ENCLOSURE 2

TECHNICAL BASIS FOR THE USE OF ENERGY ABSORBERS AS SUPPORTS OF NUCLEAR POWER PLANT PIPING SYSTEMS

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Section 1

INTRODUCTION

1.1 Current Piping Support Practice

Currently, Seismic Category I piping systems in nuclear power plants are designed for normal, seismic, and other transient loads using the following types of pipe supports:

- Spring-type supports, including variable and constant-effort types, are used as vertical dead weight supports at locations where essentially free thermal expansion is necessary. The springs in these supports are coil type, have low stiffness values, and are designed to perform elastically throughout their travel range. Spring-type supports have a negligible effect on piping response during seismic events. As such, they are not normally accounted for in the seismic analysis computer models of piping systems.

- Rigid-type supports, including rods, struts, stanchions, frames, etc., are designed to restrain the piping system under all loading conditions. They essentially prevent the pipe from moving in the restrained direction and are designed to remain elastic under all specified piping load combinations.

- Snubbers, including hydraulic and mechanical types, are used as seismic and dynamic supports only. They are either mechanically or hydraulically activated. They offer no support against gravity, allow essentially free movement under thermal expansion and contraction of piping systems, but, under rapid dynamic piping movements, they activate and function as a rigid strut. Snubbers are designed to remain elastic under specified load combinations.

With the exception of springs, pipe supports currently in use are designed with the intent of maintaining their rigidity against specified loads while remaining within the material yield stress. Seismic analyses of piping systems employ linear elastic mode superposition methods in which rigid supports and snubbers are modeled as linear elements. Although gaps and other sources of nonlinearities exist in rigid support and snubber designs, modeling these supports as linear elements has been considered adequate in light of the conservatism inherent in the overall design process. The damping values used in the seismic modal analysis are based on Regulatory Guide 1.61 for recent plants, or the values contained in the Final Safety Analysis Reports (FSARs) of operating plants.

The escalation of seismic criteria has led to a continuing increase in the number of snubbers and the overall number of pipe supports over the last few generations of nuclear plants. As a consequence, recent plants contain stiffer systems than old operating plants. Our operating experience base indicates that flexible systems perform well during seismic events when compared to rigidly constrained systems. The increase in the number of snubbers, the rise in the number of snubber operating problems, and the decrease in system flexibility has led to numerous industry programs to investigate alternatives. Two important areas covered in these investigations are damping and flexible system design. The recommendations by the Pressure Vessel Research Committee (PVRC) on alternative generic damping values, which were included in Code Case N-411 of the ASME Section III Code, are one example of damping.

The alternative damping values in Code Case N-411 were developed from available test data of piping systems typically supported with springs, rigid supports, and snubbers (1). References (2), (3), and (4) establish the fact that general system damping values are strongly dependent on the types and quantities of pipe supports used as well as the magnitude of the actual response involved. Fluids in hydraulic snubbers, small gaps in mechanical snubbers and frame supports, and

friction forces in springs and bearing supports are the energy dissipating mechanisms to which the observed damping values are attributed. Due to complexity and nonuniformity of these mechanisms, it is not feasible to predict system damping values analytically, thus test data was used to make generic recommendations.

The energy absorber designed in accordance with Code Case N-420 and described in this enclosure is an alternative that enhances both damping and system flexibility.

1.2 Energy Absorbers as Pipe Supports

The energy absorber, as presented in this enclosure, is a new pipe support concept that allows large amounts of energy dissipation under simple, well-defined, repeatable, and reliable conditions. Accurate analytical estimates of damping values associated with energy absorbers are possible. When used as seismic supports of piping systems, energy absorbers will provide the following basic benefits:

- Add significant amounts of damping that can be reliably calculated for each significant mode. The amount of damping added for significant modes of vibration can be much higher than the values recommended in Code Case N-411.

- Reduce the system frequencies, which will result in more flexible designs, especially for systems designed for high seismic loads.

- Virtually eliminate the need for snubbers, thus enhancing the system's reliability.

- Significantly enhance the system's capability to accommodate higher than design earthquake loads or other dynamic events within pipe and support allowable limits.

Energy absorbers are simple, flexible supports designed to undergo controlled and predictable yielding under dynamic displacement. The hysteretic action of the energy absorber plates results in added damping to the piping system. Cumulative fatigue effects can be evaluated according to the requirements of Code Case N-420.

Figure 1.1 shows the major activities that led to the development of this new pipe support concept. Each of the steps on the chart is shown in the sequence where it occurred. The successful completion of each step served as a benchmark for the succeeding step. Therefore, the energy absorber development and its analytical solution methods followed a course that could be verified by proven experimental data.

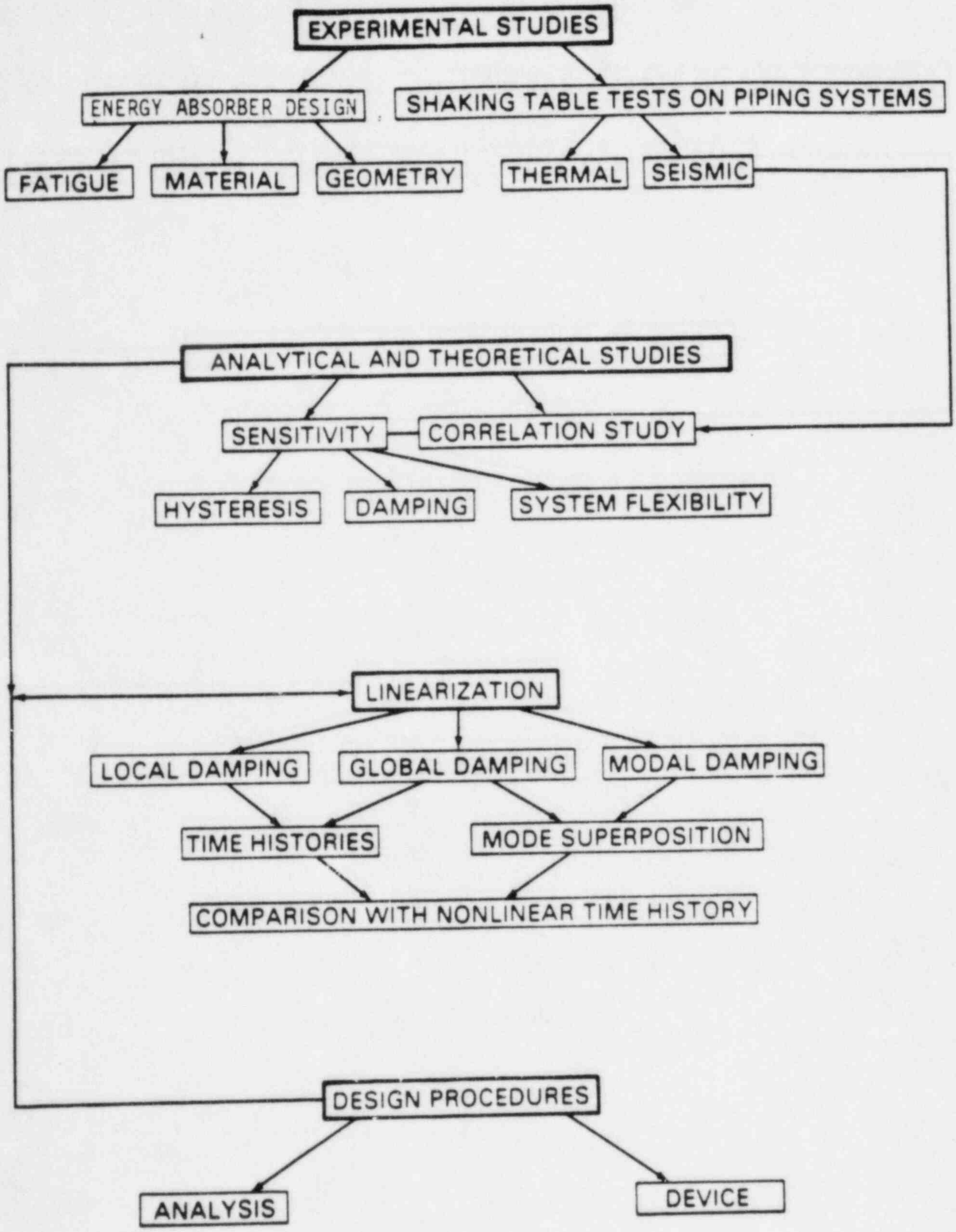


Figure 1.1 Energy Absorber Development Flow Chart

Section 2

OPERATING PRINCIPLES OF PLATE-TYPE ENERGY ABSORBERS

2.1 Performance and Design Requirements

Energy absorbers are made of simple, specially shaped steel plates designed to:

- o Exhibit a smooth, well-defined force-displacement relationship.
- o Possess moderate, finite, and well-defined stiffness and peak forces to be used in the thermal expansion analysis of piping systems.
- o Yield uniformly over the maximum possible volume of the plate's material.
- o Have a well-defined hysteretic behavior under cyclic displacement. The hysteresis loops should only be a function of the current strain status and should be independent of strain rate.
- o Exhibit negligible stiffness degradation.
- o Achieve maximum cyclic energy absorption capability per unit volume of the material, per cycle, over as large a range of strain as allowed by fatigue design considerations.
- o Possess a fatigue endurance capability sufficient to maintain the plate's integrity under cyclic design and service load conditions.
- o Be insensitive to environmental conditions, such as temperature and radiation.
- o Be of simple construction so as to enhance reliability and eliminate maintenance and functional testing.

During the past few years, several energy absorption concepts have been investigated (5), (6), leading to the conclusion that only the simplest energy absorbers made of ordinary ductile steel plates fulfill all of the above requirements. Figure 2.1 illustrates two simple concepts for steel plate energy absorbers that are ideal for satisfying all design requirements and allow for reliable calculation of their damping effects.

Concepts 1 and 2 can be used interchangeably because they possess similar characteristics and hysteretic performance and provide the same damping effect to the piping system. Concept 2, employing x-shaped plates, has been selected by and used in the Bechtel energy absorber development program. This concept was selected because its end connections are simpler than those of Concept 1. To facilitate constructibility and installation, to allow for pipe movements in the unrestrained direction, and to increase reliability, multiple x-shaped plates were incorporated in the design shown in Concept 2(a). This concept allows the use of simple pin connection at the pipe end. A detailed description of these energy absorbers is provided in Section 8.

2.2 Energy Absorber Relational Characteristics

Figure 2.2 depicts the configuration of a one-dimensional x-shaped energy absorber plate. It is readily apparent that this configuration provides a large volume of uniform plasticity when yielded, and that its hysteretic characteristics can be easily determined as a function of its dimensions. Hysteretic behavior obtained from simple bending tests on x-shaped plates has correlated very closely with that derived for an ideal x-shaped beam.

For an ideal x-shaped beam (plate), the force-displacement relationship in the elastic region is:

$$\frac{F}{d} = \frac{Et^3}{12a^2} \frac{b}{a} \qquad (2\text{-}1)$$

where F is the applied force at one end of the plate, d is the corresponding displacement, and E is the material Young's modulus. As shown in Figure 2.2, a, b, and t are plate dimensions.

The relationship between the displacement d at strain ε is

$$d = 2\varepsilon(a^2/t) \tag{2-2}$$

After the plate has yielded, the force-displacement relationship becomes:

$$\frac{F}{F_y} = \frac{3}{2} - \frac{1}{2(\varepsilon/\varepsilon_y)^2} \tag{2-3}$$

where F_y and ε_y are the yield force and yield strain respectively and ε is the strain.

Equation (2-3) indicates that the ultimate load for an x-shaped plate F_u approaches 1.5 times its yield load F_y.

Equations (2-1) through (2-3) also show that:

- o The yield force F_y and the ultimate force F_u are proportional to t^2 and b/a but independent of the plate's length (for a given ratio of b/a).
- o The initial elastic stiffness is proportional to t^3, $1/a^2$, and b/a.
- o The yield displacement d_y is proportional to a^2 and 1/t.

The above relationships are shown graphically in the force-displacement diagrams in Figure 2.3. The form of the hysteresis curves at any strain value, based on the ideal x-shaped beam relationships, is indicated by the graphs of Figure 2.3. Figure 2.4 shows a typical hysteresis curve from a test specimen. The close correlation observed in the figures has been demonstrated by subsequent analysis.

The simple energy absorber characteristics and their interrelationships shown in Figure 2.3 illustrate the capability to size energy absorbers to suit a wide variety of applications.

2.3 Operating Principles

Energy absorbers designed according to the requirements of Section 2.1 and as described in Section 2.2 are simple flexible supports that interact with the supported piping as described in the following paragraphs.

a) Thermal Expansion

Energy absorbers will accommodate piping thermal expansion by flexing. Their finite, moderate, and well-defined elastic stiffness and peak forces allow accurate and reliable thermal expansion analysis of the piping systems. Piping systems with energy absorbers are analyzed to satisfy the applicable code stress limits, nozzle load allowables, and other applicable criteria as required.

b) Seismic and Dynamic Loads

Under seismic and dynamic excitation, the cyclic displacement of the piping will result in a hysteretic behavior of the energy absorbers. The hysteretic behavior will cause an increase in the effective damping of the system dynamic response, hence it will provide the desired control. An increase in the system's response will result in an increase in the effective damping, thus converging on a stable level of system response. The design and analytical process allows complete control of damping values, strain levels in the energy absorbers, and other pertinent system response parameters. This has been proven in shaker table testing, and the test results have been correlated to theoretical and analytical methods with a high degree of accuracy as shown in the subsequent sections.

c) Seismic Anchor Movements (SAM)

Energy absorbers are considered as flexible elements. Since the energy absorbers are more flexible than a locked snubber and become even more flexible as they undergo yielding during a seismic event, the system response due to SAM will be lower than for a corresponding system supported with snubbers or rigid supports.

An important feature of energy absorber design is that loads from thermal expansion, seismic and dynamic loads, and seismic anchor movement are not additive. Once an energy absorber has yielded, no increase in load beyond its load-displacement characteristic is possible. Also, tests have demonstrated that thermal expansion loads in energy absorbers undergo a shakedown at the onset of yielding under dynamic excitation. This is further discussed in Section 3.

2.4 Fatigue Design

Energy absorbers are designed for cumulative fatigue effects resulting from all cyclic thermal, seismic, and dynamic loads in accordance with the requirements of Code Case N-420. Load rate testing of prototypical energy absorbers to develop fatigue design curves is discussed in Section 8.

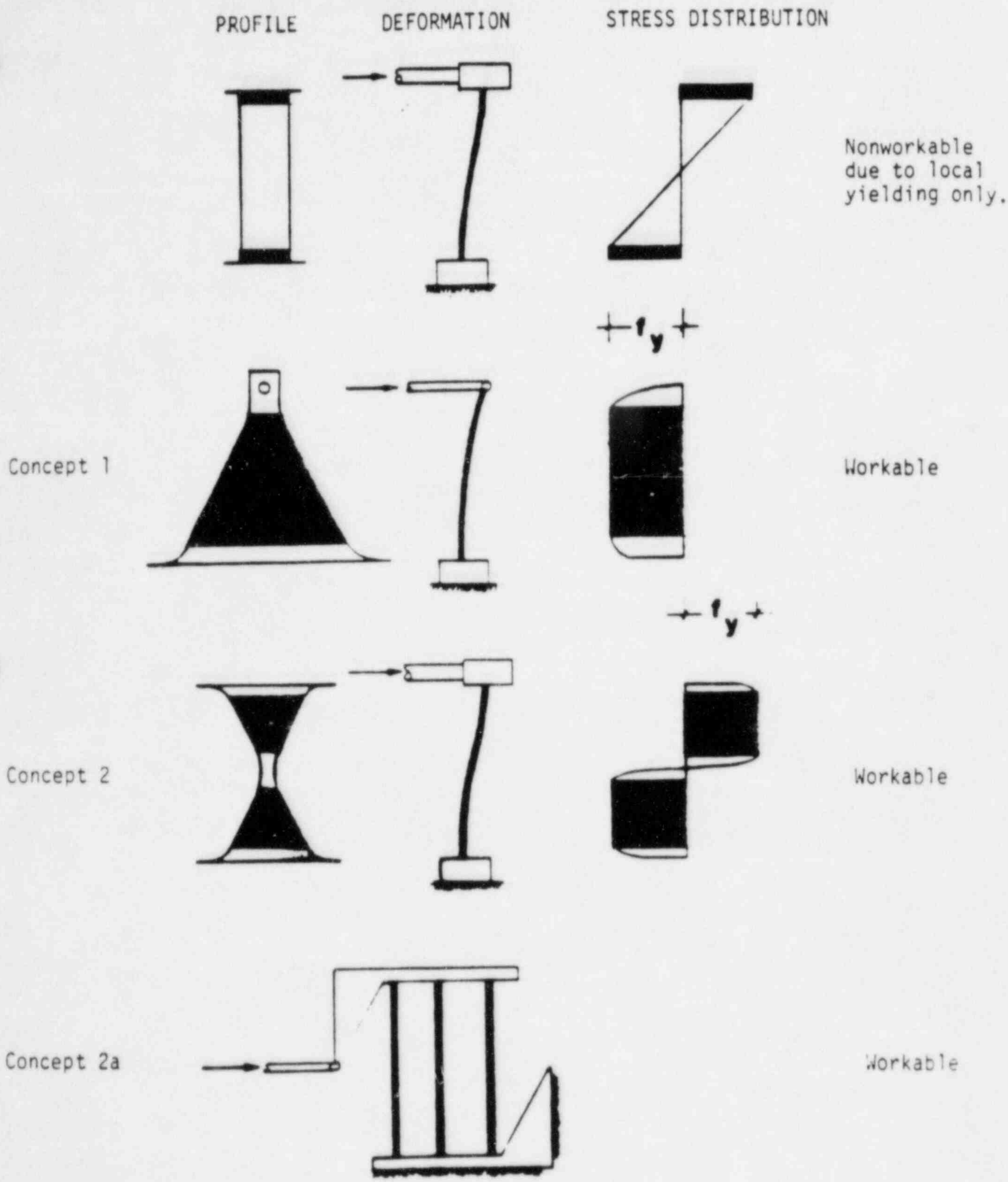


Figure 2.1 Concepts of Steel Plate Energy Absorbers

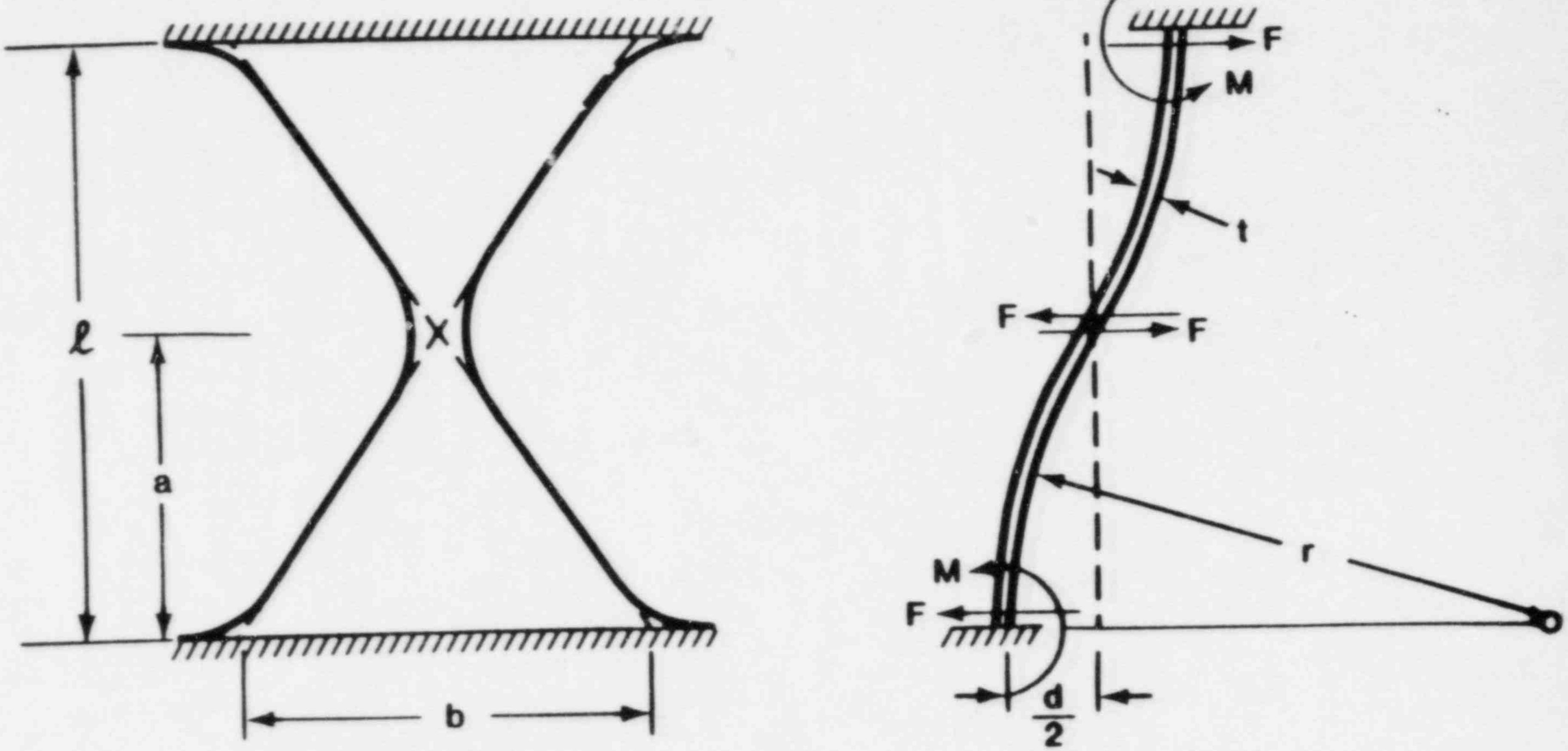
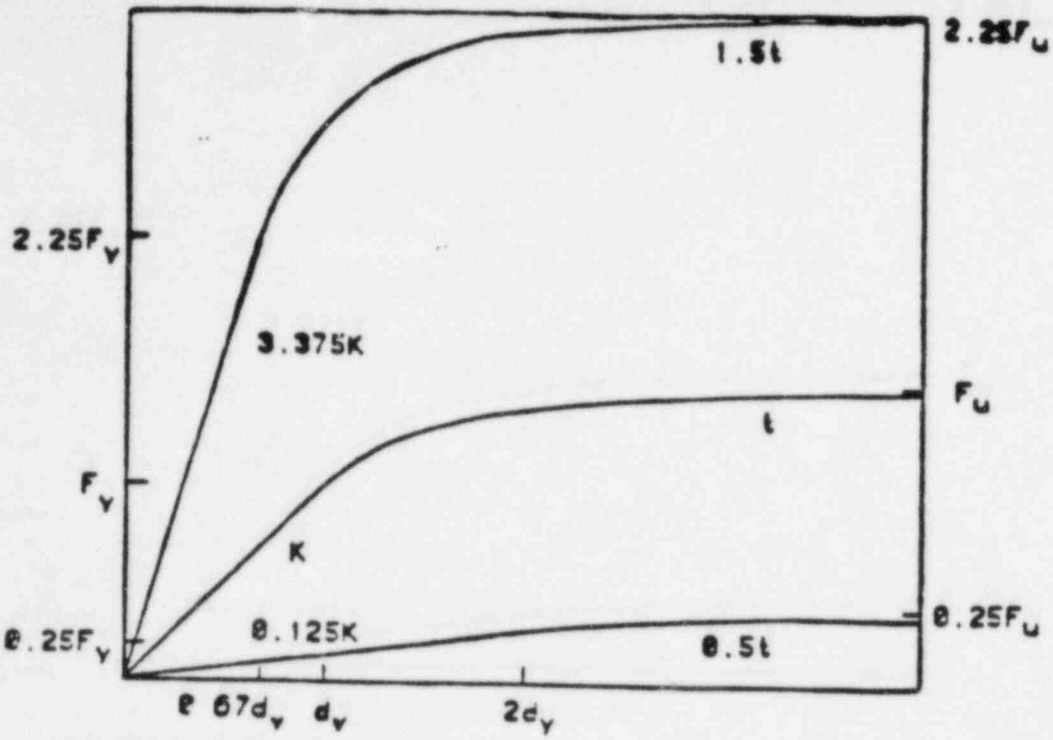
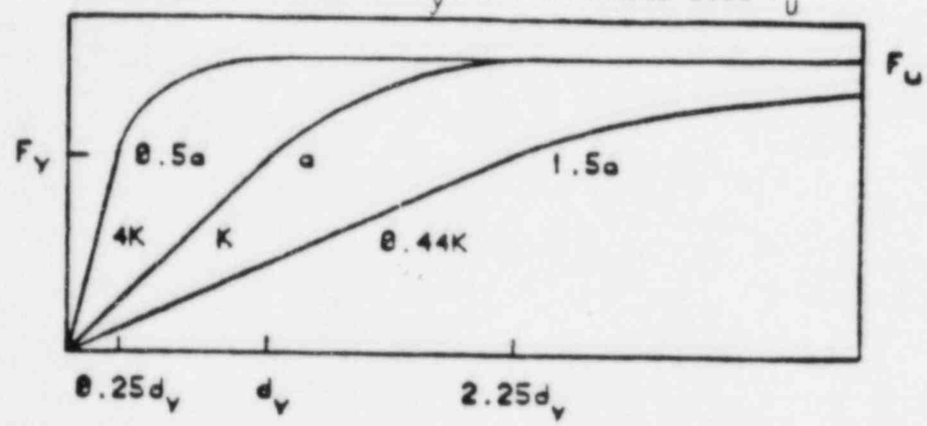


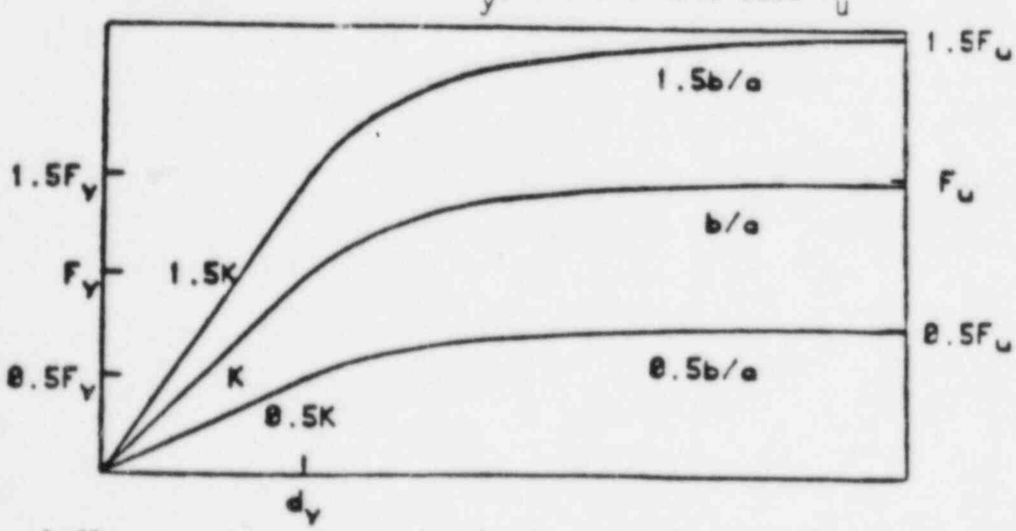
Figure 2.2 Deformation Model for X-Type Energy Absorber



Influence of the Thickness t of an Idealized X-Type Absorber to Stiffness K, Yield Load F_y, and Ultimate Load F_u



Influence of the Length a of an Idealized X-Type Absorber to Stiffness K, Yield Load F_y, and Ultimate Load F_u



Influence of the Angle (b/a) of an Idealized X-Type Absorber to Stiffness K, Yield Load F_y, and Ultimate Load F_u

Figure 2.3 Energy Absorber Characteristics

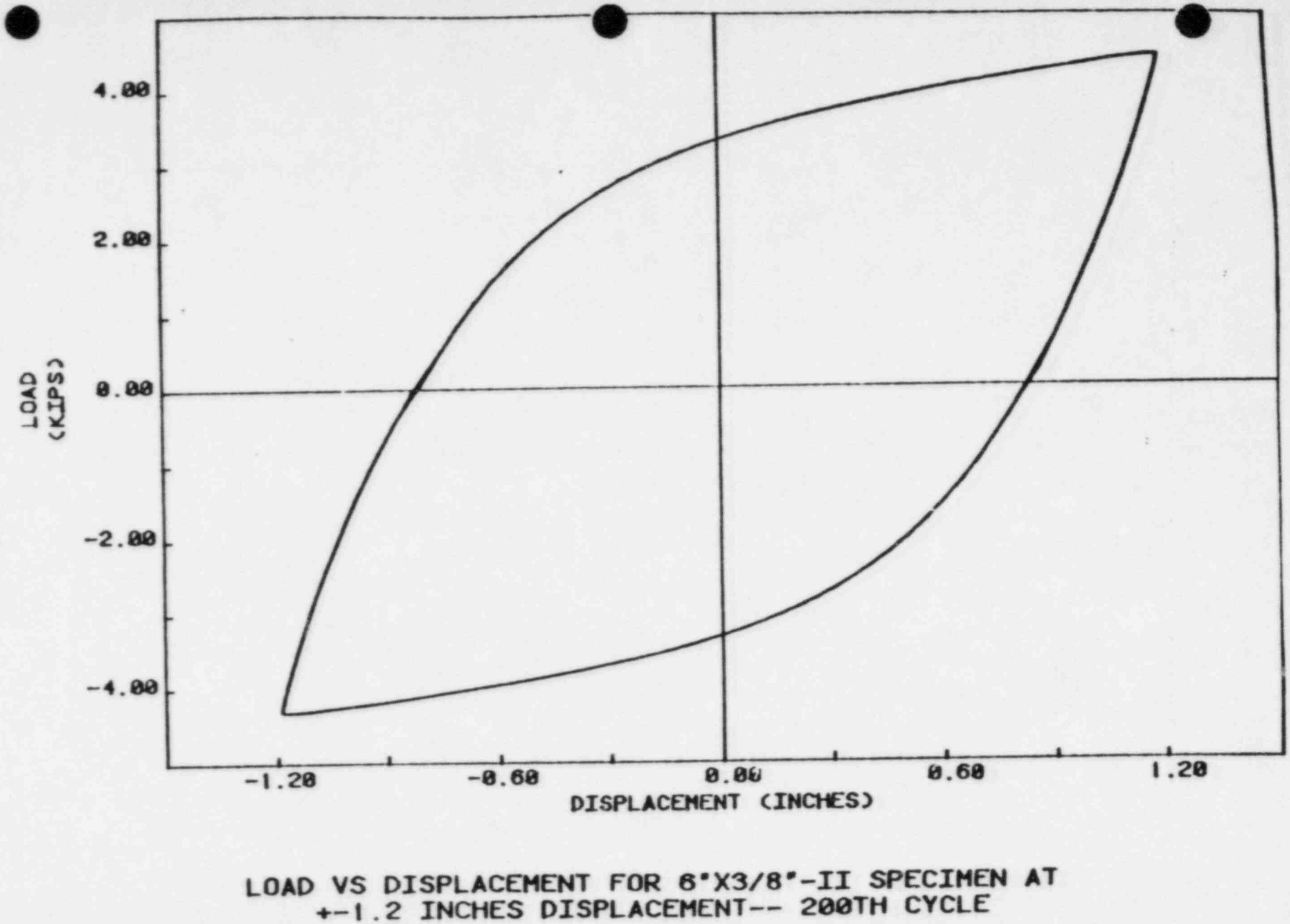


Figure 2.4 Typical Hysteresis Curve of an X-Shaped Energy Absorber

Section 3

SUMMARY OF SHAKER TABLE TEST RESULTS

Extensive experimental studies of plate-type energy absorbers have been conducted at the Earthquake Engineering Research Center (EERC) of the University of California, Berkeley. In these studies, various plate geometries and materials of construction were investigated, resulting in the development of triangular and x-shaped energy absorber concepts. Shapes similar to these have been previously utilized in some civil/structural applications of energy absorption. Fatigue testing of sample plates, fabricated from mild AISI 1020 steels, demonstrated sufficient fatigue endurance at high strain levels (up to 2.5%). Thus, the feasibility of using these energy absorbers as seismic supports of piping systems without ever replacing them was established. A series of shaker table tests at EERC was then conducted to demonstrate the concept and obtain response data for subsequent use in analytical correlation and parametric studies.

The behavior of piping systems with energy absorbers, under seismic loadings, was studied in three separate and extensive series of shaker table tests at EERC. The results of the tests are briefly summarized in the following paragraphs. Special emphasis is given to the first and third test due to the volume and significance of the test data obtained.

3.1 U-Loop Test

a) Test Objectives and Setup

The first extensive series of shaker table tests was conducted, under the sponsorship of the Department of Energy, on a single plane U-loop piping configuration using triangular energy absorbers. A complete description of this test is contained in

Reference (7). The objective of this test was to study the general concept of controlling dynamic piping response with energy absorbers and the effects of combined seismic and thermal loadings. Although triangular plates were used, the conclusions drawn from this test are equally applicable to x-shaped plates.

Figure 3.1 shows the configuration of the U-loop used. It consisted of a 3.5-inch. O.D. pipe fixed at the boundaries with concentrated masses added at each elbow and filled with water. One energy absorber in the horizontal direction and two in the vertical direction were used in various test runs, singly or in combination. Over 80 test runs were performed on the loop with or without energy absorbers, simulating both cold and hot piping conditions. Parametric studies on energy absorber sizes were performed. The table motion used was the TAFT earthquake. Peak acceleration intensities were varied between runs from 0.125g to 1.49g. Pipe stresses, displacements, accelerations, energy absorber forces, and input table motions were recorded.

b) Time-History Response of Unrestrained System

Figure 3.2 shows the measured unrestrained pipe displacement response to an earthquake of 0.142g intensity and a duration of 20 seconds. It indicates high response under the lowest input motion.

c) Time-History Response of Cold-Restrained System

Figure 3.3 shows the measured pipe response at the same location as in Figure 3.2 with one horizontal energy absorber installed on the U-loop. The test run was for a TAFT earthquake of 1.32g intensity. The effectiveness of the energy absorber in controlling the system's response is evident.

d) Time-History Response of Hot-Restrained System

Figure 3.4 shows the measured system response under the same test conditions as described in Section 3.1(c) but with simulated thermal expansion conditions. The response is shown for two conditions, one which thermally deflected the energy absorber in one direction and the other which deflected it in the opposite direction. The results indicate that under dynamic excitation, a classical shakedown of the thermal forces in the energy absorbers occurs in one to three dynamic displacement cycles. The dynamic response of the piping system is identical under cold and hot test conditions.

e) Conclusions Drawn from U-Loop Test

As is readily seen, the U-loop configuration was essentially a one degree-of-freedom system when excited in either the horizontal or the vertical directions. Therefore, important system parameters such as natural frequencies and damping coefficients were found accurately and the effects of energy absorbers were easily identified. This fact was later utilized in correlating the test results with computer solutions, verifying nonlinear programs, and gaining a clear understanding of the characteristics of energy absorbers. Several important conclusions can be drawn from this test:

- Energy absorbers are able to dissipate a significant amount of energy as can be seen from the hysteresis curves of Figure 3.5. Thus, the dynamic response of the pipe is considerably reduced as compared to the response of a free pipe, while the force transmitted from the pipe to the support structure was limited to the yield force of the energy absorbers.

- The damping coefficient of the free pipe was measured around 2% of critical. When energy absorbers were used, the system damping increased significantly, in some cases to values well above 20% of critical.

- Thermal expansion or contraction effects are not additive to the dynamic system response.

- Performance characteristics of energy absorbers, measured from the shaker table tests, were verified to have a constant strain-stress relationship, thus correlating with models using the perfect kinematic hardening rule (8), (9).

3.2 Space Frame Test

a) Test Objectives and Setup

To examine the behavior of x-shaped energy absorbers in a general uncoupled three-dimensional system, a spatial piping system supported by a three-story steel frame was mounted on the shaker table. A detailed description of this test is contained in Reference (10). The frame was 18 feet high, 12 x 6 feet in plan dimensions, and weighed approximately 26.6 kips. Several configurations were tested, such as the frame without piping, the frame with the piping rigidly attached, and the frame with the piping supported by energy absorbers. TAFT earthquake records were used for all configurations. The results showed the expected reliable performance of the energy absorbers and provided conclusions similar to those gained from the U-loop test. The following additional advantages were revealed from this interactive piping-structure experiment:

b) Conclusions Drawn from Space Frame Test

- The fundamental frequency of the piping system supported with energy absorbers was lower than that for a rigidly attached configuration.

- With energy absorbers, responses at higher frequencies were lower, overall system stresses were lower, and spectral peaks were broadened indicating that high damping was introduced by the hysteretic action of the energy absorbers.

- Energy absorbers close to valves with eccentricities were highly effective in reducing pipe stresses and valve accelerations.

3.3 Scaled Spatial Piping System Test

a) Test Objectives and Setup

This test was sponsored by the Electric Power Research Institute (EPRI). Bechtel provided advisory consultation, provided the system configuration, and facilitated the acquisition of some test material. In this experiment, an extensive series of tests (over 110 shaker table runs) were performed. A full description of the experimental setup and primary test results can be found in Reference (11). In this experiment, a half-scale model of a section of the core spray piping system design from the Hope Creek nuclear plant (Figure 3.6) was constructed inside a rigid frame and mounted on the shaker table. The snubbers were installed and tested and were then replaced with energy absorbers, which were installed and tested. The applicable Hope Creek operating basis earthquake (OBE) and safe shutdown earthquake (SSE) response spectra curves and multiples thereof, properly modified to account for the scaling effect, were used as input motions to the shaker table. Despite the modeling considerations, however, the model was viewed as a smaller prototype and tested accordingly. The purpose of this test was to:

- o Apply the findings from the previous two tests to a realistic three-dimensional system.

- o Evaluate the feasibility of replacing snubbers with appropriately sized x-shaped energy absorbers on a one-to-one basis at the same locations.

- o Obtain comparative system response data with snubbers and energy absorber setups.

- o Develop benchmark data for analytical and correlation studies.

b) Stress and Valve Accelerations

Figure 3.7 compares maximum stresses and valve acceleration in the piping at increasing intensities of earthquake. It is observed that at design earthquake intensity the two responses are approximately equal. At higher than design earthquake intensities, however, the responses with energy absorbers are lower than with snubbers.

c) Support Loads

The results here are predictable (Figure 3.8). With increasing ground motion intensity, there is no significant increase of force in energy absorbers after they have reached their yield values, whereas the snubber forces increase. This is a significant advantage because the maximum forces transmitted by energy absorbers to the building are smaller and are clearly defined. The rigid rod forces are similar in magnitude in both installations.

d) Fourier Spectrum of Pipe Acceleration Response

Another way of comparing the snubber and energy absorber system responses is via the fast Fourier transformation (FFT) of pipe accelerations Figure 3.9. The snubber system response has a random characteristic with significant energy over the whole frequency spectrum (attributed to the impacting phenomenon associated with snubber activation). The energy absorber system response is more associated with the natural frequencies of the system, thus is more predictable.

e) Load-Displacement Response

Figure 3.10 compares a snubber and its corresponding energy absorber hesteresis loops from similar tests. The snubbers displayed uneven, irregular, and multiple-impacting characteristics. The energy absorbers displayed smooth and predictable characteristics. The areas within the loops represent energy absorbed and are a measure of damping.

f) Damping

The comparison of damping values is of great interest. Figure 3.11 shows the free decay curves of the piping system without snubbers or energy absorbers, with snubbers, and with 4-inch long and 2-inch long energy absorbers. It is observed that system damping without snubbers or energy absorbers is about 1.2% of critical. With snubbers it is 5.7%. With energy absorbers it is 5.6% for the 4-inch size and 7.9% for the 2-inch size. The direct correlation of used energy absorbers to damping is evident. Given an installation in which optimization of energy absorbers is made by design, higher damping values will result. It is important to note that subsequent analytical work in which the hysteretic characteristics

of the installed energy absorbers were used, produced damping values that are virtually identical to the measured values. A direct correlation therefore exists between experimental data and analytical methods to calculate the damping associated with the use of energy absorbers.

g) Conclusions Drawn from Scaled Spatial Piping System Test

As was the case in previous tests, energy absorbers were demonstrated to be an effective means of supporting piping systems for earthquake loads. In addition, an important aspect of this test was that snubbers were actually installed and tested before being replaced with energy absorbers. After the latter were tested, a direct comparison was made of the performance of each.

The results indicated a more clearly defined behavior on the part of energy absorbers than the snubbers. The hysteresis curves of energy absorbers showed smooth and well-defined characteristics, similar to those obtained from static displacement tests. Snubbers, on the other hand, showed a behavior that is more difficult to predict or reproduce. See Figure 3.12 for comparative plots. The shakedown of thermal forces in the energy absorbers was observed in the same manner as in the U-loop test. Throughout the test series, the energy absorbers were mounted as a direct one-to-one replacement of snubbers without optimization of location. Even with straight replacement, the experimental data showed advantages of energy absorbers over snubbers.

3.4 Overall Experimental Work Conclusions

The summary of the experimental work presented in the preceding sections has conclusively proven the viability of energy absorbers as supports for piping systems. The experimental work demonstrated the following advantages of energy absorbers:

- They provide some degree of decoupling of seismic input to the piping.

- They provide as good or better control of system seismic response as snubbers.

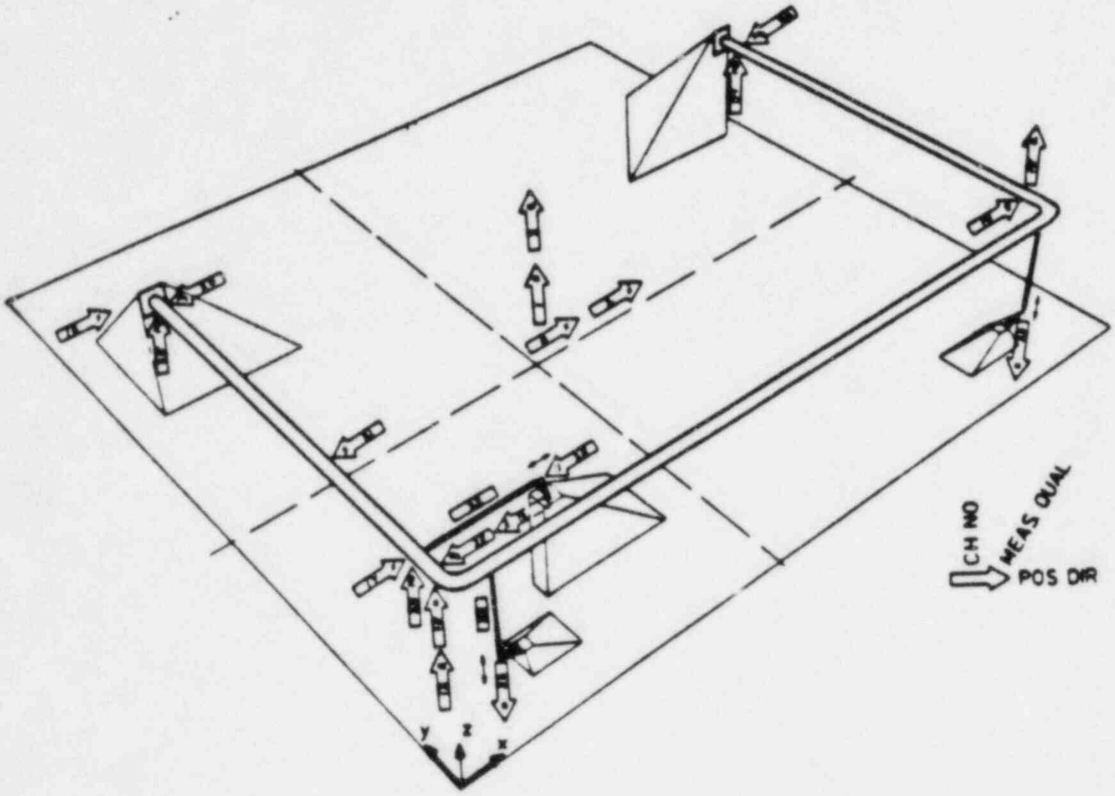
- They are more advantageous than snubbers at large intensity excitations due to the significant increase in their damping effect.

- The results are predictable and repeatable. Some energy absorbers were subjected to more than 32 earthquake tests of varying intensities with no degradation in response repeatability or characteristics.

- They possess sufficient fatigue endurance to sustain design conditions for the plant life.

- They are simple, require no maintenance, and are easily replaceable should such a need arise.

- They can be used to replace snubbers in existing plants with a resulting increase in flexibilty and system damping.



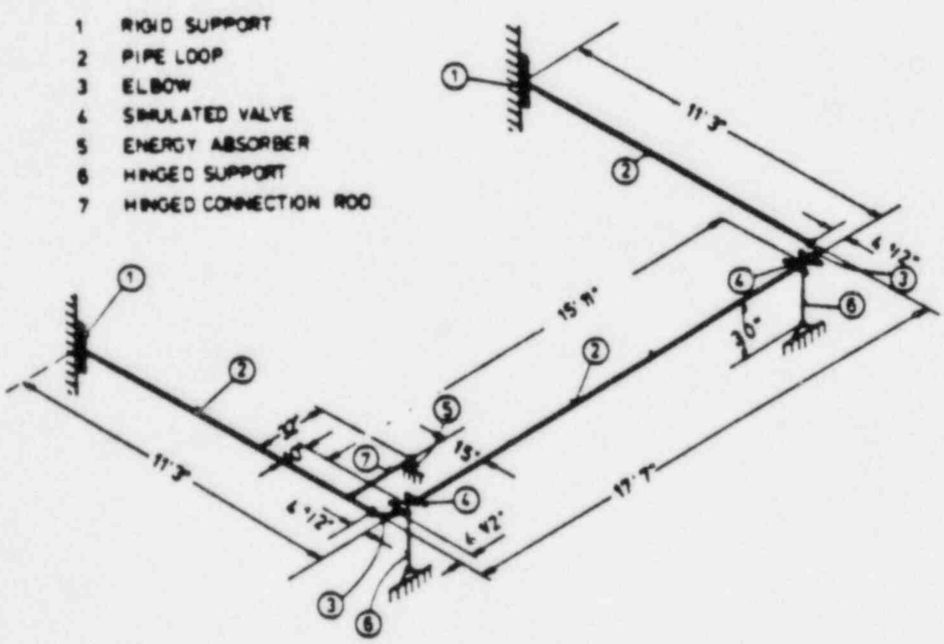


Figure 3.1 Plan of Measurement Points and Isometric of U-Loop Piping System

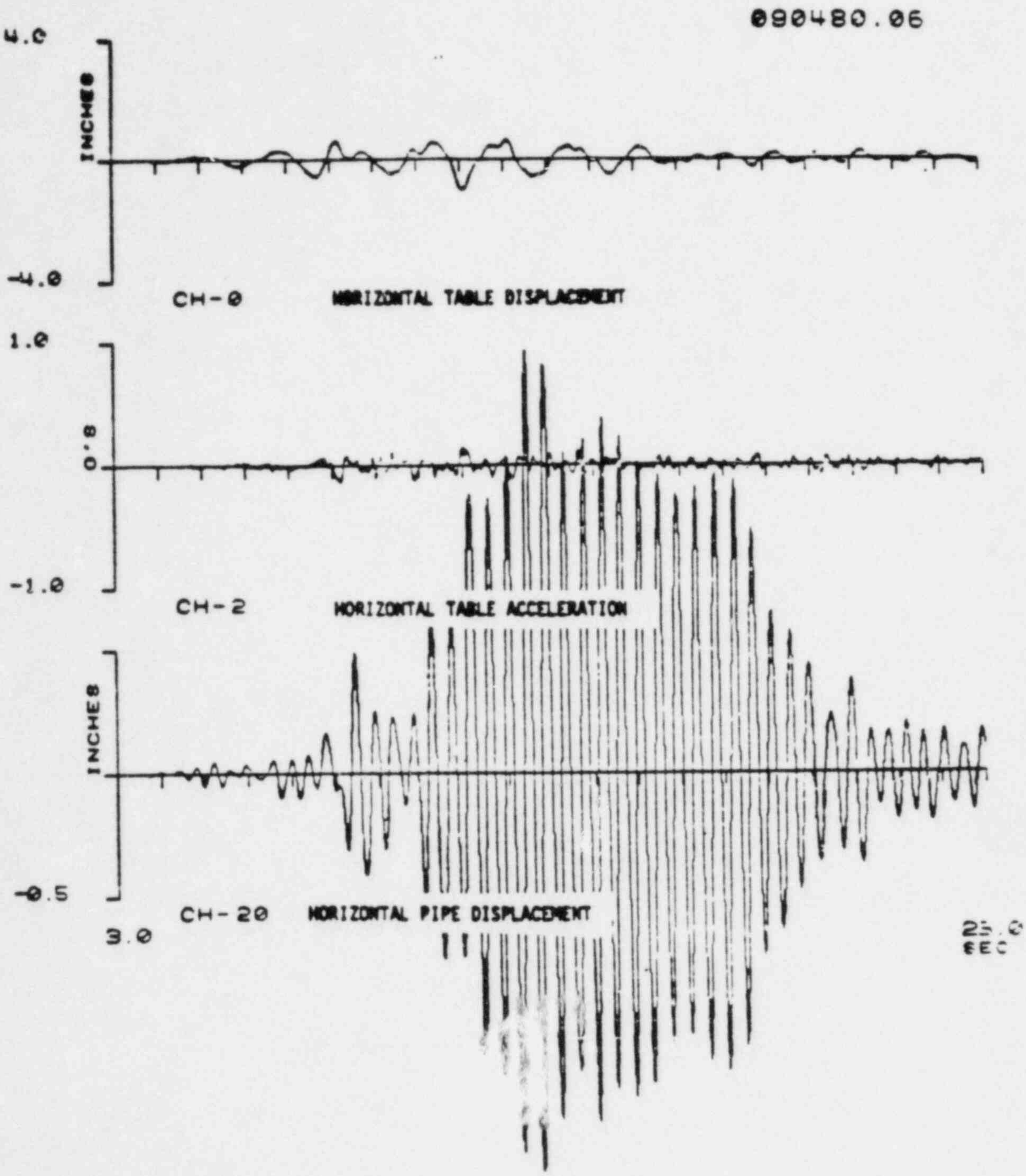


Figure 3.2 Time-Histories, Without Absorber, Peak Table Acc. = 0.142 g

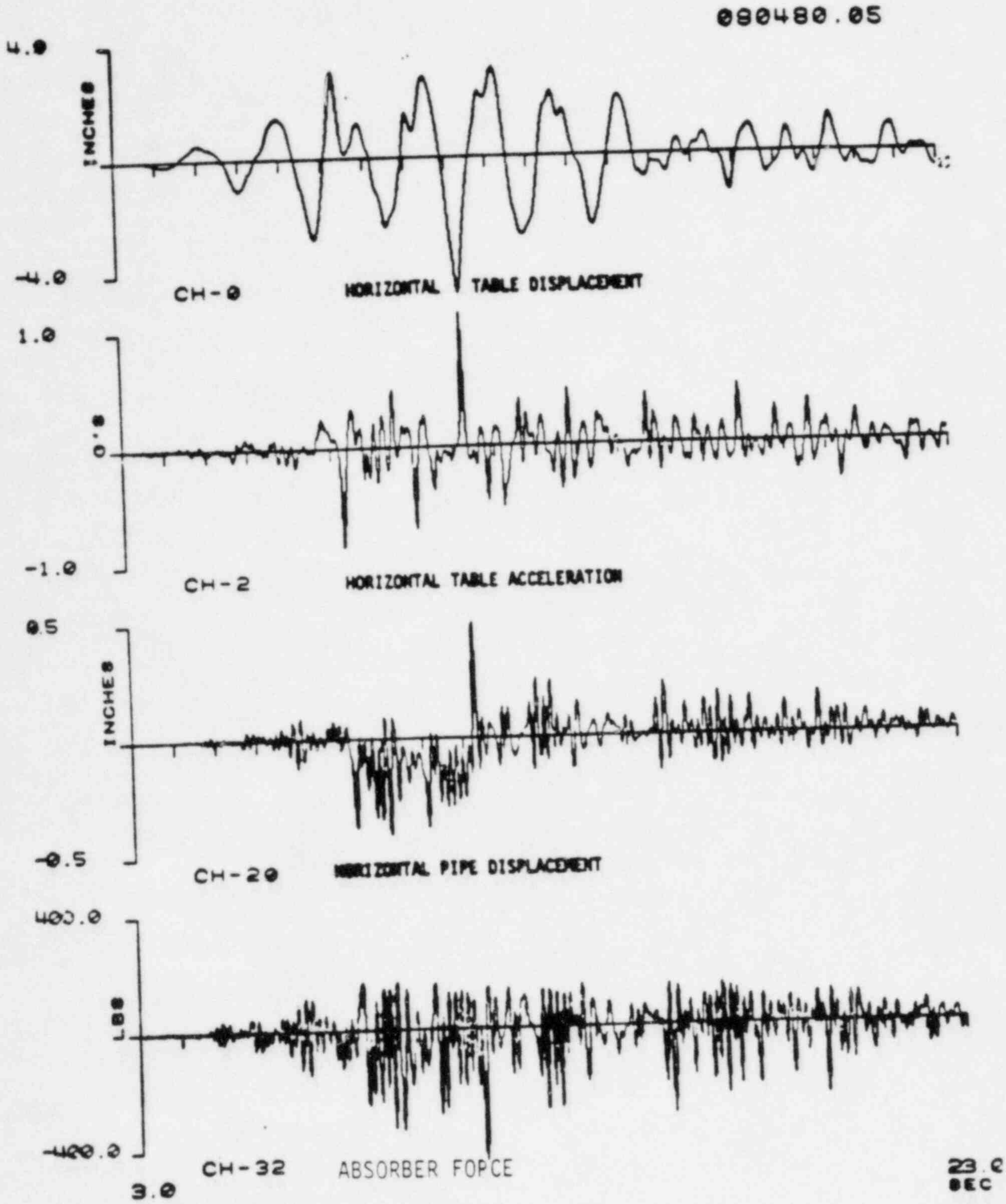


Figure 3.3 Time-Histories, with Absorber, No "Thermal" Displacement, Peak Table Acc. = 1.32 g

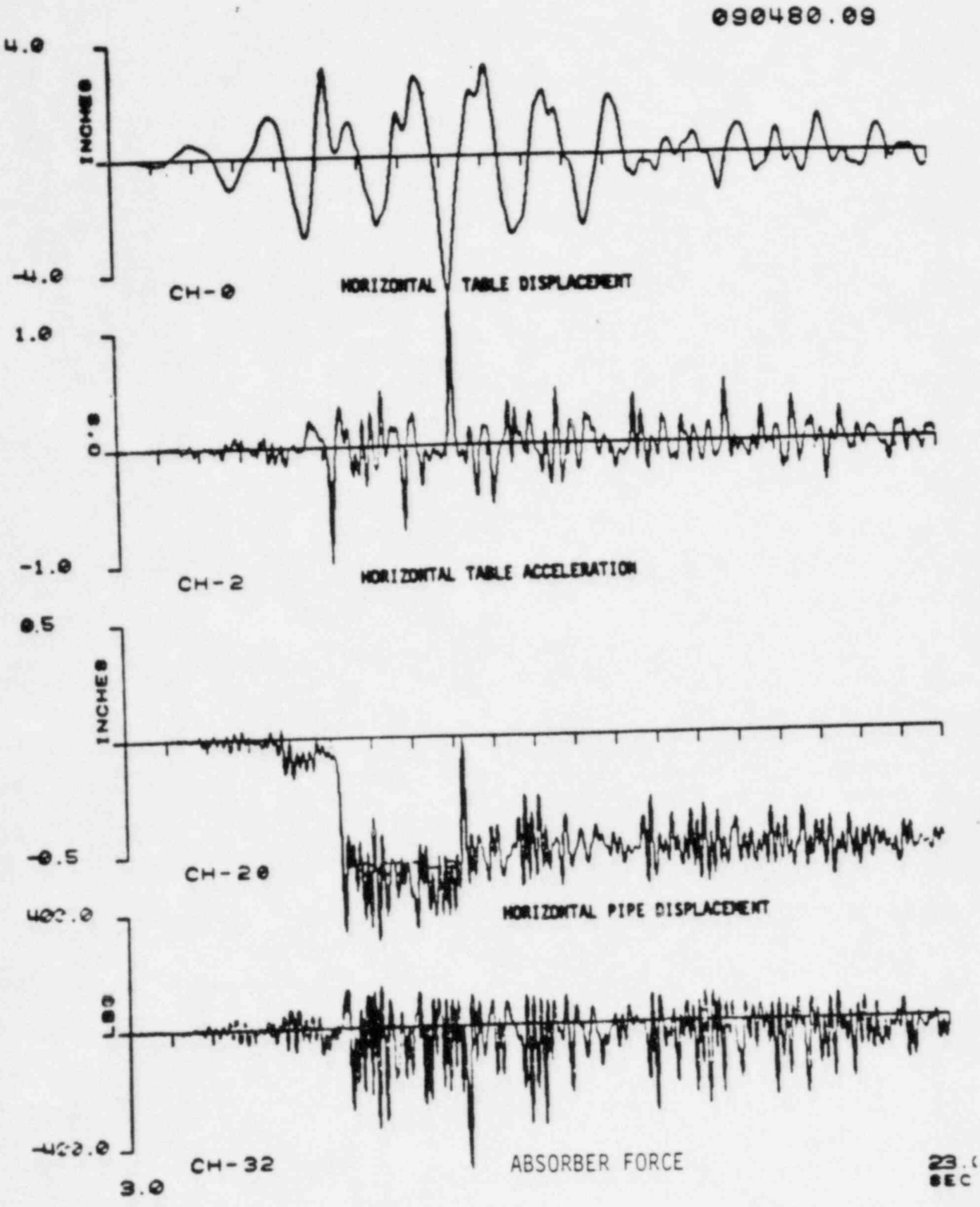


Figure 3.4a Time-Histories, with Absorber, +1.0-Inch "Thermal" Displacement, Peak Table Acc. = 1.32 g

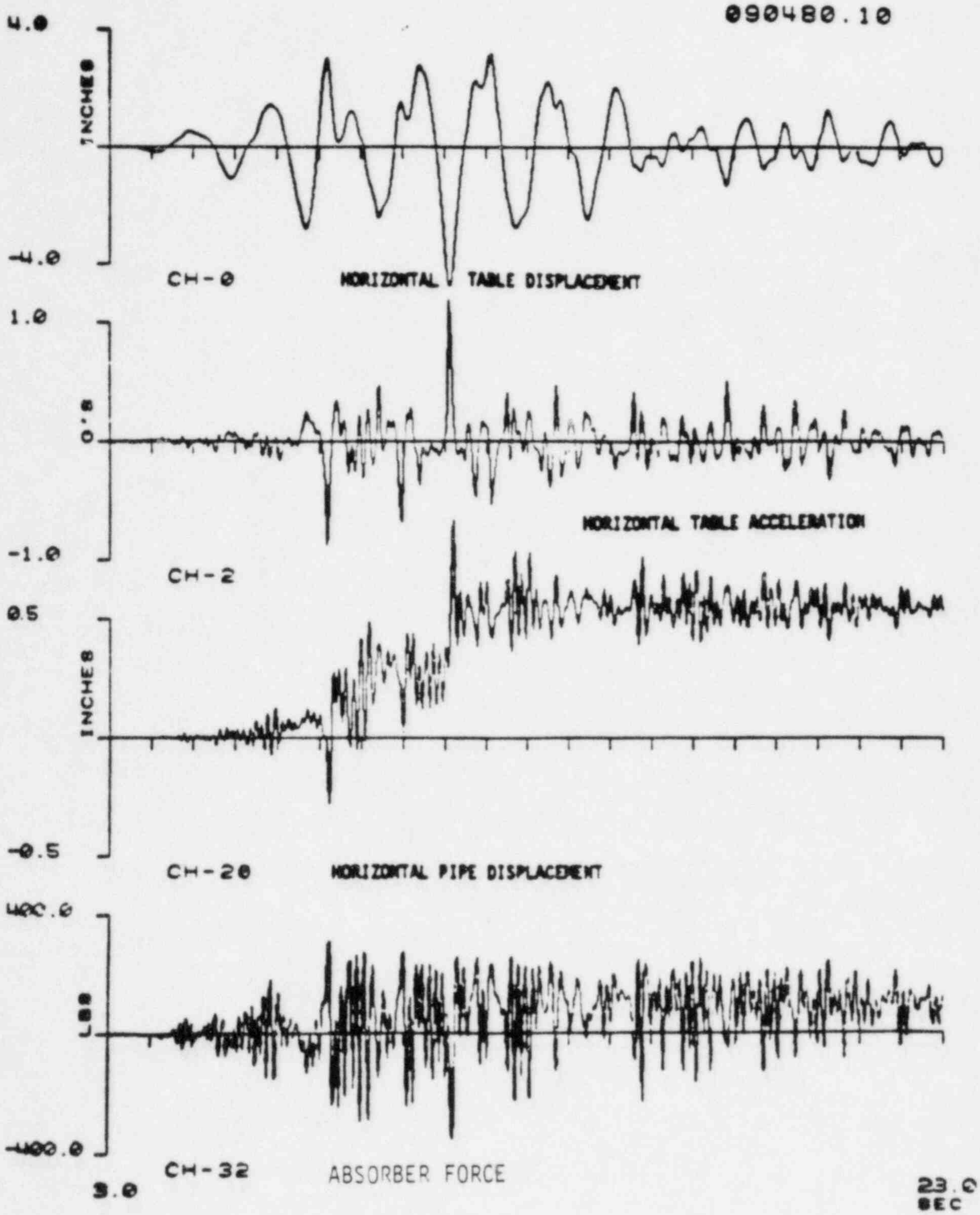
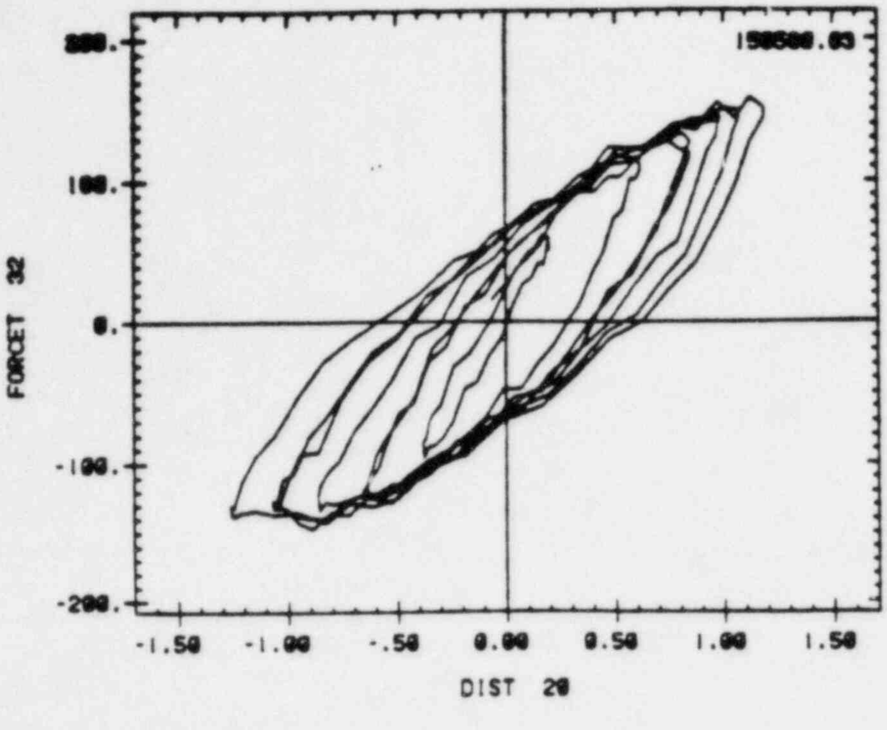


Figure 3.4b Time-Histories, with Absorber, -1.0-Inch "Thermal" Displacement, Peak Table Acc. = 1.32 g



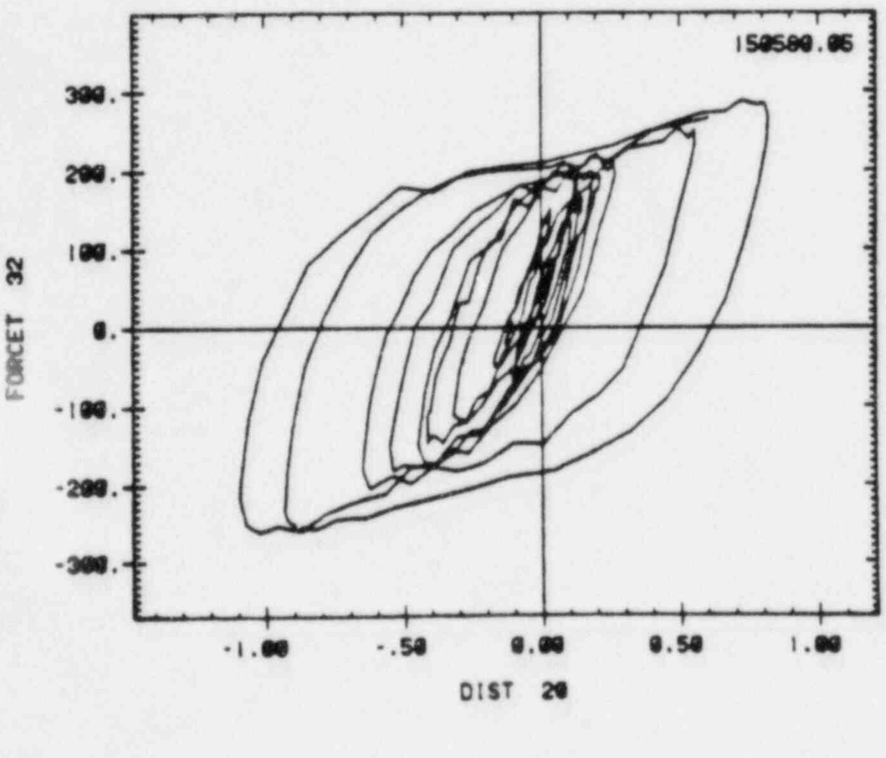


Figure 3.5 Hysteresis Curve of 1/8-Inch (Top) and 2x1/8-Inch Energy Absorbers Obtained from Shaker Table Test of U-Loop

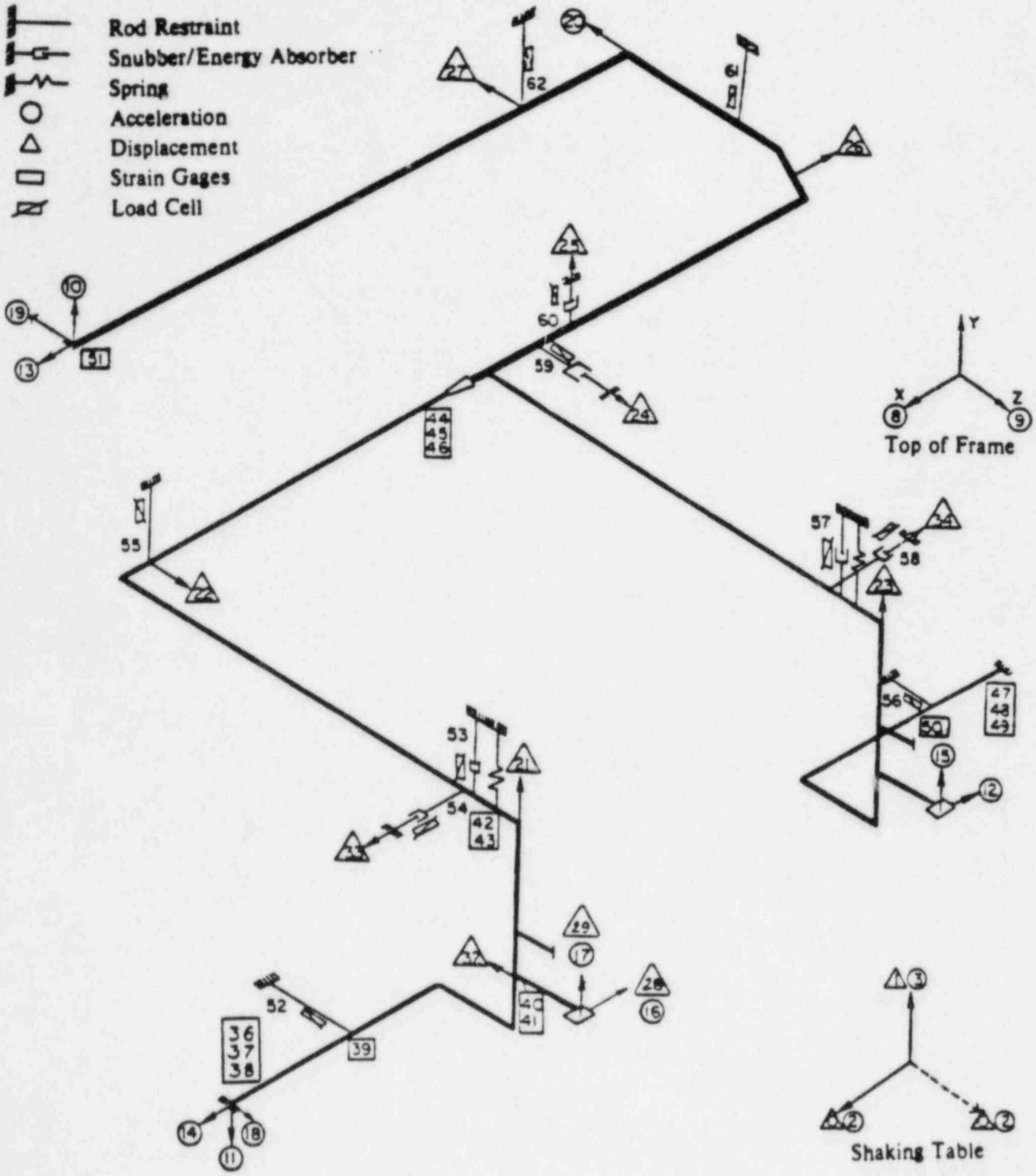


Figure 3.6 Test Model of Hope Creek Core Spray, Piping System - IV

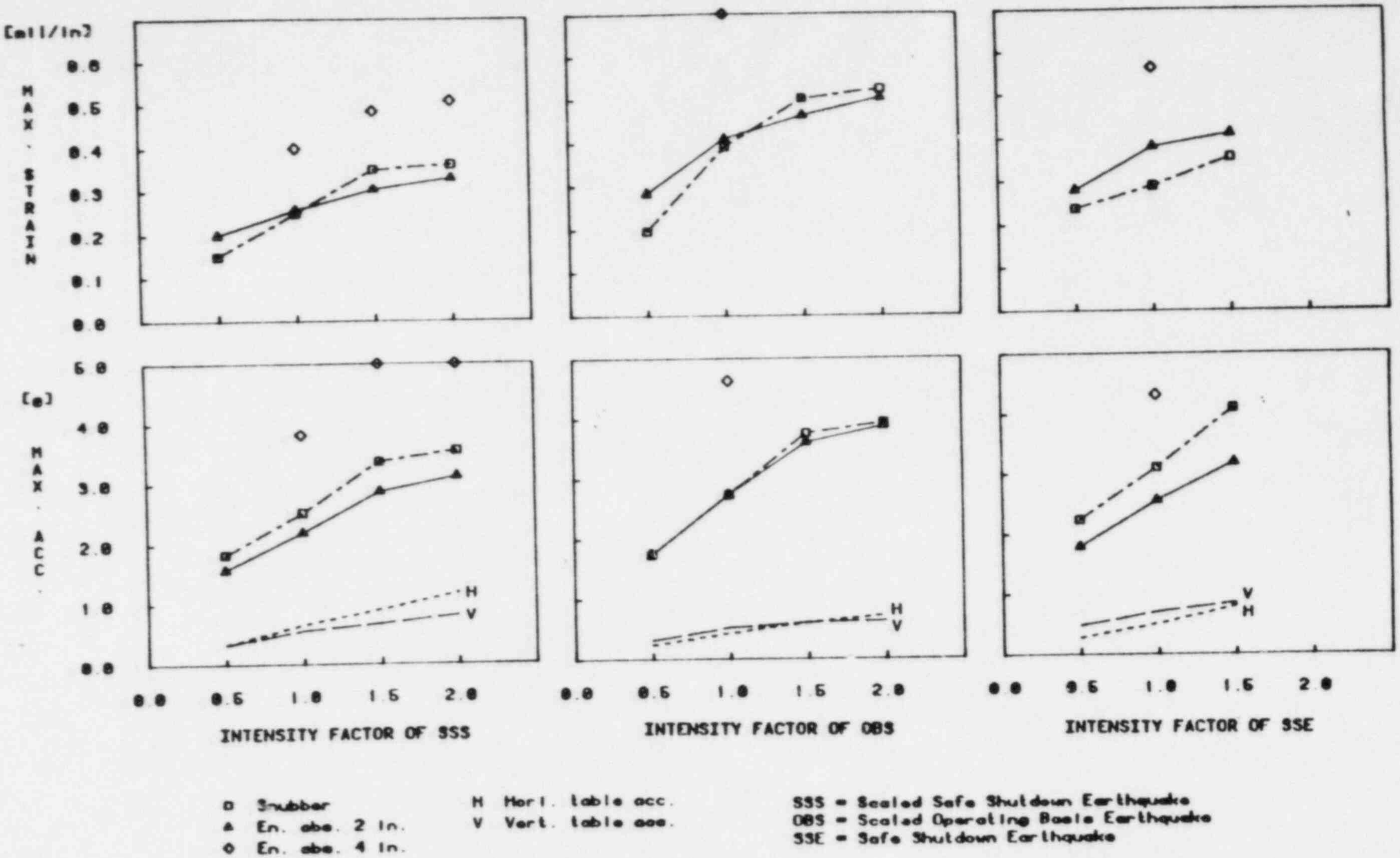
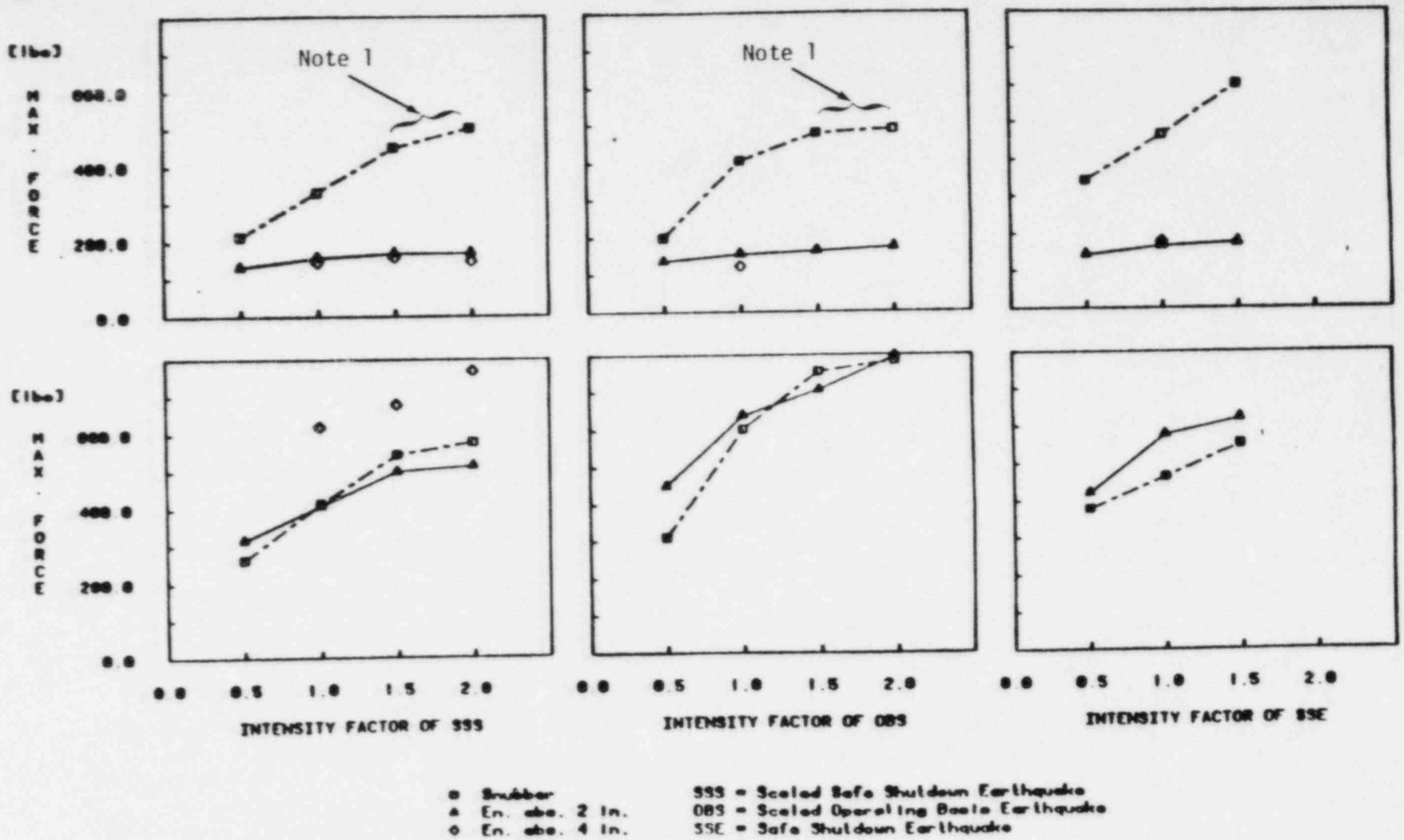


Figure 3.7 Extreme Values of Pipe Strains, Accelerations of the Valve Operator, and Corresponding Shaker Table Response for Increasing Earthquake Intensities



Note 1: Flattening of snubber forces denotes local yielding in snubber support steel.

Figure 3.8 Maximum Reaction Forces Between Pipe and Frame at Restraint Devices (Top CH 53) and Rigid Rod Connections (Bottom CH 52)

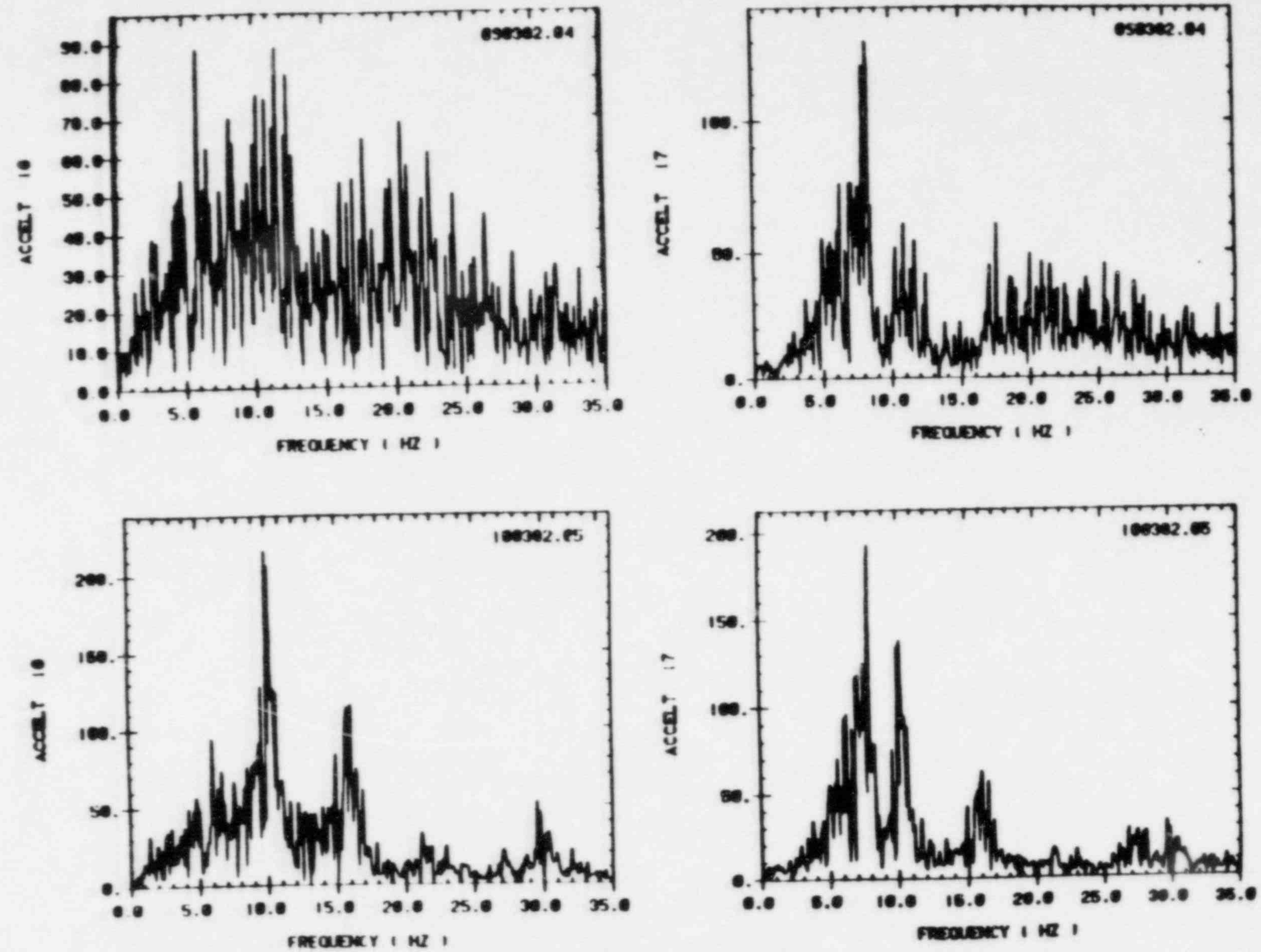


Figure 3.9 Fourier Spectra of Snubbers (Top) and Energy Absorbers (Bottom)

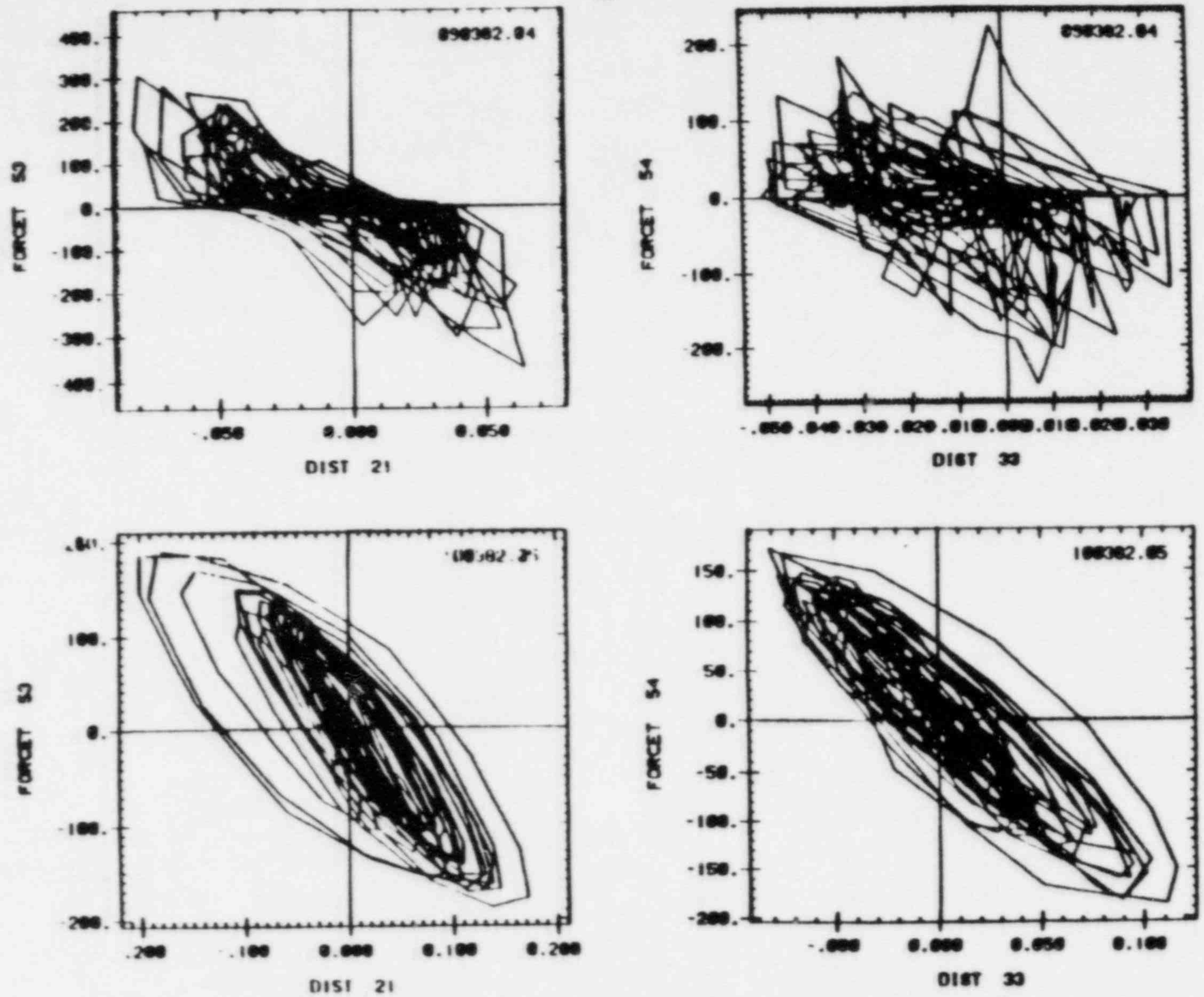


Figure 3.10 Hysteresis Loops of Snubbers (Top) and Energy Absorbers (Bottom), Subjected to the Same Earthquake

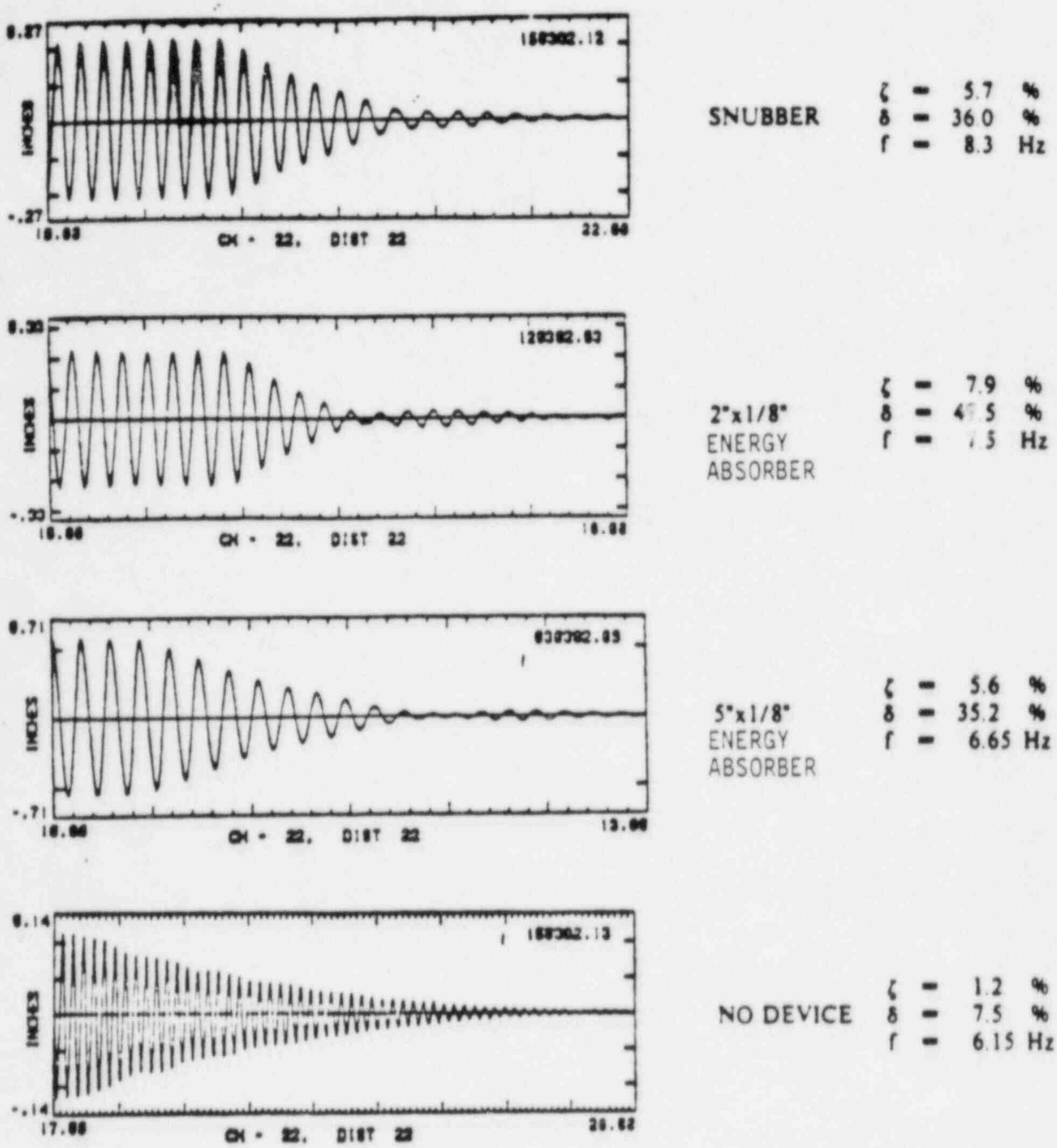


Figure 3.11 Damping Ratio of System IV with Different Support Devices in Position and Corresponding First Natural Frequencies

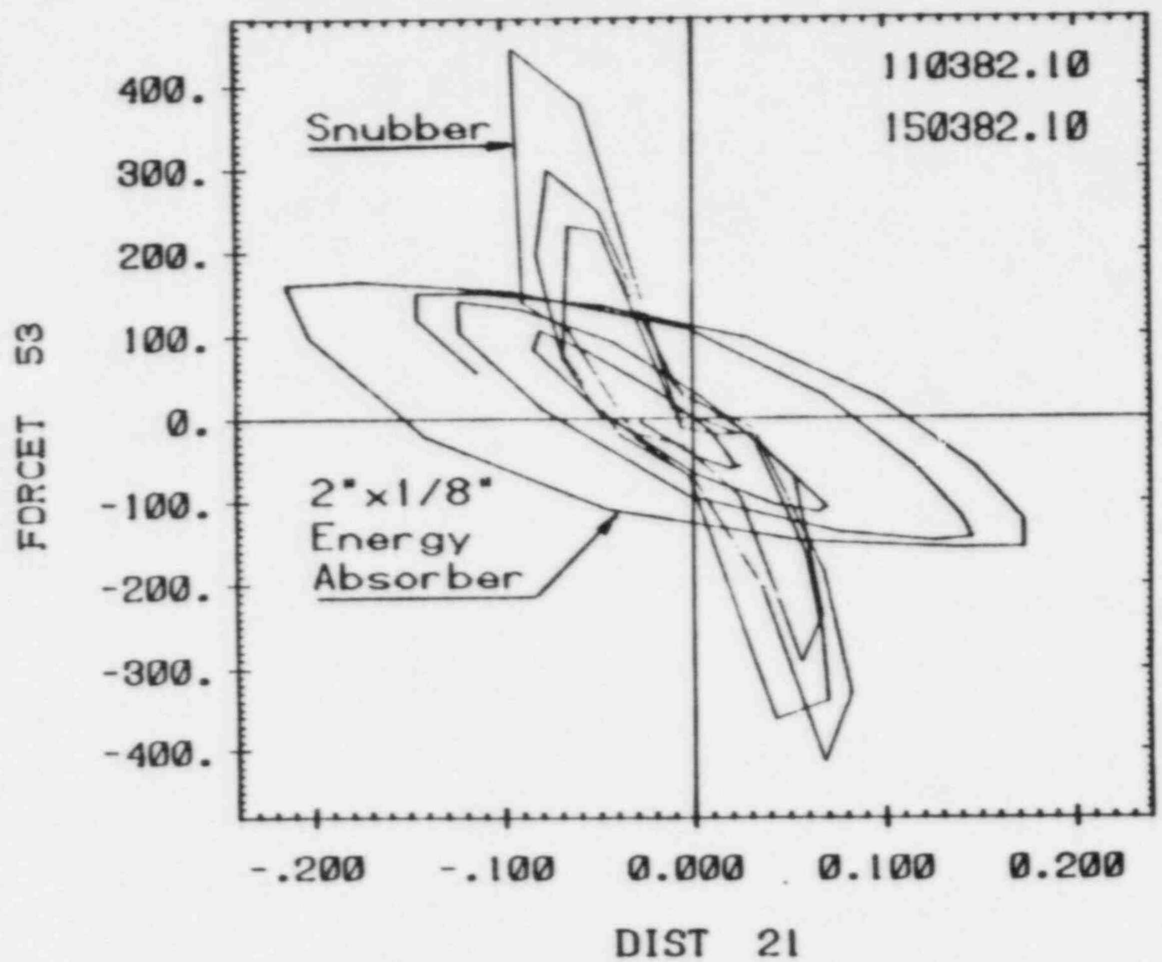


Figure 3.12 Force-Displacement Behavior of a Snubber and a 2-Inch x 1/8-Inch Energy Absorber from Separate Tests Using the Same Input Table Motion

Section 9

INSERVICE INSPECTION REQUIREMENTS

When nuclear pipe supports are constructed and installed to the rules of the ASME nuclear codes, the inservice inspection (ISI) of Section XI of the code applies. Therefore, energy absorbers constructed and installed to the rules of Code Case N-420 are subject to Section XI rules. While energy absorbers are not explicitly mentioned in Section XI requirements for ISI, the intent of the existing rules are applicable.

Table IWF-2500-1 of Section XI (enclosed as Table 9.1) specifies the examination categories for all support types. With the exception of snubbers and variable and constant springs, the required examination method is the visual, VT-3 method described in Paragraph IWA-2213:

> "IWA-2213 Visual Examination VT-3
>
> "(a) The VT-3 visual examination shall be conducted to determine the general mechanical and structural conditions of components and their supports, such as the presence of loose parts, debris, or abnormal corrosion products, wear, erosion, corrosion, and the loss of integrity at bolted or welded connections.
>
> "(b) The VT-3 visual examination may require, as applicable to determine structural integrity, the measurement of clearances, detection ofphysical displacement, structural adequacy of supporting elements, connections between load carrying structural members, and tightness of bolting.
>
> "(c) For component supports and component interiors, the visual examination may be performed remotely with or without optical aids to verify the structural integrity of the component."

Visual VT-3 examination rules apply to the energy absorbers described in this enclosure. To facilitate performance of a VT-3 examination on energy absorbers without removal or disassembly, the openings and scratch plates described in Section 8 were provided.

A visual VT-3 examination on energy absorbers will provide the level of assurance intended by the ISI requirements for the following reasons:

- Energy absorbers are merely a simple type of pipe support designed to strain and fatigue considerations. They are <u>not</u> springs. They are <u>not</u> snubbers.

  Energy absorbers do not contain activation mechanisms, internal moving parts, or fluids. They contain simple bolted connections. Therefore, from an ISI point of view, they should be viewed as being similar to rigid-type component standard supports.

- The basic failure mode of an energy absorber is fatigue cracking of an absorbing plate. Complete fatigue cracking occurs after the cyclic life of the material corresponding to the imposed strains is consumed. When energy absorbers are applied to piping systems, they are designed to satisfy design conditions and fatigue requirements without replacement. Their fatigue design will be based on fatigue design curves developed from testing of prototypical specimens per the requirements of Code Case N-420.

  Fatigue cracking, when it begins, is usually surface-type cracking originating close to plate edges and is very visible and easily identifiable by the simplest visual examination (the naked eye). Based on prototypical testing, a visible surface crack takes a relatively large number of cycles before it results in complete failure of the plate (ranging from the low 10s at the highest strain levels tested to the mid-

100s at low strain levels). Formation of a visible crack does not degrade the function of the plate until the crack has significantly propagated and resulted in separation of a large percentage (25% or more) of the plate's cross section. Therefore, plates will not fail catastrophically in fatigue, rather, if failure were to occur, it would be over a reasonably large number of cycles. One earthquake event does not contain enough cycles to cause a surface crack to propagate significantly and cause degradation of a plate's function. Thermal expansion cycles occur over a long span of time. Energy absorbers are typically designed to sustain low strain levels under thermal expansion conditions. The number of thermal cycles assumed in the design is usually very conservative. Thus, a crack propagation would require 100 or more thermal cycles. One inspection interval contains much less than 100 thermal expansion cycles.

- Perhaps most significantly, the design of energy absorbers discussed in Section 8 incorporates multiple plates. It requires two plates or more to function, and most applications will contain three or more plates. Based on fatigue testing, fatigue failure is basically limited to one plate in an assembly of plates. This is expected because random, natural distribution of crack initiating factors will favor one plate to take the lead in crack formation and propagation. Loss of one plate in a complete assembly will not completely incapacitate the energy absorber. This further reduces the significance of a fatigue failure of one plate.

- Energy absorber designs additionally incorporate two aids aimed at simplifying and enhancing the visual ISI examinations. The first is windows cut out of the sides of the boxes to facilitate viewing of the plates and bolts. The second is the scratch plate and markers at the pin location, which will provide physical evidence of pipe movements and their magnitudes. This physical evidence of pipe movement can be directly correlated to design conditions and fatigue endurance.

TABLE IWF-2500-1
EXAMINATION CATEGORIES

EXAMINATION CATEGORY F-A, PLATE AND SHELL TYPE SUPPORTS						
Item No.	Parts Examined	Examination Requirements/ Fig. No.	Examination Method[1]	Acceptance Standard	Extent of Examination	Frequency of Examination
F1.10	Mechanical connections to pressure retaining components and building structure	IWF-1300-1	Visual, VT-3	IWF-3410 IWF-3420 IWF-3430	IWF-1300 IWF-2510	Each inspection interval
F1.20	Weld connections to building structure	IWF-1300-1	Visual, VT-3	IWF-3410 IWF-3430	IWF-1300 IWF-2510	Each inspection interval
F1.30	Weld and mechanical connections at intermediate joints in multiconnected integral and nonintegral supports	IWF-1300-1	Visual, VT-3	IWF-3410 IWF-3420 IWF-3430	IWF-1300 IWF-2510	Each inspection interval
F1.40	Component displacement settings of guides and stops, misalignment of supports, assembly of support items	IWF-1300-1	Visual, VT-3	IWF-3410 IWF-3420 IWF-3430	IWF-1300 IWF-2510	Each inspection interval

NOTE:
(1) Reference IWA-2210.

Table 9.1 Section XI Support Examination Categories

TABLE IWF-2500-1 (CONT'D)
EXAMINATION CATEGORIES

EXAMINATION CATEGORY F-B, LINEAR TYPE SUPPORTS						
Item No.	Parts Examined	Examination Requirements/ Fig. No.	Examination Method[1]	Acceptance Standard	Extent of Examination	Frequency of Examination
F2.10	Mechanical connections to pressure retaining components and building structure	IWF-1300-1	Visual, VT-3	IWF-3410 IWF-3420 IWF-3430	IWF-1300 IWF-2510	Each inspection interval
F2.20	Weld connections to building structure	IWF-1300-1	Visual, VT-3	IWF-3410 IWF-3430	IWF-1300 IWF-2510	Each inspection interval
F2.30	Weld and mechanical connections at intermediate joints in multiconnected integral and nonintegral supports	IWF-1300-1	Visual, VT-3	IWF-3410 IWF-3420 IWF-3430	IWF-1300 IWF-2510	Each inspection interval
F2.40	Component displacement settings of guides and stops, misalignment of supports, assembly of support items	IWF-1300-1	Visual, VT-3	IWF-3410 IWF-3420 IWF-3430	IWF-1300 IWF-2510	Each inspection interval

NOTE:
(1) Reference IWA-2210.

Table 9.1 (Continued)

TABLE IWF-2500-1 (CONT'D)
EXAMINATION CATEGORIES

EXAMINATION CATEGORY F-C, COMPONENT STANDARD SUPPORTS

Item No.	Parts Examined	Examination Requirements/ Fig. No.	Examination Method[1]	Acceptance Standard	Extent of Examination	Frequency of Examination
F3.10	Mechanical connections to pressure retaining components and building structure	IWF-1300-1	Visual, VT-3	IWF-3410 IWF-3420 IWF-3430	IWF-1300 IWF-2510	Each inspection interval
F3.20	Weld connections to building structure	IWF-1300-1	Visual, VT-3	IWF-3410 IWF-3430	IWF-1300 IWF-2510	Each inspection interval
F3.30	Weld and mechanical connections at intermediate joints in multiconnected integral and nonintegral supports	IWF-1300-1	Visual, VT-3	IWF-3410 IWF-3420 IWF-3430	IWF-1300 IWF-2510	Each inspection interval
F3.40	Component displacement settings of guides and stops, misalignment of supports, assembly of support items	IWF-1300-1	Visual, VT-3	IWF-3410 IWF-3420 IWF-3430	IWF-1300 IWF-2510	Each inspection interval
F3.50	Spring type supports, constant load type supports, shock absorbers, hydraulic and mechanical type snubbers	IWF-1300-1	Visual, VT-4	IWF-3410 IWF-3430	IWF-1300 IWF-2510	Each inspection interval

NOTE:
(1) Reference IWA-2210.

Table 9.1 (Continued)

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