LIGO VACUUM EQUIPMENT

LEFT END STATION
ACCEPTANCE TEST REPORT

CONTRACT NO:	PC 175730
PSI DOCUMENT NO:	V049-1-168
PROGRAM I.D.:	LIGO VACUUM EQUIPMENT
CDRL NO:	06-1
APPROVAL STATUS:	A

Process Systems International, Inc.
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CALIFORNIA INSTITUTE OF TECHNOLOGY LIGO PROJECT
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

v049-1-168.doc
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LEFT END STATION
ACCEPTANCE TEST REPORT

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ISSUE DATE: **May 28, 1998**

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APPROVAL STATUS: **A**

SUBMITTED TO:

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LIGO VACUUM EQUIPMENT

LEFT END STATION
ACCEPTANCE TEST REPORT

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System Acceptance Test Procedures

End Stations (ATTACHED) V049-2-115

1. INTRODUCTION

This report summarizes the field acceptance testing conducted by Process Systems International (PSI) at Washington Site Left End Station. The station was tested in accordance with Acceptance Test Procedure V049-2-115 Rev 3.

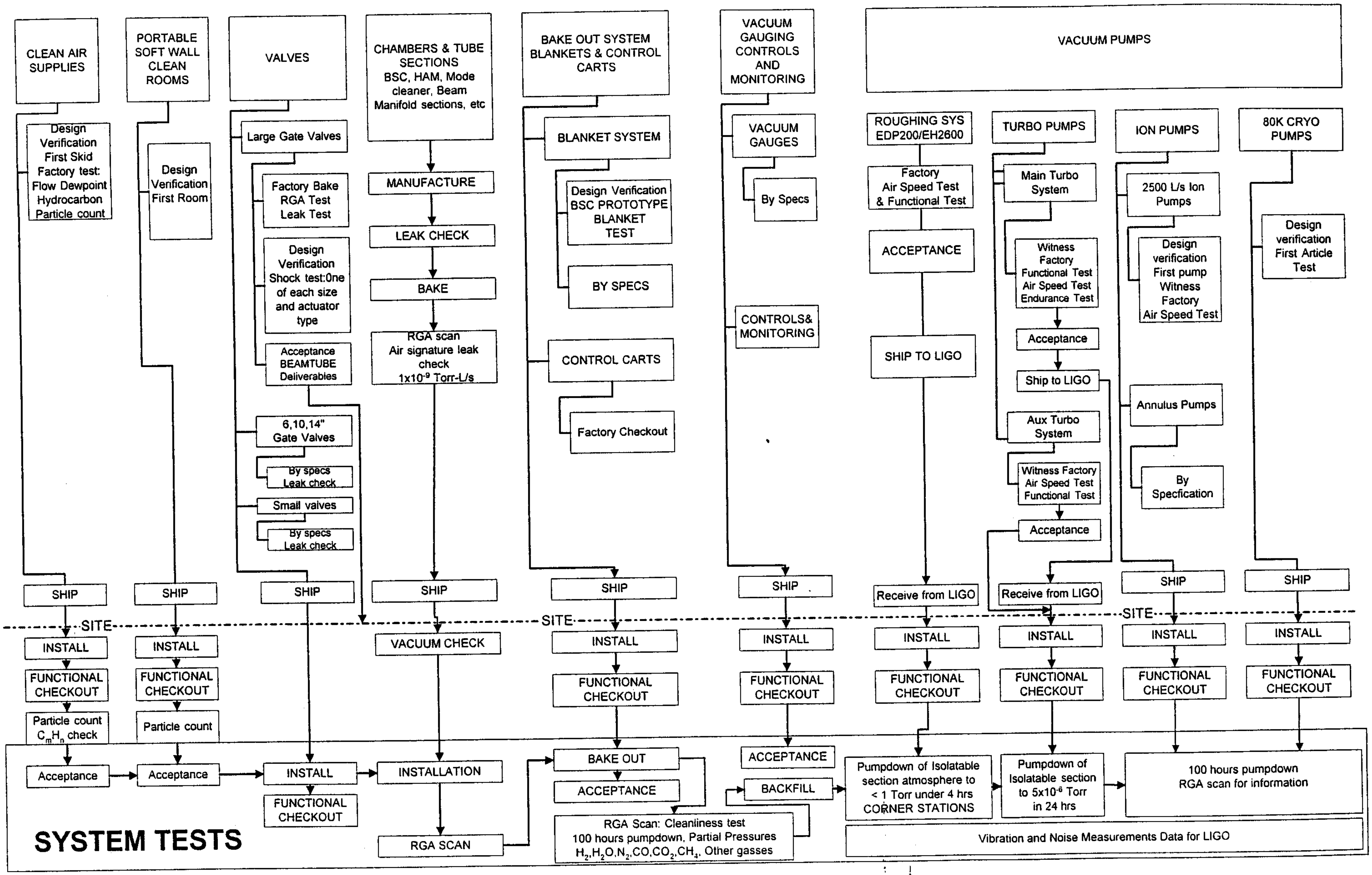
The test report is intended to meet the requirements of CDRL No. 6 for the Vacuum Equipment Contract (PC 175730).

2. SCOPE

This report addresses acceptance testing only those components/subsystems that are included in the Field Acceptance Test Procedure. Other components that have been previously tested and accepted have individual Acceptance Test Reports that are included in the Station End Data Package V049-1-170.

Figure 1 summarizes the point of acceptance of the components that comprise the station.

LIGO VACUUM EQUIPMENT ACCEPTANCE TESTS PLAN



3. ACCEPTANCE TEST CRITERIA

Item	Acceptance Criteria	Acceptance Results
Interface to CDS	Functional Checkout per V049-2-163	Checkout completed on 1/27/98
Clean Air System Test	Functional Checkout per V049-2-109 Dewpoint:<-60 C Particle Count: Class 100 @ .5 micrometer. Hydrocarbon Check:	Dewpoint: -75. C Particle Count: 0 Hydrocarbon Check: 0 PPM
Class 100 Cleanroom Test	Functional Checkout per V049-2-110 Particle Count: <100	Particle Count: <17.1
System Leak Check	Individual leaks greater than $1x10^{-9}$ torr-L/s will be repaired. Vacuum Check: Annulus: $P<3x10^{-4}$ torr 60 min for vessels and 30 min for spools and ate valves. Main Volume: by RGA air signature. Maximum rate to be consistent with system requirements and RGA sensitivity.	All components comprising the isolatable volume were helium leak checked via evacuation and spray prior to bakeout. All flange annuli checked and passed. Data recorded in site test logs. The volume is leak tight to $<6x10^{-9}$ torr-L/s
System Bake-out	Functional Checkout per V049-2-112 Rev1 Bakeout: Ramp Rate:<1C/hour Uniformity: 150 C+/-20C	The station was ramped from 18 C to 150 C over a period of 93 hours (1.4 C/hr) and held for 49 hours at 150C. Temperature data recorded in the bakeout cart data acquisition system was sub-sequently overwritten; therefore no temperature uniformity data is available. After the 48-hour hold, the temperature was ramped to 48 C over 48.5 hours (2.1C/hr) prior to shutting off the power.

Item	**Acceptance Criteria**	**Acceptance Results**
Ultimate Pressure Test (After Bake-out)	Total Pressure:<$2x10^{-8}$ torr Partial Pressure Measurements: Sum of all gasses other than H_2 and H_2O:<$3x10^{-9}$ torr	Total Pressure:$5.5x10^{-9}$ torr Partial Pressure Measurements: Sum of all gasses other than H_2 and H_2O:$1.1x10^{-9}$ torr
Backfill/100 Hr. Pumpdown Test	Roughing to < 0.2 torr in 15 hours Roughing to $5x10^{-6}$ torr in 24 hours RGA scan after 100 hours for information only	Roughing to 0.5 torr in 4 hours Roughing to $8x10^{-7}$ torr in 18.75 hours Partial pressures: AMU torr 2 $3x10^{-9}$ 16 $9x10^{-11}$ 18 $9x10^{-11}$ 28 $7x10^{-9}$ 44 $4x10^{-10}$ all others $1x10^{-9}$ Total $1.4x10^{-8}$
LN_2 Consumption Test	LN2 consumption per V049-2-208 90 days without refill.	119 days without refill.
Noise/Shock/Vibration Field Test	Per CAA Test Plan	See CAA Test Report

4. ACCEPTANCE TEST RESULTS SUMMARY

As shown in Section 3 the WA Left End Station has been successfully tested to meet the Acceptance Test Criteria with the following comments:

System Leak Check

The system is believed to be leak tight to a level of $6x10^{-9}$ Torr-L/s Air.
The minimum detectable leak from the RGA scan with the sensitivity obtained during the scan for the Left End Station is about $6x10^{-9}$ Torr-L/s Air. This was deduced based on mass 32 ion current. The Argon signal is not used because the pumping speed of the ion pump is not known accurately for Argon.

The RGA scans of just the calibration chamber isolated from the main volume, indicates that there is a leak in the calibration chamber. The observed signal for mass 32 was almost $5x10^{-13}$ A with the RGA chamber by itself. With a calibrated sensitivity of 3 Torr/Amp the partial pressure is $1.5x10^{-12}$ Torr. With a calibration chamber speed of 3.7 liter/s the leak in the RGA chamber is estimated at $3x10^{-11}$ Torr-L/s Air. If there was no leak in the RGA chamber the minimal detectable leak would be $6x10^{-9}$ Torr-L/s Air. Bagging the entire chamber with helium did not lead to a helium signal on the RGA scan.

System Bakeout

The bakeout ramp up and ramp down rates exceeded the specified rate. The design ramp rates were selected to minimize thermal stress and to keep input power requirements at reasonable levels. The actual ramp rates, although in excess of the acceptance criteria are still low and are not considered to be sufficient to cause thermal stresses, and are therefore acceptable.

The loss of the temperature data is unfortunate, but the subsequent excellent RGA scans after bakeout indicate that the system is clean and the bakeout was therefore effective.

Ultimate Pressure Test

The partial pressure measurements after bakeout readily exceeded the acceptance criteria and match very well with the LIGO goals indicating that the volume is clean and leak tight. A comparison table of the actual results vs. the LIGO is included for information.

AMU	LIGO Goals	Acceptance Test
	Partial Pressure	Partial Pressure
(Torr)	(Torr)	(Torr)
2	$5x10^{-9}$	4.4×10^{-9}
16	$2x10^{-10}$	2.2×10^{-11}
18	$5x10^{-9}$	1.7×10^{-11}
28	$1x10^{-9}$	8.9×10^{-10}
44	$2x10^{-10}$	2.5×10^{-11}
Other	$1.9x10^{-9}$	1.3×10^{-10}

Backfill/100 Hour Pumpdown Test

A comparison of the partial pressures before and after the backfill is shown below. As expected an approximate one-decade increase in N_2 and CO_2 pressures are observed. This is consistent with the prototype test program. There is also a factor of 4-5 increase for H_20, CH_4, and a one decade increase for the other gasses that did not occur in the Left Mid Station. The resulting partial pressures for all gasses are still below the LIGO goals.

	After Bakeout	After Backfill & 100 hr Pumpdown
AMU	Partial Pressure	Partial Pressure
	(Torr)	(Torr)
2	4.4×10^{-9}	3.3×10^{-9}
16	2.2×10^{-11}	8.8×10^{-11}
18	1.7×10^{-11}	9.4×10^{-11}
28	8.9×10^{-10}	$7.7x 10^{-9}$
44	2.5×10^{-11}	3.8×10^{-10}
Other	1.3×10^{-10}	9.7×10^{-10}

LN2 Consumption

Results of the Left End Station Cryopump indicates a full tank capacity of more than 100 days.

5. ACCEPTANCE TEST RESULTS

This section contains signed data sheets for each component or subsystem.

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT

5.1 Interface To CDS

The interface to LIGO's CDS computer system was tested by point to point wiring checks using the following documentation:

V049-1-163

Control functions (displays, interlocks, etc.) were checked by monitoring CDS display screens and actual equipment control.

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT

5.2 Clean Air System Test

The clean air system (class 100) was tested per Acceptance Test V049-2-109.

All test results met or exceeded the requirements.

WA LEFT MID STATION

LIGO VACUUM EQUIPMENT ACCEPTANCE TEST DATA/TEST VERIFICATION Equip. Tag W14C200 S/N 091697H-054501

Type of Test	ATP Para.	ATP Req'ment/ Actual Data	Comments	LIGO Witness Sign./date	PSI Sign./date
Visual Inspection		OK			JF/SM 2/8/98
Labelling Verification		OK			JF/SM 2/8/98
Bakeout	NA				
Leak rate	NA				
Factory Endurance Test	NA				
Factory Speed Test	NA				
Functional Test	5.1				
DEWPOINT	5.2	-75 C			JF 2/8/98
Particle Count	5.2	0 PART/FT3			JF 2/8/98
HYDROCARBON CONTENT	5.2	0.0 PPM			JF 2/8/98

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT

5.3 Class 100 Cleanroom Test

The class 100 cleanrooms were tested per Acceptance Test V049-2-110.

All test results met or exceeded the requirements.

LE CLEAN ROOM

LIGO VACUUM EQUIPMENT ACCEPTANCE TEST DATA/TEST VERIFICATION Equip. Tag____ S/N 6

Type of Test	ATP Para.	ATP Req'ment/ Actual Data	Comments	LIGO Witness Sign./date	PSI Sign./date
Visual Inspection					
Labelling Verification					
Bakeout	NA				
Leak rate	NA				
Factory Endurance Test	NA				
Factory Speed Test	NA				
Functional Test	5.1	OPERATIONAL			1/12/98
RGA Test	NA				
Particle Count	5.2	Class 100 FINAL COUNT = 17.1	EQUIPMENT: MET ONE LASER PARTICLE COUNTER CALIBRATED: 5/19/97 SN: 970500275 DUE : 5/19/98 MODEL 227B	1-15-98	1/12/98
Pumpdown	NA				

TOTAL P.10

CLEAN ROOM: Left End	DATE: 1/12/98	BY: John Flinn LIGO Witness: Kyle Ryan	TEST NO.: 3
MET ONE MODEL 227 NO. LOC.=43 Samples= 21	FLOWRATE=0.1CFM SAMP/LOC=1	PERIOD=2.0 MIN. HOLD=1.O MIN.	START TIME: 1415 STOP TIME: 1545

MEAN =	17.1
SD=	39.7
SE=	8.9

READING	CONCENTRATION (PART/CUBIC FT)		(A-MEAN)^2
0	A1=	0	293.88
0	A2=	0	293.88
0	A3=	0	293.88
2	A4=	10	51.02
4	A5=	20	8.16
10	A6=	50	1079.59
3	A7=	15	4.59
0	A8=	0	293.88
2	A9=	10	51.02
0	A10=	0	293.88
0	A11=	0	293.88
0	A12=	0	293.88
0	A13=	0	293.88
0	A14=	0	293.88
0	A15=	0	293.88
2	A16=	10	51.02
0	A17=	0	293.88
12	A18=	60	1836.73
35	A19=	175	24918.88
2	A20=	10	51.02
0	A21=	0	293.88

Title: ACCEPTANCE TEST PROCEDURE FOR PORTABLE SOFT-WALL CLEANROOMS

TABLE II - SAMPLE LOCATION GRID BSC TYPE 1,2,3

	1	2	3	4	5	6
A			X-17			
B		O-5	X-18 O-6	X-16 O-7	O-8	
C	X-20	X-19 O-4			O-9 X-15	X-14
D		X-21 O-3			O-10 X-13	
E		O-2	O-1 ~~X~~	O-12 ~~X~~	O-11	
F			~~X~~			

LE CLEAROOM
400 BUILDING

LOCATION - 43
SAMPLES - 21
PERIOD - 2 min.
HOLD - 2 min.

- vessels have been blown down, floor has been mopped.

(/) - N/A A7B SPOOL

X- Elevation = ~ 4'
O - Elevation = ~ 10'

(-X) - SAMPLE # X LOCATION

ATTACHMENT I V 0 4 9 -2-110

LEFT END STATION

PRINTING 021 RECORD(S)
DATA WILL BE REMOVED FROM THE BUFFER

LOC

DATE = 01/12/98 TIME = 14:20:17
PERIOD = 00:02:00 LOCATION NUM. 43
0.3u = 1 0.5u = 0 1

DATE = 01/12/98 TIME = 14:24:17
PERIOD = 00:02:00 LOCATION NUM. 43
0.3u = 0 0.5u = 0 2

DATE = 01/12/98 TIME = 14:28:17
PERIOD = 00:02:00 LOCATION NUM. 43
0.3u = 0 0.5u = 0 3

DATE = 01/12/98 TIME = 14:32:17
PERIOD = 00:02:00 LOCATION NUM. 43
3u = 9 0.5u = 2 4

DATE = 01/12/98 TIME = 14:36:17
PERIOD = 00:02:00 LOCATION NUM. 43
0.3u = 6 0.5u = 4 5

DATE = 01/12/98 TIME = 14:40:17
PERIOD = 00:02:00 LOCATION NUM. 43
0.3u = 19 0.5u = 10 6

DATE = 01/12/98 TIME = 14:44:17
PERIOD = 00:02:00 LOCATION NUM. 43
0.3u = 9 0.5u = 3 7

DATE = 01/12/98 TIME = 14:48:17
PERIOD = 00:02:00 LOCATION NUM. 43
0.3u = 0 0.5u = 0 8

DATE = 01/12/98 TIME = 14:52:17
PERIOD = 00:02:00 LOCATION NUM. 43
0.3u = 4 0.5u = 2 9

DATE = 01/12/98 TIME = 14:56:17
PERIOD = 00:02:00 LOCATION NUM. 43
0.3u = 0 0.5u = 0 10

E = 01/12/98 TIME = 15:00:17
PERIOD = 00:02:00 LOCATION NUM. 43
0.3u = 0 0.5u = 0 11

DATE = 01/12/98 TIME = 15:04:17
PERIOD = 00:02:00 LOCATION NUM. 43
0.3u = 2 0.5u = 0 12

DATE = 01/12/98 TIME = 15:08:17
PERIOD = 00:02:00 LOCATION NUM. 43
0.3u = 2 0.5u = 0 13

DATE = 01/12/98 TIME = 15:12:17
PERIOD = 00:02:00 LOCATION NUM. 43
0.3u = 0 0.5u = 0 14

DATE = 01/12/98 TIME = 15:16:17
PERIOD = 00:02:00 LOCATION NUM. 43
0.3u = 1 0.5u = 0 15

DATE = 01/12/98 TIME = 15:20:17
PERIOD = 00:02:00 LOCATION NUM. 43
0.3u = 6 0.5u = 2 16

DATE = 01/12/98 TIME = 15:24:17
PERIOD = 00:02:00 LOCATION NUM. 43
0.3u = 0 0.5u = 0 17

DATE = 01/12/98 TIME = 15:28:17
PERIOD = 00:02:00 LOCATION NUM. 43
0.3u = 29 0.5u = 12 18

DATE = 01/12/98 TIME = 15:32:17
PERIOD = 00:02:00 LOCATION NUM. 43
0.3u = 70 0.5u = 35 19

DATE = 01/12/98 TIME = 15:36:17
PERIOD = 00:02:00 LOCATION NUM. 43
0.3u = 3 0.5u = 2 20

DATE = 01/12/98 TIME = 15:40:17
PERIOD = 00:02:00 LOCATION NUM. 43
0.3u = 0 0.5u = 0 21

NOTE

LOCATION 19: COUNT OF 35 WAS HIGH DUE TO THE PARTICLE COUNTER SLIPPING ON TEST STAND (0→30).

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT

5.4 System Leak Check

Leak testing was conducted in stages with individual components being leak checked and baked at PSI's Westborough facility. Each building system was then leaked as a system in the field per the system Acceptance Test Procedure (End Stations V049-2-115).

The leak testing philosophy and data sheets are attached.

Philosophy of Leak Testing at PSI-Westboro

The leak test specification for the LIGO vessels is to find, and repair, all $1x10^{-9}$ Torr-l/s of helium and greater leaks in accordance to ASTM E498 Standard Test Methods for Leaks. In order to optimize the leak testing process, we have bagged the first vessels of each type: WBSC10, WHAM1, and WCP4. Additionally, three spool sections were bagged: A15 (01), A1 (01)-A7B (01), and A6 (01)-B6 (01). Bagging these vessels consisted of enclosing the chambers with tarp and filling the bag with helium again in accordance to ASTM E498 specification. This creates a concentrated helium environment enabling the leak detector to find small leaks. A total leak rate can then be quantified. All six vessels registered a ***total*** leak rate of $< 1.5x10^{-9}$ Torr-l/s per vessel. Bagging was performed to try to qualify our evacuate-and-spray techniques developed during the prototype program. The results of the bag tests verified the evacuate-and-spray techniques implemented to attain the $1x10^{-9}$ Torr-l/s leak rate specification *per joint*. The history at PSI has shown that the smallest leaks our stainless steel welding techniques yield are $1x10^{-7}$ Torr-l/s for the worst case scenario. This statement is also confirmed in *High Vacuum Technology* by Hablanian (See Attached Reference). This size weld leak is easily found using our evacuate-and-spray technique. Mechanical joints and aluminum welding are therefore the only other source of $1x10^{-9}$ Torr-l/s leaks. All aluminum cryopump reservoirs were bagged for the leak testing technique prior to and after final assembly. Mechanical joints were targeted as the probable source for very small leaks ($1x10^{-7} \rightarrow 1x10^{-9}$ Torr-l/s). Very few leaks of this size were found on the vessels.

Philosophy of Leak Testing in the Field

The philosophy of leak testing the assembled LIGO vessels in the field is to verify the integrity of the leak test performed at PSI and to test new or remade conflat assemblies. The RGA air signature is an additional confirmation as to the tightness of the complete assembly. Taking the extra step to leak check each isolatable volume reduces the risk of getting a large, and therefore unacceptable, air signature. We field leak test every joint that has been changed since the initial leak test at PSI. This is confirmed by our conflat torque tags. Any missing or newly tagged joint is rechecked, and often all joints are rechecked if time permits.

PSI Leak Testing Summary

Following all of the steps listed above helps to ensure meeting the leak test specification. As of this writing, the air signature has been demonstrated in the Left Mid, Left End, and Left Beam Manifold. The air signature method was used to identify a gate valve bellows leak in the Right Mid Station. A new test has been developed for the large gate valve bellows.

Table 11.1 Examples of Leak Rate Specifications for Various Products and Industries

Product or system	Leak rate specification (atm · cm^3/s)	Comment
Chemical process equipment	10^{-1} to 1	High process flow rates
Torque converter	10^{-3} to 10^{-4}	Retention of liquid
Beverage can end	10^{-5} to 10^{-7}	Smaller leaks, if present have negligible effect
IC package	10^{-7} to 10^{-8}	
Pacemaker	10^{-9} to 10^{-10}	Long life, implanted in body

11.2.3 Distribution of Leaks by Size

The curve in Figure 11.1 shows the general distribution by size of commonly encountered leaks based on observations over many years for many products. Knowedge of this distribution is helpful in establishing reasonable leak rate specifications for a given product. There are two regions because there are two means of gas transfer: through holes and by permeation.

Although industrial leak rate specifications range from 10^{-9} to 1 atm · cm^3/s, the majority of products have leak rate specifications lying in a narrower range, from 10^{-6} to 10^{-1} atm · cm^3/s. The upper part of this range is covered by bubble testing, down to 10^{-4} std cm^3/s. Other methods overlap the bubble method and extend well below its lower limit. The helium method can detect leaks smaller by a factor of 1,000,000. Leaks larger than 10^{-1} atm · cm^3/s can usually be spotted visually.

The large class of leaks caused by incomplete welds, brazes, seals, and so on, usually does not extend below 10^{-7} atm · cm^3/s. Smaller leaks are usually plugged by water vapor from the atmosphere. Baking, when feasible, can reopen these leaks by evaporating the water vapor.

Some products, which have to be reliable for an extended period—say 5 years or more—may warrant testing at higher sensitivity (10^{-8} to 10^{-9} atm · cm^3/s) for the reassurance of having conservative test results. An example is the pacemaker, which must function for years in a difficult environment.

HIGH VACUUM TECHNOLOGY
HABLANIAN, M.H.
MARCEL DEKKER, INC, 1990

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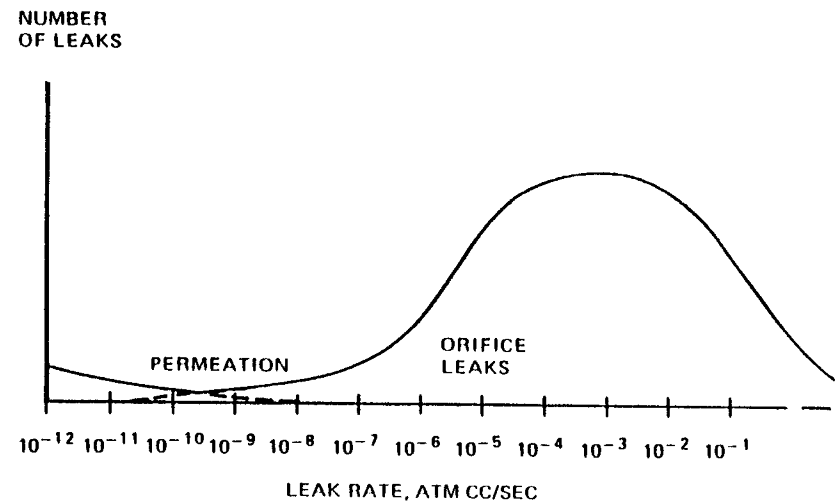


Figure 11.1 Typical distribution of leaks encountered in industrial products.

For most products, however, looking for leaks 100 or 1000 times smaller than the acceptable limit will incur unnecessary additional test expense without improving reliability. For example, it would not make economic sense to test automotive torque converters or ring pull-tab beverage can ends at 10^{-8} or 10^{-9} atm · cm^3/s; in fact, it would lead to costly rejection of perfectly serviceable products.

11.3 METHODS OF LEAK DETECTION

11.3.1 Leak Location and Measurement

The basic functions of leak detection are the location and measurement of leaks. These functions are carried out through the use of standard leak test techniques, which are usually selected according to the configuration of the part to be tested, the economics of the test, and the nature of the system. These techniques depend on the use of a tracer gas (or liquid) passing through a leak and being detected on the other side, and are applicable to most of the leak detection methods, including the helium method.

Leak Location

Leak location is the testing approach used to find the precise location of individual leaks. It is usually a qualitative procedure only. The techniques used are very dependent on the skill and alertness of an

WASHINGTON LEFT END STATION

TAG NO.		*SER. NO.*
WBSC10		01
WBE4C		03
WCP7		02
WA1B		02
WA7B		02
	GNB GATE VALVES	
WGV17		008
WGV ? 18		009

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

LEAK TEST DATA SHEET

	1	2	EQUIP #
Component Name	LEFT - END STATION	ANNULAS PIPE	WBSC 10 SN 01
Model Number			WA7B 2 SN 02
Serial Number			WA13 SN 02
Drawing Number	V049-5-007		WGV 11 SN 09
			WCP 7 SN 02
Detector Name	BALZERS	BALZERS	WGV17 SN 08
Model Number	HLT 160 DRY	HLT 160 DRY	(1) 2500 L/S IP
Serial Number	02	03	(1) 14" GV
SYSTEM	- -		(2) 10" GV
[redacted] Calibration		HLT	(3) ANNULAS ION PUMP
Expiration Date	1-12-98	INT. CAL. ONLY	ALL ANNULAS PIPE
Standard Leak Rate	4.53 x 10⁻⁹		
Background	N/A		
Standard Response	5 x 10⁻⁹		
Leak Test Data			
Location /Date	WASH. SITE	WASH	
Tracer Gas	HE	HE	
Pressure / CC G-H1	x10⁻⁶ TORR	LESS than 1x10⁻⁵ PER ANNULAS SPACE	
Duration	N/A EVACUATE + SPRAY	N/A EVACUATE + SPRAY	
Response	NDL x10⁻⁹ scale	NDL x10⁻⁹ SCALE	
Leak Rate			
Measured	NDL x10⁻⁹ E+SPRAY	NDL x10⁻⁹ SCALE EVAC + SPRAY	
Calculated			
Allowable			
Performed By : D. H.	Date : 2-24-98	2-24-98	
Witnessed By :	Date :		
Signature [signature]	Date :		
Title : PROD TECH III			

Remarks :

SPECIFICATION	
Number: V049-2-014 A	Rev. 2

LEAK TEST DATA SHEET

	1	2	3
Component Name	CRYOPUMP	SPOOL	
Model Number	WCP7	BE4C	
Serial Number	SC-5	03	
Drawing Number			
Detector Name	BALZERS		
Model Number	HLT160		
Serial Number	#2		
Detector Calibration	CF 1.2 8-2-97		
Expiration Date			
Standard Leak Rate	[illegible]		
Background			
Standard Response			
Leak Test Data			
Location /Date	cryo room		
Tracer Gas	He		
Pressure			
Duration	1:06 hr		
Response	4.0 x 10-9		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : DH	Date : 8-2-97		
Witnessed By :	Date :		
Signature :	Date :		
Title :			

Remarks : NDL on 10-9 range (int. test.)

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

SPOOL SECTION LEAK TEST SUMMARY SHEET

Name	CRYO	SPOOL					
Model No.	WCP7	BE4C					
Serial No.	SL-5	03					
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
		Torr	Torr				
Annulus-1	IV		$1x10^{-5}$	✓		DH	8-1-97
Annulus-2	IV		$1x10^{-5}$	✓		DH	8-1-97
Annulus-1	V		$1x10^{-5}$				
Annulus-2	V		$1x10^{-5}$				
		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$	✓		DH	8-1-97
Weld Joint	II		$1x10^{-9}$	✓		DH	8-1-97
Conflat	III		$1x10^{-9}$				

Comments

Witnessed
Signature DH
Title
Date 8-2-97

SPECIFICATION

Number: V049-2-014 A

Rev. 2

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

LEAK TEST DATA SHEET

	1	2	3
Component Name	A1-A7B		
Model Number			
Serial Number	02		
Drawing Number			
Detector Name	BALZERS		
Model Number	HLT 160		
Serial Number	3137944-002		
Detector Calib.Date	6-7-97		
Detector Calib.Factor	1.0		
Standard Leak Rate	4.4X10-9		
Std.Leak Expir.Date	6-27-97		
Standard Response	5.7X10-9		
Leak Test Data			
Location /Date			
Tracer Gas	HE		
Pressure @ Turbo Inlet			
Duration	20 MIN		
Response	1X10-9		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : DA	Date : 6-6-97		
Witnessed By :	Date :		
Signature : [signature]	Date : 6-6-97		
Title :			

Remarks : LEAK RATE LESS THAN 1X10-9 20MIN BAK TEST

SPECIFICATION	
Number: V049-2-014 A	p2

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	A1-A7B						
Model No.							
Serial No.	01						
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		$4x10^{-5}$	✓		[signature]	6-7-97
	II		NDL (10^{-9} Scale)	✓			6-7-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments LEAK RATE LESS THAN 1X10-9 30 min BAG TEST

Witnessed
Signature [signature]
Title
Date: 6-7-97

SPECIFICATION	
Number: V049-2-014 A	p2

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

LEAK TEST DATA SHEET

	1	2	3
Component Name	BSC		
Model Number	WBSC10		
Serial Number	001		
Drawing Number			
Detector Name	BALZERS		
Model Number	HLT 160 #2		
Serial Number			
Detector Calib.Date	4-10-97		
Detector Calib.Factor	1.1		
Standard Leak Rate	4.4x10-9		
Std.Leak Expir.Date	6-27-97		
Standard Response SYS	4.1x10-9		
Leak Test Data			
Location /Date			
Tracer Gas	HE		
Pressure @ Turbo Inlet			
Duration	50 mn		
Response	1x10-9		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By: D. H.	Date: 4.10.97		
Witnessed By:	Date:		
Signature [signature]	Date: 4-10-97		
Title:			

Remarks: LEAK RATE LESS than 1x10-9 AFTER 50 min BAG-TEST

SPECIFICATION	
Number: V049-2-014 A	p2

.28

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	BSC						
Model No.							
Serial No.	001						
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		$4x10^{-5}$	✓		D. Hunter	4-4-97
	II		NDL (10^{-9} Scale)	✓		D. Hunter	4-4-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments LEAK RATE LESS THAN $1x10^{-9}$ AFTER 50 MIN BAK TEST

Witnessed
Signature [signature]
Title
Date: 4-4-97

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT

5.5 System Bake-Out

The completed station was baked-out per Acceptance Test Procedure V049-2-112.

The bakeout passed the requirements since the ultimate pressure test was successfully completed.

LEFT END STATION

3-19-98

1500 START

1843 SHUTDOWN HIGH ΔT CART 2

2025 RESTART SP = 18°C

PRESSURE @ TURBO 5.1×10^{-7}

3-20-98

0800 SP = 42°C PRESS. 2.0×10^{-6}

1100 SP = 47°C PRESS. 2.8×10^{-6}

1410 SP = 53°C PRESS. 4.3×10^{-6}

1830 SP = 62°C PRESS. 7.0×10^{-6}

3-21-98

1000 SP = 93 PRESS. 1.6×10^{-5}

1030 START GN_2 TO CRYO.

1430 SP = 102 PRESS. 1.4×10^{-5}

1830 SP = 110 PRESS. 2.2×10^{-5}

CRYO 68°C

3-22-98

0930 SP = 140 PRESS. 1.4×10^{-5} CRYO 50°C

1100 SP = 143 PRESS. 1.6×10^{-5} CRYO 52°C

1415 SP = 150 PRESS 1.8×10^{-5} CRYO 92°C

1530 SP = 150 PRESS 2.0×10^{-5} CRYO 104°C

1800 SP = 150 PRESS 1.8×10^{-5} CRYO 150°C

3-23-98

0630	SP=150	PRESS. 1.5 x10^{-5}	CRYO 111°C
0930	SP=150	PRESS. 1.5 x10^{-5}	CRYO 116°C
1130	SP=150	PRESS. 1.5 x10^{-5}	CRYO 117°C
1330	SP=150	PRESS. 1.6 x10^{-5}	CRYO 122°C
1515	SP=150	PRESS. 1.6 x10^{-5}	CRYO 126°C
1800	SP=150	PRESS. 1.5 x10^{-5}	CRYO 127°C

3-24-98

0700	SP=150	PRESS. 1.1 x10^{-5}	CRYO 39°C
0945	SP=150	PRESS 1.2 x10^{-5}	CRYO 82°C
1100	SP=150	PRESS 1.2 x10^{-5}	CRYO 96°C
1200	SP=150	PRESS 1.1 x10^{-5}	CRYO 107°C
1300	SP=150	PRESS 1.1 x10^{-5}	CRYO 116°C
1400	SP=150	PRESS 1.1 x10^{-5}	CRYO 118°C
1515	SP=148	PRESS 1.1 x10^{-5}	CRYO 93°C

3-25-98

0800	SP=114	PRESS. 4.0 x10^{-6}	CRYO 90°C
0830	SP= 112	PRESS. 3.7 x10^{-6}	
1030	SP= 110	PRESS 3.5 x10^{-6}	
1130	SP=108	PRESS 3.2 x10^{-6}	
1230	SP=106	PRESS 2.9 x10^{-6}	
1330	SP=104	PRESS 2.7 x10^{-6}	
1430	SP=102	PRESS 2.5 x10^{-6}	
1530	SP=100	PRESS 2.4 x10^{-6}	

3-26-98

1130	SP = 64	PRESS.	5.8×10^{-7}
1230	SP = 62	PRESS.	5.3×10^{-7}
1400	SP = 56	PRESS	4.8×10^{-7}
1500	SP = 53	PRESS	4.1×10^{-7}

SYSTEM OFF

3-27-98

PRESS @ TURBO 9.1×10^{-8}

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT

5.6 Ultimate Pressure Test (After Bake-Out)

The ultimate pressure test was conducted per Acceptance Test Procedure V049-2-114.

All test results met or exceeded the requirements.

Partial Pressure Calculation

Acceptance of the Bakeout with respect to Air Signature and Partial Pressures

Date: 03/29/98
Test ID: WLERGA
PSI Engineer: S.MOTEW

AMU	F (amu) transmission efficiency wrt N_2	E (amu) ionization efficiency wrt N_2	S (p_amu) sensitivity (Torr/A)	I (amu) ion current (A)	PP (amu) (Torr)
2	-	-	2.47	1.80E-09	4.45E-09
16	0.57	1.60		1.50E-11	2.18E-11
18	0.64	1.12		7.90E-12	1.73E-11
28	-	-	3.08	2.90E-10	8.93E-10
44	1.57	1.42		9.20E-12	2.50E-11
all others	-	-	3.08	4.30E-11	1.32E-10

		LIGO Contract Limits	Actual	Pass
Primary Criteria -	Total Pressure:	2.00E-08 Torr	5.54E-09 Torr	Yes
Secondary Criteria -	Others except H_2 & H_2O:	3.00E-09 Torr	1.07E-09 Torr	N/A

LIGO: John Worden

PSI:

Title: PROCEDURE FOR RGA FIELD CALIBRATION ON AN ISOLATABLE SECTION

TITLE	RGA CAL. CHAMBER PARTIAL PRESSURE DATA SHEET
DATE: 3/29/98	
TIME:	
TEST I.D.: e.g. WBSC1_1	WLERGA_1.SAC RGA CHAMBER CALIB. BASELINE
PSI TEST ENGINEER:	Sm WLERGA-2.SAC CAL. LEAK OPEN

AMU	I_{amu} WLERGA_1 (Amp) CYCLE 4	Q_{amu_leak} Leak rate (Torr-L/s)	F_{amu} Transmission Factor wrt N_2	E_{amu} Ionization efficiency wrt N_2*	I_{leak} WLERGA-2 (Amp) CYCLE 6	S_{p_amu} (Torr/A)	P_{amu} (Torr)
H_2	7.4E-10	$4.8x10^{-6}$		0.46	1.4E-7	2.47	1.8 E-9
He	1E-13			0.18	1E-13		--
12	1.0E-11		0.42				
14	3.0E-12		0.5				
15	3.3E-12		0.54				
CH_4	2.9E-11		0.57	1.60			
17	5.0E-11		0.6				
H_2O	1.6E-10		0.64	1.12	7.0E-10		
19	6.5E-12		0.67				
26	4.4E-12		0.71				
28	1.3E-10	$9.5x10^{-7}$		1.00	8.4E-8	3.08	4.0 E-10
32	4.4E-13		1.14	1.01			
38	4.1E-13		1.36				
40	5.9E-13	$9.4x10^{-8}$		1.29	7.9E-9	3.82	2.2 E-12
43	7.4E-13		1.53				
44	9.0E-11		1.57	1.42			
129	1E-13	$2.2x10^{-8}$		2.87	2.0E-9	6.34	6.3E-13
131	1E-13	$1.8x10^{-8}$		2.87	1.5E-9		
132	1E-13	$2.2x10^{-8}$		2.87	1.9E-9		
134	1E-13	$9.0x10^{-9}$		2.87	7.4E-10		
136	1E-13	$8.0x10^{-9}$		2.87	6.3E-10		
Other				1.00			

* Values used from Granville-Phillips for their B-A ion gauges (CH_4 from Leybold)

$$S_{P_{amu}} = \frac{Q_{amu\_leak}}{S_{orifice\_amu}\,(I_{leak} - I_{amu})}$$

$$S_{orifice_{amu}} = 3.673\sqrt{\frac{28.78}{amu}}$$

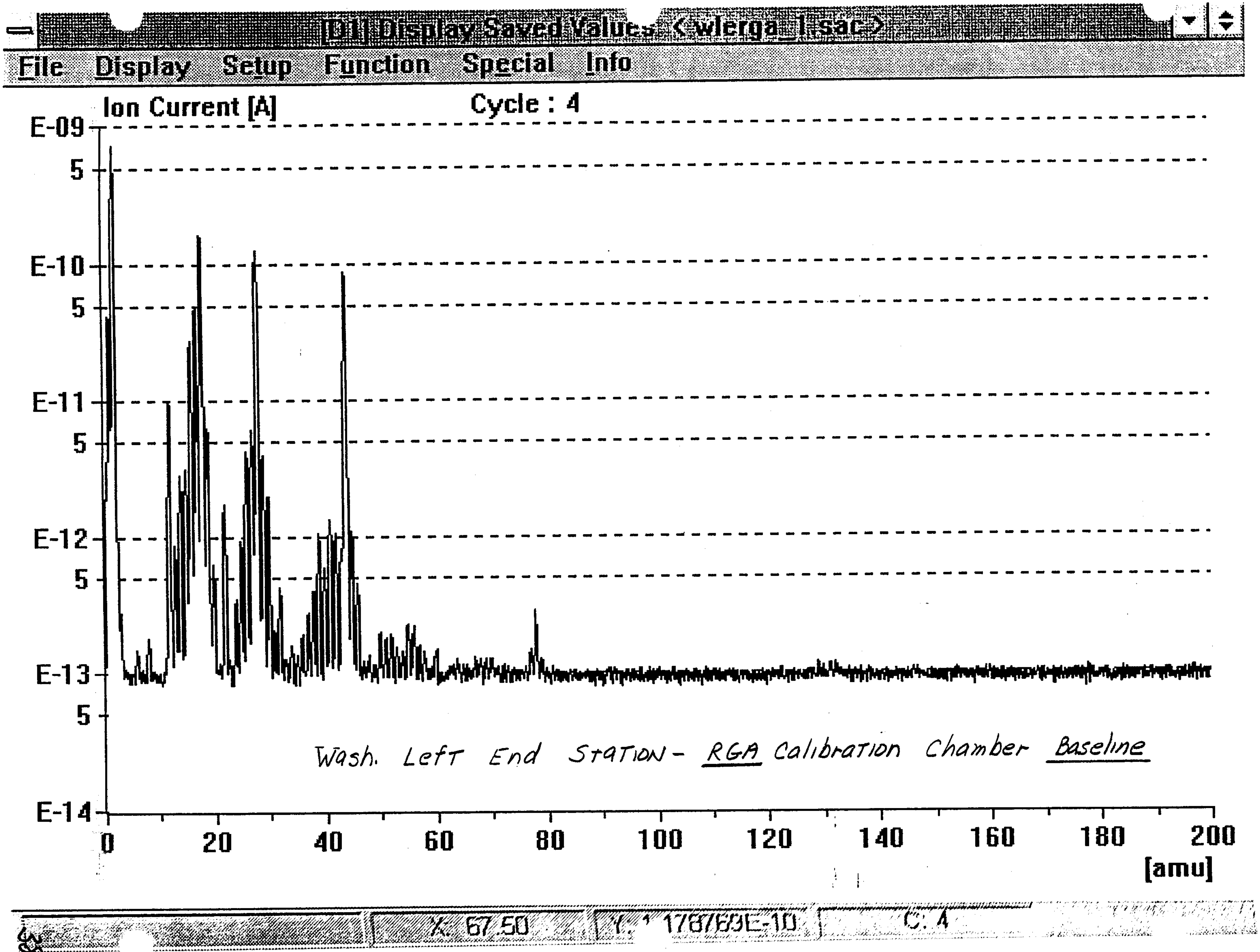
SPECIFICATION	
Number: V049-2-186 A	Rev.0

TITLE	RGA CAL. CHAMBER PARTIAL PRESSURE DATA SHEET
DATE: 3/29/98	
TIME:	
TEST I.D.: e.g. WBSC1_1	LEFT END STATION (WASH.) Wlerga-6.sac, cycle 2
PSI TEST ENGINEER:	SM

AMU	I_{amu} (Amp)	Q_{amu_leak} Leak rate (Torr-L/s)	F_{amu} Transmission Factor wrt N_2	E_{amu} Ionization efficiency wrt N_2*	I_{leak} (Amp)	S_{p_amu} (Torr/A)	P_{amu} (Torr)	
H_2	1.8 E-9	$4.8x10^{-6}$		0.46		2.47	4.4 E-9	Pass
He	1.4E-13			0.18				
12	7.9E-12		0.42			3.08	4.5 E-12	
14	6.2 E-12		0.5			3.08	1.4 E-11	
15	6.2E-12		0.54			3.08	1.4 E-11	
CH_4	1.5 E-11		0.57	1.60		3.08	2.2 E-11	Pass
17	4.7E-12		0.6			3.08	1.1 E-11	
H_2O	7.9E-12		0.64	1.12		3.08	1.7 E-11	Pass
19	7.0E-12		0.67			3.08	1.8 E-11	
26	2.3E-12		0.71			3.08	5.2 E-12	
28	2.9E-10	$9.5x10^{-7}$		1.00		3.08	8.9E-10	Pass
32	7.4E-13		1.14	1.01		3.08	2.4 E-12	
38	1.7E-13		1.36			3.08	6.1 E-13	
40	7.6E-12	$9.4x10^{-8}$		1.29		3.82	2.9E-11	
43	1.5E-13		1.53			3.08	5.7E-13	
44	9.2E-12		1.57	1.42		3.08	2.5 E-11	Pass
129	1 E-13	$2.2x10^{-8}$		2.87		6.34	6.E-13	
131		$1.8x10^{-8}$		2.87				
132		$2.2x10^{-8}$		2.87				
134		$9.0x10^{-9}$		2.87				
136		$8.0x10^{-9}$		2.87				
Other	1.1E-11			1.00		3.08	3.4E-11	Pass

* Values used from Granville-Phillips for their B-A ion gauges (CH_4 from Leybold)

TOTAL PRESS = 5.5×10^{-9} Torr Pass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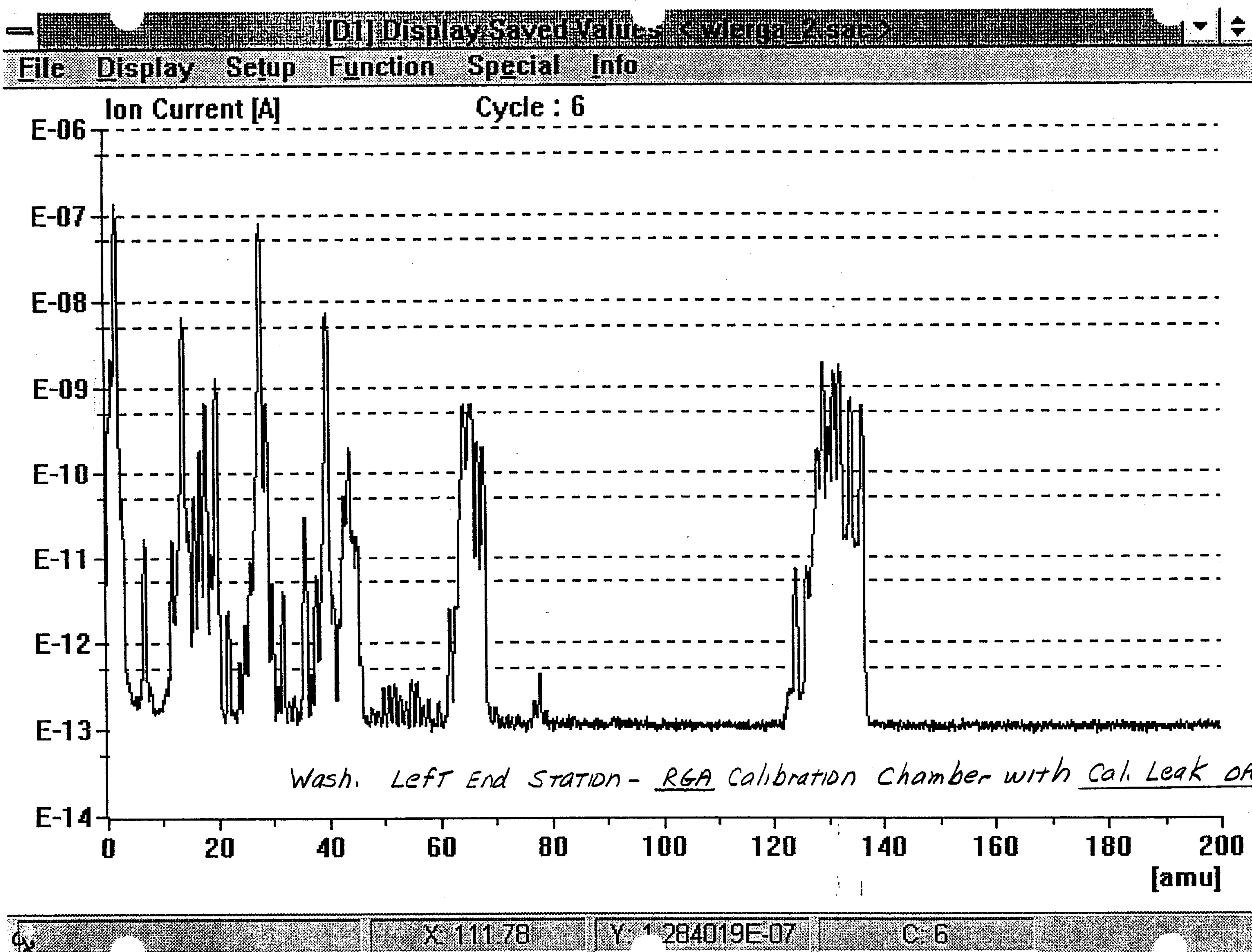
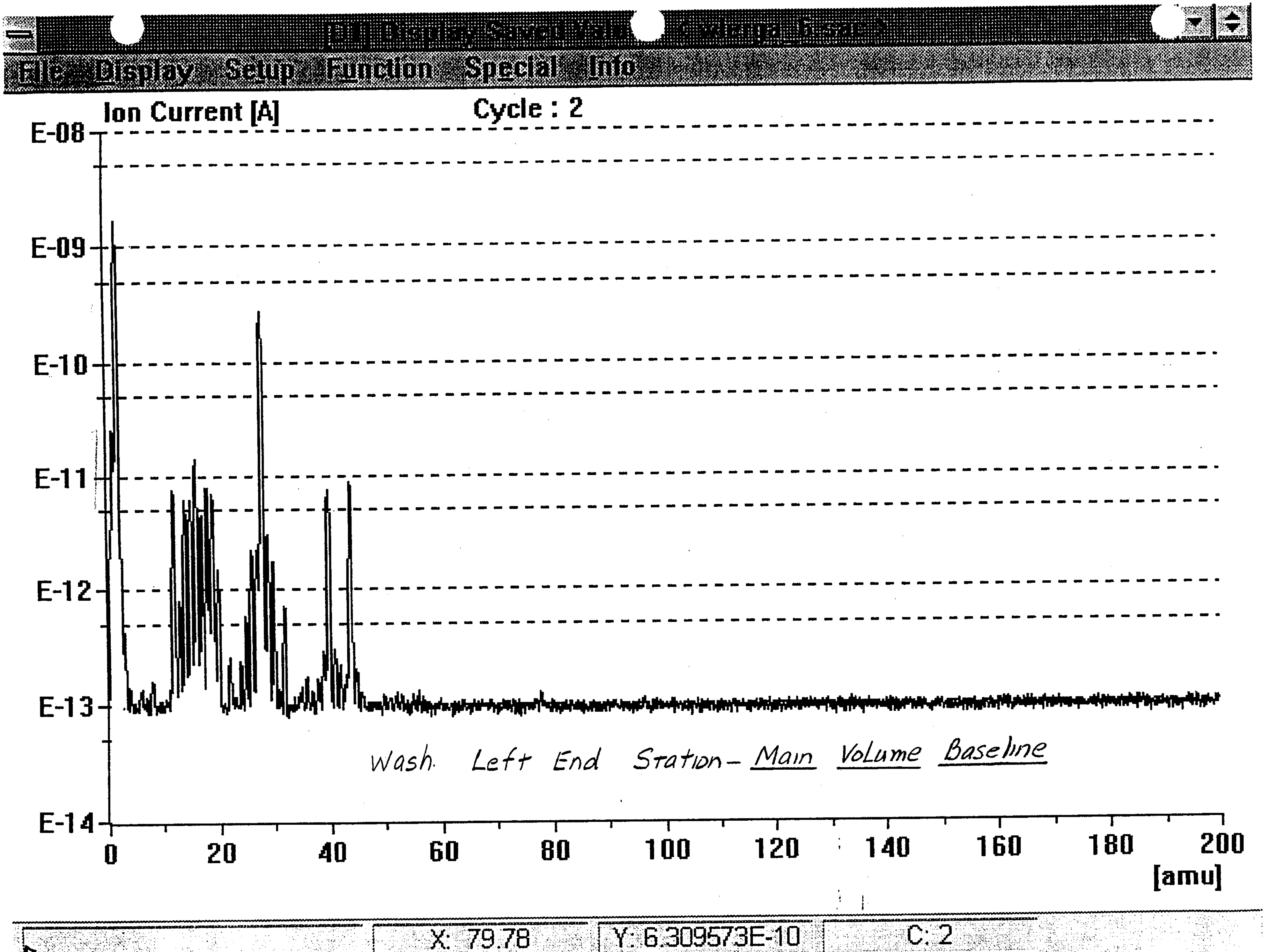
File Display Setup Function Special Info
Ion Current [A]
Cycle : 4
E-09
5
E-10
5
E-11
5
E-12
5
E-13
5
E-14
0 20 40 60 80 100 120 140 160 180 200
[amu]
Wash. Left End Station - RGA Calibration Chamber Baseline
X: 67.50
C: 4



Wash. Left End Station - RGA Calibration Chamber with Cal. Leak open



File Display Setup Function Special Info
Ion Current [A]
Cycle : 2
E-08
E-09
E-10
E-11
E-12
E-13
E-14
0
20
40
60
80
100
120
140
160
180
200
[amu]
Wash Left End Station – Main Volume Baseline
X: 79.78
Y: 6.309573E-10
C: 2

40

$\boxed{\text{RGA CALIB.}}$ WLERGA_1.5AC cycle 4 , WLERGA_2 cycle 6

H_2 $$S_{orifice\_amu} = 3.673 \sqrt{\frac{28.78}{2.0}}$$

$$= 13.93$$

$$S_{H_2} = \frac{4.8 \times 10^{-6}}{(13.93)(1.4 \times 10^{-7} - 7.4 \times 10^{-10})} \qquad \frac{\text{Torr}\,\frac{l}{s}}{\frac{l}{s}\,(\text{AMP})} \cdot \frac{\text{Torr}}{\text{AMP}}$$

$$= 2.47 \quad \frac{\text{Torr}}{\text{AMP}}$$

N_2 $$S_{N_2} = \frac{9.5 \times 10^{-7}}{(3.673)(8.4 \times 10^{-8} - 1.3 \times 10^{-10})}$$

$$= 3.08 \quad \frac{\text{Torr}}{\text{AMP}}$$

Ar $$S_{Ar} = \frac{9.4 \times 10^{-8}}{(3.673)\left(\sqrt{\frac{28.78}{40}}\right)(7.9 \times 10^{-9} - 5.9 \times 10^{-13})}$$

$$= 3.82 \quad \frac{\text{Torr}}{\text{AMP}}$$

Xe_{129} $$S_{Xe_{129}} = \frac{2.2 \times 10^{-8}}{(3.673)\left(\sqrt{\frac{28.78}{129}}\right)(2.0 \times 10^{-9} - 1.0 \times 10^{-13})}$$

$$= 6.34 \quad \frac{\text{Torr}}{\text{AMP}}$$

WLERGA26.sac cycle 2

CH4
METHANE

$$P_{amu} = \frac{I_{amu}\ F_{amu}\ S_{PN_2}}{E_{amu}} \sqrt{\frac{28}{amu}}$$

$$P_{CH_4} = \frac{(1.5E-11)(0.57)(3.08)}{1.60} \sqrt{\frac{28}{16}}$$

(AMPS)(Torr/AMP)

$$= 2.2 \times 10^{-11} \text{ Torr}$$

CO_2

$$P_{CO_2} = \frac{(9.2\ E-12)(1.57)(3.08)}{1.42}\left(\sqrt{\frac{28}{44}}\right)$$

$$= 2.5 \times 10^{-11} \text{ Torr}$$

O_2

$$P_{O_2} = \frac{(7.4E-13)(1.14)(3.08)}{1.01} \sqrt{\frac{28}{32}}$$

$$\doteq 2.4 \times 10^{-12} \text{ Torr}$$

H_2O

$$P_{H_2O} = \frac{(7.9E-12)(.64)(3.08)}{1.12} \sqrt{\frac{28}{18}}$$

$$= 1.7 \times 10^{-11} \text{ Torr}$$

AMU.

12 $P_{12} = \frac{(7.9E\text{-}12)(.42)(3.08)}{1.0} \left(\sqrt{\frac{28}{12}}\right)$

$= 4.5 \times 10^{-12}$ Torr

14 $6.2E\text{-}12\ (.5)(3.08)\sqrt{\frac{28}{14}}$

$= 1.4 \times 10^{-11}$

15 $6.2E\text{-}12\ (.54)(3.08)\sqrt{\frac{28}{15}}$

$= 1.4 \times 10^{-11}$

17 $4.7E\text{-}12\ (.6)(3.08)\sqrt{\frac{28}{17}}$

$= 1.1 \times 10^{-11}$

19 $7.0E\text{-}12\ (.67)(3.08)\sqrt{\frac{28}{19}}$

$= 1.8 \times 10^{-11}$

26 $2.3E\text{-}12\ (.71)(3.08)\sqrt{\frac{28}{26}}$

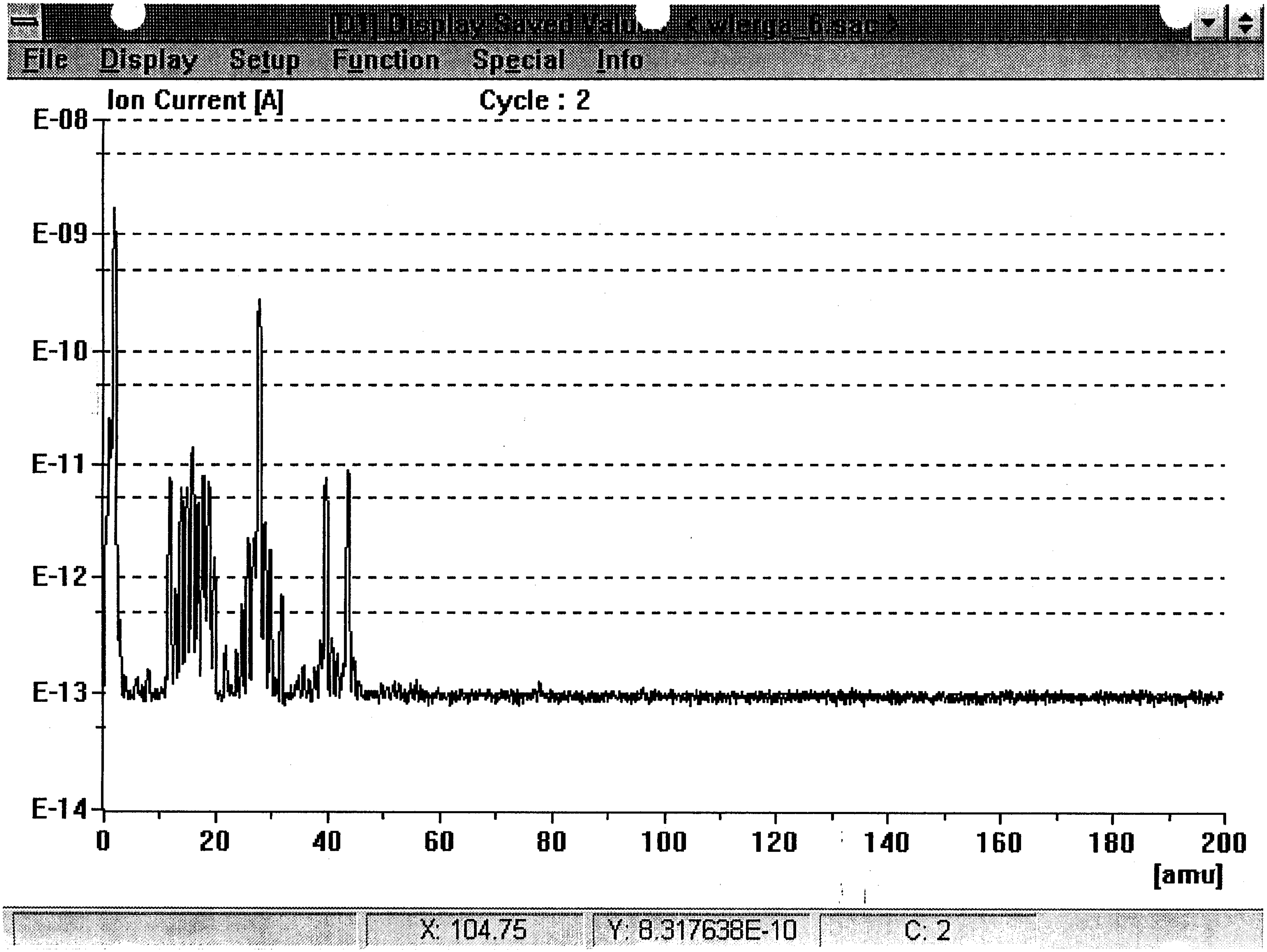
$= 5.2 \times 10^{-12}$

38 $1.7E\text{-}13\ (1.36)(3.08)\sqrt{\frac{28}{38}}$

$= 6.1 \times 10^{-13}$

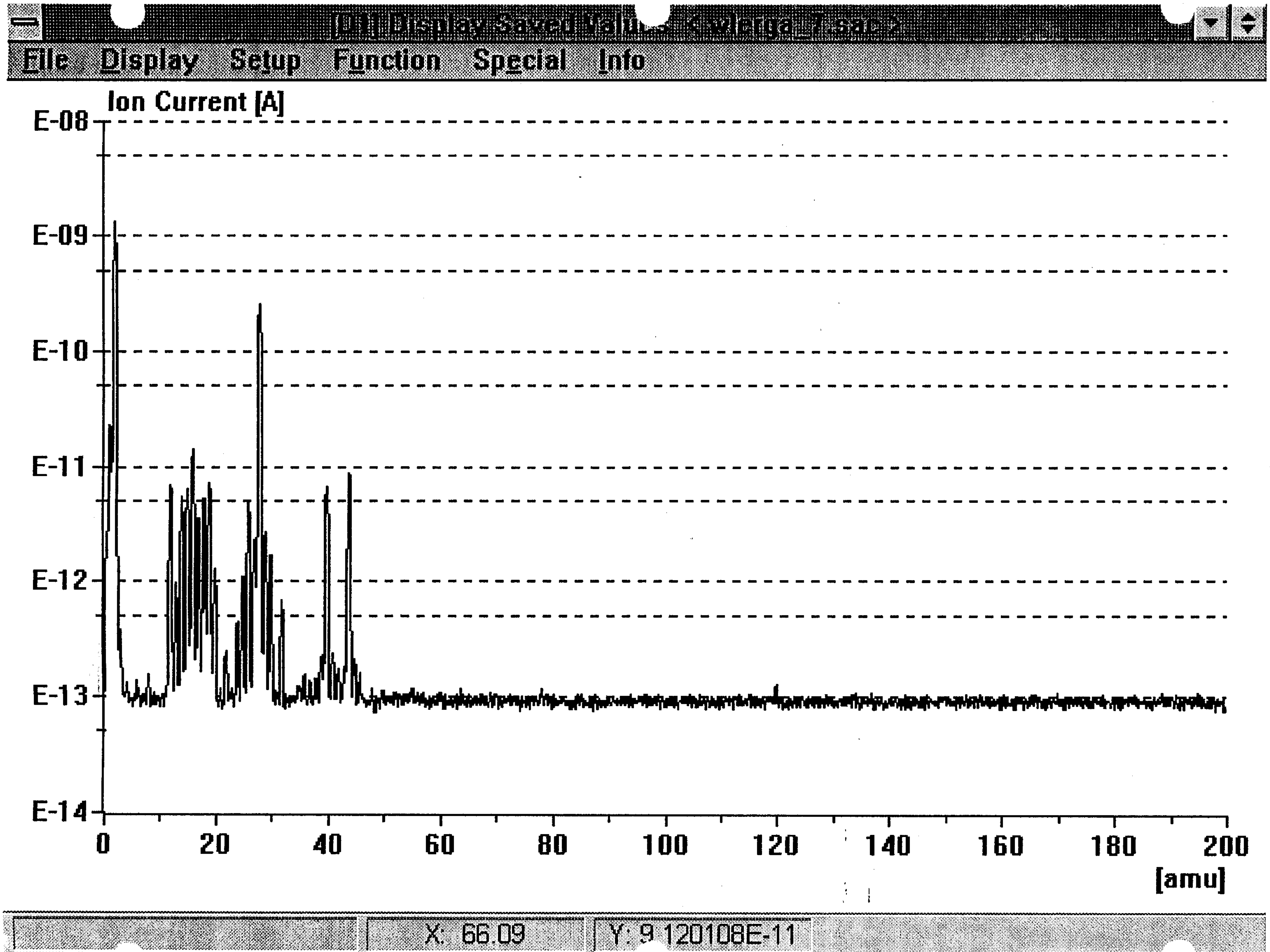
43 $1.5E\text{-}13\ (1.53)(3.08)\sqrt{\frac{28}{43}}$

$= 5.7 \times 10^{-13}$



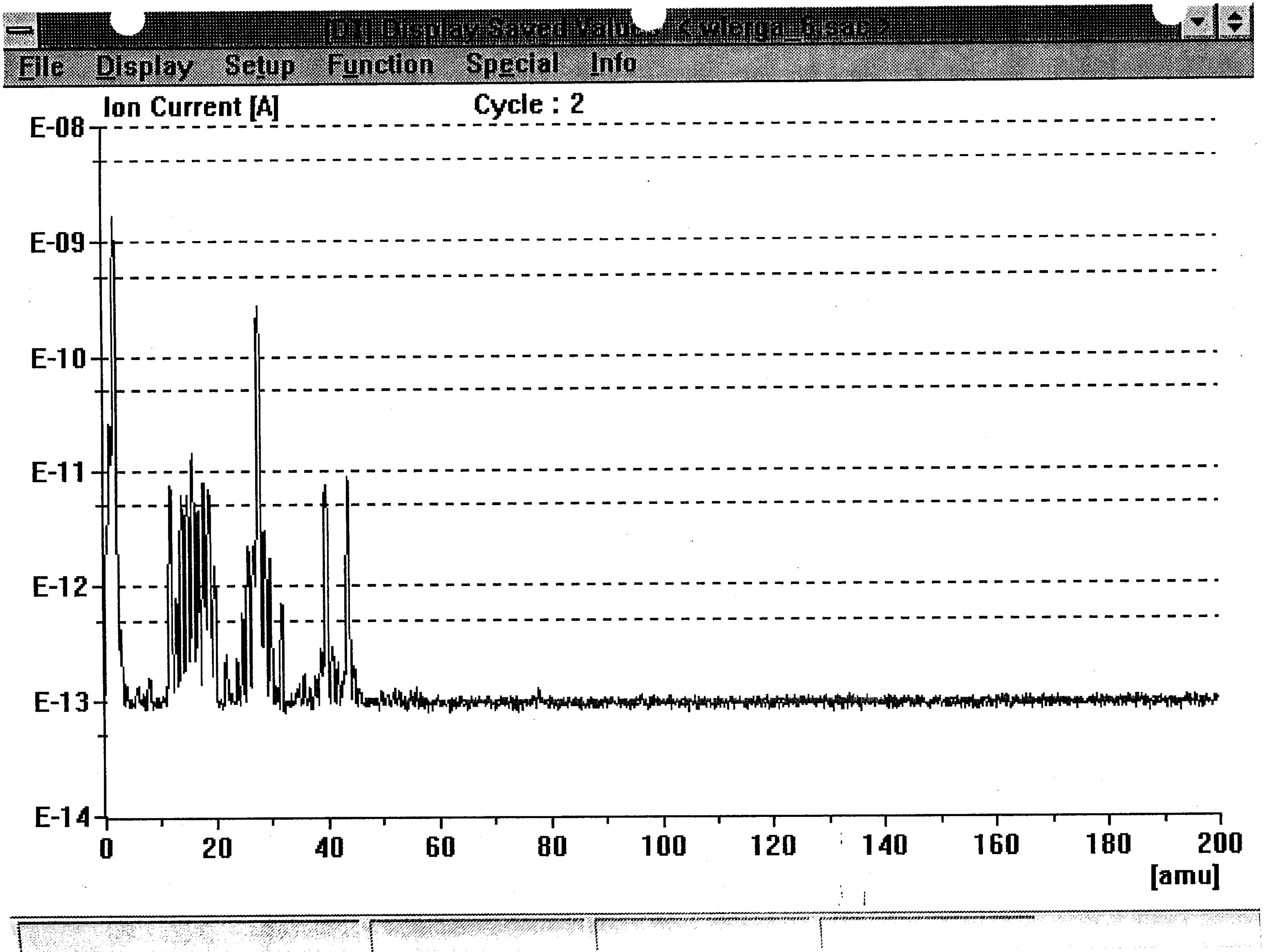
CRYOPUMP FULL 3-29-98 0810

44



CRYOPUMP LEVL 17% 3-30-98 0825

45


File
Display
Setup
Function
Special
Info
Ion Current [A]
Cycle : 2
E-08
E-09
E-10
E-11
E-12
E-13
E-14
0
20
40
60
80
100
120
140
160
180
200
[amu]

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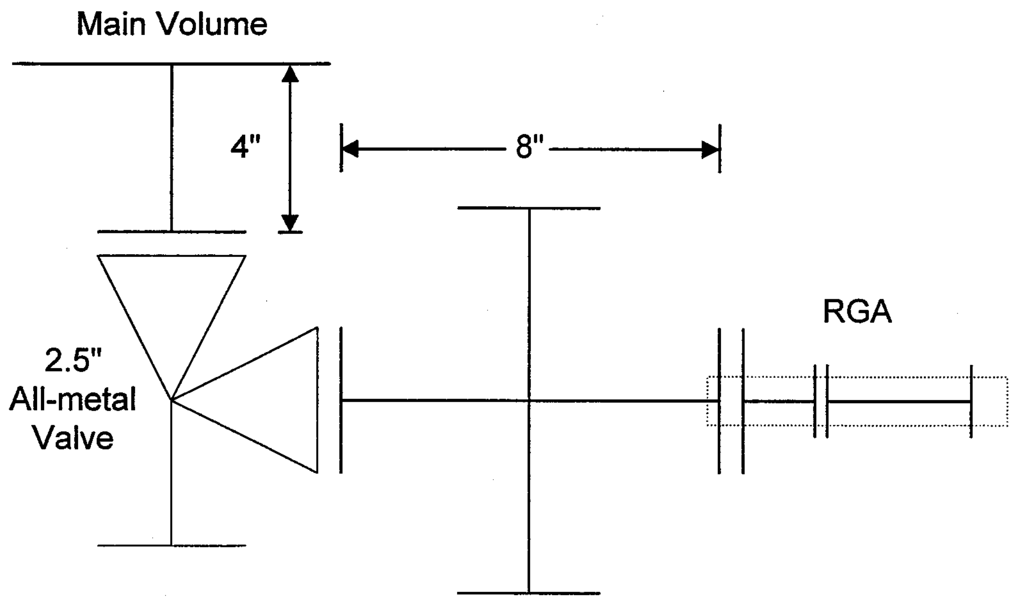
<u>Conductance Calculation for RGA Calibration Chamber at Left End Station</u>



1. $C_{2.5"\_Valve} = 80 l/s$ from published data
2. 2.5" tube path = 4" + 8" = 12"

$$P_{tube} = \left(1+\frac{3}{8}\cdot\frac{L}{r}\right)^{-1} = \left(1+\frac{3}{8}\cdot\frac{12}{1.25}\right)^{-1} = (4.6)^{-1} = 21.7\%$$

$$S_{2.5"\_orifice} = (2.5in)^2\frac{\pi}{4}\times\frac{(0.0254\ m)^2}{in^2}\times 117{,}000\ \frac{l}{s-m^2} = 370.5 l/s$$

$$C_{2.5"\_tube} = P_{2.5"\_tube}\cdot S_{2.5"\_orifice} = (0.217)\cdot(370.5 l/s) = 80.4 l/s$$

Conductance from Chamber to RGA:

$$C_{total} = \frac{1}{\dfrac{1}{80.4 l/s}+\dfrac{1}{80 l/s}} = 40.1 l/s$$

{this applies to the RGA on the cross at any location (*l*=8")}

The pumping speed to the chamber is almost 11 times greater with the 0.25" orifice (S=3.7 *l/s*).

This test configuration should provide better results than the Left Mid Station configuration.

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT

5.7 Backfill/100 Hr. Pumpdown Test

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT

5.7 Backfill/100 Hr. Pumpdown Test

The backfill and 100 hr. pumpdown test was conducted per Acceptance Test Procedure V049-2-114.

The roughing and turbo pumping requirements met or exceeded the requirements.

The ultimate pressure and partial pressure results are detailed herein. This test was for demonstration purposes only.

Partial Pressure Calculation

Demonstration of the Back-to-Air 100 hour pumpdown with respect to Partial Pressures

Date: 04/14/98
Test ID: WLEBTA (100 hr)
PSI Engineer: J. Flinn

AMU	*F (amu)* transmission efficiency wrt N_2	*E (amu)* ionization efficiency wrt N_2	*S (p_amu)* sensitivity (Torr/A)	*I (amu)* ion current (A)	*PP (amu)* (Torr)
2	-	-	2.87	1.14E-09	3.27E-09
16	0.57	1.60		4.85E-11	8.85E-11
18	0.64	1.12		3.40E-11	9.38E-11
28	-	-	3.87	1.98E-09	7.66E-09
44	1.57	1.42		1.11E-10	3.79E-10
all others	-	-	3.87	2.50E-10	9.68E-10

Total Pressure =	1.25E-08

LIGO: ______________________

PSI: ______________________

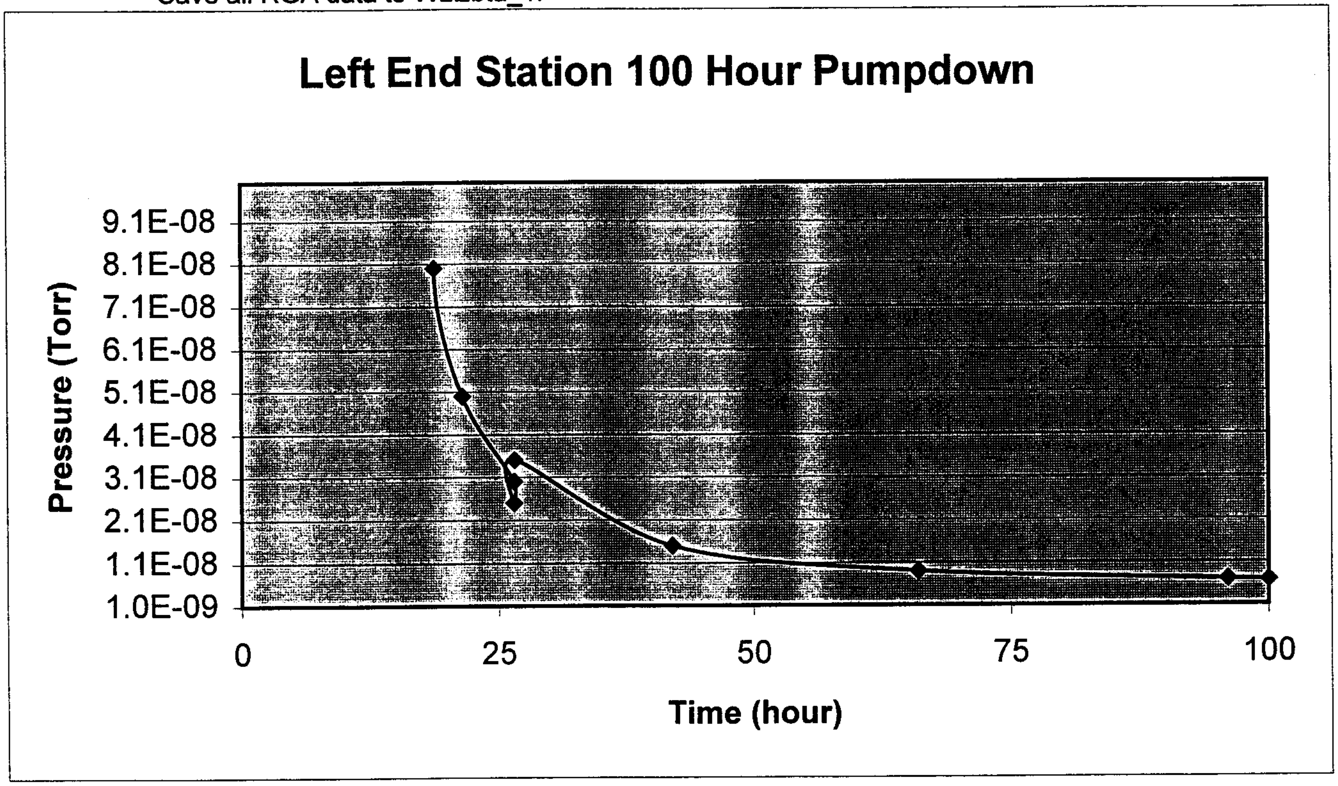
Left End Station Back-to-Air 100 Hour Pumpdown

04/02/98	1300	Start clean air purge with cryopump isolated by GV18
04/03/98	1300	End clean air purge
		Start rough pumping system with QDP80
	1700	P=0.49 Torr
		Start turbo pumping system with STP2000C
04/04/98	745	P=8.0E-8 Torr
		P(cryo)=4.0e-6 Torr
		Fill Cryopump
	830	Start 2500 l/s ion pump and close 14" gate valve
	1000	Open GV18 (44" gate valve)
	1030	P=5.0E-8 Torr
	1530	Ion Pump (Voltage=3000V, Amperage=2.5E-4A)
		P=3.0E-8 Torr
		Open 14" gate valve
	1531	P=2.5E-8 Torr
		Close 10" gate valve to isolate STP2000C
	1535	P=3.5E-8 Torr
		Ion Pump (Voltage=3000V, Amperage=5.2E-4A)
4/5/98	700	P=1.5E-8 Torr
4/6/98	700	P=9.0E-9 Torr
4/7/98	1300	P=7.0E-9 Torr
	1700	PT410=6.84E-9 Torr End of 100 hour test
		PT424=6.69E-9 Torr

Graphical Data

Time (hr)	Press (torr)
0	760
4	0.49
18.75	8.00E-08
21.5	5.00E-08
26.5	3.00E-08
26.52	2.50E-08
26.58	3.50E-08
42	1.50E-08
66	9.00E-09
96	7.00E-09
100	6.80E-09

Save all RGA data to WLEbta_1.***



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LEFT END back-to-air 100 hr pumpdown

4/2 - 4/3 24 hr purge (cryo isolated)

4/3 1300 start QDP80

1700 P = 0.49 torr

Start turbo

4/4 0745 Fill cryo

$P_{turbo} = 8.0 \times 10^{-8}$

$P_{cryo} = 4.0 \times 10^{-6}$

0830 START ION PUMP & CLOSE 14" GATE VALVE

1000 OPEN GV18 (44")

1030 $P = 5.0 \times 10^{-8}$

1530 IP = 3000 V, 2.5×10^{-4} A

OPEN 14" G.V.

$P = 3.0 \times 10^{-8}$

1531 $P = 2.5 \times 10^{-8}$

close 10" G.V. to turbo

1535 $P \to 3.5 \times 10^{-8}$

I.P. = 3000 V, 5.2×10^{-4} A

4/5 $P = 1.5 \times 10^{-8}$

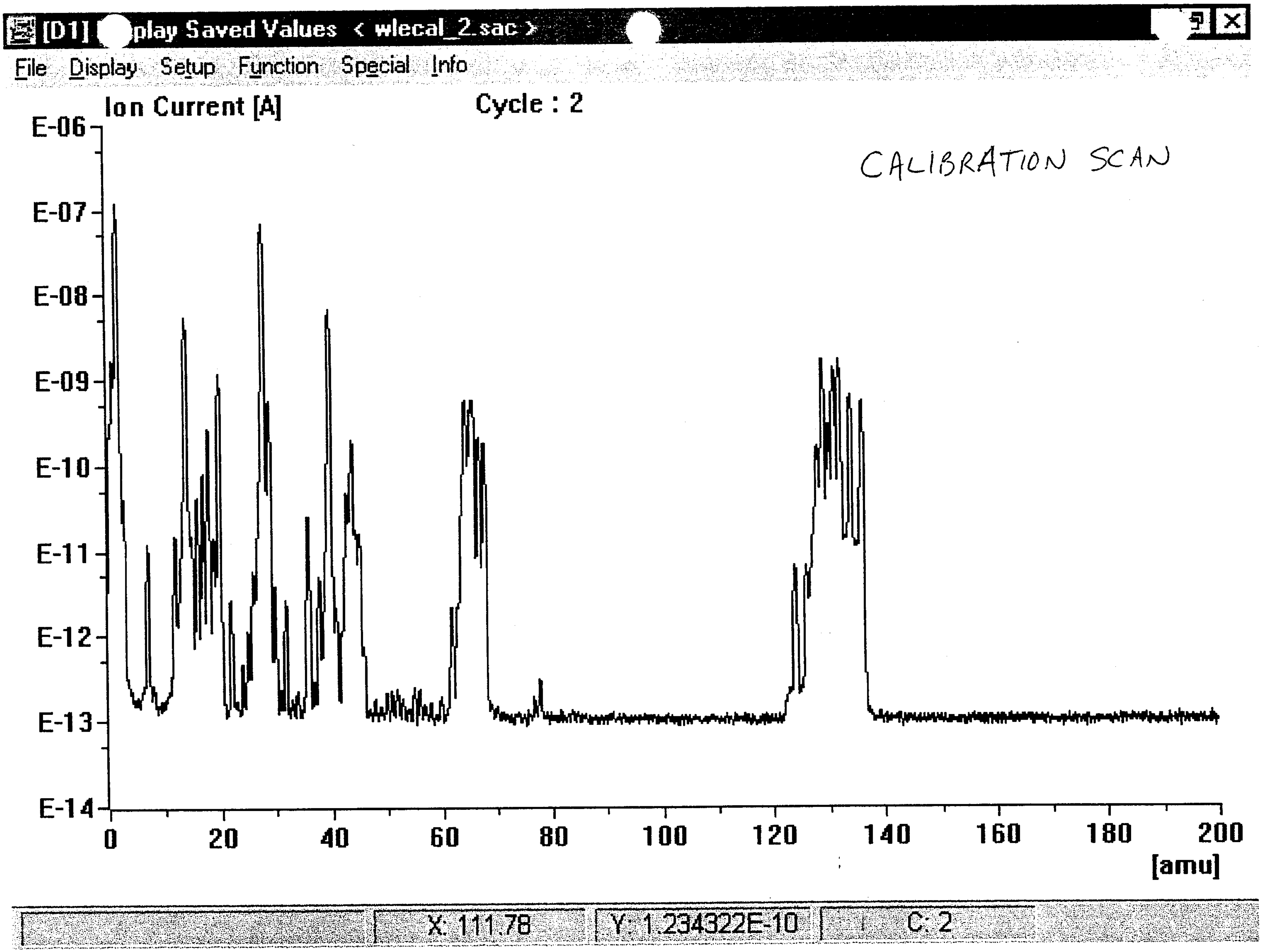
1/6 $P = 9.0 \times 10^{-9}$

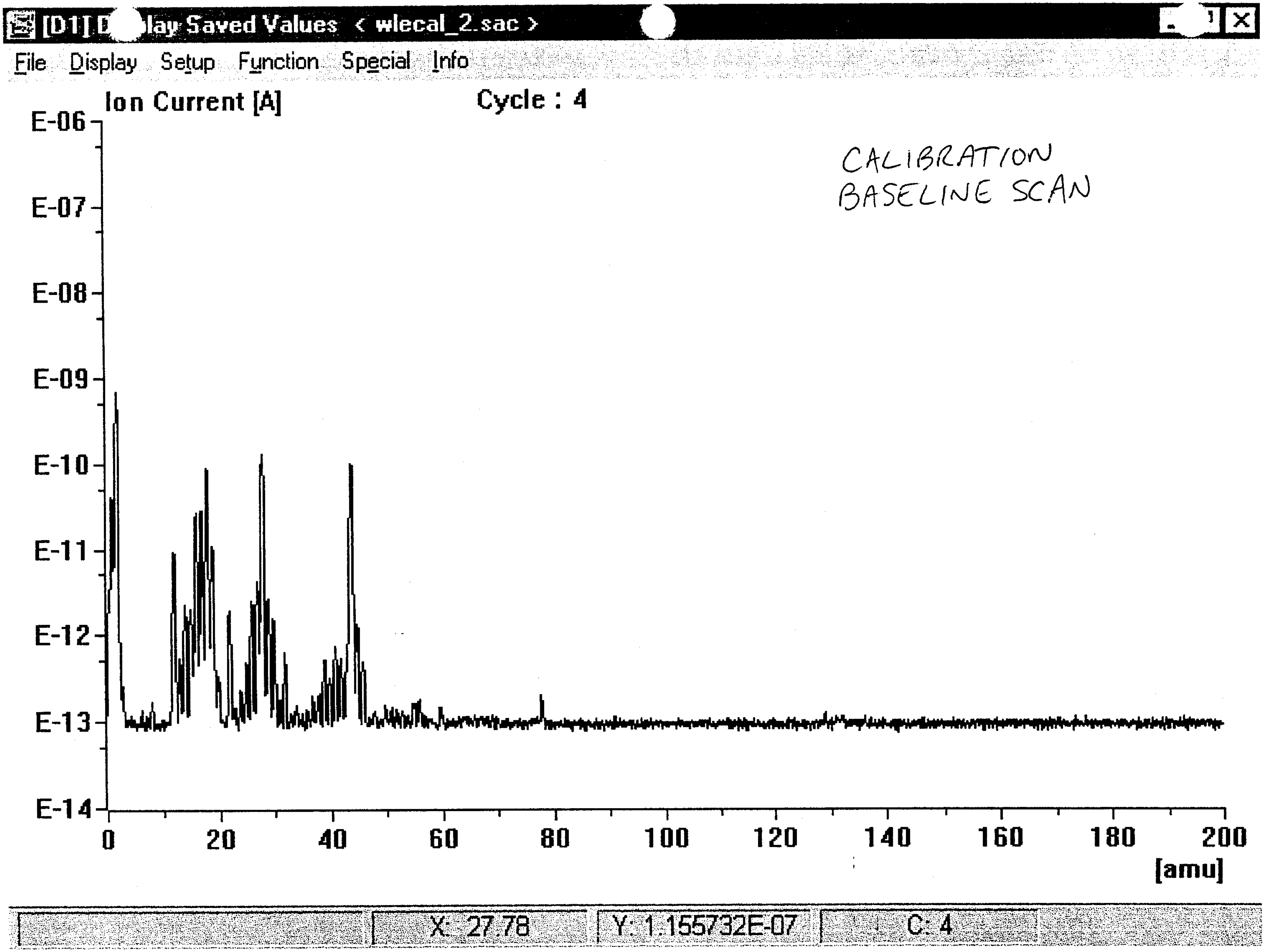
4/17 1300 $P = 7.0 \times 10^{-9}$

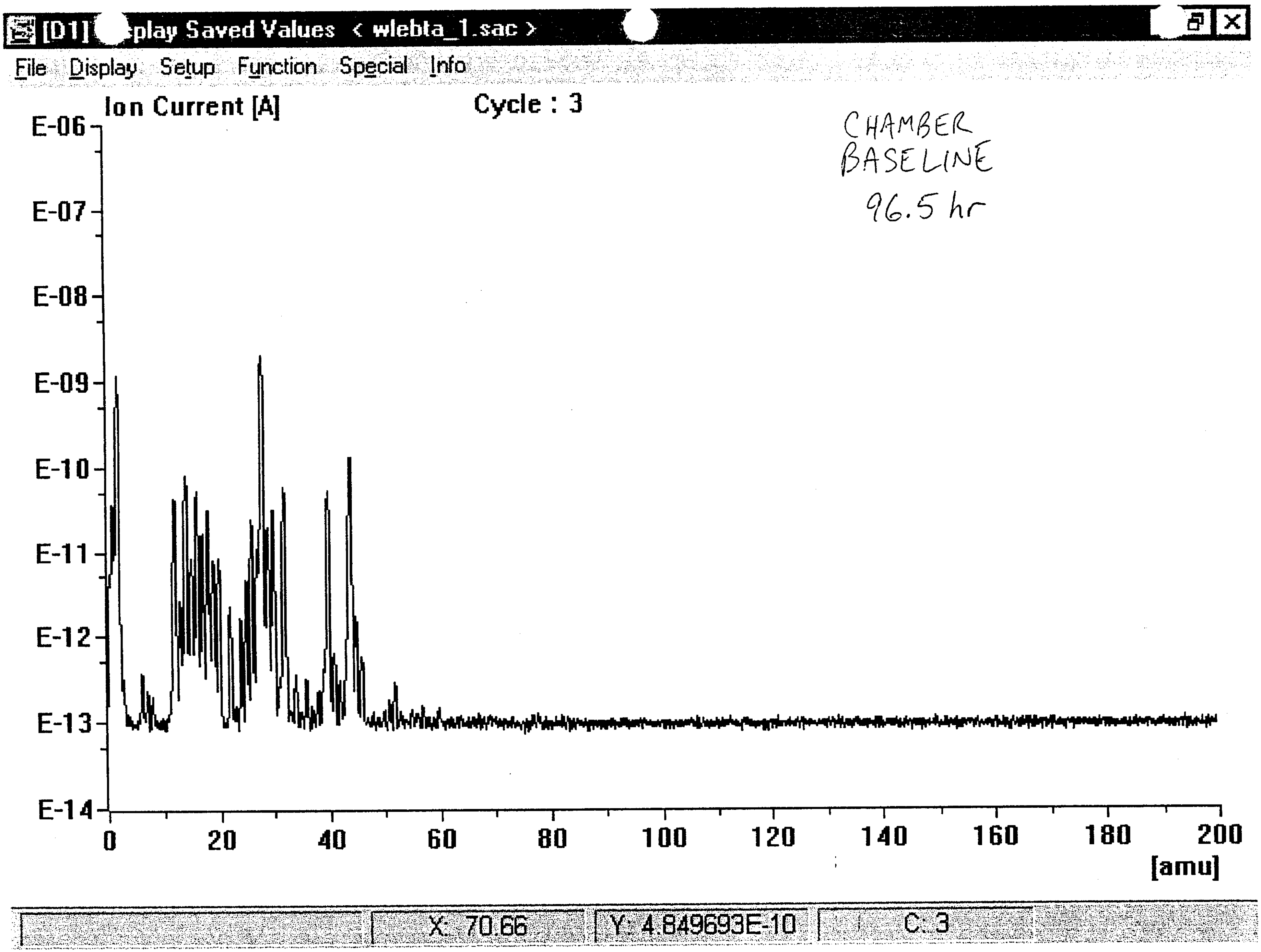
1700 PT 410 $= 6.84 \times 10^{-9}$

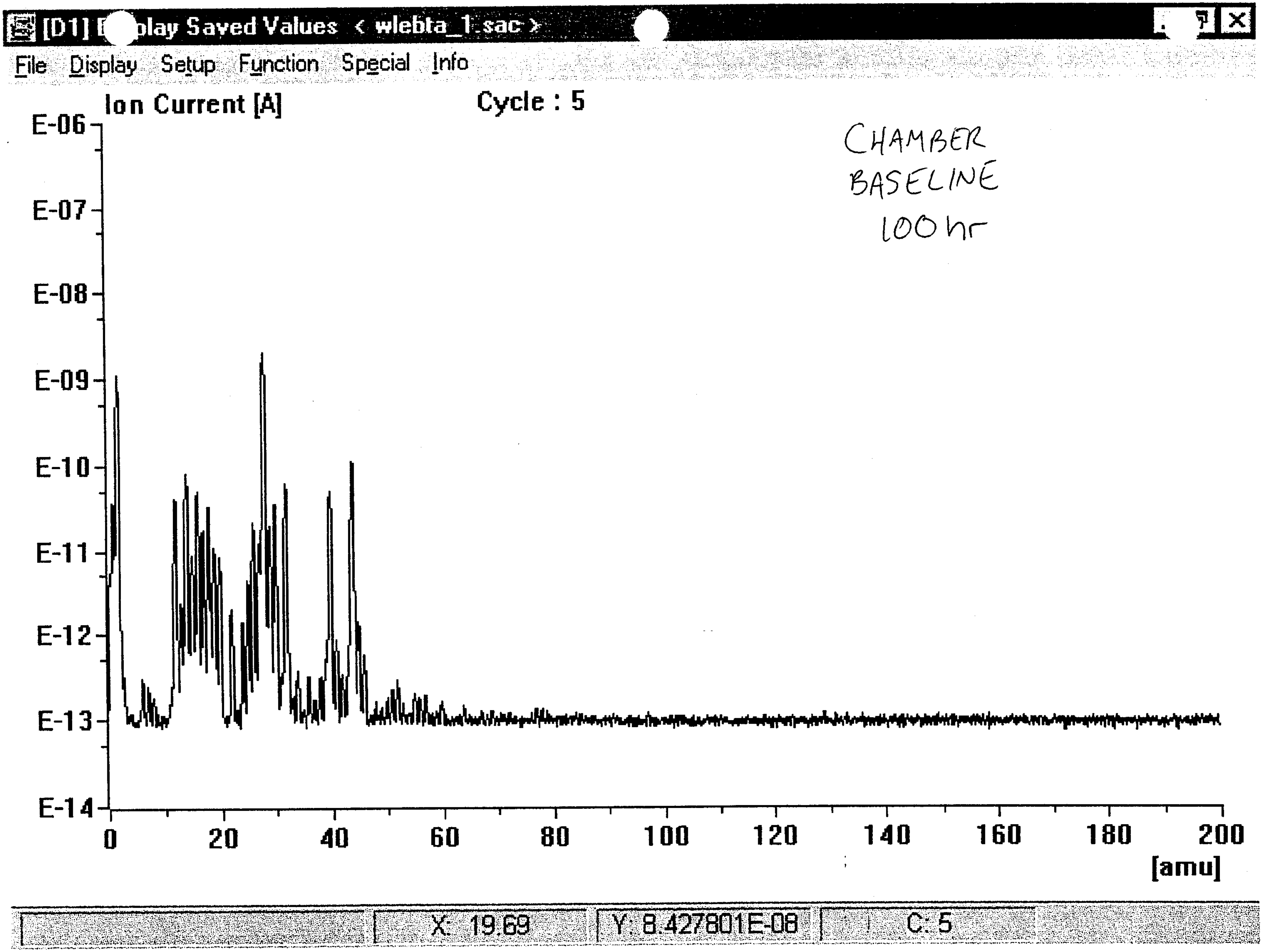
PT 424 $= 6.69 \times 10^{-9}$

save RGA data to WLEbta_1.sac


[D1] play Saved Values < wlecal_2.sac >
File Display Setup Function Special Info
Ion Current [A]
Cycle : 2
CALIBRATION SCAN
E-06
E-07
E-08
E-09
E-10
E-11
E-12
E-13
E-14
0
20
40
60
80
100
120
140
160
180
200
[amu]
X: 111.78
Y: 1.234322E-10
C: 2


[D1] D lay Saved Values < wlecal_2.sac >
File Display Setup Function Special Info
Ion Current [A]
Cycle : 4
CALIBRATION
BASELINE SCAN
E-06
E-07
E-08
E-09
E-10
E-11
E-12
E-13
E-14
0
20
40
60
80
100
120
140
160
180
200
[amu]
X: 27.78
Y: 1.155732E-07
C: 4


[D1] ...play Saved Values < wlebta_1.sac >
File Display Setup Function Special Info
Ion Current [A]
Cycle : 3
CHAMBER
BASELINE
96.5 hr
E-06
E-07
E-08
E-09
E-10
E-11
E-12
E-13
E-14
0
20
40
60
80
100
120
140
160
180
200
[amu]
X: 70.66
Y: 4.849693E-10
C: 3



[D1] D[…]play Saved Values < wlebta_1.sac >
File Display Setup Function Special Info
Ion Current [A]
Cycle : 5
CHAMBER
BASELINE
100 hr
E-06
E-07
E-08
E-09
E-10
E-11
E-12
E-13
E-14
0
20
40
60
80
100
120
140
160
180
200
[amu]
X: 19.69
Y: 8.427801E-08
C: 5

Partial Pressure Calculation

Demonstration of the Back-to-Air 100 hour pumpdown with respect to Partial Pressures

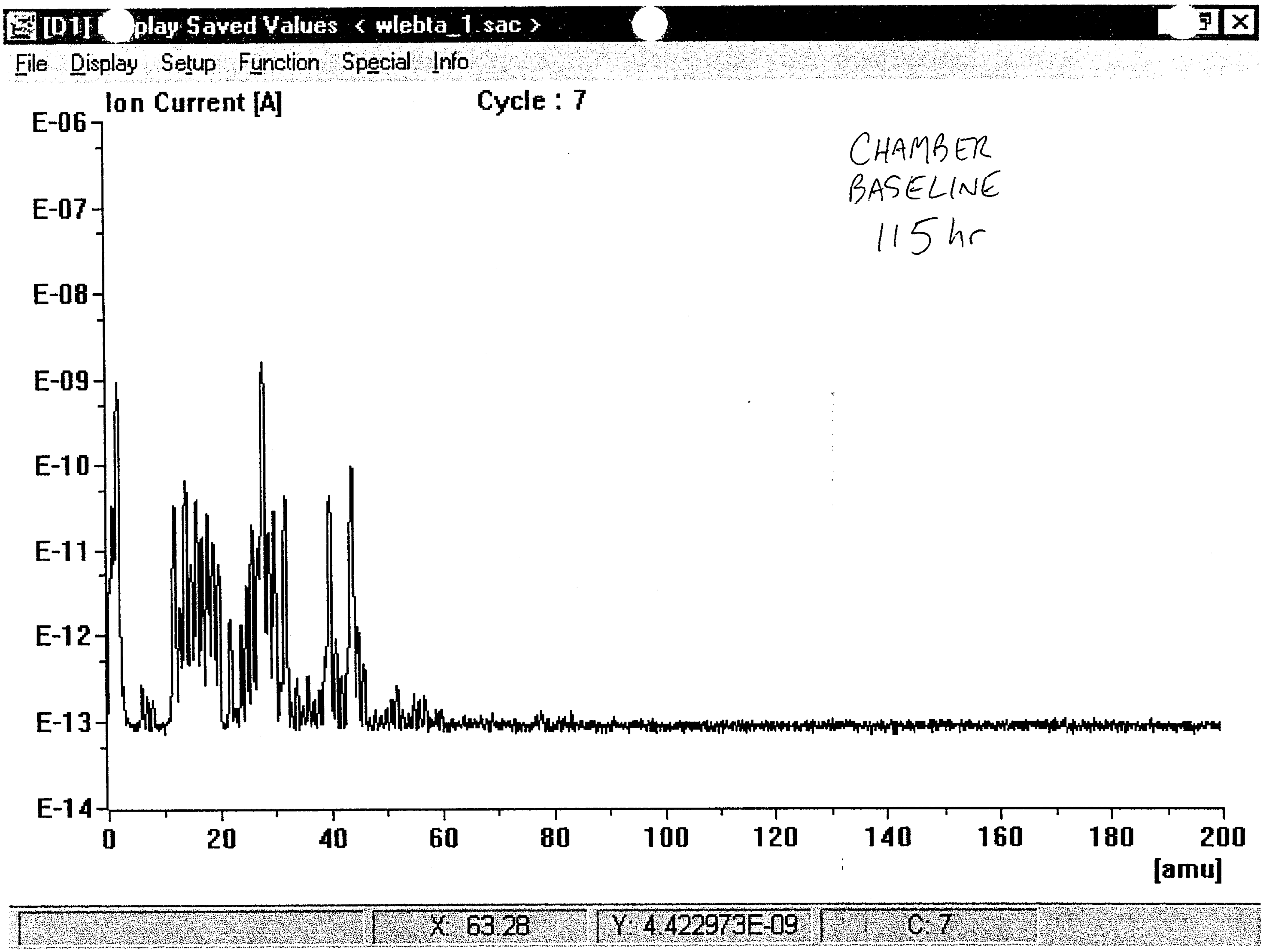
Date: 04/14/98
Test ID: WLEBTA (115 hr)
PSI Engineer: J. Flinn

AMU	F (amu) transmission efficiency wrt N_2	E (amu) ionization efficiency wrt N_2	S (p_amu) sensitivity (Torr/A)	I (amu) ion current (A)	PP (amu) (Torr)
2	-	-	2.87	9.61E-10	2.76E-09
16	0.57	1.60		3.88E-11	7.08E-11
18	0.64	1.12		2.61E-11	7.20E-11
28	-	-	3.87	1.59E-09	6.15E-09
44	1.57	1.42		9.49E-11	3.24E-10
all others	-	-	3.87	1.94E-10	7.51E-10

Total Pressure =	1.01E-08

LIGO: ______________________________

PSI: ______________________________


[D1] play Saved Values < wlebta_1.sac >
File Display Setup Function Special Info
Ion Current [A]
Cycle : 7
CHAMBER
BASELINE
115 hr
E-06
E-07
E-08
E-09
E-10
E-11
E-12
E-13
E-14
0
20
40
60
80
100
120
140
160
180
200
[amu]
X: 63.28
Y: 4.422973E-09
C: 7

Title: RGA Sensitivity Calibration
Date: 4/6/98
Test ID: WLEcal_2
PSI Engineer: John Flinn

AMU	$I_{(amu)}$ (A)	$I_{(leak)}$ (A)	$F_{(amu)}$ (-)	$E_{(amu)}$ (-)	$Q_{(amu\_leak)}$ (Torr-l/s)	$S_{(orifice\_amu)}$ (l/s)	$S_{(p\_amu)}$ (Torr/A)
2	6.91E-10	1.21E-07			4.80E-06	13.9	2.87
16	-		0.57	1.6			1.82
18	-		0.64	1.12			2.76
28	1.28E-10	6.65E-08			9.50E-07	3.7	3.87
40	2.69E-13	6.56E-09			9.40E-08	3.1	4.62
44	-		1.57	1.42			3.41
129	1.00E-13	1.63E-09			2.20E-08	1.7	7.94
131	1.00E-13	1.28E-09			1.80E-08	1.7	8.27
132	1.00E-13	1.58E-09			2.20E-08	1.7	8.19
134	1.00E-13	6.14E-10			9.00E-09	1.7	8.62
136	1.00E-13	5.34E-10			8.00E-09	1.7	8.81

WLE BJTA "OTHERS" (115 hr)

~~23~~	1.5×10^{-13}
24	1.4×10^{-12}
25	3.8×10^{-12}
26	1.9×10^{-11}
27	1.0×10^{-11}
29	1.6×10^{-11}
30	2.8×10^{-11}
31	2.8×10^{-13}
32	4.3×10^{-11}
33	1.5×10^{-13}
34	3.1×10^{-13}
35	1.5×10^{-13}
36	3.3×10^{-13}
37	1.8×10^{-13}
38	2.9×10^{-13}
39	5.7×10^{-13}
40	4.3×10^{-11}
41	8.9×10^{-13}
42	3.3×10^{-13}
43	7.3×10^{-13}
45	1.3×10^{-12}
46	4.7×10^{-13}
48	1.4×10^{-13}
50	1.4×10^{-13}
51	1.8×10^{-13}
52	2.6×10^{-13}
55	2.0×10^{-13}
56	1.7×10^{-13}
57	2.0×10^{-13}
59	1.4×10^{-13}
60	1.4×10^{-13}

16.1×10^{-11}
5.2×10^{-12}
23.6×10^{-13}

1.61×10^{-11}

161×10^{-12}
5.2×10^{-12}
2.36×10^{-12}
25.0×10^{-12}

193.56×10^{-12}
1.9356×10^{-10}
1.9

TOTAL $= 1.94 \times 10^{-10}$

total others 100hr

32	6.15×10^{-11}
40	5×10^{-11}
26	2.11×10^{-11}
27	1.21×10^{-11}
29	1.88×10^{-11}
30	3.40×10^{-11}

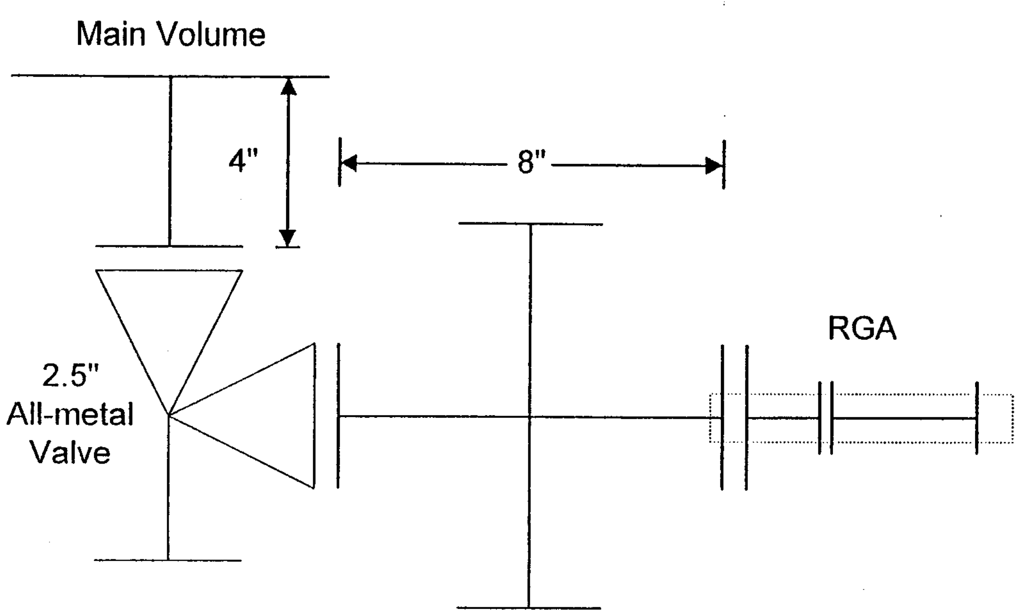
assume all others the same
add 4×10^{-11} onto 1.94×10^{-10}
$\Rightarrow$ total $\approx 2.3 \times 10^{-10}$
$= 2.5 \times 10^{-10}$

LIGO - Specific AMU - LE

AMU	Calibration	Measurement Chamber	Left End Station Main Volume	Left End Station Back to Air Test 115 hr
2	1.22E-07	6.96E-10	1.80E-09	9.74E-10
12	1.50E-11	9.06E-12	7.90E-12	3.40E-11
14	5.46E-09	2.20E-12	6.20E-12	6.40E-11
17	8.10E-11	2.87E-11	4.70E-12	1.43E-11
18	2.85E-10	8.77E-11	7.90E-12	2.58E-11

27	6.50E-11	4.25E-12	2.61E-12	1.04E-11
28	6.80E-08	1.30E-10	2.90E-10	1.56E-09
29	5.70E-10	2.60E-12	3.06E-12	1.60E-11
32	2.60E-12	6.30E-13	7.40E-13	4.30E-11
40	6.70E-09	3.27E-13	7.60E-12	4.30E-11
41	2.15E-12	7.44E-13	3.00E-13	9.00E-13
43	5.04E-11	7.68E-13	1.50E-13	6.80E-13
44	2.00E-10	1.00E-10	9.20E-12	9.49E-11

Conductance Calculation for RGA Calibration Chamber at Left End Station



1. $C_{2.5"\_Valve} = 80l/s$ from published data
2. 2.5" tube path = 4" + 8" = 12"

$$P_{tube} = \left(1 + \frac{3}{8}\cdot\frac{L}{r}\right)^{-1} = \left(1 + \frac{3}{8}\cdot\frac{12}{1.25}\right)^{-1} = (4.6)^{-1} = 21.7\%$$

$$S_{2.5"\_orifice} = (2.5in)^2\,\frac{\pi}{4}\times\frac{(0.0254\ m)^2}{in^2}\times 117{,}000\ \frac{l}{s-m^2} = 370.5l/s$$

$$C_{2.5"\_tube} = P_{2.5"\_tube}\cdot S_{2.5"\_orifice} = (0.217)\cdot(370.5l/s) = 80.4l/s$$

Conductance from Chamber to RGA:

$$C_{total} = \frac{1}{\dfrac{1}{80.4l/s} + \dfrac{1}{80l/s}} = 40.1l/s$$

{this applies to the RGA on the cross at any location (l=8")}

The pumping speed to the chamber is almost 11 times greater with the 0.25" orifice (S=3.7 l/s).

This test configuration should provide better results than the Left Mid Station configuration.

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT

5.8 LN2 Consumption Test

The LN2 consumption test has been conducted per Acceptance Test Procedure V049-2-114. The duration between refills exceeded 100 days.

LIQUID NITROGEN CONSUMPTION TEST
Ref. Spec. V049-2-208

Station	WA. Left End		**Cryopump** WCP7	
Test	Start	Finish		
Date	5/6/98	5/16/98		
Time	7:00	11:00		
Storage Tank	WDW7			
14400	gallons total volume			
13700	gallons at full trycock			
13700 x 0.9 =	12330	usable gallons		
300	in.H2O level indication at full trycock			
45.67	gallons / in.H2O			
Results				
Starting level=	154	in.H2O		
Ending level=	131	in.H2O		
Duration=	244	Hours		
Liquid consumed=	1050.3	gallons		
Tank pressure=	15	psig		
Ave.consumption for test duration=			4.30	gal/hour
Projected duration for usable gallons=			**119.3**	days

PSI S Morton 5/16/98

LIGO John Worden

Title: **PROCEDURE FOR BACKFILL/PUMPDOWN DEMONSTRATION AND LN2 CONSUMPTION TEST**

page 1

DATA SHEET

STATION	LE	ISO. SECT					
OPER.							
DATE	5/6 *	5/7	5/8	5/9	5/11	5/12	5/13
TIME	700	730	705	815	815	745	710
LN2							
PI	15 psig	15 psig	15 psig	15 psig	15 psig	15 psig	15 psig
PI							
LI	154"	150"	148" H_2O	147"	143"	140"	138"
LI							
PT 401	0.3 psig	0.3 psig	0.3 psig	0.2 psig	0.2 psig	0.2 psig	0.3 psig
PT							
LIC	39.8%	39.4%	38.6%	38.2%	37.1%	36.4%	35.8%
LIC							
LCV OP	60	60	60	60	60	60	60
LCV OP							
LCV CL	15	20	20	20	20	20	20
LCV CL							
MAIN V.							
PI 424	2.1×10^{-9}	1.9×10^{-9}	1.75×10^{-9}	1.62×10^{-9}	1.57×10^{-9}	1.48×10^{-9}	1.47×10^{-9}
PI 410			1.79×10^{-9}	1.59×10^{-9}	1.53×10^{-9}	1.42×10^{-9}	1.42×10^{-9}
PI							
PI							
GH1							
GH2							
GH3							
ION P.							
EI	3000 V	3000 V	3000 V	3000 V	3000 V	3000 V	3000 V
EI							
II CH1		3.5×10^{-5} A	3.2×10^{-5} A	2.8×10^{-5} A	2.6×10^{-5} A	2.4×10^{-5} A	2.4×10^{-5} A
II CH2		3.5×10^{-5} A	3.1×10^{-5} A	2.8×10^{-5} A	2.6×10^{-5} A	2.4×10^{-5} A	2.3×10^{-5} A

* START OF 240 hour TEST

SPECIFICATION	
Number: V049-2-208 A	Rev.0

Title: **PROCEDURE FOR BACKFILL/PUMPDOWN DEMONSTRATION AND LN2 CONSUMPTION TEST**

page 2

DATA SHEET

STATION	LE	ISO. SECT					
OPER.							
DATE	5/14	5/15	5/16/98**				
TIME	905	914	11:11				
LN2							
PI	15 psig	15 psig	14 psig				
PI							
LI	136"	~~13~~ 134"	131"				
LI							
PT 401	0.3	0.3	0.3				
PT							
LIC	35.5%	34.4%	33.7-34.3				
LIC		94%	92.1%				
LCV OP	60	60	60				
LCV OP							
LCV CL	20	20	20				
LCV CL							
MAIN V.							
PI 474	1.42×10⁻⁹	1.40E-9	1.3×10⁻⁹				
PI 410	1.34×10⁻⁹	1.34E-9	1.24×10⁻⁹				
PI							
PI							
GH1							
GH2							
GH3							
ION P.							
EI CH1,2	3000v	3000V	3000V				
EI							
II CH1	2.2×10⁻⁵A	2.1E-5	2.0E-5				
II CH2	2.2×10⁻⁵A	2.1E-5	2.0E-5				

** 240 hour test finished

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT

5.9 Noise/Shock/Vibration Field Test

The Noise/Shock/Vibration Field Testing was conducted by Cambridge Acoustical Associates (approximately .03g Vs. .01g specification requirements.

MID STATION

CAMBRIDGE ACOUSTICAL ASSOCIATES

VIBRATION, NOISE, SHOCK MEASUREMENTS OF THE PSI VACUUM EQUIPMENT AT THE LIGO END AND MID STATION

HANFORD, WA

Prepared By:

Kyle Martini

June 1998

Test Report

U-2379-8001

Prepared for:

Process Systems International, Inc.

20 Walkup Drive

Westborough, MA 01581-5003

PSI Purchase Order 554-386-00

A Department of ETC Division
Engineering Technologies Group/A&T, Inc.
84 Sherman St., Cambridge, MA 02140

VIBRATION, NOISE, SHOCK MEASUREMENTS OF THE PSI VACUUM EQUIPMENT AT THE LIGO END AND MID STATION HANFORD, WA

Prepared By:

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Cambridge Acoustical Associates, Inc.
A Department of Engineering Technologies
84 Sherman Street
Cambridge, MA 02140-3261

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TABLE OF CONTENTS

* SEE END STATION REPORT V049-1-168

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I. INTRODUCTION AND SUMMARY

The first phase of the LIGO commission test for vibration, noise, and shock has been completed at the Hanford, WA end- and mid- stations. Acoustic and vibration measurements were recorded on or near the chambers in these facilities with individual PSI vacuum equipment operating and the facility in a "quiet mode". Background measurements were also recorded. In addition manual and motorized valves were open and closed while shock measurements were recorded on the valve and on the chambers.

The results of the measurements are summarized as follows:

A. The background vibration levels, "quiet mode" (see Section II.A.2), are significantly higher than the LIGO vacuum equipment specification, and typically fluctuates about the higher LIGO building vibration specification. When measuring the vibration levels due to the operation of the vacuum equipment, the background vibration dominates much of the frequency range.

B. Operating the ion pump does not measurably increase the vibration levels.

C. Excitation frequencies of the molecular turbopump are 48 and 54 Hz due to the pump's controller, 280 Hz of unknown origin, and its spin frequency of 450 Hz and higher harmonics. A broadband resonance of the beamsplitter at 300 Hz amplified the 280 Hz excitation frequency. The vibration isolation system designed for the turbopump was short circuited during measurements to prevent the bellows from collapsing. This transmitted higher vibration than expected.

D. The excitation caused by boiling in the cryopump is broadband and tends to increase the overall level of vibration. Controlling the boil process is essential in minimizing vibration. During our measurements, we varied the operation of the cryopump (see Sections II.A.4.d and III.A.5) and significantly changed the levels of vibration. At the lower frequencies there is a 10 dB reduction in level across the beam manifold bellows between the cryopump and the beamsplitter. Overall reduction in the resonance response to the broadband excitation of cryopump as well as the background noise could be achieved by increasing the effective loss factor of the structure.

E. The noise measured during the operation of the turbopump did not meet the LIGO's noise specification above 125 Hz, as expected. A properly installed noise enclosure around the pump and its controller would reduce the noise level to the rooms background level, which also does not meet specification above 125 Hz.

F. Shock measurements on the beamsplitter chamber, when the manual valves were opened or closed, met or slightly exceeded LIGO's revised shock specification, with the exception of the 14" ion pump valve in the mid station. When the spring loaded mechanism released during opening of this valve, the specification was exceeded by a factor of 2.7. Levels on the valve body were significantly higher for all valves.

G. When operating the large gate valves, the levels on the chamber were 3-4 times greater than the specification. Levels on the large gate valve's body were not as high as for the manual valves.

H. The results at the mid-station overall are similar to the end-station, with narrow band variation.

II. MEASUREMENT DESCRIPTION

A. Vibration Measurements

1. General Test Conditions

The PSI equipment was under a high vacuum for all tests. To highlight sources of energy originating in the vacuum equipment, tests were conducted with a minimum of facility-induced background noise and vibration, "quiet mode". At each observation location, measurements were recorded with each piece of vacuum equipment (ion pump, turbopump and cryopump) operated alone. Background measurements, without any vacuum equipment operating, were recorded for comparison.

A typical measurement, at an observation or receiver location on a chamber, recorded vibration in three mutually perpendicular directions. To span the full frequency range of the LIGO specification, two high-sensitivity ultra low-noise accelerometers were utilized. A total of six measurements was recorded at each chamber receiver location. For floor measurements, a single vertical low frequency measurement was performed.

2. Instrumentation

The two vibration sensors were a Wilcoxon Research model 731A accelerometer (10V/g, 600 gm.), for frequencies from 0.1-300 Hz, and a model 916BTO-1 (7.5 V/g, 700 gm), which provided low noise capabilities above 300 Hz. Manufacturer's specifications for the two accelerometers are shown in Figure 1. The equivalent acceleration spectral densities corresponding to the electronic noise floors of the sensors are shown Figure 2. Recommended manufacturer's battery power units were used with the accelerometers.

To perform the tri-axial vibration measurements, a Wilcoxon Research Model TC1 triax cube with a non-conductive coating was utilized. The cube was designed for the Model 731 seismic sensor and can accommodate the Model 916 sensor but with a frequency limitation. Based on information from the manufacturer, it is estimated that the cube may influence measurements above 1-2 kHz. In addition, due to the mass of the accelerometers and the cube, a massive mounting location is required to measure the higher frequencies.

A digital PC based data acquisition system with a dynamic range of 72 dB recorded the vibration signals. Gain control in both the accelerometer's power unit and the data acquisition system optimized the dynamic range of the recorded signal. SIGNAL[1] software controlled the acquisition and processing of the data.

For the low frequency measurements, the data were acquired at 1250 samples per second for 98.3 seconds using a 450 Hz anti-aliasing filter. Averaged power spectral density (PSD) spectra (4096 lines and 30 averages) were created from the data using a Hanning window. Similarly, the high frequency measurements were acquired at 12,500 samples per second for 9.83 seconds using a 4,500 Hz anti-aliasing filter. Time histories were saved for all measurements, in the event that additional post-processing is required

3. Measurement locations

Measurement locations (receivers) were selected by Michael Zucker from the LIGO/MIT team[2]. Figures 3a and 3b indicate the locations of all vibration, noise, and shock measurements in the end- and mid-station respectively. Vibration measurement locations are indicated by the symbol 731/916, which relate to the sensor used. Photographs of the locations are shown in Figure 4. In this report, the locations shown in Figure 3, going from left to right, will be designated as follows:

End-Station Vibration Locations:

Position 1-	Beamsplitter Nozzle G	Circumferential Direction
		Vertical Direction
		Radial Direction
Position 2-	Beamsplitter Flange	Axial Direction
		Radial Direction
Position 3-	Cryopump Stiffener	Axial Direction
		Vertical Direction
		Radial Direction
Position 4-	(Tie Rod) Bracket Near Beam Tube	Axial Direction
		Vertical Direction
		Radial Direction
Position 5-	Floor (near Beamsplitter)	Vertical Direction

<u>Mid-Station Vibration Locations:</u>

Position 1-	Beamsplitter Nozzle G	Circumferential Direction
		Vertical Direction
		Radial Direction
Position 2-	Beamsplitter Flange	Axial Direction
		Vertical Direction*
		Radial Direction
Position 5-	Floor (near Beamsplitter)	Vertical Direction

*High frequency accelerometer only

Surface normals and space restriction did not allow a global orientation of sensors and the directions listed above are slightly rotated. At position 2 on the beamsplitter flange, the flange bolts interfered with performing measurements in the vertical direction.

4. Operating Conditions During Measurements

Vibration measurements were recorded for four different operating conditions:

a. Quiet Mode - Background vibration of the quiet mode was measured at all receiver locations. During the quiet mode, all facility equipment was shut off except lights, a transformer, and several electronic racks located in the area. With the exception of the background measurements at position 3 and 4 in the end station, the data acquisition system was located in a separate room behind closed doors. At a later time, the background measurement was repeated at location 3 and showed no significant difference.

A reference accelerometer, located on the floor of the building away from the equipment, was used to monitor changes in background levels during the measurements. Wind, traffic, and other source of external vibration could be observed.

b. Ion Pump Source - In the end station, vibration measurements were recorded at position 2 while the ion pump nearest the beamsplitter, was operating. It was determined that the ion pump was not a significant sources, and therefore no further measurements were performed.

c. Turbo Source - In both the end- and mid-stations, the turbo pump at beam manifold section WA-7 was operating. Because the mechanical room was not totally closed-off, the turbo-pump was operated without its backing pump. During the test, the bellows connecting the pump to the manifold was structurally short circuited to prevent it from collapsing under the vacuum load. This eliminated the vibration mitigation expected from the bellows. Measurements were recorded at positions 1,2 and 5 in both stations.

d. Cryo Source - Cryopump measurements were performed only in the end station at receiver positions 1,2,3 and 4. Measurements were recorded on two separate days. During both days, the pump was filled and ready to test in approximately two hours. There was some question whether the pump and/or fill line reached steady state conditions? On the first day, the pump was overfilled to 94% capacity, with the LN_2 liquid level in the vessel above the inlet line. Vibration measurements were recorded at positions 2 and 3. On the second day the LN_2 liquid level was set at the normal operating level, below the fill line, and two series of tests were performed. First, operating set points were varied while the vibration response was measured at position 3, the nearest location. Three flow rates were tested, M1, M2, and M3. M1 is the slowest, and M3 is the fastest flow speed. These flow rates were set using the ½ manual bypass valve (automatic control was not operational). Next, measurements were recorded at positions 1,2,3 and 4 for the "same" operating conditions to determine the flow of vibration energy.

e. HVAC Source - An additional measurement was recorded at position 2 with the HVAC on, and all other equipment in its quiet mode.

B. Noise Measurements

Background and turbo source noise measurements (see previous section) were recorded in both the end- and mid- stations. A Bruel and Kjaer Model 2236 Precision Sound Level Meter measured the overall sound pressure level at the microphone locations shown in Figures 3a and 3b. Octave band measurements were read directly from the sound level meter and compared with the LIGO noise specification. Narrowband measurements, recorded at 12,500 samples per second, were processed as described in the previous section for diagnostic purposes.

C. Shock Measurements

Shock measurements were recorded on sample valves, opening and closing, in both the end and mid station. Valves tested include the 10" manual turbopump valves, the 14" manual ion pump valves, the main gate valve WGV-18 in the end station, and the main gate valves WGV10 and WGV11 in the mid station.

General purpose PCB Model 338A35 accelerometers measured the shock levels. A single accelerometer was mounted on the valve body for diagnostic purposes, and a tri-axial arrangement of accelerometers was mounted on the upper "G" nozzle of the beamsplitter nearest the valve. Locations of the accelerometers are indicated in Figures 3a and 3b by the symbol 338. Photographs of the locations are shown in Figure 4.

Measurements were recorded by our data acquisition system at 1250 samples per second using a 500 Hz anti-aliasing filter. A 100 Hz low passed filter was applied to the data, and maximum and minimum shock levels were measured. These values are compared to LIGO's revised shock specification: "shock levels should be less than 0.01 g's peak to peak" (note: the absolute sum of the min-max measurements is an upper bound estimate of the peak to peak level). For diagnostic purposes, the min-max measured levels are listed from the 500 Hz filtered data.

For the manual valves, two sets of opening and closing measurements were recorded, while only one set of data was recorded for the large gate valves. Per PSI request, additional shock measurements of the large gate valves at various operating speeds were recorded.

III. MEASUREMENT RESULTS

A. Vibration Results

Some 110 different vibration measurements were recorded and analyzed. Acceleration power spectral density curves are plotted in Appendix A and B for the end- and mid-station respectively. For reference, the LIGO equipment and building vibration specifications are shown on each plot. For easy comparison between measurements, the dynamic range and number of frequency decades are the same on each plot and therefore can be overlaid.

Our comments are as follows:

1. Structural Resonances

Structural resonances can be inferred from the measurements by observing spectrum peaks that cannot be attributed to the known narrowband sources. From our previous analyses[3], we can include additional insights into the identification of the resonant modes.

The resonant frequencies identified are:

a. Below 12 Hz, the peaks are primarily due to the six isolation frequencies of the inner cryopump vessel. The analysis also predicts a lateral beam mode of the cryopump section between the two manifold bellows. Resonant responses are greatest at Position 3, located on the cryopump (see Figs E3-14&18).

b. At 15 Hz, the manifold section between the beamsplitter and the first bellows resonates in a lateral beam mode(see Fig. E2-17,22).

c. Additional beam manifold modes occur at 20 Hz and 50 Hz, (see Fig. E2-17,22 and E3-14,18).

d. At 52 Hz, an axial mode involving the mass of the large diameter manifold and the local stiffness of its neck down section is resonant (see Fig. E2-7,15).

e. At 90 Hz, there is an apparent resonance of unknown origin.

f. The cryopump vessel has a shell resonance at approximately 200 Hz. (See Fig. E3-15&19). A similar mode was evident in our previous measurement of the cryopump's inner vessel (see Fig. 3f of Ref. 3).

g. Around 300 Hz there is a broad build up owing to a beamsplitter resonance (see Fig. E1-8,10,etc.).

2. **Quiet Mode**

Background vibration measurements are significantly higher than the LIGO vacuum equipment specification (see Figs. E1-7 thru 12,E2-7 thru 11, E3-7 thru 12,21&22, E4-7 thru 12, EM-7, Mid-7 thru 12, Mid-19,21,22,&23 and Mid-29). They typically fluctuate around the higher LIGO building specification shown on the plot. Below 1 Hz, the levels are typical of background ground vibration, decreasing with increasing frequencies. Between 5 and 60 Hz, the cryopump isolation frequencies and the beam manifold resonances described above amplify the floor vibration. Narrow band line and fan blade excitations and their harmonics, evident above 29 Hz, are mixed in with additional structural resonances.

As mentioned previously, the data acquisition system was inside the vacuum equipment room when the background measurements were recorded at position 3 and 4. A repeat of measurements at position 3 (compare Figs. E3-21&22 with E3-11&10), showed no significant difference with the system in another room.

3. **Ionpump Excitation**

Measurements with the ion pump operating are shown in Figs. EM-11 thru 14. There was no significant difference in the levels with the ion pump on or off.

4. **Turbopump Excitation**

The turbo source measurements are shown in Figs. E1-14 thru 19, E2-15 thru 18, EM-9, and Mid-13 thru 18. Our comments are as follows:

a. Below 48 Hz, the measured levels are approximately the same as the background.

b. At 48 and 54 Hz, there are sharp peaks due to the turbopump's controller.

c. At approximately 280 Hz there is a sharp peak that is amplified by the beamsplitter's broad resonance at 300 Hz (see Fig. E1-15,17). It is not as dominant at the other locations, and its source is not known. It was measured previously, but not investigated, during characterization of the turbopump's vibrations (see Fig. 4c of Ref. 3).

d. The spin frequency of the turbopump at 450 Hz and harmonics at 900 Hz and above are quite evident in all the measurements. There are variations in the measured levels between the end and mid station at the same position, as much as 10 dB. This is not unusual for lightly damped systems with narrow band excitations.

e. The turbo's bellows, designed to reduce vibration, was short circuited during the measurements. If properly installed, we would expect the bellows to reduce the vibration levels by 10-20 dB.

f. Because the source consists of primarily narrow band frequencies, a dynamic absorber tuned to a structural resonance frequency that is coincident with the source will reduce the vibration response.

5. Cryopump Excitation

The cryopump source measurements are shown in Figs. E1-21, E2-20 thru 25, E3-14 thru 40, E4-13. Our comments are as follows:

a. The cryopump excitation is broadband and tends to excite the system's resonances.

b. The response to the cryopump source varied with operating conditions. In the first set of tests (see Figs. E3-14 thru 20 and E2-20 thru 24) the pump was over filled to 94% capacity, and the measured levels were higher across the frequency range than for subsequent tests.

In the second set of tests, the pump was filled to correct operating level, and an accelerometer was placed on the fill pipe away from the pump to monitor the variation of its vibrations with flow. Just prior to the first test, the fill line was open to a flow rate of M3 and measurements were recorded (E3-23&24). These measurements, although not as high as for the case when the pump was overfilled, were higher in the lower frequencies than for subsequent tests. Rich Bagley of PSI thought this occurred because the fill pipe was initially warm and additional boiling occurred inside the fill line.

In subsequent tests, the flow rate was varied (Figs. E3-25 thru 39). There was no significant change in vibration level with flow, except for the vibration on the fill line when there was no flow. Although this is puzzling, it is consistent with early measurements (see Fig. 3f of Ref. 3). In a final test, a one psi back pressure was applied to the fill line (see Fig. E3-40). This increased the level of vibration.

c. For approximately the same operating conditions, vibration measurements were recorded at all four positions in the radial direction (see Fig. E1-21,E2-25, E3-39, and E4-13). In the low frequencies, there is approximately a 10 dB reduction across the manifold bellows.

5. HVAC Excitation

A test was performed to determine the impact the HVAC has on the equipment response (see Figs. E2-12 thru 14). The levels on average are 10 dB above the background levels. They are also 10 dB above the turbopump and cryopump excited levels between 10-50 Hz.

6. Mid Station

The results at the mid-station overall are similar to the end station. Because the equipment have slightly different vibration signatures, there are narrow band variations.

B. Noise Results

Figures 5 and 6 compare the background and turbopump noise measurements in the end- and mid-stations, respectively, with the LIGO noise specification, NC-20. Below the 125 Hz octave band, the background noise dominates, but the levels are below the specification. Above 125 Hz, the turbopump noise as well as the background noise is above the specification. The background noise in the mid station is slightly lower than in the end station, but the octave band noise at 250 Hz and 1000 Hz is significantly higher. This is due to higher narrow band peaks at 270 and 900 Hz (see Figs. EM-16 and Mid-33). A properly designed noise enclosure around the turbopump would drastically reduce these levels.

C. Valve Shock Results

A tri-axial accelerometer was located on the upper "G" nozzle of the beamsplitter, nearest the valve, to monitor the shock during opening and closing of the valve. Accelerometer #1 sensed the shock in the circumferential direction of the beamsplitter, #2 sensed the vertical direction, and #3 the radial direction. In addition a fourth accelerometer, #4, was located on the valve body for diagnostic purposes.

A 500 Hz anti-aliasing filter was utilized when recording the data. Subsequently, a digital 100 Hz low pass filtering operation was performed on the data in order to compare it with the LIGO specification. In Appendix C and D are the plots of the acceleration time histories of each event for the end- and mid station respectively. Corresponding maximum and minimum acceleration shock levels recorded when the valves open and closed are listed in Tables I and II for both sets of filtered data.

IV. REFERENCES

1 - Engineering Design, SIGNAL User's Guide, Ver. 3.0, July, 1996.

2 - MEZ 4/10/98 Rev-01, Test points for Hanford Y mid- and end-station vacuum equipment acceptance vibration and acoustic testing, Personal Communication from Michael Zucker of MIT to Kyle Martini of CAA, dated 10 April, 1998.

3 - Kyle Martini, Klaus Kleinschmidt, Joel Garrelick, Carina Ting, Measurement and Analysis of LIGO Vacuum System Shock Vibration and Acoustic Noise, Rev2, CAA Report U-2379-2041, dated 10 January, 1997.

Table I - LIGO END STATION VALVE MEASUREMENT RESULTS

	500 Hz Filter		100 Hz Filter	
Accel #	Max(g)	Min(g)	Max(g)	Min(g)
1 End Station 10" turbopump valve opening				
1	0.0165	-0.0269	0.0071	-0.0062
2	0.0278	-0.0387	0.0038	-0.0048
3	0.0150	-0.0167	0.0066	-0.0062
4	0.2692	-0.2039	0.1133	-0.0409
2 End Station 10" turbopump valve closing				
1	0.0158	-0.0130	0.0043	-0.0060
2	0.0196	-0.0165	0.0039	-0.0048
3	0.0100	-0.0090	0.0040	-0.0039
4	0.1773	-0.1093	0.0274	-0.0287
3 End Station 10" turbopump valve opening				
1	0.0216	-0.0272	0.0064	-0.0073
2	0.0349	-0.0403	0.0039	-0.0039
3	0.0240	-0.0165	0.0058	-0.0056
4	0.2523	-0.2116	0.1542	-0.0332
4 End Station 10" turbopump valve opening				
1	0.0104	-0.0106	0.0059	-0.0070
2	0.0151	-0.0117	0.0051	-0.0046
3	0.0125	-0.0119	0.0066	-0.0067
4	0.2005	-0.1130	0.0567	-0.0638

	5 End Station 10" turbopump valve closing			
1	0.0081	-0.0115	0.0038	-0.0039
2	0.0114	-0.0086	0.0042	-0.0036
3	0.0071	-0.0061	0.0042	-0.0039
4	0.1066	-0.0624	0.0090	-0.0082
	500 Hz Filter		100 Hz Filter	
Accel #	Max(g)	Min(g)	Max(g)	Min(g)
	6 End Station 14" ionpump valve opening			
1	0.0276	-0.0286	0.0046	-0.0063
2	0.0324	-0.0389	0.0049	-0.0079
3	0.0166	-0.0171	0.0100	-0.0100
4	0.3636	-0.2224	0.3430	-0.1865
	7 End Station 14" ionpump valve closing			
1	0.0296	-0.0290	0.0043	-0.0041
2	0.0186	-0.0205	0.0041	-0.0043
3	0.0117	-0.0128	0.0048	-0.0045
4	0.0299	-0.0389	0.0106	-0.0096
	8 End Station 14" ionpump valve opening			
1	0.0111	-0.0113	0.0050	-0.0059
2	0.0128	-0.0151	0.0048	-0.0051
3	0.0096	-0.0075	0.0080	-0.0060
4	0.3689	-0.3157	0.3565	-0.3054
	9 End Station 14" ionpump valve closing			
1	0.0195	-0.0186	0.0043	-0.0046
2	0.0133	-0.0146	0.0048	-0.0043
3	0.0113	-0.0107	0.0047	-0.0045

Accel #	500 Hz Filter Max(g)	500 Hz Filter Min(g)	100 Hz Filter Max(g)	100 Hz Filter Min(g)
4	0.0158	-0.0247	0.0063	-0.0072

Accel #	500 Hz Filter Max(g)	500 Hz Filter Min(g)	100 Hz Filter Max(g)	100 Hz Filter Min(g)
10 End Station 42" motor valve near beamsplitter opening				
1	0.0388	-0.0452	0.0231	-0.0207
2	0.0623	-0.0636	0.0095	-0.0128
3	0.0298	-0.0308	0.0214	-0.0235
4	0.1139	-0.1244	0.0585	-0.0680
11 End Station 42" motor valve near beamsplitter closing				
1	0.0144	-0.0158	0.0091	-0.0081
2	0.0218	-0.0168	0.0080	-0.0091
3	0.0122	-0.0117	0.0091	-0.0098
4	0.0464	-0.0684	0.0434	-0.0519

Table II - LIGO END AND MID STATION VALVE MEASUREMENT RESULTS

	500 Hz Filter		100 Hz Filter	
Accel #	Max(g)	Min(g)	Max(g)	Min(g)
12 Mid Station Background levels				
1	0.0054	-0.0056	0.0050	-0.0049
2	0.0052	-0.0057	0.0050	-0.0047
3	0.0057	-0.0056	0.0051	-0.0049
4	0.0051	-0.0051	0.0044	-0.0042

	500 Hz Filter		100 Hz Filter	
Accel #	Max(g)	Min(g)	Max(g)	Min(g)
13 Mid Station 10" turbopump valve opening				
1	0.0083	-0.0059	0.0049	-0.0040
2	0.0057	-0.0055	0.0042	-0.0042
3	0.0059	-0.0049	0.0052	-0.0044
4	0.0314	-0.0267	0.0102	-0.0133
14 Mid Station 10" turbopump valve closing				
1	0.0261	-0.0198	0.0036	-0.0038
2	0.0175	-0.0162	0.0038	-0.0041
3	0.0157	-0.0194	0.0044	-0.0046
4	0.1638	-0.1487	0.0058	-0.0058
15 Mid Station 10" turbopump valve opening				
1	0.0109	-0.0155	0.0045	-0.0053
2	0.0103	-0.0102	0.0039	-0.0050
3	0.0083	-0.0093	0.0061	-0.0063
4	0.0491	-0.0335	0.0133	-0.0106

	16 Mid Station 10" turbopump valve closing			
1	0.0062	-0.0084	0.0050	-0.0043
2	0.0084	-0.0067	0.0039	-0.0043
3	0.0053	-0.0079	0.0043	-0.0055
4	0.0483	-0.0416	0.0048	-0.0050
	500 Hz Filter		100 Hz Filter	
Accel #	Max(g)	Min(g)	Max(g)	Min(g)
	17 Mid Station 14" ionpump valve opening			
1	0.0718	-0.0791	0.0081	-0.0061
2	0.0684	-0.0918	0.0058	-0.0069
3	0.0506	-0.0363	0.0095	-0.0140
4	0.5475	-0.1126	0.4695	-0.0210
	18 Mid Station 14" ionpump valve closing			
1	0.0130	-0.0129	0.0065	-0.0067
2	0.0084	-0.0062	0.0051	-0.0043
3	0.0090	-0.0081	0.0061	-0.0062
4	0.0154	-0.0109	0.0106	-0.0068
	19 Mid Station 14" ionpump valve opening			
1	0.0825	-0.0815	0.0079	-0.0071
2	0.0739	-0.0760	0.0063	-0.0054
3	0.0420	-0.0303	0.0145	-0.0131
4	0.5465	-0.1078	0.4609	-0.0266

	20 Mid Station 14" ionpump valve closing			
1	0.0163	-0.0140	0.0048	-0.0055
2	0.0091	-0.0075	0.0041	-0.0055
3	0.0091	-0.0100	0.0050	-0.0056
4	0.0124	-0.0130	0.0070	-0.0083
	500 Hz Filter		100 Hz Filter	
Accel #	Max(g)	Min(g)	Max(g)	Min(g)
21 Mid Station 42" motor valve WGV10 partial opening 1700 rpm				
1	0.1163	-0.1137	0.0119	-0.0160
2	0.0332	-0.0244	0.0117	-0.0117
3	0.0329	-0.0321	0.0171	-0.0178
4	0.0886	-0.0710	0.0551	-0.0588
22 Mid Station 42" motor valve WGV10 partial closing 1700 rpm				
1	0.1324	-0.1151	0.0166	-0.0130
2	0.0430	-0.0424	0.0130	-0.0122
3	0.0395	-0.0367	0.0199	-0.0207
4	0.2717	-0.1160	0.1554	-0.0631
23 Mid Station 42" motor valve WGV10 partial opening and closing at 1700 rpm				
1	0.1106	-0.1081	0.0141	-0.0177
2	0.0391	-0.0522	0.0157	-0.0184
3	0.0343	-0.0413	0.0242	-0.0239
4	0.2156	-0.1189	0.1385	-0.0608

24 Mid Station 42" motor valve WGV10 partial opening and closing at 850 rpm

1	0.1263	-0.1330	0.0152	-0.0139
2	0.0749	-0.0692	0.0123	-0.0123
3	0.0377	-0.0345	0.0186	-0.0174
4	0.1642	-0.1048	0.0870	-0.0644

	500 Hz Filter		100 Hz Filter	
Accel #	Max(g)	Min(g)	Max(g)	Min(g)
25 Mid Station 42" motor valve WGV11 opening 1700 rpm				
1	0.0243	-0.0270	0.0154	-0.0196
2	0.0205	-0.0092	0.0194	-0.0083
3	0.0316	-0.0313	0.0263	-0.0293
4	0.0639	-0.0499	0.0180	-0.0248
26 Mid Station 42" motor valve WGV11 closing 1700 rpm				
1	0.0226	-0.0243	0.0117	-0.0112
2	0.0104	-0.0111	0.0074	-0.0070
3	0.0182	-0.0204	0.0159	-0.0165
4	0.0360	-0.0377	0.0155	-0.0152
27 Mid Station 42" motor valve WGV11 partial opening and closing at 850 rpm				
1	0.0156	-0.0113	0.0101	-0.0075
4	0.0403	-0.0398	0.0099	-0.0104
28 Mid Station 42" motor valve WGV11 partial opening and closing at 425 rpm				
1	0.0169	-0.0153	0.0051	-0.0065
4	0.0828	-0.1227	0.0069	-0.0072

WILCOXON RESEARCH

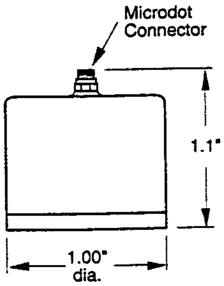
RESEARCH

Model 731-201

Fig. 1a Ultra Low Frequency Seismic Accelerometer

FEATURES:

- Compact construction to fit in tight spaces
- Ultra-high sensitivity
- Ultra low-noise electronics for clear signals at very low vibration levels
- Miswiring protection



SPECIFICATIONS

DYNAMIC

Sensitivity, ±10%, 25°C	10 V/g
Acceleration Range	0.5 g peak
Amplitude Nonlinearity	1%
Frequency Response:	
±5%	0.6 - 650 Hz
±10%	0.5 - 850 Hz
±3 dB	0.2 - 1,300 Hz
Resonance Frequency, mounted, nominal	2.4 kHz
Transverse Sensitivity, max.	1% of axial
Temperature Response	see graph

ELECTRICAL

Power Requirement:	
voltage source	18 - 30 VDC
current regulating diode	2 - 10 mA
Electrical Noise, equiv. g, nominal:	
Broadband 2.5 Hz to 25 kHz	2 μg
Spectral 2 Hz	0.12 μg/√Hz
10 Hz	0.06 μg/√Hz
100 Hz	0.03 μg/√Hz
Output Impedance, max.	500 Ω
Bias Output Voltage, nominal	10 VDC
Grounding	case grounded

ENVIRONMENTAL

Temperature Range	0 to 80°C
Vibration Limit	50 g peak
Shock Limit	250 g peak
Electromagnetic Sensitivity, equiv. g.	20 μg/gauss
Base Strain Sensitivity	0.0005 g/μstrain

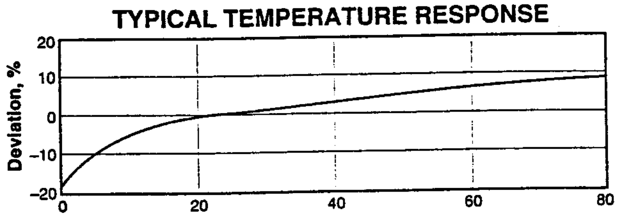
PHYSICAL

Weight	30.5 grams
Case Material	nickel plated aluminumm
Mounting	adhesive
Connections	microdot

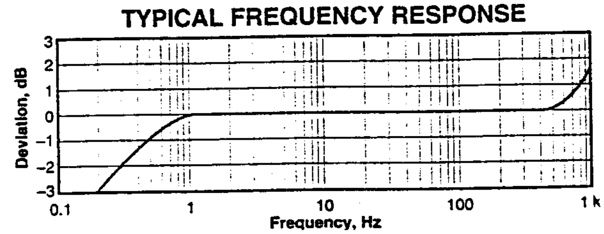
OPTIONS: Customer specified sensitivity, filtering, connectors.

ACCESSORIES AVAILABLE: Cementing studs, power supplies, amplifiers, signal conditioners, cable assemblies.

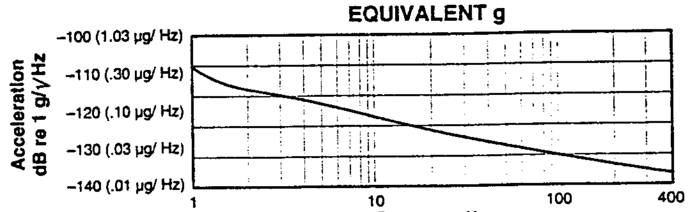
TYPICAL TEMPERATURE RESPONSE



TYPICAL FREQUENCY RESPONSE



TYPICAL NOISE RESPONSE
EQUIVALENT g



Due to continued research and product development, Wilcoxon Research reserves the right to amend this specification without notice.

Rev.A 12/92

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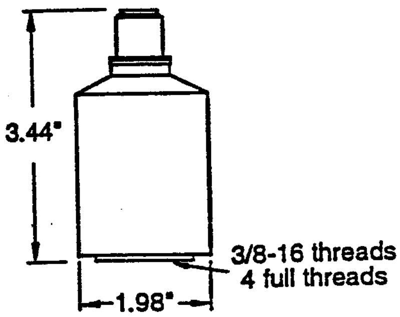
Model 916BTO-1

Fig. 1b Superquiet High Frequency Accelerometer

PRELIMINARY SPECIFICATIONS

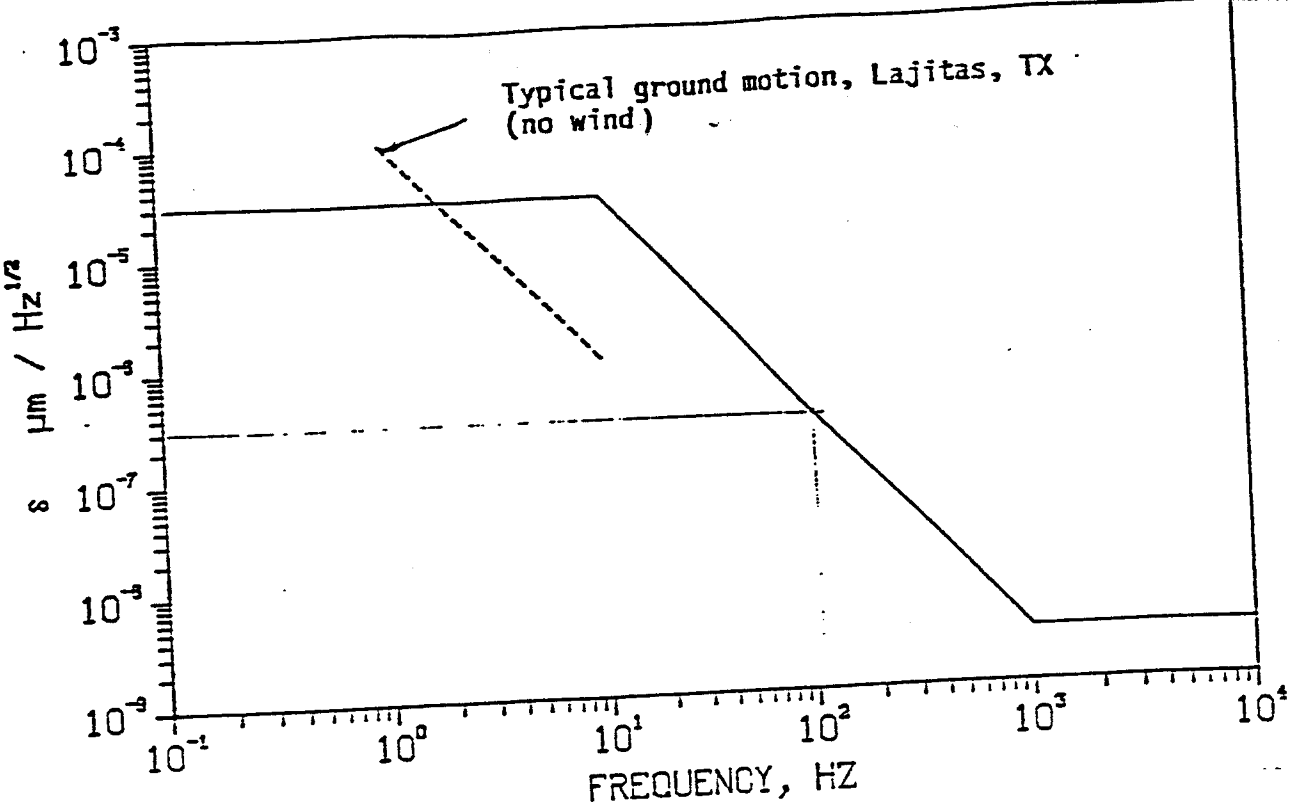


DYNAMIC	
Sensitivity	7.5 V/g, +/– 2 dB
Frequency Response:	
–3 dB	< 30 Hz
+3 dB	> 8 KHz
Resonance	> 15 KHz
Maximum Acceleration:	
Vibration	0.1 g pk
Shock	200 g pk
ELECTRICAL	
Power Requirement:	
Voltage Source (low noise)	15 - 20 VDC
Current Regulating Diode	4 - 10 mA
Electrical Noise in 1Hz bandwidth at 25°C, nominal:	
Spectral:	
100 Hz	30 nano g rms
1 kHz	3 nano g rms
10 kHz	1 nano g rms
Output Impedance, max.	500 Ω
Bias Output Voltage, typical	10 VDC
Grounding	case grounded (to common wire)
ENVIRONMENTAL	
Operating Temperature, maximum	50°C
Storage Temperature, maximum	100°C
PHYSICAL	
Weight	700 g
Size	1.98" dia x 3.5" height
Case Material	stainless steel
Mounting	3/8-16 tapped hole
Output Connector	MIL-C-5015, 2 pin
Pin A	signal, power
Pin B	common, case
Cabling	J1 PVC coaxial cable, 30 pF/ft, 0.080"

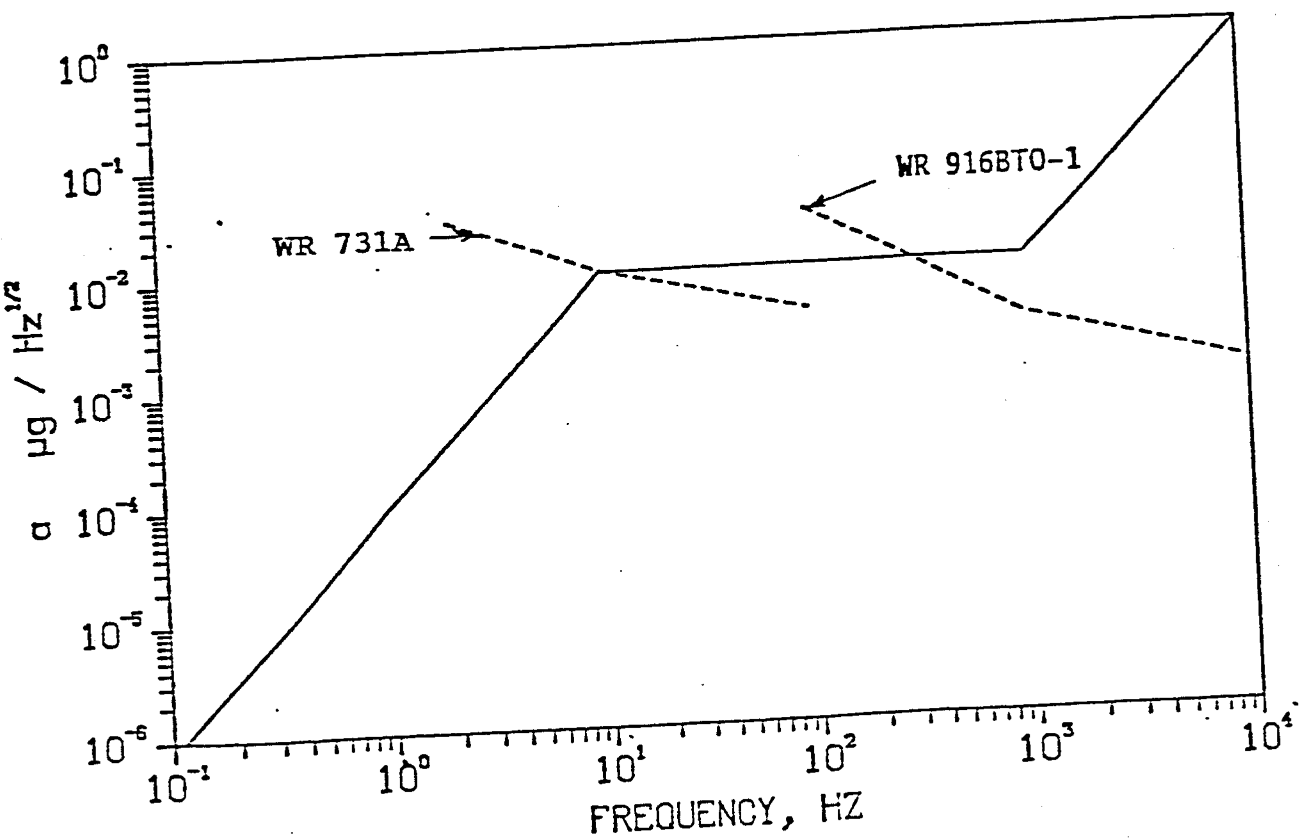
NOTES: [1] The equivalent input noise of the following electronics should be less than 2 nanovolt/root Hz at 10 KHz and should be > 20 Hz high pass filtered to avoid degrading the signal.

ACCESSORIES SUPPLIED: calibration data; SF7 mounting stud

ACCESSORIES AVAILABLE: Magnetic mounting bases; cementing stud; power supplies; amplifiers, signal conditioners



(a) Displacement



(b) Acceleration

Fig. 2 - LIGO Displacement and (equivalent) acceleration specifications

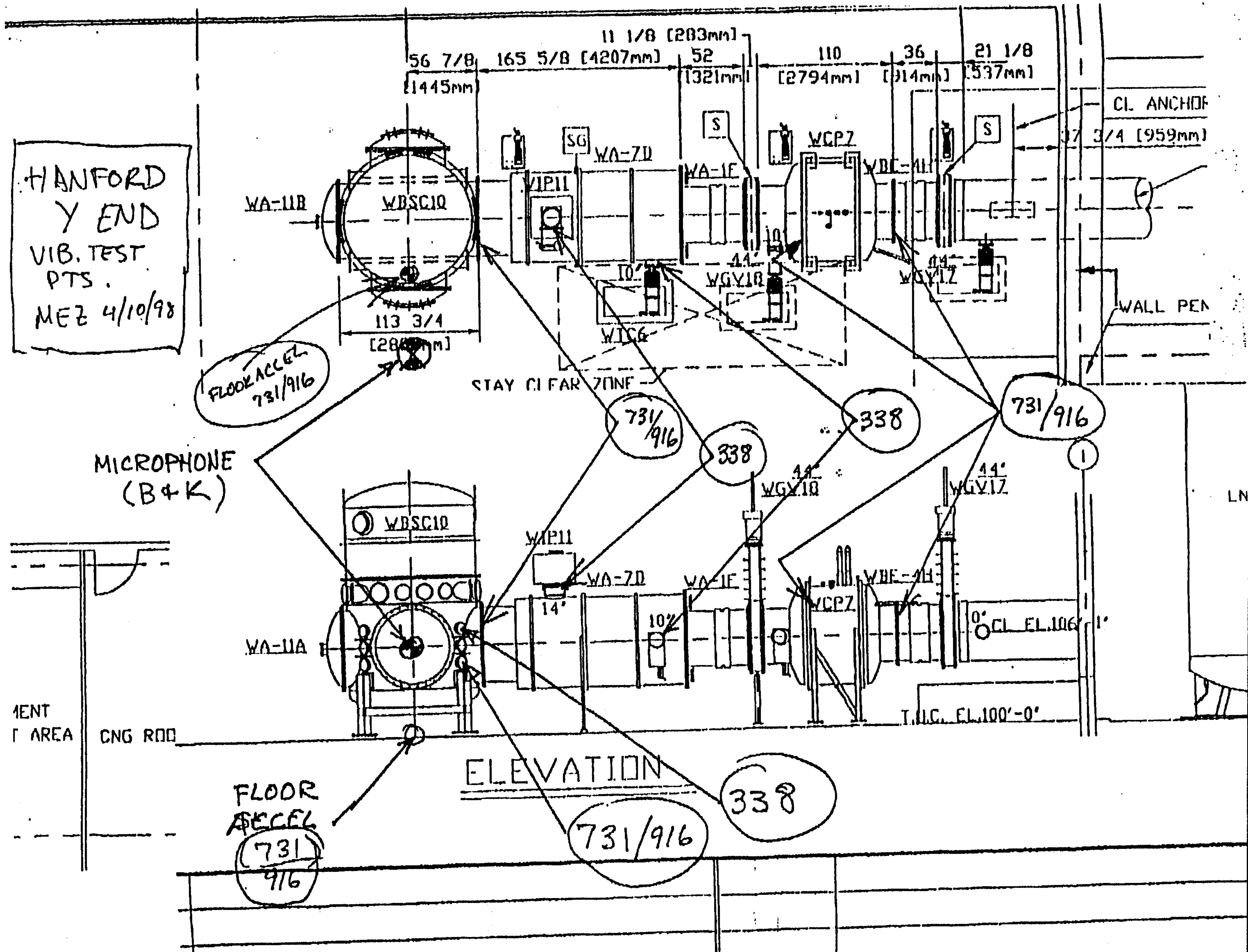


Fig. 3a End Station Measurement Locations.

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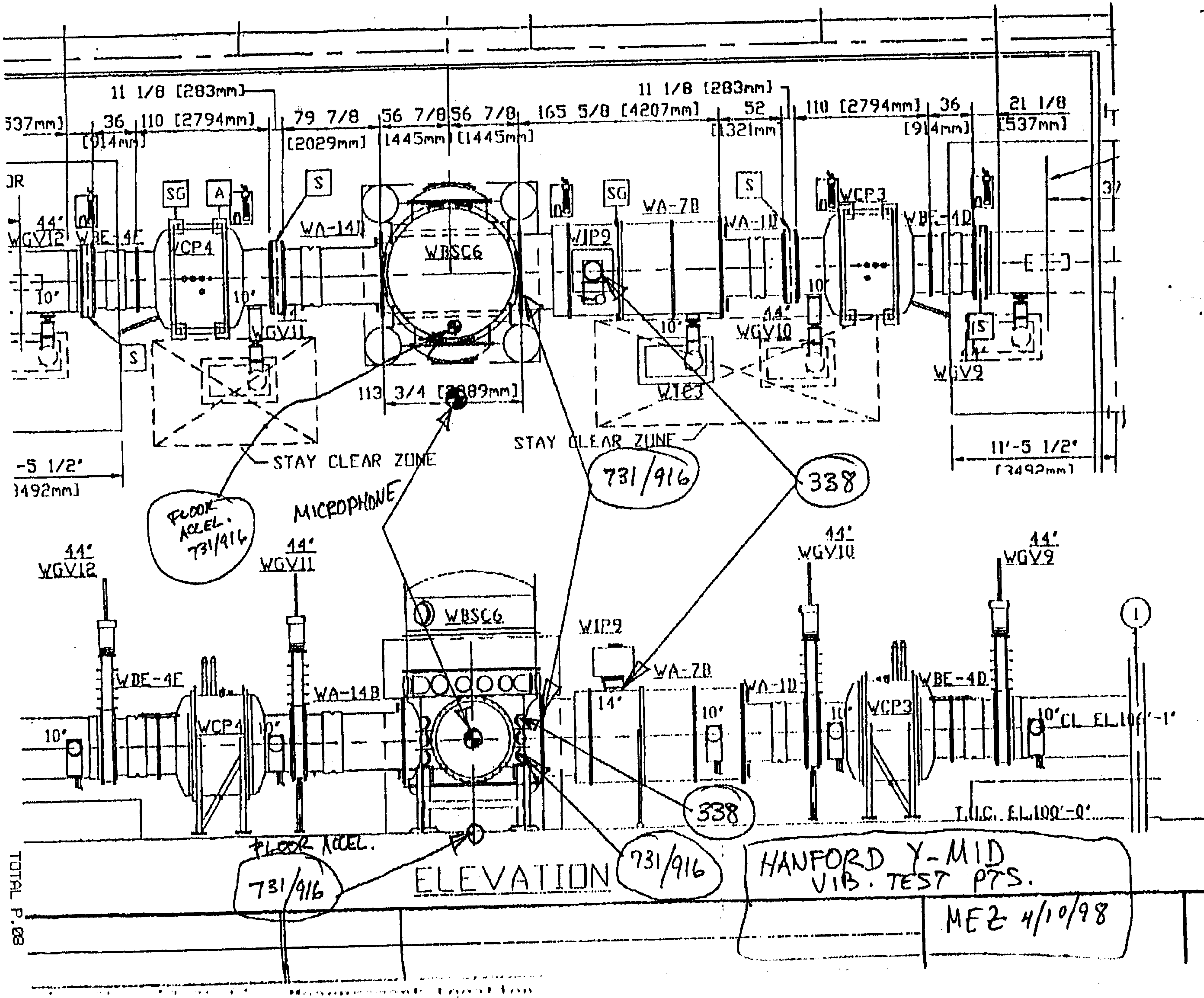


11 1/8 [283mm]
537mm]
36
[914mm]
110 [2794mm]
79 7/8
[2029mm]
56 7/8
[1445mm]
56 7/8
[1445mm]
165 5/8 [4207mm]
11 1/8 [283mm]
52
[1321mm]
110 [2794mm]
36
[914mm]
21 1/8
[537mm]
SG
A
S
WGV12
WBE-4E
WCP4
WA-14B
WBSC6
WIP9
WA-7B
WA-1D
WCP3
WBE-4D
WGV11
WGV10
WGV9
WTE3
113 3/4 [2889mm]
STAY CLEAR ZONE
STAY CLEAR ZONE
-5 1/2"
3492mm]
11'-5 1/2"
[3492mm]
FLOOR ACCEL. 731/916
MICROPHONE
731/916
338
44'
10'
14'
CL EL.106'-1"
T.O.C. EL.100'-0"
FLOOR ACCEL.
731/916
ELEVATION
731/916
338
HANFORD Y-MID
VIB. TEST PTS.
MEZ 4/10/98

TOTAL P.08

96

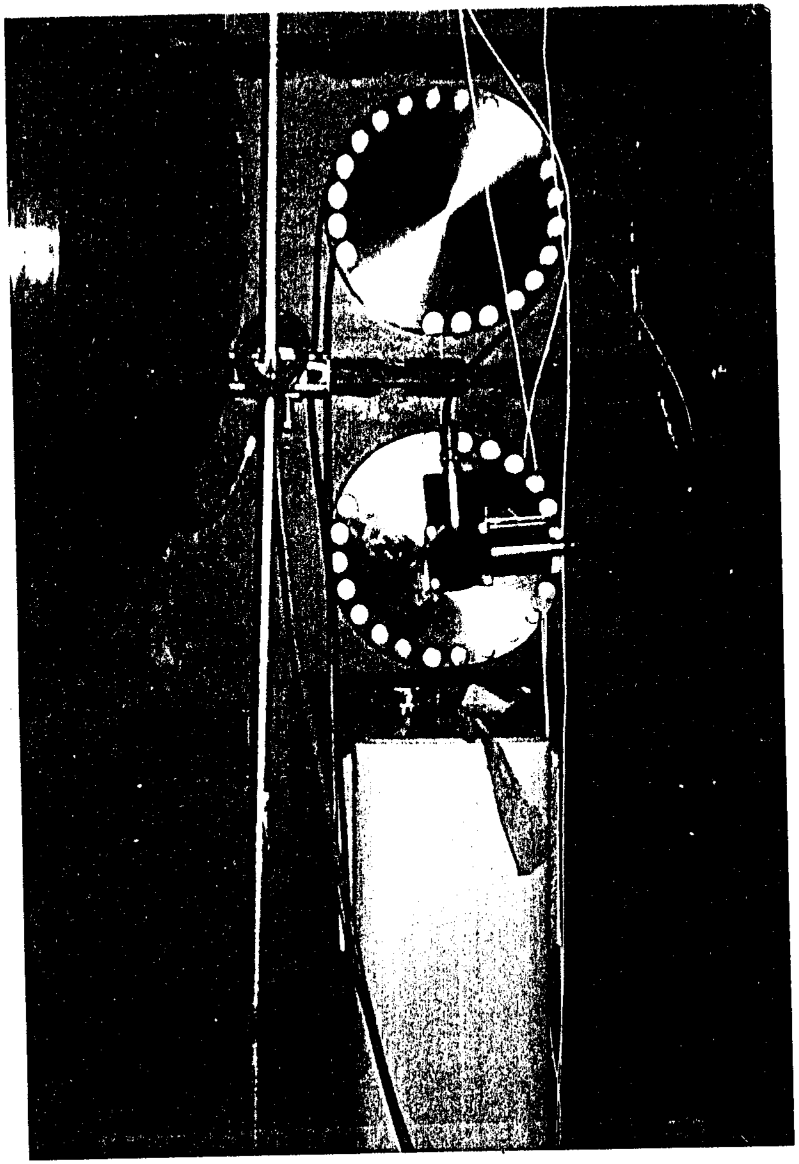


Fig. 4a Vibration Measurement Position 1

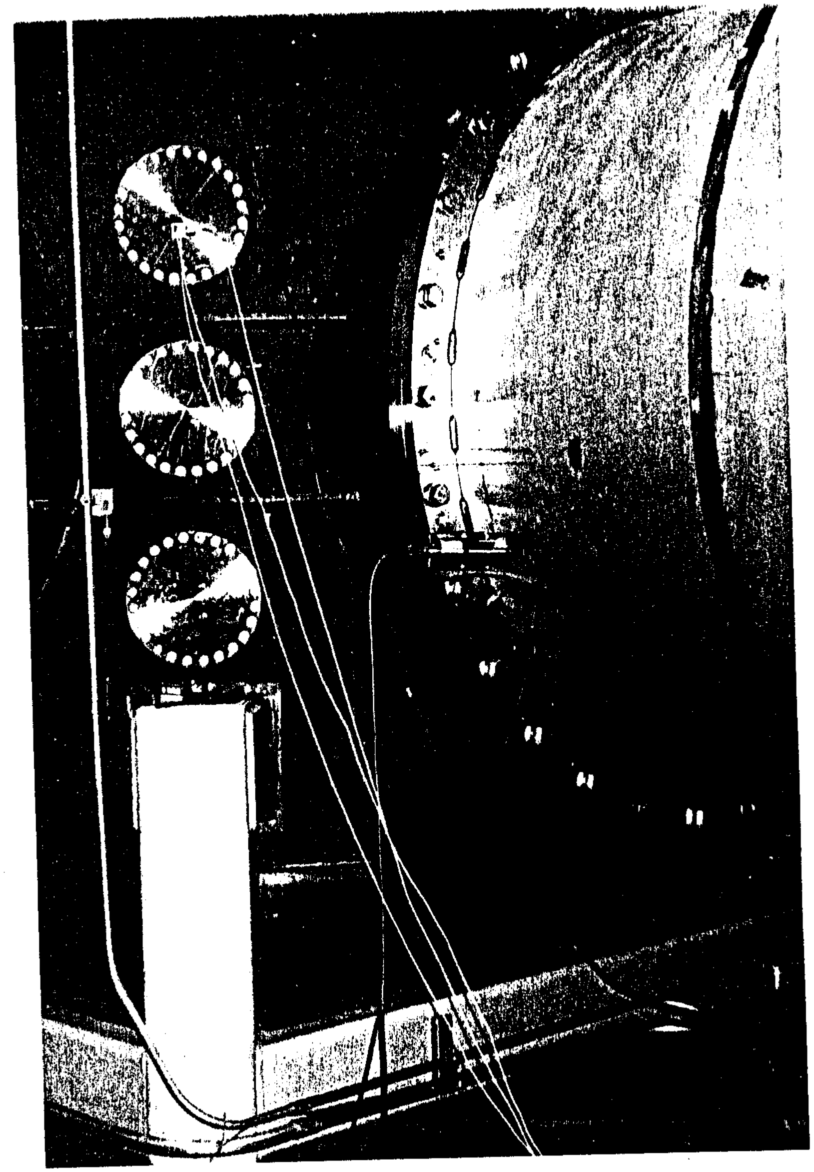


Fig. 4b Vibration Measurement Position 2 and Shock Measurement Postion

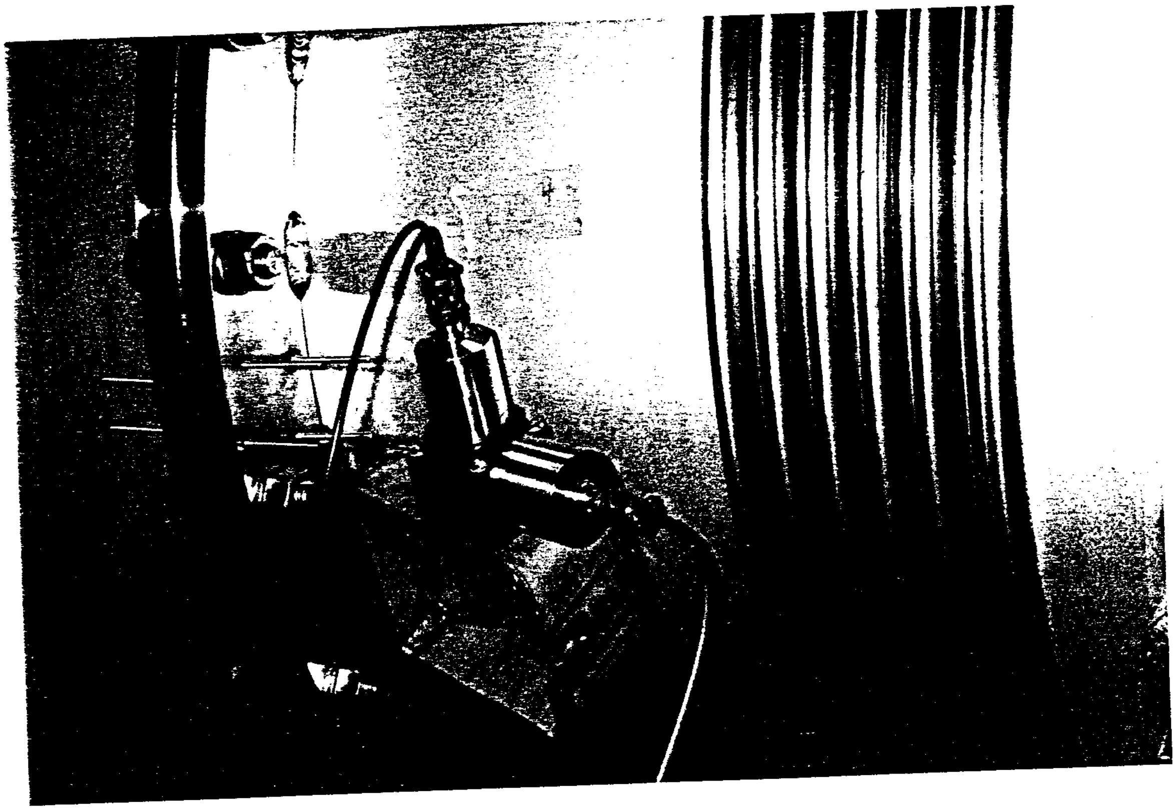


Fig. 4c Vibration Measurement Position 3

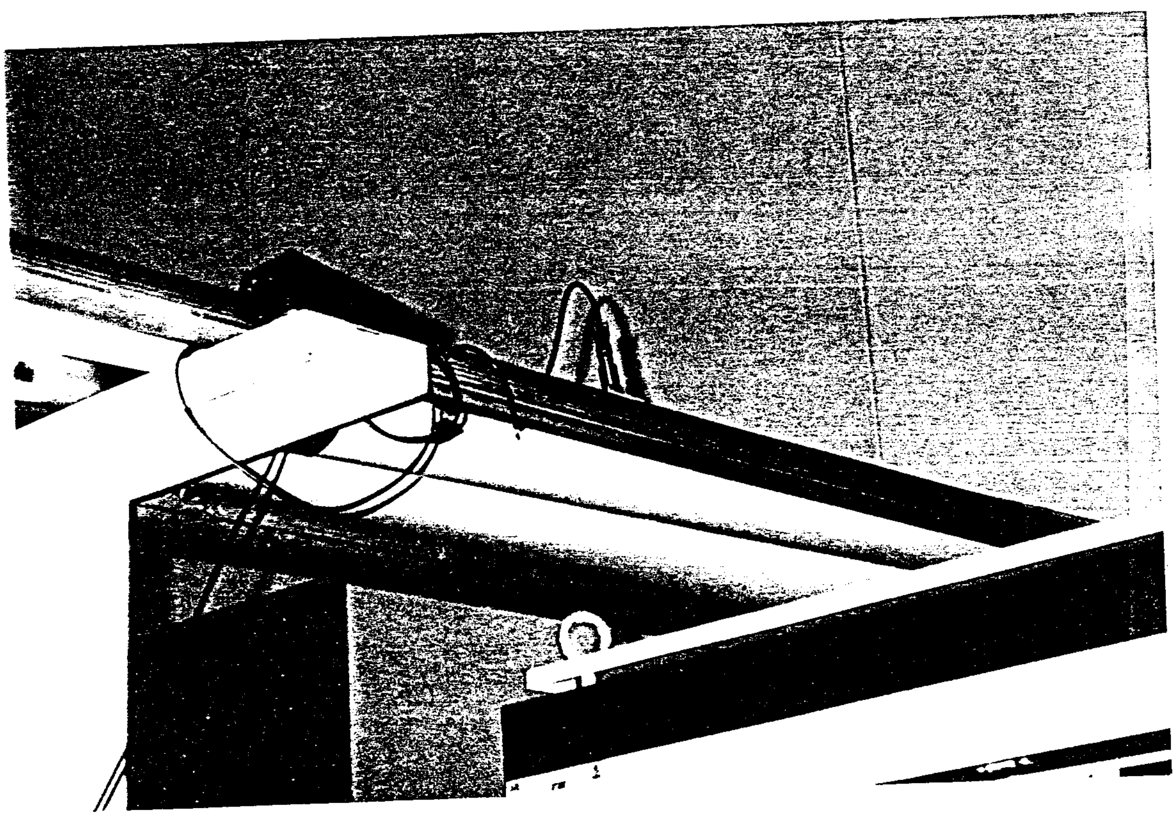


Fig. 4d Vibration Measurement on Fill Line

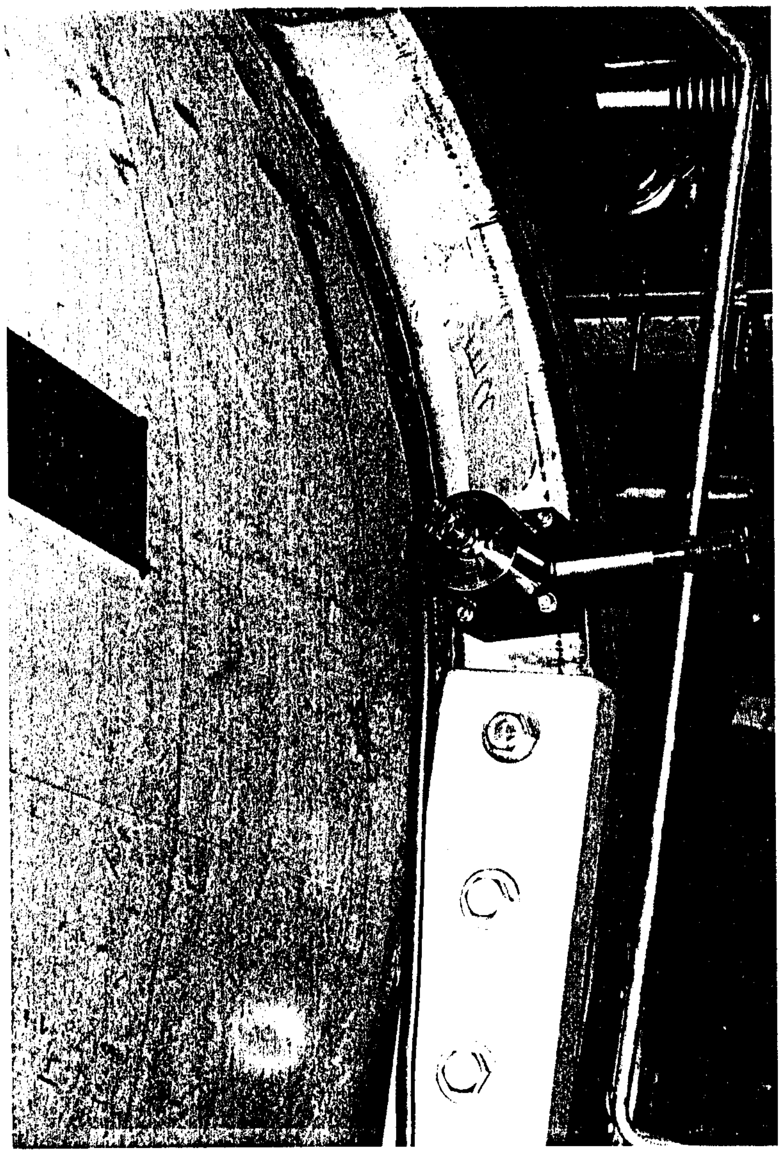


Fig. 4e Vibration Measurement Position 4

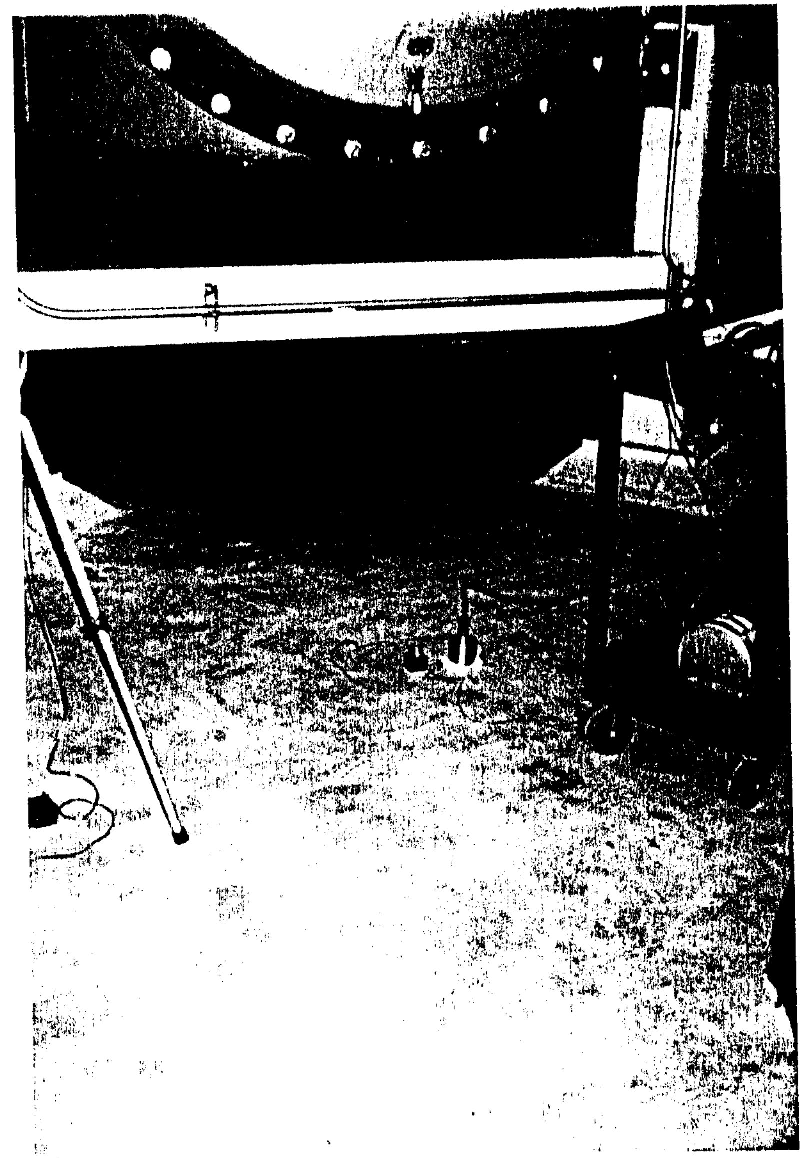


Fig. 4f Floor Vibration Measurement

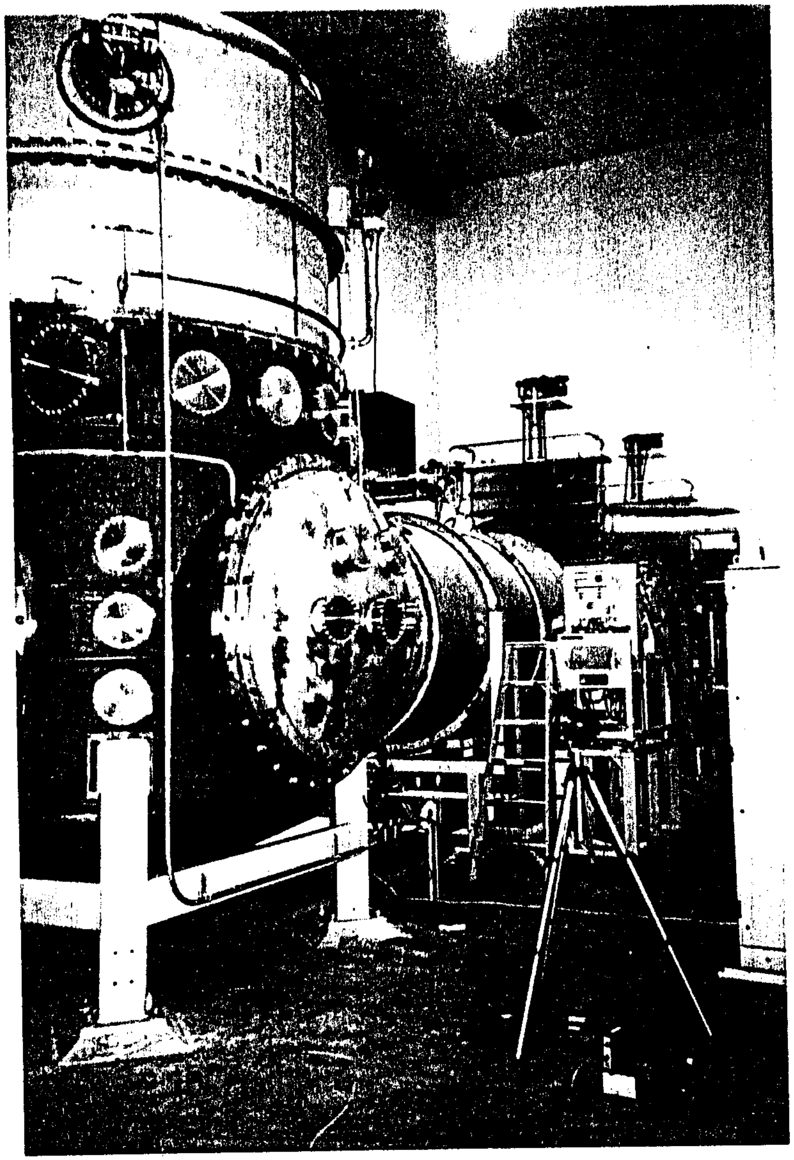


Fig. 4g Acoustic Measurement

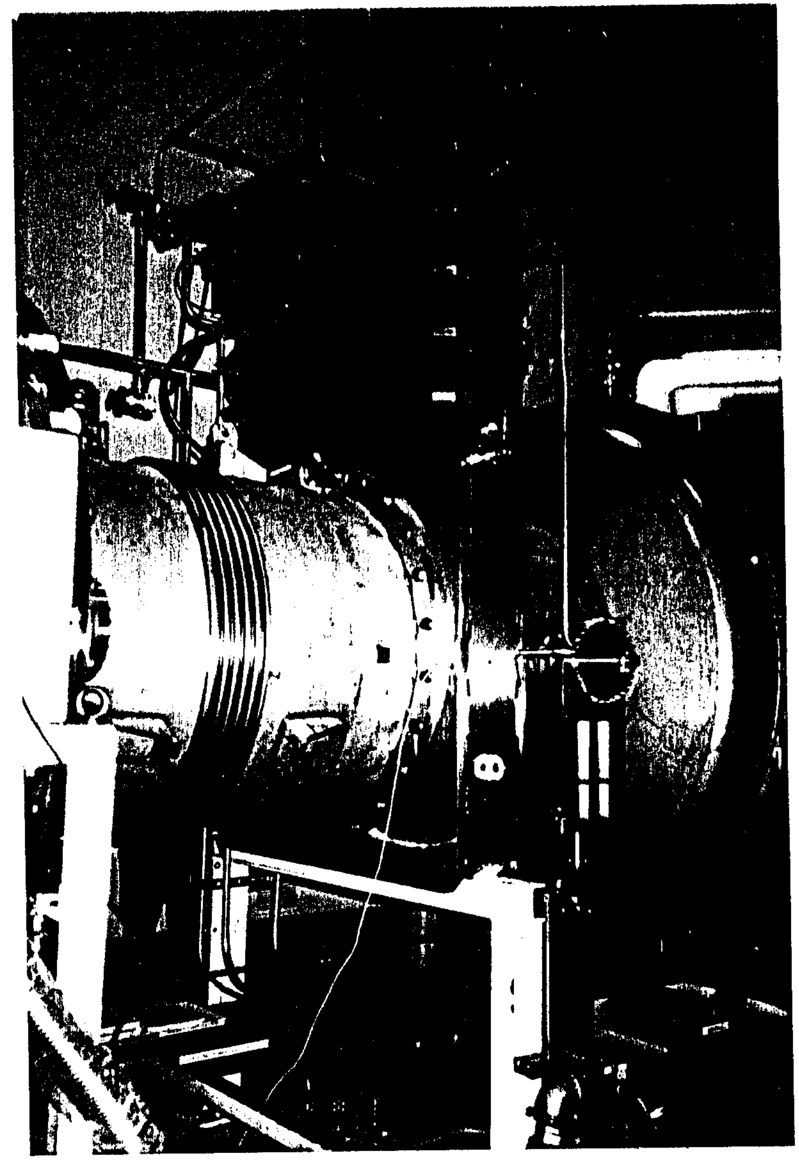


Fig. 4h Valve Schok Measurement

Fig. 5

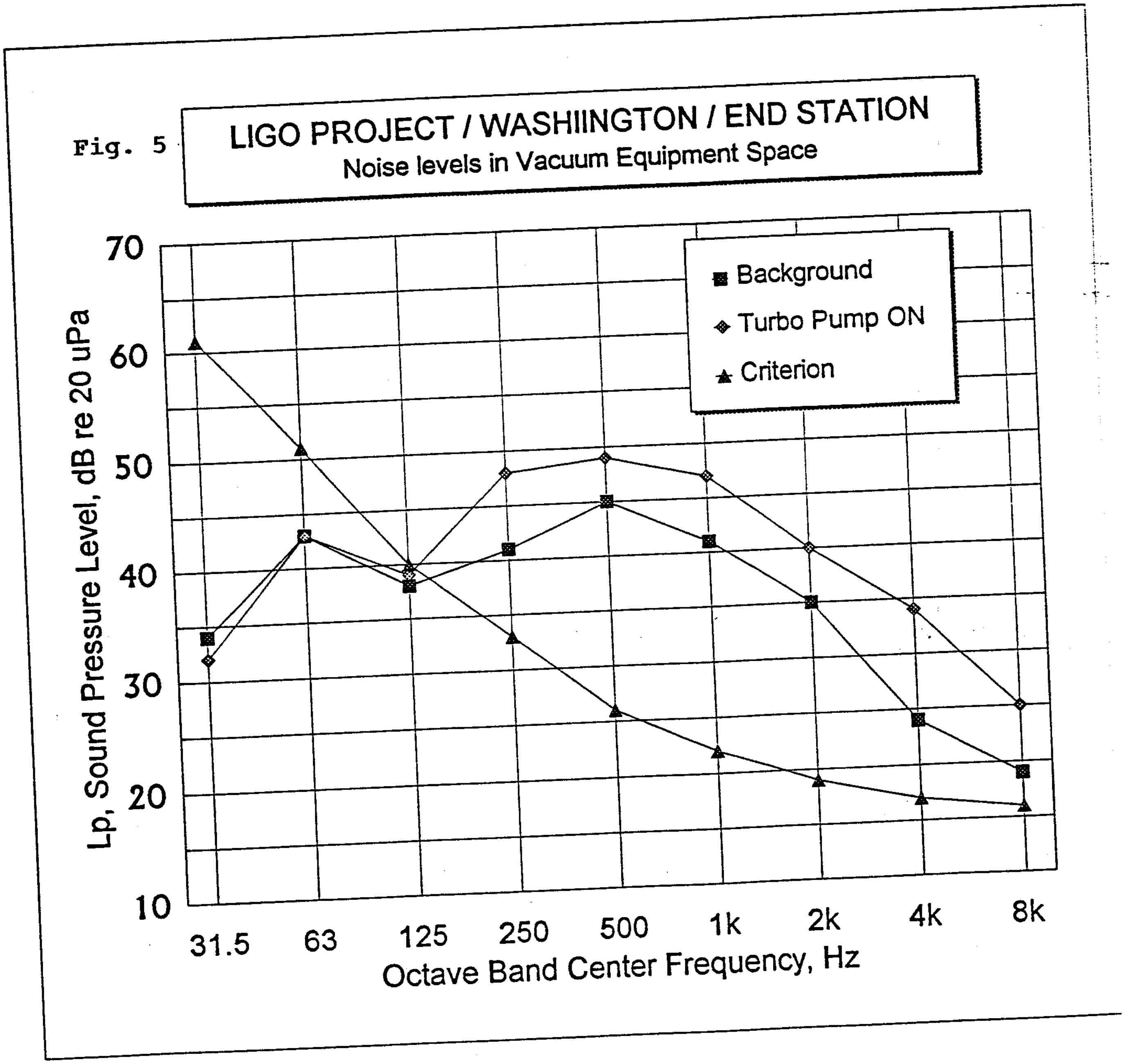
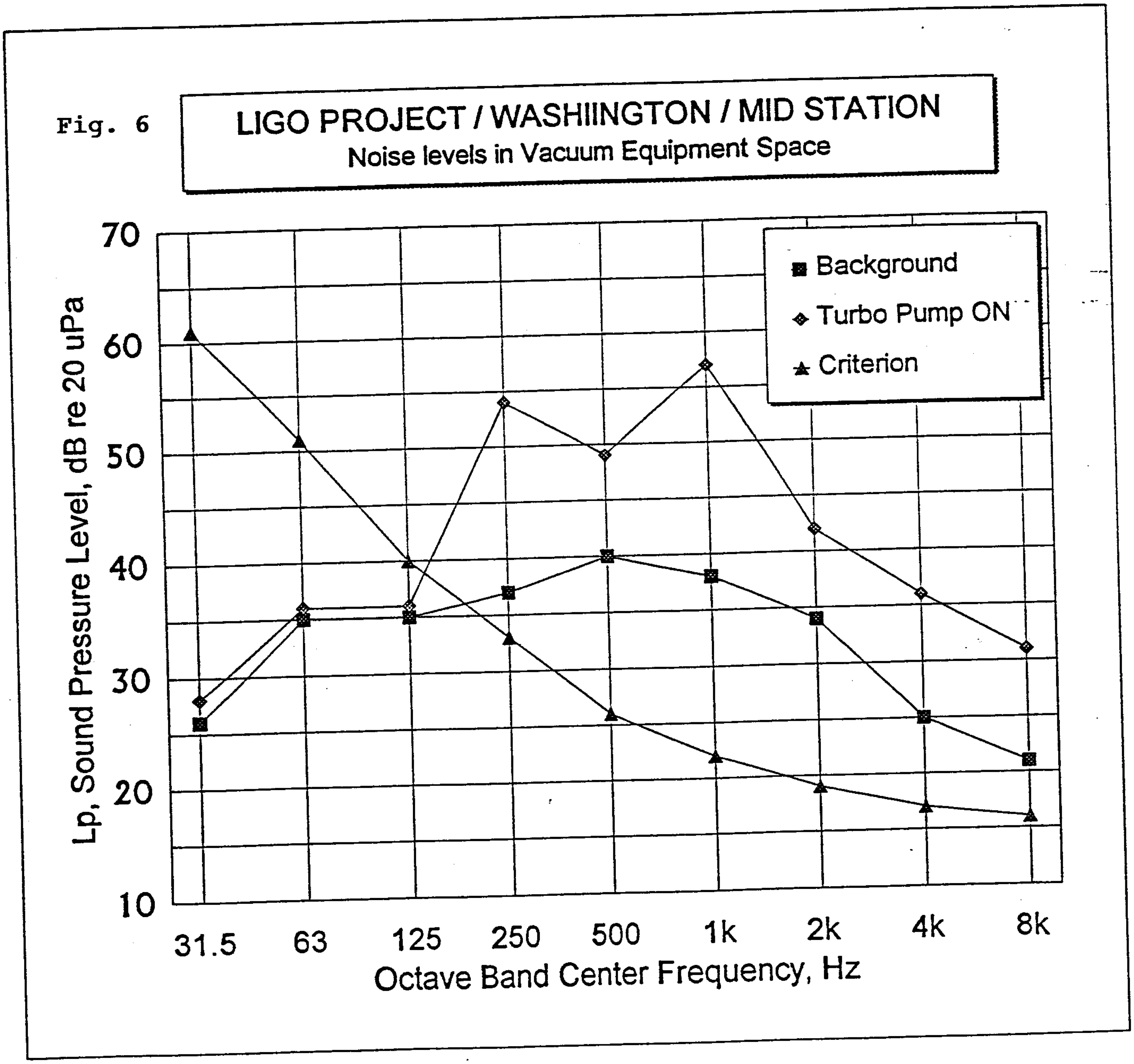

LIGO PROJECT / WASHIINGTON / END STATION
Noise levels in Vacuum Equipment Space
Background
Turbo Pump ON
Criterion
Lp, Sound Pressure Level, dB re 20 uPa
70
60
50
40
30
20
10
31.5
63
125
250
500
1k
2k
4k
8k
Octave Band Center Frequency, Hz

Fig. 6


LIGO PROJECT / WASHIINGTON / MID STATION
Noise levels in Vacuum Equipment Space
Background
Turbo Pump ON
Criterion
Lp, Sound Pressure Level, dB re 20 uPa
70
60
50
40
30
20
10
31.5
63
125
250
500
1k
2k
4k
8k
Octave Band Center Frequency, Hz

APPENDIX B

PSI EQUIPMENT VIBRATION MEASUREMENTS AT LIGO MID STATION HANFORD, WA

LIGO/PSI VIBRATION MEASUREMENT LOG

Mid Station at Hanford, WA

VI. MEASUREMENT AT MID STATION-LOWER NOZZLE G ON BEAMSPLITTER

A. **Background Measurements 4/21/98**-everything shutoff except bld. transformer and one unknown electrical cabinet, vibration measurement equipment behind door.

Mid-7 Circ. dir., Low freq. accelerometer

Mid-8 Circ. dir., High freq. accelerometer

Mid-9 Vertical dir., Low freq. accelerometer

Mid-10 Vertical dir., High freq. accelerometer

Mid-11Radial dir., Low freq. accelerometer

Mid-12Radial dir., High freq. accelerometer

B. **Turbopump 4/21/98**-Turbopump on near Beamsplitter, all other equipment off, turbo backing pump not operating.

Mid-13 Circ. dir., Low freq. accelerometer

Mid-14 Circ. dir., High freq. accelerometer

Mid-15 Vertical dir., Low freq. accelerometer

Mid-16 Vertical dir., High freq. accelerometer

Mid-17 Radial dir., Low freq. accelerometer

Mid-17 Radial dir., High freq. accelerometer

Mid-18 Floor Ref.., Zucker's accelerometer

VII. MEASUREMENT AT MID STATION-ON BEAMSPLITTER FLANGE

A. **Background Measurements 4/21/98** - everything shutoff except bld. transformer and one unknown electrical cabinet, vibration measurement equipment behind door.

Mid-19 Axial dir., Low freq. accelerometer

Mid-21 Vertical dir., High freq. accelerometer

Mid-22 Radial dir., Low freq. accelerometer

Mid-23 Radial dir., High freq. accelerometer

Turbopump 4/21/98-Turbopump on near Beamsplitter, all other equipment off, turbo backing pump not operating

Mid-24 Axial dir., Low freq. accelerometer

Mid-25 Axial dir., High freq. accelerometer

Mid-26 Vertical dir., Low freq. accelerometer

Mid-27 Vertical dir., High freq. accelerometer

Mid-28 Radial dir., Low freq. accelerometer

C. **Floor Measurements 4/21/98** - everything shutoff except bld. transformer and one unknown electrical cabinet, vibration measurement equipment behind door for all other measurements.

Mid-29 Background, Vertical dir., Low freq. accelerometer

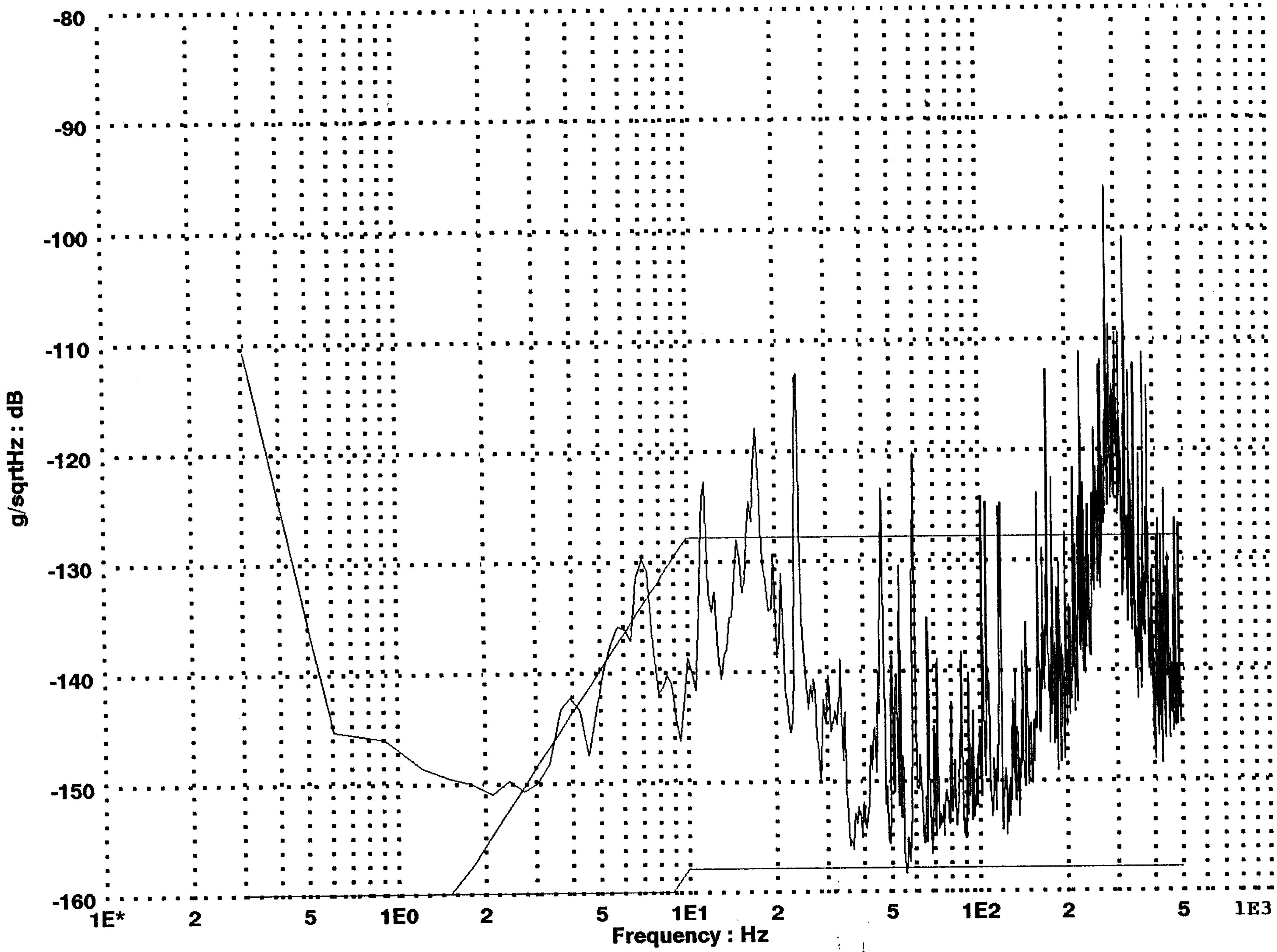
Mid-30 Background, Vertical dir., Zuckers accelerometer

Mid-31 Turbo Source, Vertical dir., Low freq. accelerometer

D. **Acoustic Measurement near Beamsplitter 4/20/98** - everything shutoff except bld. transformer and one unknown electrical cabinet, vibration measurement equipment behind door for all other measurements.

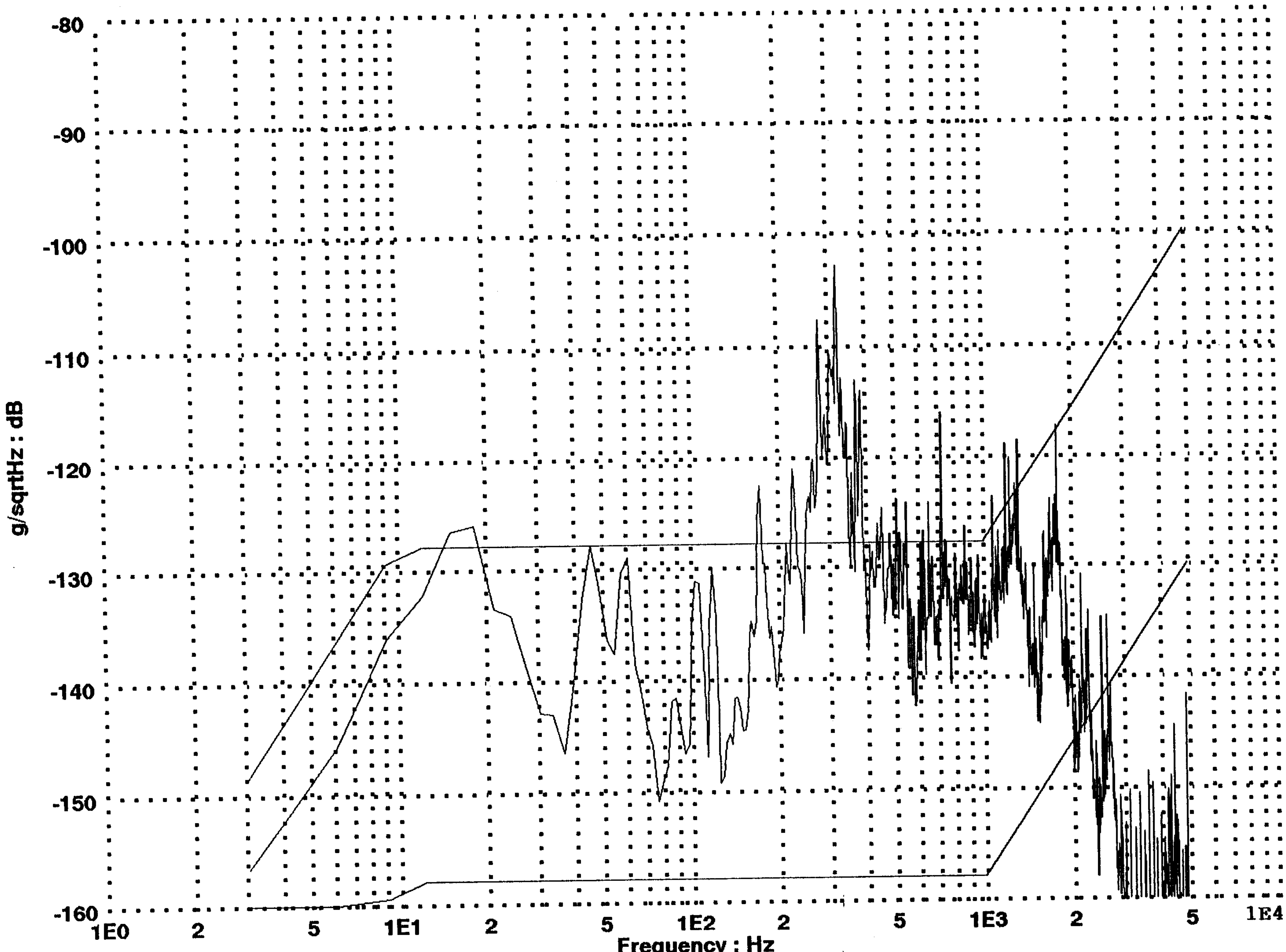
Mid-32 Background Measurement

Mid-33 Turbopump on Measurement



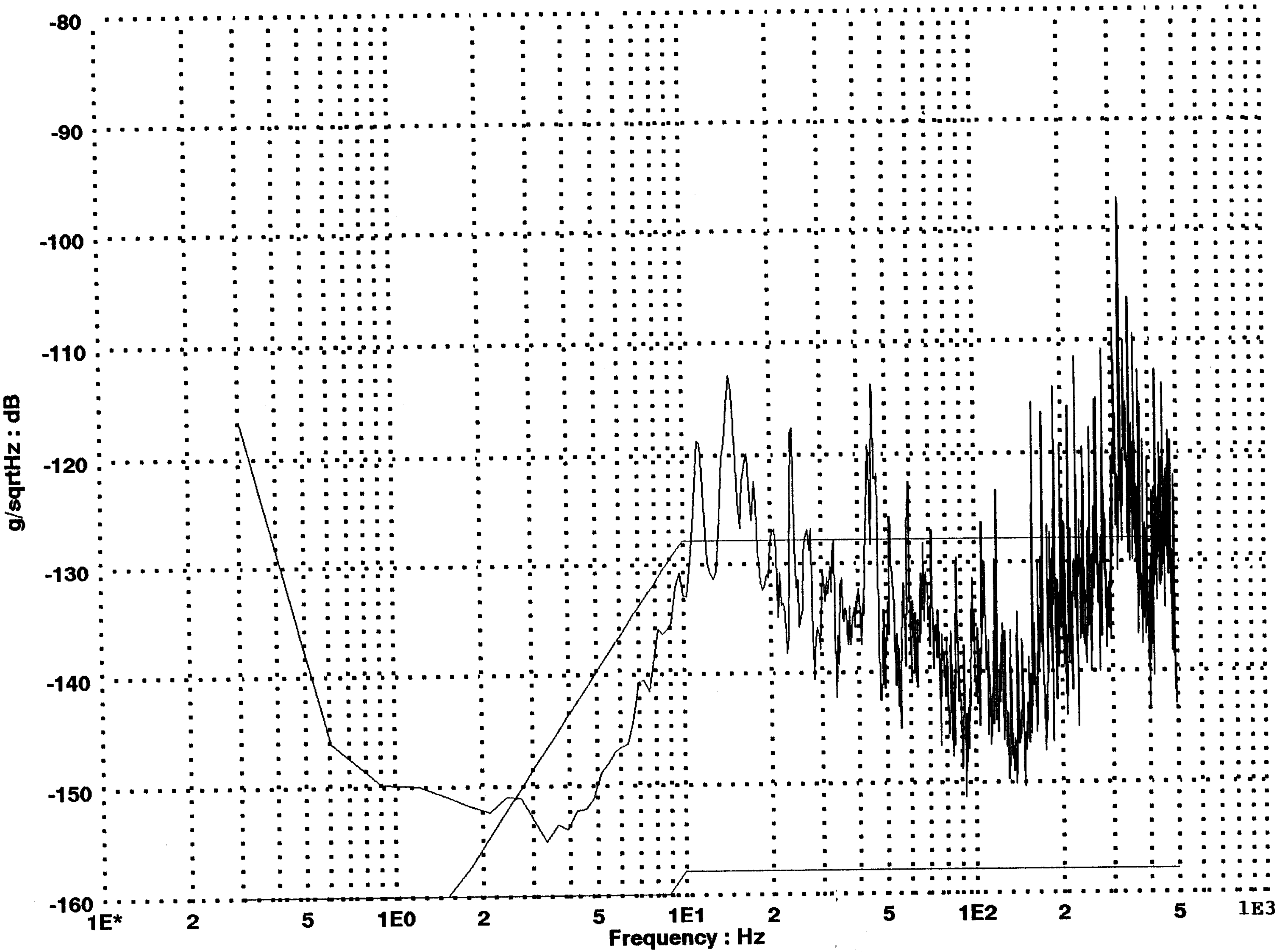
DF: 0.31 Hz T-Lo: 0.ms T-Hi: 3277.ms FFT: 4096 Wind:HANN Sm: 0.

Mid-7 4/21/98 Mid Station: BS noz G, circ. dir., no source



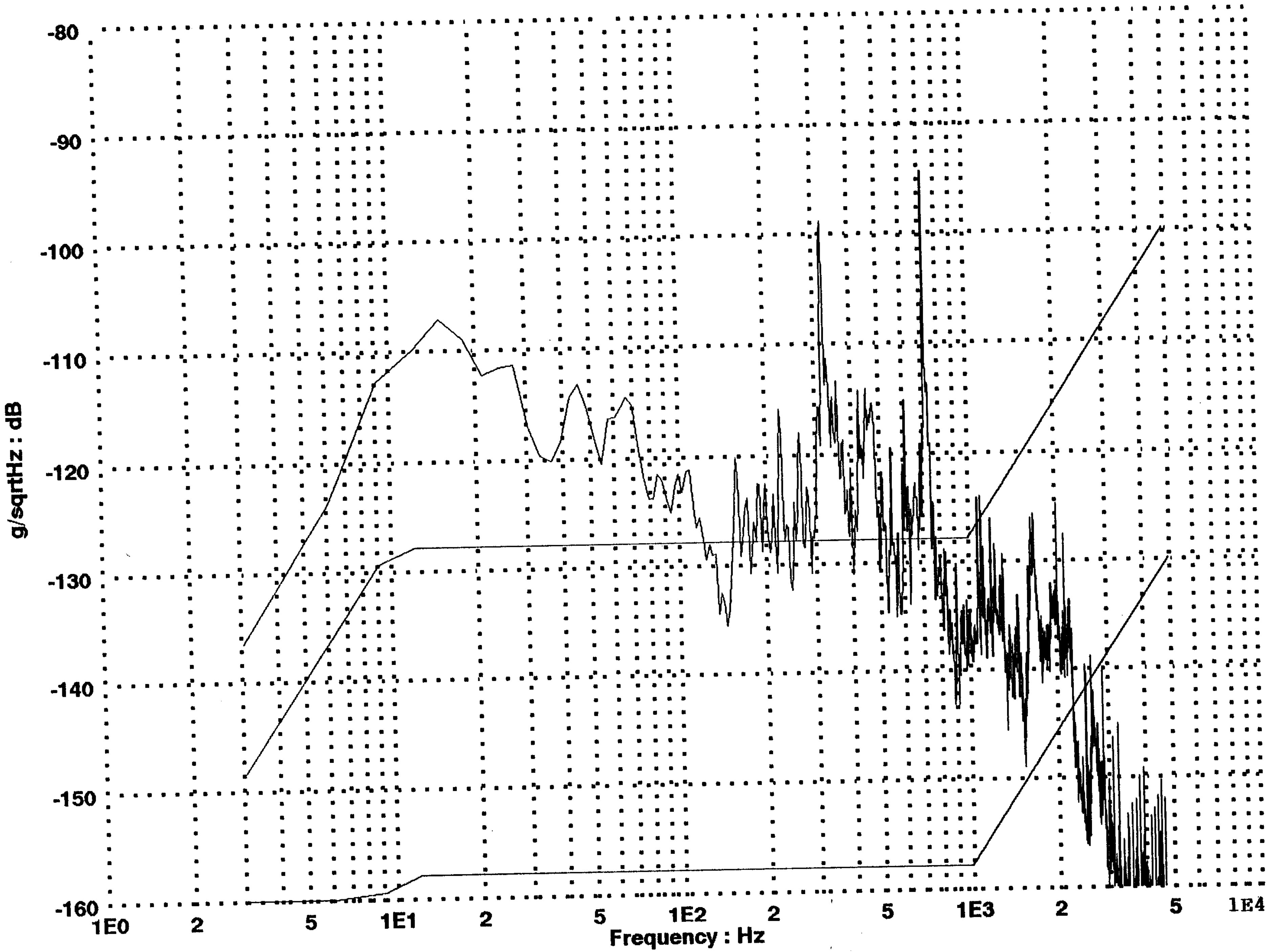
DF: 3.05 Hz T-Lo: 0.ms T-Hi: 328.ms FFT: 4096 Wind:HANN Sm: 0.

Mid-8 4/21/98 Mid Station: BS noz G, circ. dir., no source



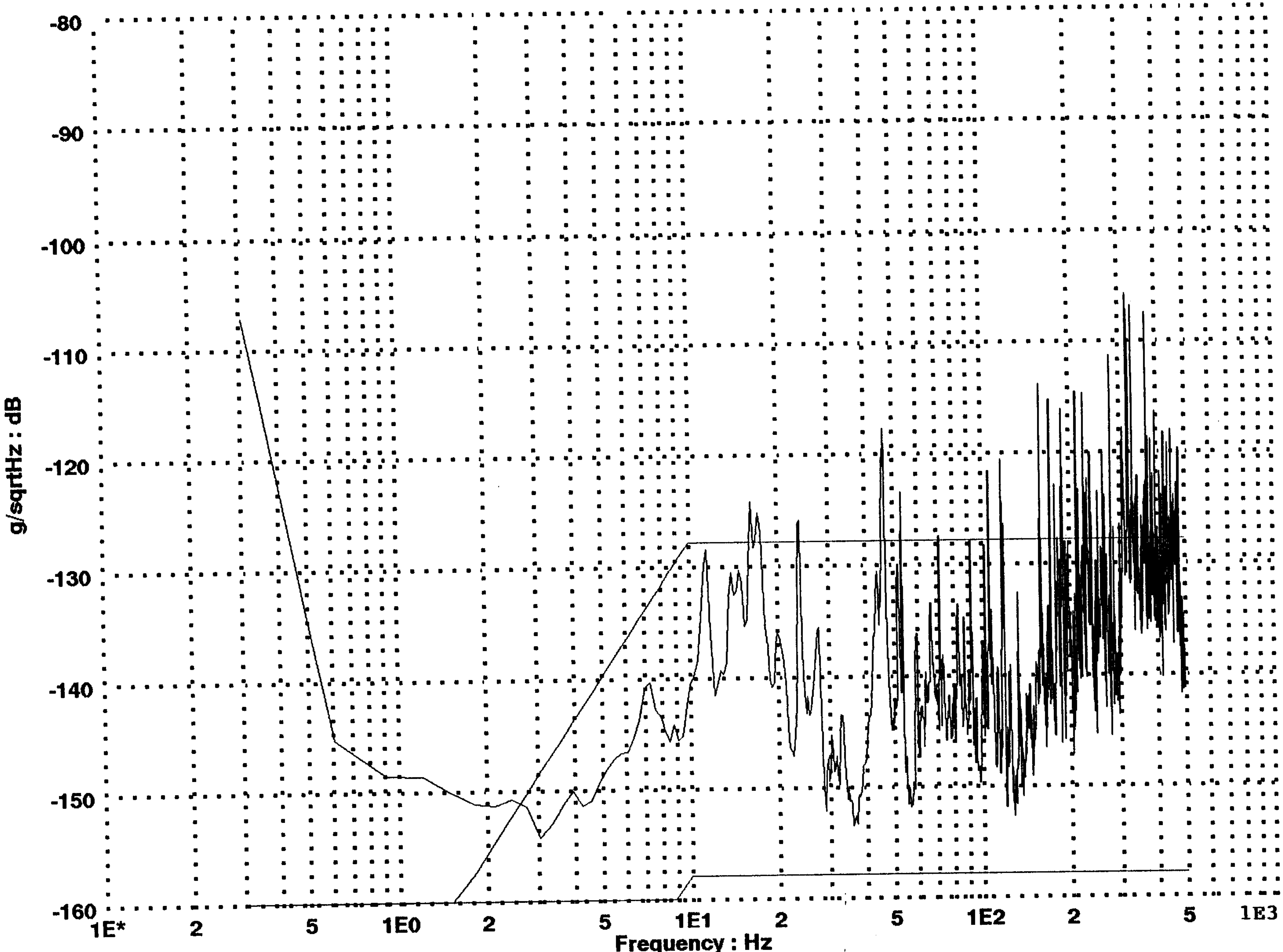
DF: 0.31 Hz T-Lo: 0.ms T-Hi: 3277.ms FFT: 4096 Wind:HANN Sm: 0.

Mid-9 4/21/98 Mid Station: BS noz G, vert. dir., no source



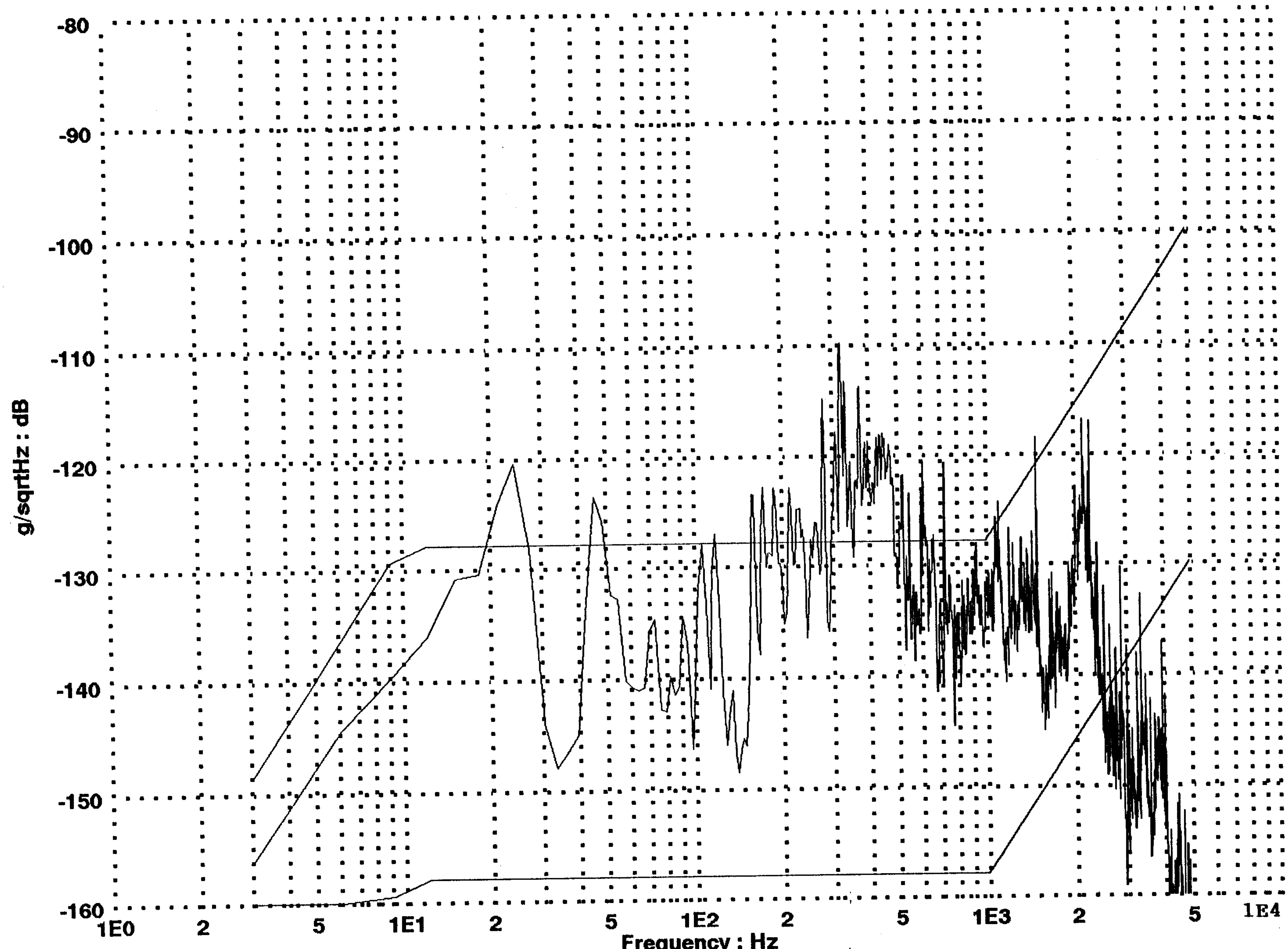
DF: 3.05 Hz T-Lo: 0.ms T-Hi: 328.ms FFT: 4096 Wind:HANN Sm: 0.

Mid-10 4/21/98 Mid Station: BS noz G, vert. dir., no source



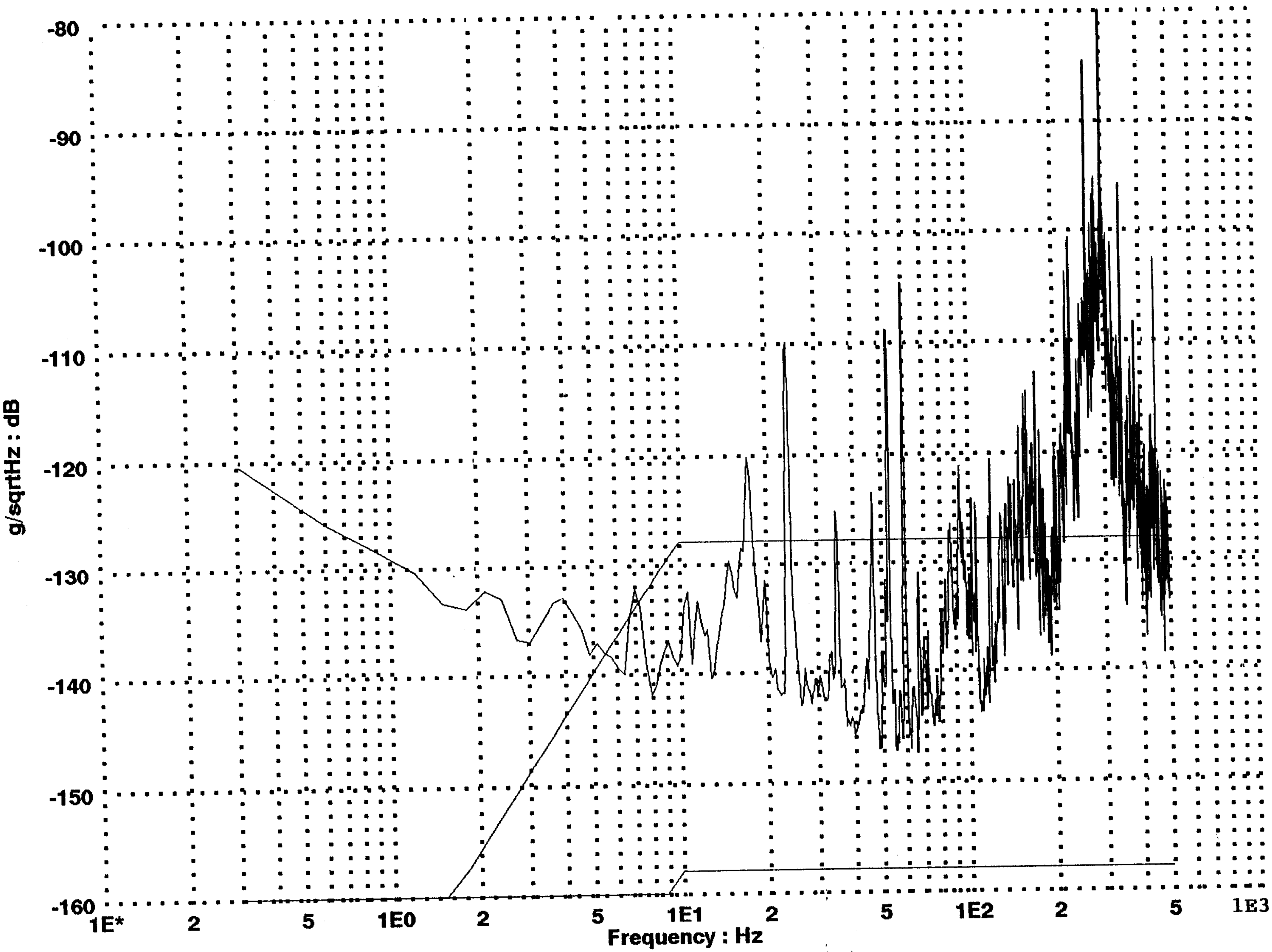
DF: 0.31 Hz T-Lo: 0.ms T-Hi: 3277.ms FFT: 4096 Wind:HANN Sm: 0.

Mid-11 4/21/98 Mid Station: BS noz G, radial dir., no source



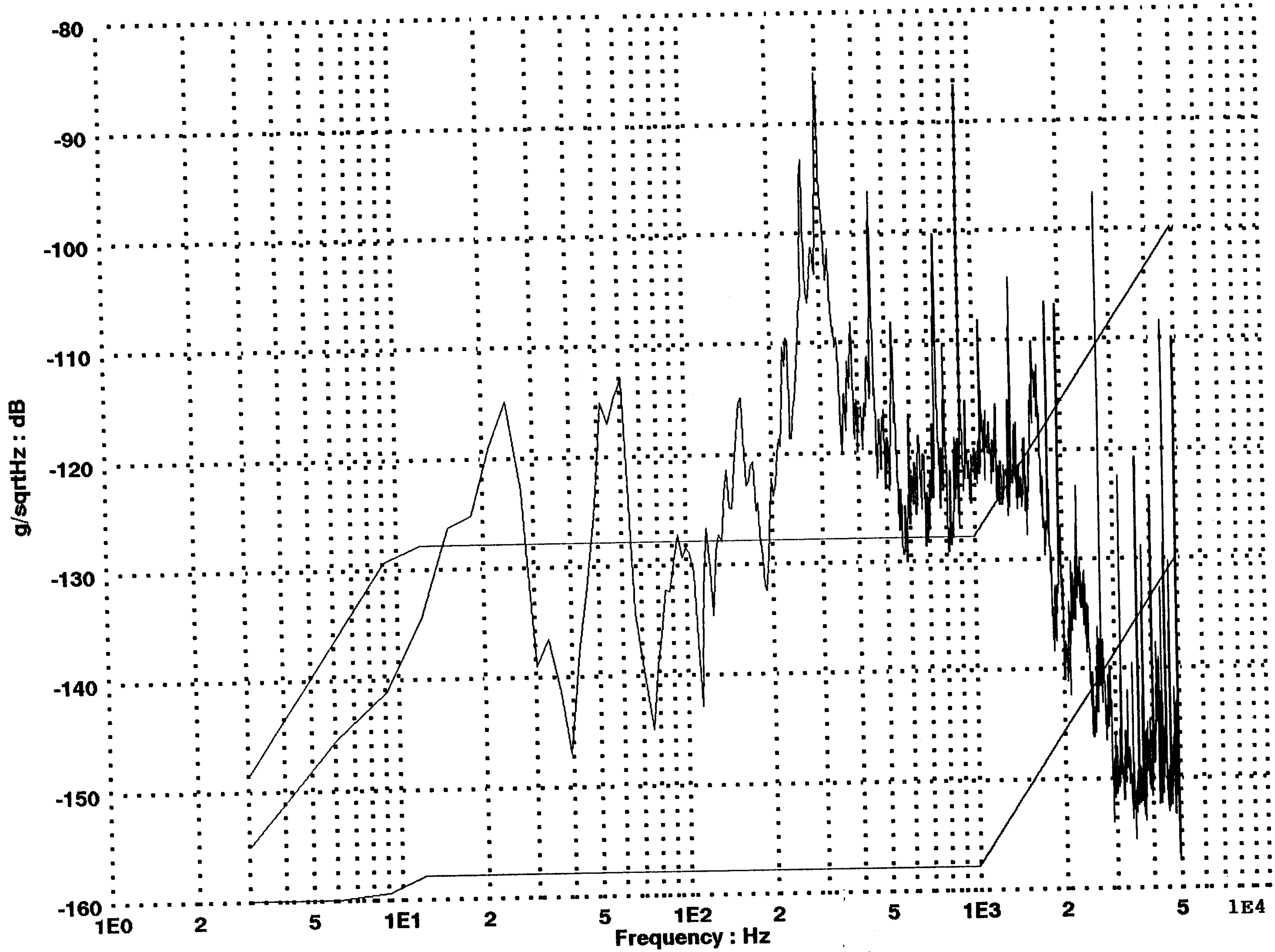
DF: 3.05 Hz T-Lo: 0.ms T-Hi: 328.ms FFT: 4096 Wind:HANN Sm: 0.

Mid-12 4/21/98 Mid Station: BS noz G, radial. dir., no source



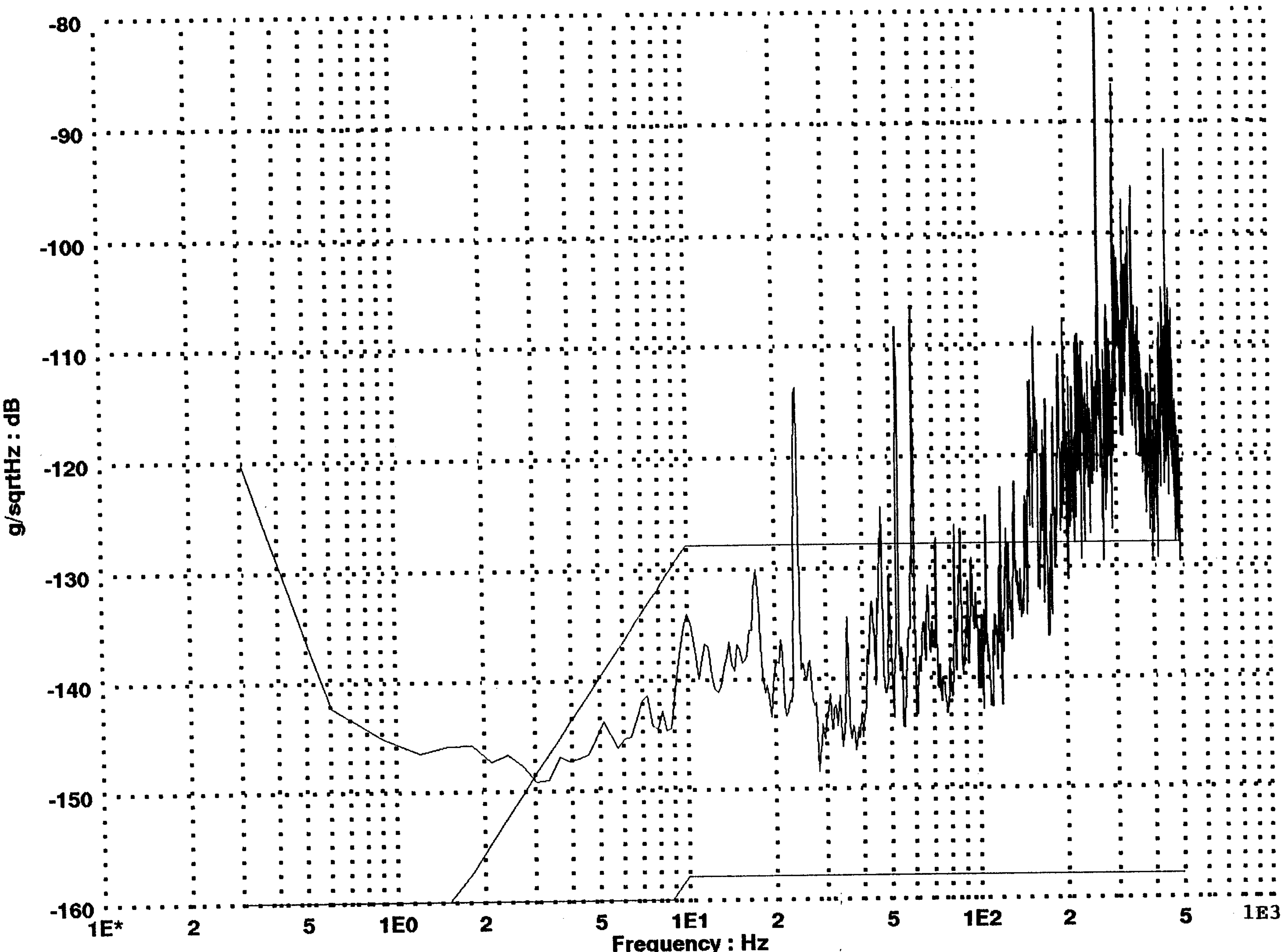
DF: 0.31 Hz T-Lo: 0.ms T-Hi: 3277.ms FFT: 4096 Wind:HANN Sm: 0.

Mid-13 4/21/98 Mid Station: BS noz G, circ. dir., turbo. source



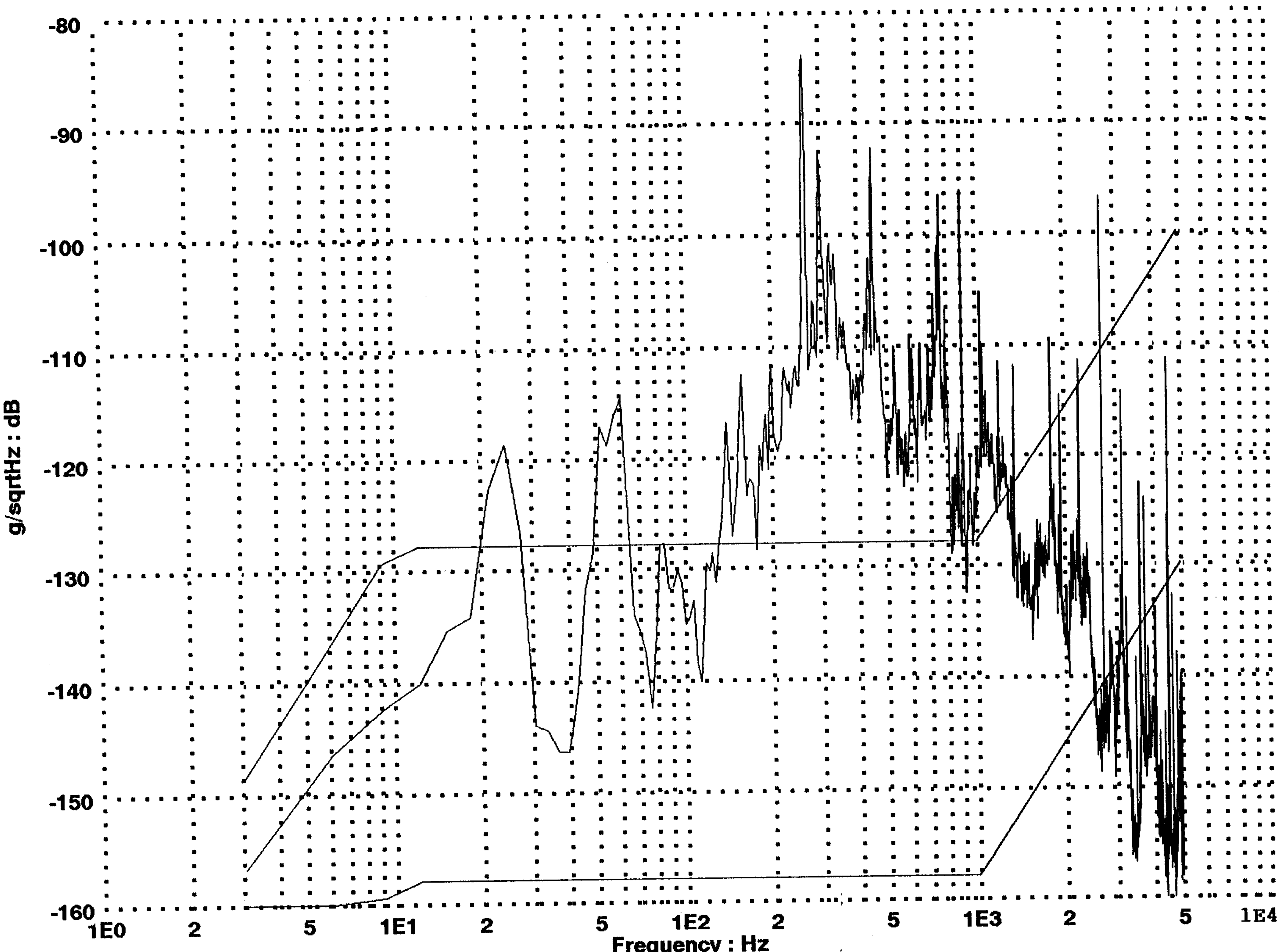
DF: 3.05 Hz T-Lo: 0.ms T-Hi: 328.ms FFT: 4096 Wind:HANN Sm: 0.

Mid-14 4/21/98 Mid Station: BS noz G, circ. dir., turbo. source



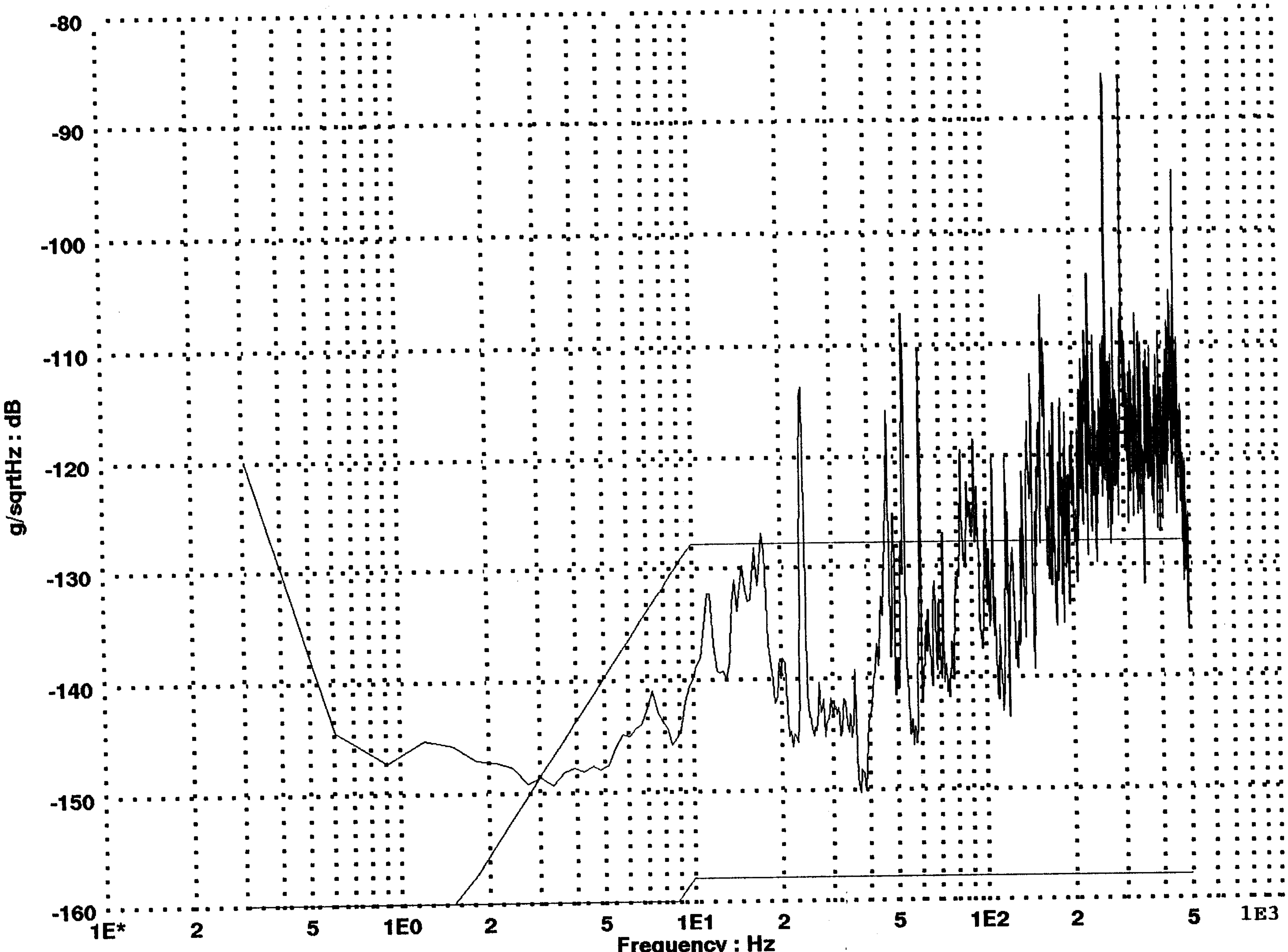
DF: 0.31 Hz T-Lo: 0.ms T-Hi: 3277.ms FFT: 4096 Wind:HANN Sm: 0.

Mid-15 4/21/98 Mid Station: BS noz G, vert. dir., turbo. source



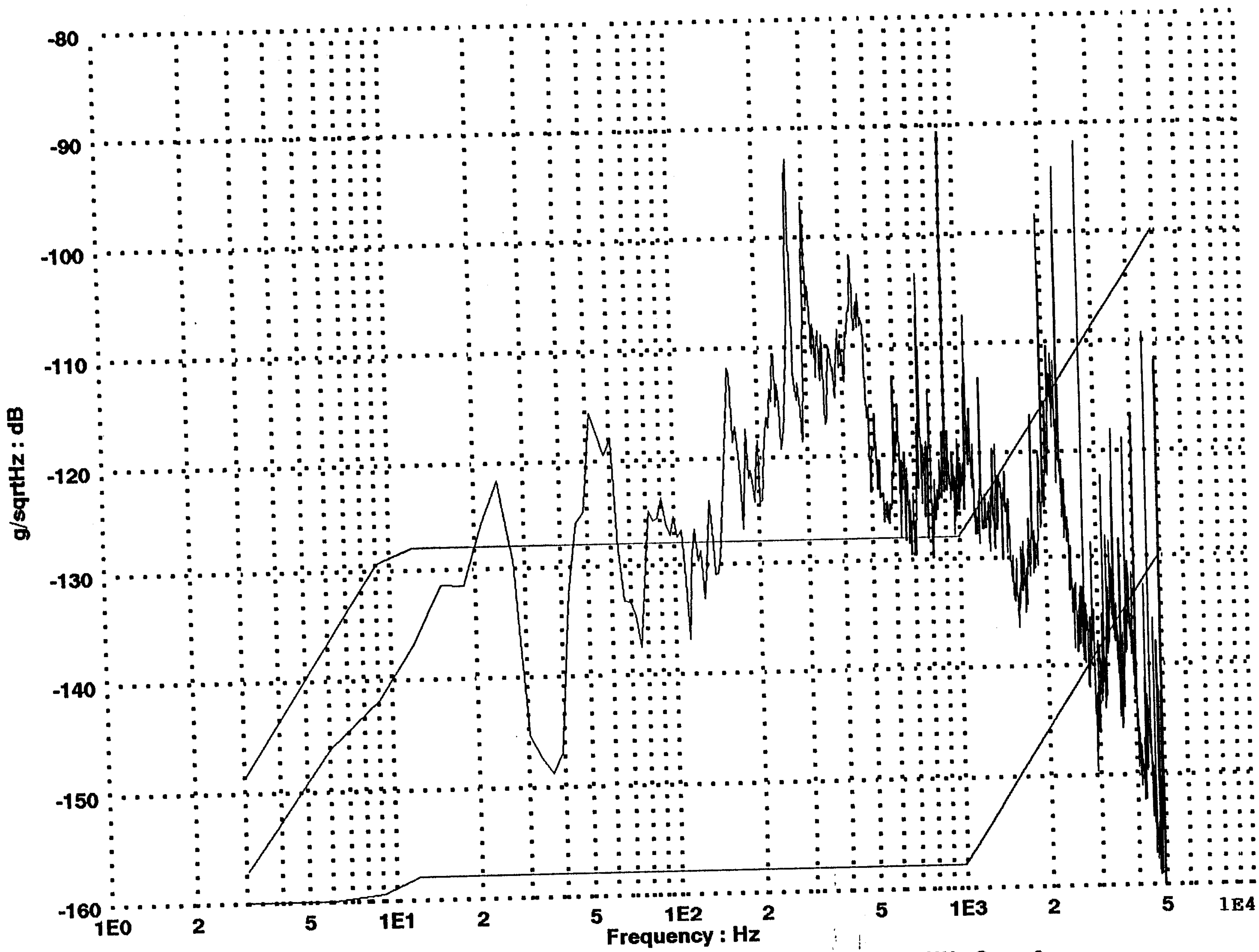
DF: 3.05 Hz T-Lo: 0.ms T-Hi: 328.ms FFT: 4096 Wind:HANN Sm: 0.

Mid-16 4/21/98 Mid Station: BS noz G, vert. dir., turbo. source



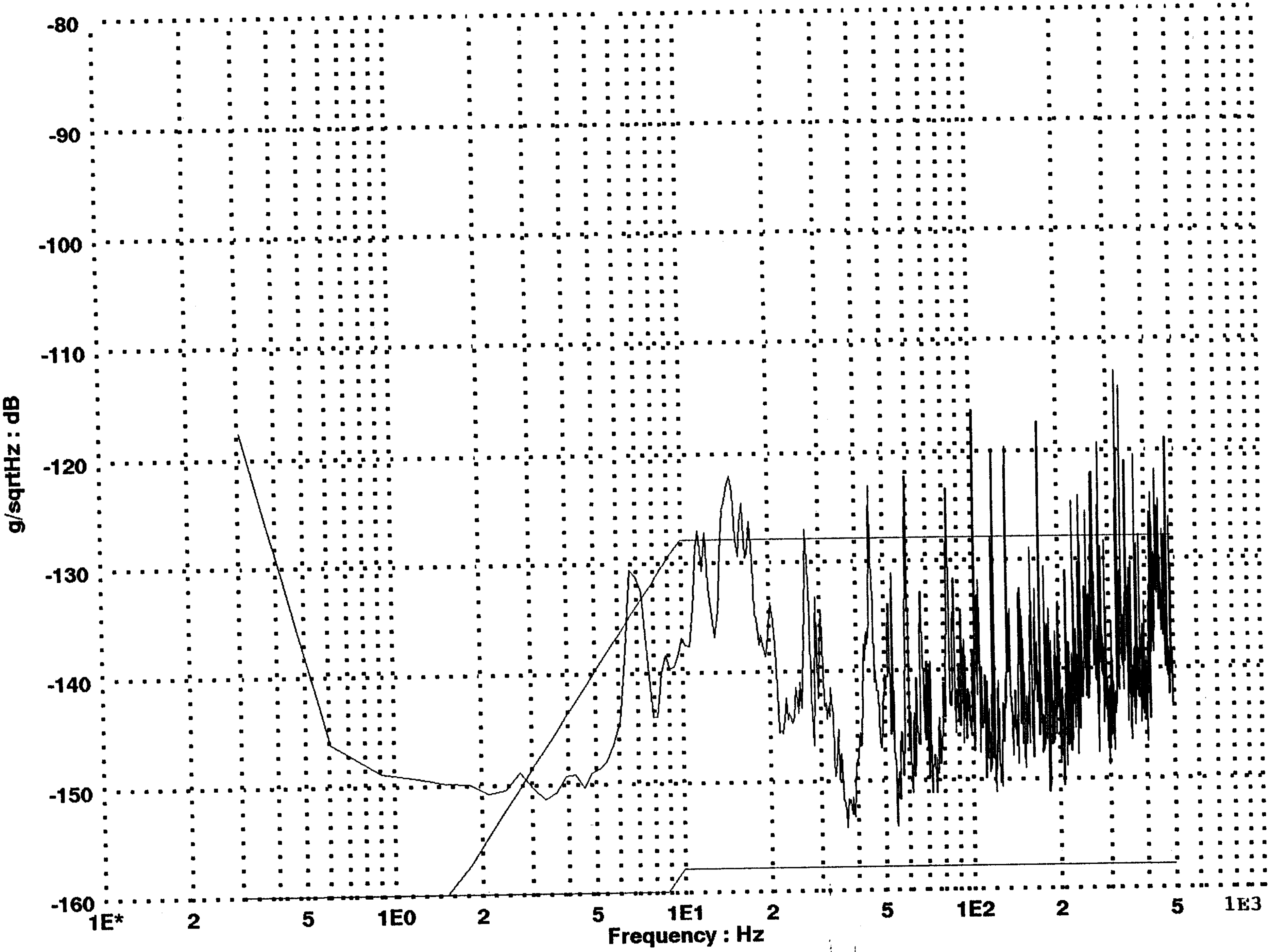
DF: 0.31 Hz T-Lo: 0.ms T-Hi: 3277.ms FFT: 4096 Wind:HANN Sm: 0.

Mid-17 4/21/98 Mid Station: BS noz G, radial dir., turbo. source



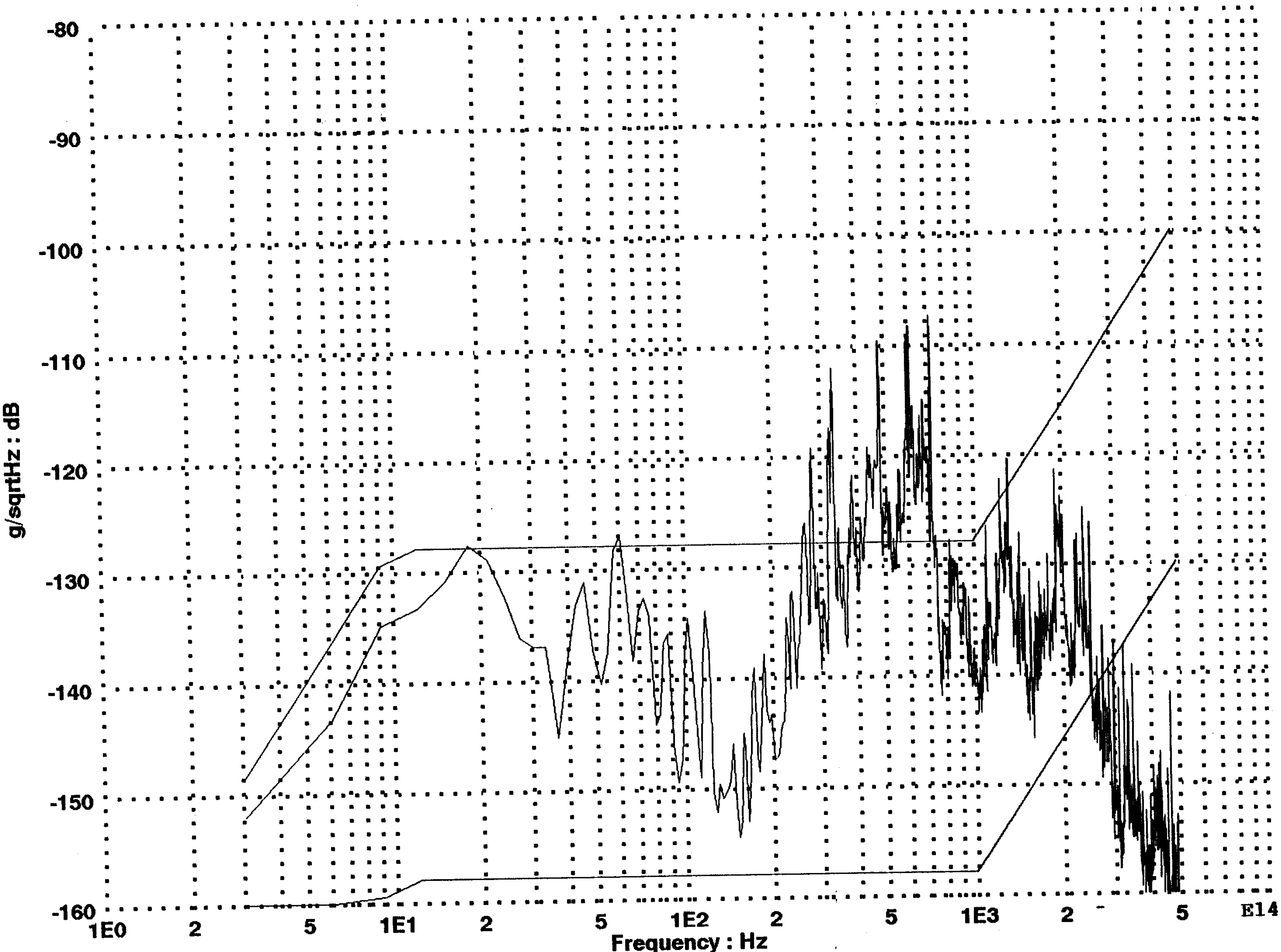
DF: 3.05 Hz T-Lo: 0.ms T-Hi: 328.ms FFT: 4096 Wind:HANN Sm: 0.

Mid-18 4/21/98 Mid Station: BS noz G, radial dir., turbo. source



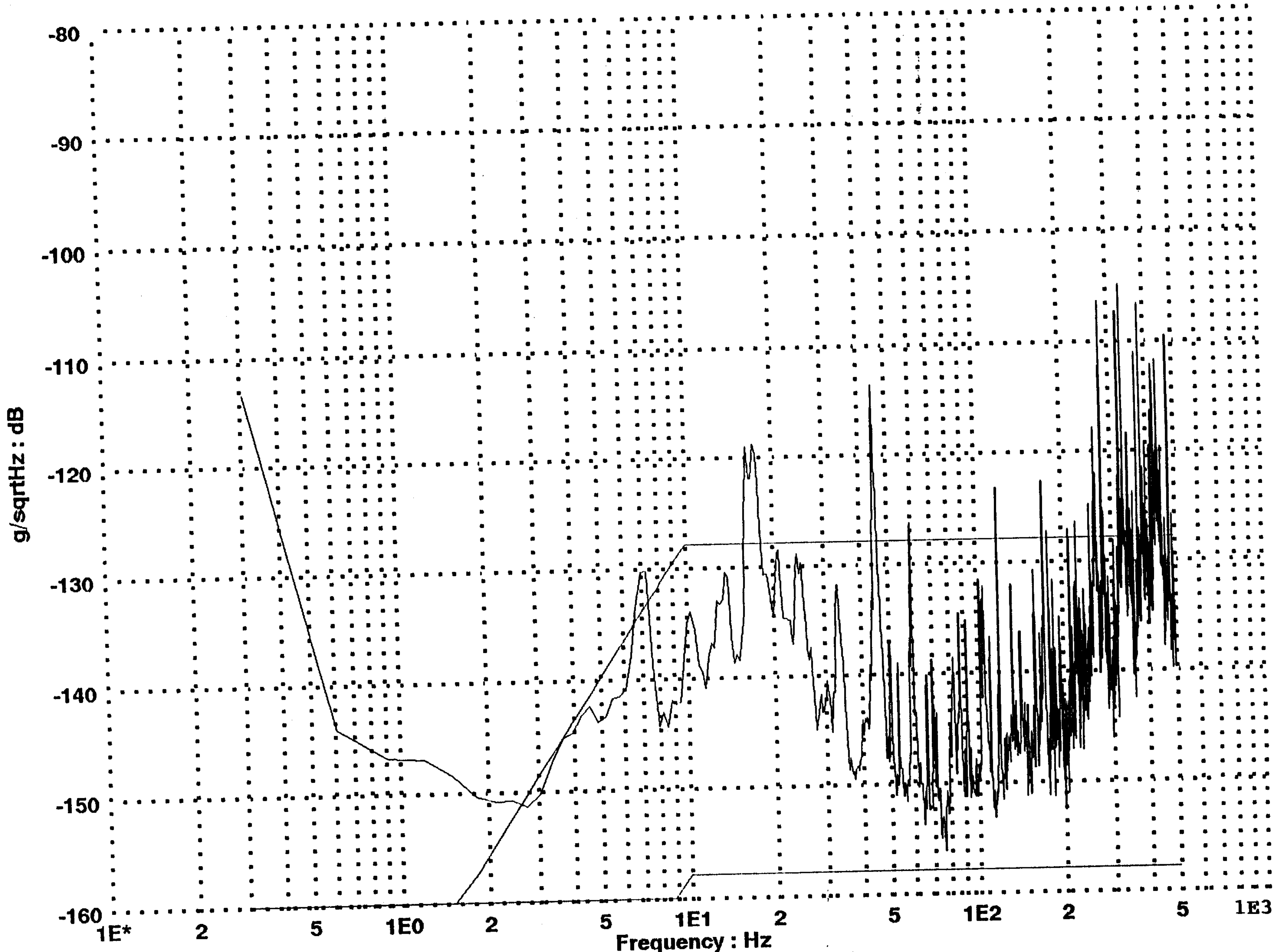
DF: 0.31 Hz T-Lo: 0.ms T-Hi: 3277.ms FFT: 4096 Wind:HANN Sm: 0.

Mid-19 4/21/98 Mid Station: BS flange, axial dir., no source



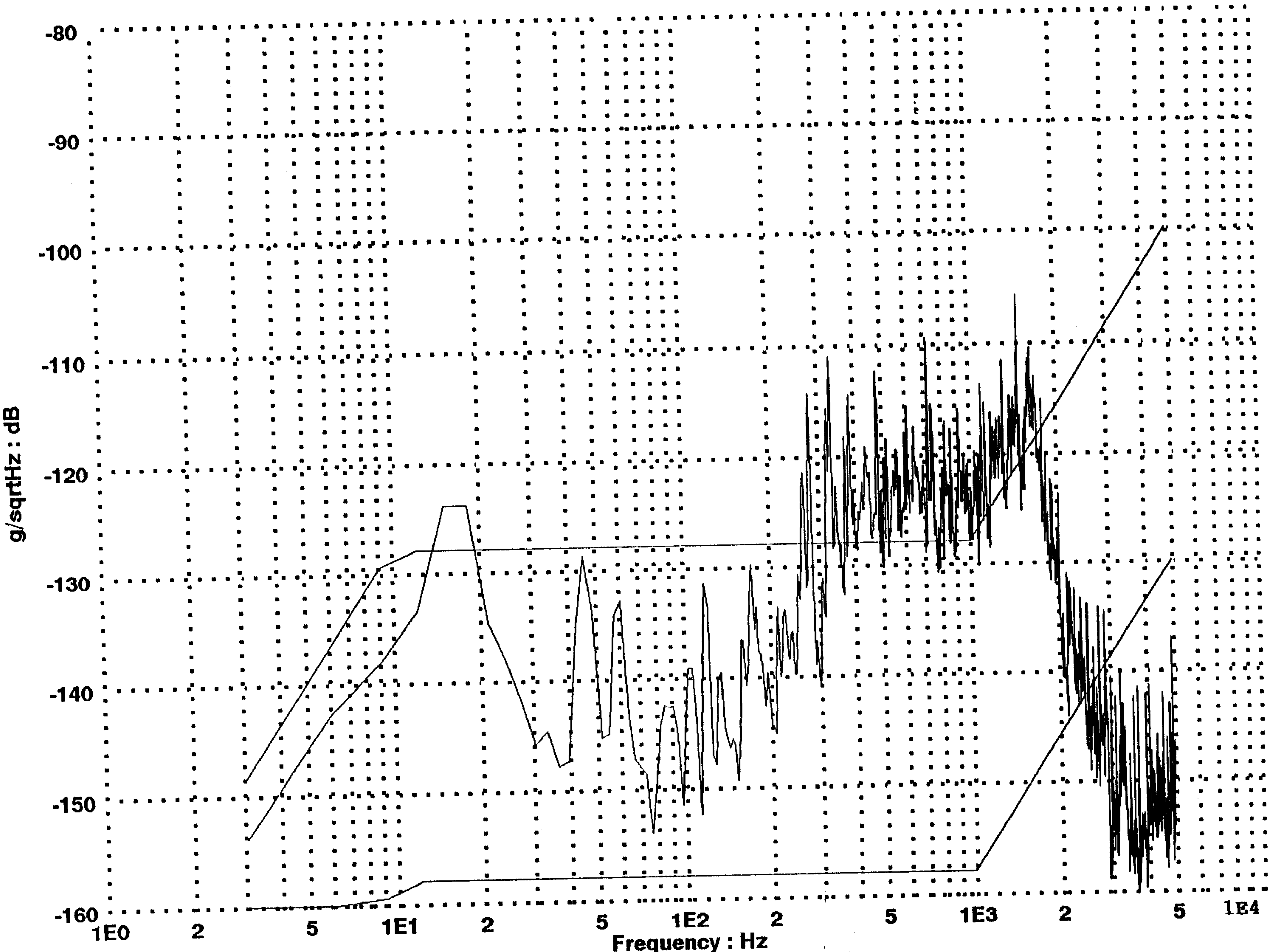
DF: 3.05 Hz T-Lo: 0.ms T-Hi: 328.ms FFT: 4096 Wind:HANN Sm: 0.

Mid-21 4/21/98 Mid Station: BS flange, vert. dir., no source



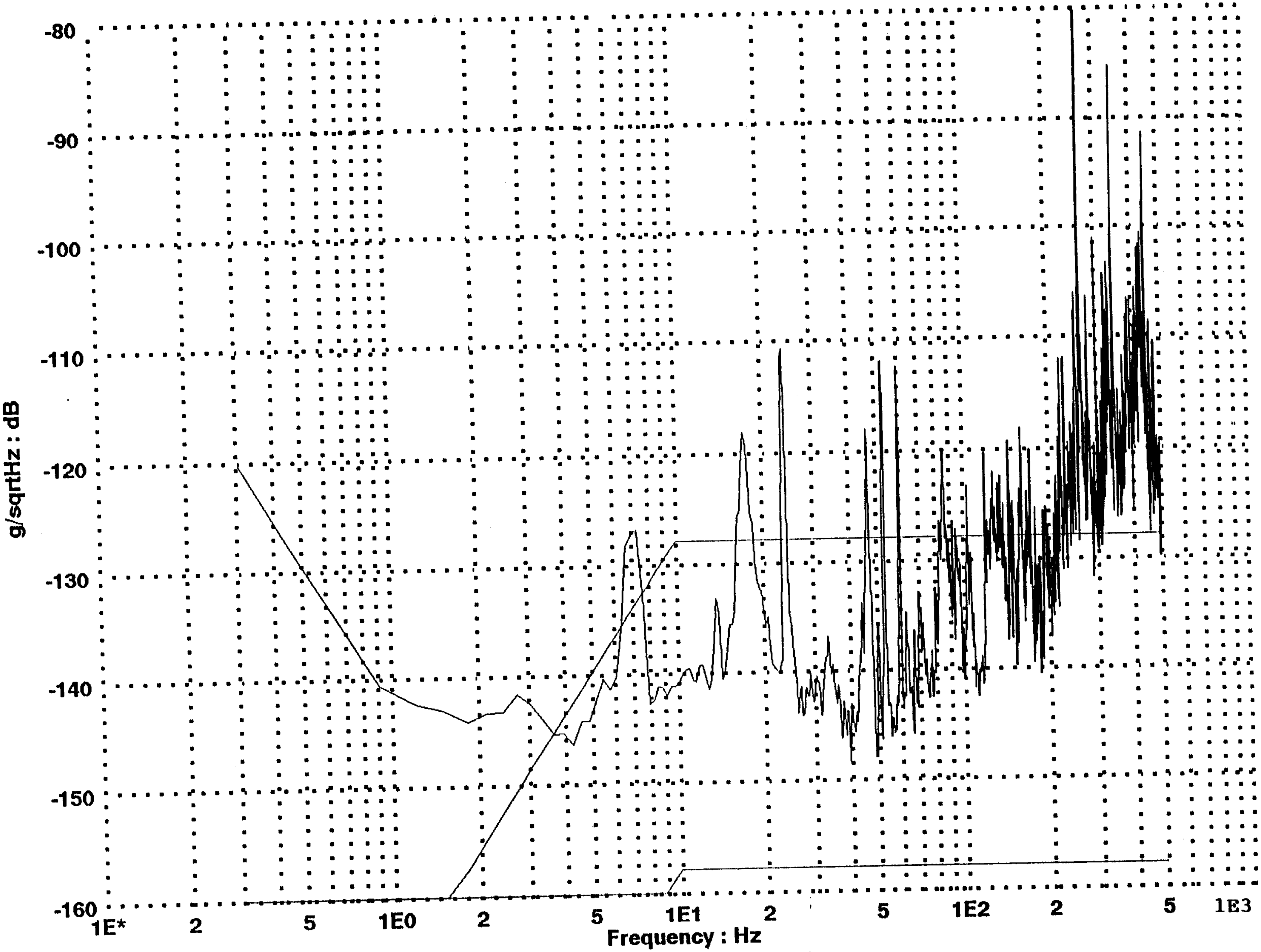
DF: 0.31 Hz T-Lo: 0.ms T-Hi: 3277.ms FFT: 4096 Wind:HANN Sm: 0.

Mid-22 4/21/98 Mid Station: BS flange, radial dir., no source



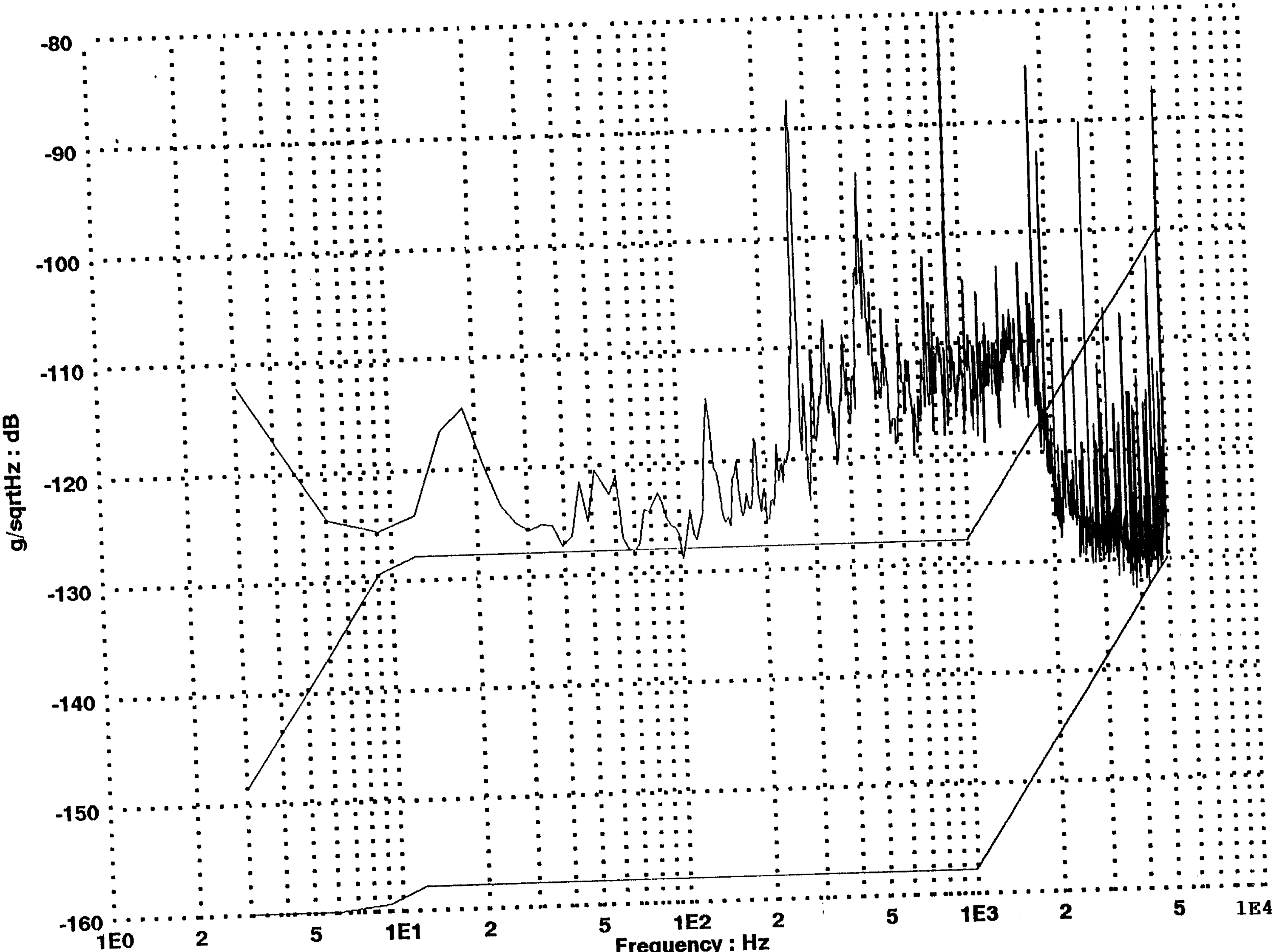
DF: 3.05 Hz T-Lo: 0.ms T-Hi: 328.ms FFT: 4096 Wind:HANN Sm: 0.

Mid-23 4/21/98 Mid Station: BS flange, radial. dir., no source



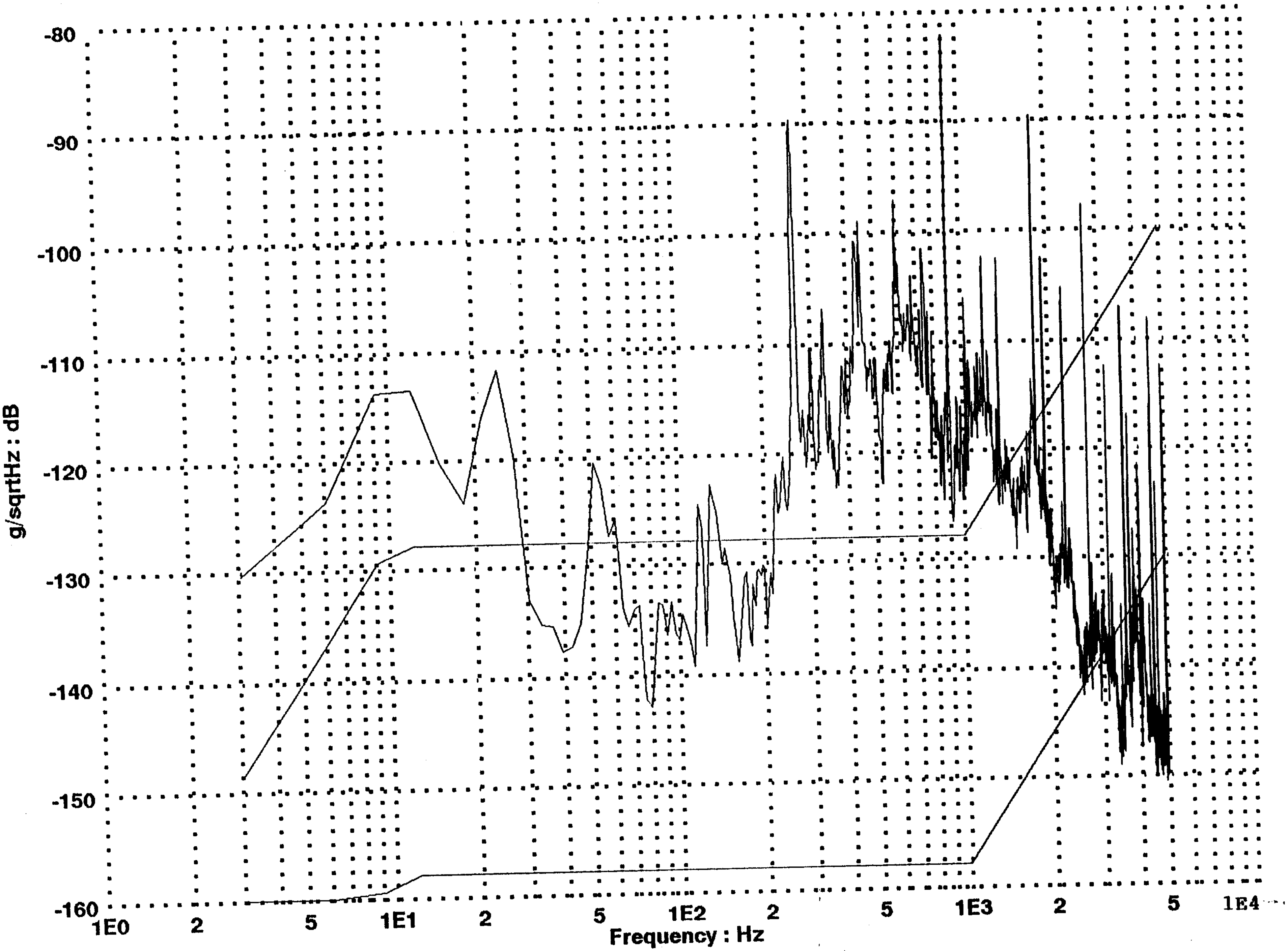
DF: 0.31 Hz T-Lo: 0.ms T-Hi: 3277.ms FFT: 4096 Wind:HANN Sm: 0.

Mid-24 4/21/98 Mid Station: BS flange, axial dir., turbo. source



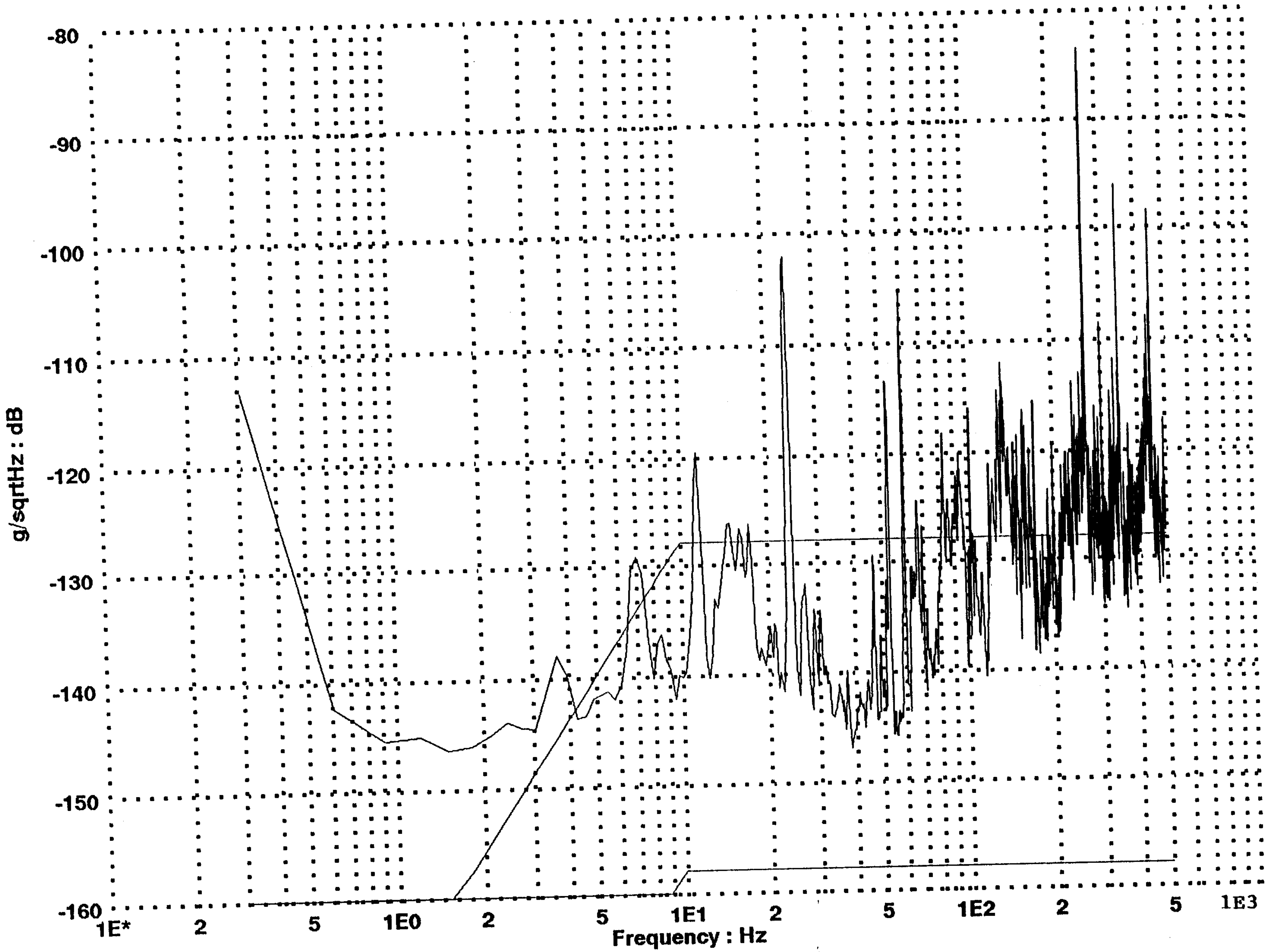
DF: 3.05 Hz T-Lo: 0.ms T-Hi: 328.ms FFT: 4096 Wind:HANN Sm: 0.

Mid-25 4/21/98 Mid Station: BS flange, axial dir., turbo. source



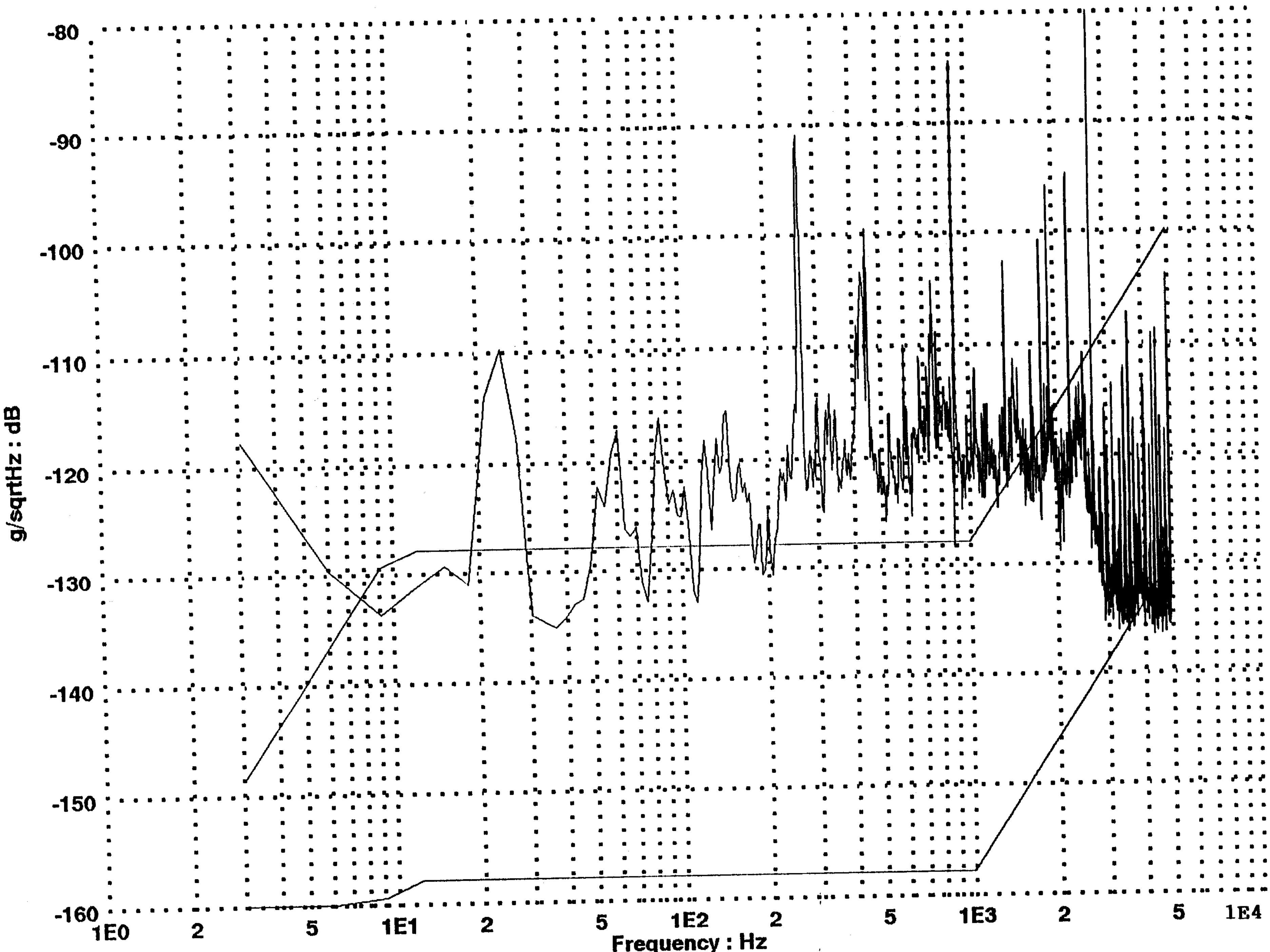
DF: 3.05 Hz T-Lo: 0.ms T-Hi: 328.ms FFT: 4096 Wind:HANN Sm: 0.

Mid-26 4/21/98 Mid Station: BS flange, vert. dir., turbo. source



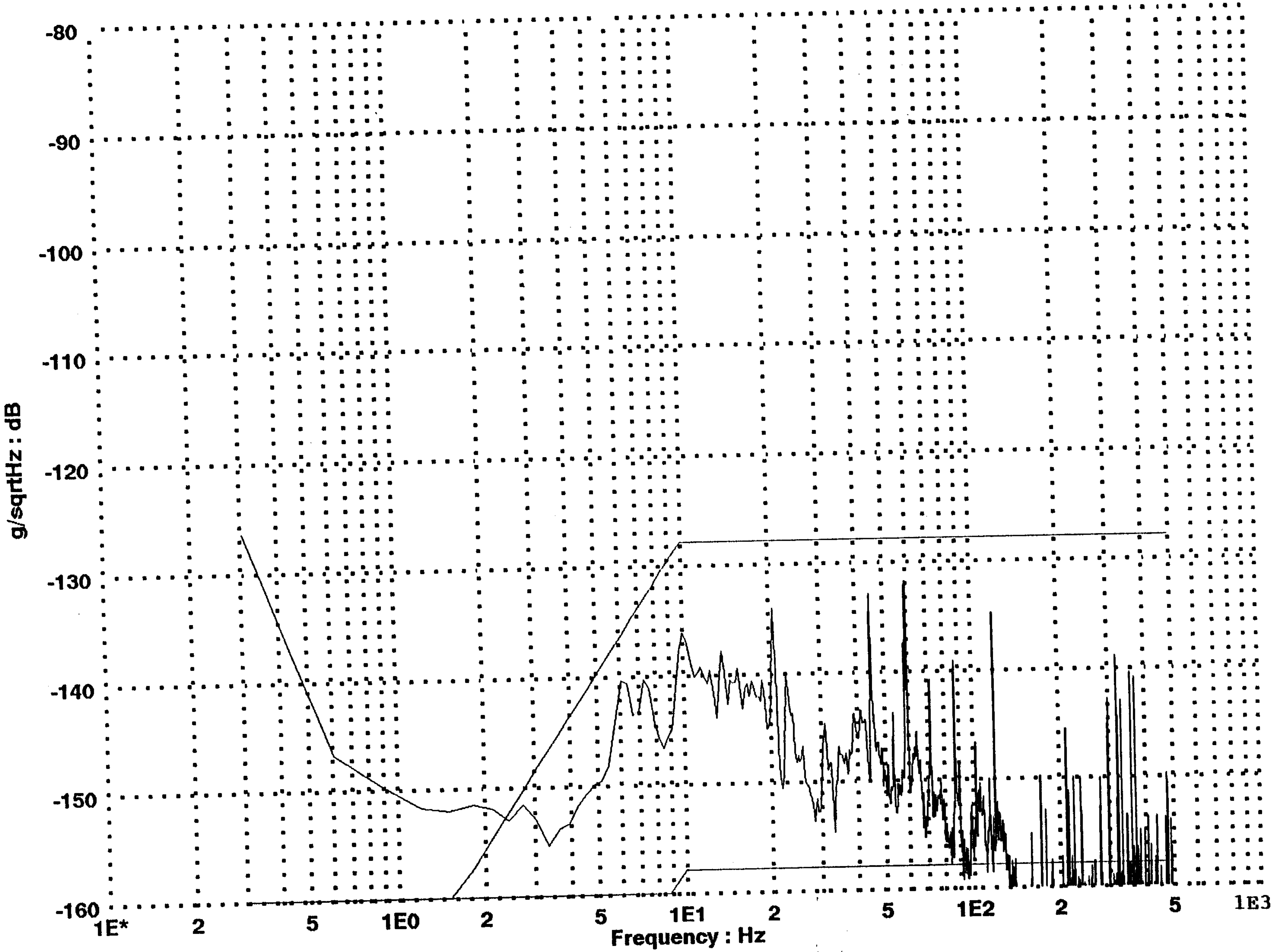
DF: 0.31 Hz T-Lo: 0.ms T-Hi: 3277.ms FFT: 4096 Wind:HANN Sm: 0.

Mid-27 4/21/98 Mid Station: BS flange, radial dir., turbo. source



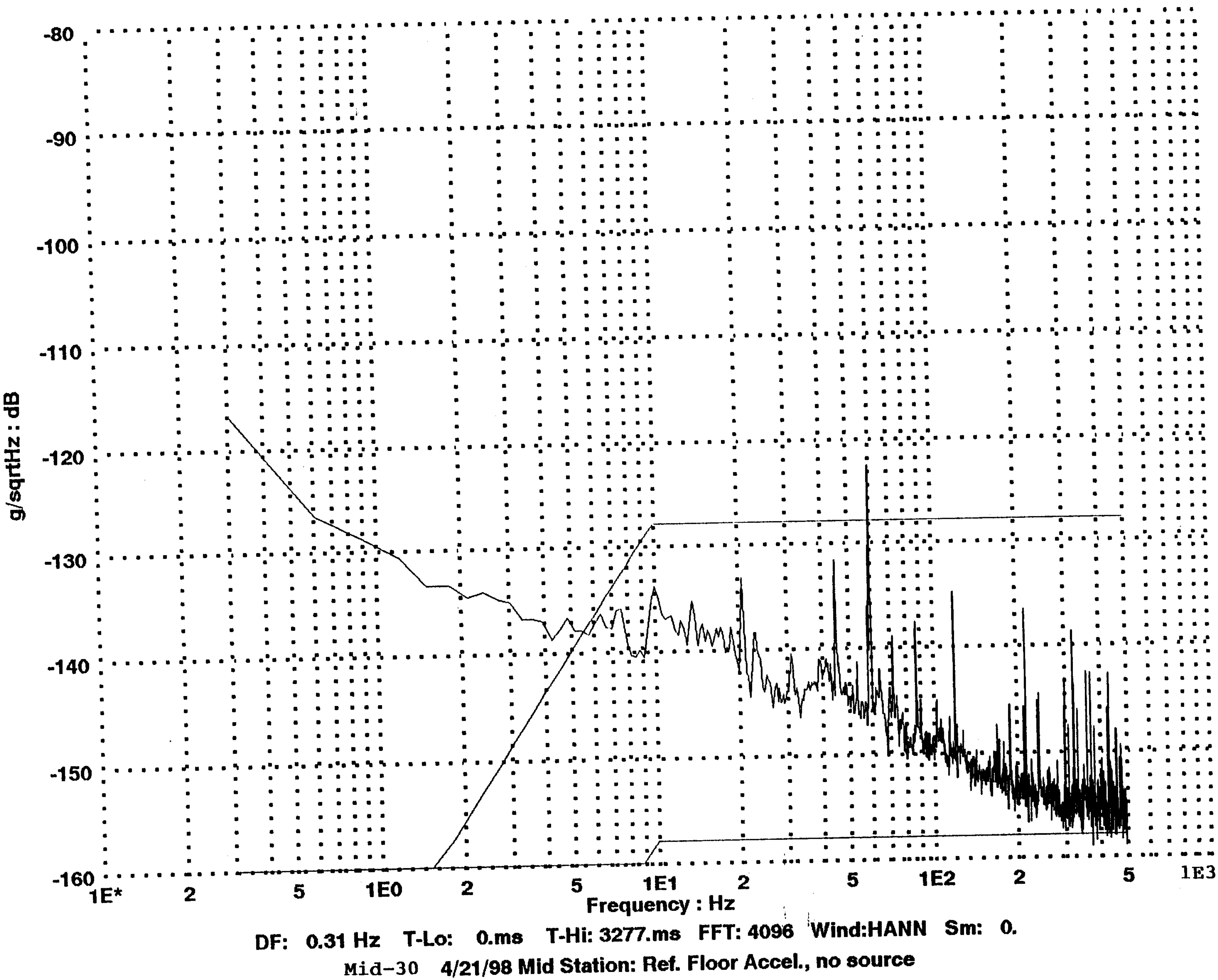
DF: 3.05 Hz T-Lo: 0.ms T-Hi: 328.ms FFT: 4096 Wind:HANN Sm: 0.

Mid-28 4/21/98 Mid Station: BS flange, radial dir., turbo. source

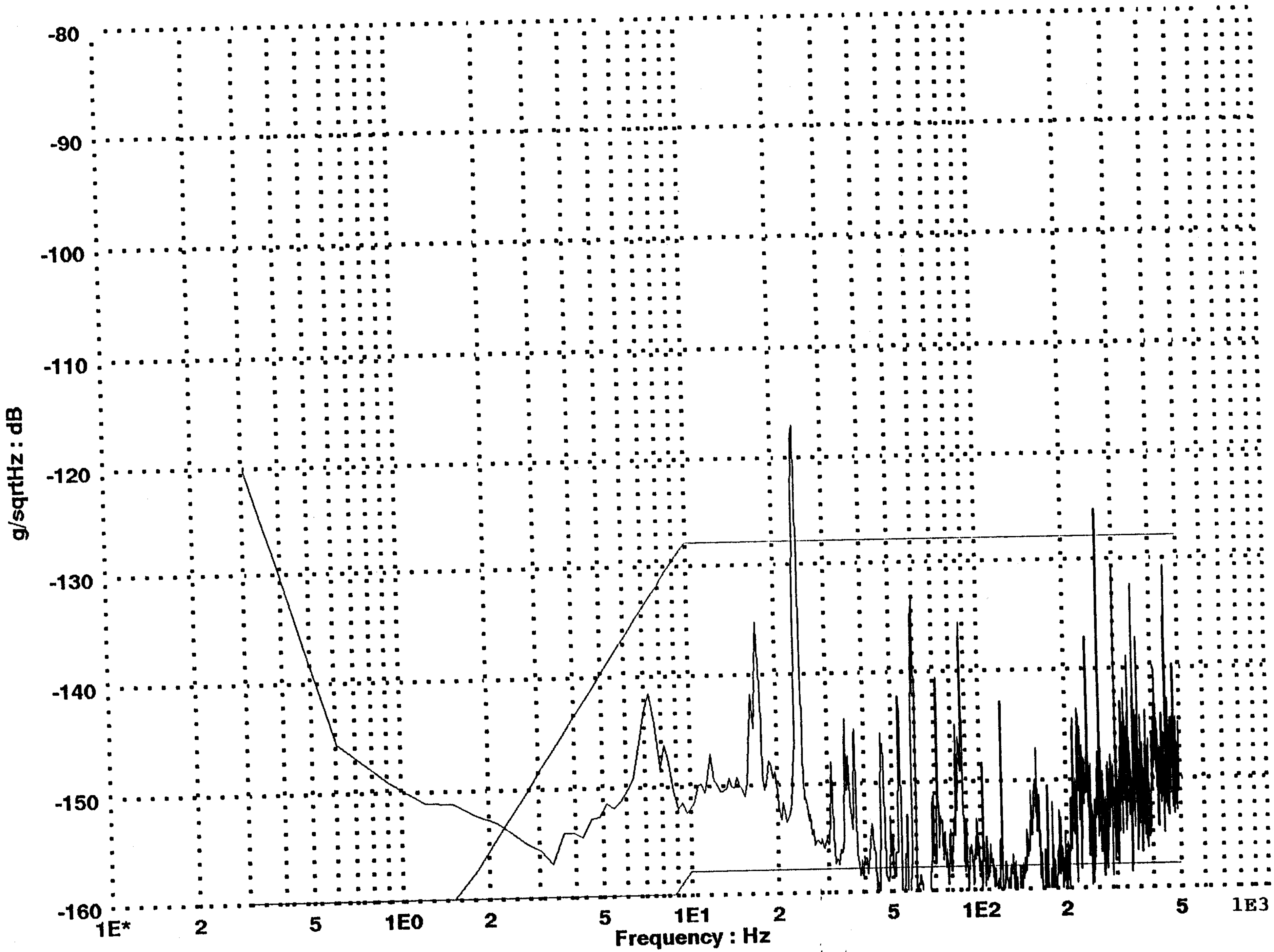


DF: 0.31 Hz T-Lo: 0.ms T-Hi: 3277.ms FFT: 4096 Wind:HANN Sm: 0.

Mid-29 4/21/98 Mid Station: Floor Accel., no source

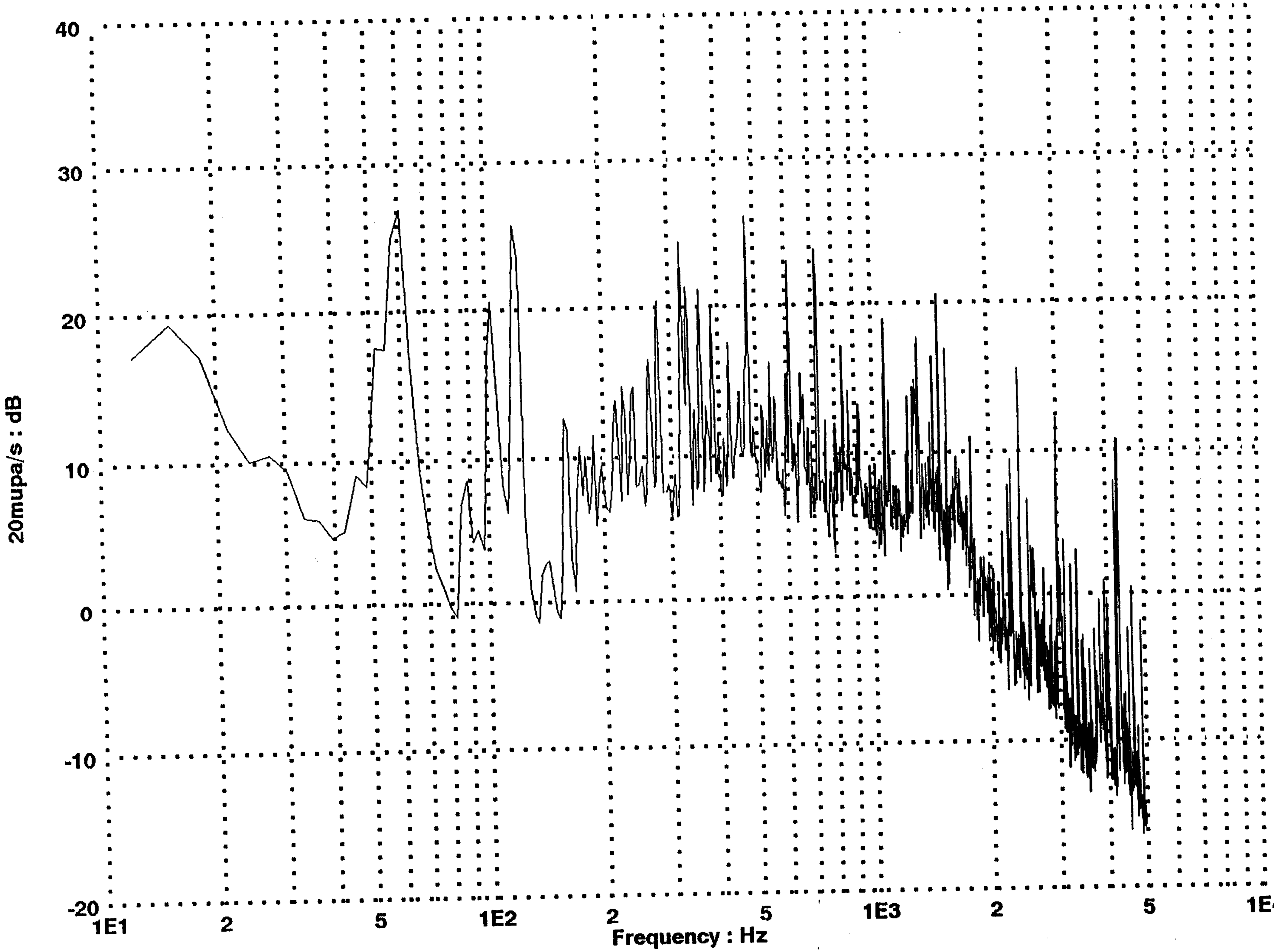


-80
-90
-100
-110
-120
-130
-140
-150
-160
g/sqrtHz : dB
1E*
2
5
1E0
2
5
1E1
2
5
1E2
2
5
1E3
Frequency : Hz
DF: 0.31 Hz T-Lo: 0.ms T-Hi: 3277.ms FFT: 4096 Wind:HANN Sm: 0.
Mid-30 4/21/98 Mid Station: Ref. Floor Accel., no source



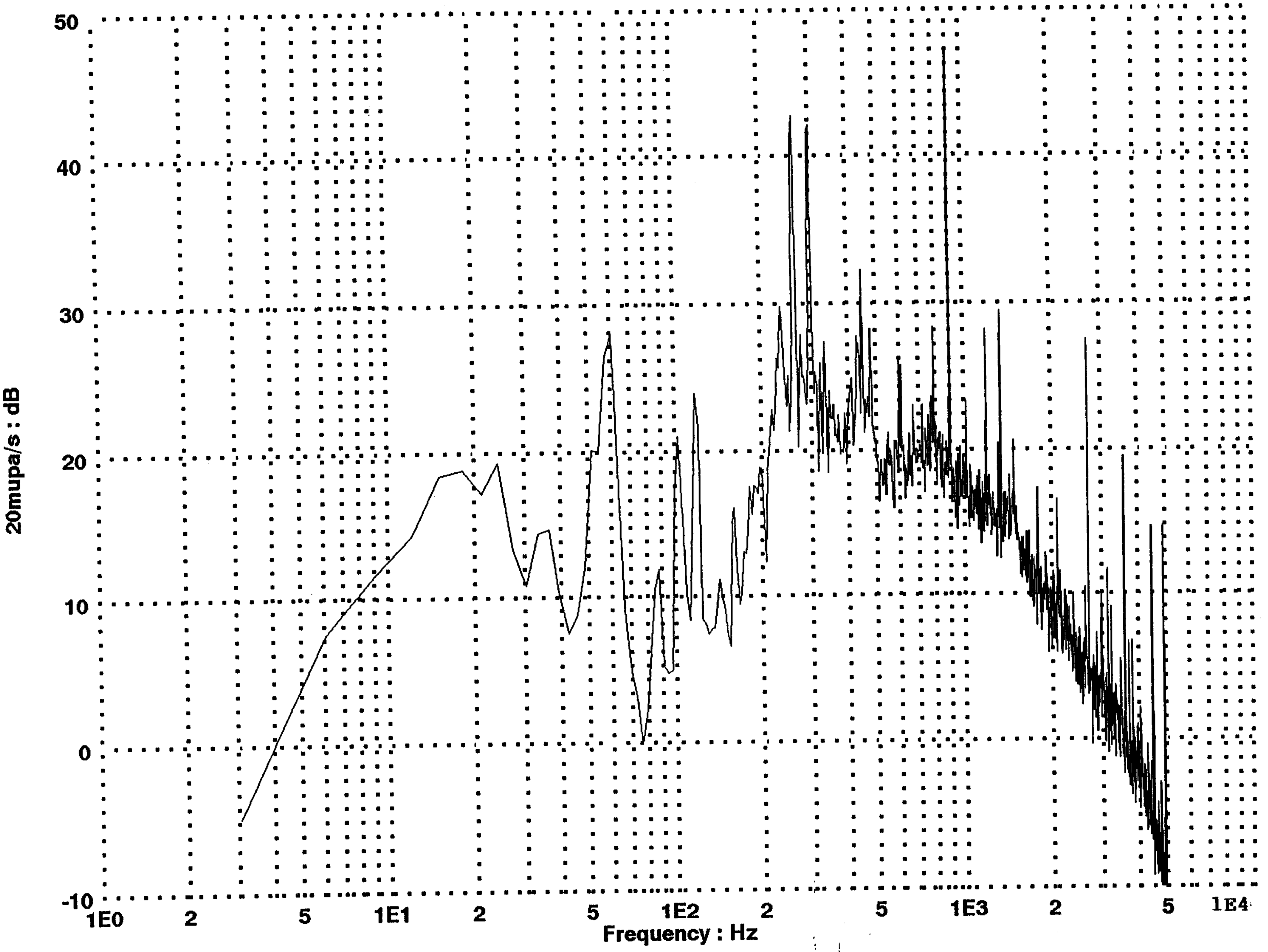
DF: 0.31 Hz T-Lo: 0.ms T-Hi: 3277.ms FFT: 4096 Wind:HANN Sm: 0.

Mid-31 4/21/98 Mid Station: Floor Accel., turbo. source



DF: 3.05 Hz T-Lo: 0.ms T-Hi: 328.ms FFT: 4096 Wind:HANN Sm: 0.

Mid-32 4/21/98 Mid Station: Acoustics nnr. BS, no source



DF: 3.05 Hz T-Lo: 0.ms T-Hi: 328.ms FFT: 4096 Wind:HANN Sm: 0.

Mid-33 4/21/98 Mid Station: Acoustics nnr. BS, turbo. source

APPENDIX D

PSI VALVE SHOCK MEASUREMENTS AT
LIGO MID STATION
HANFORD, WA

LIGO/PSI VALE SHOCK MEASUREMENT LOG

Mid Station at Hanford, WA

For each valve opening or closing test, eight curves are plotted. Plots 1-4 are shock measurements of accelerometers 1-4 with a 500 Hz low pass filter. Plots 5-8 are the same measurements using a 100 Hz low pass filter.

V12 Mid Station Background levels

V13 Mid Station 10" turbopump valve opening

V14 Mid Station 10" turbopump valve closing

V15 Mid Station 10" turbopump valve opening

V16 Mid Station 10" turbopump valve closing

V17 Mid Station 14" ionpump valve opening

V18 Mid Station 14" ionpump valve closing

V19 Mid Station 14" ionpump valve opening

V20 Mid Station 14" ionpump valve closing

V21 Mid Station 42" motor valve WGV10 partial opening 1700 rpm

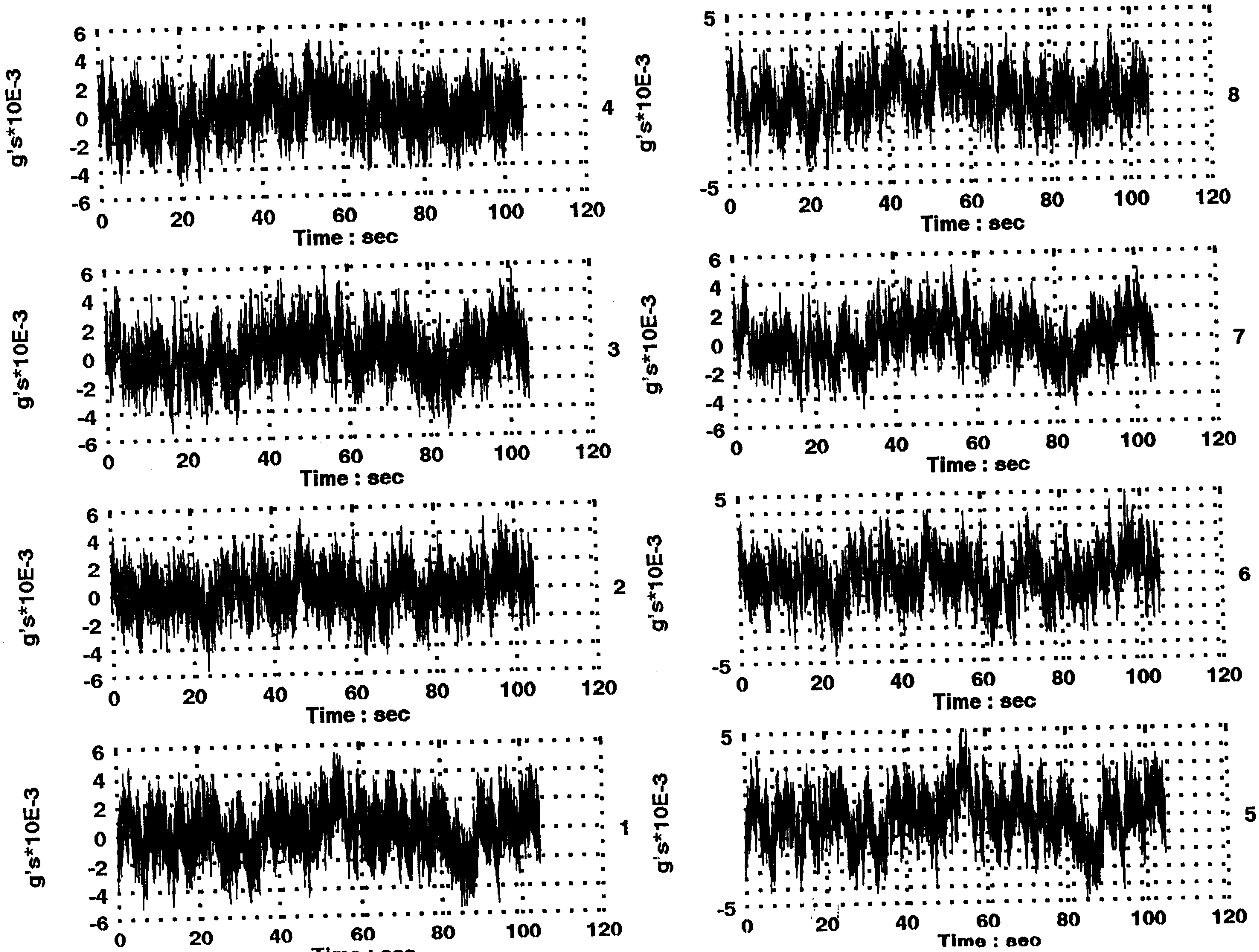
V22 Mid Station 42" motor valve WGV10 partial closing 1700 rpm

V23 Mid Station 42" motor valve WGV10 partial opening and closing at 1700 rpm

V24 Mid Station 42" motor valve WGV10 partial opening and closing at 850 rpm

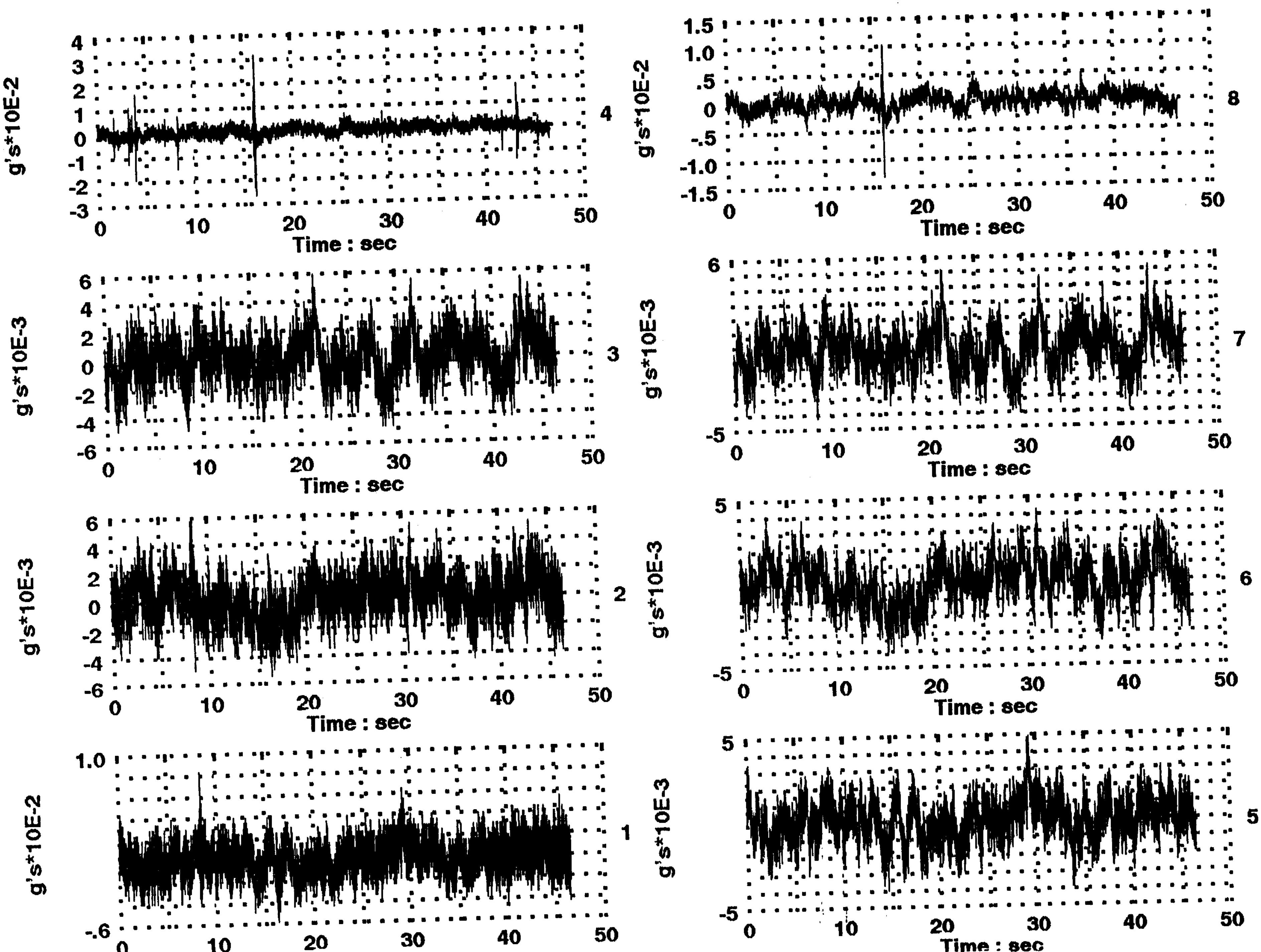
V25 Mid Station 42" motor valve WGV18 opening 1700 rpm

V26 Mid Station 42" motor valve WGV18 closing 1700 rpm

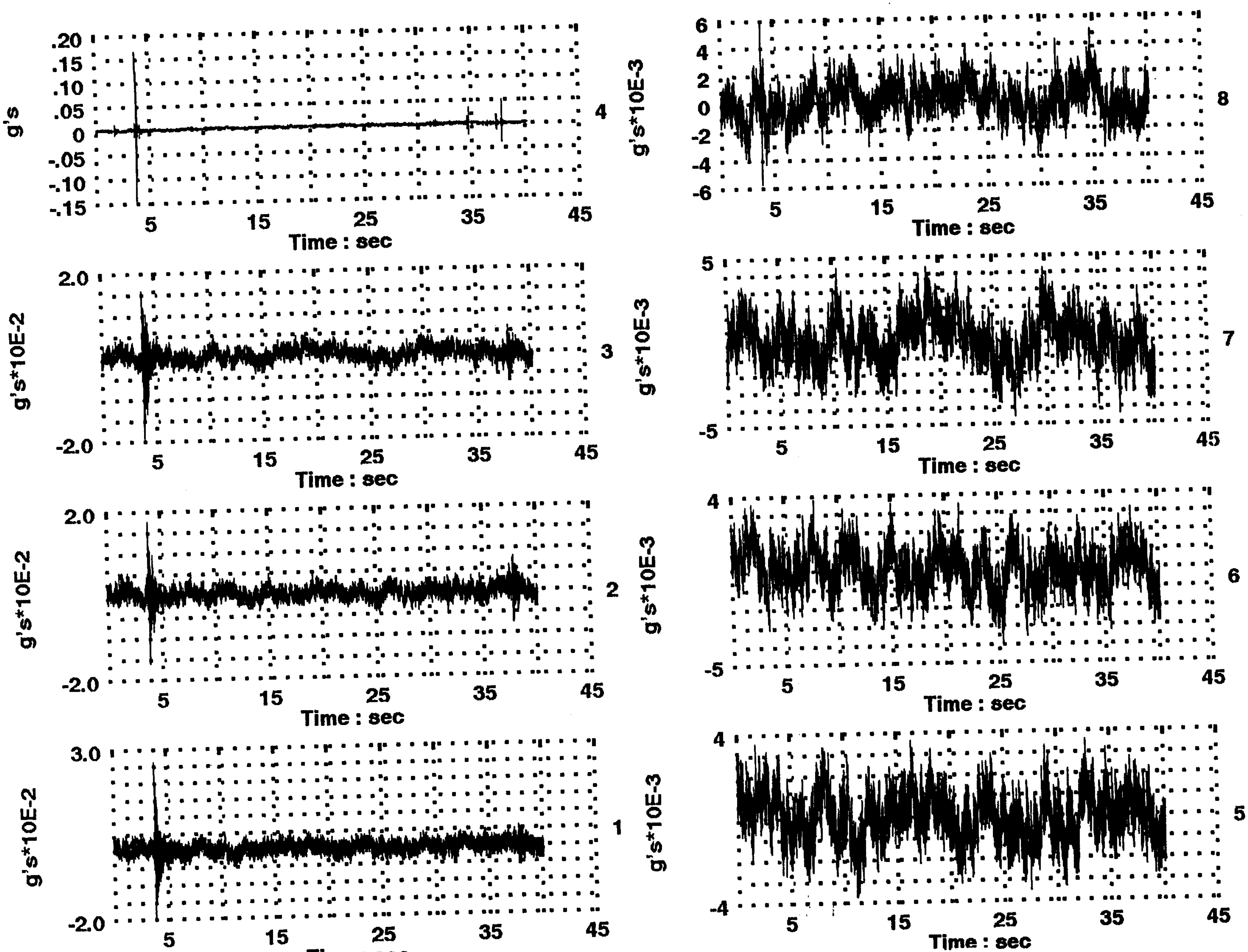


V12 Mid Station Background level, 1-4 500 Hz data, 5-8 100 Hz data

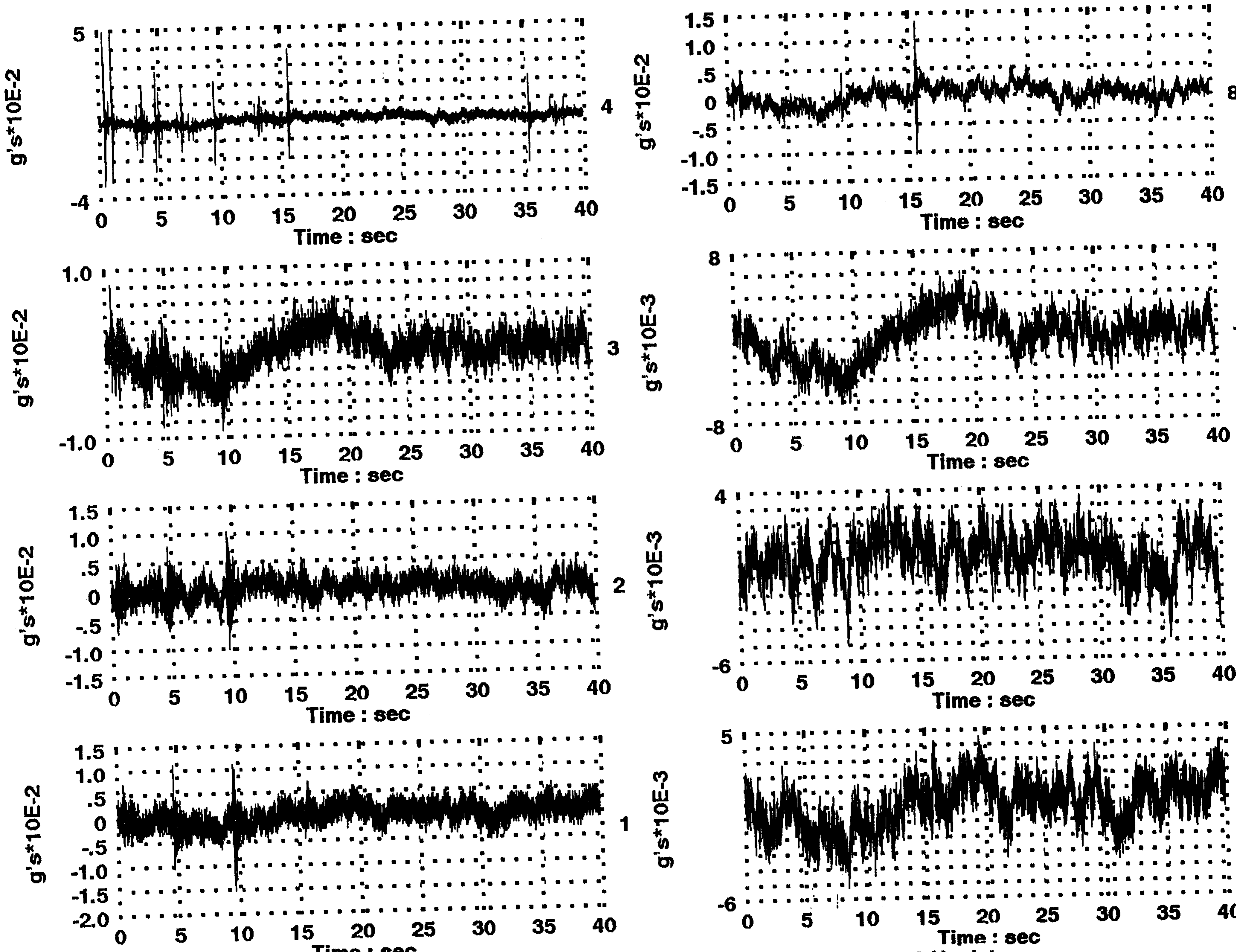
137



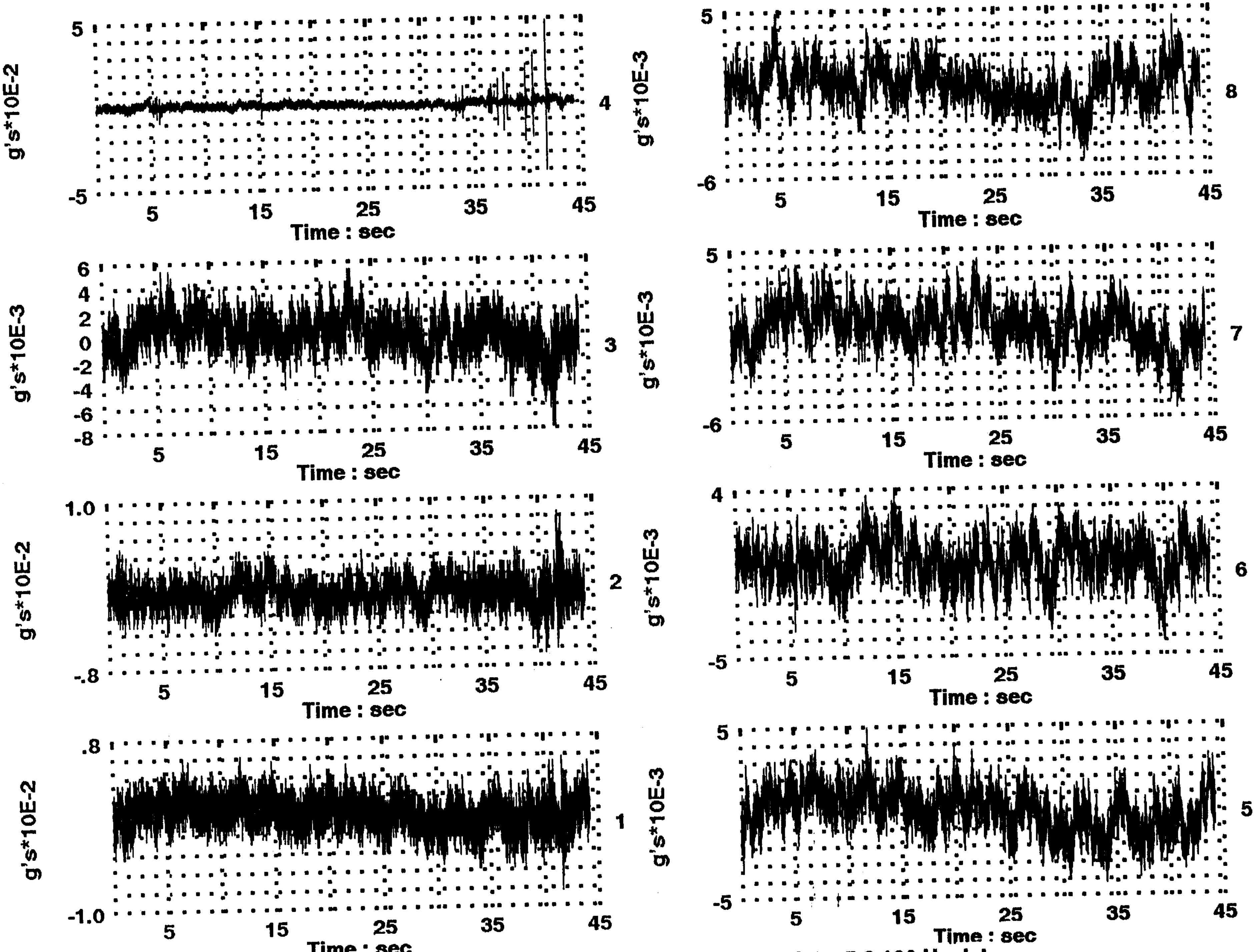
V13- Mid Station 10" turbo valve opening, 1-4 500 Hz data, 5-8 100 Hz data



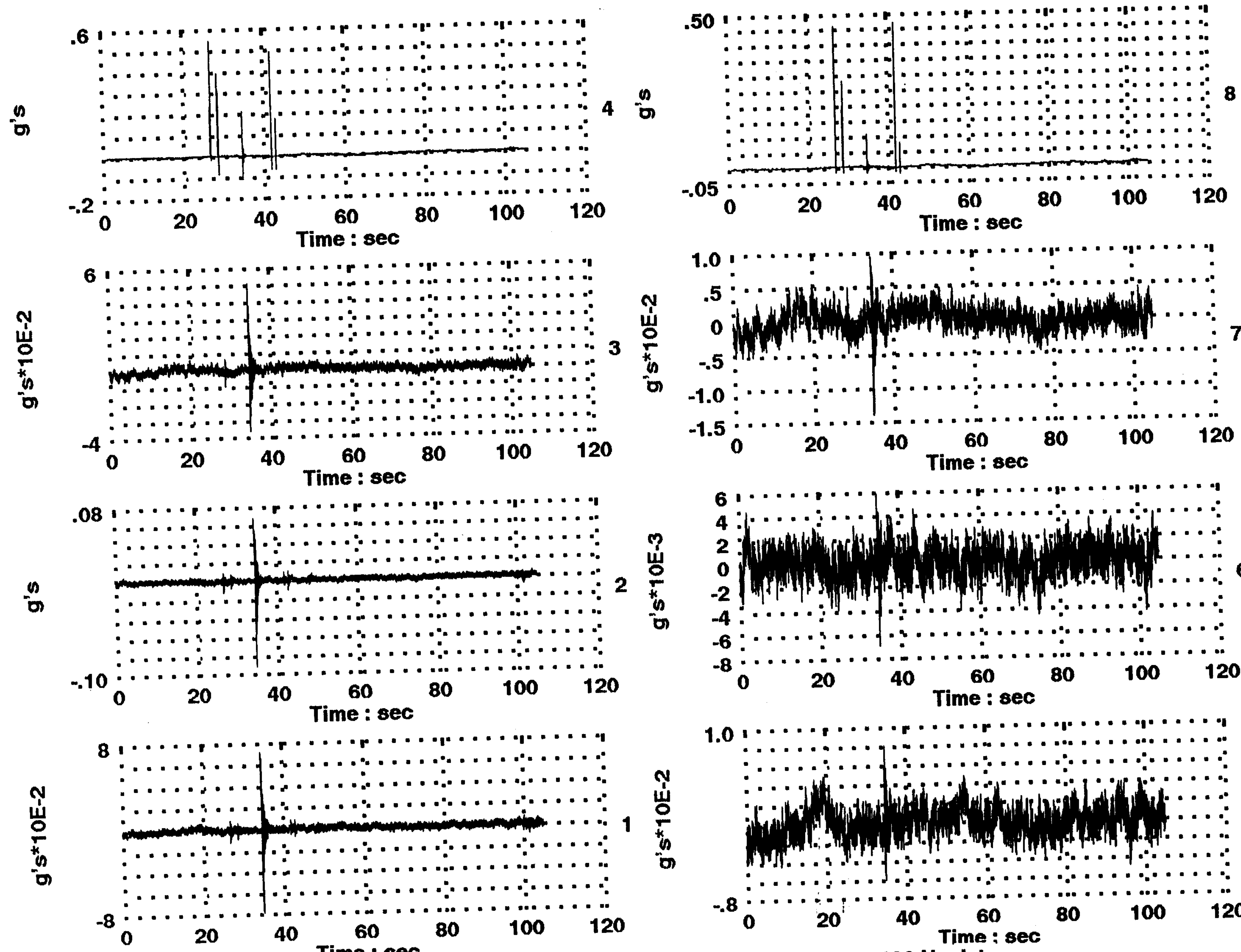
V14- Mid Station 10" turbo valve closing, 1-4 500 Hz data, 5-8 100 Hz data



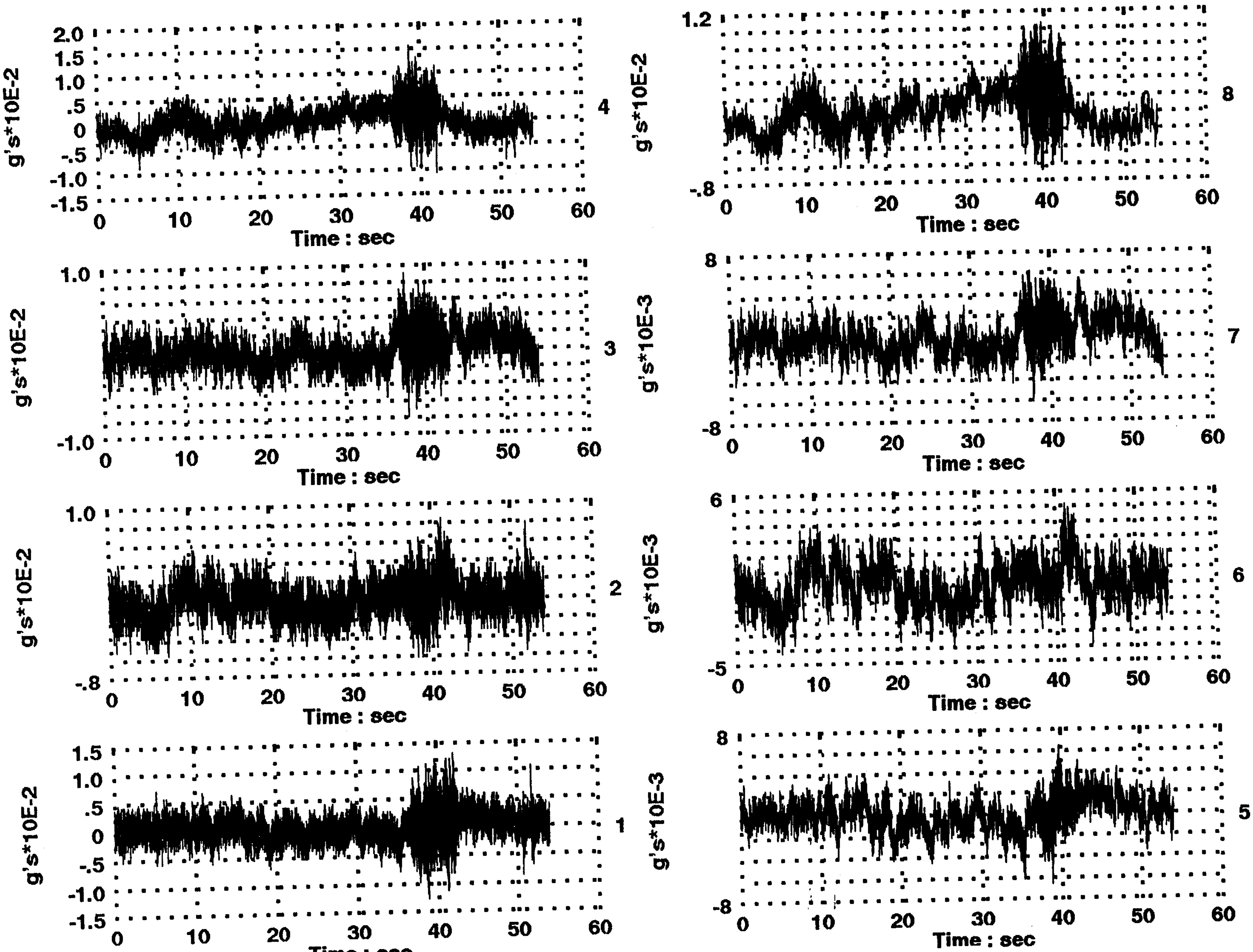
V15-- Mid Station 10" turbo valve opening, 1-4 500 Hz data, 5-8 100 Hz data



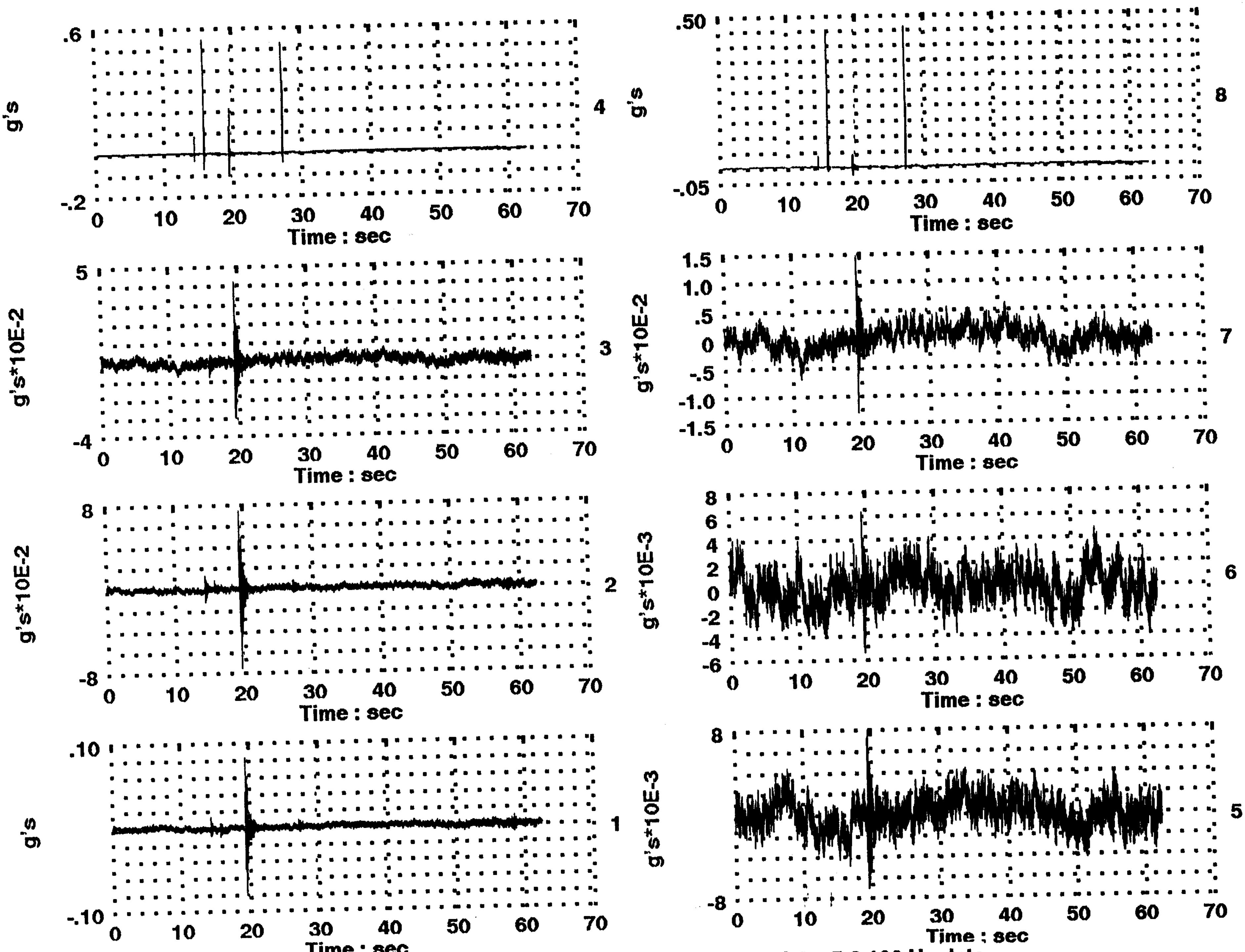
V16- Mid Station 10" turbo valve closing, 1-4 500 Hz data, 5-8 100 Hz data



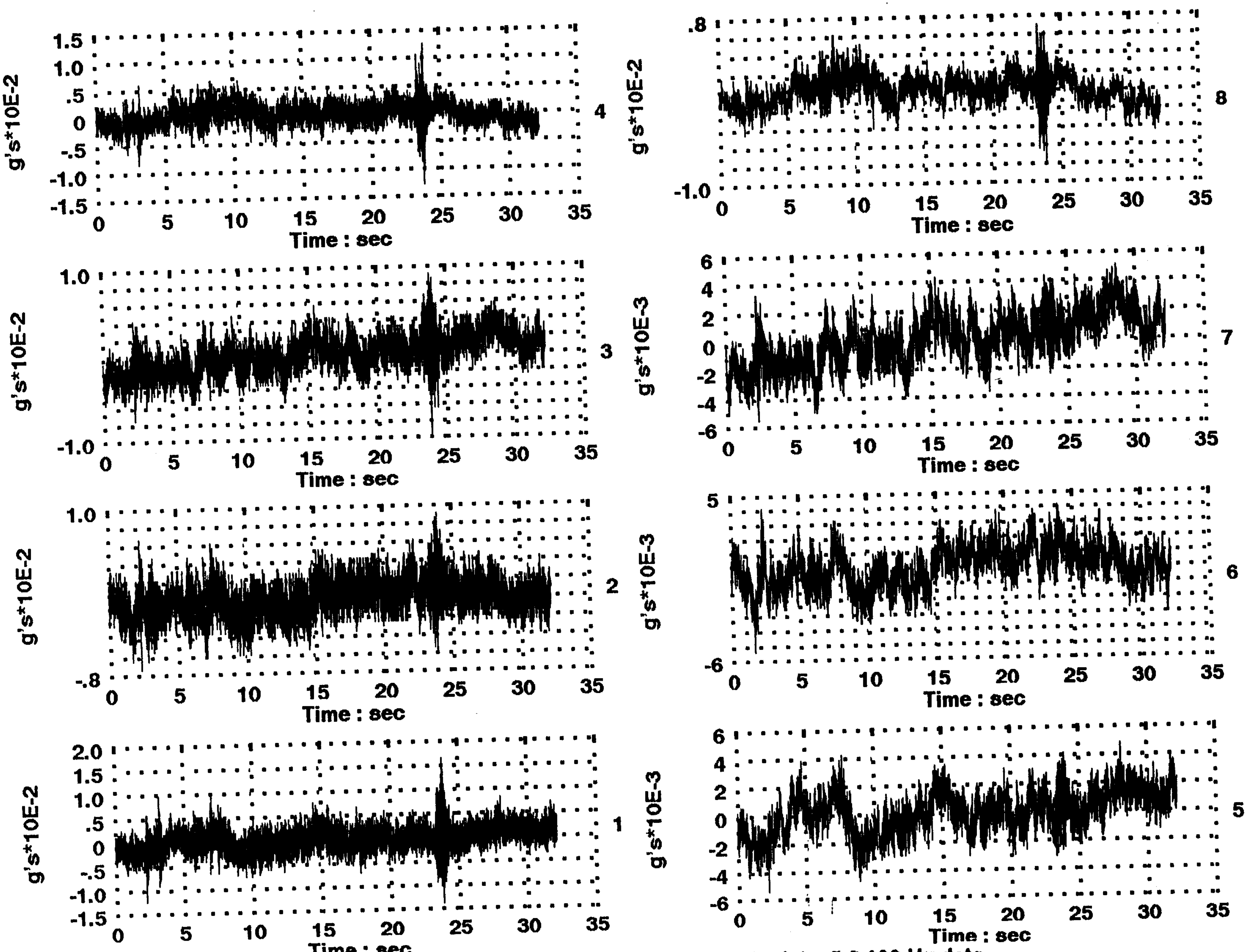
V17– Mid Station 14" ion valve opening, 1-4 500 Hz data, 5-8 100 Hz data



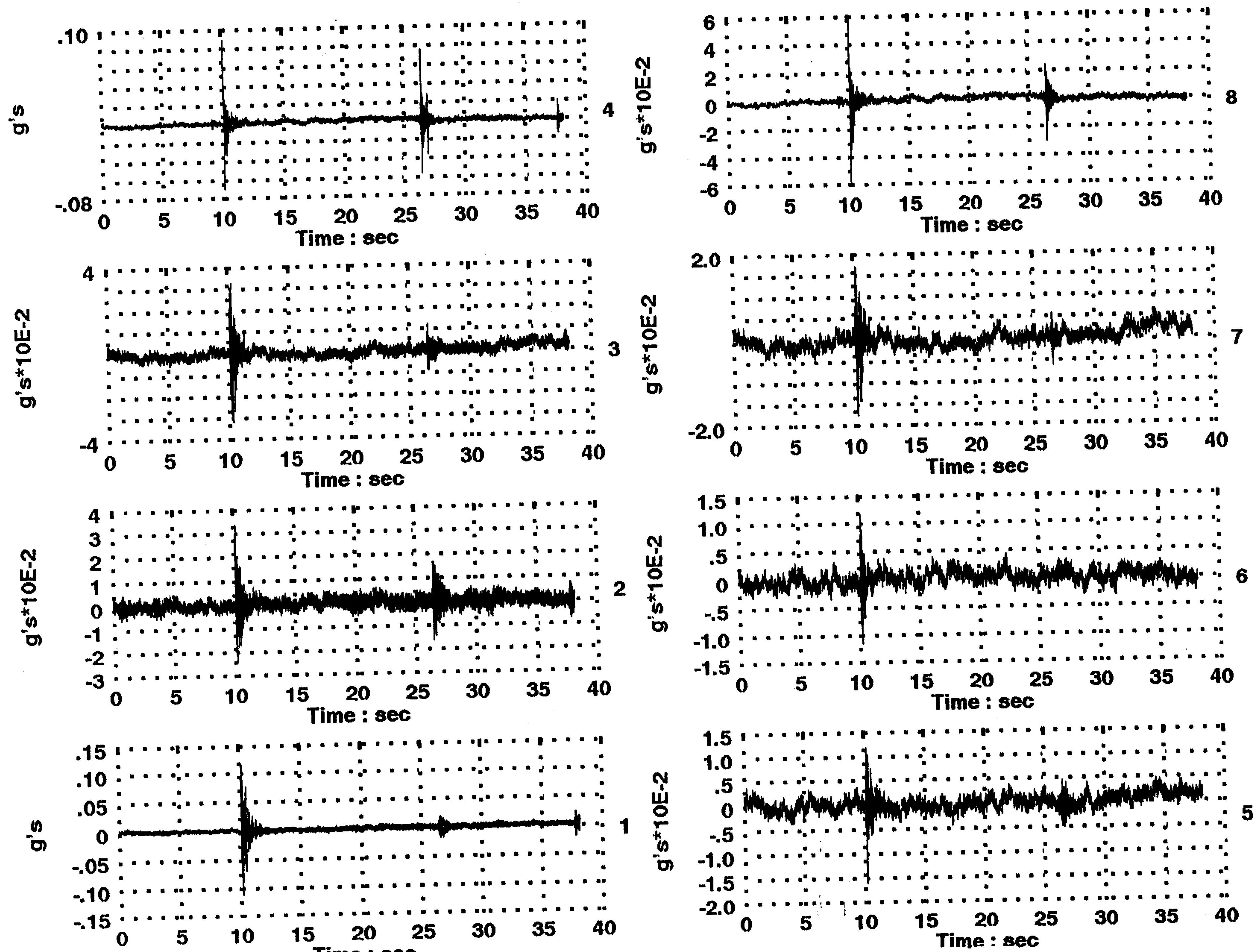
V18- Mid Station 14" ion valve closing, 1-4 500 Hz data, 5-8 100 Hz data



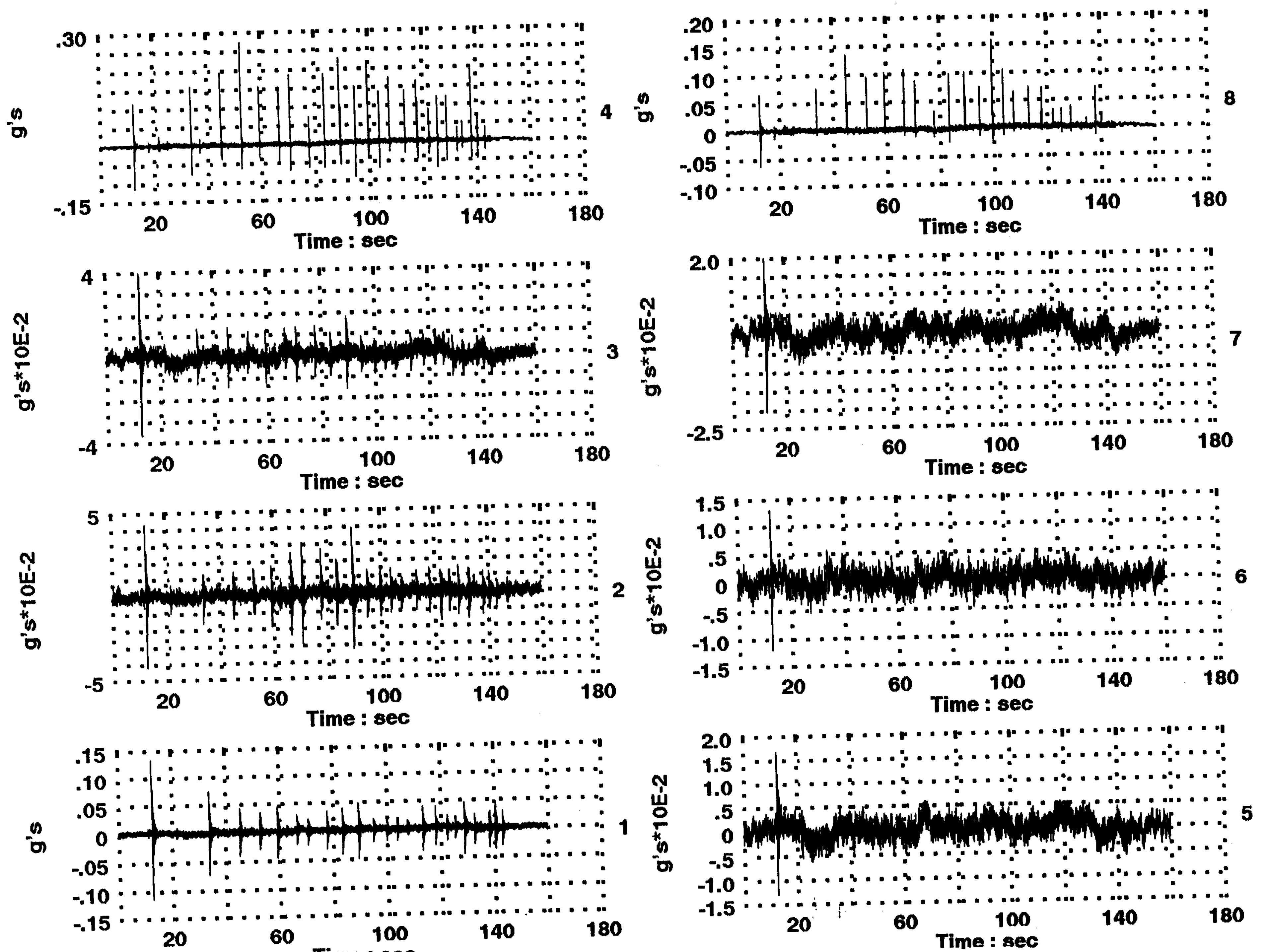
V19– Mid Station 14" ion valve opening, 1-4 500 Hz data, 5-8 100 Hz data



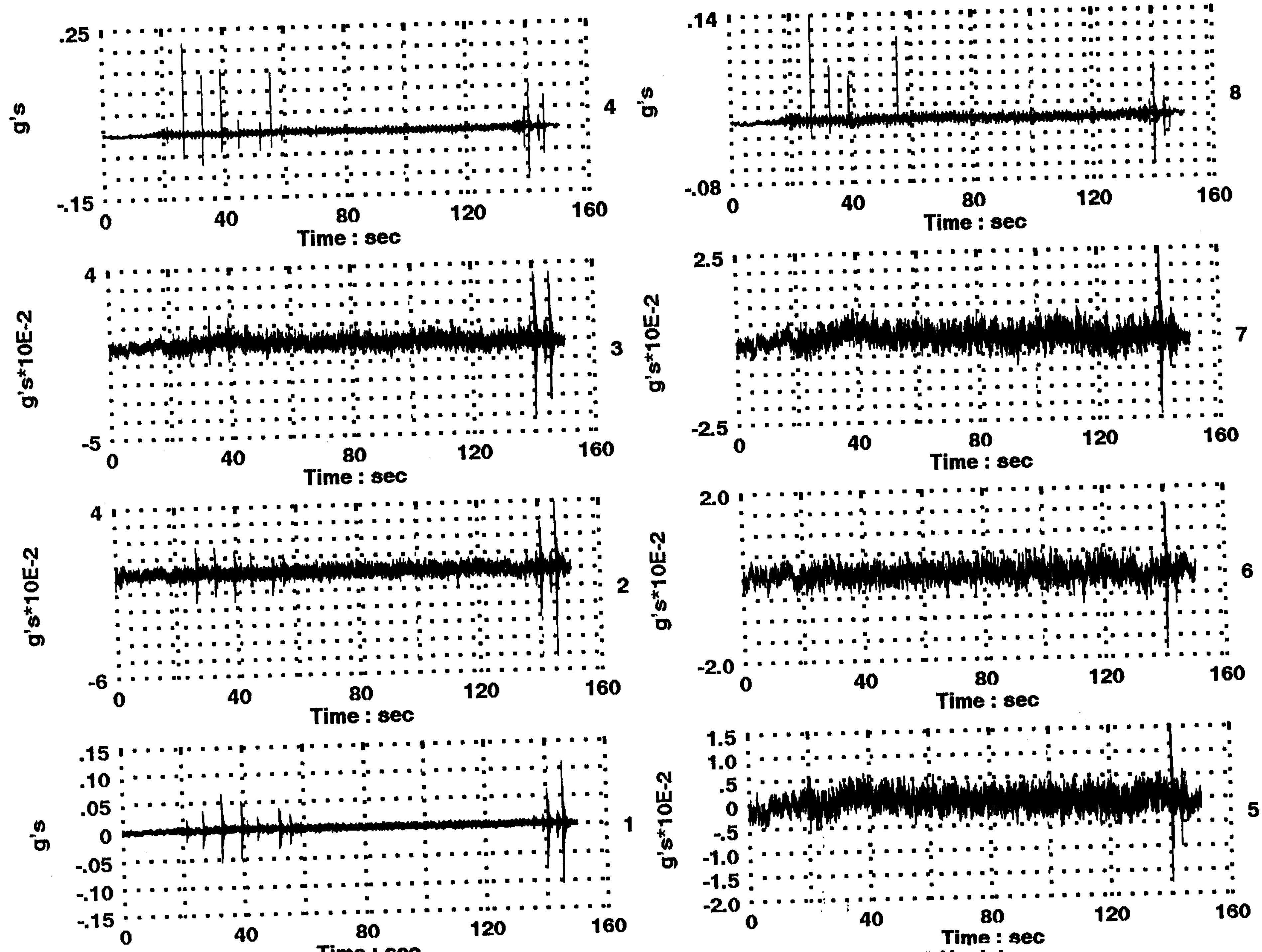
V20- Mid Station 14" ion valve closing, 1-4 500 Hz data, 5-8 100 Hz data



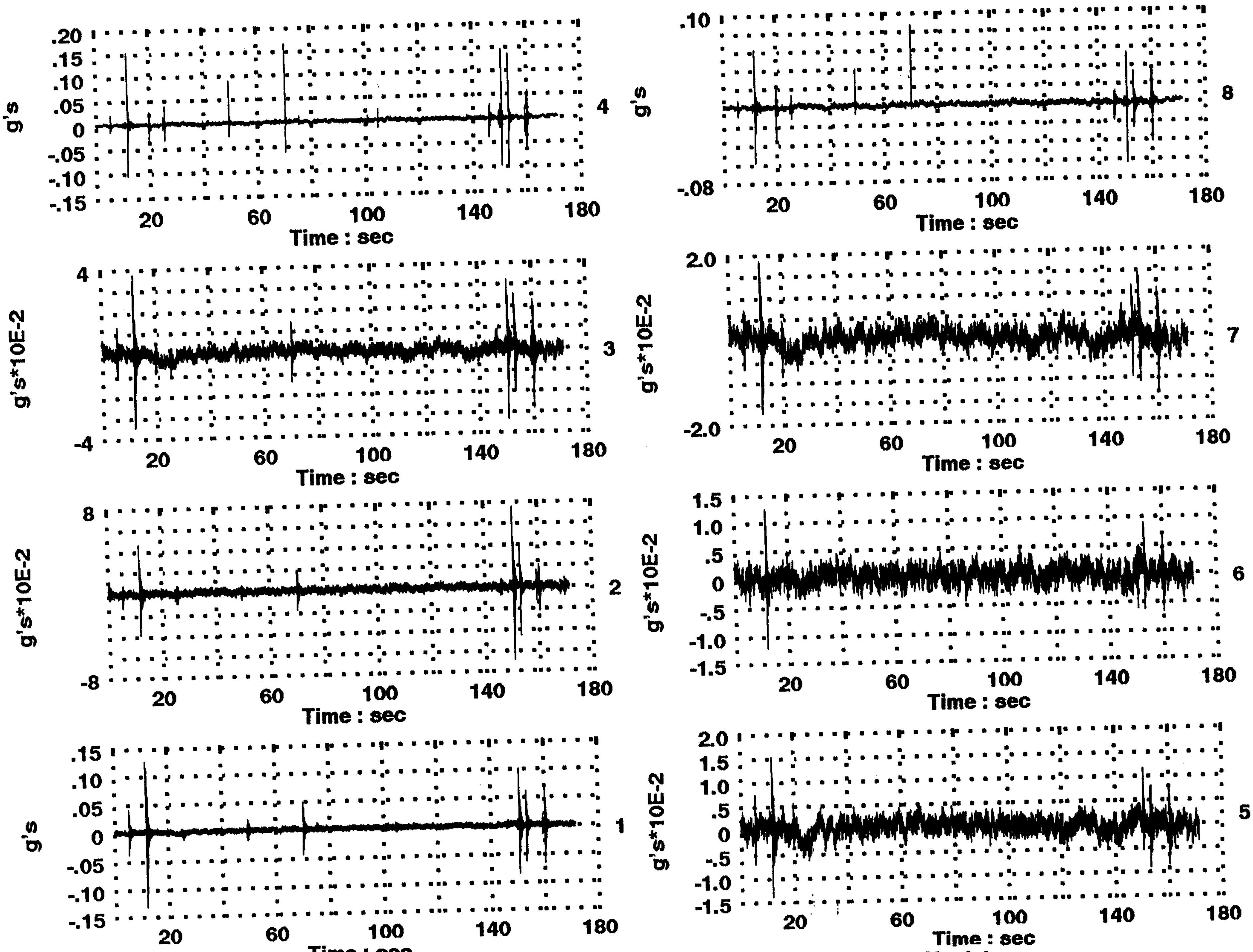
V21- Mid Station 42" WGV10 valve opening, 1-4 500 Hz data, 5-8 100 Hz data



V22- Mid Station 42" WGV10 valve closing, 1-4 500 Hz data, 5-8 100 Hz data

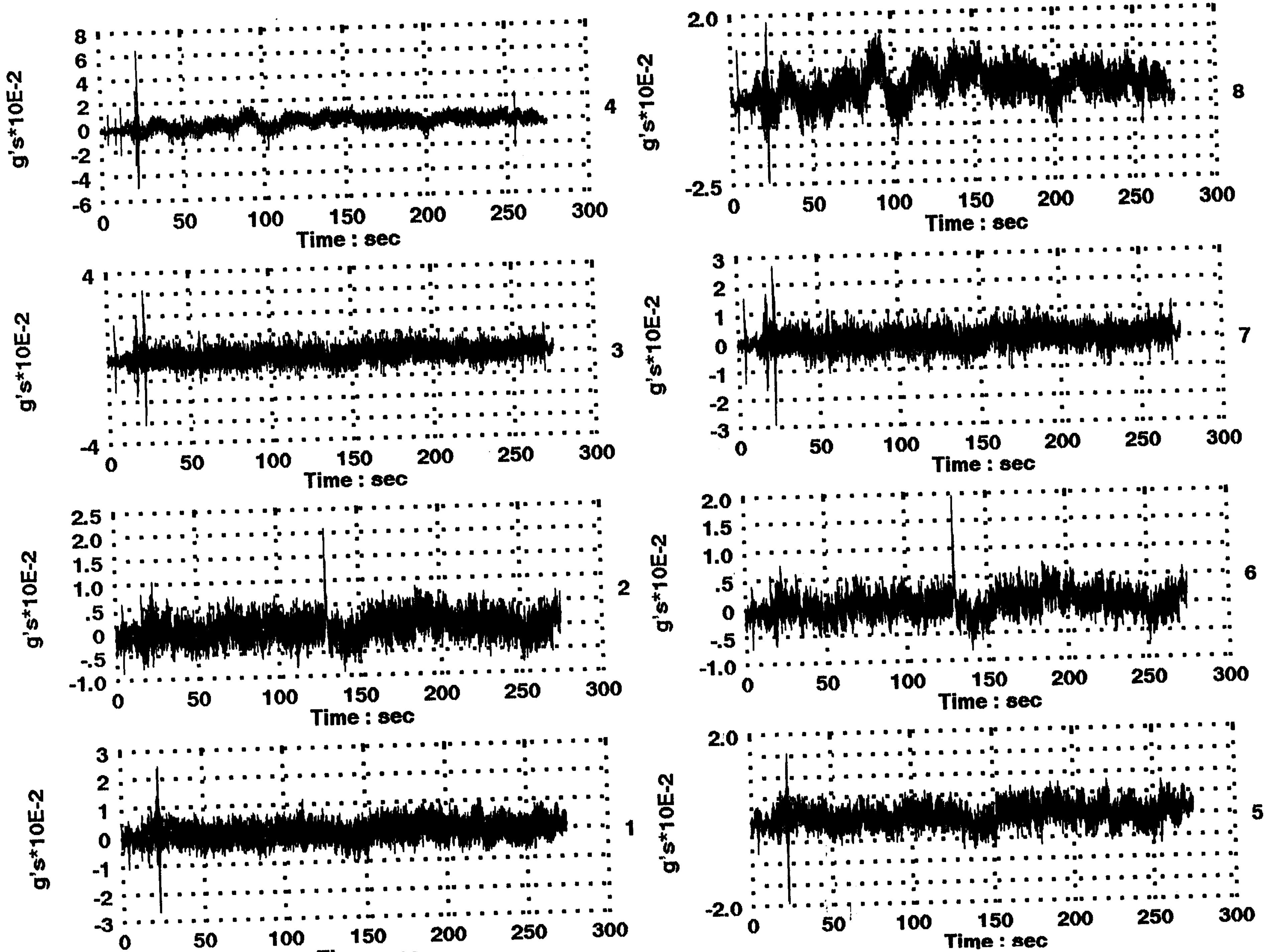


V23- Mid Station 42" WGV10 o/c 1700 rpm, 1-4 500 Hz data, 5-8 100 Hz data

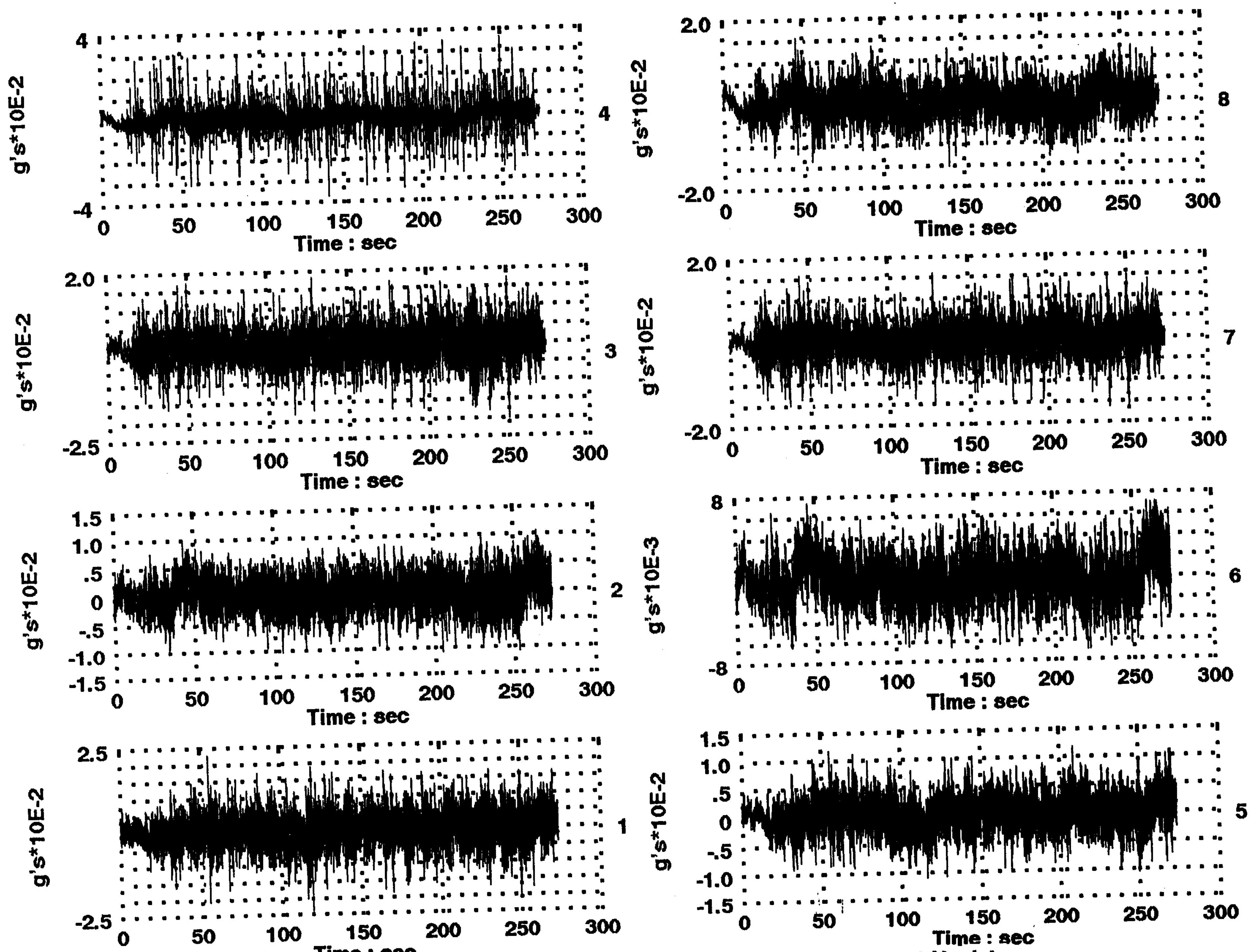


V24- Mid Station 42" WGV11 o/c 850 rpm, 1-4 500 Hz data, 5-8 100 Hz data

146



V25– Mid Station 42" WGV10 valve opening, 1-4 500 Hz data, 5-8 100 Hz data



V26-- Mid Station 42" WGV11 valve closing, 1-4 500 Hz data, 5-8 100 Hz data

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT

5.10 Station Acceptance Test Summary and Signoff Sheet

ATTACHMENT II

LIGO PROJECT – PROCESS SYSTEMS INTERNATIONAL

END STATION ACCEPTANCE TESTING AND INSPECTION SUMMARY

WA LEFT END STA.	By	Date Complete	Comments
1. LN_2 Tank Inspection Tank S/N C08696 (per V049-2-102)	Sm	11/10/97	75 mTorr @ 38°F
2. Regeneration Heater Inspection HTR # ______ (per V049-2-102)	JF	2-19-98	need to reduce power input
3. Cryopump Instrumentation Calibration & Functional Test (per)	JF/Sm	2-19-98	
4. Vacuum Instrumentation Checkout	JF/DH RW	2-19-98	
5. Fill LN_2 Tank	Sm	1/16/98	52 mTorr, INITIAL FILL 125", 6 PSIG
6. Instrument/Electrical Wiring Checkout (per V049-1-163)	RW	1-27-98	
7. Clean Air Compressor Checkout (per V049-2-109)	Sm	2-13-98	Dew PT = -75.3C Particulates = 0 part/FT³ HYDROCARBONS = 0.0 PPM
8. Clean Room Testing (per V049-2-110)	JF	1-10-98	37 part./CF
9. Gate Valve Operational Test (per V049-2-107)	JF		
10. N/A			
11. Turbopump Skid Operational Test (per V049-2-105)	Sm	2-17-98	QOP80 operational 2-13-98
12. 10 & 14 In. Manual Valves (per V049-2-108)	JF/DH	2-18-98	10" VALVES ON CRYOPUMP NOT OPENED.
13. Auxiliary Turbopump Test (per V049-2-105)	Sm	2-13-98	

F:\HV\LIGO\CORRESPO\MISC\ENDACCEP.DOC

ATTACHMENT II

LIGO PROJECT – PROCESS SYSTEMS INTERNATIONAL

END STATION ACCEPTANCE TESTING AND INSPECTION SUMMARY
(continued)

WA LEFT END STA.	By	Date Complete	Comments
14. Main Ion Pump Testing (per V049-2-106)	JF/Sm	2-19/20	PUMP OPERATED OVERNIGHT NORMALLY
15. Bake-out Cart/System (per V049-2-112)	Sm/RW	3-28-98	
16. Annulus Ion Pump Functional Test (per V049-2-106)	JF/DH	2-19-98	
17. Flange Annulus Leak Test (per V049-2-115)	D.H.	2-20-98	
18. Main Volume Leak Test (per V049-2-115)	D.H	2-20-98	
19. Ultimate Pressure/RGA Test (per V049-2-115)	Sm	3-29-98	

Acceptance Testing Complete

Signed John Flin

Date 4-13-98

Backfill/Pumpdown Demonstration (One Demonstration per Station Type)

Signed John Flin

Date 4-13-98

Shock/Noise/Vibration Survey Complete (C.A.A.)

Signed ______________

Date ______________

ATTACHMENTS

Component Acceptance Test Procedures (REF ONLY)	Document No.
80K Pumps	V049-2-102
Roughing Pumps	V049-2-104
Turbomolecular Pumps	V049-2-105
Ion Pumps	V049-2-106
Large Gate Valves	V049-2-107
6, 10, 14" Gate Valves	V049-2-108
Clean Air Supplies	V049-2-109
Portable Soft Wall Cleanrooms	V049-2-110
Small Valves	V049-2-111
Bakeout System Blankets and Carts	V049-2-112

System Acceptance Test Procedures (ATTACHED)

End Stations	V049-2-115

Title: SPECIFICATION FOR SYSTEM ACCEPTANCE TESTS PLAN, END STATIONS

SYSTEMS ACCEPTANCE TEST PROCEDURE

LIGO VACUUM EQUIPMENT

END STATIONS

Hanford, Washington and Livingston, Louisiana

JOB NO. V59049

PREPARED BY: Roberto Than

QUALITY ASSURANCE: Alan R. Bradbrook

TECHNICAL DIRECTOR: D. C. McWilliams

PROJECT MANAGER: Bertil Bagge

REV LTR	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
3	RB 11/13/97	REB 11/13/97	Revised per DEO 0564
2	DM 9/19/97	REB 9/22/97	Revised per DEO #0475
1	DM 5/7/96	REB 5/7/96	Revised per DEO #0178
0	R.T. 5/1/96	REB 5/2/96	INITIAL RELEASE PER DEO 0157 FOR FDR

PROCESS SYSTEMS INTERNATIONAL, INC.		SPECIFICATION	
INITIAL APPROVALS	PREPARED R.T. DATE 5/1/96	Approved REB DATE 5/2/96	Number: V049-2-115 A	Rev. 3

TABLE OF CONTENTS

1.0 PURPOSE

The purpose of this Acceptance Test Procedure (ATP) is to define the overall plan for systems acceptance testing of the vacuum envelope and vacuum pumping system in order to demonstrate that it meets the requirements of the LIGO Vacuum Equipment Specification, LIGO-E940002-02-V, Revision 2, dated August 31, 1995.

This document will be part of the Acceptance Test Report as required by CDRL No.06.

2.0 GENERAL

2.1 The plan will generally apply to all the end stations.

2.2 Tests will be performed by PSI personnel, and will be witnessed by an agent designated by LIGO.

2.3 **An Authorization to Vacuum Test Form shall be signed off by the Project Manager or his designated representative prior to any vacuum testing of systems or components (see Attachment III).**

3.0 REFERENCE DOCUMENTS

The following documents shall be used in conjunction with this one for performing the ATP:

Description	Document No.
Leak Check Procedure	V049-2-014
Bakeout System Procedure	V049-2-116
80K Cryopump Operating Procedure	V049-2-143
Bakeout System Control Cart Operating Manual & Procedure	
RGA Calibration Procedure (Field)	V049-2-186
RGA Operating Manual	
EDP200/EH2600 Roughing Pumps Operating Manuals	
STPH2000C Turbomolecular Pump Operating Manuals	
Auxiliary Turbomolecular Pump Operating Manuals	
QDP80 Dry Backing Pump Operating Manuals	
Vacuum Gauges: Cold Cathode & Pirani Gauges Operating Manuals	
2500 L/s, 75L/s, 25L/s Ion Pumps Operating Manuals	
Acceptance Test Procedure for Clean Air Supplies	V049-2-109

4.0 RESPONSIBILITY

It shall be the responsibility of the project engineer assigned to this component or subsystem to ensure that all procedures required by this acceptance test procedure are performed, and that the LIGO designated witnessing agent, who has signoff authority, shall sign the data sheet/test certification attached to this procedure, verifying that the procedures have been performed. The data sheet shall also be signed by the project engineer or other designee as assigned by the PSI project manager. Any test listed in the data sheet which is not applicable to this component or subsystem shall be noted by writing “N/A” in the appropriate space. Any deviations from the test procedures or parameters shall be noted on this data sheet.

5.0 FIELD TEST PROCEDURES

5.1 Leakage Test

5.1.1 Chamber and Tube Section Leak Tests

The specification requires all component leaks greater than $1x10^{-9}$ torr-l/s of helium to be repaired in accordance with LIGO approved procedures. Leak checking shall conform to ASTM E498 "Standard Test Methods for Leaks using the Mass Spectrometer Leak Detector". (Ref. Specification V049-2-014, Leak Test Procedure). The following is a summary of the field leak testing plan.

5.1.1.1 Prerequisites

The individual vacuum enclosures have completed their manufacturing cycle and have been cleaned, baked, factory leak tested and sealed for shipment. The unit is then wrapped and packaged for shipment.

Upon arrival at the installation site, the unit will be visually inspected for any shipping damage.

5.1.1.2 Isolated Sections

Individual vacuum components are assembled into isolated sections which will be leak checked as an independent volume. The procedures used to leak check the isolated sections are similar to the procedures used for individual components and in general follow the guidelines of ASTM E498.

Each isolated section has basically two types of vacuum volumes; the main chamber volume and the annulus volume between the dual o-ring seals. When leak checking the main chamber volume, it is important to prevent permeation of tracer gas(es) through the Viton o-rings. To eliminate this potential source of high background readings, the o-ring flanges will be bagged and purged with pure nitrogen gas as required.

5.1.1.2.1 Annulus Leak Check

The annuli of each vessel will be leak checked by a simple pumpdown test. The annuli shall be considered tight if the pumpdown for each vessel or component to 3 x 10 –4 torr is within the limits of Table 5.1.1.2.1.

Table 5.1.1.2.1

Component	Max Allowable Pumpdown TimeMinutes
BSC	60
Spools	30
Gate valves	30

5.1.1.2.2 Main Volume Leak Check

Each isolated section will be leak checked by the air signature method after bakeout using an RGA. The maximum acceptable leak rate shall be consistent with the system requirements as determined by isolated volume size and RGA sensitivity, as mutually agreed upon by LIGO and PSI. Method and leak rate to be consistent with the BSC prototype chamber test results.

This leak will be performed at the completion of bakeout in conjunction with the ultimate pressure test.

5.2 Bakeout and Ultimate Pressure Test: End Station

An ultimate pressure test is performed after bakeout to determine that the system is clean and leak tight. The ultimate pressure test is performed on the isolatable section with an 80K pump. Before a pumpdown and ultimate pressure test is performed, the sections that make up the isolatable section must be baked.

5.2.1 Annuli pumpdown

The annuli on the flanges will have been pumped during installation for leak checking. Any remaining flange annuli at atmosphere will be pumped prior to start of bakeout. Because of greatly increased outgassing from the O-rings during bakeout, the annulus ion pumps may be inadequate to maintain the annulus within the operating range of the ion pump with its standard Minivac controller. The use of an auxiliary turbo pump cart or a Multivac controller to operate the annulus ion pump is required during bakeout. Because of the limited quantity of auxiliary turbo pump carts available, these should be used on the components with the largest amount of O-ring area; i.e., the BSC's.

Note that the gate valve's gate seal annulus must also be evacuated during bakeout.

5.2.2 Vacuum equipment

The roughing carts, and main turbomolecular pumping system and main ion pump system will have been tested already. A functional test may be required prior to start of the bakeout to ensure proper operation of the equipment.

The main ion pumps will be evacuated and baked after installation onto the vacuum envelope. The main ion pumps will then started to ensure proper operation.

5.2.2.3 Deleted

5.2.2.4 System/Isolatable section bakeout.

The bakeout system will be installed on the isolatable section and baked out according to the bakeout procedures. Prior to the start of bakeout, the system will be evacuated using the roughing system.

The isolatable section will be heated to 150°C (at 1.0°C/hr maximum) and soaked for 48 hours at 150°C ±20°C.

Cooldown of the system will be carried out with the heating system operating to maintain temperature uniformity (logging rate = 1.0°C/hr maximum). This is done by ramping down the setpoints to ambient temperature.

Install bakeout blankets on the mid station, and ion pumps.

Install roughing and turbo pumps.

Evacuate volume to 0.1 torr using roughing pump prior to starting blankets or turbo pump. Bake section at 150°C for 48 hours.

Allow section to cool. When temperature is less than 100°C, the RGA electronics may be installed and the ion pumps may be started.

When the section reaches ambient temperature, the section is ready for the ultimate pressure test.

5.2.2.5 Residual gas analysis after bakeout and cooldown

With the system baked and cooled down, a residual gas analysis will be carried out to determine the presence of any air leaks and cleanliness of the system.

5.2.2.6 Ultimate Pressures after 100 hours

The isolatable section shall attain a total pressure of 2 x 10 –8 torr or less (N_2 equivalent), measured with a calibrated Granville-Phillips "stabil" ion gauge at a BSC RGA port after bakeout and cooldown to ambient temperature (approximately 100 hours after start of pumpdown for bakeout). The partial pressure shall be measured with an RGA at a BSC RGA Port. If the hydrogen content of the steel prevents the attainment of this value, then the total pressure of the gases, other than H_2 and H_2O, shall not exceed 3 x 10 –9 torr. Only the main ion pumps and 80K cryopumps are permitted to operate during this test.

Table 5.2.2.6 shows the LIGO specification and partial pressure goals and the corresponding partial pressure acceptance criteria.

Table 5.2.2.6

Gas Species	LIGO Partial Pressure Goals Torr	Acceptance Partial Pressures Torr
H_2 H_2O	5x10-9 5x10-9	
Total H_2O, H_2	1x10-8	
N_2	5x10-10	
CO	5x10-10	
CO_2	2x10-10	
CH_4	2x10-10	
All others	5x10-10	
Total other	1.9x10-9	3x10-9
Total	1.2x10-8	2x10-8*

*Exclusion for H2

Partial pressure of H_2O is expected to be higher at the BSC because the ultimate pressure calculation is based on pressure of water at the cryopump. The partial pressure of water will be measured near the inlet of the cryopump.

5.3 Backfill and purge with dry air, and 100 hour pumpdown

The system will be back filled with dry air from the Class 100 air system, and purged for 24 hours. This test is for information only.

5.3.1 Pumpdown of isolatable section with 80K cryopump

End station:
Once the isolatable section has been baked and back filled, the vacuum pumpdown test can be initiated. The section shall be pumped for 100 hours. Pressure shall be measured throughout the pumpdown. Partial pressures shall be recorded at 100 hours.

5.3.2 Pumpdown from atmosphere to 0.2 Torr using the roughing system

End stations:
The isolatable section will be pumped using the backing pump of the main turbo pump to a pressure below 0.2 Torr. Acceptance will be when the pressure of 0.2 Torr is reached in less than 15 hours.

5.3.3 Pumpdown from 0.2 Torr to 10^{-6} Torr using the main turbomolecular system

End stations:
The isolatable section will be pumped using one main turbomolecular pump system to a pressure of less than $5x10^{-6}$ Torr. Acceptance will be when the pressure of less than $5x10^{-6}$ Torr is reached in 24 hours.

5.3.4 80K Cryopump

The cryopump will be turned on when a pressure of less than $5X10^{-6}$ Torr has been reached. To minimize cryotrapping of CO2, the cryopump should be cooled down as late as possible, (between t=16 and 24 hrs) during the turbomolecular pump roughing stage.

5.3.5 Main Ion Pumps

The main ion pumps will be turned on after the cryopump is cold and has been pumping for several hours. (between 24 hours to 30 hours into the pumpdown).

5.4 Noise, Shock, and Vibration

During the commissioning process, measurements of vibration, shock, and noise generated by vacuum system equipment will be conducted in accordance with the CAA test plan (Attachment 1). No tests will be conducted in Louisiana.

5.5 Interface to the CDS

All CDS cabinets are supplied and installed by LIGO. PSI will terminate all VE instruments and other system interlocks as shown on PSI electrical drawings. CDS cabinet locations are shown on the following drawings:

V049-3-408 (2 sheets)

V049-3-508 (2 sheets)

V049-3-708 (2 sheets)

V049-3-808 (2 sheets)

Acceptance test for instrument loops and other wiring installed by PSI and terminated in the CDS's, will be performed as follows:

a. Check point to point continuity of each conductor to insure that wiring is intact and terminated at the proper place at both ends.
b. Verify wire connections are made in accordance with terminal wiring diagrams and schedules.
c. Using highlighter (transparent marker), indicate on terminal wiring diagram sheets that each wire and connection has been verified. These sheets will be made available to the buyer.
d. Replace defective wiring and retest.
e. Additional testing requirements are listed in V049-2-022 (Electrical and Instruments Construction Work).

PSI will supply LIGO with sufficient information for set up of the monitoring of the pressure gauges, the monitoring of the ion pumps, and control loops for the 80K cryopump level control valves.

5.6 Liquid Nitrogen Consumption

Liquid nitrogen consumption during cryopump operation will be determined by monitoring and recording the liquid nitrogen storage tank level and pressure. Each LN2 storage tank is equipped with a local level indicator, pressure gauge, and a differential pressure level transmitter for remote level indication and low level alarm functions. The data will be taken over a time period sufficient to calculate a meaningful average consumption. Ten days of continuous operation with the tank level between 30-70% full should be adequate.

Acceptance Criteria:

Measurements are taken for data only. Acceptance was done based on calculations presented during the FDR review.

5.7 Clean Air System Commissioning

After installation and prior to admitting clean air into any vacuum component, the clean air supply, at the point of usage, will be sampled for particulates (class 100), hydrocarbons and dew point (< 60 C). The purpose of this testing is to verify compliance with LIGO specifications and preclude the introduction of contaminants into the vacuum equipment. The results of the sampling will be documented for future reference.

Hydrocarbons shall be monitored both at the inlet to the air compressor and at the point of usage to confirm that no hydrocarbons are being added to the system via the clean air system. The hydrocarbon analyzer shall be calibrated against both a zero gas and span gas to measure the absolute level.

Acceptance Criteria:

The hydrocarbon content of the air leaving the clean air system will not be higher than the air supplied to the clean air system. The dew point of the air leaving the system will be -60 C or less. Particulates in the air leaving the system will not exceed class 100 requirements for 0.5 micron particle size.

ACCEPTANCE TEST: LEAKAGE ISOLATED SECTION

STATION:		
SECTION:		
AFTER COOLDOWN		
RESULTS FROM THE RGA TEST INDICATE AN AIR LEAK OF :		Torr-L/-s Helium equivalent
AFTER 100 HR PUMPDOWN		
RESULTS FROM THE RGA TEST INDICATE AN AIR LEAK OF :		Torr-L/-s Helium equivalent
ACCEPTANCE		

	ENGINEER NAME & TITLE	SIGNATURE
PSI		
PSI		
LIGO		
LIGO		

INCLUDE ALL RAW DATA AND CALCULATION SHEETS

Title: SPECIFICATION FOR SYSTEM ACCEPTANCE TEST PLAN, END STATIONS

ACCEPTANCE TEST: PUMPDOWN ISOLATED SECTION, END STATION

STATION: MID			
SECTION:		TIME	DATE
		24 hr clock hour : min	mm/dd/yy
ROUGHING 760 Torr to 0.2 Torr			
PUMPS TURNED ON, ELAPSED TIME	HR, MIN		
at PRESSURE	Torr		
TURNED OFF, ELAPSED TIME	HR, MIN		
at PRESSURE	Torr		
ACCEPTANCE			
PUMPDOWN from 0.2 Torr to < $5x10^{-6}$			
PUMPS TURNED ON, ELAPSED TIME	HR, MIN		
at PRESSURE	Torr		
TURNED OFF, ELAPSED TIME	HR, MIN		
at PRESSURE	Torr		
ACCEPTANCE			
80K CRYOPUMP			
PUMPS TURNED ON, ELAPSED TIME	HR, MIN		
at PRESSURE	Torr		
MAIN ION PUMPS			
PUMPS TURNED ON, ELAPSED TIME	HR, MIN		
at PRESSURE	Torr		

	ENGINEER NAME & TITLE	SIGNATURE
PSI		
PSI		
LIGO		
LIGO		

SPECIFICATION	
Number: V049-2-115 A	Rev.3

RGA DATA

RESULTS OF THE RGA TEST	
RGA TEST :	BEFORE BAKE / 100 HR PUMP
DATE:	
TIME:	
TEST I.D.:	
PSI TEST ENGINEER:	
LIGO SITE ENGINEER:	

SPECIES	ION CURRENT	Partial Pressure
	A	Torr
2		
4		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
24		
25		
26		
27		
28		
29		
30		
31		
32		

RGA DATA

RESULTS OF THE RGA TEST	
RGA TEST :	BEFORE BAKE / 100 HR PUMP
DATE:	
TIME:	
TEST I.D.:	
PSI TEST ENGINEER:	
LIGO SITE ENGINEER:	

SPECIES	ION CURRENT	Partial Pressure
	A	Torr
33		
34		
35		
36		
37		
38		
39		
40		
41		
42		
43		
44		
45		
46		
47		
48		
49		
50		
55		
57		
58		
59		
60		
78		
95		

RGA DATA / ULTIMATE PRESSURES

RESULTS OF THE RGA TEST	
RGA TEST :	100 HR PUMPDOWN, ULTIMATE PRESSURES
LOCATION OF RGA:	MAIN ION PUMP
DATE:	
TIME:	
TEST I.D.:	
PSI TEST ENGINEER:	
LIGO SITE ENGINEER:	

SPECIES	**Partial Pressure**	**ACCEPTANCE**
	Torr	
H_2		
H_2O		
CO		
CO_2		
CH_4		
N_2		
Others		

	ENGINEER NAME & TITLE	**SIGNATURE**
PSI		
PSI		
LIGO		
LIGO		

Title: SPECIFICATION FOR SYSTEM ACCEPTANCE TEST PLAN, END STATIONS

NOISE / VIBRATION MEASUREMENTS

RESULTS NOISE/VIBRATION	
DATE:	
TIME:	
TEST I.D.:	
PSI TEST ENGINEER:	
LIGO SITE ENGINEER:	

	VIBRATION MEASUREMENTS	COMPLETED
1	Tri-axis measurements, BSC (WBSC?) during operation of 122 cm gate valves At one End or Mid station only	
	NOISE MEASUREMENTS	
	Sound pressure levels measurements each chamber	

	ENGINEER NAME & TITLE	SIGNATURE
PSI		
PSI		
LIGO		
LIGO		

SPECIFICATION

Number: V049-2-115 A | Rev.3

ELECTRICAL / INSTRUMENTS CHECK OUT & INTERFACE TO CDS

		COMPLETED
1	Wiring checkout	
2	Vacuum equipment instruments information for setup and scaling for control system.	
3		
4		
5		
6		
7		
8		
9		
10		

	ENGINEER NAME & TITLE	SIGNATURE
PSI		
PSI		
LIGO		
LIGO		

Equipment summary
End Stations

	Component	Quantity
Vacuum Envelope	BSC	1
	Interconnecting Spools	various
	Short 80K Pump Chamber	1
Vacuum Pumps	Main Ion Pump	1
	Main Turbo Pumpcart	1
	Aux Turbo Cart	1
	Annulus Pumps	3
Cryopumps	Short 80K Pump	1
	LN2 Dewar	1
Valves	44" Gate Valves	2
	48" Gate Valves	
	14" Gate Valves	1
	10" Gate Valves	2
Clean Air System	Clean Air Compressor System 50 CFM	1
	Back to Air Valve Systems	1
	Back to Air Portable Controller Box	1
Bakeout System	Blankets	From Corner station
	Control Cart	"
Vacuum Gauging	Cold Cathode / Pirani Gauge Pair	2

ATTACHMENT I

CAMBRIDGE ACOUSTICAL ASSOCIATES, INC.
CONSULTING IN ACOUSTICS • NOISE & VIBRATION • STRUCTURAL & FLUID DYNAMICS
200 Boston Avenue, Suite 2500 • Medford, MA 02155-4243 • Telephone (617) 396-1421 • Fax (617) 396-1607

LIGO COMMISSION TEST PLAN FOR VIBRATION, NOISE, AND SHOCK

I. INTRODUCTION

During the commission process of the installations in Hanford, WA and Livingston, LA, measurements of shock, vibration, and noise generated by PSI's vacuum system will be conducted. Vibration measurements will be made on one each of the following chambers at each station where they exist: horizontal access module (HAM); beam splitter chamber (BSC); 80 k cryopump (CP); a substitute chamber for the test mass chamber. At each chamber, normal vibration (i.e., single axis) measurements will be made at one location on the floor within one meter of the chamber. Tri-axis measurements will be made at two locations on each chamber. Measurements will be made with and without operating auxiliary equipment for the purpose of establishing ambient levels. Additionally, sound pressure levels will be measured in the vicinity of each chamber with all vacuum systems components in normal operation.

Vibration measurements will be made on a representative chamber during the operation of 48,44,14,10 and 6 inch gate valves (GV). Tri-axis measurements will be made at two locations on the chamber.

II. TEST PROCEDURE

A. VIBRATION AND NOISE

Vibration and noise tests will be performed on or near the following chambers:

a. corner station- HAM5, HAM6, BSC7 and CP2

b. right mid-station- BSC5 and CP6

c. left mid-station- BSC6 and CP4

d. right end-station- BSC9 and CP8

e. left end-station- BSC10 and CP7

Measurements will be made with the Ion pumps, the cryogenic 80K pump, the purge and vent compressor (corner station only) and the turbomolecular pump(s) nearest the chamber operating. LIGO's equipment will be operating in a "quiet mode". For comparison, a background measurement will be performed with PSI's equipment "turn off" and the LIGO equipment in its "quiet mode".

Tri-axis vibration measurement will be made at two locations on each chamber, one near the nozzle connecting the vacuum tubing and one near the attachment to the support leg. One vertical floor measurement will be made at the support to LIGO's equipment inside the chamber or in the case of the cryopump at one of its support legs. Power spectral density plots will be created from the measurements.

In order to span the full frequency range of the LIGO specification, two high-sensitivity ultra low-noise accelerometers will be used. The Wilcoxon Research model 731A accelerometer (10V/g) will be used for the frequency bandwidth from 0.1-300 Hz and the Wilcoxon Research model 916BTO-1 (7.5V/g) will provide low noise capabilities above 300 Hz. The equivalent acceleration spectral densities corresponding to the electrical noise floor of these sensors are shown on Fig 1. Above 10 Hz, the noise floor of the model 731A is lower than the specified amplitude. Above 300 Hz, the noise floor of the 916BTO-1 is below the specified amplitude.

B. NOISE

Operating equipment noise will be measured using a Bruel and Kjaer type model Precision Sound Level Meter octave band analyzer. Sound pressure measurements will be measured in the vicinity of each chamber with equipment operating as described in Section A. Octave band levels will be recorded.

C. SHOCK

Shock measurements will be performed with the following valves opening and closing:

<u>corner station</u>-

a. 48" electric operated gate valve GV2
b. 44" pneumatic operated gate valve GV8
c. 14" manual gate valve at IP3
d. 10" manual gate valve at the turbomolecular pump near HAM6
e. 6" manual gate valve near HAM5.

<u>right mid-station</u>-

a .44" electric operated gate valve GV14
b. 14" manual gate valve at IP10
c. 10" manual gate valve at the turbomolecular pump near CP6

<u>left mid-station-</u>

a .44" electric operated gate valve GV11
b. 14" manual gate valve at IP9
c. 10" manual gate valve at the turbomolecular pump near CP4

<u>right end-station-</u>

a .44" electric operated gate valve GV20
c. 14" manual gate valve at IP12
d. 10" manual gate valve at the turbomolecular pump near BSC9

<u>left end-station-</u>

a .44" electric operated gate valve GV18
c. 14" manual gate valve at IP11
d. 10" manual gate valve at the turbomolecular pump near BSC10

Peak accelerations and power spectral density curves will be obtained from the measurements. Acceleration measurements will be made at two locations (described in Section A) at the chamber nearest the valve. General purpose PCB 338A35 accelerometers (100mv/g) will be used to perform the measurements. The broadband resolution of the accelerometer is +/- 0.002 g's peak.

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END STATION ACCEPTANCE TESTING AND INSPECTION SUMMARY

	By	Date Complete	Comments
1. LN_2 Tank Inspection Tank S/N ______ (per V049-2-102)			
2. Regeneration Heater Inspection HTR # ______ (per V049-2-102)			
3. Cryopump Instrumentation Calibration & Functional Test (per)			
4. Vacuum Instrumentation Checkout			
5. Fill LN_2 Tank			
6. Instrument/Electrical Wiring Checkout (per V049-1-163)			
7. Clean Air Compressor Checkout (per V049-2-109)			
8. Clean Room Testing (per V049-2-110)			
9. Gate Valve Operational Test (per V049-2-107)			
10. N/A			
11. Turbopump Skid Operational Test (per V049-2-105)			
12. 10 & 14 In. Manual Valves (per V049-2-108)			
13. Auxiliary Turbopump Test (per V049-2-105)			

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END STATION ACCEPTANCE TESTING AND INSPECTION SUMMARY
(continued)

	By	Date Complete	Comments
14. Main Ion Pump Testing (per V049-2-106)			
15. Bake-out Cart/System (per V049-2-112)			
16. Annulus Ion Pump Functional Test (per V049-2-106)			
17. Flange Annulus Leak Test (per V049-2-115)			
18. Main Volume Leak Test (per V049-2-115)			
19. Ultimate Pressure/RGA Test (per V049-2-115)			

Acceptance Testing Complete

Signed ______________________________

Date ______________________________

Backfill/Pumpdown Demonstration (One Demonstration per Station Type)

Signed ______________________________

Date ______________________________

Shock/Noise/Vibration Survey Complete (C.A.A.)

Signed ______________________________

Date ______________________________

LIGO PROJECT – PROCESS SYSTEMS INTERNATIONAL

AUTHORIZATION TO VACUUM TEST

System:	
Test Procedure:	
References Needed:	
Cautions:	
Notes:	

Authorized By: ______________________

Date: ______________________

Test Performed By: ______________________

Date: ______________________

AUTHORIZATION NO.

WA-_____