Title: Analysis of a Buried Pipeline at WWER 440/213 Paks NPP

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Date: June 1996

Analysis of a Buried Pipeline at VVER 440/213 PAKS NPP

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1 Introduction

According to regulations, all safety-related structures of a nuclear power plant have to be designed to withstand loads induced by earthquake loading. This applies also to safety-related underground piping systems. These structures are typically embedded in about 2-3 meters of layered soil, and sometimes protected by concrete slabs resting on the ground surface. A rigorous solution for the dynamic response of such a structure would require accounting for nonlinear and three-dimensional effects. A nonlinear analysis is possible by using specialized computer programs and material models for consideration of the nonlinear behavior of the soil. Such an analysis, however, would be prohibitively expensive, and would require assessment of the real, nonlinear soil behavior by detailed laboratory tests. Considering this, this paper presents some results obtained by an alternative procedure in which the soil properties are assumed to be nearly linear-elastic. It seems that this procedure may be effectively used for design purposes.

To perform the numerical analysis a 3D finite element code (SASSI/S) based on the "Flexible Volume Method" /1/ was used. It includes the use of transmitting boundaries and modification of the lower boundary as a half space. As practical example, the cold water supply intake pipeline of the nuclear power plant Paks was investigated.

The aim of this study was to reanalyze the pipeline mentioned above to demonstrate its dynamic behavior in interaction with the soil and the connected buildings as well as to determine of the dynamic responses and the stresses in characteristic regions of the pipeline.

2 Description and Modelling of the Buried Pipeline

The emergency cooling water supply pipeline is located between the condensing and emergency cooling water building and the turbine house. It is buried in the soil at a depth of about 3 m.

However there are still important differences in the spectral acceleration (displacements) which finally result in internal member forces and stresses in the pipeline system.

The forces (stresses) induced due to these differences are shown in Figures 16 to 18. According to the largest differences in the relative displacements, the largest forces/ moments and consequently stresses are expected in areas in which the pipeline is connected to the building foundations. These results correspond however to the boundary assumptions made for these regions of the pipeline (rigid connection conditions). The maximum values of stresses were about 520 N/mm² for the bending stresses and about 40 N/mm² for the axial stresses.

5 Conclusion

It is difficult to represent the typical nonlinear (elasto-plastic) soil behavior realistically by means of a less appropriate model. The chosen linear-elastic model (state-o-the-art procedure) did, however, allow the dynamic behavior as well as the dynamic response of the turbine house as well as the condensing and emergency cooling water supply building to be investigated appropriately. Therefore, the motion (displacements) of the pipeline sections connected to the buildings in the axial direction should also be nearly realistic.

It may therefore be assumed that also the moments/stresses obtained for the first section (up to the first elbows) of the pipeline (for the assumption of rigid connection of the pipeline to the foundation mat) are quite realistic.

Only the stresses in the pipeline sections arranged parallel to the buildings may be less reliable. However the stresses in these sections are of minor importance because of lower relative displacement in these regions. This can also be seen from an evaluation of the response spectra obtained for the characteristic regions of the pipeline.

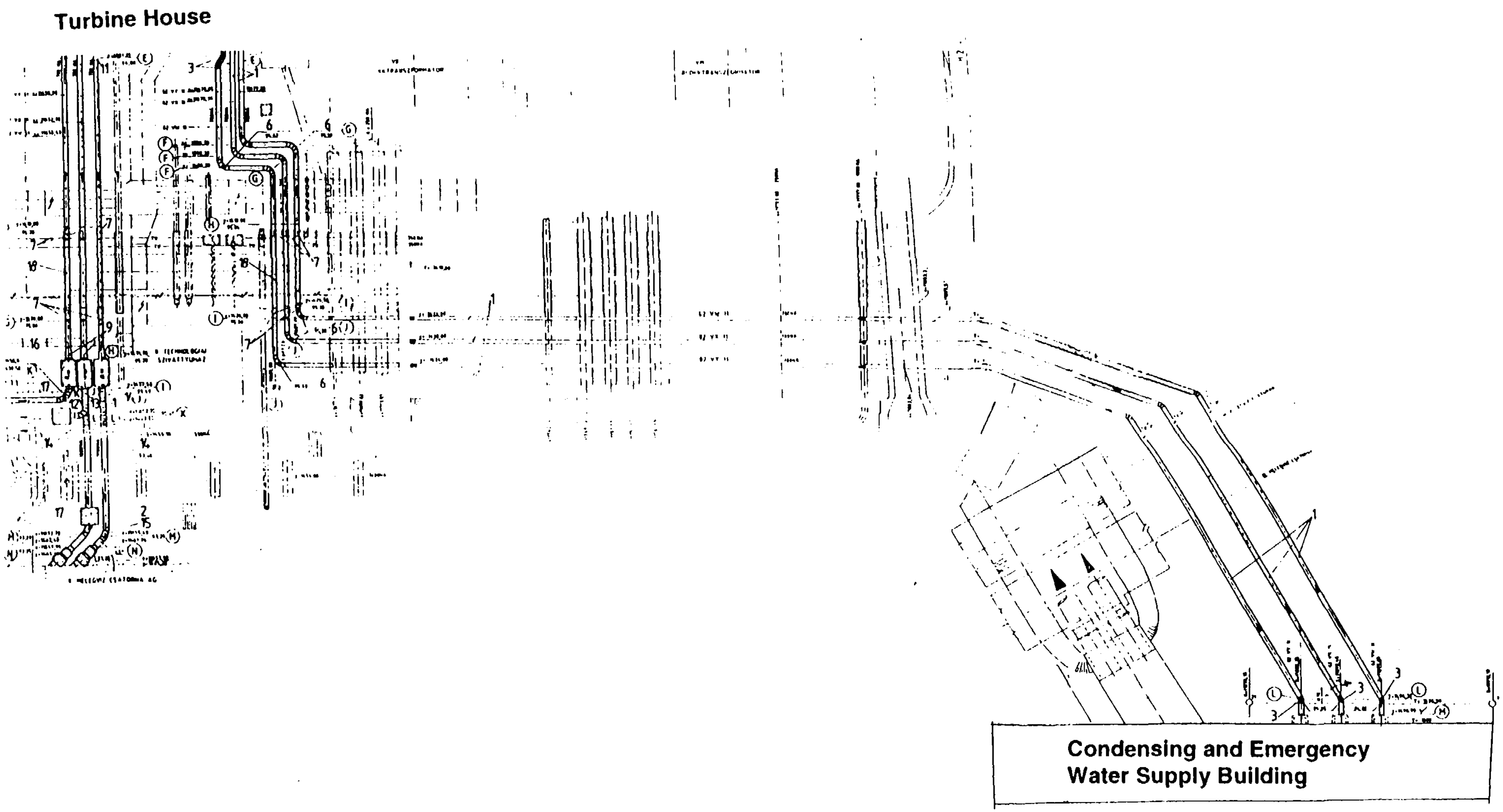


Fig. 1 Arrangement of the Cold Water Supply Intake Pipelines VVER-440/213 PAKS, Unit 1 to 2

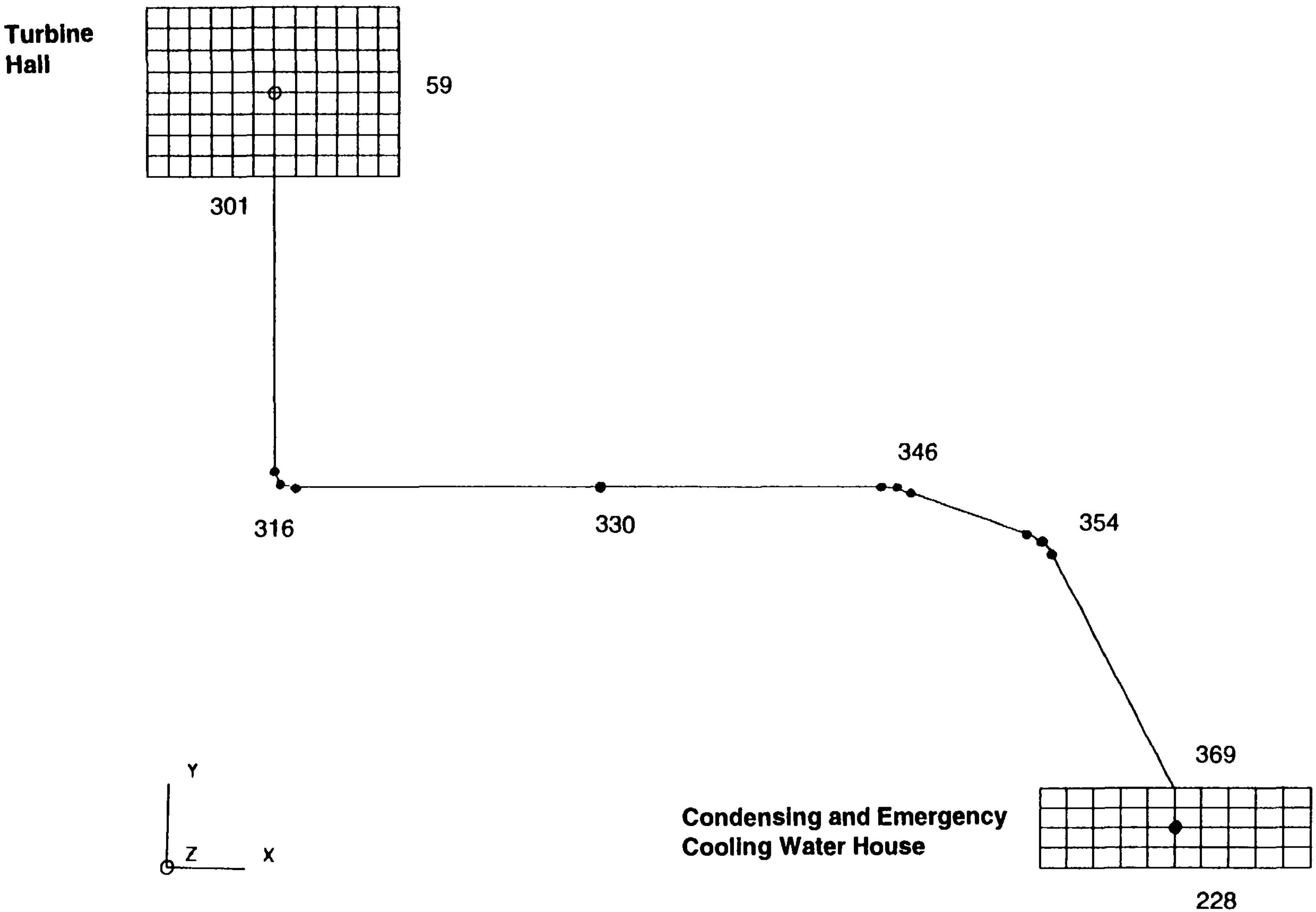
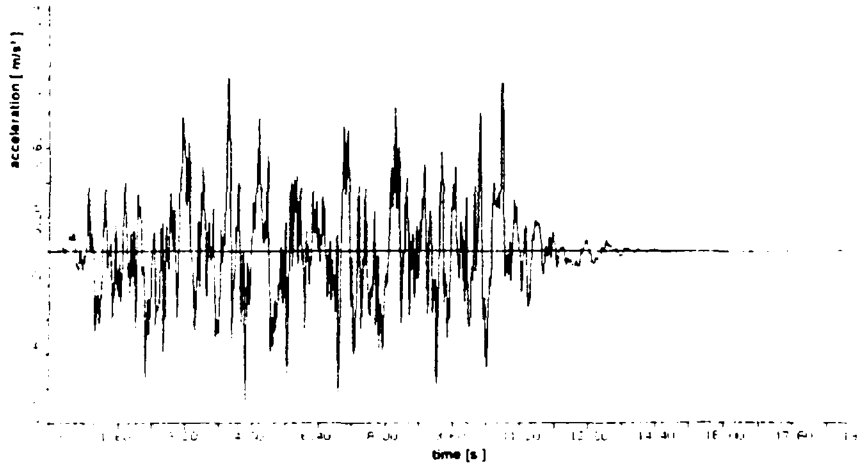
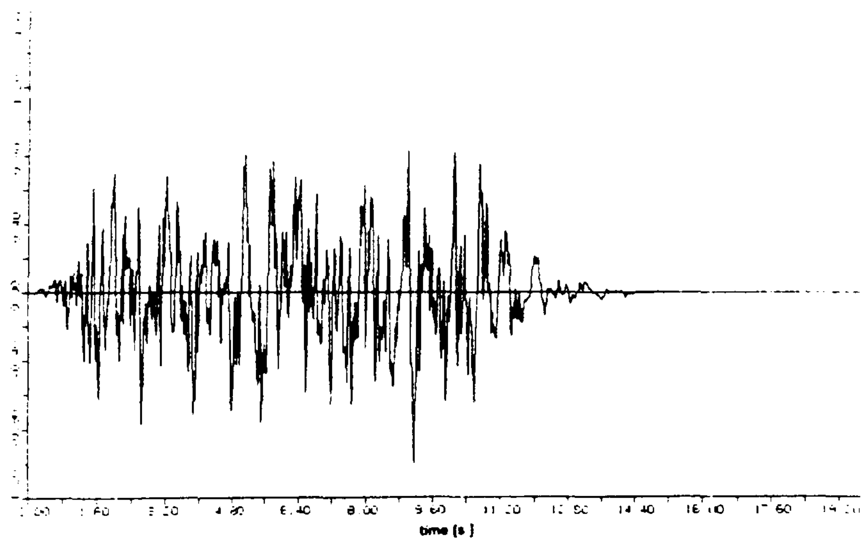


Fig. 2 Mathematical Model



Time history TH429 (horizontal)



Time history TH131 (horizontal)

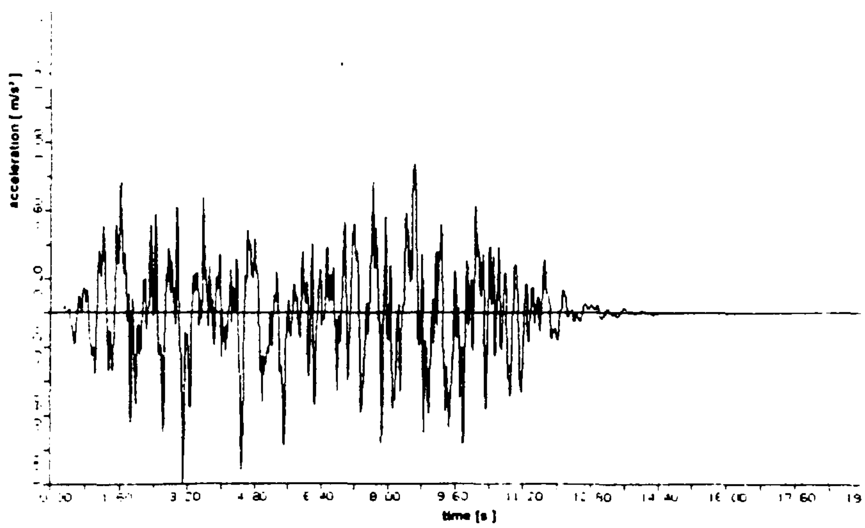


Fig.:2.4 Time history TH481 (vertical)

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Fig. 3 Artificial Time Histories Compatible to the NUREG 0098 Free-Field Spectra

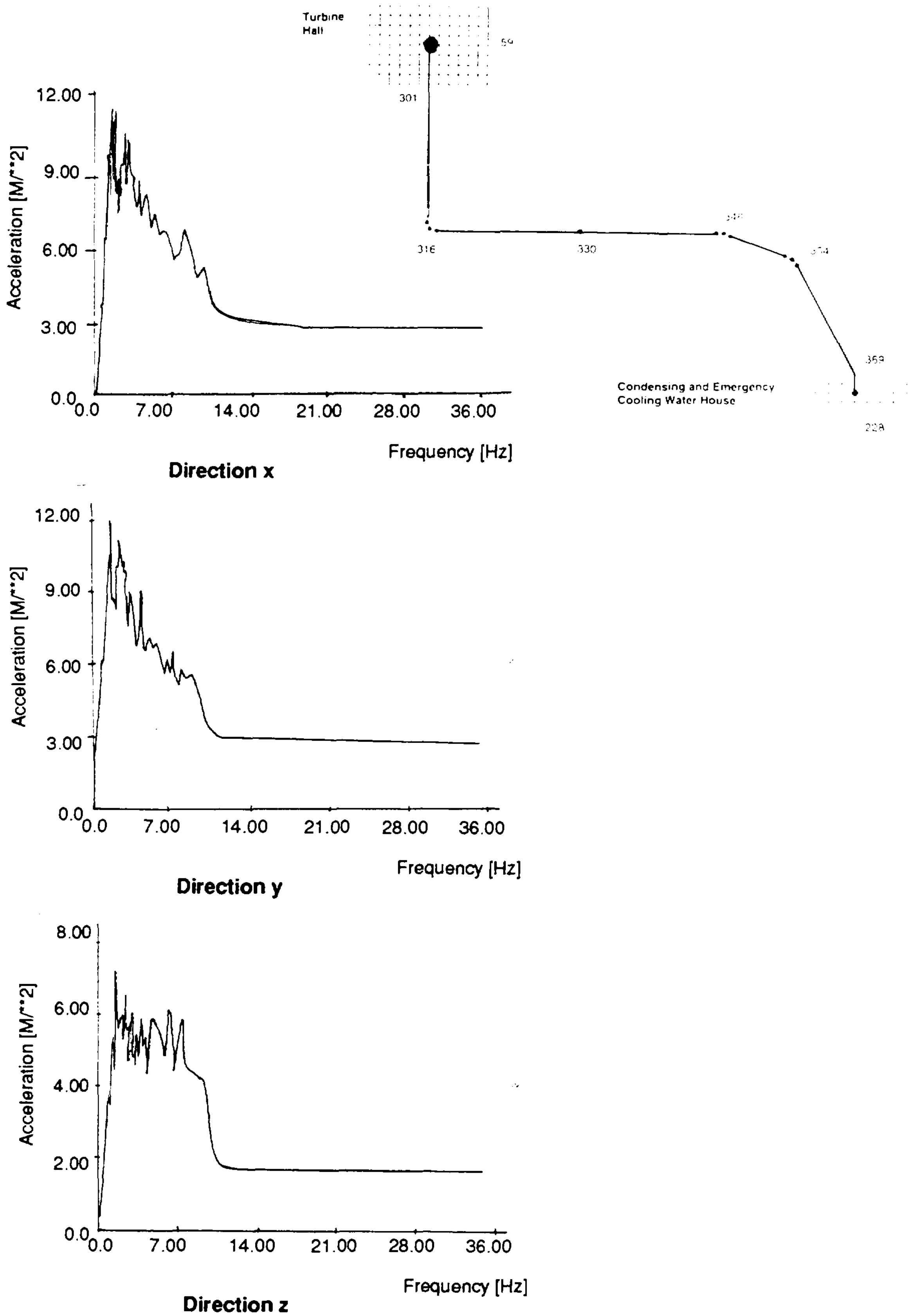


Fig. 4 Buried Cooling Water Pipeline PAKS, Unit 1 to 2
Dynamic Response in Location 59

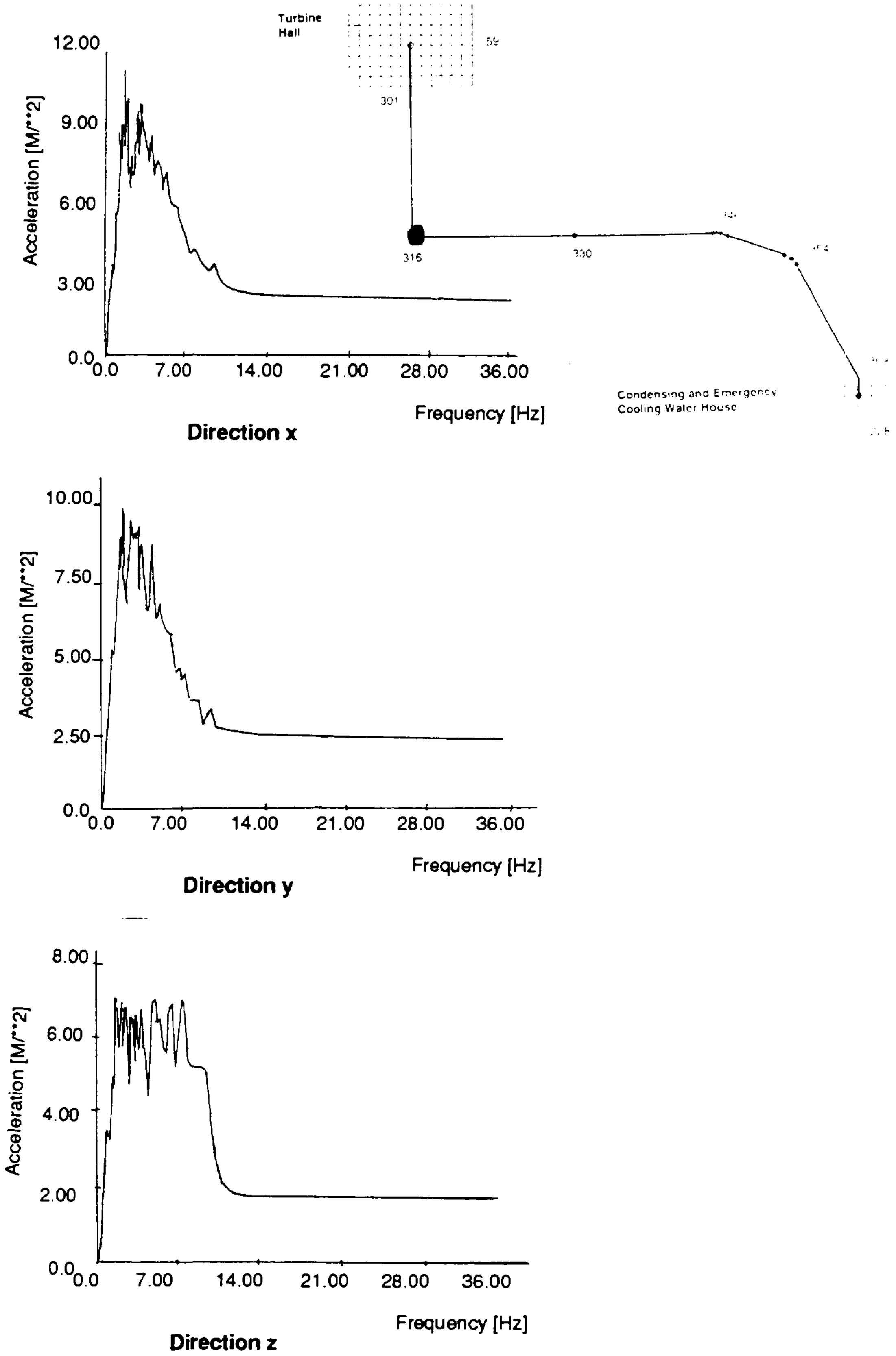
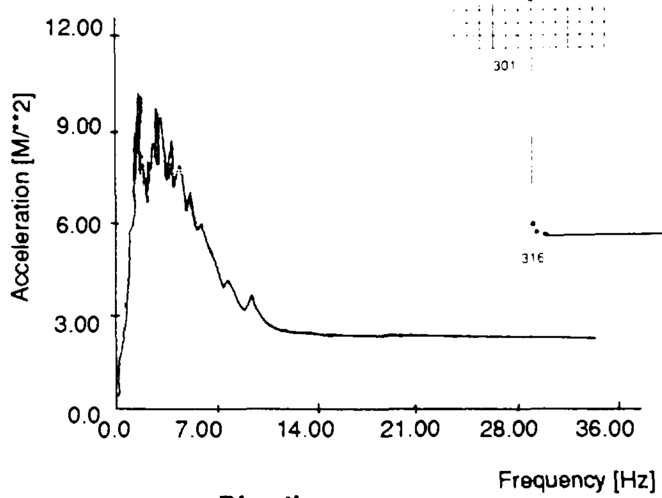
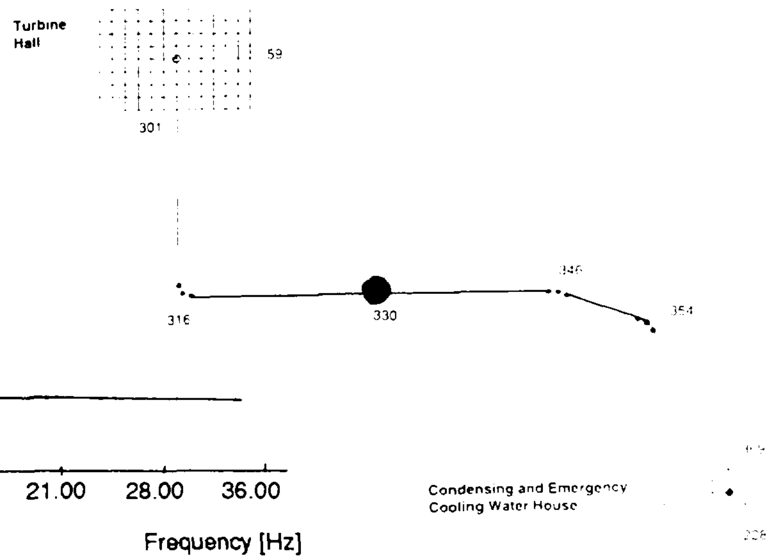
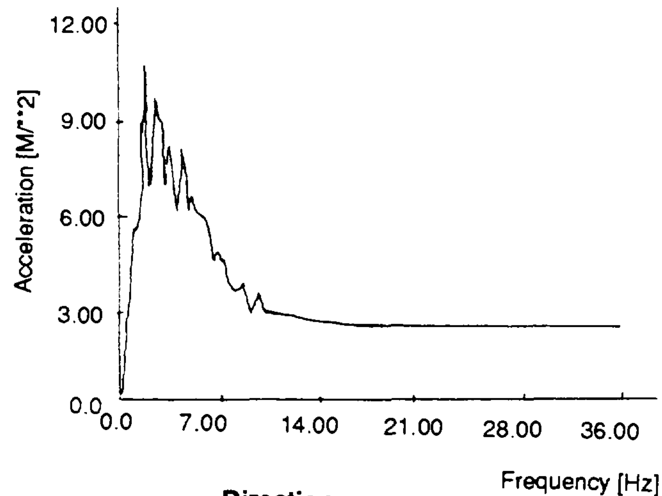


Fig. 5 Buried Cooling Water Pipeline PAKS, Unit 1 to 2
Dynamic Response in Location 316

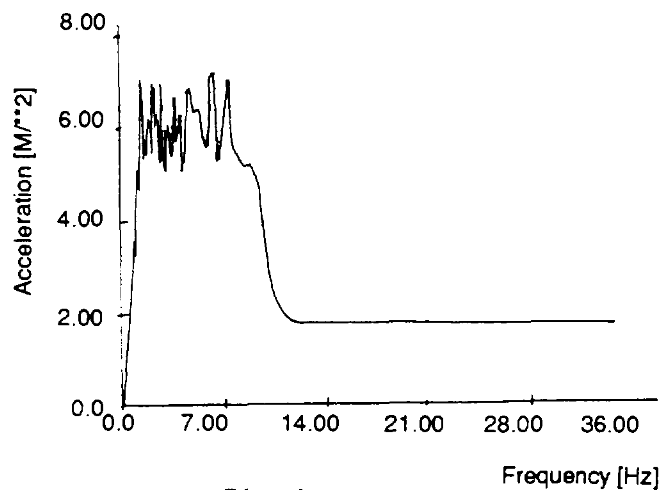




Direction x



Direction y



Direction z

**Fig. 6 Buried Cooling Water Pipeline PAKS, Unit 1 to 2
Dynamic Response in Location 330**

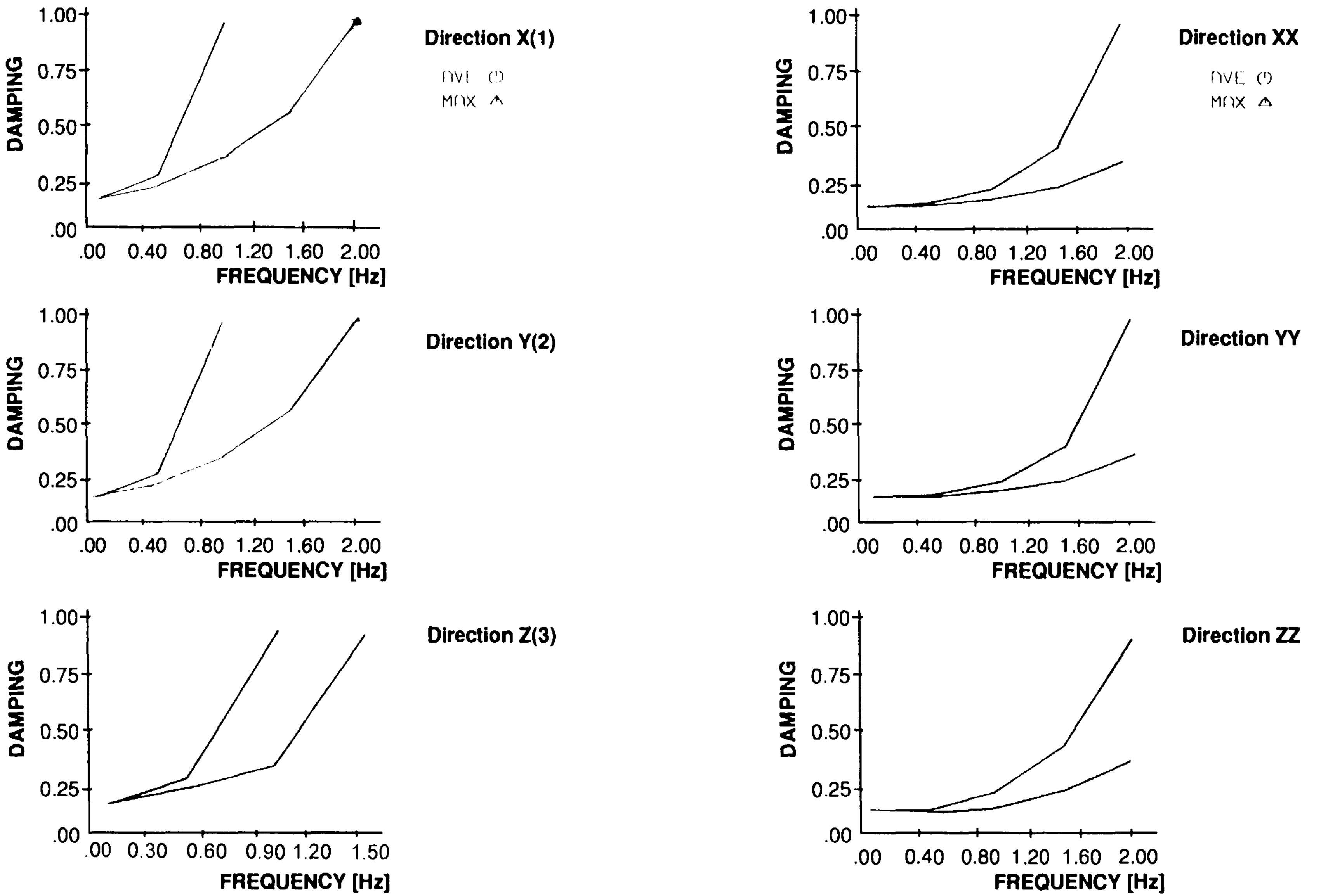
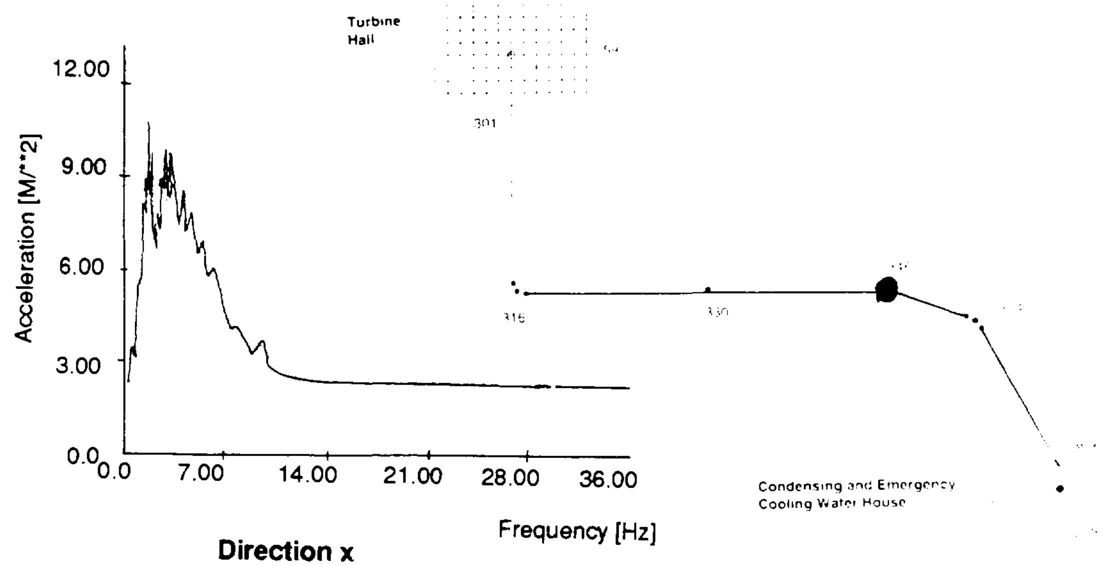


Fig. 6a Reactor Building VVER-440/213 PAKS
Damping Ratioo for Translational and Rotational Modes



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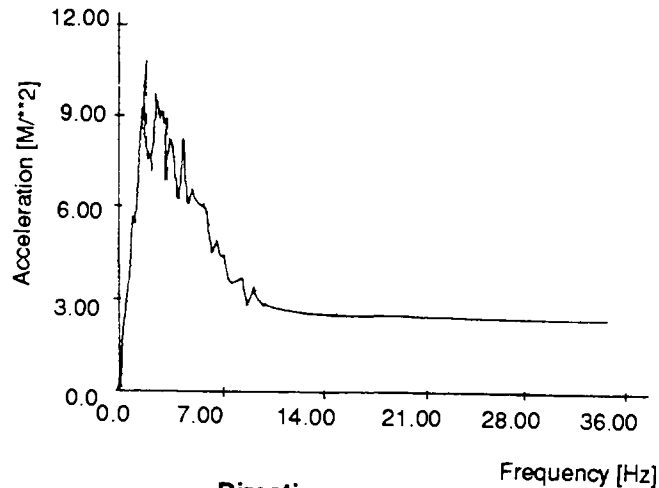

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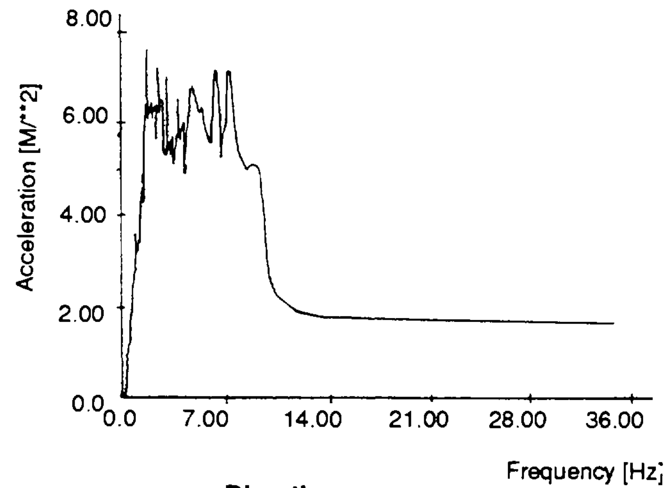


Direction z

Fig. 7 Buried Cooling Water Pipeline PAKS, Unit 1 to 2 Dynamic Response in Location 346

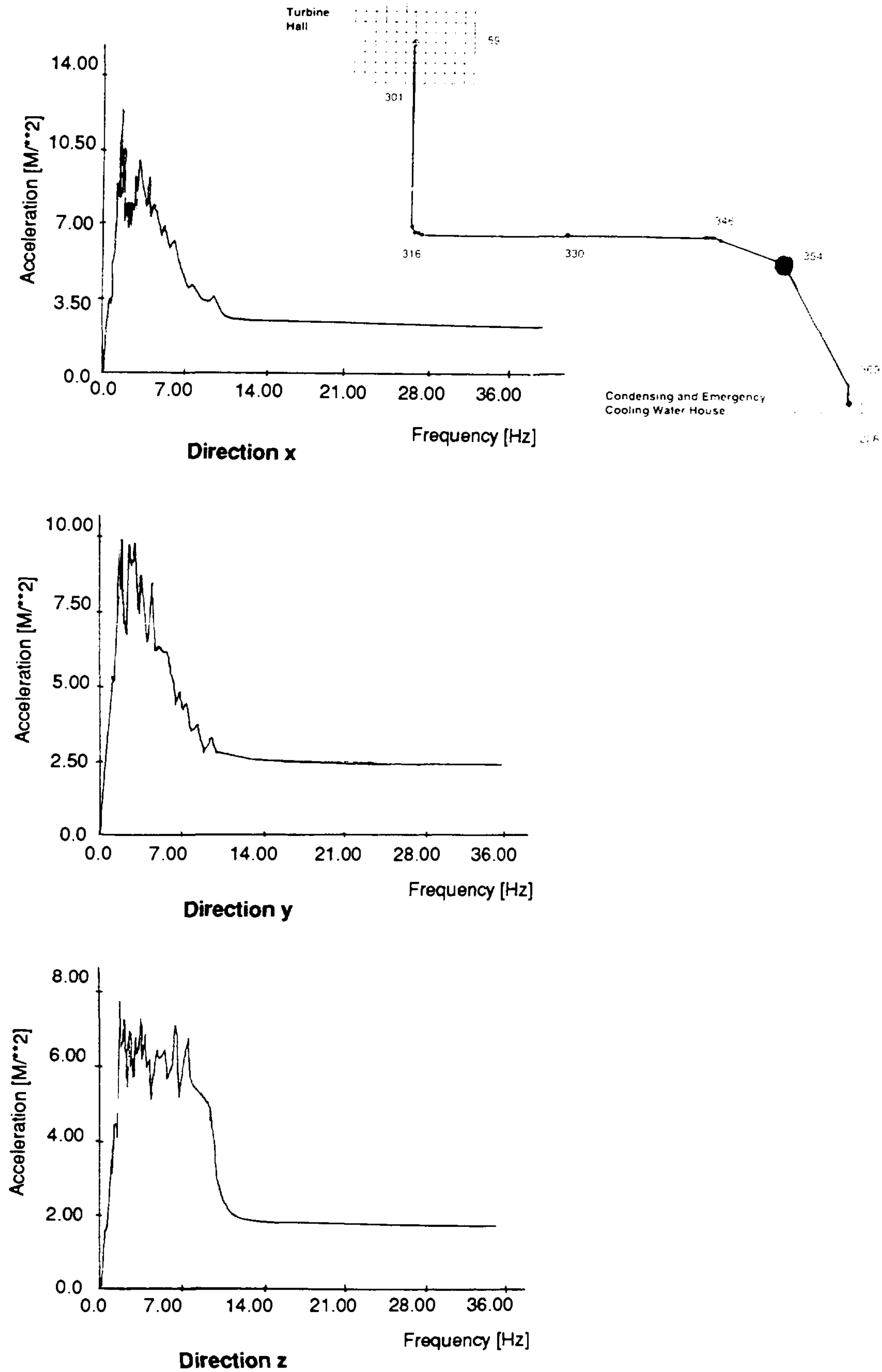
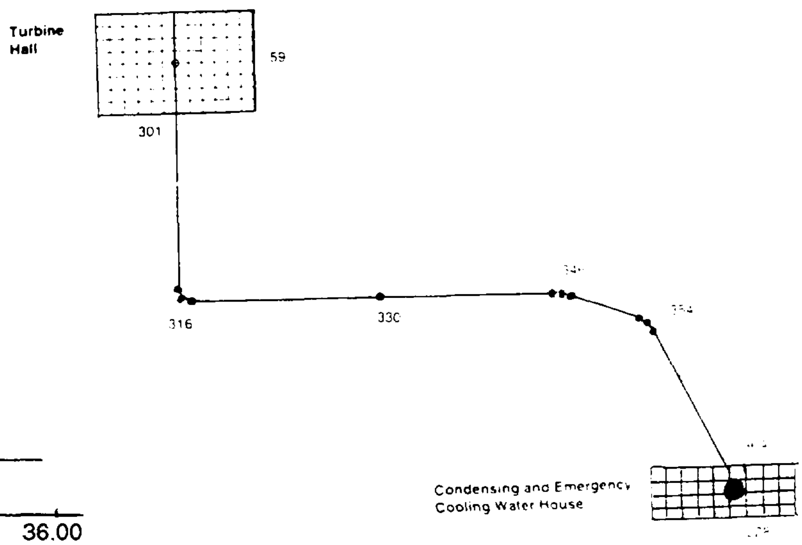
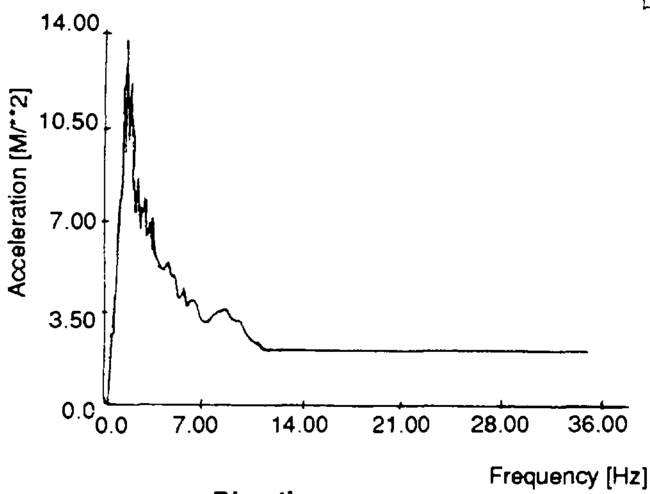
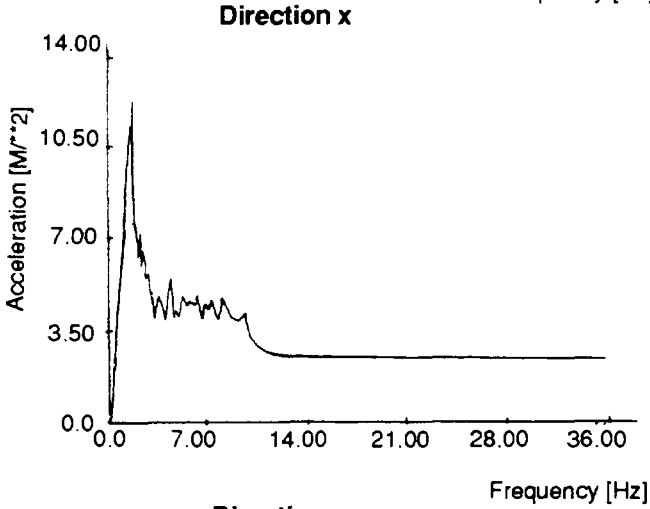


Fig. 8 Buried Cooling Water Pipeline PAKS, Unit 1 to 2
Dynamic Response in Location 354

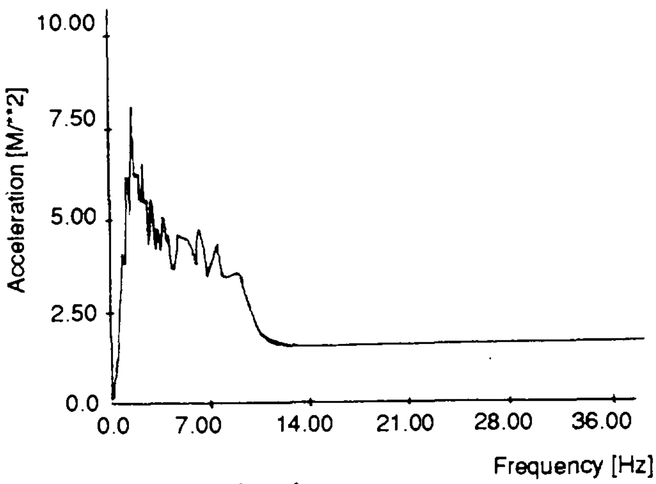




Direction x



Direction y



Direction z

Fig. 9 Buried Cooling Water Pipeline PAKS, Unit 1 to 2 Dynamic Response in Location 228

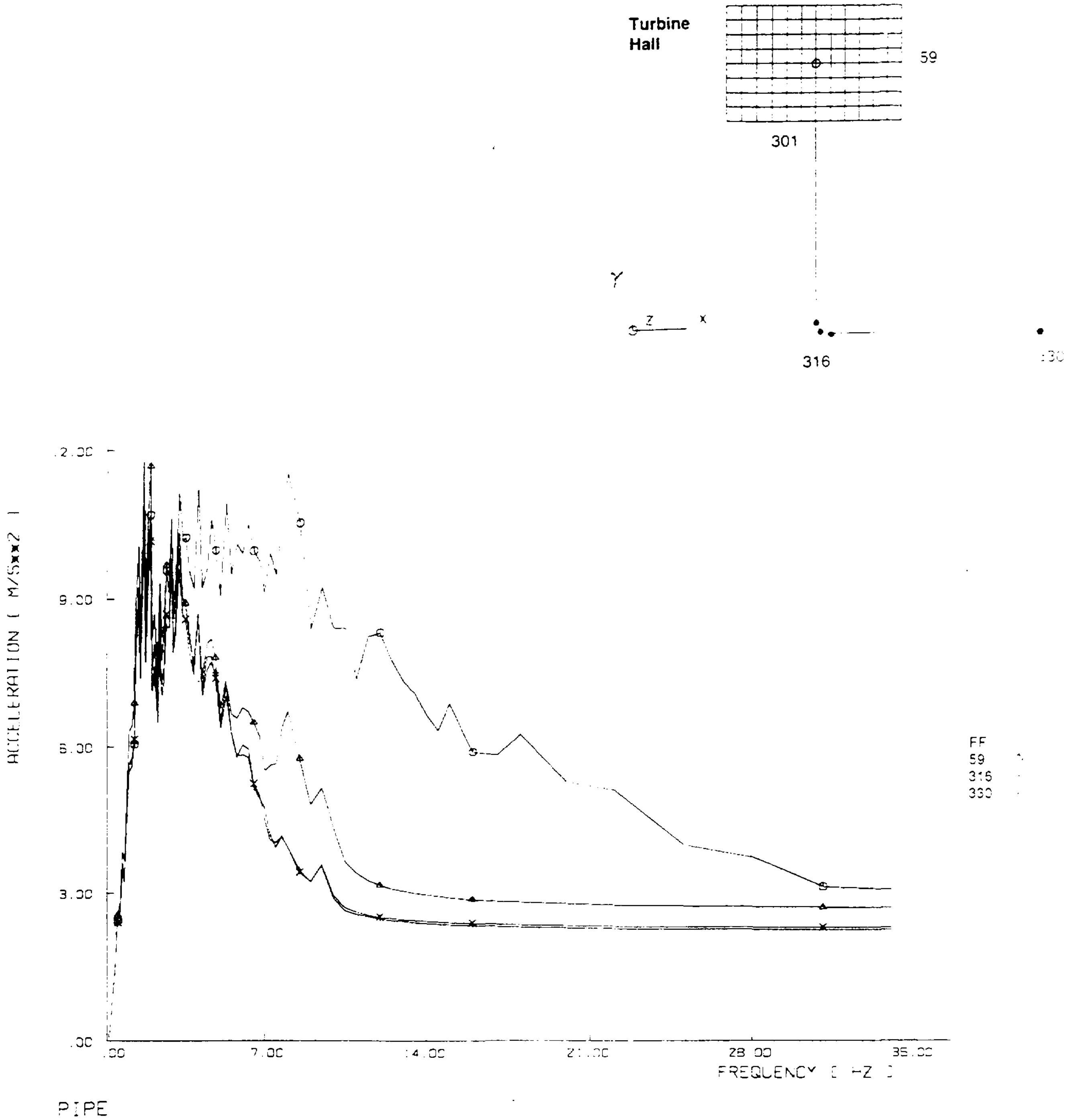


Fig. 10 Buried Cooling Water Pipeline PAKS, Unit 1 to 2
Comparison of Dynamic Response in Direction x

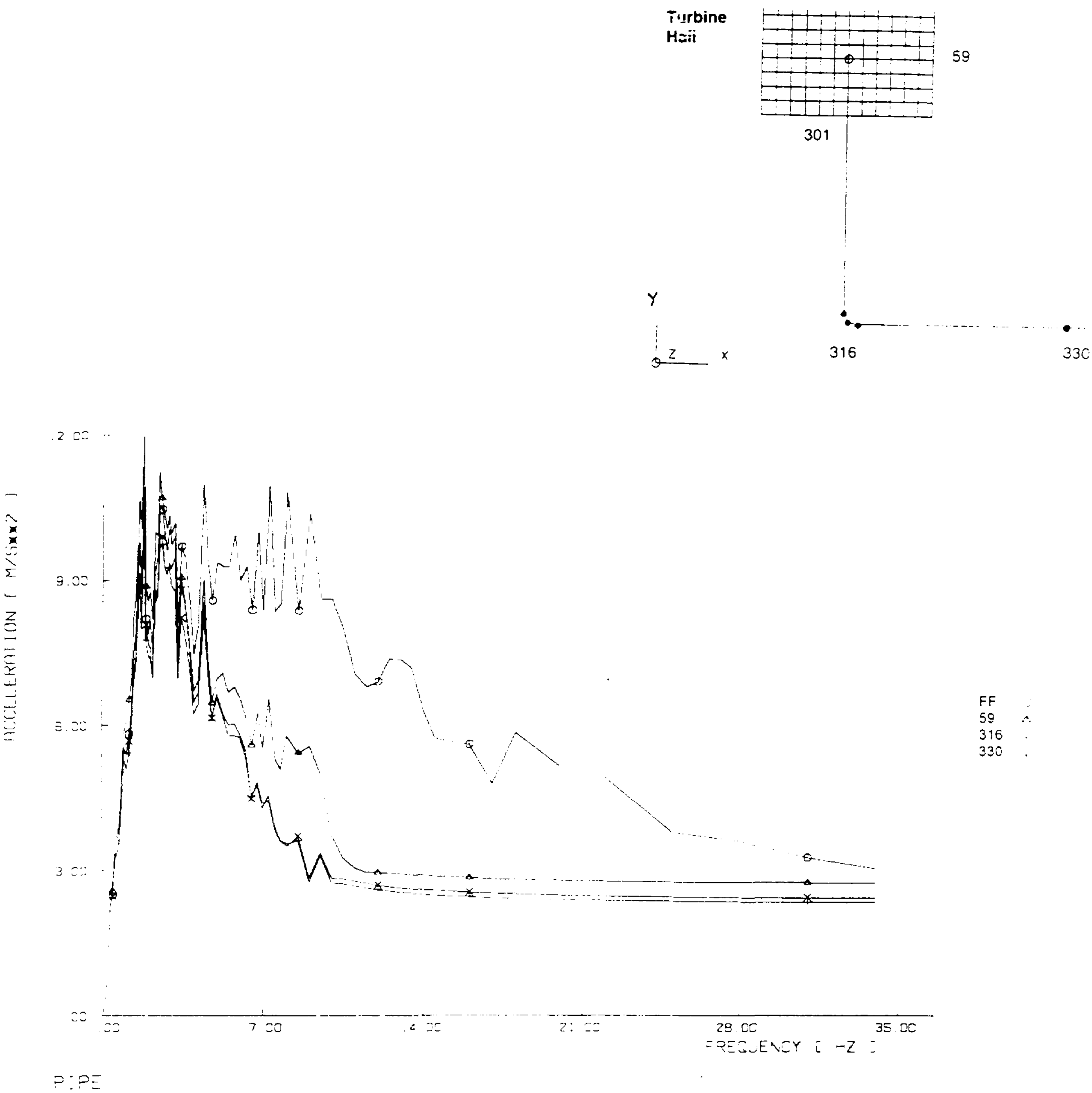
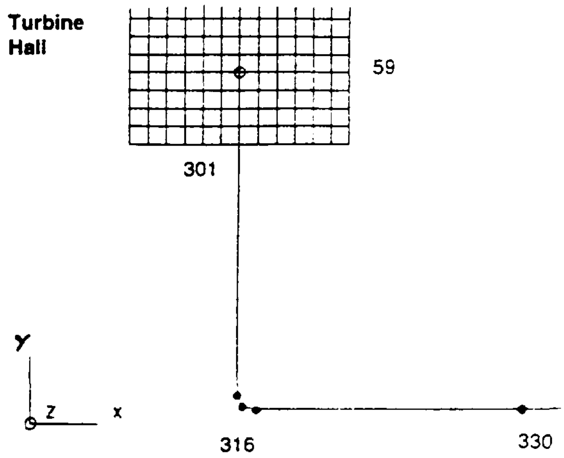


Fig. 11 Buried Cooling Water Pipeline PAKS, Unit 1 to 2 Comparison of Dynamic Response in Direction y



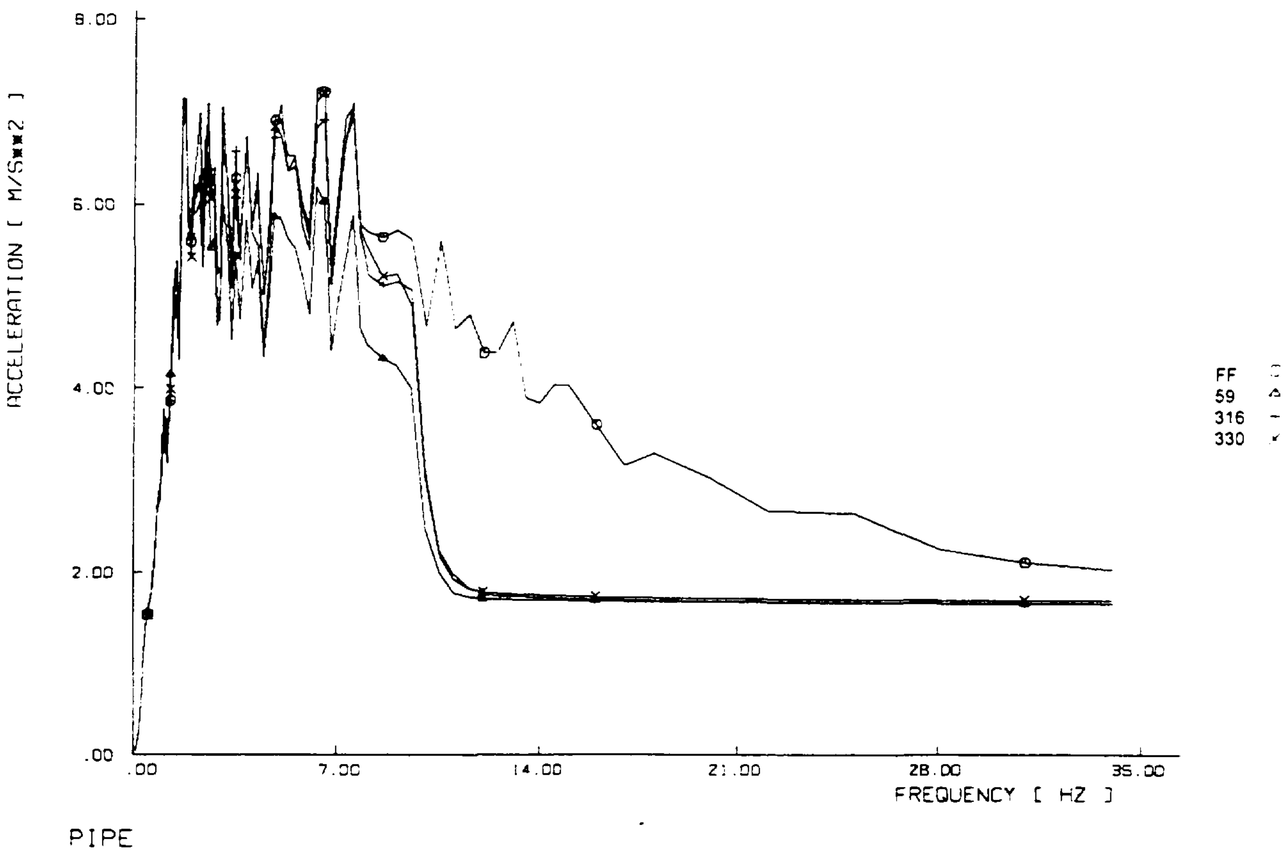
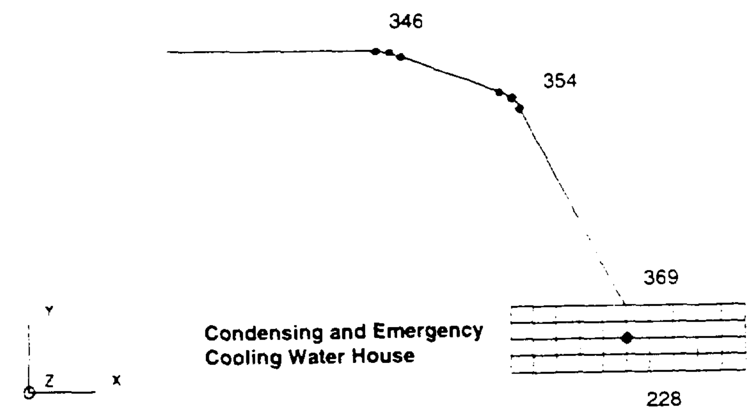


**Fig. 12 Buried Cooling Water Pipeline PAKS, Unit 1 to 2
Comparison of Dynamic Response in Direction z**



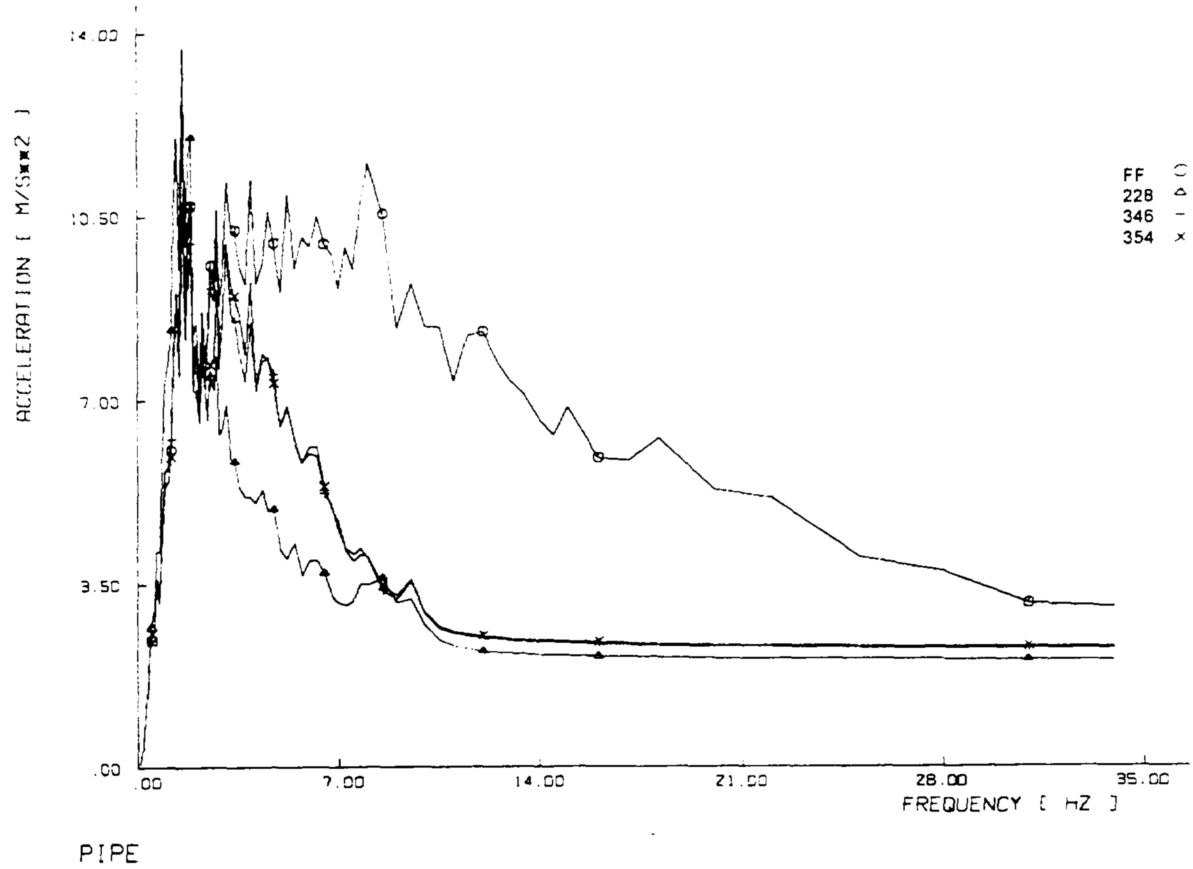
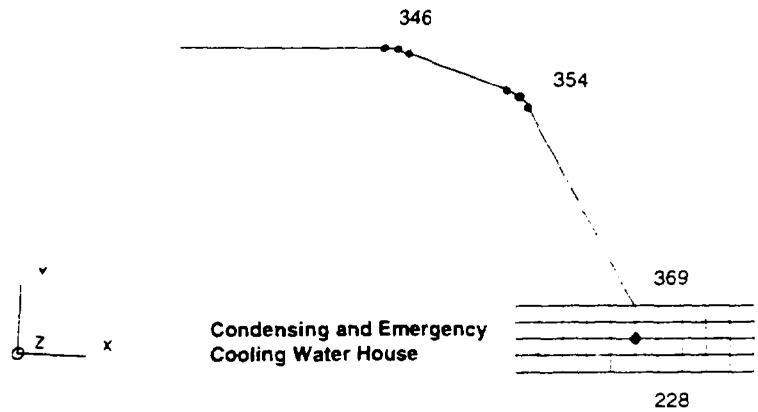


Fig. 13 Buried Cooling Water Pipeline PAKS, Unit 1 to 2 Comparison of Dynamic Response in Direction x



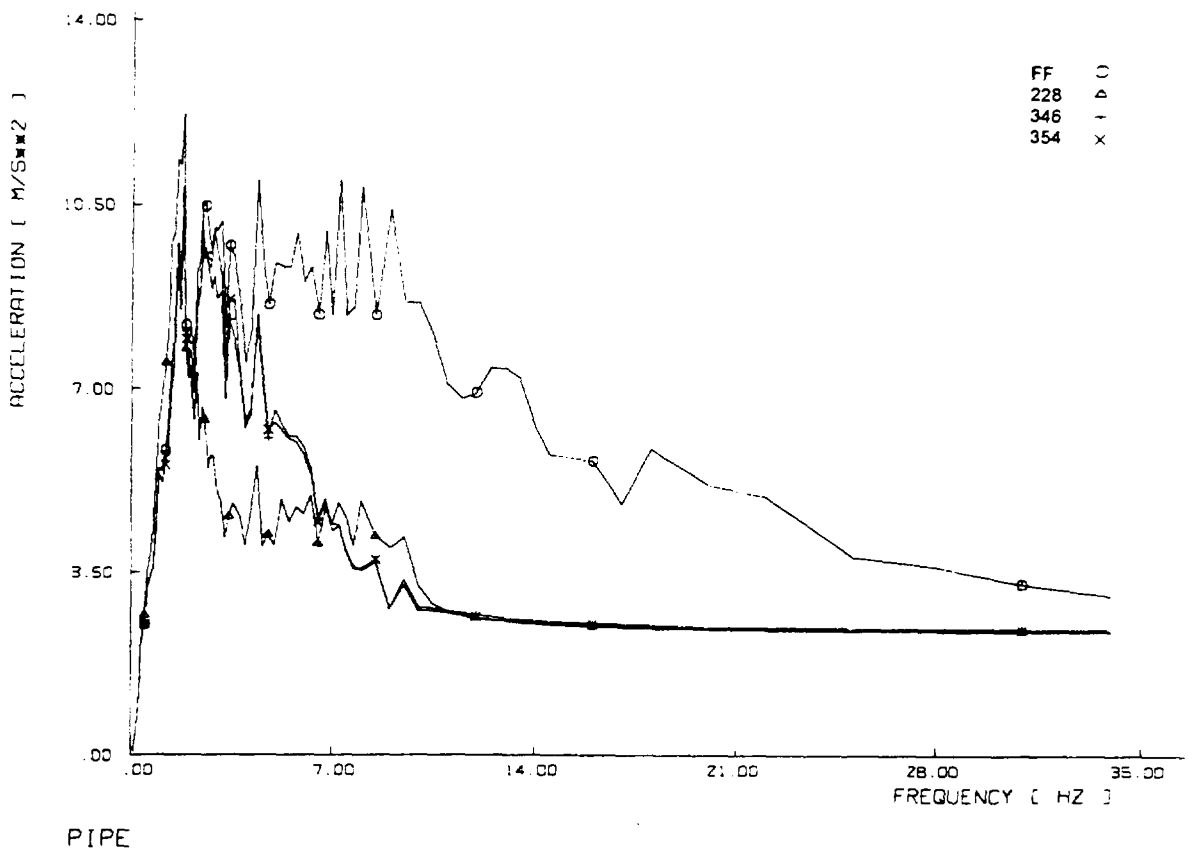
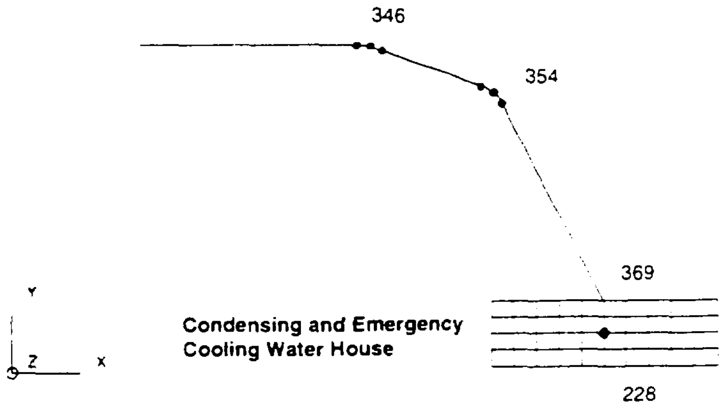


Fig. 14 Buried Cooling Water Pipeline PAKS, Unit 1 to 2
Comparison of Dynamic Response in Direction y



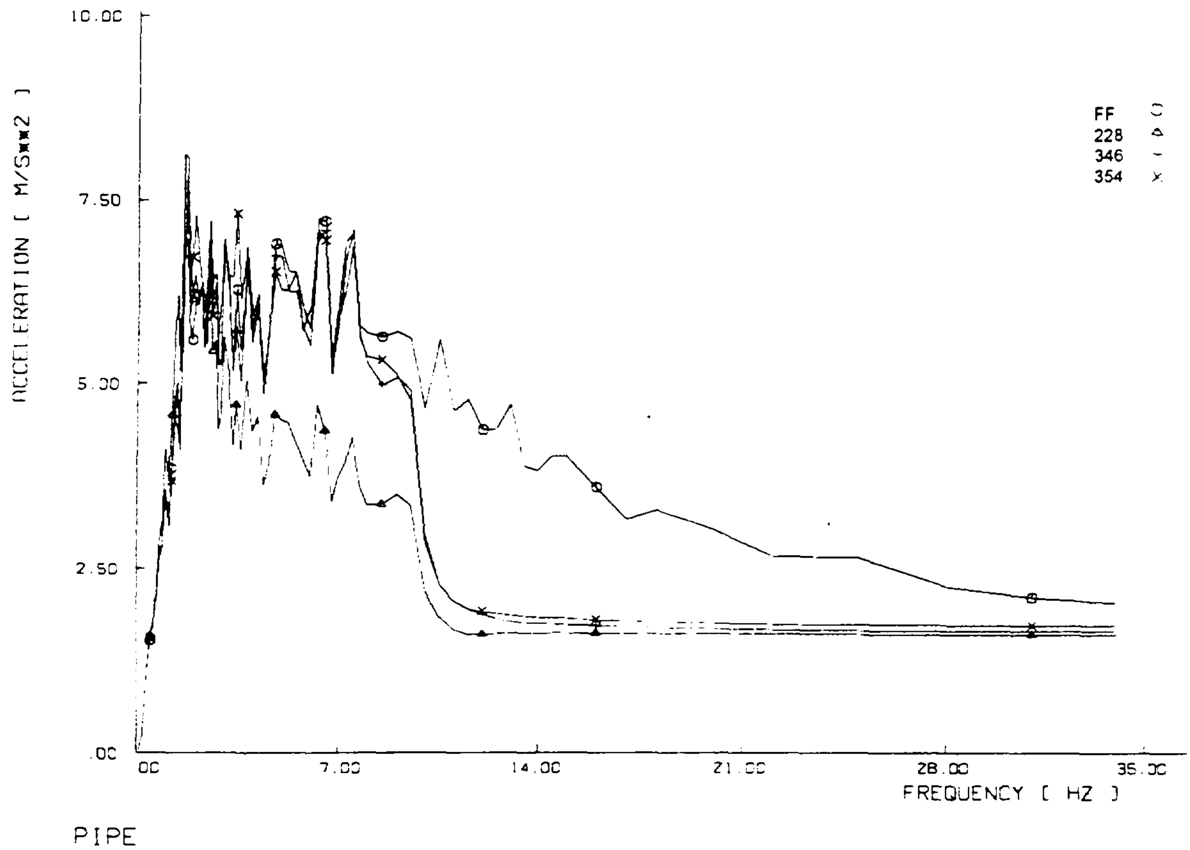


Fig. 15 Buried Cooling Water Pipeline PAKS, Unit 1 to 2
Comparison of Dynamic Response in Direction z

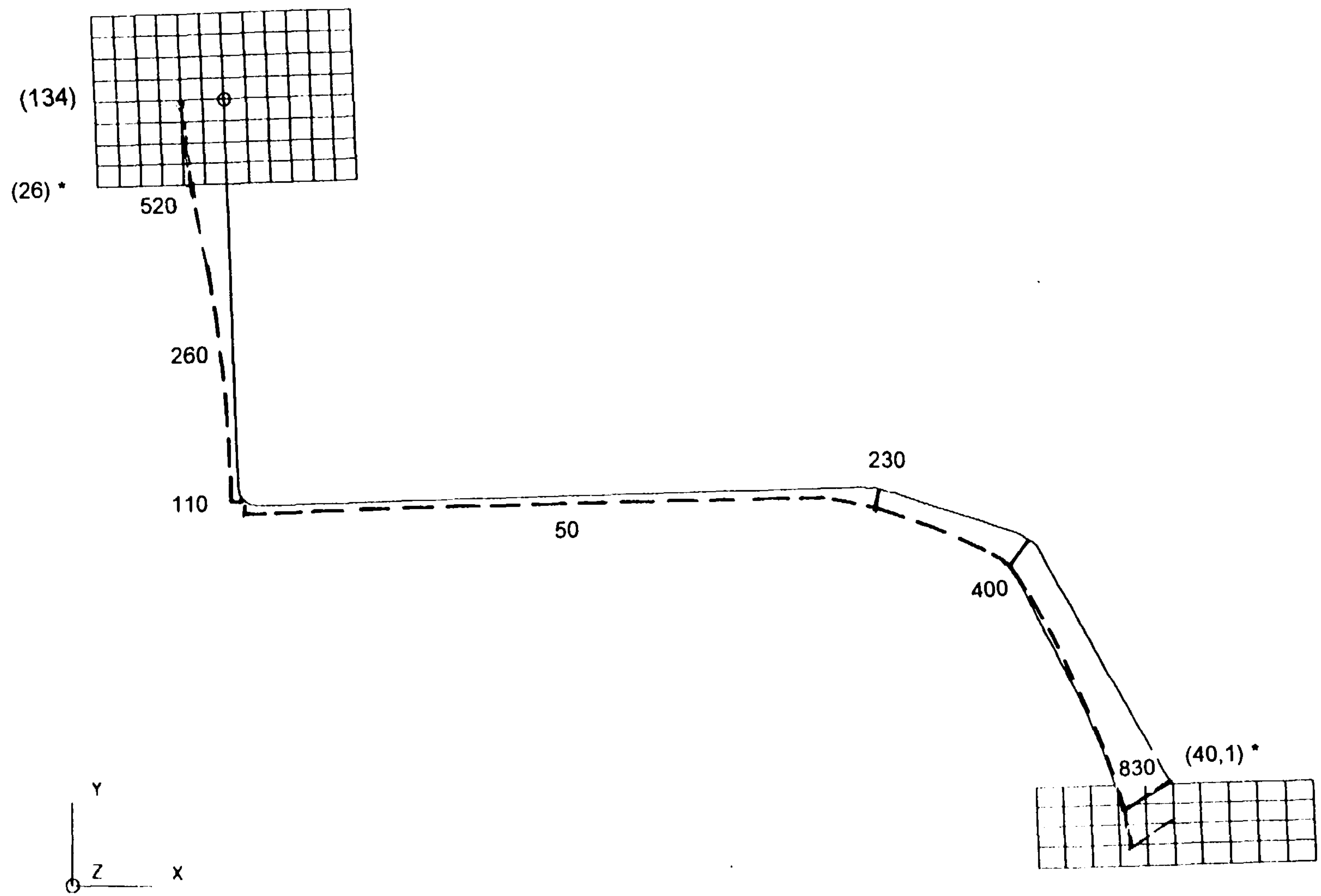


Fig. 16 Buried Cooling Water Pipeline PAKS, Unit 1 and 2
Distribution of Normal Forces (kN) and Associated Stresses ()*

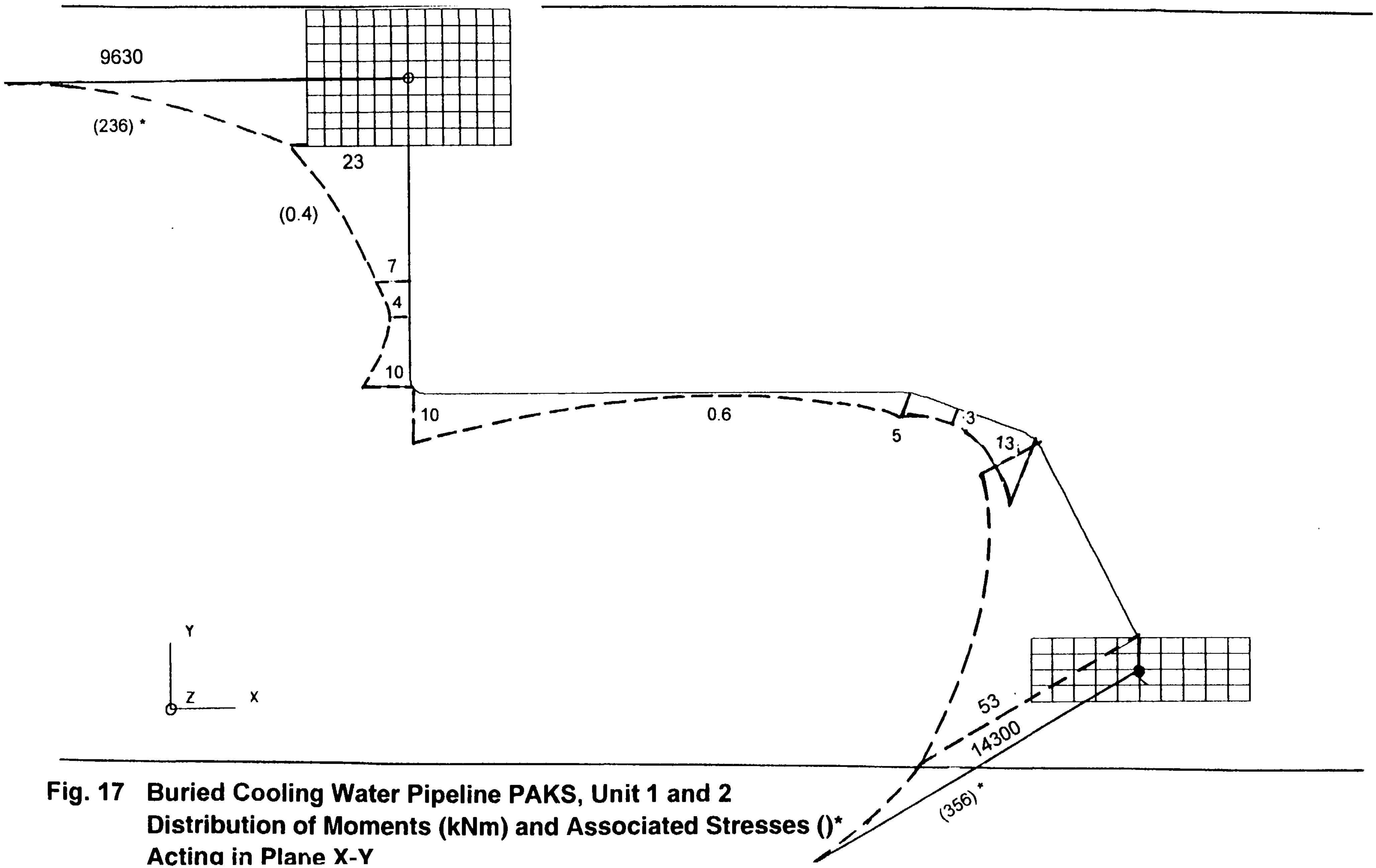


Fig. 17 Buried Cooling Water Pipeline PAKS, Unit 1 and 2 Distribution of Moments (kNm) and Associated Stresses ()* Acting in Plane X-Y

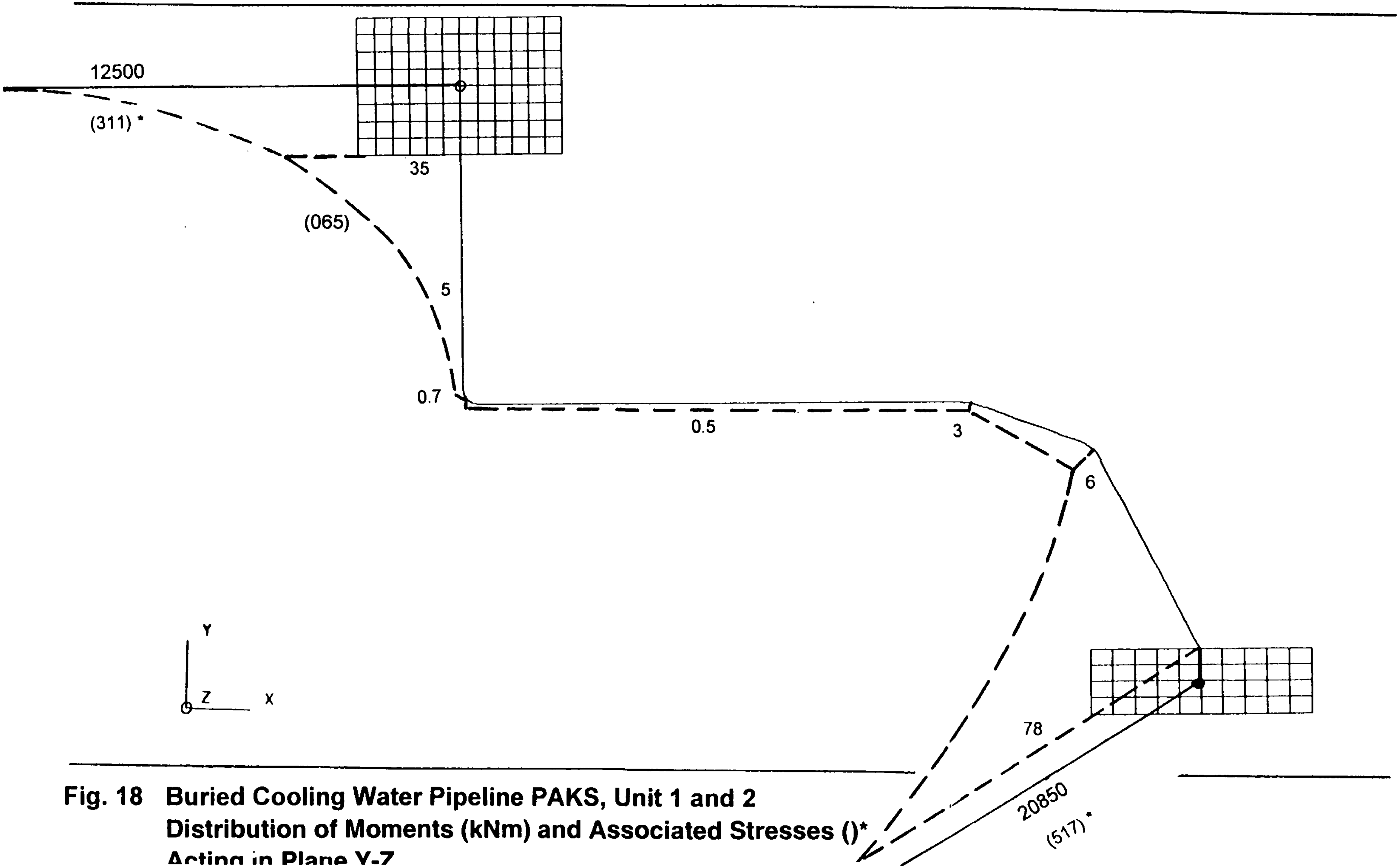


Fig. 18 Buried Cooling Water Pipeline PAKS, Unit 1 and 2
Distribution of Moments (kNm) and Associated Stresses ()*
Acting in Plane Y-Z

Depth	Soil	G_0 MN/m²	ρ t/m³	ν -	D_0 %
0.0 – 7.64	Sand loose to dense	95	1,94	0.49	1
7.64 – 13.70	Sand	127	2.0	0.49	1
13.70 – 18.70	Sand + Gravel	147	2.0	0.49	1
18.70 – 24.70	- " -	164	2.0	0.49	1
24.70 – 36.70	Dense to very dense	189	2.0	0.49	1
36.70 – 41.00	Marl	233	2.0	0.49	1
41.00 – 45.00	Sand with clay	299	2.0	0.49	1
45.00 – 48.00	Sand stone	307	1.85	0.99	1

Tab. 1 Dynamic Soil Properties (Site PAKS)