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# HDR URL Confirmatory Evaluations*

By

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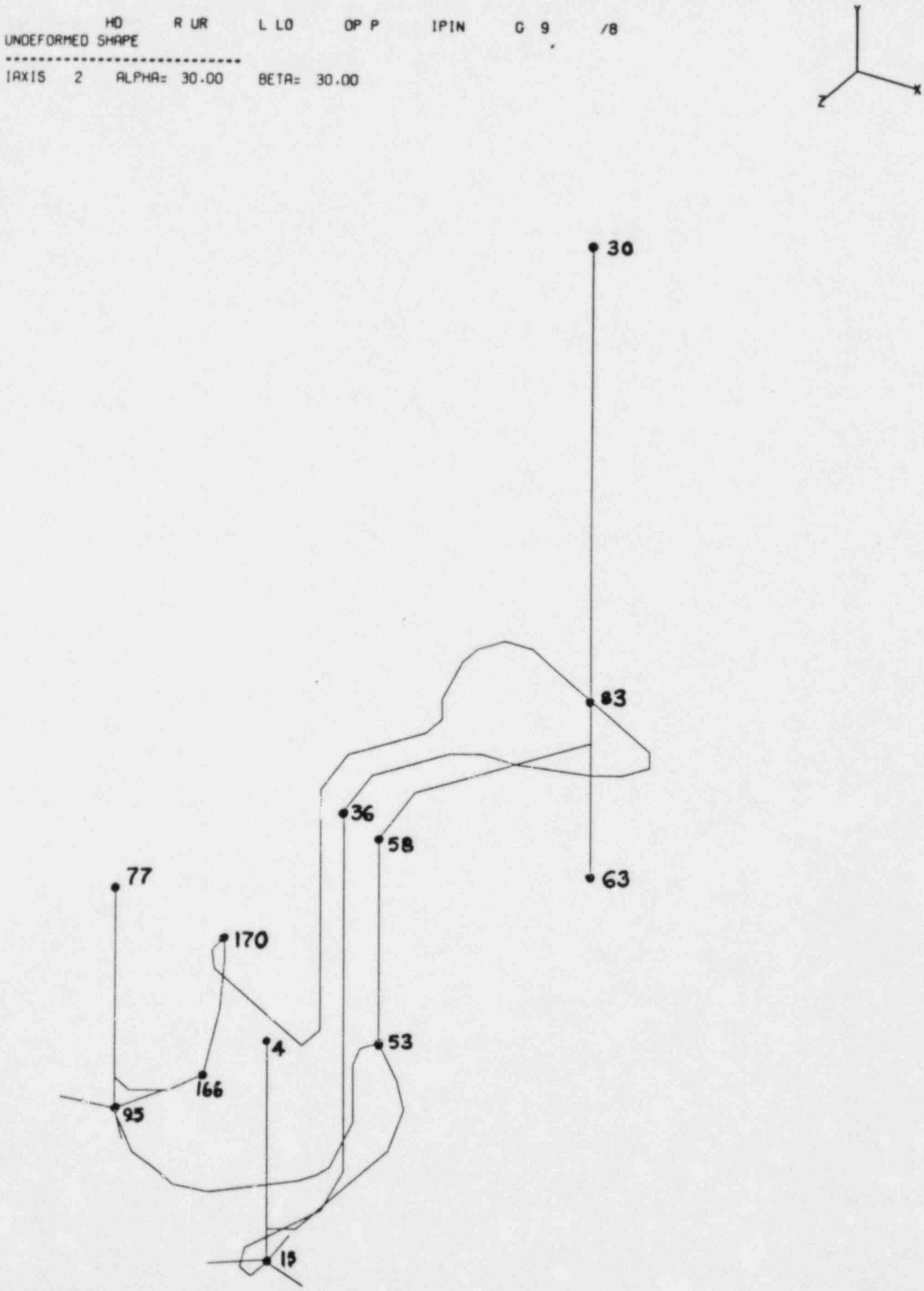
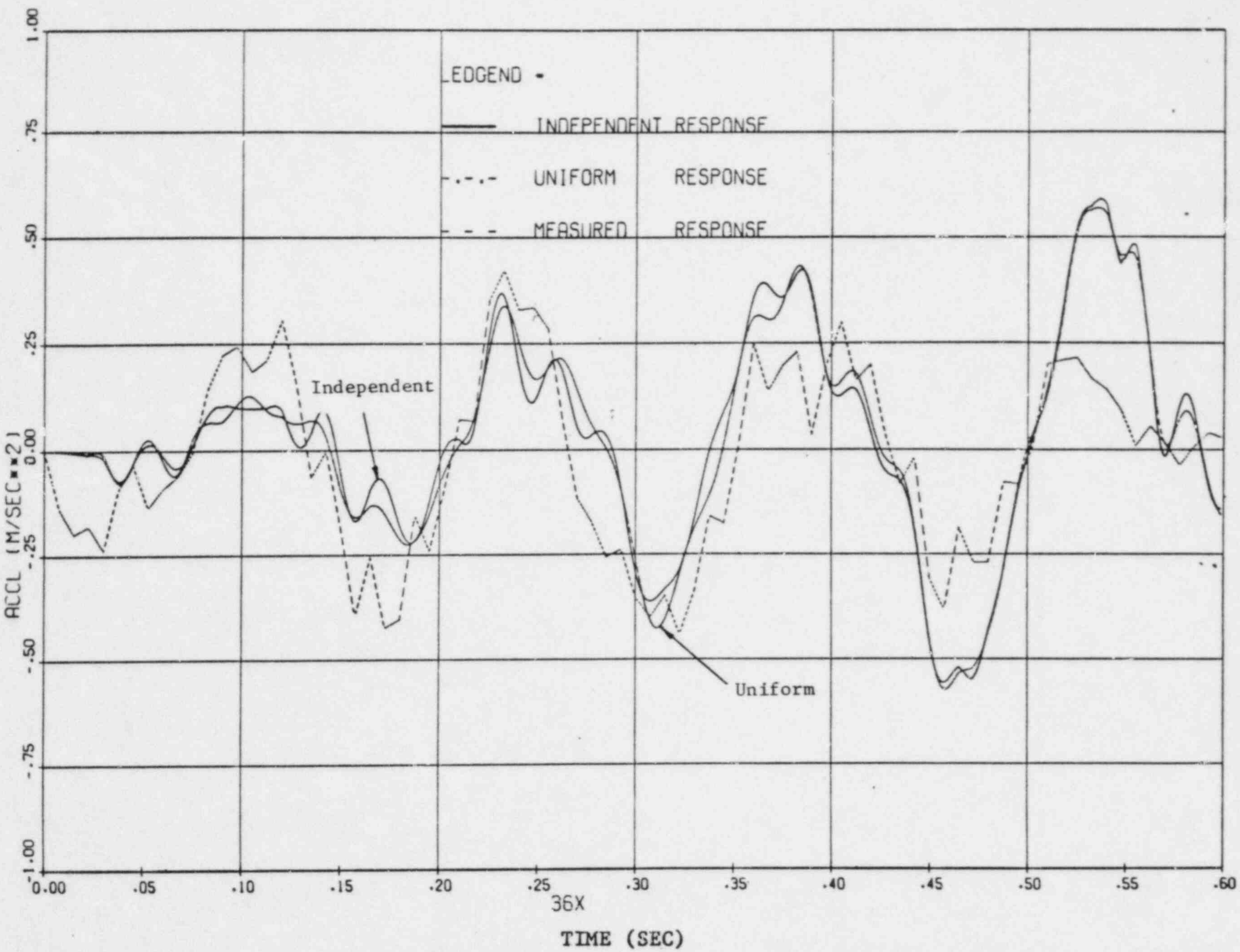



Figure 1. URL Piping Model

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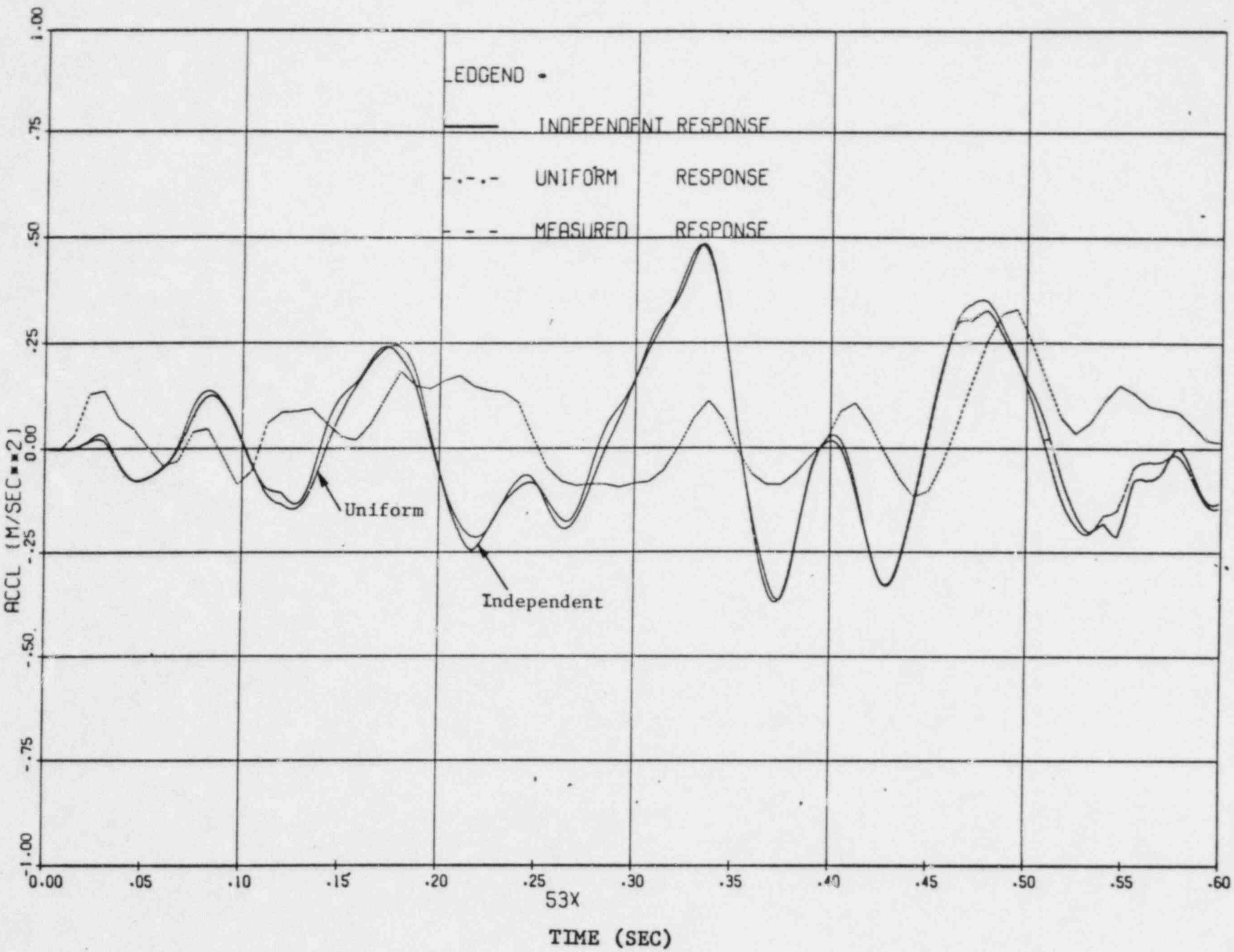


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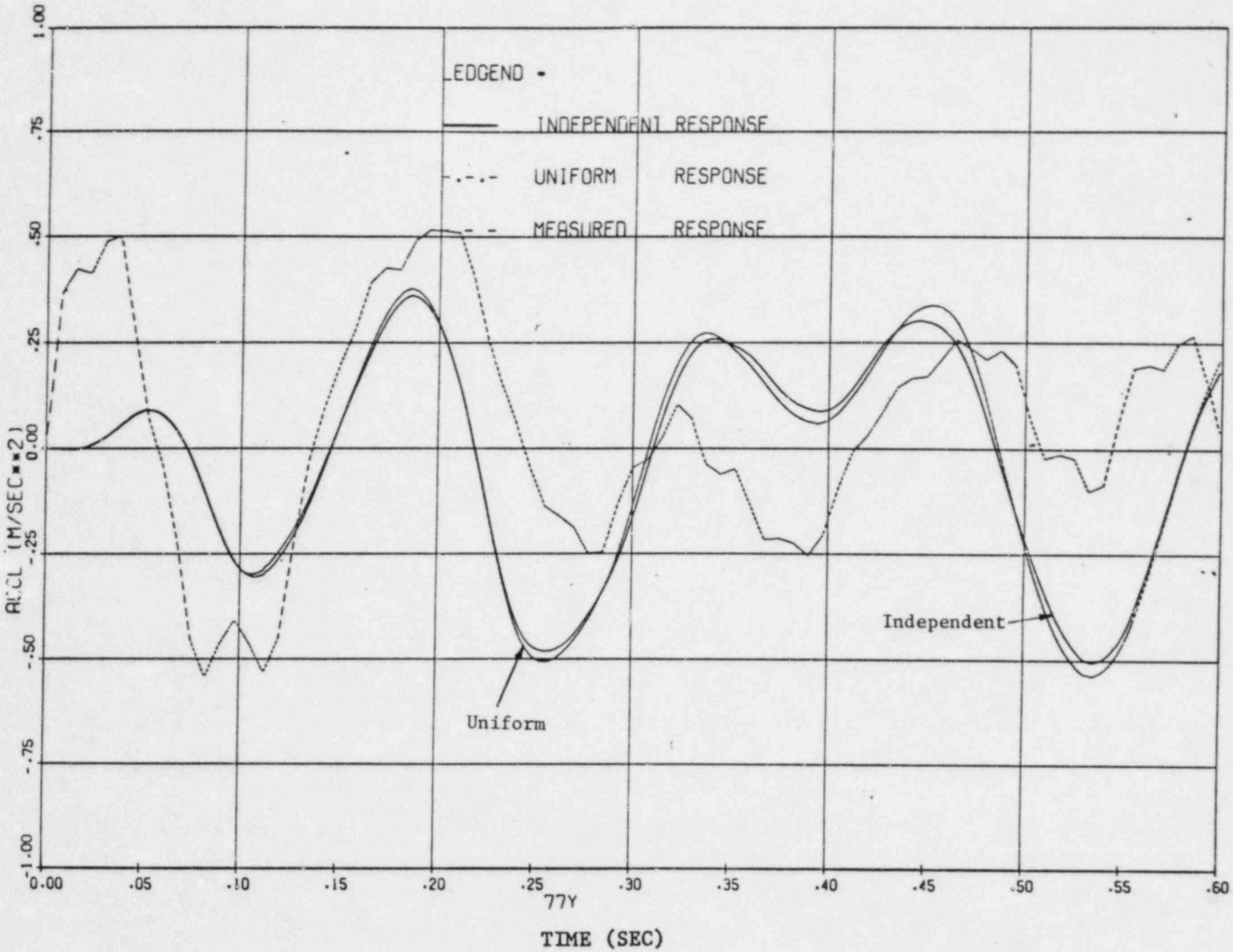


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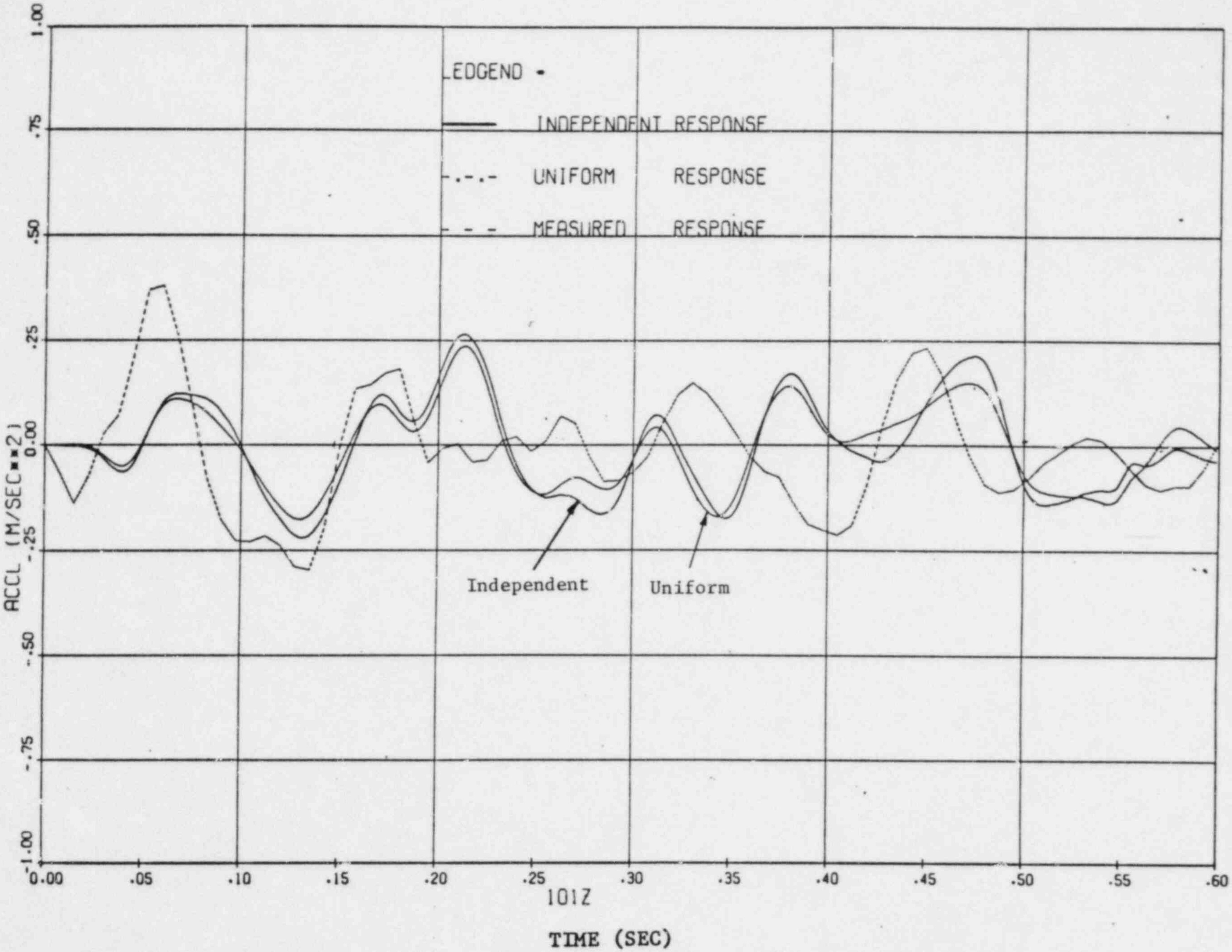


Figure 5. Z-Direction Acceleration Response at Node 101

One phase of the seismic studies conducted with the decommissioned Heissdampfreaktor in Kahl, West Germany was the prediction of the response of the Recirculation Loop piping (URL) to the 5 Kg blast loading. As a follow-on study to the US effort in this area, BNL performed linear analyses of the URL piping to corroborate the linear analyses performed by an alternate NRC contractor and to verify those analyses considering distinct, independent support excitations. In this study the computer models and processed input data developed by the alternate contractor were used.

The BNL effort was initiated in FY 1982 under the Mechanical Piping Benchmark Project. Specifically response predictions were made for the HDR URL system subjected to the 5 Kg blast loading considering uniform support motion with elastic supports and independent support motion with elastic supports. For the evaluations the independently developed BNL finite element piping analysis code, PSAFE2, was used.

The overall agreement between the results predicted with a linear model and the measured results for the HDR URL system is relatively poor. This agreement did not improve when processed independent support excitations were considered. In general the predicted peak response amplitudes agreed with the measured peak amplitudes but there was little correspondence between the actual time history traces. Better results were obtained for points located at, or near supports. Apparently this improvement corresponds to the close proximity of the input excitation for these points.

In all major aspects the results developed at BNL with the linear analysis code PSAFE2 match those developed for the same model with the linear analysis code NUPIPE II. Additionally the BNL results agree well with those predicted for an alternate model with the nonlinear analysis code ANSYS.

The paper includes a description of the computer model and comparisons between measured and predicted acceleration time history records for selected points in the system. Predicted results considering both uniform support excitation and independent support excitation are provided.

1. Introduction

In 1979 the decommissioned Heissdampfreaktor (HDR) in Kahl, West Germany was subjected to excitation developed by the detonation of a buried 5 Kg explosive charge located in the soil near the containment building. Installed instrumentation recorded both the input excitation to, and the response of the recirculation loop piping. Subsequent to the test the response of the system was calculated using both linear and nonlinear analysis methods and the measured motions as inputs. As a follow-on study to these original evaluations, BNL independently developed linear response predictions for the system considering uniform support excitation with elastic supports. In this study the originally developed computer models and processed input data were used in conjunction with the BNL developed finite element piping analysis code PSAFE2, Subudhi [1].

2. Model Description

The finite element model used in these evaluations was, to the extent possible when using different analysis methods, identical to the model used in the original evaluations, Thinnes [2]. Figure 1 shows a computer generated sketch of the entire system with only some key nodal points labeled. The reactor, node 30-63 was modeled with 15 heavy walled pipe elements. The two recirculation loop pumps, nodes 77-95 and nodes 4-15 were each modeled with five heavy walled pipe elements. All pump and reactor supports were modeled with linear spring elements. The included piping was modeled appropriately with approximately 90 pipe and elbow elements. For all components the pipe element wall thicknesses were selected to simulate the stiffness of the component while the mass density was adjusted to provide the proper weight. The nodes for which response predictions were made are shown on the figure.

3. Analysis

Two separate response evaluations were made. In the first analysis all supports were assumed to exhibit uniform support excitation where the inputs were the processed averages of the accelerations measured at some four points in the recirculation piping room.

In the second analysis independent support motions, Subudhi [3], were considered. In this case all the loop support elements were divided into three groups, each exhibiting a separate excitation. The first group consisted of all supports other than the reactor supports and the support at node 170. The support at node 170 formed the second group while the reactor supports, nodes 30 and 63, formed the third group. The processed input support acceleration records for the X and Z direction were different for each of the groups while the Y direction input for each group was identical and equal to that used in the uniform support motion analysis. All records were of 0.6 sec duration and none differed significantly from the uniform support motion accelerograms.

For both analyses modal superposition time history methods of solution were used with a 30 mode approximation, 2% uniform damping and a solution time step of 0.001 sec.

4. Results

The computed natural frequencies for the system ranged from 1.835 Hz for the fundamental mode to 36.14 Hz for the thirtieth mode. These corresponded reasonably well to those predicted with the NUPIPE II code for the same model, the largest difference being 2.8% for mode 12. In the first five modes the pumps exhibit rigid body displacements and rotations with associated displacements and rotations of the connecting piping. In fact the pumps participate strongly in all modes up to the twentieth natural frequency.

Figures 2 through 5 show the predicted and measured absolute acceleration data for selected points in the system. On each figure three curves are shown, the solid line corresponds to the accelerations predicted using independent support excitation, the center line symbol to the accelerations predicted using uniform support excitation and the dashed line corresponds to the measured acceleration record. The legend for each curve lists the node number and coordinate direction for the data depicted.

A description of all the data developed is provided in reference [4].

5. Discussion of Results

From a consideration of all the response results the following general observations were made. For all cases the response predicted for independent support excitation almost coincides with the response predicted for uniform support excitation. This was expected since the independent excitations differed little from the uniform excitation. Where these two response curves differ the predicted response for the uniform support excitation case in general envelopes that predicted for independent support excitation. When measured response is considered, no consistent trend was apparent. For point 36 the computed and measured responses are similar in both magnitude and phase. For some points there is a similarity in phase for the early time period while for other points no similarity in phase exists for any time. Regarding amplitude the peak predicted amplitude does seem to match or exceed the peak measured amplitude. Lastly the correspondence between measured and predicted response did seem to improve as the point of comparison approached a support or the source of excitation.

In conclusion, the overall agreement between the results predicted with a linear model and the measured results for the HDR URL system is relatively poor. This agreement did not improve when processed independent support excitations were considered. In general the predicted peak response amplitudes agreed with the measured peak amplitudes but there was little correspondence between the actual time history traces. Better results were obtained for points located at, or near supports. Apparently this improvement corresponds to the close proximity of the input excitation for these points.

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References

[1] SUBUDHI, M., BEZLER, P., "PSAFE2-Piping Analysis Program - Version 1981", BNL report, July 1981.

[2] THINNES, G. L., RAHL, R. G., "Experimental and Analytical Results of Blast Induced Seismic Studies at HDR", NUREG/CR-2463, EGG-2158, November 1981.

[3] SUBUDHI, M., BEZLER, P., WANG, Y. K., HARTZMAN, M., "Seismic Analysis of Piping Systems Subjected to Independent Support Excitations by Using Response Spectrum and Time History Methods", BNL-NUREG-31296, April 1982.

[4] BEZLER, P., SUBUDHI, M., "Corroboration of Heissdampfreaktor Reactor Recirculation Loop Piping Investigations", BNL-NUREG-31732, August 1982.