LIGO-G910002-00-M

LIGO PROJECT

CALIFORNIA INSTITUTE OF TECHNOLOGY

TO Distribution DATE October 14, 1991

FROM Stan Whitcomb EXT 2131 MAIL 102–33 EMAIL stan@ligo.caltech.edu

SUBJECT Preliminary Agenda for Next LIGO Monthly Review Meeting

Please contact me before October 21 if you wish to suggest changes in the agenda.

Agenda for LIGO Monthly Review of October 24, 1991
9:00 a.m., 360 West Bridge

A. Project Status (RV)
B. Review and Disposition of Pending Action Items (see Attachment 1)
C. Review of Major Tasks
  1. Interferometers
    a. 40-m prototype investigations (MZ)
    b. Fixed-mass interferometer investigations (DS)
    c. Planning future R&D on interferometer facilities (DS, MZ)
  2. Development Tasks
    a. Beam-tube demonstration (RW, FR)
    b. VTF measurements (RW, AA)
    c. 40-m lab rebuild (RS)
    d. Spectra Physics laser stabilization (AA)
    e. Mode cleaner development (AA)
    f. Auto alignment development (DS)
    g. Seismic motion measurements (LS)
  3. Optics
    a. Scattering analysis (RW, YG)
    b. Optics Simulations [GLAD V] (YG)
    c. Optics testing and development (FR)
  4. Vacuum Technology
    a. Vacuum-compatibility testing (FR)
    b. Vacuum screening (AA)
  5. Software Development
    a. General computer software (DS, YG)
    b. Laboratory computer software (YG, DS)
D. LIGO Interferometer Conceptual Design
  1. Report on "Optical Topology and Modulation" tasks (AA, DS, RS, RW)
  2. Report on "Vibration Isolation" task (LS, RW)
  3. Report on "Test Mass Suspension and Control" task (MZ, LS, SK)

Attachment 1: Action Items from Prior Reviews

Distribution:

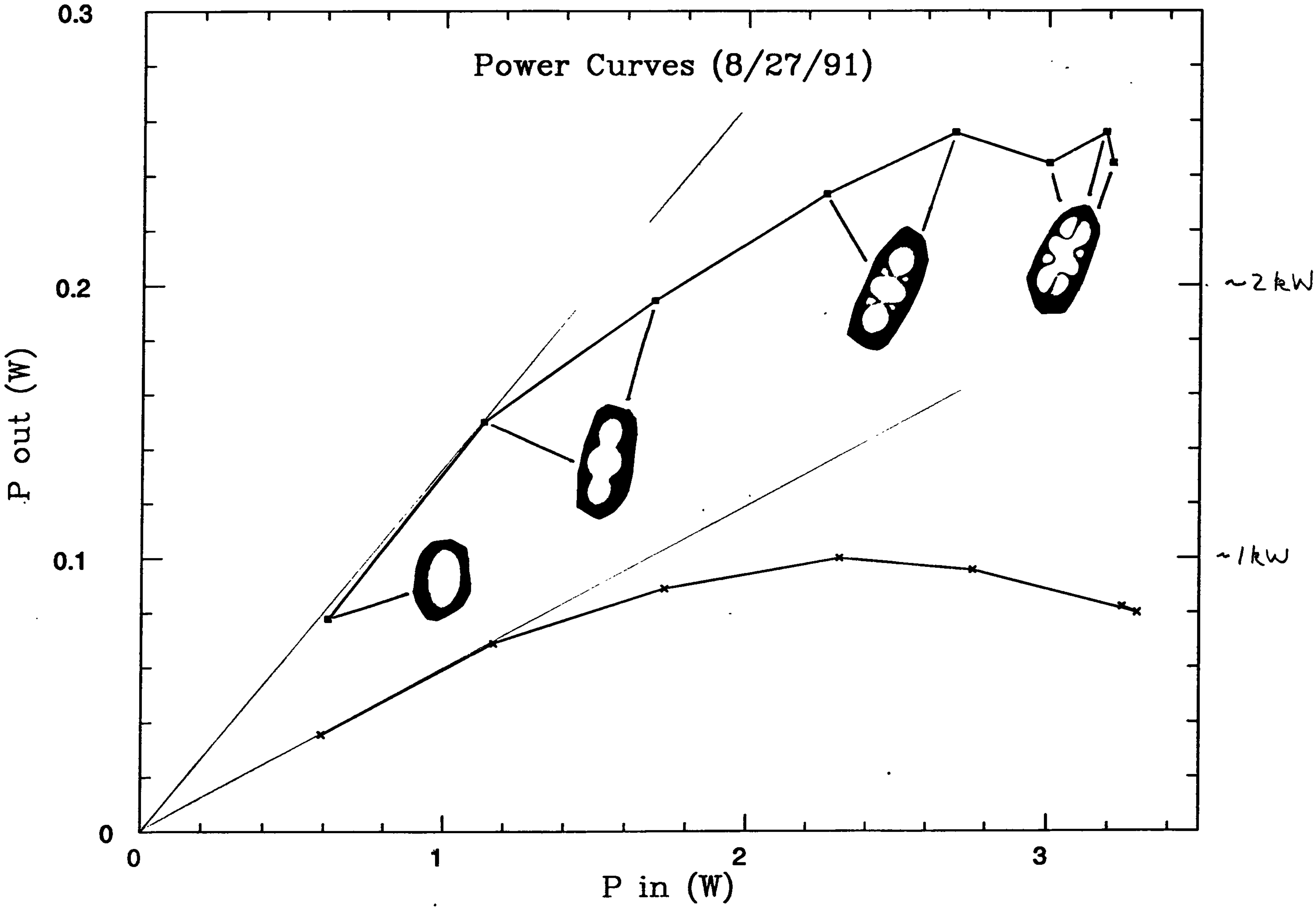
A. Abramovici	Y. Hefetz	R. Spero
C. Akutagawa (file)	S. Kawamura	K. Thorne
W. Althouse	S. Merullo (file)	R. Vogt
B. Behnke (file)	F. Raab	R. Weiss
R. Drever	D. Shoemaker	S. Whitcomb
Y. Gürsel	L. Sievers	M. Zucker

Attachment 1

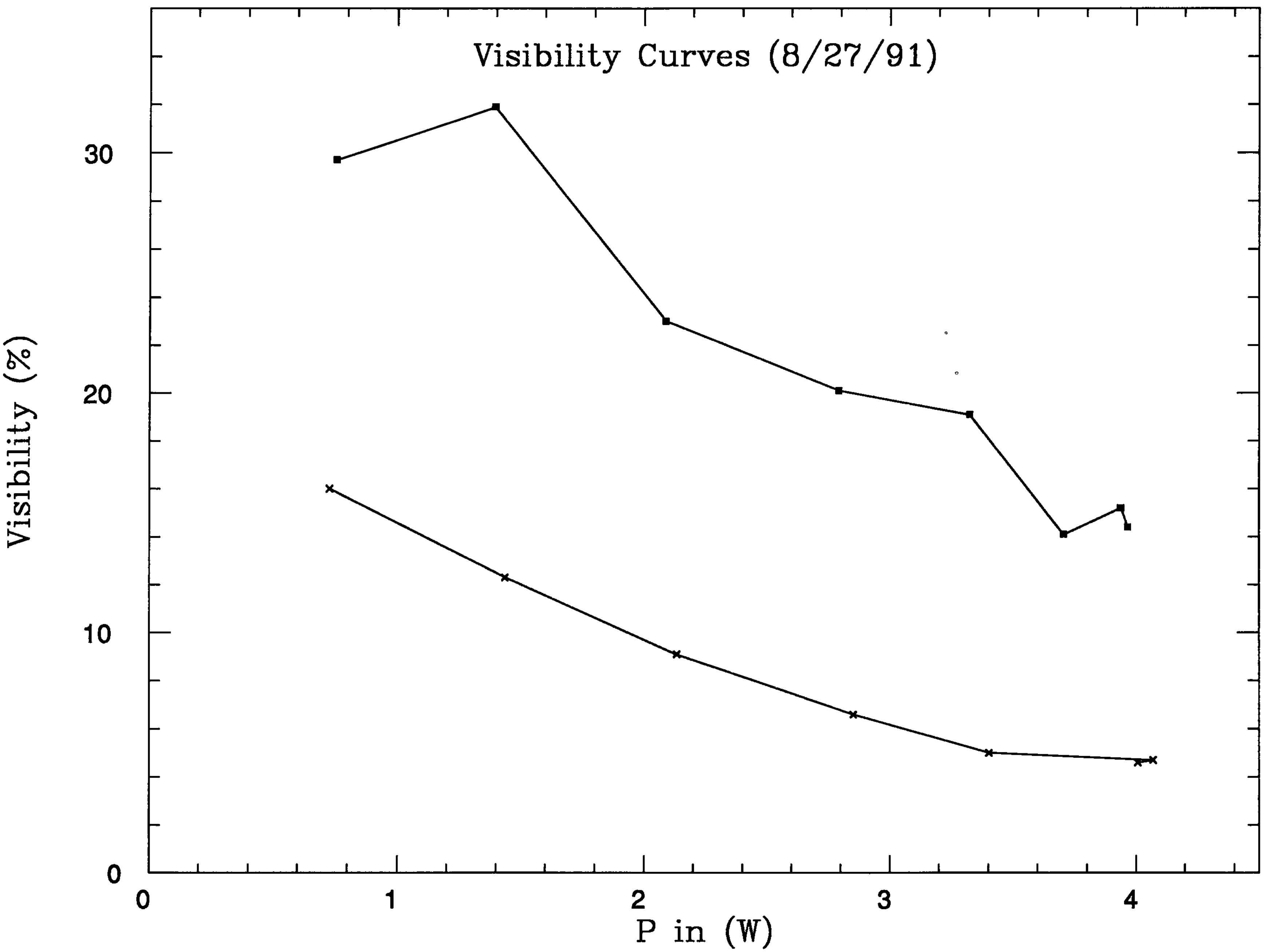
LIGO REVIEW MEETING
OPEN ACTION ITEMS

AUGUST 22, 1991

Set up a design review for the autoalignment development. **(DS)**



Power Curves (8/27/91)
P out (W)
P in (W)
0
0.1
0.2
0.3
0
1
2
3
~2kW
~1kW



Visibility Curves (8/27/91)
Visibility (%)
P in (W)
0
10
20
30
0
1
2
3
4

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LIGO MEETING SUMMARY

Attendees

A. Abramovici, W. Althouse, R. Drever, Y. Gürsel, Y. Hefetz, S. Kawamura, F. Raab, D. Shoemaker, L. Sievers, R. Spero, S. Whitcomb, R. Weiss, M. Zucker

A. Project Status

R. Vogt is recovering from a recent injury, and is unable to attend this Review. The deadline for G. Bush to sign the budget bill that includes LIGO funding is about a week away. A site evaluation panel will convene at Caltech on November 21 and 22; almost all of W. Althouse's time will be devoted to site issues in the immediate future.

B. Disposal of Action Items

The autoalignment action item remains open.

C. Review of Major Tasks

1. *Interferometers*

1. R. Weiss presented a calculation demonstrating that a measurement of suspension wire Q provides enough information for a prediction of suspension thermal noise. The suspension Q's will be measured by timing the ringdown after wire-pusher piezo excitation.
2. A large variation between test masses in coupling from vertical excitation of optical tables to interferometer output was observed. These measurements will be repeated, and similar measurements will be made for horizontal excitation.

2. *Development Tasks*

1. S. Whitcomb requested that presentations of results from the Beam Tube Demonstration include top-level plots of results of measurements.
2. One of the cavities used for the Spectra Physics laser stabilization is showing rapid degradation of mirror reflectivity.
3. Development of a separately suspended mode cleaner has been delayed by a diversion of people to the beam tube outgassing measurements. Regular meetings on the mode cleaner work with D. Shoemaker as a participant will be set up.

4. A review for autoalignment development, to include Y. Hefetz, will be set up in about a month.

3. Optics

1. Within a few weeks there will be a kickoff meeting with Breault Research to begin the scattering calculations.
2. The optics simulation work is close to being able to predict contrast for typical LIGO optical arrangements, using measurements of mirror surface imperfections.

4. Vacuum Technology

S. Whitcomb requested that A. Abramovici prepare for the next monthly review a summary of all the vacuum screening and VTF work that has gone on to date.

5. Software Development

1. There has been no progress on laboratory computer software, due to lack of personnel—particularly undergraduate programmers.
2. PV-Wave was recommended as the standard commercial program for graphical display and analysis of laboratory data.

D. Interferometer Conceptual Design

Optical topology and vibration isolation experiments continued; there was no new work on test mass suspension and control.

40m Prototype Interferometer
Progress Report
24 October, 1991

RES, MEZ

1. Instrumentation improvements
   - 18 kHz notch for "new" TM resonance (also helps cut line pulses)
   - remote TM alignment controls (75% complete)
   - very low noise custom readout filter
   - PC for disk/file translation (50% complete)
2. Seismic isolation measurements
   - vertical measurements at vertex, both ends
   - XF's different, H the "worst"
3. Low-frequency background investigations
   - effect of vertical beam translation
   - line harmonics due to wirepushing; 4 Hz sidebands
   - not really f^{-3}; appears nonstationary
   - somewhat lower late at night (below 100 Hz)

4. Low–frequency noise sources "ruled out" by tests:
   - electronic noise
   - TM orientation system noise
   - TM damping system noise (except at line frequencies)
   - laser frequency noise
   - laser intensity noise
   - RF amplitude modulation
   - "scattered light noise" (Post-it effects, beam tube motion effects)
   - seismic noise (above 100 Hz)
5. Zoom-in on 330 Hz wire resonances (H mass)
   - $Q \sim 10^4$
   - observed amplitude $\sim$ thermal excitation (!)
6. Test for stress–induced glue noise
   - applied $4\,\mathrm{mN_{p-p}}$ common mode to both end TM drive coils, 20 Hz and 100 Hz sine (natural noise $\ll 1\,\mathrm{mN_{p-p}}$ at ~ 5 Hz)
   - no increase in interferometer noise at $\sim$ 800 Hz (upper limit $\tilde{x}_{\mathrm{glue}}(f) < 1.5 \times 10^{-18}\,\mathrm{m}/\sqrt{\mathrm{Hz}}$)
7. Residual gas index fluctuation tests
   - clear signature observed for N_2, Xe, CO_2
   - excellent agreement with calculation

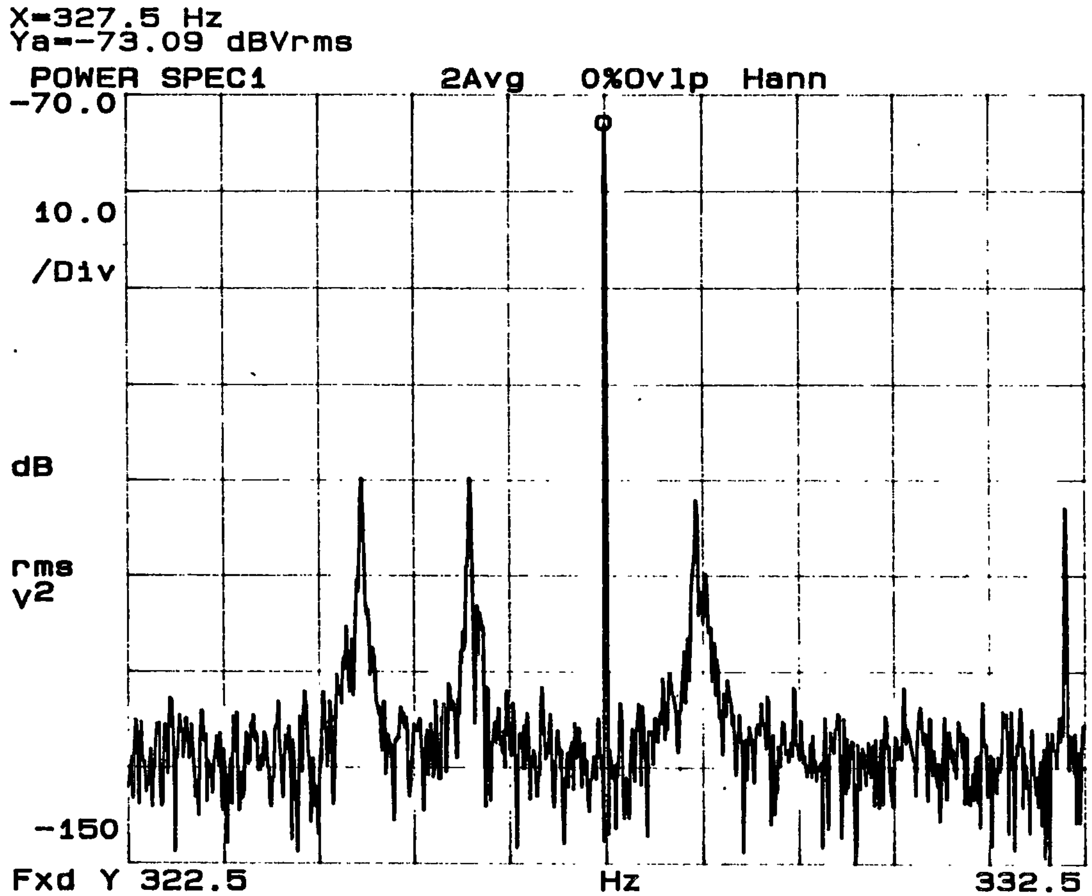
8. Planned noise investigations

- seismic isolation
  - completion of total isolation tests
  - factor out acoustic coupling
  - return to suspension characterization
- beamsplitter control system noise check
- nonlinear intensity noise analysis (bilinear model?)
- increase/redistribute secondary cavity LF servo gain
- investigate test mass internal Q problem (?)
- seismic upconversion tests
- nonlinear intensity noise analysis (bilinear model?)
- RFAM and splitter tests

9. Planned instrumentation changes

- power stabilizer upgrade
- secondary cavity servo
  - comprehensive computer model
  - better SNR greater range of P, V
  - more dynamic reserve
  - more LF gain
- cover on laser table
- turbopump interlock upgrade

11 Oct 91
15:46

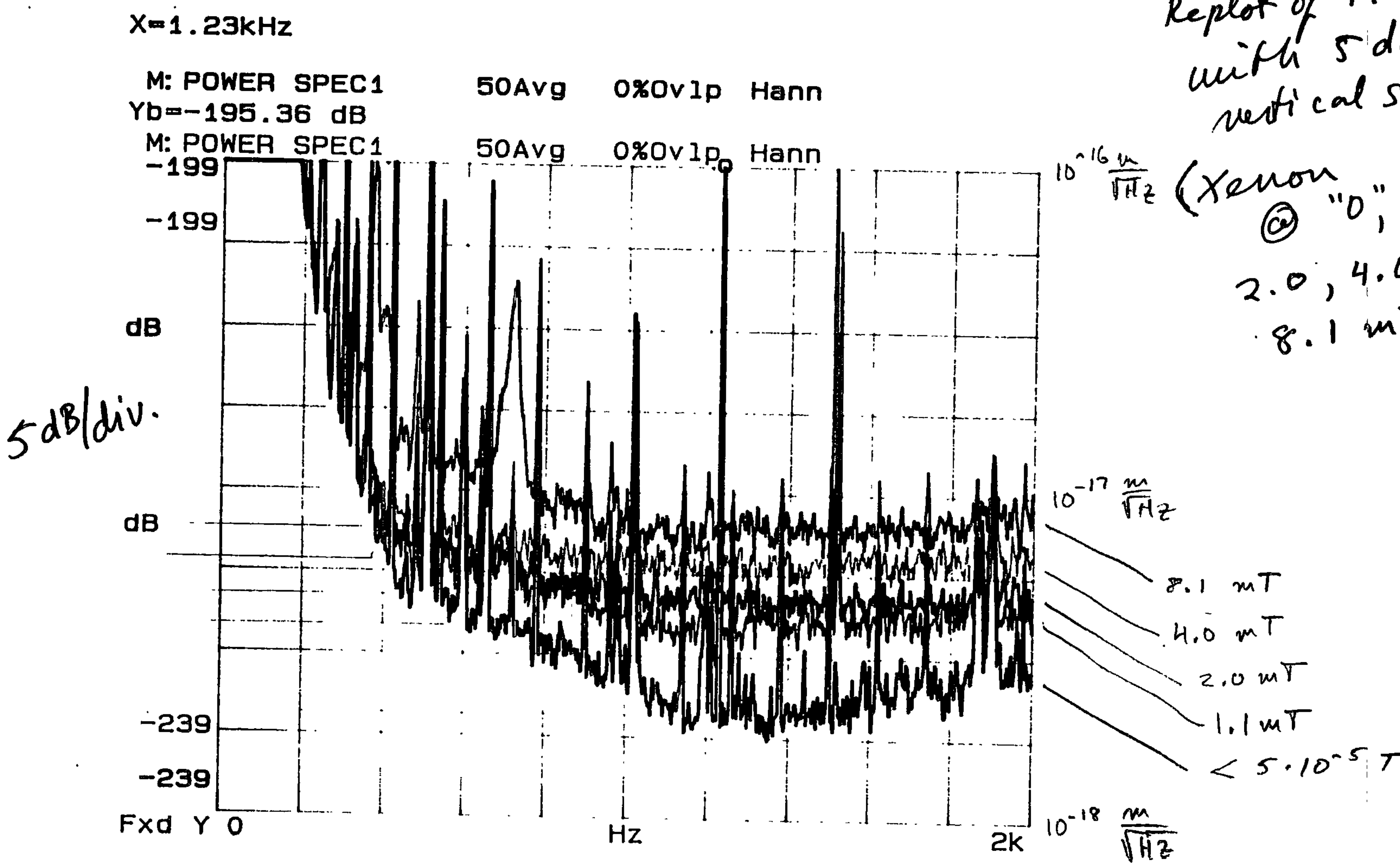


File HWA1

ZOOM-IN ON H WIRE RESONANCES
(UNCALIBRATED STRAIN SIGNAL)

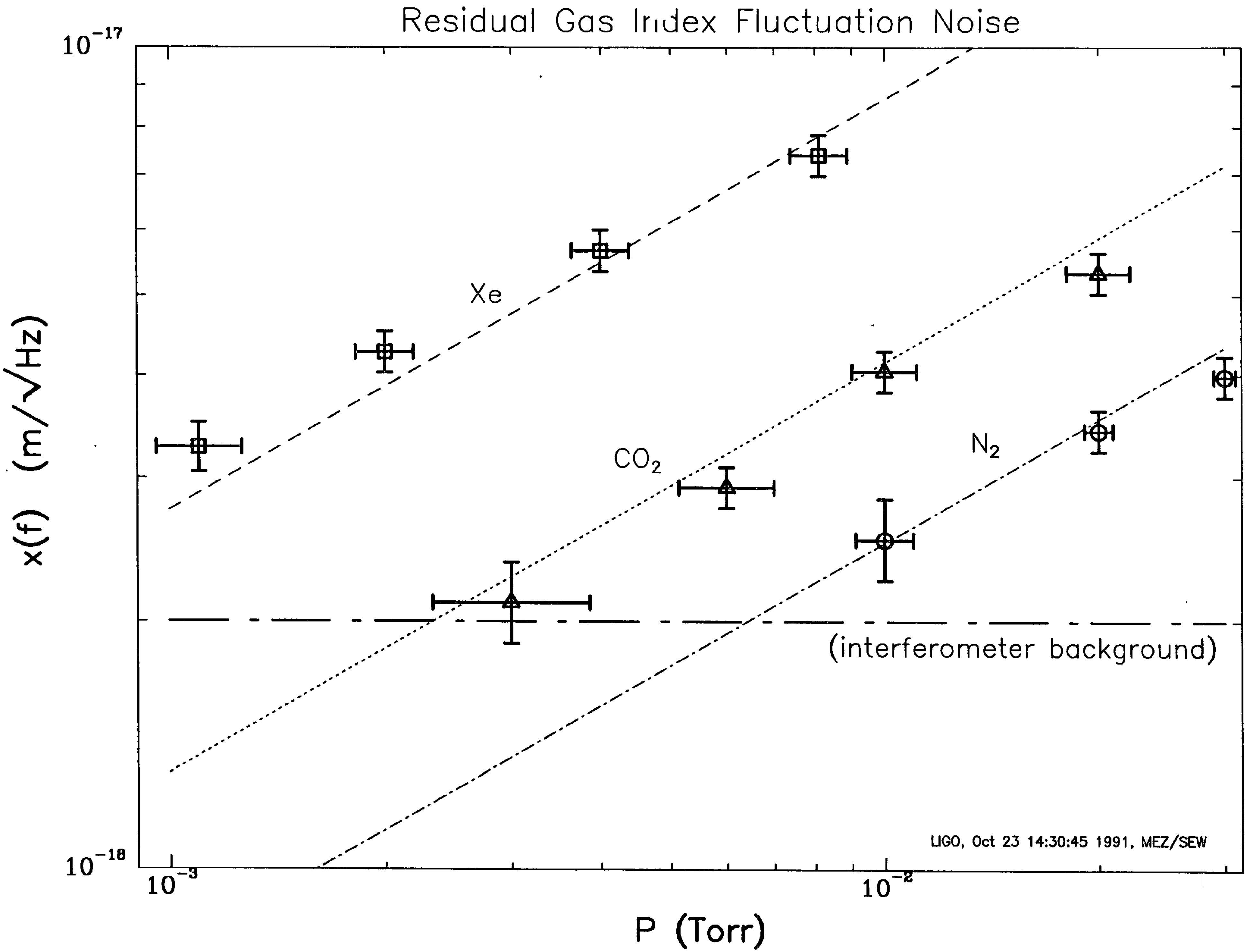
C1a.4

10/17/91
19:52
Replot of 19:40
with 5 dB/div
vertical scale



(Xenon @ "0", 1.1, 2.0, 4.0 and 8.1 mT)

INTERFEROMETER DISPLACEMENT NOISE WITH NORMAL VACUUM AND FOUR DIFFERENT PRESSURES OF XENON GAS ADMITTED


Residual Gas Index Fluctuation Noise
10^{-17}
10^{-18}
x(f) (m/√Hz)
Xe
CO_2
N_2
(interferometer background)
LIGO, Oct 23 14:30:45 1991, MEZ/SEW
10^{-3}
10^{-2}
P (Torr)

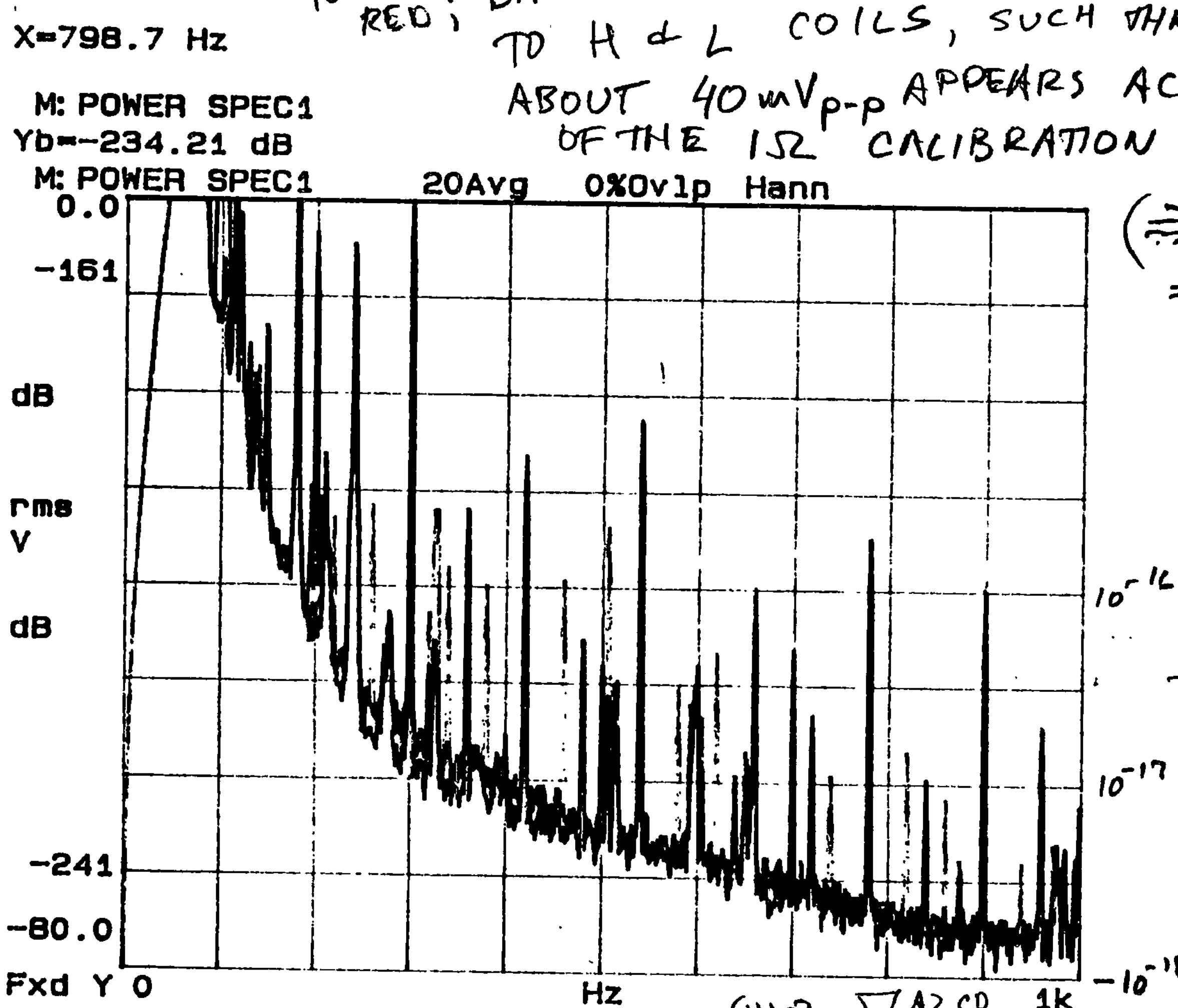
c1a.6

BLACK; NO DRIVE

TEST FOR COIL/MAGNET NONLINEARITY & UPCONVERSIO

PURPLE, RED; BALANCED DRIVE @ 100, 20 Hz (RESP.) TO H & L COILS, SUCH THAT ABOUT 40 mV$_{p-p}$ APPEARS ACROSS EACH OF THE 1Ω CALIBRATION RESISTORS

(⇒ 40 mA$_{p-p}$ ⇒ 4×10^{-3} N$_{p-p}$ FORCE >> NATURAL FORCES)



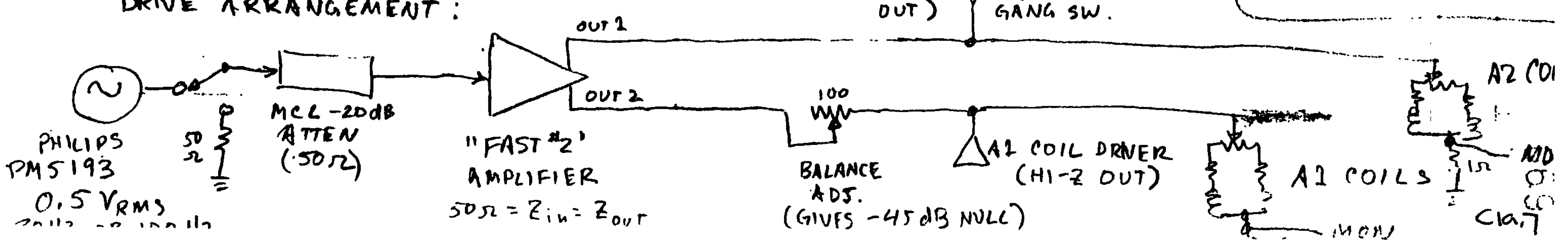
BLACK "NODR"

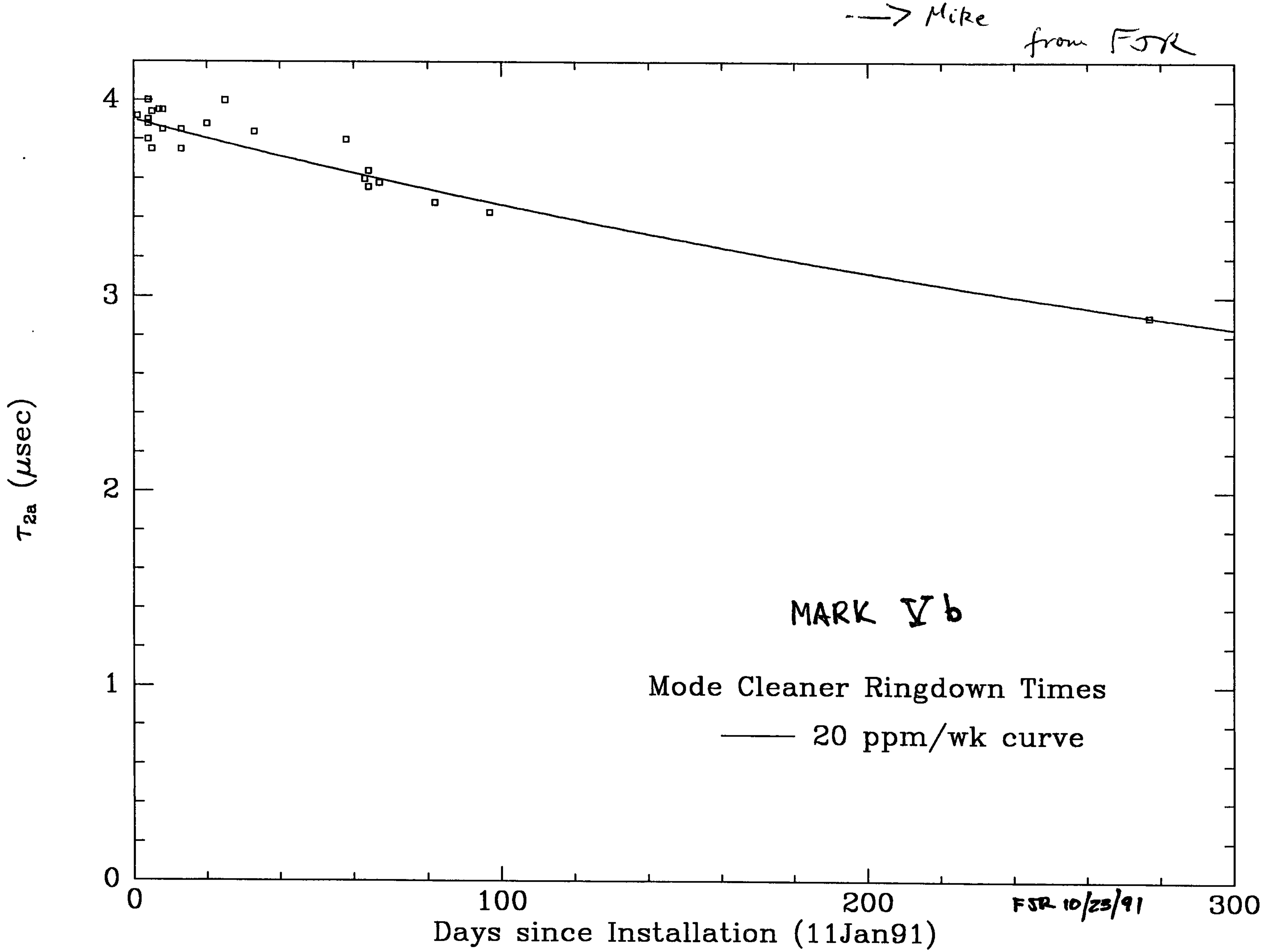
PURPLE "DR100Hz"

RED "DR20Hz"

HARD DISK "B"

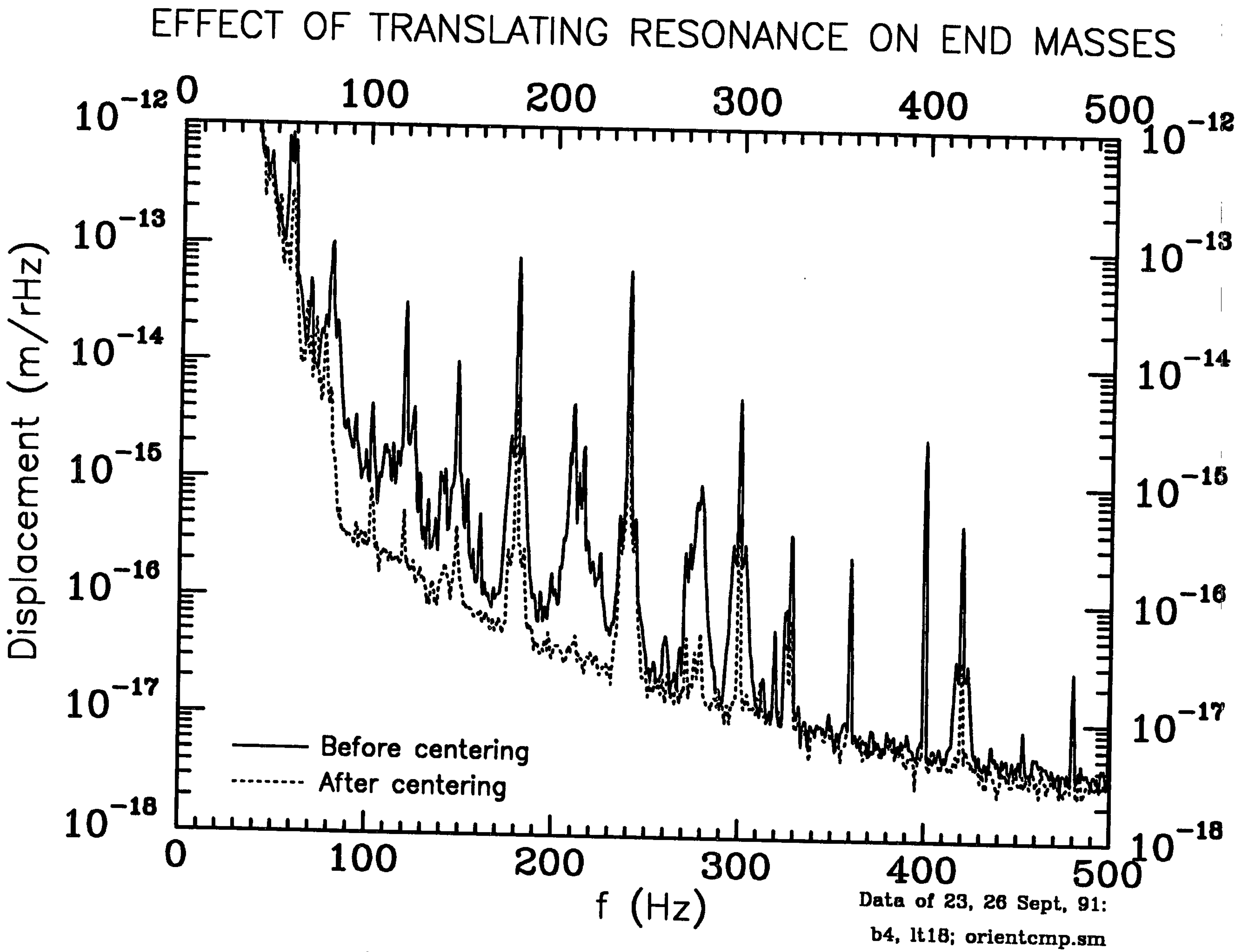
DRIVE ARRANGEMENT:





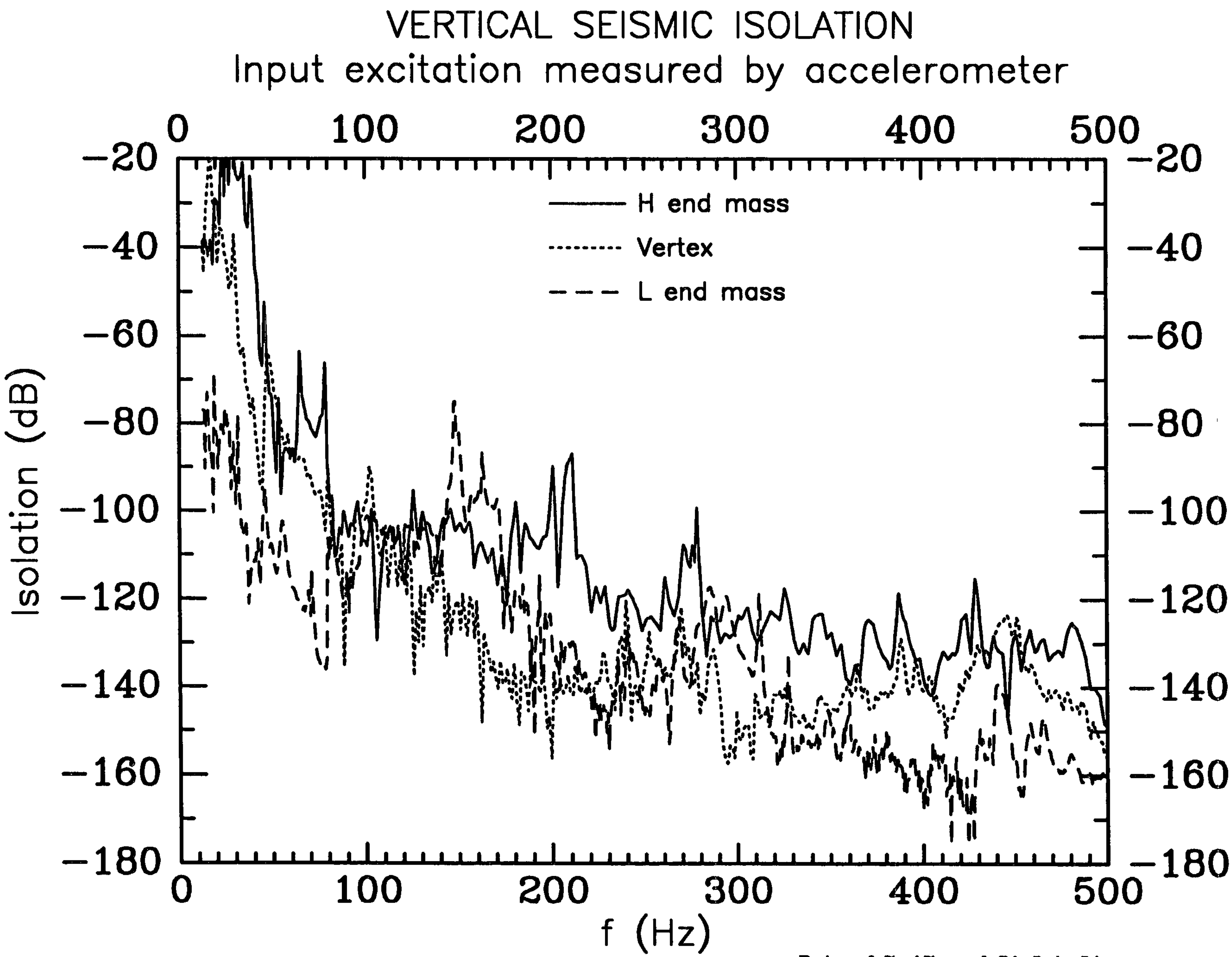
→ Mike
from FJR
MARK V b
Mode Cleaner Ringdown Times
20 ppm/wk curve
τ_{2a} (μsec)
0
1
2
3
4
0
100
200
300
Days since Installation (11Jan91)
FJR 10/23/91

Cla.8



EFFECT OF TRANSLATING RESONANCE ON END MASSES
0
100
200
300
400
500
10^{-12}
10^{-13}
10^{-14}
10^{-15}
10^{-16}
10^{-17}
10^{-18}
Displacement (m/rHz)
Before centering
After centering
f (Hz)
Data of 23, 26 Sept, 91:
b4, lt18; orientcmp.sm

cla.9

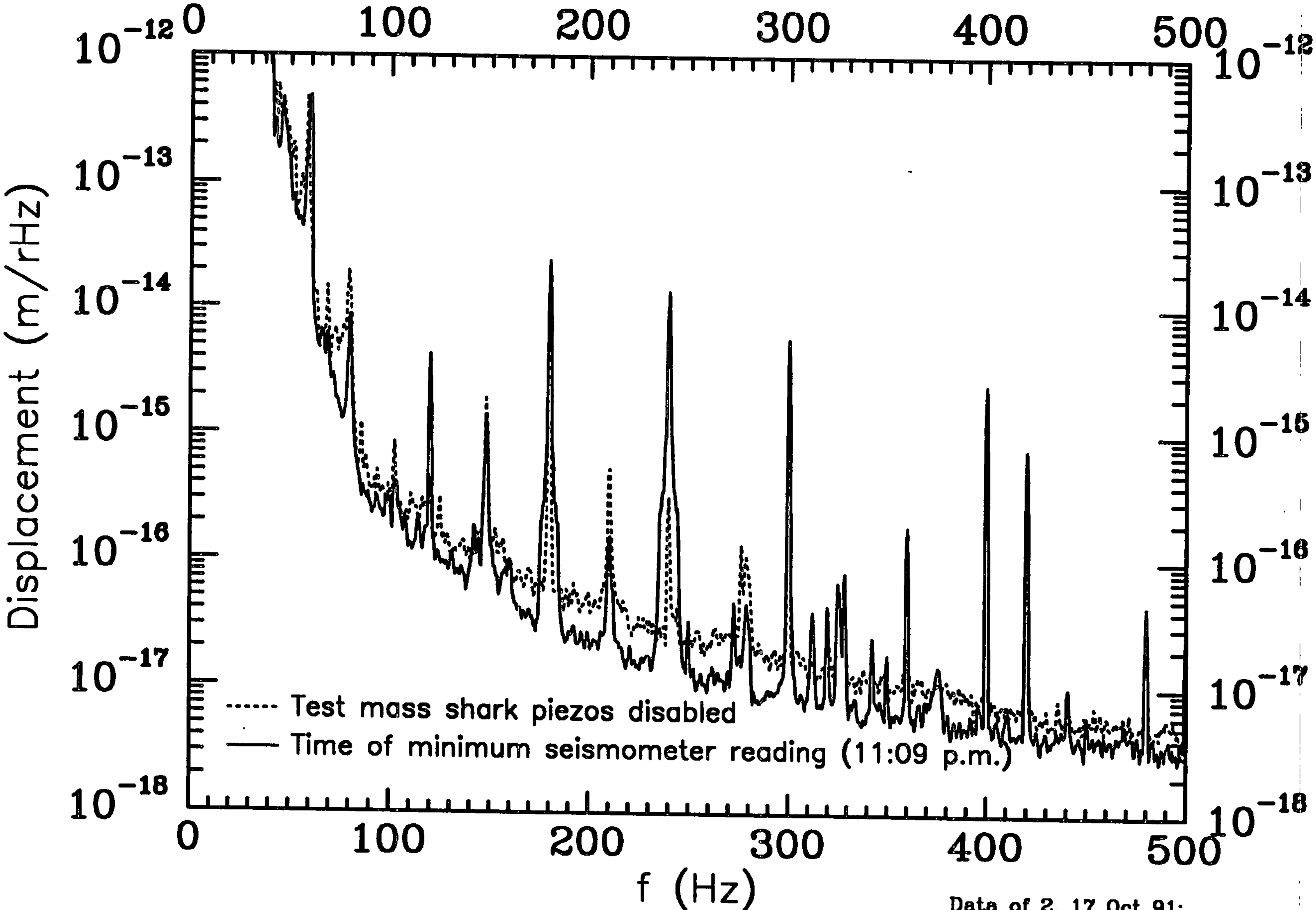


Data of 7, 17, and 21 Oct, 91:
shv1, shvb1, seihnv, seihnv2, seislvs, seislvs2; seis24.sm

C1a.10

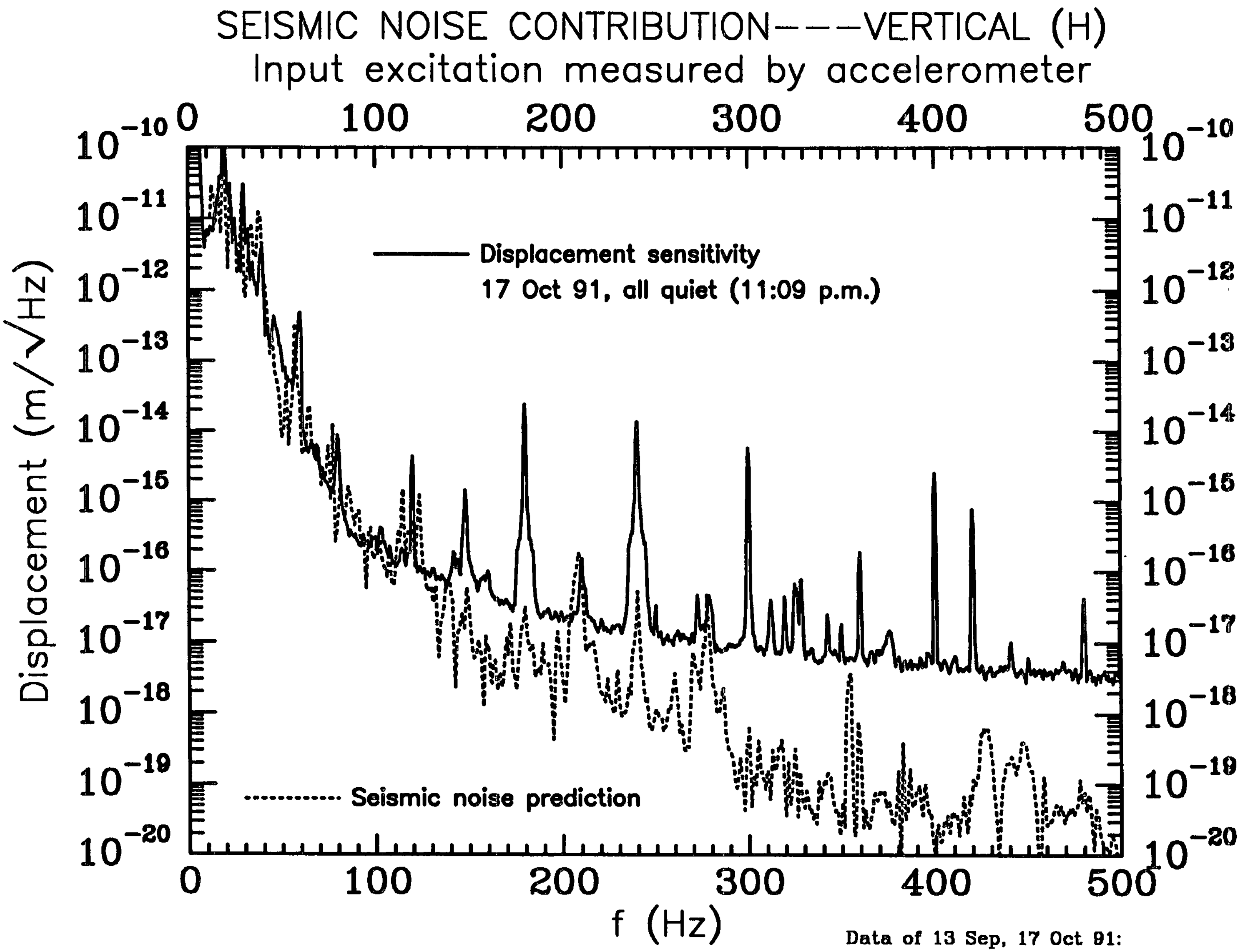
TWO TESTS FOR SOURCE OF LOW-FREQUENCY NOISE

A/C off; cryopump off



Data of 2, 17 Oct 91:
late, late1, ds911002; shlt.sm

C1a.11



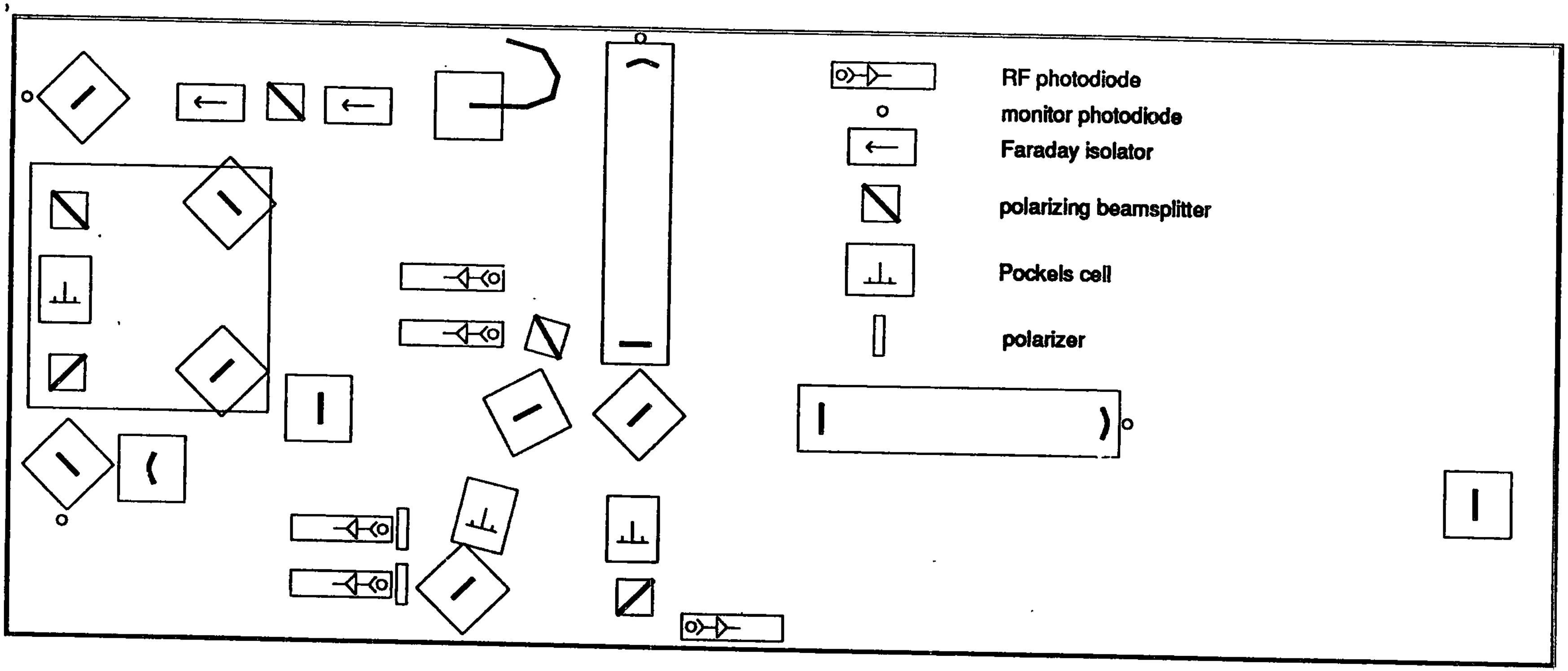
Data of 13 Sep, 17 Oct 91:

shv1, shv4, shv2, shv8, late, late1; sepspv.sm

c1a.12

Fixed-mass interferometer

DHS NM 24 Oct 91



- experiment physically transported into Vassar St. lab!
  - optics roughly in place
  - frequency stablization working
  - laser and experiment dust covers in place
- things yet to do for installation
  - fiber installation finished (maybe already done)
  - cabling
- real work
  - ssb scheme tests
  - test of long input cavity locking
  - alignment of optics

C1b.1

TUBE TEST AND DEMONSTRATION

OUTGASSING STUDIES

WATER: 140C bake began October 18, 1991

Prediction $J_{H_2O} \leq 3 \times 10^{-16}$ torr liters/sec/cm^2 after 30 day bake followed by 30 day pumping - 8×10^{-13} torr final water pressure.

Improvements in system reliability completed

Measures taken to reduce H_2O background in measurement

Separately pumped manifold for calibration leaks

Low H_2O Nitrogen calibration leak installed

RGA, RGA chamber,valves and leak manifold to be baked concurrently with beam tube.

LN2 trap accumulation experiment indicated that RGA chamber walls dominated water outgassing in RGA system.

Full LIGO beam tube model of water outgassing with finite pumping speed of tubes being run on supercomputer.

HYDROGEN: Role of parent metal and welds in outgassing?

Hydrogen outgassing in BTD before current bake: $J_{H_2} = 1.2 \times 10^{-12}$ torr liters/sec cm^2. At this level require 10 to 20 times 1989 proposal pumping capacity to attain LIGO pressure goal. Hydrogen outgassing steady for the past two months (not falling as $1/\sqrt{t}$) but was rising before 100C bake.

New findings

Average Hydrogen concentration is $1 \pm .3$ ppm by weight - J and L steel is factor of 2 to 3 better than ordinary 304 SS.

Unwelded sample pieces show similar but larger (x50) jump in hydrogen outgassing after bake (615K) than original VTF chambers and BTD. baked at lower temperatures.

Concentration measurements and published Hydrogen diffusion constants are consistent with outgassing by sample pieces at 615K.

Increased outgassing rate after bake is consistent with concentration and extrapolated diffusion constant at room temperature. Low initial outgassing before bake is not understood.

Measurements of original VTF chambers after 1 - 2 years show 1 to 1/5 change in Hydrogen outgassing after bake.

Average Hydrogen concentration of TIG welds is 10 ppm by weight.

Both Roscoe Moss and Northwest welds show contiguous large ferrite grain growth in welds, typically 5% of weld is composed of ferrite grains.

Surface analysis: Oxide less than 300A thick, Carbon islands (100μ) below oxide $\approx 1\%$ of surface, surface densely pock marked with $\approx 1\mu$ craters .

VTF Research Short Term Goals

Is it possible to change the steel processing to attain low Hydrogen steel economically?

Are the welds really implicated and if so what should be done to reduce the weld permeation?

VTF Research in Current Plan

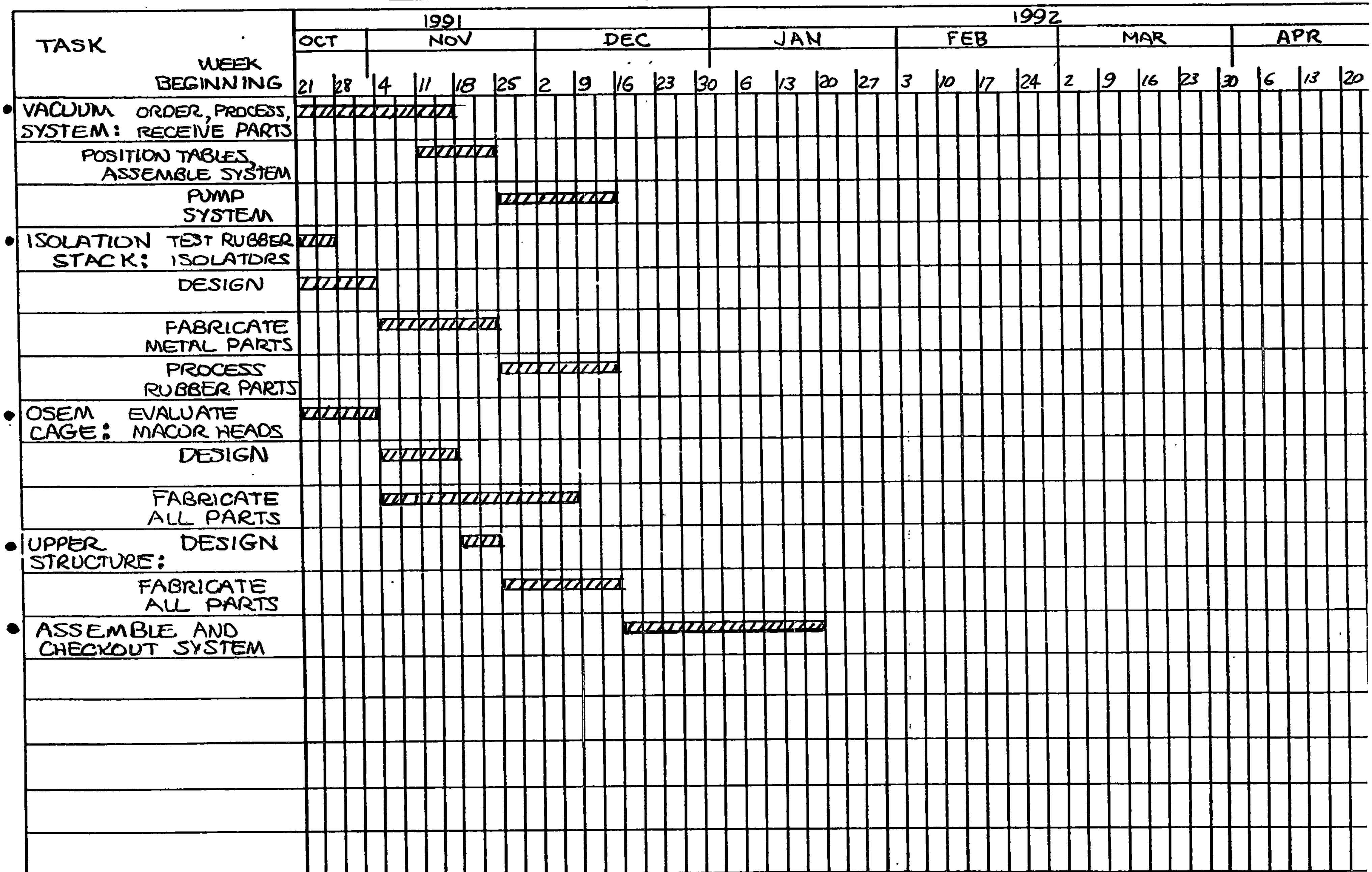
Measurement of spiral welded chambers: RM and NW welded with no stiffening ring.

Measurement of spiral welded chambers: RM and NW welded with stiffening rings.

Major Issue

Develop a set of options for the project consistent with being able to let a design contract in three months.

SUSPENSION MIRROR MODE CLEANER - MECHANICAL TASKS

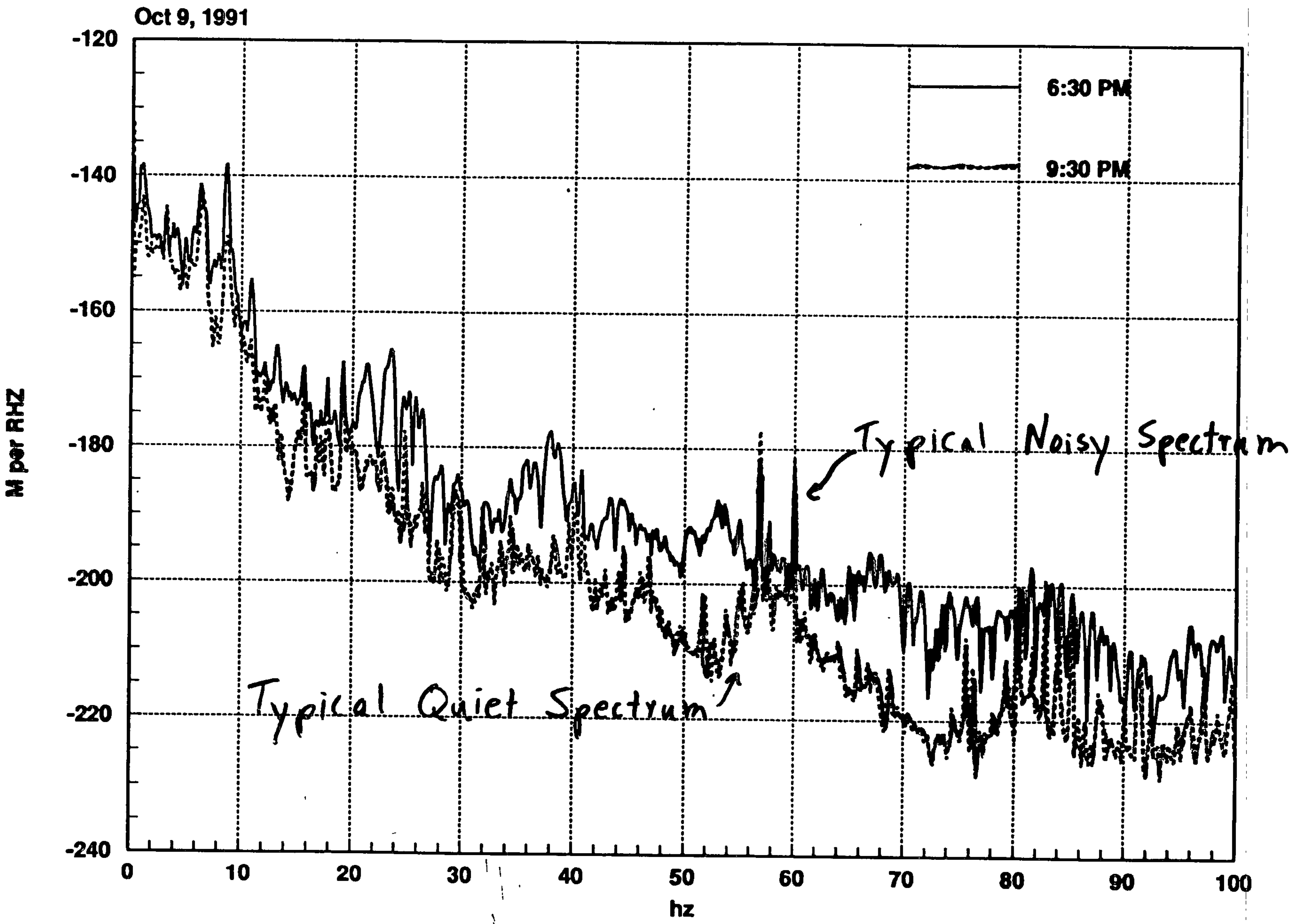


PREPARED BY:	L. JONES	DATE:	10-18-9
APPROVED BY:		DATE:	

1 YEAR SCHEDULE

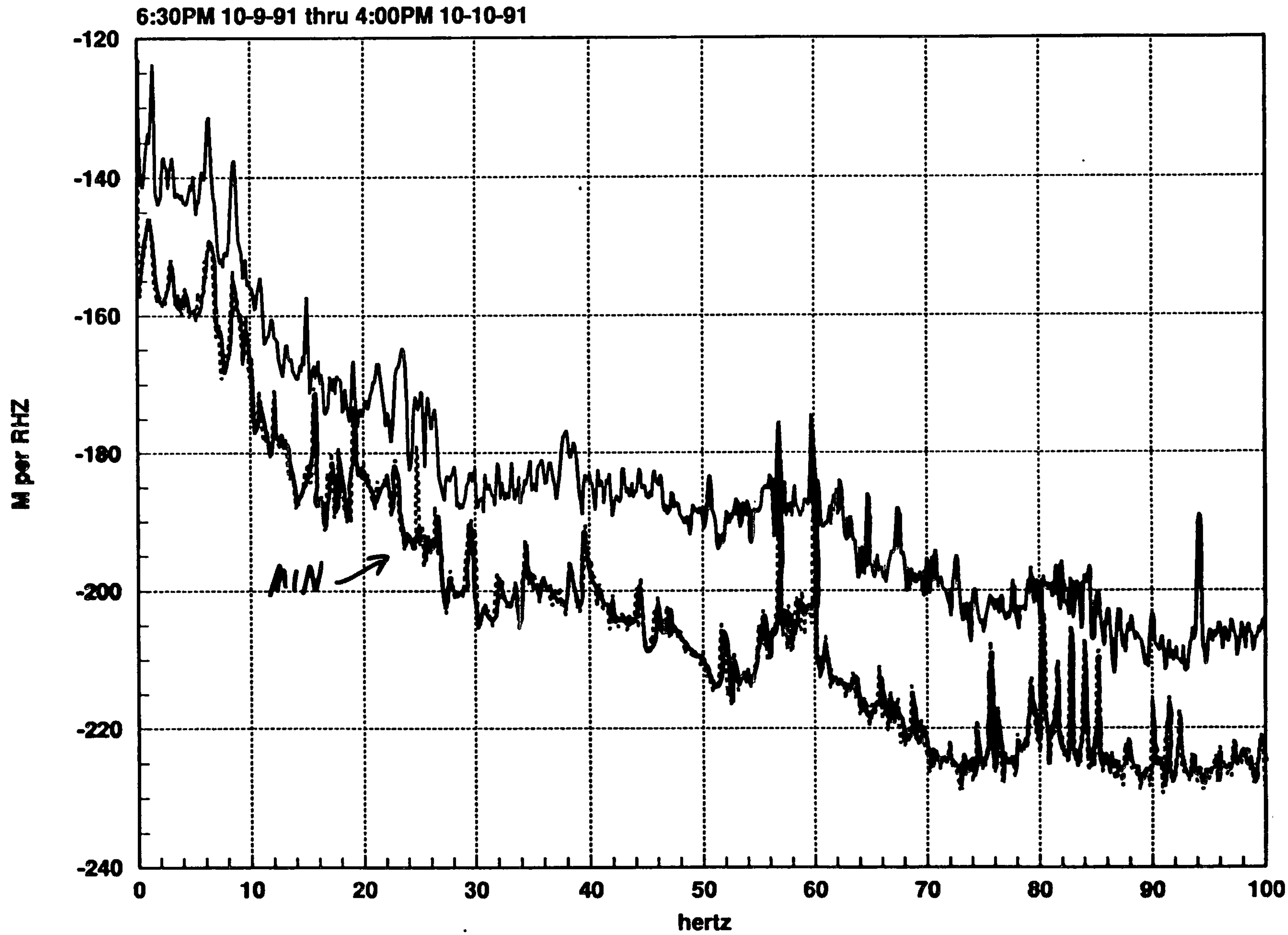
2947-S MA

C2e.1



Noise Measurments on Pad in CES using Ranger Seismometer

C29.1



MAX and MIN noise level on pad in CES over 22 hour period

C29.2

Zygo data analysis
and
GLAD V simulation status

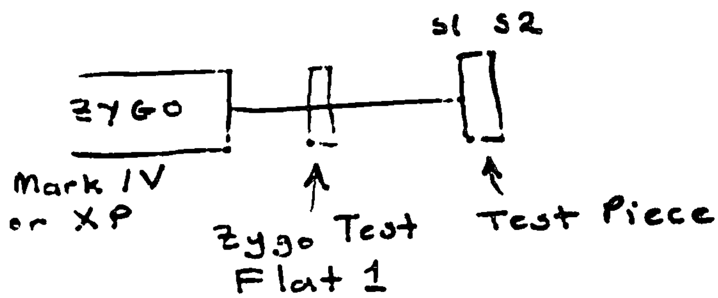
1) Zygo data analysis:

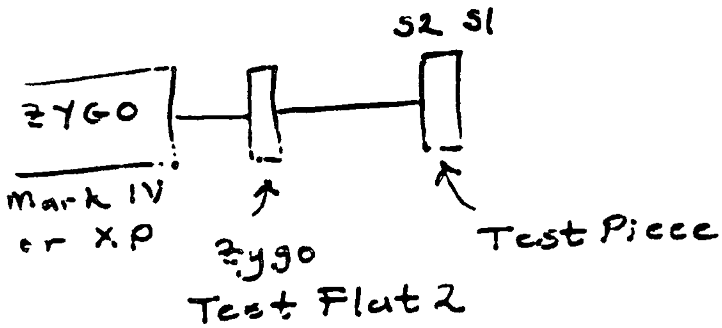
Most of the difficulties encountered with the Zygo 1990 data have been resolved. [Conversation with Mike Burka; re-analysis of data]

M. Burka sent documentation about the details of the experimental set-up.

Experimental Set-up:

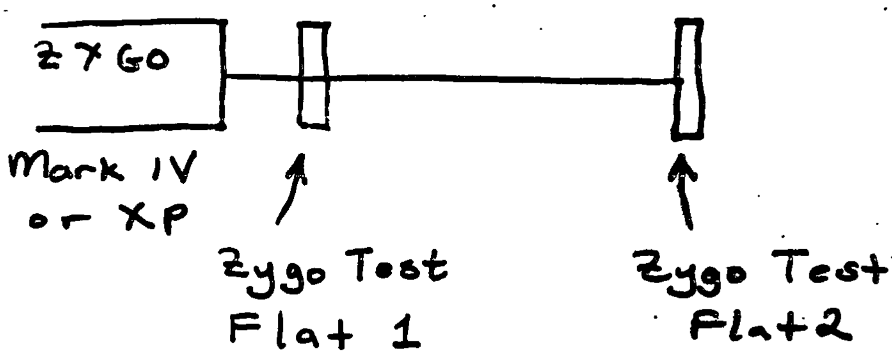
(a) Surface Measurements:



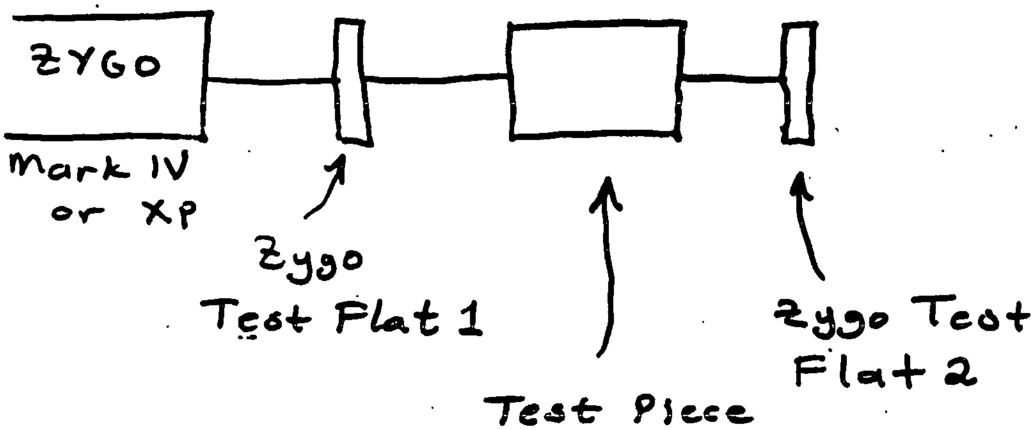


(b) Transmission Measurements:

(i) Background Measurements:



(ii) Measurement with test piece:



The Zygo Flats were $\frac{\lambda}{100}$.

The measurement with Mark IV XP is believed to be better than $\lambda/50$. The differences between two measurements of the same piece in a given instrument is caused by handling of the piece.

[Thermal Expansion]

The difference between two measurements of the same piece in Mark IV and in Mark IV XP was caused by

C3D.2

digitization range of the Mark IV XP instrument.

The Mark IV instrument has a digitization range of 512 counts/fringe.

The Mark IV XP instrument has a digitization range of 4096 counts/fringe.

Because of this and the magnitude of the in-homogeneity/surface-figure the background subtraction is attempted using only Mark IV XP data. The subtraction was successfull. The program averages over near-neighbors to remove any registration errors; and produces files that are compatible with the "GLAD" program.

GLAD V simulation status:

Last months results were inaccurate due to various reasons:

(a) Apertures in the simulation were too small causing the diffraction pattern of the aperture to be super-imposed on the resulting wave-forms.

(b) The input beam was a plane wave which was <u>not</u> mode controlled. [It has all the modes]

(c) because of (b), Aliasing had occurred.

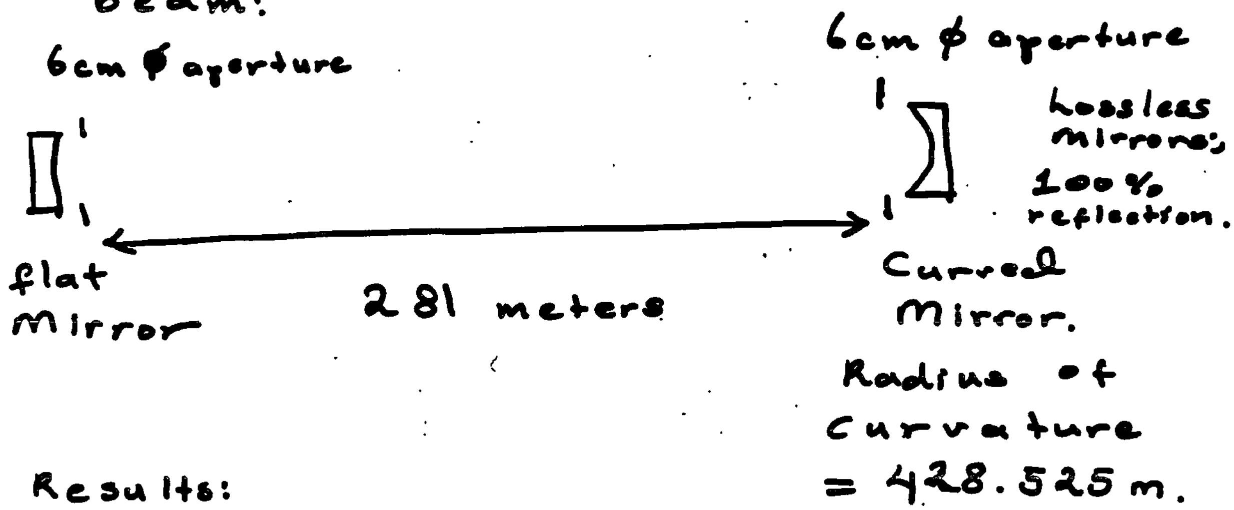
(d) There is a subtle bug in the GLAD program. A work-around is developed.

(e) The method did not seem to be converging; the "numerical errors" were not behaving according to the estimates.

These problems have been resolved:

(i) The simulation set-up:

1) "Perfect" Cavity with "perfect" input beam:



Results:

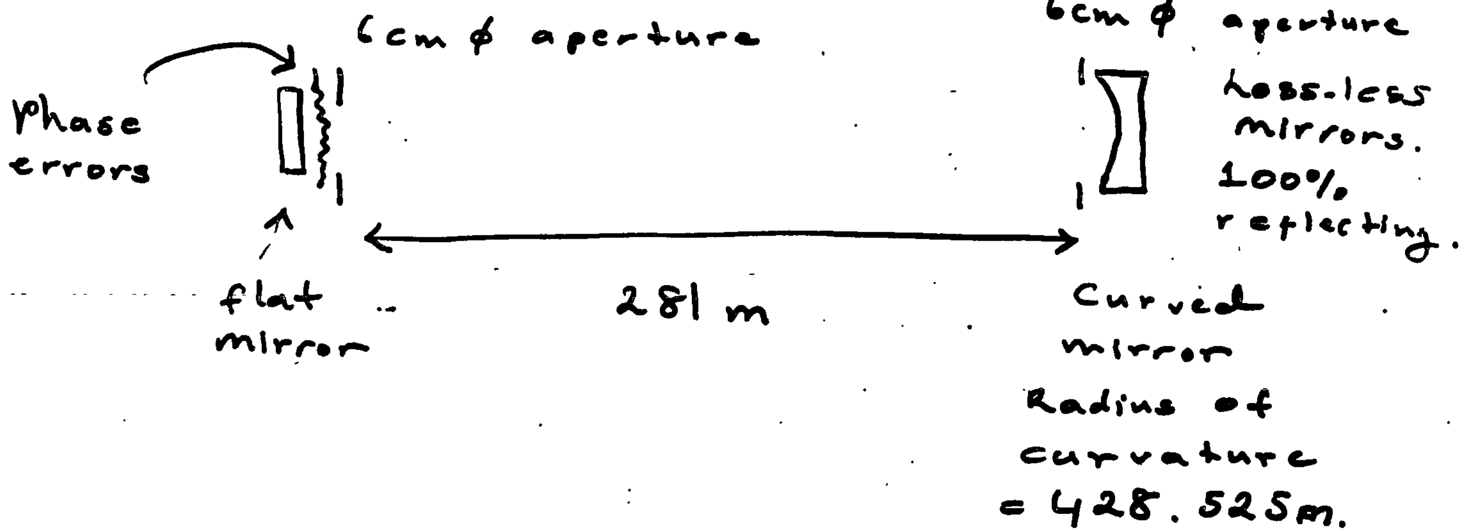
1) Frequency scan performed:
The resonance frequency is at the expected location.

2) The resulting mode wave-form is identical to the theoretical wave form + the diffraction pattern of the apertures [Small].

2) "Perfect" cavity with "imperfect" mode controlled input beam:

A bug in GLAD is encountered here. The bug causes "independent" loop iterations to interact. A work-around is developed by redefining all units; apertured, coordinates at the beginning of each iteration. The work-around produces satisfactory results. The bug will be traced and reported.

3) "Imperfect" cavity with "perfect" input beam:



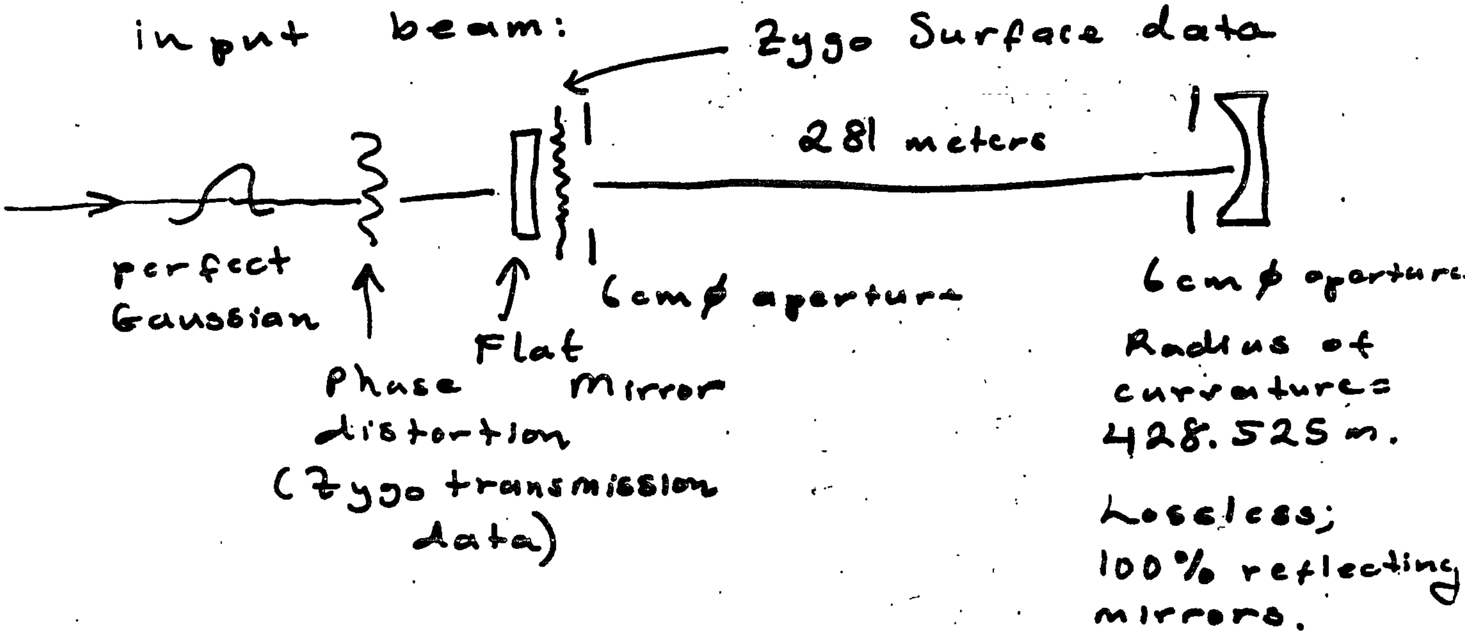
Results:

1) The iterations converge; ie the results are independent of the number of iterations.

2) The actual Zygo data was used in the simulations.

3) For a small figure error ~ λ/40 rms; the distortions of the mode is small; the frequency shift is about 1/300 of the free-spectral range. Cb3.5

4) "Imperfect" cavity with distorted
input beam:



Results:

1) The iterations converge; ie the results are independent of the number of iterations.

2) The frequency of the mode is independent of the input mode shape.

3) There seems to be some dependendence of the output mode shape on the input mode shape. Checks are performed to determine whether these are consistent with numerical errors.

5) Simulations with finite transmission mirrors:
These are underway to compute the contrast with distorted mirrors.

6) [illegible]

No further work was done on this problem since last month.

7) The issue of "numerical precision":

Z20.ZCLAP (14.C)

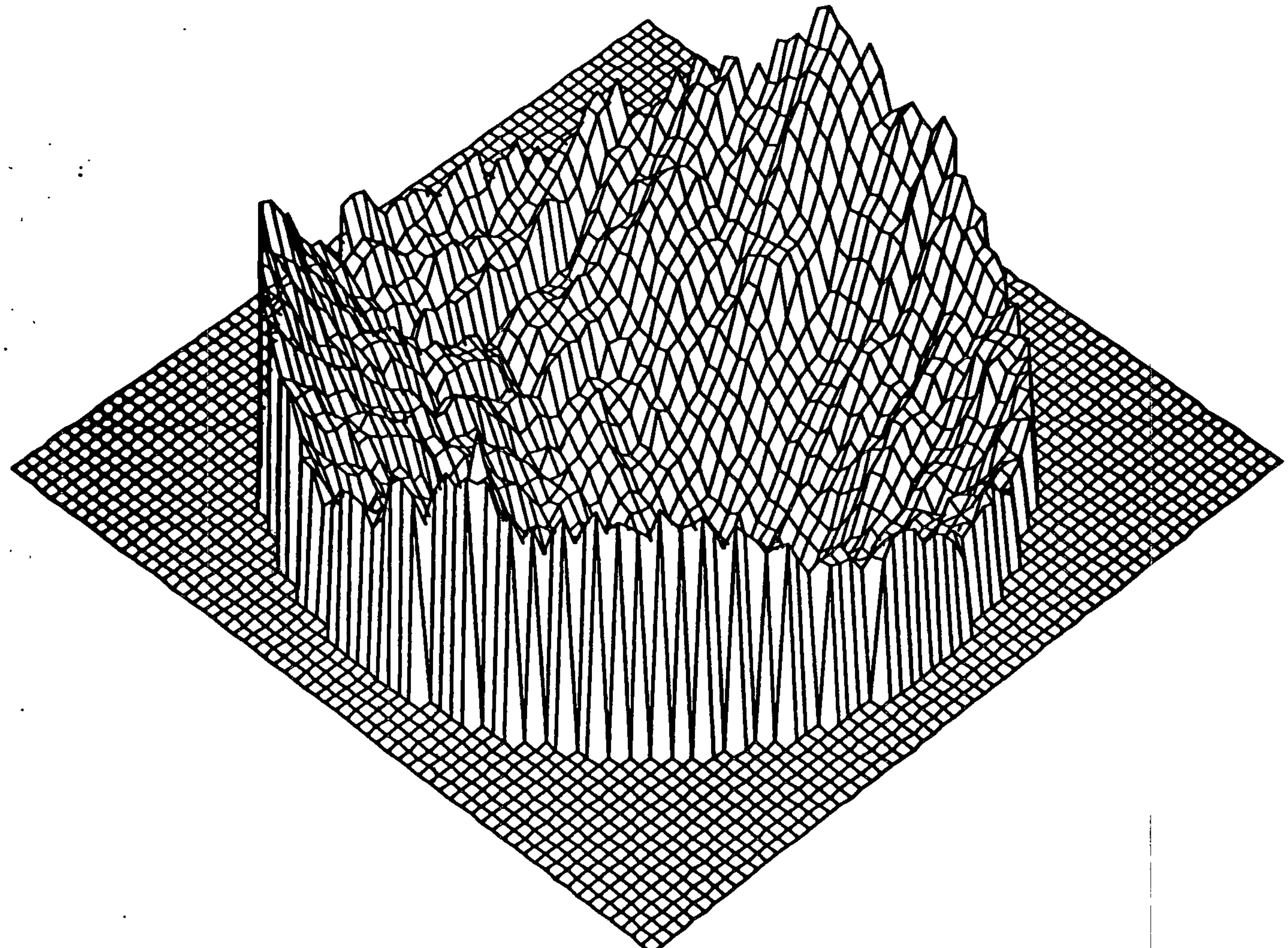
PLOT LIMITS
(X AND Y IN CM)

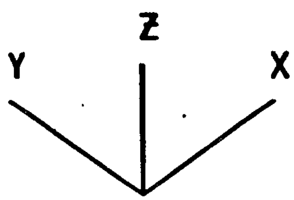
	MIN	MAX
X	-3.52	3.52
Y	-3.52	3.52
Z	-0.056	0.061

PHASE

BEAM NO. 3

WAVELEN = 0.515 MIC

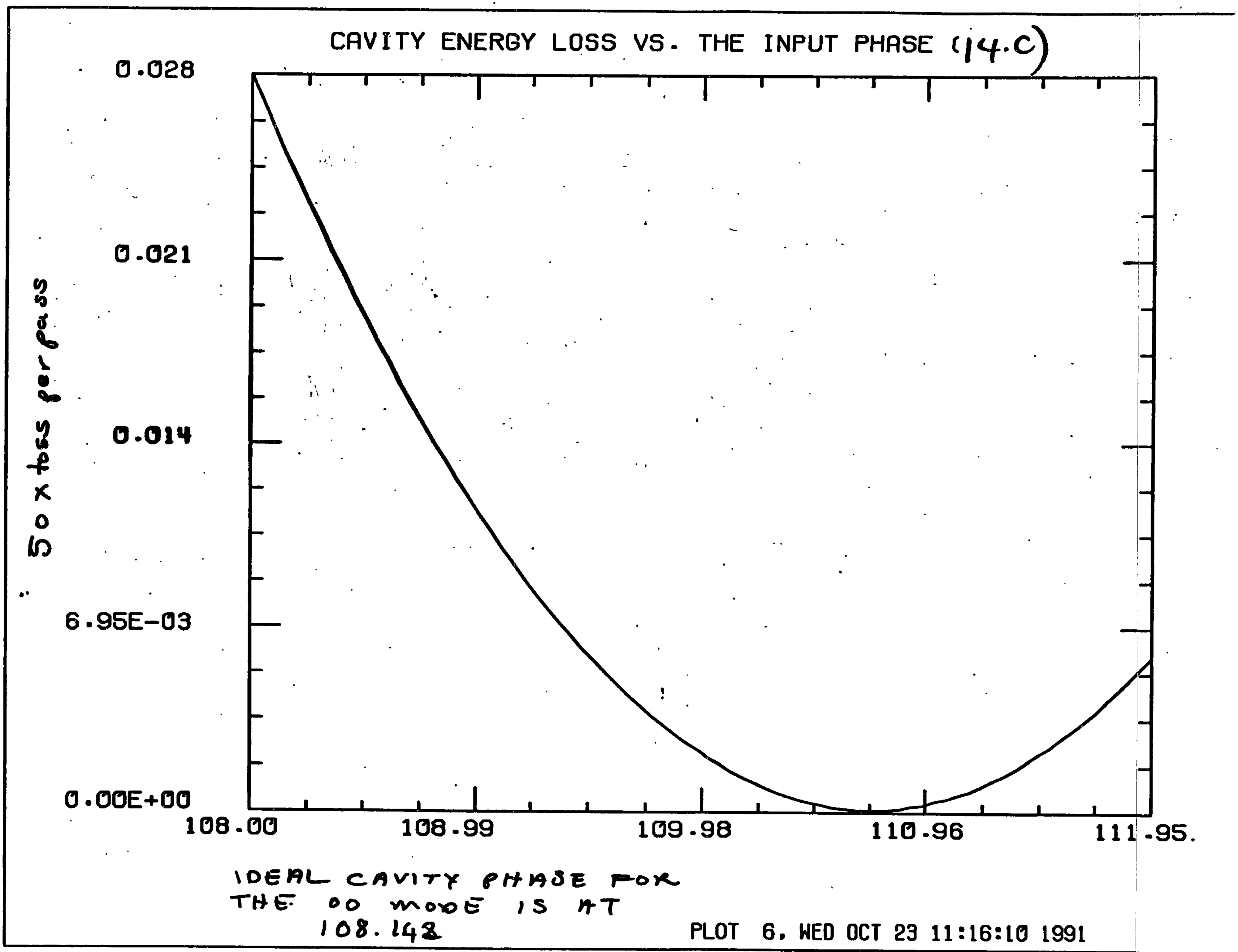




Apertured phase error in front of the flat mirror.

PLOT 5, TUE OCT 22 18:11:00 1991

Cb3.8


CAVITY ENERGY LOSS VS. THE INPUT PHASE (14.C)
0.028
0.021
0.014
6.95E-03
0.00E+00
50 x loss per pass
108.00
108.99
109.98
110.96
111.95.
IDEAL CAVITY PHASE FOR
THE 00 MODE IS AT
108.142
PLOT 6. WED OCT 23 11:16:10 1991

C63.9

DIFFERENCE BETWEEN ~~IDEAL~~ INPUT AND CONVERGED (14.C)

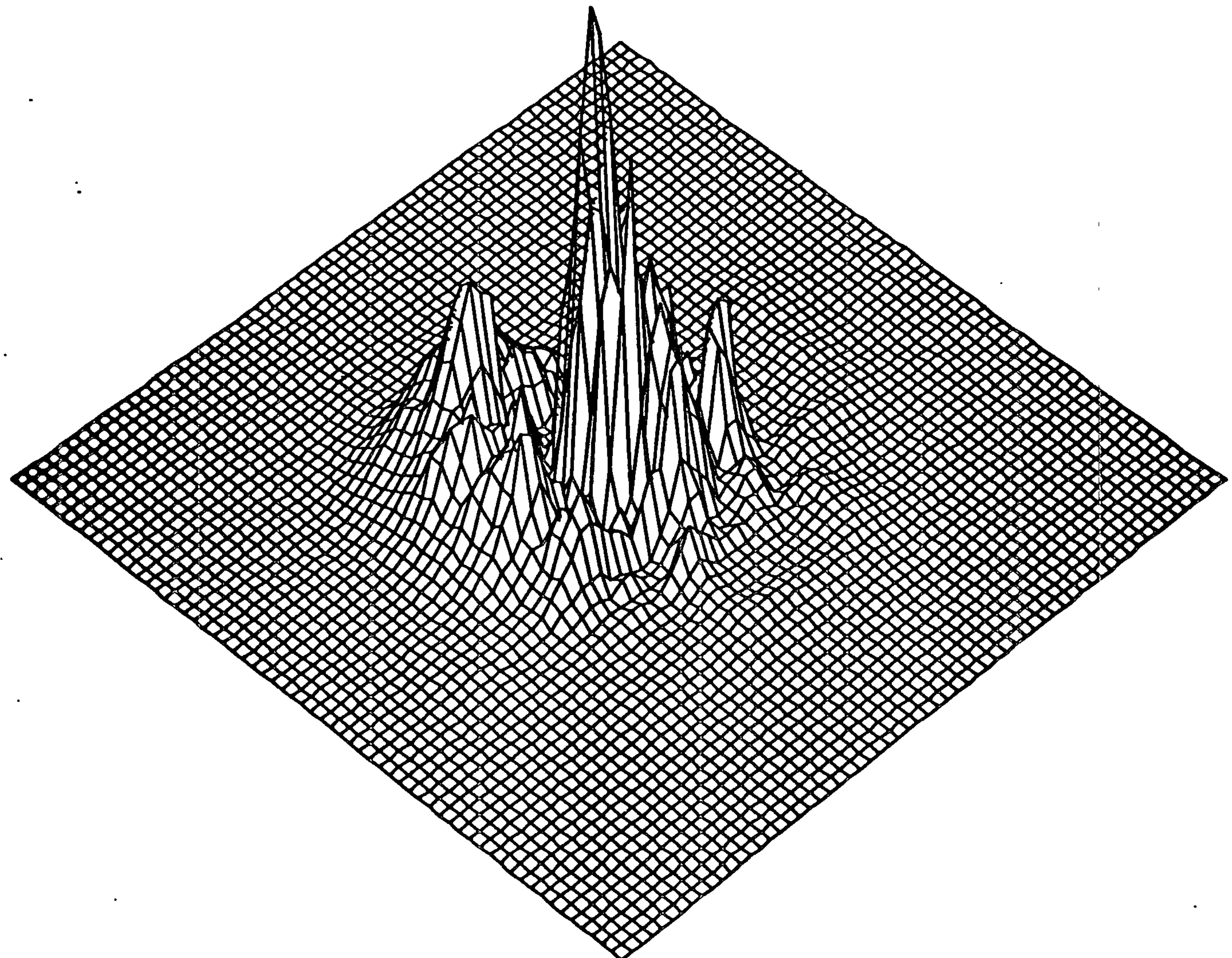
PLOT LIMITS
(X AND Y IN CM)

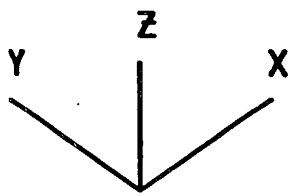
	MIN	MAX
X	-1.76	1.76
Y	-1.76	1.76
Z	9.91E-10	2.92E-04

INTENSITY

BEAM NO. 1

WAVELEN = 0.515 MIC





The difference between the input mode and the converged mode in the cavity.

PLOT 4, WED OCT 23 11:16:08 1991

Cb3.10

VIBRATION ISOLATION: TESTING OF PROTOTYPE

August 1991

JG, LS, RW

PROGRESS REPORT

I. Michelle's interferometer assembled on stack so could measure horizontal transfer functions using ground noise—would not keep lock due to low frequency ground motion.

II. Presently driving stack in vertical direction—some questions about calibration so transfer function data is still preliminary.

FUTURE WORK

I. Finish vertical measurements

II. Drive in horizontal direction

III. Test for tilt and rotation coupling

IV. Test to see if viton springs become stiff at some frequency.

Design of Top Plate and Down Tube

I. Abaqus model of Al top plate and down tube:

   A. Top Plate: diameter=42in, thickness=3in, mass=183kg

   B. Down Tube: diameter=18in, wall thickness=3/8in, mass=35kg

   C. Bottom Plate: diameter=18in, thickness=.5in, mass=5.6kg

II. Results and implications of Abaqus modeling:

   A. Lowest internal resonance is $\geq$ 330 hz using above parameters

   B. Should be able to design less massive top stage and also keep internal resonances above 300 hz by adding stiffeners in key locations

   C. If rubber remains compliant in 300 to 500 hertz range, top plate and down tube can have Q of 1000 and not effect strain spectrum.

III. Open Questions

   A. Effect of down tube on rms motion of test mass

   B. Thermal noise contribution of top stage of stack

IV. Work Plan

   A. Consider design of the cage attached to the base of down tube.

   B. Defer detailed design until measurements of prototype stack are complete.

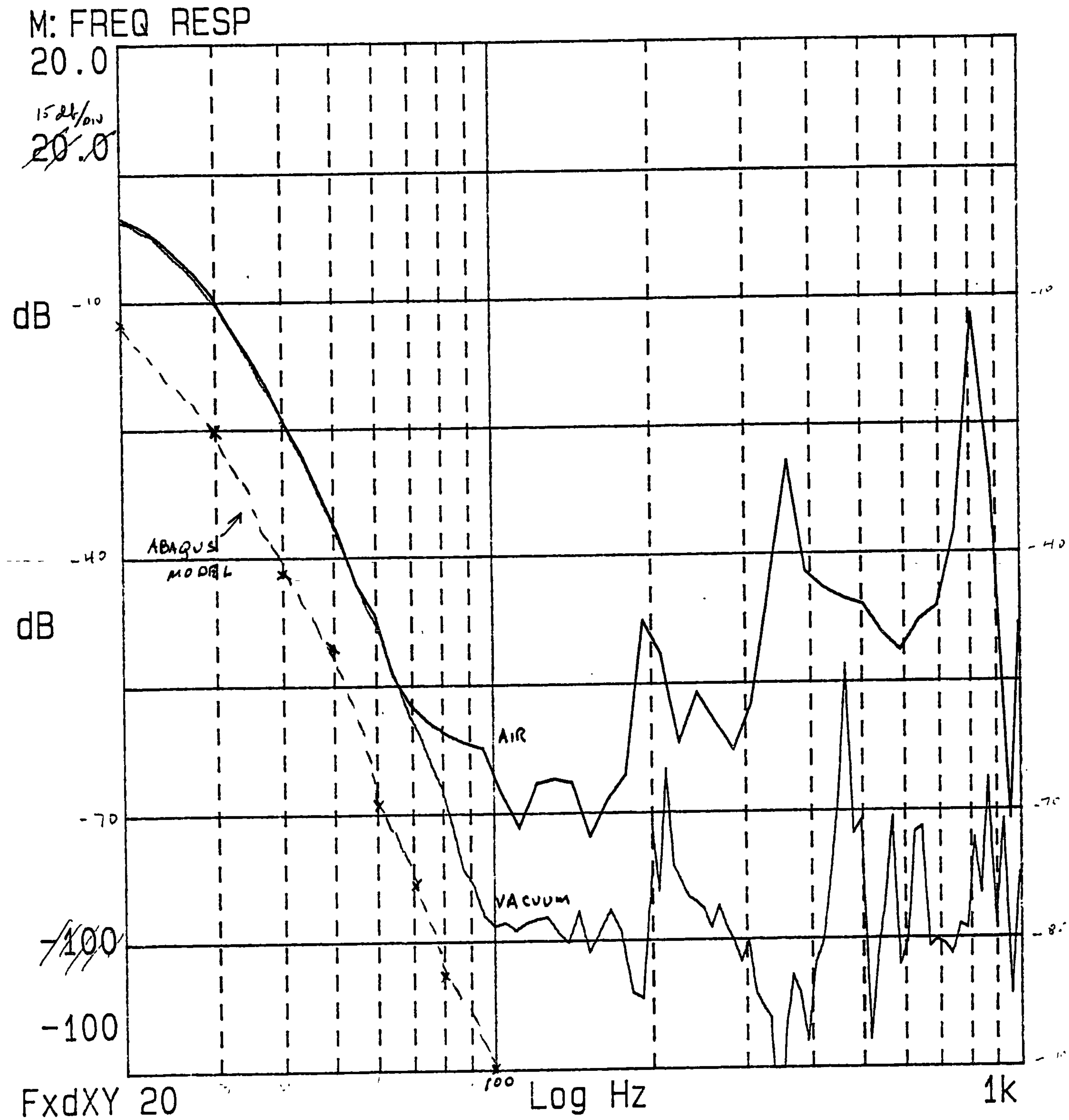
NS20

$\frac{NS17}{NS21} + \frac{NS18}{NS22}$ = green

air + vacuum

green = $\frac{Z_4}{Z_g}$ at 2×10^{-5} torr

M: FREQ RESP



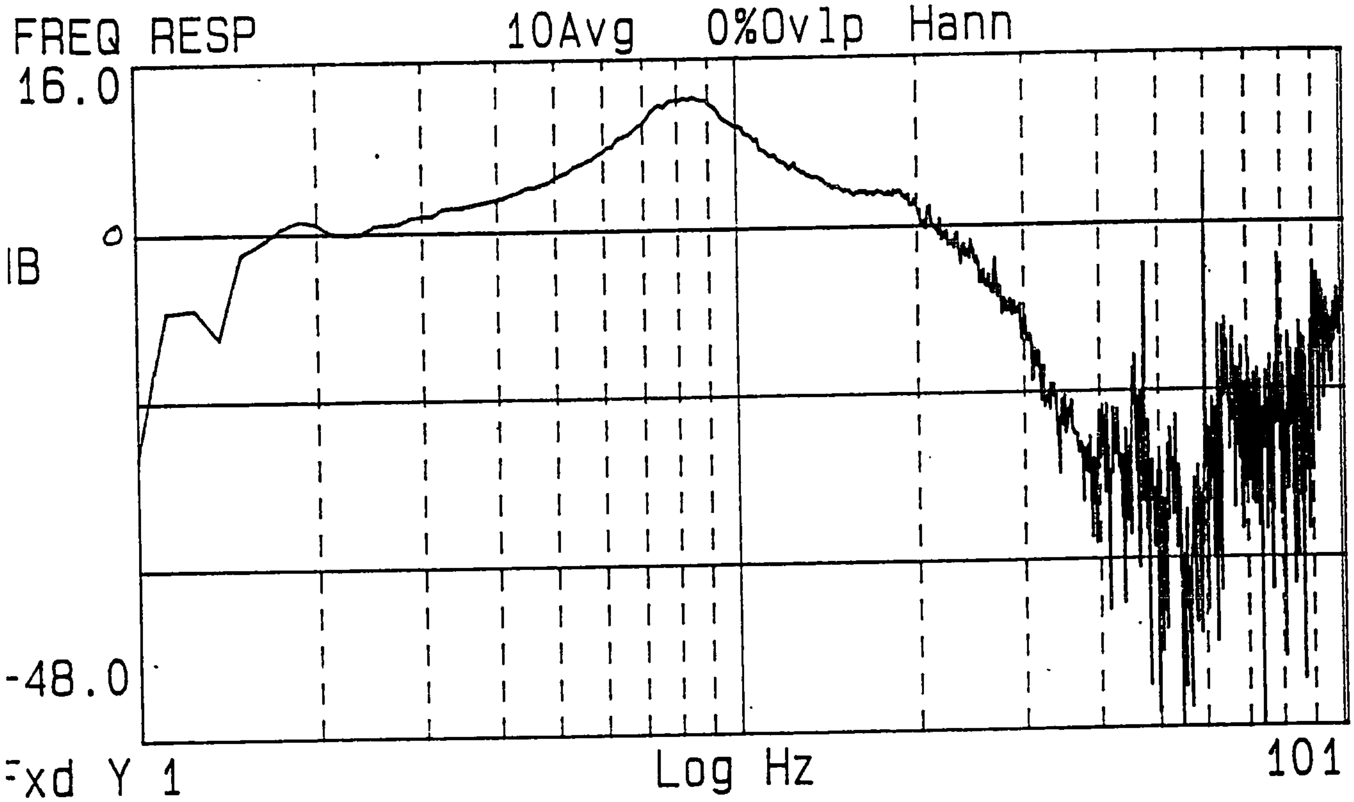
#1

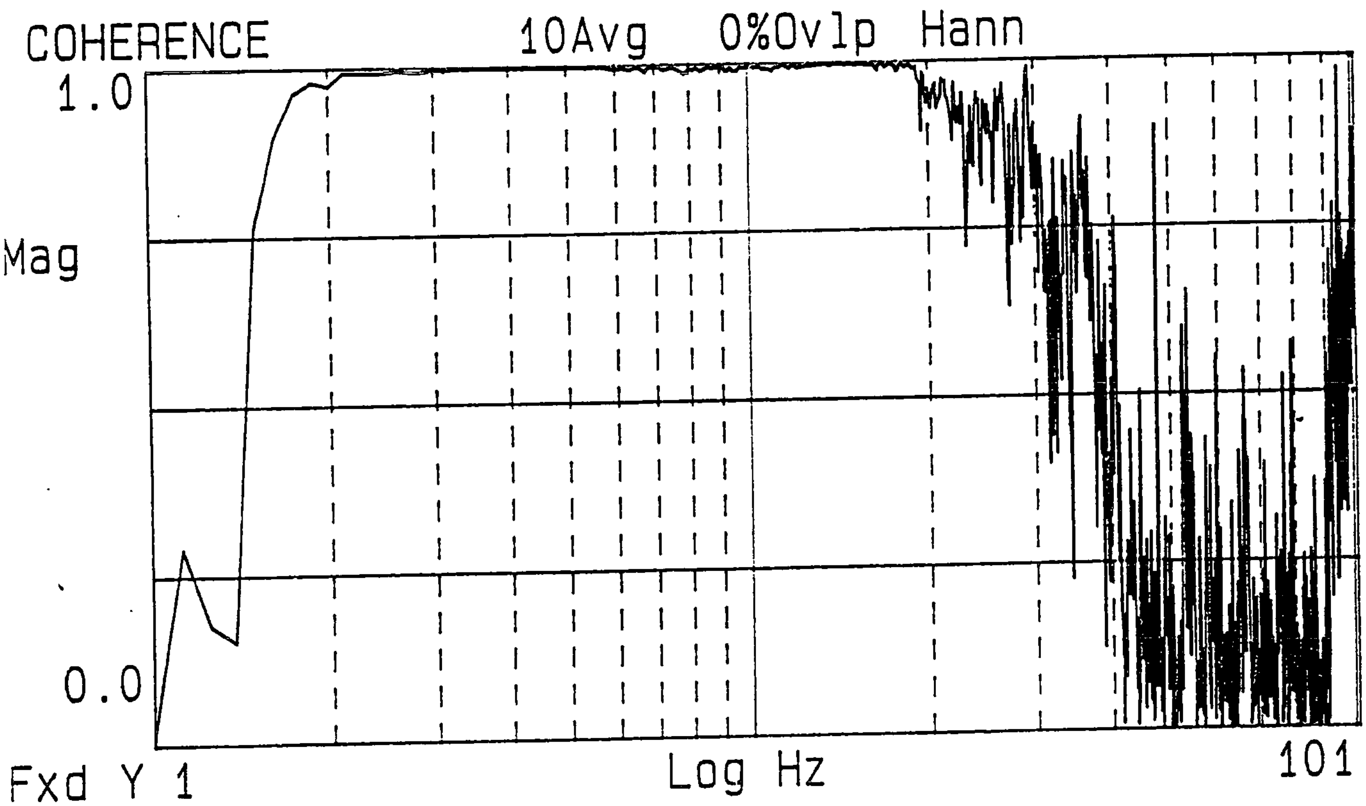
D 2.3

NS4
NS4C

(Ground noise data) Vertical trans. fn

Y=43.5944mdB





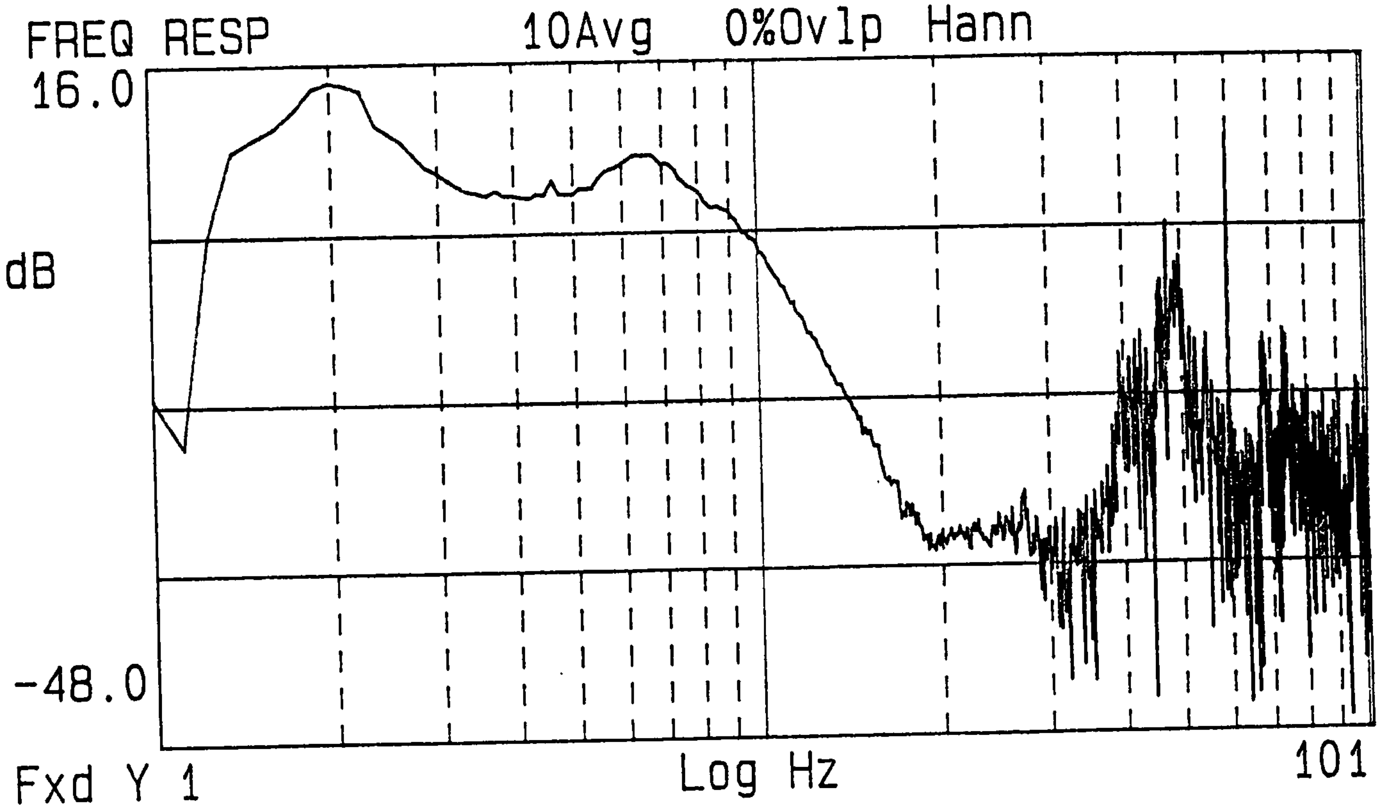
02.4

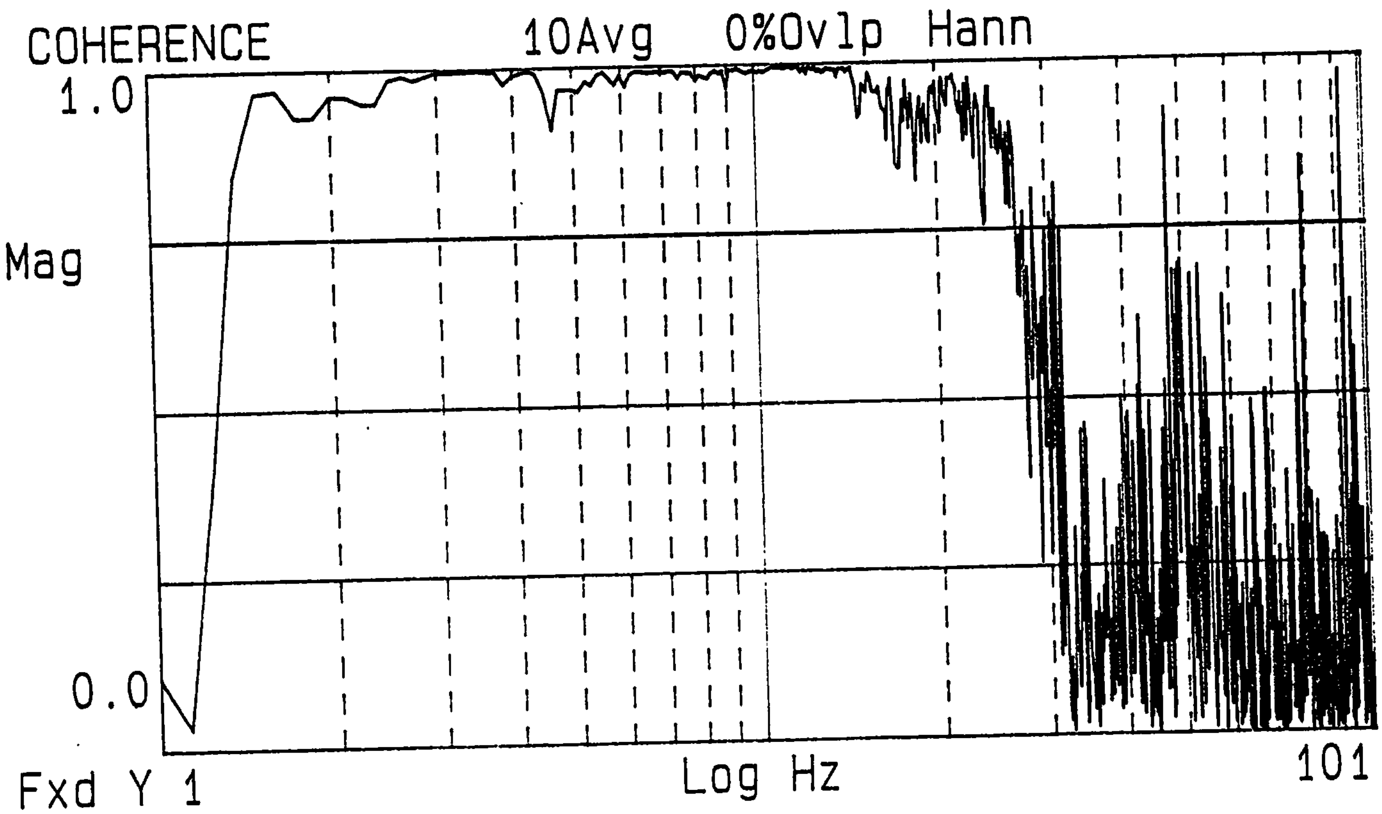
NS6
NS6C

(Ground noise data)

Horizontal trans. fn

Y=750.681m





D2.5