pipe break loads (MS/FWPB or LOCA) can be ignored for the PSARV system. These loads have very little impact on the pressurizer safety and relief system when compared to the loading conditions discussed in this report.

5.3 SECONDARY STRESS EVALUATION

The combined stresses due to the secondary loadings of thermal, pressure, and deadweight using applicable stress intensification factors must not exceed the allowable limit. For the resultant moment loading, M_i, thermal moments are combined as shown below:

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

$M_{x_{MAX}}, M_{y_{MAX}}, M_{z_{MAX}}$ = maximum thermal moment considering all thermal cases including normal operation

$M_{x_{MIN}}, M_{y_{MIN}}, M_{z_{MIN}}$ = minimum thermal moment considering all thermal cases including normal operation

This, M_i, is then substituted into the appropriate equations of the applicable code.

SECTION 6

RESULTS

6.1 EVALUATION PRIOR TO EPRI TEST PROGRAM

The J. M. Farley Unit 1 and Unit 2 safety and relief valve discharge piping system has received a very detailed thermal hydraulic and structural dynamic evaluation to insure the operability and structural integrity of the as-built system (WCAP-9718). This structural evaluation, including the thermal hydraulic analysis, was based on the criteria and methods that were current prior to the availability of the data from the EPRI Test Program. The thermal hydraulic forcing functions were generated assuming simultaneous opening of either the safety valves or the relief valves, since they represent the worst applicable loading conditions for the piping and supports for this specific layout. These forcing functions were then used as input to the structural evaluation in which the primary and secondary stresses were determined. The methods used and the loadings considered are consistent with Section 2.0 and Section 3.0 of this report, respectively. Results of this extensive analysis and evaluation have demonstrated that the PSARV piping meets all the applicable design limits for the various loading cases. In addition, the acceptability of the valve nozzles, equipment nozzles, and pressurizer shell was assured for the applied loads.

6.2 EVALUATION SUBSEQUENT TO EPRI TESTING

The evaluation subsequent to the EPRI Testing Program uses the same procedure as the prior as-built analysis. The only difference occurs in the thermal hydraulic evaluation and analysis which uses computer programs which have been shown to match the test results of the EPRI Program. The thermal hydraulic forcing functions were generated using the same criteria as before, that is, the simultaneous opening of either the safety valves or the relief valves. These forcing functions were input into the structural analysis using the same mathematical model as used in the as-built analysis. The methods used and the loadings considered are consistent with Sections 2.0, 3.0, 4.0 and 5.0 of

this report. For the loads other than the regenerated Thermal Hydraulic loads, (i.e., Deadweight, Seismic, Thermal), the results and loads from the as-built analysis were used.

6.2.1 THERMAL HYDRAULIC RESULTS

The regeneration of time history thermal hydraulic loads subsequent to the EPRI testing, as previously discussed, was completed. The thermal hydraulic analysis was performed based on cold loop seals, the present as-built configuration for both units. Tables 6-1 and 6-2 show the comparisons between the forces previously generated (as-built analysis) and the forces calculated subsequent to the EPRI testing program. These tables illustrate the peak forces encountered by each straight run of pipe during the transient. Table 6-1 compares the forces obtained from the safety valve discharge case. Table 6-2 compares the forces obtained from the relief valve discharge case. The forces included in these two tables are only the forces resulting from the thermal hydraulic analyses and do not account for any other loading conditions or system reaction.

Based on analytical work and tests to date, all acoustic pressures in the upstream piping calculated or observed prior to and during safety valve loop seal discharge are below the maximum permissable pressure. An evaluation of this inlet piping phenomenum 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. The piping between the pressurizer nozzle and the inlet of the safety valves is 6-inch schedule 160. The calculated maximum upstream pressure for this size of piping is below the maximum permissable pressure.

6.2.2 STRUCTURAL RESULTS

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 stress summaries for the various loading conditions considered are provided in Tables 6-3 through 6-16. The corresponding node points are shown in Figures 6-1 through 6-8. All stresses listed in the summary tables are for Unit 2. The stress levels are slightly lower in certain instances for Unit 1. Not tabulating the Unit 1 results would in no way affect the overall results and conclusions presented in this document.

Our initial evaluation of the new loadings and the old forcing functions subsequent to relief valve discharge indicated that the relief line piping could be qualified upon completion of the structural analysis. The final structural analyses have confirmed and quantified this.

The revised analyses of the PSARV piping subsequent to cold loop seal - safety valve discharge identified an over-stress region in the piping downstream of the safety valves. This is due to the high magnitude thrust forces immediately upstream of, into and along the common header. The 6-inch safety line branches and the piping immediately upstream of the branch connections are realizing higher than allowable stresses due to these forces. Section 5.2.2.2 of the Joseph M. Farley FSAR was utilized to evaluate this potential overstressed region.

As stated in the FSAR, "A support is provided on the discharge piping as close as possible to each safety and relief valve discharge nozzle so that forces and moments (including pipe whip and reactions following an assumed discharge pipe rupture) will not jeopardize the integrity of the valves, the inlet lines to the valves or the nozzles on the pressurizer." Based on engineering judgement, the pressurizer itself would not

be affected by the consequences of the overstressed piping if the rupture occurs nor would the operability of the safety valves, inlet lines to the valves or the nozzles on the pressurizer be jeopardized.

6.3 SUMMARY OF RESULTS AND CONCLUSIONS

The evaluation conducted prior to the completion of the structural analysis and based upon the thermal hydraulic loadings subsequent to the simultaneous discharge of all relief valves, the limiting case for relief valve discharge, indicated that the relief line piping could be qualified upon completion of the analysis for the present as-built configuration for the J. M. Farley Unit 1 and Unit 2. The structural analyses summarized herein have confirmed and quantified this.

The analyses and evaluation of the present system subsequent to the simultaneous discharge of all safety valves identified potential overstress regions immediately upstream of, into and along the common header near where the safety lines branch in. However, based upon engineering judgement, the analyses results substantiate the fact that the integrity of the valves, the inlet lines to the valves or the pressurizer nozzles is not jeopardized.

TABLE 6-1

UNIT 2 HYDRAULIC FORCE COMPARISONS - SAFETY LINES

Table 1 - Safety Line A

		Force (lbs)	
	Location	Pre	Post
1	Valve Outlet	9933.	4960.
2	1st to 2nd elbow after valve	24553.	7162.
3	Vertical Run	52049.	37205.
4	Run into Header	5907.	36778.

Table 1 - Safety Line B

		Force (lbs)	
	Location	Pre	Post
5	Valve Outlet	23293.	6528.
6	Vertical Run	53699.	37229.
7	Run into Header	10344.	39906.

Table 3 - Safety Line C

		Force (lbs)	
	Location	Pre	Post
8	Valve Outlet	22463.	5956.
9	Vertical Segment	60526.	29330.
10	2nd to 3rd elbow after valve	6518.	35410.
11	Vertical Segment	2518.	38350.
12	4th to 5th elbow after valve	2702.	39279.
13	Run into Header	9423.	35707.

Table 4 - Common Header to PRT

		Force (lbs)	
	Location	Pre	Post
14	Header at Safety Branch Connections	15274.	65200.
15	Downstream Header	6449.	24279.
16	Downstream Header	7683.	22811.
17	Vertical Run to PZR Relief Tank	53730.	51570.

FORCE IDENTIFICATION:

Pre - Force from analysis prior to EPRI program.

Post - Force regenerated in analysis subsequent to EPRI program.

NOTE: Location numbers correspond to segment numbers on Figure 4-1.

TABLE 6-2

UNIT 2 HYDRAULIC FORCE COMPARISON - RELIEF LINE

	Force Location	Pre-EPRI Force (lbs)	Post-EPRI Force (lbs)
1	Pressurizer nozzle	492.	73.
2	Tee into valve header	627.	101.
3	6" line north of Tee	514.	63.
4	6 x 3 Reducer	465.	83.
5	Valve set "A"	6063.	748.
6	Vertical run to common header	11108.	6837.
7	6 inch horizontal run	3630.	5430.
8	Common header/safety line branches	19165.	3100.
9	Downstream of common header	1385.	1701.
10	Downstream of common header	1414.	1583.
11	Vertical run to relief tank	8903.	2827.
12	Valve set "B"	2603.	377.
13	Vertical 3" section	1684.	871.
14	Tee into 6" vertical pipe	3360.	857.

The force location numbers correspond to the force numbers on Figure 4-2.

TABLE 6-3

PRIMARY STRESS SUMMARY - UPSTREAM OF VALVES

Piping System: Pressurizer Relief Line

Combination 2 - N + OBE + SOT_U

Node Point	Piping Component	Maximum Stress (ksi)	Allowable Stress (ksi)
1895	Butt weld	27.233	28.98
1160	Long radius elbow	28.962	28.98
1090	Tee	19.500	28.98
1890	Reducer	35.85	36.00
5000	Branch connection	19.873	28.98
1110	Short radius elbow	18.555	28.98

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

TABLE 6-4

PRIMARY STRESS SUMMARY - UPSTREAM OF VALVES

Piping System: Pressurizer Relief Line

Combination 3 - N + SOT_E

Node Point	Piping Component	Maximum Stress (ksi)	Allowable Stress (ksi)
1895	Butt weld	24.906	45.0
1150	Long radius elbow	36.278	45.0
1090	Tee	17.980	45.0
1890	Reducer	38.343	45.0
5000	Branch connection	12.827	45.0
1110	Short radius elbow	14.333	45.0

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

TABLE 6-5

PRIMARY STRESS SUMMARY - UPSTREAM OF VALVES

Piping System: Pressurizer Relief Line

Combinations 4 and 5 - N + LOCA + SSE + SOT_F

Node Point	Piping Component	Maximum Stress (ksi)	Allowable Stress (ksi)
1895	Butt weld	42.595	60.0
1150	Long radius elbow	49.654	60.0
1090	Tee	24.412	60.0
1890	Reducer	58.318	60.0
5000	Branch connection	23.275	60.0
1110	Short radius elbow	20.866	60.0

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

TABLE 6-6

PRIMARY STRESS SUMMARY - SEISMICALLY DESIGNED DOWNSTREAM PORTION

Piping System: Pressurizer Relief Line

Combination 2 - N + SOT_U

Node Point	Piping Component	Maximum Stress (ksi)	Allowable Stress (ksi)
1995	Butt weld	20.428	22.56
1975	Long radius elbow	7.502	22.56
1340	Reducer	9.147	22.56
2000	Tee	20.417	22.56
4490	Branch	8.169	22.56
1640	Welded attachment	6.132	22.56

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

TABLE 6-7

PRIMARY STRESS SUMMARY - SEISMICALLY DESIGNED DOWNSTREAM PORTION

Piping System: Pressurizer Relief Line

Combination 3 - N + OBE + SOT_U

Node Point	Piping Component	Maximum Stress (ksi)	Allowable Stress (ksi)
1995	Butt weld	20.933	29.16
1975	Long radius elbow	9.466	29.16
1340	Reducer	18.630	29.16
2000	Tee	23.503	29.16
4490	Branch	13.833	29.16
1640	Welded attachment	7.655	29.16

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

TABLE 6-8

PRIMARY STRESS SUMMARY - SEISMICALLY DESIGNED DOWNSTREAM PORTION

Piping System: Pressurizer Relief Line

Combination 4 - N + SOT_E

Node Point	Piping Component	Maximum Stress (ksi)	Allowable Stress (ksi)
1570	Butt weld	60.478*	33.84
1310	Long radius elbow	29.864	33.84
1580	Reducer	90.858*	33.84
2000	Tee	13.480	33.84
4490	Branch	37.498*	33.84
1500	Welded attachment	15.159	33.84

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

* These points are in the common header portion.

TABLE 6-9

PRIMARY STRESS SUMMARY - SEISMICALLY DESIGNED DOWNSTREAM PORTION

Piping System: Pressurizer Relief Line

Combinations 5 and 6 - N + LOCA + SSE + SOT_F

Node Point	Piping Component	Maximum Stress (ksi)	Allowable Stress (ksi)
1570	Butt weld	65.119*	45.12
1300	Long radius elbow	40.902	45.12
1570	Reducer	97.674*	45.12
2000	Tee	19.505	45.12
4490	Branch	46.154*	45.12
1500	Welded attachment	23.112	45.12

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

* These points are in the common header portion.

TABLE 6-10

PRIMARY STRESS SUMMARY - UPSTREAM OF VALVES

Piping System: Pressurizer Safety Line

Combination 2 - N + OBE + SOT_U

Node Point	Piping Component	Maximum Stress (ksi)	Allowable Stress (ksi)
2130	Butt weld	16.334	36.0
2150	Long radius elbow	30.714	36.0
2150	Branch connection	16.506	36.0
2110	Welded attachment	12.126	36.0

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

TABLE 6-11

PRIMARY STRESS SUMMARY - UPSTREAM OF VALVES

Piping System: Pressurizer Safety Line

Combination 3 - N + SOT_E

Node Point	Piping Component	Maximum Stress (ksi)	Allowable Stress (ksi)
3020	Butt weld	24.779	36.225
3030	Long radius elbow	32.69	36.225
4110	Branch connection	19.428	36.225
4080	Welded attachment	11.019	36.225

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

TABLE 6-12

PRIMARY STRESS SUMMARY - UPSTREAM OF VALVES

Piping System: Pressurizer Safety Line

Combinations 4 and 5 - N + LOCA + SSE + SOT_F

Node Point	Piping Component	Maximum Stress (ksi)	Allowable Stress (ksi)
3020	Butt weld	27.225	48.3
3030	Long radius elbow	46.480	48.3
2150	Branch connection	24.280	48.3
2110	Welded attachment	15.467	48.3

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

TABLE 6-13

PRIMARY STRESS SUMMARY - SEISMICALLY DESIGNED DOWNSTREAM PORTION

Piping System: Pressurizer Safety Line

Combination 2 - N + SOT_U

Node Point	Piping Component	Maximum Stress (ksi)	Allowable Stress (ksi)
4200	Butt weld	5.149	22.56
4420	Long radius elbow	4.655	22.56
4280	Welded attachment	4.260	22.56
4490	Branch	6.988	22.56

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

TABLE 6-14

PRIMARY STRESS SUMMARY - SEISMICALLY DESIGNED DOWNSTREAM PORTION

Piping System: Pressurizer Safety Line

Combination 3 - N + OBE + SOT_U

Node Point	Piping Component	Maximum Stress (ksi)	Allowable Stress (ksi)
2240	Butt weld	12.266	33.84
2260	Long radius elbow	12.848	33.84
3350	Welded attachment	7.994	33.84
3480	Branch	14.694	33.84

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

TABLE 6-15

PRIMARY STRESS SUMMARY - SEISMICALLY DESIGNED DOWNSTREAM PORTION

Piping System: Pressurizer Safety Line

Combination 4 - N + SOT_E

Node Point	Piping Component	Maximum Stress (ksi)	Allowable Stress (ksi)
4390	Butt weld	58.462	33.84
4390	Long radius elbow	72.646	33.84
4360	Welded attachment	75.681	33.84
4490	Branch	95.917	33.84
4370	Clear run	88.954	33.84

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

TABLE 6-16

PRIMARY STRESS SUMMARY - SEISMICALLY DESIGNED DOWNSTREAM PORTION

Piping System: Pressurizer Safety Line

Combinations 5 and 6 - N + LOCA + SSE + SOT_F

Node Point	Piping Component	Maximum Stress (ksi)	Allowable Stress (ksi)
4390	Butt weld	62.464	45.12
4390	Long radius elbow	77.683	45.12
4360	Welded attachment	78.619	45.12
4490	Branch	113.882	45.12

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

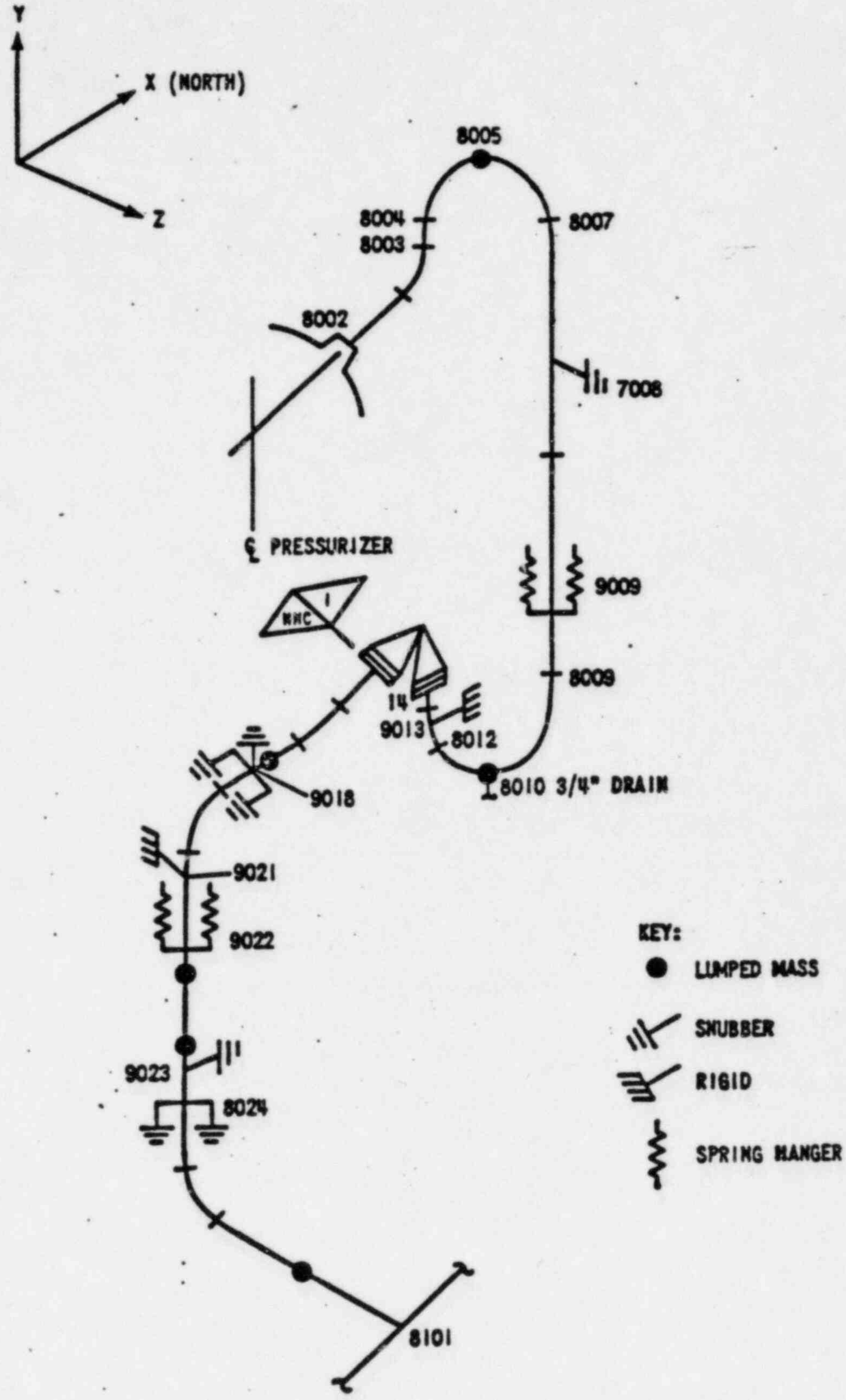

FIGURE 6-1:. Pressurizer Safety Line A Model

J. M. FARLEY UNIT #1 PSARV

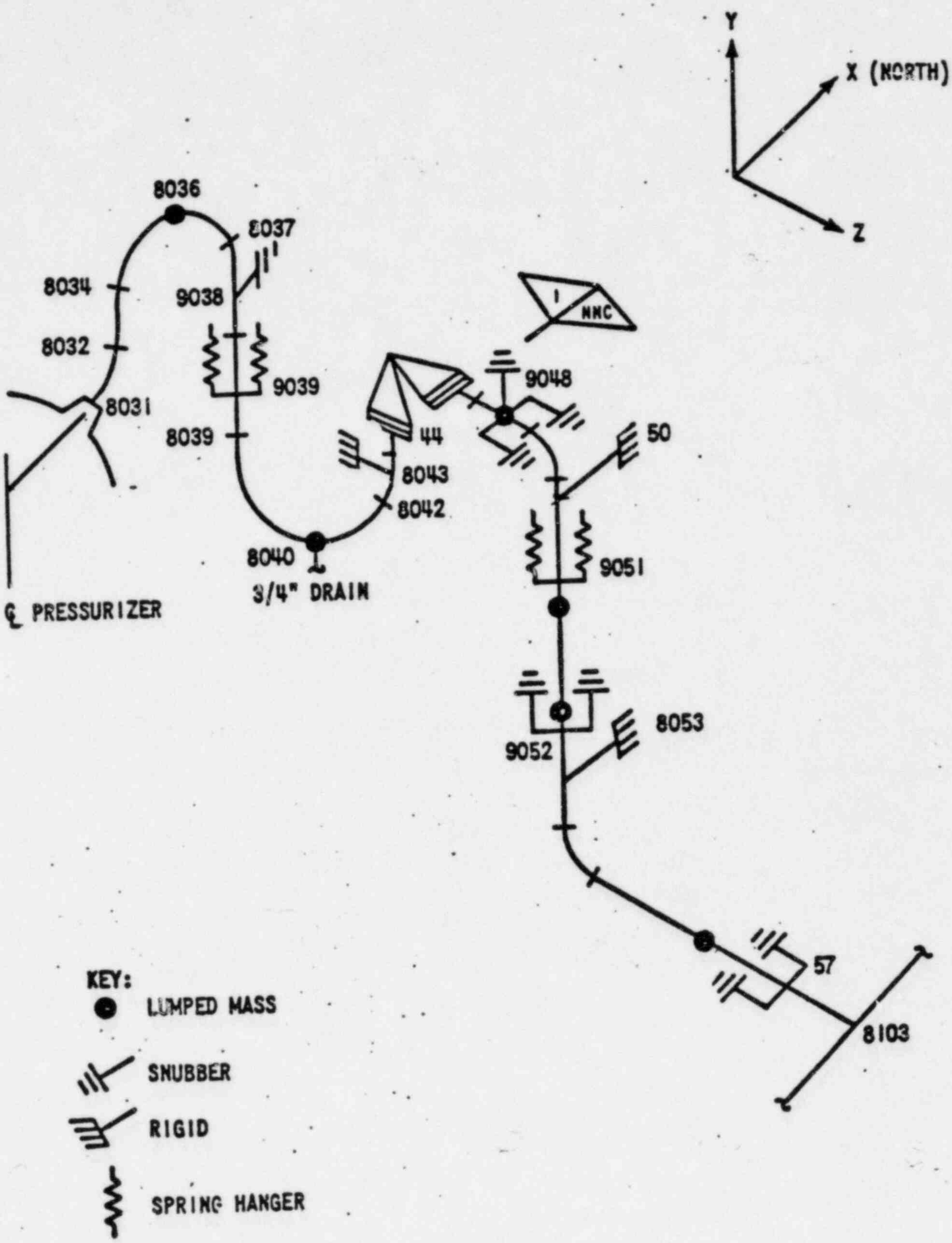

FIGURE 6-2: Pressurizer Safety Line B Model

J. M. FARLEY UNIT #1 PSARV

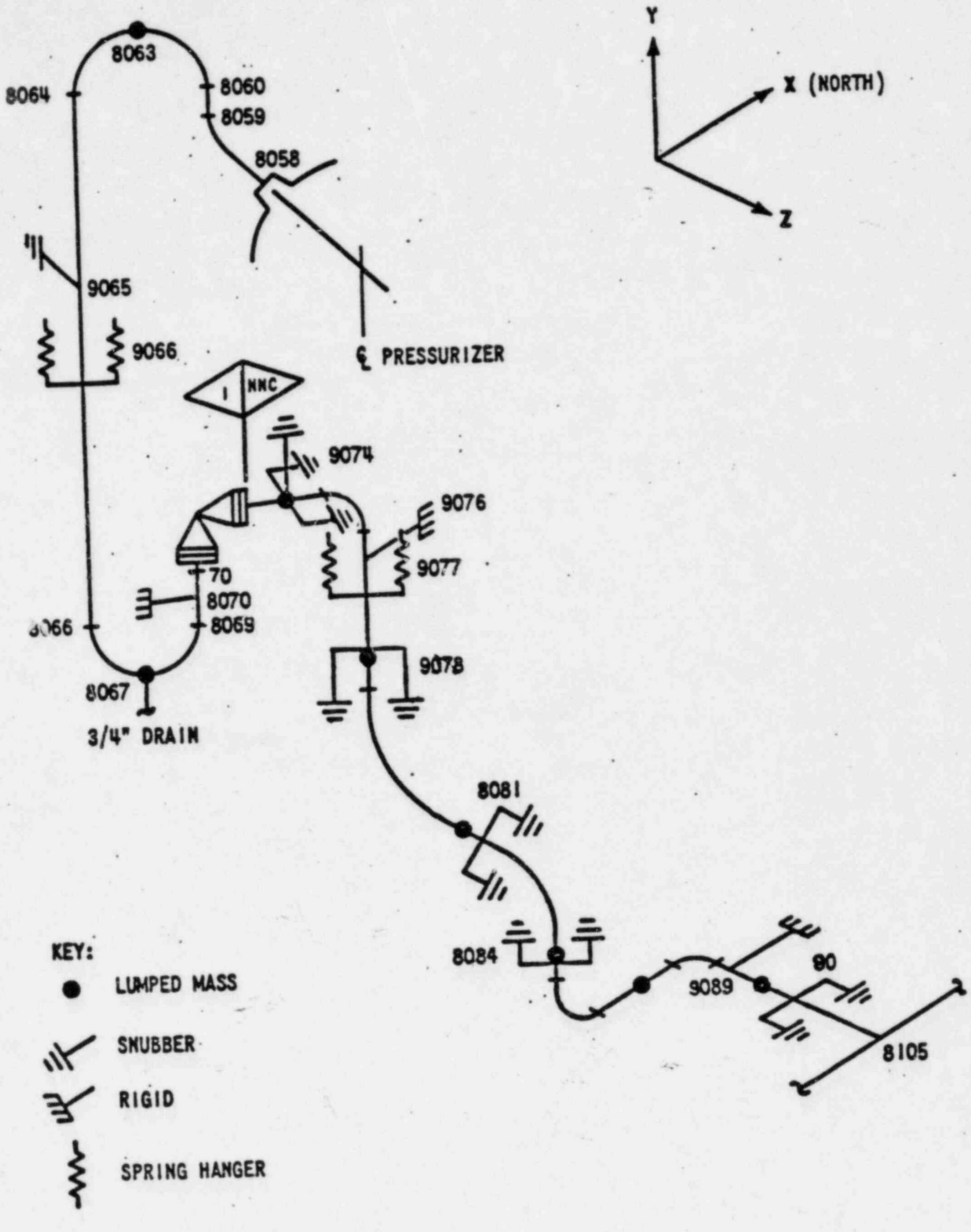

FIGURE 6-3: Pressurizer Safety Line C Model

J. M. FARLEY UNIT #1 PSARV

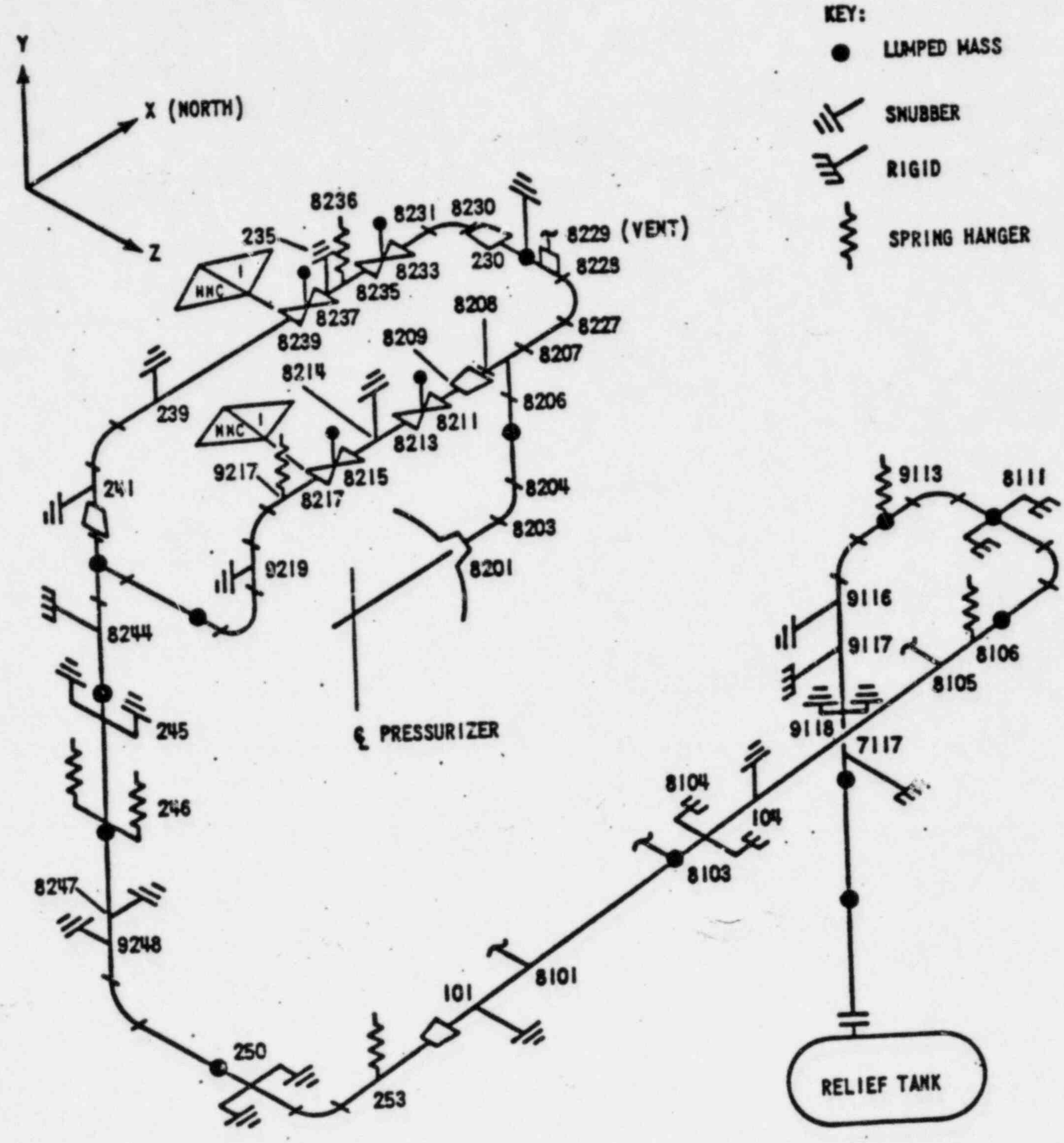

FIGURE 6-4: Pressurizer Relief Line Model

· J. M. FARLEY UNIT #1 PSARV

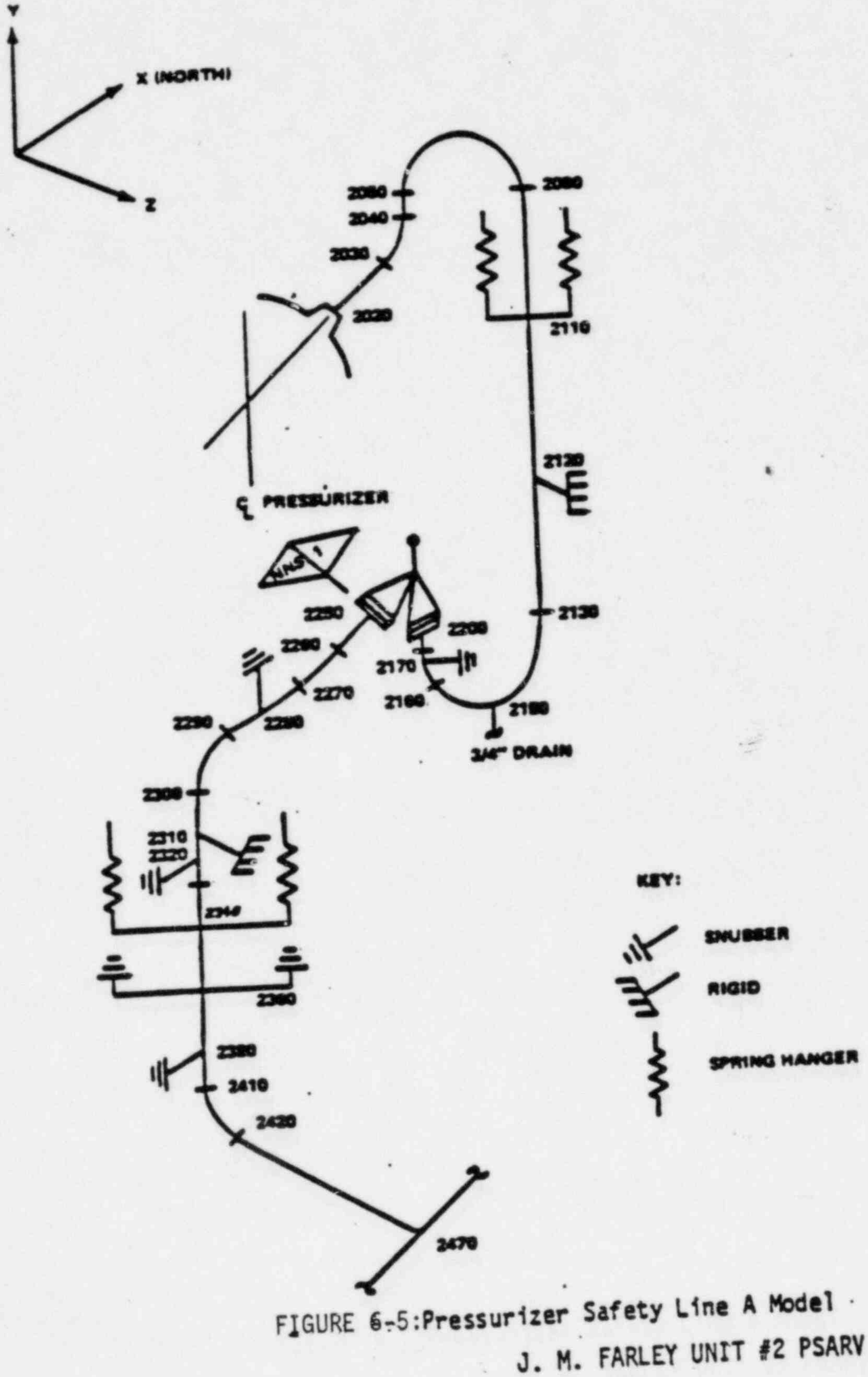

FIGURE 6-5: Pressurizer Safety Line A Model

J. M. FARLEY UNIT #2 PSARV

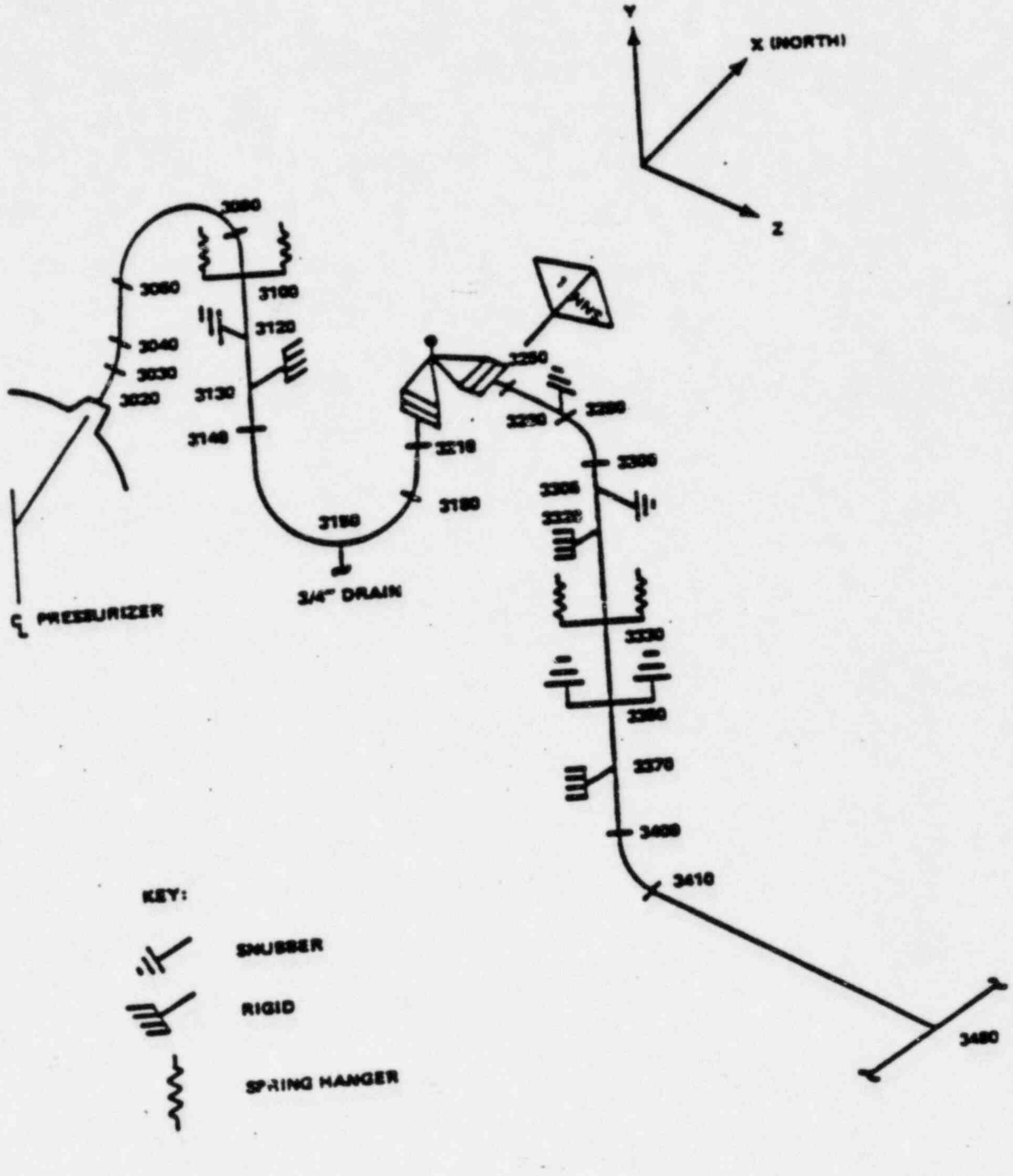

FIGURE 6-6; Pressurizer Safety Line B Model
J. M. FARLEY UNIT #2 PSARV

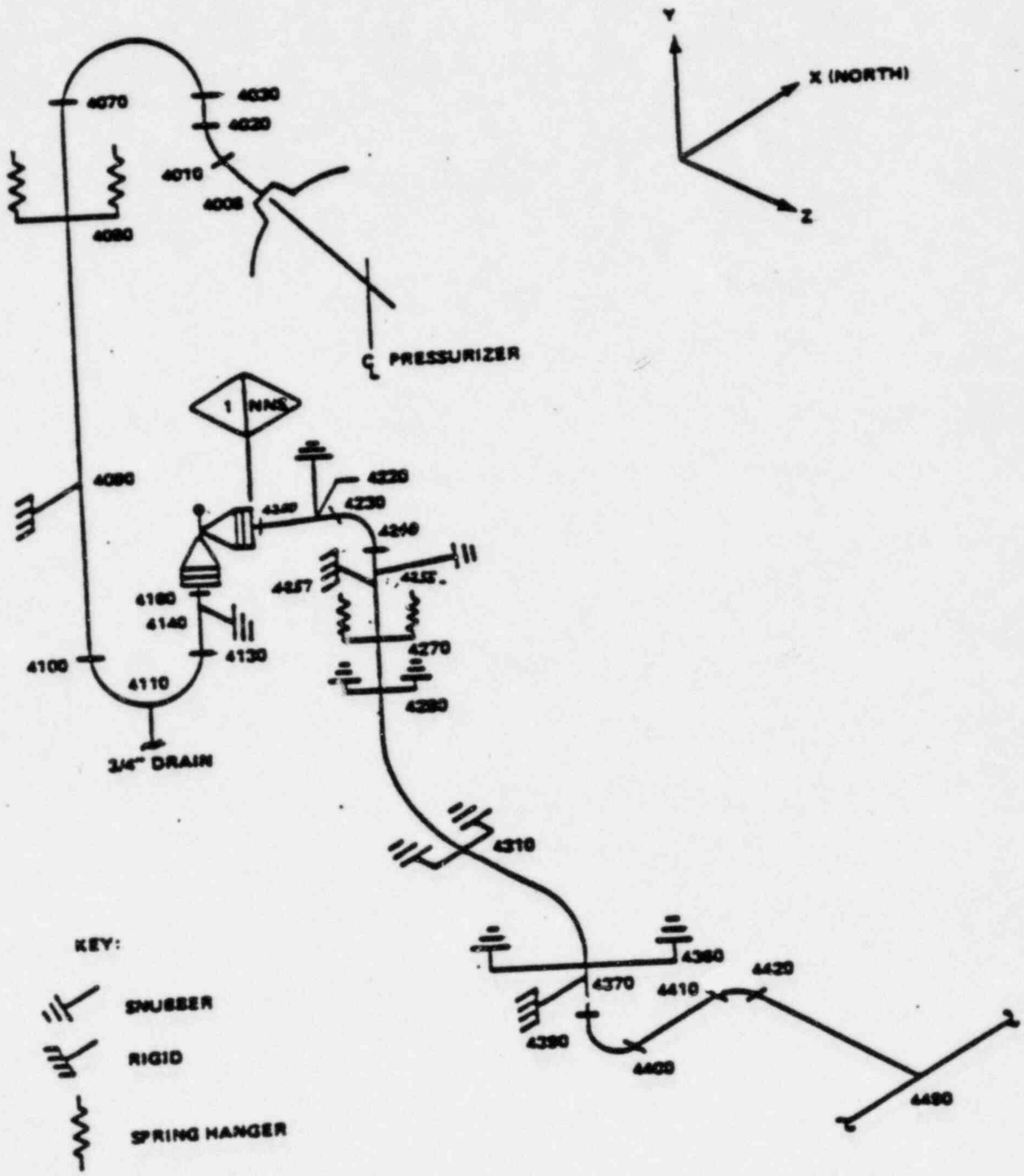

FIGURE 6-7: Pressurizer Safety Line C Model
J. M. FARLEY UNIT #2 PSARV

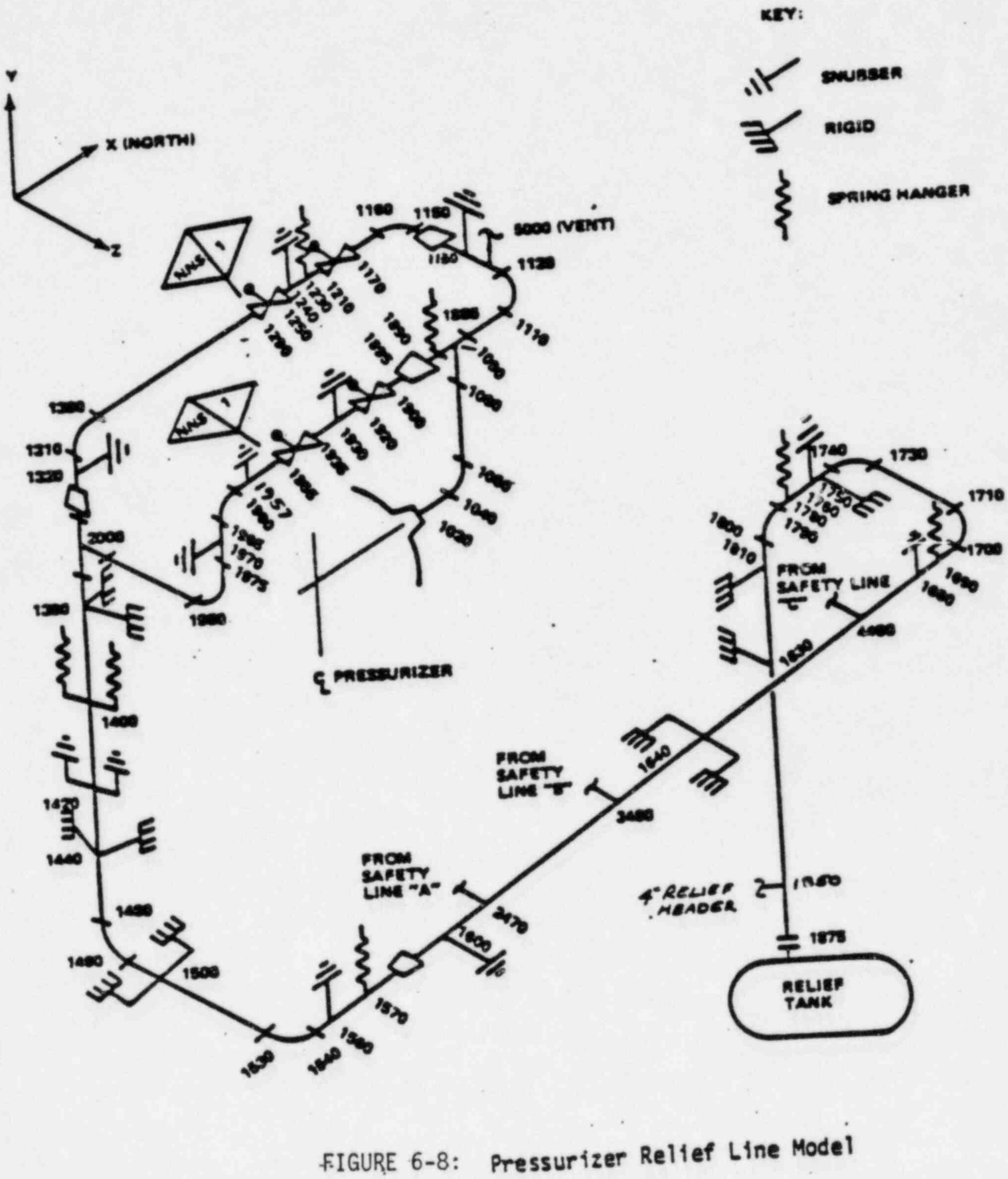

FIGURE 6-8: Pressurizer Relief Line Model

J. M. FARLEY UNIT #2 PSARV