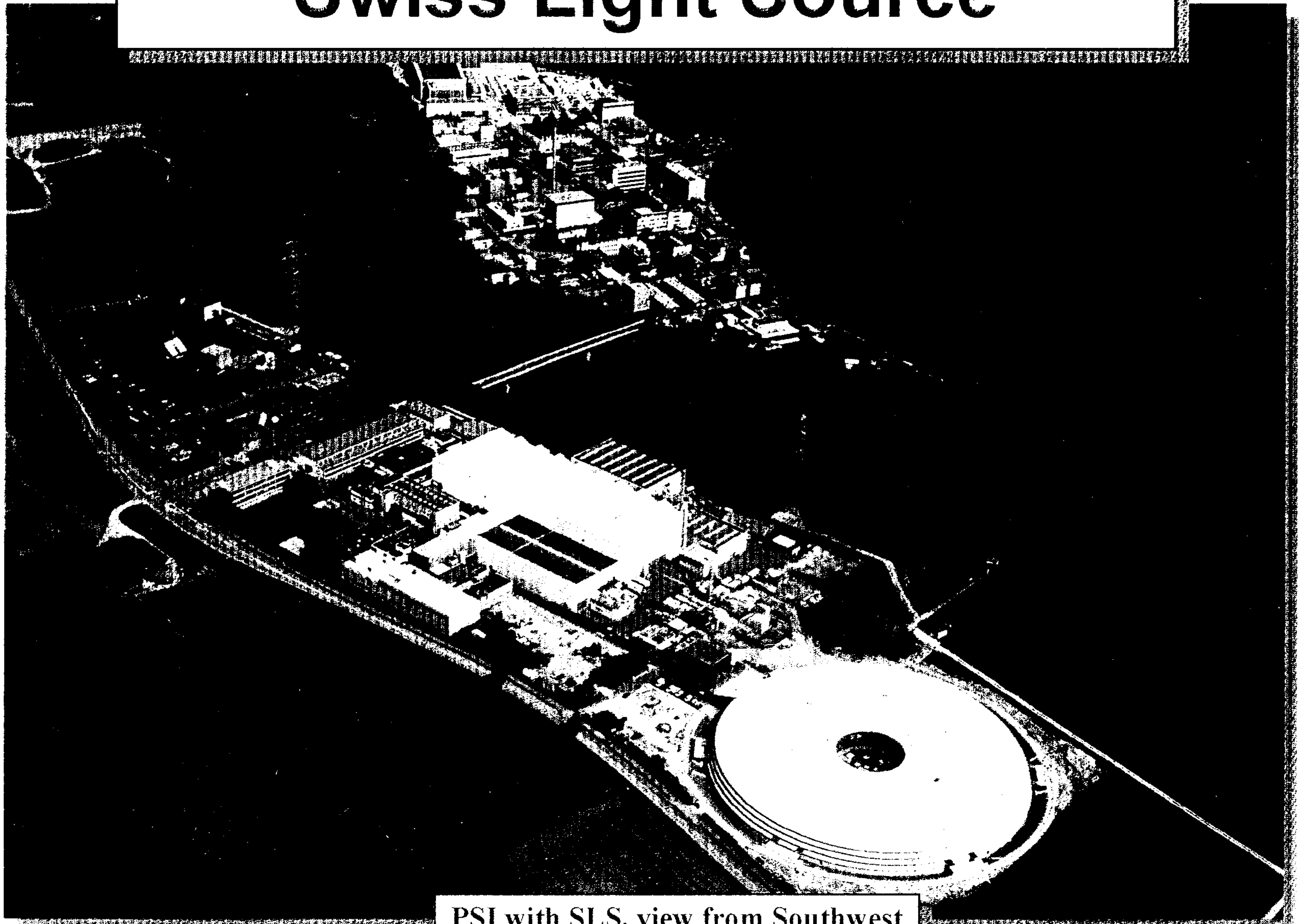
Swiss Light Source (SLS) design and engineering experience

Can ME help?

Saša Zelenika

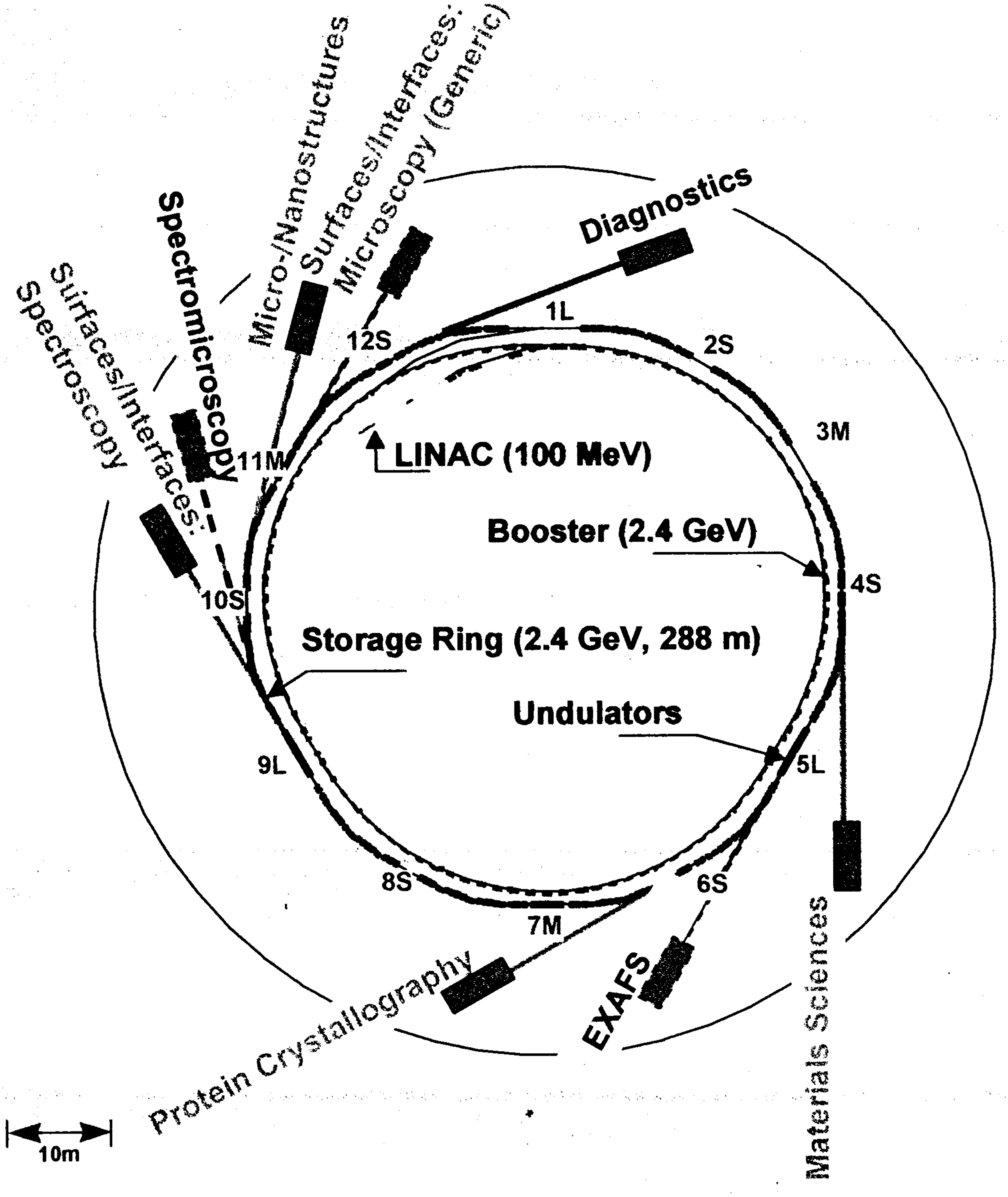
for the SLS ME Group and other involved groups/collaborators

Swiss Light Source



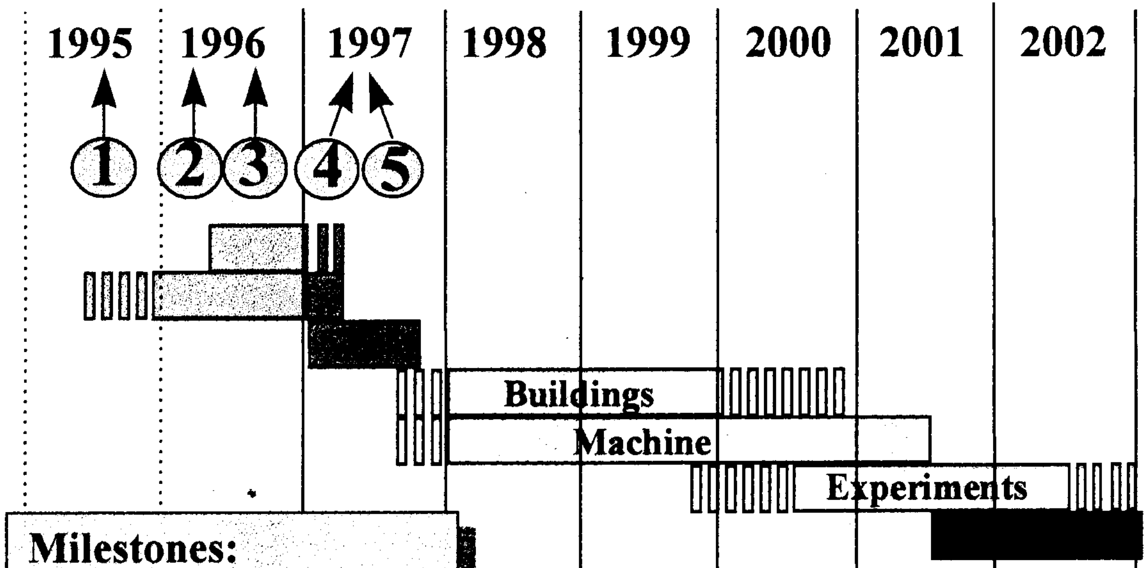
PSI with SLS, view from Southwest

SLS Layout



The lines marked in green indicate the planned beamlines of the first generation from "insertion devices" like wigglers, wavelength shifters or undulators and from superconducting bending magnets. The lines marked in red indicate second phase beamlines.

Time Schedule and Milestones



Concept and Project:
* Civil Construction
* Accelerators
Approval SLS proposal

Realization

Operation

Milestones:

①	**ETH Board:**	Principal decision to build SLS (Sep 13/14, 1995)
②	**Federal Government:**	Release of planning funds (Mar 18, 1996)
③	**Federal Government:**	Decision on proposal (Nov 20,1996)
	Parliament:	
④	**Nationalrat** (National Council):	Approval 142 pro, 1 contra, 6 abstentions (March 20, 1997)
⑤	**Ständerat** (Council of State):	Unanimous approval (June 18, 1997)

INSTALLATION MILESTONES

LINAC:

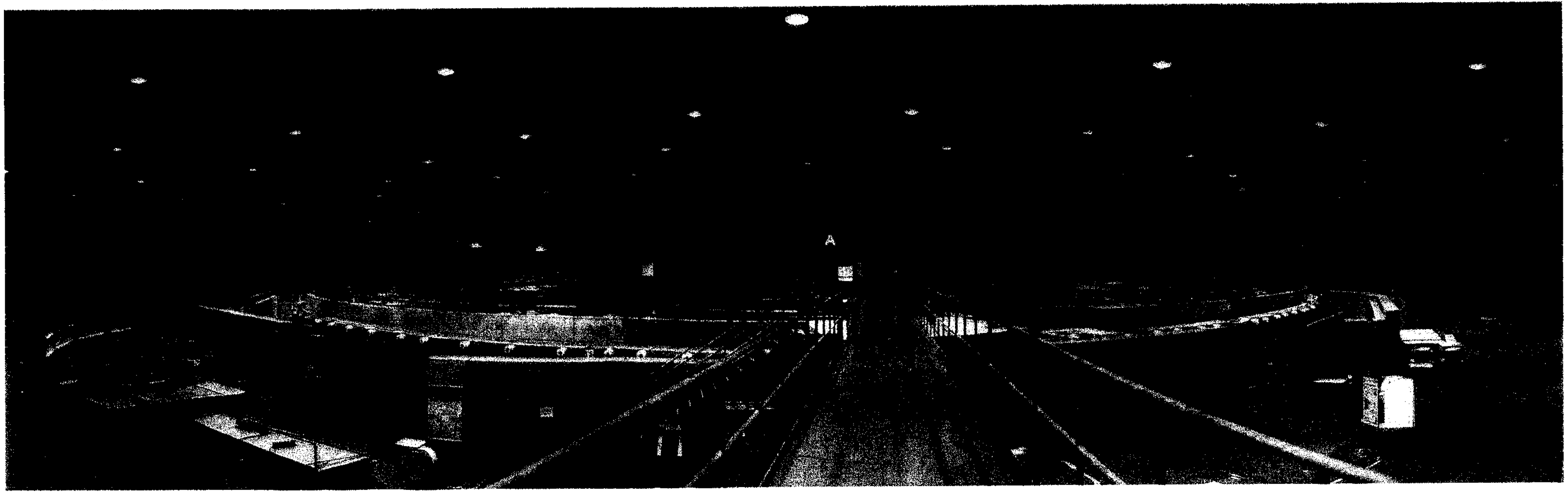
Installation	Jul. - Nov.	1999
Commissioning	Dec.	1999

BOOSTER:

Installation	Jul. 1999 - Jun.	2000
Commissioning	Jul. - Sep.	2000

STORAGE RING:

Installation	Jul. 1999 - Jun.	2000
	Oct. 2000 - Dec.	2000
Start Commissioning	**Jan.**	**2001**



- SLS: 1st medium energy range machine which will enter the hard X-ray region by utilisation of undulators with a short period and a small gap
- Main goal: high quality source
- 3rd generation SR sources, with resulting higher brightness -> quest for lower emittance and increased lifetimes

=> severe challenges in terms of stability and reproducibility of the stored beam

- room left for lattices optimisation is very limited -> increasing positioning, re-positioning and alignment precisions of the magnets becomes a must to reach small emittance and reduce orbit distorsions before switching on correction dipoles
- provisions for accurate positioning and dynamic minimisation of ground motion and thermal effects have been foreseen during the design of the SLS storage ring

VIBRATIONS (fast motion)

DYNAMIC STABILITY

VIBRATIONS DISPLACE THE MAGNETIC ELEMENTS AND GENERATE A TIME-DEPENDENT CLOSED ORBIT DISTORSION

EXPERIMENTS AT SLS REQUIRE A HIGHLY STABILISED PHOTON BEAM BELOW 100 Hz

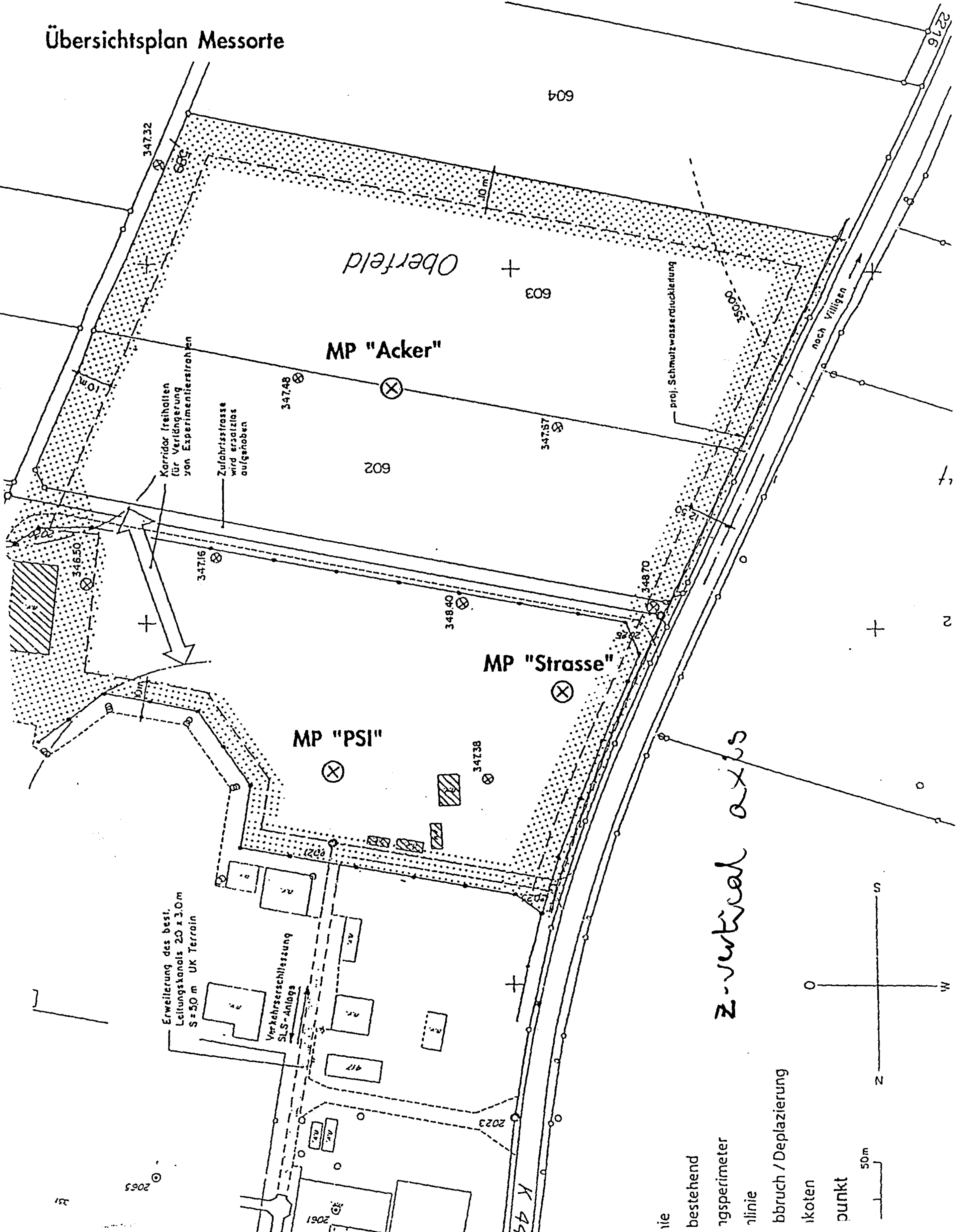
GOAL: REDUCE RESIDUAL RMS BEAM JITTER TO 10% OF ELECTRON BEAM SIGMAS (i.e., WITH A 1% EMITTANCE COUPLING TO 1μm VERTICALLY AND 10 μm HORIZONTALLY)

NEED TO EVALUATE:

- INCOMING GROUND NOISE SPECTRUM
- TRANSMISSIBILITY OF GIRDER/MAGNETS ASSEBLIES (G. E. Fisher [1984]: “All component support designs should be analyzed for their dynamic mechanical response”)
- ORBIT RESPONSE

11/1996
03/1997

Übersichtsplan Messorte



- ground w/o excitation

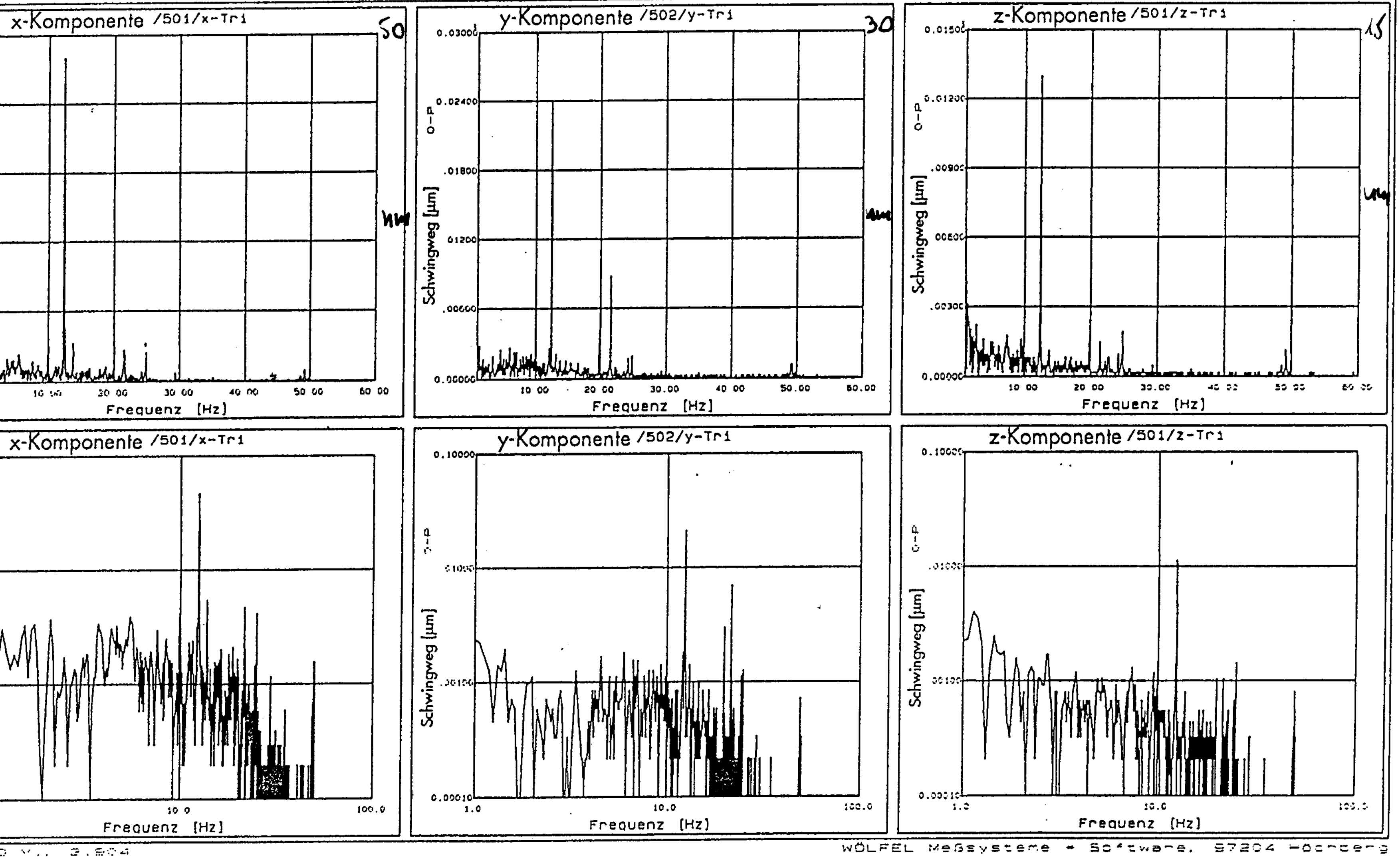
Messort "PSI": Verschiebungsspektren der normalen Bodenunruhe

ft. KB-3 V1 ***
: C: Bezeichnung : Betriebsunruhe
ner : 4937 Bearbeiter : AF
e Synchron Kommentar : PSI Geländemessung
: PSI :
er Messung: 501 :
27/11/1996
: 11/05/97

Zeitfenster für Spektrum: 16 s

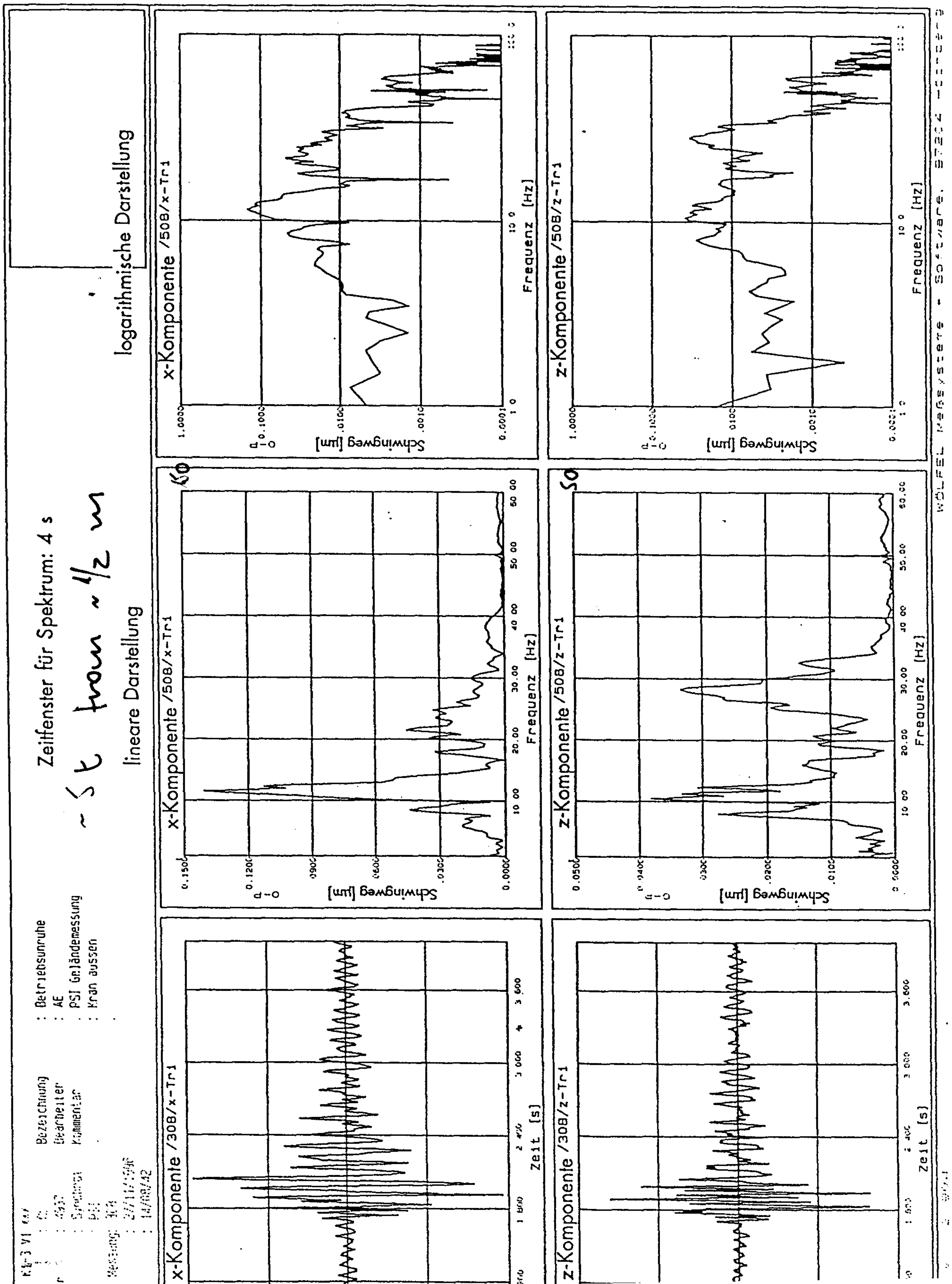
oben: lineare Darstellung

unten: logarithmische Darstellung

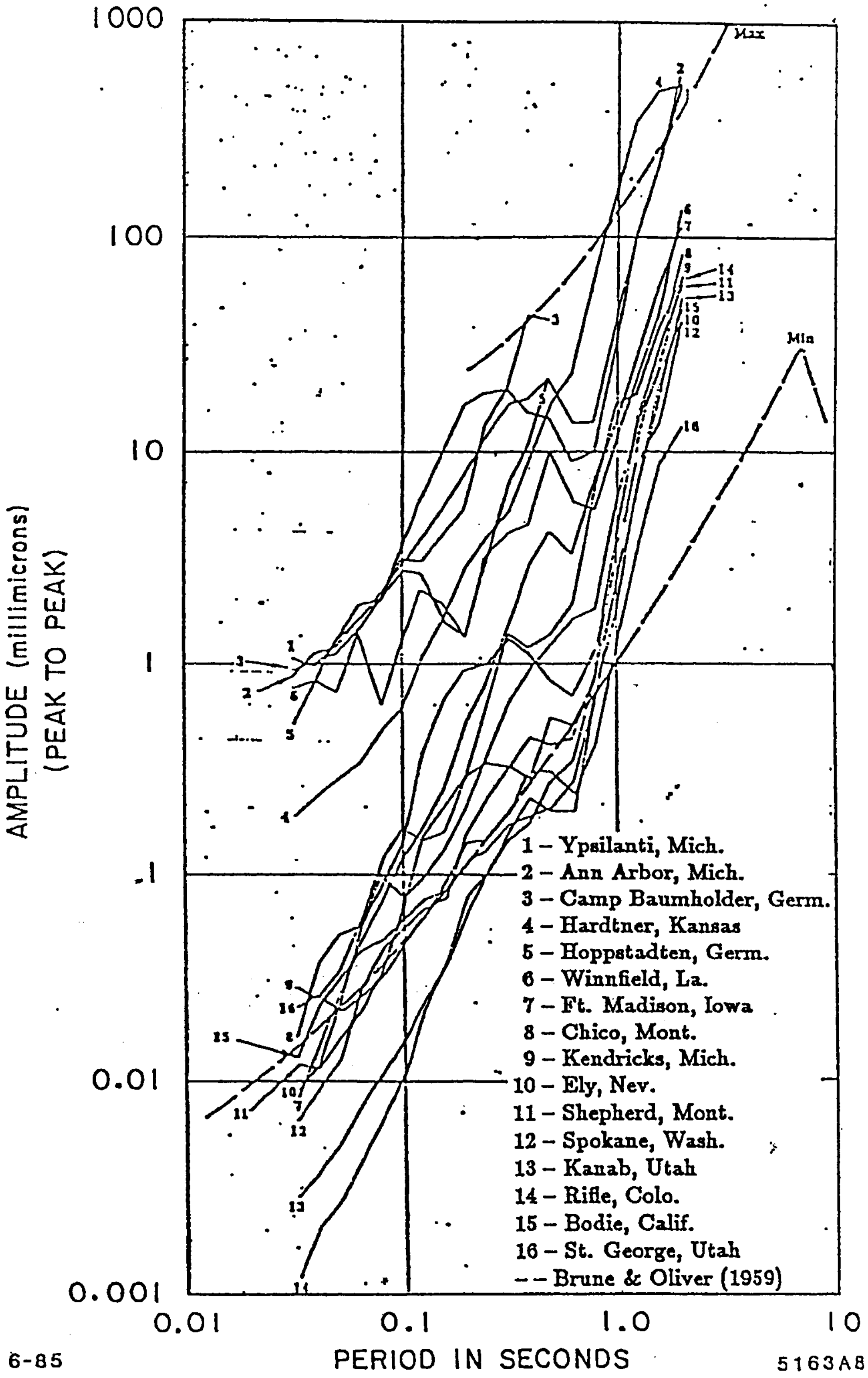


D V.. 3.604 WÖLFEL Meßsysteme + Software, 97204 Höchberg

Messort "PSI": Zeitausschnitt (Schwingweg) und Verschiebungsspektren von ausgesprochen "unsanftem" Absetzen eines Abschirmelementes



Bezeichnung : Betriebsunruhe
Bearbeiter : AE
Kommentar : PSI Geländemessung
: Kran aussen

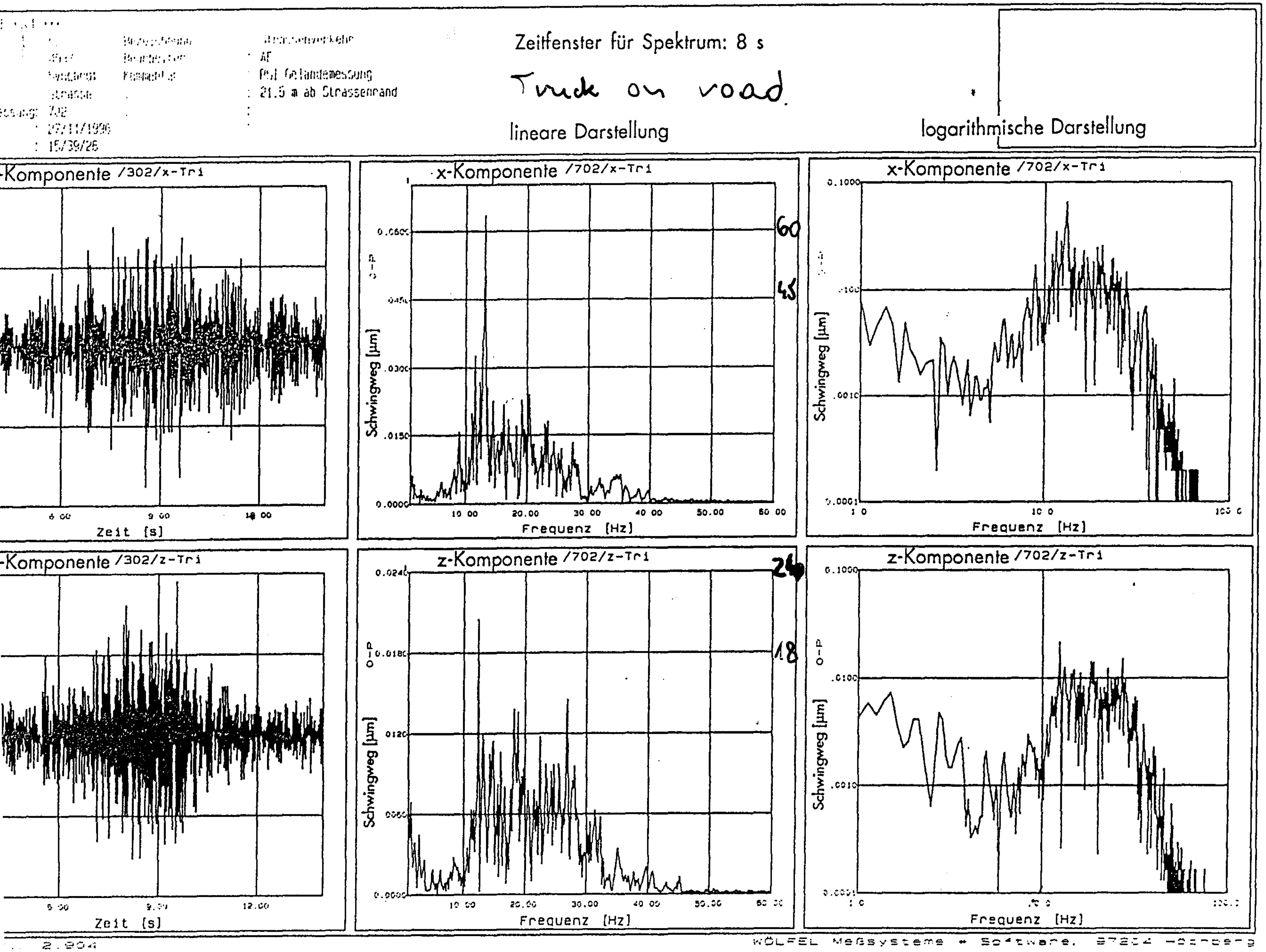


6-85 5163A8

Fig. 2.9. High Frequency Side of the Noise Spectrum (from Ref. 9).

[Fisher, 1984]

Messort "Strasse": Zeitausschnitt (Schwingweg) und Verschiebungsspektren einer LKW-Vorbeifahrt auf der Kantonsstrasse



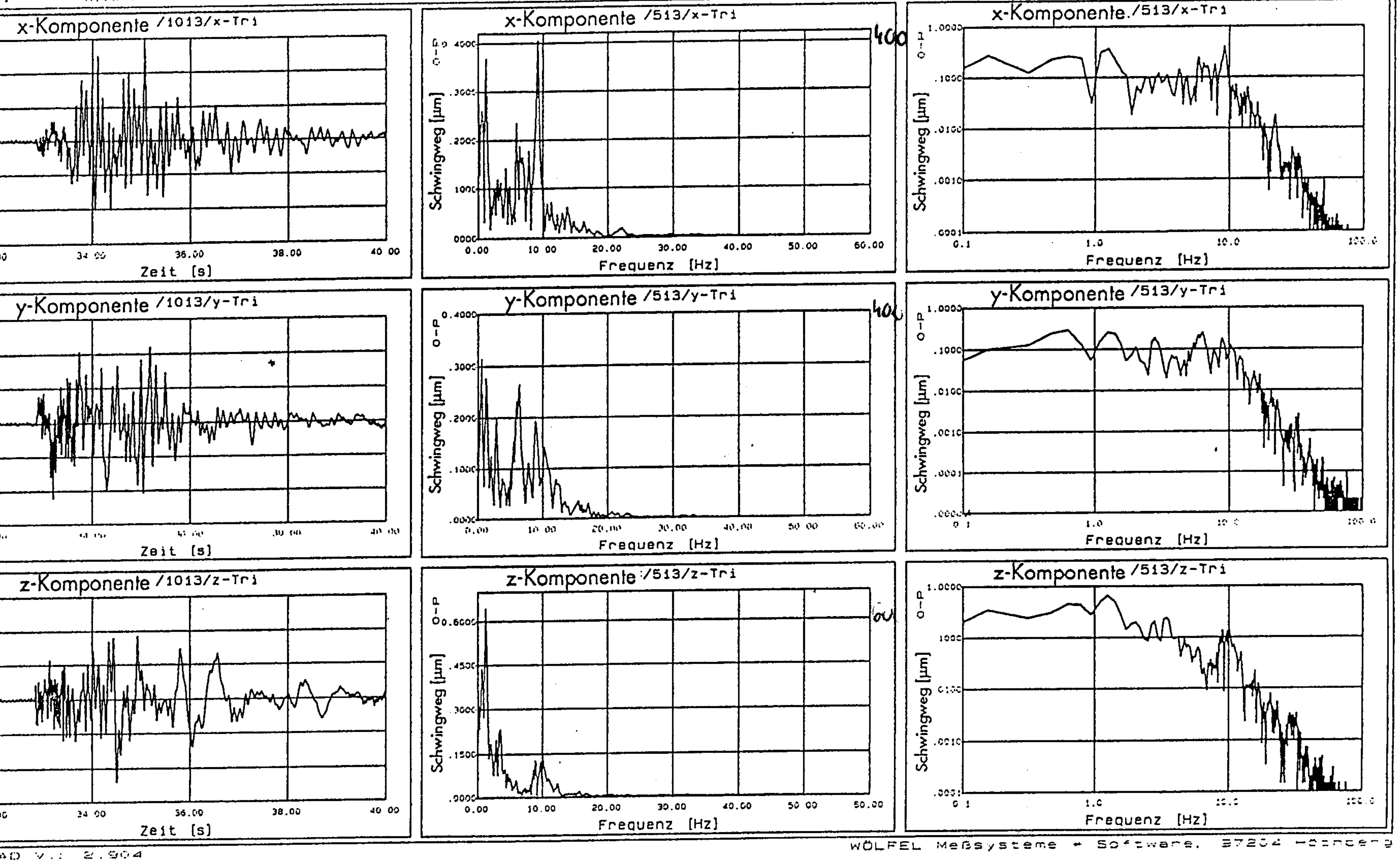
Messort "Acker": Zeitausschnitt (Schwingweg) und Verschiebungsspektren der 1. Sprengung im Steinbruch Villigen vom 12.3.97

C: — Bezeichnung : Sprengung Steinbruch Villigen
mer 4937 — Bearbeiter : AE
e Synchrot — Kommentar : PSI Geländemessung
Acker . : 20.0 m ab Ackerrand (Arealgrenze)
er Messung 313 . :
12/03/1997 . :
15/56/41

Zeitfenster für Spektrum: 6.4 s

Explosion in rock breaking facility '1 km away'

lineare Darstellung — logarithmische Darstellung



Measured spectrum of ground noise at the SLS site:

a) conventional sources of noise:

	Usual ground motion	Truck on road, response measured close to the road ***	Tractor plowing the ground near by ****
Frequency range of meaningful noise (Hz)	0 - 25	0 - 45	0 - 37
Max horizontal peak: frequency (Hz) / amplitude (nm)	12 / 45* (22 / 10; 25 / 5)	13 / 70** (20 / 23)	20-23 / 60 (11 / 23)
Average horizontal peak amplitudes (nm)	3	8	15
Max vertical peak: frequency (Hz) / amplitude (nm)	12 / 10* (22 -25 / 1)	12 / 20** (27 / 15; 18 / 12)	13 / 20 (10 / 8; 22 / 6)
Average vertical peak amplitudes (nm)	1	6	3

* This large peak was due to a nearby kompressor which should be dumped (?)

** Still probably at least partly due to the nearby compressor.

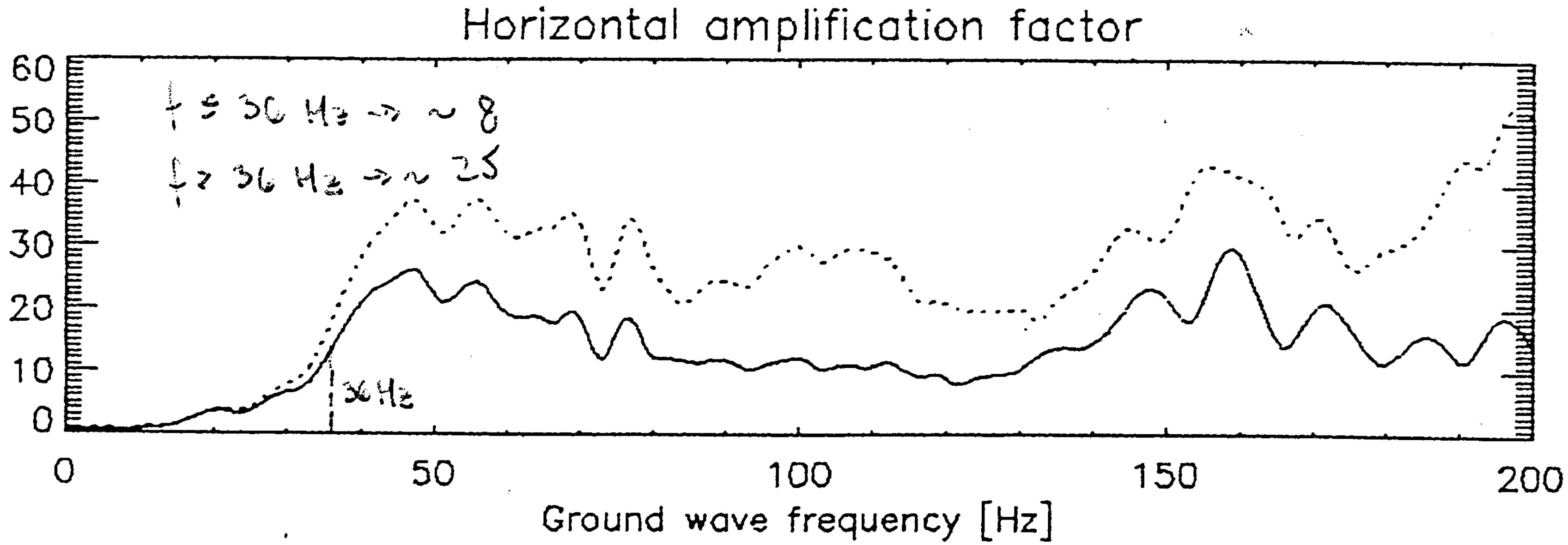
*** The biggest noise in the proximity of the road is registered at around 9.00 a.m., 14.30 p.m. and 17.00 p.m.

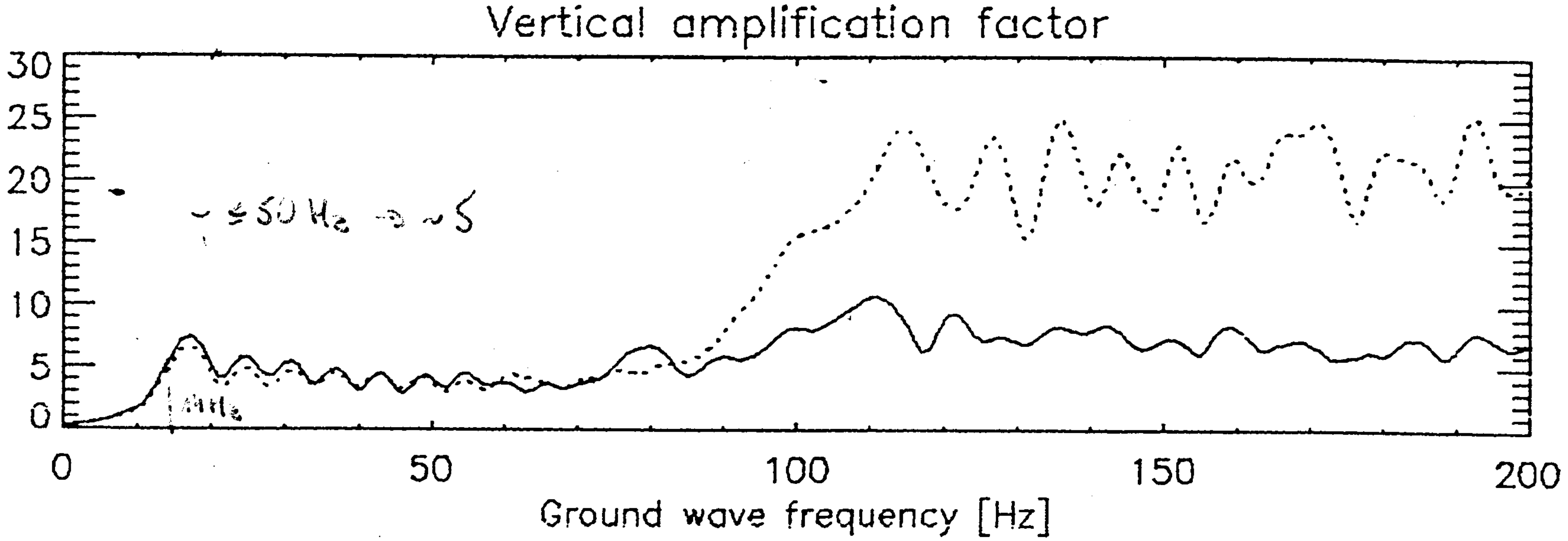
**** Further away from the compressor

b) unconventional sources of noise:

	5 t weight dropped from a certain height (cca. 0.5 m)	5 t weight lowered slowly with a crane	Explosion 1 km away
Frequency range of meaningful noise (Hz)	0 - 42	0 - 42	0 - 23
Max horizontal peak: frequency (Hz) / amplitude (nm)	12 / 140* (22 / 40)	13 / 48* (22 / 20)	5-9 / 400(1-3 / 350)
Average horizontal peak amplitudes (nm)	15	8	20
Max vertical peak: frequency (Hz) / amplitude (nm)	11 / 38* (28 / 35)	12 / 11* (29 / 7)	3 / 650
Average vertical peak amplitudes (nm)	15	4	20

* Still probably at least partly due to the nearby compressor.





- - - single elements

—— elements on girders

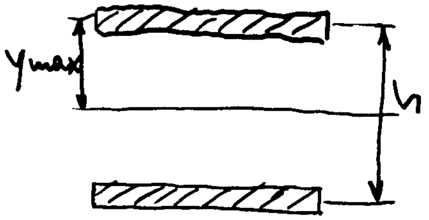
[M. Böge et al., PAC 99]

ease of ampl. factor: @ λ = betatron wavelength (assumed v_{sound} = 500 m/s)

Bending

$\sigma = \frac{M}{I} \cdot y$ $W \geq \frac{I}{y_{max}}$ - elastic section modulus

$W_{opt} \to A \cdot y_{max} \Rightarrow$



$\eta = \frac{W}{W_{opt}} \leq 1$

$W = \frac{1}{2} A h \eta$

◍	$\eta = 0.25$	▣	$\eta = 0.67$
◎	$\eta = 0.5$	I	$\eta = 0.61 \div 0.65$
▨	$\eta = 0.33$	⊔	$\eta = 0.59 \div 0.61$

Torsion

Closed form is better than opened

$\tau = \frac{M_t}{W_t} \leftrightarrow$ Min area for a certain stress

$\frac{A_{◎}}{A_{▨}} \leq 0.815 \Rightarrow$ ◎ is better than ▨

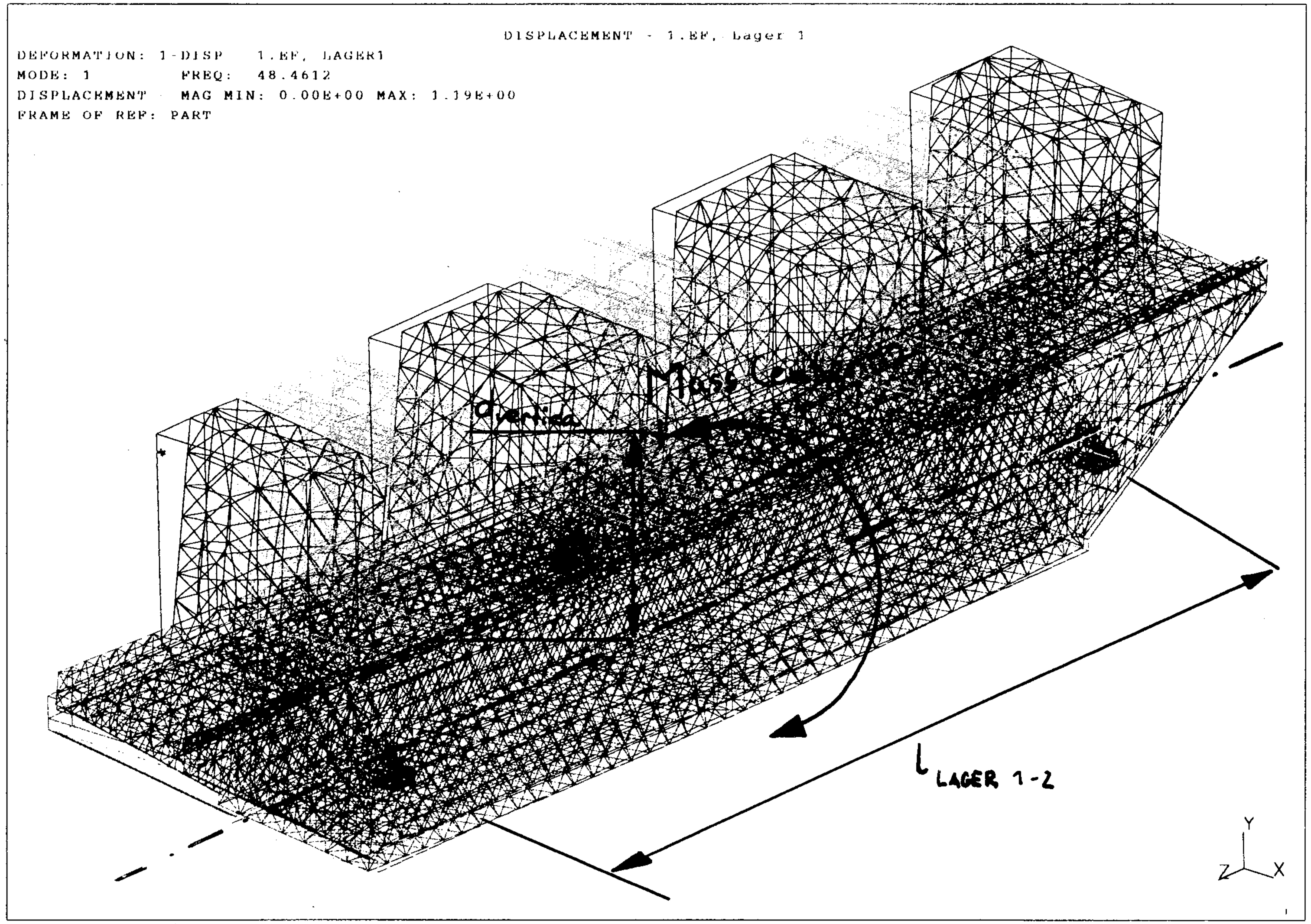
$\frac{A_{◎}}{A_{◍}} \leq 1 \Rightarrow$ ◎ is better than ◍

▣ seems better than ▨

DESIGN GOALS

- Design a hollow-square girder structure as the basic support unit of the storage ring elements
- No coupling of eigenfrequencies with ground motion noise
- Max. mechanical vibration amplitudes shold be lower than ~0.2 μm in the vertical and 1.25 μm in the horizontal plane
- Experimental assessment of the performances of the system

```
I-DEAS Master Series 4:    Simulation                                   07-Apr-97    06:43:14
Database: /usr/people/wiegand/SLS/girder_v4.mf1                                     Units    : SI
View    : GIRDER - ISO                                          Display : No stored Option
  Task : Post Processing                                    Model/Part Bin: SLS - GIRDER
  Model: FEM   girder 1 (var.5)                             Parent Part: girder 1 - var.5
```



DISPLACEMENT - 1.EF, Lager 1

DEFORMATION: 1-DISP   1.EF, LAGER1

MODE: 1   FREQ: 48.4612

DISPLACEMENT   MAG MIN: 0.00E+00 MAX: 1.19E+00

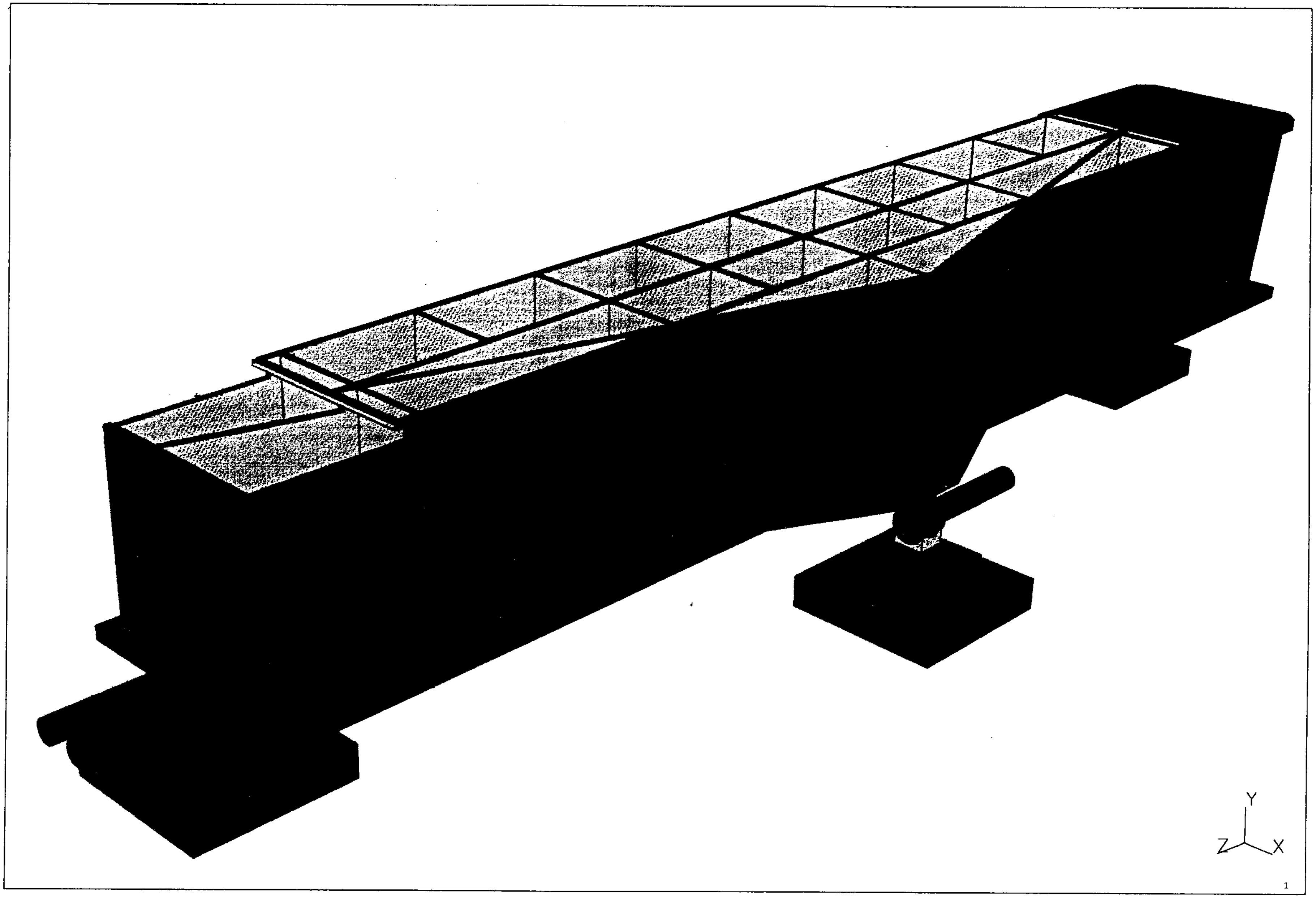
FRAME OF REF: PART

I-DEAS Master Series 4:   Simulation

06-Nov-97   02:50:21

Database: /usr1/people/wiegand/SLS/GIRDER/girder8_3d.mf1
View   : PERSP VIEW 1
Task : Boundary Conditions
Model: <none on workbench>

Units   : SI
Display : No stored Option



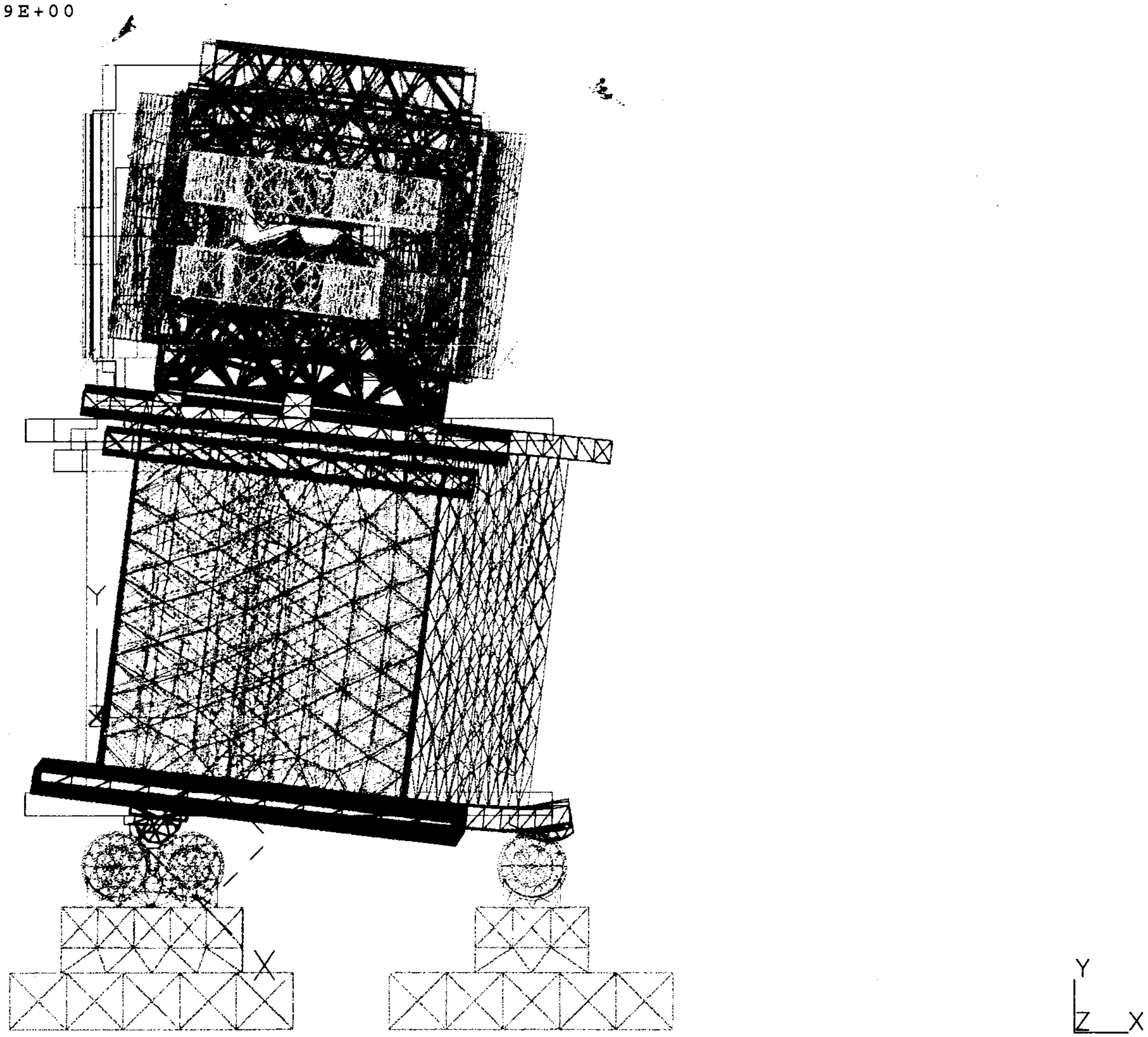
I-DEAS Master Series 4:   Simulation   06-Nov-97   01:55:22

Database: /usr1/people/wiegand/SLS/GIRDER/girder8_3d.mf1
View   : CROSS SECTION V.2
Task : Post Processing
Model: FEM - girder assembly 9

Units   : SI
Display : No stored Option
Model/Part Bin: GIRDER
Parent Part: Girder assembly 9

DISPLACEMENT - 1. EF, girder assembly Var.9   (L=4.5m)

DEFORMATION: 1-DISP - 1.EF LAGER1
MODE: 1   FREQ: 19.71315
DISPLACEMENT - MAG MIN: 0.00E+00 MAX: 1.09E+00
FRAME OF REF: PART

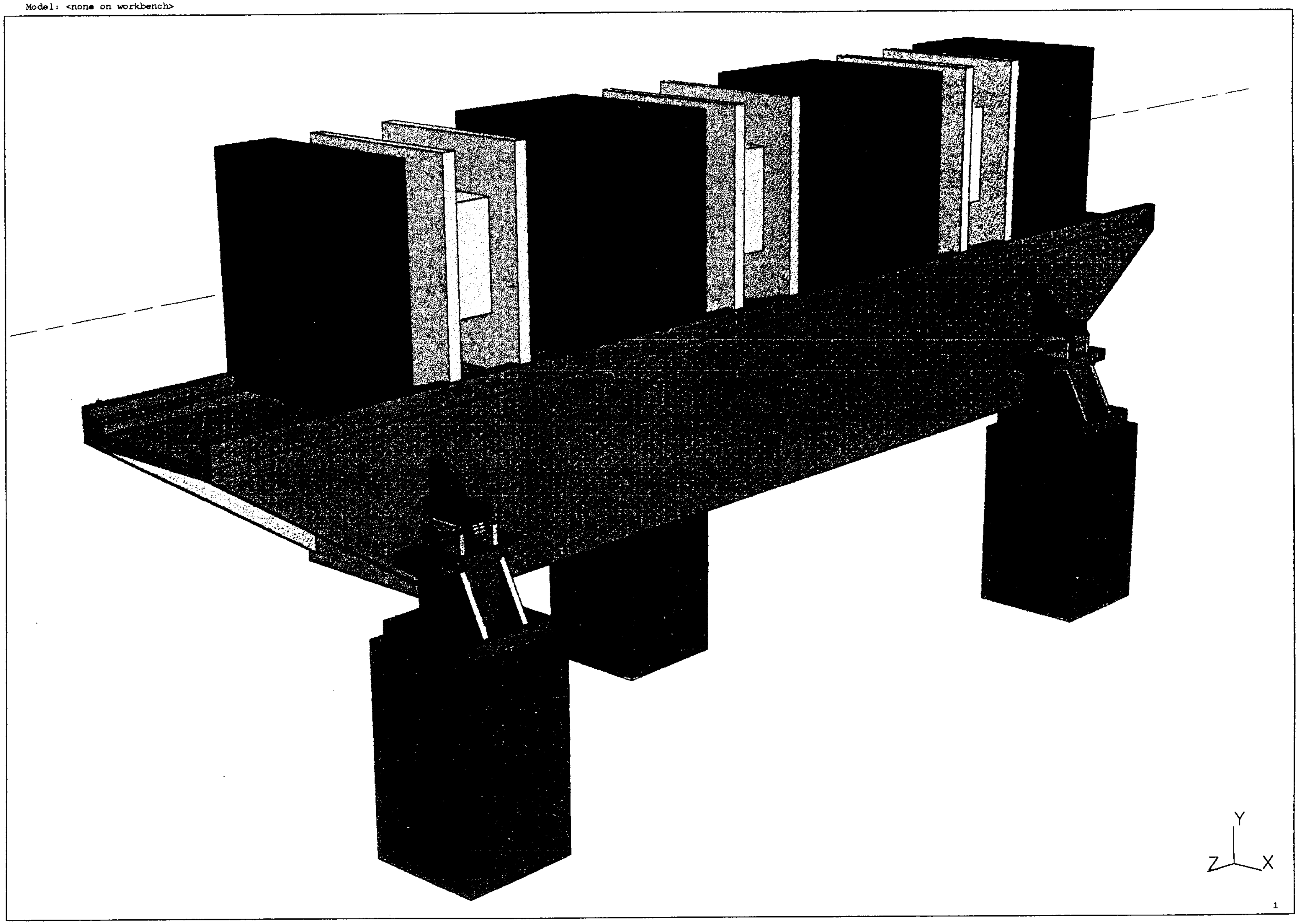


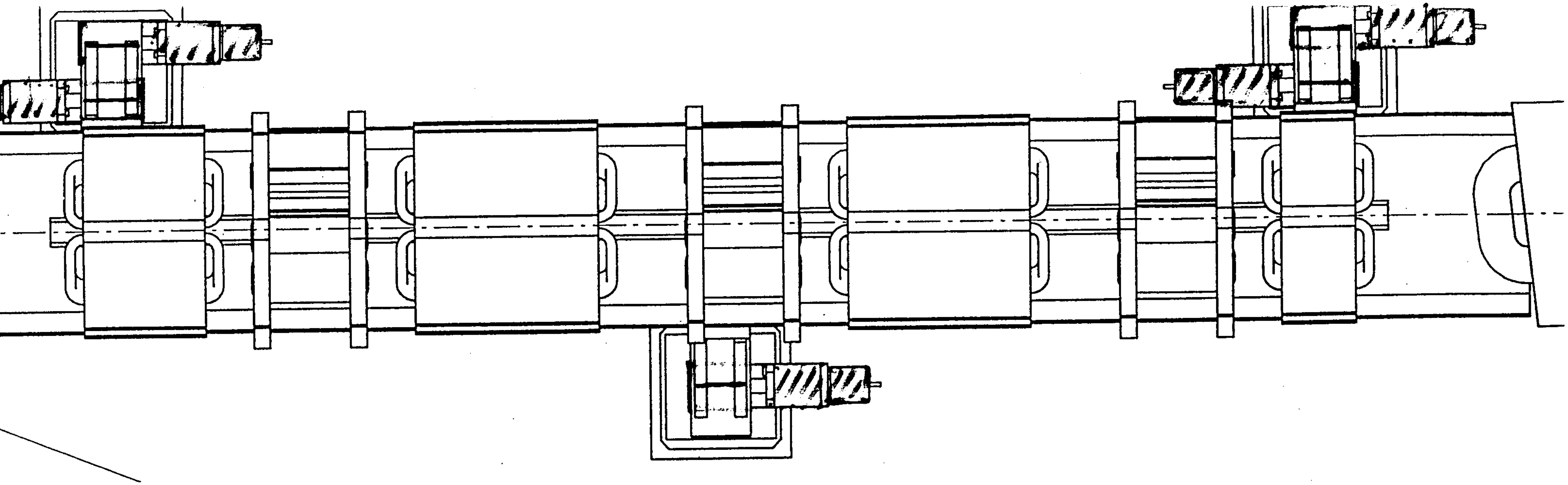
I-DEAS Master Series 4:   Simulation

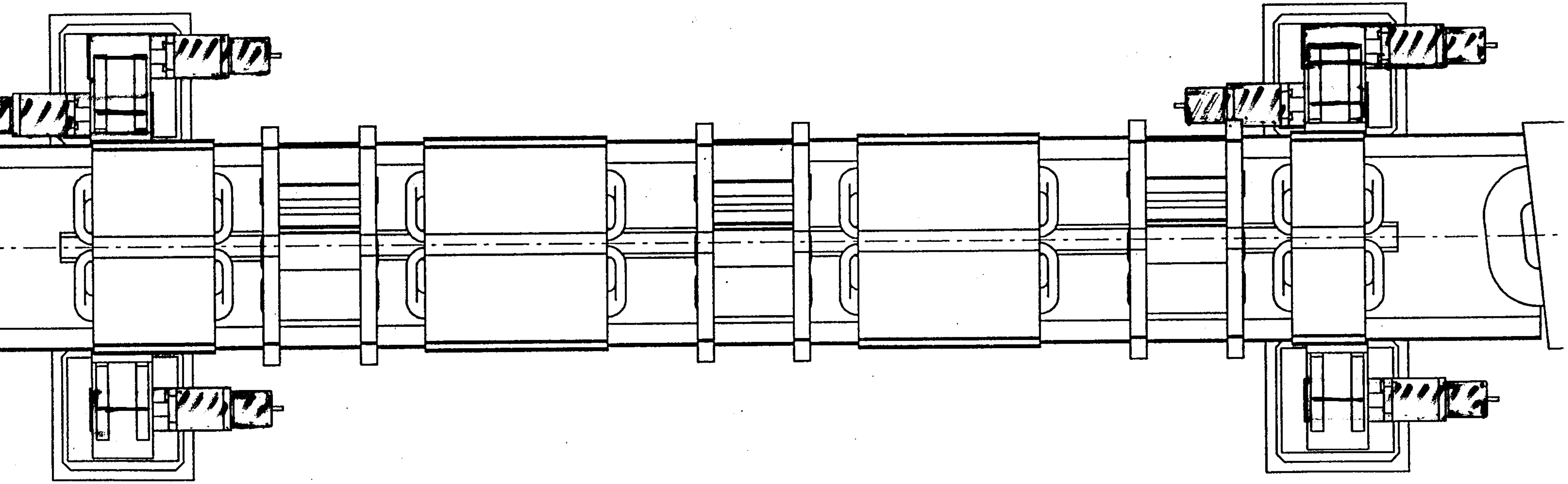
05-May-97   04:54:41

Database: /usr/people/wiegand/SLS/girder_v4.mf1
View   : GIRDER - PERSP
  Task : Master Surfacing
  Model: <none on workbench>

Units   : SI
Display : No stored Option





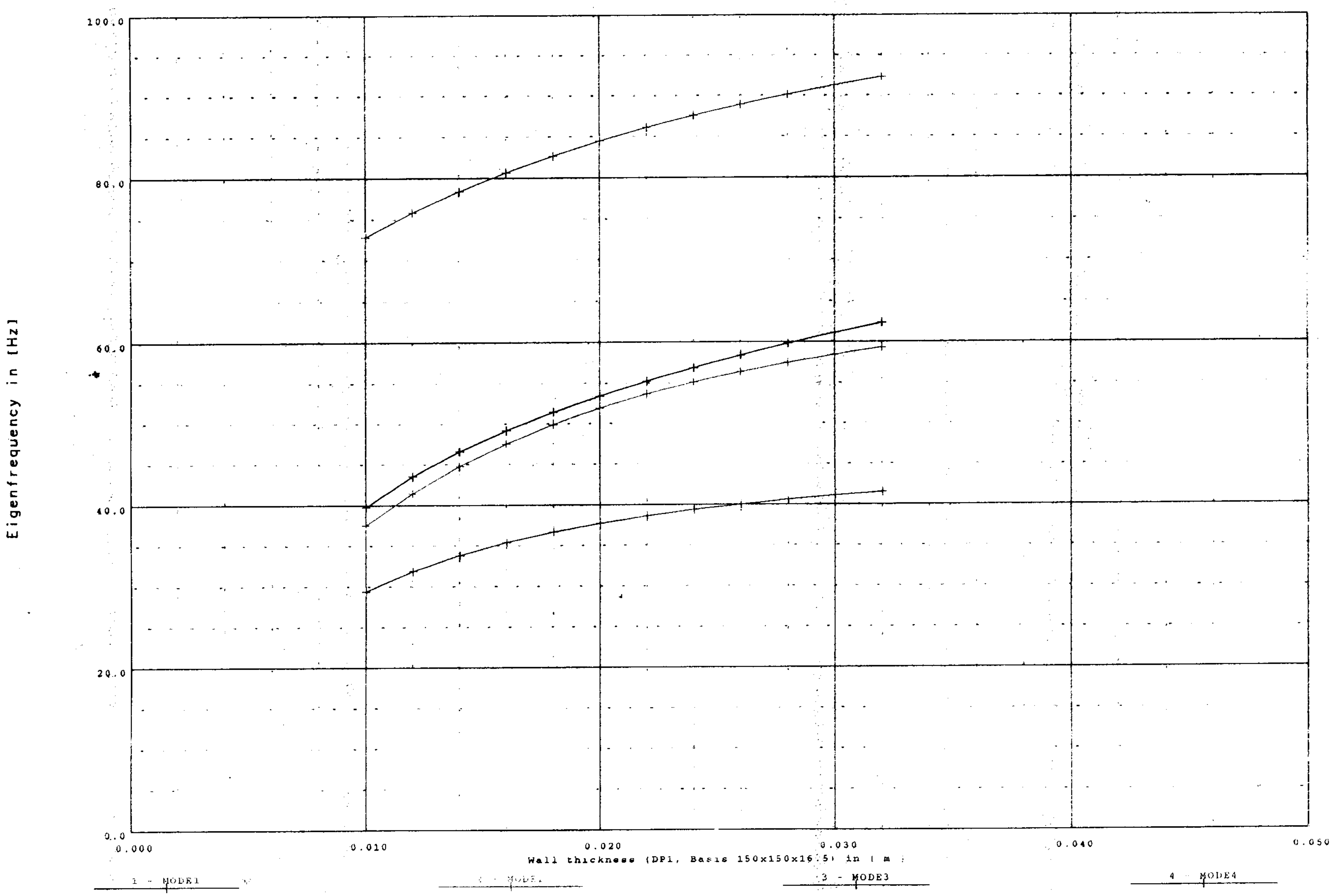


I-DEAS Master Series 4   Simulation   07-May-97   00:29:38

Database: /usr/people/wiegand/SLS/girder_v4.mf1
View   : GIRDER - PERS
Task : Optimization
Model: FEM - girder + support

Units : SI
Display : No stored Option
Model/Part Bin: SLS - GIRDER
Parent Part: g+s shell study

EIGENFREQUENCY - Parameter study, profil wall thickness



Girder design - status of work *SLS - meeting, 19.11.97*

Comparison - girder lengths and assemblies

Design	***Girder Var. 1 (old lattice)***		***Girder Var. 7 (new lattice)***			***G. Var. 8***	***G. Var. 9 (russia)***
Girder length	*4.0 m*	*4.0 m*	*4.5 m*	*4.5 m*	*4.5 m*	*3.7 m*	*4.55 m*
bearing distance	*2.8 m*	*2.8 m*	*2.8 m*	*2.8 m*	*2.8 m*	*2.5 m*	*2+2 m*
bending magnets	-	include, B2	include, w.o. bearing	-	include, B2	include, B2	include, B2
assembly mass	*3.7 t*	*7.4 t*	*7.8 t*	*4.1 t*	*7.8 t*	*5.7 t*	*10.7 t*
Eigenfrequencies (based on FEM - calc.)							
1. EF	*50.0 Hz*	*46.5 Hz*	*58.4 Hz*	[illegible]	***44.0 Hz***	***51.2 Hz***	***19.7 Hz***
2. EF	*60.2 Hz*	*52.7 Hz*	*64.9 Hz*	[illegible]	***46.5 Hz***	***56.7 Hz***	***32.6 Hz***
3. EF	[illegible] *Hz*	[illegible]	*70.5 Hz*	[illegible]	***51.5 Hz***	***60.1 Hz***	***44.1 Hz***
4. EF	[illegible] *Hz*	[illegible]	[illegible] *Hz*	[illegible]	***65.8 Hz***	***75.0 Hz***	***59.2 Hz***

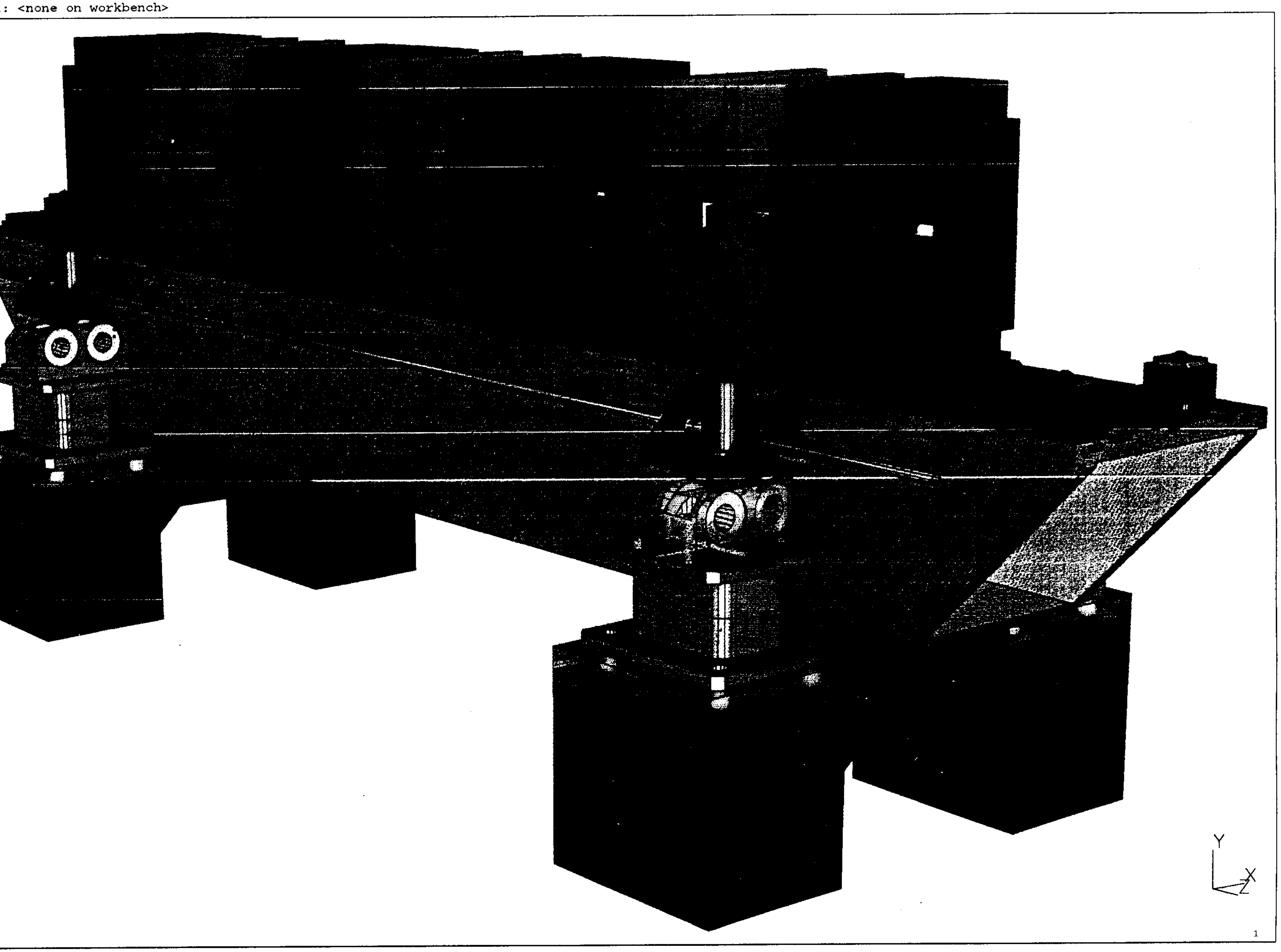
⇨ *Bearing variante B2 release higher EF's and "train links" between girders !*

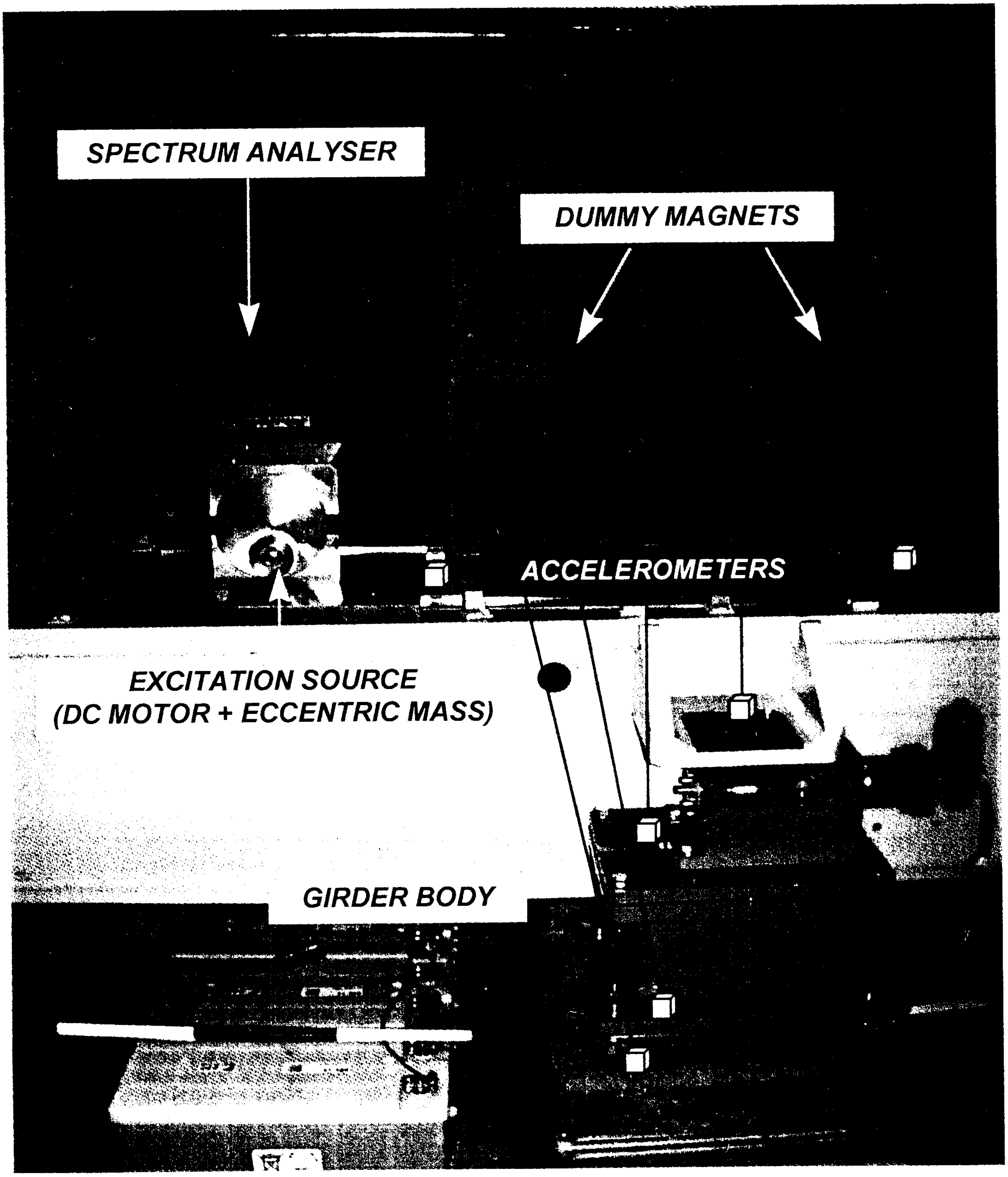
I-DEAS Master Series 6: Simulation

17-Jul-98 10:14:09

e: /usr1/people/wiegand/IDEAS_STUDY/STUDY_ASSEMBLY/girder_ass5.
: VIEW3 (modified)
: Master Modeler
: <none on workbench>

Units : SI
Display : No stored Option




SPECTRUM ANALYSER
DUMMY MAGNETS
ACCELEROMETERS
EXCITATION SOURCE
(DC MOTOR + ECCENTRIC MASS)
GIRDER BODY

Model Number
M 393B31

SEISMIC ICP® ACCELEROMETER SPECIFICATIONS

Revision: A
ECN #: 5628
Dmn 3/29/95

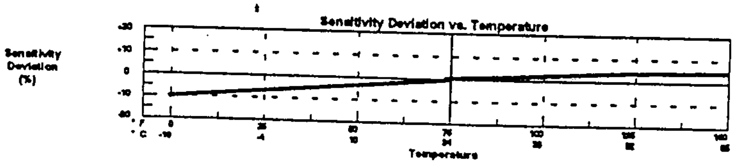
DYNAMIC PERFORMANCE			
Voltage Sensitivity	V/g [V/(m/s²)]	10.0 [1.02]	[1]
Measurement Range (for ±5V output)	±g pk [±m/s² pk]	0.5 [4,9]	
Frequency Range: (±5%)	Hz	0.1-200	
(±10%)	Hz	0.07-300	
Mounted Resonant Frequency	Hz	≥1000	
Resolution - Broadband (1 Hz to 10 kHz)	µg [µm/s²]	1 [9,8]	
Amplitude Linearity	%	±1	[2]
Transverse Sensitivity	%	≤5	[3]
ENVIRONMENTAL			
Shock Limit (Maximum)	±g pk [±m/s² pk]	40 [392]	
Operating Temperature Range	°F [°C]	0 to +150 [-18 to +65]	
Temperature Response		See Graph	[4]
Strain Sensitivity	g/µε [(m/s²)/µε]	≤0.005 [≤0,05]	
ELECTRICAL			
Excitation Voltage/Constant Current	VDC/mA	24-28/2-10	
Output Impedance	ohms	500	
Output Bias	VDC	8-14	
Discharge Time Constant	sec	≥5	
Warm Up Time (within 10% of output bias)	sec	60	
Spectral Noise: (1 Hz)	µg/√Hz [(µm/s²)/√Hz]	0.06 [0,6]	[5]
(10 Hz)	µg/√Hz [(µm/s²)/√Hz]	0.01 [0,1]	
(100 Hz)	µg/√Hz [(µm/s²)/√Hz]	0.004 [0,04]	
Ground Isolation	ohms	$>10^8$	
MECHANICAL			
Sensing Element	material/geometry	Ceramic/Flexural	
Housing	material/sealing	316L St. Steel/ Welded Hermetic	
Size (hex x height)	inch [mm]	2.25 x 2.8 [57,2 x 71,1]	
Weight	oz [gm]	22.4 [635]	
Electrical Connector	type/location	Mil-C-5015/Top	
Mounting Thread	size	1/4-28 UNF	
Mounting Torque	in-lb (N-m)	2 to 5 [2,7 to 6,8]	

OPTIONAL VERSIONS

Optional versions have identical specifications and accessories as listed for the standard model except where noted by the letter prefixes below. More than one option may be used.

☒ M - Metric
Supplied Accessories: Model M081B20 Mounting Stud replaces Model 081B20

PIEZOTRONICS



NOTES:
[1] Supplied with a sensitivity tolerance of ±5%.
[2] Zero based best straight line method.
[3] Transverse sensitivity is typically ≤3%.
[4] Specification within ±2% of typical curve.
[5] Acceleration level equivalent.

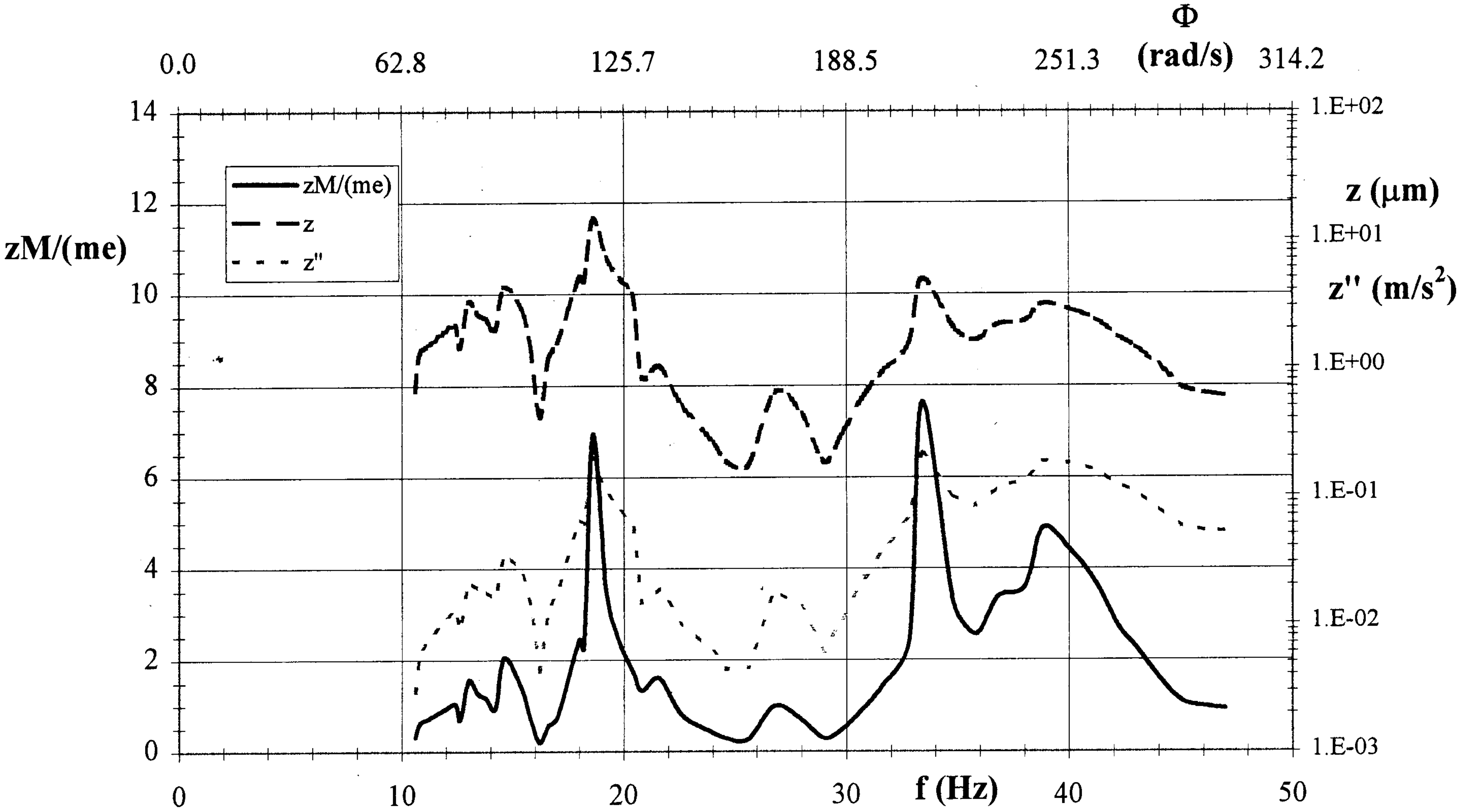
SUPPLIED ACCESSORIES:
081B20 Mounting Stud (1)
Calibration Certificate
0.5-200 Hz

Drawn: JMW	Engineer: NF	Sales:	Approved:	Spec Number:
Date: 3-28-95	Date: 3/24/95	Date: 3/30/95	Date: 3/29/95	2005

ICP® is a registered trademark of PCB Piezotronics, Inc.

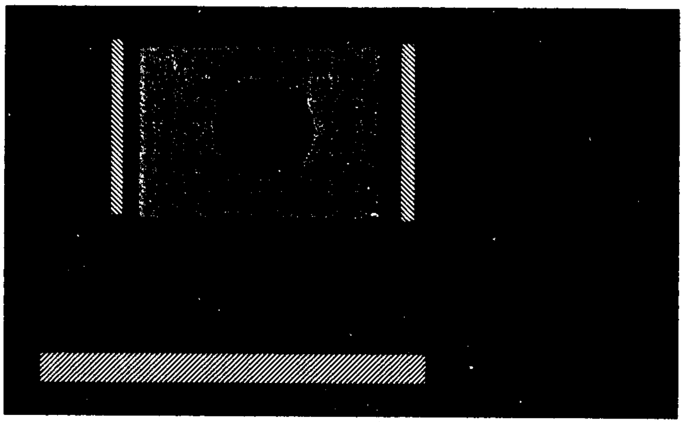
Form DD033 Rev.NR 01/20/95

Response of the girder system to an excitation by an excentric mass - 5 contact points without filling



EXPERIMENTAL AND ANALYTICAL ANALYSYS OF THE VIBRATIONAL RESPONSE OF THE GIRDER SYSTEM

Since the excitation applied experimentally to our girder system was obtained by using an excentric mass, it is useful at the beginning to understand the basic 1D theory behind the vibrational response of a mechanical system to an excitation by an excentric mass:



General formula for system's dynamics:

$$Mx'' + cx' + kx = me\Omega^2\sin(\Omega t)$$

where e is the radius of excentricity of mass m

General formula for the response of the system:

$$-M\Omega^2 x\sin(\Omega t-\Phi) + cx\Omega\cos(\Omega t-\Phi)+kx\sin(\Omega t-\Phi)=me\Omega^2\sin(\Omega t)$$

or, after the necessary transformations:

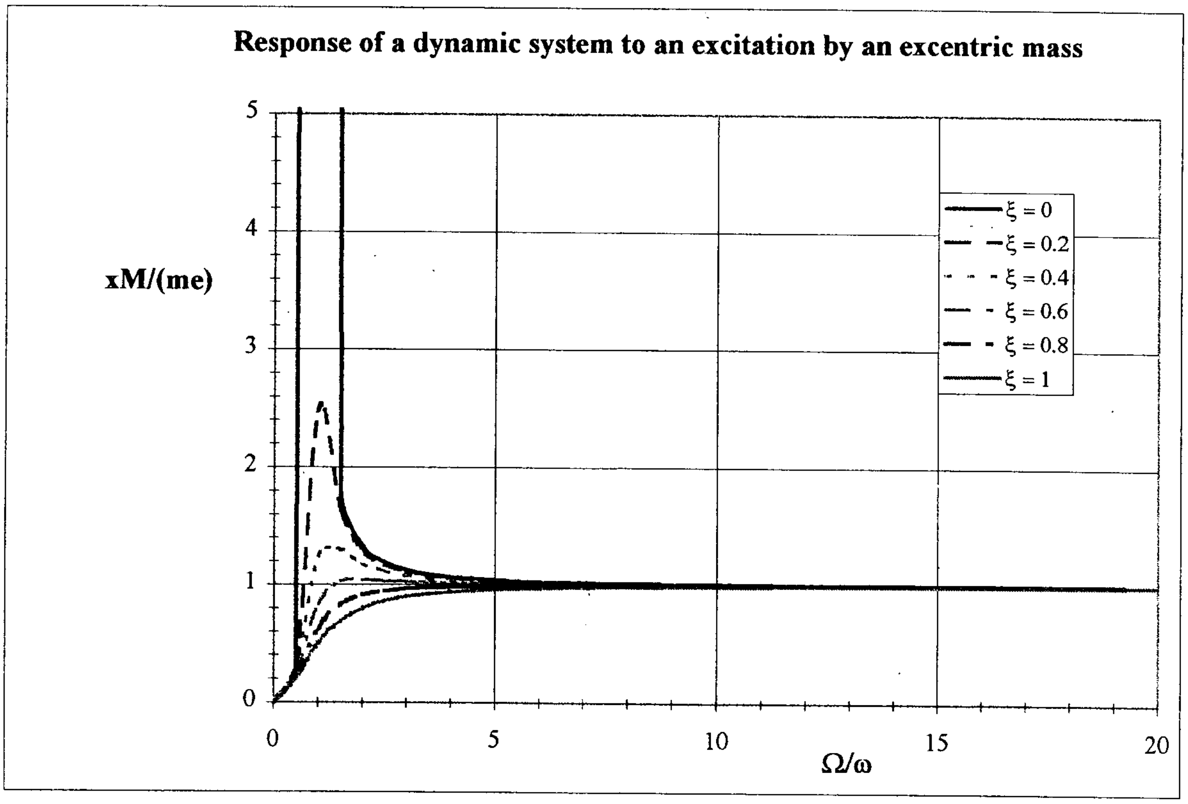
$$xM/(me) = (\Omega/\omega)^2/\mathrm{sqrt}((1-(\Omega/\omega)^2)^2+4\xi^2(\Omega/\omega)^2)$$

where:

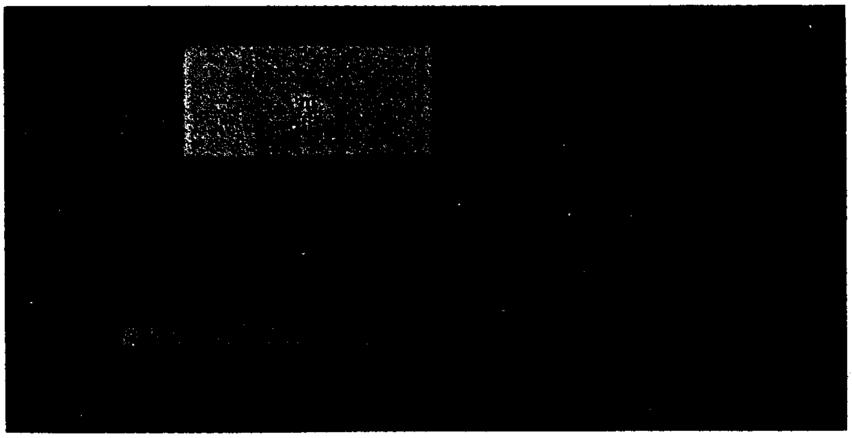
$\xi = c/(2\mathrm{sqrt}(kM))$ - damping ratio

Ω - oscillating frequency of mass m

$\omega = \mathrm{sqrt}(k/M) = 2\pi f$ - oscillating (natural) frequency (eigenfrequncy) of mass M



Once an estimate of the stiffness and the damping of the system is obtained, the transmisability of an excitation from the ground to the system can be obtained by considering the vibrational response of a mechanical system to the vibrations of its basement:



General formula for system's dynamics:

$$mx'' + cx' + kx = cX' + kX$$

General formula for the response of the system:

$$-m\Omega^2 x\sin(\Omega t-\Phi)+c\Omega x\cos(\Omega t-\Phi)+kx\sin(\Omega t-\Phi)=cX\Omega\cos(\Omega t)+kX\sin(\Omega t)$$

or, after the necessary transformations:

$$x/X = \sqrt{1+(2\xi\Omega/\omega)^2}/\sqrt{(1-(\Omega/\omega)^2)^2+(2\xi\Omega/\omega)^2}$$ - transmisibility equation

where:

$\xi = c/(2\sqrt{km})$ - damping ratio

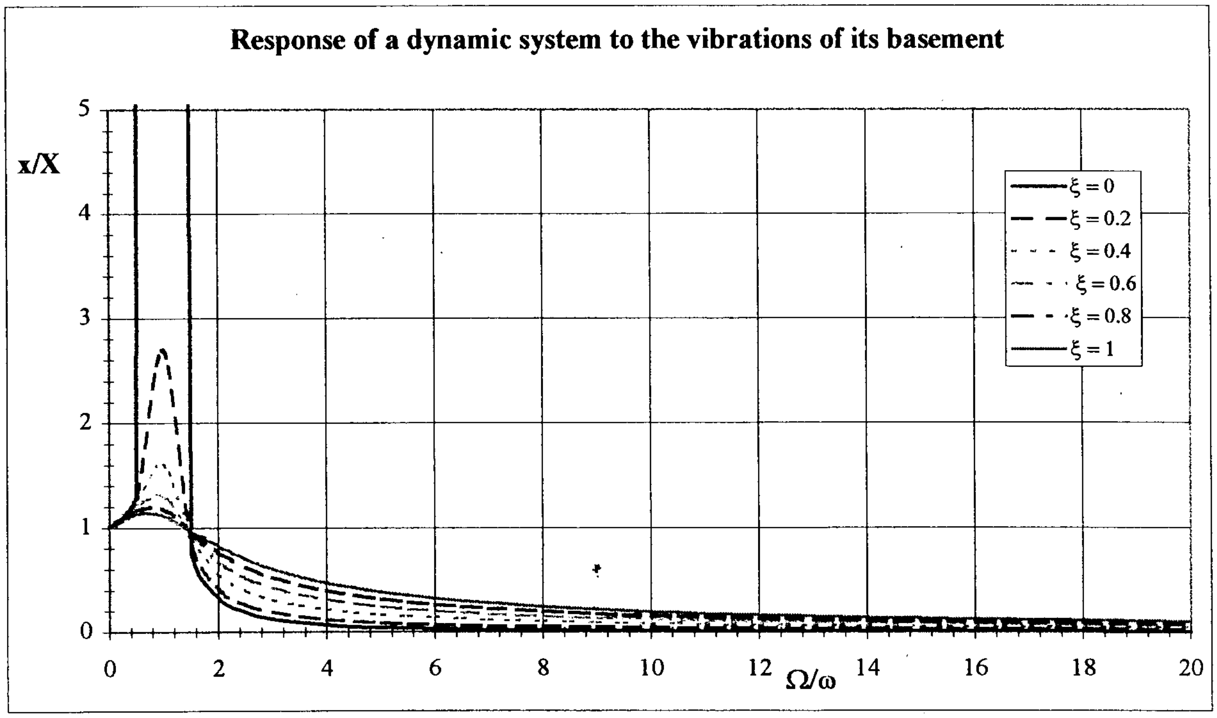
Ω - oscillating frequency of the support

$\omega = \sqrt{k/m} = 2\pi f$ - oscillating (natural) frequency (eigenfrequncy) of mass m

It can be shown that this response is identical to the ratio of the force that is transmitted to the sourroundings to an exciting force acting on the mechanical system under consideration.

Phase angle between the two oscillations:

$$\tan\Phi = (c\Omega x - c\Omega X\cos\Phi)/(kx - kX\cos\Phi)$$



Response of a dynamic system to the vibrations of its basement

For $\Omega = \omega$ (resonance) => $x/X = \sqrt{1+(2\xi)^2}/(2\xi)$

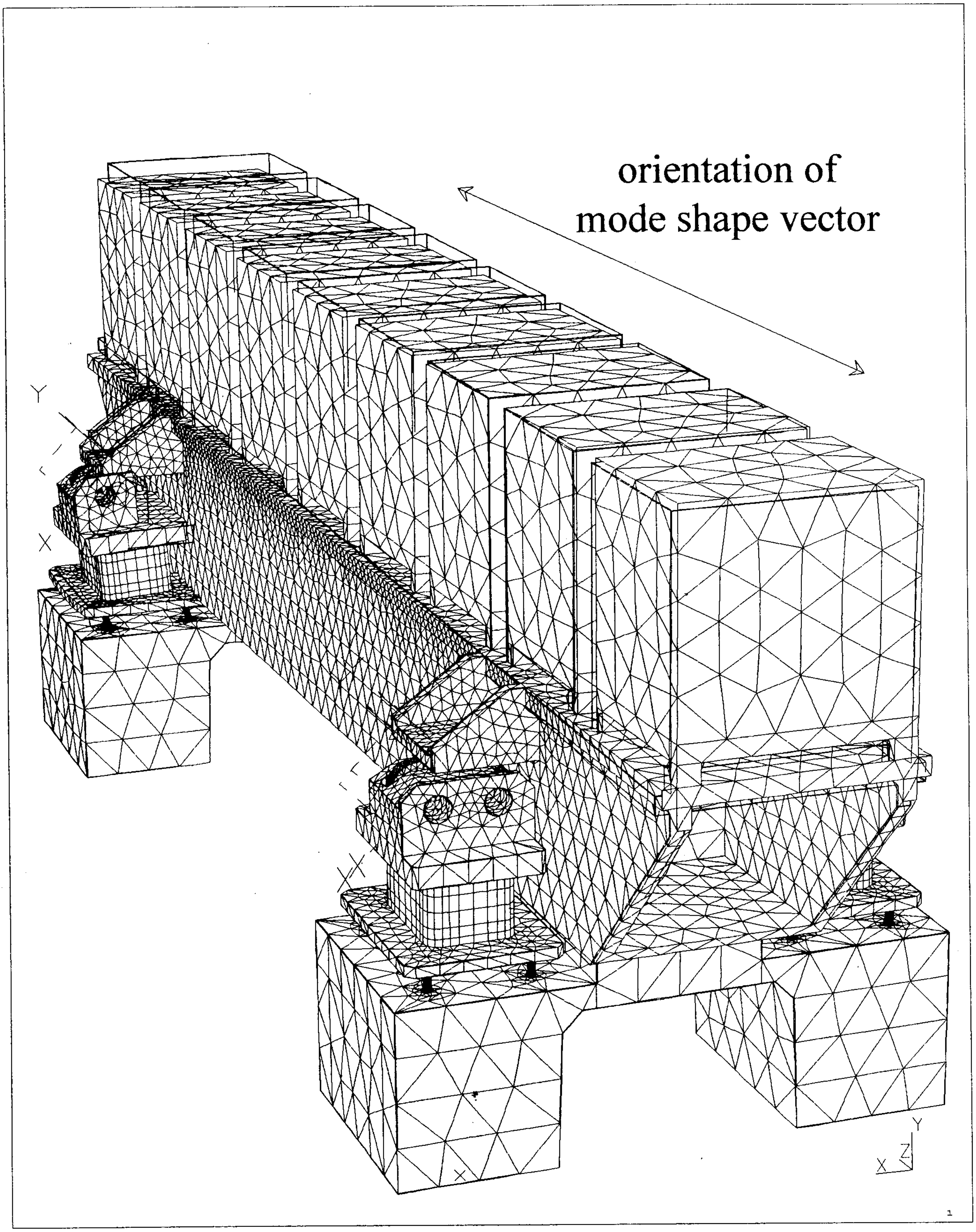
SUMMARY OF THE EXPERIMENTAL RESULTS AND COMPARISON WITH FEM CALCULATIONS:

Experimental results:

5 CONTACT POINTS WITHOUT FILLING						
Eigenfrequncy (Hz) and direction in which it is seen	xM/(me) in main direction	ξ - average at the most prominent peaks	c (Ns/m) - average at the most prominent peaks	k (N/m) - average at the most prominent peaks	Worst case amplitude vs. excitation force at girder ratio (nm/N)	Calculated transmisibility (μm incoming from the environment/μm at the girder)
12.4 - z	1.04	0.0645	1.8E+05	2.3E+08	70 horizontally 100 vertically	7.8
13 - z	1.56					
14.6 - x, y, z	2.1					
17 - x	6.82					
18 - y	8.98					
18.6 - y (z, x)	12.01					
21.6 - x (z)	2.29					
29.8 - x (y)	7.7					
33.4 - z (y)	7.64					
38.8 - z	4.88					

5 CONTACT POINTS WITH FILLING						
Eigenfrequncy (Hz) and direction in which it is seen	xM/(me) in main direction	ξ - average at the most prominent peaks	c (Ns/m) - average at the most prominent peaks	k (N/m) - average at the most prominent peaks	Worst case amplitude vs. excitation force at girder ratio (nm/N)	Calculated transmisibility (μm incoming from the environment/μm at the girder)
16 - x	1.3	0.0815	2.2E+05	2.4E+08	50 horizontally 52 vertically	6.2
17.8 - x, y (z)	5.6					
21 - y (x, z)	5.5					
23.8 - y (x, z)	7.26					
27.8 - z	1.31					
33.2 - x	4					
36 - y (z)	7.1					
40.6 - z	3.42					
49.4 - z	2.15					

6 CONTACT POINTS WITHOUT FILLING						
Eigenfrequncy (Hz) and direction in which it is seen	xM/(me) in main direction	ξ - average at the most prominent peaks	c (Ns/m) - average at the most prominent peaks	k (N/m) - average at the most prominent peaks	Worst case amplitude vs. excitation force at girder ratio (nm/N)	Calculated transmisibility (μm incoming from the environment/μm at the girder)
13.8 - z	1	0.0783	1.9E+05	2.0E+08	55 horizontally 32 vertically	6.5
14.4 - x, z	1.7					
15.4 - x	2.11					
17.4 - x (y, z)	5.6					
18.6 - x	4.42					
19.2 - z	1.54					
20.8 - x (z)	2.71					
21.6 - y	5.2					
26.6 - z	1.17					
30.8 - y (z)	10.06					
32 - x	0.92					
38.2 - y	4.63					
39.2 - z (x)	4.82					
41.6 - x	1.42					

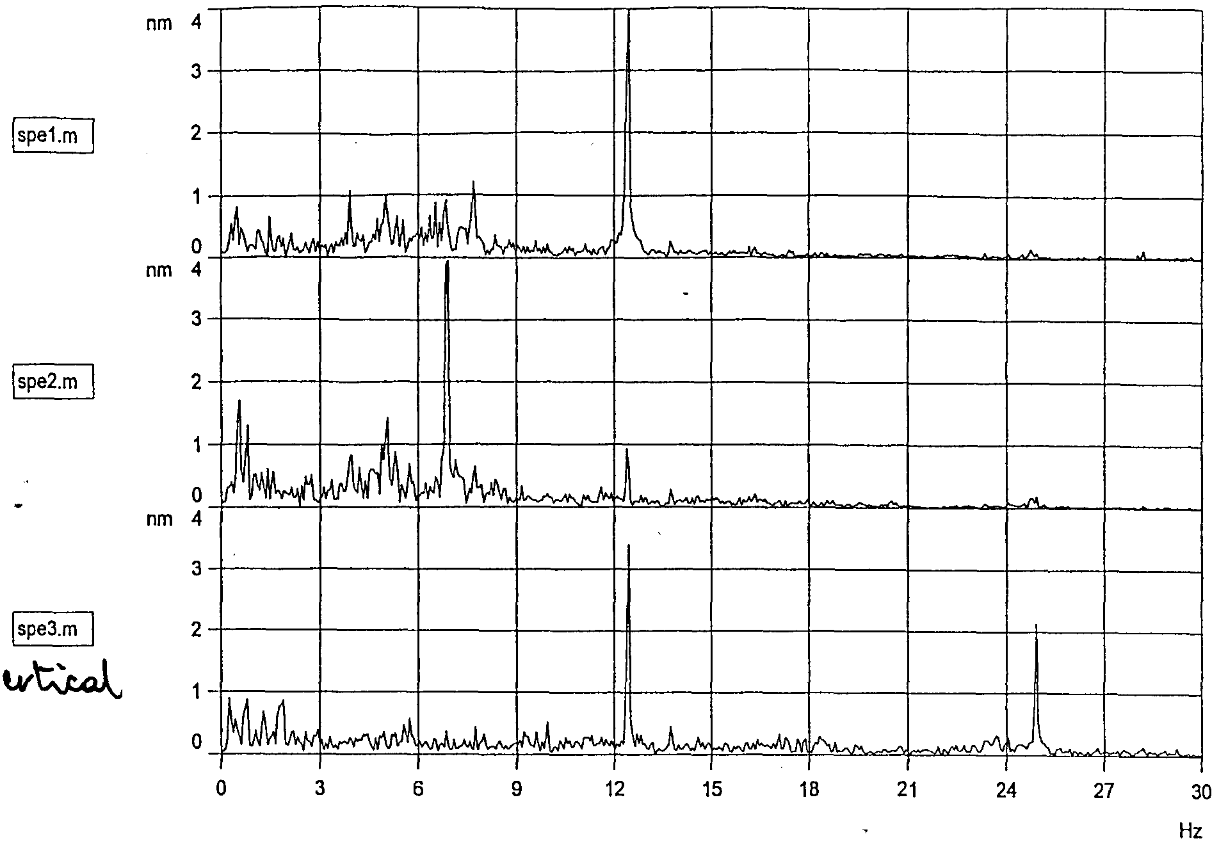


orientation of
mode shape vector

Spektren auf Ihren Wunsch Δf = 0.06 Hz

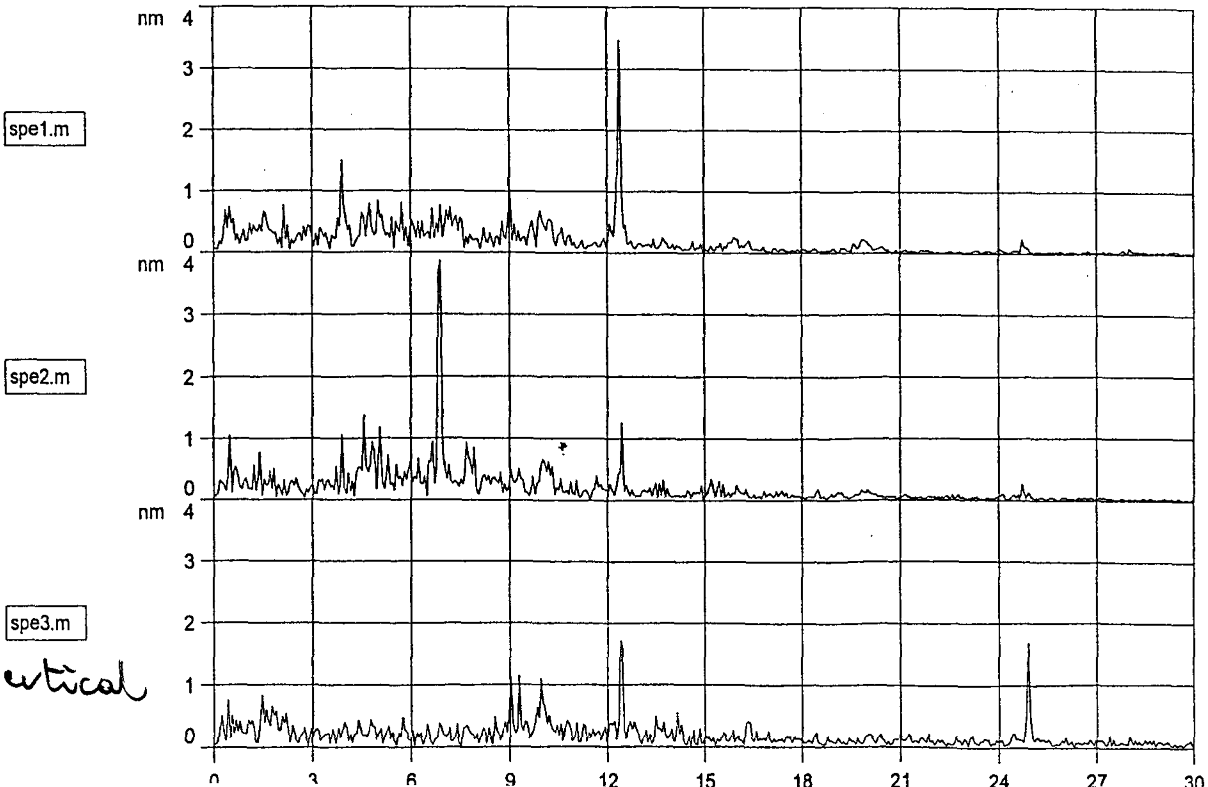
April '99

Displacement spectra - ambient vibrations



vertical

Displacement spectra - ambient vibrations + monobloc



vertical

ISMB Dietrich GmbH (D) March 2000

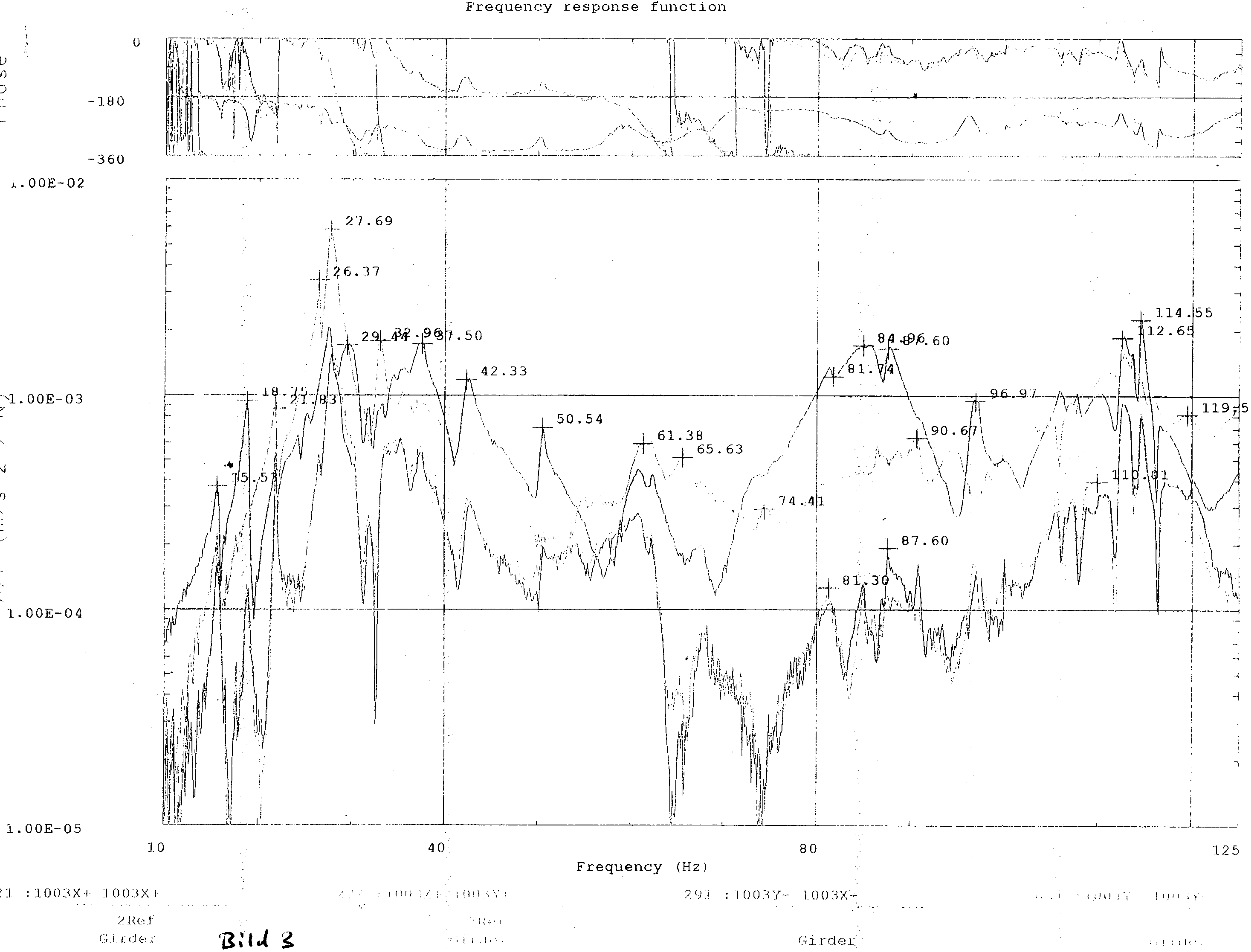
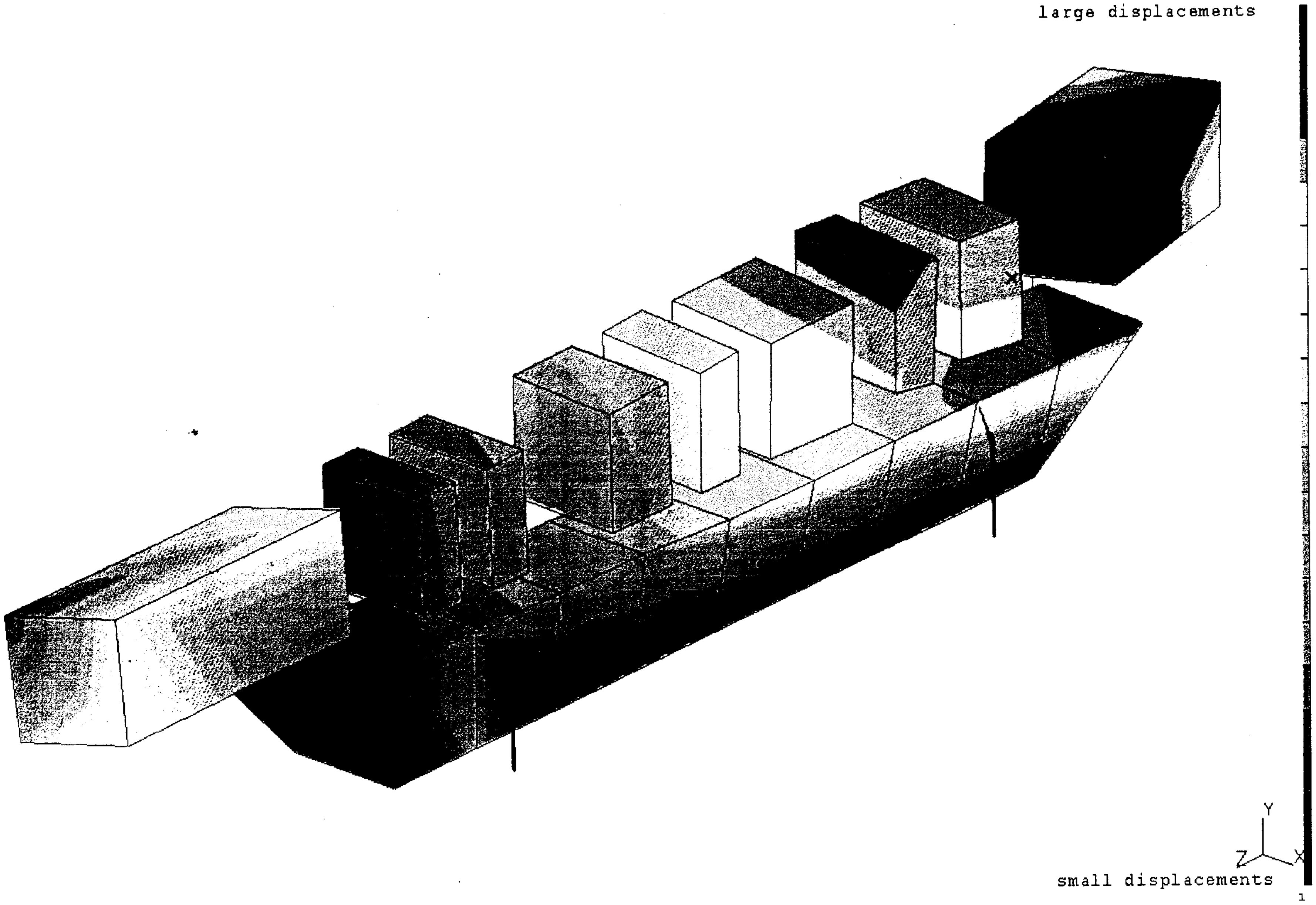


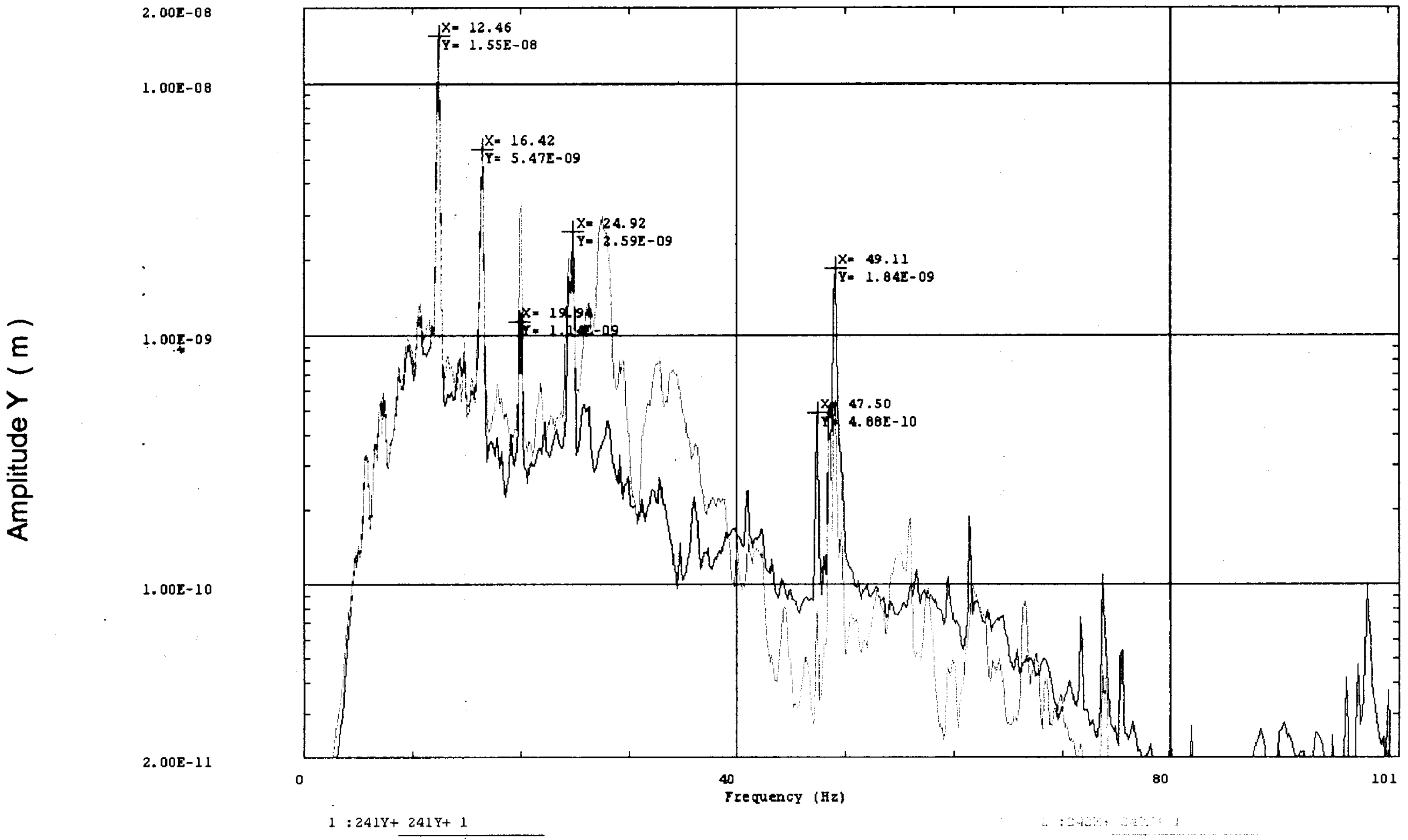
Bild 3


large displacements
small displacements
Y
Z
X
1

SLS - SR Girder, vibration tests

08.05.2000

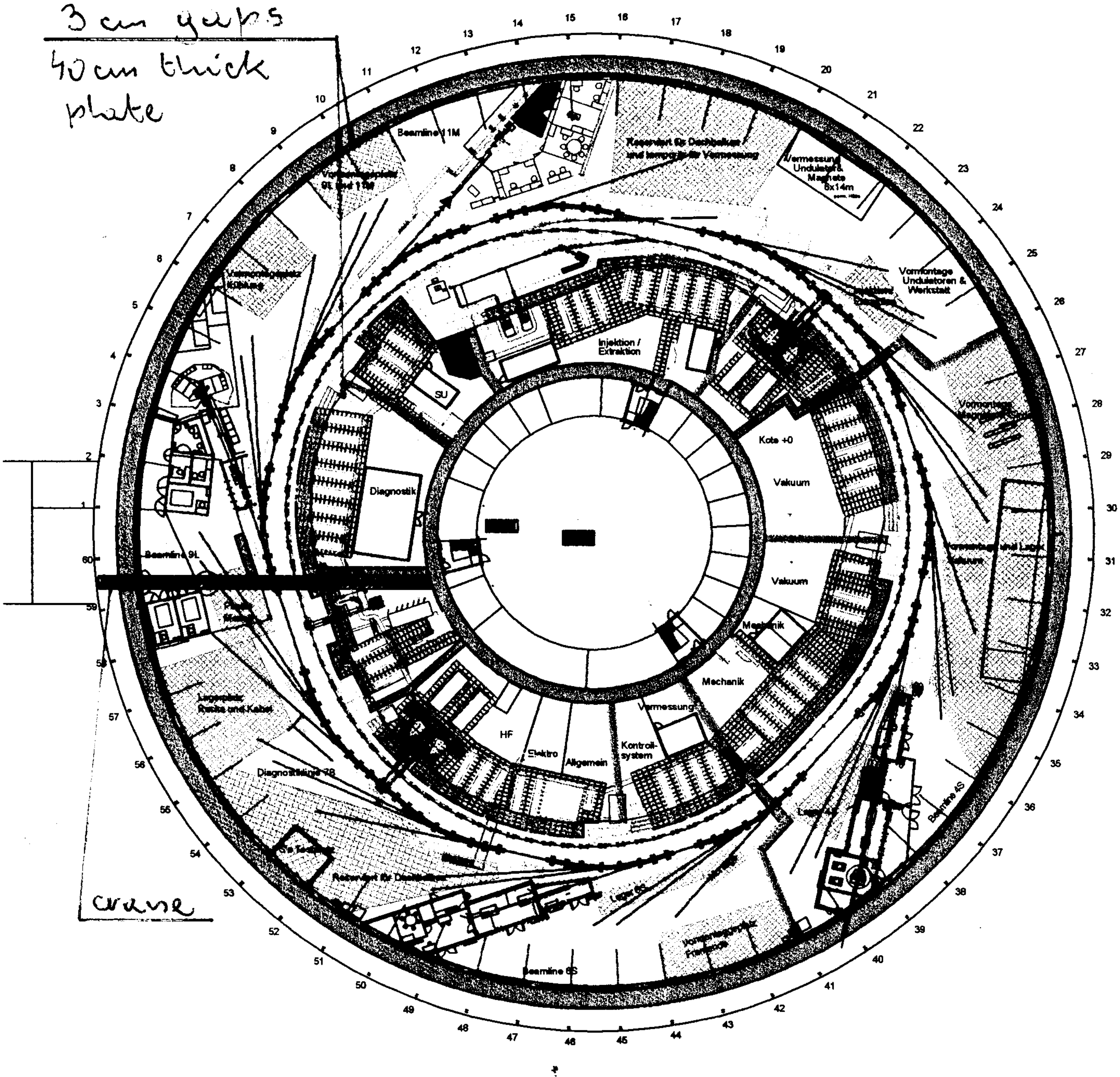
Spectrum - SLS tunnel: 'natural' noise, no add. excitation source



Meas. Point 241 : tunnel ground floor

Meas. Point 242 : girder reference surface

SLS Layout



3 cm gaps
40 cm thick plate

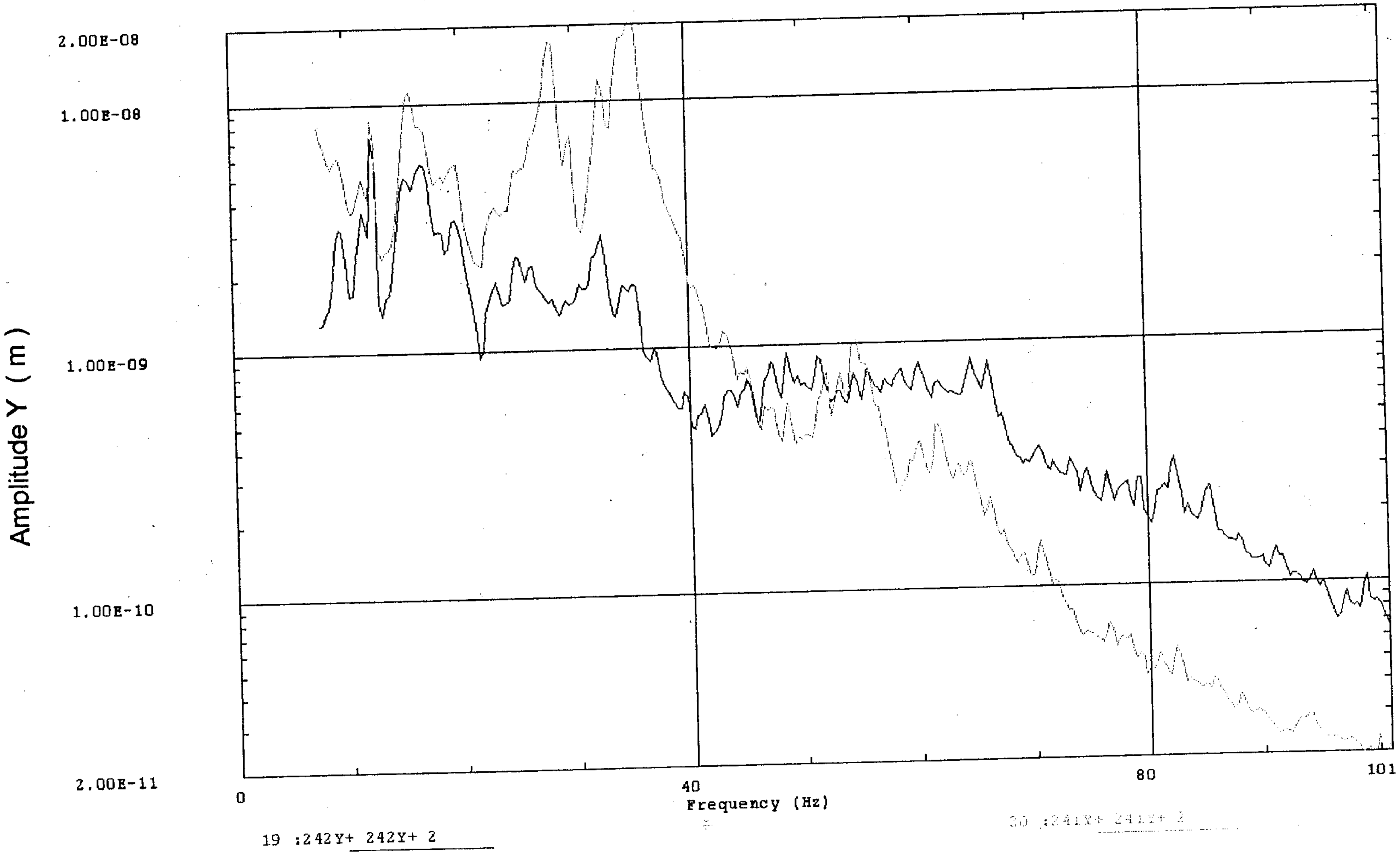
crane

Markus Lüthy
Koordination Betrieb Anlagen West 8830
Abteilung Koordination und Technik 8800

SLS - SR Girder, vibration tests

08.05.2000

Spectrum - SLS tunnel: crane operation mode



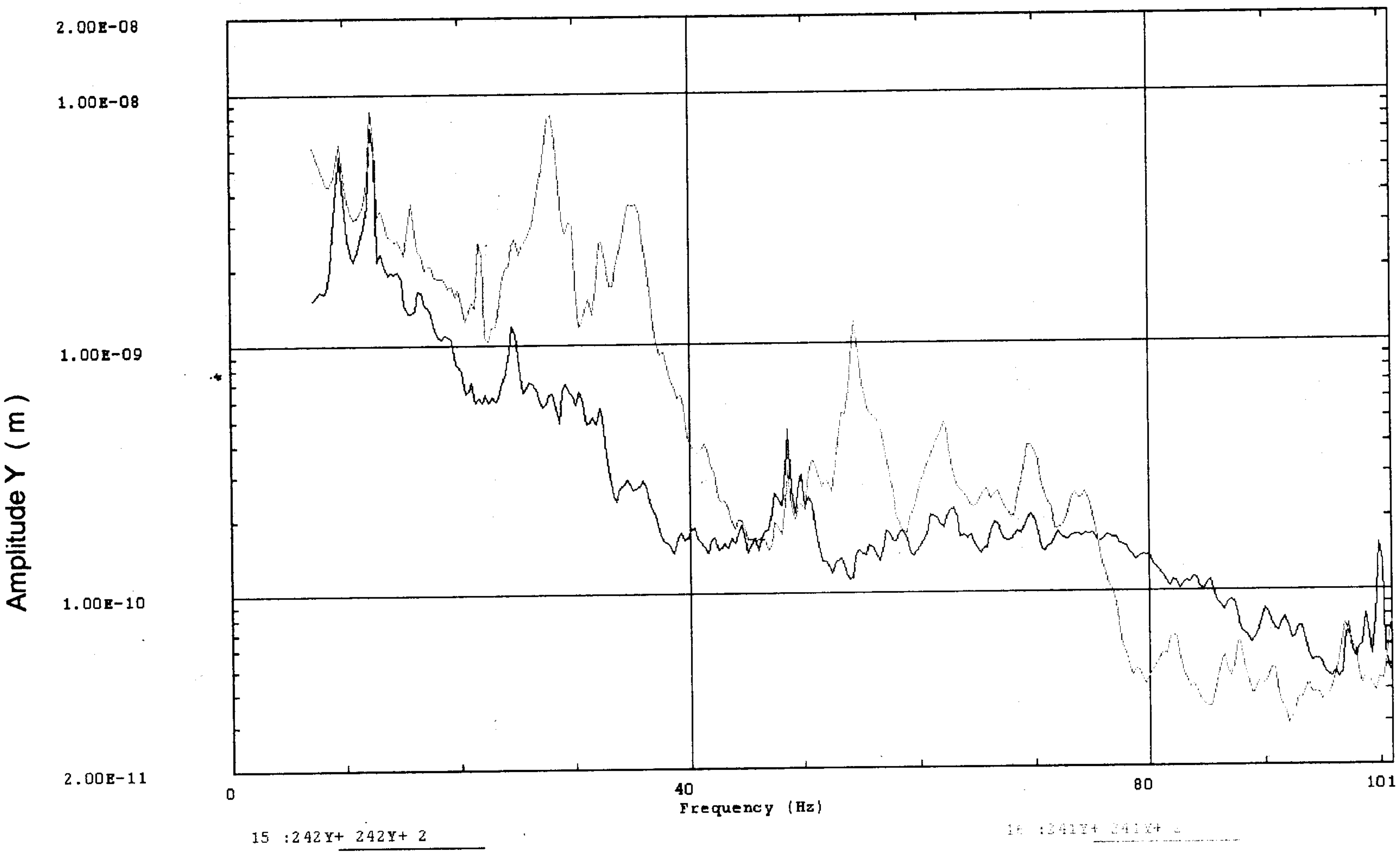
Meas. Point 242 : tunnel ground floor

Meas. Point 241 : girder reference surface

SLS - SR Girder, vibration tests

08.05.2000

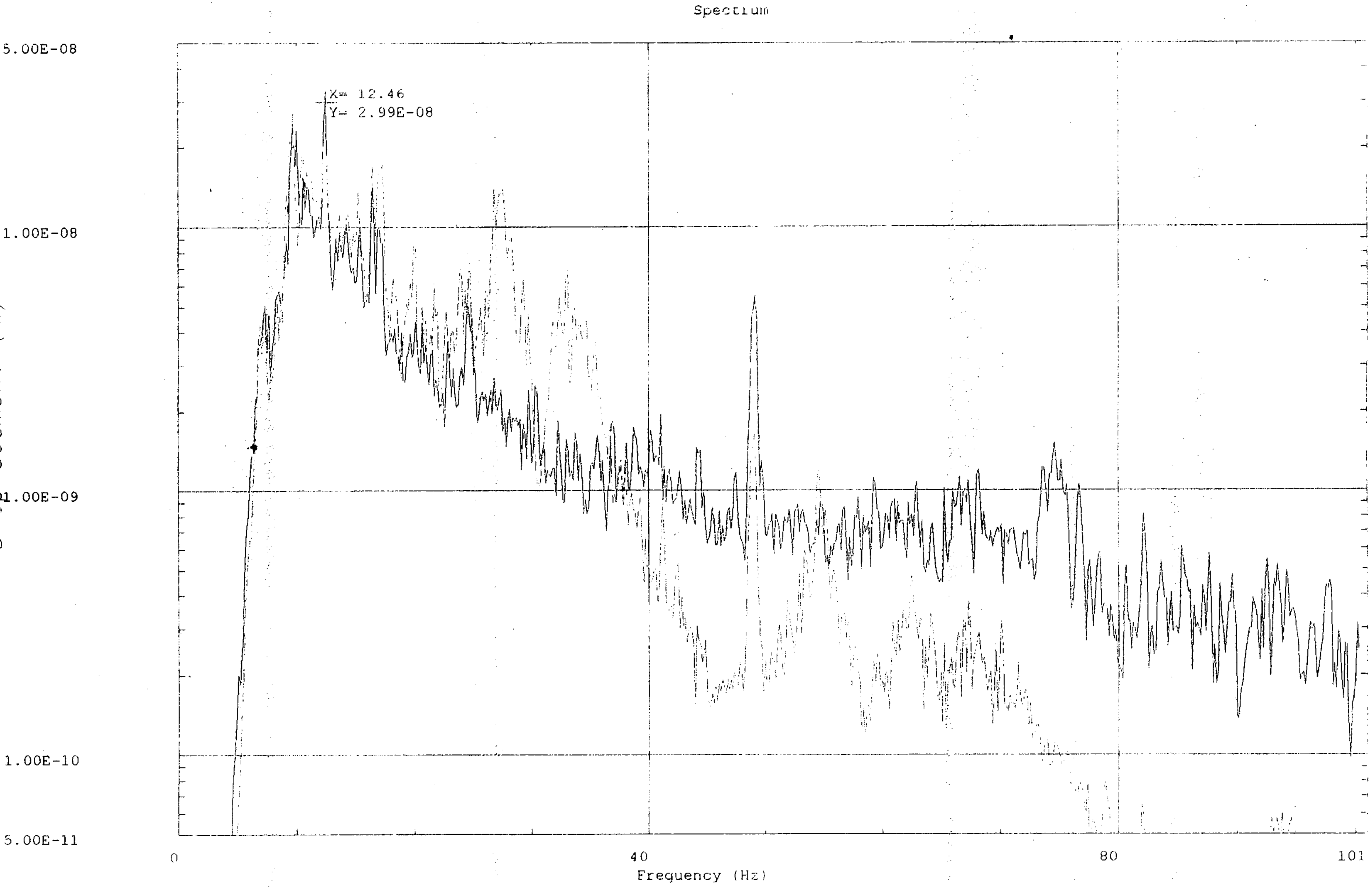
Spectrum - SLS tunnel: water operation mode



Meas. Point 242 : tunnel ground floor

Meas. Point 241 : girder reference surface

I-DEAS Master Series 7 :



7 :241Y+ 241Y+ 4
Girder, Peak Hold
31.Mar.2000-12.15 Truck

61

Some significant eigenfrequencies in the range of exitations produced by the technical devices present at and around SLS are present - especially in the 25÷40 Hz range.

The resulting amplitudes are, nevertheless, in the worst cases still in the 10÷30 nm range (TR ≤ 10), and hence an order of magnitude lower than those which would produce significant perturbations of the storage ring performances.

SLOW GROUND MOTION

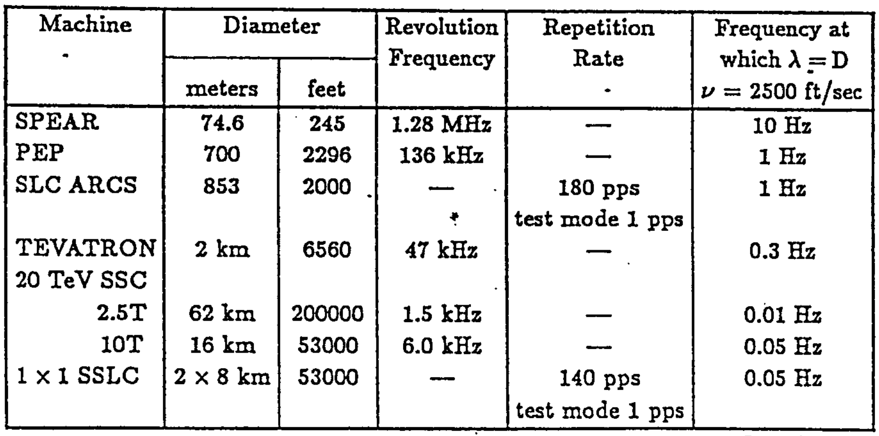
TIDAL MOTION: T ~ 12 h; has an enormous correlation length => can be neglected

MICROSEISMIC PEAK: caused by ocean waves hitting the coasts; f = 0.14 Hz, A ~ 1 µm, with λ of several tens of km i.e. large compared to betatron wavelength. Has a "2nd harmonic" caused by the generation of oppositely directed waves off shore

BANDPASS BEHAVIOUR OF THE UPPER EARTH CRUST: f ~ 2.5 Hz, λ ~ 200 m

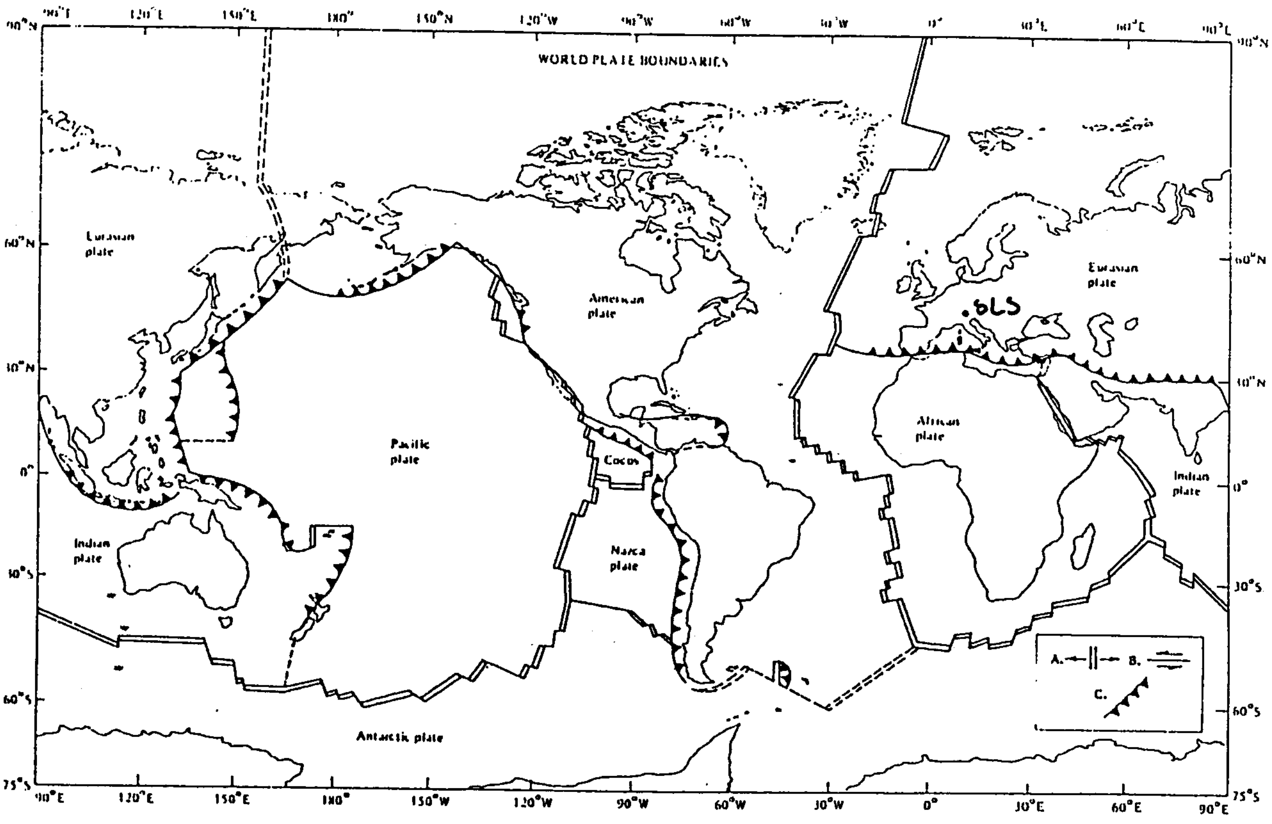
EARTHQUAKES: f ~ 0.0003 – 20 Hz, A ~ 10^{-10} – 10^{-1} m; the event rates are too low to affect daily operation and performance

Table 4.1. Diameters of Various Machine and Frequencies of Interest



Machine	Diameter		Revolution Frequency	Repetition Rate	Frequency at which $\lambda = D$ $\nu = 2500$ ft/sec
	meters	feet			
SPEAR	74.6	245	1.28 MHz	—	10 Hz
PEP	700	2296	136 kHz	—	1 Hz
SLC ARCS	853	2000	—	180 pps test mode 1 pps	1 Hz
TEVATRON	2 km	6560	47 kHz	—	0.3 Hz
20 TeV SSC					
2.5T	62 km	200000	1.5 kHz	—	0.01 Hz
10T	16 km	53000	6.0 kHz	—	0.05 Hz
1 × 1 SSLC	2 × 8 km	53000	—	140 pps test mode 1 pps	0.05 Hz
SLS	91,6	300			8 Hz (5.5 Hz @ 500 m/s)

[Fisher, 1984]

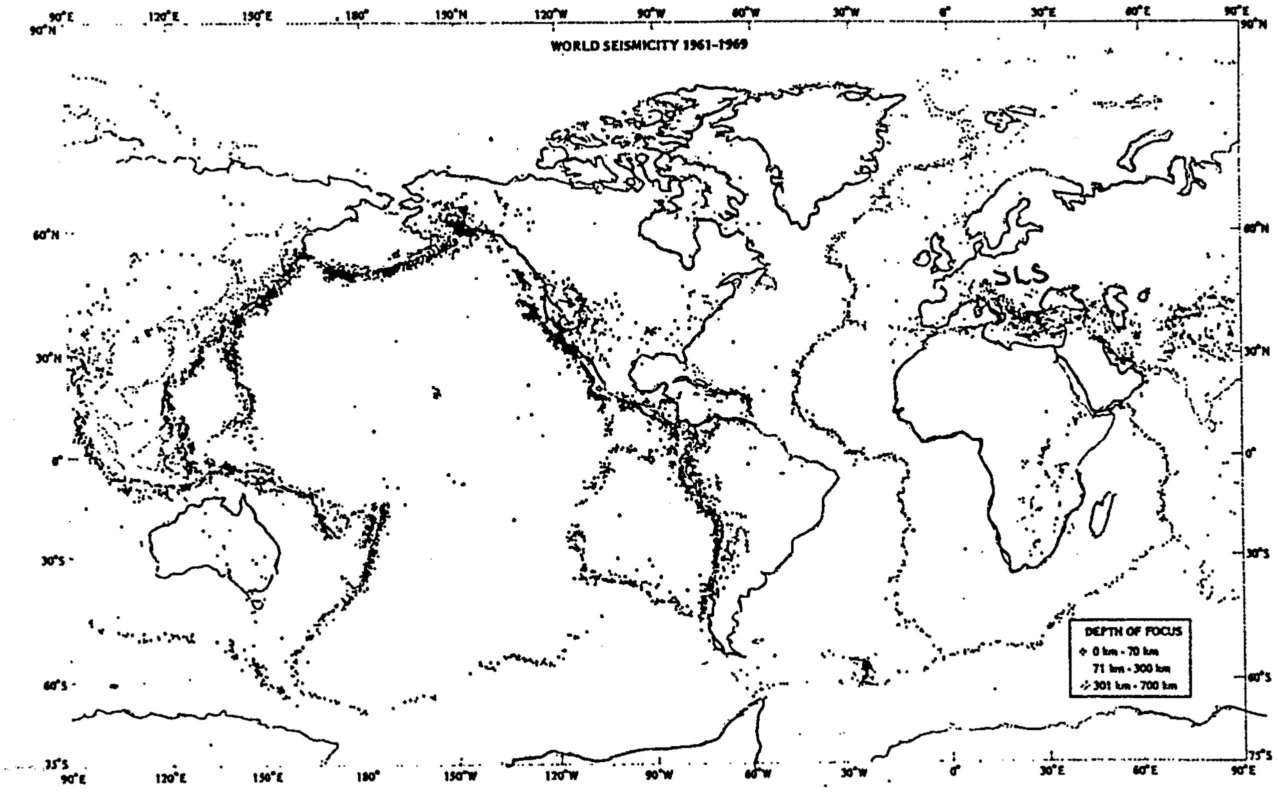


9-86

Fig. 2.3. Tectonic Plates of the Earth's Surface (from Ref. 3). See text for Key.

5163A51

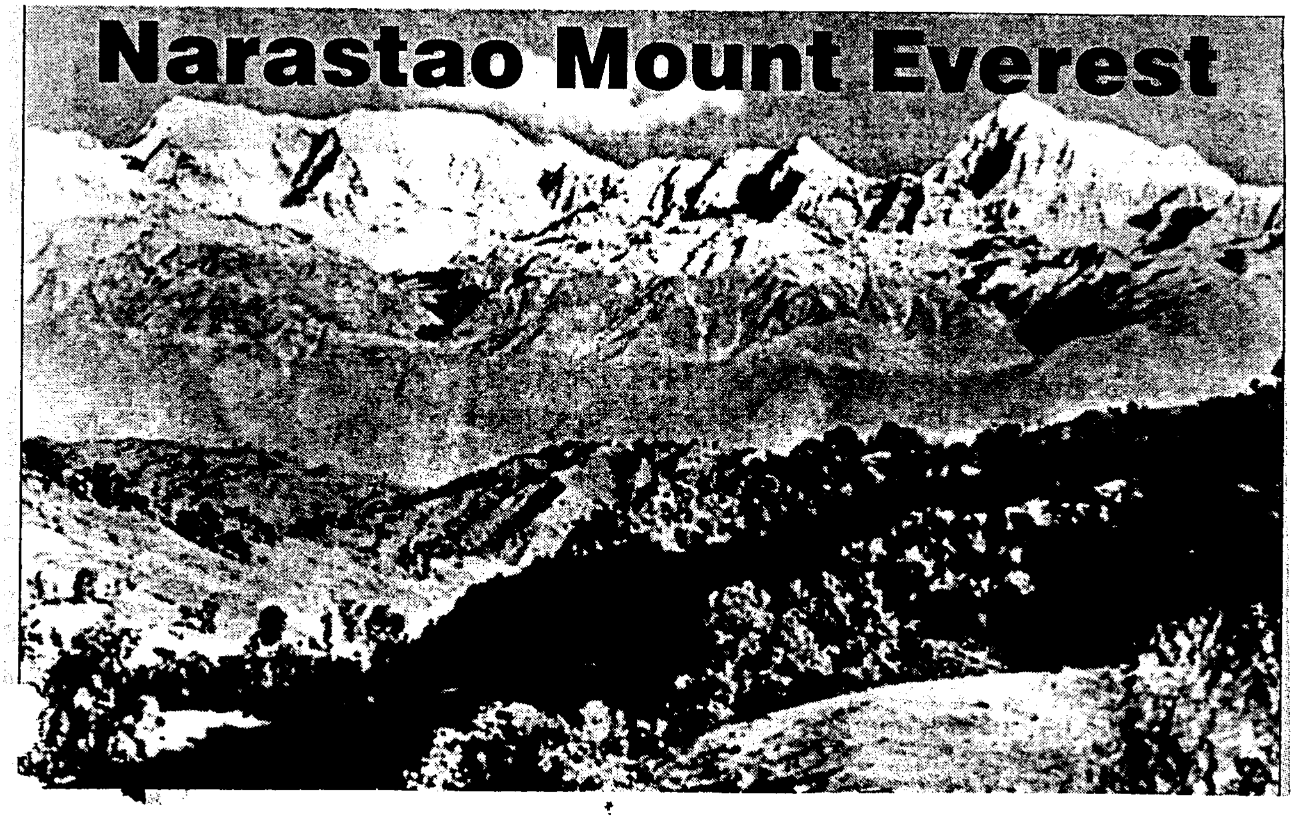
[Fischer, 1984]



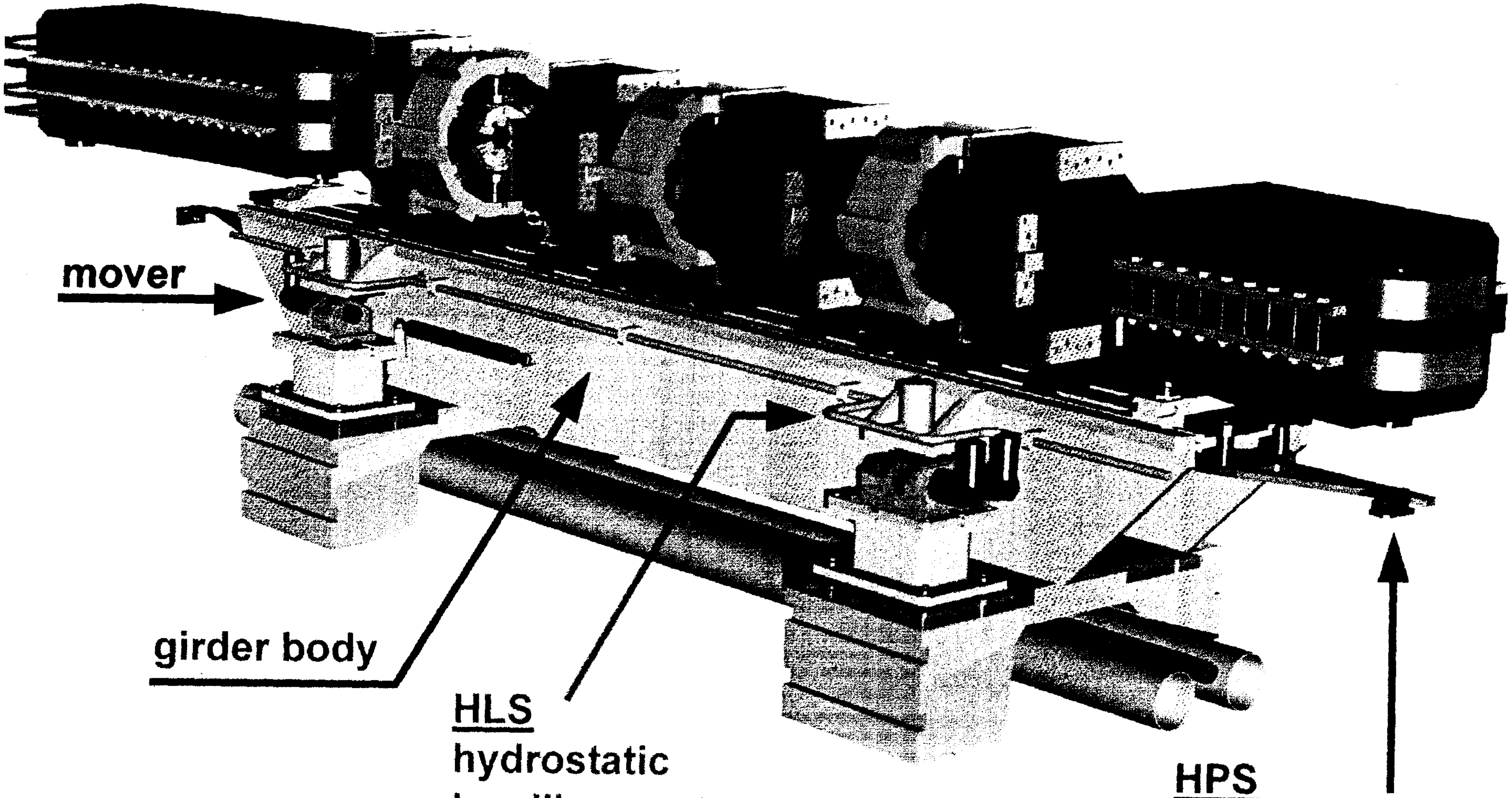
GROUND SETTLEMENT: due to seasonal variation of local ground water table, water content of the soil, compaction of fill, rebound of ground under cuts, creeping, t+p variations

SLOW GEOLOGICAL PROCESSES (systematic?):

GPS Mt. Everest measurement in 1999



Mt. Everest has grown by 2 m since last official measurement in 1954



mover

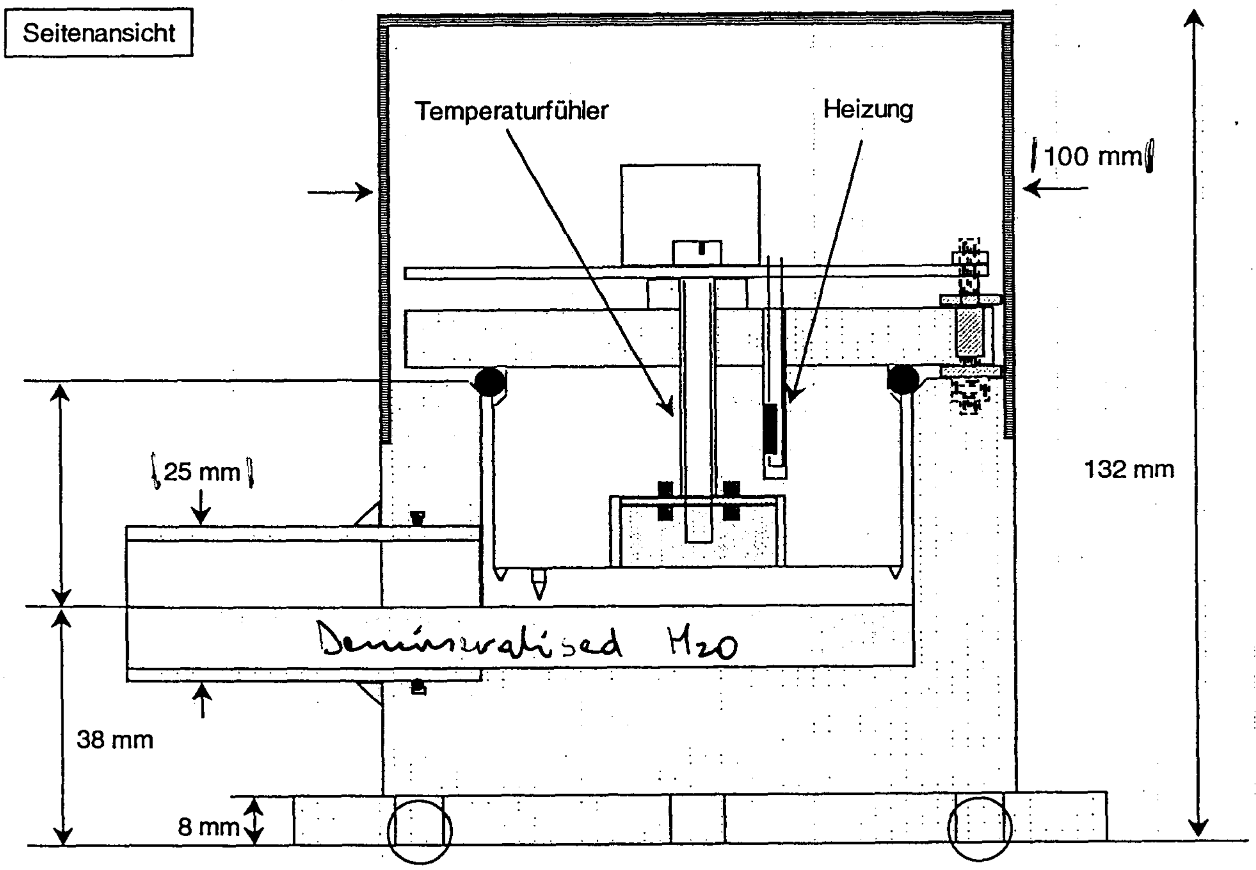
girder body

HLS
hydrostatic levelling system

HPS
horizontal positioning system

Sensor Design

capacitive proximity gauge based



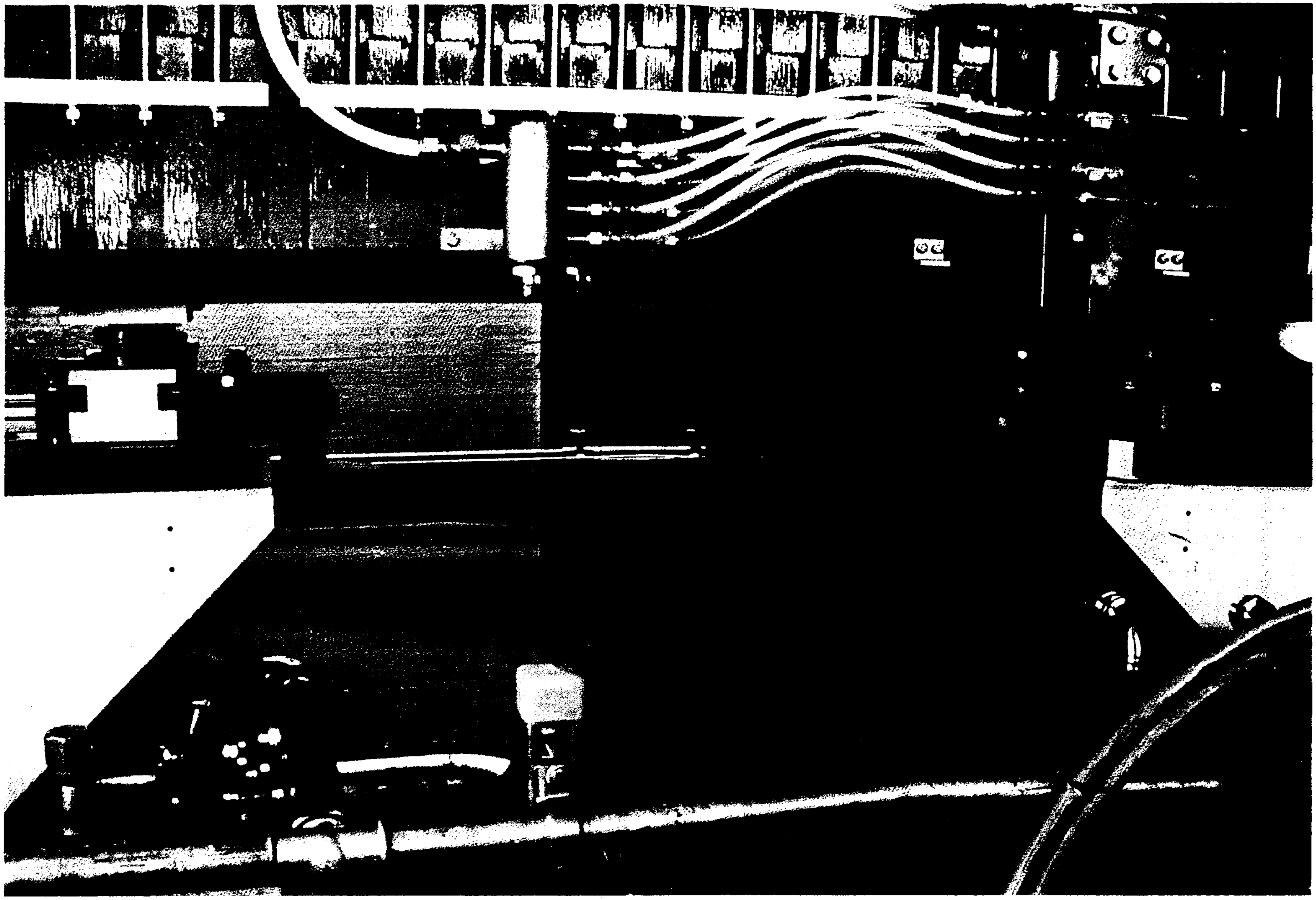
resolution ~ 2µm

range ± 2.5 mm

1 air intake

SLS - SR Girder, HPS arms with sensor

Meeting, 28.06.2000



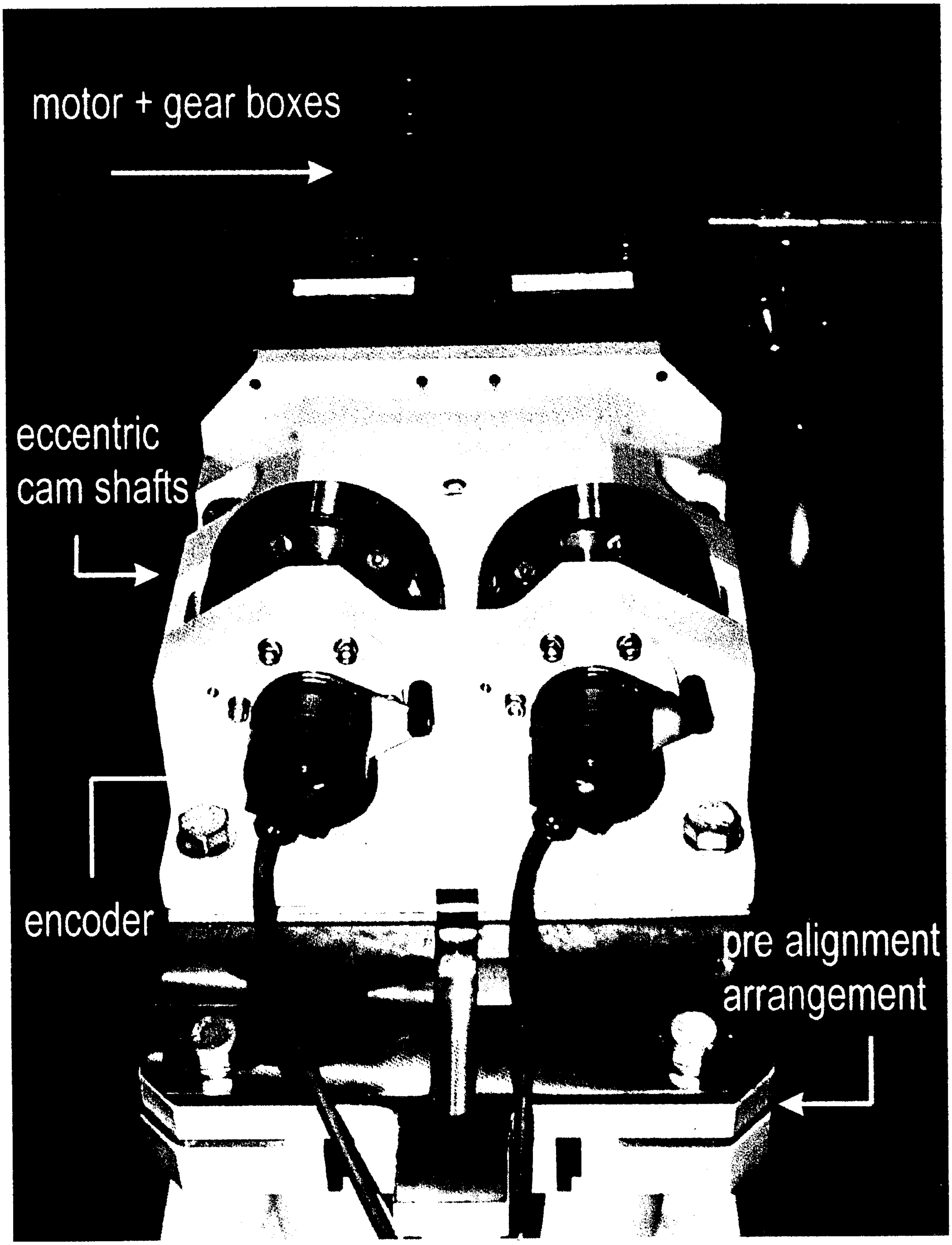
0.5 μm

[illegible]

3 0.5 um

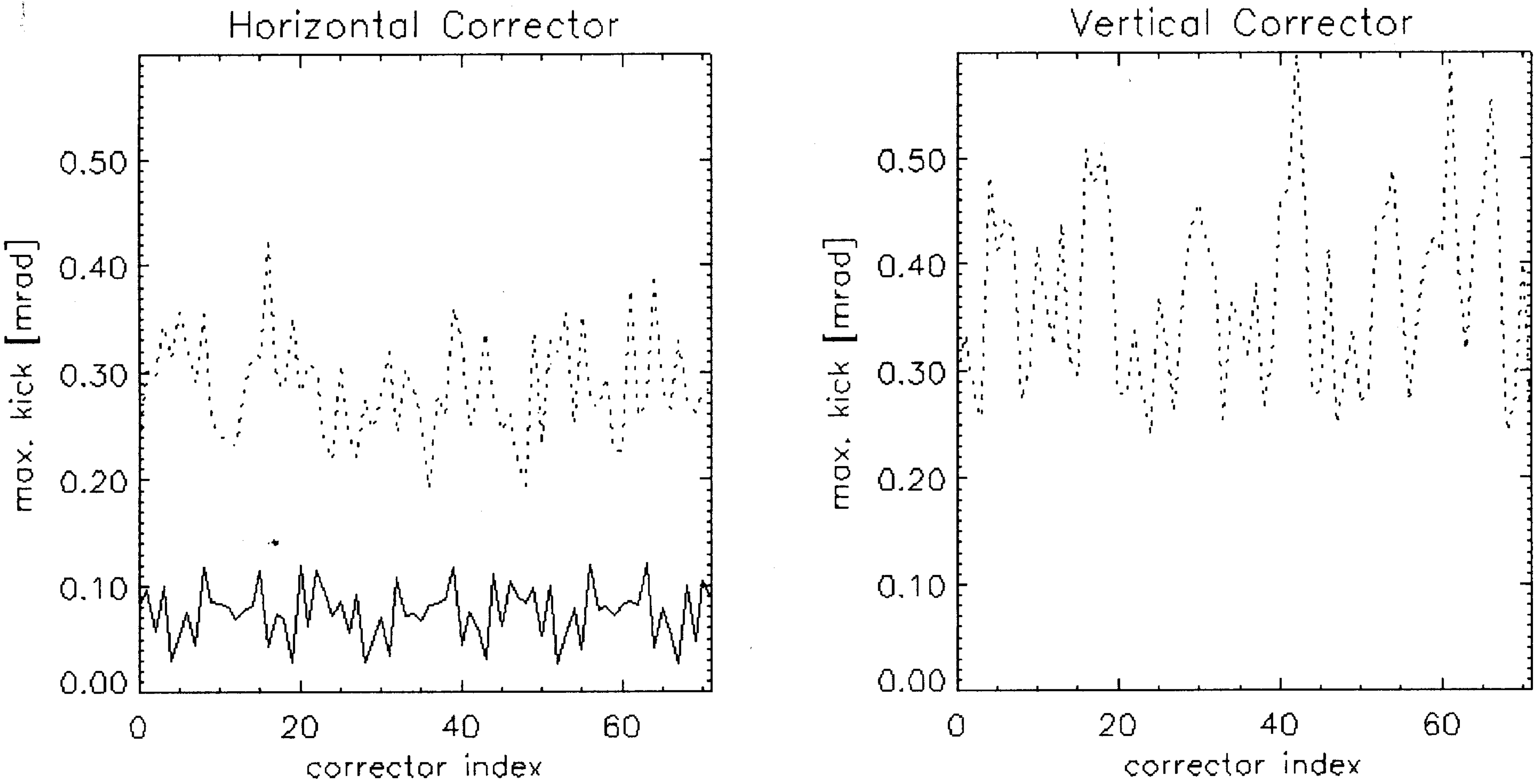
SLS - SR Girder mover system

28.06.2000



BEAM-BASED ALIGNMENT

- Beam trajectory measured by 72 BPMs; encoders monitor the positions of BPMs with respect to adjacent quadrupoles
- Obtained data can be used to remotely align the girders via the mover system (like the corrector magnets) to obtain closed orbit and even coupling correction
- **Beam-based alignment is hence obtained**
- Beam tracing simulations: all static vertical closed orbit corrections can be covered by girder alignment; horizontally: a proper selection of girders to be re-positioned allows to reduce corrector magnet strength by a factor 4 => corrector strengths can be used for dynamic correction (active orbit feedback) and local bump creation for matching the beamline acceptances or for machine studies.
- Beam-based girder alignment is a dynamic method and may be done on-line with the stored beam: it is a superior substitute for magnet sorting



orrector magnet strengths before (dashed) and after (full line) closed orbit correc-
on through girder alignment. 200 random seeds formisalignments were generated
nd corrected. The application of random errors assumed partial train links over four
rders with rms (2σ cut) displacement errors of 300 μm for the (virtual) girder
ints, 100 μm for the joint play (i.e. errors in the HPS and HLS readings) and 50 μm
r magnets and BPMs positioning tolerances relative to the surfaces of the girders.

CONCLUSIONS

GM&V PROBLEMS CAN BE EFFECTIVELY DEALTH WITH

AN INTERDISCIPLINARY APPROACH IS HOWEVER NEEDED (this Workshop is a proof of this statement)

ME CAN CONTRIBUTE IN THIS JOINT EFFORT