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HDR Response - Experimental and Analytical

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ABSTRACT

NRC's Office of Nuclear Regulatory Research, Division of Reactor Safety Research has initiated a cooperative effort with the Federal Republic of Germany in the Heissdampfreaktor (HDR) testing program to study the response of nuclear power plant piping systems subjected to ground excitation. The HDR is a decommissioned reactor being used for structural and hydraulic reasearch.

EG&G Idaho is supporting the NRC by making "blind" predictions of the response of the HDR recirculation loop piping to explosive excitation of the HDR containment. Contained in this interim report are predictions using a nonlinear transient time history structural analysis. Input functions consisted of experimental accelerations supplied by ANCO Engineers of California.

Also included in this interim report are comparisons of the predictions with experimen[illegible]ata supplied after the predictions were made. Finally, this repor[illegible] a brief look at parameters which may improve the comparison and in[illegible]es the direction of future work.

SUMMARY

A nonlinear structural analysis of the HDR recirculation loop piping has been performed to predict the piping response to explosively generated ground excitations. This system was modeled on the computer program ANSYS and included the reactor vessel, two recirculation pumps, and the recirculation piping. Input consisted of uniform ground motion acceleration time histories in three orthogonal directions since the room was assumed to move as a rigid body with no rotational accelerations.

Results from ANSYS included acceleration histories at instrumented points on the piping and response spectra generated from the acceleration histories of these points. These spectra were compared to spectra generated from measured acceleration histories at the instrumented points. Parameters which may improve the correlations between measured and predicted response were enumerated and the effects of structural damping and support stiffness were investigated briefly. Sensitivity to the two parameters investigated is indicated by comparisons in the report.

This interim report presents the initial results and describes the current status of this NRC task. A final report will be developed upon completion of the task.

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FIGURES

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HDR RESPONSE--EXPERIMENTAL AND ANALYTICAL

I. INTRODUCTION

The Heissdampfreaktor (HDR) is a decommissioned superheated steam reactor located approximately 50 kilometers east of Frankfurt, West Germany, on the north shore of the Main River. This reactor was a 100 megawatt demonstration plant. The general layout of the plant area is shown on Figure 1. HDR is tied to an auxiliary building containing offices and the reactor control room. Weak coupling exists between the buildings through interconnecting passageways and the foundation. An operating nuclear plant called VAK is approximately 100 meters from HDR. This is a 15-megawatt plant and has been operating for nearly 25 years. VAK is an important limiting factor in the magnitude of seismic testing being allowed on the HDR facility.

The HDR safety program is divided into six component categories as shown on Figure 2. The area of EG&G's investigation was the recirculation piping. Four types of experiments were performed on the facility. These included excitation of containment with mechanical shakers and by attaching rocket engines to the containment, snapback testing of components in the containment, and blast testing with explosive charges detonated in the ground near the containment.

Blast testing consisted of a series of tests originally scheduled to use up to 50 kilograms of high explosives detonated at a distance of 31 meters from the reactor vessel centerline. Because of concerns for the VAK reactor, the maximum scheduled test was reduced. Tests started with a 2.5-kilogram charge as planned but were halted at the 5-kilogram level because of high acceleration measurements at VAK.

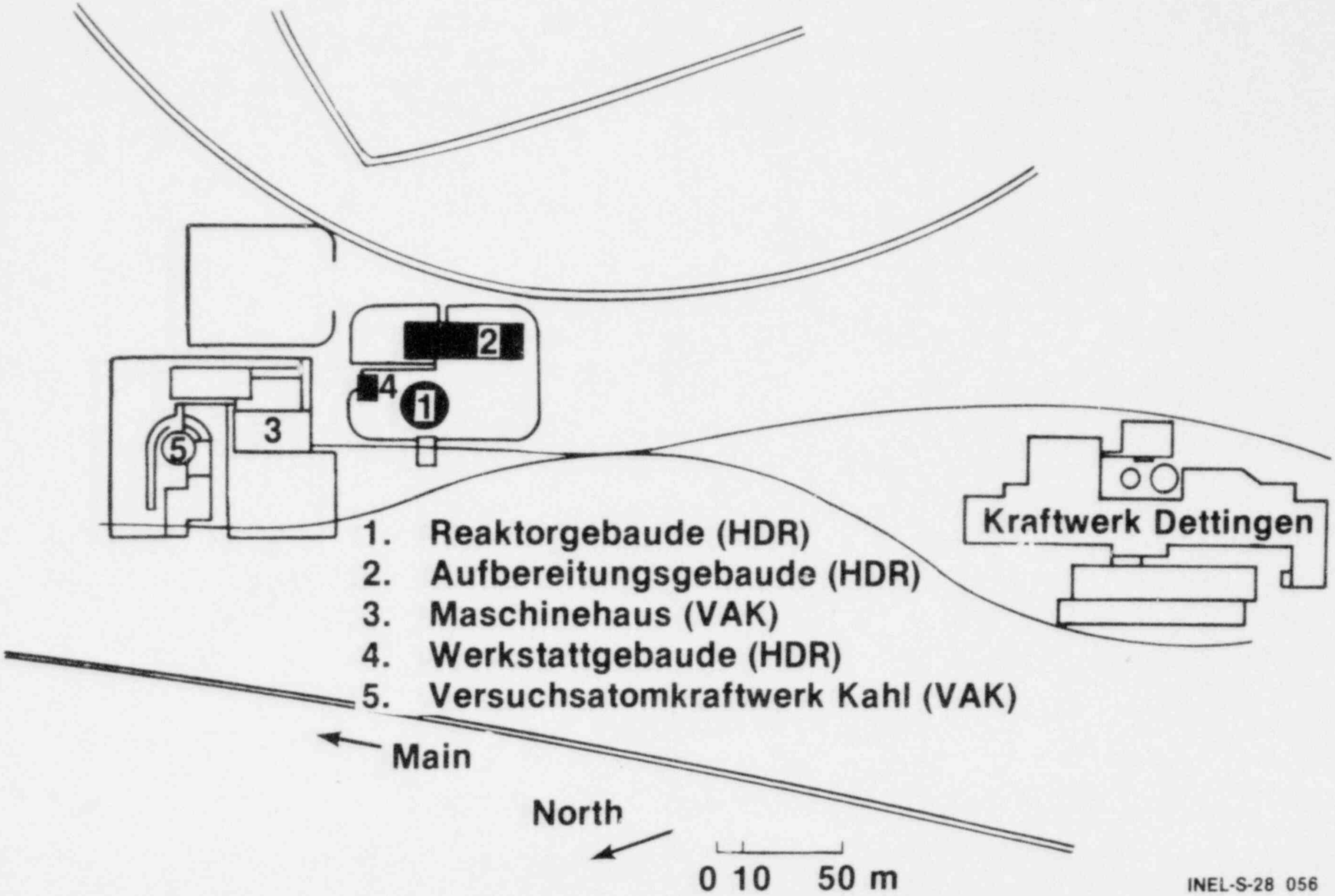

Figure 1. Plot Plan of HDR

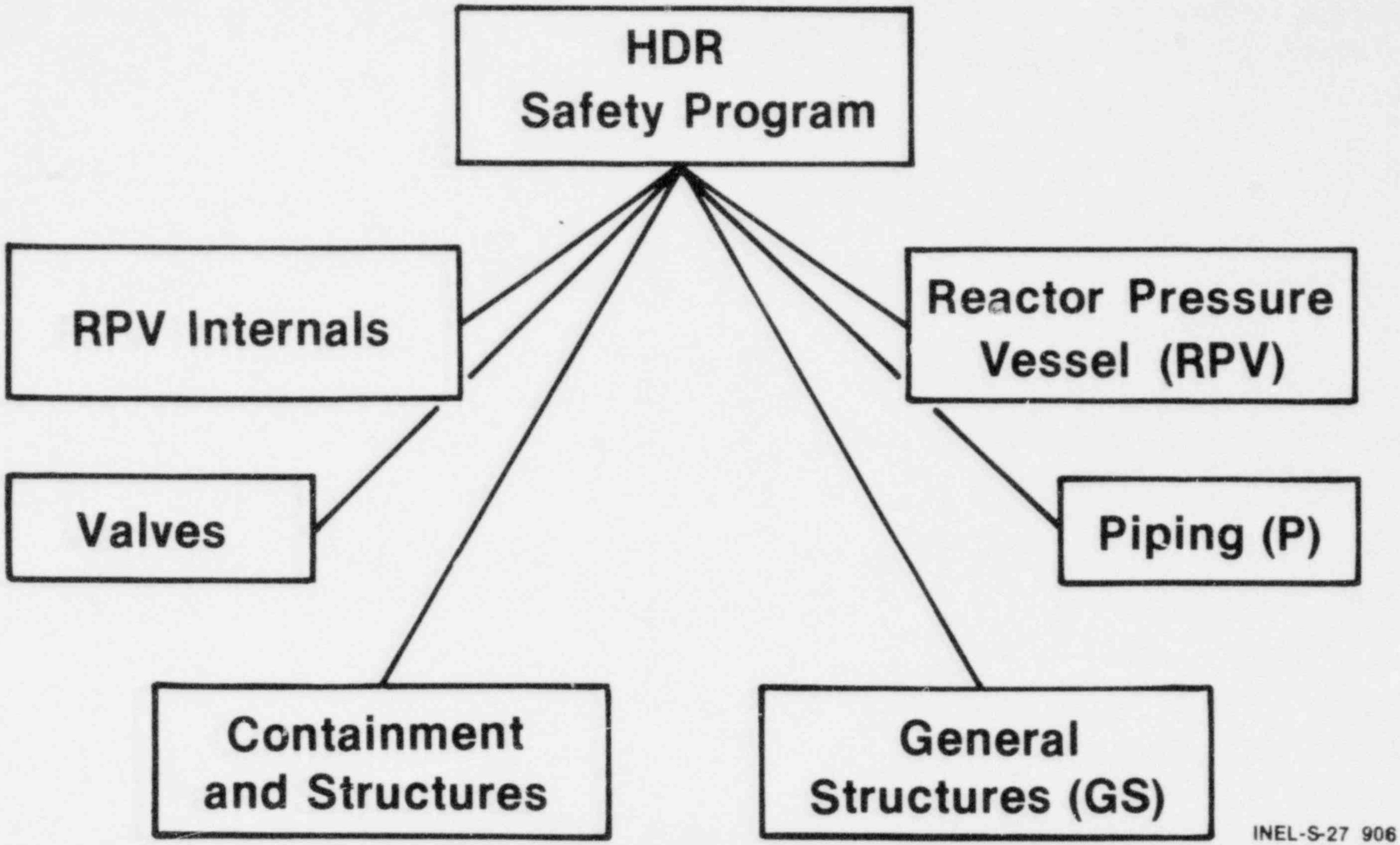

Figure 2. HDR Program Categories

Subsequent sections of this interim report describe the scope of work and the finite element representations of the recirculation piping system. The source of the input loading is then discussed. Results are presented by comparing the "blind" predictions with measured data supplied at a later date. Finally, some conclusions are discussed and recommendations for future refinement of the analytical model are provided.

II. SCOPE OF WORK

The overall HDR effort consists of essentially three parts. The first part of this investigation was performed to make a blind prediction of the mechanical response of the recirculation (URL) piping system based on measured accelerations at various points in the containment. The loading case originally to be considered was the 50 kilogram test. After the nonlinear model was completed, test limits were reduced so the case considered was the 5-kilogram explosive test performed in December 1979. The second part of this investigation was to compare the blind predictions with the measured test response as recorded by ANCO Engineers of California. The third part of this investigation, a small part of which is contained in this report, is to explain differences between predicted and measured data. Much of this work is continuing and will be reported in the 1981 fiscal year.

III. MODELING

A finite element, structural representation was developed for the URL piping system. The equipment considered in this representation included the recirculation piping, reactor vessel, two recirculation pumps, and associated piping supports. Three computer models were used in this investigation. The first model was an ANSYS[1] model. A linear version of this model was received from ANCO Engineers and modified to reflect the nonlinear experimentally determined properties of the piping supports. This modified model was used to predict piping motion of the loop. In addition, an identical model was made for use in the program ADINA.[2] This model was used to calculate frequencies as a check against the ANSYS model. Finally, in comparison stage of this investigation, the linear piping program NUPIP . as used to investigate sensitivity of the model to various parameters.

1. STRUCTURAL MODEL VALIDATION

The accuracy of the prediction models was checked with the use of experimental and analytical data. Experimental data was provided by ANCO Engineers[4] via shaker and snapback tests conducted upon the URL system in 1975. This system configuration was similar but not identical to the 1979 test configuration. Modal analysis was also performed on a structural ADINA model constructed to reproduce the ANSYS model of the URL. Both of these were nonlinear models. A linear NUPIPE model of the URL piping system was also used and its calculated modal frequencies are listed with the other calculations and measurements in Table I. The frequencies are in hertz and are listed in consecutive modal order. Dashed lines indicate modal frequencies which were not discovered in each particular test or analysis. The experimental modal testing and nonlinear model calculations were performed with the piping system empty. The NUPIPE results designated by "M1" also reflect no water in the piping. "M2" reflects the NUPIPE frequency calculation with the system full of water.

Analysis		Experiment	
ANSYS	ADINA	Vibrator	Snapback
1.9	1.9	—	1.6
2.6	—	—	2.4
3.3	3.0	—	3.3
3.6	3.8	3.6	3.9
4.3	4.3	4.9	4.4
5.7	—	5.7	—
—	—	6.5	—

NUPIPE (M1)	NUPIPE (M2)
1.3	1.4
1.3	1.4
2.0	2.0
2.5	2.5
2.7	2.8
3.0	3.1

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TABLE I. FREQUENCIES COMPARISON

2. ANSYS MODEL

A representation of the ANSYS model is illustrated on Figure 3 with only selected node points shown. Figures 4, 5, and 6 illustrate the nodal detail of each section of the model. The actual model contains 182 node points. With the exception of the supports, this model was used as received from ANCO Engineers. Standard modeling procedures had been used by ANCO.

Figures 7 and 8 show typical, measured curves describing the two typical, nonlinear support types. Based on these curves, the sway braces were modeled as nonlinear elastic trusses with a gap derived from measured data. The constant force hangers were modeled as elastic-plastic trusses with kinematic hardening while the spring hangers were modeled as linear elastic trusses.

Damping in the ANSYS analysis shown in Figure 9 is proportional to mass and stiffness. This damping function was chosen to approximate previously determined 1975 experimental damping values.[4] It is noted that the function adequately represents damping determined by test only in the 3-8 Hz range. Test data indicates the first mode (1.6 Hz) damping to be approximately 45% (0.45 on the scale) while the modes above 8 Hz are generally in the 2-3% range.

3. ADINA MODEL

The ADINA model[a] was constructed to have the same properties as the ANSYS model. Although ADINA was used for the modal analysis, program limitations made it easier to use ANSYS in the prediction phase.

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a. The term model is used in this report to mean a finite element representation of the structure.

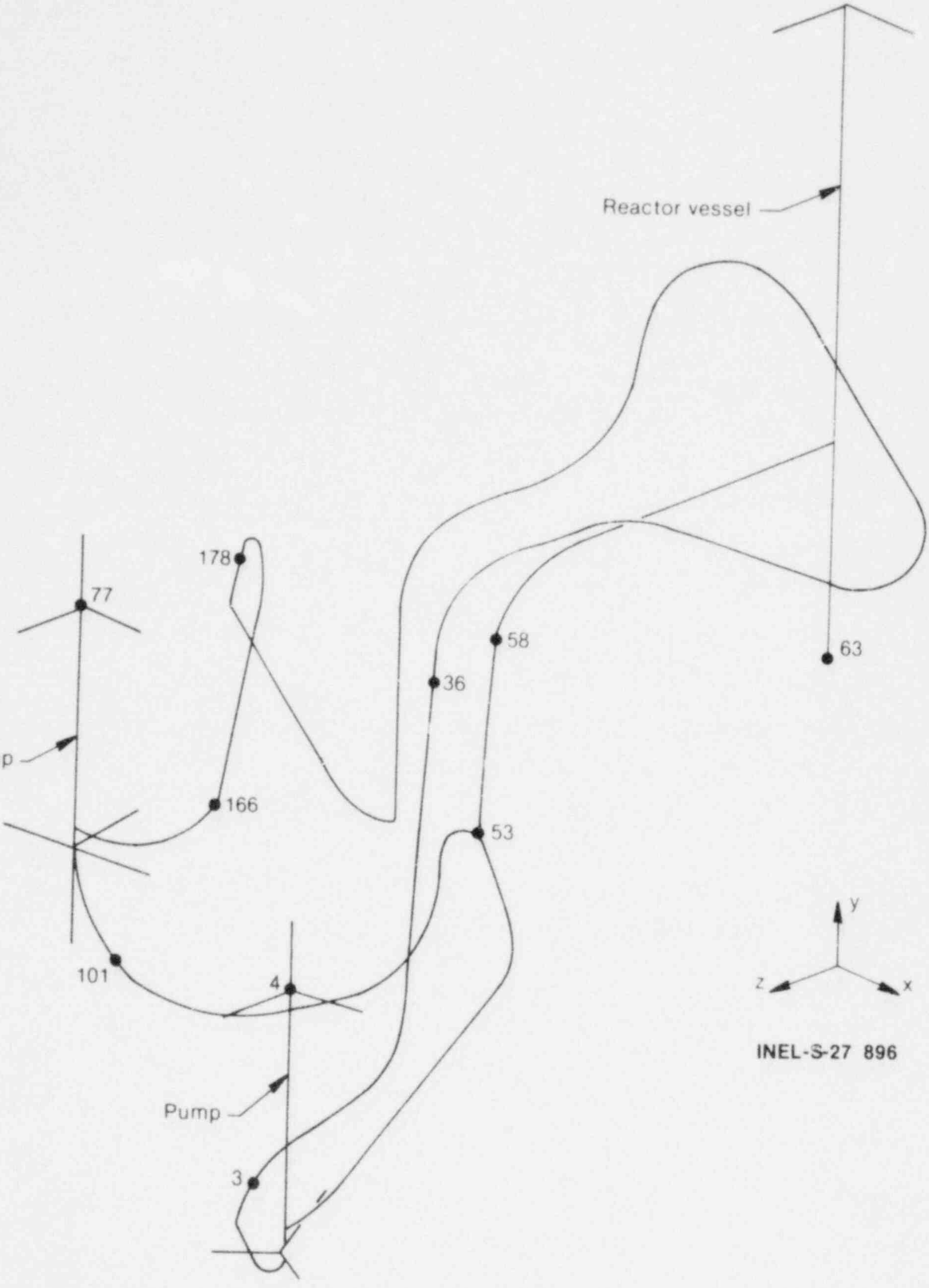

Figure 3. Computer Model URL Piping

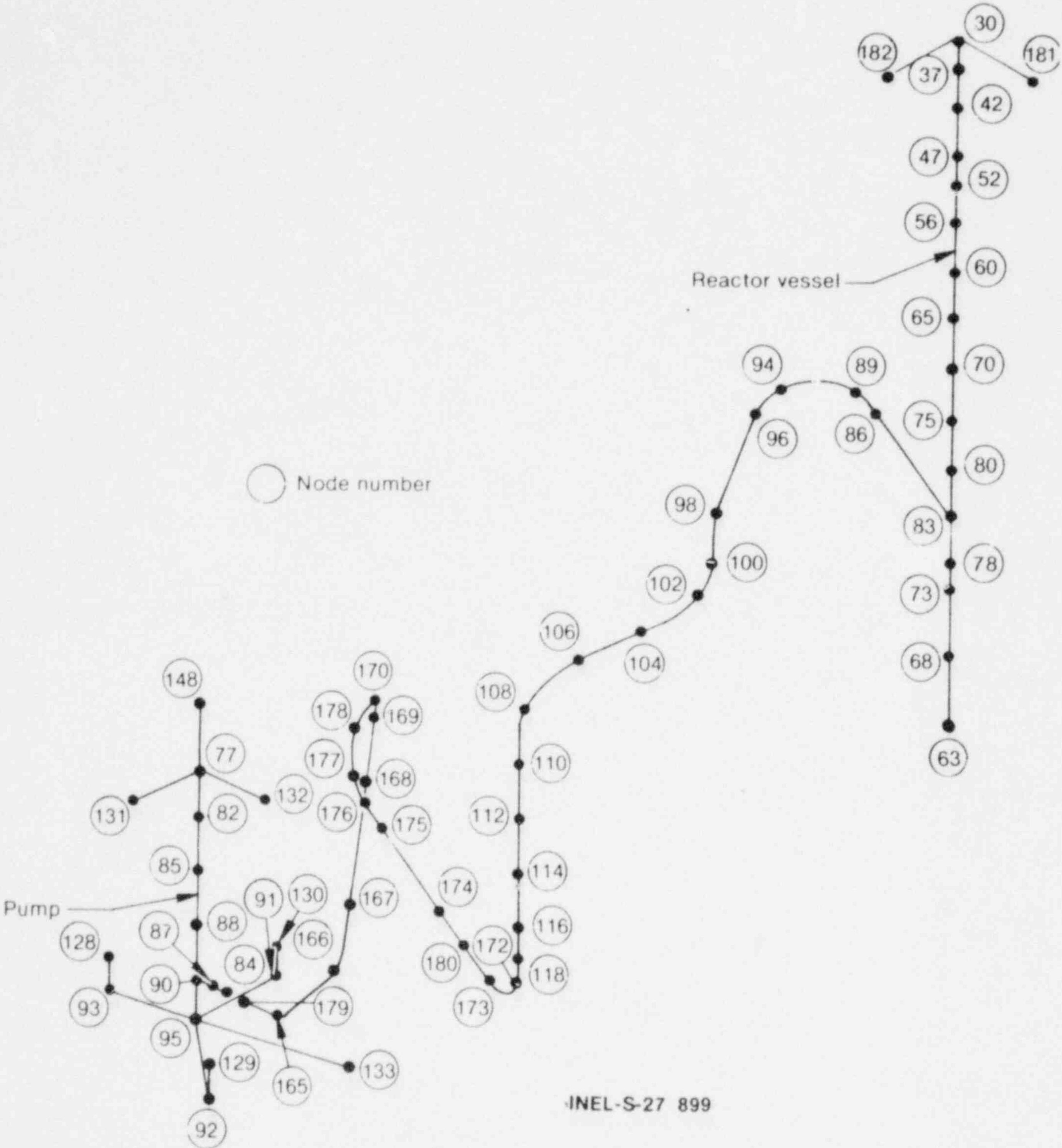

Figure 4. URL Piping System - Model Detail A

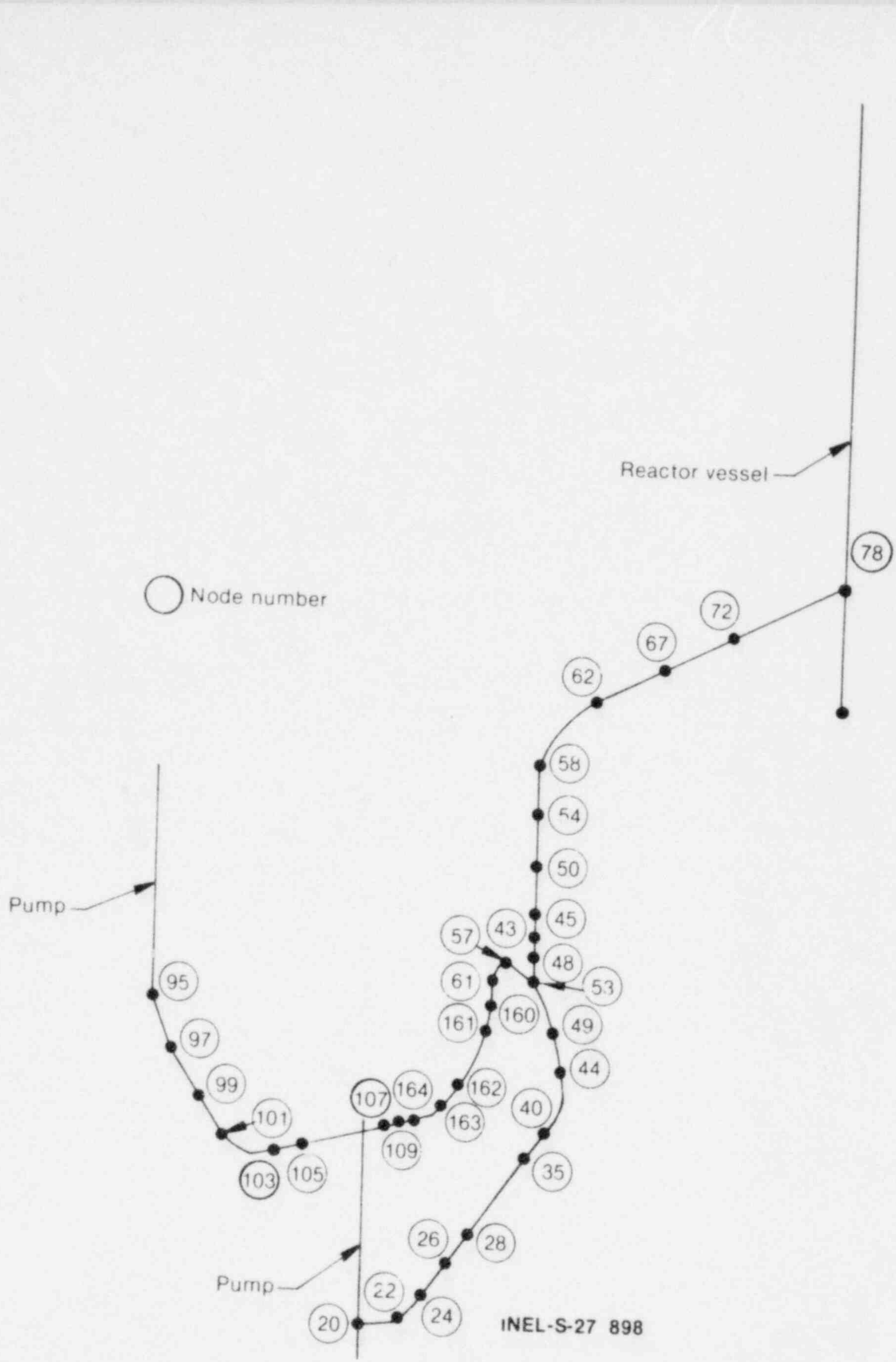

Figure 5. URL Piping System - Model Detail B

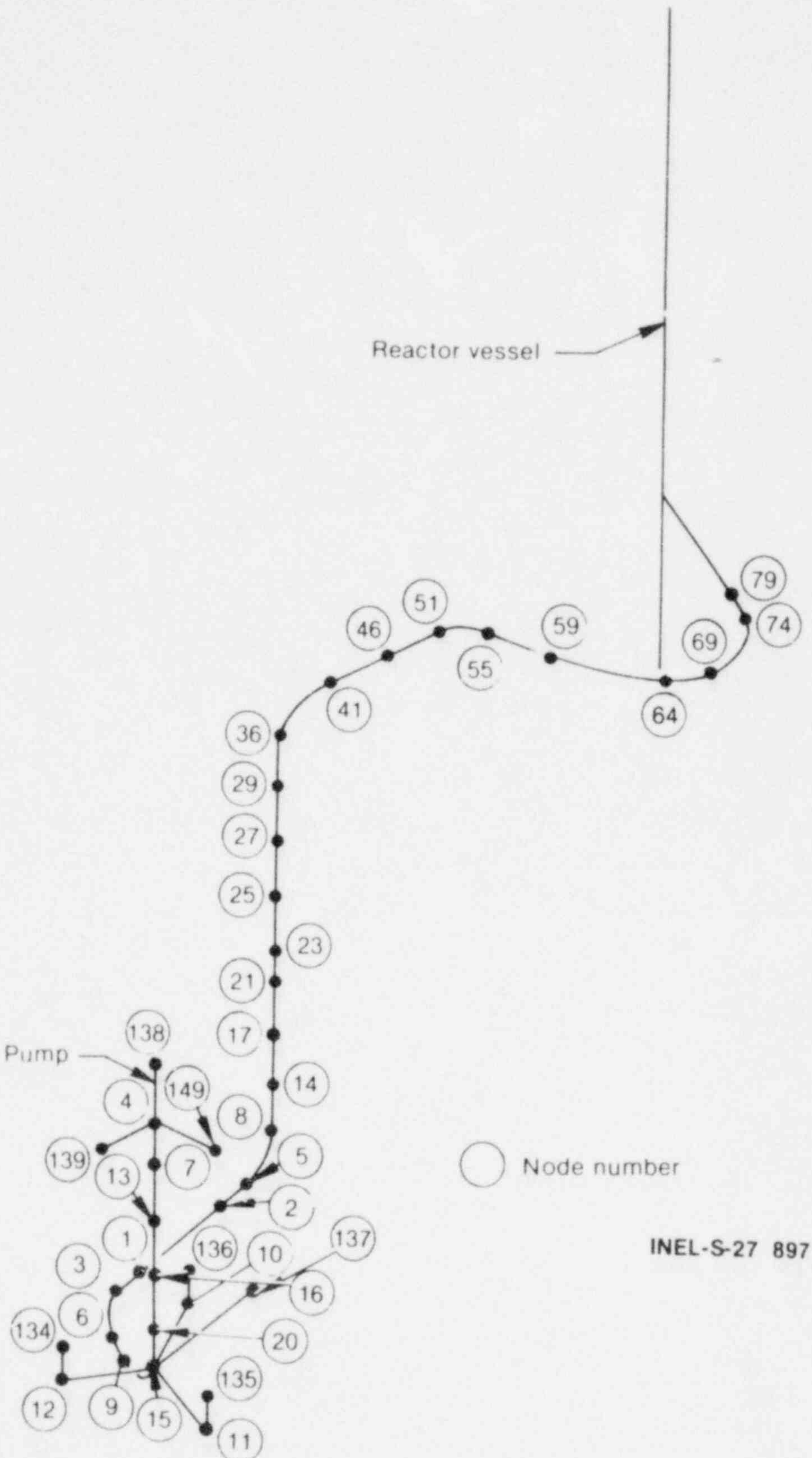

Figure 6. URL Piping System - Model Detail C

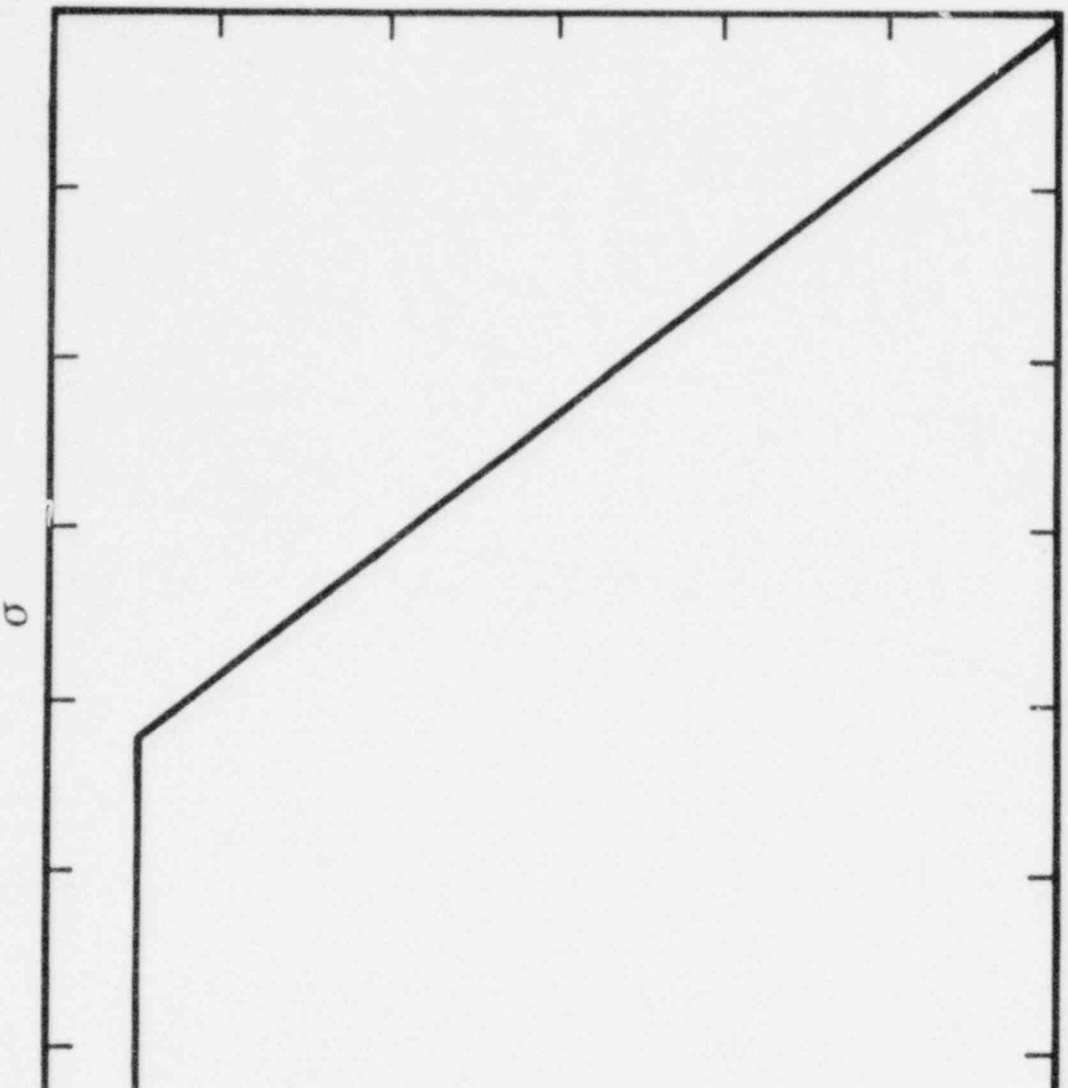

Figure 7. Typical Sway Brace Stress-Strain Curve

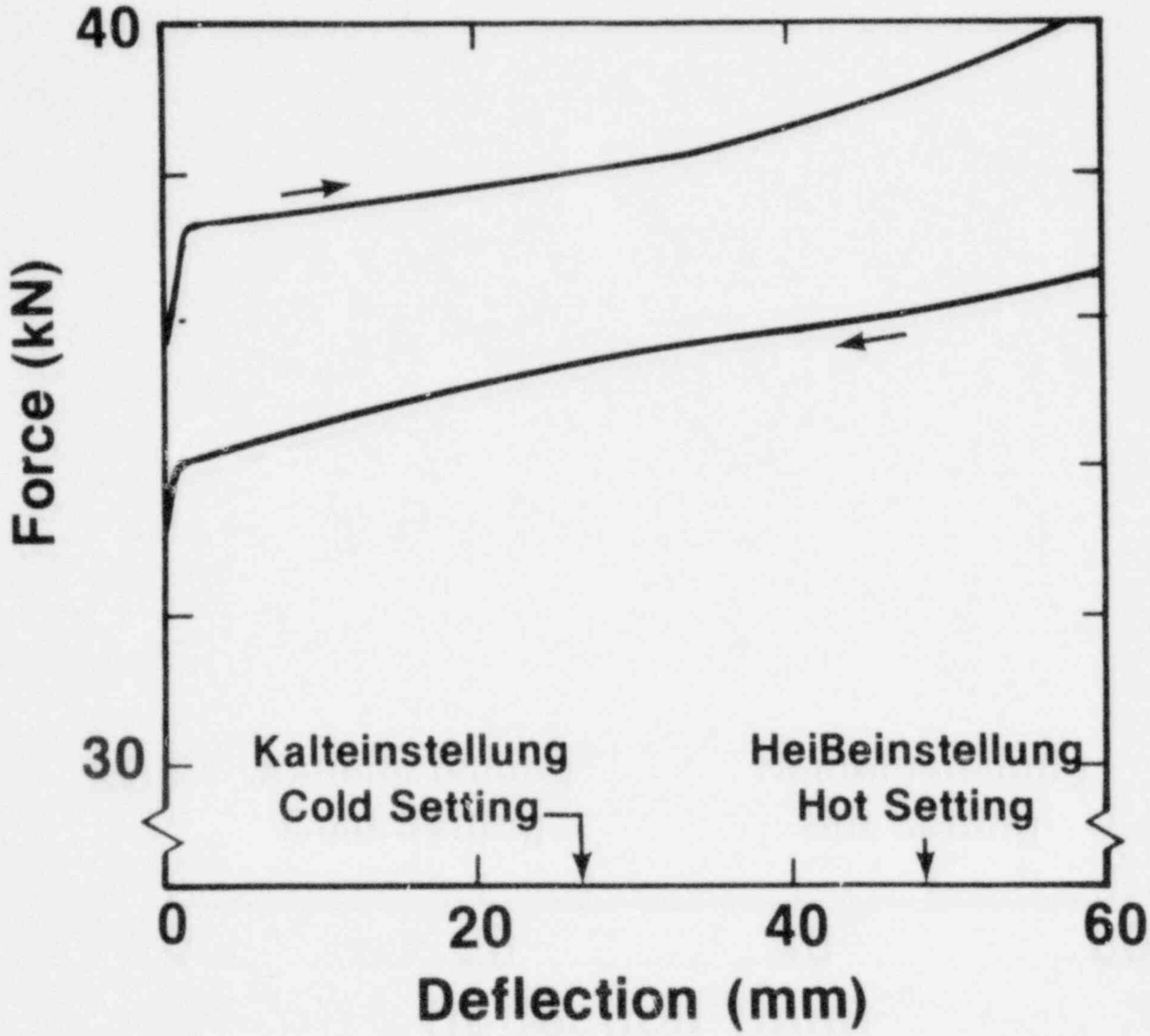

Figure 8. Typical Force-Deflection Curve for Constant Force Hanger

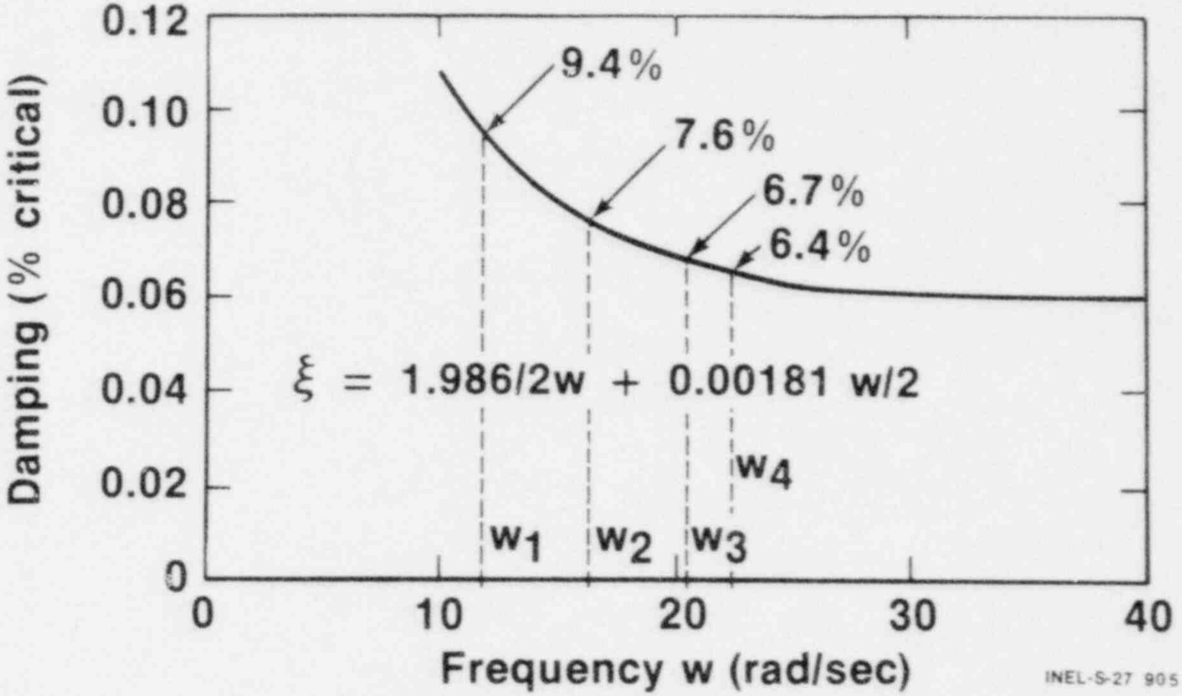

Figure 9. Percent Critical Damping Versus Frequency

4. NUPIPE MODEL

Since the tests were limited to the low level explosive charge when they were finally performed, it was expected that the system would respond in a linear fashion as, indeed, the ANSYS analysis indicated. With this in mind a third set of models of the URL was constructed using the linear elastic structural piping code, NUPIPE, and was used for parameter studies.

This code varies from ANSYS and ADINA in the way it applies the damping scheme to the structural model. Where the other two codes use mass and stiffness proportional damping, NUPIPE uses constant damping for all modes considered. Another difference is the use of modal superposition instead of direct integration in the solution technique. As a result, the modal calculation was performed only for modes having frequencies up to 33 Hz as prescribed by the Regulatory Guides for seismic analysis.

Two linear models were used and sensitivity to two different parameters were investigated on each of the two models. The first model used standard procedures for modeling supports. In other words, stiffness properties were taken from manufacturers' catalogues. The second model used stiffness properties based on the undeflected value of the nonlinear load-deflection curves determined by static tests. Each of the models was run for both 1% and 7% damping to determine sensitivity to this parameter.

During the comparison stage of this study, some of the information EG&G had received concerning mass modeling was found to be incorrect. Each of the NUPIPE models was run with mass corrections to determine sensitivity to this problem. Indication of mass sensitivity to frequency calculations in NUPIPE can be seen in Table I.

IV. LOADING

The inertial loading considered in this investigation was the motion of the URL pump cubicle walls, floor, and ceiling caused by a 5 kg charge of buried explosive located outside of containment on the positive X axis of Figure 10. Details of the test which was conducted in December 1979 were reported by ANCO Engineers[5] in April 1980. Comparisons of vertical accelerations at various points in the URL cubicle indicate extremely good correlation. Horizontal acceleration history correlations are good when a slight amount of torsional motion of containment is considered. Accelerometers located at the four points illustrated in Figures 10 and 11 provided accelerations which were recorded on computer tape and strip chart recorders. After comparison of the strip charts, it became apparent that the region of the [illegible]ng where the recirculation loop was supported was behaving essentia[illegible] as a rigid body. This is illustrated on Figure 12, where three segments of strip chart accelerations are shown.

The accelerations shown on Figure 12 are at three different points (1, 2, 3) on the building shown on Figures 10 and 11. The three charts shown on Figure 12 are for vertical (Y) acceleration at the three different node points. Horizontal accelerations of different node points cannot be compared directly since the coordinate systems used for the accelerometers are not the same. Coordinate transformations of the horizontal accelerations a[illegible] points in the pump cubicle were made and compared to each other. While the comparison showed a slight rigid body rotation of the cubicle about the center of containment, that effect was small. Therefore, for this first analysis uniform ground motion with no rotation was assumed for simplicity.

Appendix B shows the response spectra generated from the three components of uniform ground motion used for transient input to the computer analyses.

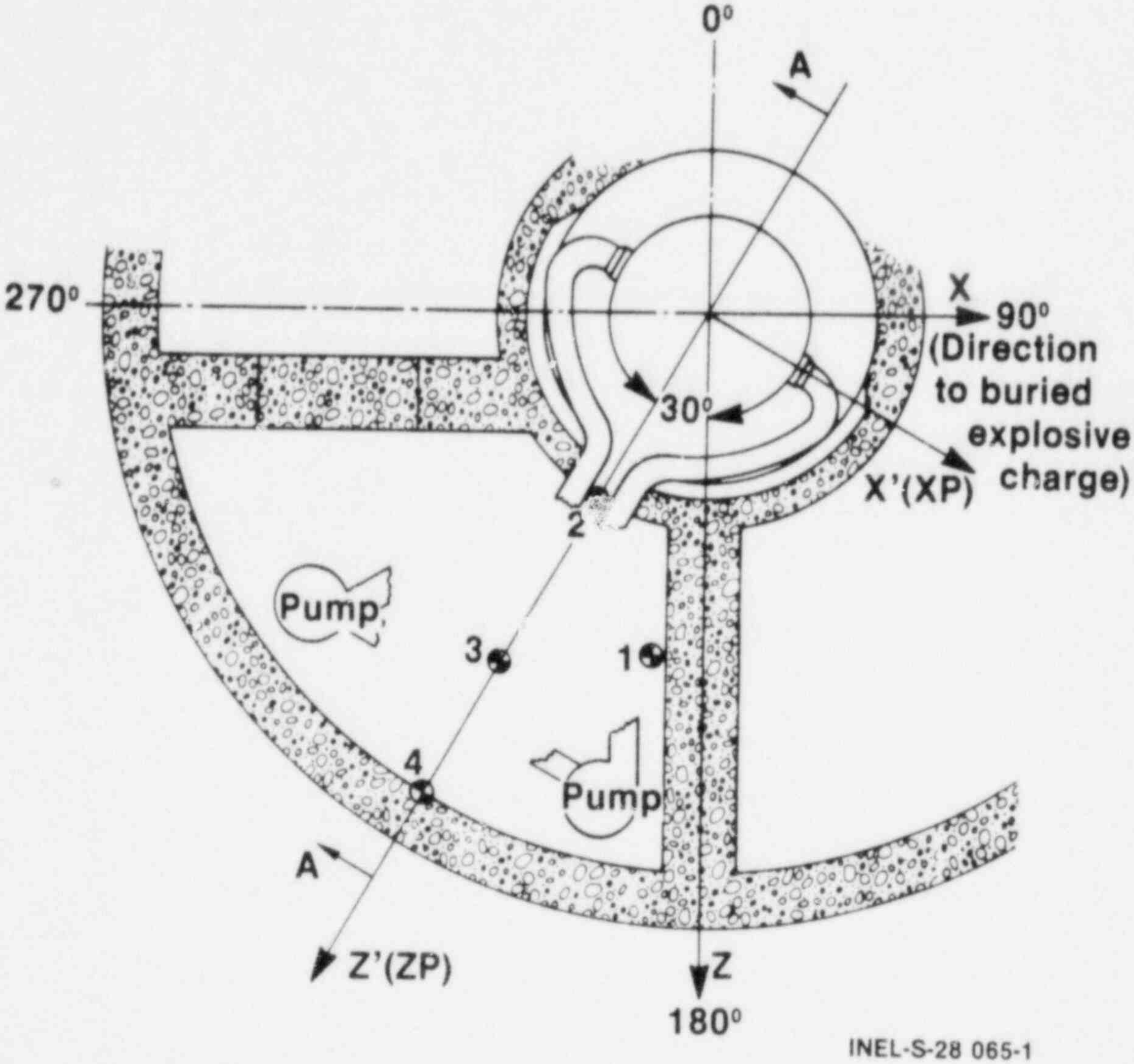

Figure 10. URL Loop Locations and Instrumentation Points Plan View

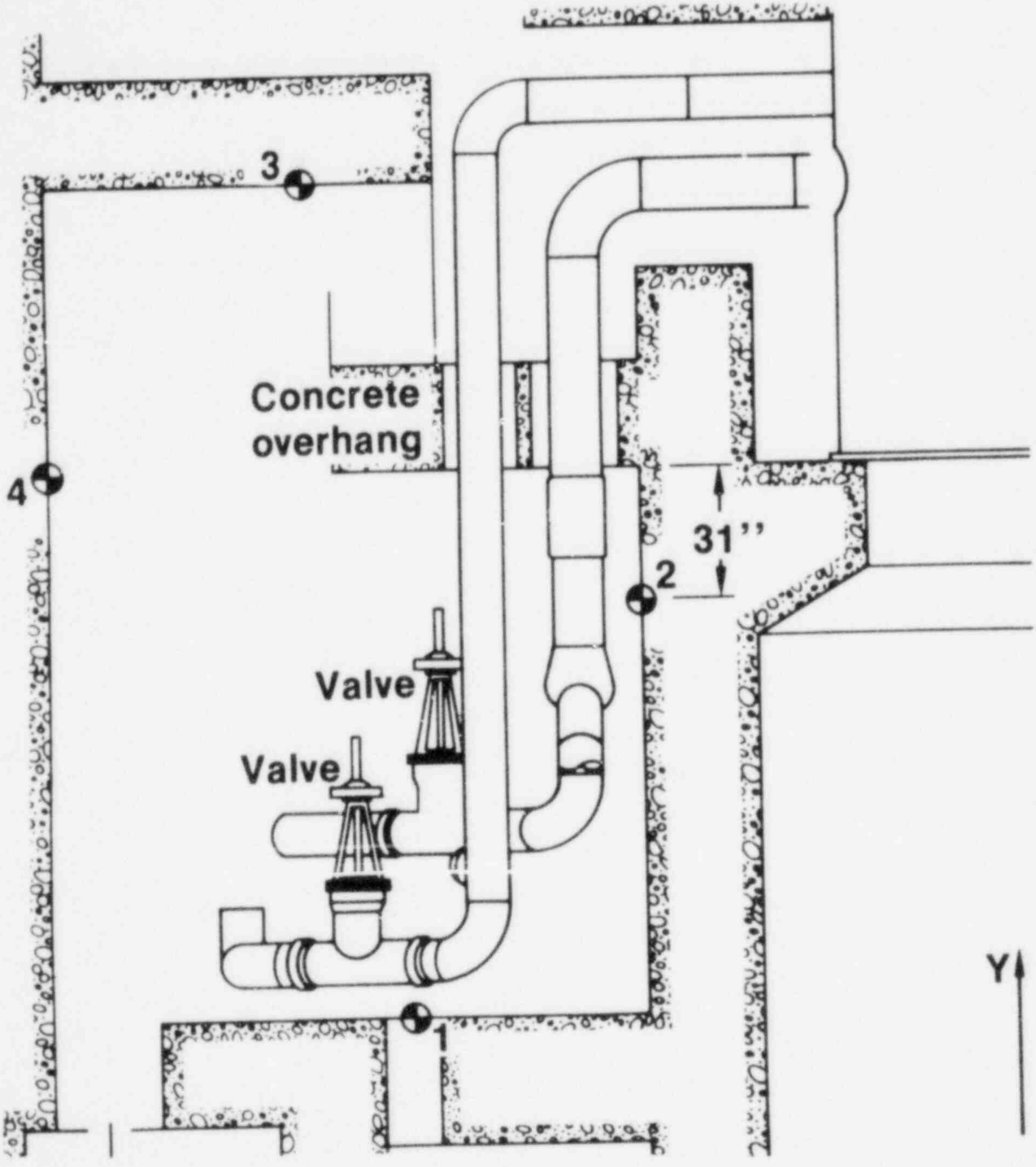

Figure 11. URL Loop Locations and Instrumentation Points Elevation View

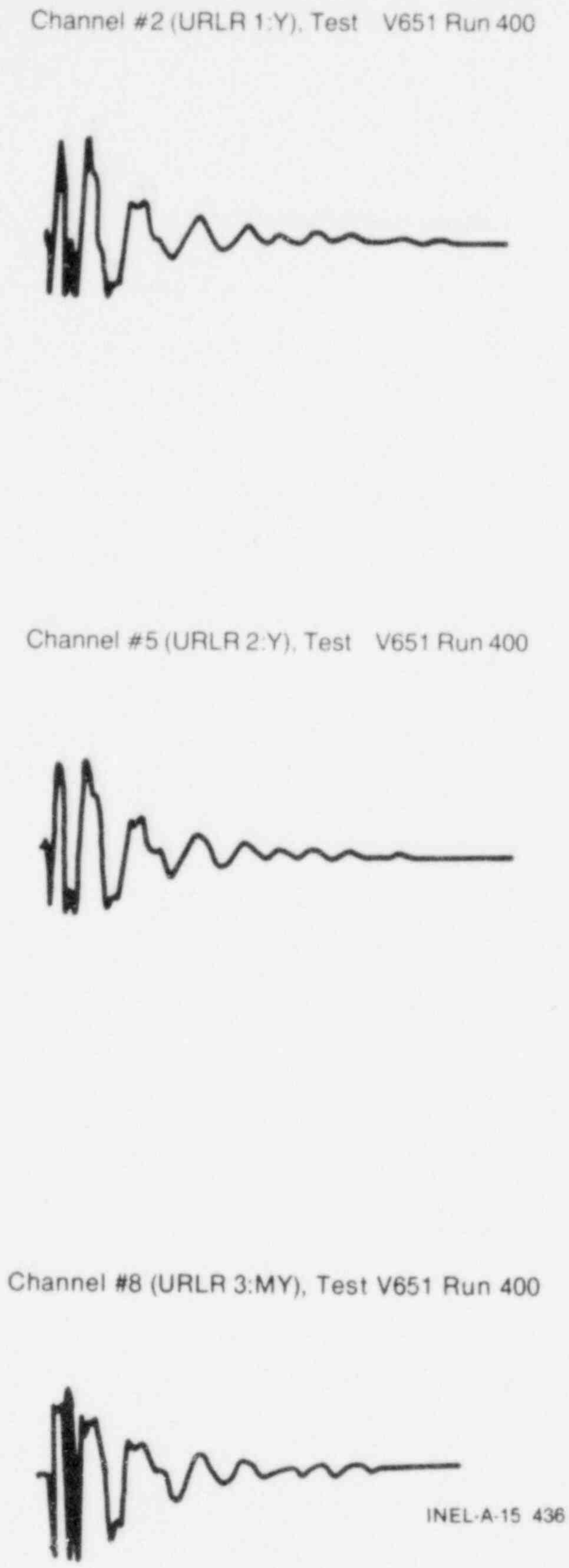

Figure 12. Vertical Base Motion Accelerations

V. SPECTRAL ANALYSIS

The responses of the URL system determined from accelerometer measurements and analytical calculations were compared in the frequency rather than the time domain. To implement this comparison a spectral analysis was performed on both the measured and calculated response acceleration time histories. This analysis numerically integrated the normal convolution time integral for natural periods from 1-100 Hz with the given acceleration histories as input functions. This integration was performed for both measured and calculated data assuming zero damping, thus causing the peaks of the spectra to be maximized.

VI. RESULTS

1. FORMAT OF RESULTS

This analytical study has produced some interim results which are presented in two parts. The first part consists of the "blind" predictions. These are in the form of acceleration response spectra derived from the ANSYS time history analysis of the URL piping system. After these predictions were publicized, the measured acceleration histories of various points in the piping system were provided. Comparisons of the measured data and the original "blind" calculations and subsequent comparisons of modified model calculations with measured data compose the second part of these interim results. The comparison studies are also based upon acceleration spectra. Details of these results are included in Appendix A.

2. COMPARISONS

Table II summarizes the comparisons of ANSYS and NUPIPE calculations with the measured data. It must be noted that, while the NUPIPE data in this summary reflects the appropriate modeling of masses in the URL system, the ANSYS model does not. Specifically, it was originally thought that the 5 kg test was run with no water in the URL piping. During the NUPIPE analyses, it was discovered that the piping was actually at operating conditions during testing and that some significant differences in actual valve weights existed. Since the NUPIPE analysis was in progress at that time, both conditions were analyzed. Such modification was not made in the ANSYS analysis. NUPIPE results in this table are based on a calculation at 7% damping.

TABLE II. RESPONSE ACCELERATION SPECTRA COMPARISONS AT VARIOUS NODE LOCATIONS

Node	Ansys vs. Measured			Nupipe vs. Measured		
	Peak amplitude	Peak amplitude frequency	Curve shape	Peak amplitude	Peak amplitude frequency	Curve shape
166x	P	P	P	P	P	P
166z	P	P	P	F	P	P
77x	P	G	F	F	G	G
77y	F	G	G	G	G	P
77z	P	F	F	G	P	F
36x	F	G	G	F	G	G
36y	F	G	G	G	G	G
36z	F	G	G	F	G	G
3x	F	F	F	F	F	F
3z	F	F	F	F	F	F
58x	P	P	P	P	F	P
58z	P	F	F	F	G	P
53x	F	G	G	G	G	P
53y	P	G	F	F	G	F
53z	P	F	F	G	G	F

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The table rates the qualitative comparison of analytical to measured data, which is detailed in Appendix A, in three aspects of the spectral curves up to 33 Hz. They are: (1) peak amplitude; (2) peak amplitude frequency; (3) curve shape. The rating criteria is as follows:

	Calculated Peak Amplitude	Calculated Peak Amplitude Frequency	Curve Shape
Good	Within 30% of measured	Within 20% of measured	Same number of significant peaks and peaks in fairly good proportion
Fair	Within 60% of measured	Within 40% of measured	Peak amplitude in rough proportion to rest of curve

A rating of "Poor" is given when neither of the other ratings are justified. Model node location and directional response are noted and correspond to those of Figure 3.

This comparison suggests several observations: (1) linear response, for this loading, is a pretty good assumption; (2) there also seems to be a need for less damping in the ANSYS model; (3) the mass modeling inaccuracy in the ANSYS model may have caused minor frequency shifts in the peak calculated amplitude.

Table III compares the parameter variations carried out with the NUPIPE analysis which are detailed in Appendix A. The effect of damping changes is, by far, the largest effect. That large effect might be expected. When these damping levels are compared to measured data, it points out the fact that current standard practice may be quite conservative resulting in calculation of high peak accelerations.

TABLE III. COMPARISON OF PEAK ACCELERATIONS FROM NUPIPE PARAMETER STUDIES

Node	1% vs 7% Damping*	Typical Supports vs Actual **
166x	100%	90%
166z	260%	27%
77x	90%	67%
77y	167%	38%
77z	210%	64%
36x	250%	17%
36y	200%	88%
36z	240%	26%
3x	220%	65%
3z	220%	51%
58x	300%	0%
58z	350%	0%
53x	300%	10%
53y	400%	0%
53z	400%	0%

*% change of 1% damping peak from 7% damping peak

**% change of analysis with typical support stiffnesses from that of actual support stiffnesses

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The second parameter variation studies the effects of differences between assumed "standard catalog" stiffness values for supports and those stiffnesses actually encountered in the field. Static testing was performed upon the supports to determine the in situ data. As can be seen, the effect ranges from none to almost a factor of two in this case.

3. OBSERVATIONS

The data comparisons of Appendix A show a significant amount of system response in the 25-50 Hz range in the measured data. Looking at the horizontal spectra of the input ground motion for the analyses in Appendix B confirms that there is, indeed, a significant contribution from the horizontal base motion in that frequency range. These do not follow the typical form of seismic spectra which are generally flat and at a lower (relative to the peak) level in this frequency range because the earthquake epicenter is usually farther away and high frequencies are damped out of the excitation.

The analytical models were constructed with seismic analysis in mind and, for that reason, did not have the capability of picking up response in the higher frequency ranges, i.e., above 33 Hz. The ANSYS analysis used a solution time step of 0.0075 seconds which could, at best, be sensitive to frequencies up to 33 Hz in its direct integration solution and could comfortably assure accurate frequency response through 13 Hz. The NUPIPE analysis used a time step of 0.003 seconds and a cutoff frequency of 33 Hz in its modal superposition solution. That time step should have been sufficient to pick up the response in the 25-33 Hz range.

The comparisons presented in Appendix A suggest that the NUPIPE model did not respond in the 25-33 Hz range as expected. The most probable reason for this discrepancy is the fact that the NUPIPE computer code used in the analyses prints accelerations only at every third time step. This could have an effect upon the generated spectra similar to performing the dynamic analysis with a time step of .009 seconds which could be too large for picking up the 25-50 Hz acceleration response.

A second possible explanation considers the use of modal forces derived from the truncated set of mode shapes. Although the higher modes may not respond dynamically, the "static" or load following response of these higher modes may effect the overall dynamic response.

A third possibility may be the need for model refinement. Eccentricities of the quick closing and check valves have not been included in the model and may effect some localized modes in the frequency range concerned.

The effect of the higher frequency response has not been addressed in this study. Inspection of the input acceleration time history indicates the amplitude of the high frequency component to be small compared to that of the low frequency component.

Two additional areas of parameter variation may be attributed to existing URL pipe wall thickness variations and the use of static, instead of dynamic, testing of existing system supports. Before EG&G's first ANSYS analysis was made, the variation of pipe wall thicknesses in the URL system was discovered to be as much as 20% greater than nominal in some areas. Those changes had been made to the structural model by applying the 20% increase to the outside dimension of the pipe in the designated areas. Check calculations have also been made with decreases of 20% on the inside diameters in those areas and no significant changes were noted in the system frequencies calculated.

Comparison of the variations in support stiffnesses point out the need for accurate data in this area. It is also suspected that differences between test results of dynamic and static testing of supports could prove to be significant in the analytical results.

VII. CONCLUSIONS

Good predictions for this experiment were obtained using the computer code NUPIPE with 7% critical damping, stiffness values based on experiment, and mass modeling changes as indicated. An analysis using current industry practices would have used 1% damping, manufacturers recommended stiffness values, linear response assumptions, and, in general, would have predicted a conservative response. Differences between the NUPIPE and ANSYS model predictions have not, as yet, been resolved. This remains to be investigated in the following weeks.

Variations in pipe wall thicknesses seem to have small effect upon the system analysis when compared to other parametric changes. Support stiffness variation, however, has a wide range of effect on the system and points out the need to use accurate support stiffness values for analytical model input.

VIII. RECOMMENDATIONS

The following recommendations are presented based upon the interim results of this study:

(1) This investigation should be continued to determine more precisely the reason for differences between the results of the ANSYS and NUPIPE analyses.

(2) Although the present analysis was performed to obtain dynamic response below 33 Hz, additional analyses should be performed to obtain better correlation between analytical and measured results in the higher frequency range.

(3) Further study into the effects of model damping, mass refinement, multi-support input motions, and dynamic support stiffness values should be performed.

IX. REFERENCES

1. G. J. DeSalvo. and J. A. Swanson, "ANSYS User's Manual," Swanson Analysis Systems, Inc., Elizabeth, Pennsylvania, 1975.

2. Klaus-Jurgen Bathe, "ADINA, A Finite Element Program for Automatic Dynamic Incremental Nonlinear Analysis," September 1975 (revised May, 1976).

3. Nuclear Services Corporation, NUPIPE II: Computer Code for Stress Analysis of Nuclear Piping, EG&G Computer Code Configuration Control C00340.

4. ANCO Engineers, Inc., "Forced Vibration Tests at the Heissdampfreaktor (HDR) using Structural Vibrators and Explosives," ANCO Report No. 1083-3, April 1976.

5. ANCO Engineers, Inc., "Heissdampfreaktor Dynamic Test Program," ANCO Progress Report No. 1182-8.2, April 1980.

APPENDIX A

COMPARISONS OF PREDICTED VERSUS MEASURED ACCELERATIONS RESPONSE SPECTRA

GUIDE TO NOMENCLATURE AND FIGURE NUMBERING SCHEME FOR TYPES OF COMPARISON CURVES IN APPENDIX A

1. Consider Figure 1.36.Z labeled SPECTRA-MEASURED vs. ANSYS ANALYSIS:

1 corresponds to the title SPECTRA-MEASURED VS. ANSYS ANALYSIS

SPECTRA-MEASURED is the response spectra generated by using acceleration histories from accelerometers at instrumented locations.

ANSYS ANALYSIS is the response spectra generated by ANSYS using acceleration histories predicted at the instrumented points by the time history analysis.

36 refers to instrumented point number 36 as shown on Figure A of following page.

Z refers to the accelerations in the global Z-direction as shown on Figure A.

2. Consider Figure 2.36.Z

2 corresponds to the title MEASURED vs. TYPICAL (D=.01, D=.07)

MEASURED is the response spectra generated by using acceleration histories from accelerometers at instrumented locations.

TYPICAL refers to the response spectra generated using accelerations predicted in NUPIPE for the case of support stiffnesses obtained from manufacturers catalogs. Masses for these typical runs contained the same inaccuracies as the ANSYS run. These are addressed later. The two TYPICAL curves shown are for constant 1% and 7% critical damping respectively.

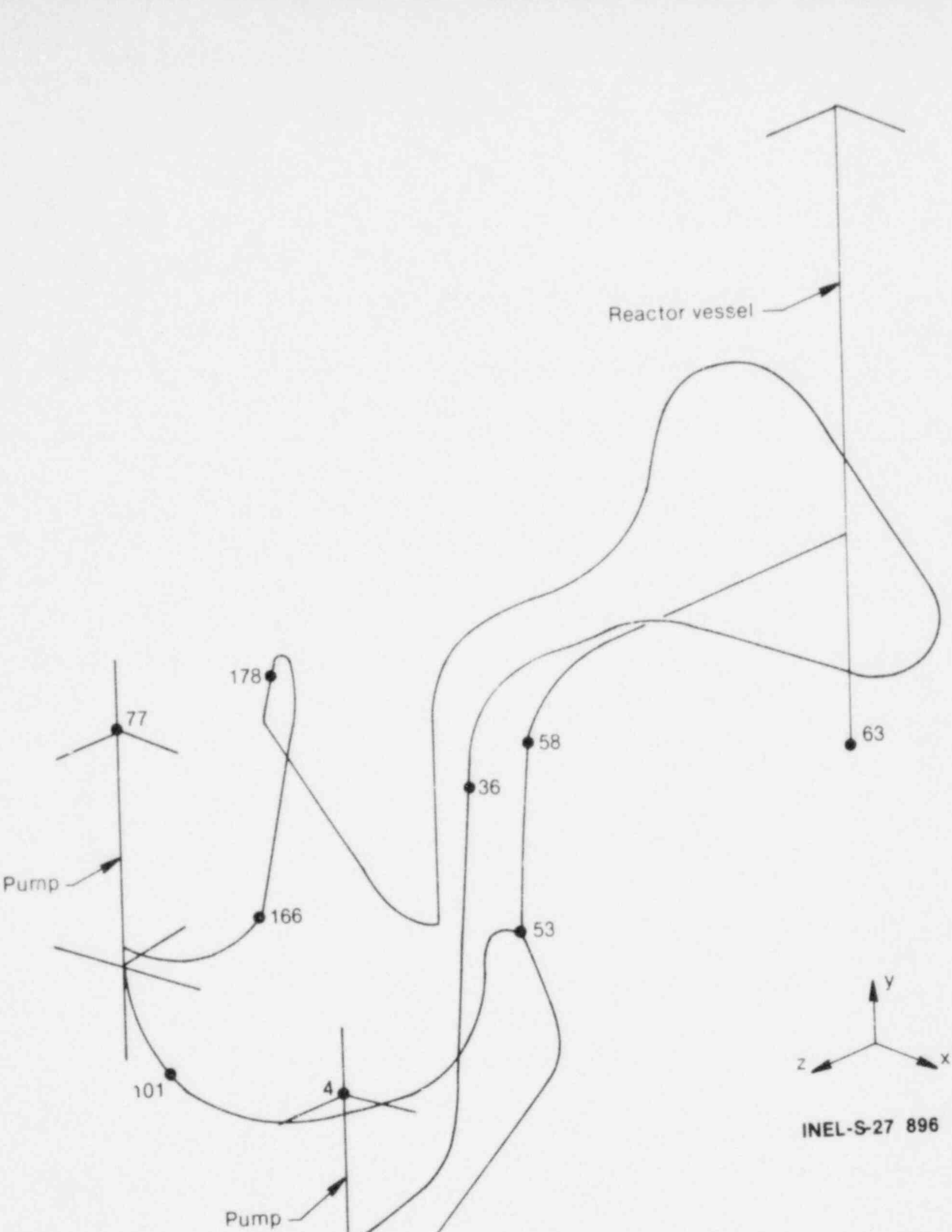


Figure A. Computer Model URL Piping

3. Consider Figure 3.36.Z

3 corresponds to the title MEASURED vs. NTYPICAL vs. NACTUAL (D=.07)

MEASURED is as described earlier.

NTYPICAL is the response spectra based on NUPIPE acceleration predictions using support stiffnesses as listed in manufacturer's catalog as would be done on a "typical" commercial analysis.

NACTUAL is the response spectra based on NUPIPE acceleration predictions with support stiffnesses based on measured support characteristics.

Both NTYPICAL and NACTUAL used 7% of critical damping and masses as used in the ANSYS analysis.

4. Consider figure 4.36.Z

4 corresponds to the title MEASURED vs. TYPICAL (M1 vs. M2) D=.07

MEASURED is as described earlier.

TYPICAL is the response spectra based on NUPIPE acceleration predictions using support stiffnesses as listed in manufacturers catalog as would be done in a "typical" commercial analysis.

TYPICAL M1 is a "typical" analysis using masses as used in the ANSYS analysis which did contain inaccuracies.

TYPICAL M2 is a "typical" analysis using corrected mas values (pipes full of water and valve weights corrected).

Both "TYPICAL" analyses use 7% critical damping.

5. Consider Figure 5.36.Z

5 corresponds to the title MEASURED vs. ACTUAL K (M1 vs. M2) (D=.07)

MEASURED is as described earlier.

ACTUAL K means support stiffnesses were based on actual measurements of existing support characteristics. Both "ACTUAL K" runs used NUPIPE. As before M1 corresponds to ANSYS mass modeling and M2 contains mass modeling corrections for pipes full of water and two corrected valve weights.

APPENDIX A FIGURES

TYPES OF COMPARISONS CURVES:

1. SPECTRA-MEASURED vs. ANSYS ANALYSIS

2. MEASURED vs. TYPICAL (D=.01, D=.07)

3. MEASURED vs. NTYPICAL vs NACTUAL (D=.07)

4. MEASURED vs. TYPICAL (M1 vs. M2) D=.07

5. MEASURED vs. ACTUAL K (M1 vs. M2) D=.07

FIGURES:

SPECTRA-MEASURED VS ANSYS ANALYSIS
NØDE 3,X

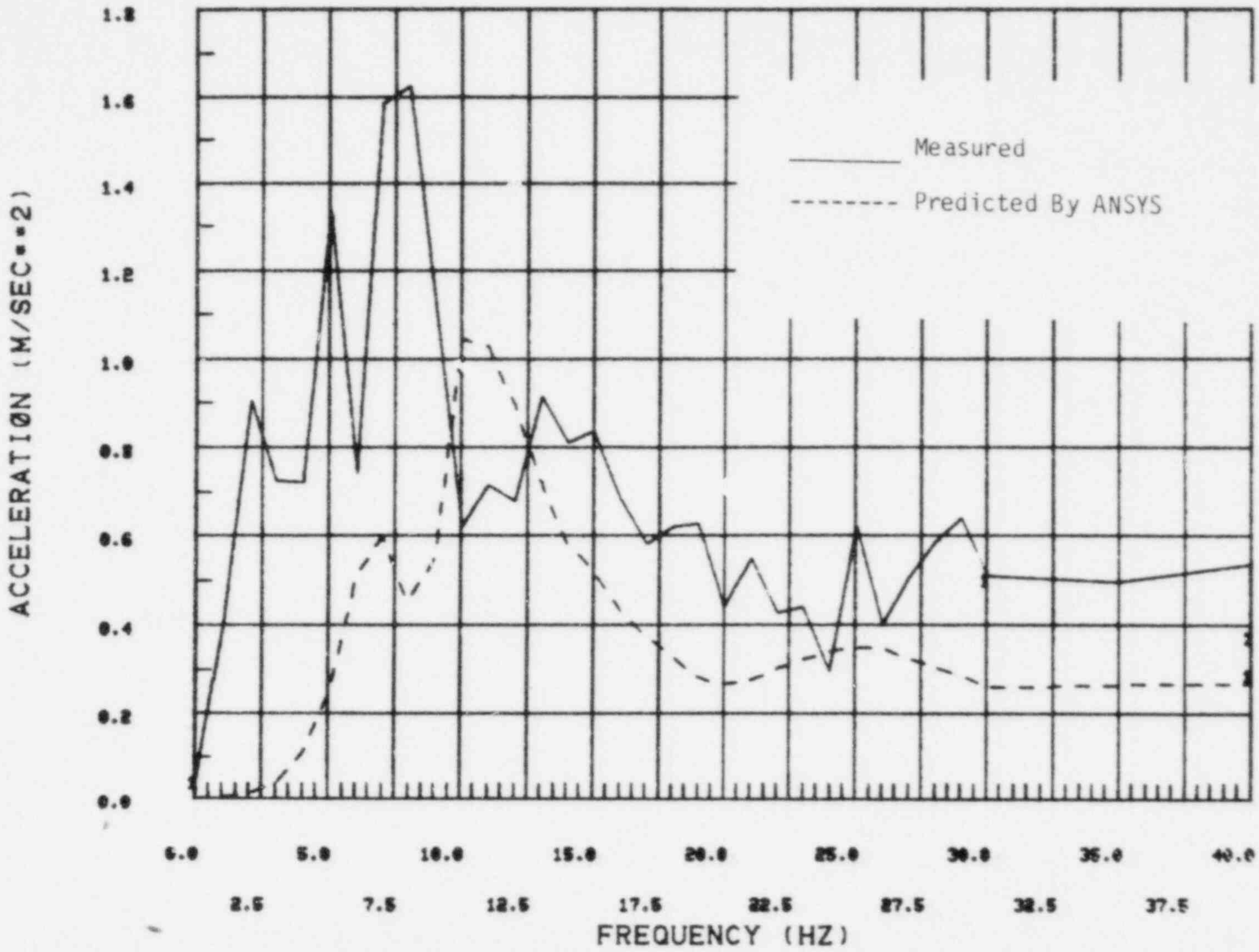


Figure 1.3.X

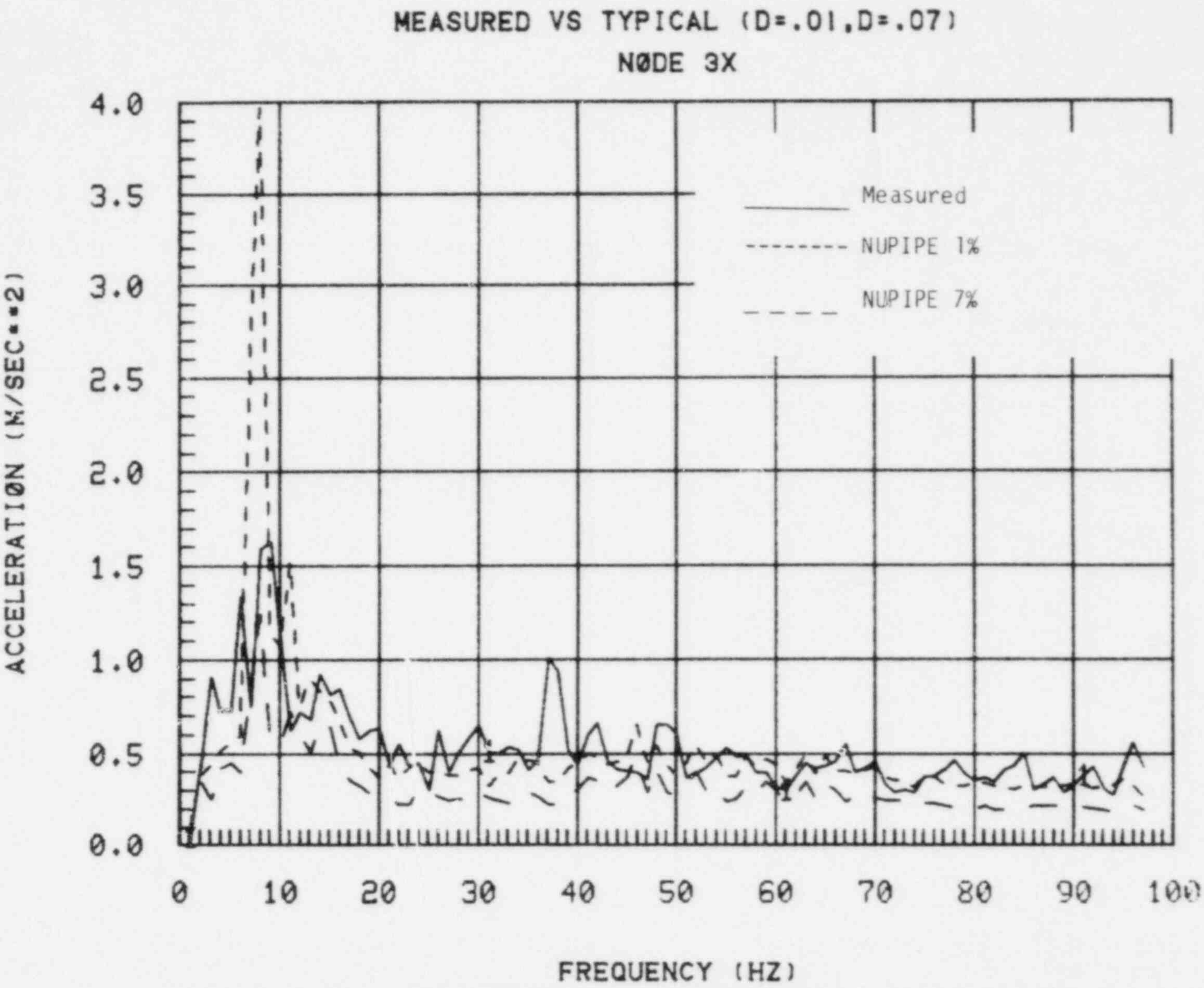
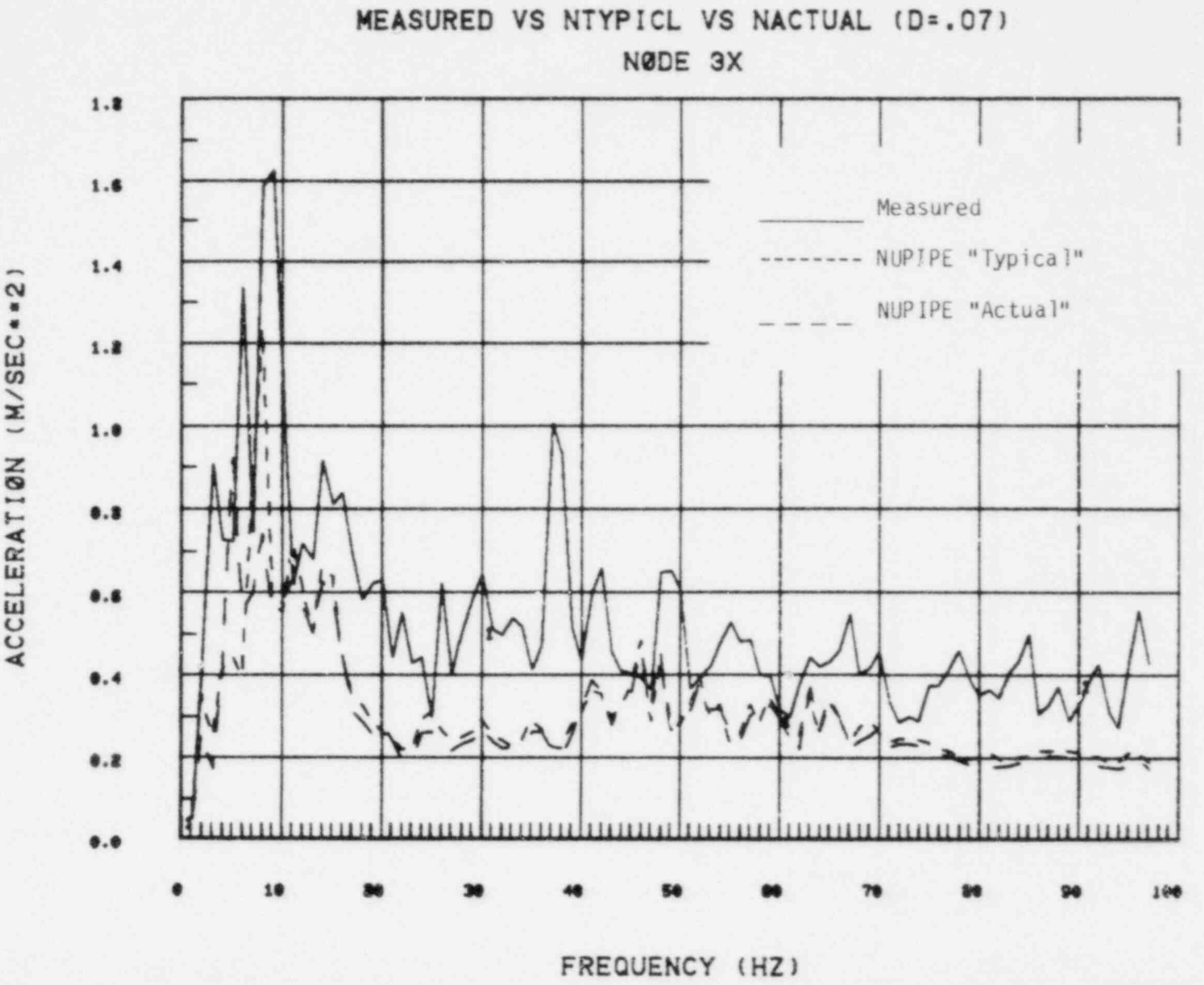

MEASURED VS TYPICAL (D=.01,D=.07)
NØDE 3X
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
Measured
NUPIPE 1%
NUPIPE 7%
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
70
80
90
100

Figure 2.3.X



MEASURED VS NTYPICL VS NACTUAL (D=.07)
NØDE 3X
Measured
NUPIPE "Typical"
NUPIPE "Actual"
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)

Figure 3.3.X

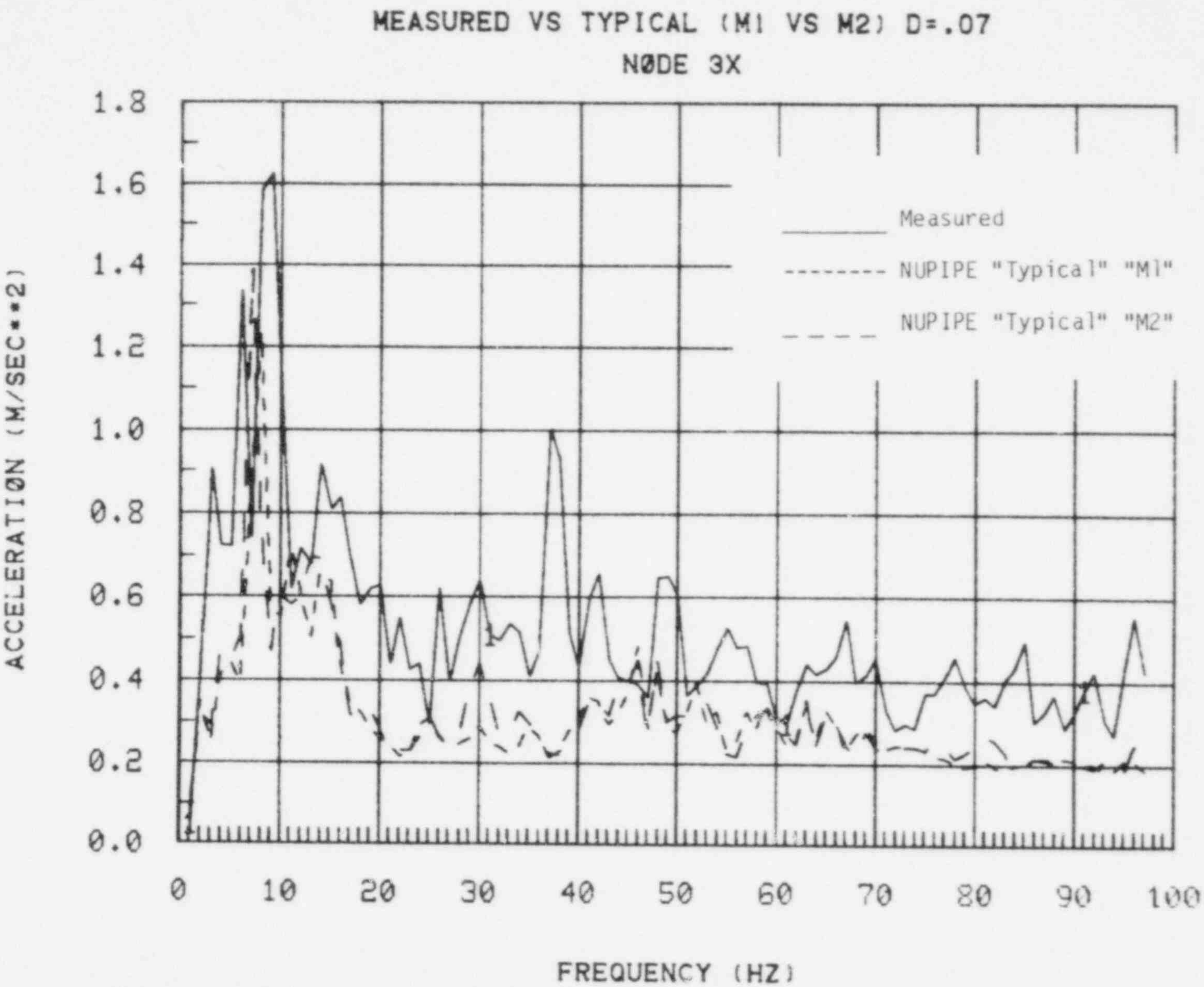

MEASURED VS TYPICAL (M1 VS M2) D=.07
NØDE 3X
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
Measured
NUPIPE "Typical" "M1"
NUPIPE "Typical" "M2"
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
0
10
20
30
40
50
60
70
80
90
100

Figure 4.3.X

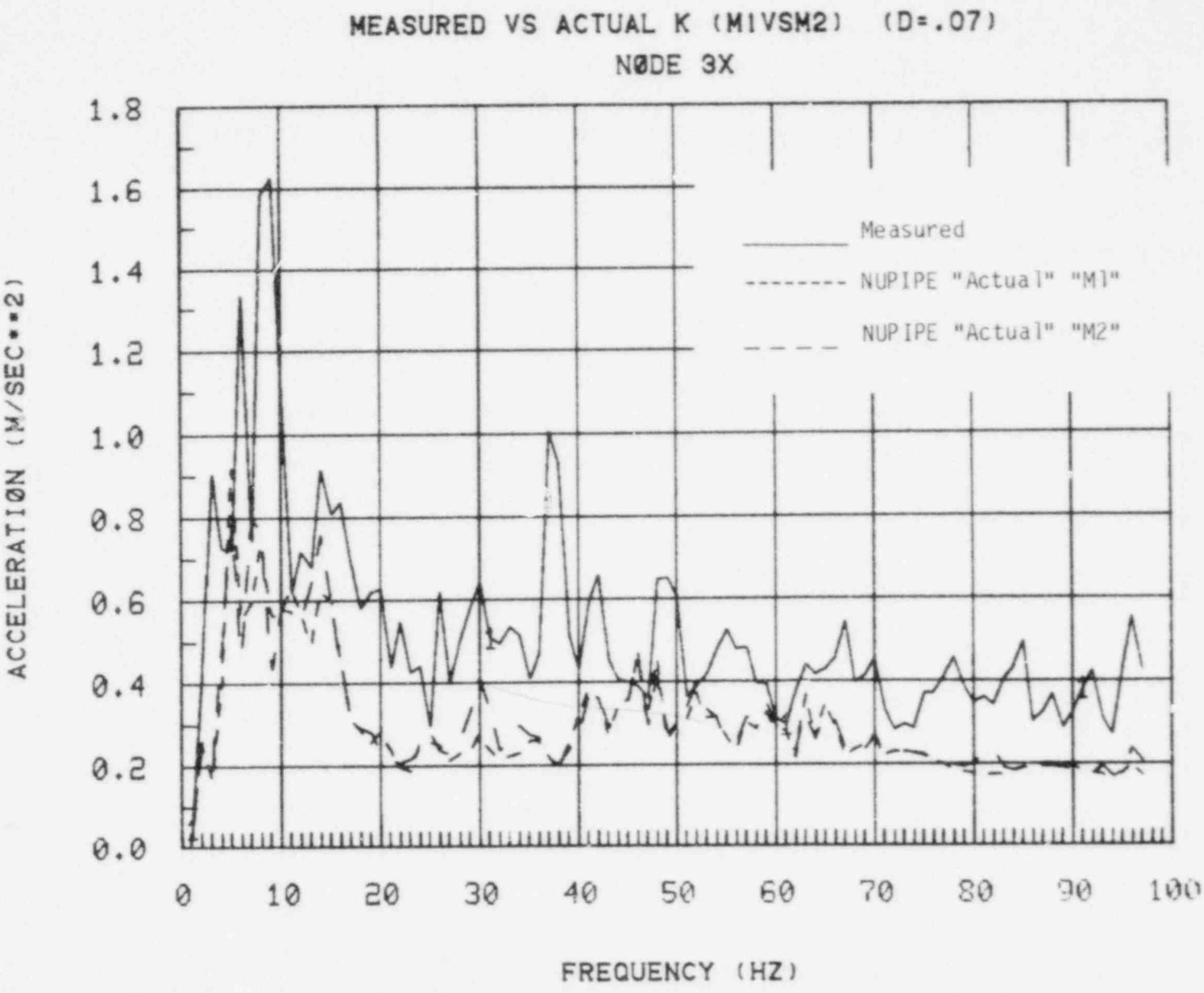
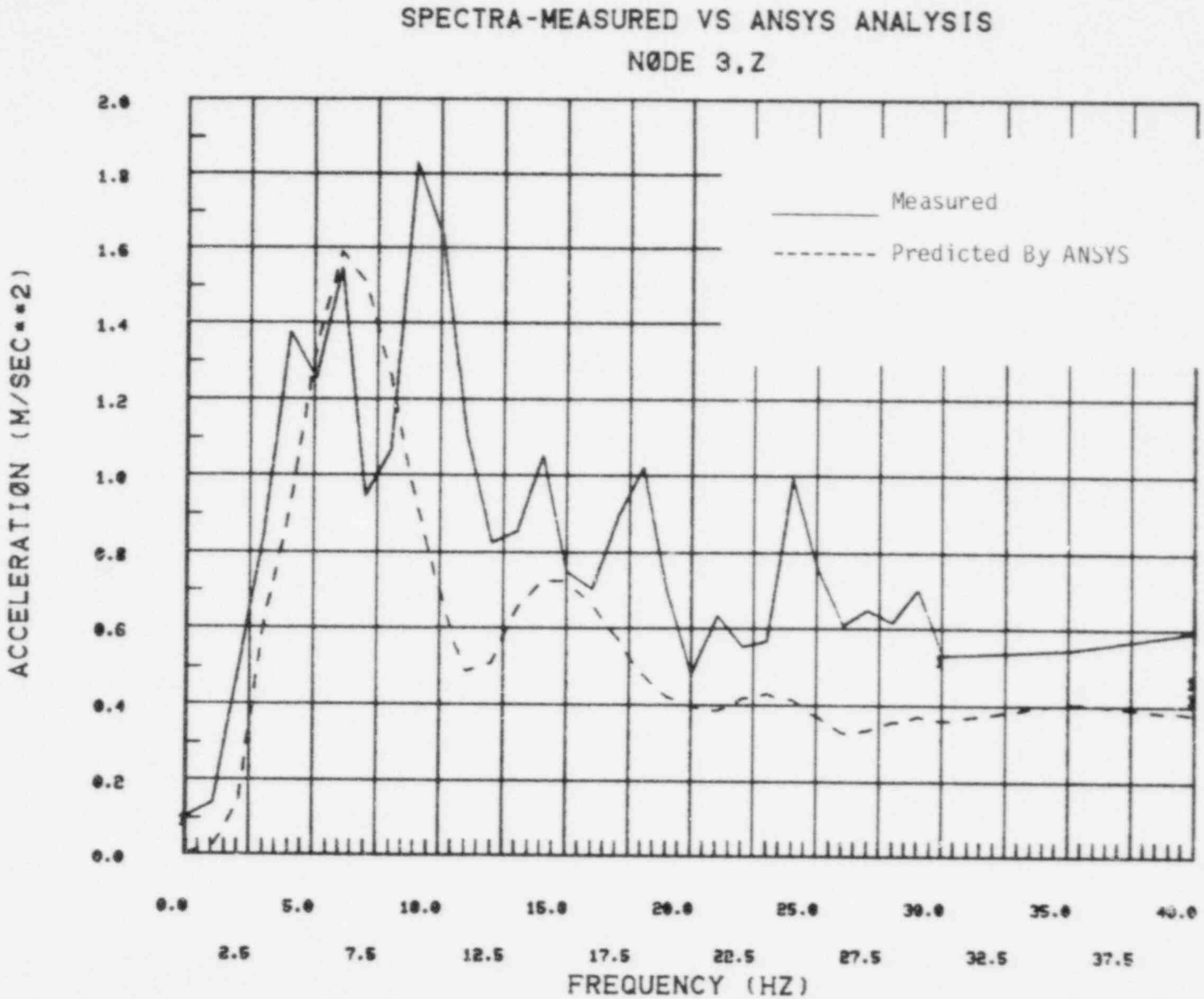
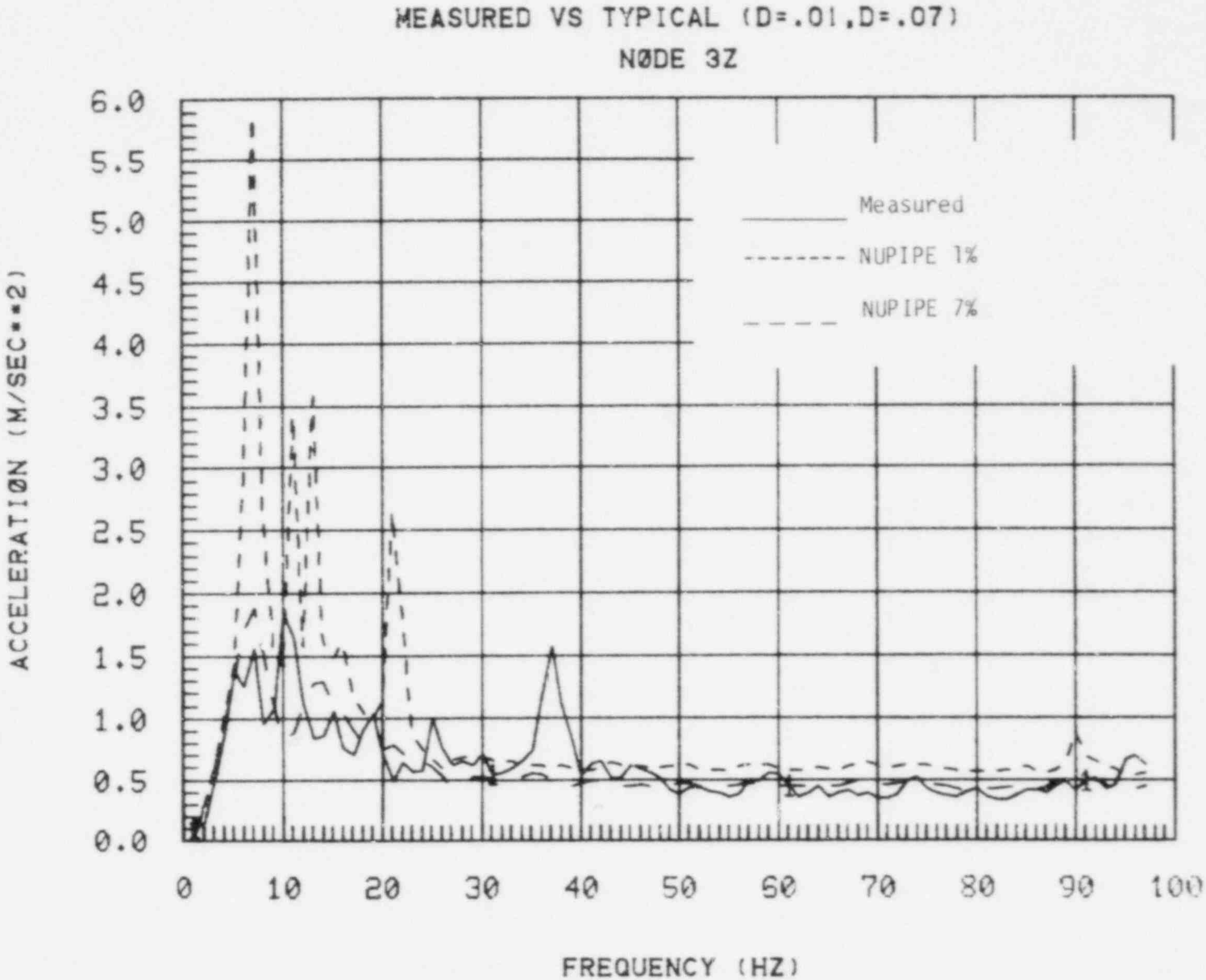

MEASURED VS ACTUAL K (M1VSM2) (D=.07)
NØDE 3X
Measured
NUPIPE "Actual" "M1"
NUPIPE "Actual" "M2"
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30
40
50
60
70
80
90
100

Figure 5.3.X



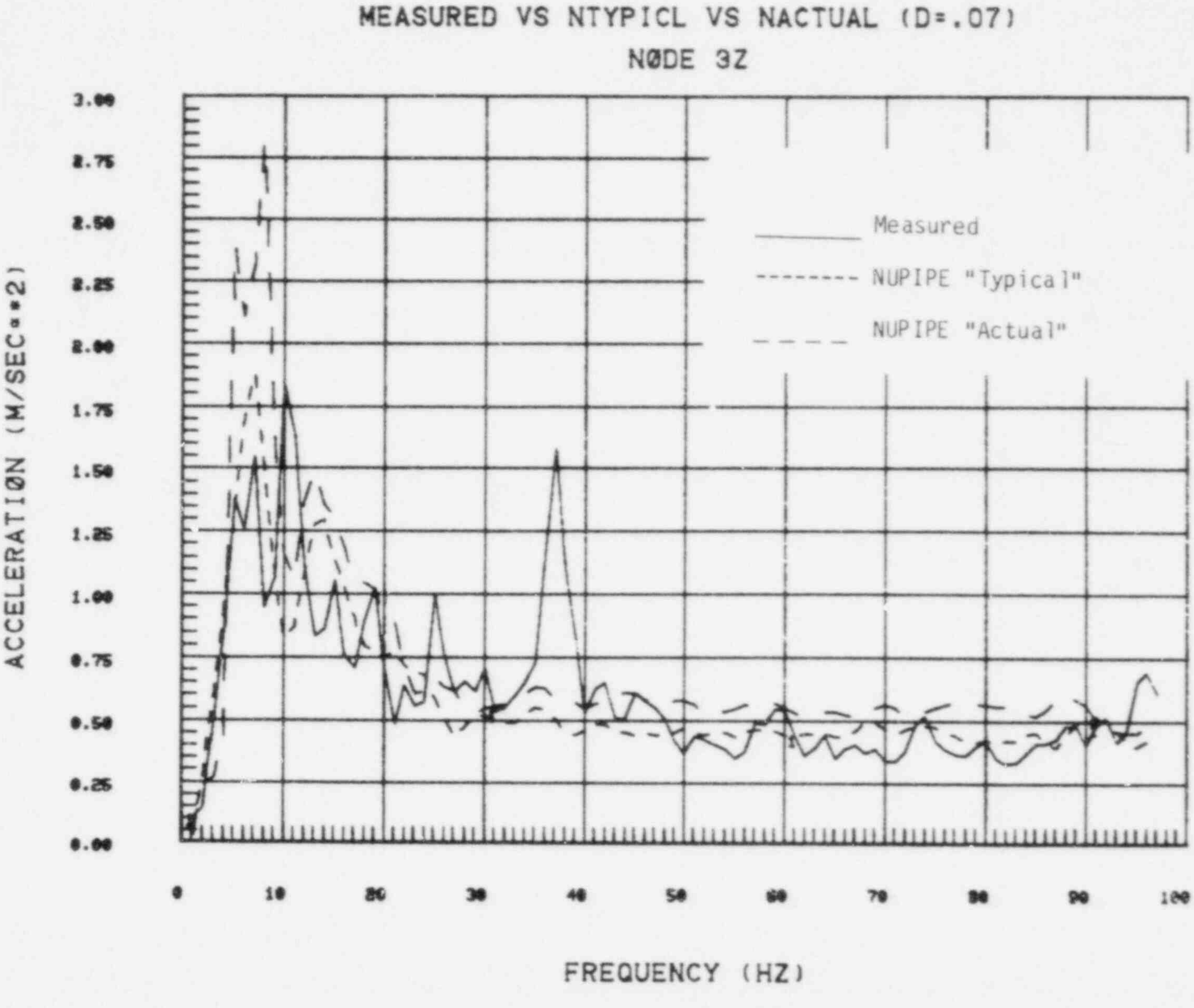
SPECTRA-MEASURED VS ANSYS ANALYSIS
NØDE 3,Z
Measured
Predicted By ANSYS
ACCELERATIØN (M/SEC**2)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
22.5
25.0
27.5
30.0
32.5
35.0
37.5
40.0
FREQUENCY (HZ)

Figure 1.3.Z



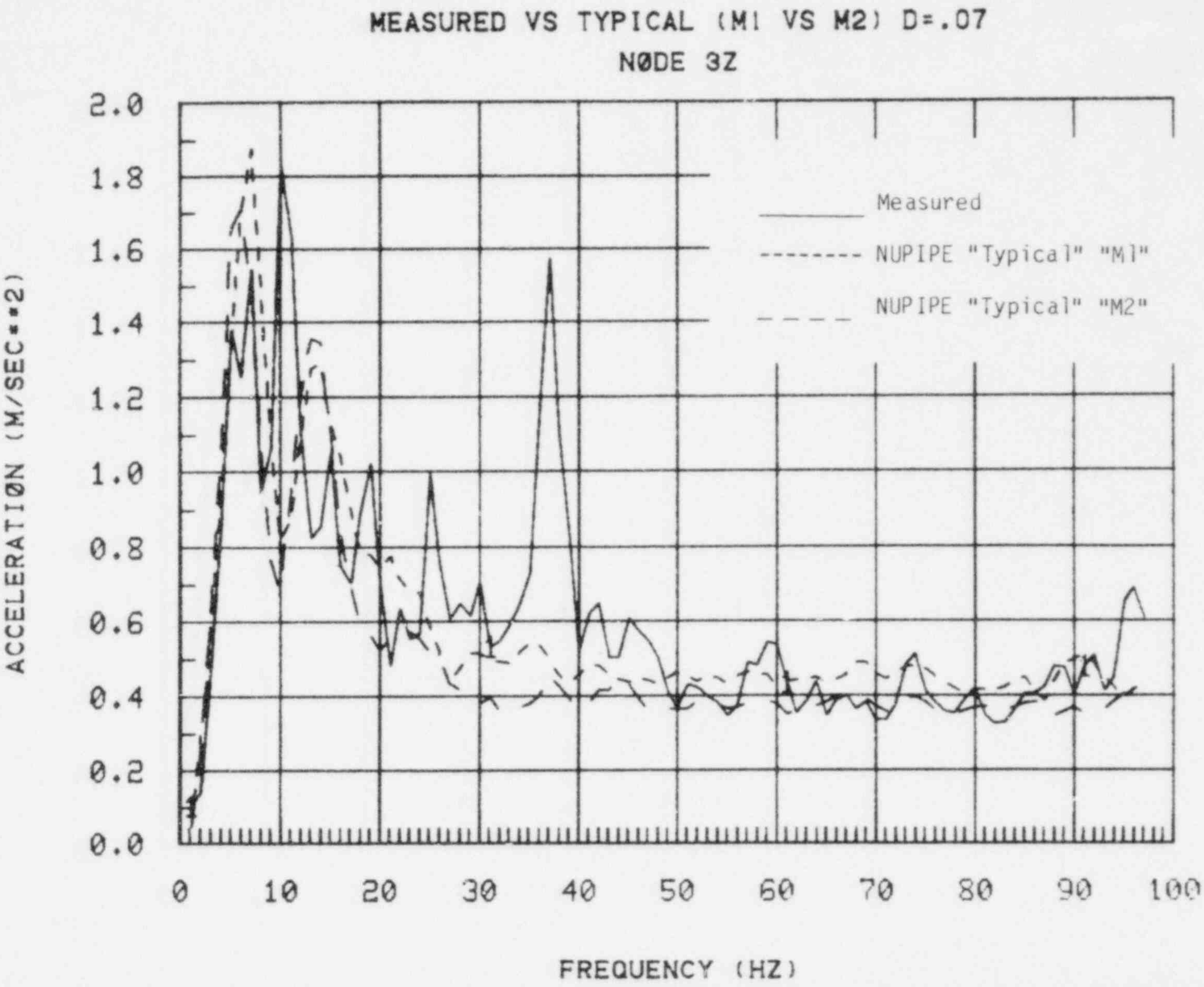
MEASURED VS TYPICAL (D=.01,D=.07)
NØDE 3Z
Measured
NUPIPE 1%
NUPIPE 7%
ACCELERATIØN (M/SEC**2)
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
70
80
90
100
FREQUENCY (HZ)

Figure 2.3.Z



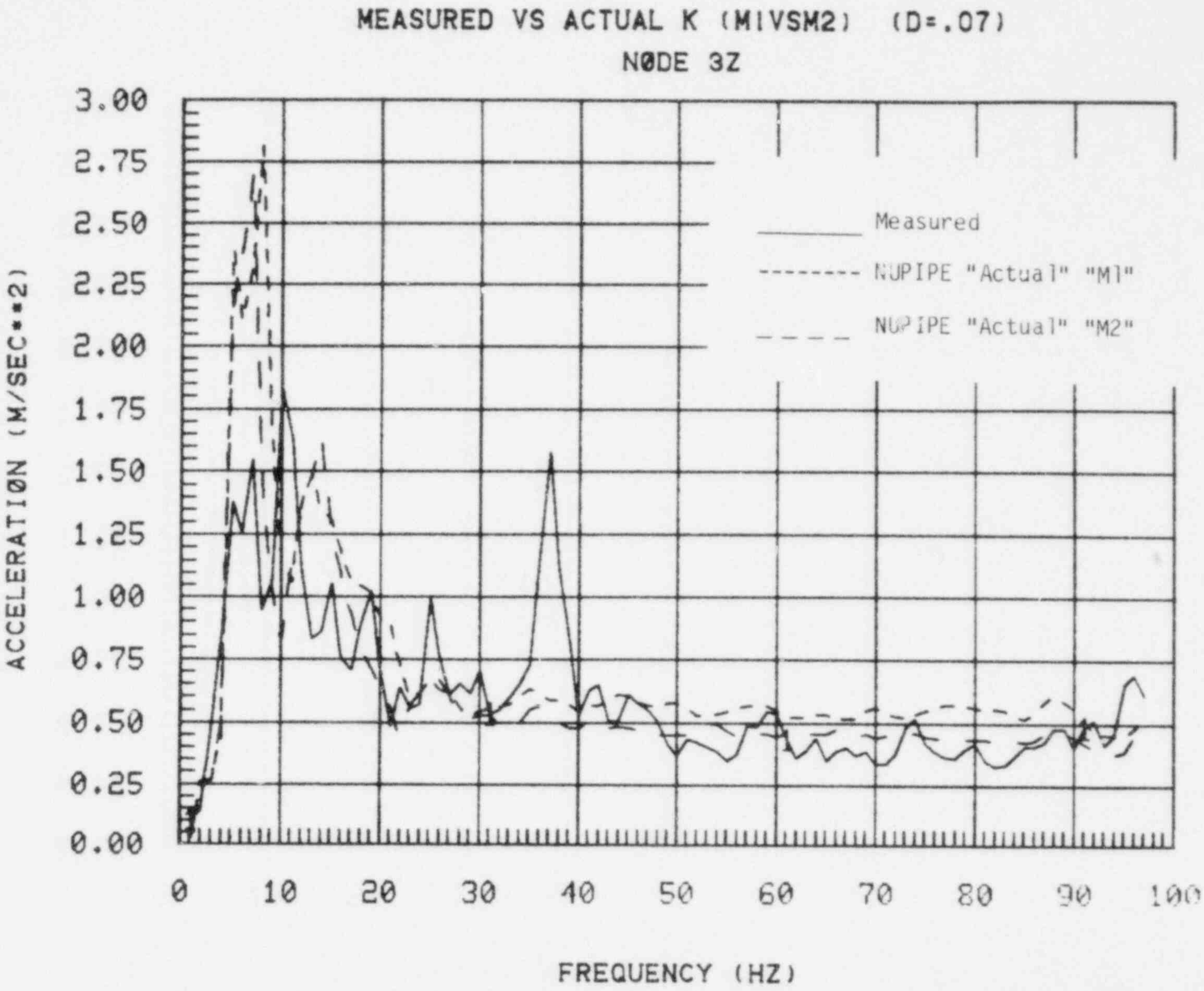
MEASURED VS NTYPICL VS NACTUAL (D=.07)
NØDE 3Z
Measured
NUPIPE "Typical"
NUPIPE "Actual"
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)

Figure 3.3.Z



MEASURED VS TYPICAL (M1 VS M2) D=.07
NØDE 3Z
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30
40
50
60
70
80
90
100
Measured
NUPIPE "Typical" "M1"
NUPIPE "Typical" "M2"

Figure 4.3.Z



MEASURED VS ACTUAL K (M1VSM2) (D=.07)
NØDE 3Z
ACCELERATIØN (M/SEC**2)
3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0
10
20
30
40
50
60
70
80
90
100
FREQUENCY (HZ)
Measured
NUPIPE "Actual" "M1"
NUPIPE "Actual" "M2"

Figure 5.3.Z

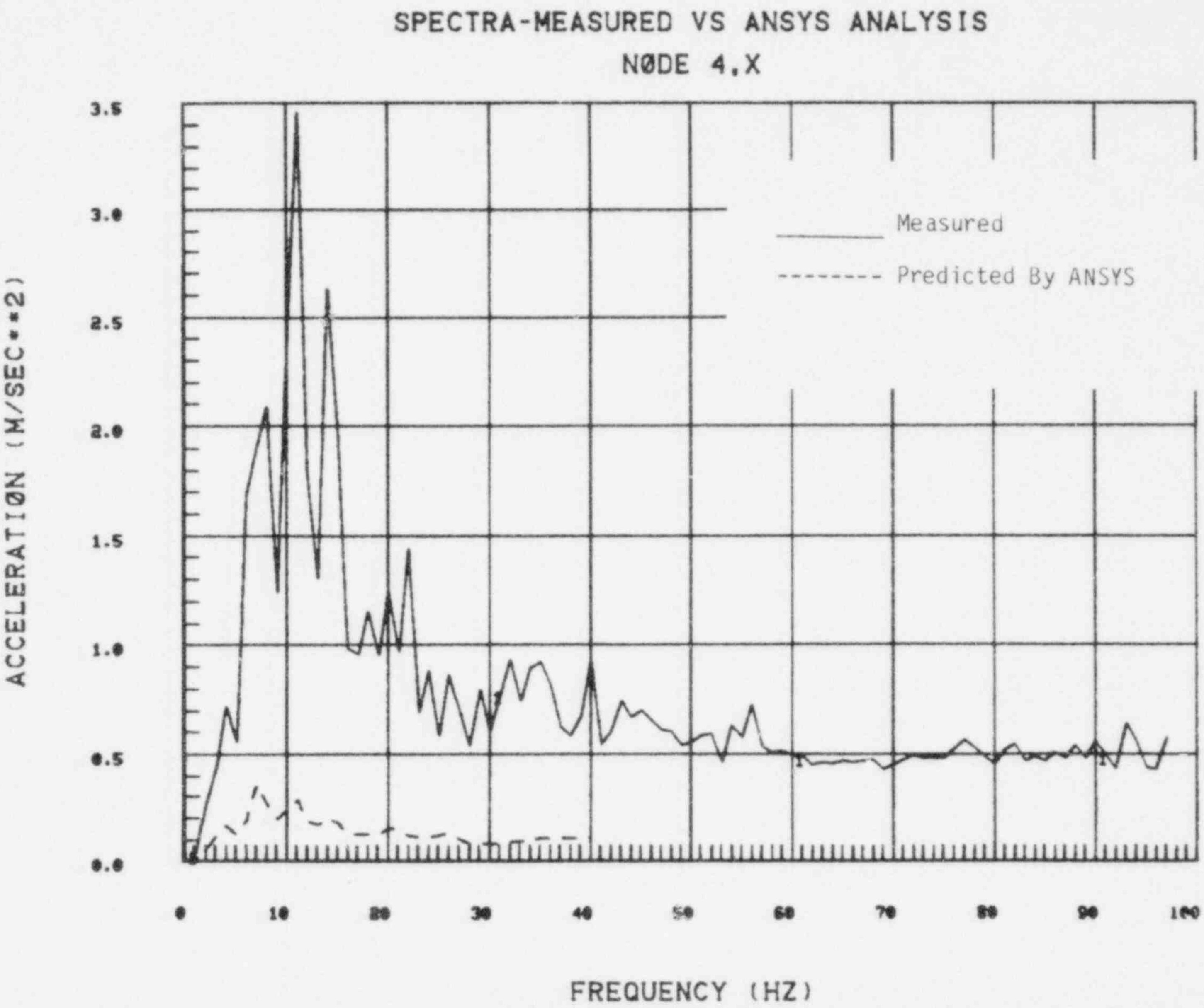
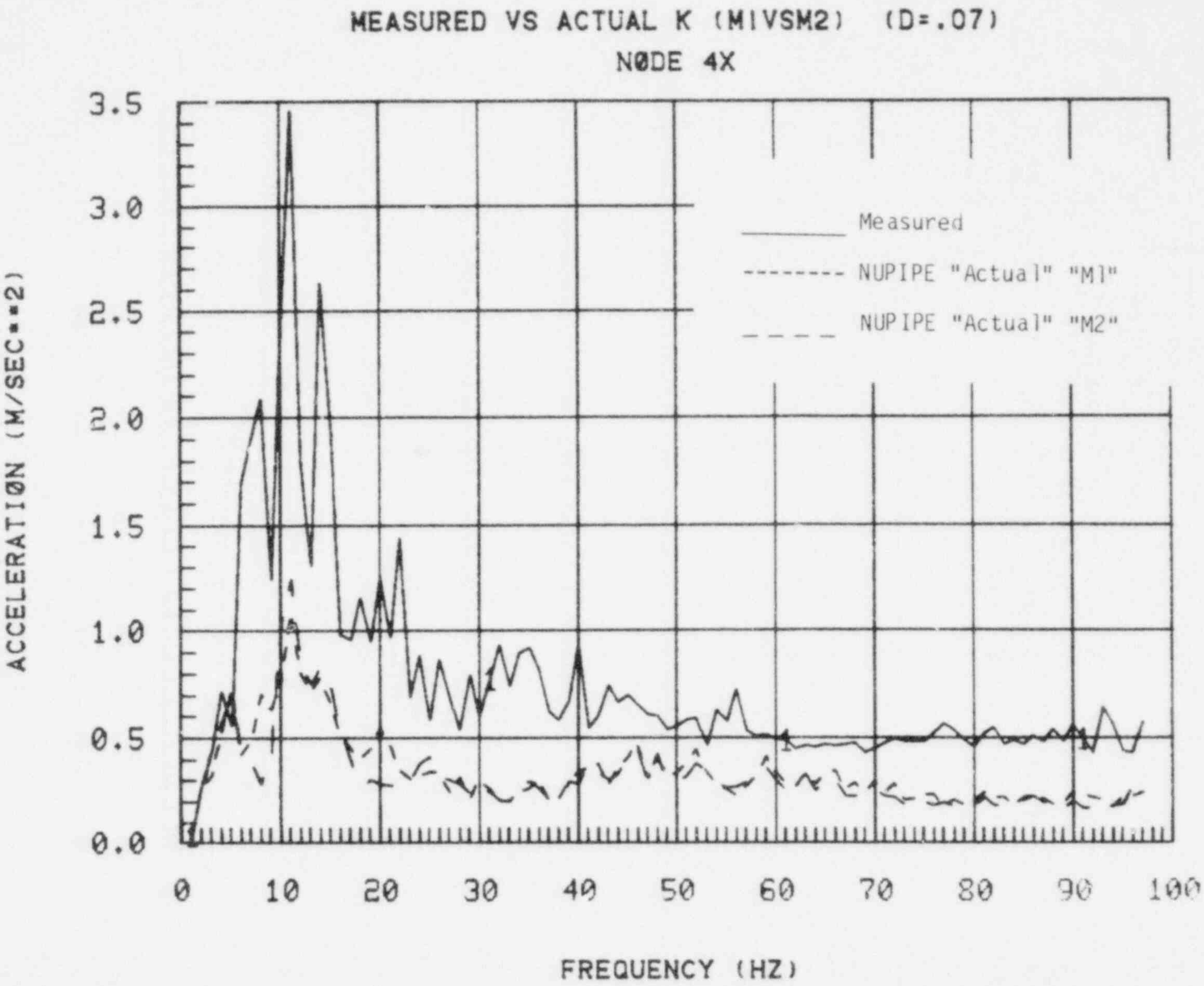
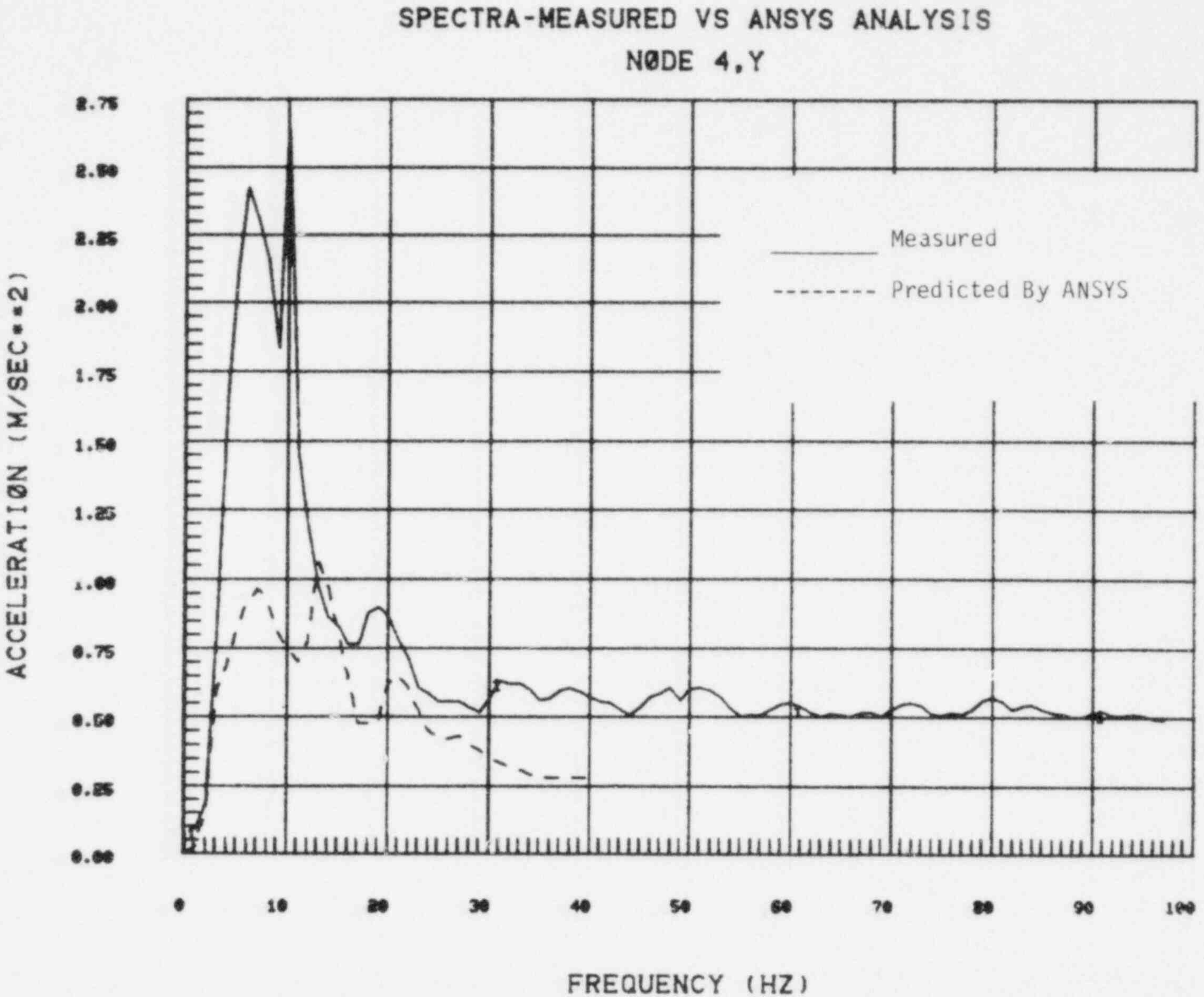

SPECTRA-MEASURED VS ANSYS ANALYSIS
NØDE 4.X
Measured
Predicted By ANSYS
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
70
80
90
100

Figure 1.4.X



MEASURED VS ACTUAL K (M1VSM2) (D=.07)
NØDE 4X
Measured
NUPIPE "Actual" "M1"
NUPIPE "Actual" "M2"
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
0
10
20
30
40
50
60
70
80
90
100

Figure 4.4.X



SPECTRA-MEASURED VS ANSYS ANALYSIS
NØDE 4,Y
ACCELERATIØN (M/SEC**2)
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0
10
20
30
40
50
60
70
80
90
100
FREQUENCY (HZ)
Measured
Predicted By ANSYS

Figure 1.4.Y

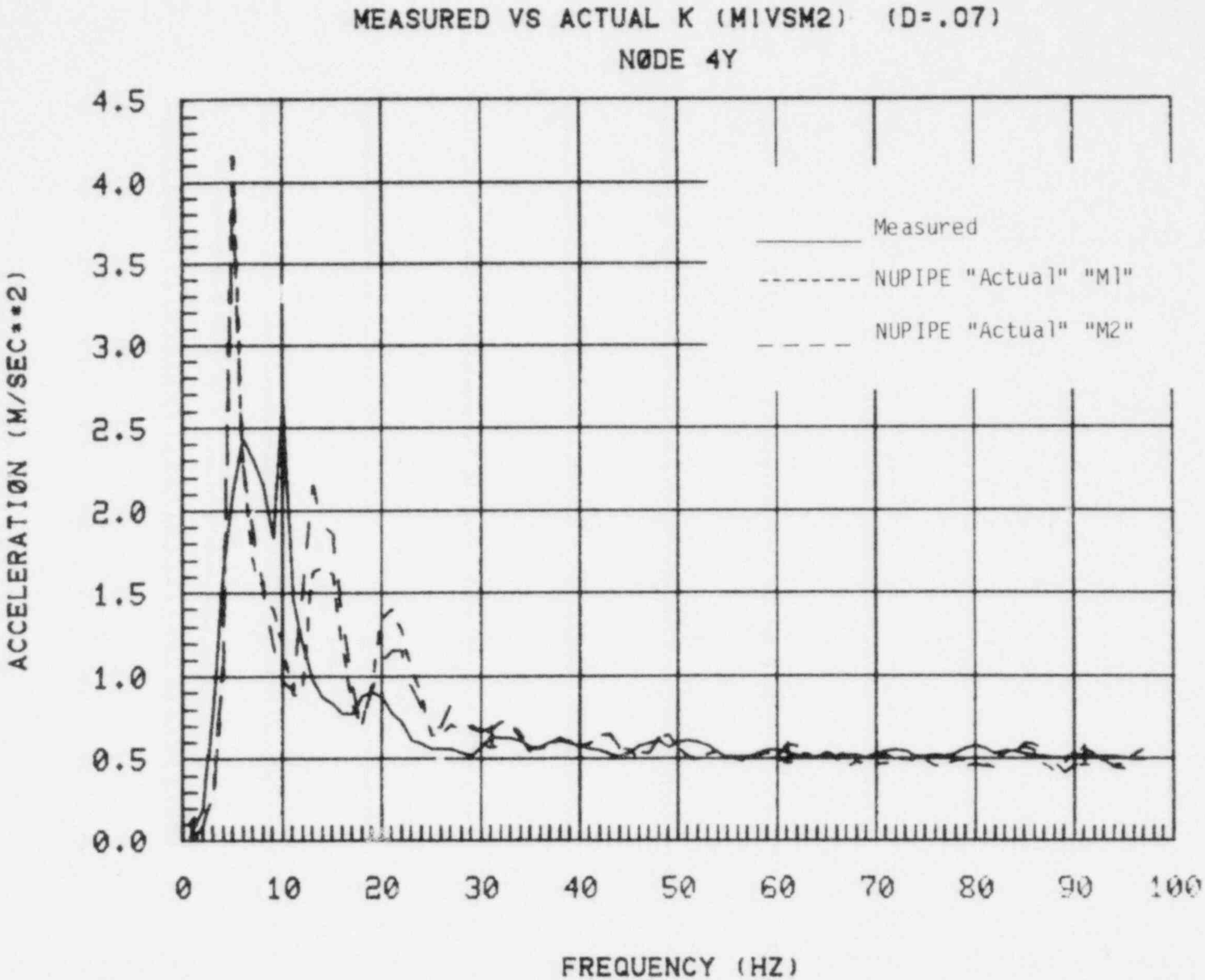
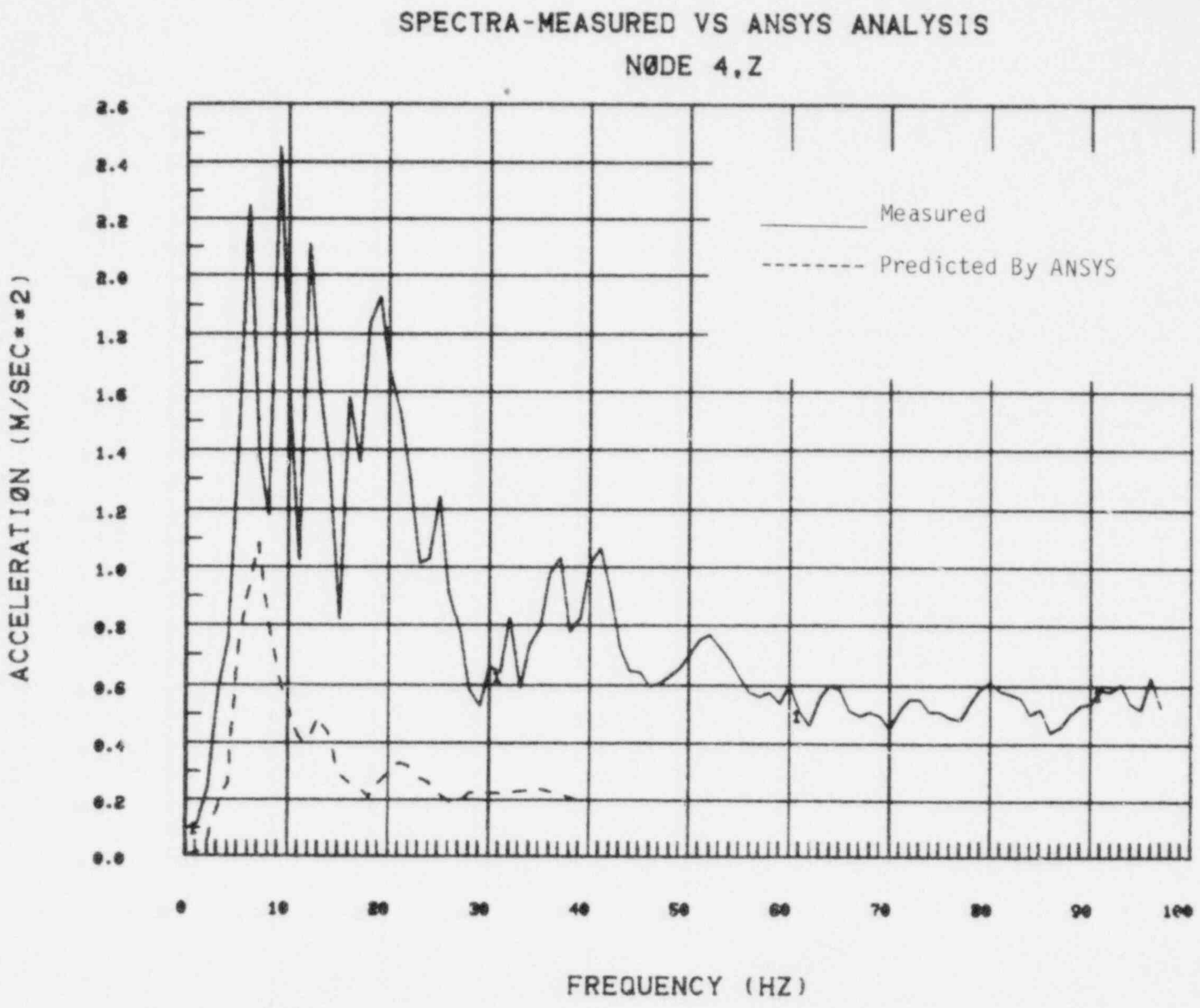
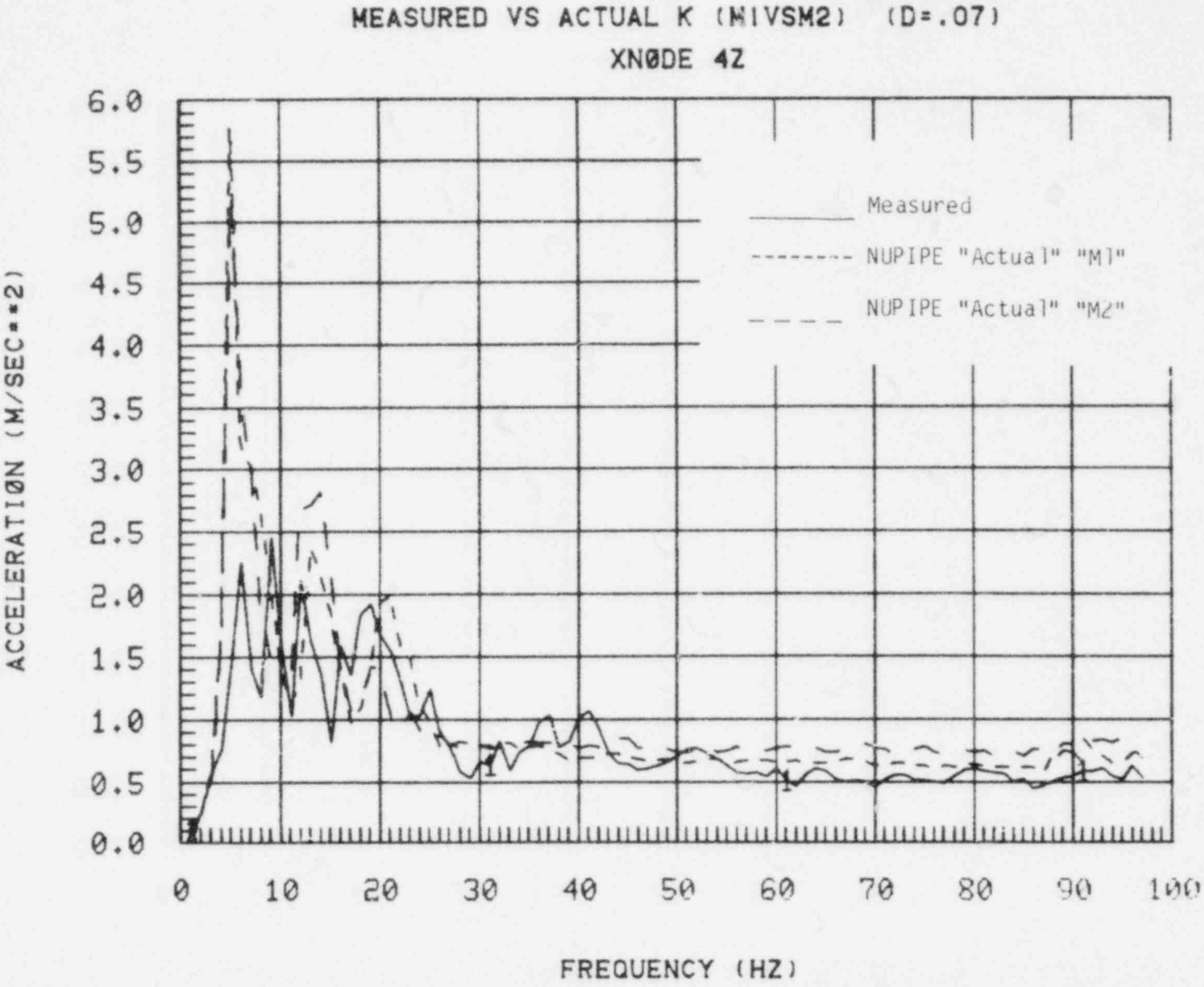

MEASURED VS ACTUAL K (M1VSM2) (D=.07)
NØDE 4Y
ACCELERATIØN (M/SEC**2)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
70
80
90
100
FREQUENCY (HZ)
Measured
NUPIPE "Actual" "M1"
NUPIPE "Actual" "M2"

Figure 5.4.Y



SPECTRA-MEASURED VS ANSYS ANALYSIS
NØDE 4,Z
Measured
Predicted By ANSYS
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)

Figure 1.4.Z



MEASURED VS ACTUAL K (M1VSM2) (D=.07)
XNØDE 4Z
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
Measured
NUPIPE "Actual" "M1"
NUPIPE "Actual" "M2"
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
70
80
90
100

Figure 5.4.Z

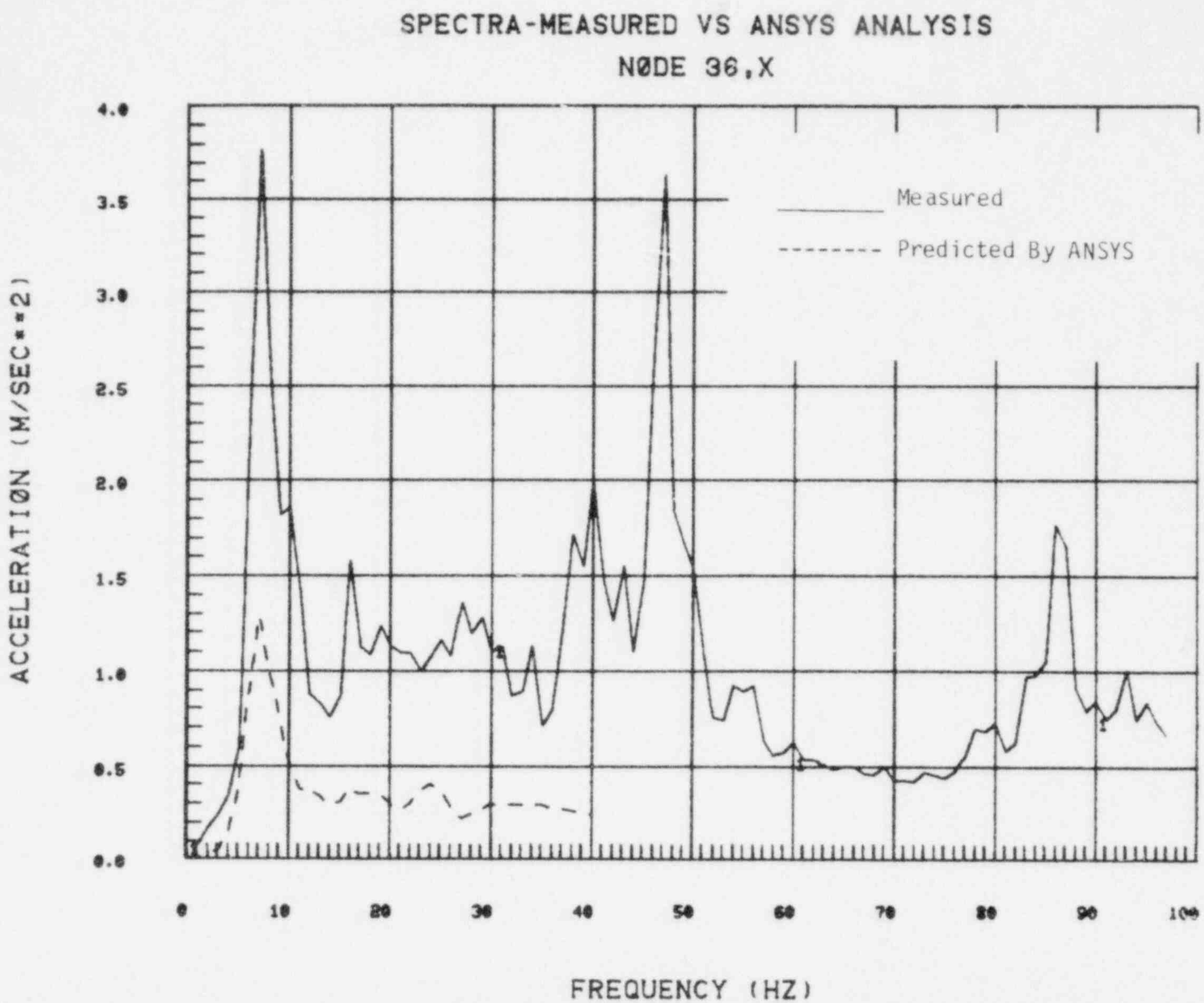

SPECTRA-MEASURED VS ANSYS ANALYSIS
NØDE 36,X
ACCELERATIØN (M/SEC**2)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
70
80
90
100
FREQUENCY (HZ)
Measured
Predicted By ANSYS

Figure 1.36.X

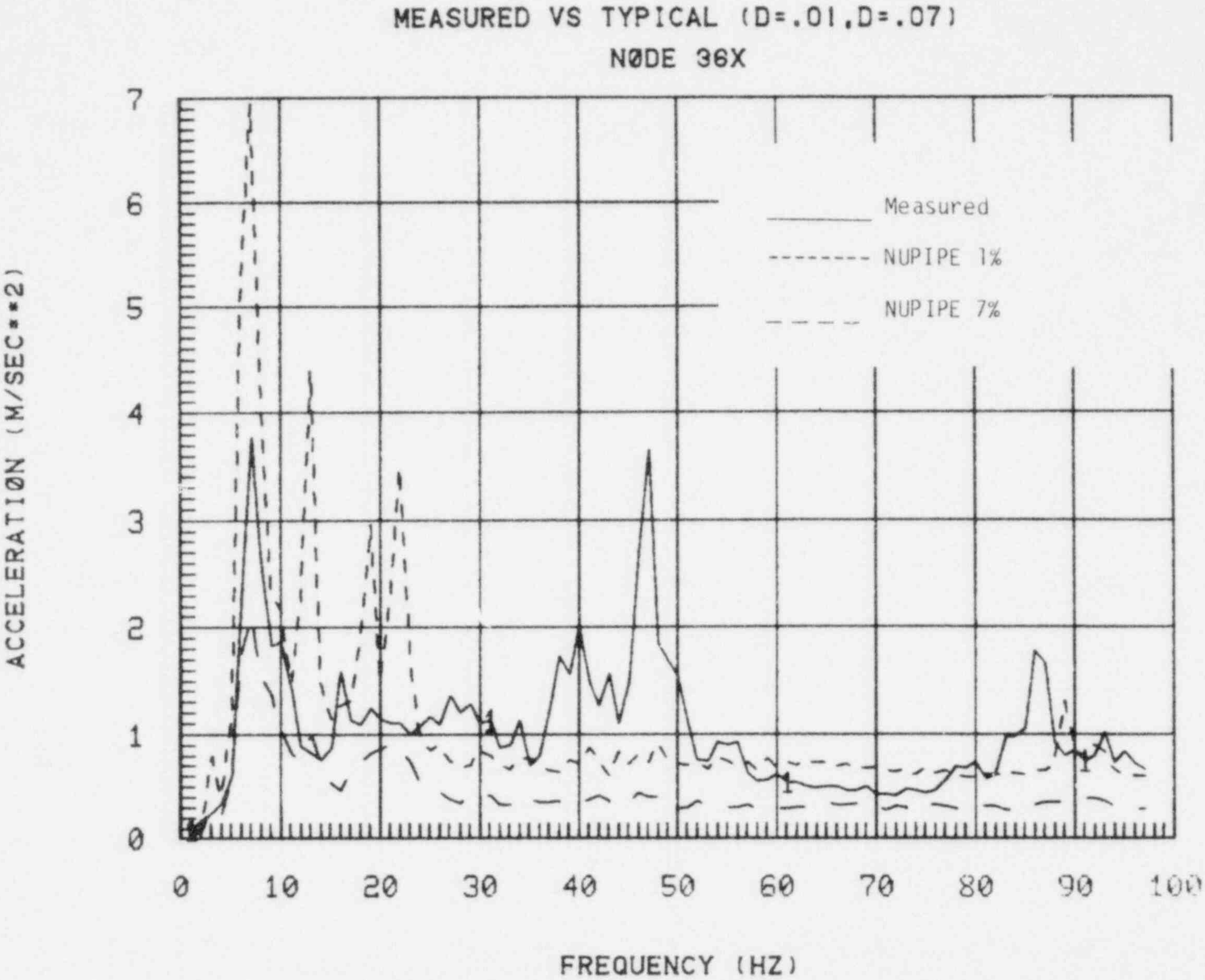
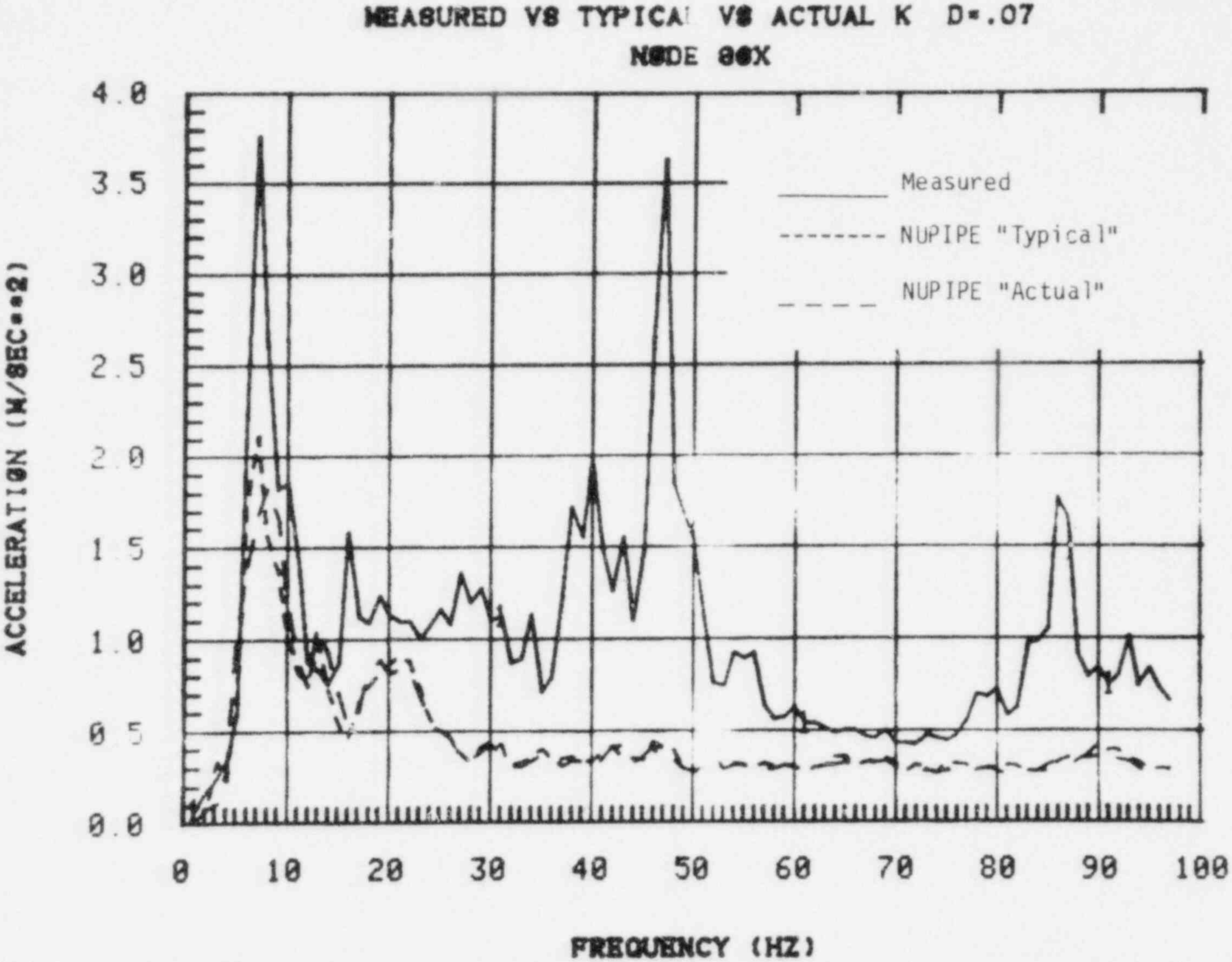

MEASURED VS TYPICAL (D=.01,D=.07)
NØDE 36X
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
Measured
NUPIPE 1%
NUPIPE 7%
0
1
2
3
4
5
6
7
0
10
20
30
40
50
60
70
80
90
100

Figure 2.36.X



MEASURED VS TYPICAL VS ACTUAL K D=.07
NODE 80X
ACCELERATION (M/SEC**2)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
70
80
90
100
FREQUENCY (HZ)
Measured
NUPIPE "Typical"
NUPIPE "Actual"

Figure 3.36.X

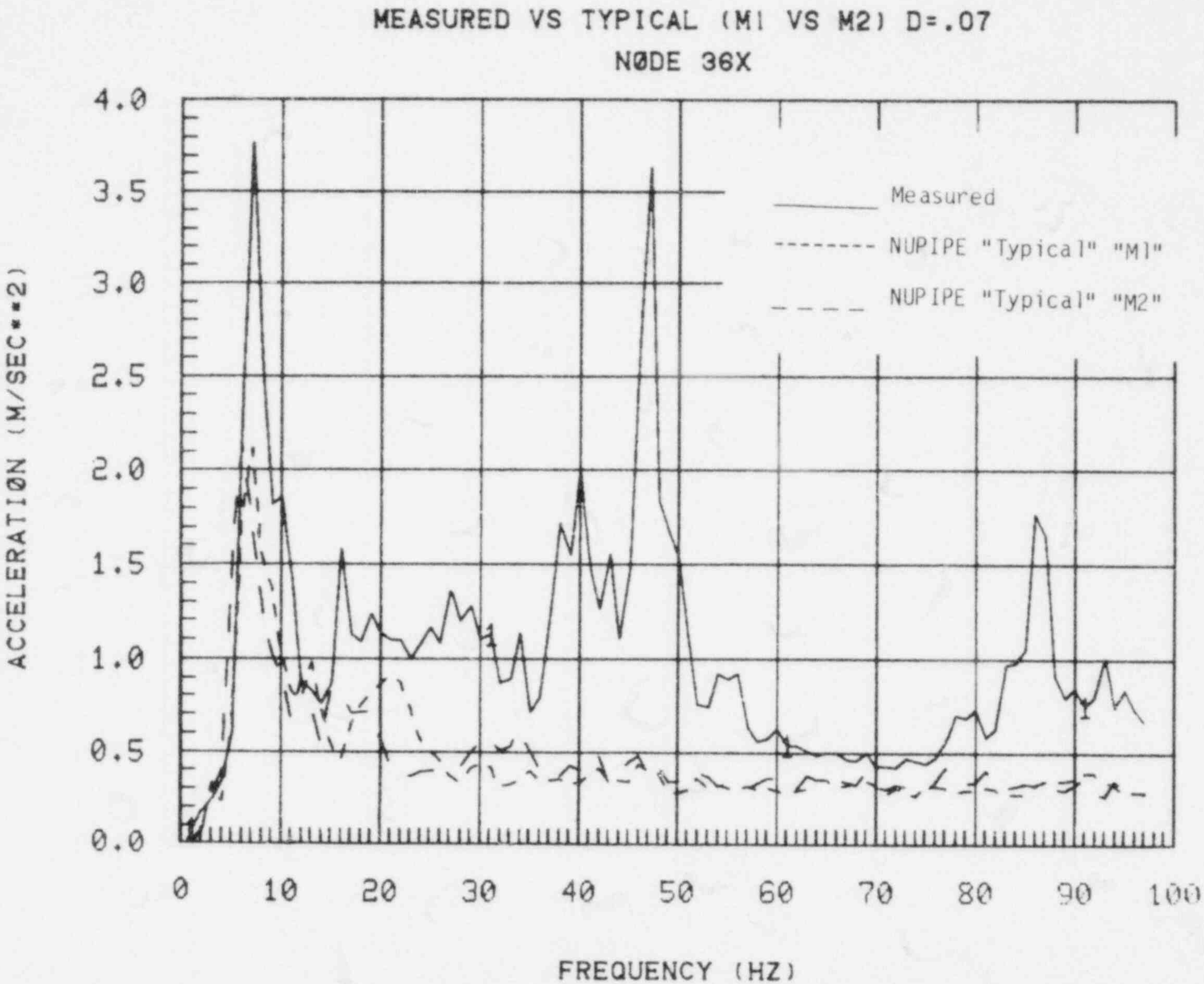
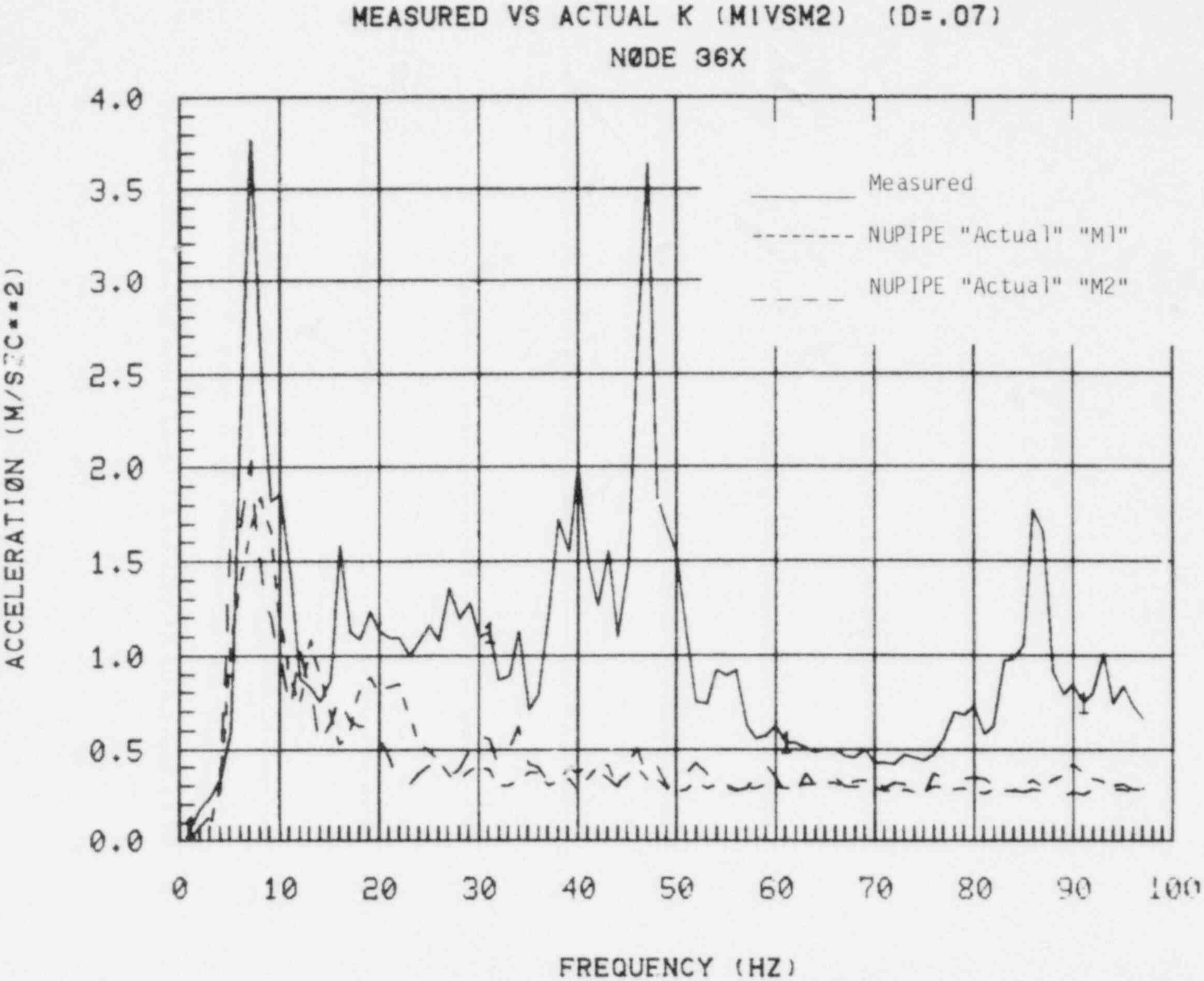
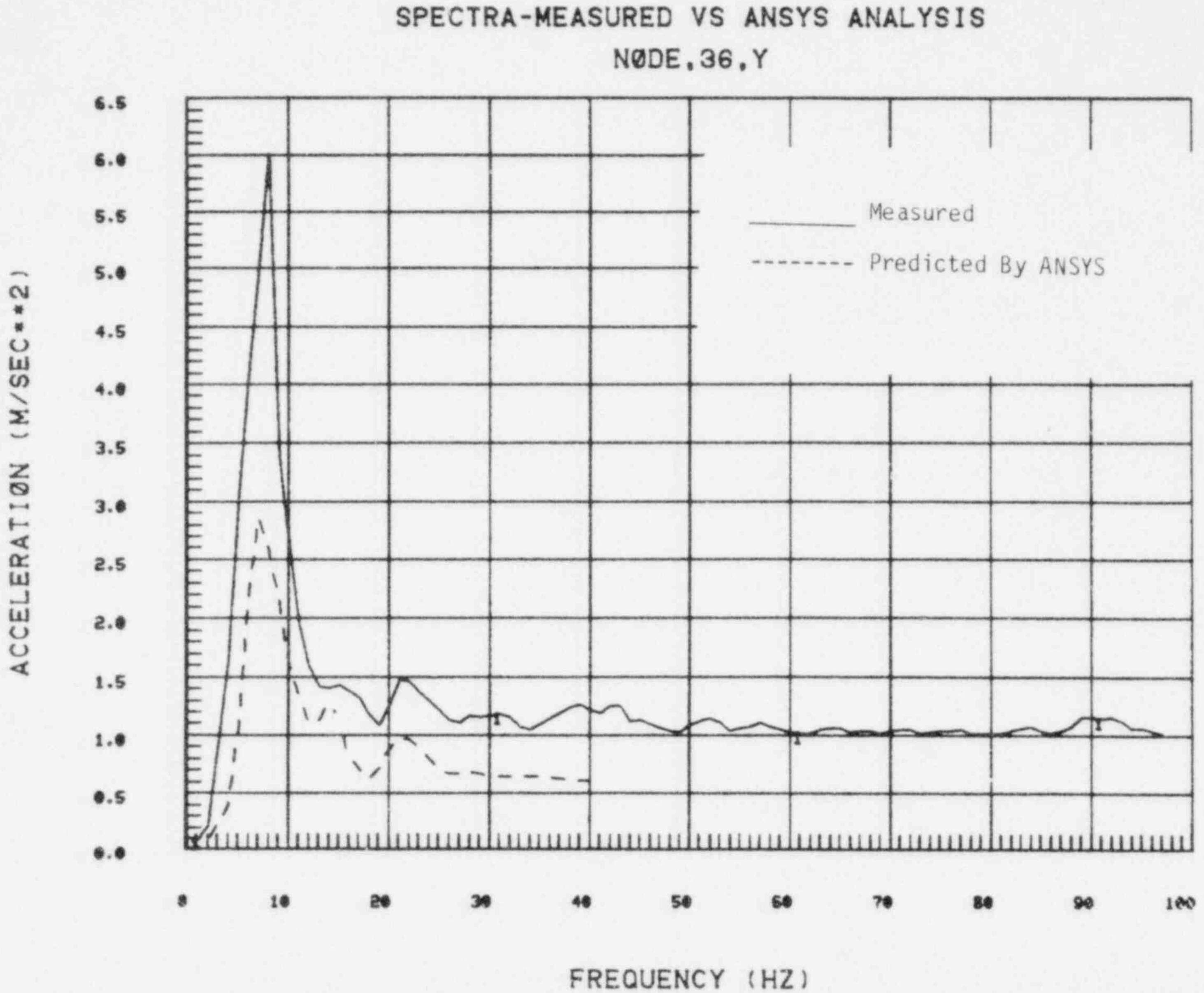

MEASURED VS TYPICAL (M1 VS M2) D=.07
NØDE 36X
ACCELERATIØN (M/SEC**2)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
70
80
90
100
FREQUENCY (HZ)
Measured
NUPIPE "Typical" "M1"
NUPIPE "Typical" "M2"

Figure 4.36.X



MEASURED VS ACTUAL K (M1VSM2) (D=.07)
NØDE 36X
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
Measured
NUPIPE "Actual" "M1"
NUPIPE "Actual" "M2"
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
70
80
90
100

Figure 5.36.X



SPECTRA-MEASURED VS ANSYS ANALYSIS
NØDE,36,Y
Measured
Predicted By ANSYS
ACCELERATIØN (M/SEC**2)
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
70
80
90
100
FREQUENCY (HZ)

Figure 1.36.Y

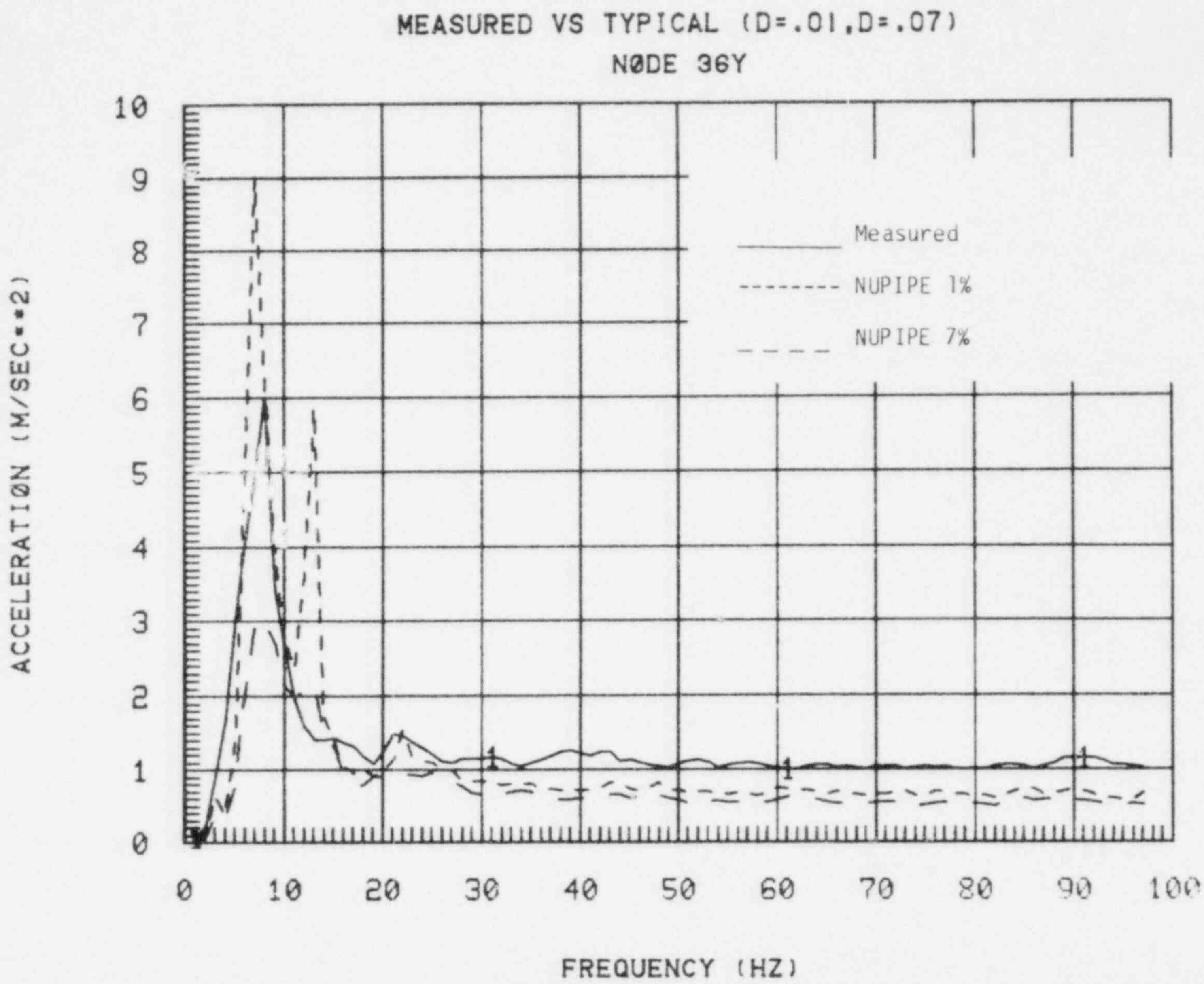

MEASURED VS TYPICAL (D=.01,D=.07)
NØDE 36Y
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
Measured
NUPIPE 1%
NUPIPE 7%
0
1
2
3
4
5
6
7
8
9
10
0
10
20
30
40
50
60
70
80
90
100

Figure 2.36.Y

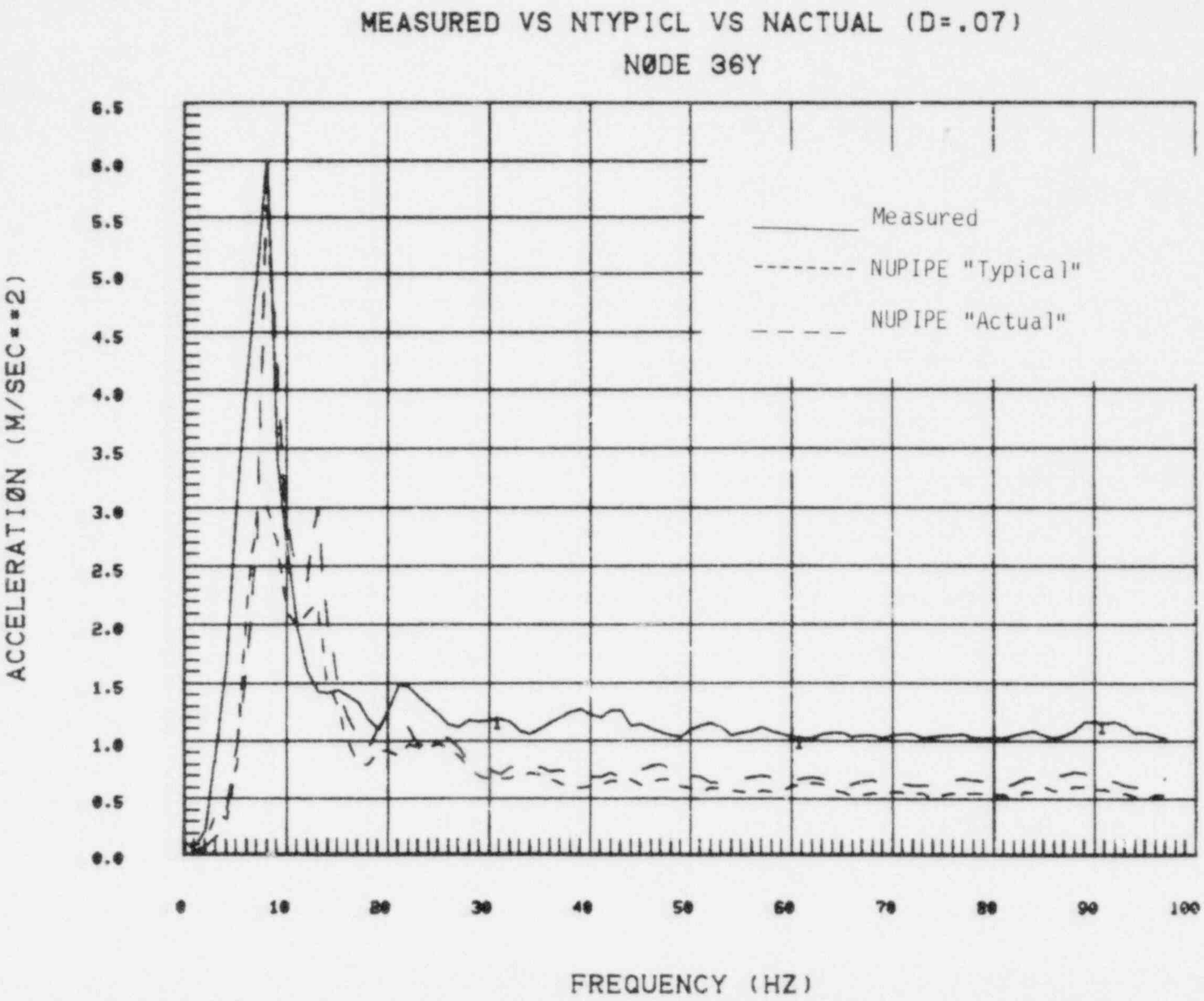

MEASURED VS NTYPICL VS NACTUAL (D=.07)
NØDE 36Y
ACCELERATIØN (M/SEC**2)
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
70
80
90
100
FREQUENCY (HZ)
Measured
NUPIPE "Typical"
NUPIPE "Actual"

Figure 3.36.Y

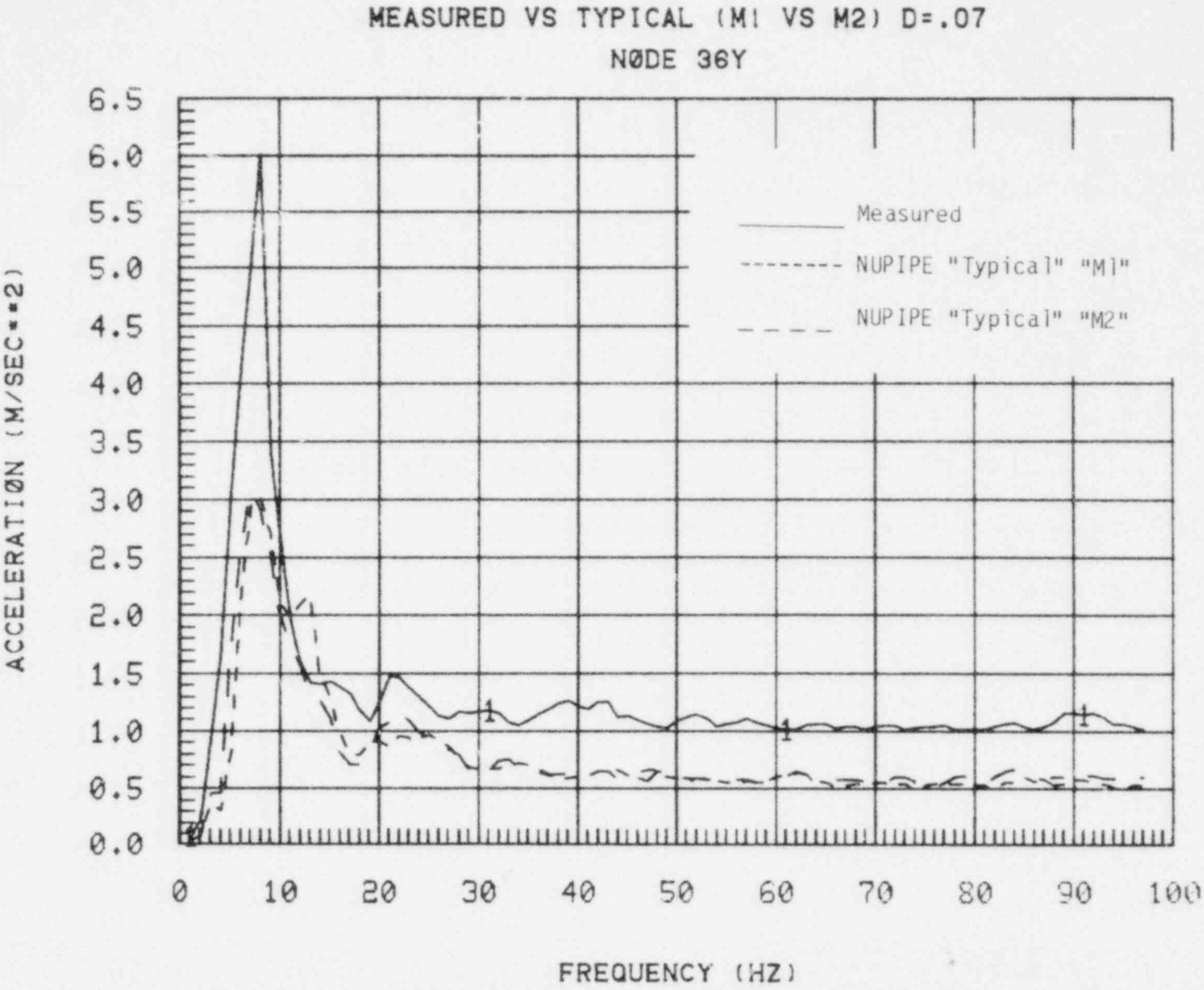

MEASURED VS TYPICAL (M1 VS M2) D=.07
NØDE 36Y
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
Measured
NUPIPE "Typical" "M1"
NUPIPE "Typical" "M2"
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
0
10
20
30
40
50
60
70
80
90
100

Figure 4.36.Y

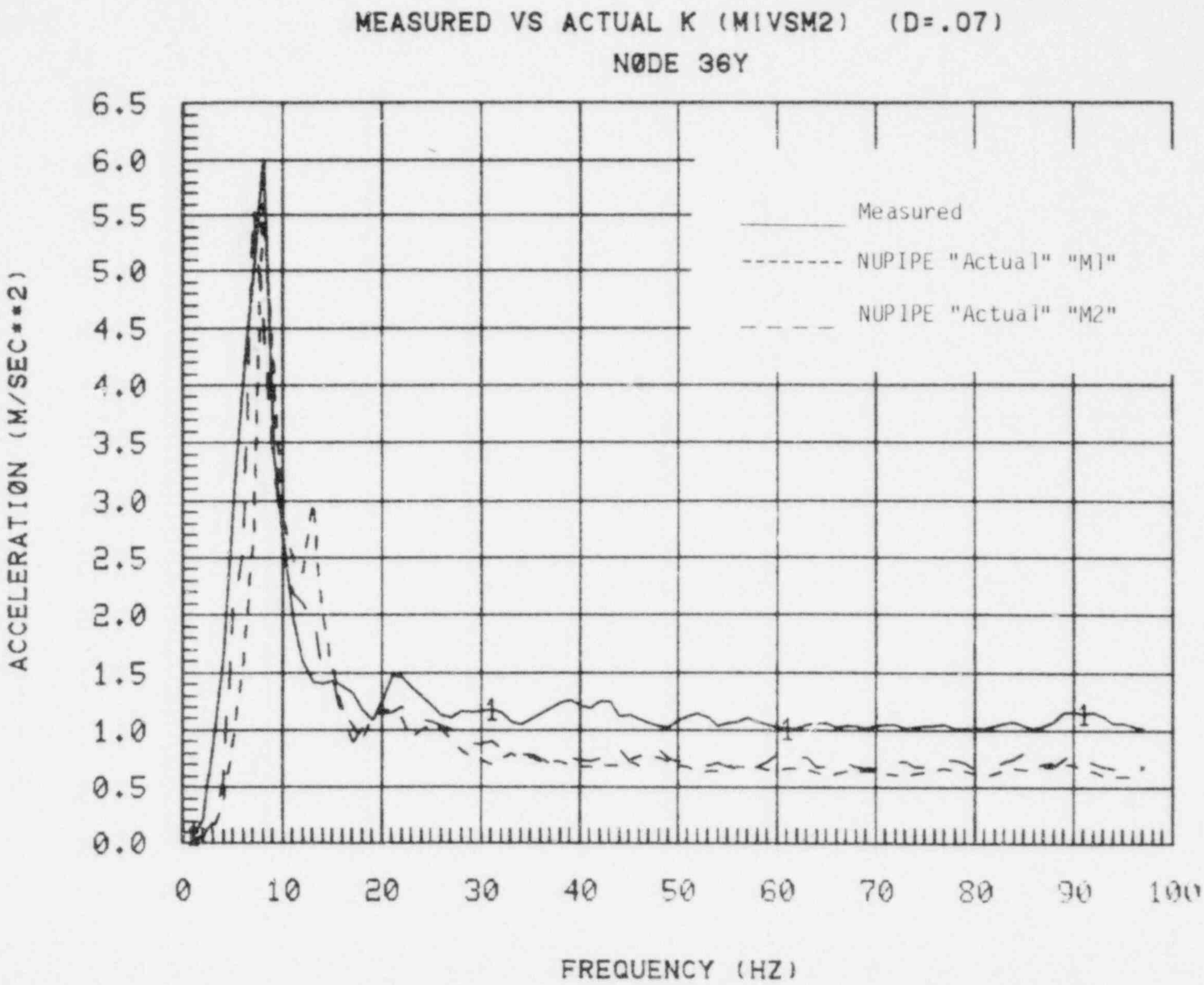
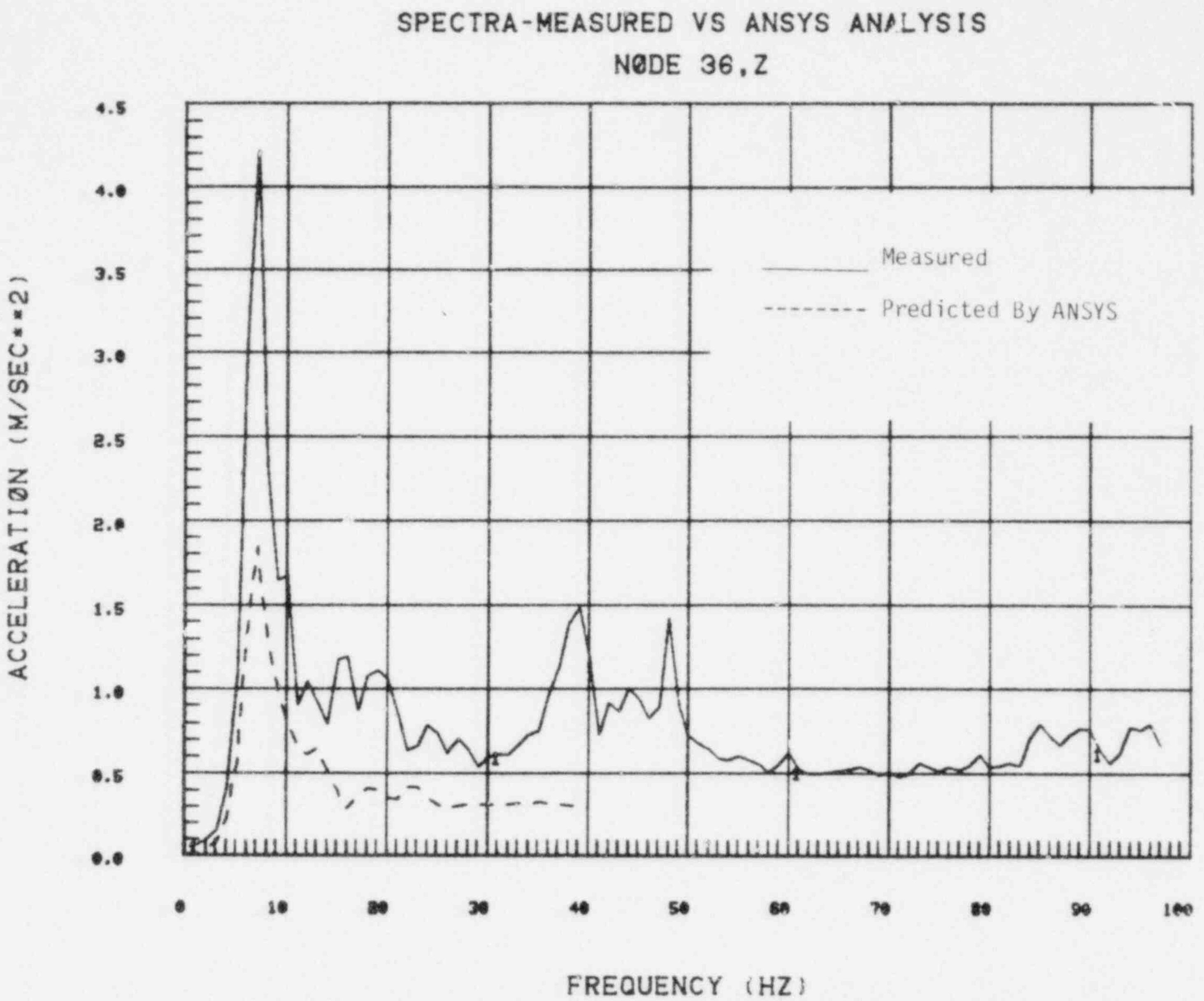

MEASURED VS ACTUAL K (M1VSM2) (D=.07)
NØDE 36Y
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
Measured
NUPIPE "Actual" "M1"
NUPIPE "Actual" "M2"
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
70
80
90
100

Figure 5.36.Y



SPECTRA-MEASURED VS ANSYS ANALYSIS
NØDE 36,Z
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
Measured
Predicted By ANSYS

Figure 1.36.Z

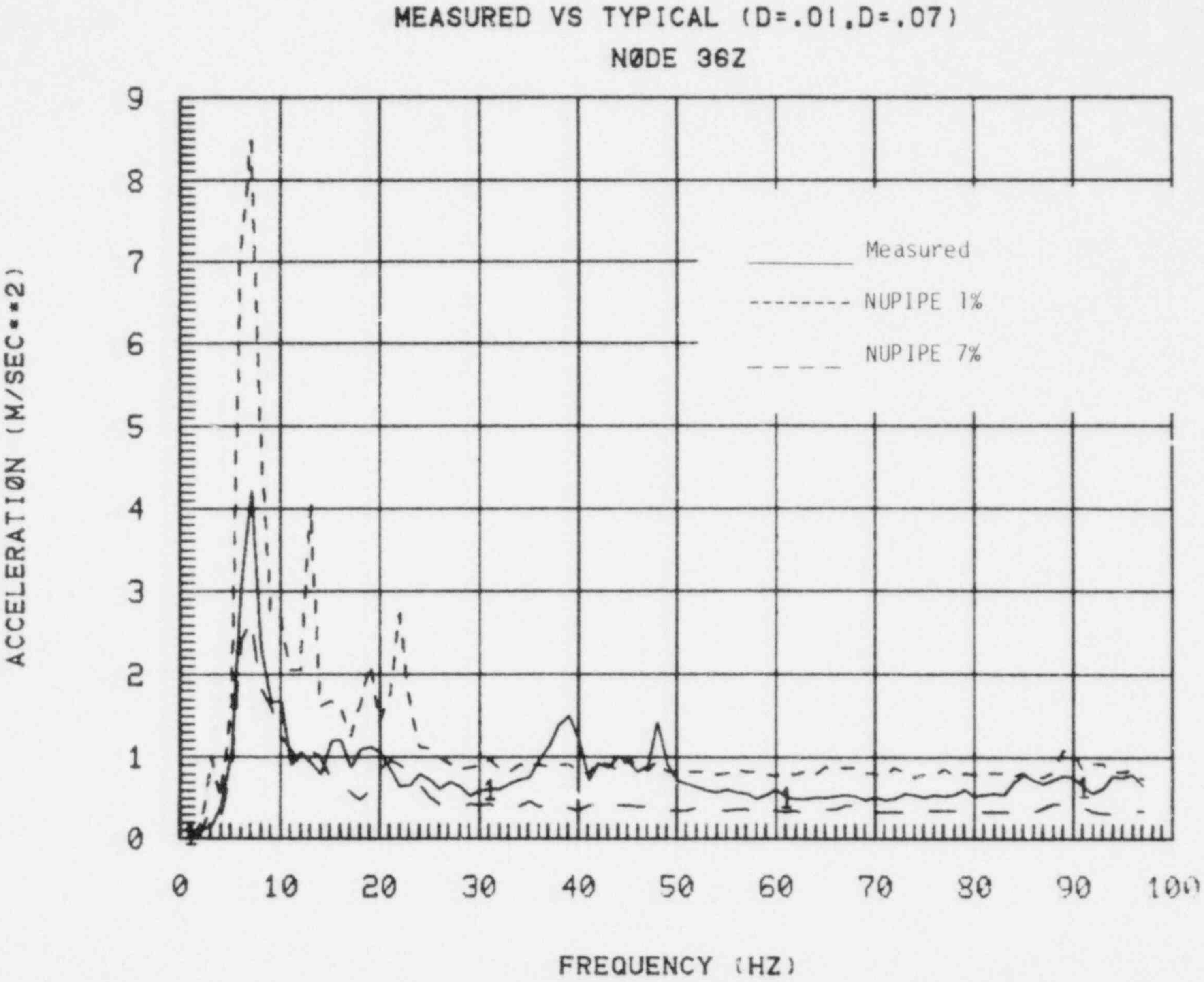

MEASURED VS TYPICAL (D=.01,D=.07)
NØDE 36Z
Measured
NUPIPE 1%
NUPIPE 7%
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
0
1
2
3
4
5
6
7
8
9
0
10
20
30
40
50
60
70
80
90
100

Figure 2.36.Z

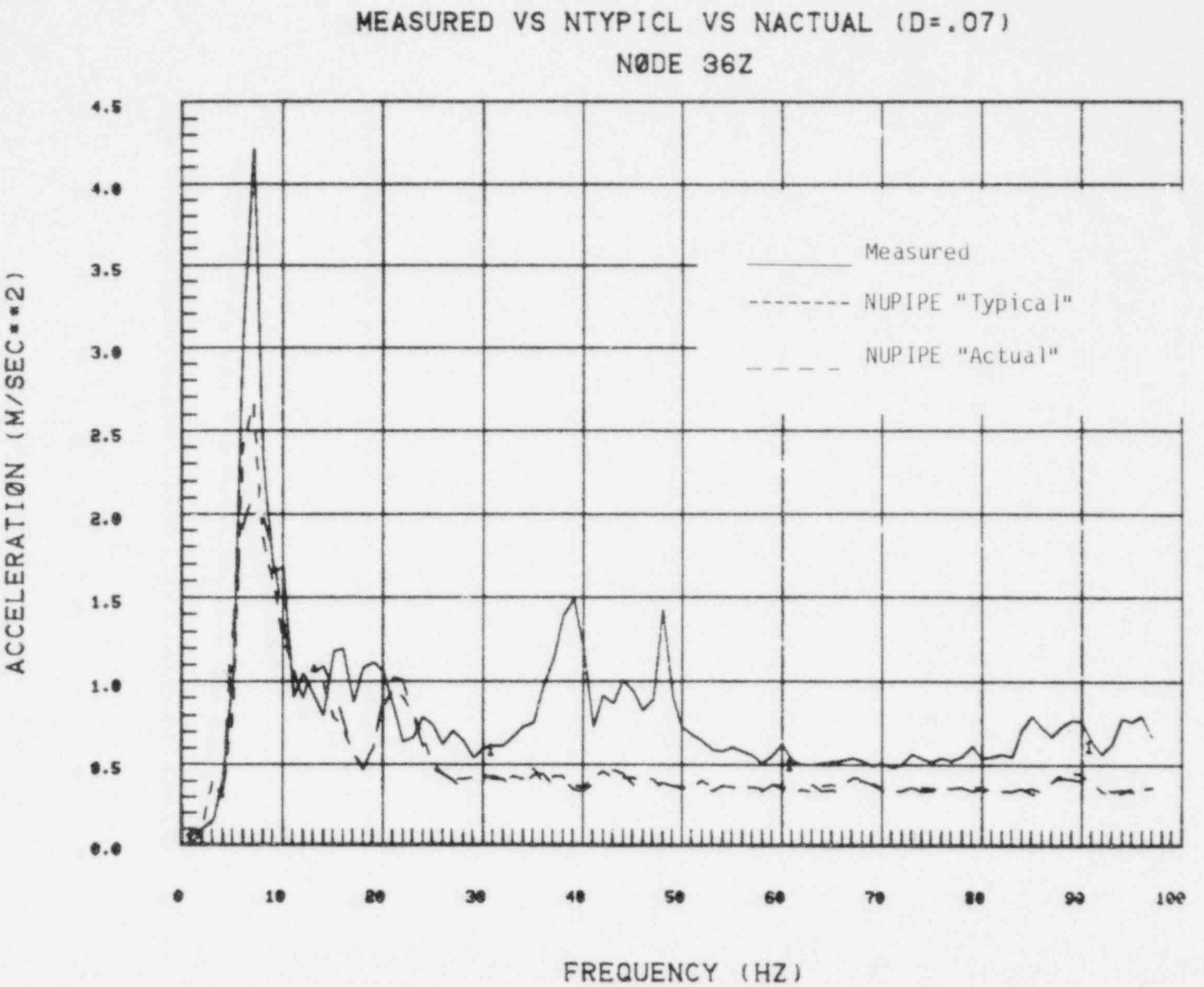

MEASURED VS NTYPICL VS NACTUAL (D=.07)
NØDE 36Z
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
Measured
NUPIPE "Typical"
NUPIPE "Actual"
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
0
10
20
30
40
50
60
70
80
90
100

Figure 3.36.Z

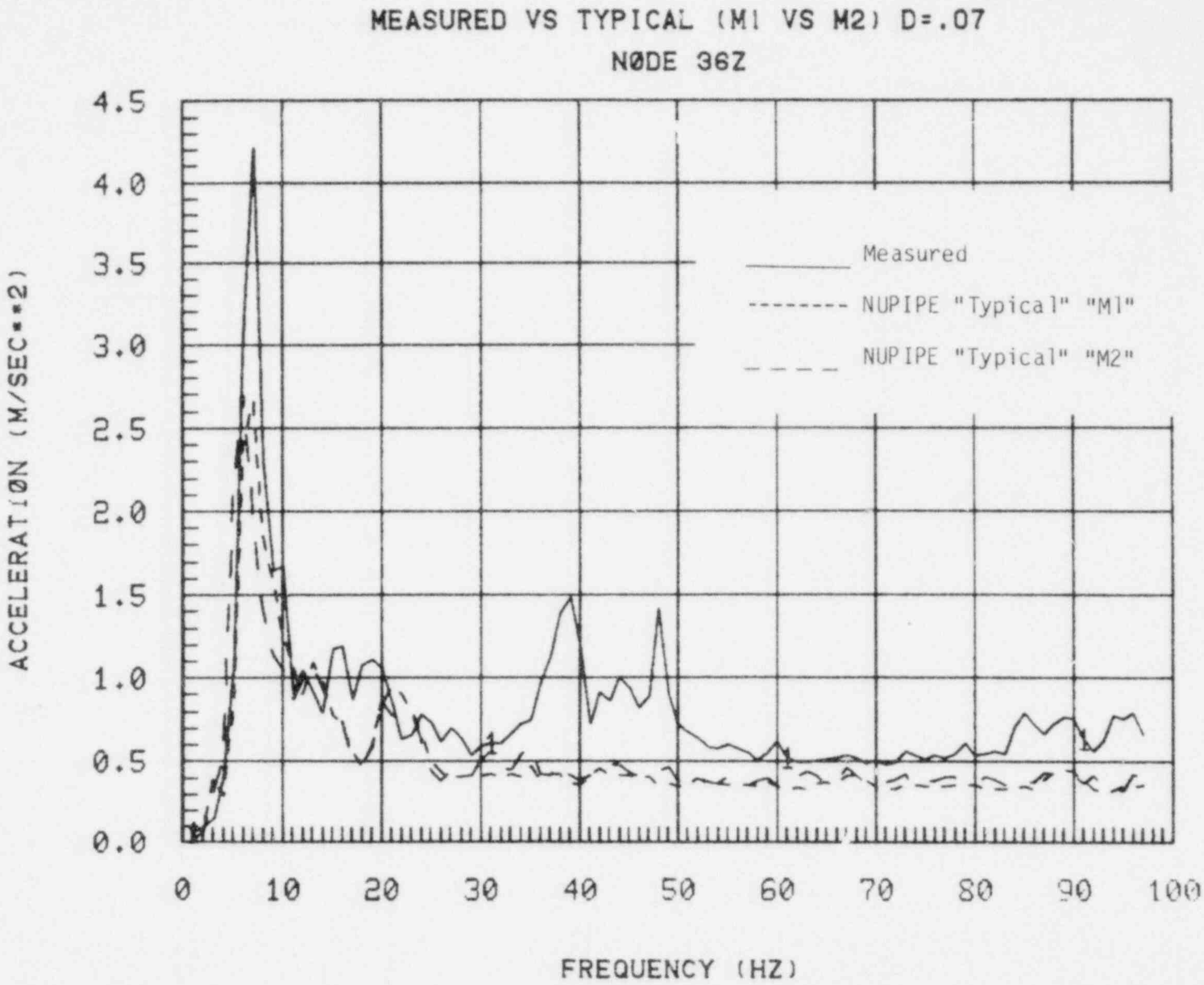

MEASURED VS TYPICAL (M1 VS M2) D=.07
NØDE 36Z
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
ACCELERATIØN (M/SEC**2)
0
10
20
30
40
50
60
70
80
90
100
FREQUENCY (HZ)
Measured
NUPIPE "Typical" "M1"
NUPIPE "Typical" "M2"

Figure 4.36.Z

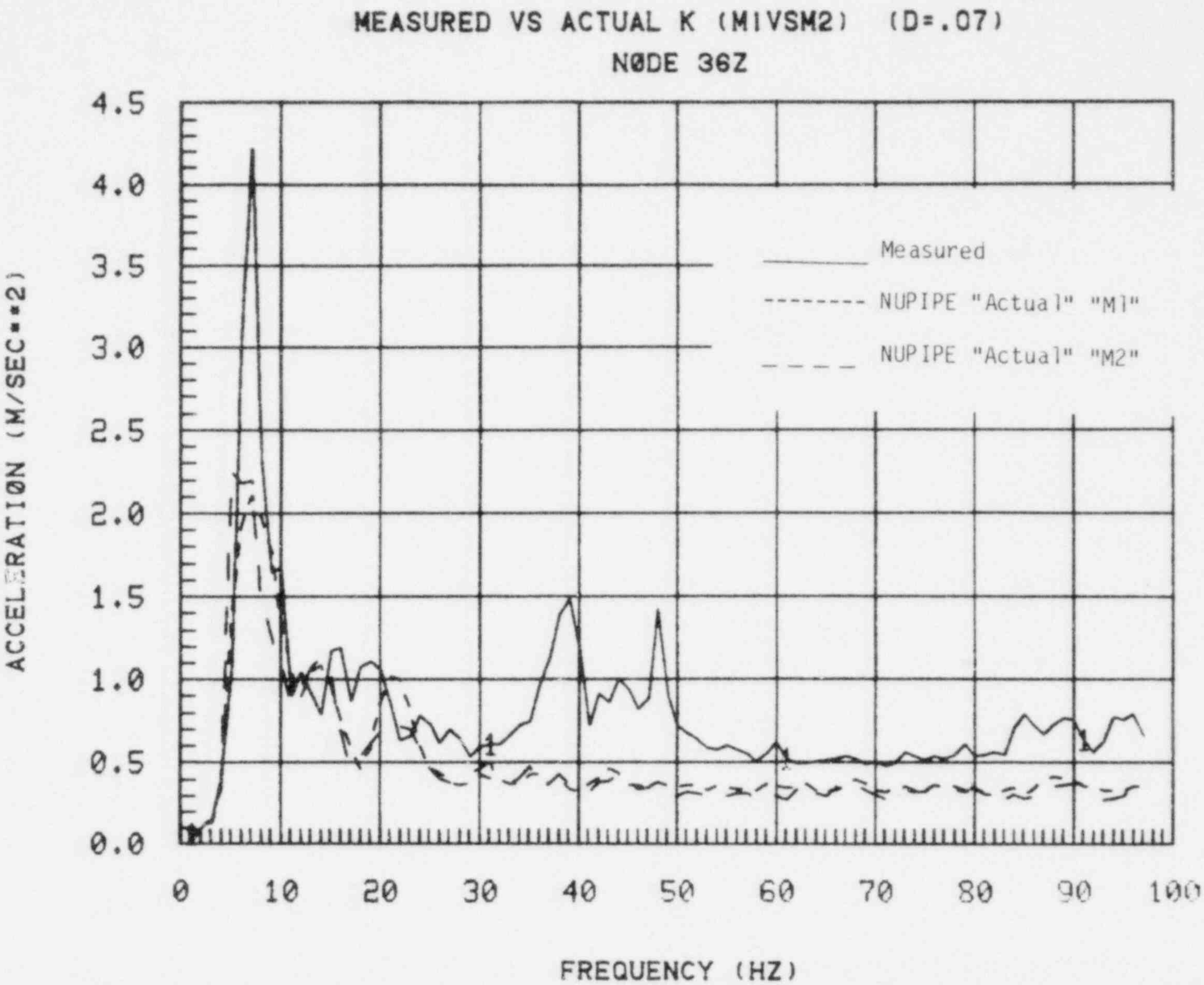

MEASURED VS ACTUAL K (MIVSM2) (D=.07)
NØDE 36Z
Measured
NUPIPE "Actual" "M1"
NUPIPE "Actual" "M2"
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
0
10
20
30
40
50
60
70
80
90
100

Figure 5.36.Z

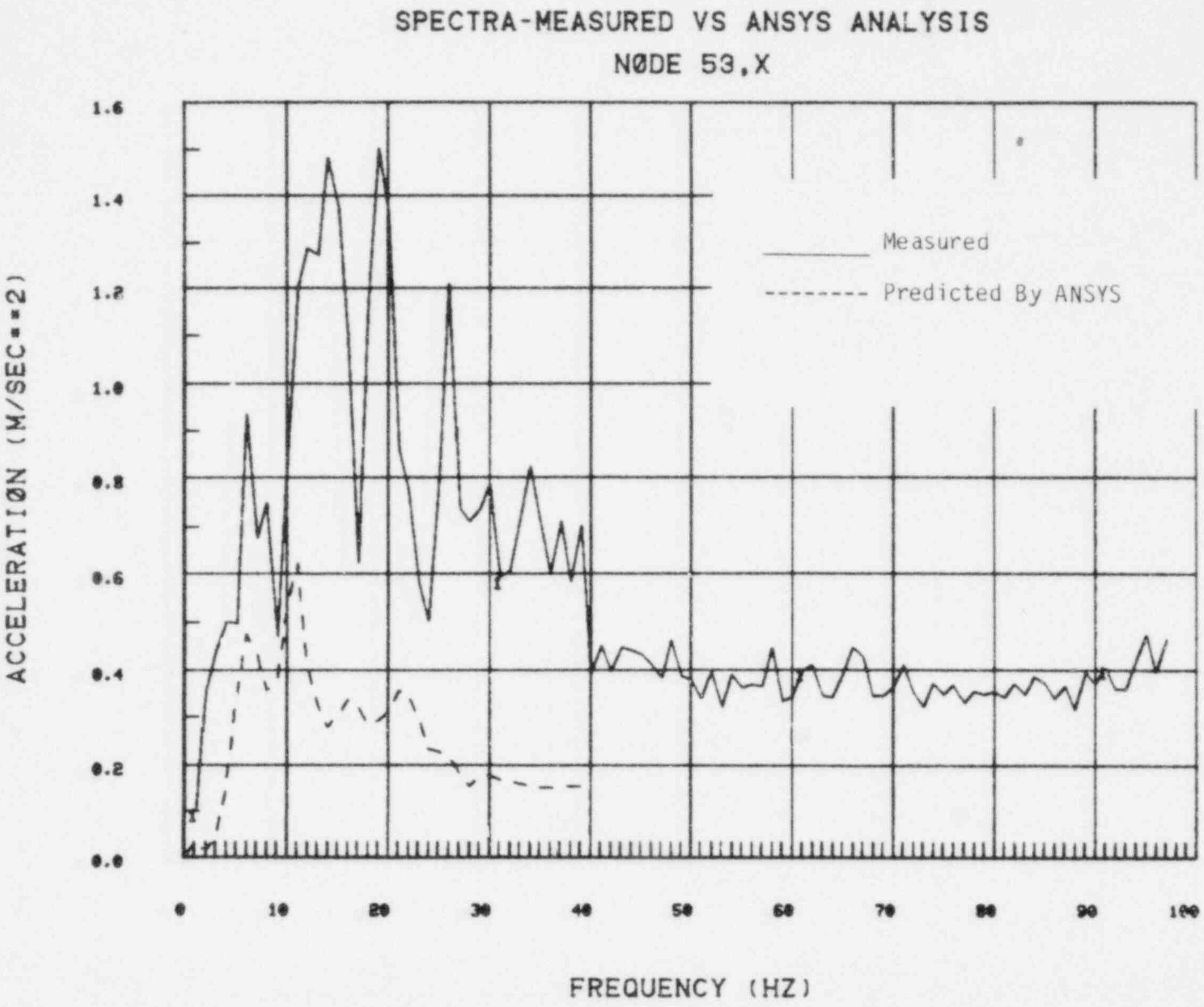
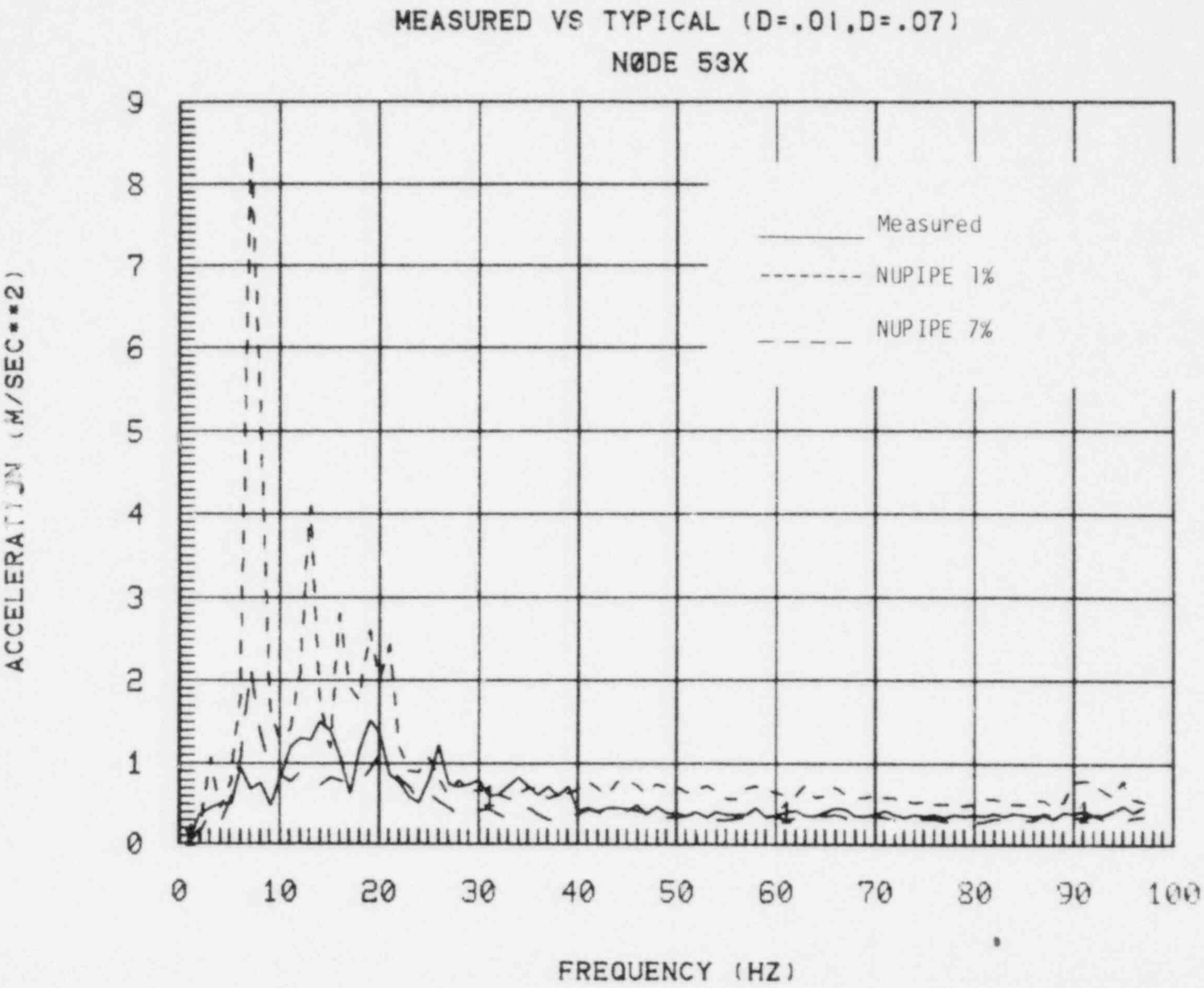

SPECTRA-MEASURED VS ANSYS ANALYSIS
NØDE 53,X
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
Measured
Predicted By ANSYS
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
0
10
20
30
40
50
60
70
80
90
100

Figure 1.53.X



MEASURED VS TYPICAL (D=.01,D=.07)
NØDE 53X
Measured
NUPIPE 1%
NUPIPE 7%
ACCELERATION (M/SEC**2)
FREQUENCY (HZ)
0
1
2
3
4
5
6
7
8
9
0
10
20
30
40
50
60
70
80
90
100

Figure 2.53.X

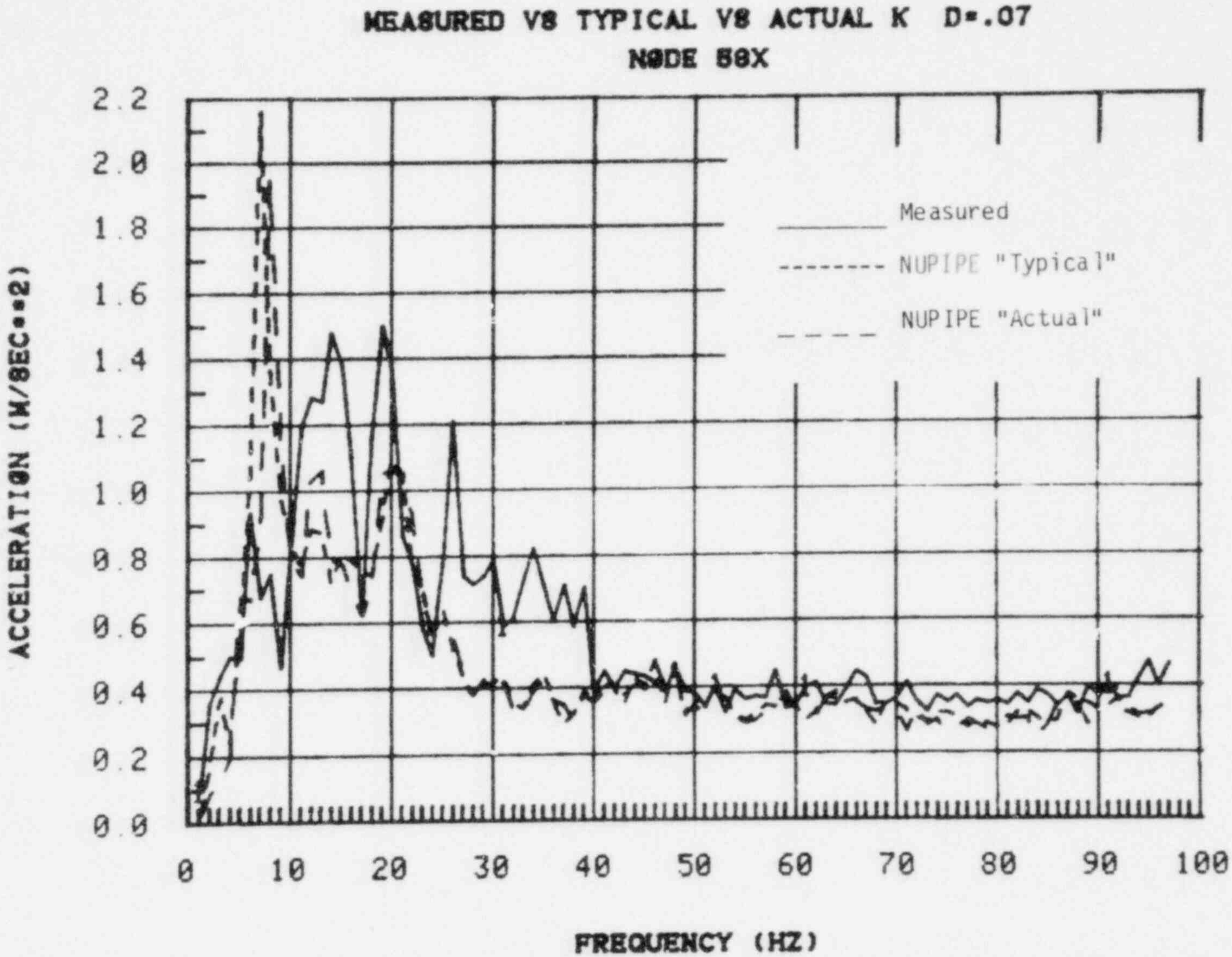
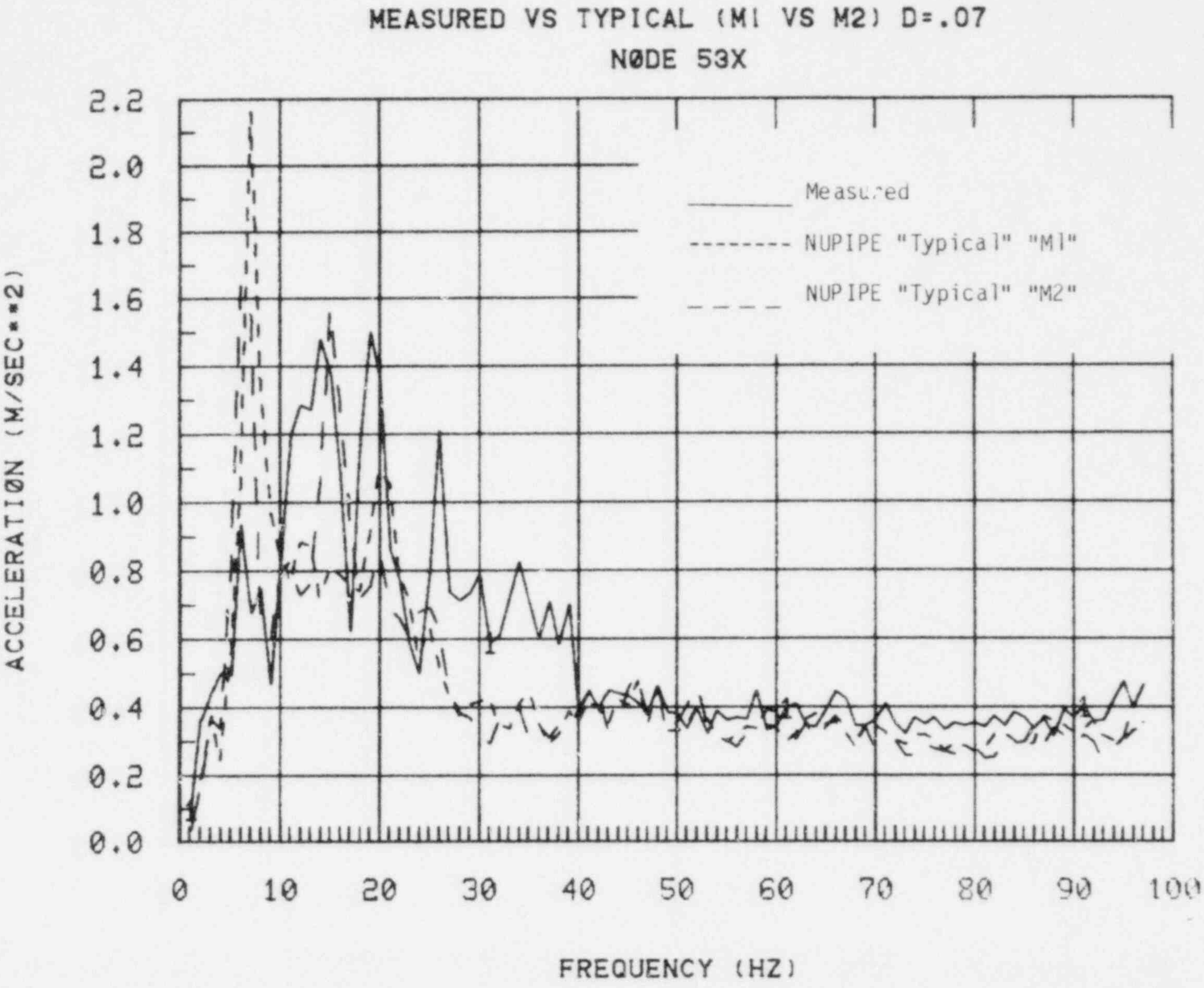

MEASURED VS TYPICAL VS ACTUAL K D=.07
NODE 58X
ACCELERATION (M/SEC**2)
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30
40
50
60
70
80
90
100
FREQUENCY (HZ)
Measured
NUPIPE "Typical"
NUPIPE "Actual"

Figure 3.53.X



MEASURED VS TYPICAL (M1 VS M2) D=.07
NØDE 53X
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30
40
50
60
70
80
90
100
Measured
NUPIPE "Typical" "M1"
NUPIPE "Typical" "M2"

Figure 4.53.X

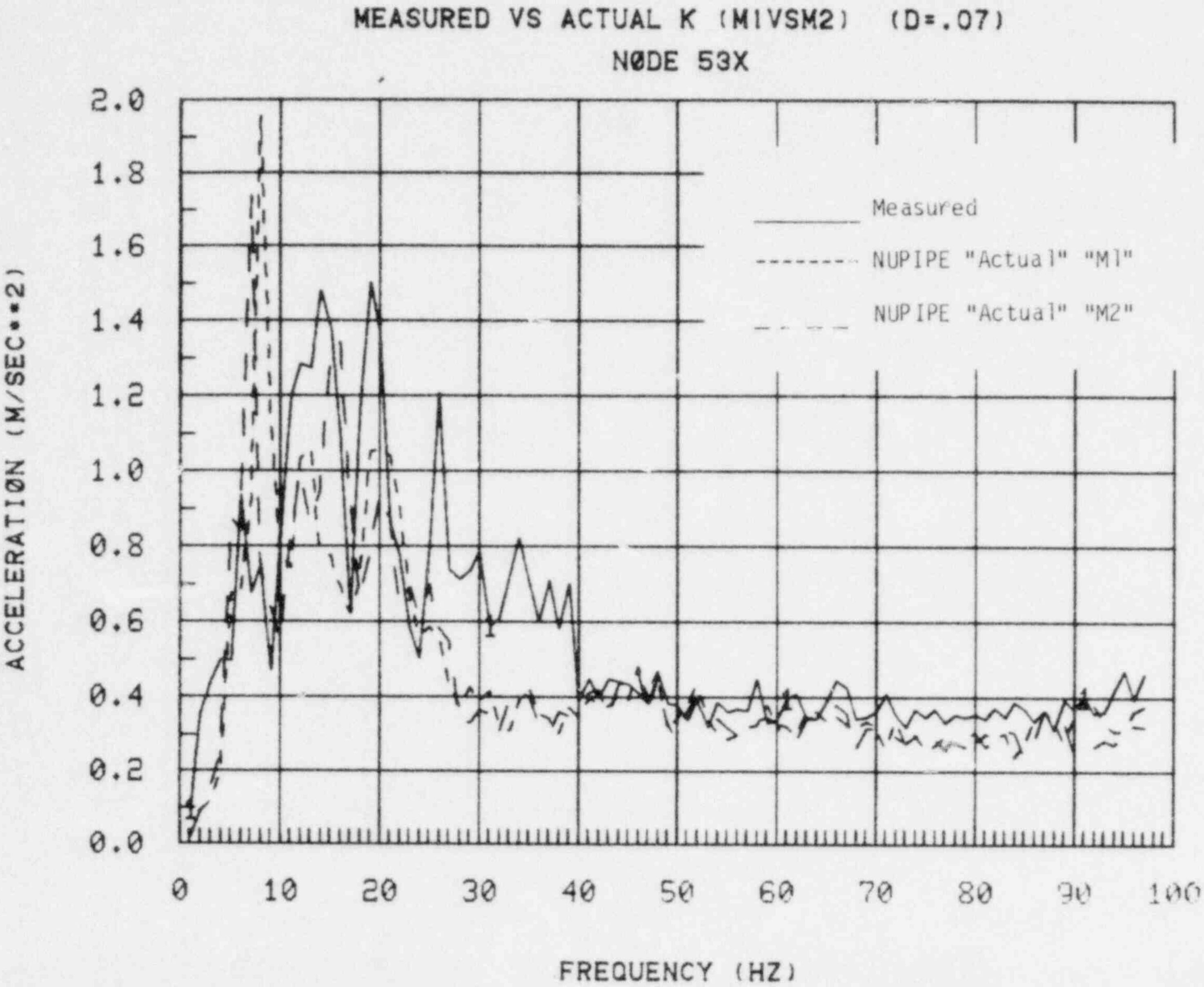

MEASURED VS ACTUAL K (M1VSM2) (D=.07)
NØDE 53X
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
Measured
NUPIPE "Actual" "M1"
NUPIPE "Actual" "M2"
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
0
10
20
30
40
50
60
70
80
90
100

Figure 5.53.X

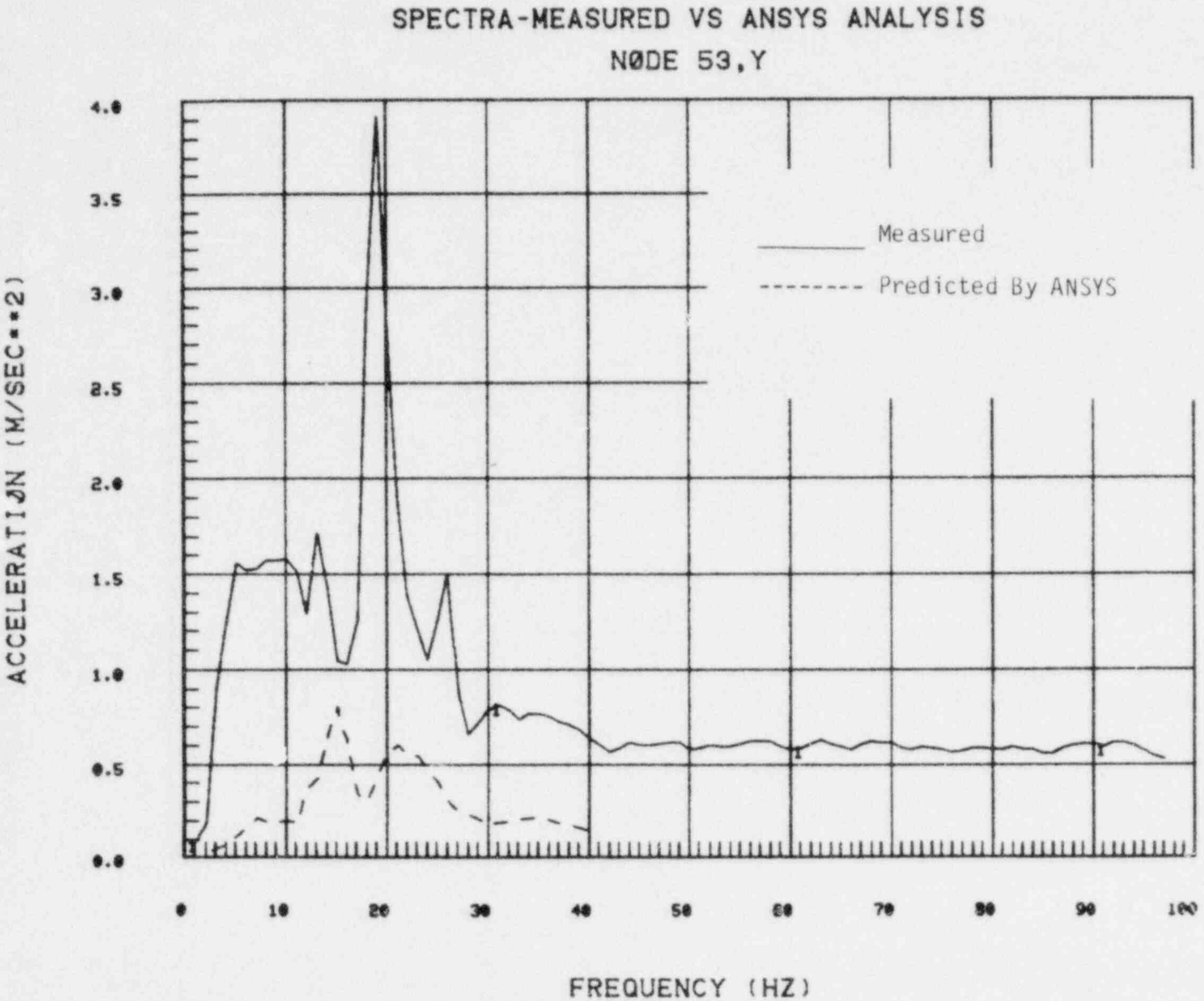

SPECTRA-MEASURED VS ANSYS ANALYSIS
NØDE 53,Y
Measured
Predicted By ANSYS
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
0
10
20
30
40
50
60
70
80
90
100

Figure 1.53.Y

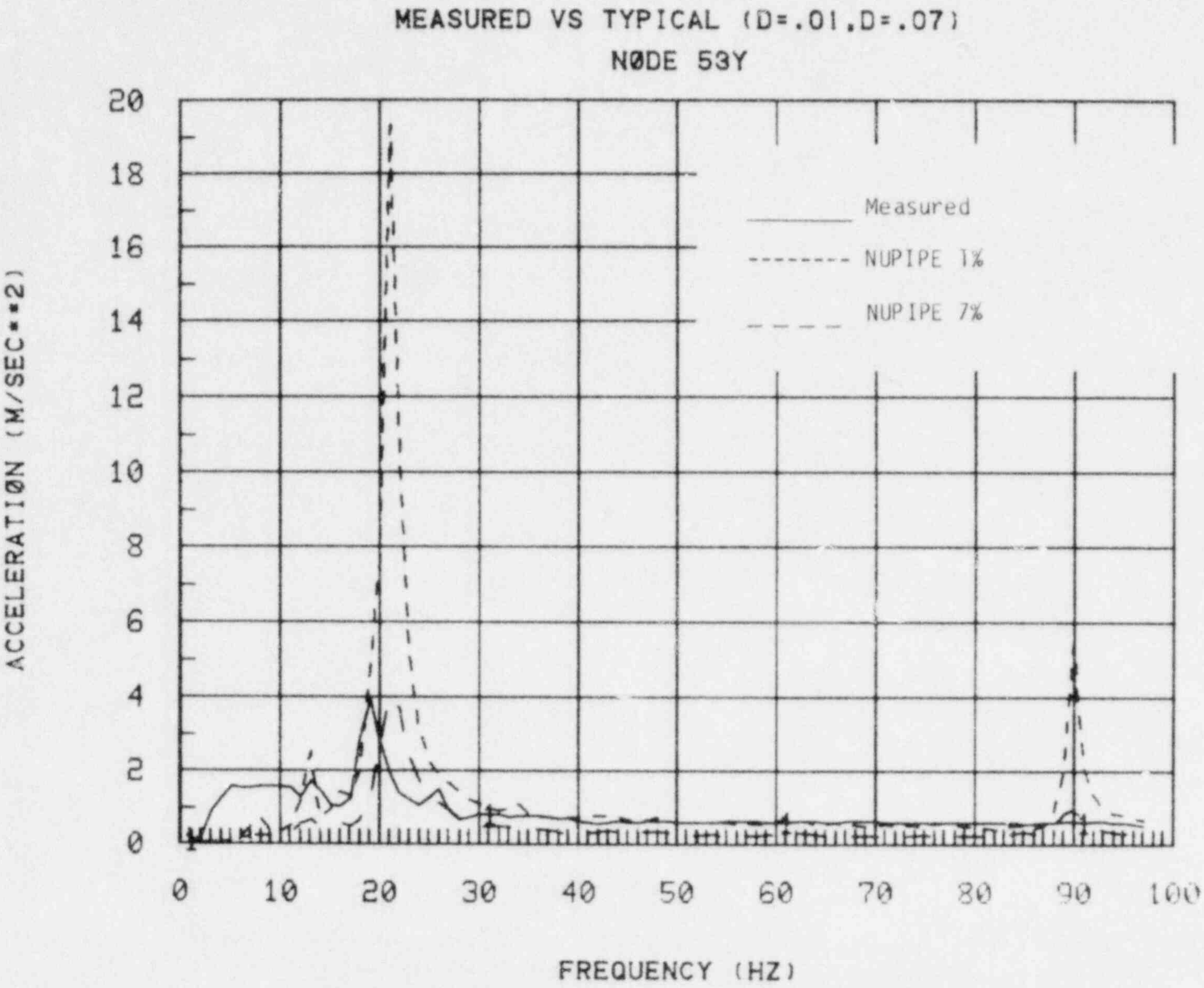

MEASURED VS TYPICAL (D=.01,D=.07)
NØDE 53Y
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
Measured
NUPIPE 1%
NUPIPE 7%
0
2
4
6
8
10
12
14
16
18
20
0
10
20
30
40
50
60
70
80
90
100

Figure 2.53.Y

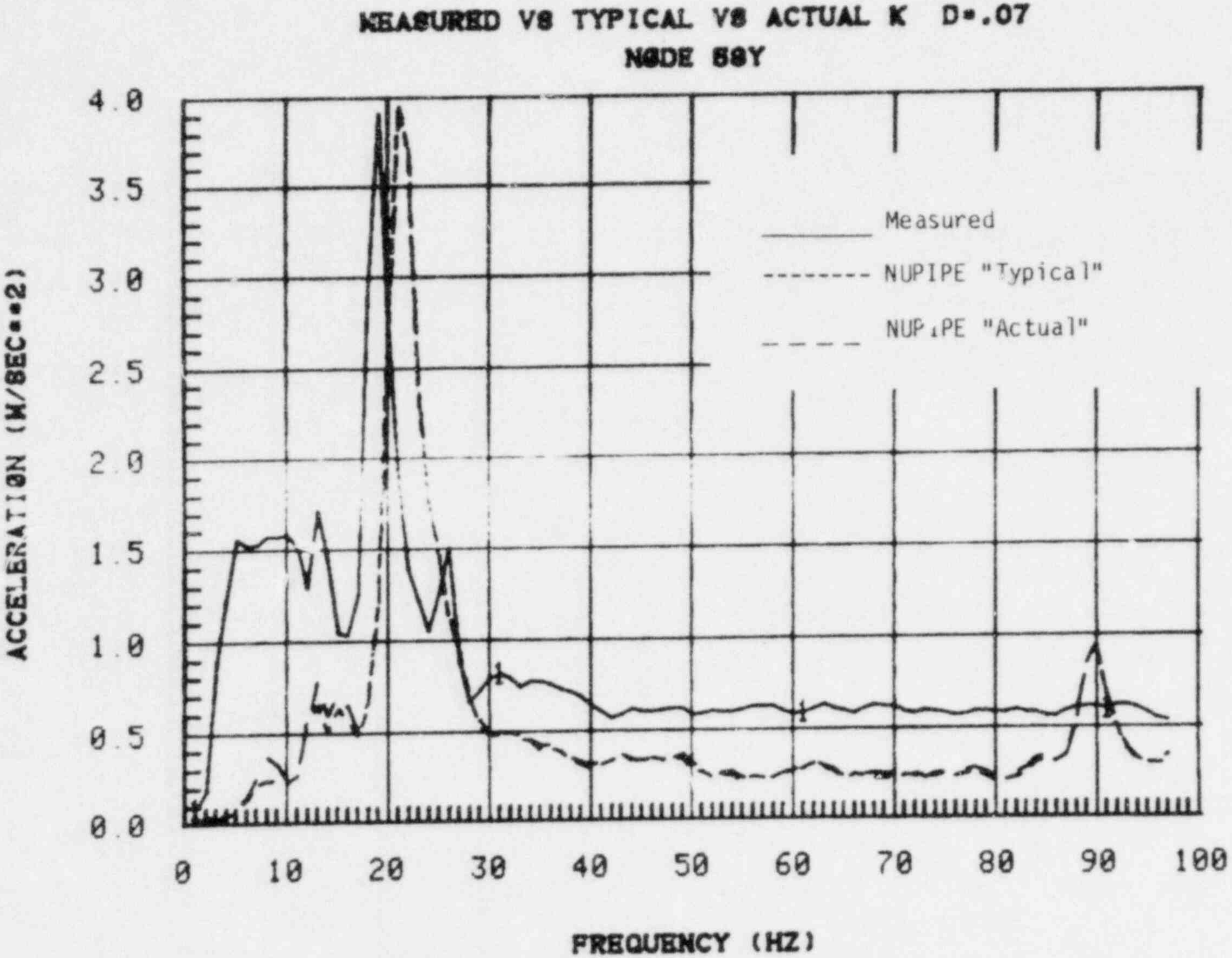

MEASURED VS TYPICAL VS ACTUAL K D=.07
NODE 58Y
Measured
NUPIPE "Typical"
NUPIPE "Actual"
ACCELERATION (M/SEC**2)
FREQUENCY (HZ)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
0
10
20
30
40
50
60
70
80
90
100

Figure 3.53.Y

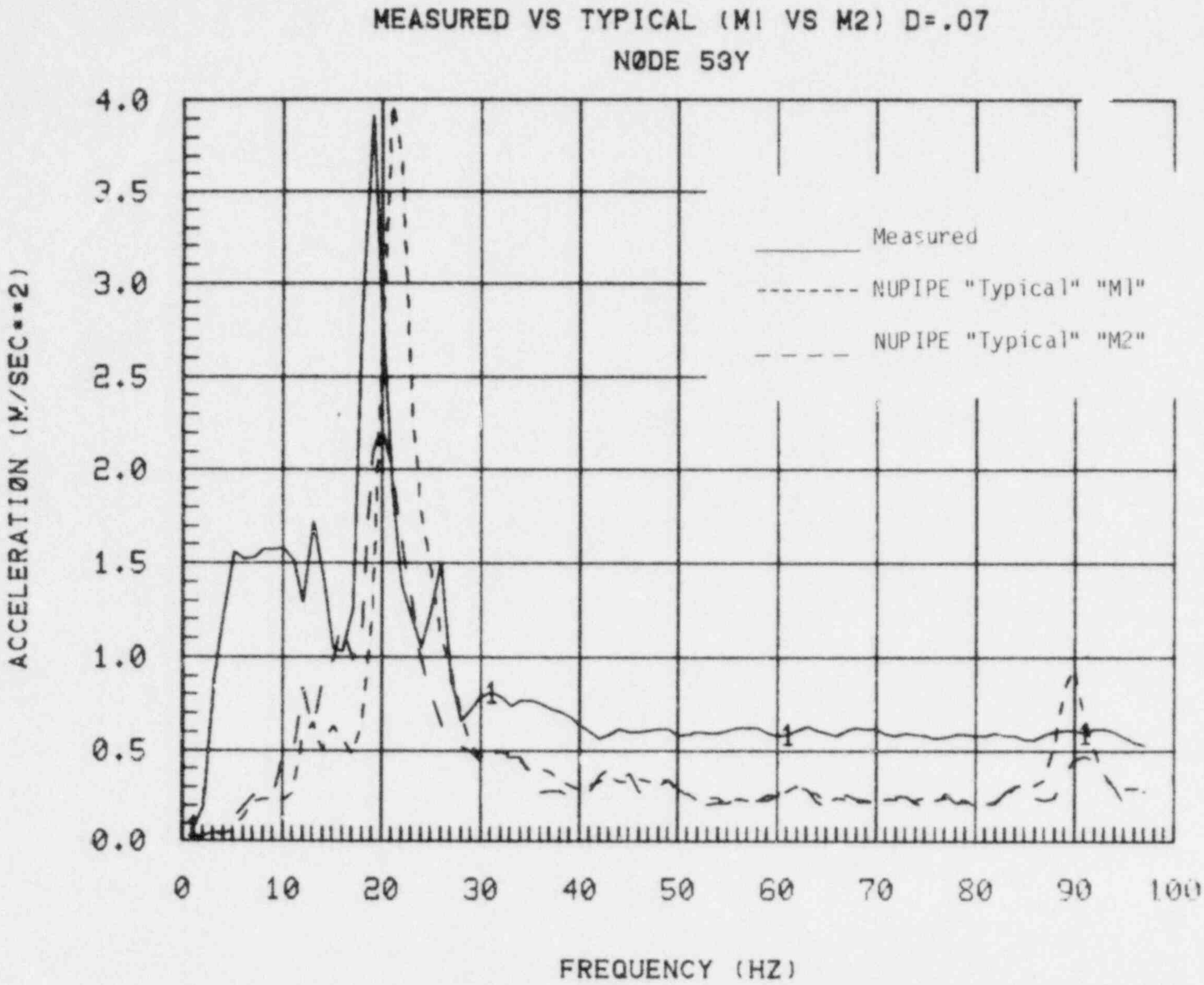

MEASURED VS TYPICAL (M1 VS M2) D=.07
NØDE 53Y
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
Measured
NUPIPE "Typical" "M1"
NUPIPE "Typical" "M2"
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
0
10
20
30
40
50
60
70
80
90
100

Figure 4.53.Y

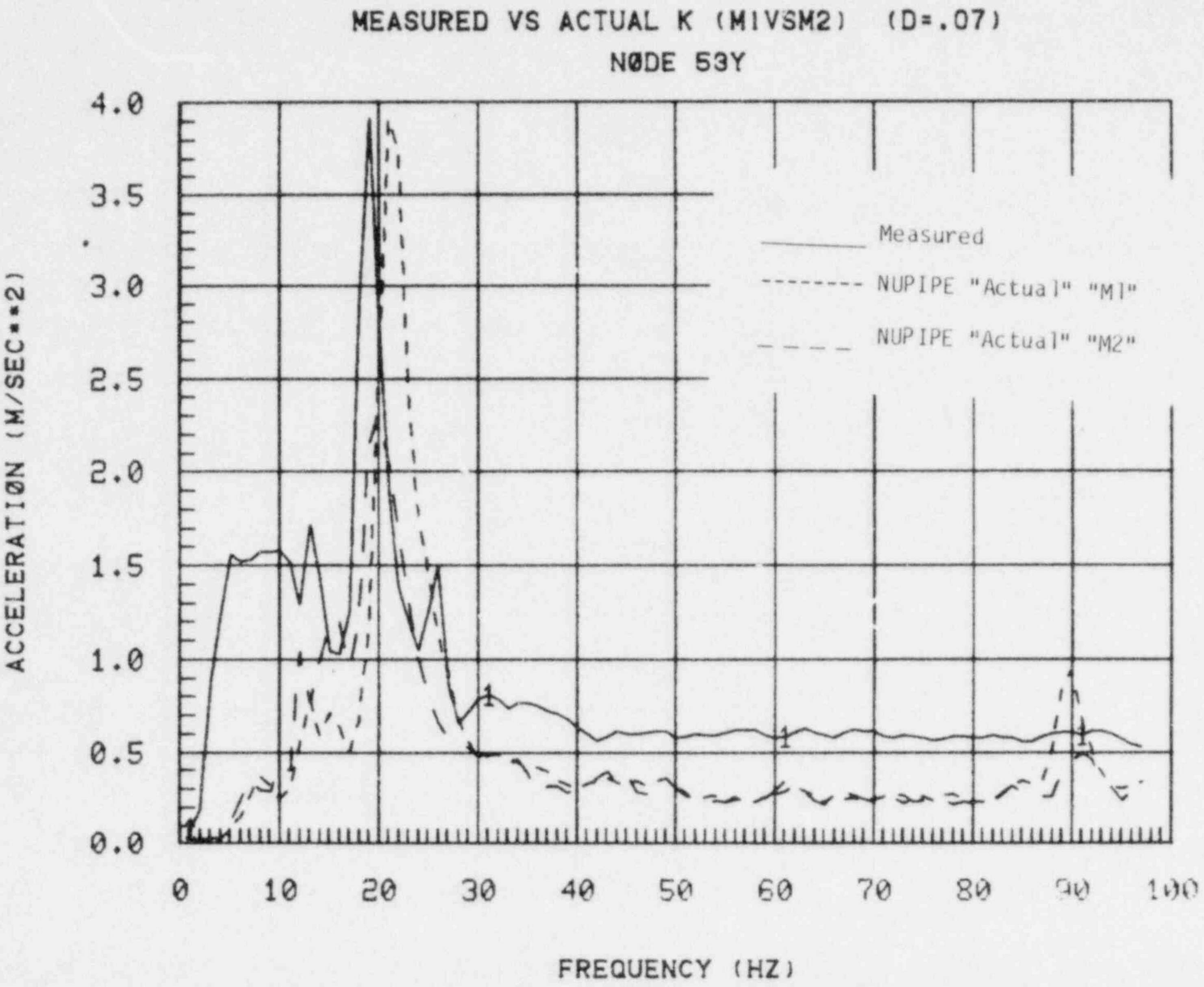

MEASURED VS ACTUAL K (M1VSM2) (D=.07)
NØDE 53Y
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
Measured
NUPIPE "Actual" "M1"
NUPIPE "Actual" "M2"
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
0
10
20
30
40
50
60
70
80
90
100

Figure 5.53.Y

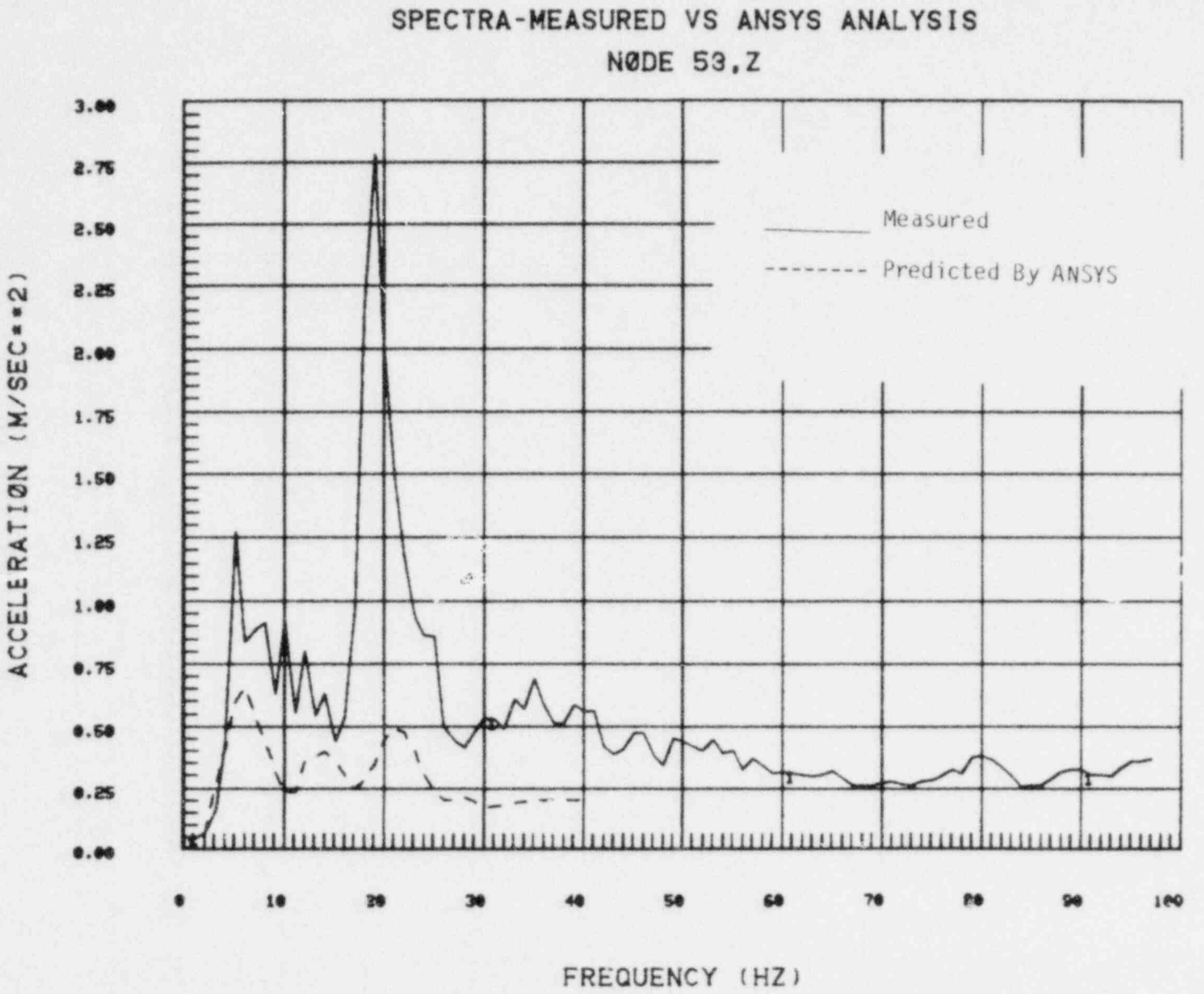

SPECTRA-MEASURED VS ANSYS ANALYSIS
NØDE 53,Z
ACCELERATIØN (M/SEC**2)
3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0
10
20
30
40
50
60
70
80
90
100
FREQUENCY (HZ)
Measured
Predicted By ANSYS

Figure 1.53.Z

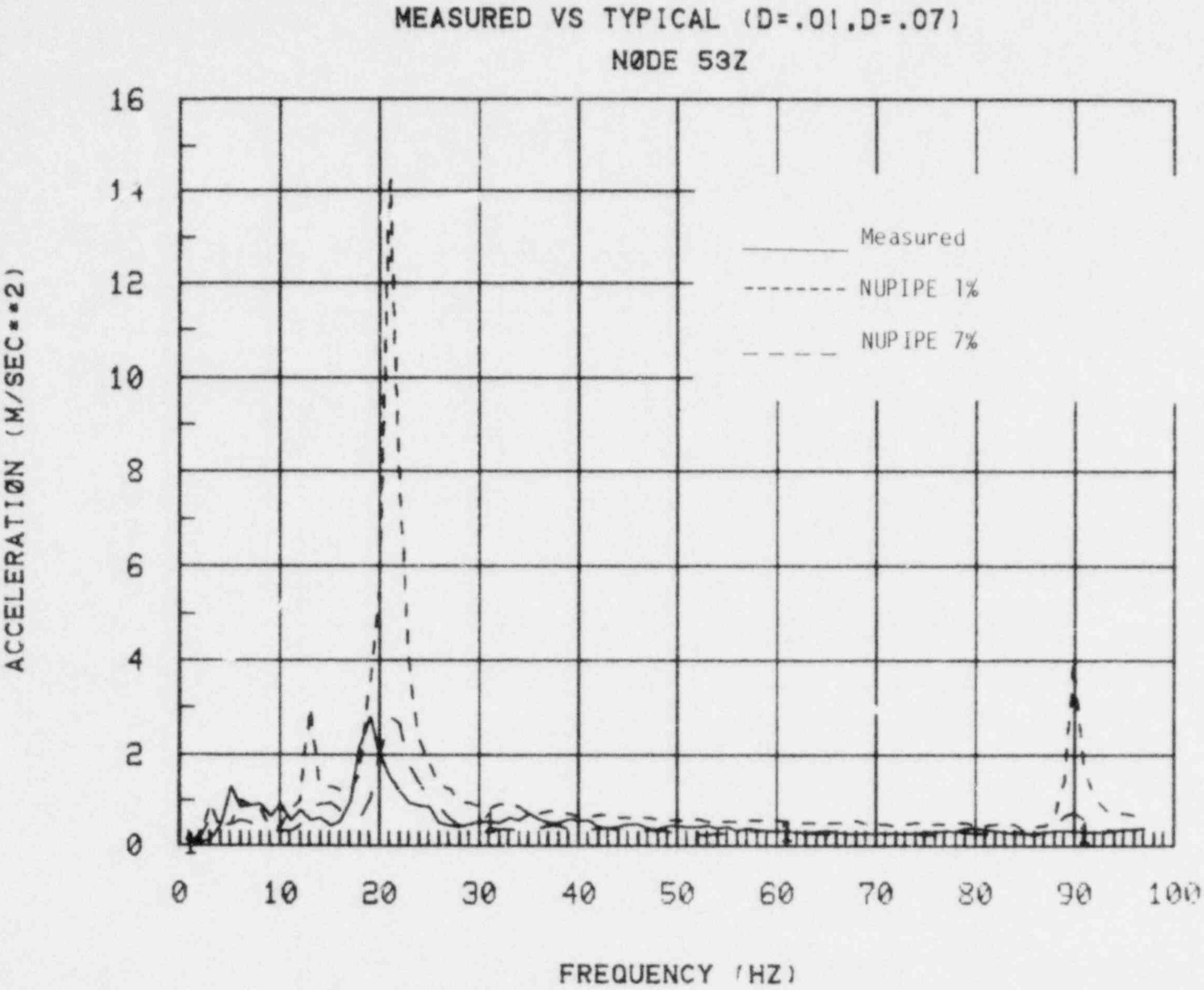

MEASURED VS TYPICAL (D=.01,D=.07)
NØDE 53Z
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
Measured
NUPIPE 1%
NUPIPE 7%
0
2
4
6
8
10
12
14
16
0
10
20
30
40
50
60
70
80
90
100

Figure 2.53.Z

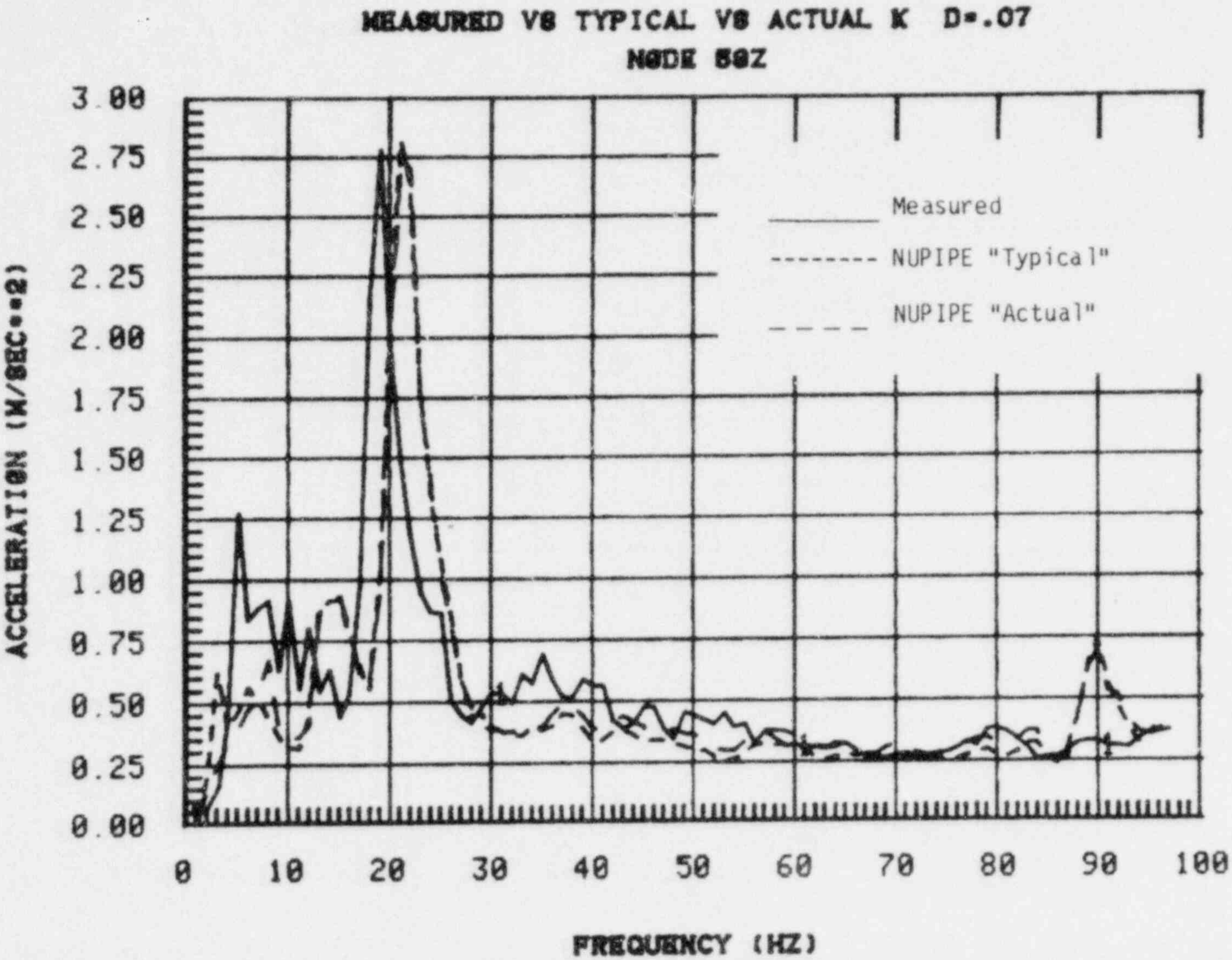

MEASURED VS TYPICAL VS ACTUAL K D=.07
NODE 59Z
ACCELERATION (M/SEC**2)
3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0 10 20 30 40 50 60 70 80 90 100
FREQUENCY (HZ)
Measured
NUPIPE "Typical"
NUPIPE "Actual"

Figure 3.53.Z

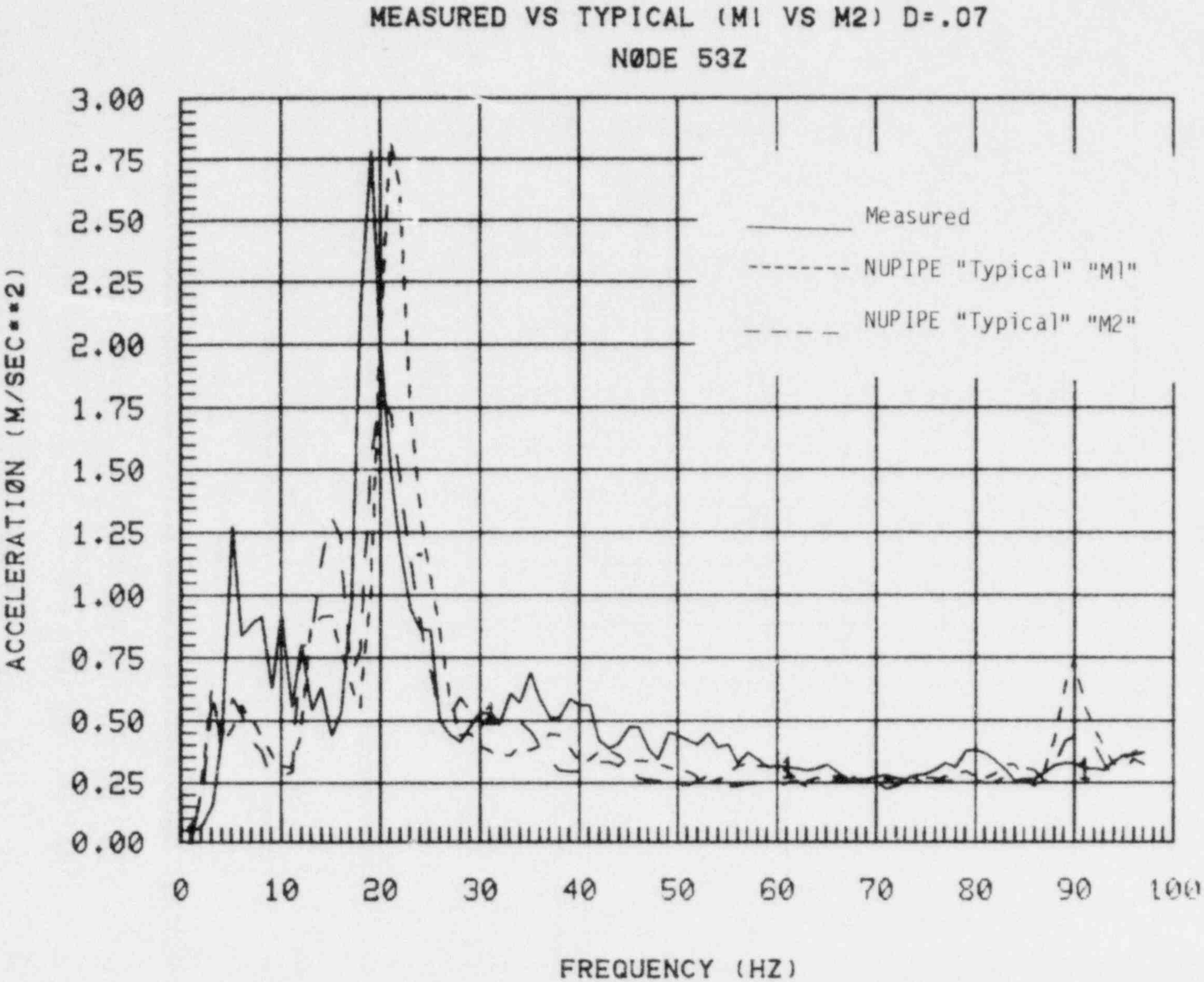

MEASURED VS TYPICAL (M1 VS M2) D=.07
NØDE 53Z
3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
ACCELERATIØN (M/SEC**2)
0
10
20
30
40
50
60
70
80
90
100
FREQUENCY (HZ)
Measured
NUPIPE "Typical" "M1"
NUPIPE "Typical" "M2"

Figure 4.53.Z

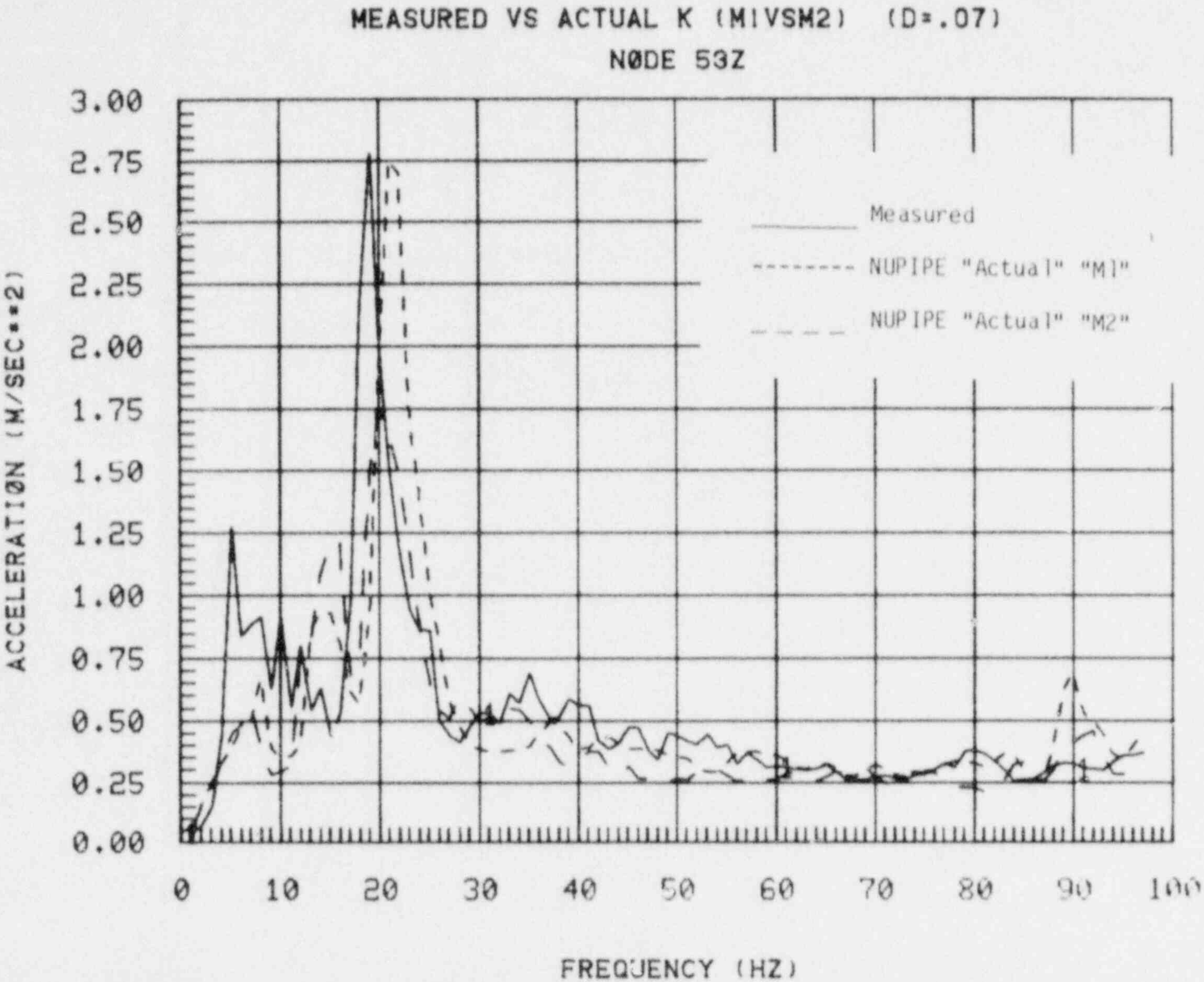

MEASURED VS ACTUAL K (M1VSM2) (D=.07)
NØDE 53Z
3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
ACCELERATIØN (M/SEC**2)
Measured
NUPIPE "Actual" "M1"
NUPIPE "Actual" "M2"
0
10
20
30
40
50
60
70
80
90
100
FREQUENCY (HZ)

Figure 5.53.Z

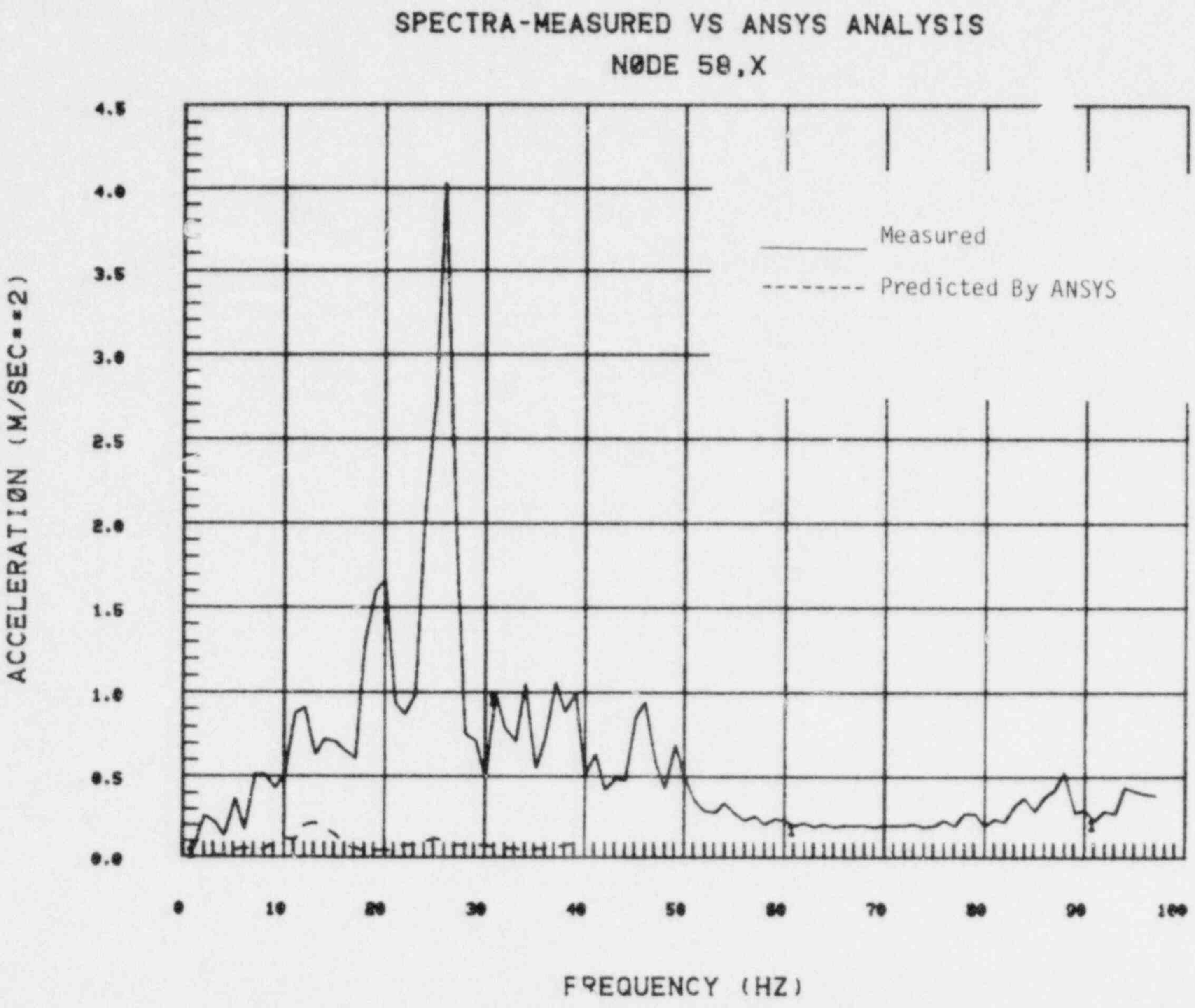

SPECTRA-MEASURED VS ANSYS ANALYSIS
NØDE 58,X
Measured
Predicted By ANSYS
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
70
80
90
100

Figure 1.58.X

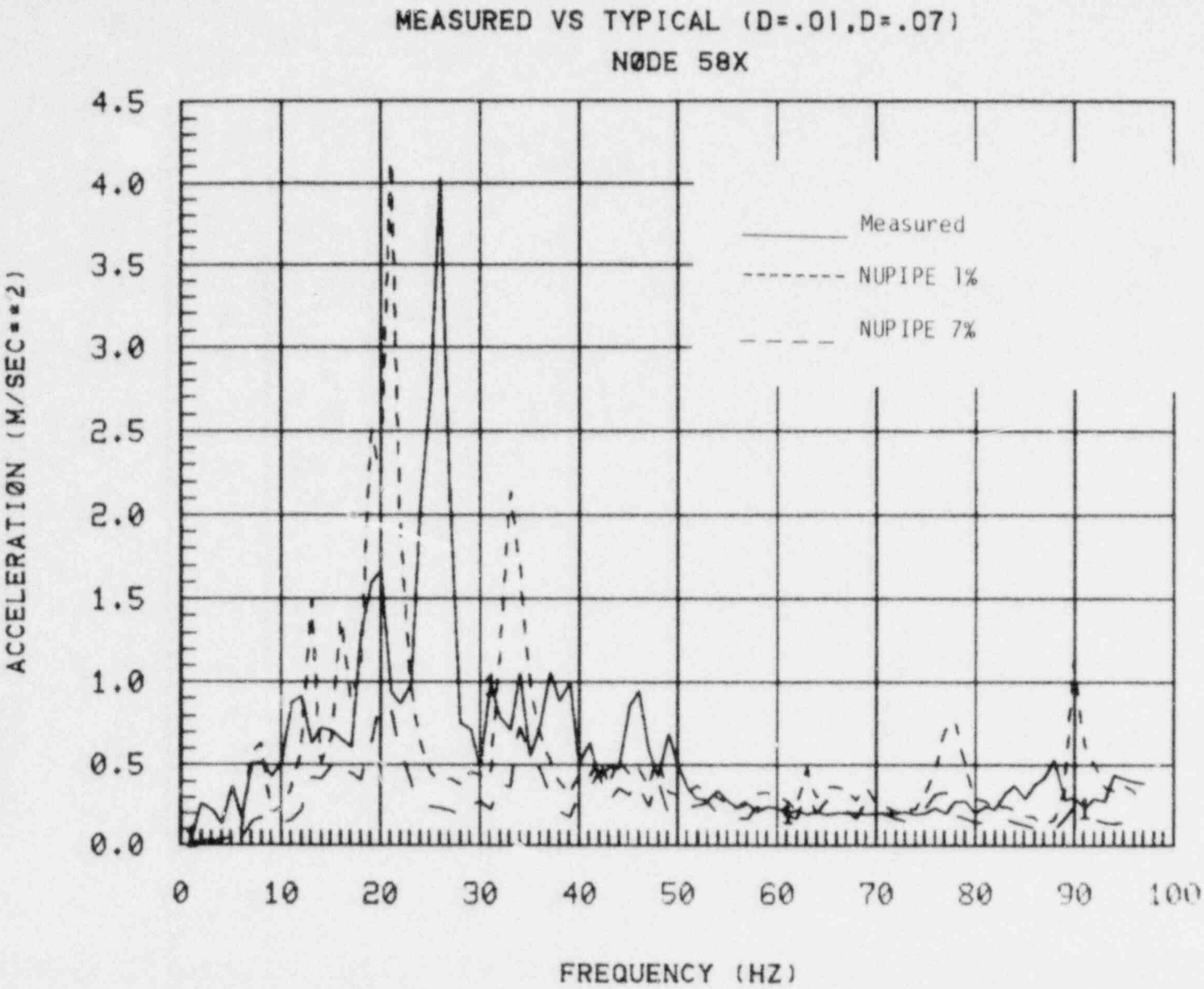

MEASURED VS TYPICAL (D=.01,D=.07)
NØDE 58X
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
Measured
NUPIPE 1%
NUPIPE 7%
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
70
80
90
100

Figure 2.58.X

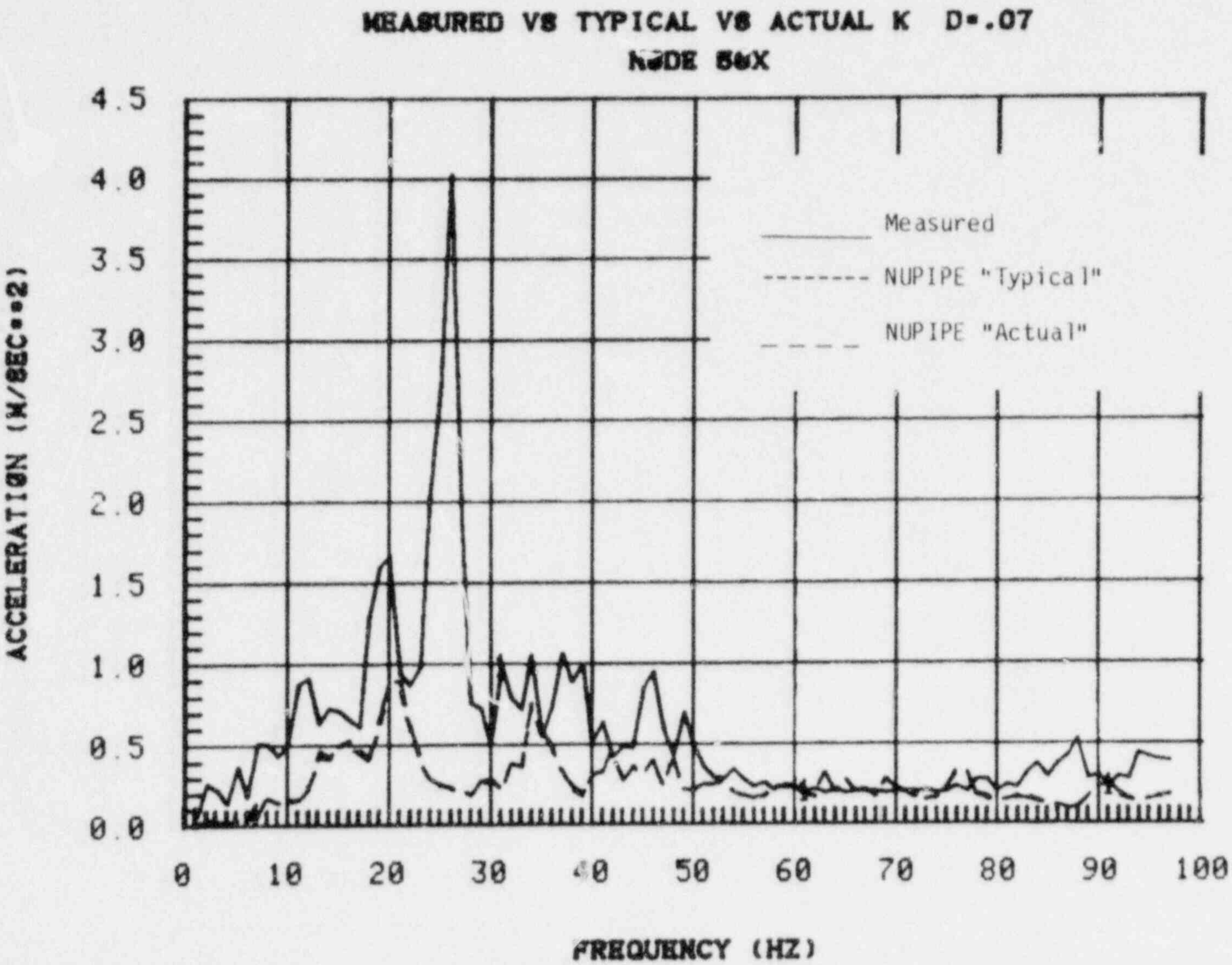

MEASURED VS TYPICAL VS ACTUAL K D=.07
NODE 58X
ACCELERATION (M/SEC**2)
FREQUENCY (HZ)
Measured
NUPIPE "Typical"
NUPIPE "Actual"
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
70
80
90
100

Figure 3.58.X

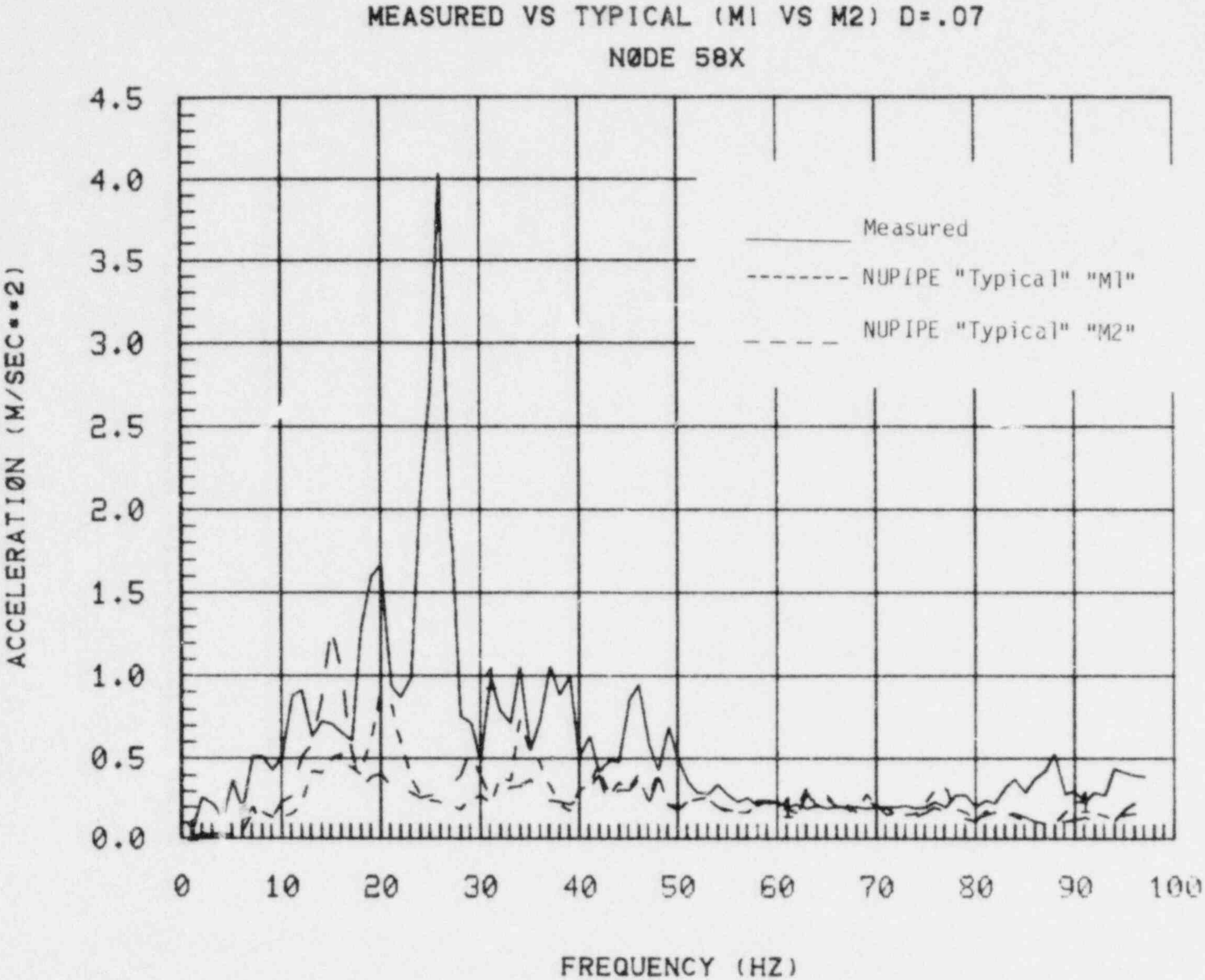

MEASURED VS TYPICAL (M1 VS M2) D=.07
NØDE 58X
ACCELERATIØN (M/SEC**2)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
70
80
90
100
FREQUENCY (HZ)
Measured
NUPIPE "Typical" "M1"
NUPIPE "Typical" "M2"

Figure 4.58.X

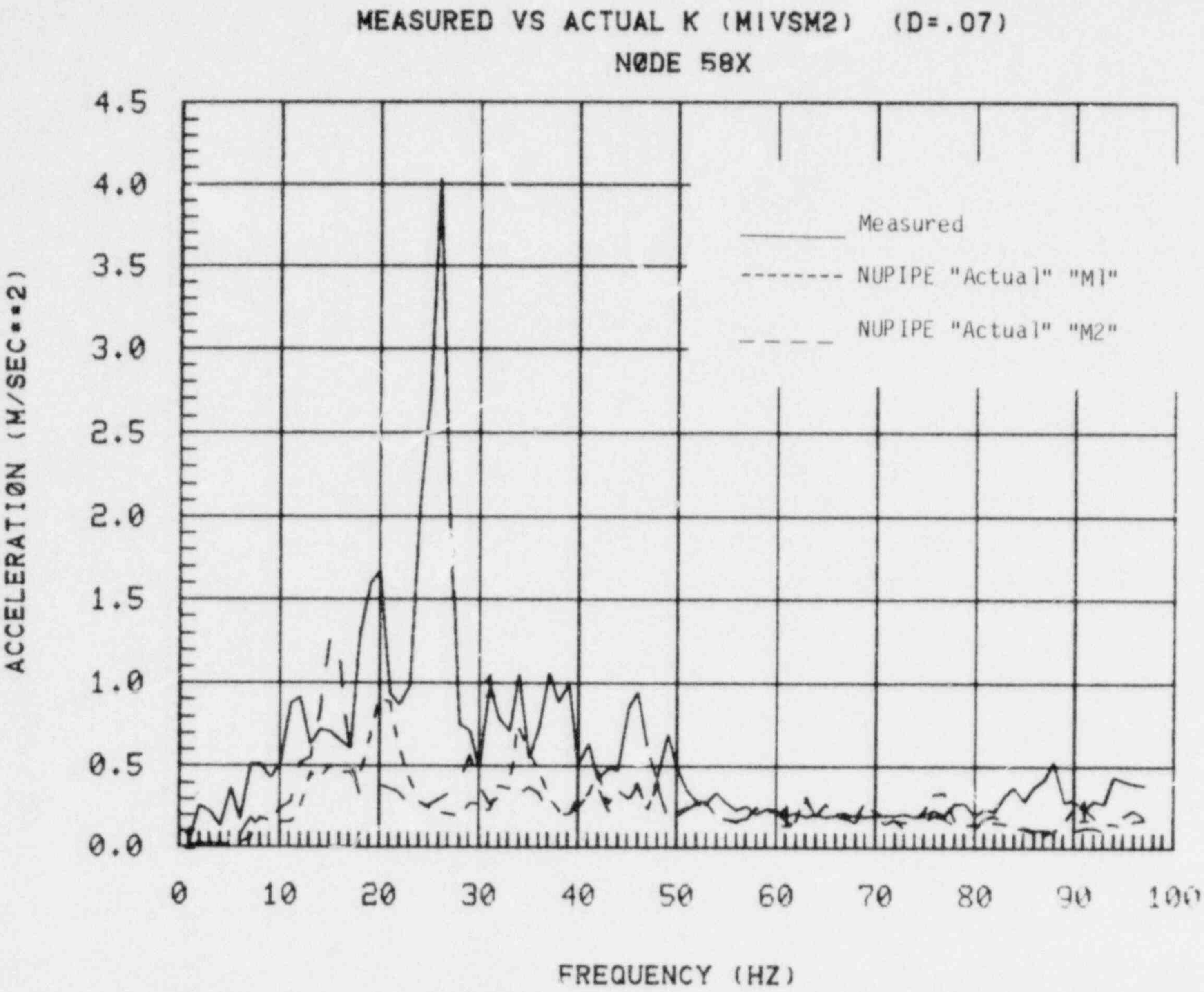

MEASURED VS ACTUAL K (MIVSM2) (D=.07)
NØDE 58X
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
Measured
NUPIPE "Actual" "M1"
NUPIPE "Actual" "M2"
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
0
10
20
30
40
50
60
70
80
90
100

Figure 5.58.X

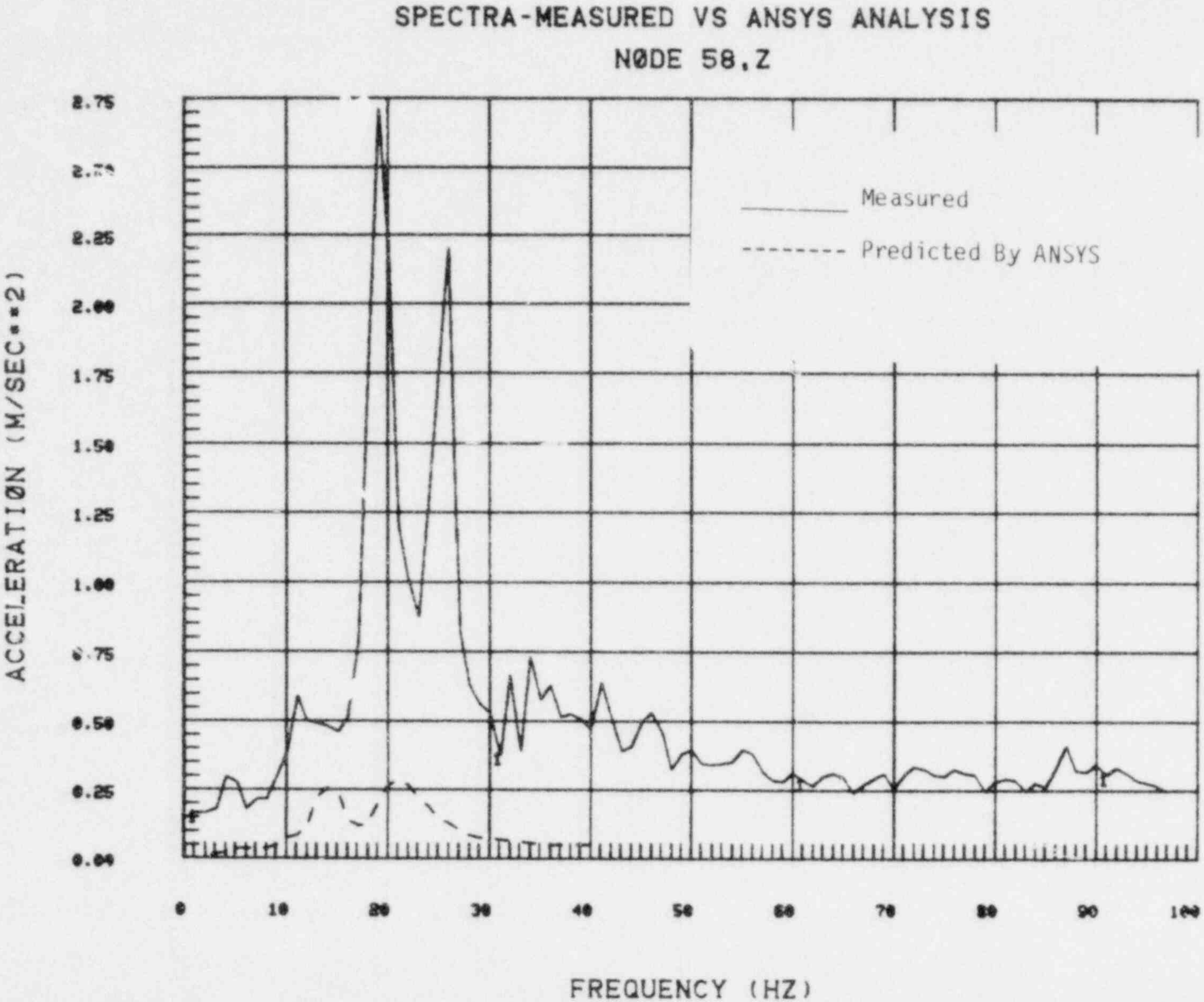
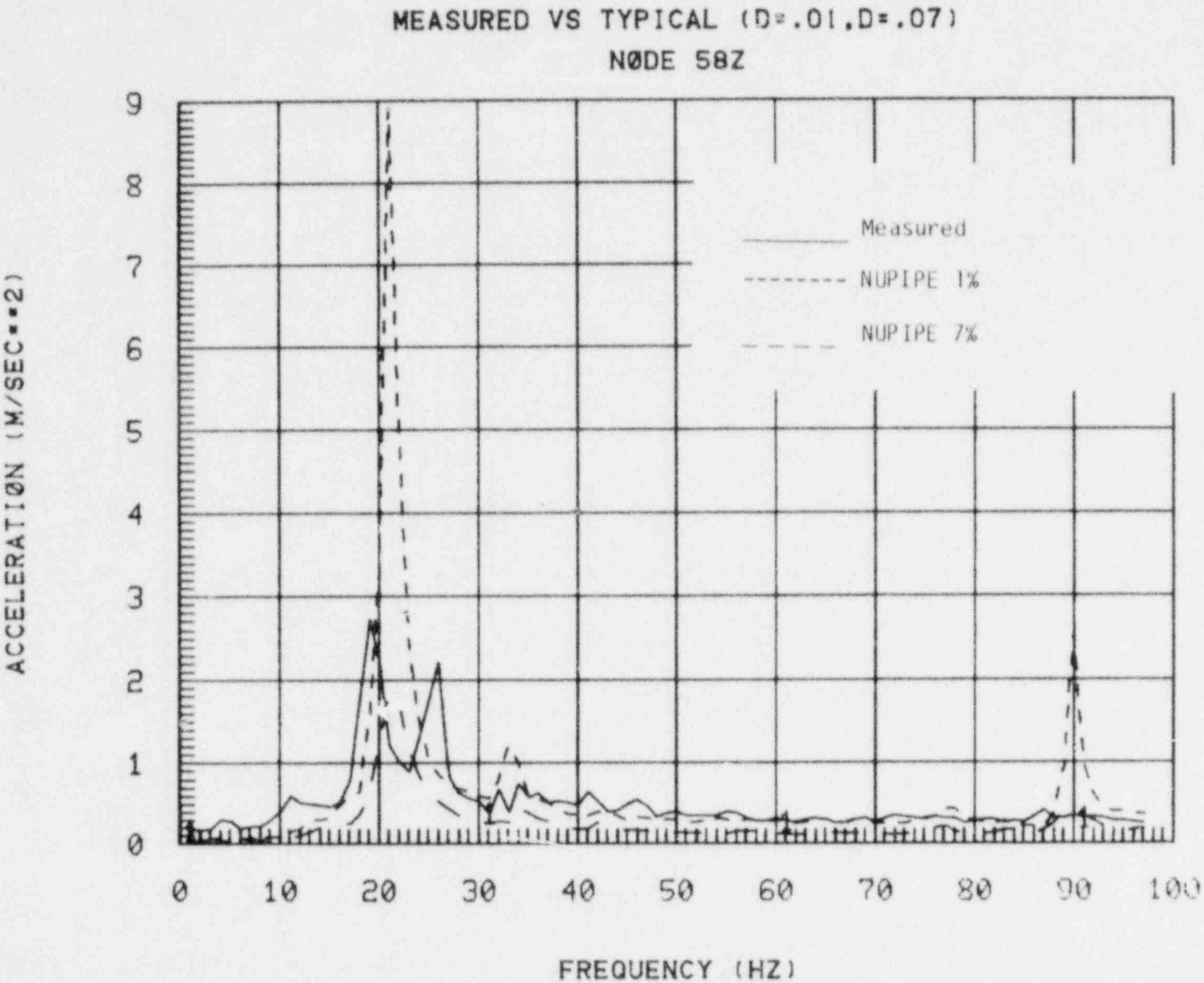

SPECTRA-MEASURED VS ANSYS ANALYSIS
NØDE 58.Z
Measured
Predicted By ANSYS
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
0
10
20
30
40
50
60
70
80
90
100

Figure 1.58.Z



MEASURED VS TYPICAL (D=.01,D=.07)
NØDE 58Z
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
Measured
NUPIPE 1%
NUPIPE 7%
0
1
2
3
4
5
6
7
8
9
0
10
20
30
40
50
60
70
80
90
100

Figure 2.58.Z

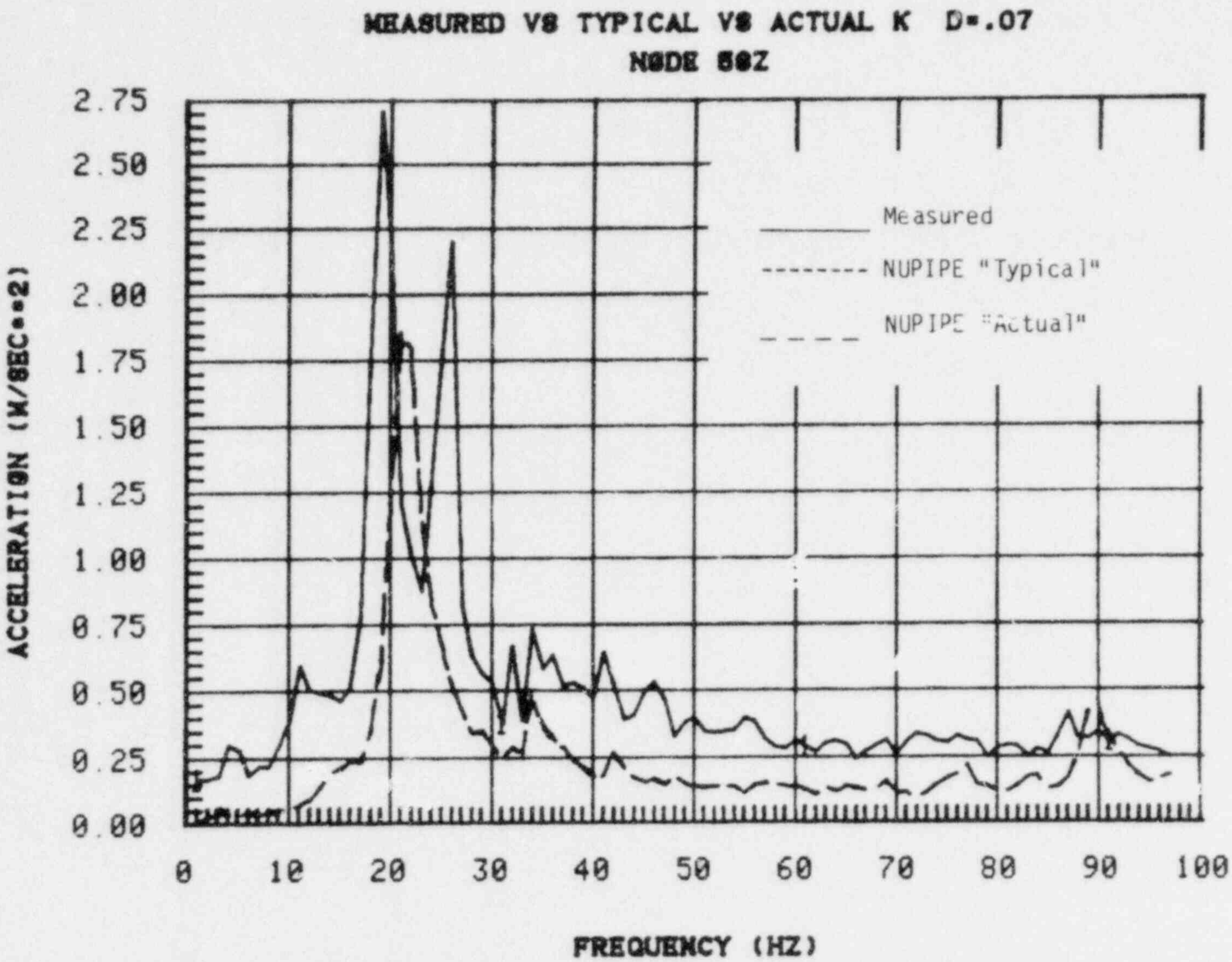

MEASURED VS TYPICAL VS ACTUAL K D=.07
NODE 58Z
ACCELERATION (M/SEC**2)
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0
10
20
30
40
50
60
70
80
90
100
FREQUENCY (HZ)
Measured
NUPIPE "Typical"
NUPIPE "Actual"

Figure 3.58.Z

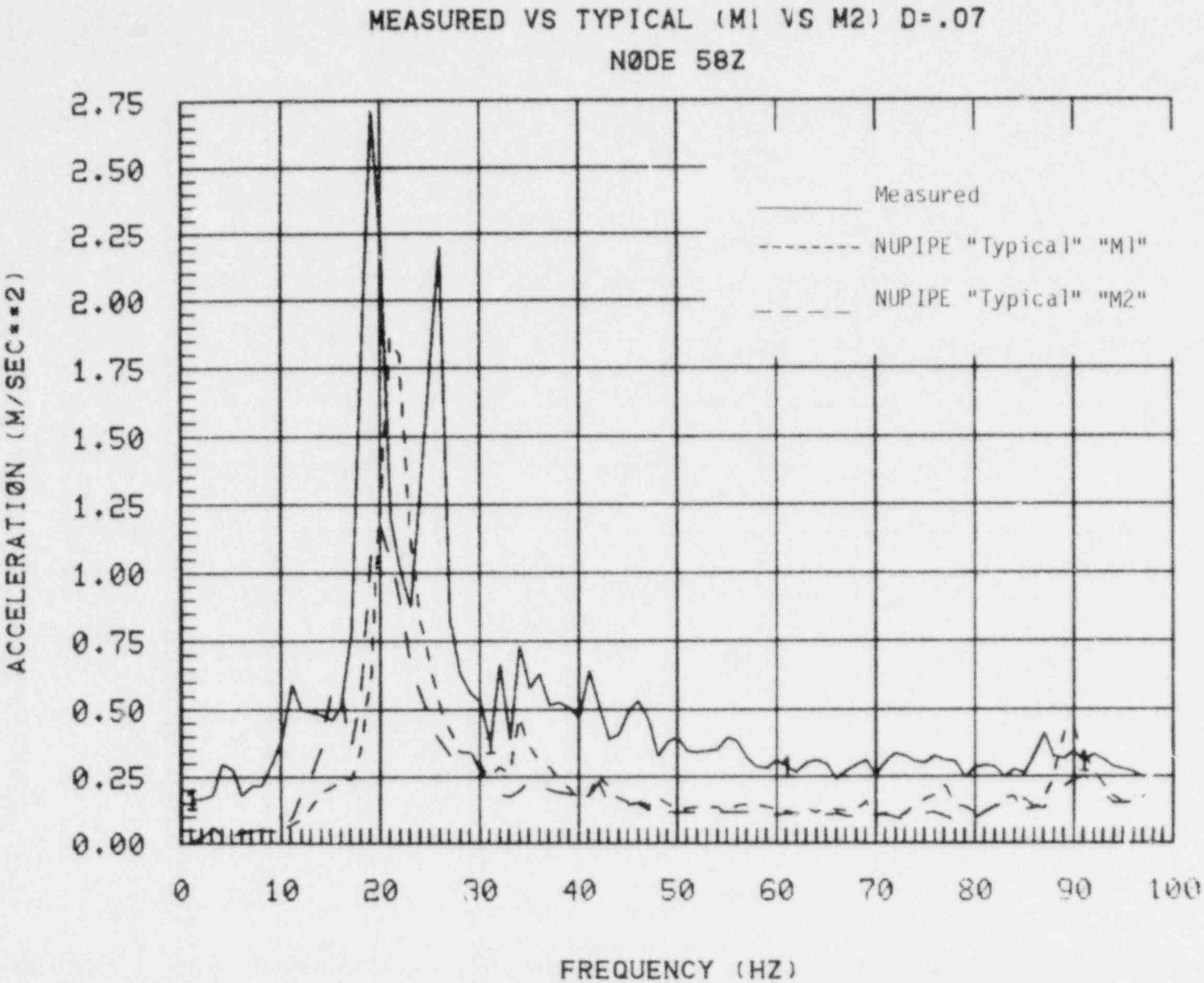

MEASURED VS TYPICAL (M1 VS M2) D=.07
NØDE 58Z
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
Measured
NUPIPE "Typical" "M1"
NUPIPE "Typical" "M2"
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
0
10
20
30
40
50
60
70
80
90
100

Figure 4.58.7

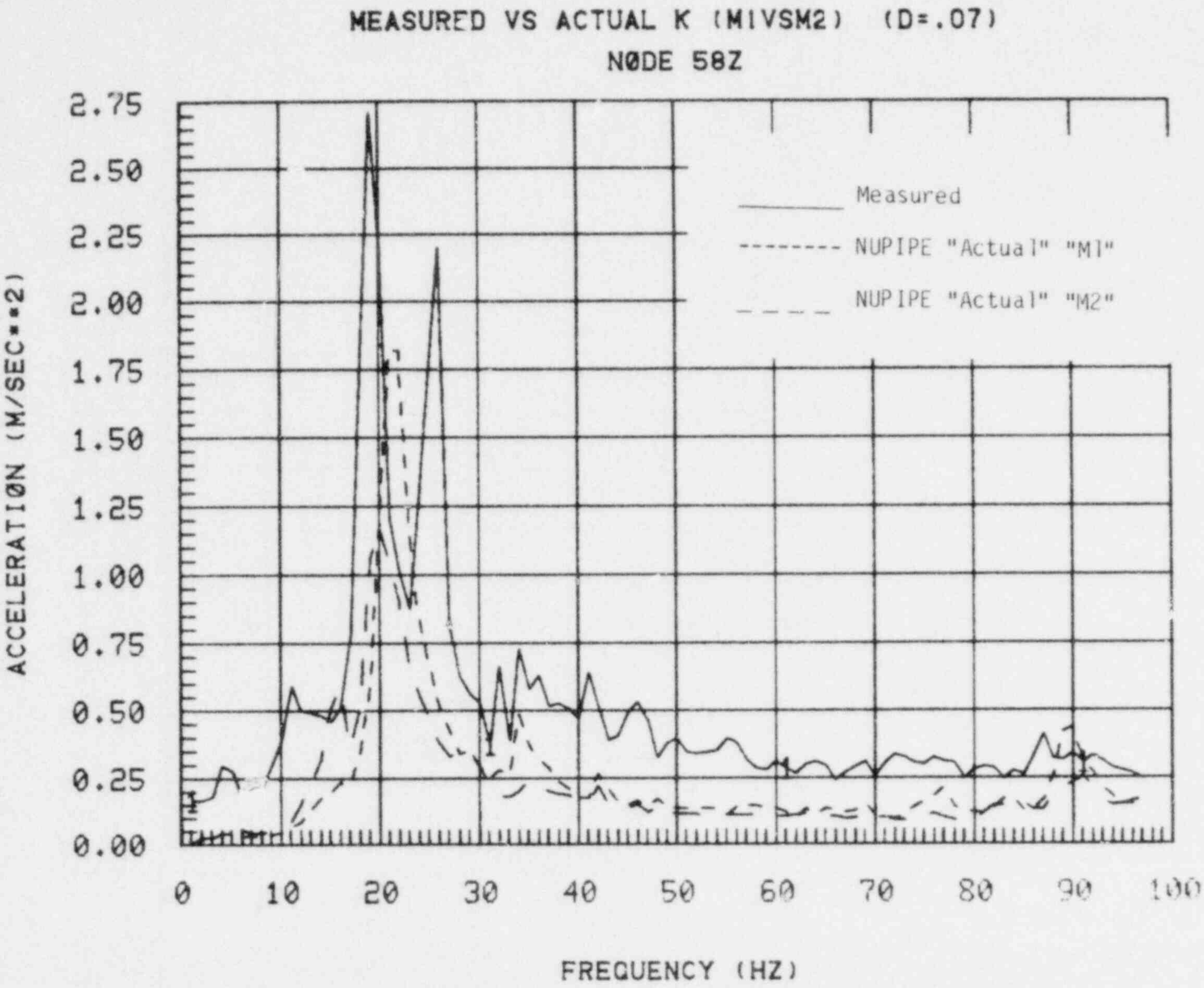

MEASURED VS ACTUAL K (M1VSM2) (D=.07)
NØDE 58Z
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
ACCELERATIØN (M/SEC**2)
Measured
NUPIPE "Actual" "M1"
NUPIPE "Actual" "M2"
0
10
20
30
40
50
60
70
80
90
100
FREQUENCY (HZ)

Figure 5.58.Z

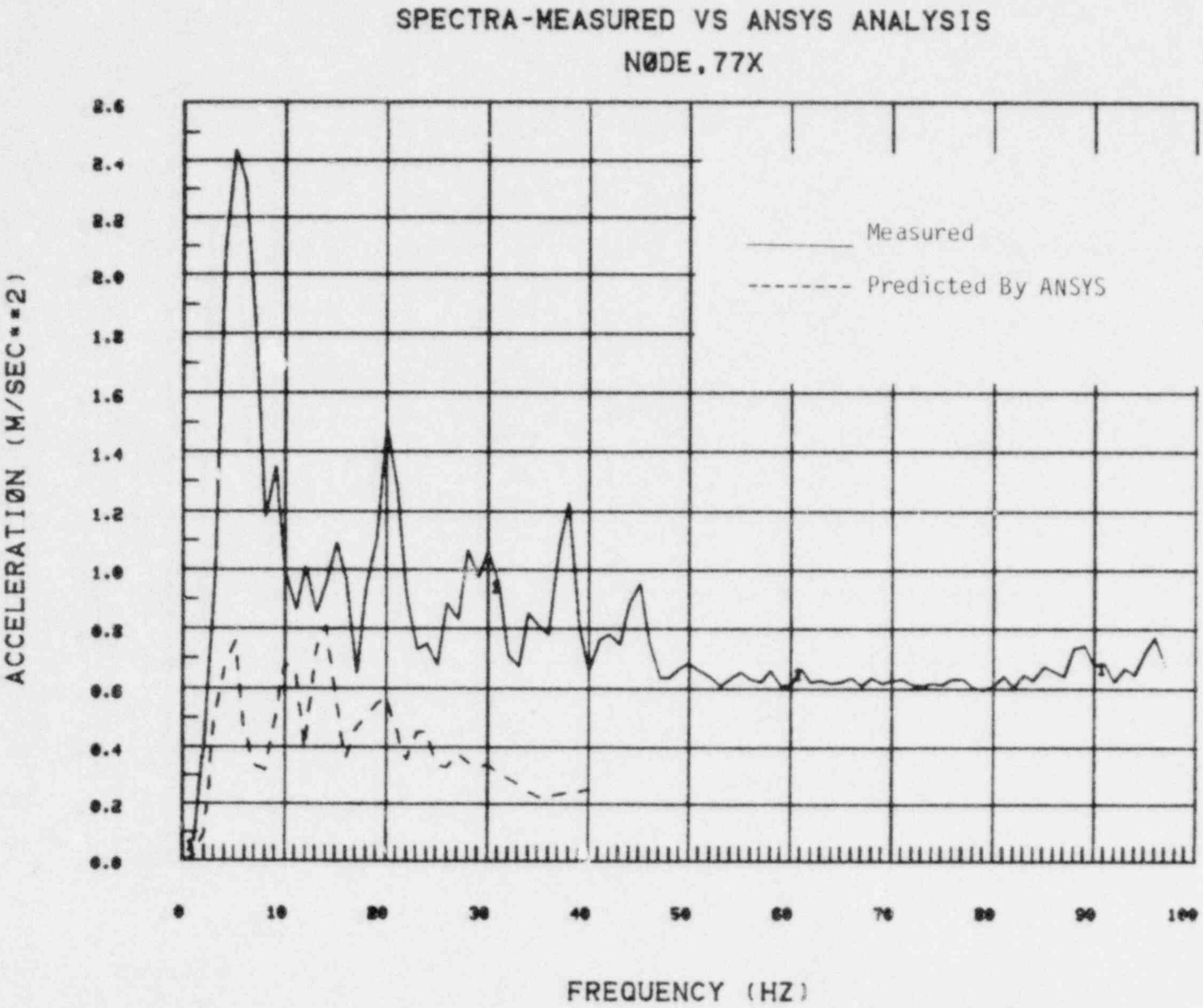

SPECTRA-MEASURED VS ANSYS ANALYSIS
NØDE.77X
Measured
Predicted By ANSYS
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
0
10
20
30
40
50
60
70
80
90
100

Figure 1.77.X

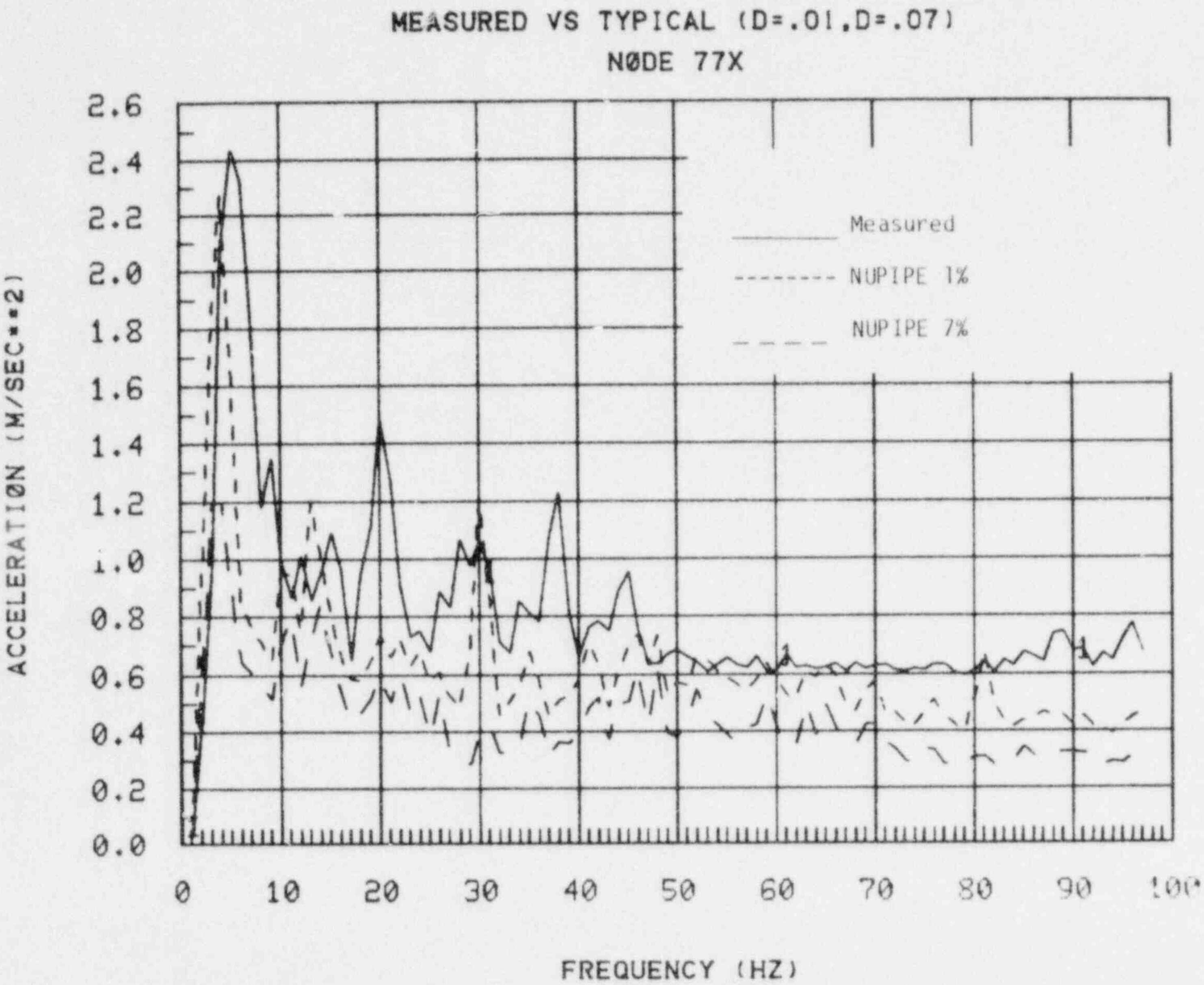

MEASURED VS TYPICAL (D=.01,D=.07)
NØDE 77X
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
Measured
NUPIPE 1%
NUPIPE 7%
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
0
10
20
30
40
50
60
70
80
90
100

Figure 2.77.X

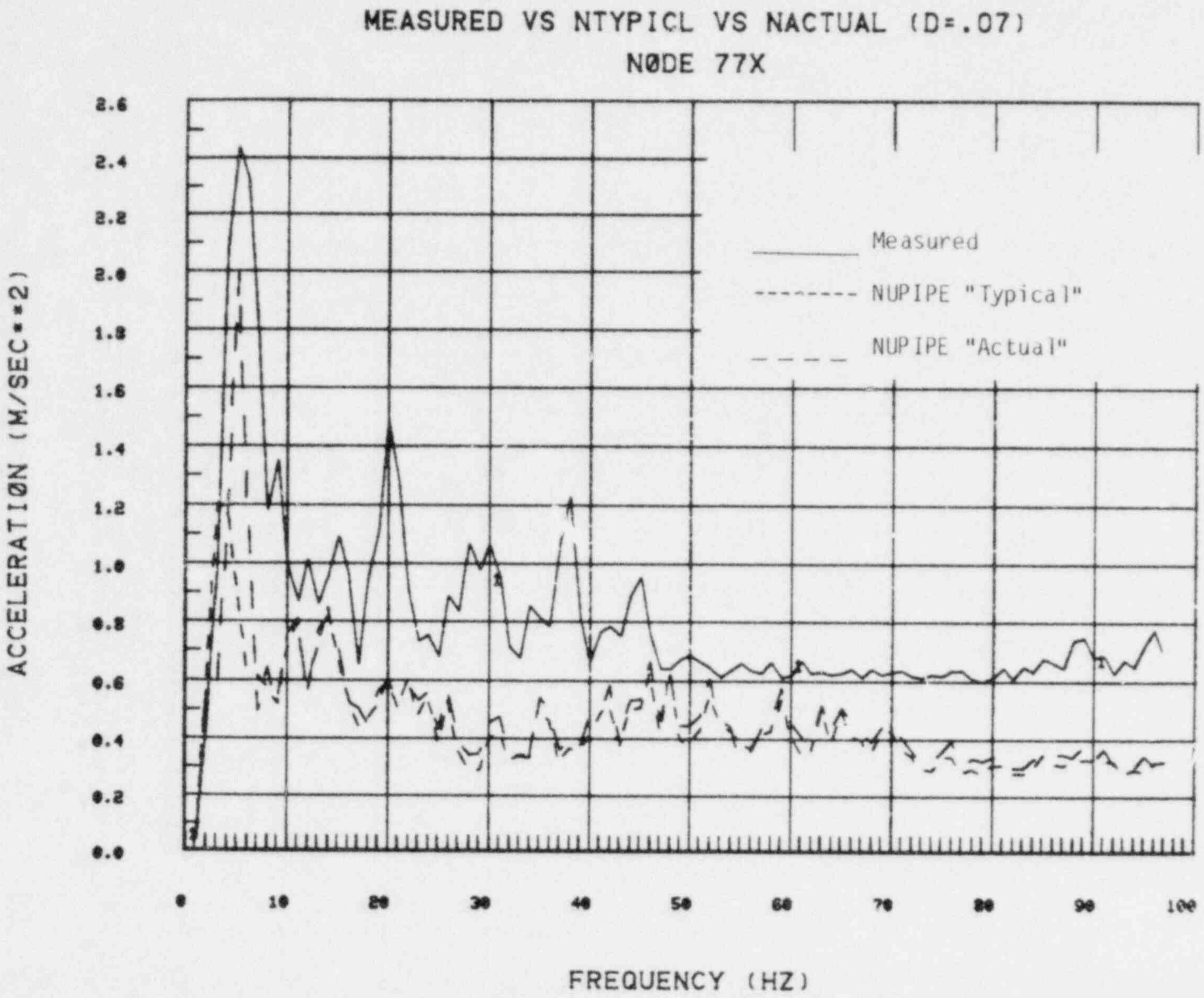

MEASURED VS NTYPICL VS NACTUAL (D=.07)
NØDE 77X
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
Measured
NUPIPE "Typical"
NUPIPE "Actual"
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
0
10
20
30
40
50
60
70
80
90
100

Figure 3.77.X

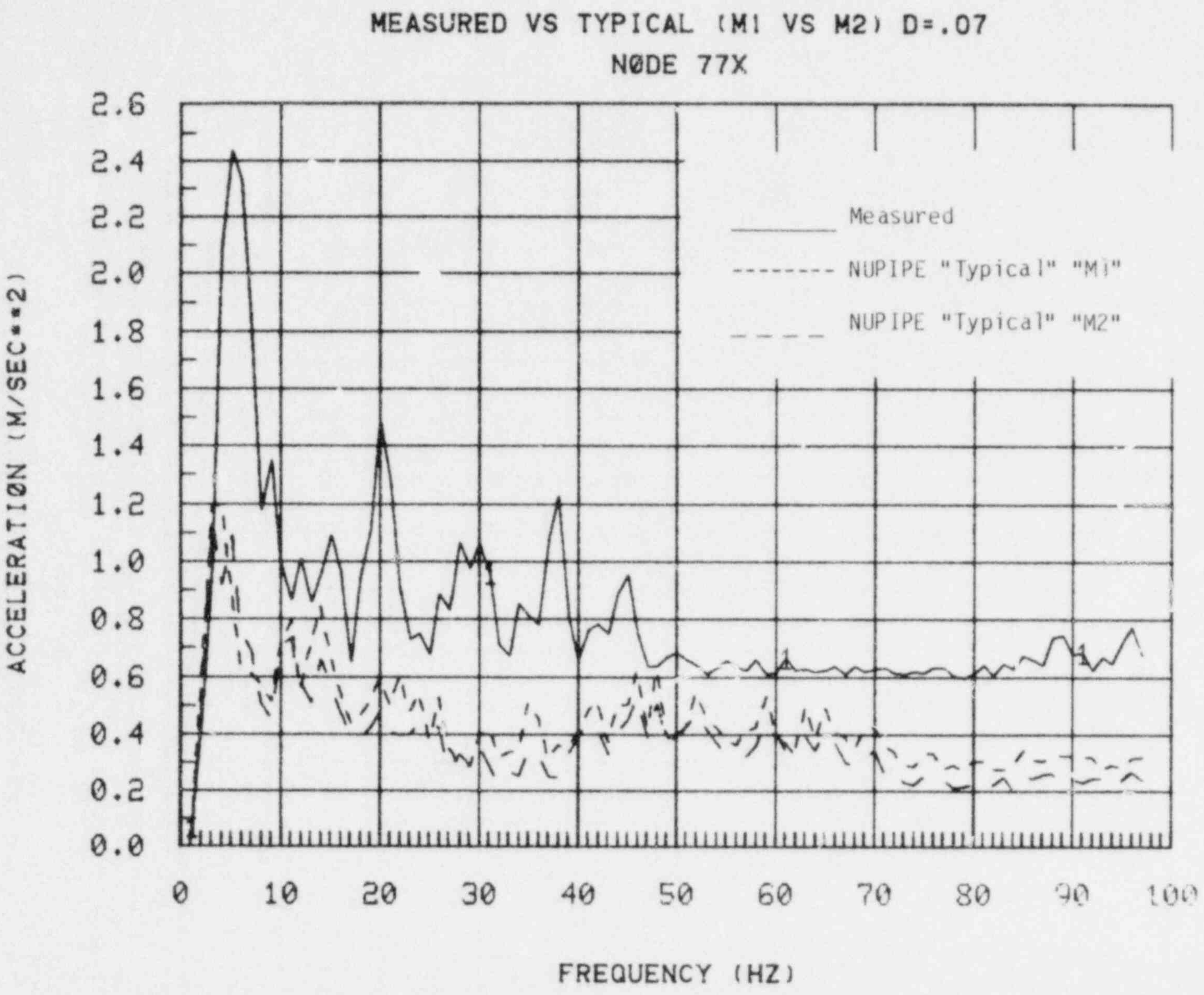
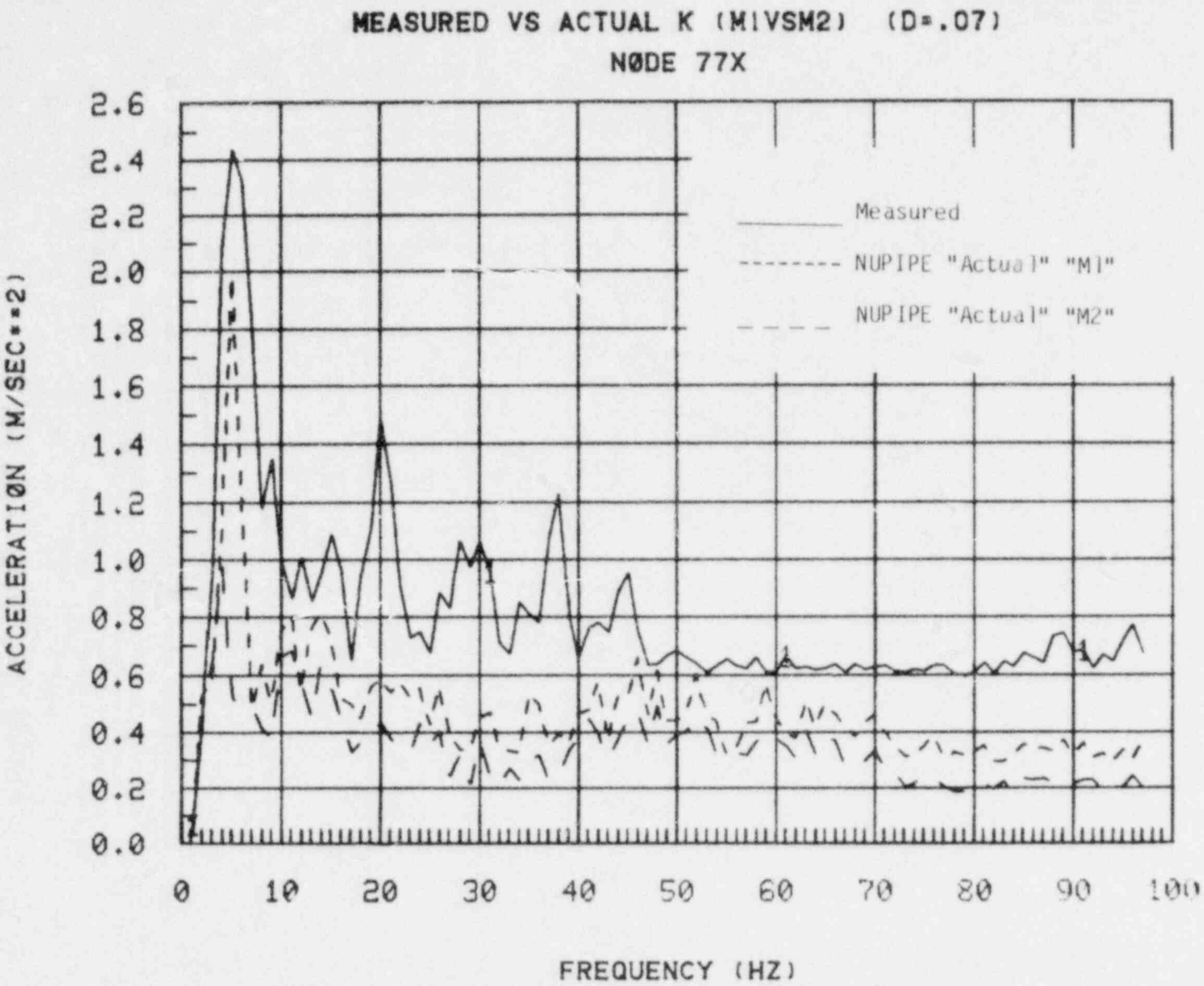
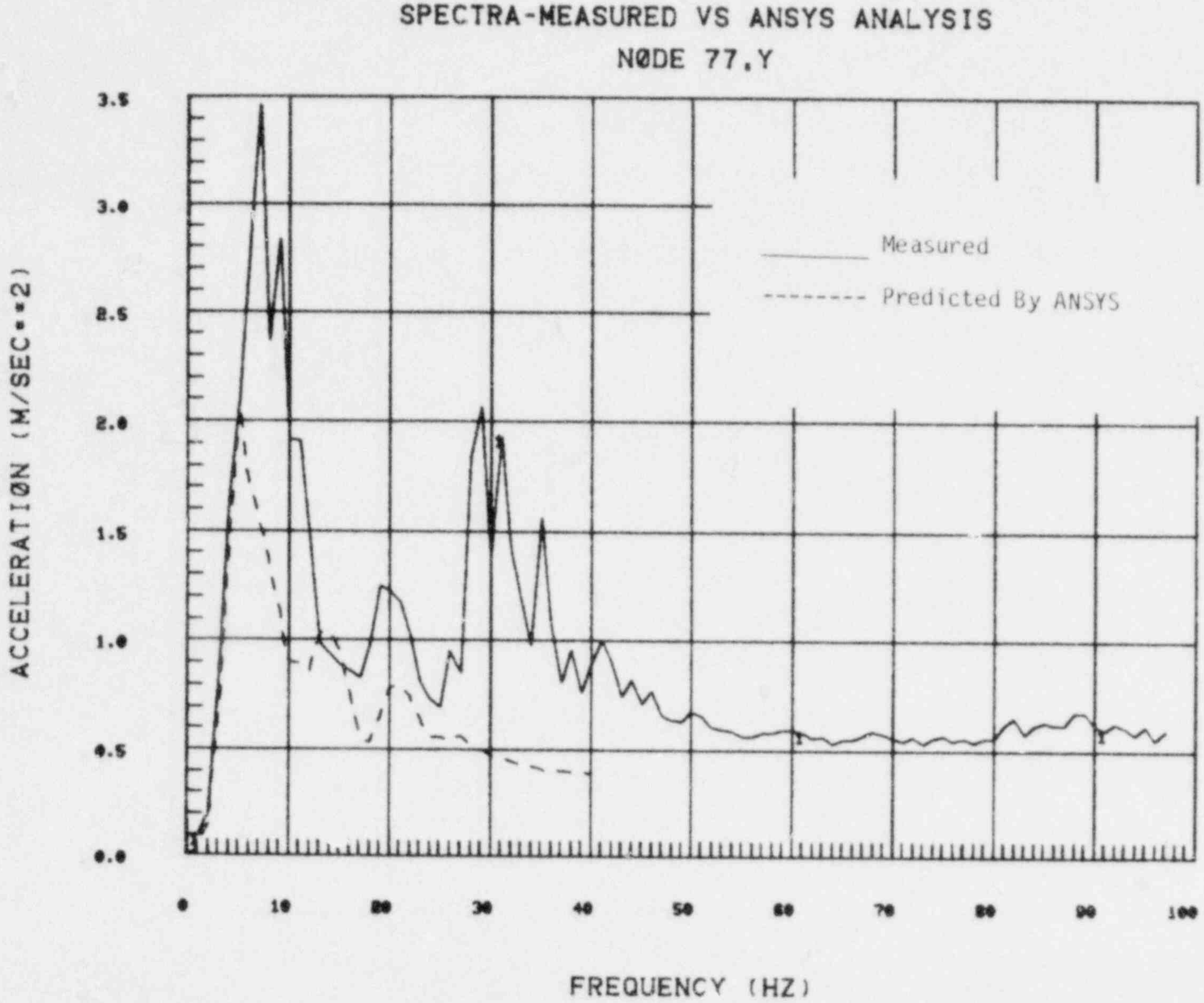

MEASURED VS TYPICAL (M1 VS M2) D=.07
NØDE 77X
Measured
NUPIPE "Typical" "M1"
NUPIPE "Typical" "M2"
ACCELERATIØN (M/SEC**2)
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
10
20
30
40
50
60
70
80
90
100
FREQUENCY (HZ)

Figure 4.77.X



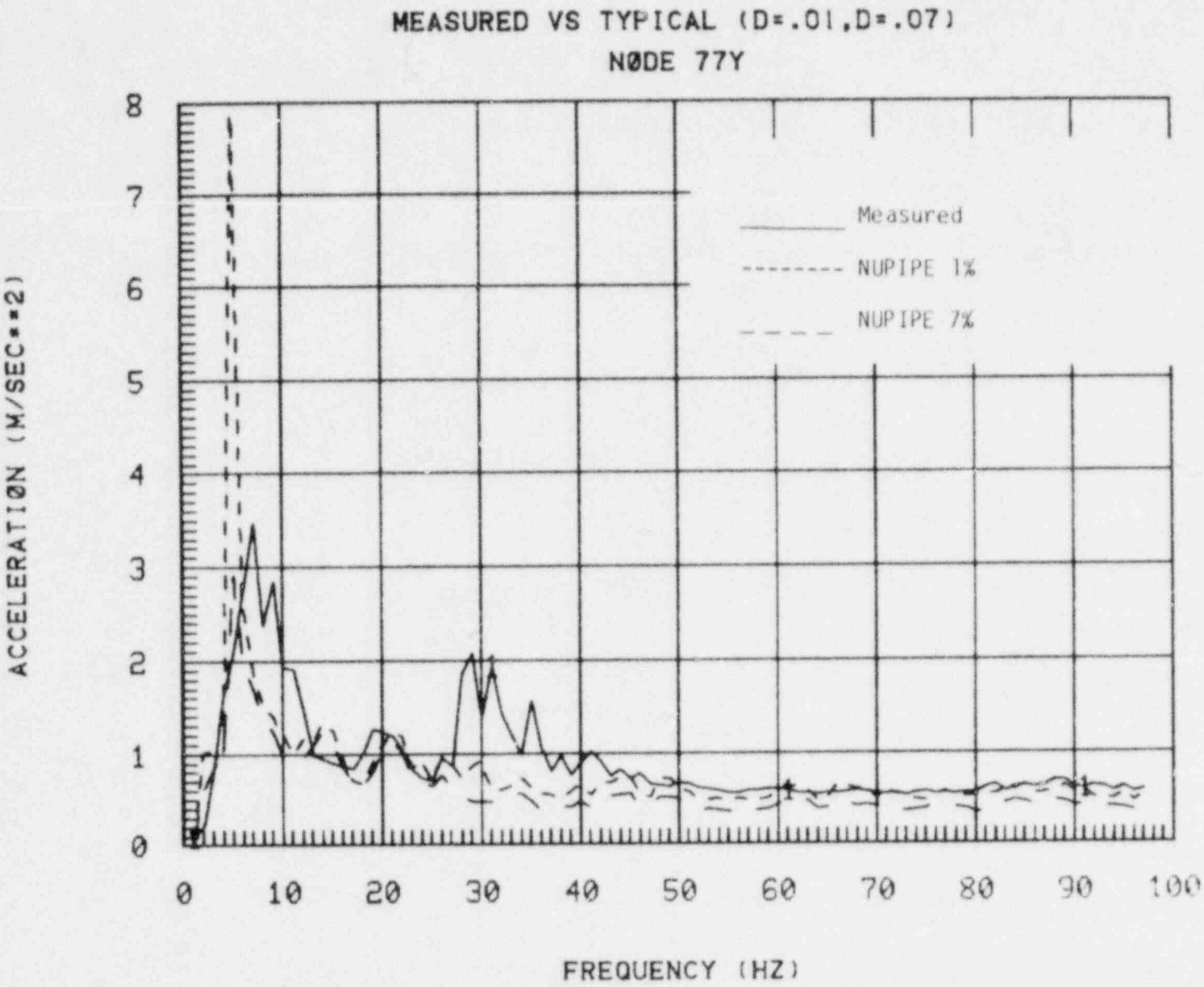
MEASURED VS ACTUAL K (M1VSM2) (D=.07)
NØDE 77X
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
Measured
NUPIPE "Actual" "M1"
NUPIPE "Actual" "M2"
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
0
10
20
30
40
50
60
70
80
90
100

Figure 5.77.X



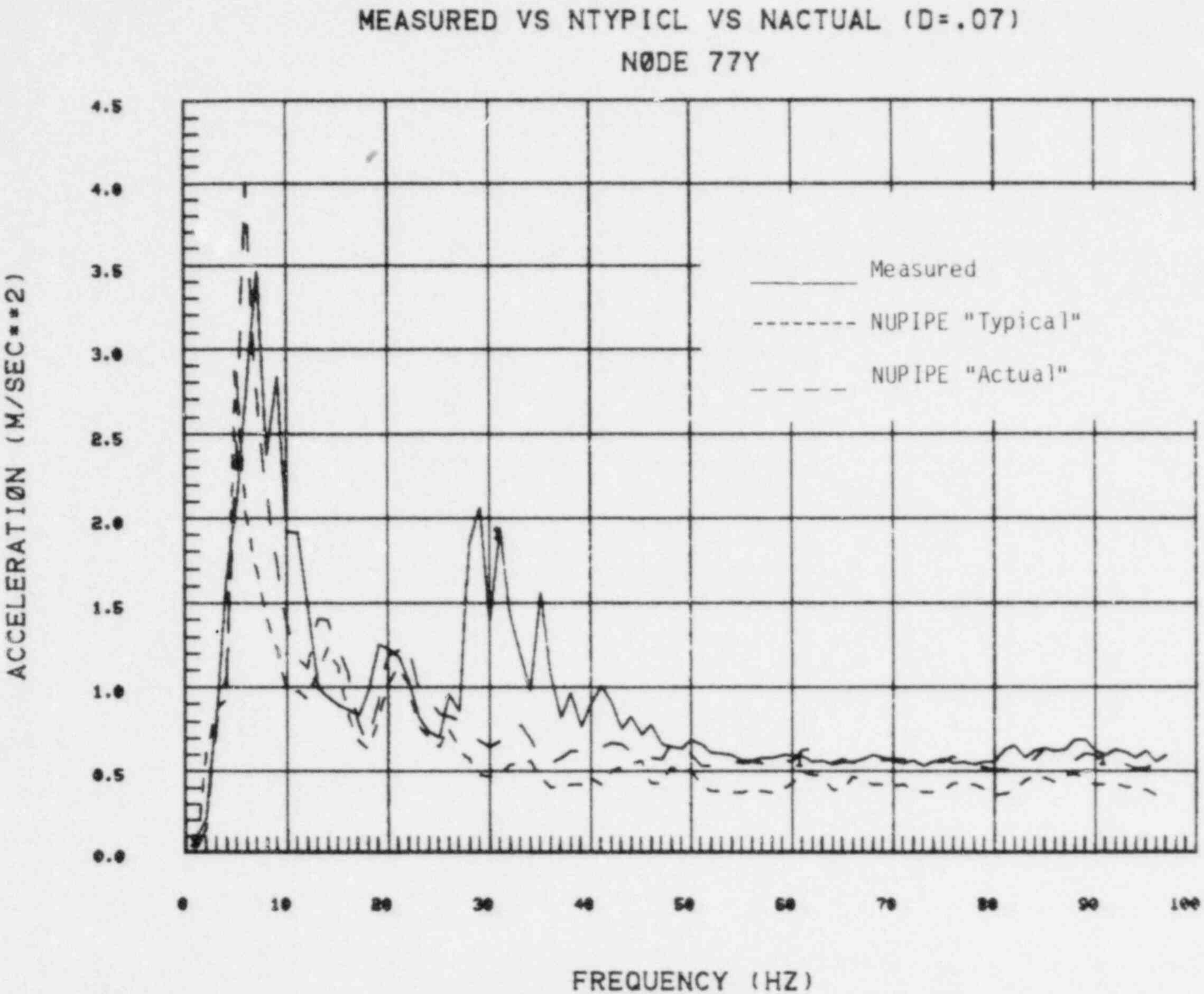
SPECTRA-MEASURED VS ANSYS ANALYSIS
NØDE 77.Y
Measured
Predicted By ANSYS
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
70
80
90
100

Figure 1.77.Y



MEASURED VS TYPICAL (D=.01,D=.07)
NØDE 77Y
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
Measured
NUPIPE 1%
NUPIPE 7%
0
1
2
3
4
5
6
7
8
0
10
20
30
40
50
60
70
80
90
100

Figure 2.77.Y



MEASURED VS NTYPICL VS NACTUAL (D=.07)
NØDE 77Y
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
Measured
NUPIPE "Typical"
NUPIPE "Actual"
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
0
10
20
30
40
50
60
70
80
90
100

Figure 3.77.Y

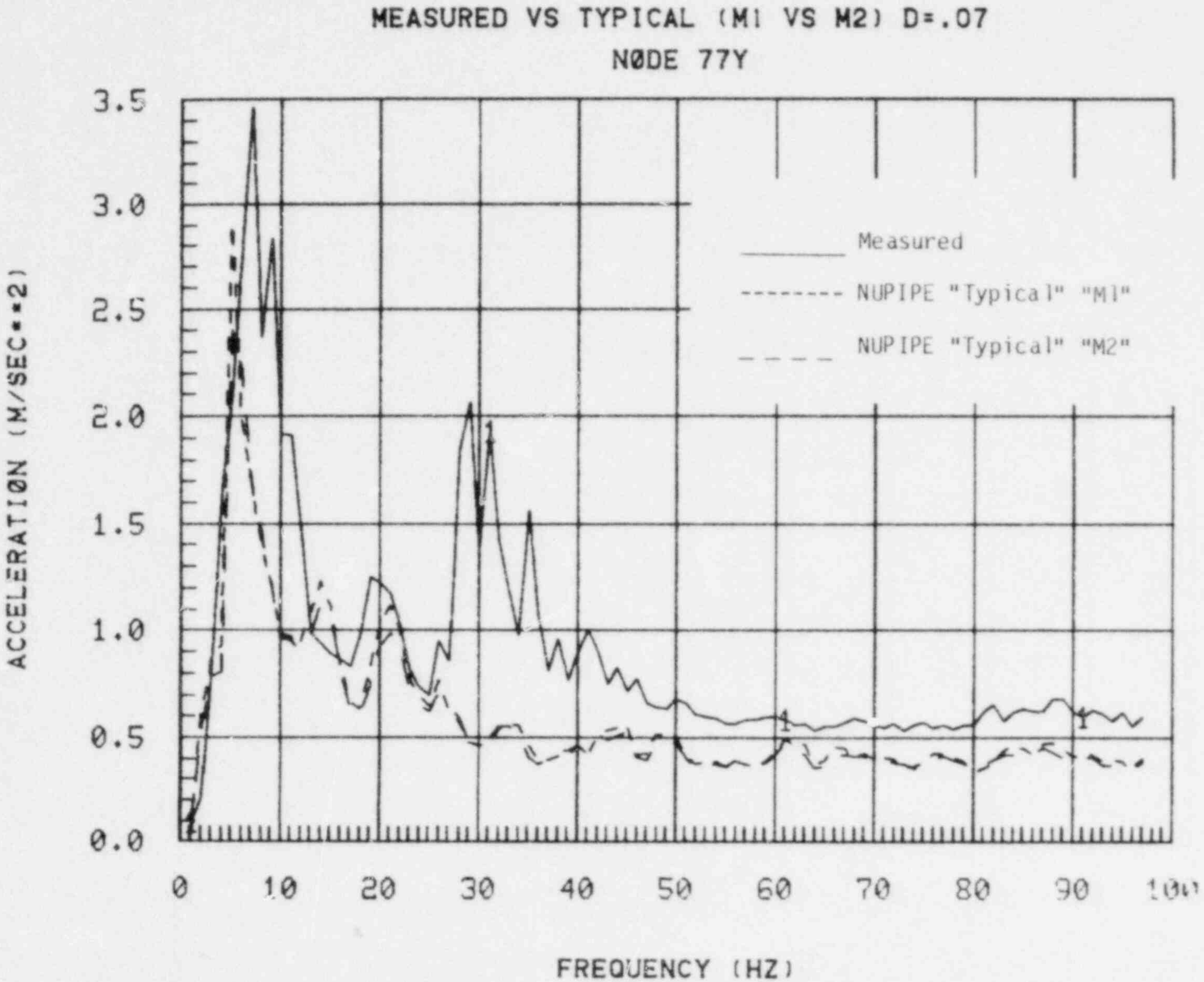
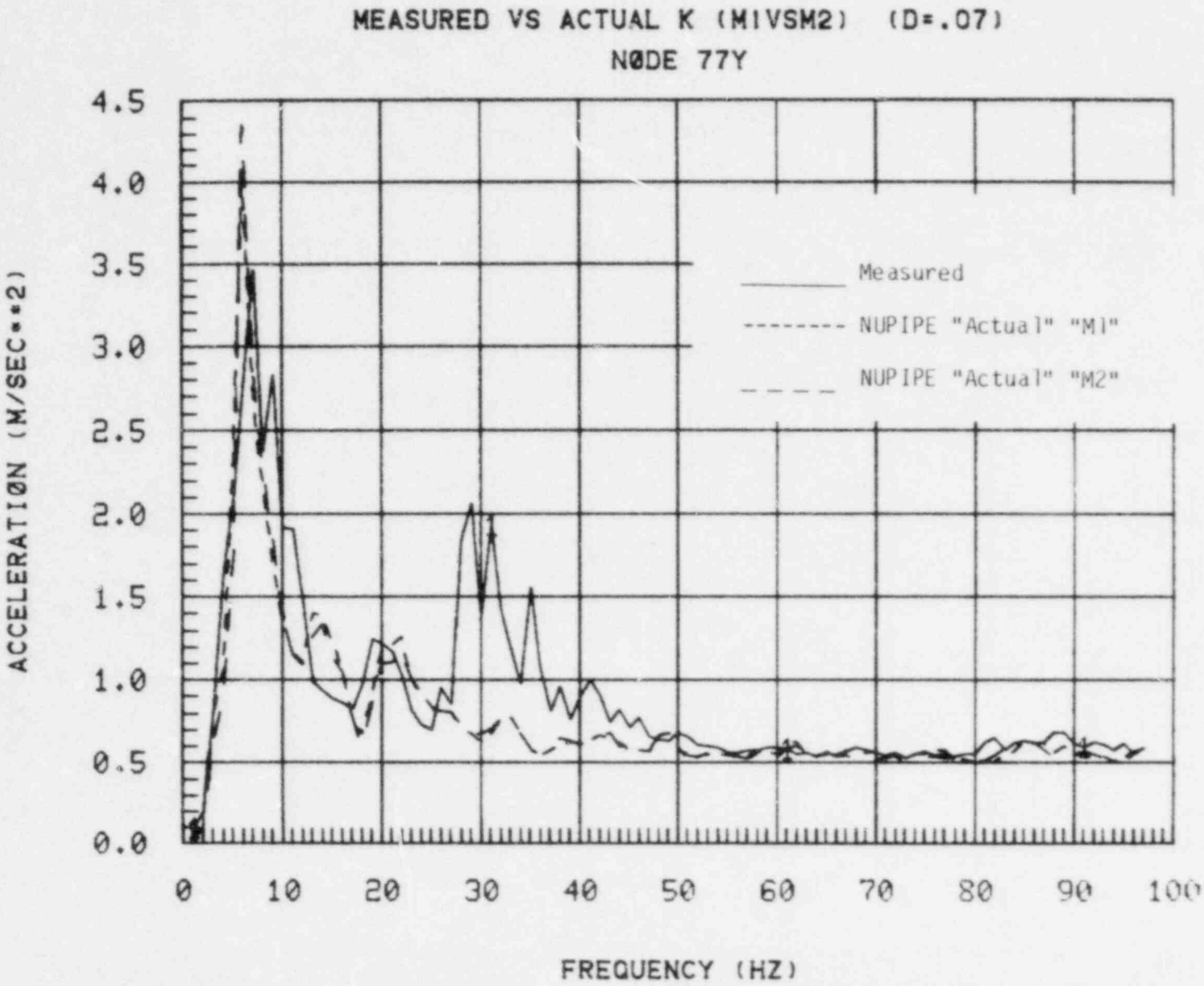

MEASURED VS TYPICAL (M1 VS M2) D=.07
NØDE 77Y
ACCELERATIØN (M/SEC**2)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
70
80
90
100
FREQUENCY (HZ)
Measured
NUPIPE "Typical" "M1"
NUPIPE "Typical" "M2"

Figure 4.77.Y



MEASURED VS ACTUAL K (M1VSM2) (D=.07)
NØDE 77Y
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
Measured
NUPIPE "Actual" "M1"
NUPIPE "Actual" "M2"
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
0
10
20
30
40
50
60
70
80
90
100

Figure 5.77.Y

SPECTRA-MEASURED VS ANSYS ANALYSIS
NØDE 77.Z

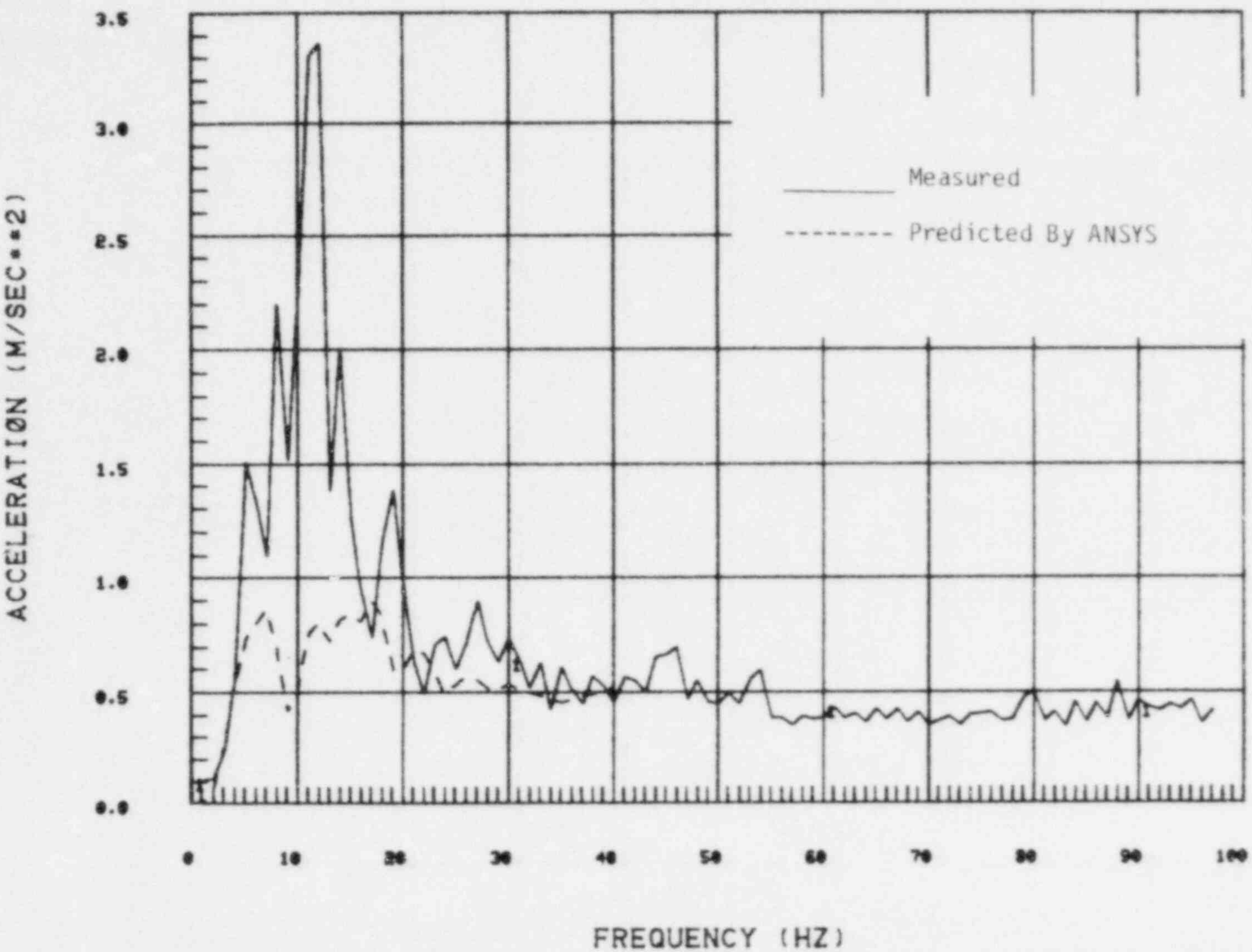


Figure 1.77.Z

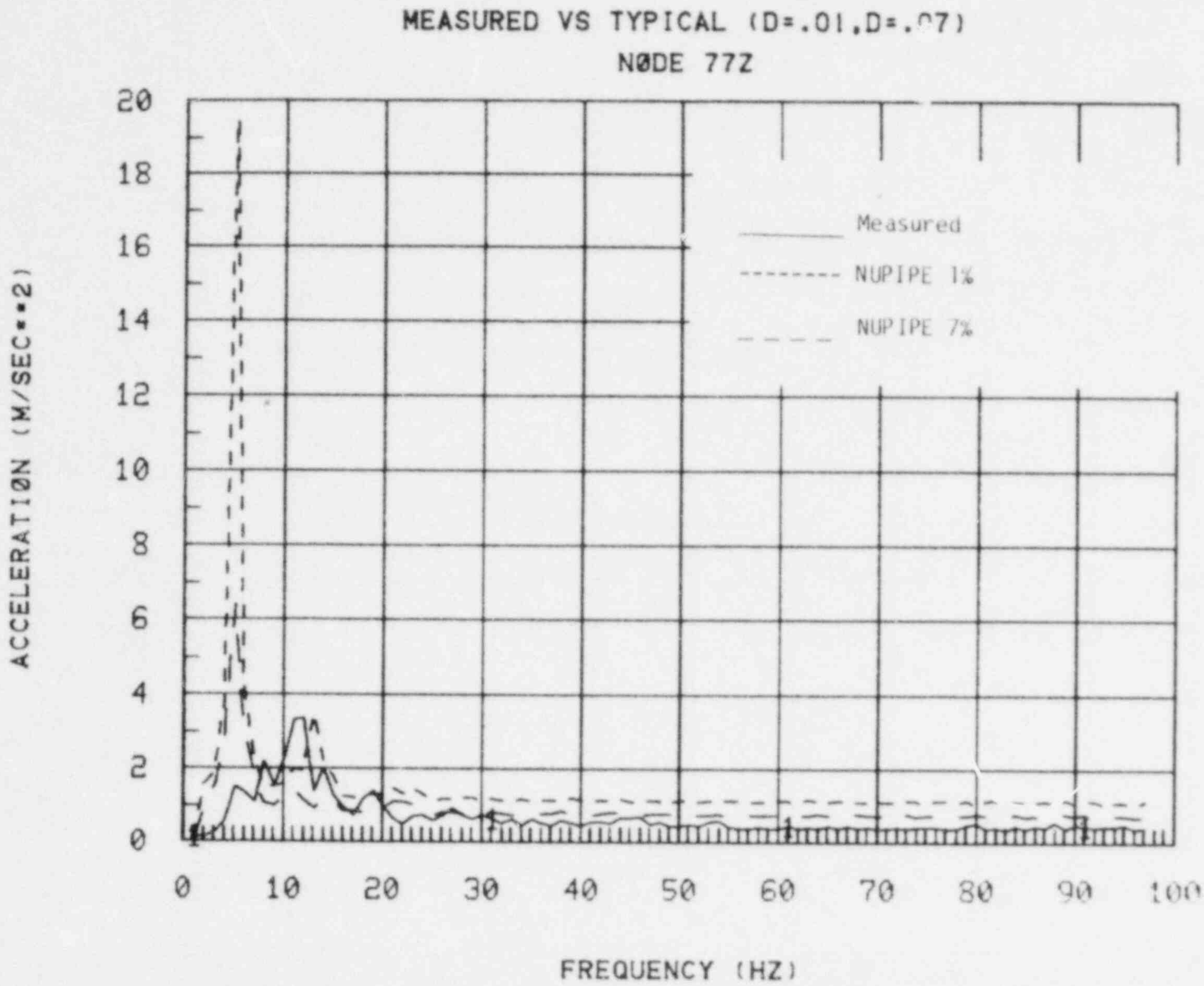
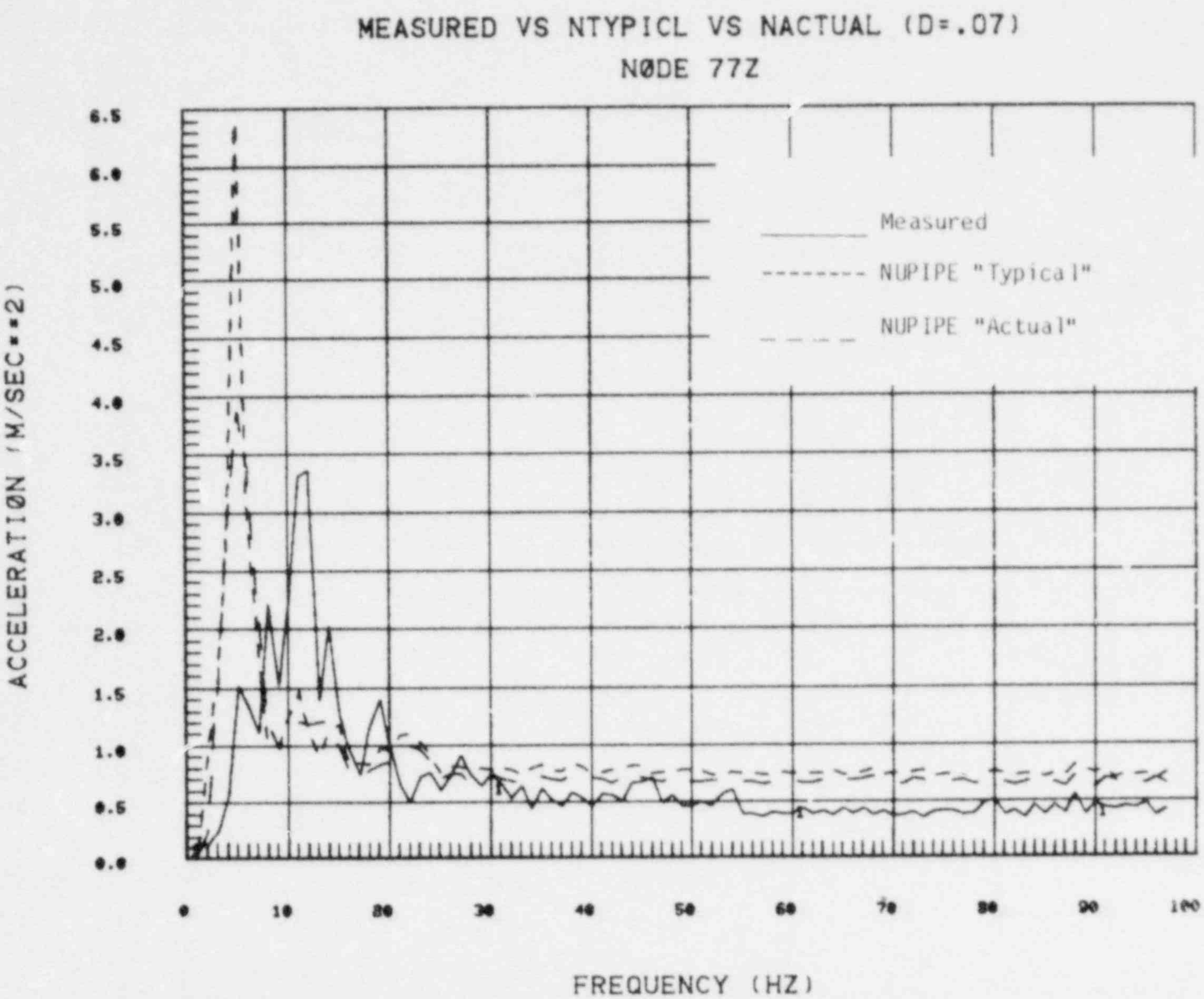

MEASURED VS TYPICAL (D=.01,D=.07)
NØDE 77Z
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
Measured
NUPIPE 1%
NUPIPE 7%
0
2
4
6
8
10
12
14
16
18
20
0
10
20
30
40
50
60
70
80
90
100

Figure 2.77.Z



MEASURED VS NTYPICL VS NACTUAL (D=.07)
NØDE 77Z
Measured
NUPIPE "Typical"
NUPIPE "Actual"
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)

Figure 3.77.Z

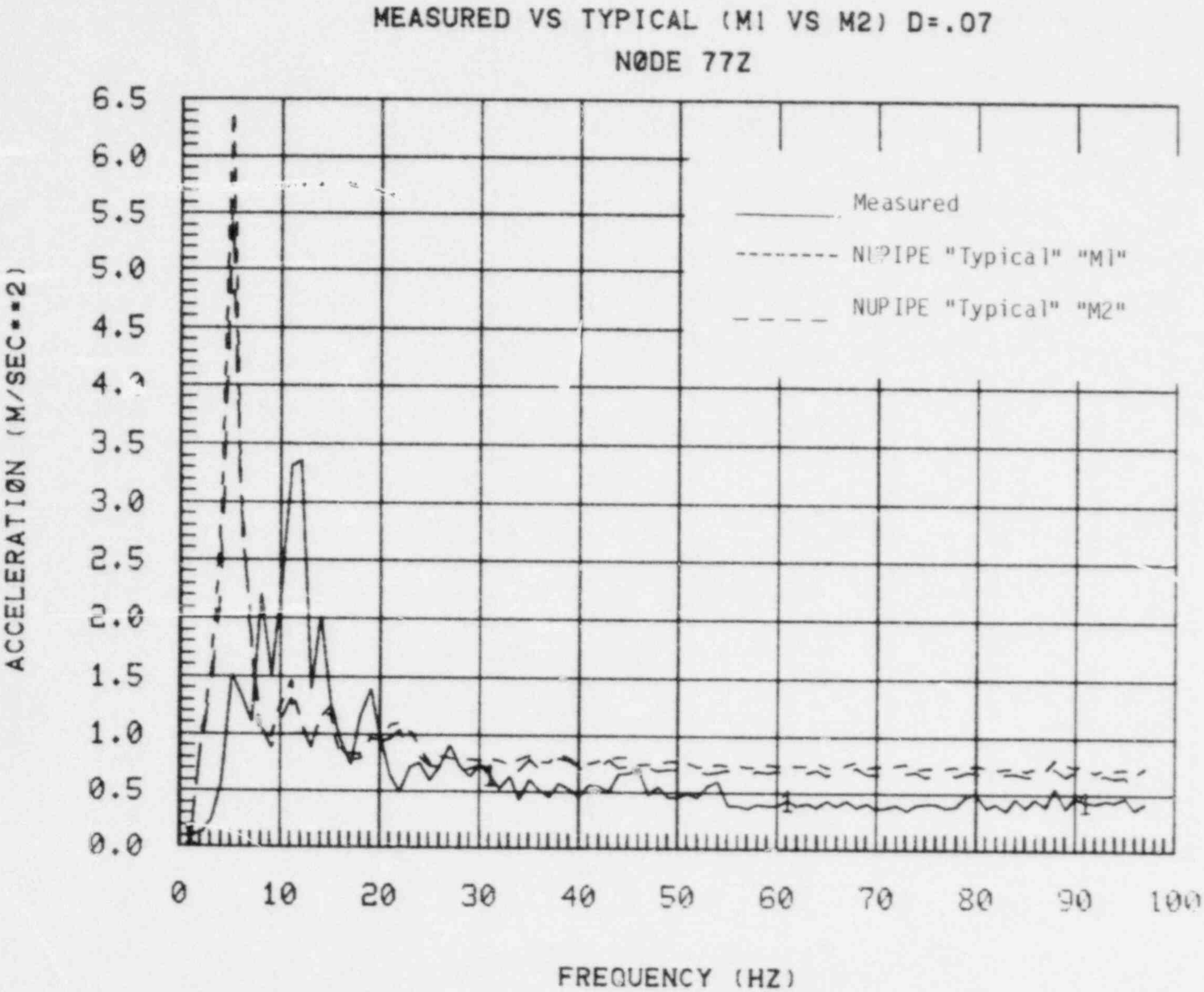

MEASURED VS TYPICAL (M1 VS M2) D=.07
NØDE 77Z
ACCELERATIØN (M/SEC**2)
FREQUENCY (HZ)
Measured
NUPIPE "Typical" "M1"
NUPIPE "Typical" "M2"
6.5
6.0
5.5
5.0
4.5
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
70
80
90

Figure 4.77.Z

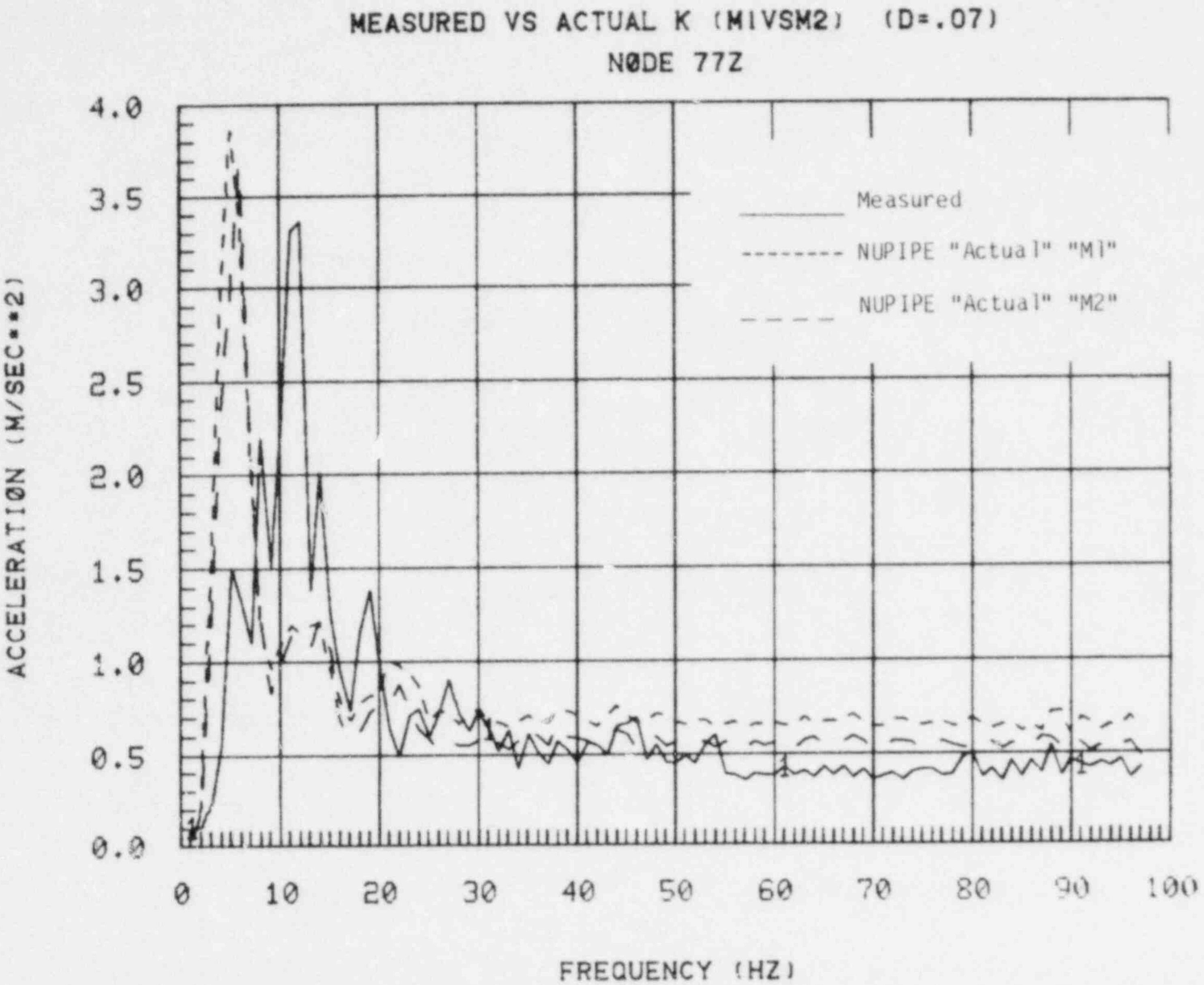

MEASURED VS ACTUAL K (MIVSM2) (D=.07)
NØDE 77Z
ACCELERATIØN (M/SEC**2)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
70
80
90
100
FREQUENCY (HZ)
Measured
NUPIPE "Actual" "M1"
NUPIPE "Actual" "M2"

Figure 5.77.Z

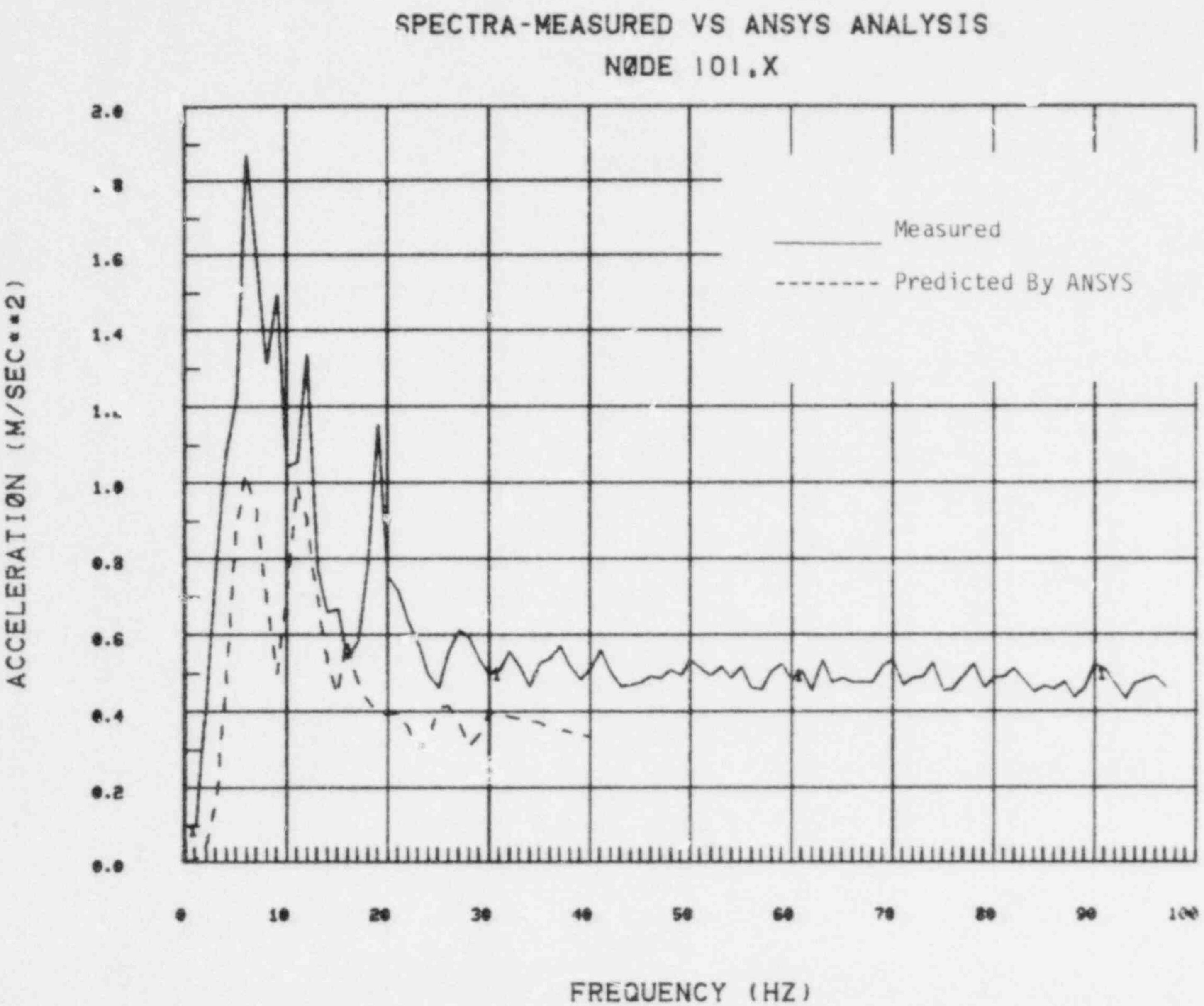


Figure 1.101.X

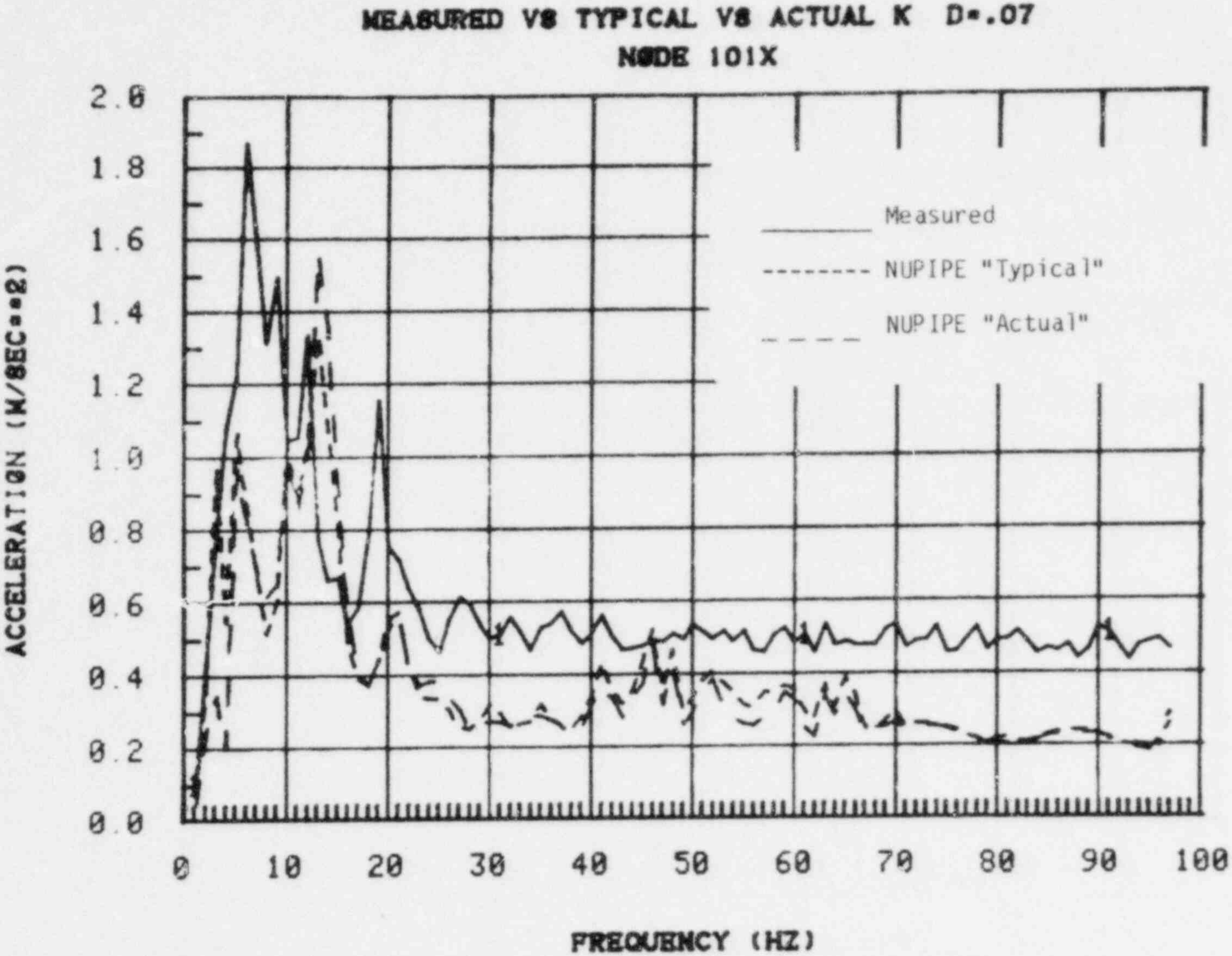


Figure 3.101.X

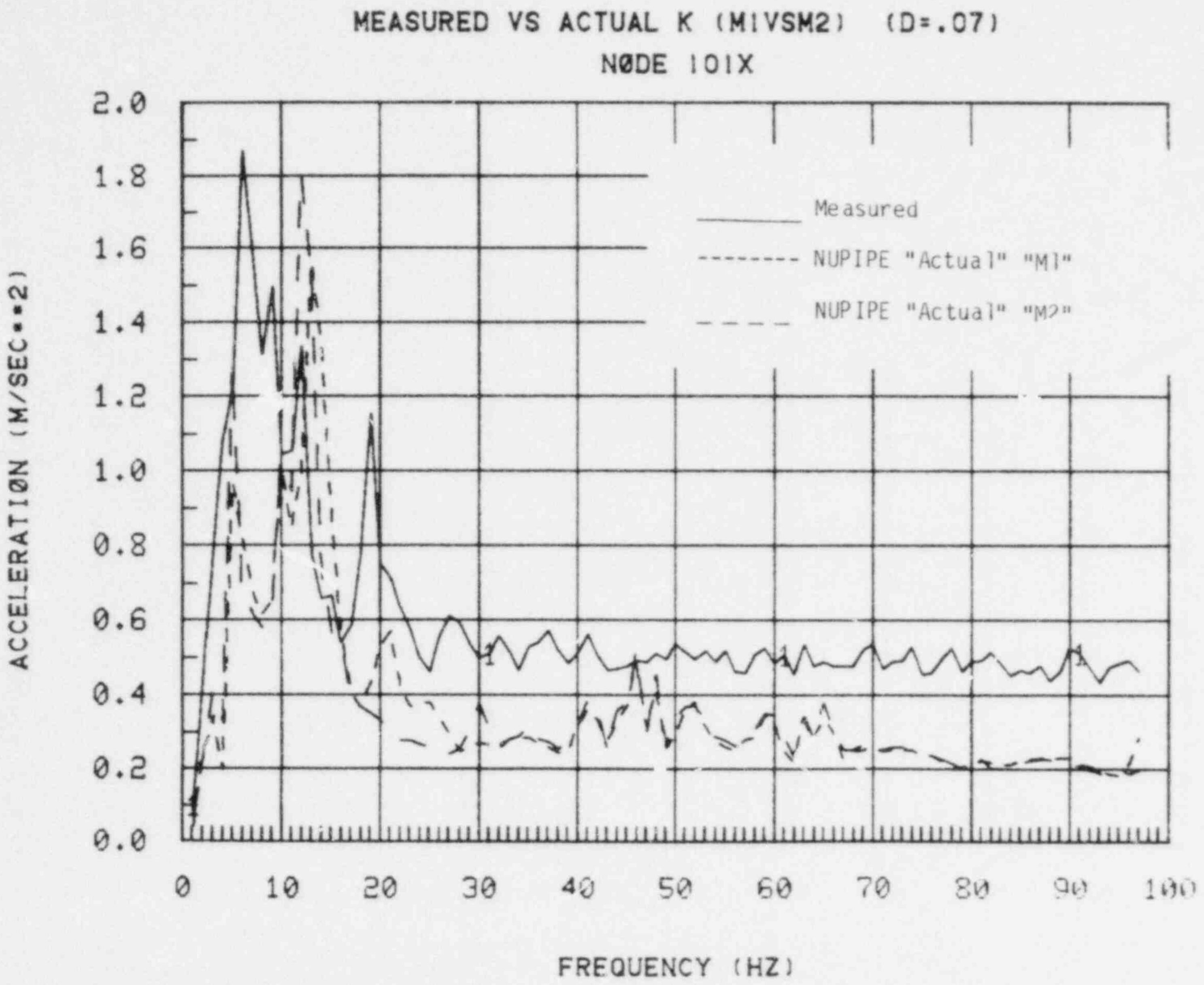


Figure 5.101.X

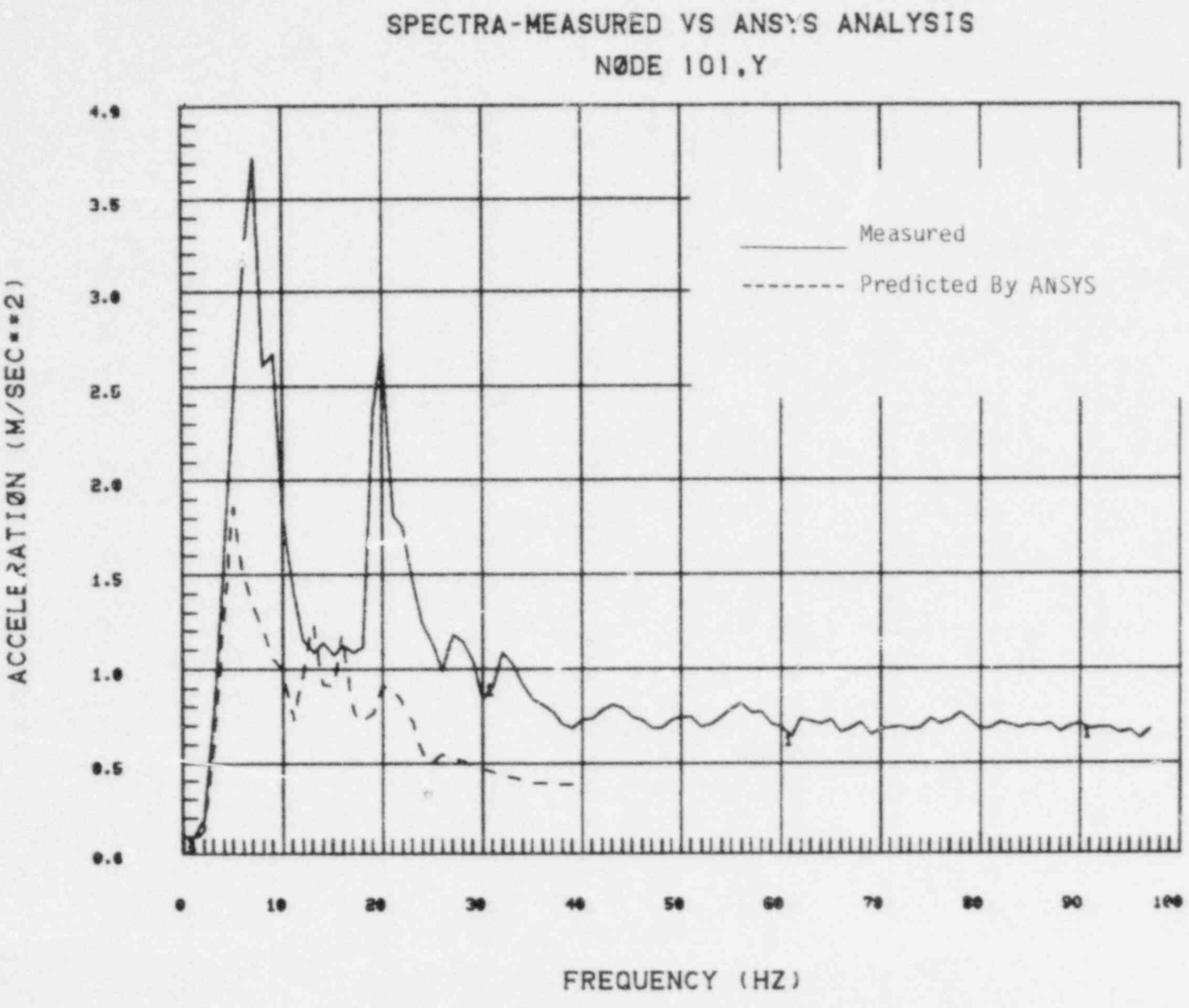


Figure 1.101.Y

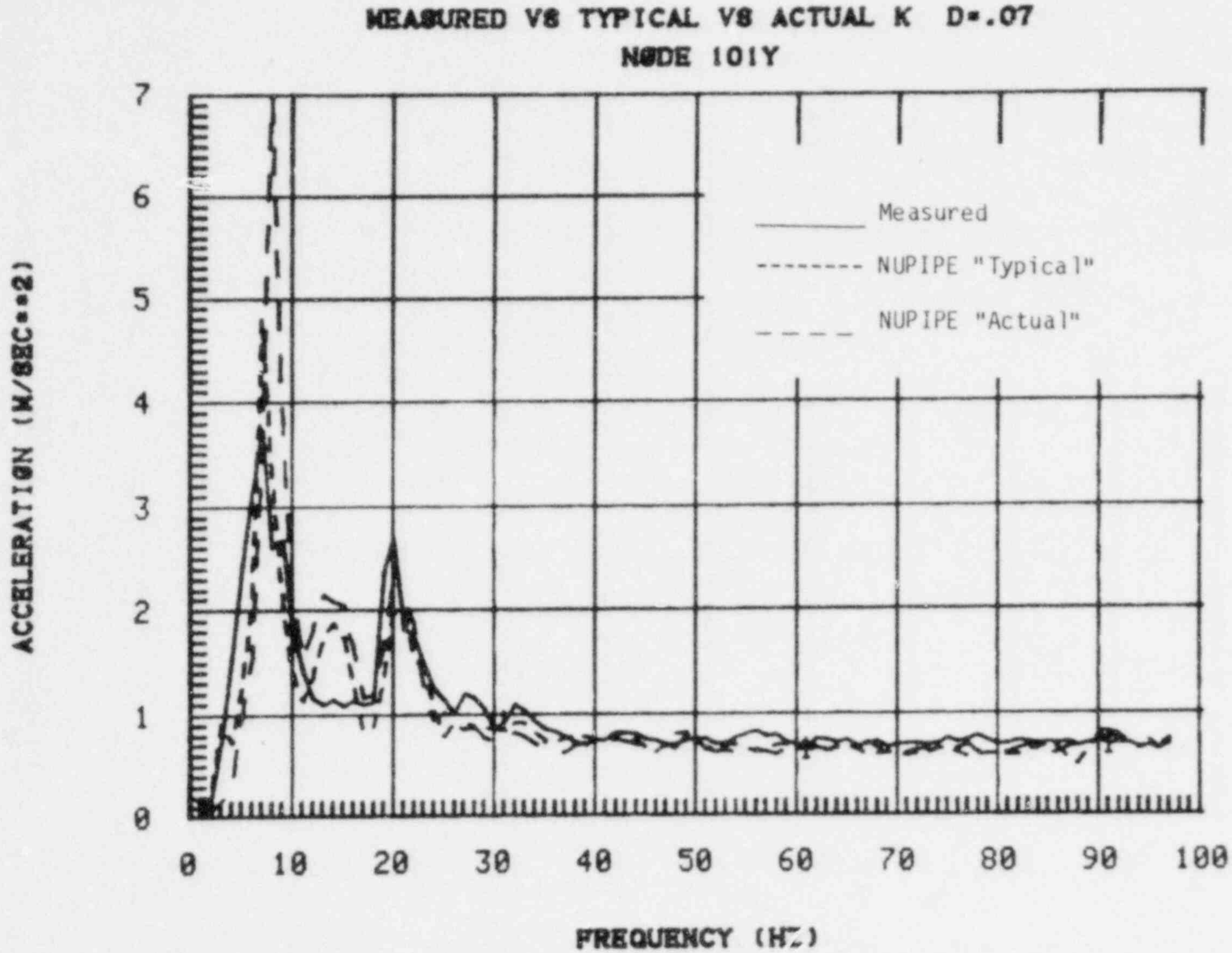


Figure 3.101.Y

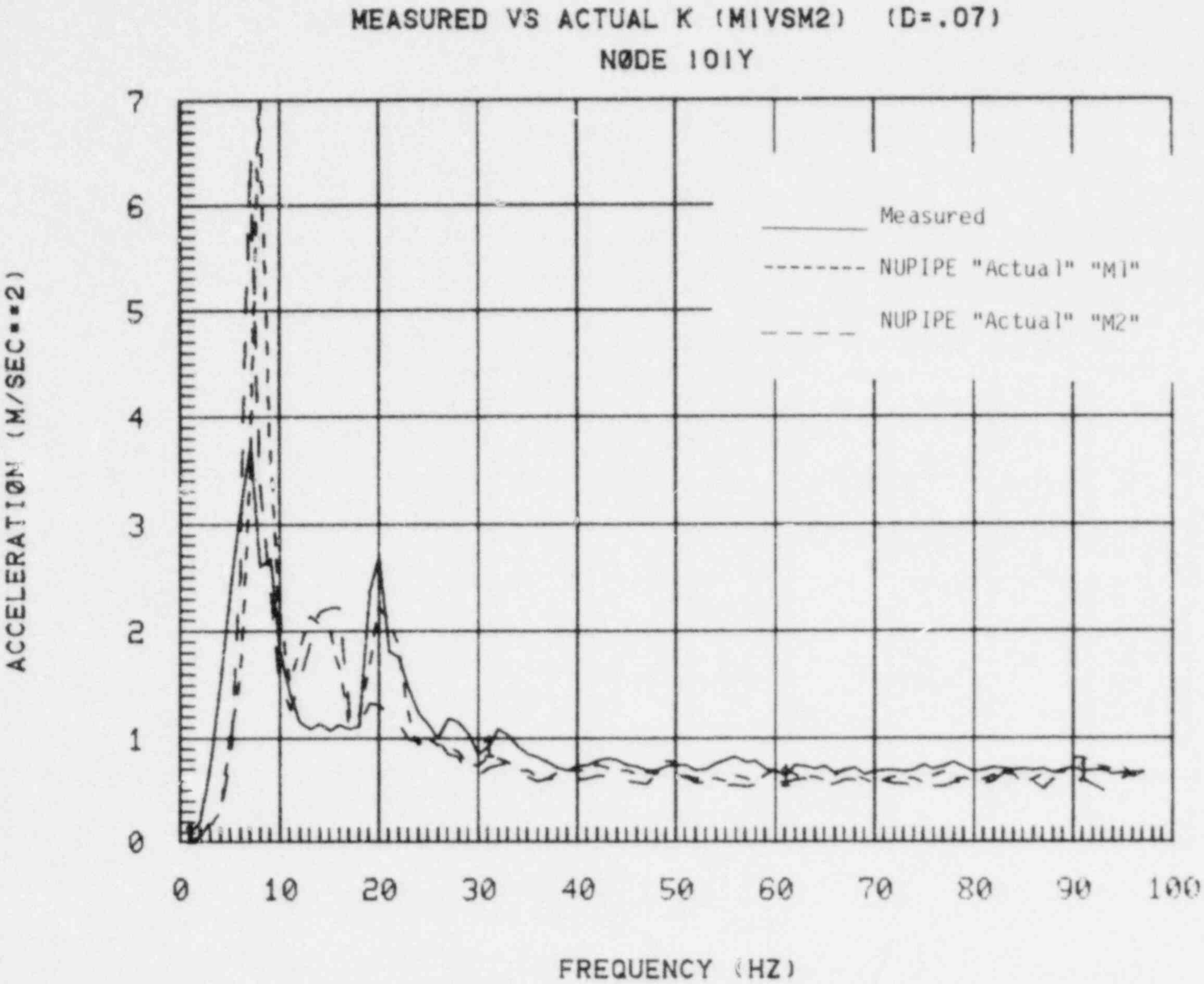


Figure 5.101.Y

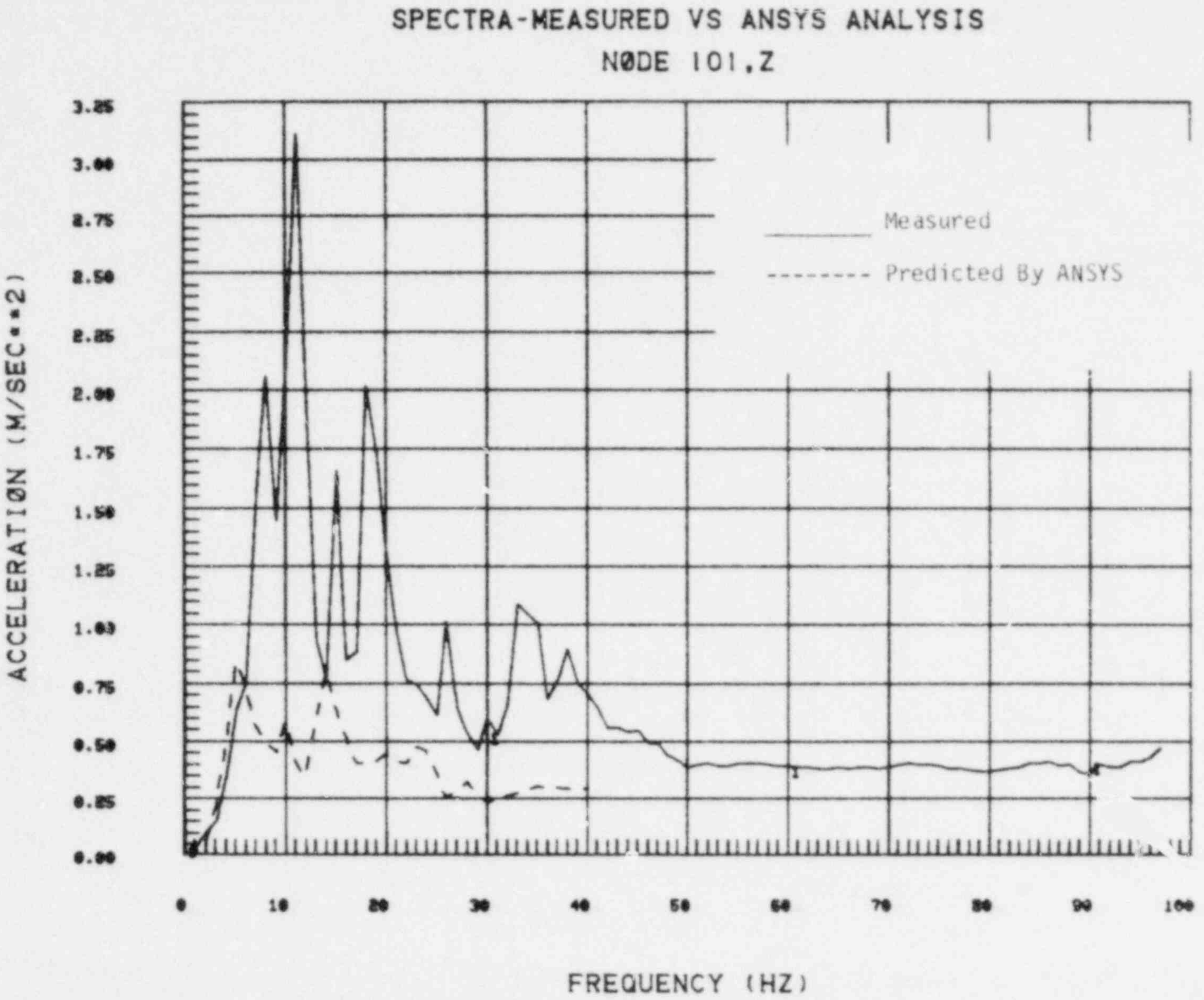


Figure 1.101.Z

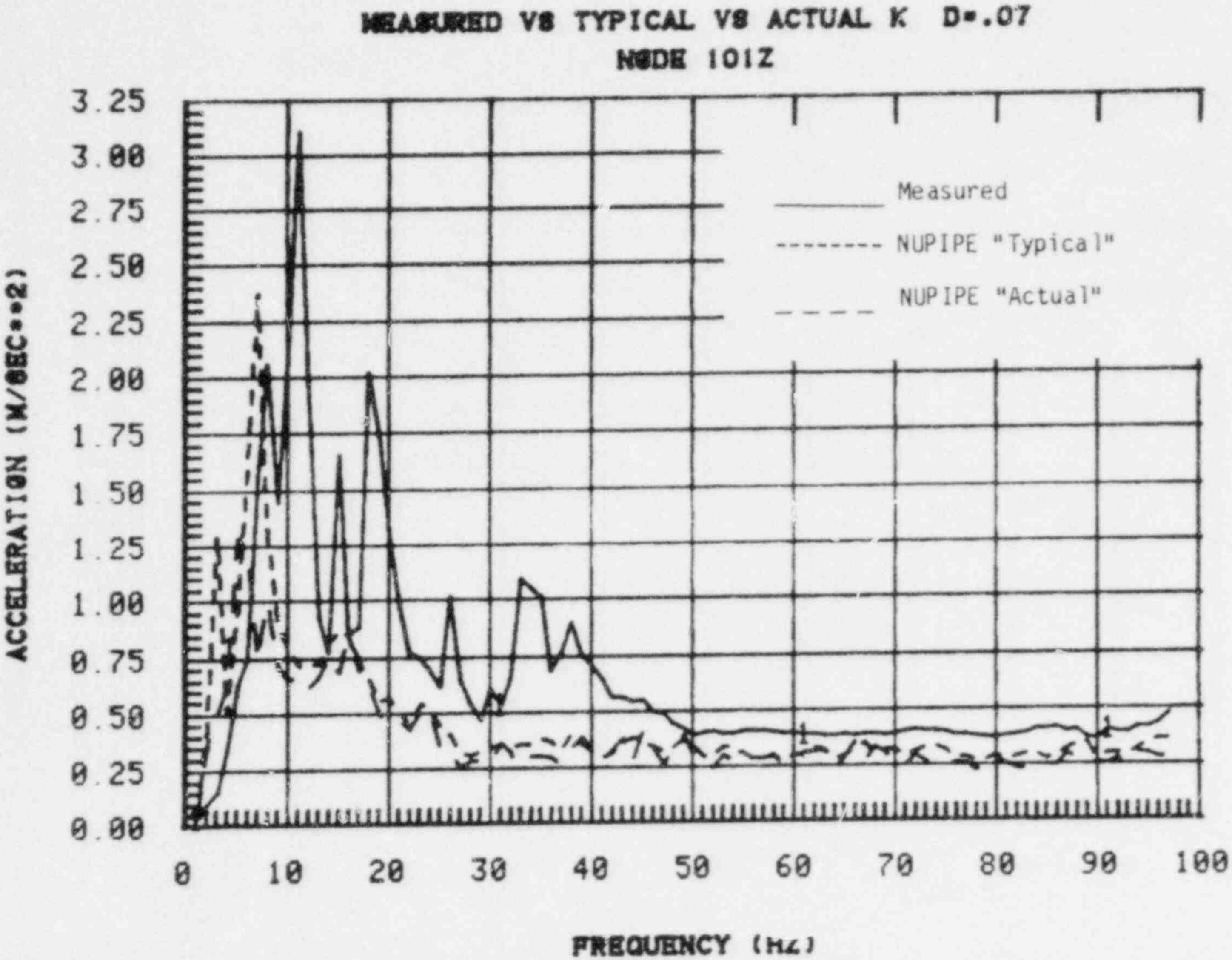


Figure 3.101.Z

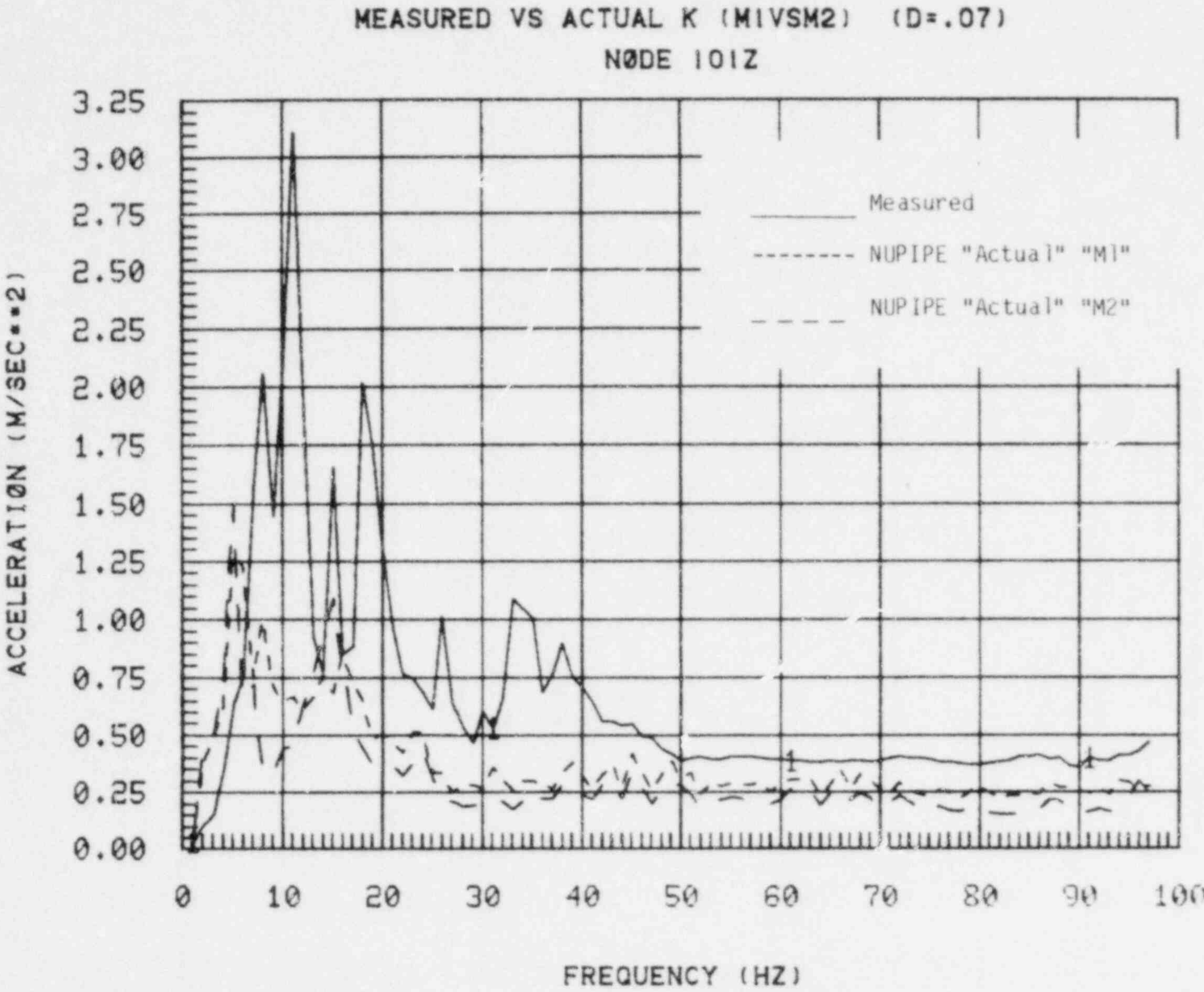


Figure 5.101.Z

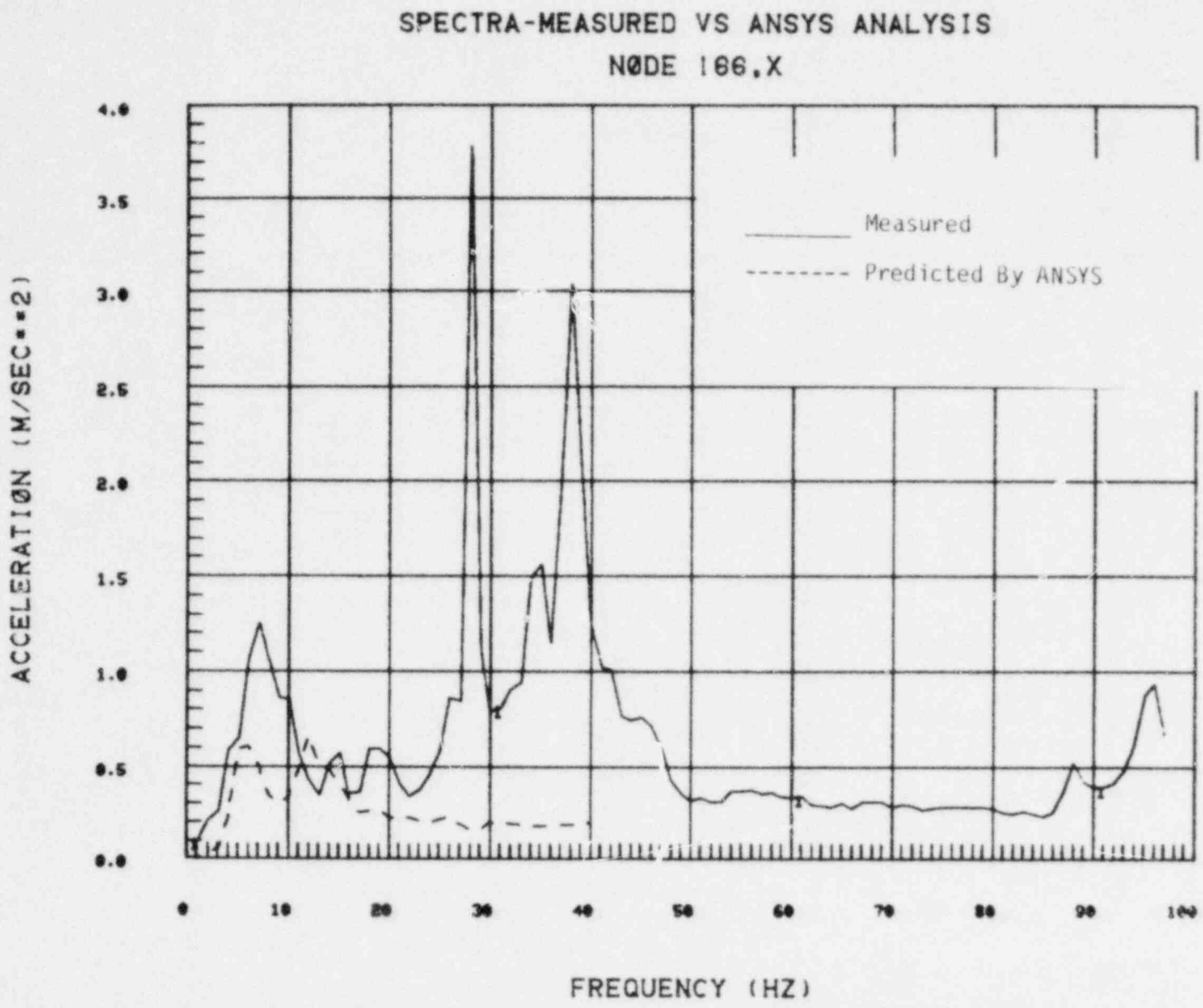


Figure 1.166.X

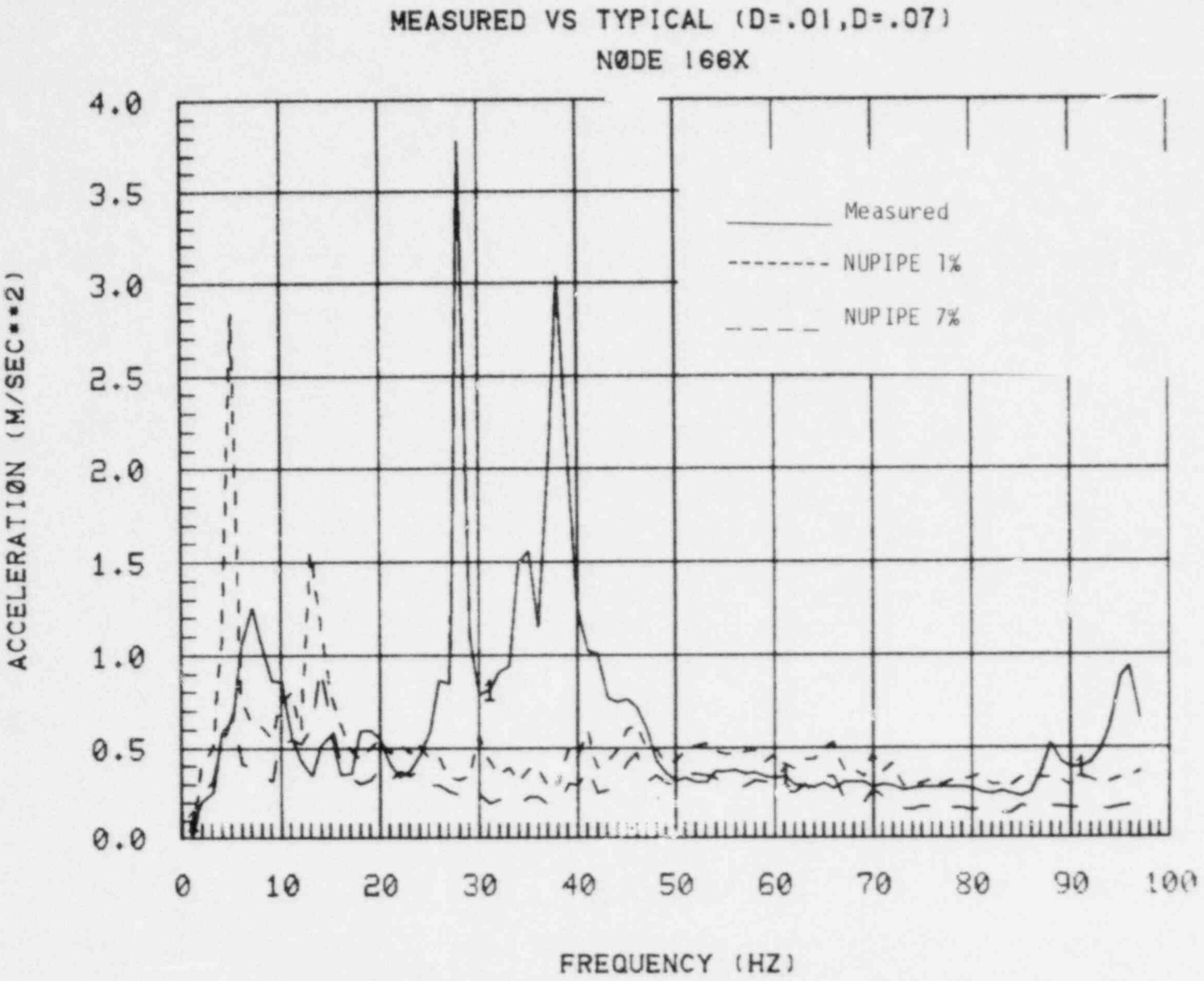


Figure 2.166.X

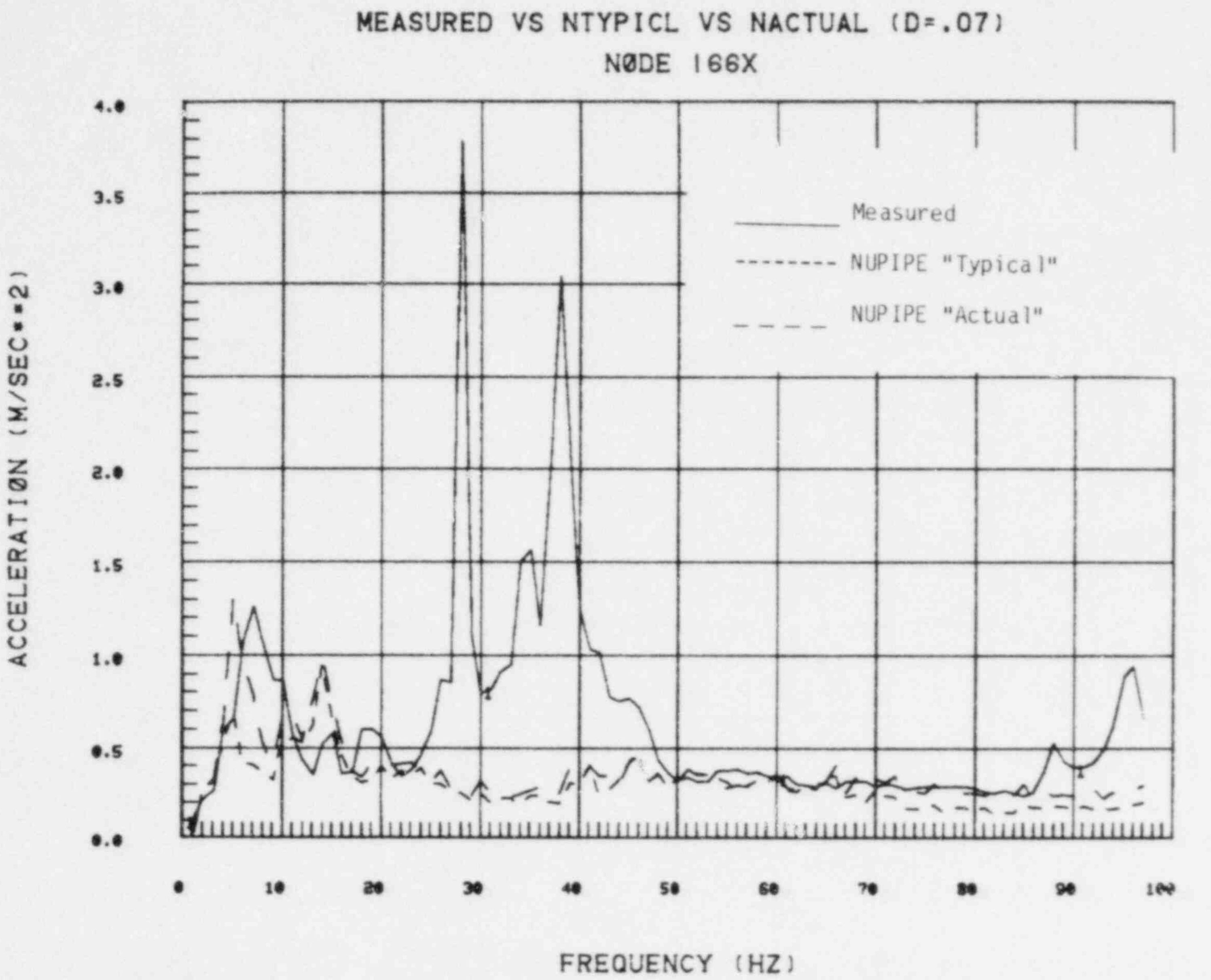


Figure 3.166.X

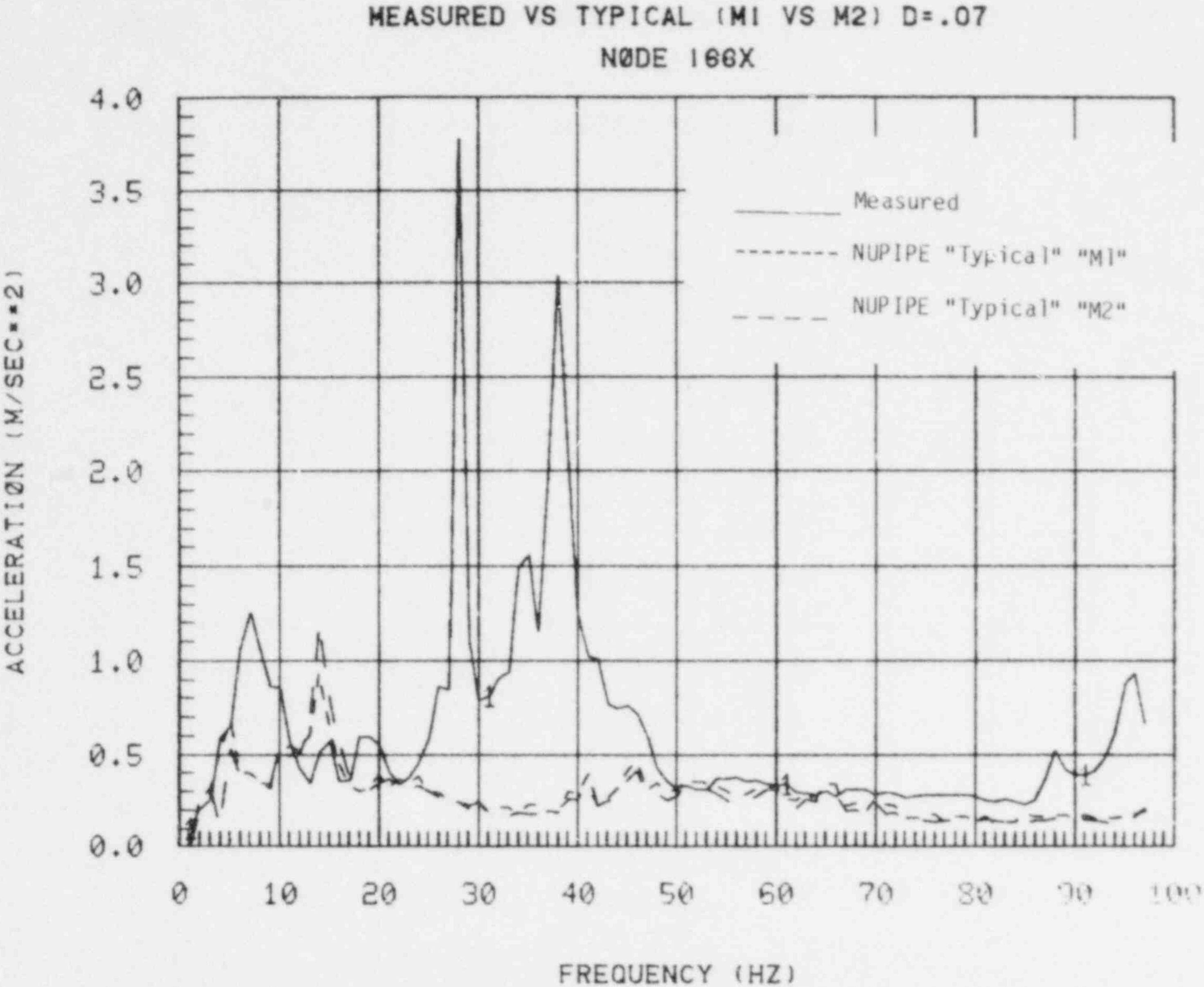


Figure 4.166.X

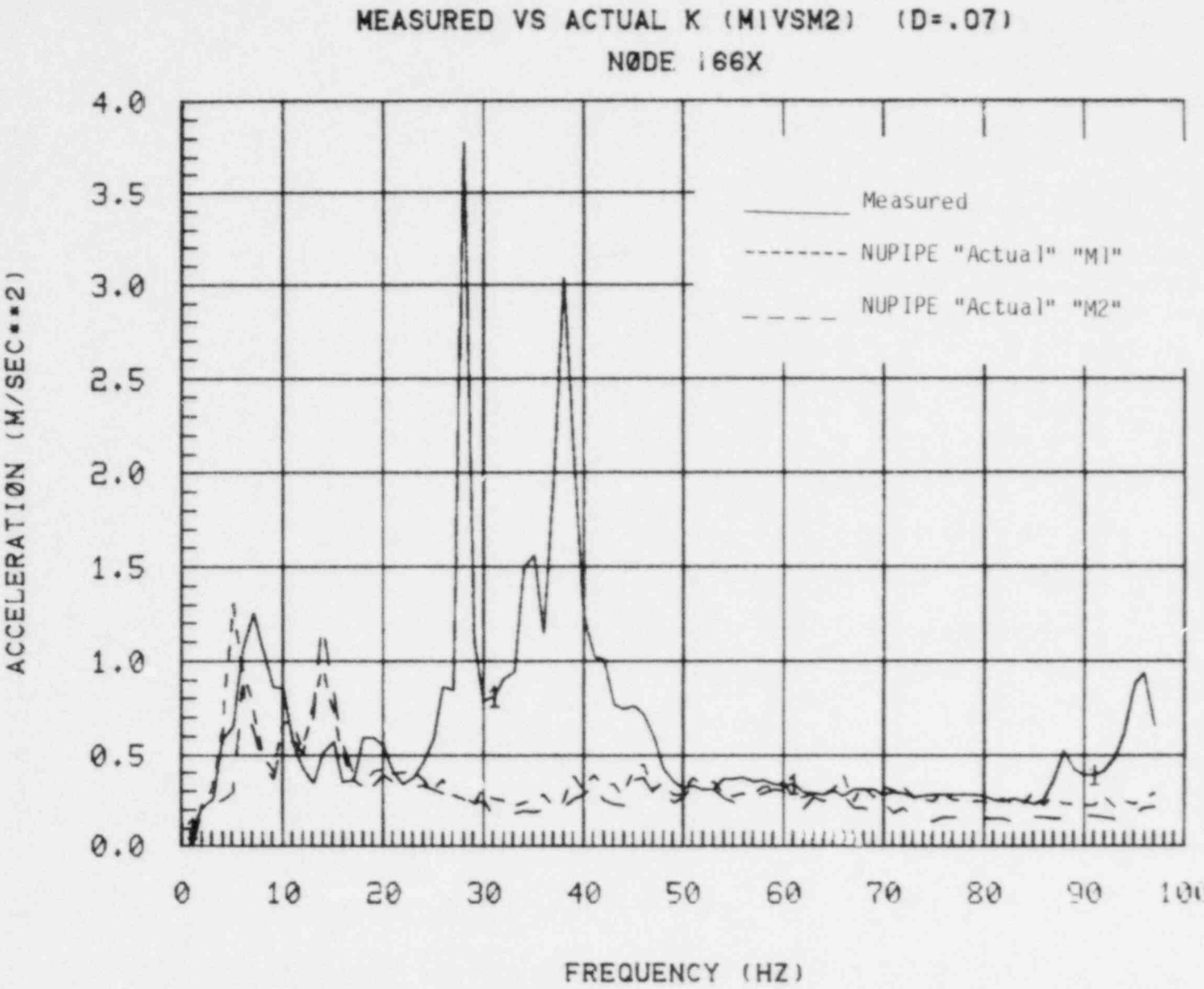


Figure 5.166.X

SPECTRA-MEASURED VS ANSYS ANALYSIS

NØDE 166.Z

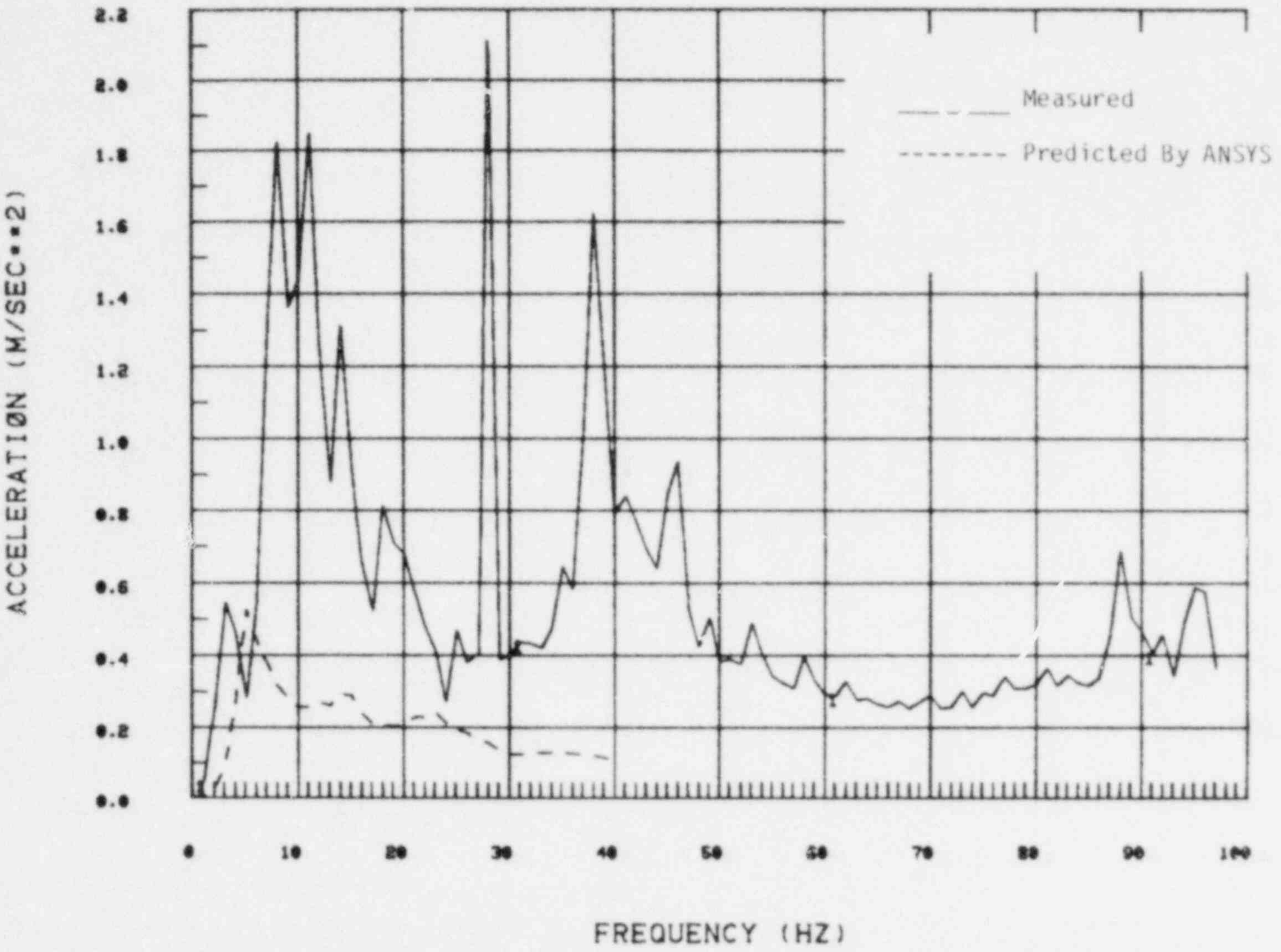


Figure 1.166.Z

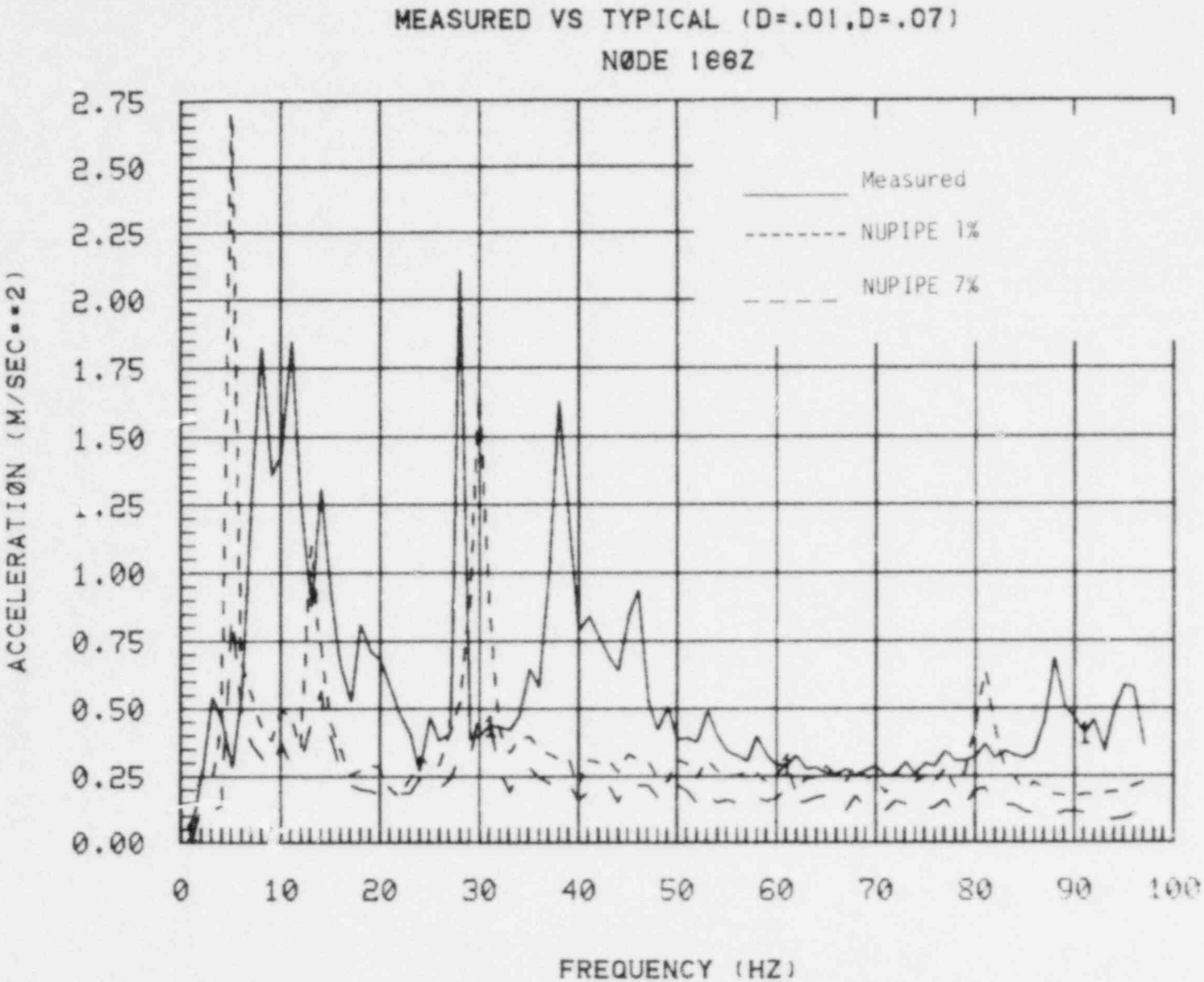


Figure 2.166.Z

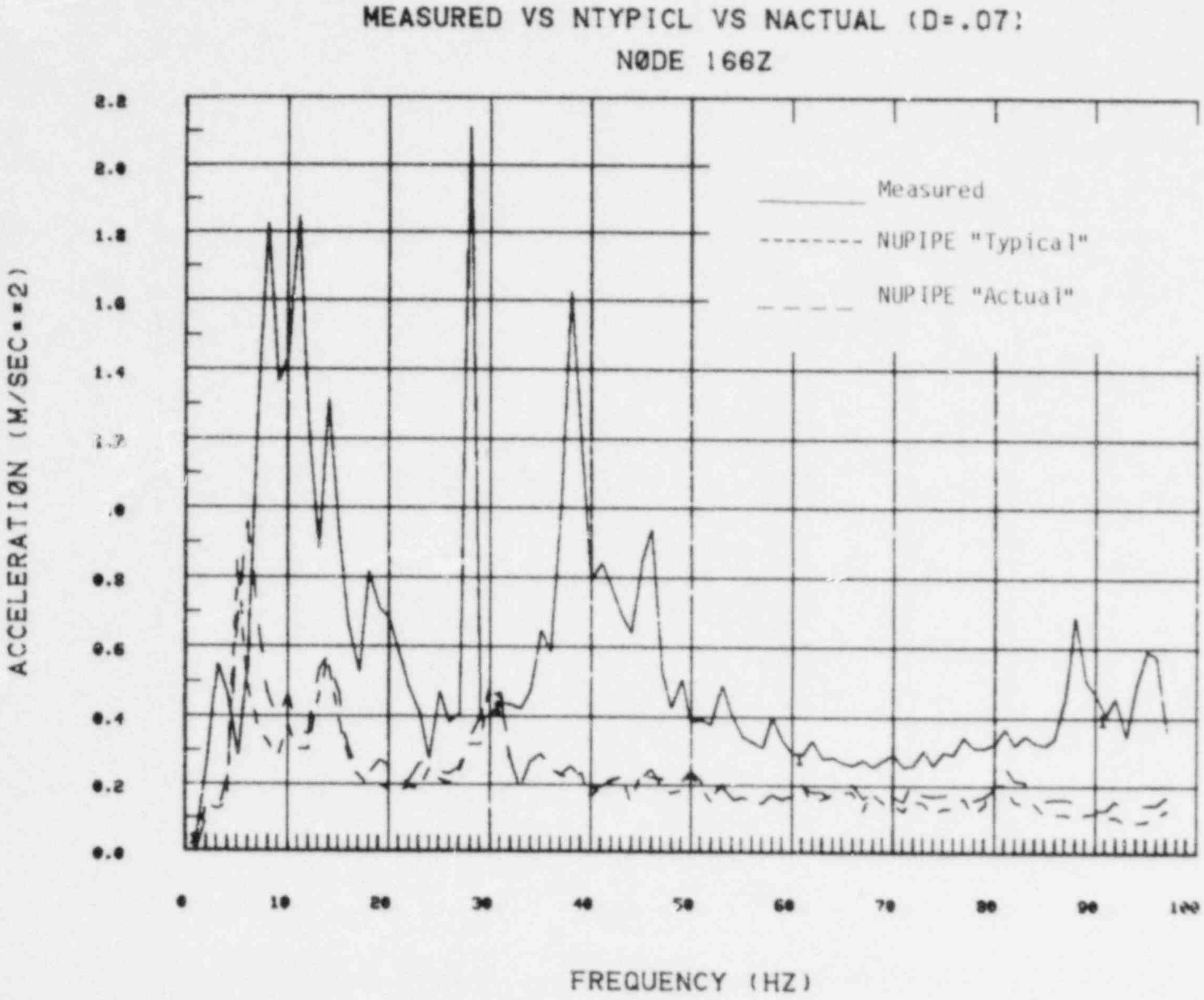


Figure 3.166.Z

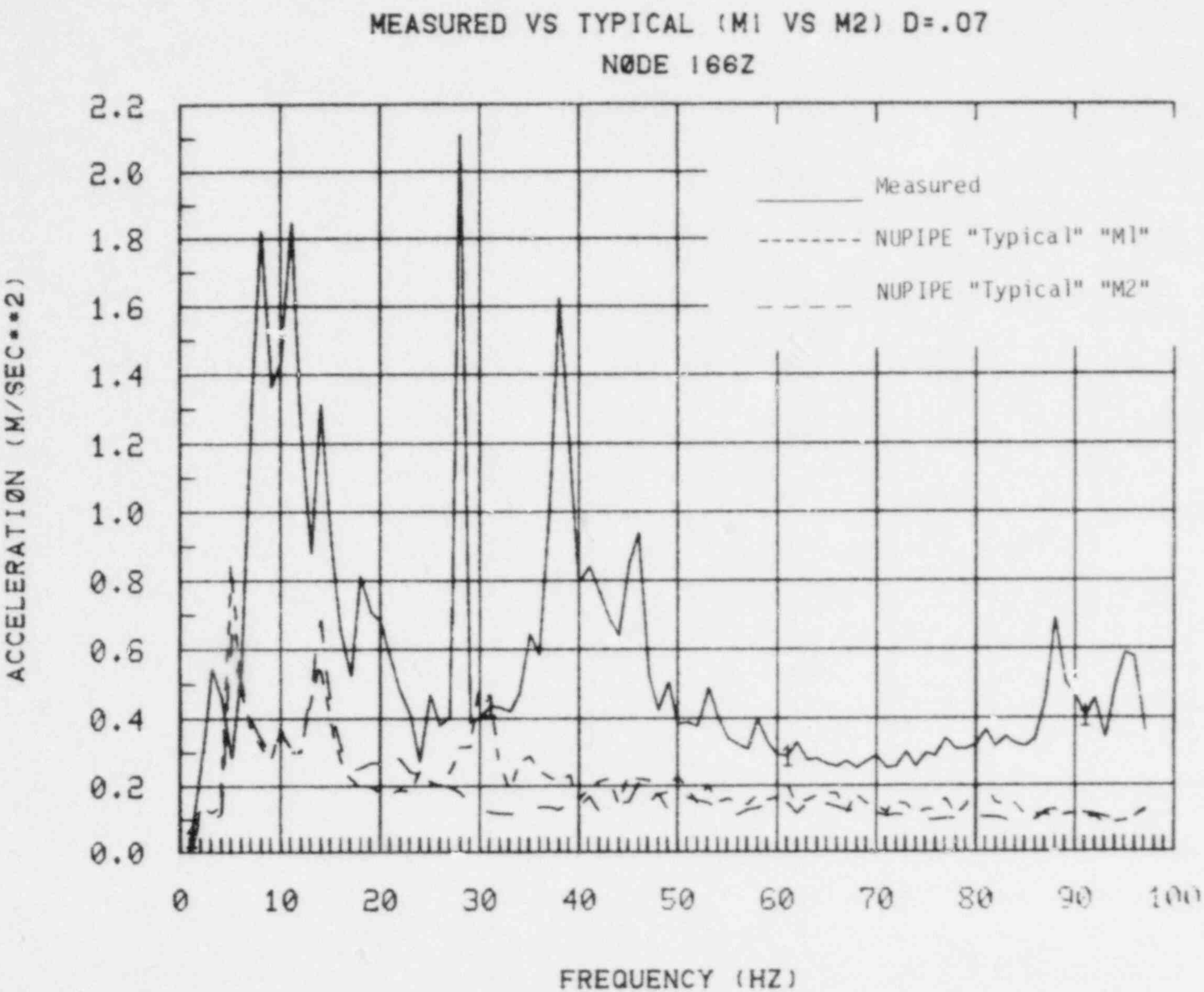


Figure 4.166.Z

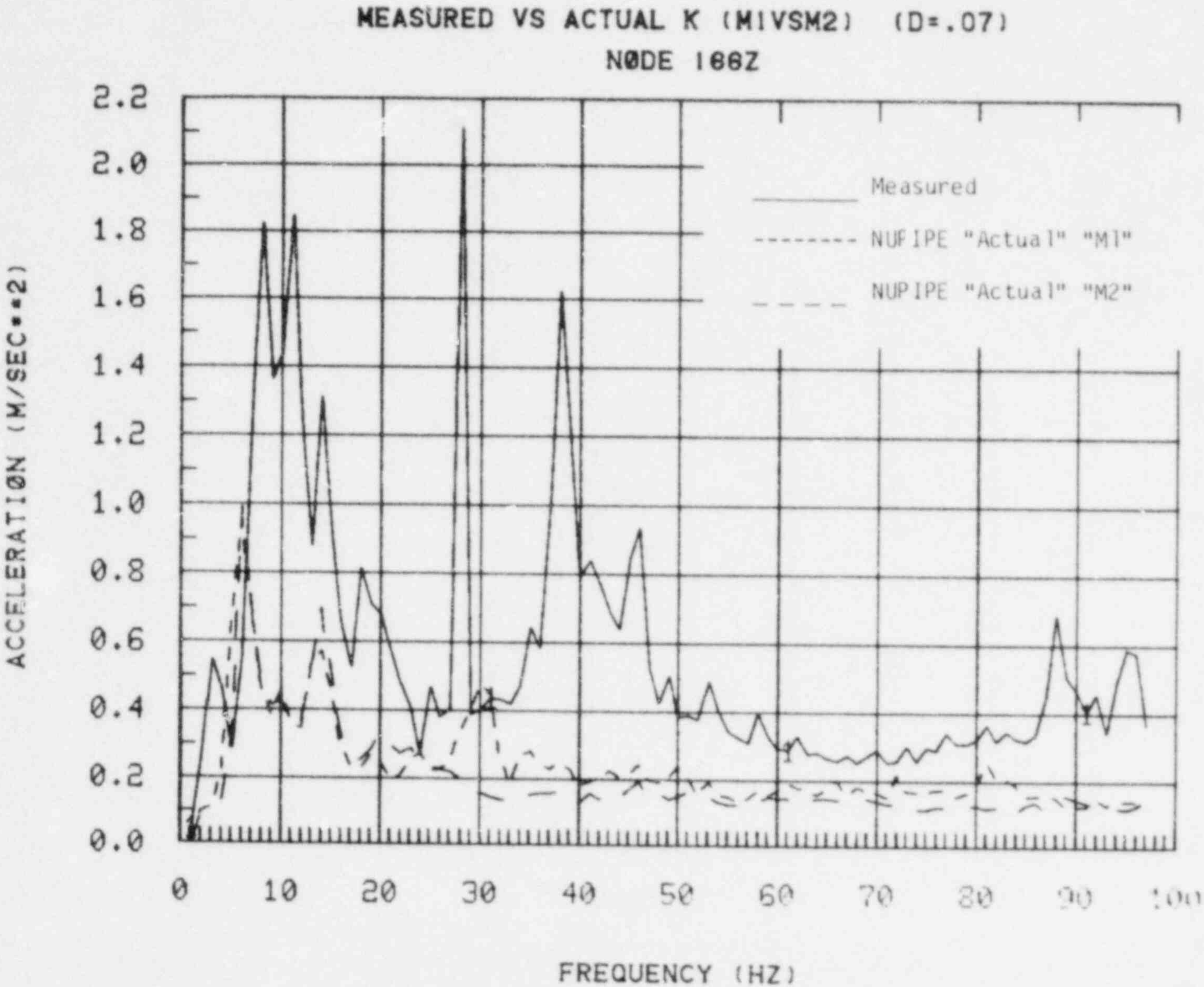


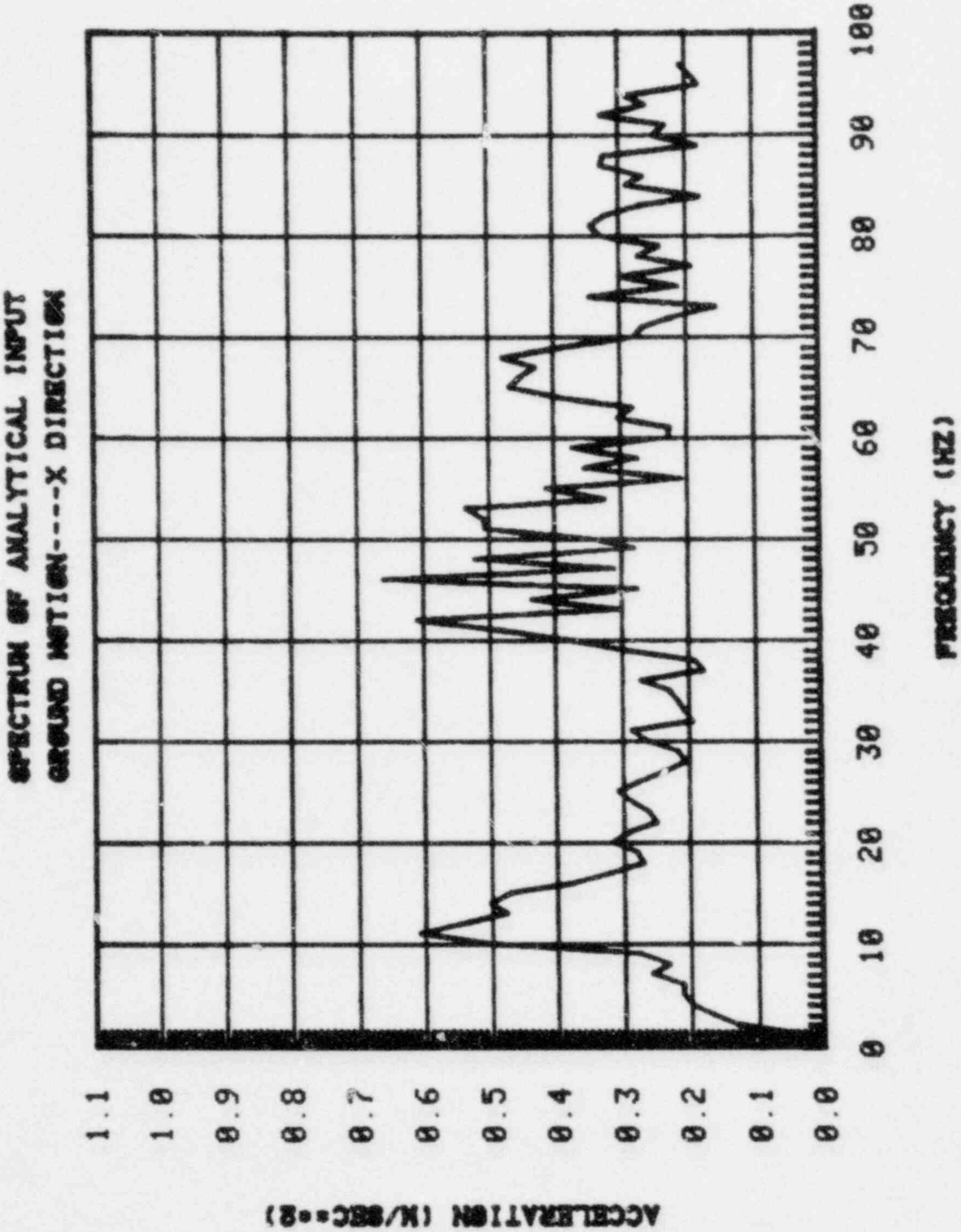
Figure 5.166.Z

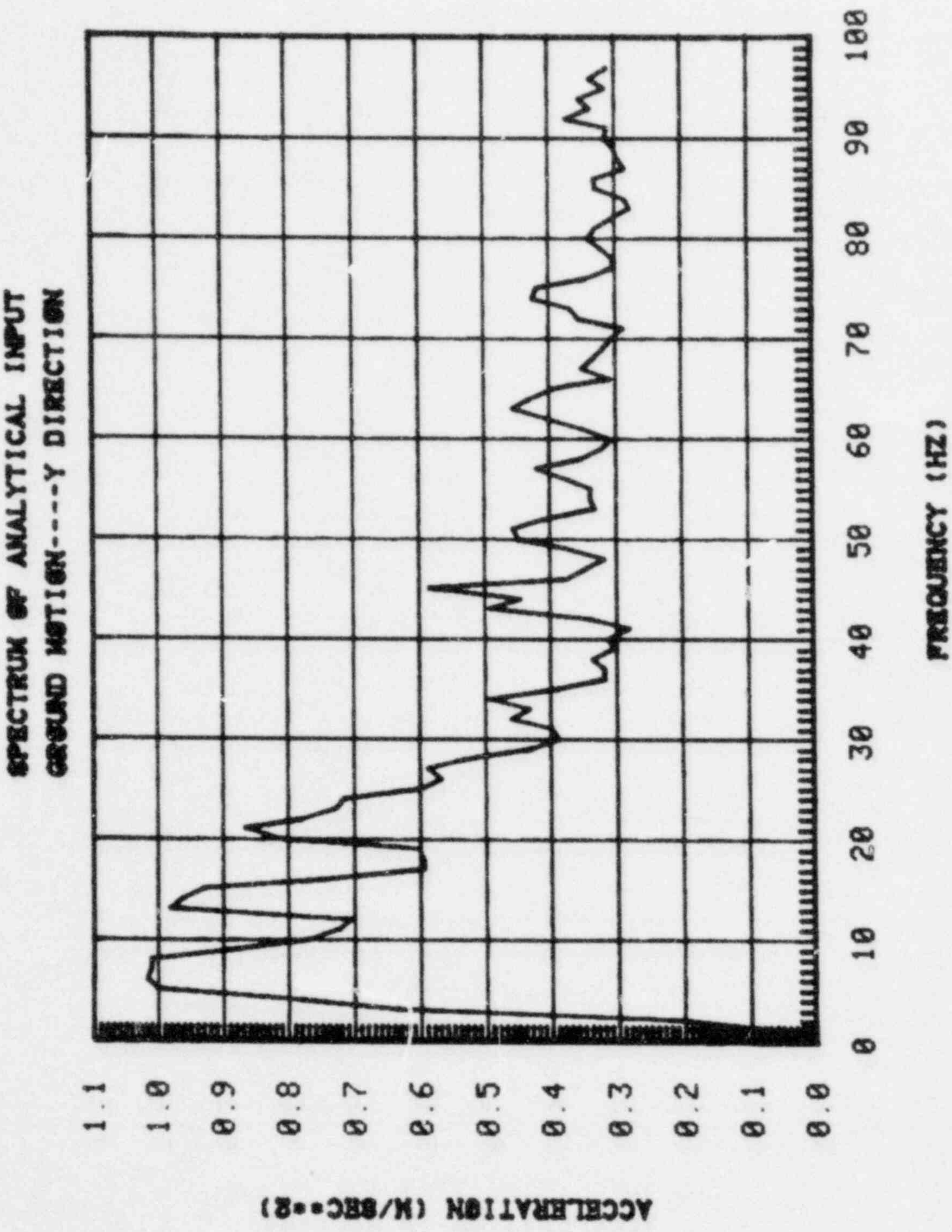
APPENDIX B

ACCELERATION SPECTRA OF

ANALYTICAL INPUT TIME HISTORIES

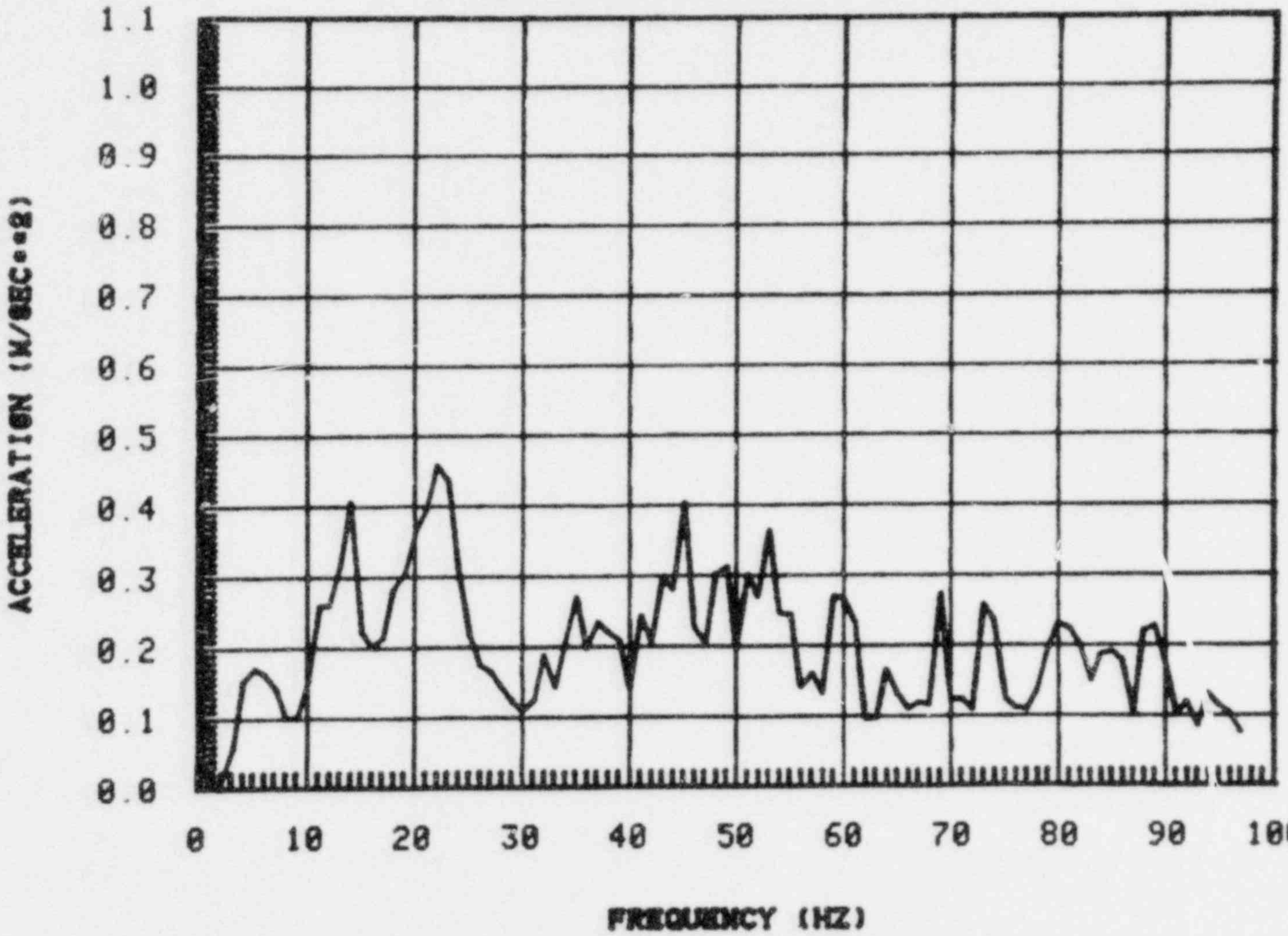
APPENDIX B FIGURES


SPECTRUM OF ANALYTICAL INPUT
GROUND MOTION----X DIRECTION
ACCELERATION (M/SEC**2)
FREQUENCY (HZ)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
0
10
20
30
40
50
60
70
80
90
100



SPECTRUM OF ANALYTICAL INPUT
GROUND MOTION----Y DIRECTION
ACCELERATION (M/SEC**2)
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
10
20
30
40
50
60
70
80
90
100
FREQUENCY (HZ)

SPECTRUM OF ANALYTICAL INPUT
GROUND MOTION----Z DIRECTION



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A nonlinear structural analysis of the HDR recirculation loop piping has been performed to predict the piping response to explosively generated ground excitations. This system was modeled on the computer program ANSYS and included the reactor vessel, two recirculation pumps, and the recirculation piping. Input consisted of uniform ground motion acceleration time histories in three orthogonal directions since the room was assumed to move as a rigid body with no rotational accelerations.

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