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P. BEZLER AND M. SUBUDHI

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STRUCTURAL ANALYSIS DIVISION

DEPARTMENT OF NUCLEAR ENERGY BROOKHAVEN NATIONAL LABORATORY
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Corroboration of Heissdampfreaktor Reactor Recirculation Loop Piping Investigations

by

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Prepared for
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U.S. Nuclear Regulatory Commission
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ABSTRACT

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 to corroborate the linear analyses performed by EG&G Idaho and to verify those analyses considering distinct, independent support excitations. In this study the computer models and processed input data developed by EG&G were 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. Better results were obtained for points located at, or near supports.

In all major aspects the results developed at BNL with the linear analysis code PSAFE2 match those developed by EG&G 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.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (CONT'D)

INTRODUCTION

In December 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. Through a cooperative effort with Kernforschungszentrum Karlsruhe KfK, two NRC contractors participated in this seismic test and the subsequent efforts to predict the response of the recirculation loop piping systems of the reactor with advanced computer methods. ANCO Engineers Inc. installed instrumentation on piping, supports and the recirculation piping room and recorded both the input excitation and the response of the recirculation loop piping to the blast excitation. EG&G Idaho using both linear and non-linear analysis methods and the measured motions recorded by ANCO as inputs calculated the response of the system. Subsequent to this EG&G effort, the measured pipe response data was compared to the predicted response data and an assessment of advanced computer methods was made.

In FY 1982, BNL was requested to corroborate the linear analyses performed by EG&G and to verify those analyses considering distinct, independent support excitations. Towards this end the computer models and processed input data developed by EG&G were to be used in conjunction with the independently developed BNL analysis code PSAFE2. This report presents the results of this study.

BACKGROUND

The Heissdampfreactor (HDR) is a decommissioned superheated steam demonstration reactor located near Frankfurt, West Germany. It is being used as a test platform to perform realistic seismic and hydraulic tests; some of which are used to assess the accuracy of the analytical methods currently employed in reactor piping design. Figure 1 shows a schematic cross section of the reactor, containment vessel and pertinent structures.

One series of seismic tests involved the excitation of the reactor system with the detonation of buried explosive charges located near the containment building. During these tests the response of the reactor, its associated primary piping system, the Recirculation Loop Piping (URL), and the containment structure were recorded through the use of judicously placed accelerometers, load cells and strain gauges. The instrumentation was sufficient to define the input and the response of the URL system during this blast event.

The Recirculation Loop (URL) consists of two recirculation pumps, five valves, the piping between the reactor and the pumps and the support structure as shown in Figure 2. The piping has nominal diameters of 350 mm and 450 mm and is fabricated of material designated Werkstoff Nr. 4550 with a Young's Modulus of 199 GPA cold (1GPA = 145 Ksi). The pipe and pumps are supported by both spring and constant force hangers.

One phase of the seismic studies involved the blind prediction of the response of the URL system to the 5 Kg blast loading using as input the measured accelerations at selected points of the URL containment room. These studies were performed by European organizations and through cooperative agreements by US organizations as well. This report presents the results of a follow on study to the US efforts in this area.

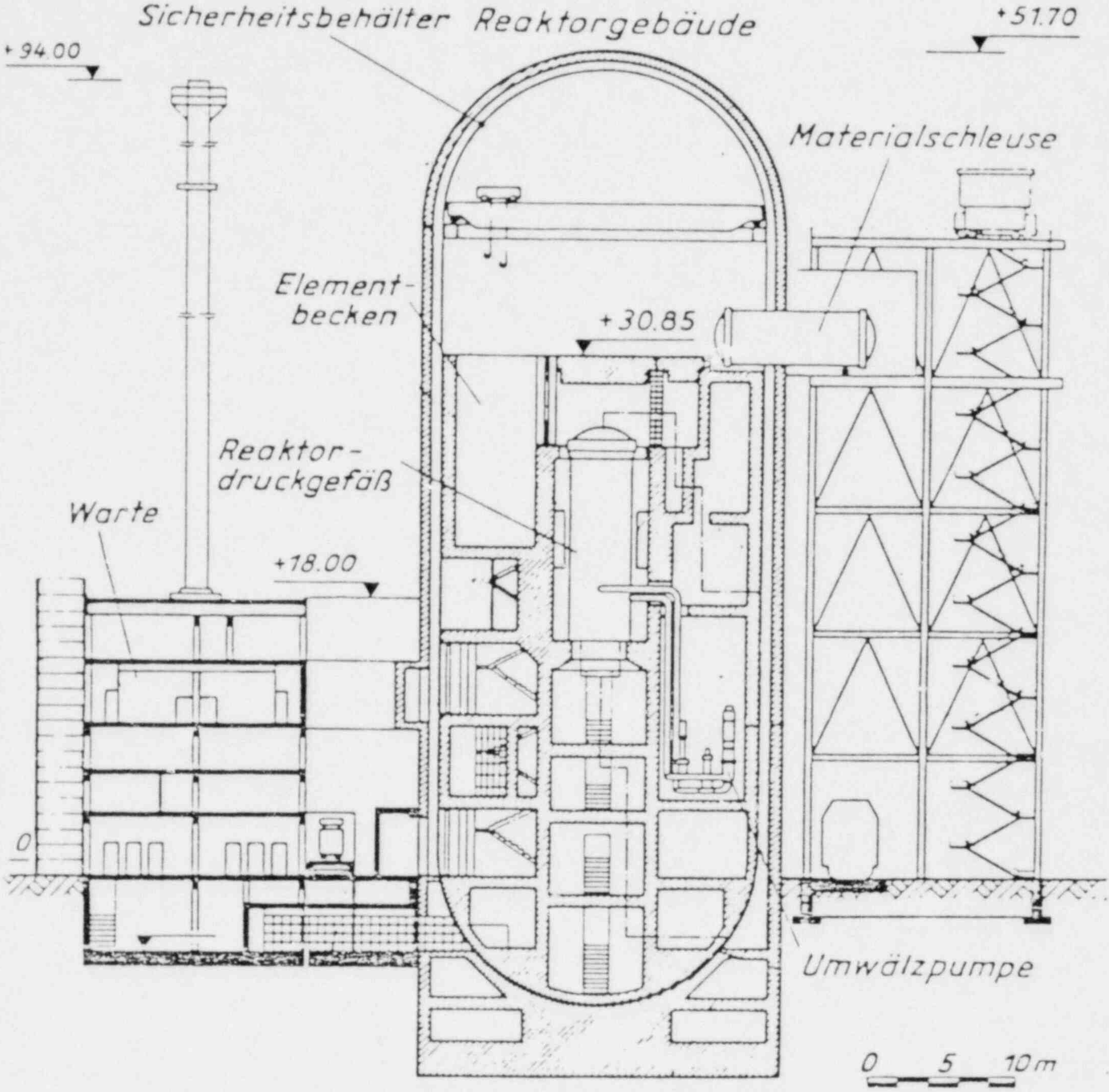


Figure 1. Heissdampfreaktor (HDR)

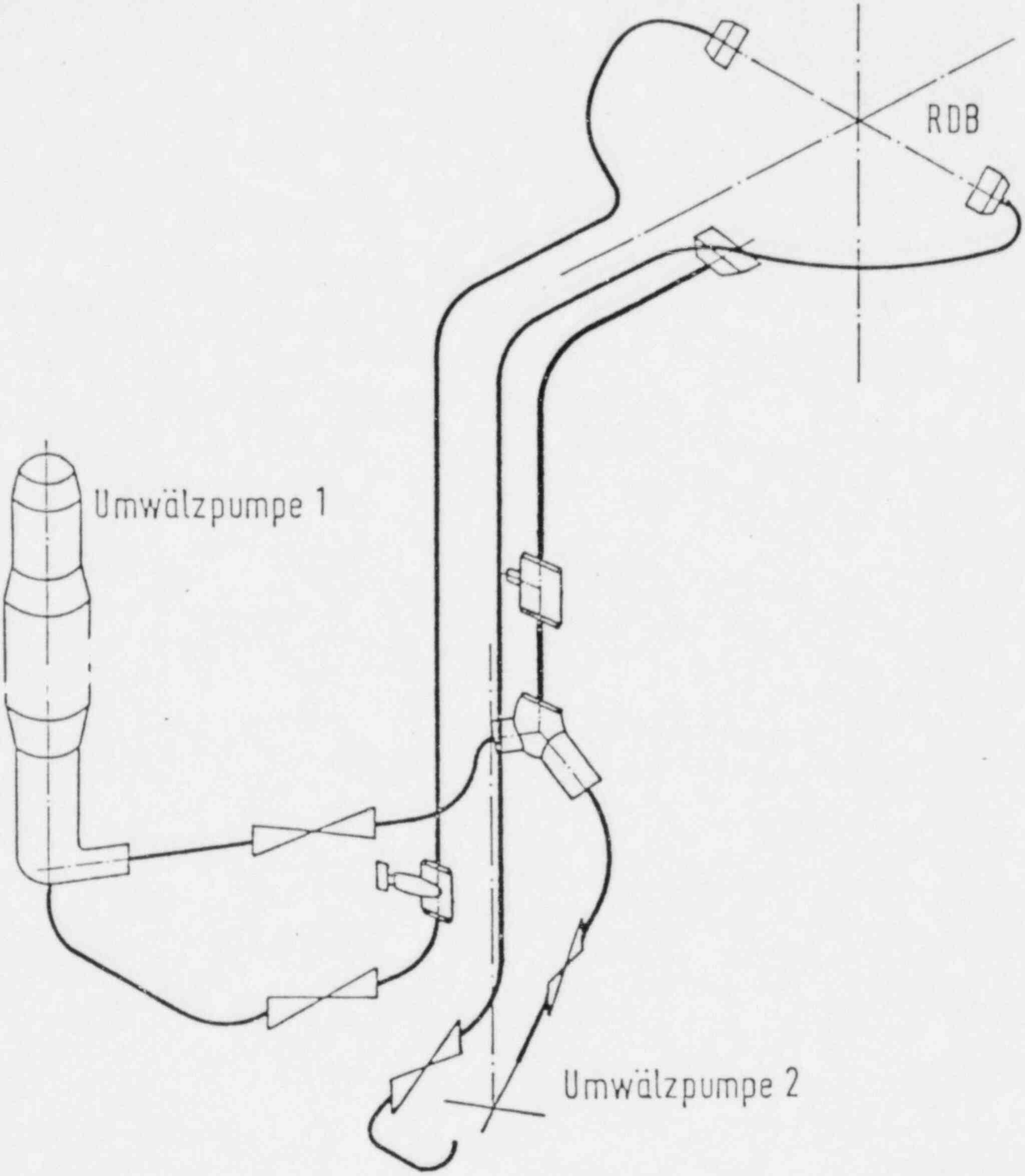


Figure 2. Recirculation Loop (URL)

SCOPE OF WORK

EG&G Idaho under NRC contract participated in the HDR, URL blind prediction studies. Towards this end they predicted the response of the URL system to the 5 Kg blast loading using both linear and non-linear analysis methods and considering uniform support excitation. As a follow up study they performed additional linear evaluations considering independent support excitation.

The BNL effort was initiated in FY 1982 under the Mechanical Piping Benchmark Project. Specifically response predictions were to be made for the HDR URL system subjected to the 5 Kg blast loading considering:

a. Uniform support motion, elastic supports.

b. Independent support motion, elastic supports.

In the evaluations the linear elastic model of the URL system developed by EG&G and the EG&G processed input data were to be used. The independently developed BNL finite element piping analysis code, PSAFE2, was to be used for the evaluations.

MODEL DESCRIPTION

The EG&G model of the HDR URL system is shown by sections in Figs. 3 through 5. The BNL model, to the extent possible when using different computational methods, is identical to this model. Figure 6 shows a BNL computer generated sketch of the entire system.

The reactor vessel is represented by the vertical line bounded by nodes 30 and 63. It was modeled with very heavy walled pipe elements and supported at nodes 30 and 63. The two pumps were modelled with heavy pipe and are represented by the two vertical lines bounded by nodes 4-15 and 77-95, respectively with the base and supports represented by nodes 10-12 and 91-93. The five valves, nodes 1-2, 167-174, 166-175, 105-107 and 28-35, were each represented by heavy walled pipe and additional mass. For all of these 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. In the case of the valves concentrated weights were added at the valve centers to more accurately model the valve mass distribution.

Although every effort was made to develop a model which was identical to the EG&G model, several sources of potential difference, associated with the computer methods, do exist. Specifically, the distribution of element mass between the nodes assigned internally for distributed mass systems and the manner in which support or boundary elements are modeled may differ. To circumvent differences associated with mass distribution, all mass was input as concentrated masses in the BNL model using the quantities specified in the EG&G output mass listing. As regards boundary elements no corrections were possible.

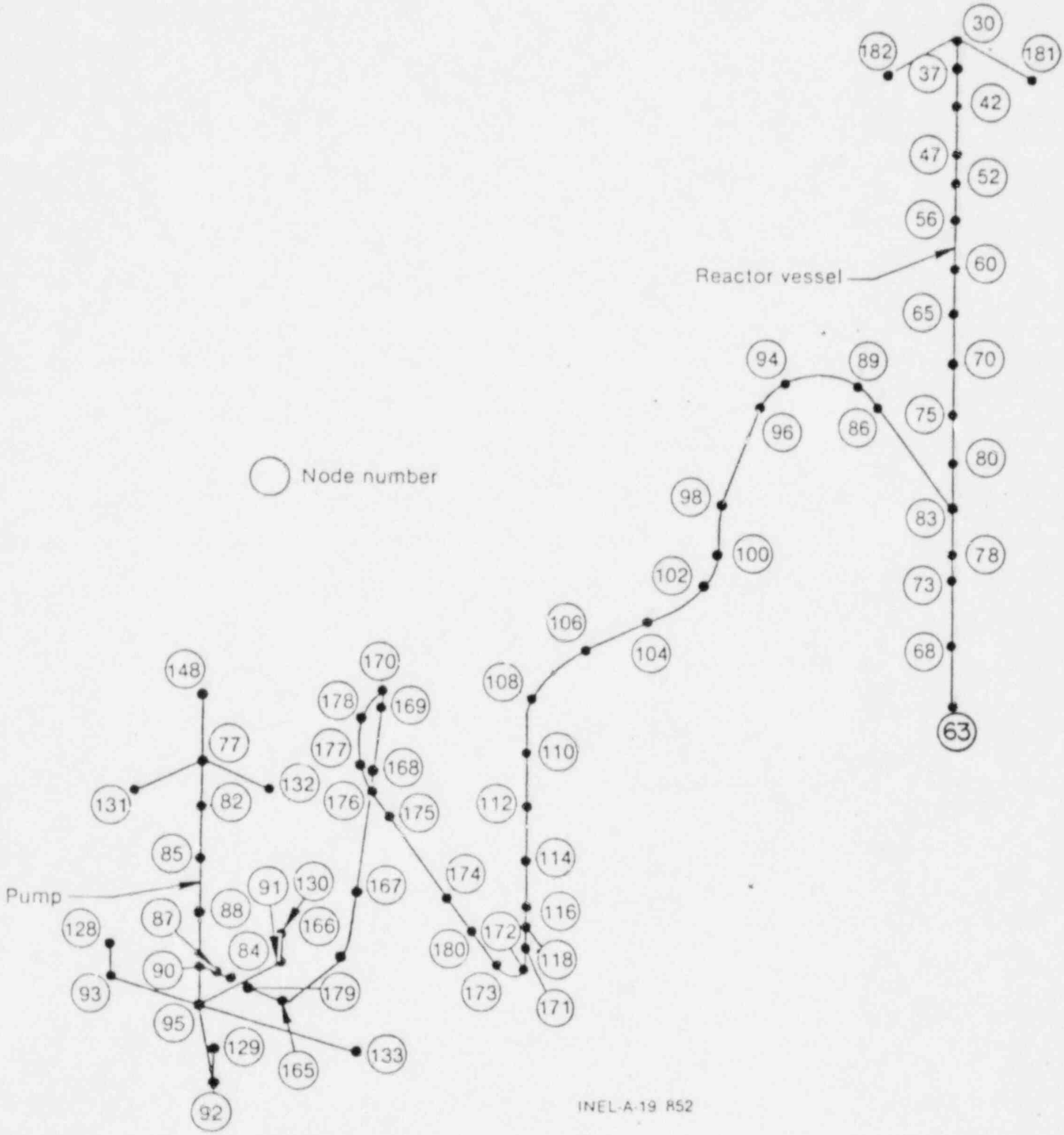


Figure 3. URL piping model - Detail A.

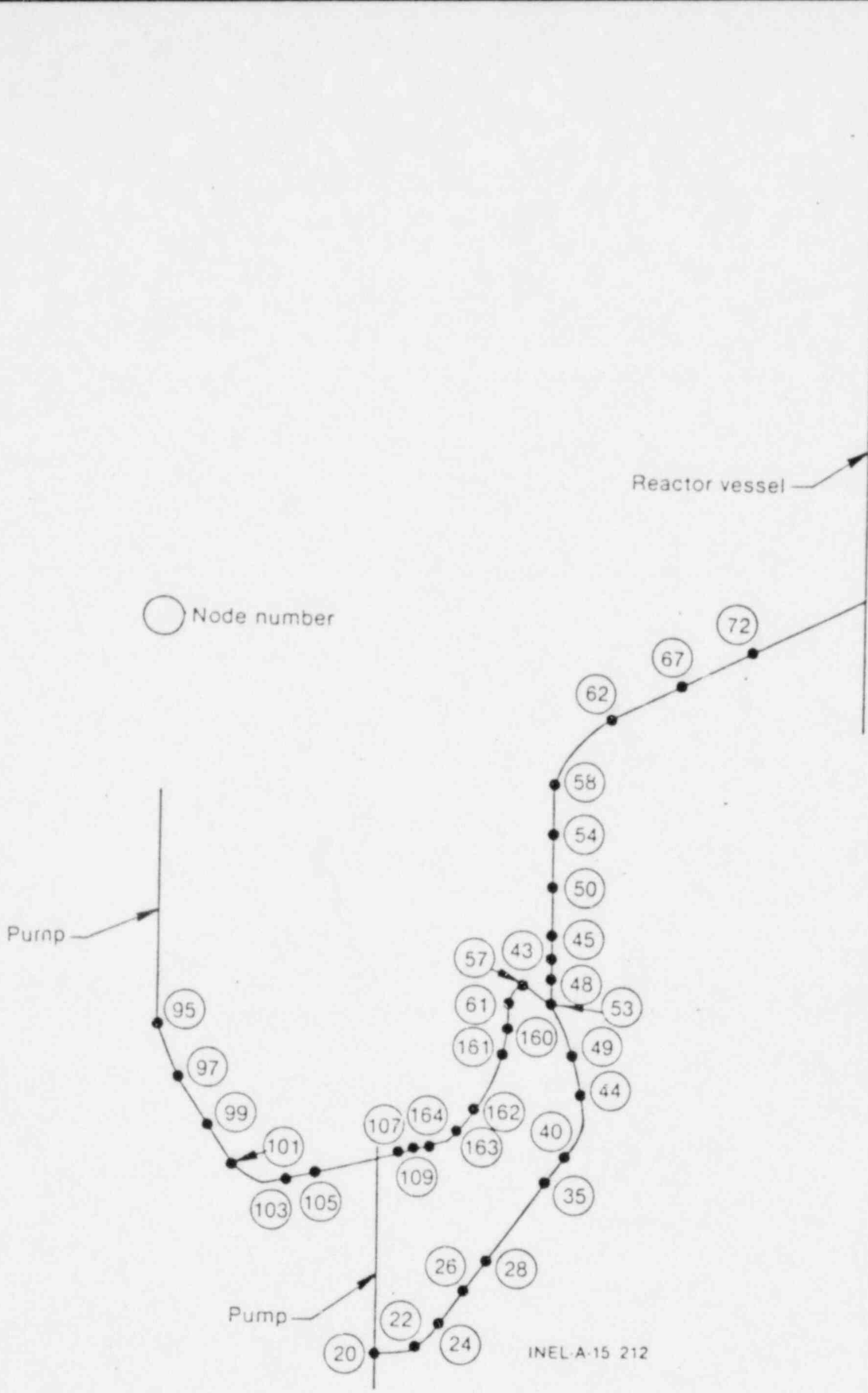


Figure 4. URL piping model - Detail B.

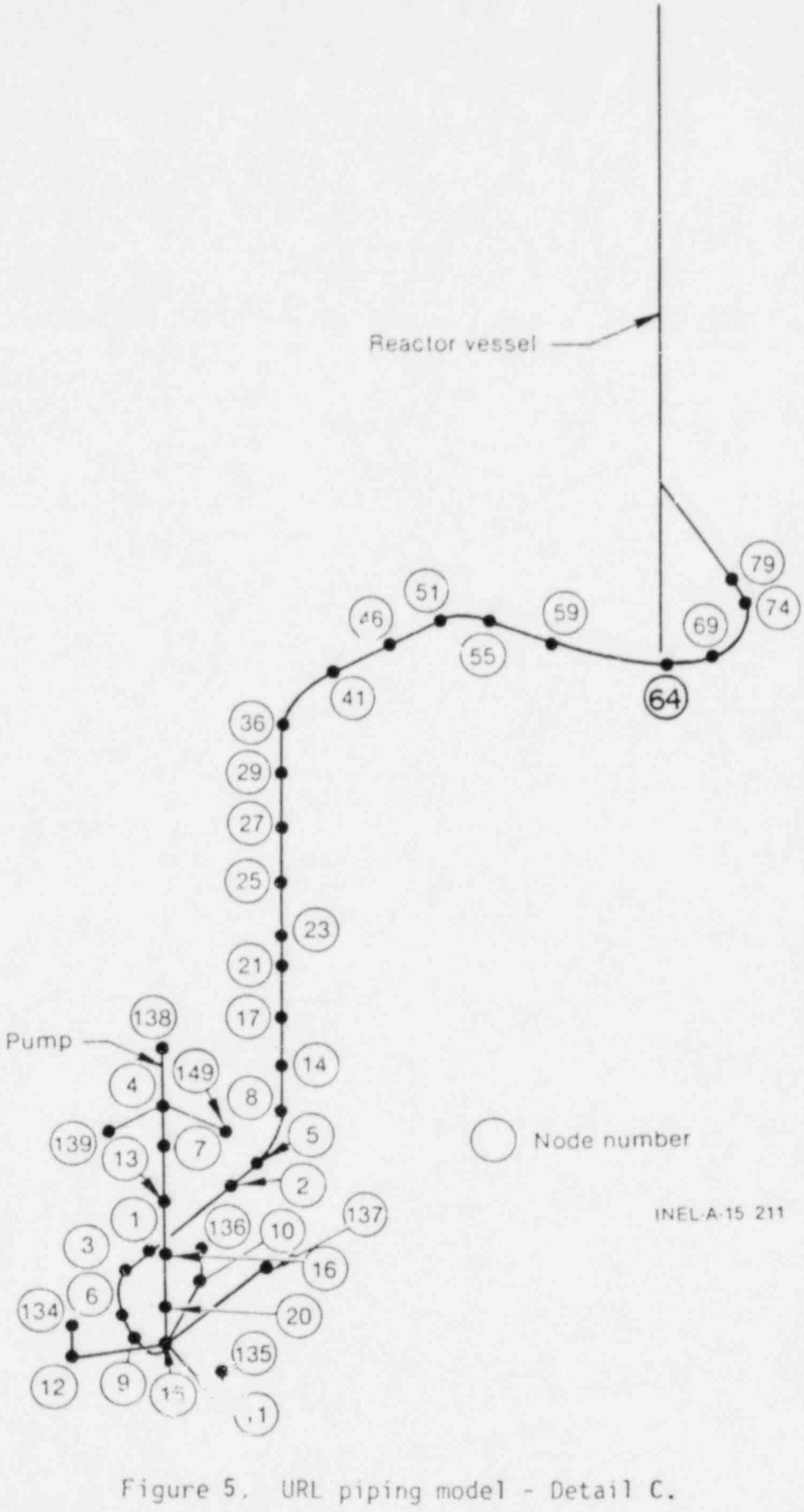


Figure 5. URL piping model - Detail C.

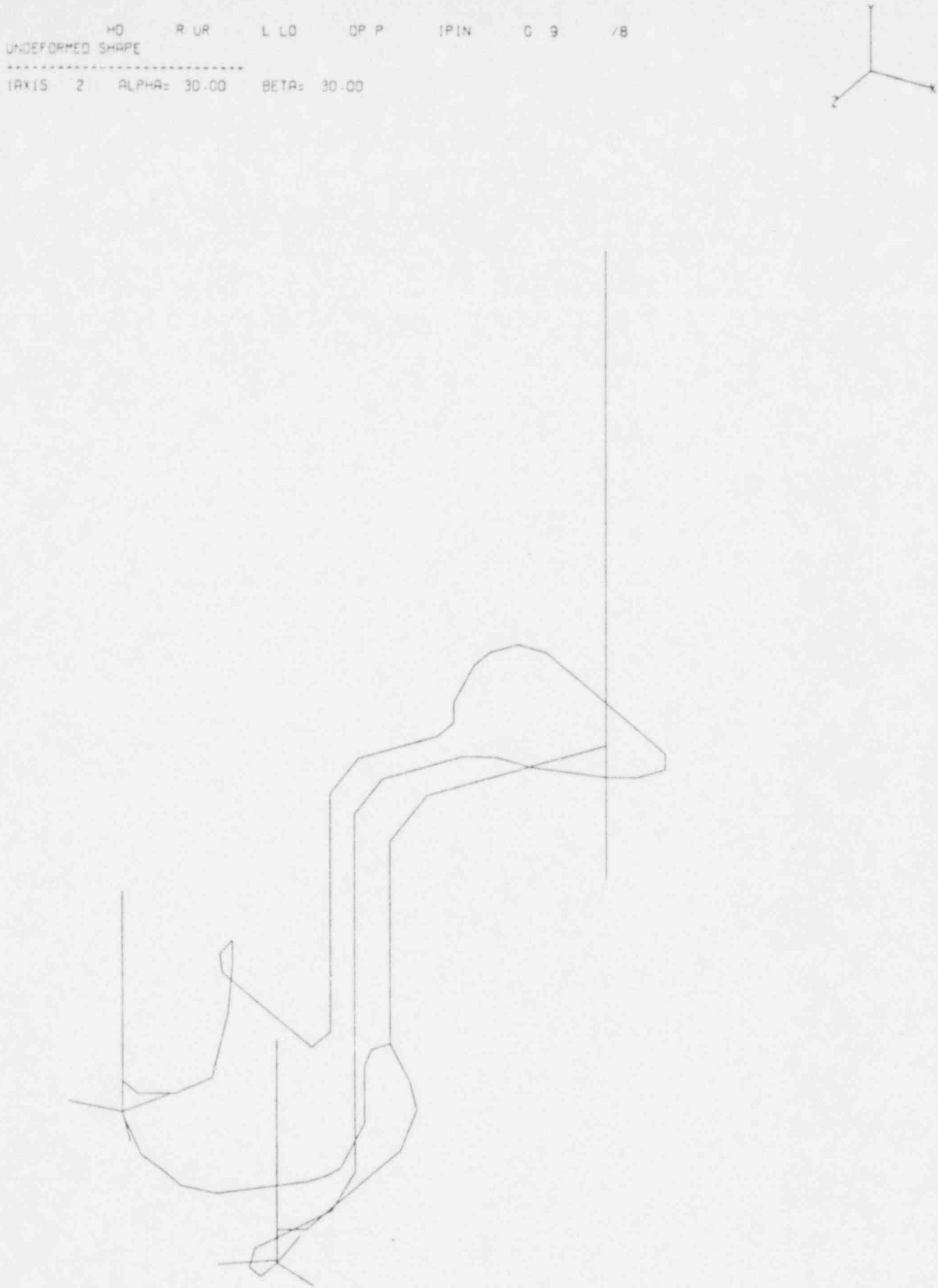


Figure 6. Piping Isometric

ANALYSIS RESULTS

Table 1 presents a listing of the first thirty predicted natural frequencies for the system. These correspond reasonably well with those predicted by EG&G with the NUPIPE II code for the same model. The largest difference occurs for mode 12 where the NUPIPE II result was 8.375 Hz for a difference of 2.8%. Differences of this magnitude also occured for modes 7 and 14. The differences are felt to be due to slight modeling differences as well as the use of independent analysis methods.

Figures 7-11 show computer graphics representations of the first 5 mode shapes of the system. On each figure the undeformed structure is shown in dashed line while the mode shape is shown by the solid line. As the scale factors for displacements differ from figure to figure no comparisons between gross displacements from mode to mode should be made. Referring to the figures it is evident that the first five modes exhibit rigid body displacements and rotations of the pumps with associated displacements and rotations of the connecting piping. A review of all the mode shape information indicates that the pumps participate strongly in most modes to the twentieth frequency. A comparison of this mode shape data with that predicted with NUPIPE II showed reasonable agreement.

After the good frequency match confirmed the correctness of the system model, time history solutions were developed for both uniform support excitation and independent support excitation. Two independent support excitation calculations were in fact performed, the first predicting relative accelerations and the second absolute accelerations. For all these calculations processed, input accelerations supplied by EG&G Idaho were used as the input support point excitations.

Figures 12a, b and c show the input support acceleration records for the X, Y and Z directions, uniform support motion case. These curves represent processed averages of the accelerations measured during the 5 Kg blast test at some four points in the URL recirculation piping room. The records extend for 0.6 sec and exhibit peak accelerations of less than 0.2 m/sec^2.

Table 1

Predicted Natural Frequencies with PSAFE2

Mode No.	Frequency Hz	Mode No.	Frequency Hz
1	1.835	16	12.82
2	2.788	17	13.70
3	3.589	18	15.88
4	4.053	19	15.93
5	4.908	20	16.43
6	5.193	21	18.83
7	5.275	22	19.37
8	5.416	23	21.12
9	6.316	24	23.42
10	7.048	25	25.55
11	7.561	26	27.88
12	8.150	27	30.55
13	9.640	28	32.47
14	9.749	29	34.86
15	12.26	30	36.14

Figure 7. Mode 1

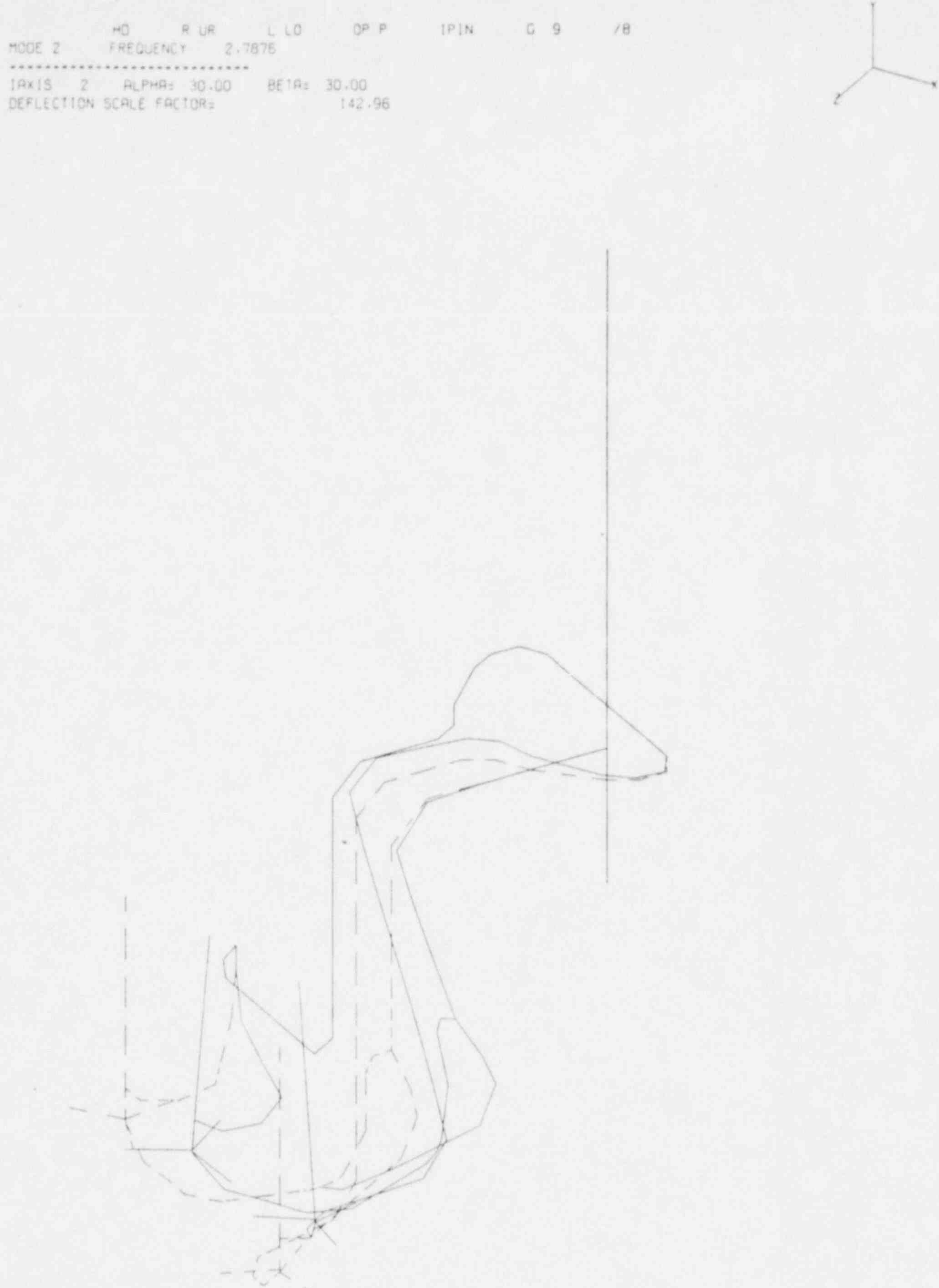


Figure 8. Mode 2

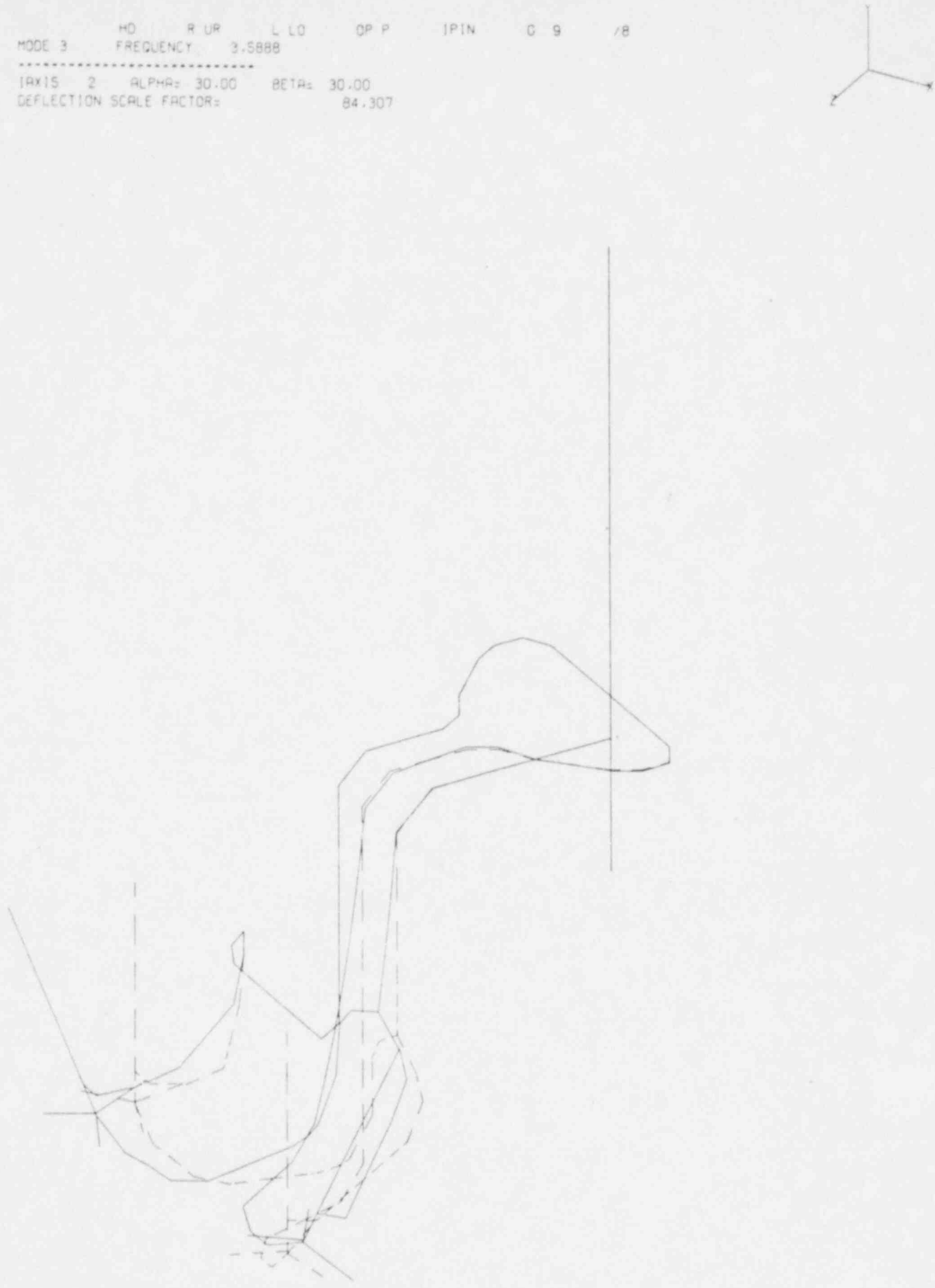


Figure 9. Mode 3

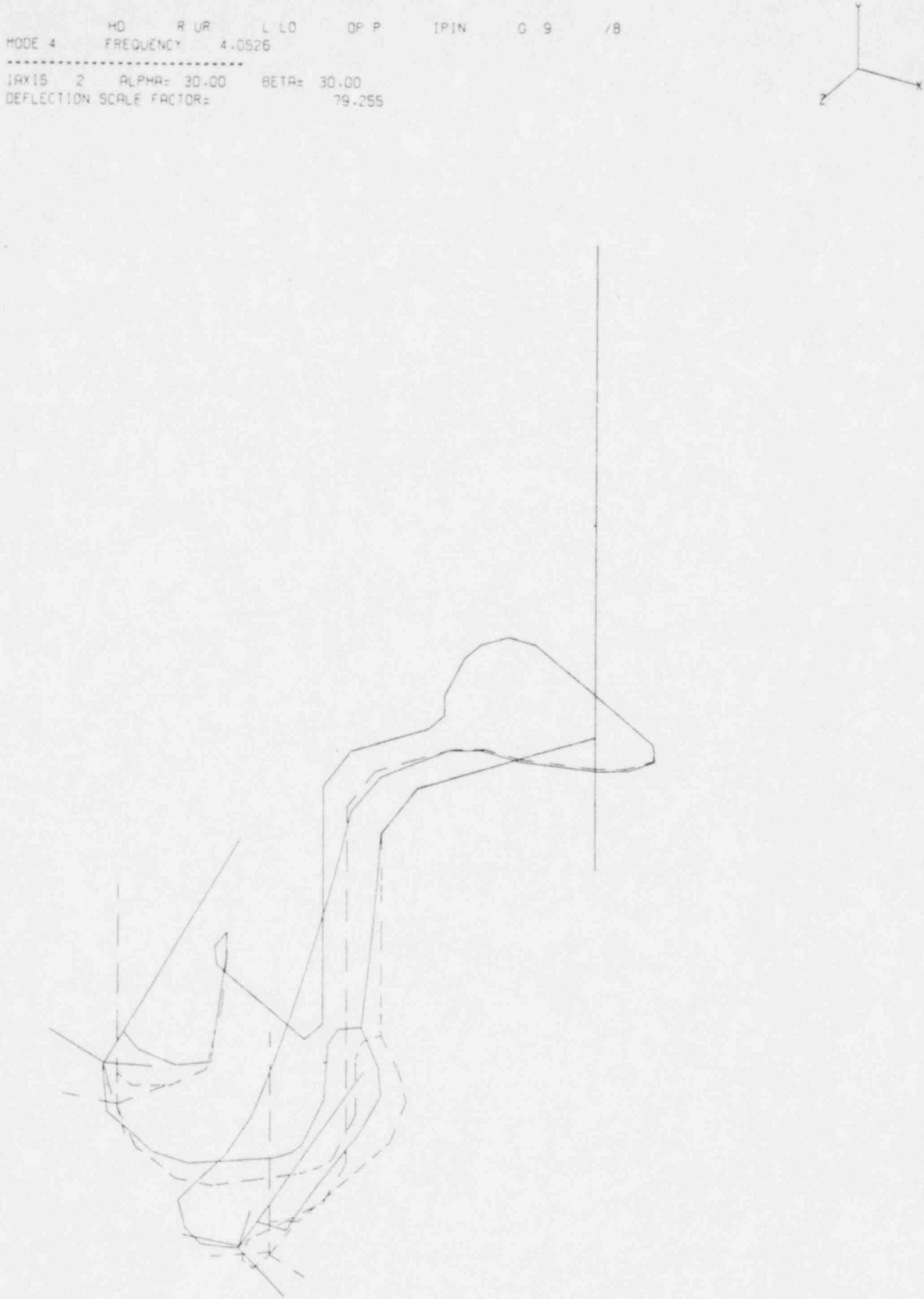


Figure 10. Mode 4

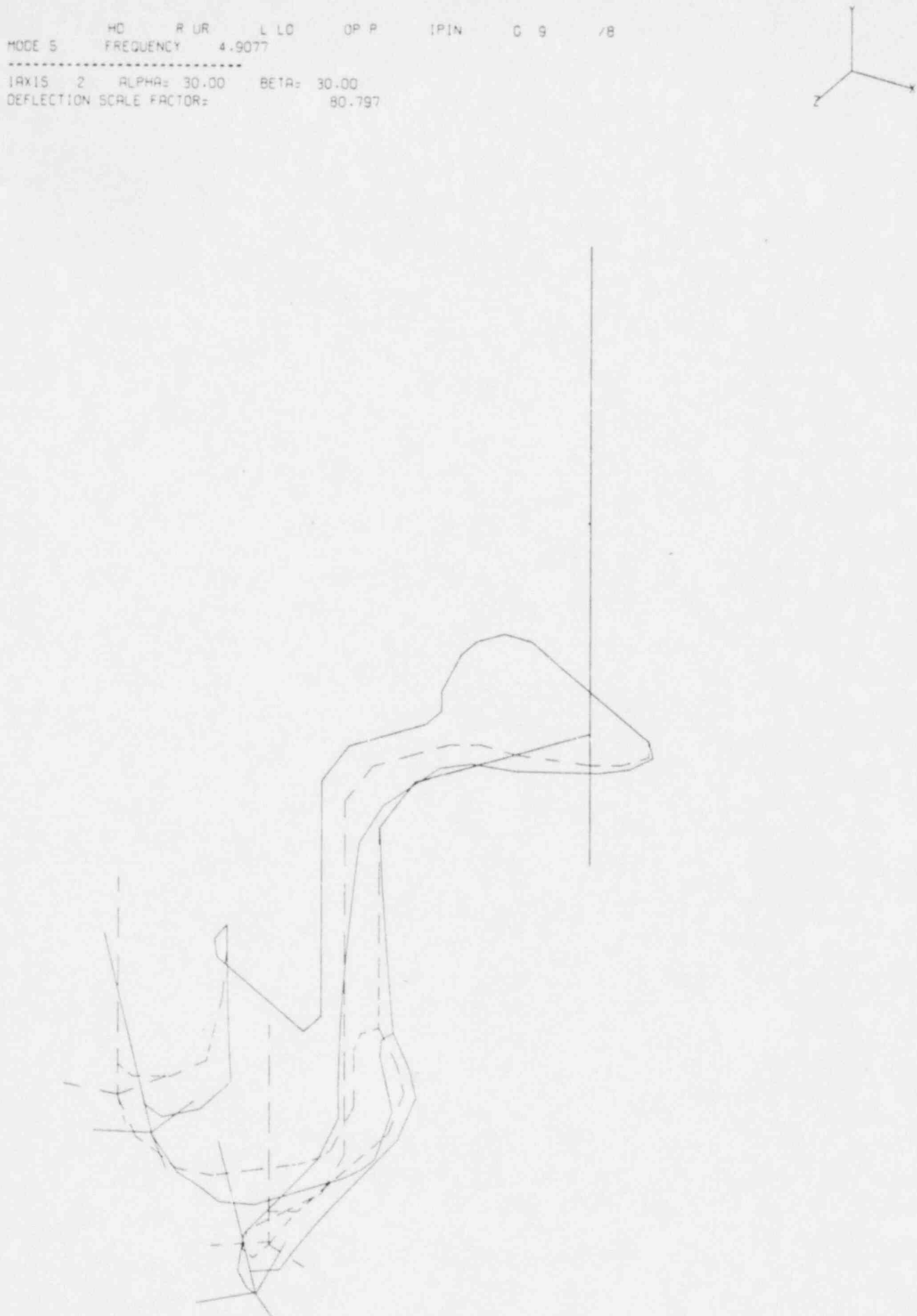


Figure 11. Mode 5

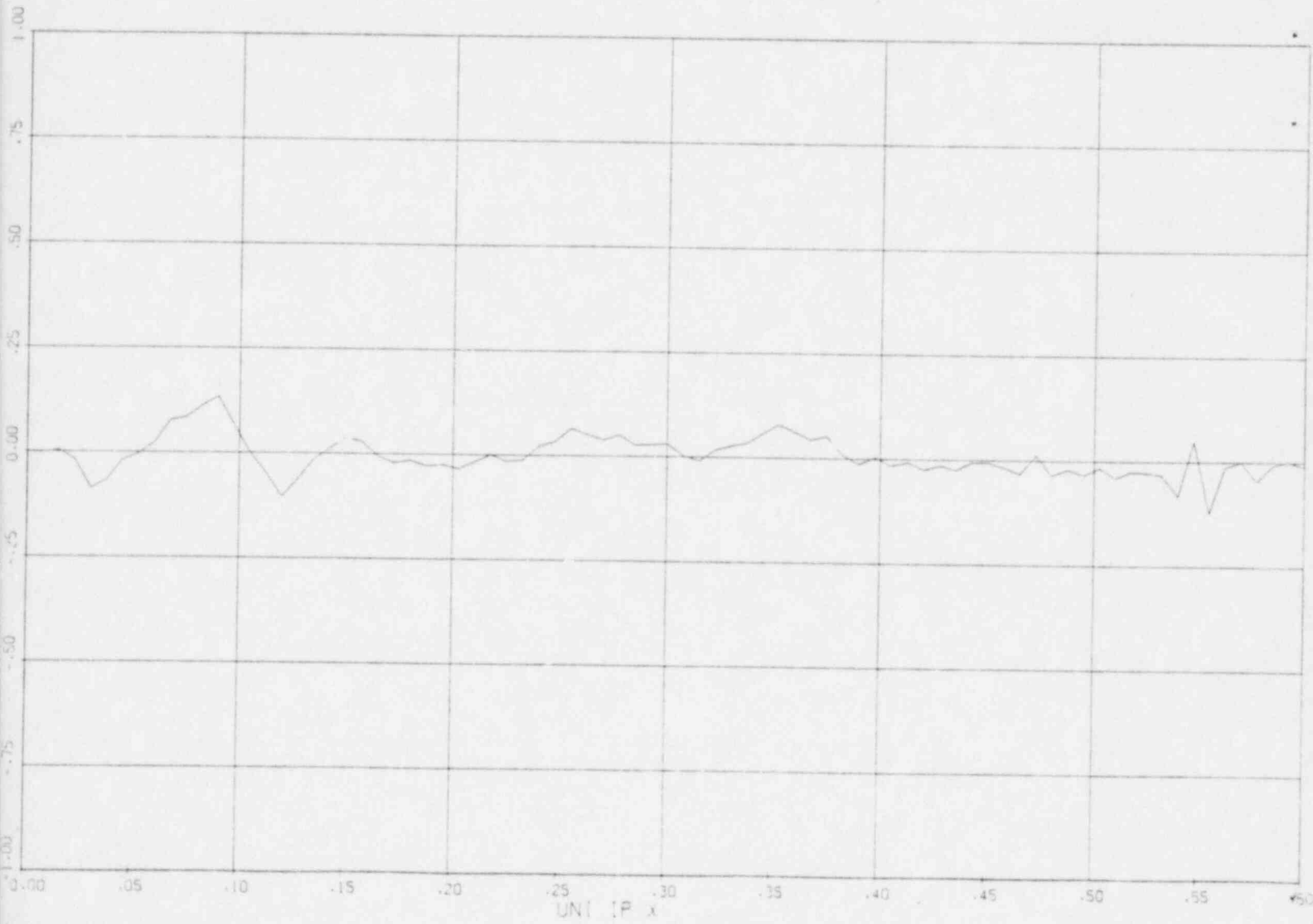


Figure 12a. Uniform Excitation X

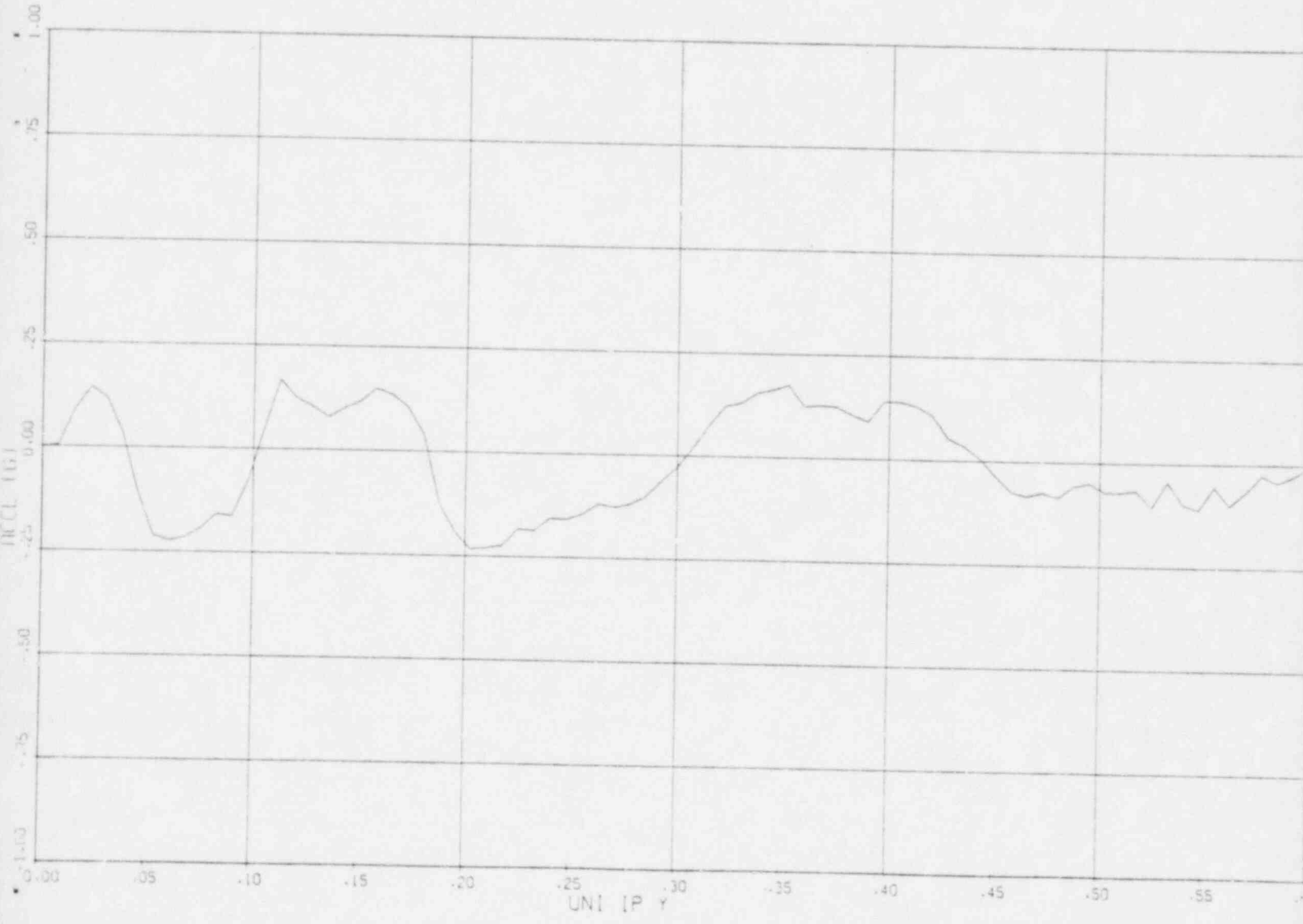


Figure 12b. Uniform Excitation Y

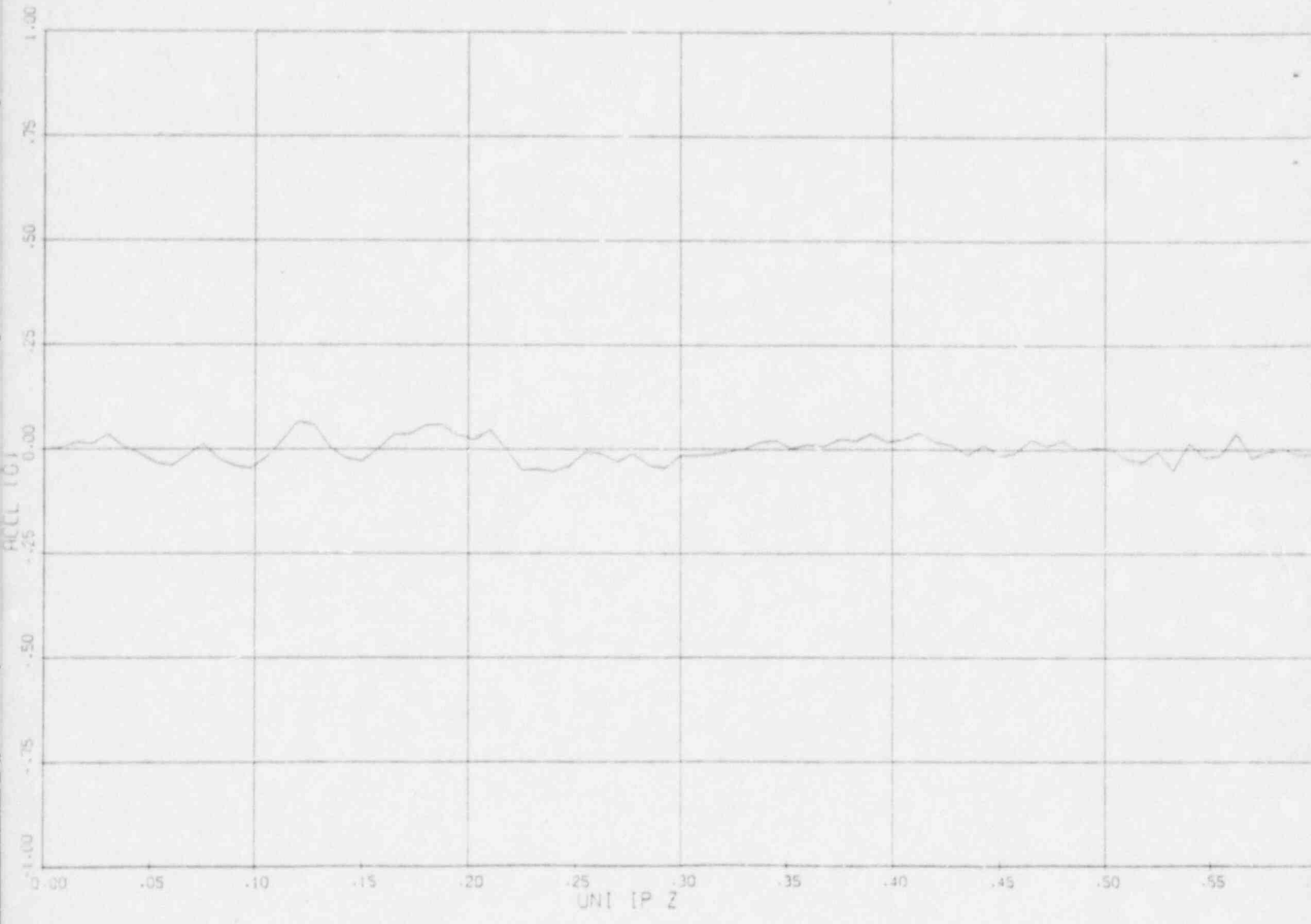


Figure 12c. Uniform Excitation Z

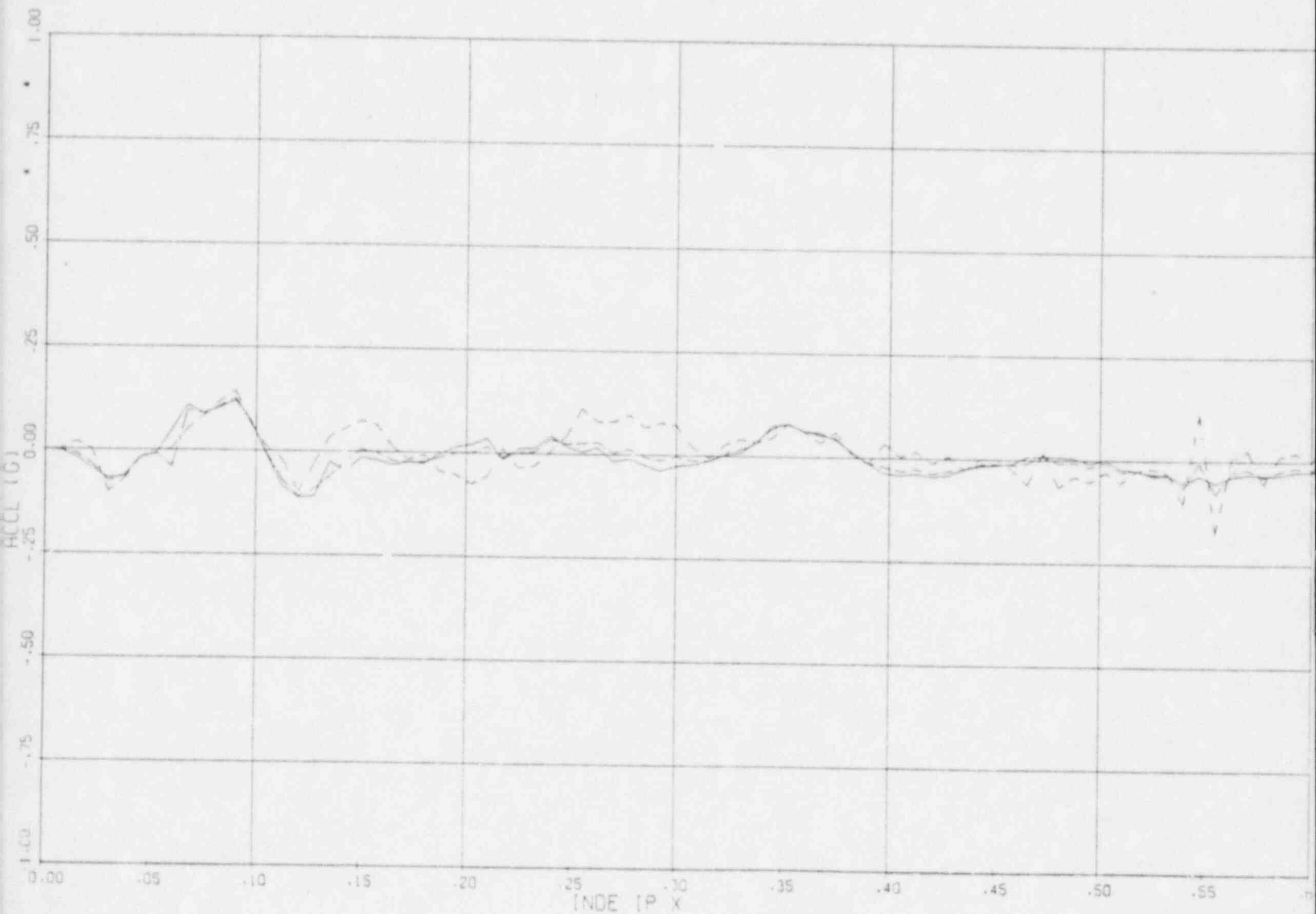


Figure 13a. Independent Excitation X

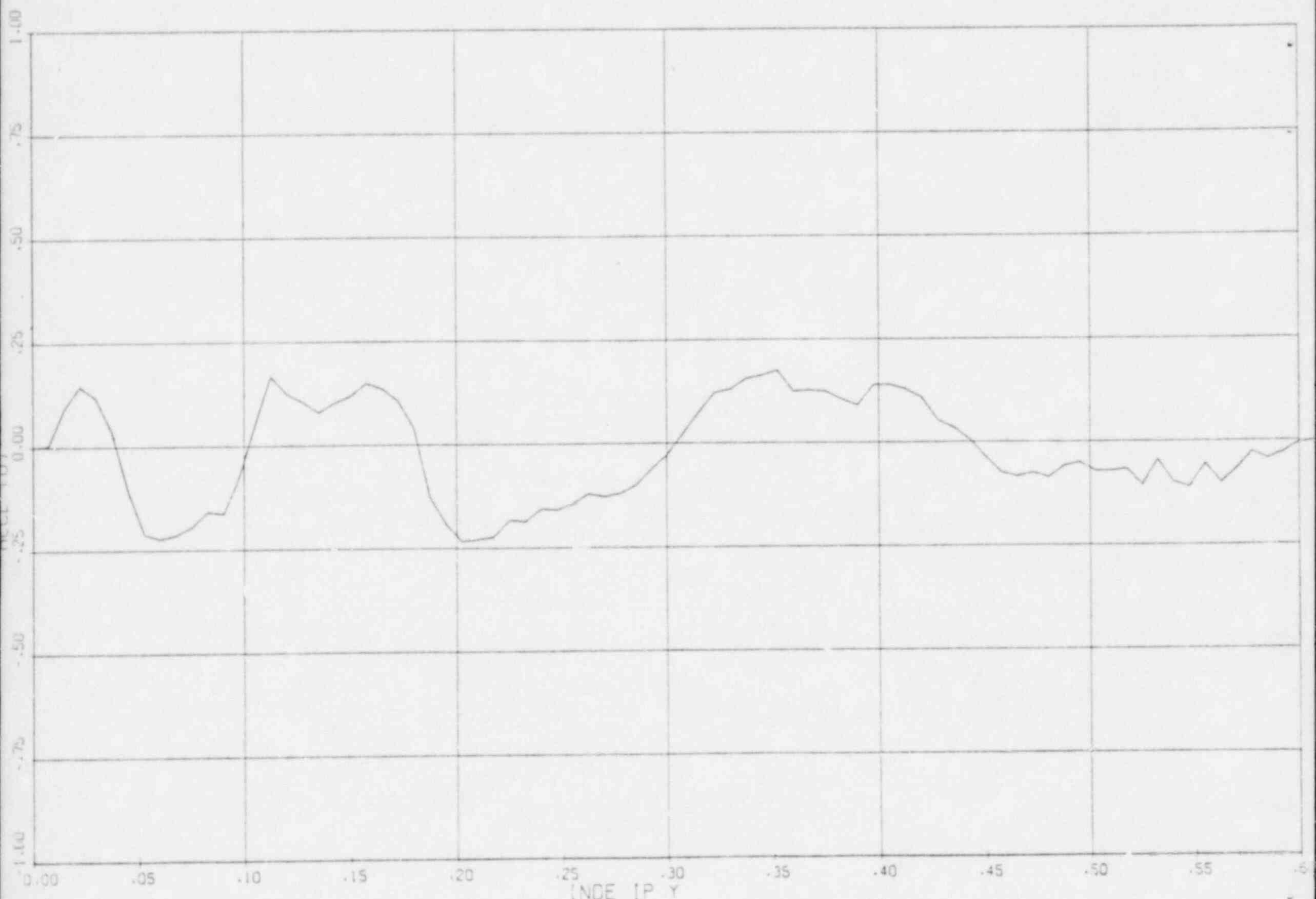


Figure 13b. Independent Excitation Y

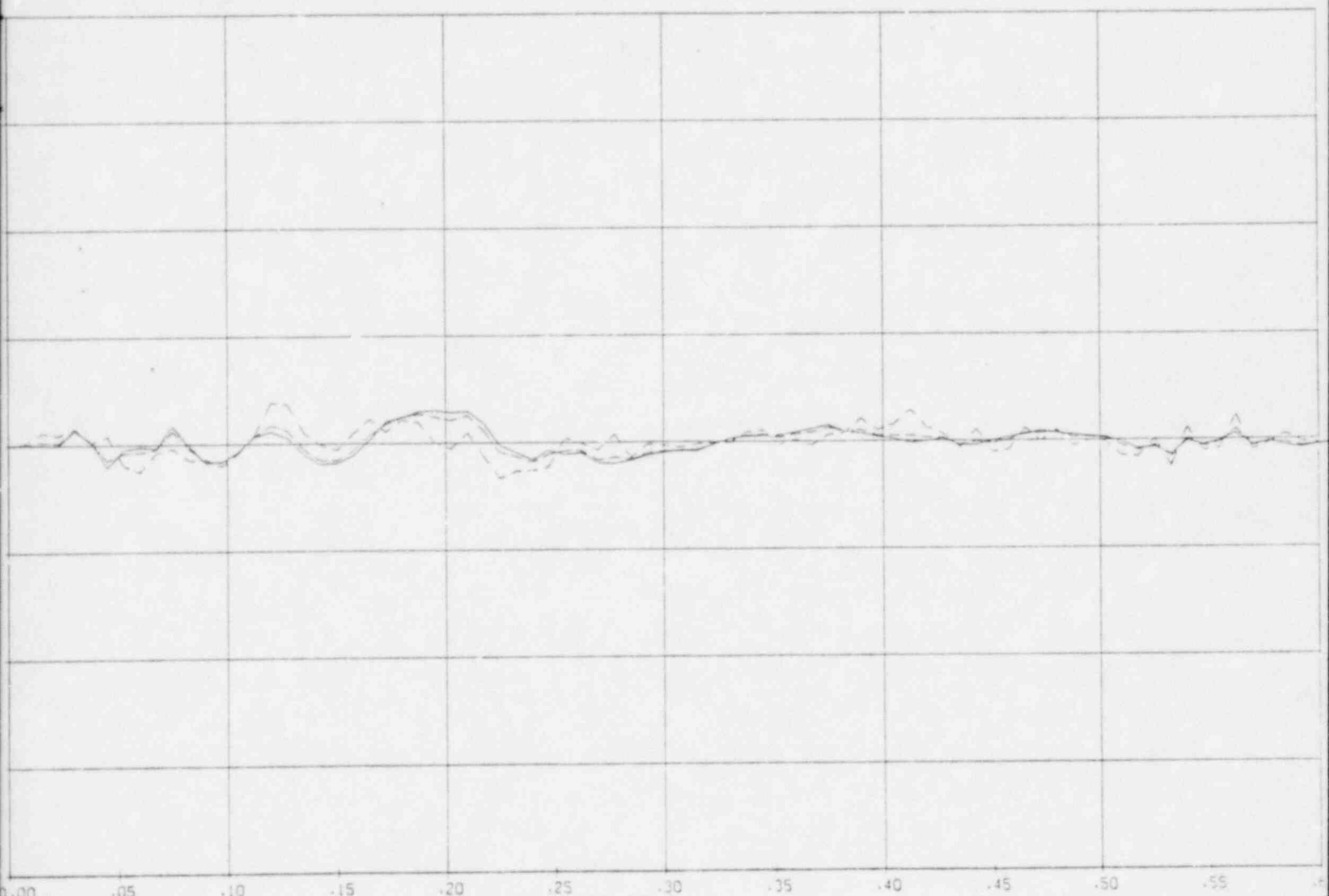


Figure 13c. Independent Excitation Z

For the independent support motion computation the loop support elements were divided into three groups, each exhibiting a separate excitation. Supports connected to points 1, 2, 10, 11, 12, 21, 28, 35, 77, 91, 92, 93, 105, 107 and 118 formed the first group. The support at point 170 formed the second group while the supports at points 30 and 63 formed the third group. The processed input support acceleration records for the X, Y and Z directions, independent support motion case are shown in Fig. 13a, b and c. All three group excitations are shown on each plot. As can be seen the excitation for the separate groups are identical in the Y direction and very similar in the X and Z directions.

The predicted and measured absolute acceleration data for selected points in the system are depicted in Figs. 14-31. 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. On some figures only, two curves are shown. These correspond to the computed responses only as no measured response data was available.

Another comparison between the measured and predicted response data is presented in Figs. 32-45. Each of these figures shows two curves each showing the results of a fourier decomposition of the response signal. One curve, labeled with the letter M, shows the fourier content of the measured acceleration record for the point, while the other curve shows the fourier content of the predicted acceleration record, either uniform or independent support excitation case, for that point. These curves are presented for all acceleration components for which measured response data are available.

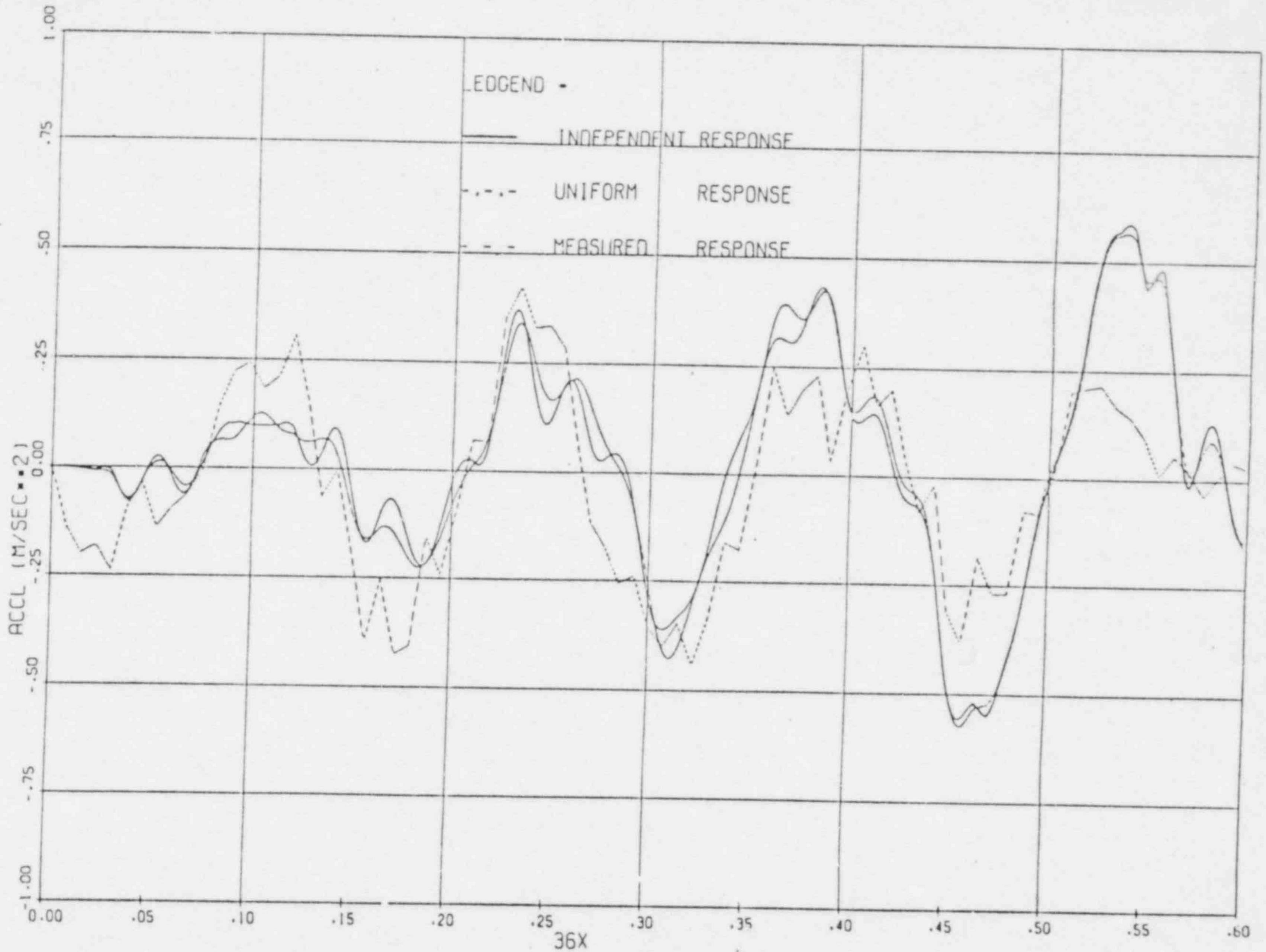


Figure 14 Absolute Acceleration Response

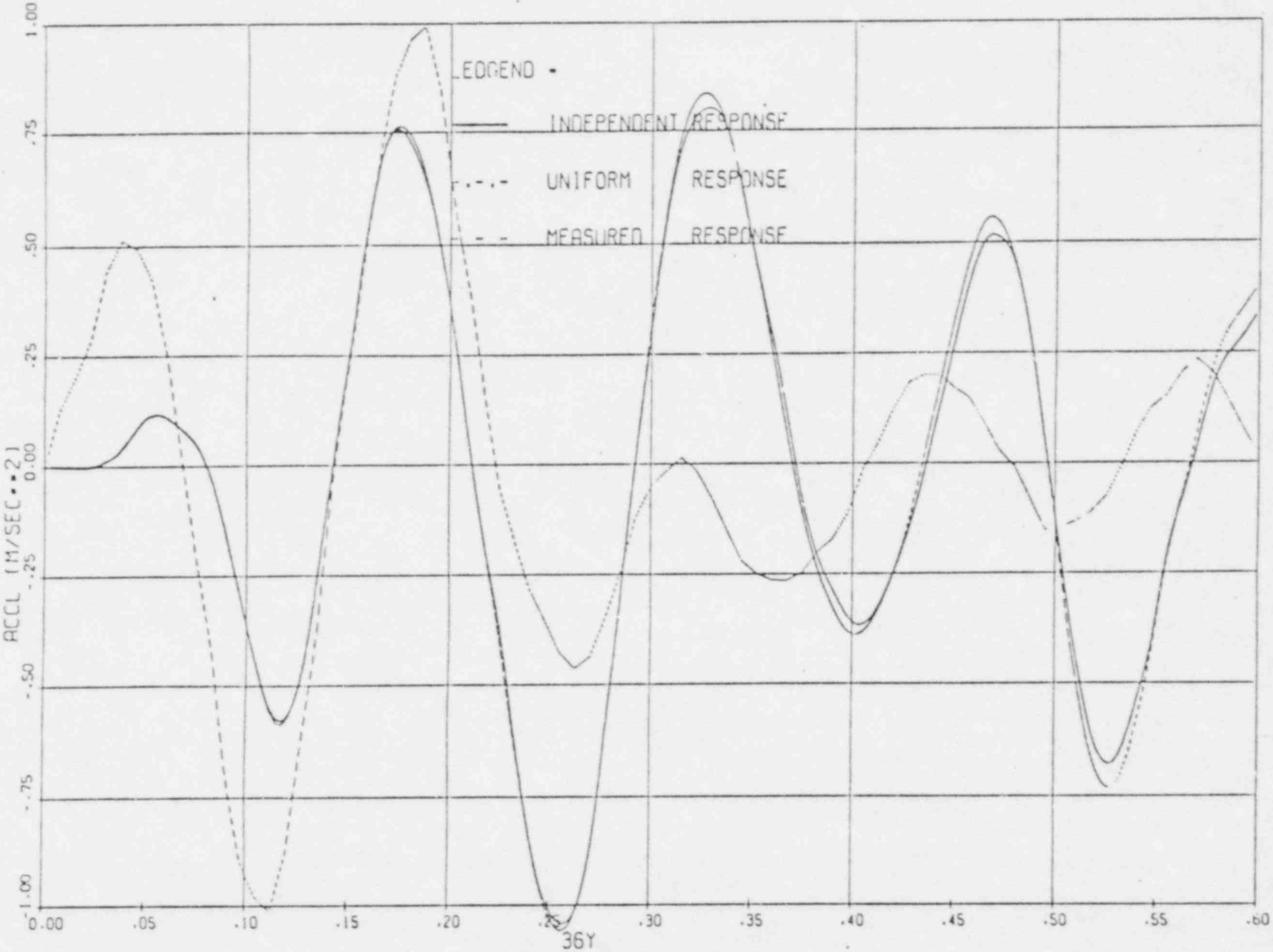


Figure 15 Absolute Acceleration Response

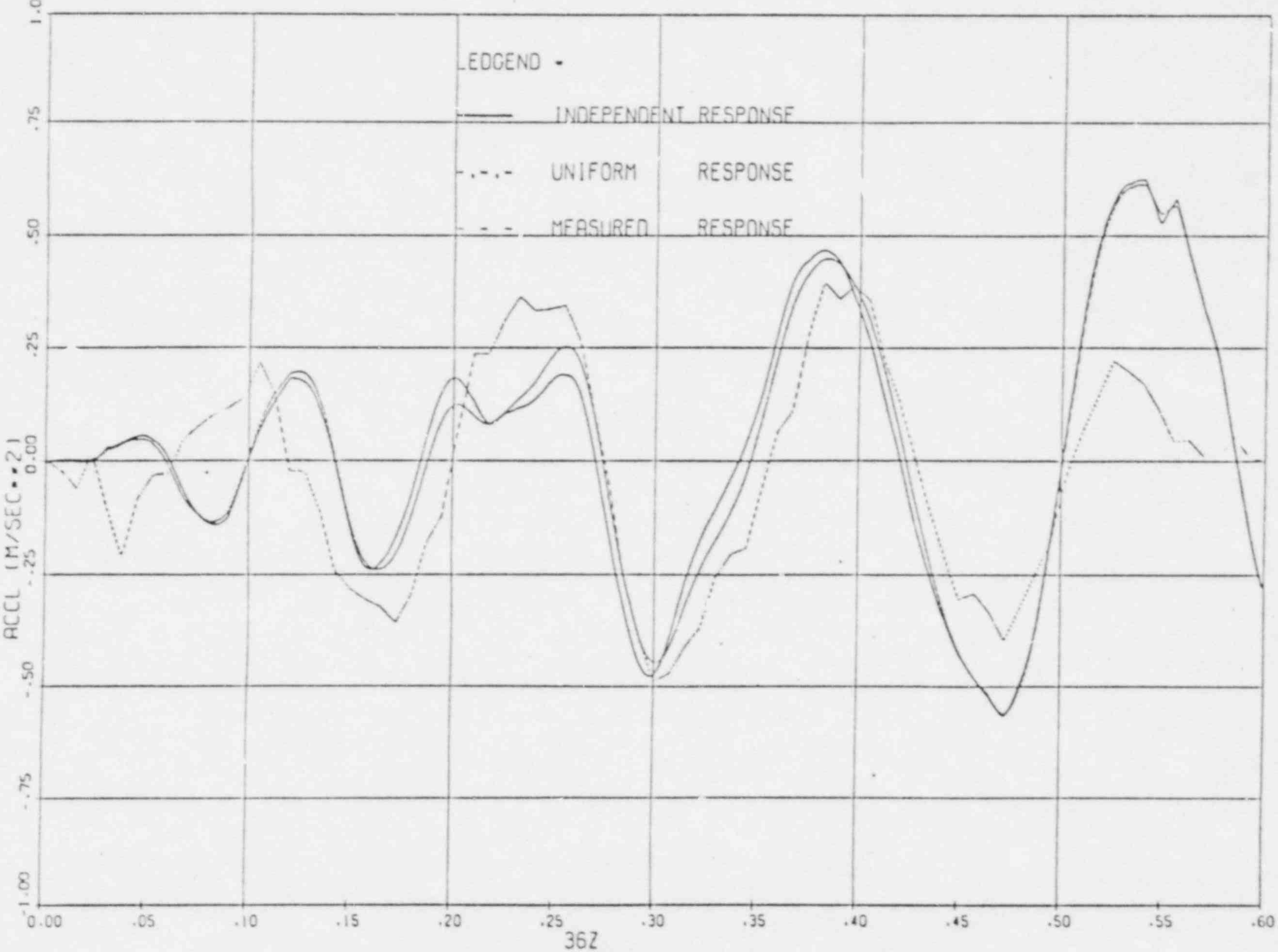


Figure 16 Absolute Acceleration Response

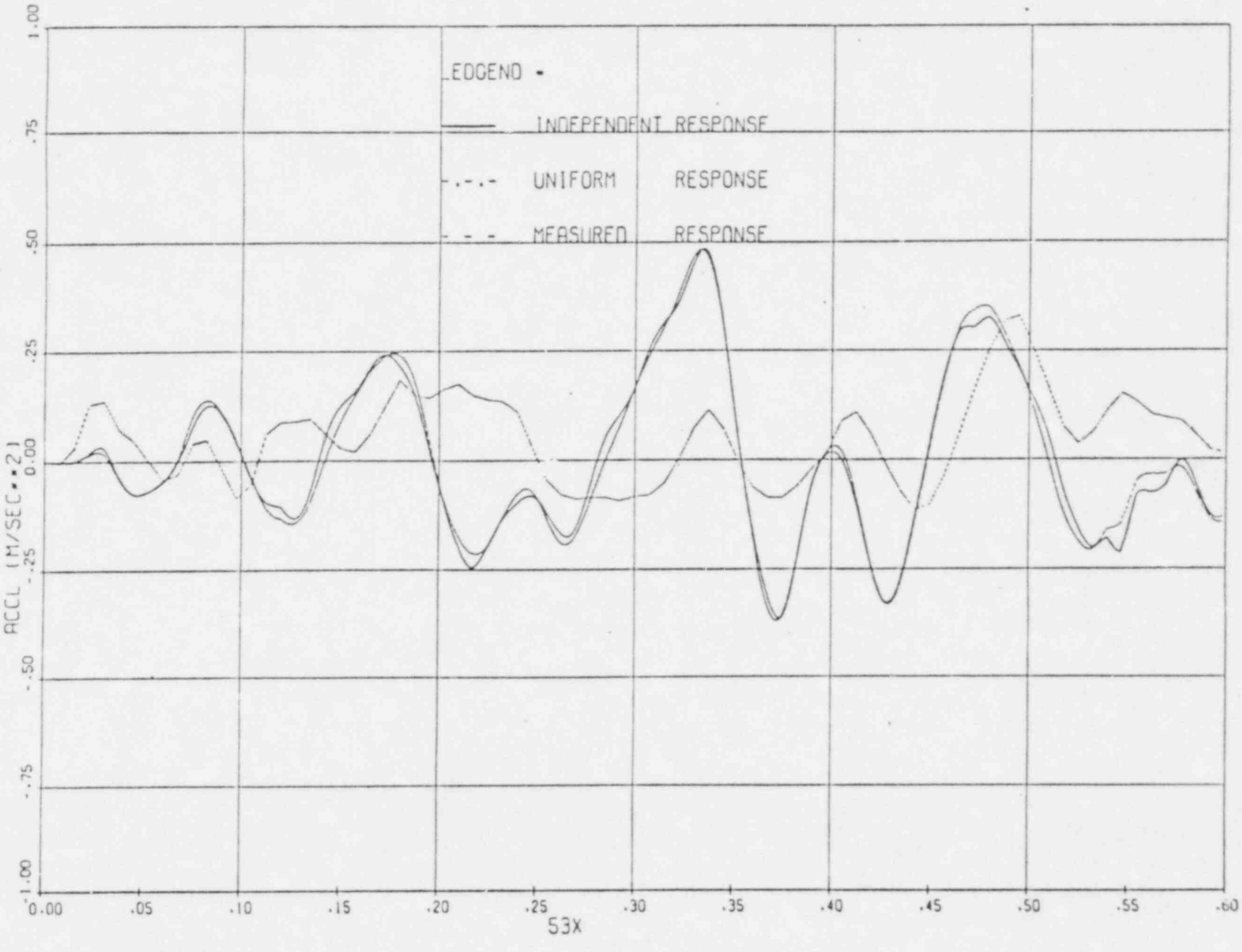


Figure 17 Absolute Acceleration Response

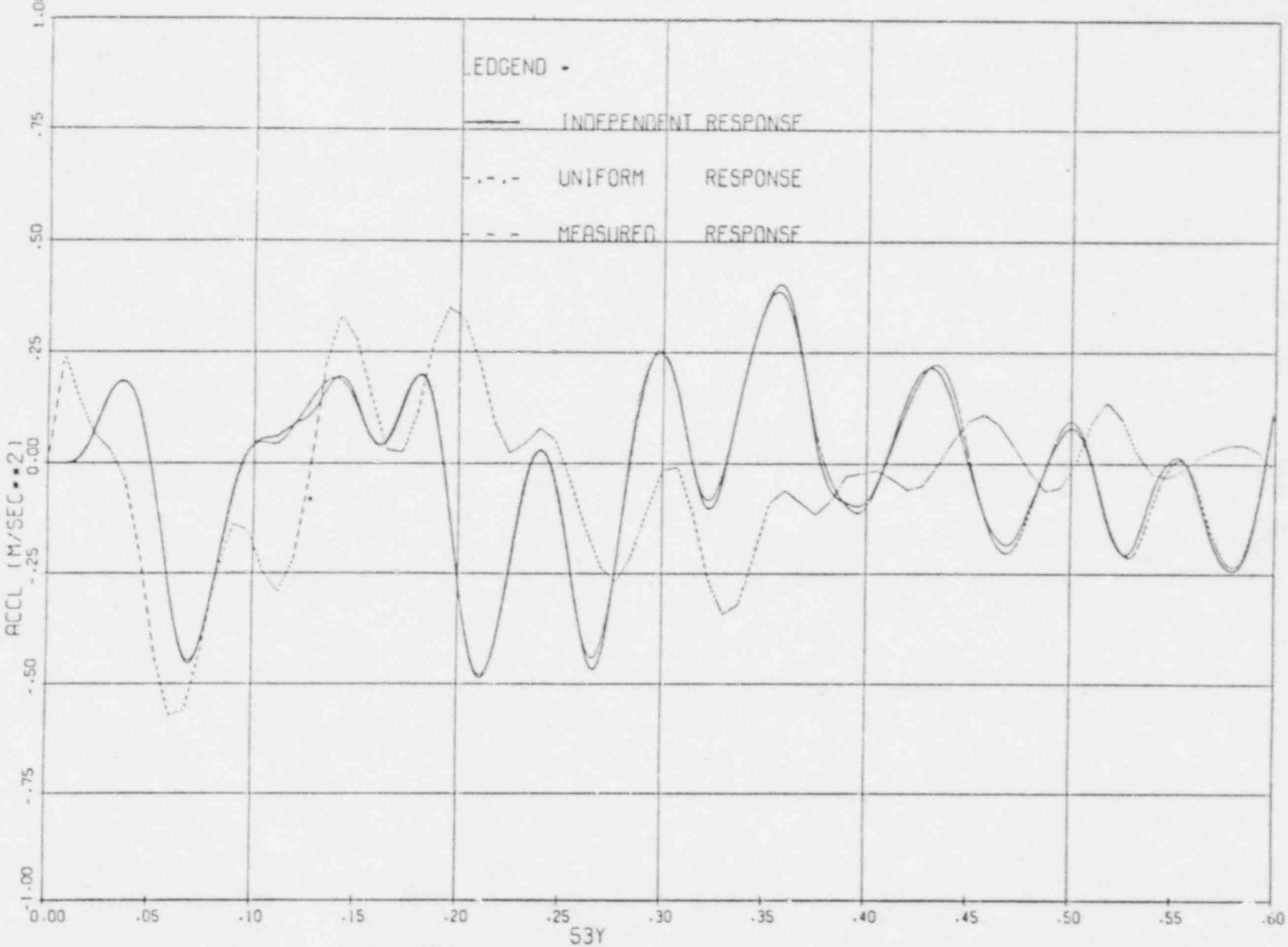


Figure 18 Absolute Acceleration Response

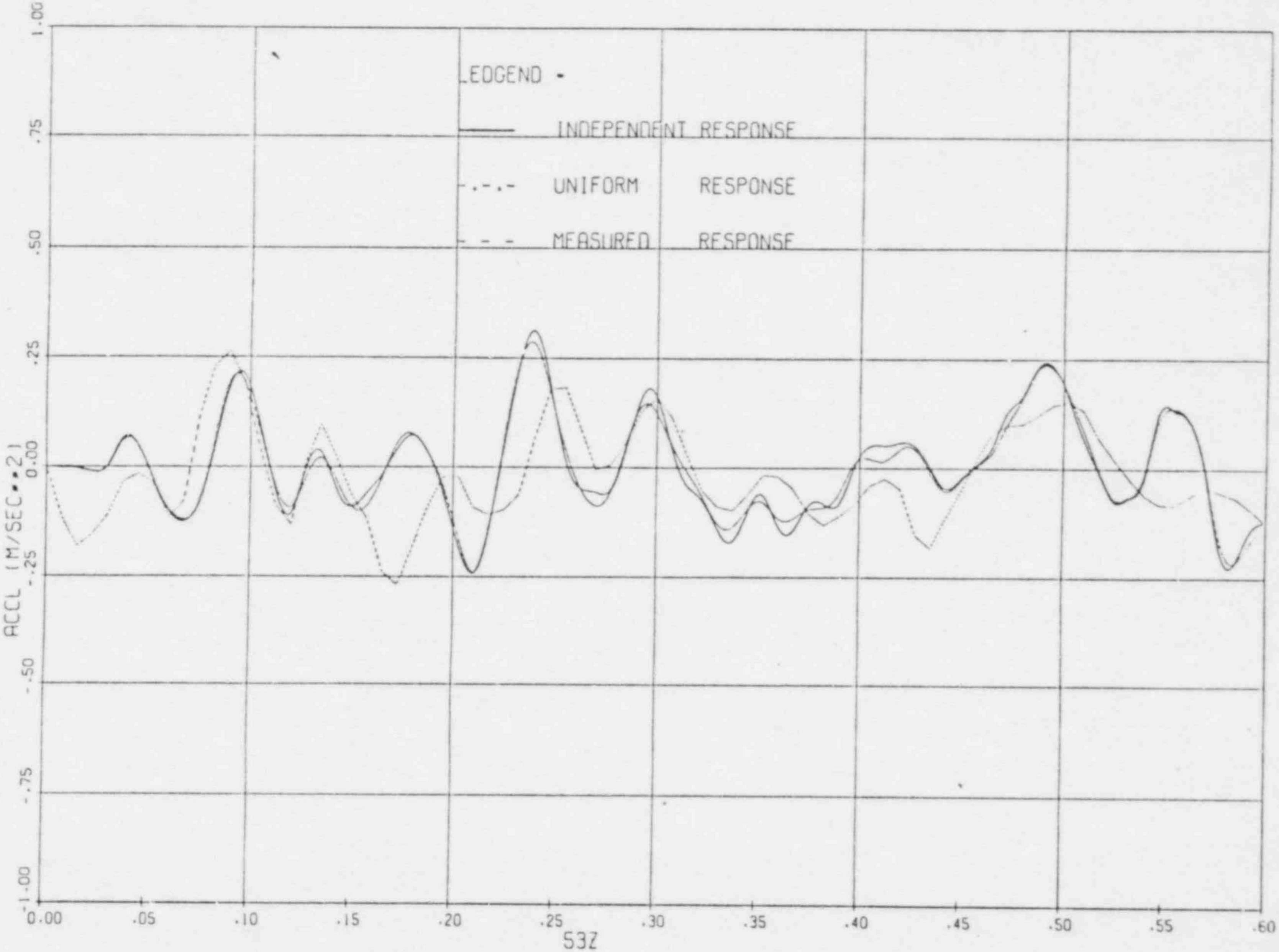


Figure 19 Absolute Acceleration Response

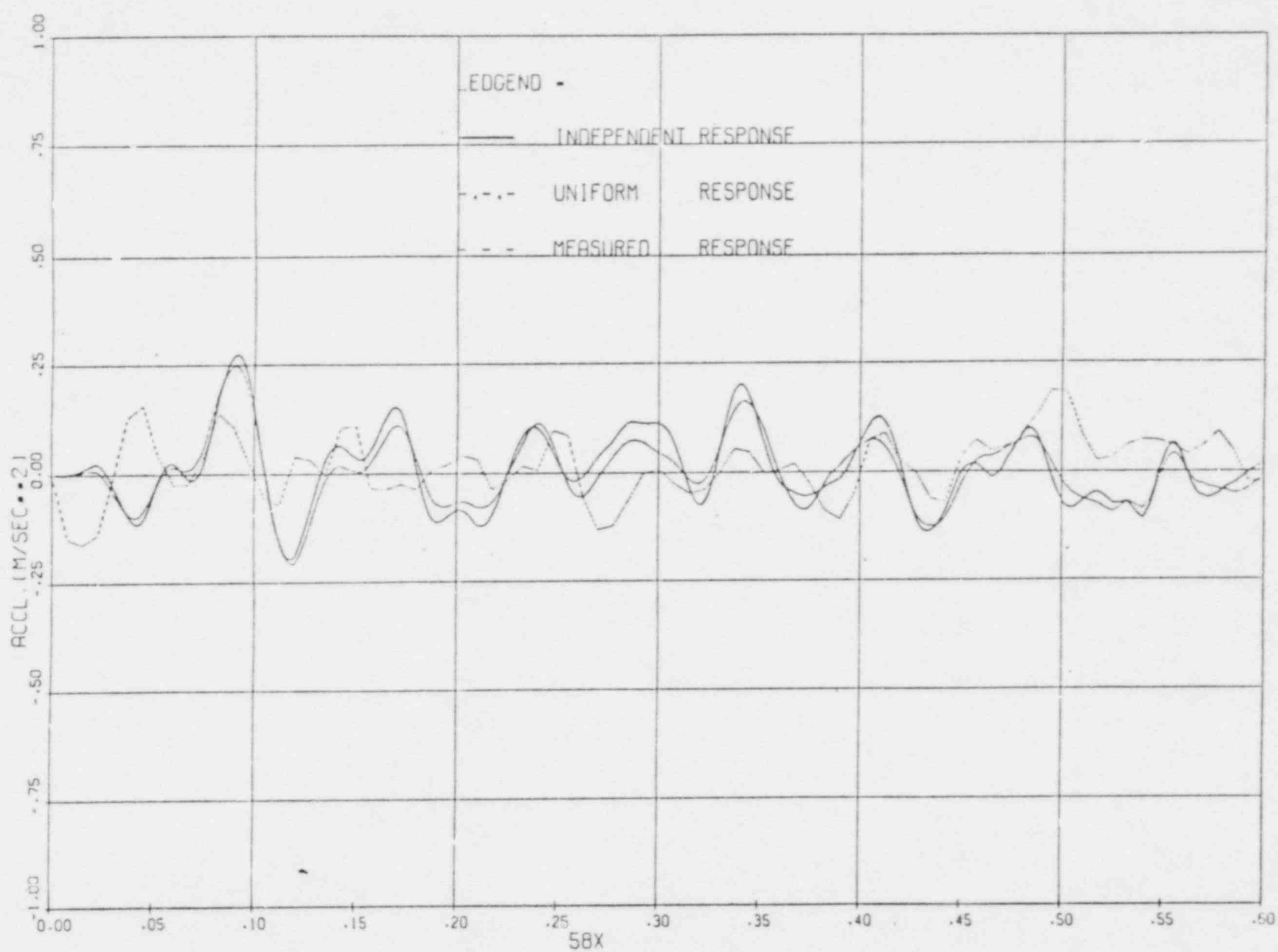


Figure 20 Absolute Acceleration Response

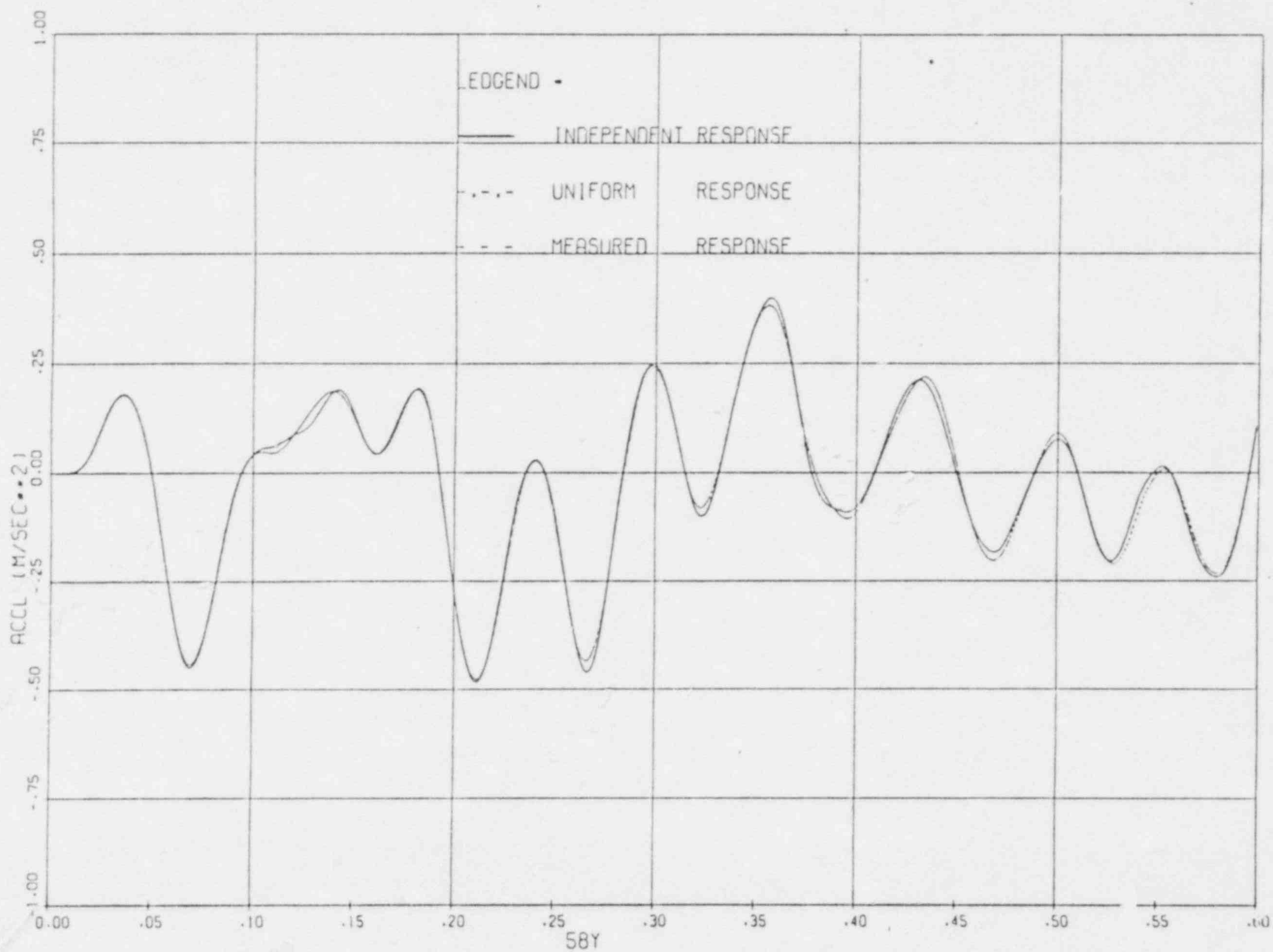


Figure 21 Absolute Acceleration Response

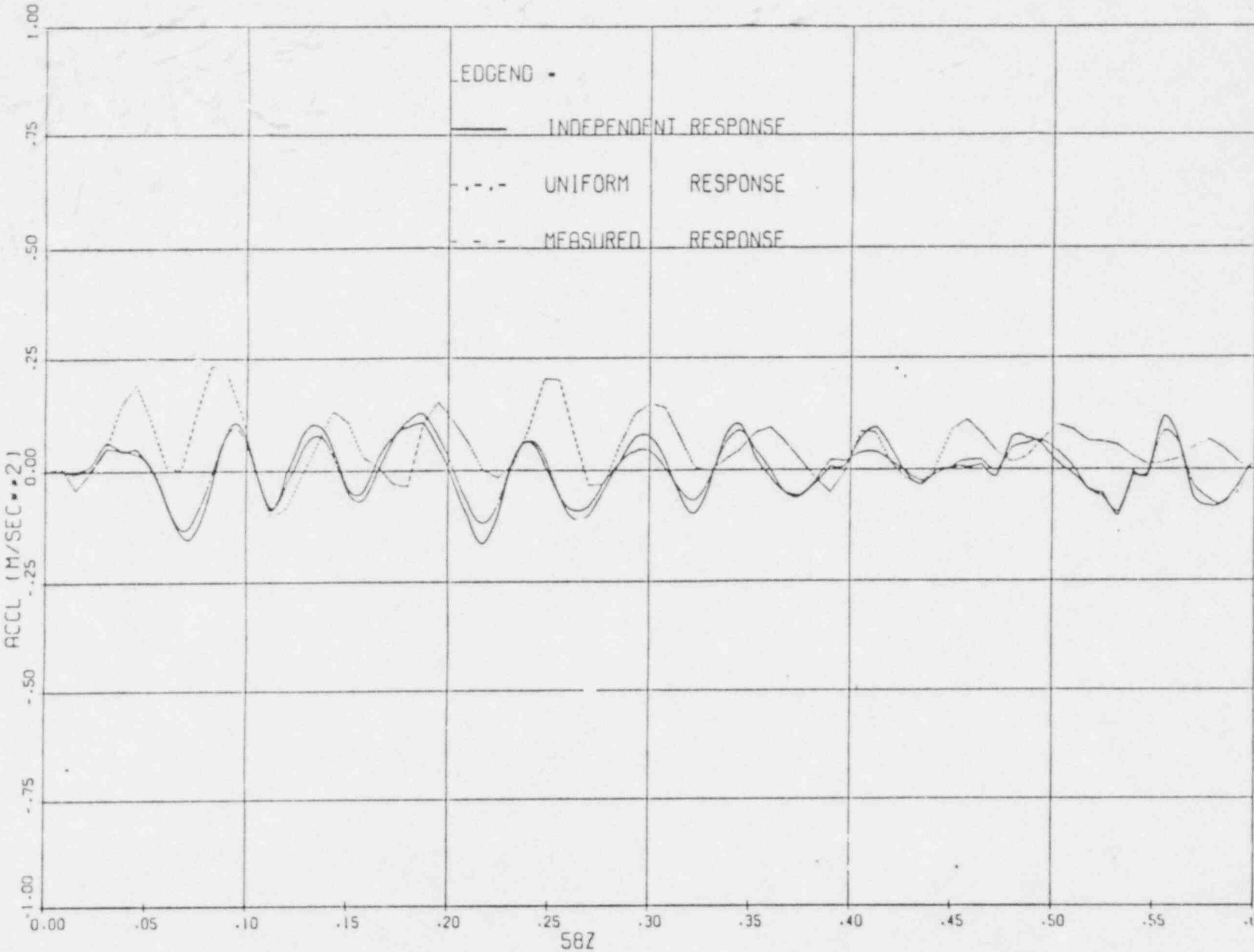


Figure 22 Absolute Acceleration Response

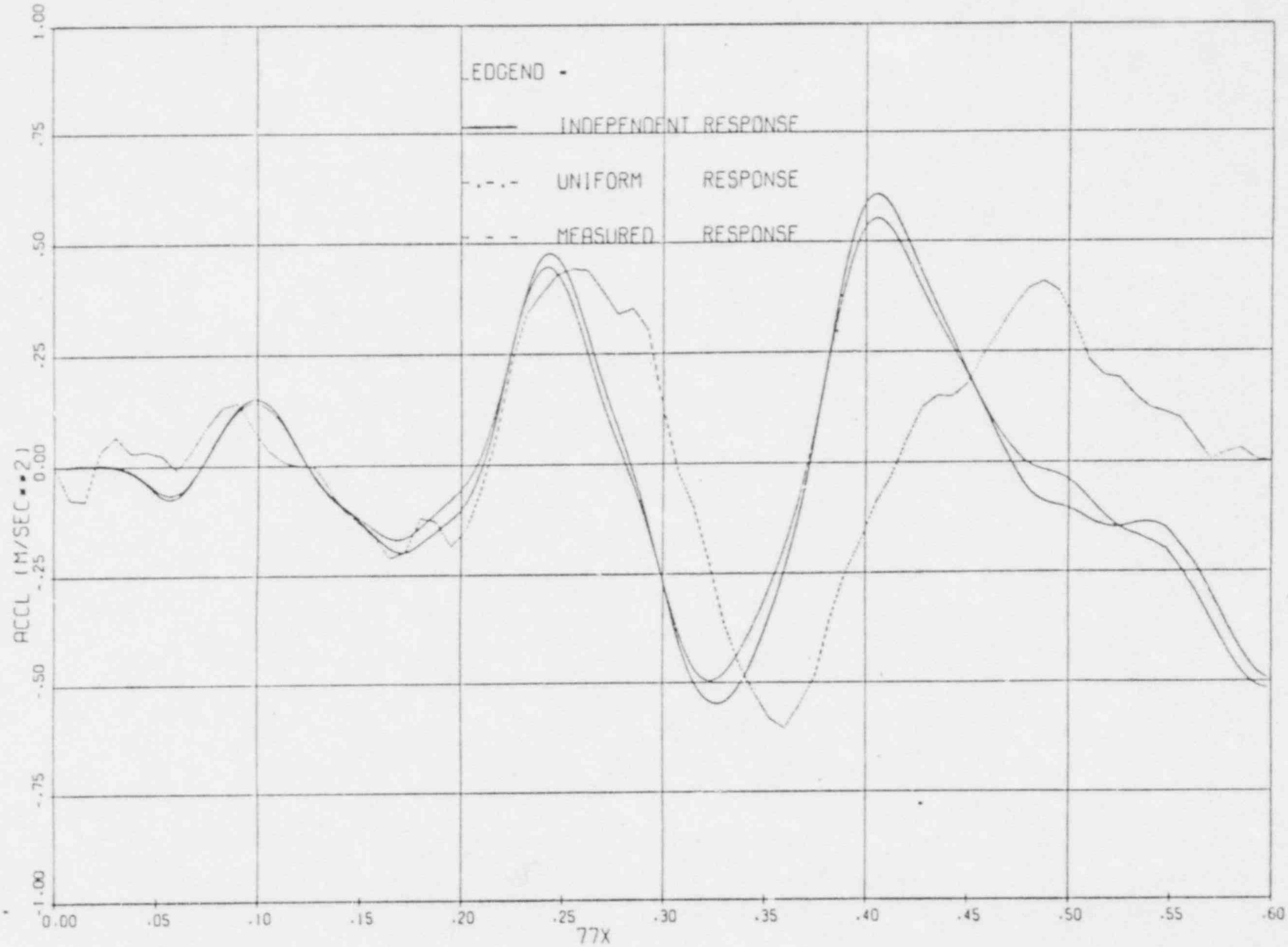


Figure 23 Absolute Acceleration Response

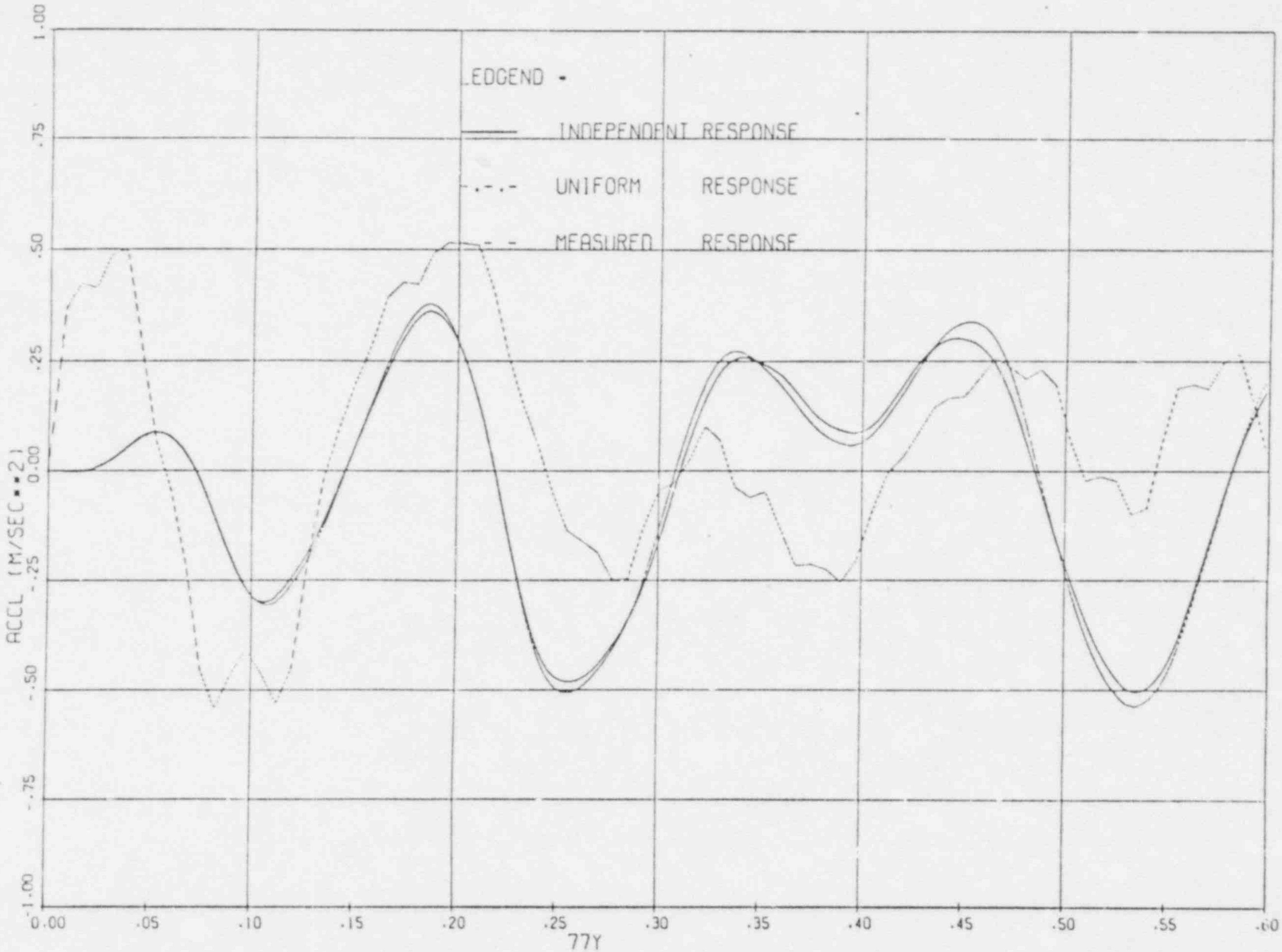


Figure 24 Absolute Acceleration Response

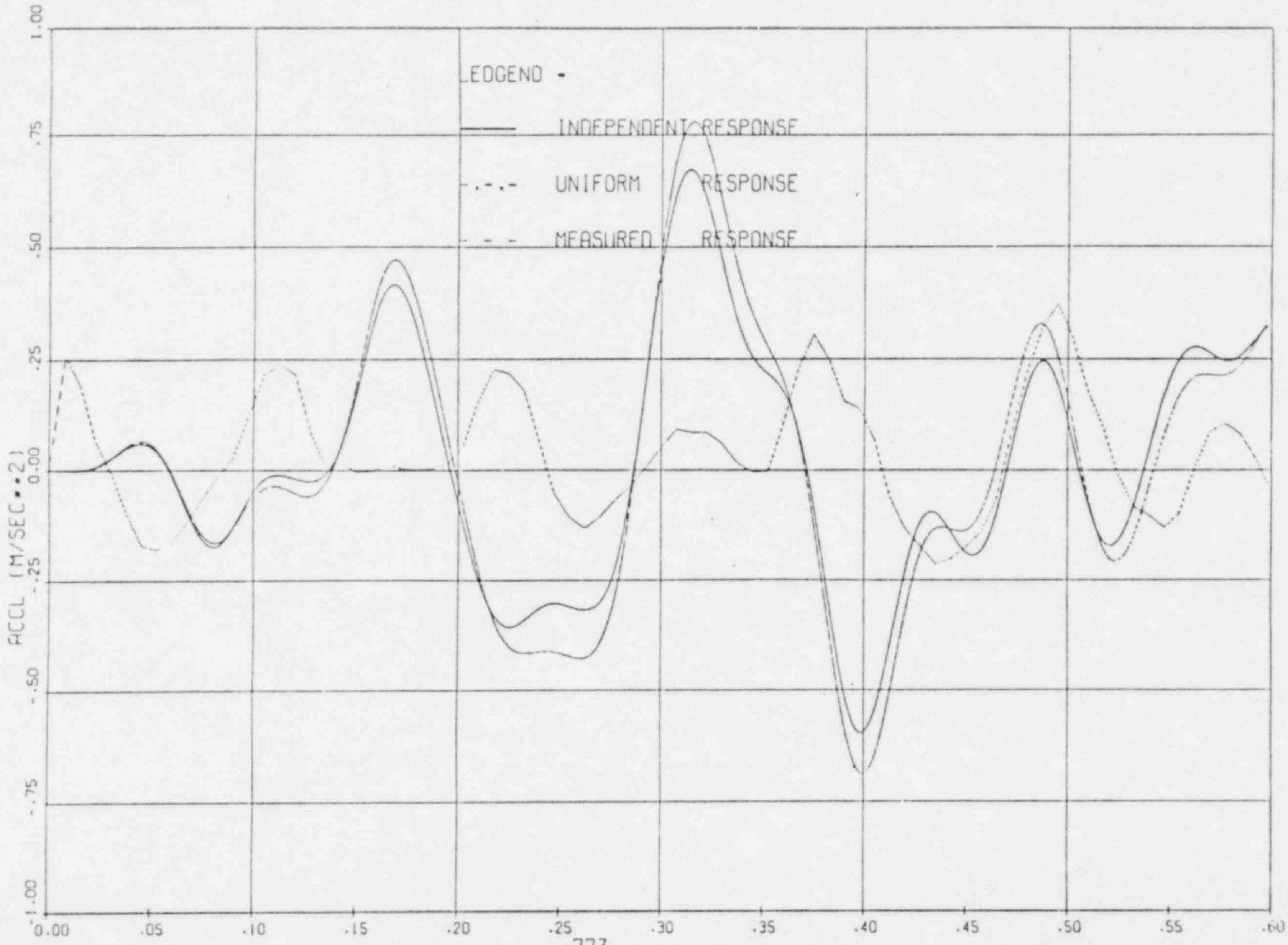


Figure 25 Absolute Acceleration Response

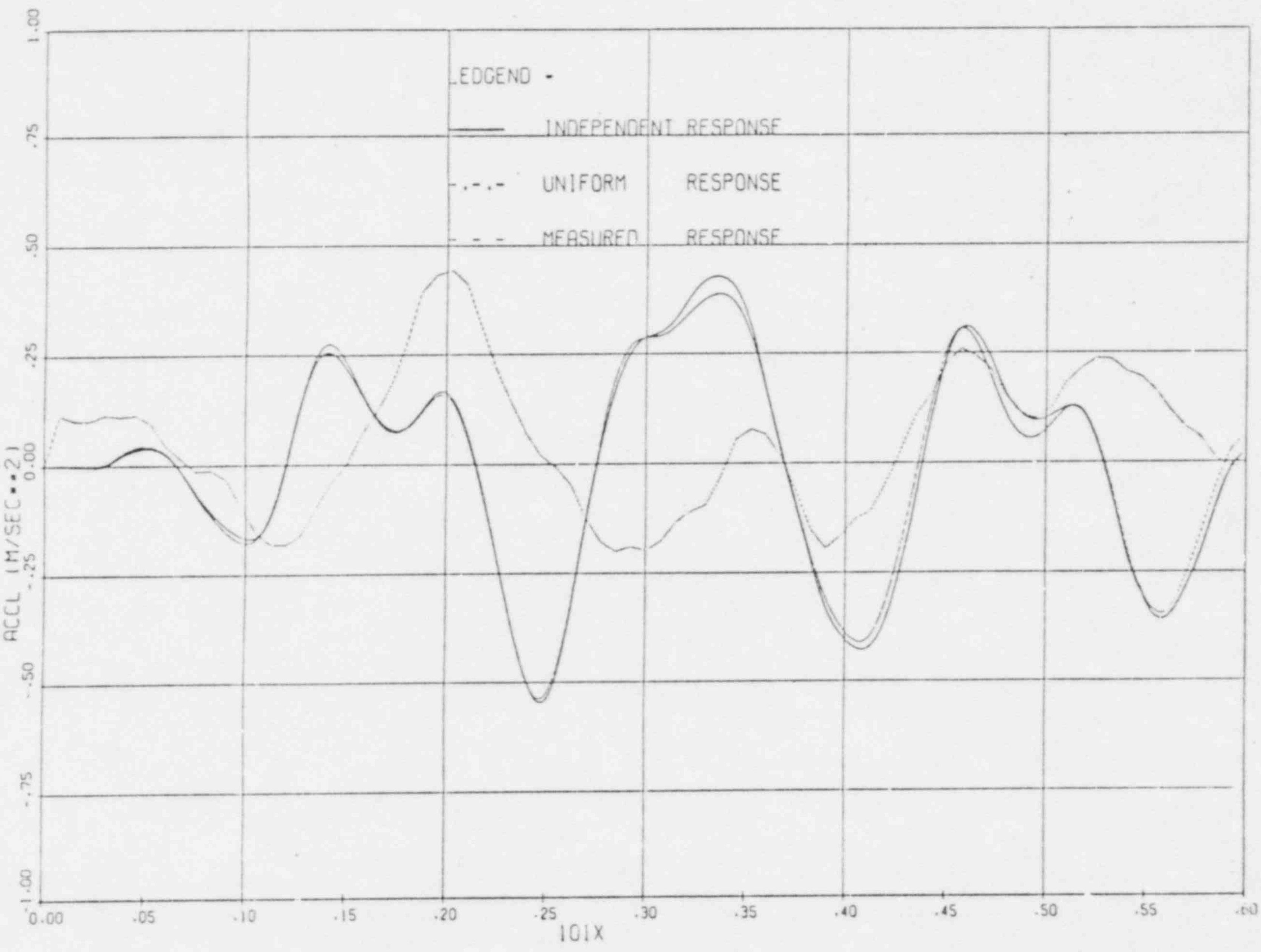


Figure 26 Absolute Acceleration Response

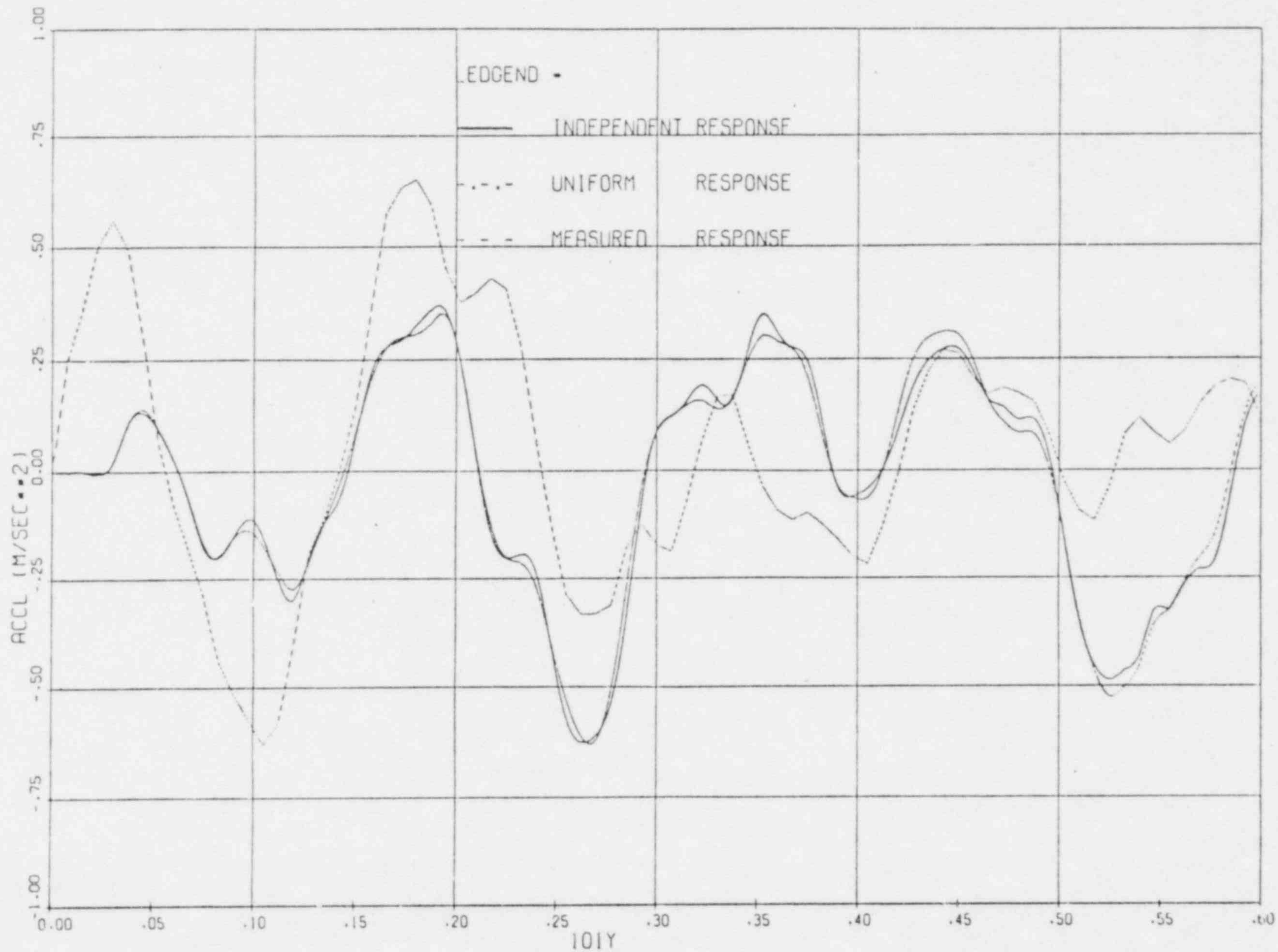


Figure 27 Absolute Acceleration Response

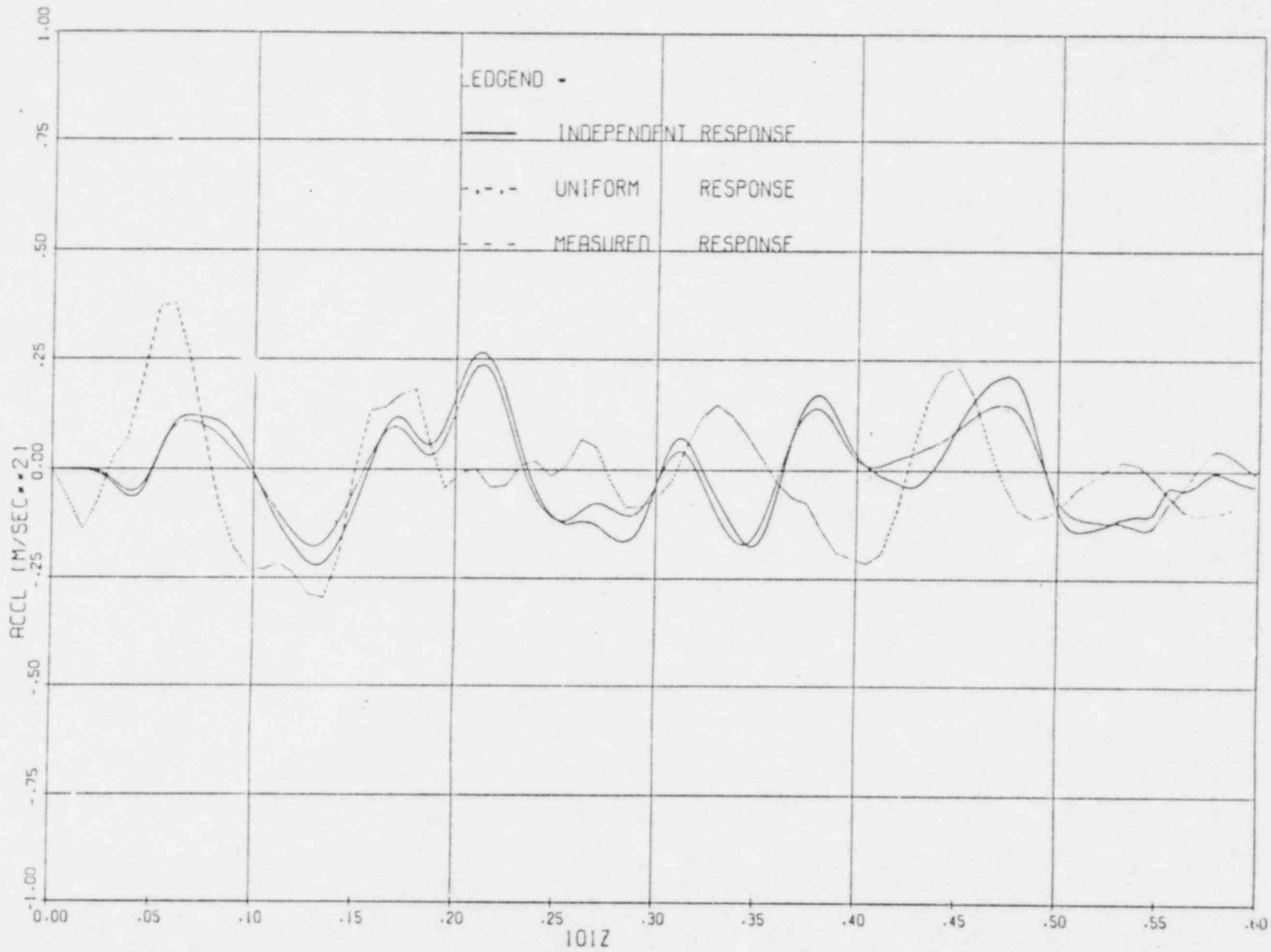


Figure 28 Absolute Acceleration Response

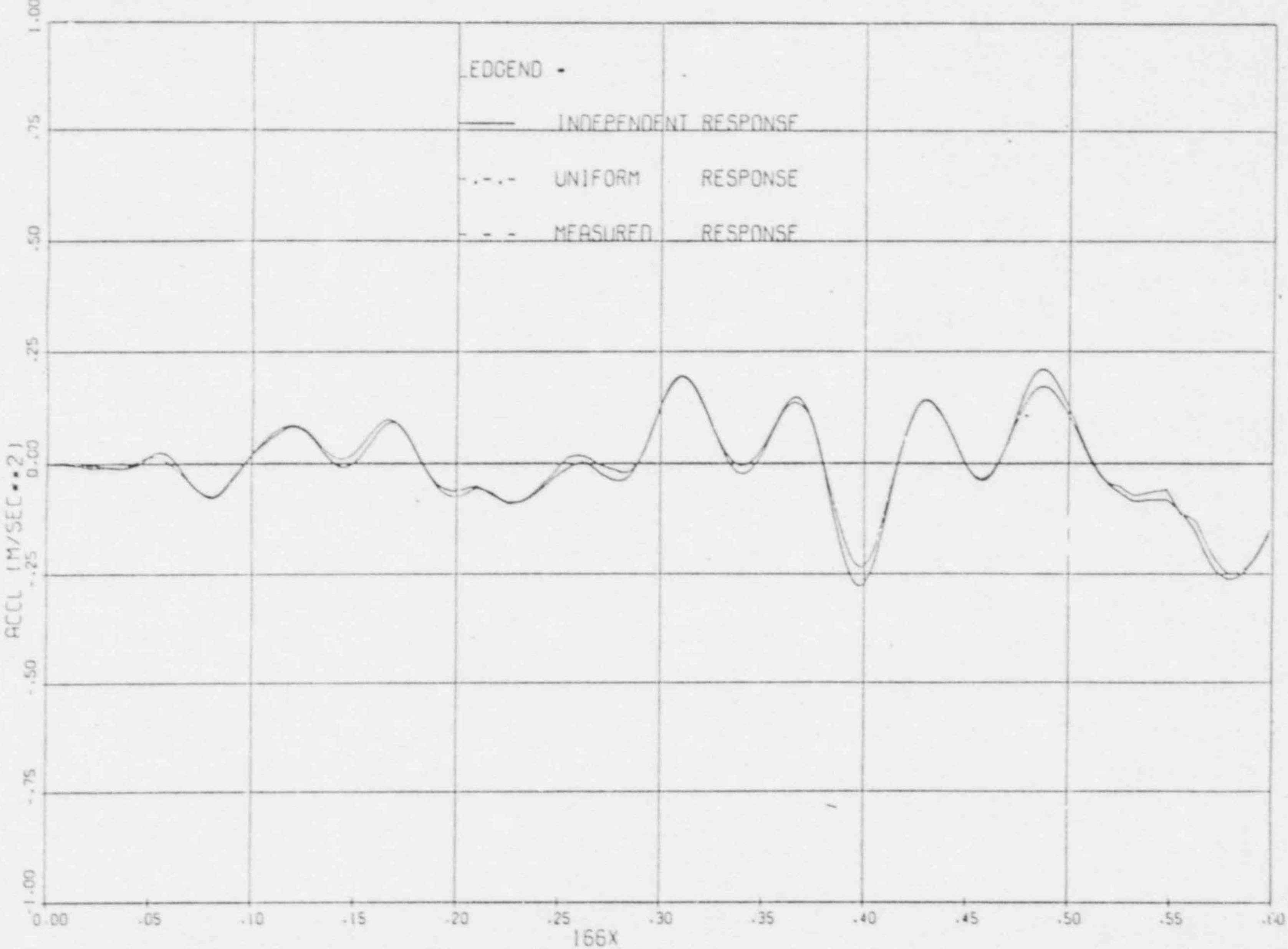


Figure 29 Absolute Acce'eration Response

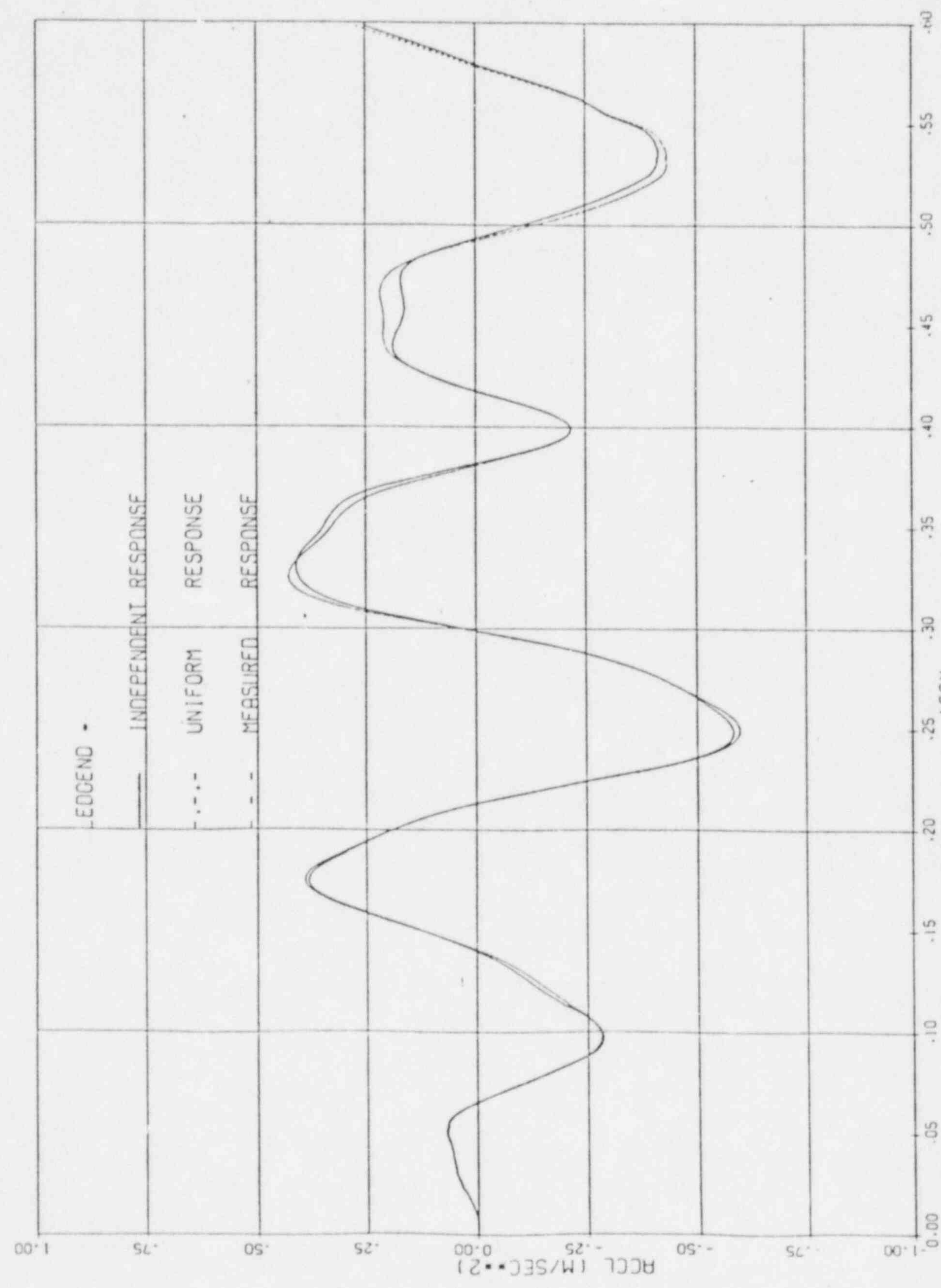


Figure 30 Absolute Acceleration Response

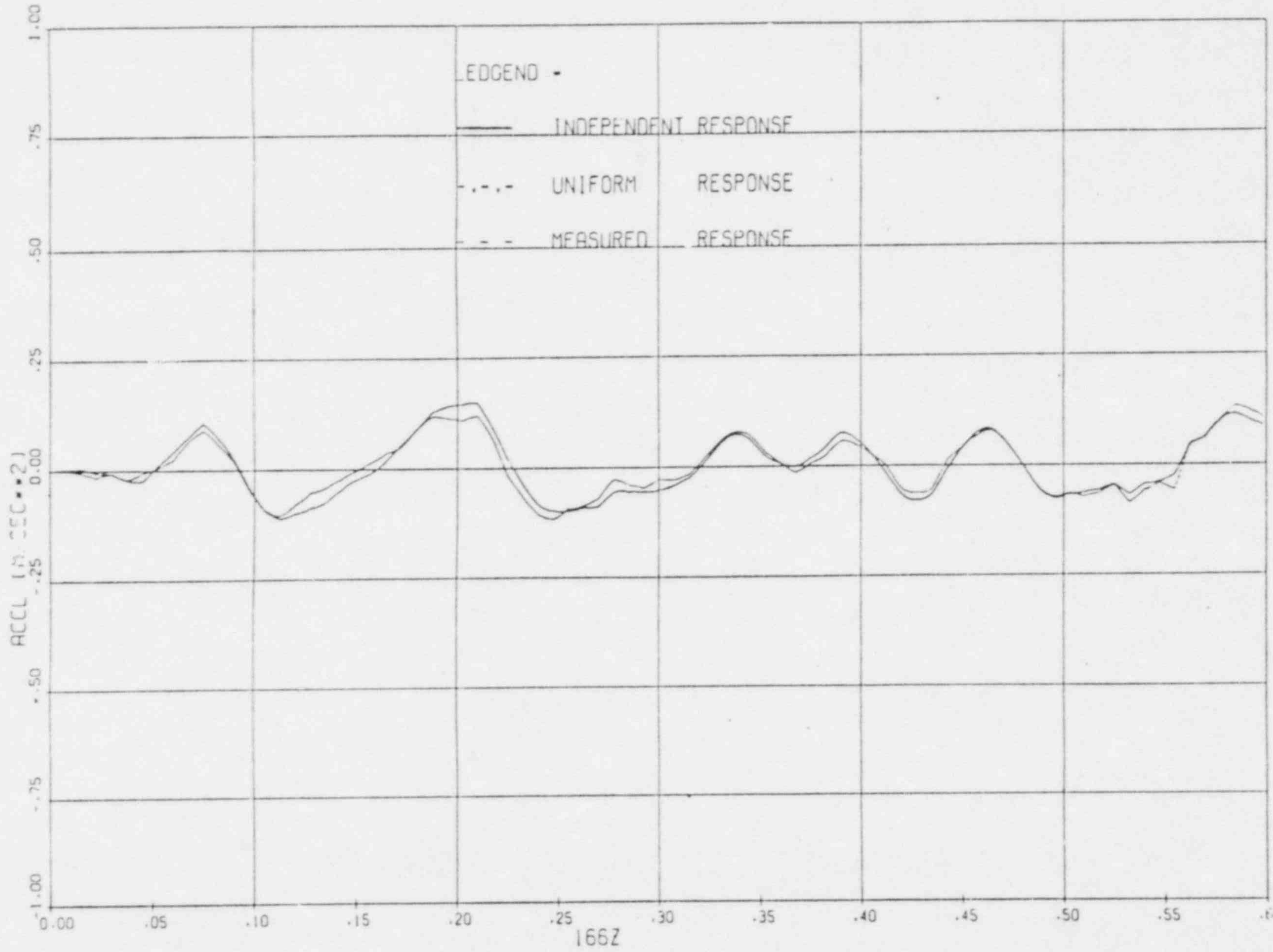
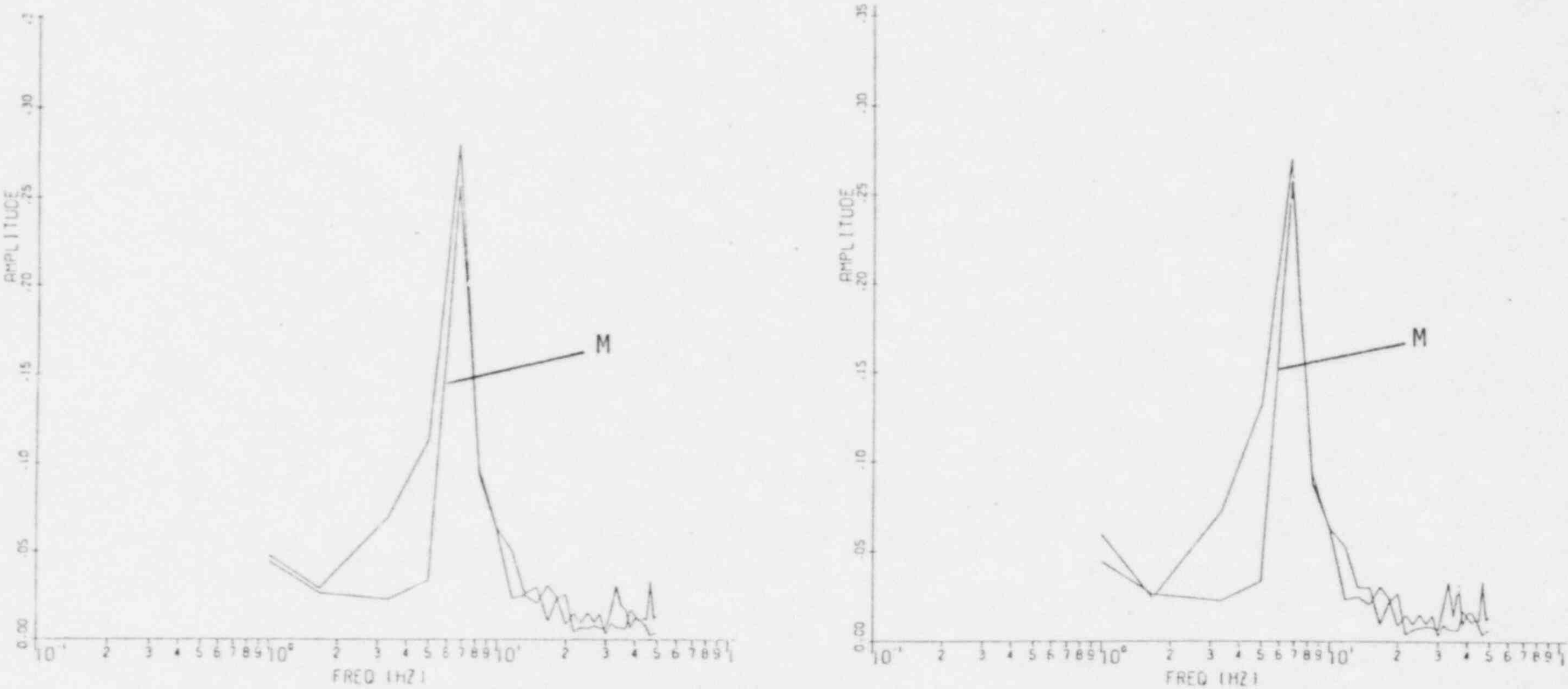


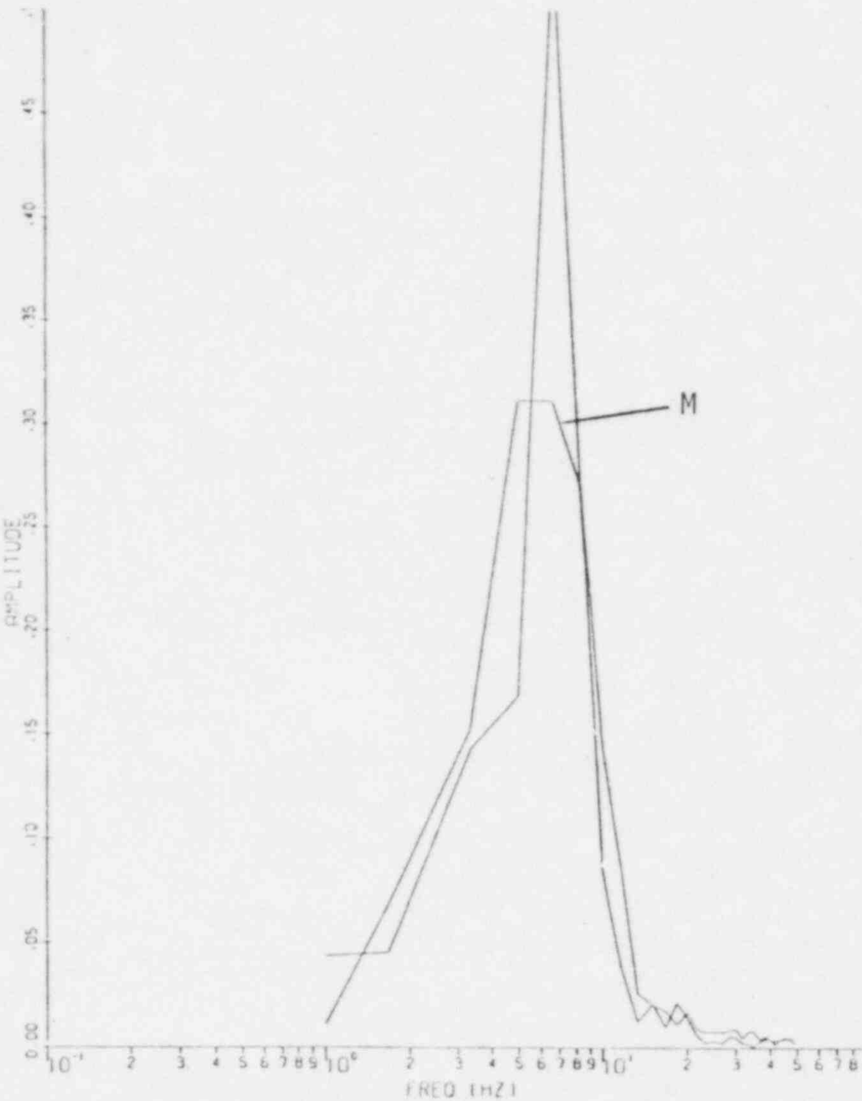
Figure 31 Absolute Acceleration Response



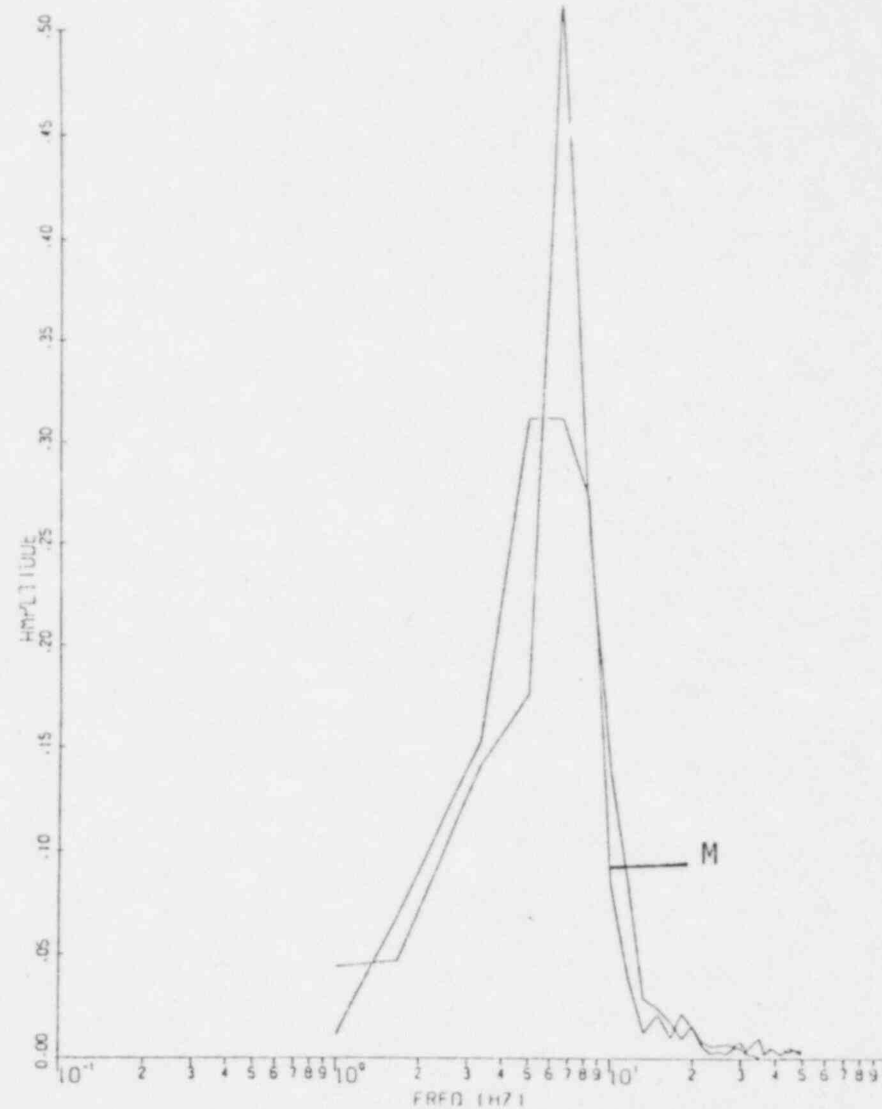
Uniform Excitation

Independent Excitation

Figure 32. Fourier Spectra for 36X



Uniform Excitation



Independent Excitation

Figure 33. Fourier Spectra for 36Y

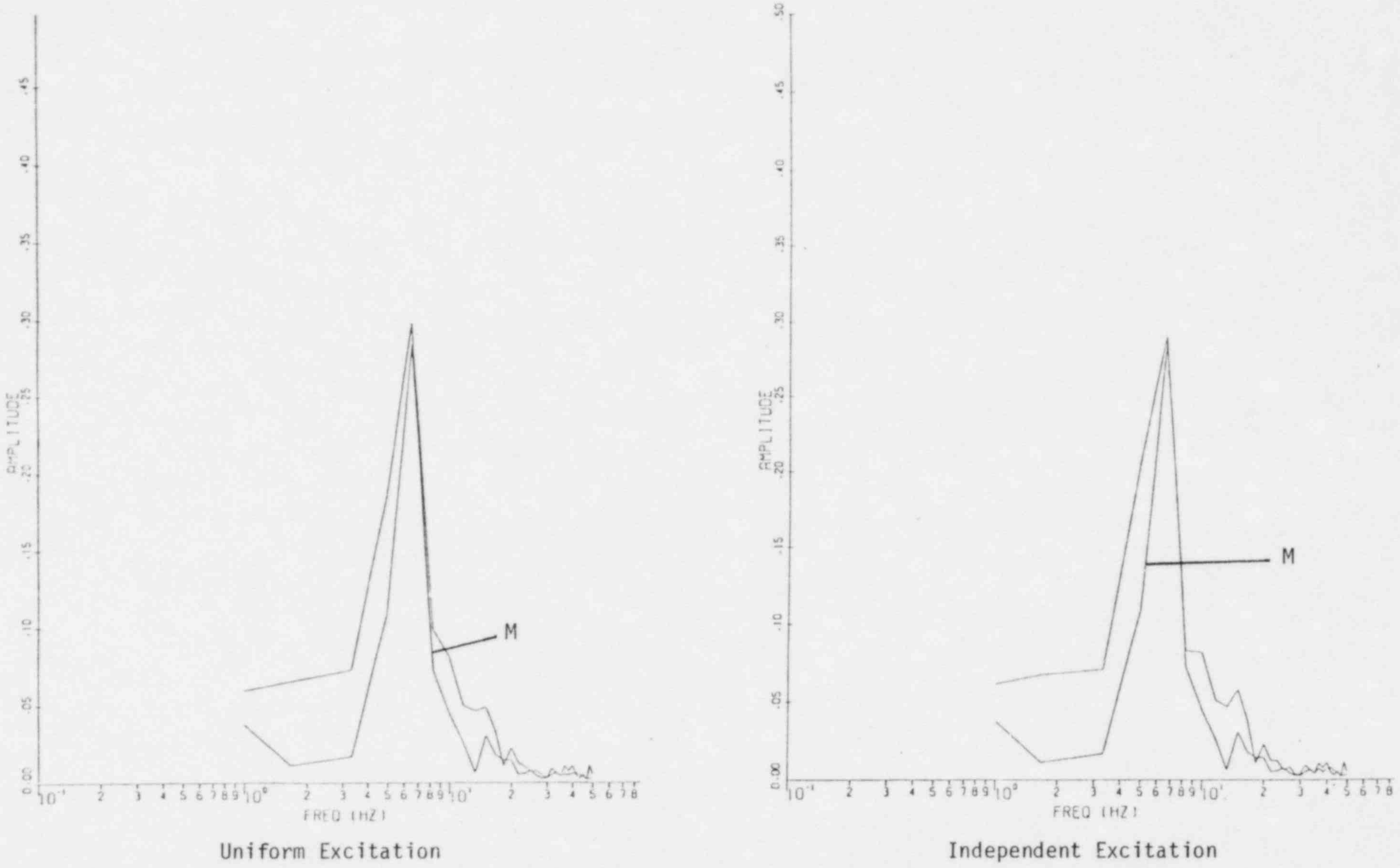
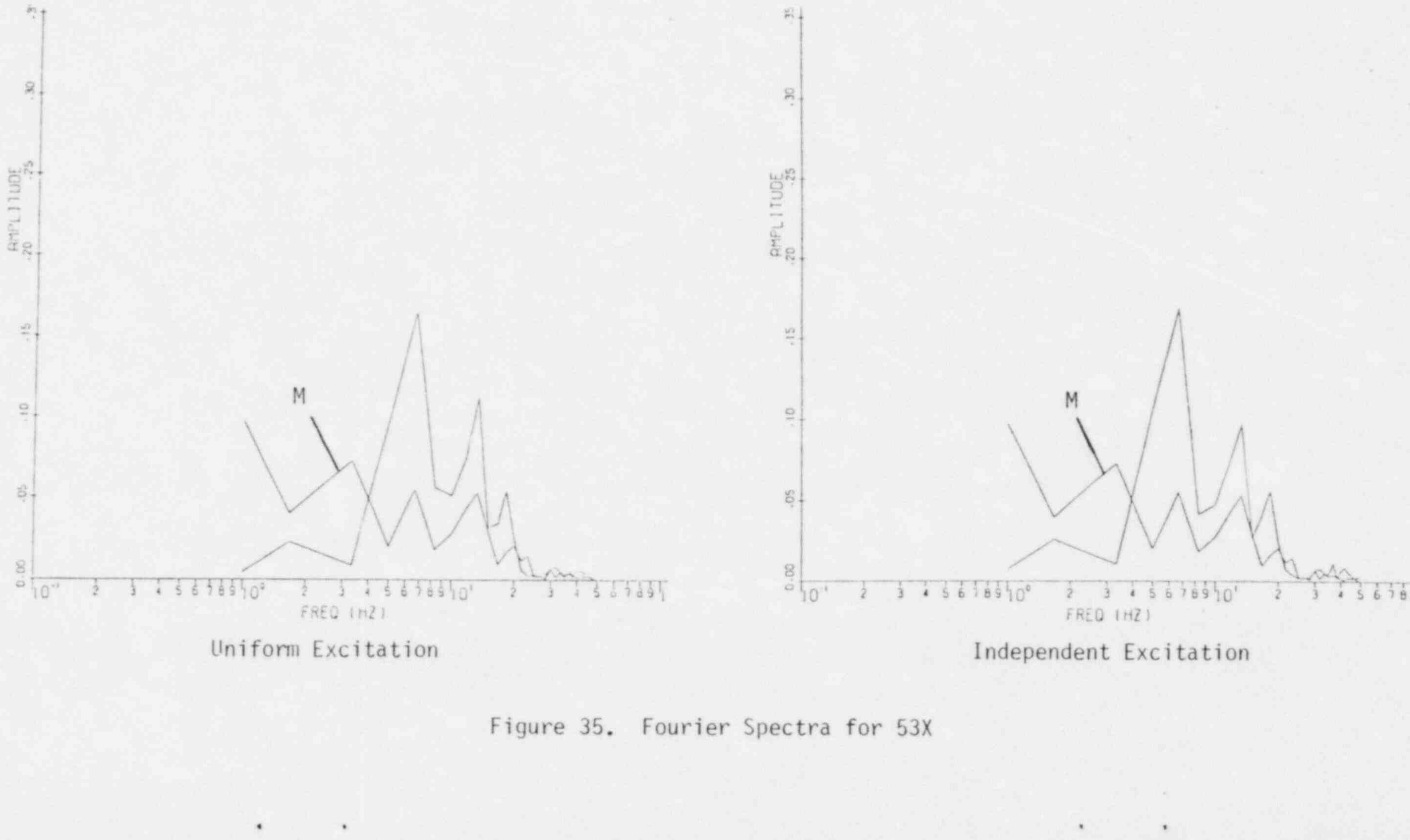


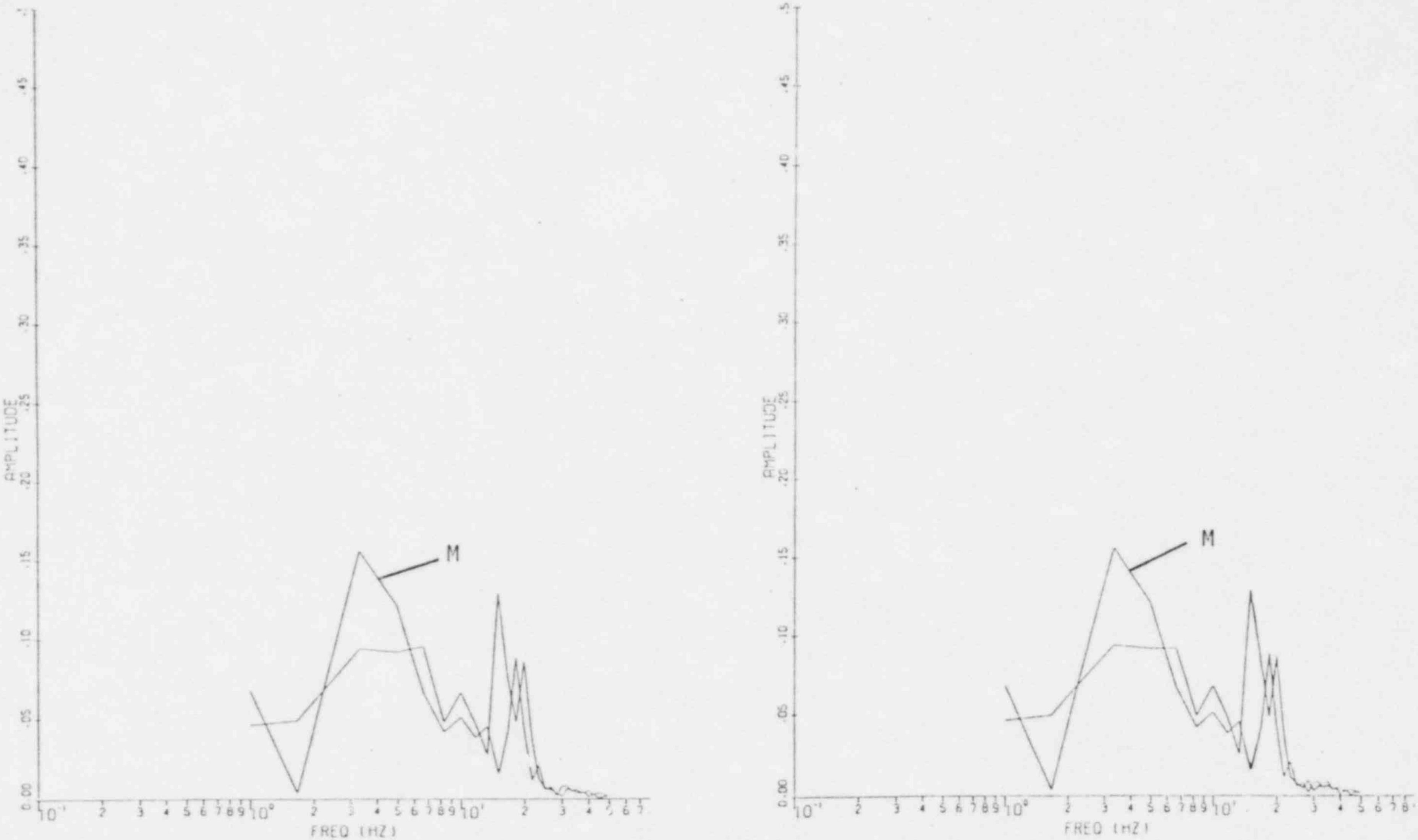
Figure 34. Fourier Spectra for 36Z



Uniform Excitation

Independent Excitation

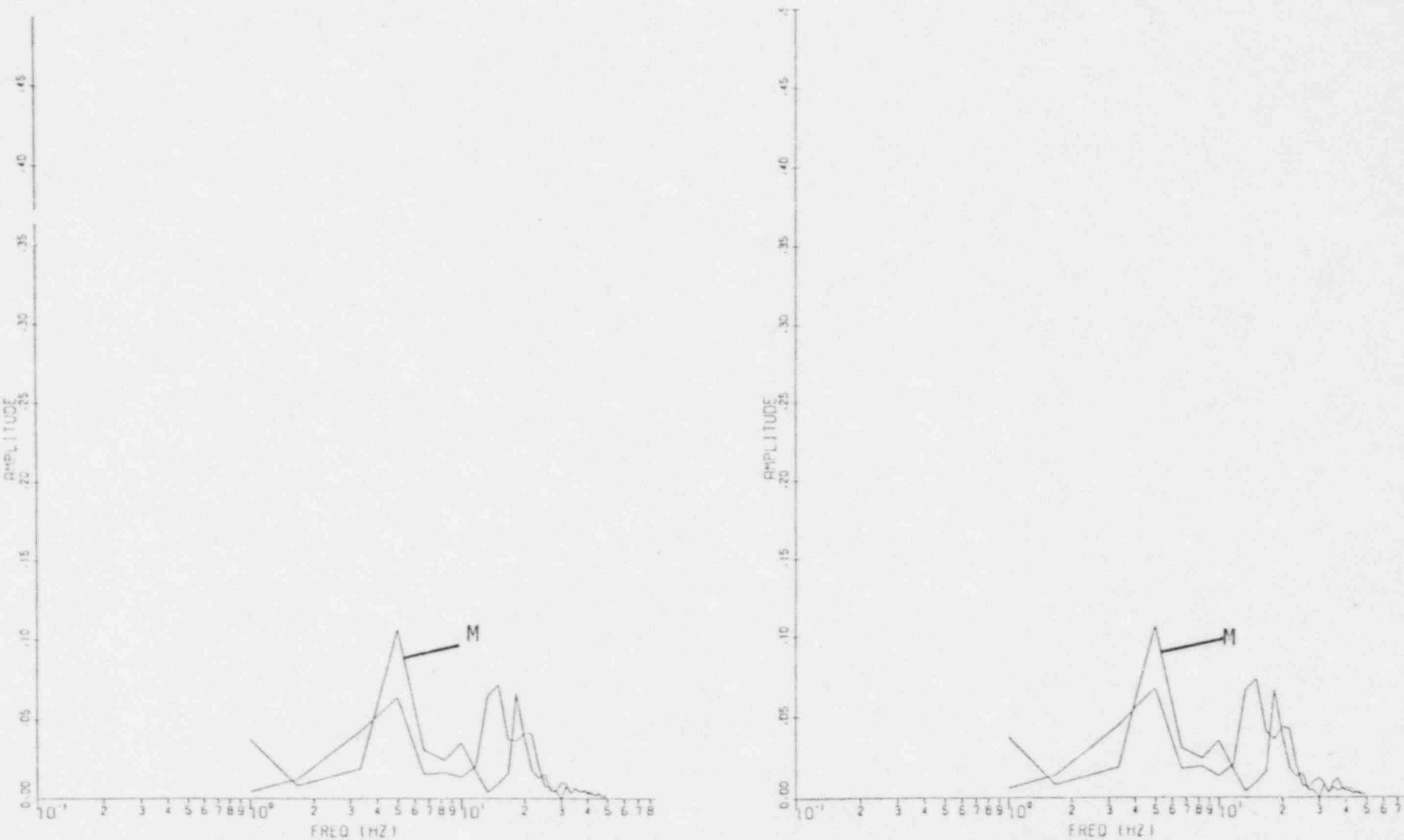
Figure 35. Fourier Spectra for 53X



Uniform Excitation

Independent Excitation

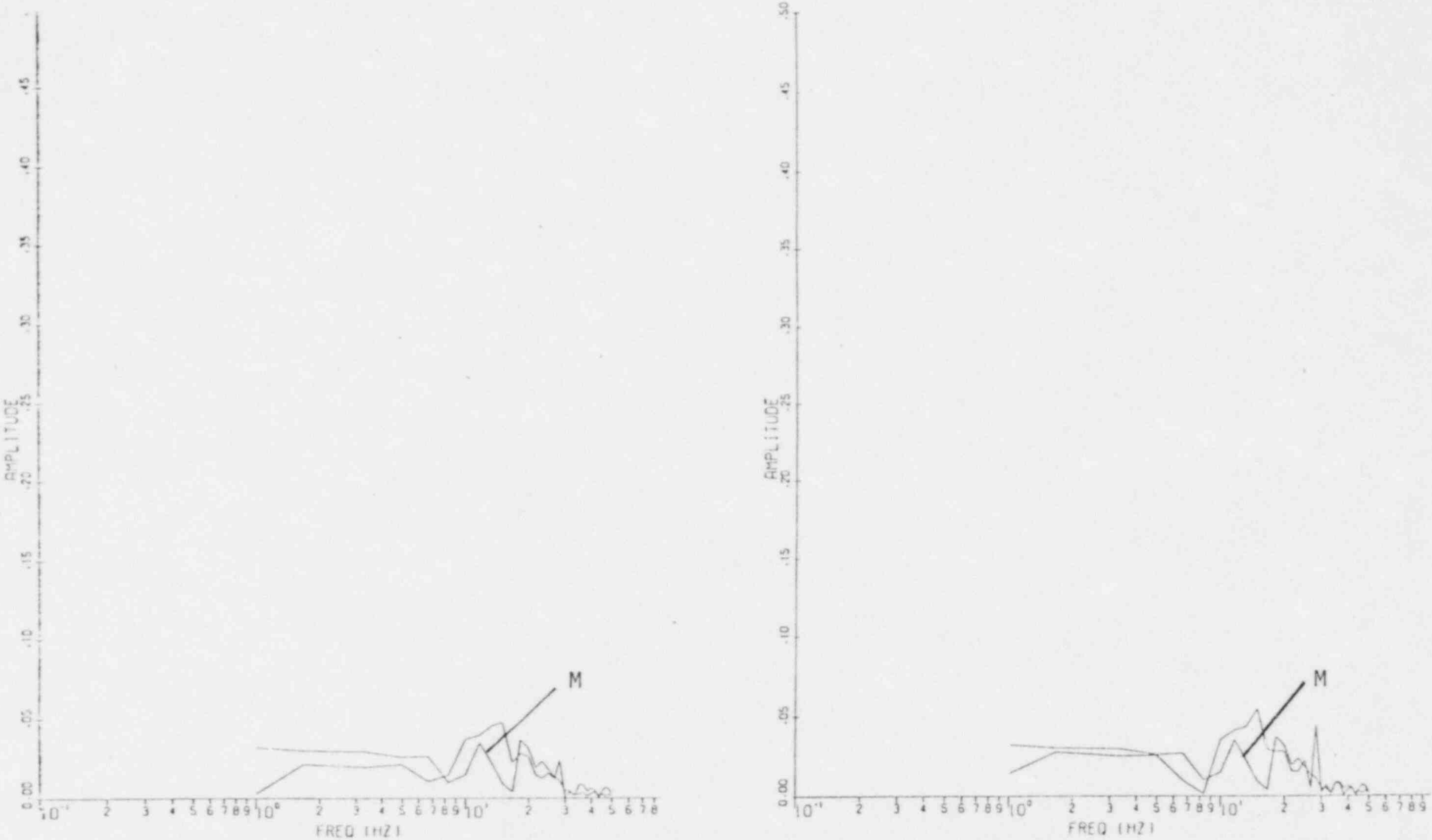
Figure 36. Fourier Spectra for 53Y



Uniform Excitation

Independent Excitation

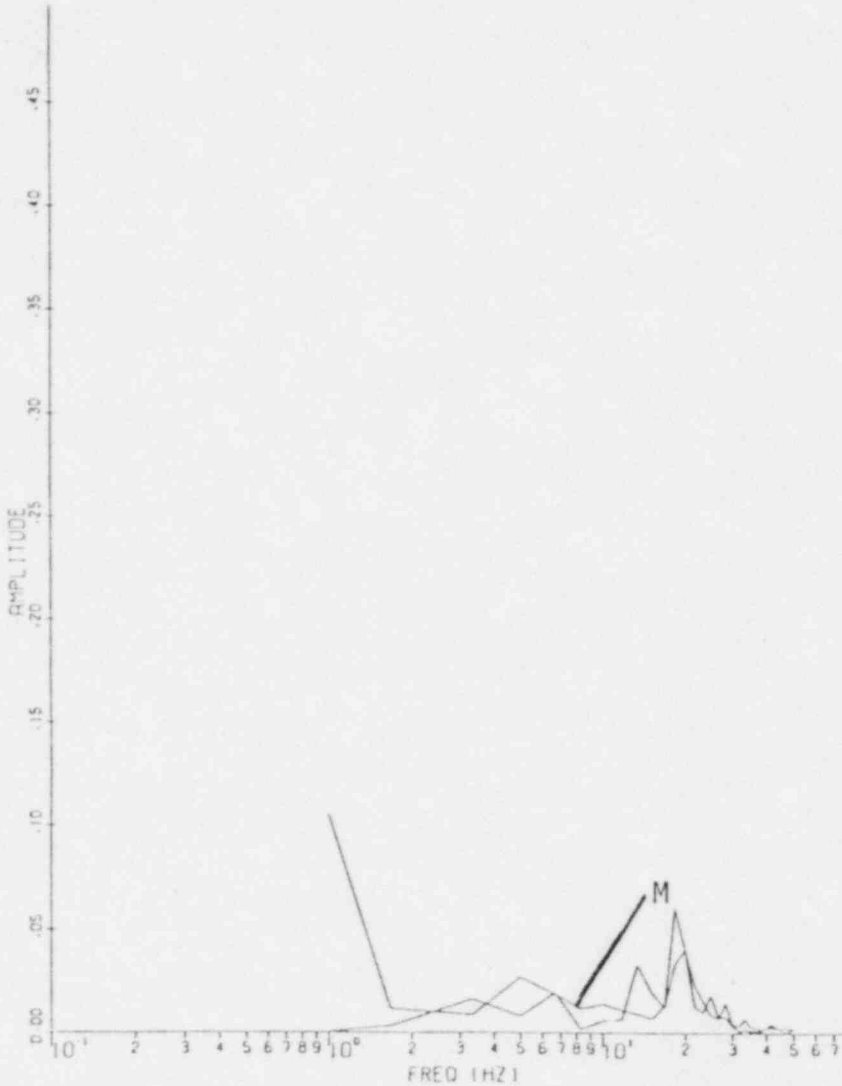
Figure 37. Fourier Spectra for 53Z



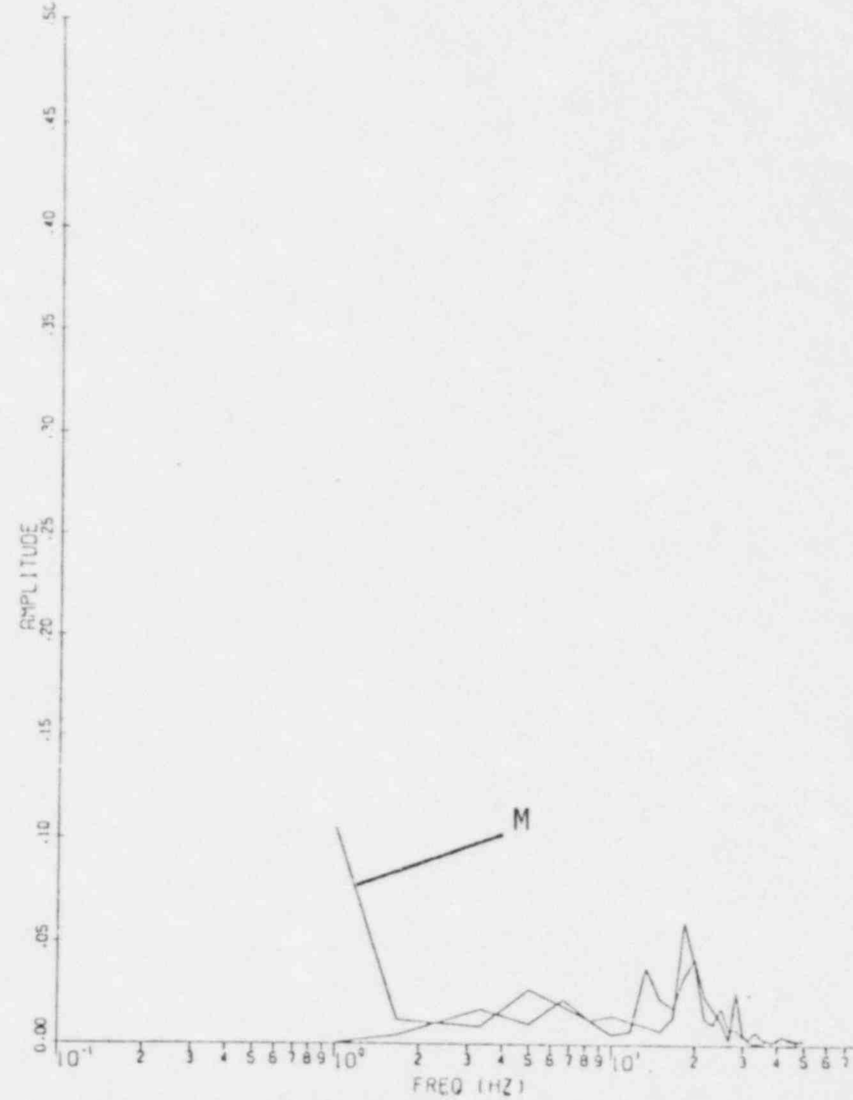
Uniform Excitation

Independent Excitation

Figure 38. Fourier Spectra for 58X

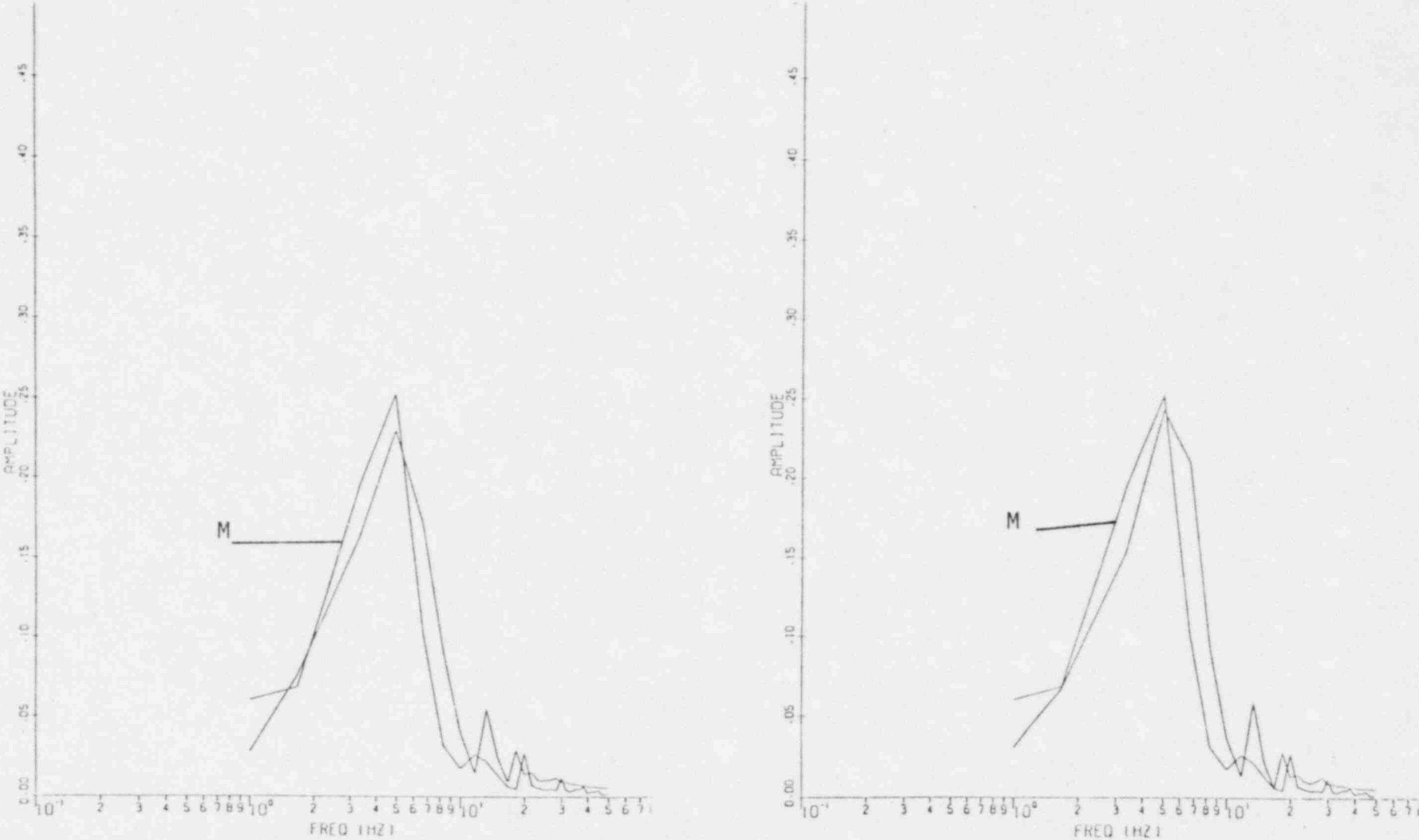


Uniform Excitation



Independent Excitation

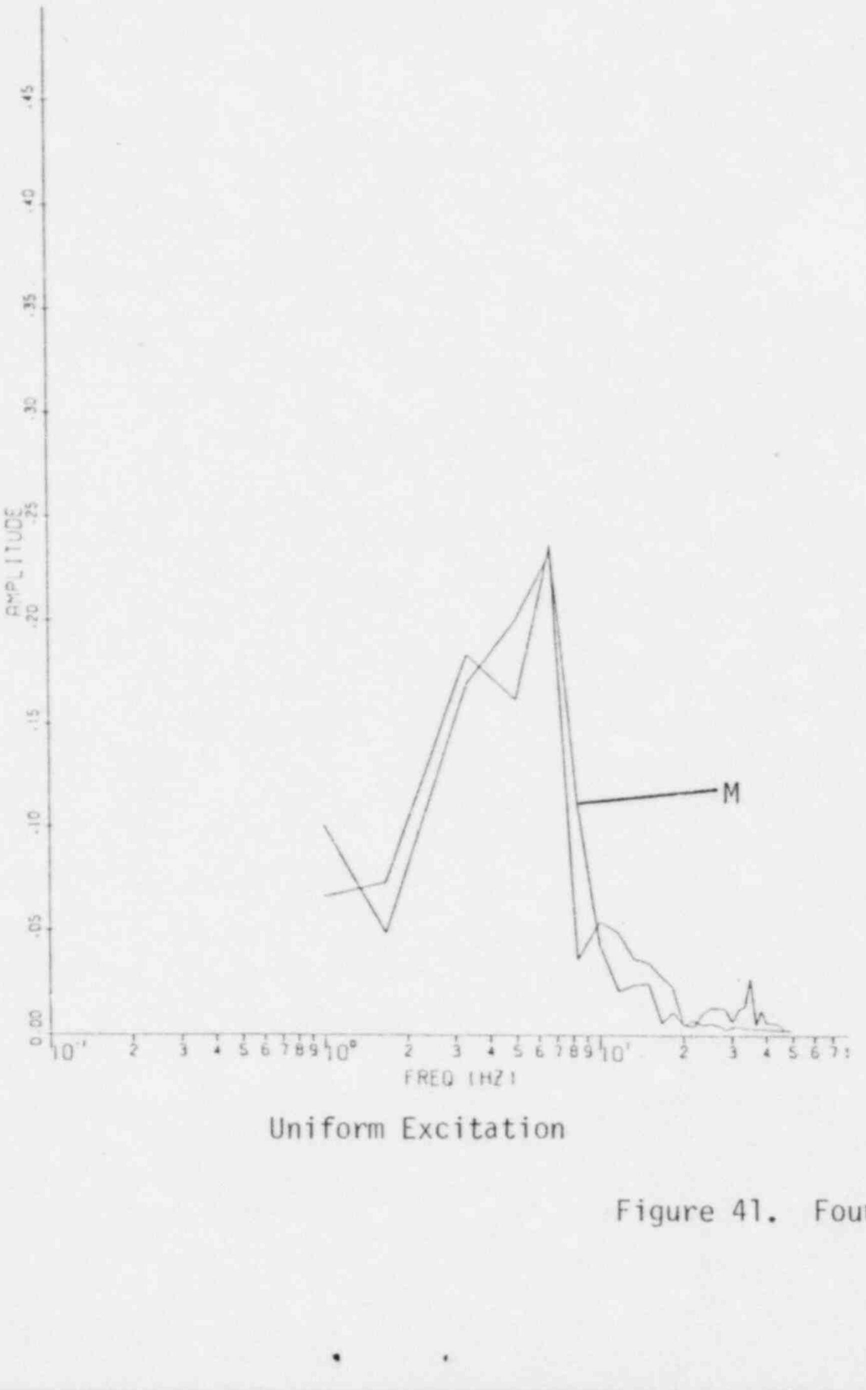
Figure 39. Fourier Spectra for 58Z



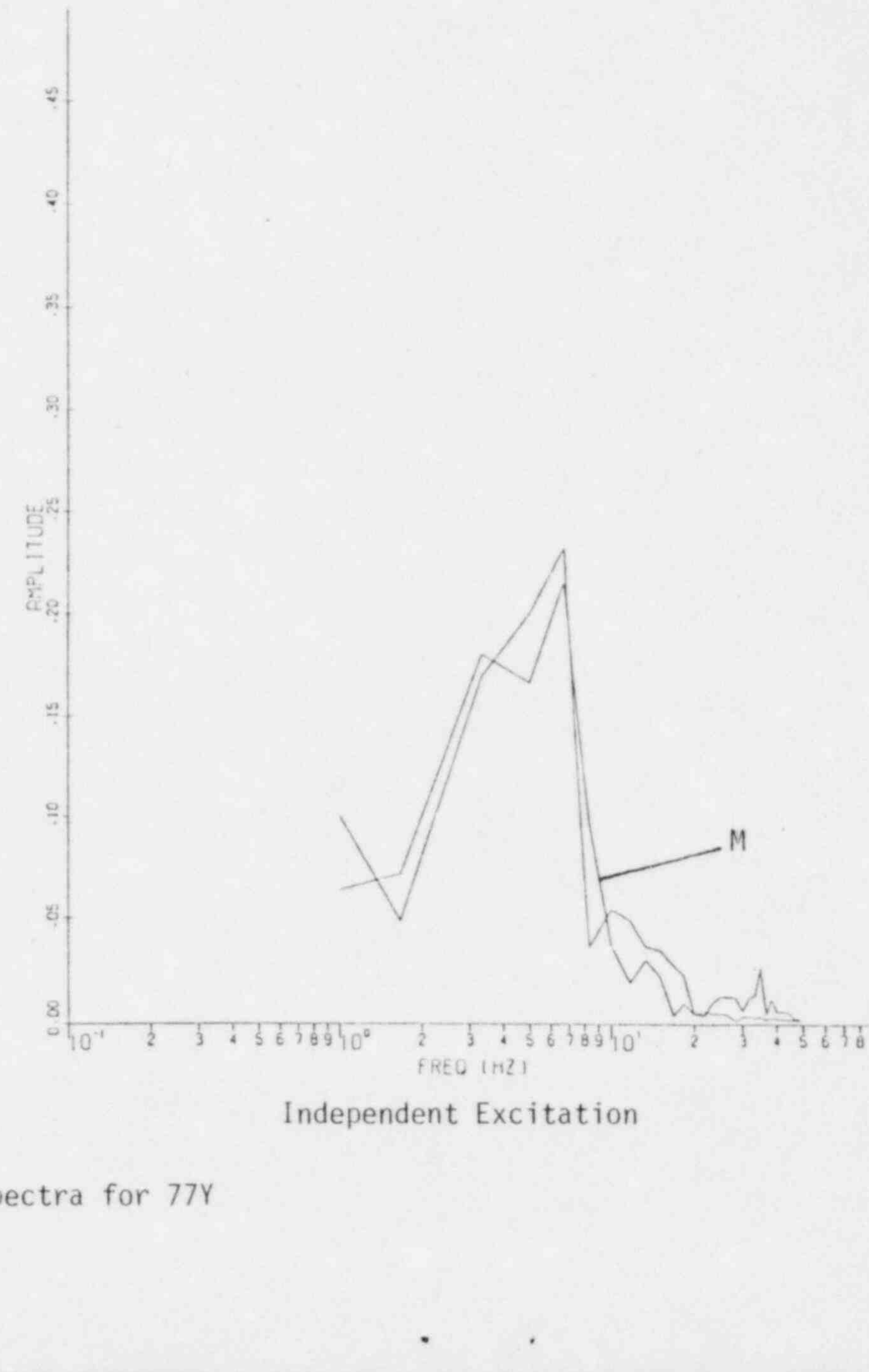
Uniform Excitation

Independent Excitation

Figure 40. Fourier Spectra for 77X

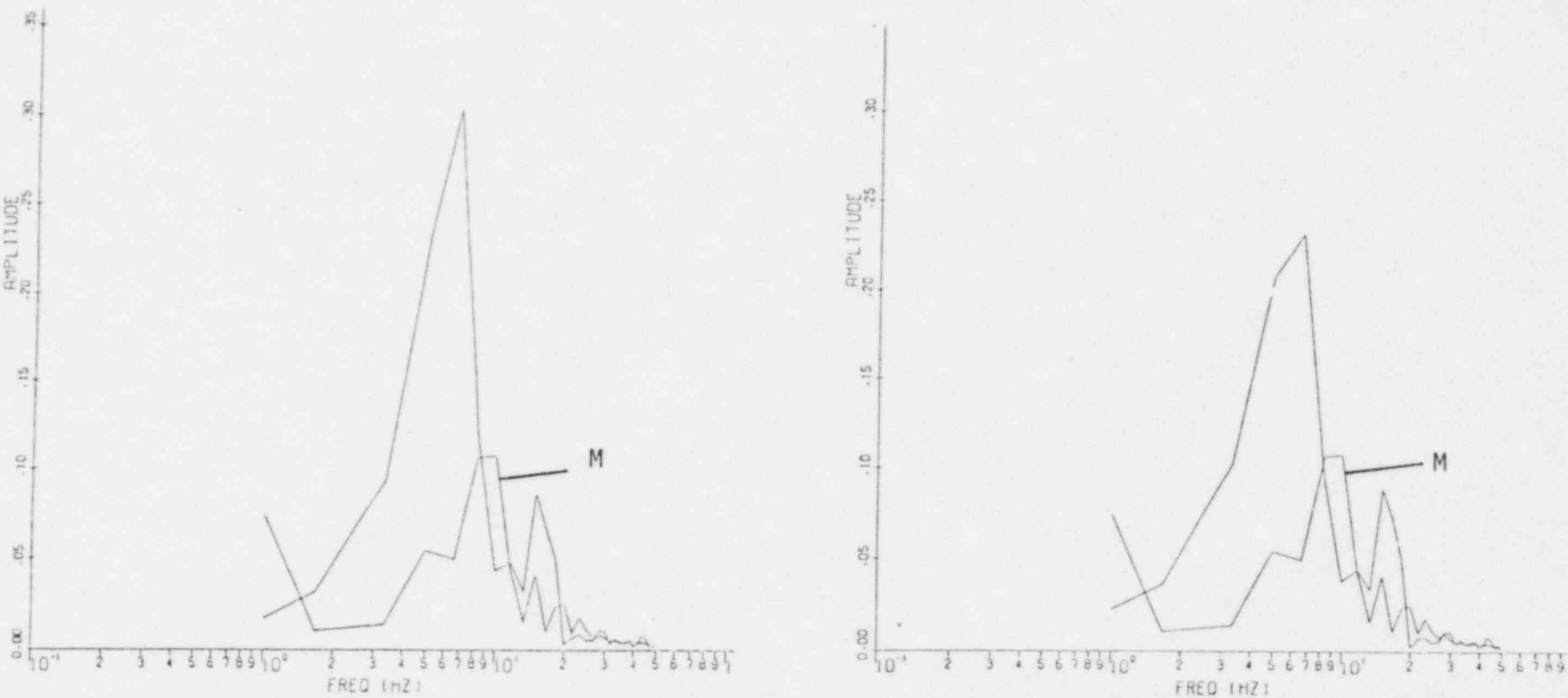


Uniform Excitation



Independent Excitation

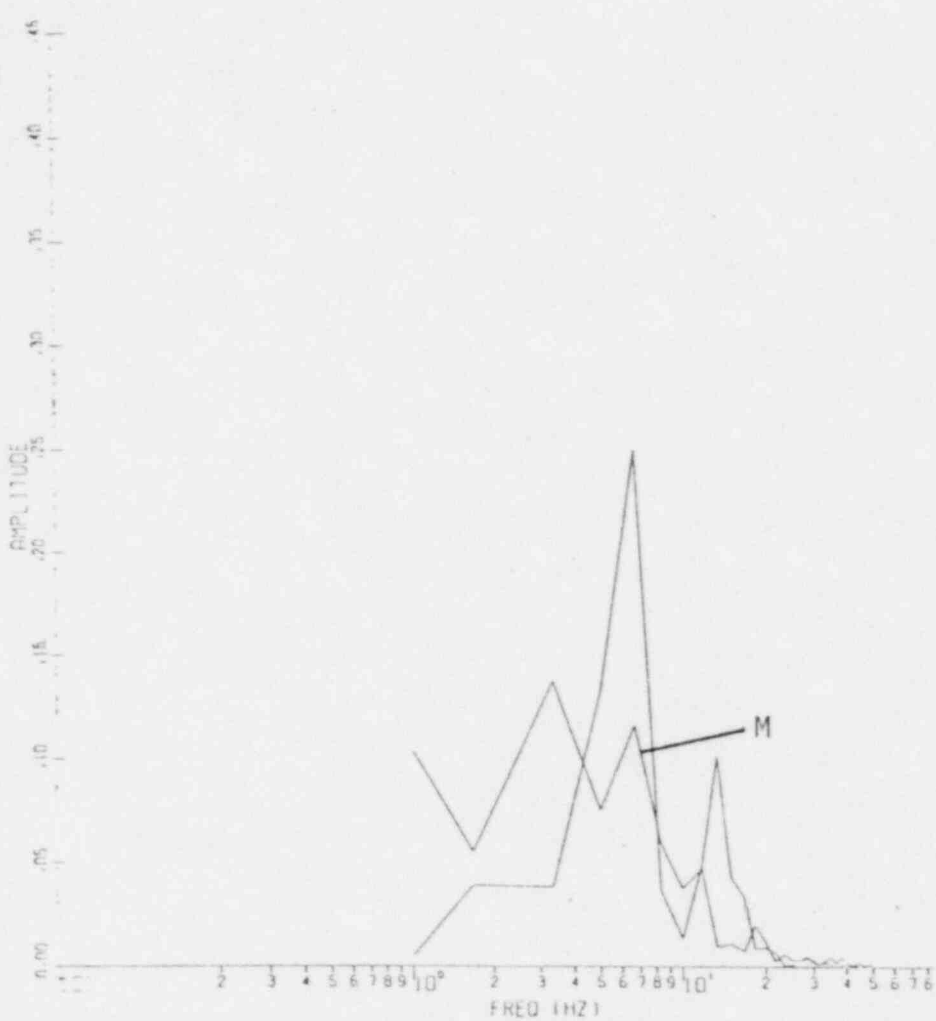
Figure 41. Fourier Spectra for 77Y



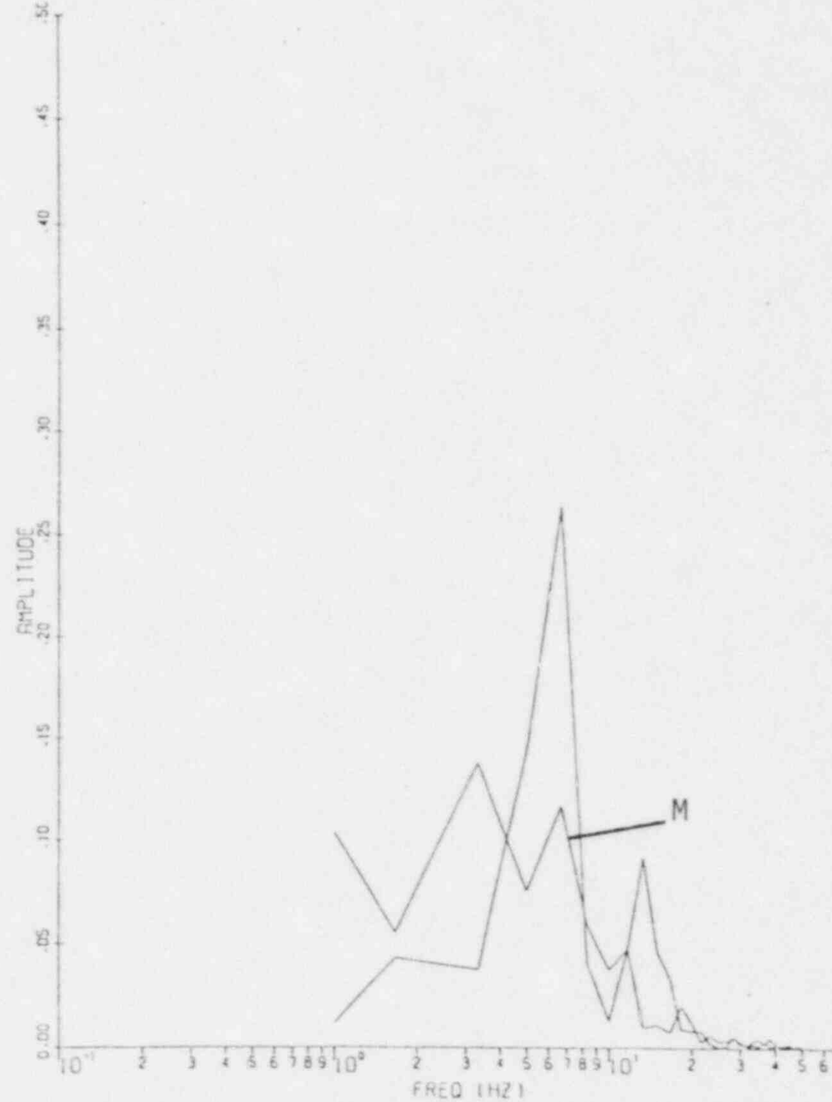
Uniform Excitation

Independent Excitation

Figure 42. Fourier Spectra for 77Z

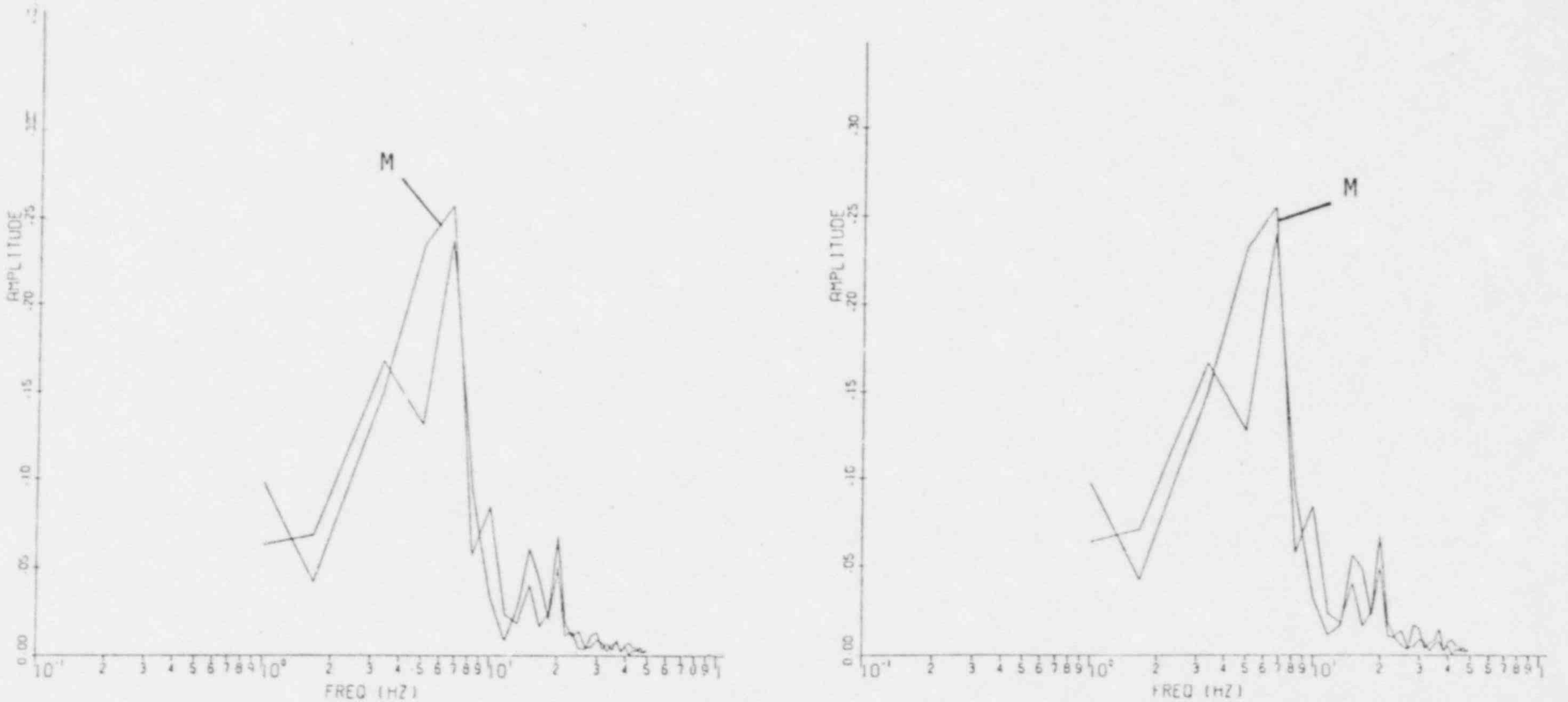


Uniform Excitation



Independent Excitation

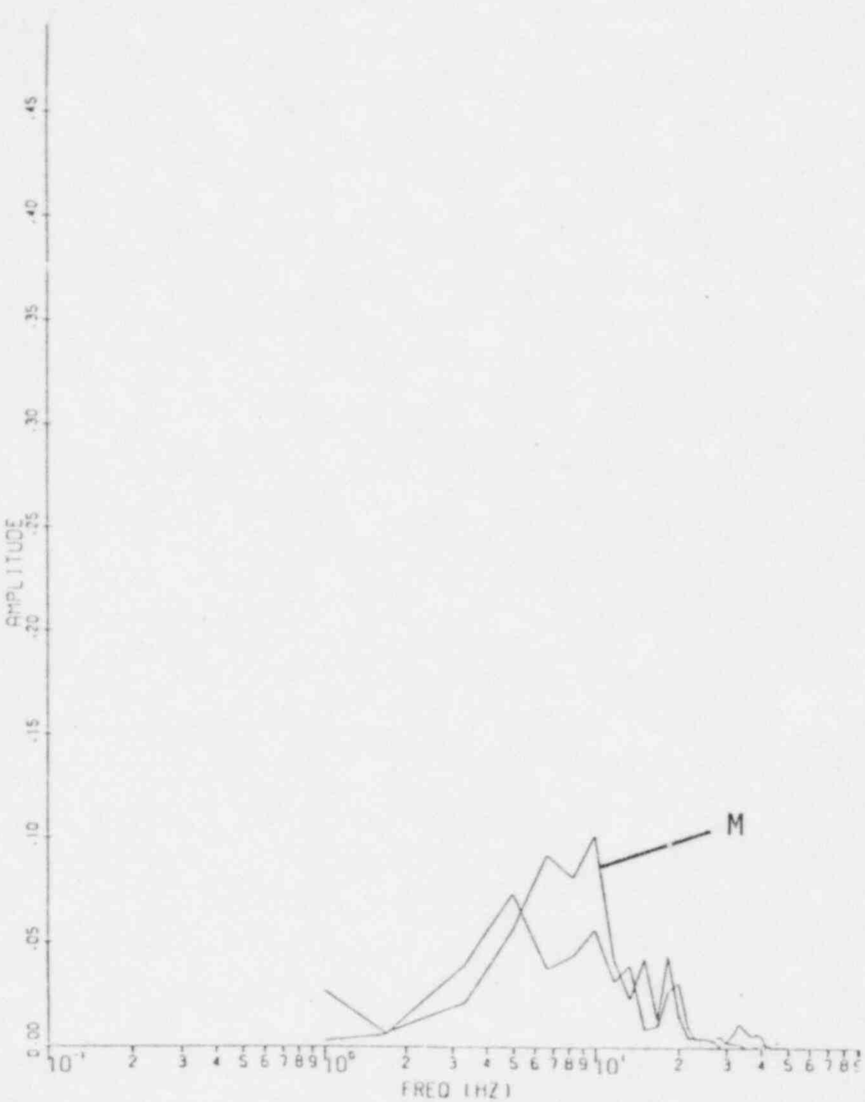
Figure 43. Fourier Spe tra for 101X



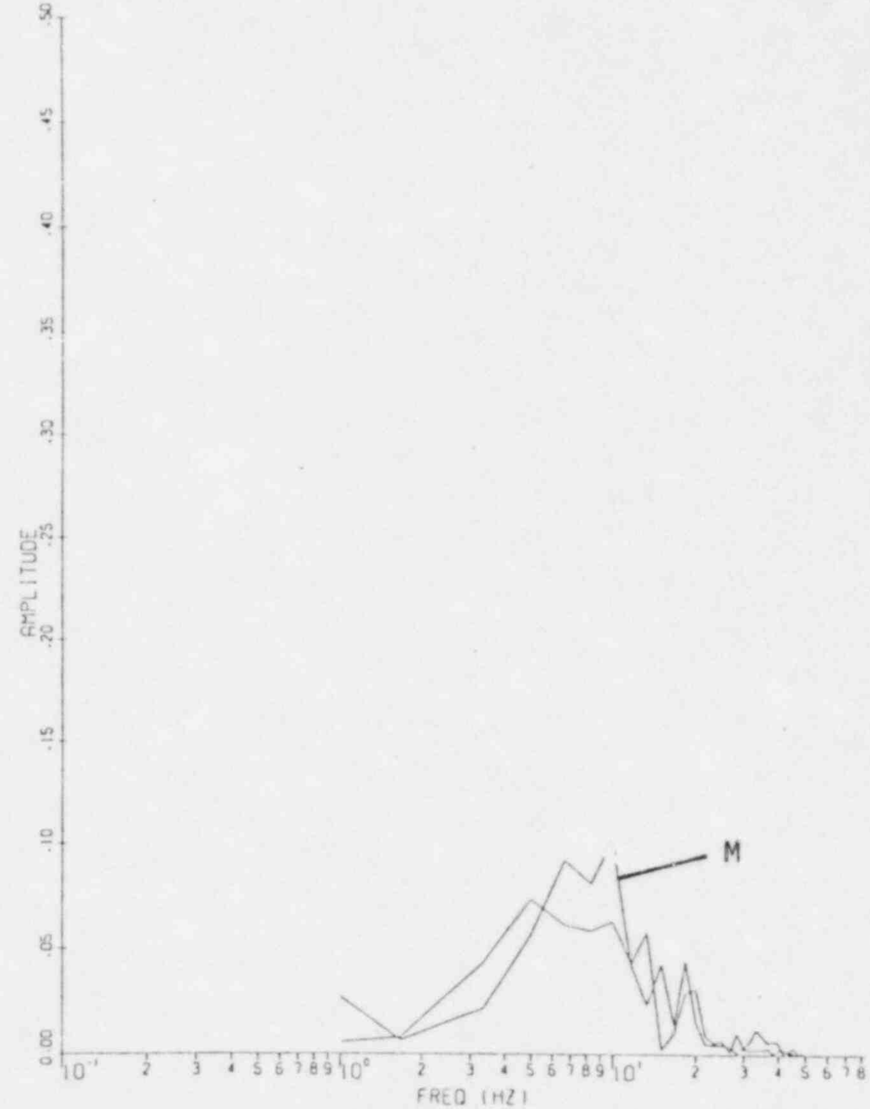
Uniform Excitation

Independent Excitation

Figure 44. Fourier Spectra for 101Y



Uniform Excitation



Independent Excitation

Figure 45. Fourier Spectra for 101Z

DISCUSSION OF RESULTS

Considering the response plots the following general observations can be made. For all cases the response predicted for independent support excitation almost coincides with the response predicted for uniform support 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 is apparent. For point 36 the computed and measured response 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.

It was mentioned that separate computations had been made to predict the relative acceleration components for the URL. The predicted relative acceleration data exhibited the same characteristics as the absolute acceleration data presented herein. All the observations stated above based on the absolute acceleration data apply as well to the relative acceleration data. A complete presentation of the predicted relative acceleration data is provided in the BNL Quarterly Progress Report, NUREG/CR-2331, Vol. 2, 1982.

Referring to the Fourier Spectra plots, the frequency content of the predicted and measured responses are quite similar for approximately 2/3 of the points compared, see points 36X and 101Y. For the remaining points the correspondence is relatively poor with shifts in both magnitude and dominant frequency evident. This level of correspondence applies equally as well to the results predicted with independent support excitation and uniform support excitation. On the whole, the correspondence between the Fourier Spectra plots seems better than the correspondence between the acceleration plots.

Table 2 presents a qualitative summary of results for all the points considered in the evaluation. In the table the relative correspondence between the phase, amplitude and fourier content of the predicted response and the measured response is indicated. As can be seen the results for points 36, 77 and 101Y are good while for the remaining points the results are poor. Point

Table 2

	Phase	Amplitude	Fourier Spectra
36 X	good	good	good
Y	fair	poor	poor
Z	good	good	good
53 X	poor	poor	poor
Y	poor	poor	fair
Z	good	fair	fair
58 X	fair	fair	fair
Z	fair	fair	fair
77 X	good	good	good
Y	good	fair	good
Z	fair	poor	poor
101 X	fair	poor	poor
Y	good	fair	good
Z	fair	fair	fair

NOTE: No measured data available for 58Y, 166X, 166Y and 166Z.

77 is a supported point while point 101 is adjacent to vertically supported points. The good results for these points seems to coincide with their close proximity to the sites of input excitation. Points 53 and 58 are located at distances from supports and show poor results, supporting the statement above. The results for point 36 however are at odds with this apparent trend. This point is located at a distance from supports and yet shows good results. In summary the correspondence of predicted and measured results seems to improve as the point of comparison approaches a site of input excitation. However, this observation is based on a very limited amount of data and cannot be stated as a firm conclusion.

As can be observed, the response predicted for independent support excitation almost coincides with the response predicted for uniform support excitation. This may seem improbable, however, if comparison is made between the uniform and independent input acceleration data it will be noted that the individual group excitations do not differ appreciably from each other or from the uniform excitation data. In such a case it would be expected that the uniform support excitation solution would not differ greatly from that predicted with independent support excitation.

Comparisons were made between the BNL PSAFE2 results and those presented in pertinent EG&G reports and EG&G supplied computer outputs. The findings may be summarized as:

1. The natural frequencies predicted with PSAFE2 match those developed by EG&G with the NUPIPE II code.

2. The relative accelerations predicted with PSAFE2 for uniform support excitation match those predicted with the NUPIPE II code.

3. The absolute accelerations predicted with PSAFE2, for either uniform support excitation or independent support excitation agree well with those predicted with the ANSYS code as presented in NUREG/CR-2463.

4. The absolute accelerations predicted with PSAFE2 do not agree with those predicted with NUPIPE II as presented in NUREG/CR-2463.

The lack of agreement between the PSFAE2 and NUPIPE II results for the absolute acceleration components seems to be related to the phasing of the relative acceleration component to the input acceleration component. If the PSAFE2 results for the relative acceleration component are shifted 180° in phase, that is subtracted from rather than added to, the input acceleration component the PSAFE2 and NUPIPE II results are similar. This aspect is receiving further consideration.

CONCLUSIONS

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 by EG&G 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.

REFERENCES

1. G. L. Thinnes, R. G. Rahl, "Experimental and Analytical Results of Blast Induced Seismic Studies at HDR", NUREG/CR-2463, ECG-2158, November 1981.
2. W. B. Walton, G. H. Howard, B. Johnson, "German Standard Problem 4a", NUREG/CR-2390, November 1981.
3. D. P. Finicle, R. C. Guenzler, R. G. Rahl, "HDR Response-Experimental and Analytical", NUREG/CR-1913, EGG-EA-5261, February 1981.
4. M. Subudhi, P. Bezler, "PSAFE2-Piping Analysis Program - Version 1981", BNL report, July 1981.
5. M. Subudhi, P. Bezler, Y. K. Wang, M. Hartzman, "Seismic Analysis of Piping Systems Subjected to Independent Support Excitations by Using Response Spectrum and Time History Methods", BNL-NUREG-31296, April 1982.
6. "Safety Research Programs Sponsored by Office of Nuclear Regulatory Research - Quarterly Progress Report, Vol. 2, Nos. 1-4, NUREG/CR-2331, BNL-NUREG-51454, 1982.