LIGO VACUUM EQUIPMENT

WASHINGTON CORNER STATION ACCEPTANCE TEST REPORT

CONTRACT NO:	**PC 175730**
PSI DOCUMENT NO:	**V049-1-183**
PROGRAM I.D.:	**LIGO VACUUM EQUIPMENT**
CDRL NO:	**06-1**
APPROVAL STATUS:	**A**

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CALIFORNIA INSTITUTE OF TECHNOLOGY LIGO PROJECT
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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ISSUE DATE:	**October 23, 1998**
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WASHINGTON CORNER STATION
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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
Bake-out System Blankets and Carts	V049-2-112

I. System Acceptance Test Procedures (Attached)

Corner Station	V049-2-113

1. INTRODUCTION

This report summarizes the field acceptance testing conducted by Process Systems International, Inc. (PSI) at the LIGO Washington Site Corner Station. The station was tested in accordance with Acceptance Test Procedure V049-2-113, Rev. 3.

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

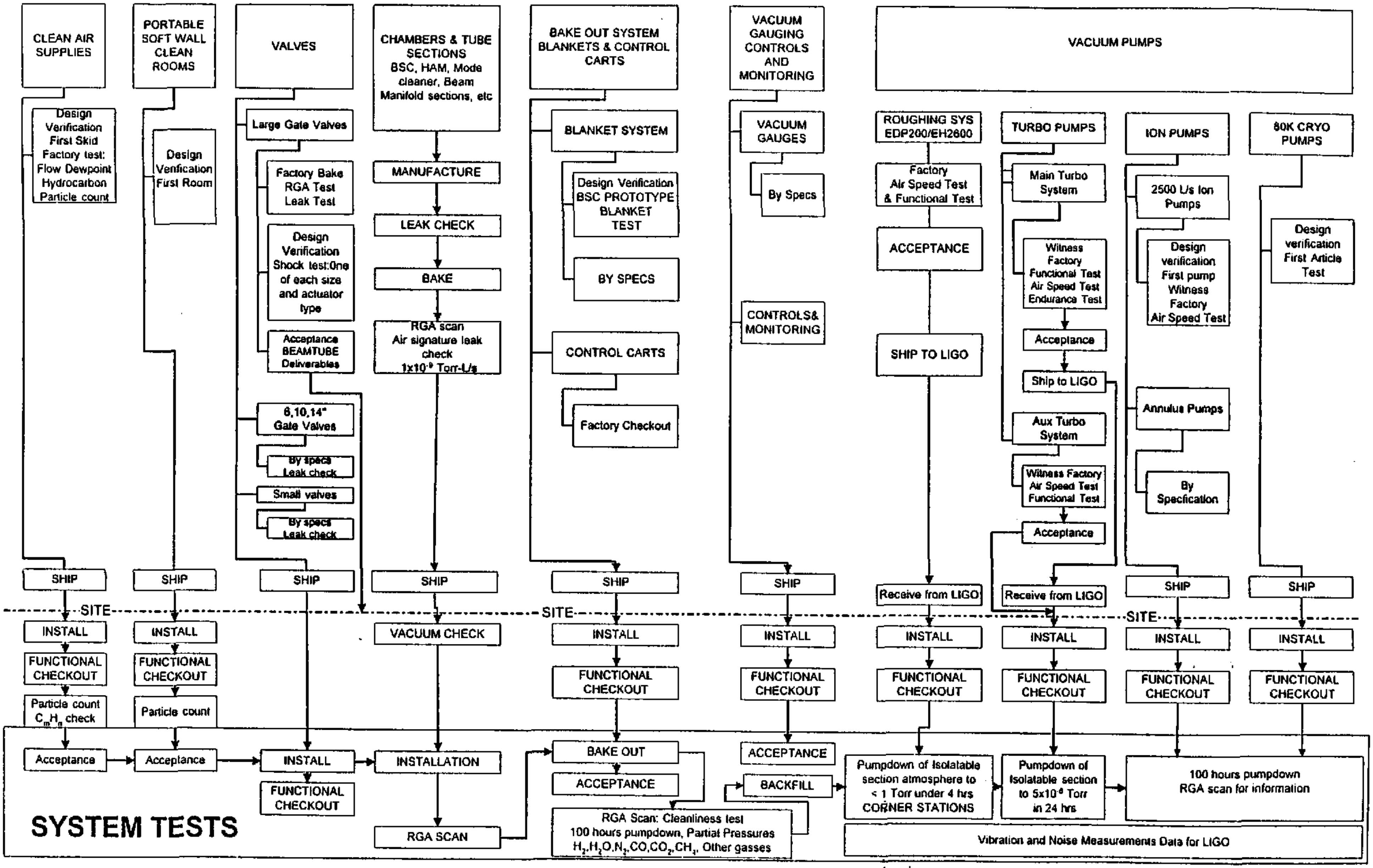
2. SCOPE

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 Item Data Package V049-1-177.

The WA site GNB large gate valve modification program is documented in a separate volume V049-1-185.

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

LIGO VACUUM EQUIPMENT ACCEPTANCE TESTS PLAN



3. ACCEPTANCE TEST CRITERIA

3.1 LEFT BEAM MANIFOLD

Item	Acceptance Criteria	Acceptance Results
Interface to CDS	Functional Checkout per V049-2-163	Checkout completed on 5/14/98
Clean Air System Test	Functional Checkout per V049-2-109 Dewpoint:<-60 C Particle Count: Class 100 @ .5 micrometer. Hydrocarbon Check:	Dewpoint: -69°C Particle Count: 0 Hydrocarbon Check: 0 PPM
Class 100 Cleanroom Test	Functional Checkout per V049-2-110 Particle Count: <100	Particle Count: HAM = 2.8 BSC = 11.3
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 bake-out. All flange annuli checked and passed. Data recorded in site test logs. The volume is leak tight to $<5x10^{-8}$ torr-L/s

3.1 LEFT BEAM MANIFOLD – (continued)

Item	Acceptance Criteria	Acceptance Results
System Bake-out	Functional Checkout per V049-2-112 Rev1 Bake-out: Ramp Rate: 1.8°C/hour Uniformity: 150°C+/-20°C	The station was ramped from 18°C to 150°C over a period of 67 hours and held for 48.5 hours at 130-150°C. After the hold, the temperature was ramped to 49°C over 51.0 hours prior to shutting off the power.
Ultimate Pressure Test (After Bake-out)		
Primary	Total Pressure:<$2x10^{-8}$ torr	Total Pressure: 2.0×10^{-8} torr
Secondary (if H_2 is High)	Partial Pressure Measurements: Sum of all gasses other than H_2 and H_2O:<$3x10^{-9}$ torr	Partial Pressure Measurements: Sum of all gasses other than H_2 and H_2O: 1.85×10^{-9} torr
LN_2 Consumption Test	LN2 consumption per V049-2-208 90 days without refill.	107 days without refill.
Noise/Shock/ Vibration Field Test	Per CAA Test Plan	See CAA Test Report

3. ACCEPTANCE TEST CRITERIA

3.2 DIAGONAL SECTION

Item	Acceptance Criteria	Acceptance Results
Interface to CDS	Functional Checkout per V049-2-163	Checkout completed on 5/14/98
Clean Air System Test	Functional Checkout per V049-2-109 Dewpoint:<-60 C Particle Count: Class 100 @ .5 micrometer. Hydrocarbon Check:	Dewpoint: -69°C Particle Count: 0 Hydrocarbon Check: 0 PPM
Class 100 Cleanroom Test	Functional Checkout per V049-2-110 Particle Count: <100	Particle Count: HAM = 2.8 BSC = 11.3
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 gate 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 bake-out. All flange annuli checked and passed. Data recorded in site test logs. The volume is leak tight to <$5x10^{-8}$ torr-L/s

3.2 DIAGONAL SECTION – (continued)

Item	Acceptance Criteria	Acceptance Results
System Bake-out	Functional Checkout per V049-2-112 Rev1 Bake-out: Ramp Rate: 1.8°C/hour Uniformity: 150°C+/-20°C	The station was ramped from 20°C to 150°C over a period of 79 hours and held for 48 hours at 130-150°C. After the 48-hour hold, the temperature was ramped to 60°C over 38.0 hours prior to shutting off the power.
Ultimate Pressure Test (After Bake-out) Primary Secondary (if H_2 is High)	 Total Pressure:$<2x10^{-8}$ torr Partial Pressure Measurements: Sum of all gasses other than H_2 and H_2O:$<3x10^{-9}$ torr	 Total Pressure: 1.33×10^{-8} torr Partial Pressure Measurements: Sum of all gasses other than H_2 and H_2O: 1.3×10^{-9} torr
Noise/Shock/ Vibration Field Test	Per CAA Test Plan	See CAA Test Report

3. ACCEPTANCE TEST CRITERIA

3.3 RIGHT BEAM MANIFOLD

Item	Acceptance Criteria	Acceptance Results
Interface to CDS	Functional Checkout per V049-2-163	Checkout completed on 5/14/98
Clean Air System Test	Functional Checkout per V049-2-109 Dewpoint:<-60 C Particle Count: Class 100 @ .5 micrometer. Hydrocarbon Check:	Dewpoint: -69°C Particle Count: 0 Hydrocarbon Check: 0 PPM
Class 100 Cleanroom Test	Functional Checkout per V049-2-110 Particle Count: <100	Particle Count: HAM = 2.8 BSC = 11.3
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 gate 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 bake-out. All flange annuli checked and passed. Data recorded in site test logs. The volume is leak tight to $<6.0 \times 10^{-9}$ torr-L/s

3.3 RIGHT BEAM MANIFOLD – (continued)

Item	Acceptance Criteria	Acceptance Results
System Bake-out	Functional Checkout per V049-2-112 Rev1 Bake-out: Ramp Rate: 1.8°C/hour Uniformity: 150°C+/-20°C	The station was ramped from 19°C to 150°C over a period of 89.5 hours and held for 48 hours at 130-150°C. After the hold, the temperature was ramped to 63°C over 38.0 hours prior to shutting off the power.
Ultimate Pressure Test (After Bake-out) Primary Secondary (if H_2 is High)	 Total Pressure:<$2x10^{-8}$ torr Partial Pressure Measurements: Sum of all gasses other than H_2 and H_2O:<$3x10^{-9}$ torr	 Total Pressure: 6.6×10^{-9} torr Partial Pressure Measurements: Sum of all gasses other than H_2 and H_2O: 5.4×10^{-10} 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 $1.3x10^{-2}$ torr in 6 hours Roughing to $1.3x10^{-7}$ torr in 21.5 hours Partial pressures: AMU — torr 2 — $2.6x10^{-9}$ 16 — $2.0x10^{-10}$ 18 — $2.9x10^{-10}$ 28 — $5.3x10^{-9}$ 44 — $3.0x10^{-10}$ All others — $1x10^{-9}$ Total — $9.6x10^{-9}$

3.3 RIGHT BEAM MANIFOLD – (continued)

Item	Acceptance Criteria	Acceptance Results
LN_2 Consumption Test	LN2 consumption per V049-2-208 90 days without refill.	148 days without refill.
Noise/Shock/ Vibration Field Test	Per CAA Test Plan	See CAA Test Report

3. ACCEPTANCE TEST CRITERIA

3.4 VERTEX SECTION

Item	Acceptance Criteria	Acceptance Results
Interface to CDS	Functional Checkout per V049-2-163	Checkout completed on 5/14/98
Clean Air System Test	Functional Checkout per V049-2-109 Dewpoint:<-60 C Particle Count: Class 100 @ .5 micrometer. Hydrocarbon Check:	Dewpoint: -69°C Particle Count: 0 Hydrocarbon Check: 0 PPM
Class 100 Cleanroom Test	Functional Checkout per V049-2-110 Particle Count: <100	Particle Count: HAM = 2.8 BSC = 11.3
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 gate 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 bake-out. All flange annuli checked and passed. Data recorded in site test logs. The volume is leak tight to $<2x10^{-8}$ torr-L/s

3.4 VERTEX SECTION – (continued)

Item	Acceptance Criteria	Acceptance Results
System Bake-out	Functional Checkout per V049-2-112 Rev1 Bake-out: Ramp Rate: 1.8°C/hour Uniformity: 150°C+/-20°C	The station was ramped from 20°C to 150°C over a period of 53 hours and held for 48 hours at 130-150°C. The system was ramped down at the standard rate.
Ultimate Pressure Test (After Bake-out)		
Primary	Total Pressure:<2x10^{-8} torr	Total Pressure: 4.4 x 10^{-9} torr
Secondary (if H_2 is High)	Partial Pressure Measurements: Sum of all gasses other than H_2 and H_2O:<3x10^{-9} torr	Partial Pressure Measurements: Sum of all gasses other than H_2 and H_2O: 7.8 x 10^{-10} 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 1.3x10^{-2} torr in 6 hours Roughing to 1.3x10^{-7} torr in 21.5 hours Partial pressures: AMU — torr 2 — 2.6x10^{-9} 16 — 2.0x10^{-10} 18 — 2.9x10^{-10} 28 — 5.3x10^{-9} 44 — 3.0x10^{-10} All others — 1x10^{-9} Total — 9.6x10^{-9}
Noise/Shock/ Vibration Field Test	Per CAA Test Plan	See CAA Test Report

4. ACCEPTANCE TEST RESULTS SUMMARY

4.1 ACCEPTANCE TEST RESULTS SUMMARY – LEFT BEAM MANIFOLD

As shown in Section 3, the WA Left Beam Manifold 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 $5x10^{-8}$ torr-L/s Air.

The minimum detectable leak from the RGA scan with the sensitivity obtained during the scan for the Left Beam Manifold Station is about $5x10^{-8}$ 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.

System Bake-out

The design ramp rates were selected to minimize thermal stress and to keep input power requirements at reasonable levels.

The excellent RGA scans after bake-out indicate that the system is clean and the bake-out was therefore effective.

Ultimate Pressure Test

The partial pressure measurements after bake-out met or exceeded the acceptance criteria except for hydrogen, due to the lack of pumping speed. This matched 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	$5x10^{-9}$	1.8×10^{-8}
16	$2x10^{-10}$	1.0×10^{-10}
18	$5x10^{-9}$	1.1×10^{-10}
28	$1x10^{-9}$	1.3×10^{-9}
44	$2x10^{-10}$	8.5×10^{-11}
Other	$1.9x10^{-9}$	3.6×10^{-10}

Backfill/100 Hour Pumpdown Test

See Vertex/Right Beam Manifold Test, Section 4.4, for typical data.

LN2 Consumption

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

4.2 ACCEPTANCE TEST RESULTS SUMMARY – DIAGONAL SECTION

As shown in Section 3, the WA Diagonal 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 2.5×10^{-8} torr-L/s Air.

The minimum detectable leak from the RGA scan with the sensitivity obtained during the scan for the Diagonal Station is about 2.5×10^{-8} 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. This is an estimate based on a correlation between the RGA in the diagonal section and the RGA in the L.M. manifold (with the calibration system).

System Bake-out

The design ramp rates were selected to minimize thermal stress and to keep input power requirements at reasonable levels.

The excellent RGA scans after bake-out indicate that the system is clean and the bake-out was therefore effective.

Ultimate Pressure Test

The partial pressure measurements after bake-out met or exceeded the acceptance criteria except for hydrogen, due to the lack of pumping speed. This matched 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	5×10^{-9}	1.2×10^{-8}
16	2×10^{-10}	8.1×10^{-11}
18	5×10^{-9}	6.1×10^{-11}
28	1×10^{-9}	1.1×10^{-9}
44	2×10^{-10}	5.5×10^{-11}
Other	1.9×10^{-9}	8.5×10^{-11}

Backfill/100 Hour Pumpdown Test

See Vertex/Right Beam Manifold Test, Section 4.4, for typical data.

LN2 Consumption

Not applicable.

4.3 ACCEPTANCE TEST RESULTS SUMMARY – RIGHT BEAM MANIFOLD

As shown in Section 3, the WA Vertex 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 less than $6x10^{-9}$ torr-l/s nitrogen equivalent. This figure was determined from an accumulation test carried out over a 3-hour period. Three out of five masses correlated well. Mass 40, 28, 29 yielded leak rates of $3x10^{-9}$, $7x10^{-9}$, and $1x10^{-8}$ torr-l/s, respectively. Assigning the entire increase to argon or nitrogen will lead to a maximum value, where the actual leak rate may be less.

System Bake-out

The design ramp rates were selected to minimize thermal stress and to keep input power requirements at reasonable levels.

The excellent RGA scans after bake-out indicate that the system is clean and the bake-out was therefore effective.

Ultimate Pressure Test

The partial pressure measurements after bake-out closely met or exceeded the acceptance criteria except for hydrogen, due to the lack of pumping speed. This matched 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	$5x10^{-9}$	6.1×10^{-9}
16	$2x10^{-10}$	7.0×10^{-11}
18	$5x10^{-9}$	1.2×10^{-11}
28	$1x10^{-9}$	4.5×10^{-10}
44	$2x10^{-10}$	7.9×10^{-12}
Other	$1.9x10^{-9}$	2.8×10^{-11}

Backfill/100 Hour Pumpdown Test

The right beam manifold and vertex were pumped together. See Vertex Section 3.4.

LN2 Consumption

Results of the Right Beam Manifold Station Cryopump indicates a full tank capacity of more than 100 days.

4.4 ACCEPTANCE TEST RESULTS SUMMARY – VERTEX SECTION

As shown in Section 3, the WA Vertex 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 less than $2x10^{-8}$ torr-l/s nitrogen equivalent. This figure was determined from an accumulation test carried out over a 3-hour period. Three out of five masses correlated well. Mass 40, 28, 29 yielded leak rates of $3x10^{-9}$, $7x10^{-9}$, and $1x10^{-8}$ torr-l/s, respectively. Assigning the entire increase to argon or nitrogen will lead to a maximum value, where the actual leak rate may be less.

System Bake-out

The design ramp rates were selected to minimize thermal stress and to keep input power requirements at reasonable levels.

The excellent RGA scans after bake-out indicate that the system is clean and the bake-out was therefore effective.

Ultimate Pressure Test

The partial pressure measurements after bake-out met or exceeded the acceptance criteria except for hydrogen, due to the lack of pumping speed. This matched 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	$5x10^{-9}$	3.6×10^{-9}
16	$2x10^{-10}$	5.8×10^{-11}
18	$5x10^{-9}$	2.4×10^{-11}
28	$1x10^{-9}$	6.5×10^{-10}
44	$2x10^{-10}$	1.6×10^{-11}
Other	$1.9x10^{-9}$	4.8×10^{-11}

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. The resulting partial pressures for all gases are still below the LIGO goals.

AMU	After Bake-out	After Backfill & 100 Hr. Pumpdown
	Partial Pressure	Partial Pressure
(Torr)	(Torr)	(Torr)
2	3.6×10^{-9}	2.6×10^{-9}
16	5.8×10^{-11}	2.0×10^{-10}
18	2.4×10^{-11}	2.9×10^{-10}
28	6.5×10^{-10}	5.3×10^{-9}
44	1.6×10^{-11}	3.0×10^{-10}
Other	4.8×10^{-11}	9.9×10^{-10}

5. ACCEPTANCE TEST RESULTS – LEFT BEAM MANIFOLD

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

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5.1 Interface To CDS – Left Beam Manifold

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.

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5.2 Clean Air System Test – Left Beam Manifold

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

All test results met or exceeded the requirements.

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

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				
DEWPOINT	5.2	-60C / -69.C			Am 3/27/98
Particle Count	5.2	100. PART/FT3 REQ 0.0 PART/FT3 MEAS	0.5 μ		Am 3/27/98
HYDROCARBON CONTENT	5.2	0.0PPM			Am 3/27/98

WASH. CORNER CLEAN AIR SYS.

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5.3 Class 100 Cleanroom Test – Left Beam Manifold

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

All test results met or exceeded the requirements.

See Vertex Section 8.3 for details.

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5.4 System Leak Check – Left Beam Manifold

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 · cm³/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 · cm³/s, the majority of products have leak rate specifications lying in a narrower range, from 10^{-6} to 10^{-1} atm · cm³/s. The upper part of this range is covered by bubble testing, down to 10^{-4} std cm³/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 · cm³/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 · cm³/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 · cm³/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.

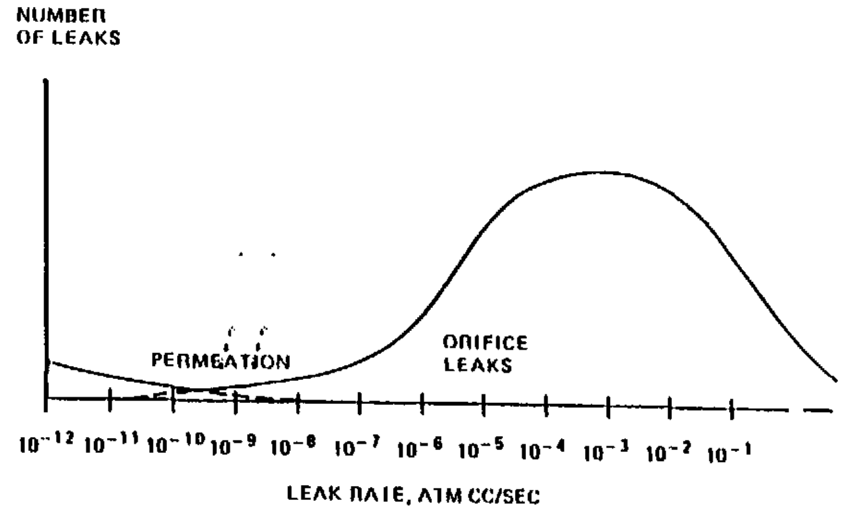


Figure 11.1 Typical distribution of leaks encountered in industrial products.

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 convertors or ring pull-tab beverage can ends at 10^{-8} or 10^{-9} atm · cm³/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

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

LEAK TEST DATA SHEET - FIELD TESTS

	1	2	3
Component Name	WASH LEFT BEAM MAN	ANNULUS - PIPE	EQUIP.
Model Number			
Serial Number			
Drawing Number			
Detector Name	BALZERS	BALZERS	BSC8
Model Number	HLT 160 DRY	HLT 160 DRY	CP1, BE4F
Serial Number	03	03	A1F
SYS ~~Detector~~ Calibration	..		A12B
Expiration Date	1-12-98	INT CAL ONLY	A13B
Standard Leak Rate	4.53x10^-9		A15B
Background	N/A		B1B
Standard Response	40x10^-9	CF 1.3	B4B
			B8B
Leak Test Data			B9B
Location /Date	WASH 4-22-98		BE6
Tracer Gas	HE		
Pressure CC AHL	5.7x10^-7	<1x10^-5 PER ANNULUS	
Duration	3 HRS EVAC + SPRAY	SPACE	
Response	NDL x10^-9 SCALE	NDL x10^-9 — EVAC + SPRAY	
Leak Rate			
Measured	NDL x10^-9 SCALE		
Calculated			
Allowable			
Performed By: D.H.	Date: 4-22-98	4-98	
Witnessed By:	Date:		
Signature: [signature]	Date: 4-22-98		
Title: PROD TECH III			

Remarks: LEAKS (1) BELLOWS OR CRYOPUMP (2) TEST INCLUDES CP1 INTERNAL LOG RES TEST

SPECIFICATION

Number: V049-2-014 A — Rev. 2

WASHINGTON SITE CORNER STATION
PSI FACTORY LEAK TEST DATA SHEETS
LEFT BEAM MANIFOLD

Tag No.	*Serial No.*
WBSC 8	08
WCP1	01
WA1F	05
WA12B	02
WA13B	02
WA15B	02
WB1B	02
WB4B	02
WB8B	02
WB9B	02
WBE6	01
WBE4F	06

L.B.M.

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

LEAK TEST DATA SHEET

	1	2	3
Component Name	BSC		
Model Number	WBSC 8		
Serial Number	08		
Drawing Number			
Detector Name	BALZERS		
Model Number	HLT 160 DRY		
Serial Number	03		
Detector Calib.Date	7-25-97		
Detector Calib.Factor	1.2		
Standard Leak Rate	4.53×10^{-9}		
Std.Leak Expir.Date			
Standard Response	4.0×10^{-9}		
Leak Test Data			
Location /Date	clean room / 7-25-97		
Tracer Gas	He		
Pressure @ Turbo Inlet	2.1×10^{-6}		
Duration	1 HR		
Response	NDC EVAC + SPRAY		
	$\times 10^{-9}$ SCALE		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By :	Date :		
Witnessed By :	Date :		
Signature : [signature]	Date : 7-25-97		
Title :			

Remarks :

SPECIFICATION	
Number: V049-2-014 A	p2

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	BSC						
Model No.	WBSC8						
Serial No.	08						
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		$5x10^{-5}$	✓		[signature]	7-25-97
	II		NDL (10^{-9} Scale)	✓		[signature]	7-25-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments PCC 3x10-8

Witnessed
Signature [signature]
Title
Date: 7-25-97

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

LEAK TEST DATA SHEET

	1	2	3
Component Name	80K PUMP	SPOOL	LN2 RES
Model Number	WCP1	BE4	
Serial Number	LL1	-F	
Drawing Number			
Detector Name	BALZERS		
Model Number	HLT 160 DRY		
Serial Number	3		
Detector Calib.Date	8-9-97		
Detector Calib.Factor	1.3		
Standard Leak Rate	4.8×10^{-9}		
Std.Leak Expir.Date	6-3-98		
Standard Response	3.8×10^{-9}		
Leak Test Data			
Location /Date	CRYO ROOM /		
Tracer Gas	HE		
Pressure @ Turbo Inlet	~~8-9-97~~ 2.8×10^{-6}		
Duration	2 HR		
Response	NDL EVAC + SPRAY		
	$\times 10^{-9}$ SCALE		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : D. H	Date :		
Witnessed By :	Date :		
Signature : [signature]	Date : 8-9-97		
Title :			

Remarks : WCP1 + BE4F TESTED TOGETHER ALSO LN2 RES TESTED NDL $\times 10^{-9}$

SPECIFICATION	
Number: V049-2-014 A	p2

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	80 K Pump	Spool					
Model No.	WCP1	BE4					
Serial No.	LL1	-F					
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		$2x10^{-5}$	✓		[illegible]	8-9-97
	II		NDL (10^{-9} Scale)	✓		[illegible]	8-9-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments PCC $3.7x10^{-5}$ ALL ANNULAS TIED TOGETHER

Witnessed
Signature
Title
Date:

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	SPOOL		
Model Number	WA1		
Serial Number	-F		
Drawing Number			
Detector Name	BALZERS		
Model Number	HLT 160 - DRY		
Serial Number	01		
Detector Calib.Date	9-10-97		
Detector Calib.Factor	1.2		
Standard Leak Rate	4.8×10^{-9}		
Std.Leak Expir.Date	6-3-98		
Standard Response	4.7×10^{-9}		
Leak Test Data			
Location /Date	CLEAN ROOM / 9-10-97		
Tracer Gas	He		
Pressure @ Turbo Inlet	7.3×10^{-7}		
Duration	1.½ HRS		
Response	NDL $\times 10^{-9}$ EVAC +		
	SPRAY		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : D. H	Date :		
Witnessed By :	Date :		
Signature : [signature]	Date : 9-10-97		
Title :			

Remarks :

SPECIFICATION	
Number: V049-2-014 A	p2

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	SPOOL						
Model No.	WA1						
Serial No.	F						
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		3x10^{-5}	✓		[signature]	9-10-97
	II		NDL (10^{-8} Scale)	✓		[signature]	9-10-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		1x10^{-9}				
Weld Joint	II		1x10^{-9}				
Conflat	III		1x10^{-9}				

Comments PCC 2.1x10^{-5} All annulas tested together.
HLT # 3 CF = 1.4

Witnessed
Signature [signature]
Title
Date: 9-10-97

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	SPOOL	WB8B	WB1B
Model Number	A13		
Serial Number	B	2	2
Drawing Number			
Detector Name	BALZERS		
Model Number	HLT 160 DRY		
Serial Number	2		
Detector Calib.Date	8-18-97		
Detector Calib.Factor	.8		
Standard Leak Rate	NOT USED		
Std.Leak Expir.Date			
Standard Response			
Leak Test Data			
Location /Date	clean room		
Tracer Gas	He		
Pressure @ Turbo Inlet	9.0x10-7		
Duration	1 1/4 HRS		
Response	NDL EVAC + SPRAY x10-9		
	SCALE		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : P.H.	Date : 8-18-97		
Witnessed By : D.H.	Date :		
Signature : [signature]	Date : 8-18-97		
Title :			

Remarks : SPOOL TESTED TOGATHER with A B8 and B1

SPECIFICATION

Number: V049-2-014 A p2

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	SPOOL						
Model No.	A13						
Serial No.	B						
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		$3x10^{-5}$	✓		[illegible]	8-18-97
	II		NDL (10^{-9} Scale)	✓		[illegible]	8-18-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments PCC $1.4x10^{-5}$ ANNULAS TESTED TOGATHER WITH.
SPOOL A13-BB-A1 COMBO

Witnessed
Signature
Title
Date:

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	SPOOL		
Model Number	B9		
Serial Number	-B		
Drawing Number			
Detector Name	Balzers		
Model Number	HLT 160 - DRY		
Serial Number	3		
Detector Calib.Date	8-27-97		
Detector Calib.Factor	1.5		
Standard Leak Rate	4.8x10-9		
Std.Leak Expir.Date	6-3-98		
Standard Response	4.0x10-9		
Leak Test Data			
Location /Date	CRYO Room 8-27-97		
Tracer Gas	He		
Pressure @ Turbo Inlet	7.2x10-7		
Duration	2 HRS		
Response	NDC x10-9 EVAC + SPRAY		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : ER	Date : 8-27-97		
Witnessed By : D.H.	Date :		
Signature [signature]	Date : 8-27-97		
Title :			

Remarks : B9B mated to A1B during 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	SPool						
Model No.	B9						
Serial No.	-B						
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		$4x10^{-5}$	✓		[signature]	8-27-97
	II		NDL (10^{-9} Scale)	✓		[signature]	8-27-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments B9B mated to A1B HLT 3 CF 1.4
EACH ANNULAS <1x10^-5 TORR

Witnessed
Signature [signature]
Title
Date: 8-27-97

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	SPOOL		
Model Number	BE6		
Serial Number	01		
Drawing Number			
Detector Name	BALZERS		
Model Number	HLT 160 DRY		
Serial Number	2		
Detector Calib.Date	7-29-98		
Detector Calib.Factor	1.0		
Standard Leak Rate	4.5x10-9		
Std.Leak Expir.Date	7-14.98		
Standard Response	5.4x10-9		
Leak Test Data			
Location /Date	CRYO ROOM 7-29-97		
Tracer Gas	HE		
Pressure @ Turbo Inlet	1.4x10-7		
Duration	30 min		
Response	NDL x10-9 EVAC. SPRAY		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : PH	Date : 7-29-97		
Witnessed By : DH	Date : 7-29-97		
Signature :	Date :		
Title :			

Remarks :

SPECIFICATION	
Number: V049-2-014 A	p2

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	SPOOL						
Model No.	BE6						
Serial No.	01						
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr	✓		D. [illegible]	7-29-97
	IV-V		4x10^{-5}	✓		D. [illegible]	7-29-97
	II		NDL (10^{-9} Scale)				
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		1x10^{-9}				
Weld Joint	II		1x10^{-9}				
Conflat	III		1x10^{-9}				

Comments

Witnessed
Signature
Title
Date:

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	WA12B	WB4B	
Model Number			
Serial Number	2	2	
Drawing Number			
Detector Name	Balzers		
Model Number	HLT160		
Serial Number	3		
Detector Calib.Date	6-28-97		
Detector Calib.Factor	1.2		
Standard Leak Rate			
Std.Leak Expir.Date			
Standard Response			
Leak Test Data			
Location /Date	Clean room / 6-28-97		
Tracer Gas	He		
Pressure @ Turbo Inlet	6.4x10-7		
Duration	2 hrs		
Response	NDL 10-9 scale		
	evac & spray		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : D. Hillis	Date : 6-28-97		
Witnessed By : (JP)	Date :		
Signature : Dan Hillis	Date : 6-28-97		
Title :			

Remarks :

SPECIFICATION

Number: V049-2-014 A | p2

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	A12B	B4B					
Model No.							
Serial No.	2	2					
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		$4x10^{-3}$	✓		D. Hillier	6-28-97
	II		NDL (10^{-9} Scale)	✓		(JF) D. Hillier	6-28-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments

Witnessed
Signature
Title
Date:

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	A15B w/BSC4		
Model Number			
Serial Number	2		
Drawing Number			
Detector Name	Balzers		
Model Number	HLT160		
Serial Number	3		
Detector Calib.Date	8-8-97		
Detector Calib.Factor	1.3		
Standard Leak Rate	4.5x10-9		
Std.Leak Expir.Date			
Standard Response	5 min		
Leak Test Data			
Location /Date	Clean room/8-6-97		
Tracer Gas	He		
Pressure @ Turbo Inlet	1.X10-6		
Duration	6 Hours		
Response	NDL x10-9 scale		
	evac + spray		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : P.T./D.H.	Date : 8-8-97		
Witnessed By :	Date :		
Signature : D. Hillis	Date : 8-8-97		
Title :			

Remarks :

SPECIFICATION	
Number: V049-2-014 A	p2

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	A15B						
Model No.							
Serial No.	2						
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		$4x10^{-5}$	✓		Ed Rolfes	8-8-97
	II		NDL (10^{-9} Scale)	✓		Ed Rolfes	8-8-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments

Witnessed
Signature
Title
Date:

SPECIFICATION

Number: V049-2-014 A p2

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT

5.5 System Bake-Out – Left Beam Manifold

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

The bake-out passed the requirements since the ultimate pressure test was successfully completed.

CORNER - LEFT BEAM MANIFOLD LBM 1

5-9-98

1700 BAKE LEFT BEAM MANIFOLD

$P = 8.5 \times 10^{-5}$

AUX @ GV3 $= 4.4 \times 10^{-5}$

AUX @ BSC8 $= 1.3 \times 10^{-5}$

AUX @ GV5 $= 5.5 \times 10^{-6}$

AUX @ GV 6 $= 3.8 \times 10^{-6}$

AUX @ B1 $= 3.8 \times 10^{-6}$

1915

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

AUX @ GV3 4.6×10^{-5}

@ BSC8 2.5×10^{-5}

@ GV5 1.1×10^{-5}

@ GV6 5.0×10^{-6}

@ B1 1.2×10^{-5}

5-10-98

0846 54

$P = 6.6 \times 10^{-6}$

AUX @ GV3 7.5×10^{-5}

@ BSC8 1.0×10^{-4}

@ GV5 7.6×10^{-5}

@ GV6 2.6×10^{-5}

@ B1 4.2×10^{-5}

1400 63

$P = 8.8 \times 10^{-6}$

AUX @ GV3 7.5×10^{-5}

@ BSC8 1.2×10^{-4}

@ GV5 8.8×10^{-5}

@ GV6 2.9×10^{-5}

@ B1 1.9×10^{-5}

LBM 2

5-10-98

1900

$P = 1.3 \times 10^{-5}$

AUX @ GV3	8.3×10^{-5}
@ BSC8	1.7×10^{-4}
@ GV5	1.4×10^{-4}
@ GV6	4.2×10^{-5}
@ B1	7.0×10^{-5}

5-11-98 · TURBO IS DOWN, AUX CARTS ARE DOWN } NO IN AIR

0630 94

$P = 3.4 \times 10^{-3}$

AUX @ GV3	1.1×10^{-7}
@ BSC8	1.6×10^{-7}
@ GV5	2.1×10^{-7}
@ GV6	7.0×10^{-8}
@ B1	1.1×10^{-7}

0900 98 $P = 2.6 \times 10^{-5}$

AUX @ GV3	1.1×10^{-4}
@ BSC8	2.4×10^{-4}
@ GV5	2.3×10^{-4}
@ GV6	6.7×10^{-5}
@ B1	1.0×10^{-4}

1100 103 $P = 2.3 \times 10^{-5}$

AUX @ GV3	1.1×10^{-4}
@ BSC8	2.1×10^{-4}
@ GV5	2.0×10^{-4}
@ GV6	6.4×10^{-5}
@ B1	9.5×10^{-5}

LBM 3

5-11-98
1330 108
P= 2.3×10^{-5}
AUX @ GV3 1.1×10^{-4}
@ BSC8 2.0×10^{-4}
@ GV5 1.9×10^{-4}
@ GV6 6.4×10^{-5}
@ B1 9.4×10^{-5}
1500 REGEN HEATER ON

[illegible]
1530 112
P= 2.1×10^{-5}
AUX @ GV3 ~~[illegible]~~ 1.2×10^{-4}
@ BSC8 2.0×10^{-4}
@ GV5 1.8×10^{-4}
@ GV6 6.3×10^{-5}
@ B1 9.2×10^{-5}

5-12-98

800 CART 3 . 142
$P_{CH} = 2.6 \times 10^{-5}$ TORR

CART 3 ZONES 52, 53 are low ARE TURNED OFF 44, 25 °C
100 ERROR, 95 °C

LBM 4

1030 144
P = 2.7 x10^{-5}
AUX @ GV3 8.6 x10^{-5}
@ BSC8 1.1 x10^{-4}
@ GV5 8.8 x10^{-5}
@ GV6 3.9 x10^{-5}
@ B1 5.7 x10^{-5}
1200 TARGET —
1400 150.
P = 2.9 x10^{-5}
AUX @ GV3 8.4 x10^{-5}
@ BSC8 1.1 x10^{-4}
@ GV5 8.9 x10^{-5}
@ GV6 3.8 x10^{-5}
@ B1 5.6 x10^{-5}
1630 150
P = 2.8 x10^{-5}
AUX @ GV3 8.0 x10^{-5}
@ BSC8 1.0 x10^{-4}
@ GV5 8.1 x10^{-5}
@ GV6 3.4 x10^{-5}
@ B1 5.0 x10^{-5}
REGEN 159°C

5-13-98
1000 150
P = 2.5 x10^{-5}
AUX @ GV3 5.8 x10^{-5}
@ BSC8 6.4 x10^{-5}
@ GV5 5.1 x10^{-5}
@ GV6 1.9 x10^{-5}
@ B1 2.7 x10^{-5}
REGEN 159°C

LIBMS

5-13-98
1330 1SD
P = 2.5 x 10-5
AUX @GV3 5.6 x 10-5
@BSC8 6.1 x 10-5
@GV5 4.8 x 10-5
@GV6 1.8 x 10-5
@B1 2.6 x 10-5
REGEN 167°C

1700 1SD
P = 2.3 x 10-5
AUX @GV3 5.5 x 10-5
@BSC8 5.8 x 10-5
@GV5 4.6 x 10-5
@GV6 1.7 x 10-5
@B1 2.5 x 10-5
REGEN OFF ON OVERTEMP
RESTARTED

5-14
900 30° Delta (20° Delta alarm)
P = 2.2 x 10-5
THIGH = 160°C

LBM6

5-14-98 150
0930 P=2.2x10^-5
AUX @GV3 5.1x10^-5
@BSC8 5.0x10^-5
@GV5 4.2x10^-5
@GV6 1.4x10^-5
@B1 2.3x10^-5
REGEN 161°C

1230 START RAMP DOWN
P=2.1 x10^-5
AUX @GV3 5.0x10^-5
@BSC8 4.9x10^-5
@GV5 4.1x10^-5
@GV6 1.4x10^-5
@B1 2.3 x10^-5
REGEN 161°C
1330 144
P= 1.8 x10^-5
AUX @ GV3 4.9x10^-5
@BSC8 4.4 x10^-5
@GV5 3.6 x10^-5
@GV6 1.3x10^-5
@B1 2.0 x10^-5
REGEN 161°C
5-15-98 111
P= 7.7 x10^-6
AUX @GV3 3.8x10^-5
@BSC8 1.6 x10^-5
@GV5 1.6 x10^-5
@GV6 5.5 x10^-6
@B1 7.2 x10^-6
REGEN 158°C

LBM7

5-15-98
1500 98
P = 4.3 x 10^-5
AUX @ GV3 3.8 x 10^-5
@ BSC8 1.0 x 10^-5
@ GV5 1.0 x 10^-5
@ GV6 3.8 x 10^-6
@ B1 4.4 x 10^-6
REGEN OFF

Sat. 5/16/98 SET POINT = 57°C
1129
$P_{c/c}$ = 8.1 x 10^-7 Torr } MAIN TURBO
P_{GH_3} = 8.4 x 10^-3 Torr
B1 = 9.5 x 10^-7 Torr
GV3 = 3.2 x 10^-5 Torr
BSC8 = 2.2 x 10^-6 Torr
GV5 = 2.5 x 10^-6 Torr
GV6 = 1.0 x 10^-6 Torr
ANAFAZE P = 5.1 x 10^-7 T = 150°C, ch 1-4

DIAGONAL MAIN TURBO P = 3.6 x 10^-7

LEFT MANIFOLD ~~BAKE~~ COMPLETE

5/16/98 Shut down bakeout carts
1525 SET point = 49°C
$P_{c/c}$ = 5.8 x 10^-7 Torr
B1 = 7.2 x 10^-7 Torr
GV3 = 3.1 x 10^-5
BSC8 = 1.6 x 10^-6
GV5 = 1.9 x 10^-6

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT

5.6 Ultimate Pressure Test (After Bake-Out) – Left Beam Manifold

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

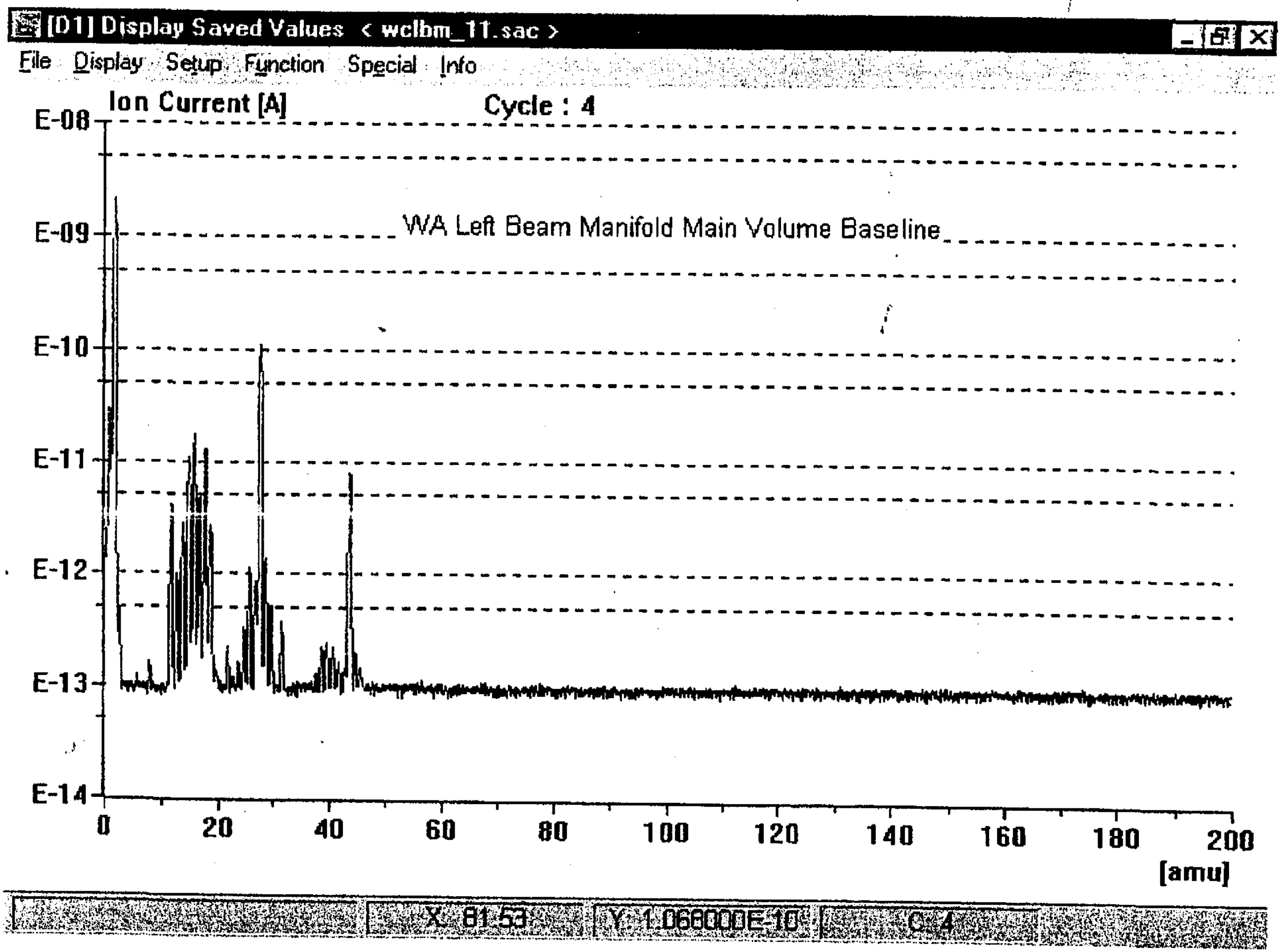
Date: 05/25/98
Test ID: WCLBM
PSI Engineer: S.Motew

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	-	-	8.26	2.20E-09	1.82E-08
16	0.57	1.60		1.80E-11	1.00E-10
18	0.64	1.12		1.30E-11	1.09E-10
28	-	-	11 80	1.10E-10	1.30E-09
44	1.57	1.42		8.20E-12	8.53E-11
all others	-	-	11 80	3.08E-11	3.63E-10

		LIGO Contract Limits	Actual	Pass
Primary Criteria -	Total Pressure:	2.00E-08 Torr	2.01E-08 Torr	yes
Secondary Criteria -	Others except H_2 & H_2O:	3.00E-09 Torr	1.85E-09 Torr	yes

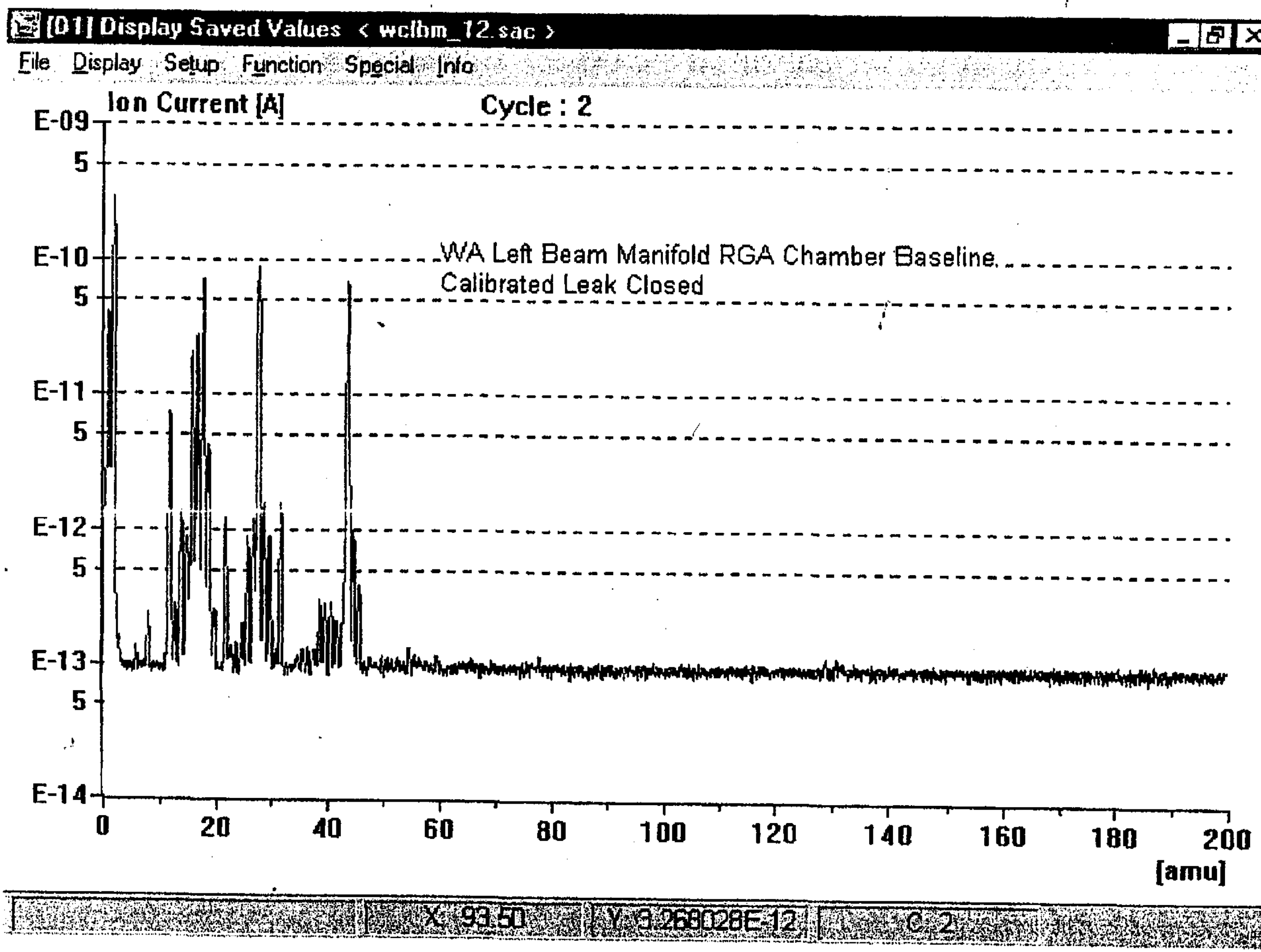
LIGO: John Worden

PSI: SMotew 5/25/98


[D1] Display Saved Values < wclbm_11.sac >
File Display Setup Function Special Info
Ion Current [A]
Cycle : 4
WA Left Beam Manifold Main Volume Baseline
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: 81.53
Y: 1.068000E-10
C: 4

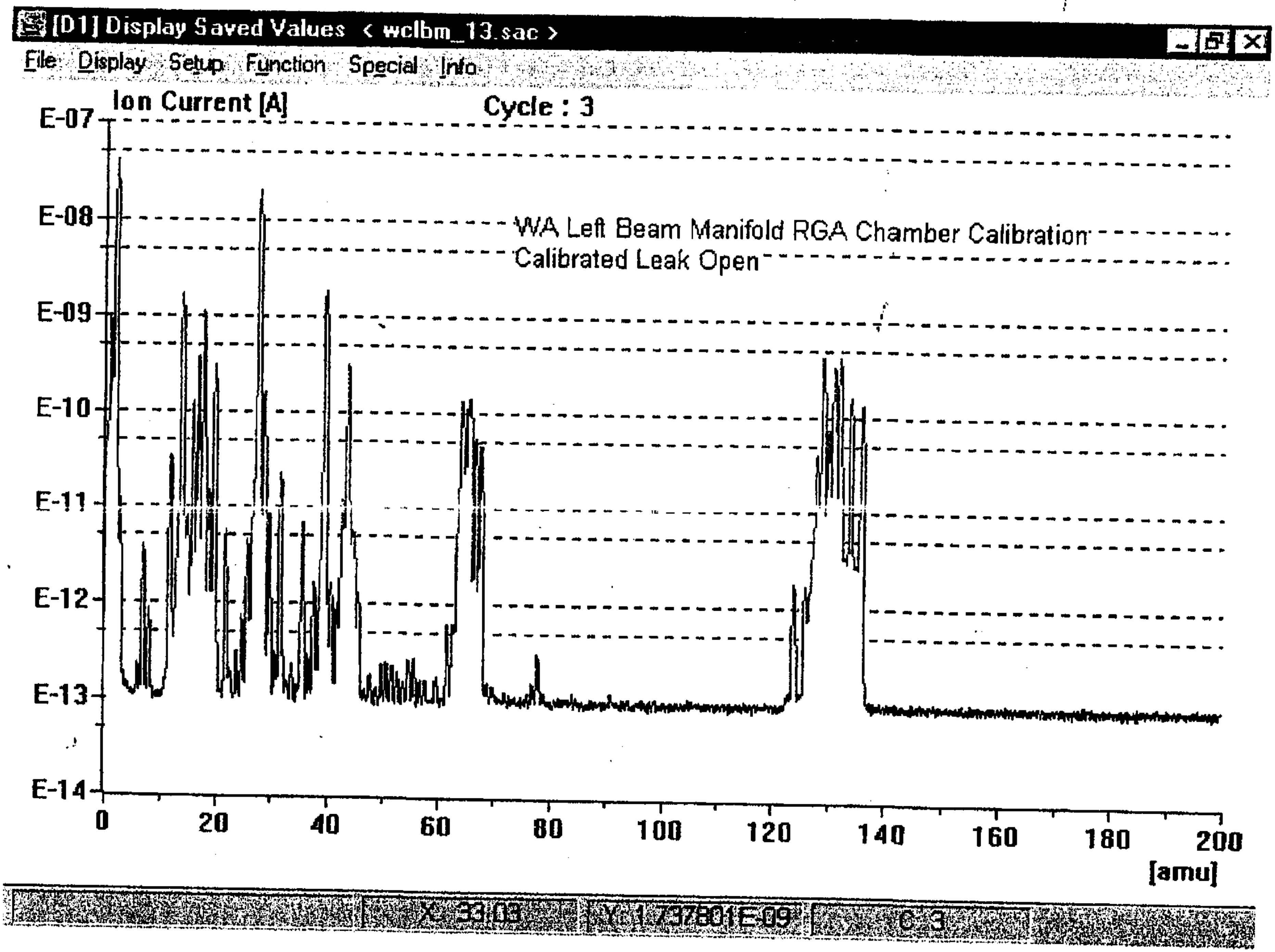
64

dm 5/25/98


[01] Display Saved Values < wclbm_12.sac >
File Display Setup Function Special Info
Ion Current [A]
Cycle : 2
E-09
5
E-10
5
E-11
5
E-12
5
E-13
5
E-14
WA Left Beam Manifold RGA Chamber Baseline.
Calibrated Leak Closed
0
20
40
60
80
100
120
140
160
180
200
[amu]
X: 93.50
Y: 3.268028E-12
C: 2

65

dm 5/25/98


[D1] Display Saved Values < wclbm_13.sac >
File Display Setup Function Special Info
Ion Current [A]
Cycle : 3
E-07
E-08
E-09
E-10
E-11
E-12
E-13
E-14
WA Left Beam Manifold RGA Chamber Calibration
Calibrated Leak Open
0
20
40
60
80
100
120
140
160
180
200
[amu]
X: 33.03
Y: 1.737801E-09
C: 3

DM 5/25/98

66

Title: PROCEDURE FOR RGA FIELD CALIBRATION ON AN ISOLATABLE SECTION

TITLE	RGA CAL. CHAMBER PARTIAL PRESSURE DATA SHEET
DATE: 5/25/98	WA LEFT BEAM MANIFOLD
TIME:	
TEST I.D.: e.g. WBSC1_I	WCLBM_12 SAC WCLBM-13.SAC (RGA CHAMBER)
PSI TEST ENGINEER: [illegible]	

AMU	I_{amu} 12.SAC (Amp) CYCLE 2	Q_{amu_leak} Leak rate (Torr-L/s)	F_{amu} Transmission Factor wrt N_2	E_{amu} Ionization efficiency wrt N_2*	I_{leak} 13.SAC (Amp) Cycle 3	S_{p_amu} (Torr/A)	P_{amu} (Torr)
H_2	3.0E-10	4.8x10^{-6}		0.46	4.2E-8	8.26	
He				0.18			
12			0.42				
14			0.5				
15			0.54				
CH_4			0.57	1.60			
17			0.6				
H_2O			0.64	1.12			
19			0.67				
26			0.71				
28	9.0E-11	9.5x10^{-7}		1.00	2.2E-8	11.8	
32			1.14	1.0			
38			1.36				
40	3.0E-13	9.4x10^{-8}		1.29	2.0E-9	15.1	
43			1.53				
44			1.57	1.42			
129	1E-13	2.2x10^{-8}		2.87	4.6E-10	27.6	
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				1.00			

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

SPECIFICATION

Number: V049-2-186 A — Rev.0

Title: PROCEDURE FOR RGA FIELD CALIBRAT ON ON AN ISOLATABLE SECTION

TITLE	RGA CAL. CHAMI ER PARTIAL PRESSURE DATA SHEET
DATE: 5/25/98	WA LEFT BEAM MANIFOLD
TIME:	
TEST I.D.: e.g. WBSCI_1	WLBM-11.SAC LEFT BEAM MANIFOLD
PSI TEST ENGINEER: AM	

AMU	I_{amu} (Amp)	Q_{amu_leak} Leak rate (Torr-L/s)	F_{amu} Transmission Factor wrt N_2	E_{amu} Ionization efficiency wrt H_2*	I_{leak} (Amp)	S_{p_amu} (Torr/A)	P_{amu} (Torr)
✓ H_2	2.2E-9	4.8×10^{-6}		0.45		8.26	1.82×10^{-8}
He				0.13			
12	4.3E-12		0.42			11.8	3.2×10^{-11}
14	2.8E-12		0.5			11.8	2.3×10^{-11}
15	1.1E-11		0.54			11.8	9.6×10^{-11}
✓ CH_4	1.8E-11		0.57	1.6		11.8	1.0×10^{-10}
17	5.0E-12		0.6			11.8	4.5×10^{-11}
✓ H_2O	1.3E-11		0.64	1.1		11.8	1.1×10^{-10}
19	2.6E-12		0.67			11.8	2.5×10^{-11}
26	1.1E-12		0.71			11.8	9.6×10^{-12}
✓ 28	1.1E-10	9.5×10^{-7}		1.00		11.8	1.30×10^{-9}
32	3.7E-13		1.14	1.01		11.8	4.6×10^{-12}
38	—		1.36				
40	2.5E-13	9.4×10^{-8}		1.29		15.1	3.8×10^{-12}
43	—		1.53				
✓ 44	8.2E-12		1.57	1.42		11.8	8.5×10^{-11}
129	1E-13	2.2×10^{-8}		2.87		27.6	2.8×10^{-12}
131		1.8×10^{-8}		2.87			
132		2.2×10^{-8}		2.87			
134		9.0×10^{-9}		2.87			
136		8.0×10^{-9}		2.87			
Other	3.4×10^{-12}			1.00		11.8	4.0×10^{-11}

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

27-8.5 E-13
29-1.4 E-12
30-5.0E-13
39-2.2E-13
41-2.3E-13
45-2.0E-13

TOT. PRESS = 2.0×10^{-8} Torr (OK)

TOT. PRESS LESS H_2 & H_2O
$= 2.00 \times 10^{-8} - 1.82 \times 10^{-8} - 1.1 \times 10^{-10}$
$= 1.69 \times 10^{-9}$ Torr. (OK)

SPECIFICATION

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

WA | LEFT BEAM MAN | RGA CALIBRATION | 5/25/98 DM | ①

WCLBM-11.SAC , WCLBM-12.SA:

$$S_{H_2} = \frac{(4.8 \times 10^{-6})\ \text{Torr-}\ell/s}{(13.93)(4.2 \times 10^{-8} - 3.0 \times 10^{-10})\ \ \ell/s\cdot\text{AMPS}}$$

$$= 8.26\ \frac{\text{Torr}}{\text{AMP}}$$

$$S_{N_2} = \frac{9.5 \times 10^{-7}}{(3.673)(2.2 \times 10^{-8} - 9 \times 10^{-11})}$$

$$= 11.8\ \frac{\text{Torr}}{\text{AMP}}$$

$$S_{Ar} = \frac{9.4 \times 10^{-8}}{(3.673)\sqrt{\frac{28.78}{40}}\,(2.0 \times 10^{-9} - 3.0 \times 10^{-13})}$$

$$= 15.1\ \frac{\text{Torr}}{\text{AMP}}$$

$$S_{Xe,129} = \frac{2.2 \times 10^{-8}}{(3.673)\sqrt{\frac{28.78}{129}}\,(4.\ \times 10^{-10}\ \ 1 \times 10^{-13})}$$

$$= 27.6\ \frac{\text{Torr}}{\text{AMP}}$$

22-141 50 SHEETS
22-142 100 SHEETS
22-144 200 SHEETS
AMPAD

LEFT BEAM MAN. 5/25/98 Dm ②

CH_4 : $\frac{1.8 \times 10^{-11} (0.57)}{1.6} (11.8) \left(\sqrt{\frac{28}{16}}\right)$

$= 1.0 \times 10^{-10}$ Torr

H_2O : $\frac{1.3 \times 10^{-11} (.64)}{1.12} (11.8) \left(\sqrt{\frac{28}{18}}\right)$

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

CO_2 $\frac{8.2 \times 10^{-12}}{1.42} (1.57) (11.8) \left(\sqrt{\frac{28}{44}}\right)$

$= 8.5 \times 10^{-11}$

AMU

12 : $\frac{(4.3 \times 10^{-12}) (.42)}{1.0} (11.8) \sqrt{\frac{28}{12}}$

$= 3.2 \times 10^{-11}$ Torr

14 : $\frac{(2.8 \times 10^{-12})}{1.0} (.5) (11.8) \sqrt{\frac{28}{14}}$

$= 2.3 \times 10^{-11}$

15 : $\frac{1.1 \times 10^{-11}}{1.0} (.54) (11.8) \sqrt{\frac{28}{15}}$

$= 9.6 \times 10^{-11}$

LEFT BEAM MAN. | 5/25/98 AM | (3)

AMU

17 $\frac{(5.0\times10^{-12})}{1.0}(.6)(11.8)\sqrt{\frac{28}{17}}$

$= 4.5\times10^{-11}$ Torr

19 $\frac{(2.6\times10^{-12})}{1.0}(.67)(11.8)\sqrt{\frac{28}{17}}$

$= 2.5\times10^{-11}$ Torr

26 $\frac{(1.1\times10^{-12})}{1.0}(.71)(11.8)\sqrt{\frac{28}{26}}$

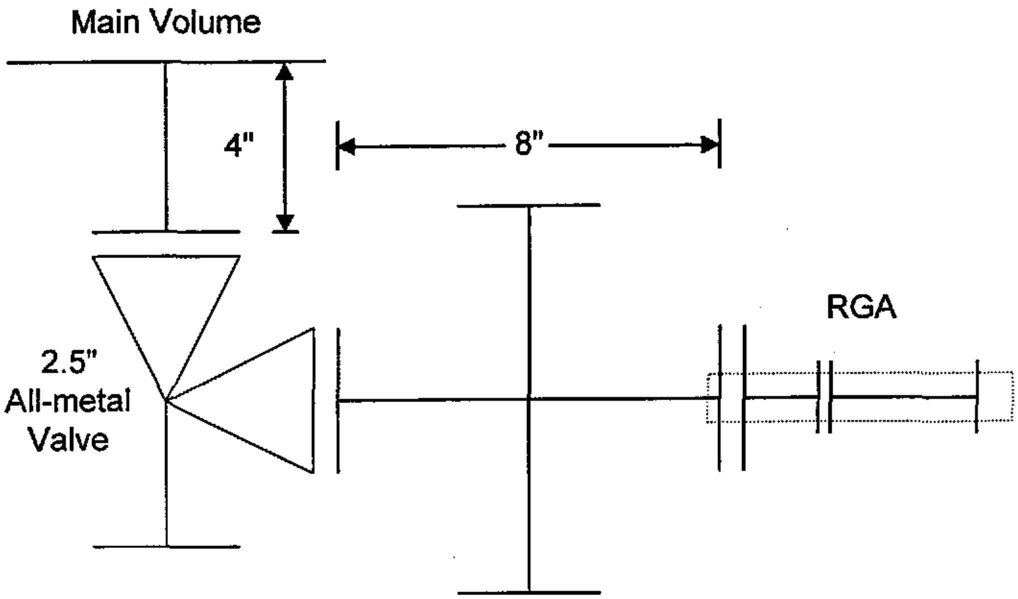
$= 9.6\times10^{-12}$ Torr

32 $\frac{(3.7\times10^{-13})}{1.01}(1.14)(11.8)\sqrt{\frac{28}{32}}$

= Torr

22-141 50 SHEETS
22-142 100 SHEETS
22-144 200 SHEETS
AMPAD

Conductance Calculation for RGA Calibration Chamber



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:

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

{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*).

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT

5.7 Backfill/100 Hr. Pumpdown Test – Left Beam Manifold

Not performed (N/A).

Not necessary according to John W.

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT

5.8 LN2 Consumption Test – Left Beam Manifold

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

V049-6.2-91

LIQUID NITROGEN CONSUMPTION TEST
Ref. Spec. V049-2-205

Station	WA. CORNER	**Cryopump** WCP1		
Test	Start	Finish		
Date	6/17/98	6/26/98		
Time	1300	1530		
Storage Tank	WDW1			
17263	gallons total volume			
16440	gallons at full trycock			
16440 x 0.95 =	15618	usable gallons		
360	in.H2O level indication at full trycock			
45.67	gallons / in.H2O			
Results				
Starting level=	179	in.H2O		
Ending level=	150	in.H2O		
Duration=	218.5	Hours		
Liquid consumed=	1324.3	gallons		
Tank pressure=	15	psig		
Ave.consumption for test duration=			6.06	gal/hour
Projected duration for usable gallons=			**107.4**	days
Projected duration to empty tank =			**113.0**	days

PSI [signature]

LIGO [signature]

375
TANK PRESS. 16

WCP I

DATE & TIME	PUMP PRESS	PUMP LEVEL	DEWAR LEVEL	WIP5	WIP7	WIP8
7/17 1300	.5	91.8	179"	3.6×10^{-5}	3.3×10^{-5}	3.3×10^{-5}
				5.4×10^{-5}	4.8×10^{-5}	4.7×10^{-5}
7/18 1000	.5	92.2	175"	5.4×10^{-5}	5.0×10^{-5}	5.6×10^{-5}
					5.8×10^{-5}	5.6×10^{-5}
7/18 1530	.2	94.1	174"	6.2×10^{-5}	6.0×10^{-5}	6.5×10^{-5}
7/19 0800	.4	90.7	172"	1.3×10^{-4}	1.3×10^{-4}	1.4×10^{-4}
7/19 1600	.5	89.7	171"	2.8×10^{-4}	2.8×10^{-4}	2.8×10^{-4}
7/20 0900	1.2	92.3	170"	5.2×10^{-4}	5.2×10^{-4}	5.6×10^{-4}
7/20 1600	.5	94.3	169"	5.3×10^{-4}	5.6×10^{-4}	5.6×10^{-4}
7/21 1400	.4	93.7	166"	8.2×10^{-5}	8.2×10^{-5}	8.4 / 9.0 $\times 10^{-5}$
7/21 1800	.5	88.0	165"	1.7×10^{-4}	1.6×10^{-4}	1.7×10^{-4}
7/22 0800	.5	88.6	163"	4.2×10^{-4}	4.2×10^{-4}	4.5×10^{-4}
7/22 1430	.6	89.0	162"	4.6×10^{-4}	4.6×10^{-4}	4.7×10^{-4}
7/23 0630	.4	86.1	159"	2.7×10^{-4}	2.6×10^{-4}	2.7×10^{-4}
7/23 1530	.5	92.8	158"	1.5×10^{-4}	1.5×10^{-4}	1.6×10^{-4}
7/24 0630	.4	92.1	157"	6.5×10^{-5}	6.2×10^{-5}	6.8 / 6.4 $\times 10^{-5}$
7/24 1500	.5	89.7	156"	5.4×10^{-5}	4.9×10^{-5}	5.6 / 5.2 $\times 10^{-5}$
7/25 0900	.5	93.0	154"	4.3×10^{-5}	4.0×10^{-5}	4.3×10^{-5}
7/25 1530	.5	93.9	153"	4.2×10^{-5}	3.9×10^{-5}	4.3×10^{-5}
7/26 1100	.6	87.8	151"	3.9×10^{-5}	3.6×10^{-5}	3.9×10^{-5}
7/26 1530	.5	90.5	150"	3.9×10^{-5}	3.6×10^{-5}	3.9×10^{-5}

6. ACCEPTANCE TEST RESULTS – DIAGONAL SECTION

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

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT

6.1 Interface To CDS – Diagonal Section

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

6.2 Clean Air System Test – Diagonal Section

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

All test results met or exceeded the requirements.

V049-2-109 ATT 1 REV 1

LIGO VACUUM EQUIPMENT ACCEPTANCE TEST DATA/TEST VERIFICATION Equip. Tag_____ S/N_____________

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				
DEWPOINT	5.2	-60C / -69.C			Sm 3/27/98
Particle Count	5.2	100. PART/FT3 REQ 0.0 PART/FT3 MEAS	0.5 M		Sm 3/27/98
HYDROCARBON CONTENT	5.2	0.0 PPM			Sm 3/27/98

WASH. CORNER CLEAN AIR SYS.

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT

6.3 Class 100 Cleanroom Test – Diagonal Section

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

All test results met or exceeded the requirements.

See Vertex Section 8.3 for details.

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT

6.4 System Leak Check – Diagonal Section

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-Westborough

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.

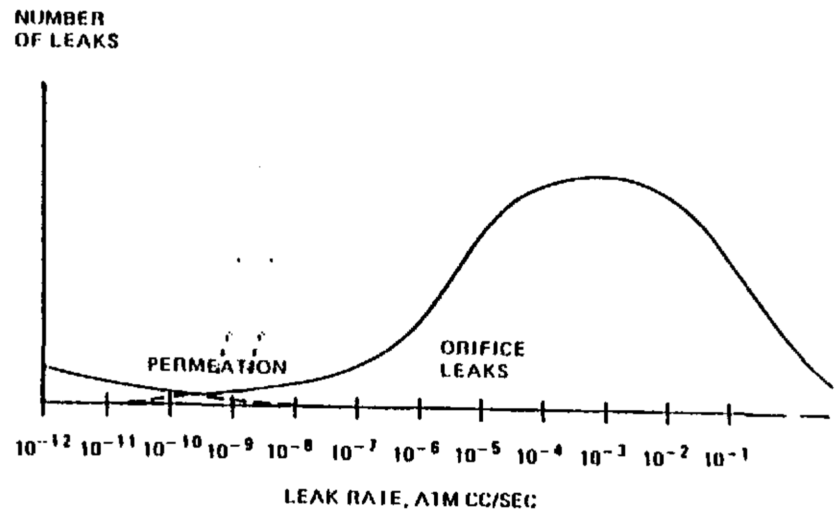


Figure 11.1 Typical distribution of leaks encountered in industrial products.

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

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

LEAK TEST DATA SHEET – FIELD TESTS

	1	2	3
Component Name	WASH DIAG.	ANNULAR PIPE	EQUIP
Model Number			
Serial Number			
Drawing Number			
Detector Name	BALZERS	BALZERS	BSC4
Model Number	HLT 160 DRY	HLT 160 DRY	HAM 7,8,9,10,11,12
Serial Number	03	03	A6A
			A6B
~~Detector~~ Calibration		INT CAL ONLY	B2A
Expiration Date	H2-98		B2B
Standard Leak Rate	4.53X10-9		B6
Background	NA		B7
Standard Response	4.6X10-9	CF 1.2	BE3A2
			BE3C
Leak Test Data			
Location /Date	WASH 5-6-98	5-6-98	
Tracer Gas	HE	HE	
Pressure CC GHI	6.3X10-7	LESS THAN 1X10-5	
Duration		PER ANNULAS	
Response	NTL EVAC + SPRAY	SPACE	
	X10-9 SCALE		
Leak Rate			
Measured	NTL X10-9 SCALE		
Calculated			
Allowable			
Performed By D.H	Date :		
Witnessed By :	Date :		
Signature [signature]	Date : 5-6-98	5-6-98	
Title : PROD TECH III			

Remarks :

SPECIFICATION	
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WASHINGTON SITE CORNER STATION
PSI FACTORY LEAK TEST DATA SHEETS
DIAGONAL SECTION

Tag No.	*Serial No.*
WBSC 4	06
WHAM 7	11
WHAM 8	06
WHAM 9	08
WHAM 10	09
WHAM 11	10
WHAM 12	12
WA6A	01
WA6B	02
WB2A	01
WB2B	01
WB6	01
WB7	01
WBE3A2	02
WBE3C	02

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

LEAK TEST DATA SHEET

	1	2	3
Component Name	AC-BG		
Model Number			
Serial Number	01		
Drawing Number			
Detector Name	BALZERS		
Model Number	HLT 160		
Serial Number	3137944-007		
Detector Calib.Date	5-28-97		
Detector Calib.Factor	1.0		
Standard Leak Rate	4.4x10-9		
Std.Leak Expir.Date	6-27-97		
Standard Response	4.6x10-9		
Leak Test Data			
Location /Date			
Tracer Gas	HE		
Pressure @ Turbo Inlet	[illegible]		
Duration	15 MIN		
Response	1x10-9		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : DH.	Date : 5-28-97		
Witnessed By :	Date :		
Signature [signature]	Date : 5-28-97		
Title :			

Remarks : LEAK RATE LESS THAN 1x10-9 15 MIN BAG TEST

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	A6-B7 Spool		
Model Number			
Serial Number	01		
Drawing Number			
Detector Name	BALZERS		
Model Number	HLT 160		
Serial Number	3137944-007		
Detector Calib.Date	5-20-97		
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			
Pressure @ Turbo Inlet			
Duration	20 min		
Response	1x10-9		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : D. H.	Date : 5-20-97		
Witnessed By :	Date :		
Signature [signature]	Date : 5-20-97		
Title :			

Remarks :

SPECIFICATION

Number: V049-2-014 A | p2

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

SPOOL ~~VESSEL(BSC/HAM)~~ LEAK TEST SUMMARY SHEET

Name	AG-B7						
Model No.							
Serial No.	02						
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		$4x10^{-5}$	✓		[signature]	5-5-20-97
	II		NDL (10^{-9} Scale)	✓		[signature]	5-20-97
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 20 MIN BAG TEST

Witnessed
Signature [signature]
Title
Date: 5-20-97

SPECIFICATION

Number: V049-2-014 A p2

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

SPOOL

~~VESSEL~~(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	A6-B6						
Model No.							
Serial No.							
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		$4x10^{-5}$	✓		[illegible]	5-28-97
	II		NDL (10^{-9} Scale)	✓		[illegible]	5-29-97
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 IS ON BAK TEST

Witnessed
Signature
Title
Date:

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	SPOOL		
Model Number	BE3 E		
Serial Number	02		
Drawing Number			
Detector Name	BALZERS		
Model Number	HLT 160 DRY		
Serial Number	3		
Detector Calib.Date	7-30-98		
Detector Calib.Factor			
Standard Leak Rate	NOT USED		
Std.Leak Expir.Date			
Standard Response			
Leak Test Data			
Location /Date	CLEAN ROOM / 7-30-98		
Tracer Gas	HE		
Pressure @ Turbo Inlet	6.0x10^-7		
Duration	30 min		
Response	NDL x10^-9 SCALE		
	EVACUATE + SPRAY		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : P.H.	Date :		
Witnessed By : D.H.	Date : 7.30.98		
Signature :	Date :		
Title :			

Remarks :

SPECIFICATION

Number: V049-2-014 A | p2

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	SPOOL						
Model No.	BE3						
Serial No.	02						
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		$4x10^{-5}$	✓		[signature]	7-30-99
	II		NDL (10^{-9} Scale)	✓			
						[signature]	7-30-99
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments

Witnessed
Signature
Title
Date:

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

LEAK TEST DATA SHEET

	1	2	3
Component Name	WHAM7		
Model Number			
Serial Number	11		
Drawing Number			
Detector Name	BALZERS		
Model Number	HLT160		
Serial Number	#1		
Detector Calib.Date	7-30-97		
Detector Calib.Factor	1.0		
Standard Leak Rate			
Std.Leak Expir.Date			
Standard Response			
Leak Test Data			
Location /Date	Flanders / 7-30-97		
Tracer Gas	He		
Pressure @ Turbo Inlet	9.7x10-7		
Duration	3.25 hours		
Response	NDL 10-9 range		
	EVAC + SPRAY		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : Paul Tatro	Date : 7-30-97		
Witnessed By : DH	Date : 7-30-97		
Signature : Paul Tatro (JF)	Date : 7-30-97		
Title :			

Remarks :

SPECIFICATION	
Number: V049-2-014 A	p2

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	WHAM7						
Model No.							
Serial No.	11						
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr	✓			
	IV-V		$4x10^{-5}$	✓		Paul Tatro (JF)	7-30-97
	II		NDL (10^{-9} Scale)	✓		Paul Tatro (JF)	7-30-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments P=1.2x10-5

Witnessed
Signature
Title
Date:

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	WHAM8		
Model Number			
Serial Number	6		
Drawing Number			
Detector Name	BALZERS		
Model Number	HLT160		
Serial Number	#1		
Detector Calib.Date	8-12-97		
Detector Calib.Factor	1.0		
Standard Leak Rate			
Std.Leak Expir.Date			
Standard Response			
Leak Test Data			
Location /Date	Flanders / 8-12-97		
Tracer Gas	He		
Pressure @ Turbo Inlet	1 x 10-6		
Duration	4 hours		
Response	NDL 10-9 scale		
	evac. + spray		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : Paul Tatro	Date : 8-12-97		
Witnessed By :	Date :		
Signature : Paul Tatro	Date : 8-12-97		
Title : (JF)			

Remarks :

SPECIFICATION	
Number: V049-2-014 A	p2

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	WHAM8						
Model No.							
Serial No.	6						
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		$4x10^{-5}$	✓		D.H/J.F	8-19-97
	II		NDL (10^{-9} Scale)	✓		D.H./J.F	8-19-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments metal chip found on Oring (caused a 10^{-3} leak)
replace oring & retest on 8-19-97

Witnessed
Signature
Title
Date:

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	WHAM9		
Model Number			
Serial Number	8		
Drawing Number			
Detector Name	Balzers		
Model Number	HLT160		
Serial Number	#1		
Detector Calib.Date	8-29-97		
Detector Calib.Factor	1.1		
Standard Leak Rate			
Std.Leak Expir.Date			
Standard Response			
Leak Test Data			
Location /Date	Flanders		
Tracer Gas	He		
Pressure @ Turbo Inlet	8.2×10^{-8}		
Duration	2 hours		
Response	NDL 10^{-9} scale		
	evac. & spray		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : Ed Rolfes	Date : 8-29-97		
Witnessed By : DH	Date : 8-29-97		
Signature : Ed Rolfes (JF)	Date : 8-29-97		
Title :			

Remarks :

SPECIFICATION

Number: V049-2-014 A | p2

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	WHAM9						
Model No.							
Serial No.	8						
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		$4x10^{-5}$	✓		Ed Rolfes	8-22-97
	II		NDL (10^{-9} Scale)	✓		Ed Rolfes	8-22-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments $P=1.6\times10^{-5}$

Witnessed
Signature
Title
Date:

SPECIFICATION

Number: V049-2-014 A | p2

LEAK TEST DATA SHEET

	1	2	3
Component Name	WB2A		
Model Number			
Serial Number	1		
Drawing Number			
Detector Name	Balzers		
Model Number	HLT160		
Serial Number	2		
Detector Calib.Date			
Detector Calib.Factor			
Standard Leak Rate	4.8×10^{-9} std cc/s		
Std.Leak Expir.Date			
Standard Response	4 min / 7-14-97		
Leak Test Data			
Location /Date	clean weld room / 7-14-97		
Tracer Gas	He		
Pressure @ Turbo Inlet	5.6×10^{-8}		
Duration	4 hours		
Response	NDL 10^{-9} scale		
	evac & spray		
Leak Rate			
Measured			
Calculated			
Allowable P.H.			
Performed By : Don Hillier	Date : 7-14-97		
Witnessed By :	Date :		
Signature : Don Hillier (JA)	Date : 7-14-97		
Title :			

Remarks :

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	WB2A						
Model No.							
Serial No.	1						
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		$4x10^{-5}$	✓		Paul Harrison D.H	7-14-97
	II		NDL (10^{-9} Scale)	✓		Paul Harrison D.H	7-14-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments

Witnessed
Signature
Title
Date:

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	WB2B		
Model Number			
Serial Number	1		
Drawing Number			
Detector Name	Balzers		
Model Number	HLT160		
Serial Number	2		
Detector Calib.Date	7-18-97		
Detector Calib.Factor	1.0		
Standard Leak Rate			
Std.Leak Expir.Date			
Standard Response			
Leak Test Data			
Location /Date	Clean weld room / 7-19-97		
Tracer Gas	He		
Pressure @ Turbo Inlet	1.5×10^{-6}		
Duration	2.5 hours		
Response	NDL 10^{-9} range		
	revac. & spray		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : D. Hillier	Date : 7-19-97		
Witnessed By : (JF)	Date :		
Signature : D. Hillier	Date : 7-19-97		
Title : (JF)			

Remarks :

SPECIFICATION

Number: V049-2-014 p2

A

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	WB2B						
Model No.							
Serial No.	1						
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		$4x10^{-5}$	✓		D. Hillier (JF)	7-19-97
	II		NDL (10^{-9} Scale)	✓		D. Hillier (JF)	7-19-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments

Witnessed
Signature
Title
Date:

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

LEAK TEST DATA SHEET

	1	2	3
Component Name	WBE3A2 w/ BE3A1		
Model Number			
Serial Number	02		
Drawing Number			
Detector Name	Balzers		
Model Number	HLT160		
Serial Number	3		
Detector Calib.Date	8-16-97		
Detector Calib.Factor	1.2		
Standard Leak Rate			
Std.Leak Expir.Date			
Standard Response			
Leak Test Data			
Location /Date	clean weld room / 8-16-97		
Tracer Gas	He		
Pressure @ Turbo Inlet	4.8x10⁻⁷		
Duration	2.33 hrs		
Response	NDL 10⁻⁹ scale		
	evac. & spray		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : D.H.	Date : 8-16-97		
Witnessed By : D.H.	Date : 8-16-97		
Signature : Dan Hillier	Date : 8-16-97		
Title : (JF)			

Remarks :

SPECIFICATION

Number: V049-2-014 A | p2

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	WBE3A2						
Model No.							
Serial No.	02						
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		$4x10^{-5}$	✓		D. Hillier	8-20-97
	II		NDL (10^{-9} Scale)	✓		D. Hillier (JF)	8-20-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments

Witnessed
Signature
Title
Date:

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	WHAM10		
Model Number			
Serial Number	9		
Drawing Number			
Detector Name	Balzers		
Model Number	HLT160		
Serial Number	1		
Detector Calib.Date	8-26-97		
Detector Calib.Factor	1.1		
Standard Leak Rate			
Std.Leak Expir.Date			
Standard Response			
Leak Test Data			
Location /Date	cleanroom / 8-22-97		
Tracer Gas	He		
Pressure @ Turbo Inlet	3.5×10^{-7}		
Duration	1.5 hr		
Response	NDL 10^{-9} range		
	evac & spray		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : D Hiller Date : 8-26-97			
Witnessed By : (JF) Date :			
Signature : D. Hiller Date : 8-26-97			
Title :			

Remarks :

SPECIFICATION	
Number: V049-2-014 A	p2

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	WHAM10						
Model No.							
Serial No.	9						
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr	✓			
	IV-V		$4x10^{-3}$	✓		Ed Rolfes	8-27-97
	II		NDL (10^{-9} Scale)	✓		Ed Rolfes	8-27-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments
HLT#3 CF 1.2

Witnessed
Signature
Title
Date:

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

LEAK TEST DATA SHEET

	1	2	3
Component Name	WHAM11		
Model Number			
Serial Number	10		
Drawing Number			
Detector Name	Balzers		
Model Number	HLT160		
Serial Number	#3		
Detector Calib.Date	9-9-97		
Detector Calib.Factor	2.1		
Standard Leak Rate			
Std.Leak Expir.Date			
Standard Response			
Leak Test Data			
Location /Date	oven / 9-9-97		
Tracer Gas	He		
Pressure @ Turbo Inlet	1.6×10^{-2}		
Duration	3 hours		
Response	NDL 10^{-9} scale		
	evac & spray		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : D. Hillier	Date : 9-9-97		
Witnessed By : (JF)	Date :		
Signature : Don Hillier	Date : 9-9-97		
Title :			

Remarks :

SPECIFICATION	
Number: V049-2-014 A	p2

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	WHAM11						
Model No.							
Serial No.	10						
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		$4x10^{-5}$	✓		D. Hillier	9-9-97
	II		NDL (10^{-9} Scale)	✓		(JP) D. Hillier	9-9-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments

Witnessed
Signature
Title
Date:

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	WHAM 12		
Model Number			
Serial Number	12		
Drawing Number			
Detector Name	Balzers		
Model Number	HLT 160		
Serial Number	|		
Detector Calib.Date	9-5-97		
Detector Calib.Factor	2.2		
Standard Leak Rate			
Std.Leak Expir.Date			
Standard Response			
Leak Test Data			
Location /Date	clean weld room / 9-4-97		
Tracer Gas	He		
Pressure @ Turbo Inlet	3.4×10^{-7}		
Duration	4 hours		
Response	NDL 10^{-9} range		
	(evac + spray)		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : D. Hillier	Date : 9-5-97		
Witnessed By : (JF)	Date :		
Signature : Don Hillier	Date : 9-5-97		
Title :			

Remarks : FINISHED IN OVEN ON 9-9-97

SPECIFICATION

Number: V049-2-014 A | p2

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	WHAM12						
Model No.							
Serial No.	12						
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		$4x10^{-5}$	✓		D Hillier	9-8-97
	II		NDL (10^{-9} Scale)	✓		D Hillier	9-6-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments leak found & repaired

Witnessed
Signature
Title
Date:

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	BSC4 w/A15B		
Model Number			
Serial Number	6		
Drawing Number			
Detector Name	Balzers		
Model Number	HLT160		
Serial Number	3		
Detector Calib.Date	8-8-97		
Detector Calib.Factor	1.3		
Standard Leak Rate	4.5x10-9		
Std.Leak Expir.Date			
Standard Response	5 min		
Leak Test Data			
Location /Date	Clean room / 8-6-97		
Tracer Gas	He		
Pressure @ Turbo Inlet	1x10-6		
Duration	6 hours		
Response	NDL 10-9 scale		
	evac + spray		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : P. Tatro	Date : 8-8-97		
Witnessed By : D. Hillier	Date:		
Signature : Dan Hillier	Date : 8-8-97		
Title :			

Remarks :

SPECIFICATION	
Number: V049-2-014 A	p2

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	BSC4						
Model No.							
Serial No.	6						
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		$4x10^{-5}$	✓		Ed Rolfes	8-8-97
	II		NDL (10^{-9} Scale)	✓		Ed Rolfes	8-8-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments

Witnessed
Signature
Title
Date:

SPECIFICATION

Number: V049-2-014 A p2

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT

6.5 System Bake-Out – Diagonal Section

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

The bake-out passed the requirements since the ultimate pressure test was successfully completed.

D 1

DIAGONAL BAKE

6-3-98

1500 START SP=20 TURBO 1.4×10^{-6}

1700 SP=24 TURBO 1.1×10^{-6}

6-4-98

0900 SP=49°C TURBO 6.5×10^{-6}

AUX @ HAM 7 3.0×10^{-5}

@ GV4 5.7×10^{-5}

@ HAM 9 1.4×10^{-4}

@ HAM 12 5.8×10^{-5}

@ HAM 10 4.2×10^{-4}

@ GV3 4.0×10^{-6}

15:30 SP=61°C TURBO 8.5×10^{-6}

AUX @ HAM 7 1.1×10^{-5}

@ GV4 5.4×10^{-5}

@ HAM 9 1.4×10^{-4}

@ HAM 12 3.1×10^{-5}

@ HAM 10 6.4×10^{-5}

@ GV3 7.2×10^{-6}

6-5-98

1100 SP=100 TURBO 2.1×10^{-5}

AUX @ HAM 7 5.7×10^{-5}

@ GV4 8.6×10^{-5}

@ HAM 9 1.8×10^{-4}

@ HAM 12 7.9×10^{-5}

@ HAM 10 GAUGE IS DEAD

@ GV3 1.8×10^{-5}

DZ

6-5-98

1330 SP=125 TURBO 2.1×10^{-5}
AUX @ HAM 7 5.6×10^{-5}
@ GV4 8.5×10^{-5}
@ HAM 9 1.7×10^{-4}
@ HAM 12 7.6×10^{-5}
@ HAM 10 DEAD GAUGE
@ GV3 2.0×10^{-5}

2000 SP = 120 TURBO 2.0×10^{-5}
AUX @ HAM 7 4.9×10^{-5}
@ GV4 8.0×10^{-5}
@ HAM 9 9.7×10^{-5}
@ HAM 12 6.2×10^{-5}
@ HAM 10 DEAD GAUGE
@ GV3 2.0×10^{-5}

6-6-98

0900 SP=127 TURBO 1.3×10^{-5}
AUX @ HAM 7 2.3×10^{-5}
@ GV4 4.7×10^{-5}
@ HAM 9 7.6×10^{-5}
@ HAM 12 3.6×10^{-5}
@ HAM 10 4.5×10^{-4}
@ GV3 1.9×10^{-5}
1400 SP= 136 TURBO 1.6×10^{-5}
AUX @ HAM 7 2.4×10^{-5}
@ GV4 4.6×10^{-5}
@ HAM 9 8.3×10^{-5}
@ HAM 12 3.4×10^{-5}
@ HAM 10 5.0×10^{-4}
@ GV3 2.0×10^{-5}

D3

2000 SP = 150 TURBO 2.3×10^{-5}
AUX @ HAM 7 2.6×10^{-5}
@ GV4 5.1×10^{-5}
@ HAM 9 9.5×10^{-5}
@ HAM 12 3.7×10^{-5}
@ HAM 10 6.3×10^{-4}
@ GV3 2.4×10^{-5}

6-7-98
1200 SP = 150 TURBO 1.9×10^{-5}
AUX @ HAM 7 2.4×10^{-5}
@ GV4 3.4×10^{-5}
@ HAM 9 6.4×10^{-5}
@ HAM 12 2.7×10^{-5}
@ HAM 10 3.1×10^{-4}
@ GV3 2.1×10^{-5}

1900 SP = 150 TURBO 1.8×10^{-5}
AUX @ HAM 7 2.3×10^{-5}
@ GV4 3.2×10^{-5}
@ HAM 9 6.0×10^{-5}
@ HAM 12 2.6×10^{-5}
@ HAM 10 2.9×10^{-4}
@ GV3 2.0×10^{-5}

6-8-98
0630 SP = 150 TURBO 1.6×10^{-5}
AUX @ HAM 7 2.8×10^{-5}
@ GV4 2.6×10^{-5}
@ HAM 9 5.3×10^{-5}
@ HAM 12 2.3×10^{-5}
@ HAM 10 2.1×10^{-4}
@ GV3 2.0×10^{-5}

D4

6-8-98
1200 SP=150 TURBO 1.6×10^{-5}
AUX @ HAM 7 2.1×10^{-5}
@ GV4 2.5×10^{-5}
@ HAM 9 5.2×10^{-5}
@ HAM 12 2.3×10^{-5}
@ HAM 10 2.0×10^{-4}
@ GV3 1.9×10^{-5}

1900 SP=150 TURBO 1.5×10^{-5}
AUX @ HAM 7 2.0×10^{-5}
@ GV4 2.4×10^{-5}
@ HAM 9 5.0×10^{-5}
@ HAM 12 2.2×10^{-5}
@ HAM 10 1.7×10^{-4}
@ GV3 1.9×10^{-5}
START RAMP DOWN

6-9-98
0730 SP=125 TURBO 6.2×10^{-6}
AUX @ HAM 7 1.3×10^{-5}
@ GV4 1.3×10^{-5}
@ HAM 9 2.3×10^{-5}
@ HAM 12 1.3×10^{-5}
@ HAM 10 6.7×10^{-5}
@ GV3 1.2×10^{-5}

1230 SP=115 TURBO 3.8×10^{-6}
AUX @ HAM 7 1.1×10^{-5}
@ GV4 1.0×10^{-5}
@ HAM 9 1.7×10^{-5}
@ HAM 12 1.0×10^{-5}
@ HAM 10 5.3×10^{-5}
@ GV3 9.2×10^{-6}

D5

1500 SP= 110 TURBO 3.1×10^{-6}
AUX @ HAM 7 9.7×10^{-6}
@GV4 9.6×10^{-6}
@HAM 9 1.5×10^{-5}
@HAM 12 9.4×10^{-6}
@HAM 10 4.8×10^{-5}
@GV3 9.0×10^{-6}

6-10-98
1000 SP= 93 TURBO 1.6×10^{-6}
AUX @ HAM 7 2.8×10^{-6}
@GV4 5.5×10^{-6}
@Ham 9 8.3×10^{-6}
@HAM 12 5.3×10^{-6}
@HAM 10 2.6×10^{-5}
@GV3 5.3×10^{-6}

1300 SP= 87 TURBO 1.2×10^{-6}
AUX @ HAM 7 1.7×10^{-6}
@GV4 4.5×10^{-6}
@HAM 9 7.4×10^{-6}
@HAM 12 4.3×10^{-6}
@HAM 10 2.3×10^{-5}
@GV3 4.8×10^{-6}

1430 SP= 84 TURBO 1.1×10^{-6}
AUX @HAM 7 3.1×10^{-6}
@GV4 4.0×10^{-6}
@Ham 9 6.7×10^{-6}
@HAM 12 4.0×10^{-6}
@HAM 10 2.1×10^{-5}
@GV3 4.4×10^{-6}

D6

6-11-98

900 SP. = 60°C

P_{GH1} = 3.5×10^{-7}

SYSTEM OFF

BAKE COMMENTS

1000 TURBO 3.1×10^{-7}

AUX @ HAM 7 1.4×10^{-6}

@ GV4 2.0×10^{-6}

@ HAM 9 2.6×10^{-6}

@ HAM 12 1.3×10^{-6}

@ HAM 10 8.3×10^{-6}

@ GV3 2.2×10^{-6}

1400 TURBO 1.6×10^{-7}

TURN ON WIP8

1445 TURBO 4.9×10^{-7}

VALVED OFF WIP8

TURN ON WIP7

1515 VALVED OFF WIP7

1600 TURBO 1.3×10^{-7}

6-12-98

815 P_{GH1} = 3.9×10^{-8}

BOTH I.P. @ 3000V + ~1×10^{-5} A

T ~77-47°C CONT'D

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT

6.6 Ultimate Pressure Test (After Bake-Out) – Diagonal Section

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

All test results met or exceeded the requirements.

Title: Partial Pressure Calculation for Left Beam Manifold and Diagonal Sections - 45 hours after opening WGV3
Date: 06/13/98
Test ID: WCLBM_D
PSI Engineer: J. Flinn

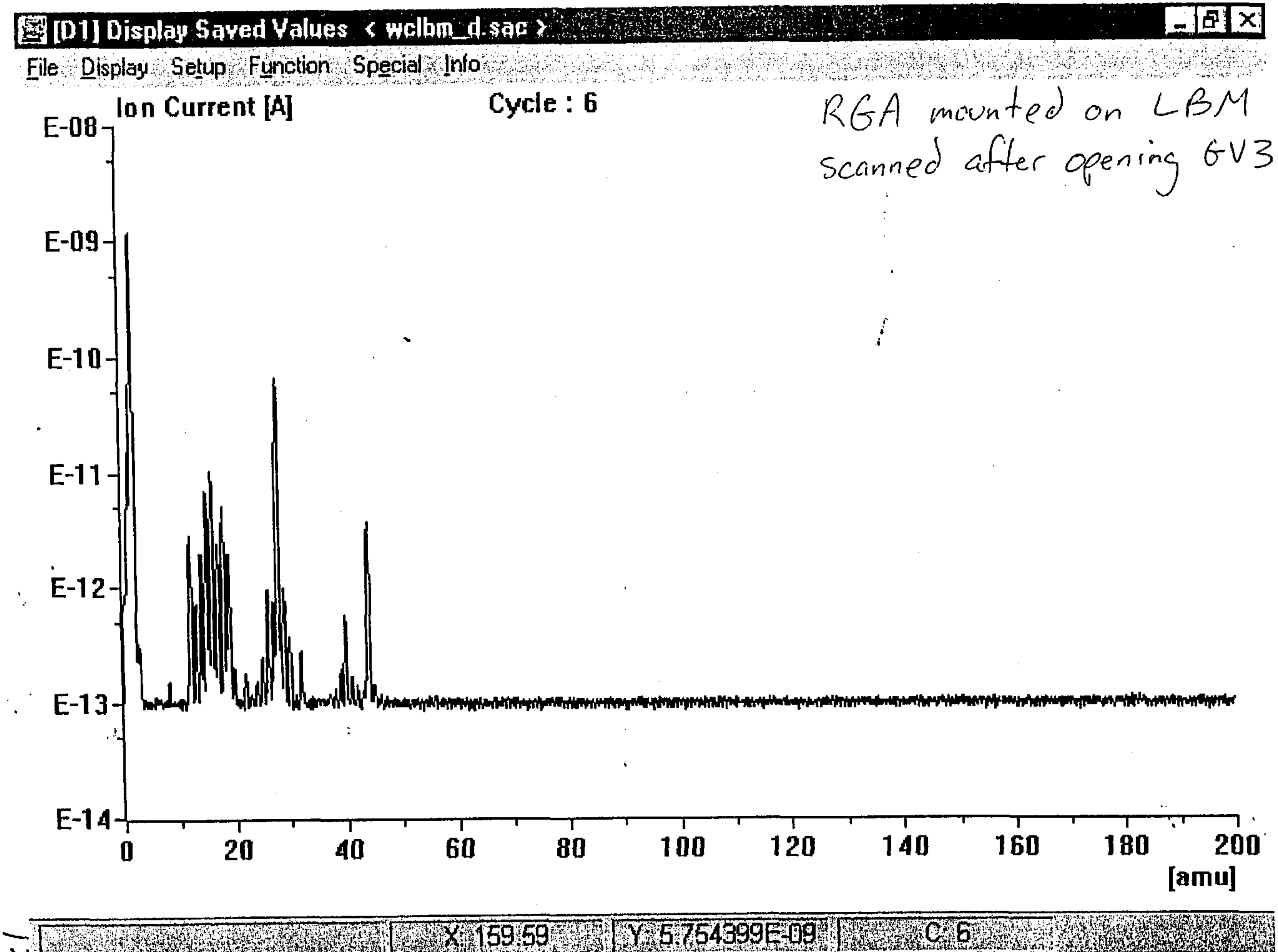
AMU	*F (amu)* transmission efficiency wrt N_2	*E (amu)* ionization efficiency wrt N_2	*S (p_amu)* sensitivity (Torr/A)	*I (amu)* ion current (A)	*PP (amu)* (Torr)
2	-	-	10.35	1.16E-09	1.20E-08
16	0.57	1.60		1.03E-11	8.15E-11
18	0.64	1.12		5.11E-12	6.11E-11
28	-	-	16.78	6.31E-11	1.06E-09
44	1.57	1.42		3.73E-12	5.52E-11
all others	-	-	16.78	5.06E-12	8.49E-11

Total Pressure =	1.33E-08

Partial Pressure and Air Signature Acceptance

LIGO: John Worden

PSI: ____________________


[D1] Display Saved Values < wclbm_d.sac >
File Display Setup Function Special Info
Ion Current [A]
Cycle : 6
RGA mounted on LBM
scanned after opening GV3
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: 159.59
Y: 5.754399E-09
C: 6

OTHERS FOR 45 HOURS ON LBM
FOR LBM & DIAG.

24	1.5×10^{-13}
25	2.4×10^{-13}
26	9.4×10^{-13}
27	7.3×10^{-13}
29	9.5×10^{-13}
30	3.6×10^{-13}
32	2.7×10^{-13}
[illegible]	[illegible]
38	1.3×10^{-13}
39	1.8×10^{-13}
40	5.5×10^{-12}
41	1.6×10^{-13}
42	1.4×10^{-13}
43	1.2×10^{-13}
45	1.4×10^{-13}

50.6×10^{-13}

Title: Partial Pressure Calculation for Left Beam Manifold and Diagonal Sections - 4.5 hours after opening WGV3
Date: 06/13/98
Test ID: WCLBM_D
PSI Engineer: J. Flinn

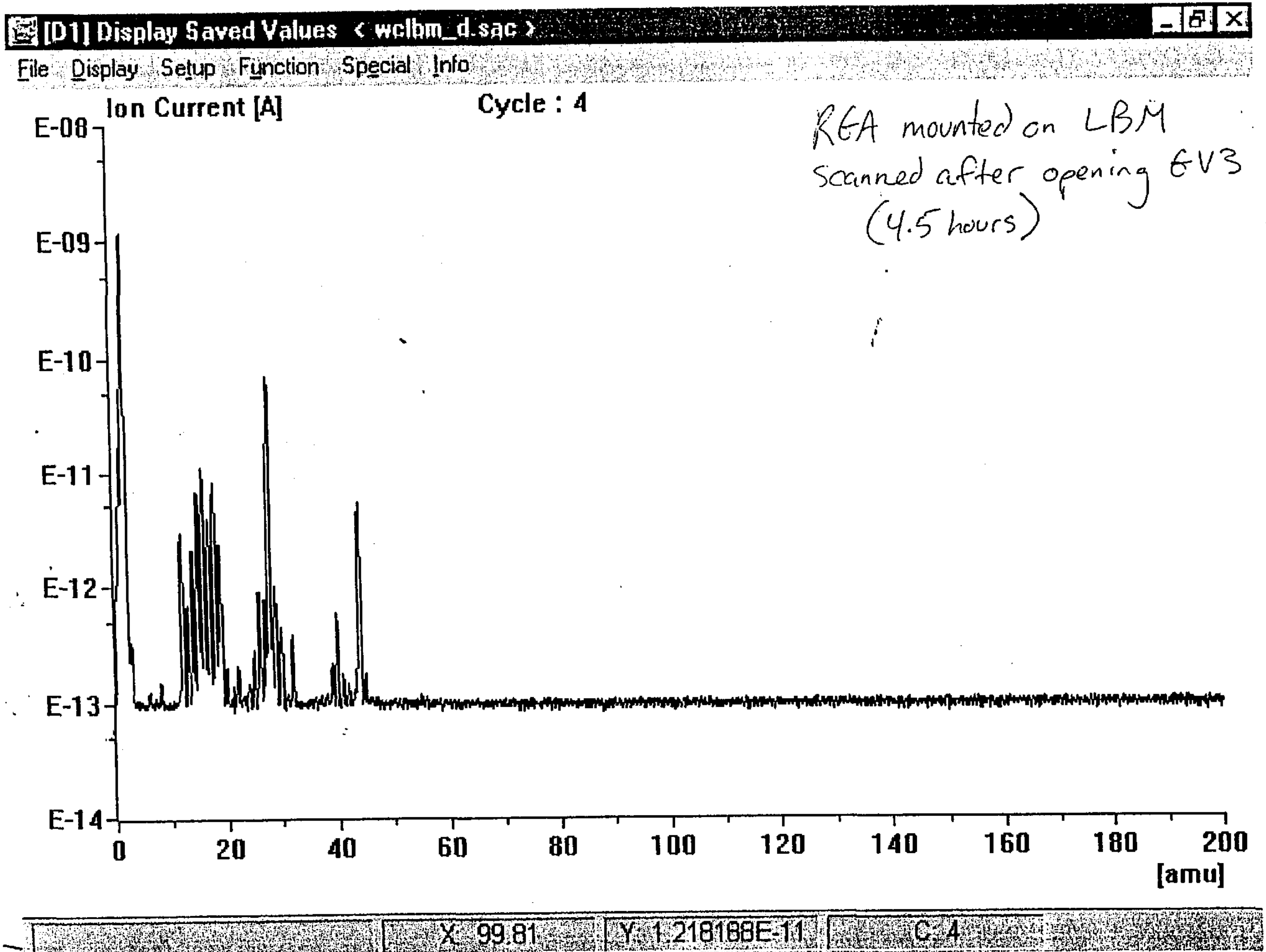
AMU	F (amu) transmission efficiency wrt N2	E (amu) ionization efficiency wrt N2	S (p_amu) sensitivity (Torr/A)	I (amu) ion current (A)	PP (amu) (Torr)
2	-	-	10.35	1.19E-09	1.23E-08
16	0.57	1.60		1.13E-11	8.94E-11
18	0.64	1.12		8.21E-12	9.82E-11
28	-	-	16.78	6.92E-11	1.16E-09
44	1.57	1.42		5.32E-11	7.87E-10
all others	-	-	16.78	1.00E-11	1.68E-10

Total Pressure =	1.46E-08

Partial Pressure and Air Signature Acceptance

LIGO: ______________________

PSI: ______________________


[D1] Display Saved Values < wclbm_d.sac >
File Display Setup Function Special Info
Ion Current [A]
Cycle : 4
RGA mounted on LBM
scanned after opening GV3
(4.5 hours)
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: 99.81
Y: 1.218188E-11
C: 4

125

Title: Partial Pressure Calculation for Left Beam Manifold and Diagonal Sections - 30 minutes after opening WGV3
Date: 06/13/98
Test ID: WCLBM_D
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	-	-	10.35	1.28E-09	1.32E-08
16	0.57	1.60		1.81E-11	1.43E-10
18	0.64	1.12		1.13E-11	1.35E-10
28	-	-	16.78	1.11E-10	1.86E-09
44	1.57	1.42		8.21E-12	1.22E-10
all others	-	-	16.78	1.00E-11	1.68E-10

Total Pressure =	1.57E-08

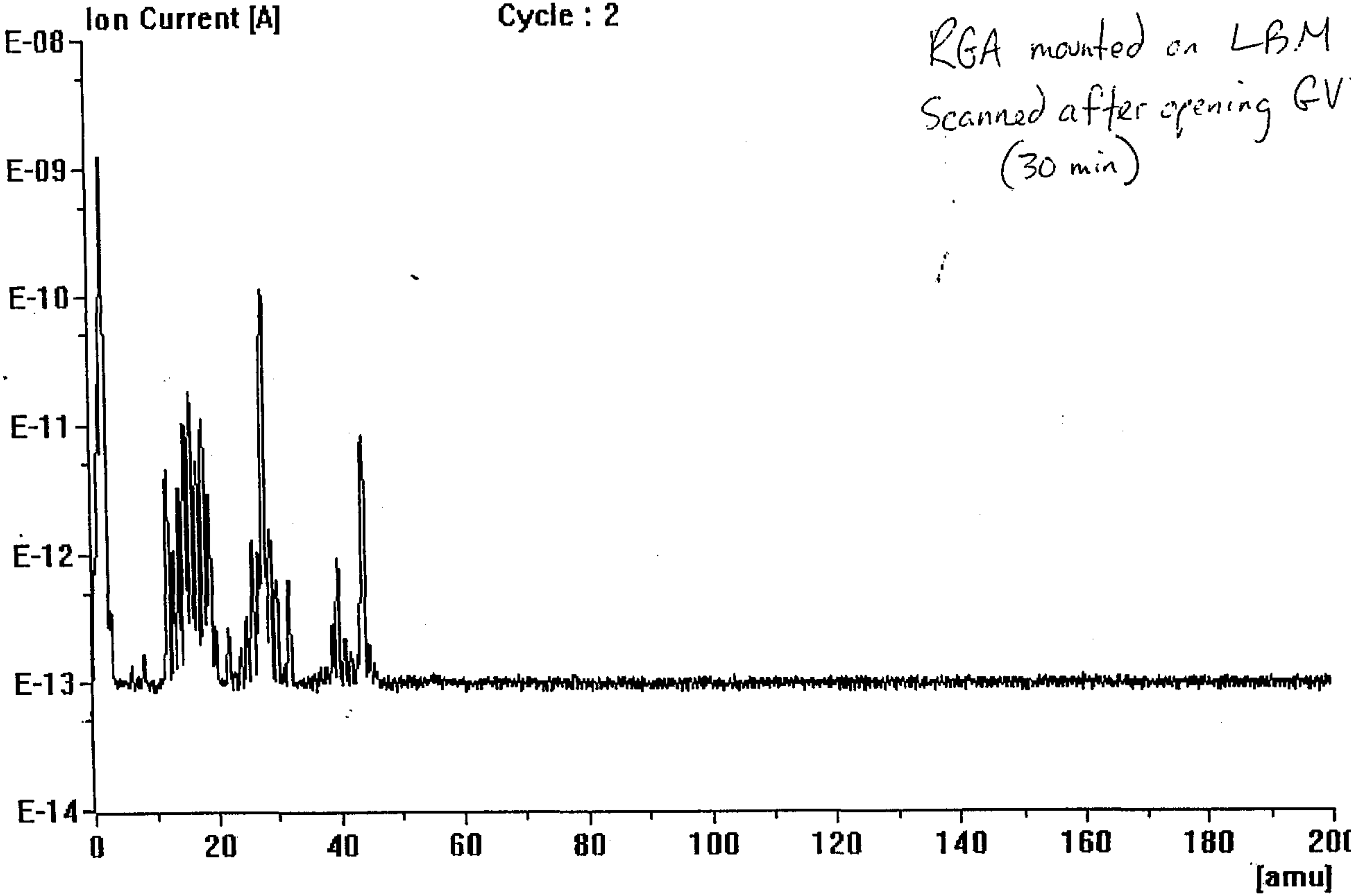
Partial Pressure and Air Signature Acceptance

LIGO: ______________________________

PSI: ______________________________

[D1] Display Saved Values < wclbm_d.sac >

File Display Setup Function Special Info

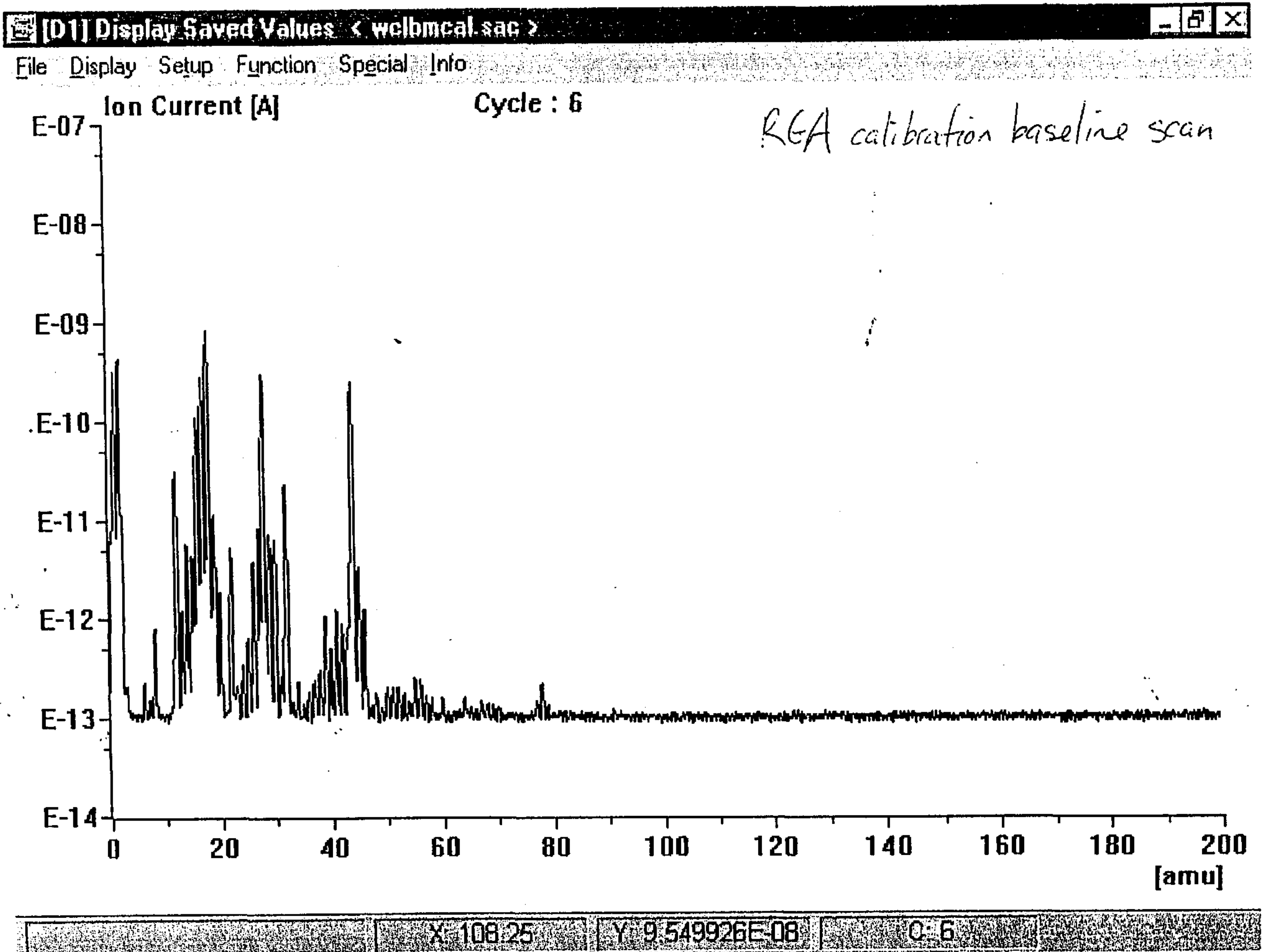


RGA mounted on LBM
Scanned after opening GV3
(30 min)

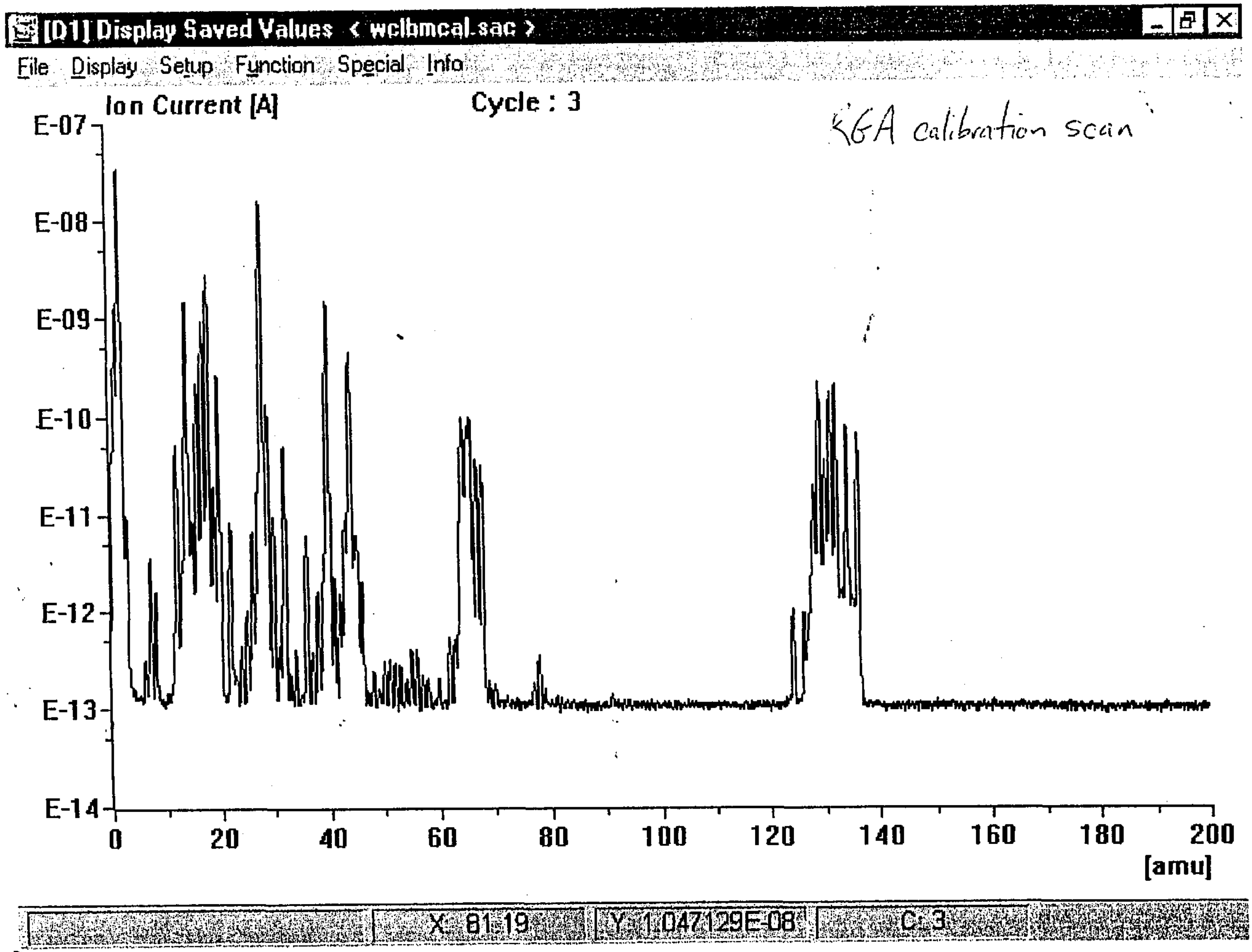
X: 70.66 | Y: 6.563611E-10 | C: 2

Title: RGA Sensitivity Calibration
Date: 6/13/98
Test ID: WCLBMcal
PSI Engineer: John Flinn

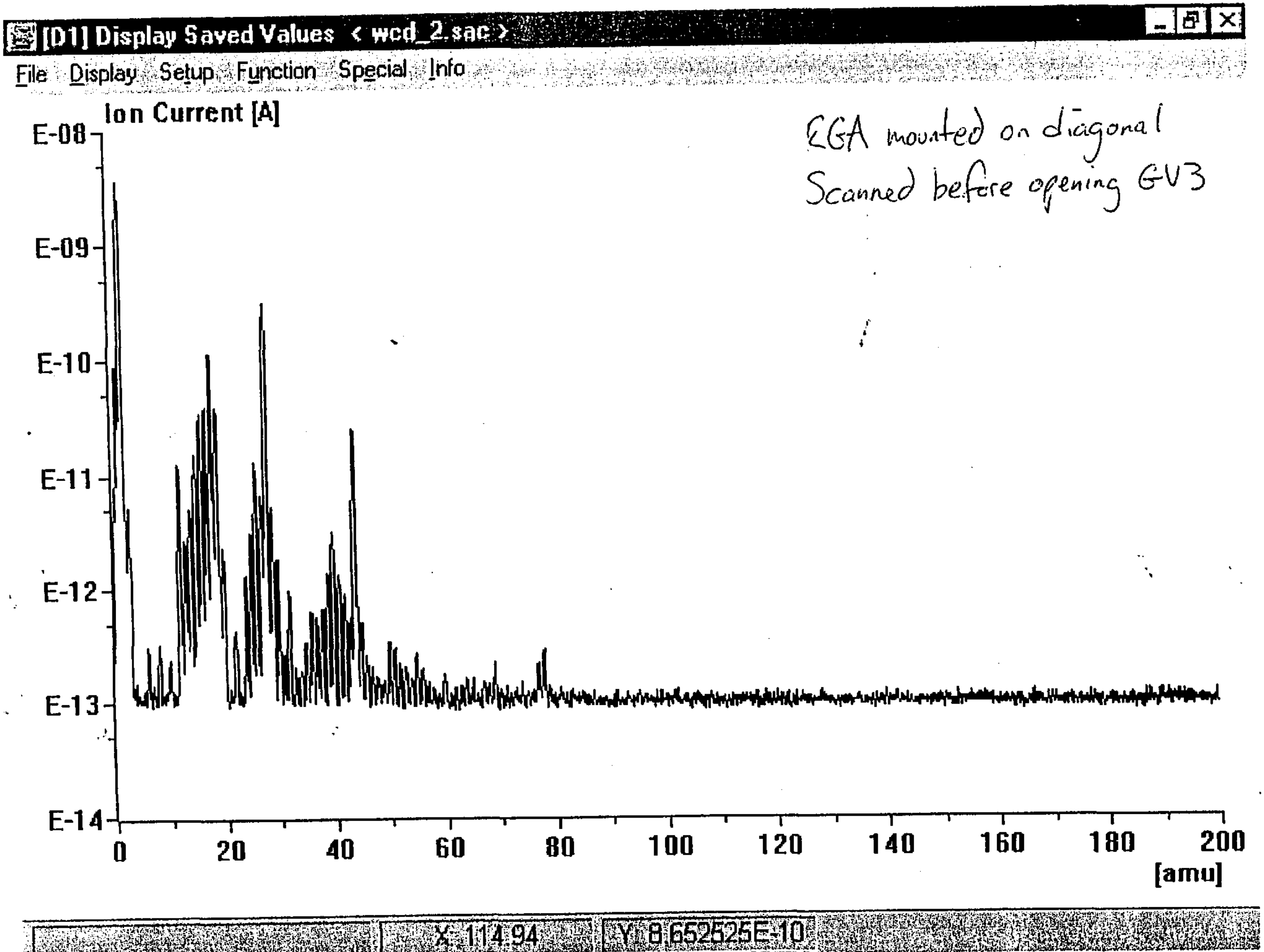
AMU	$I_{(amu)}$ (A)	$I_{(leak)}$ (A)	$F_{(amu)}$ (-)	$E_{(amu)}$ (-)	$Q_{(amu\_leak)}$ (Torr-l/s)	$S_{(orifice\_amu)}$ (l/s)		$S_{(p\_amu)}$ (Torr/A)
2	4.28E-10	3.38E-08			4.80E-06	13.9		10.35
16	-		0.57	1.6				7.91
18	-		0.64	1.12				11.96
28	3.00E-10	1.56E-08			9.50E-07	3.7		16.78
40	4.85E-13	1.44E-09			9.40E-08	3.1		21.06
44	-		1.57	1.42				14.80
129	1.00E-13	2.06E-10			2.20E-08	1.7		62.85
131	1.00E-13	1.63E-10			1.80E-08	1.7		65.00
132	1.00E-13	2.01E-10			2.20E-08	1.7		64.42
134	1.00E-13	7.59E-11			9.00E-09	1.7		69.84
136	1.00E-13	6.15E-11			8.00E-09	1.7		76.64

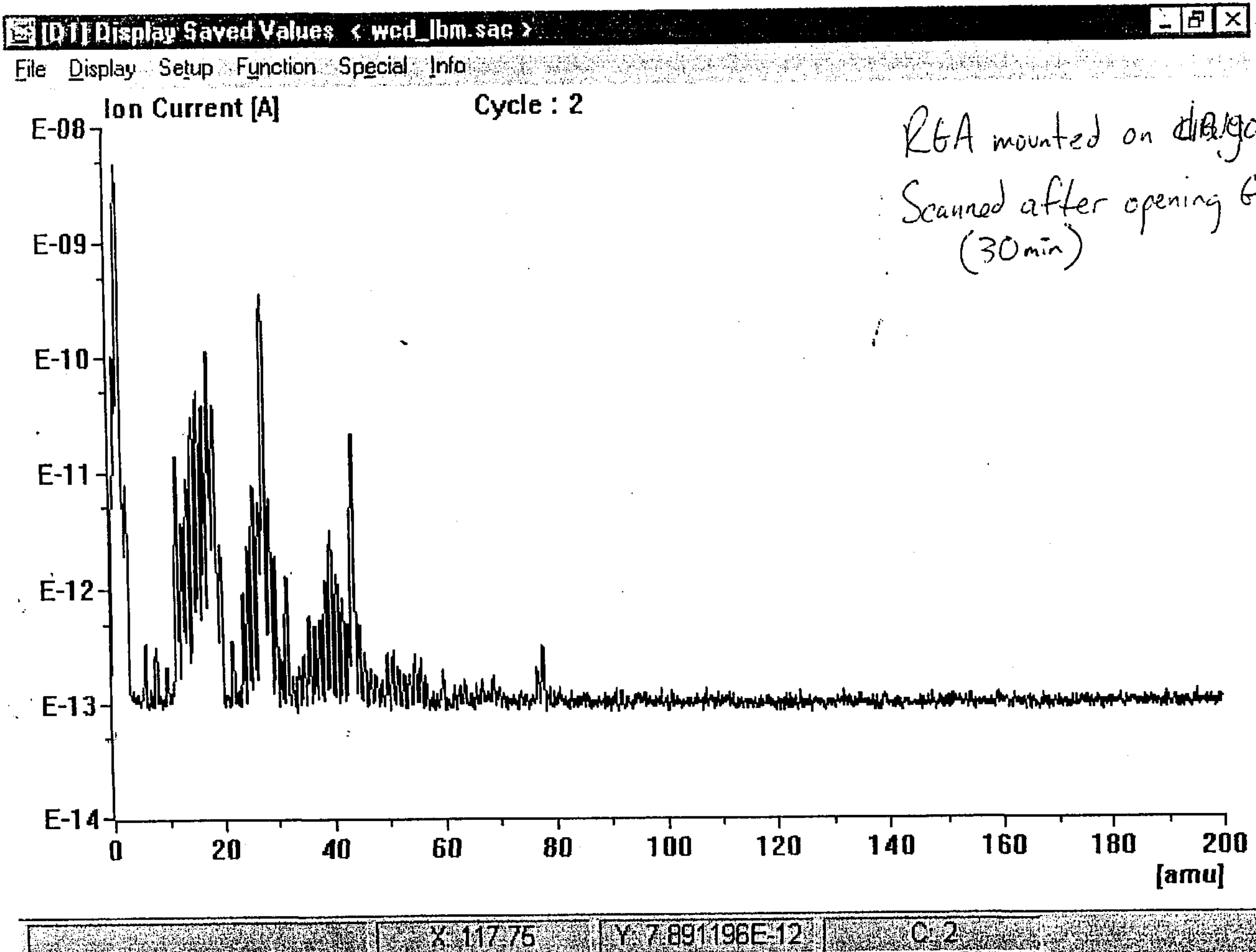


RGA calibration baseline scan


[D1] Display Saved Values < wclbmcal.sac >
File Display Setup Function Special Info
Ion Current [A]
Cycle : 3
RGA calibration scan
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: 81.19
Y: 1.047129E-08
C: 3

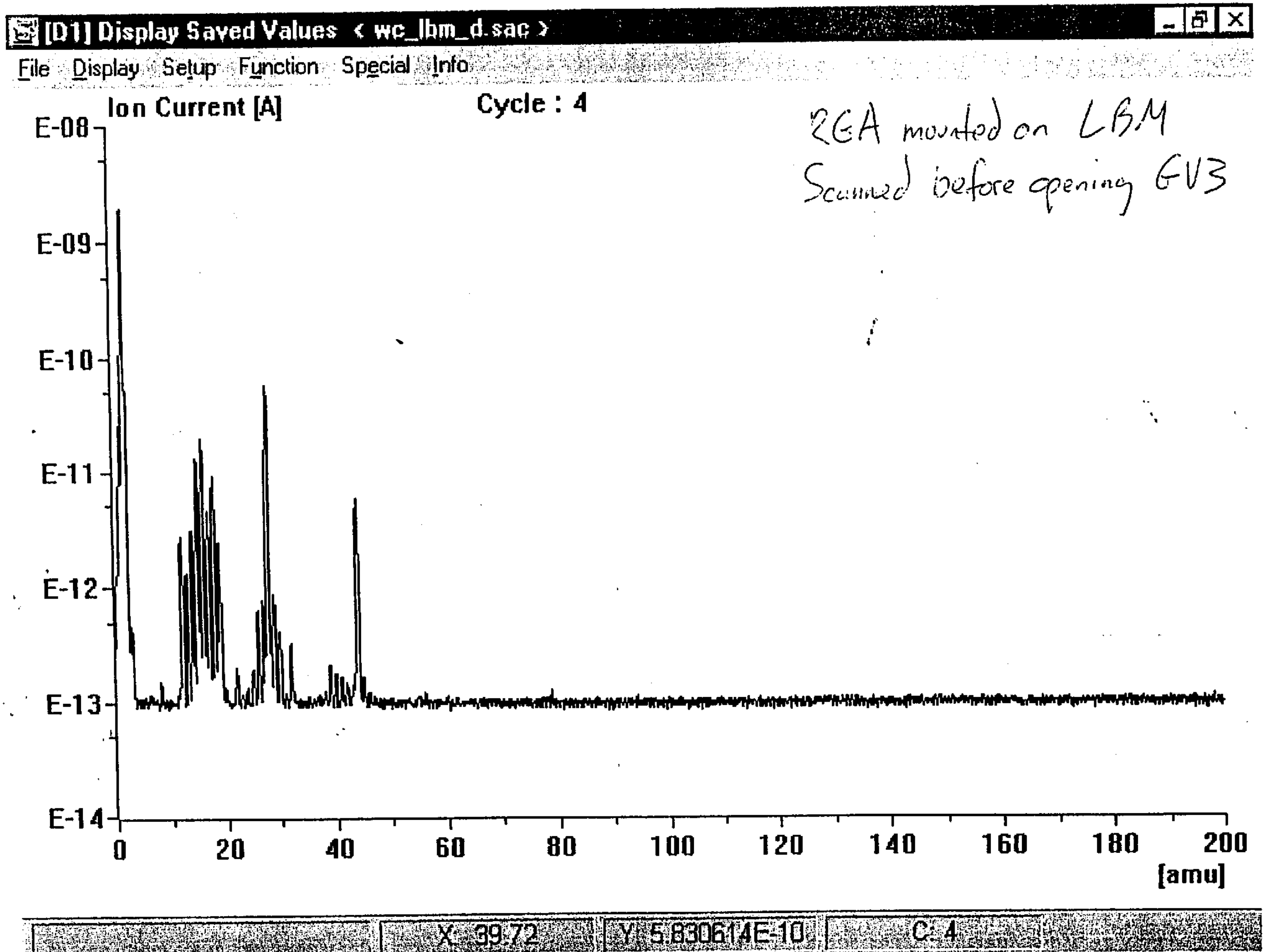
130


[D1] Display Saved Values < wcd_2.sac >
File Display Setup Function Special Info
Ion Current [A]
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: 114.94
Y: 8.652525E-10
RGA mounted on diagonal
Scanned before opening GV3



RGA mounted on diagonal

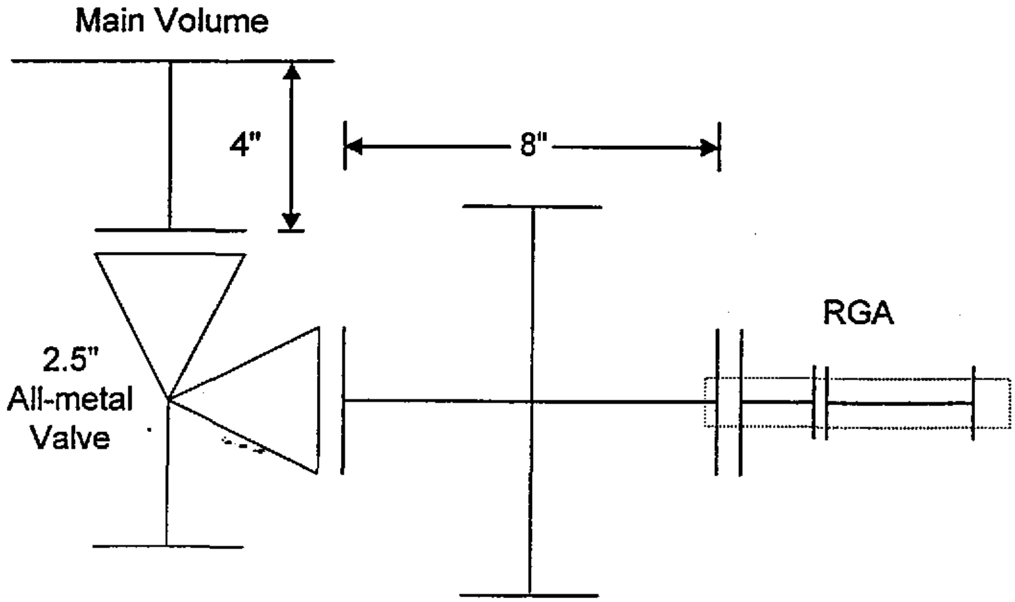
Scanned after opening GV3 (30min)



RGA mounted on LBM
Scanned before opening GV3

LBM/ CHAPMAN

Conductance Calculation for RGA Calibration Chamber at ~~Left End~~ Station



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:

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

{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

6.7 Backfill/100 Hr. Pumpdown Test – Diagonal Section

This test was only performed on the Vertex and Right Beam Manifold. See Section 8.7 for typical data.

7. ACCEPTANCE TEST RESULTS – RIGHT BEAM MANIFOLD

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

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT

7.1 Interface To CDS – Right Beam Manifold

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

7.2 Clean Air System Test – Right Beam Manifold

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

All test results met or exceeded the requirements.

LIGO VACUUM EQUIPMENT ACCEPTANCE TEST DATA/TEST VERIFICATION Equip. Tag_____ S/N____________

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				
DEWPOINT	5.2	-60C / -69.C			Am 3/27/98
Particle Count	5.2	100. PART/FT3 REQ 0.0 PART/FT3 MEAS	0.5 M		Am 3/27/98
HYDROCARBON CONTENT	5.2	0.0PPM			Am 3/27/98

WASH. CORNER CLEAN AIR SYS.

135

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT

7.3 Class 100 Cleanroom Test – Right Beam Manifold

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

All test results met or exceeded the requirements.

See Vertex Section 8.3 for details.

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT

7.4 System Leak Check – Right Beam Manifold

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-Westborough

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.

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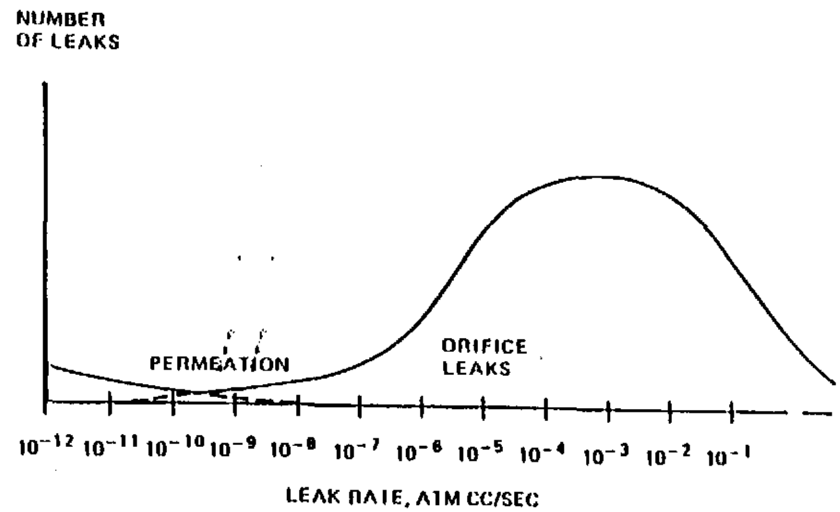

Figure 11.1 Typical distribution of leaks encountered in industrial products.

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

		Cycle 1/2 A	Torr/A	Torr	Cycle 40 A	Torr/A	Torr	Δ P	Volume liters	DTime s	T-L/s	FractionF	N2 Equiv T-L/s	T-L/s-cm2
	0													
	1													
	2	5.80E-09	1	5.80E-09	4.70E-07	1	4.70E-07	4.64E-07	130000	10000	6.03E-06	1	6.03E-06	8.62E-12
	3	2.90E-09	1	2.90E-09										
	4		1	0.00E+00										
	6	3.20E-12	1	3.20E-12										
	7		1	0.00E+00										
	8	1.00E-12	1	1.00E-12										
	12	8.50E-11	1.5	1.28E-10	5.17E-11	1.5	7.76E-11							
	13	4.80E-11	1.5	7.20E-11	1.92E-11	1.5	2.88E-11	-4.32E-11	130000	10000	-5.62E-10	0.07	-8.02E-09	
14 from CH4		1.78E-11	1.5	2.67E-11	1.78E-11	1.5	2.67E-11	0.00E+00	130000	10000	0.00E+00	0.156	0.00E+00	
14 from N2		3.00E-11	1.5	4.50E-11	4.74E-11	1.5	7.11E-11	2.61E-11	130000	10000	3.39E-10	0.072	4.71E-09	
	15	8.80E-11	1.5	1.32E-10	9.20E-11	1.5	1.38E-10	6.00E-12	130000	10000	7.80E-11	0.85	9.18E-11	
	16	1.60E-10	1.5	2.40E-10	1.10E-10	1.5	1.65E-10	-7.50E-11	130000	10000	-9.75E-10	1	-9.75E-10	
	17		1.5	0.00E+00										
	18		1.5	0.00E+00										
	19		1.5	0.00E+00										
	20	3.00E-13	1.5	4.50E-13	5.00E-13	1.5	7.50E-13	3.00E-13	130000	10000	3.90E-12	0.002	1.95E-09	
	22		1.5	0.00E+00										
	25		1.5	0.00E+00										
	26		1.5	0.00E+00										
	27		1.5	0.00E+00										
	28	2.90E-10	1.5	4.35E-10	4.90E-10	1.5	7.35E-10	3.00E-10	130000	10000	3.90E-09	1	3.90E-09	
	29	4.00E-12	1.5	6.00E-12	4.50E-12	1.5	6.75E-12	7.50E-13	130000	10000	9.75E-12	0.008	1.22E-09	
	30		1.5	0.00E+00										
	32	5.00E-13	1.5	7.50E-13										
	39		1.5	0.00E+00										
	40	3.00E-13	2.5	7.50E-13	2.10E-12	2.5	5.25E-12	4.50E-12	130000	10000	5.85E-11	0.01	5.85E-09	
	41		1.5	0.00E+00										
	44	4.30E-12	1.5	6.45E-12	7.50E-12	1.5	1.13E-11							

BALZERS SPECTRA LIBRARY

	46	45	44	40	38	36	29	28	22	20	19	18	17	16	15	14	13	12
CO2	0.4	1.3	100					11.4	1.2					8.5				6
Ar				100	0.06					20		0.068						
CO							1.1	100						0.9		0.6		4.5
N2							0.8	100								7.2		
O2																		
H2O										0.3	0.1	100	23	1.1				
CH4													1.2	100	85.8	15.6	7.7	2.4

Using the change in signal of mass 28 and assigning it all to N2 leads to 4E-9 leak
Using the change in signal of mass 14 and assigning it all to N2 leads to 5E-9 leak
Using the change in signal of mass 40 and assigning it all to Ar leads to 6E-9 leak
Using the change in signal of mass 20 and assigning it all to Ar leads to 2E-9 leak using spectra library values
Using the change in signal of mass 29 and assigning it all to N2 leads to 2E-9 leak using spectra library values

Oxygen is consumed to form CO2?
Carbon is consumed
Argon is not likely being pumped by cryopump
Entire change in mass 14 used in the calc. for leak rate, no seperation between CH4 and N

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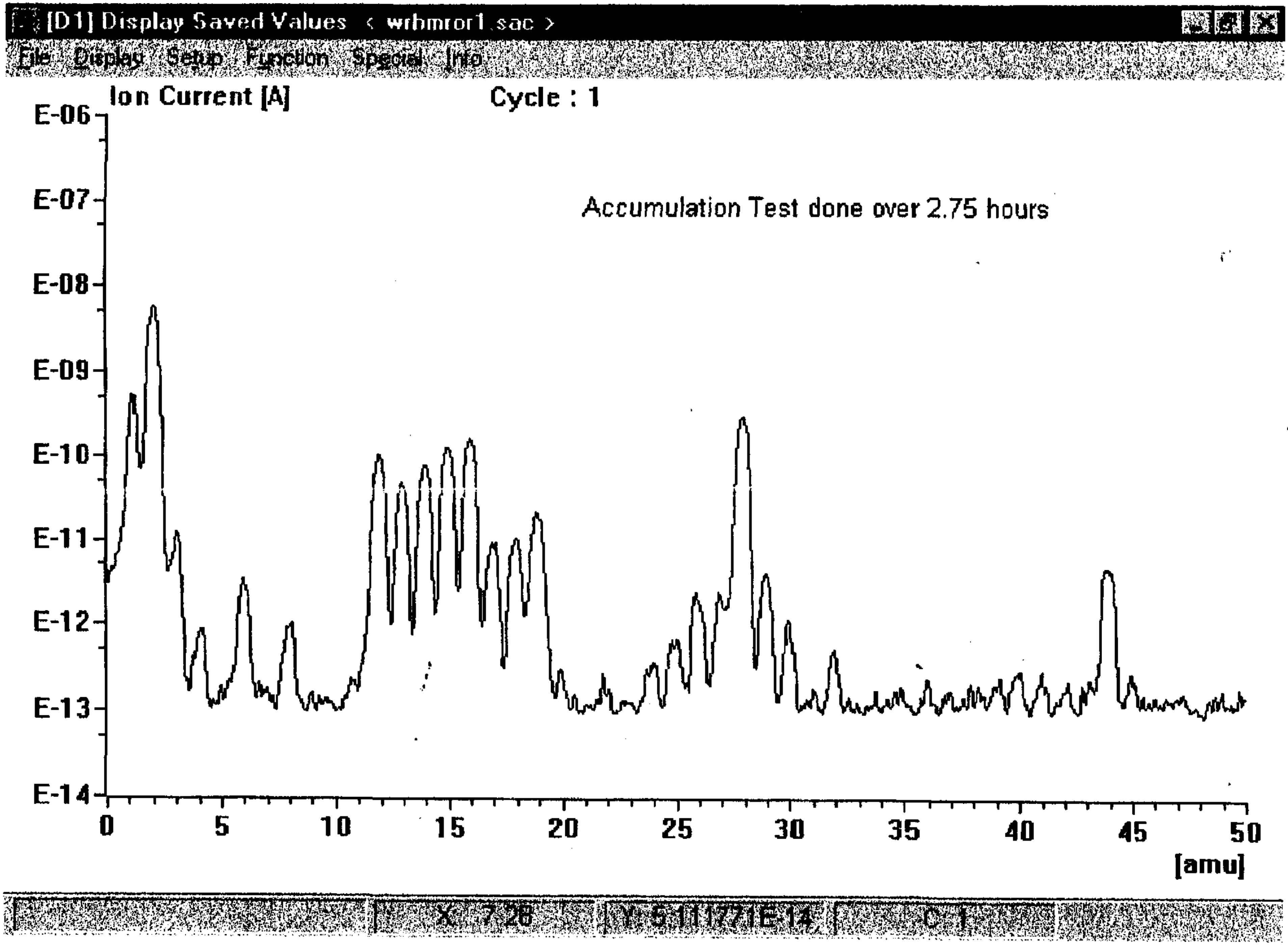
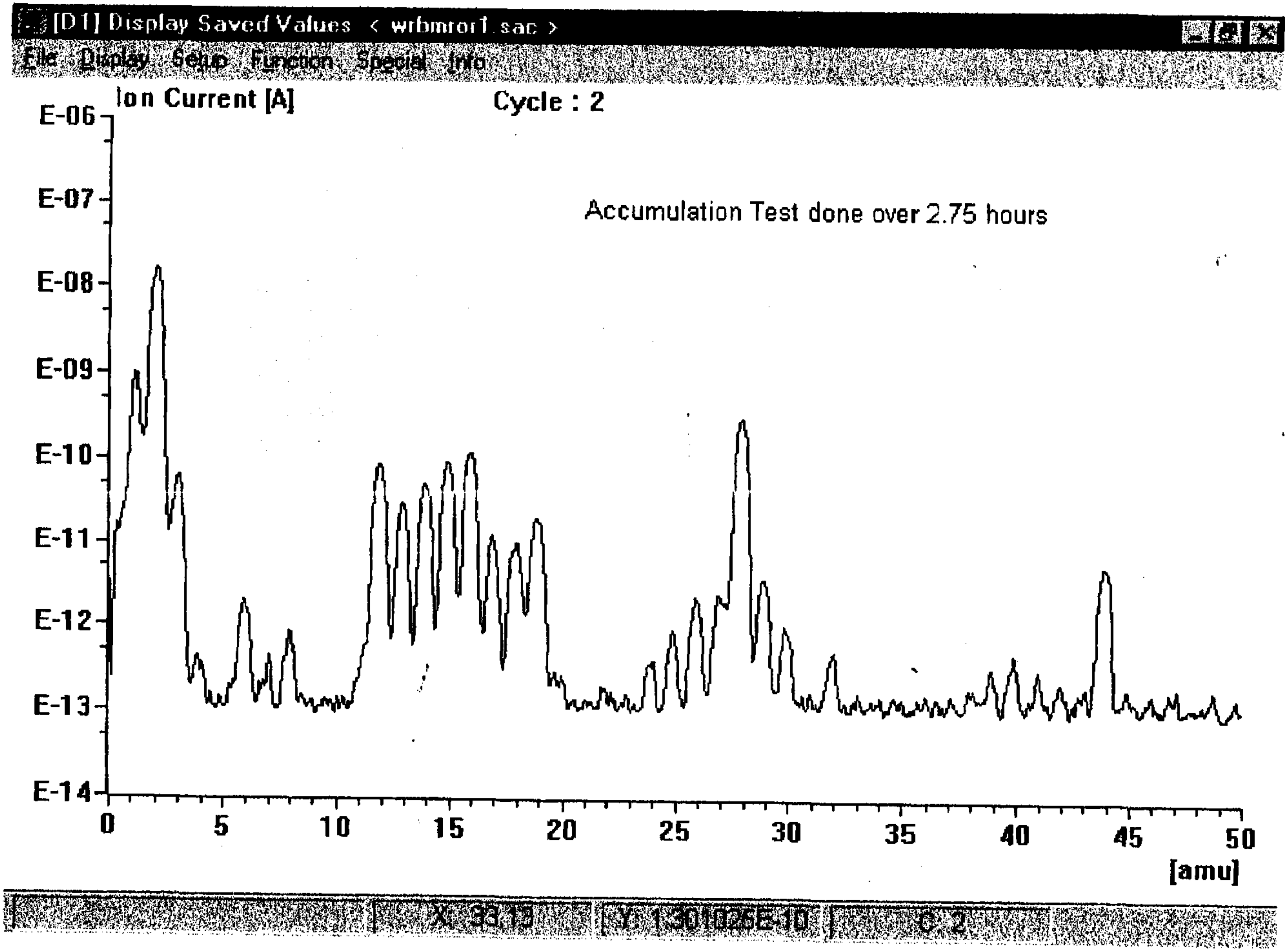

[D1] Display Saved Values < wrbmror1.sac >
File Display Setup Function Special Info
Ion Current [A]
Cycle : 1
Accumulation Test done over 2.75 hours
E-06
E-07
E-08
E-09
E-10
E-11
E-12
E-13
E-14
0
5
10
15
20
25
30
35
40
45
50
[amu]
X: 7.28
Y: 5.111771E-14
C: 1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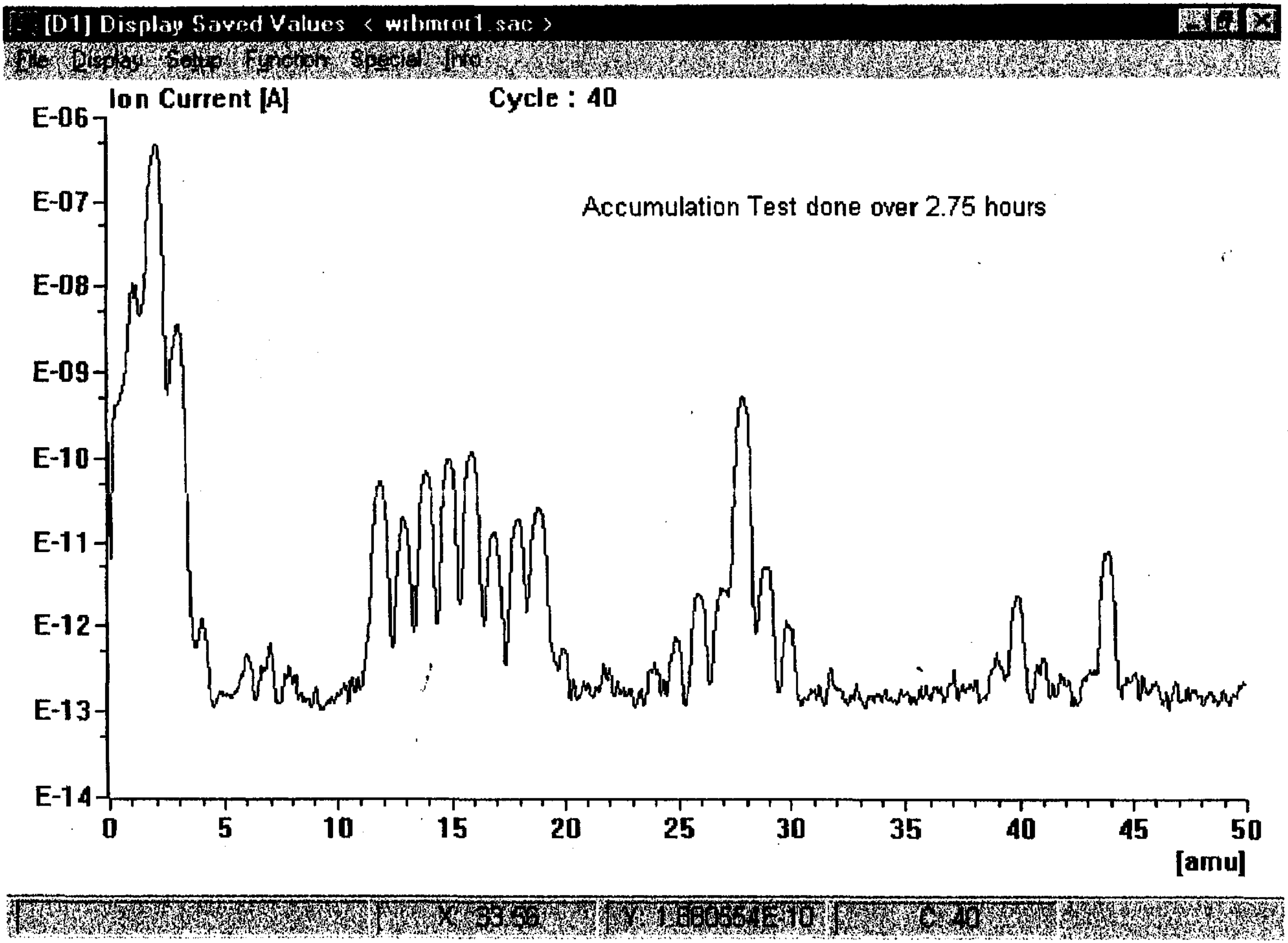
File Display Setup Function Special Info
Ion Current [A]
Cycle : 2
Accumulation Test done over 2.75 hours
E-06
E-07
E-08
E-09
E-10
E-11
E-12
E-13
E-14
0
5
10
15
20
25
30
35
40
45
50
[amu]
X: 33.13
Y: 1.301026E-10
C: 2


[D1] Display Saved Values < wrbmror1.sac >
File Display Setup Function Special Info
Ion Current [A]
Cycle : 40
Accumulation Test done over 2.75 hours
E-06
E-07
E-08
E-09
E-10
E-11
E-12
E-13
E-14
0
5
10
15
20
25
30
35
40
45
50
[amu]
X: 33.56
Y: 1.860554E-10
C: 40

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

LEAK TEST DATA SHEET - FIELD TEST

	1	2	3
Component Name	WASH - RGHT Beam Mod.	Annulus PIPE	
Model Number			EQUIP.
Serial Number			
Drawing Number			
Detector Name	BALZERS	BALZERS	
Model Number	HLT 160 DRY		B3C7
Serial Number		HLT 160 DRY	CP2 BE4B
	-	03	A1C
Detector Calibration			A12A
Expiration Date	1-12-98	INT CAL ONLY	A13A
Standard Leak Rate	4.53X10-9		A15A
Background	NA		B1A
Standard Response	4.5X10-9		B8A
		CF 1.2	B9A
Leak Test Data			B4A
Location /Date	WASH 5-30-98		BE5
Tracer Gas	HE		
Pressure	3.3X10-7	<1X10-5 PER ANNULUS	
Duration	NA	SPACE	
Response			
	NDL EVAC + SPRAY	NDL EVAC + SPRAY	
	X10-9 SCALE	X10-9 SCALE	
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By: D. H.	Date: 5-30-98	5-4-98	
Witnessed By:	Date:		
Signature: [signature]	Date: 5-30-98		
Title PROD TECH III			

Remarks: (1) LEAK REPAIRED 4.5 CFF BURST DISC CP2
TEST INCLUDES INTERNAL CAP RES CP2

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

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WASHINGTON SITE CORNER STATION
PSI FACTORY LEAK TEST DATA SHEETS
RIGHT BEAM MANIFOLD

Tag No.	*Serial No.*
WBSC 7	05
WCP 2	01
WA1C	03
WA12A	01
WA13A	01
WA15A	01
WB1A	01
WB8A	01
WB9A	01
WB4A	01
WBE4E	05
WBE5	01

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

LEAK TEST DATA SHEET

	1	2	3
Component Name	BSC		
Model Number	WBSC 7		
Serial Number	05		
Drawing Number			
Detector Name	BALZERS		
Model Number	HLT 160 DRY		
Serial Number	02		
Detector Calib.Date	8-16-79		
Detector Calib.Factor	.7		
Standard Leak Rate	NONE		
Std.Leak Expir.Date			
Standard Response			
Leak Test Data			
Location /Date	clean room / 8-16-97		
Tracer Gas	HE		
Pressure @ Turbo Inlet	6.3×10^{-7}		
Duration	3 HRS		
Response	NDL $\times 10^{-9}$ SCALE		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : D H	Date :		
Witnessed By :	Date :		
Signature [signature]	Date : 8-16-97		
Title :			

Remarks :

SPECIFICATION	
Number: V049-2-014 A	p2

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	BSC						
Model No.	W BSC 7						
Serial No.	05						
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		4×10^{-5}	✓		[signature]	8-15-97
	II		NDL (10⁸ Scale)	✓		[signature]	8-15-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		1×10^{-9}				
Weld Joint	II		1×10^{-9}				
Conflat	III		1×10^{-9}				

Comments HLT #3 PCC 2.0×10^{-5}

Witnessed Signature [signature]

Title

Date: 8-15-97

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	A15A SPEC		
Model Number			
Serial Number	01		
Drawing Number			
Detector Name	BALZERS		
Model Number	HLT 160		
Serial Number	3137944-002		
Detector Calib.Date	5-17-97		
Detector Calib.Factor	1.0		
Standard Leak Rate	4.4X10-9		
Std.Leak Expir.Date	6-27-97		
Standard Response	4.2X10-9		
Leak Test Data			
Location /Date			
Tracer Gas	HE		
Pressure @ Turbo Inlet			
Duration	20 min		
Response	1X10-9		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : DH	Date : 5-17-97		
Witnessed By :	Date :		
Signature [signature]	Date : 5-17-97		
Title :			

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

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	WBE5		
Model Number			
Serial Number	01		
Drawing Number			
Detector Name	Balzers		
Model Number	HLT160		
Serial Number	#2		
Detector Calib.Date	8-2-97		
Detector Calib.Factor	0.9		
Standard Leak Rate	4.5x10^-9		
Std.Leak Expir.Date			
Standard Response			
Leak Test Data			
Location /Date	Clean weld room / 8-2-97		
Tracer Gas	He		
Pressure @ Turbo Inlet	1.7x10^-7		
Duration	1.75 hours		
Response	NDL 10^-9 range		
	evac. & spray		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : D. Hilliard	Date : 8-2-97		
Witnessed By : (GF)	Date:		
Signature : D. Hilliard	Date : 8-2-97		
Title : (GF)			

Remarks :

SPECIFICATION	
Number: V049-2-014 A	p2

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	WBE5						
Model No.							
Serial No.	01						
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		$4x10^{-3}$	✓		D.Hillier (JF)	8-4-98
	II	--	NDL (10^{-9} Scale)	✓		D.Hillier (JF)	8-4-98
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments

Witnessed
Signature
Title
Date:

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	WA13A	WB1A	WB8A
Model Number			
Serial Number	01	01	01
Drawing Number			
Detector Name	Balzers		
Model Number	HCT160		
Serial Number	3		
Detector Calib.Date	8-14-97		
Detector Calib.Factor	1.4		
Standard Leak Rate	4.8x10-9 cc/s		
Std.Leak Expir.Date			
Standard Response	4 min		
Leak Test Data			
Location /Date	clean weld room / 8-13-97		
Tracer Gas	He		
Pressure @ Turbo Inlet	2x10-7		
Duration	1/2 hour		
Response	NDL 10-9 range		
	evac & spray		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : D.H / P.T.	Date : 8-14-97		
Witnessed By : (JF?)	Date:		
Signature : Don Hillier	Date : 8-14-97		
Title :			

Remarks :

SPECIFICATION	
Number: V049-2-014 A	p2

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	WA13A	WB1A	WB8A				
Model No.							
Serial No.	01	01	WB8 01				
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr			Paul Tatro	~~8-14-97~~
	IV-V		$4x10^{-5}$	✓		Paul Tatro	8-14-97
	II		NDL (10^{-9} Scale)	✓		(JF)	8-14-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments

Witnessed
Signature
Title
Date:

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	WA12A	WB4A	
Model Number			
Serial Number	01	01	
Drawing Number			
Detector Name	Balzers		
Model Number	HLT 160		
Serial Number	#2 [illegible]		
Detector Calib.Date	6-28-97		
Detector Calib.Factor	NA		
Standard Leak Rate			
Std.Leak Expir.Date			
Standard Response			
Leak Test Data			
Location /Date	Clean room / 6-20-97		
Tracer Gas	He		
Pressure @ Turbo Inlet	5.7x10-7		
Duration	1 hour		
Response	NDL 10-9 range		
	evac & spray		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : D. Hillier	Date : 6-21-97		
Witnessed By :	Date :		
Signature : Don Hillier	Date : 6-21-97		
Title :			

Remarks :

SPECIFICATION

Number: V049-2-014 A | p2

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	WA12A	WB4A					
Model No.							
Serial No.	01	01					
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		$4x10^{-5}$	✓		D. Hillier	6-21-97
	II		NDL (10^{-9} Scale)	✓		(JF) D. Hillier	6-21-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments

Witnessed
Signature
Title
Date:

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	WB9A	WA1C	
Model Number			
Serial Number	01	03	
Drawing Number			
Detector Name	Balzers		
Model Number	HLT160		
Serial Number	3		
Detector Calib.Date	8-23-97		
Detector Calib.Factor	1.6		
Standard Leak Rate			
Std.Leak Expir.Date			
Standard Response			
Leak Test Data			
Location /Date	clean weld room / 8-22-97		
Tracer Gas	He		
Pressure @ Turbo Inlet	4.1 x 10-6		
Duration	3 hours		
Response	NDL 10-9 scale		
	evac & spray		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : R.I./D.H.	Date : 8-23-97		
Witnessed By : (JF)	Date :		
Signature [signature]	Date : 8-23-97		
Title :			

Remarks :

SPECIFICATION	
Number: V049-2-014 A	p2

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	WB9A	WA1C					
Model No.							
Serial No.	01	03					
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		$4x10^{-5}$	✓		D. Hillier	8-23-97
	II	---	NDL (10^{-9} Scale)	✓		D. Hillier	8-23-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments

Witnessed
Signature
Title
Date:

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

LEAK TEST DATA SHEET

	1	2	3
Component Name	WCP2	WBE4E	
Model Number			
Serial Number	01	05	
Drawing Number			
Detector Name	Balzers		
Model Number	HLT 160		
Serial Number	2		
Detector Calib.Date	9-13-97		
Detector Calib.Factor	1.0		
Standard Leak Rate	4.8x10-9		
Std.Leak Expir.Date			
Standard Response	10 minute max.		
Leak Test Data			
Location /Date	Clean room /9-12-97		
Tracer Gas	He		
Pressure @ Turbo Inlet	2.0x10-6		
Duration	8 hours (shell & res)		
Response	NDL 10-9 scale		
	evac & spray		
Leak Rate			
Measured			
Calculated			
Allowable	shell res.		
Performed By : D Hillier	Date : 9-13-97 / 9/15/97		
Witnessed By :	Date :		
Signature : Don Hillier	Date : 9/13/15/97		
Title :			

Remarks : bellows 4" damaged after test
respray that joint in oven on 10/29

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	WCP2	WBE4E					
Model No.							
Serial No.	01	05					
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		$4x10^{-5}$	✓		Paul Tatro	9-15-98
	II		NDL (10^{-9} Scale)	✓		Paul Tatro (PT)	9-15-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments

Witnessed
Signature
Title
Date:

SPECIFICATION

Number: V049-2-014 A p2

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT

7.5 System Bake-Out – Right Beam Manifold

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

The bake-out passed the requirements since the ultimate pressure test was successfully completed.

RBM 1

RIGHT BEAM MANIFOLD

6-16-98

1530 START SP = 19

~~TURBO~~ START TURBO

~~AUX @ GV04~~

1645 SP = 21

TURBO 1.2 $\times 10^{-6}$

6/17/98

-S.P. = 37 CART 3, ZONE 55 HI, ZONE 39 LO, HOLDING UP RAMP RATE

P = 1.5 $\times 10^{-6}$

SHUT OFF ZONE 55 (WAS RUNNING 0% ANYWAY)

1000 SP = 41 TURBO 2.1 $\times 10^{-6}$

AUX @ GV4 7.6 $\times 10^{-7}$

@ GV7 1.5 $\times 10^{-5}$

@ GV8 1.4 $\times 10^{-4}$

@ B1 2.3 $\times 10^{-5}$

@ BSC8 4.1 $\times 10^{-5}$

@ GV2 1.9 $\times 10^{-5}$

1200 SP = 45 TURBO 2.8 $\times 10^{-6}$

1600 SP = 55 TURBO 5.6 $\times 10^{-6}$

AUX @ GV4 1.2 $\times 10^{-6}$

@ GV7 3.5 $\times 10^{-5}$

@ GV8 1.5 $\times 10^{-4}$

@ B1 3.3 $\times 10^{-5}$

@ BSCB 7.3 $\times 10^{-5}$

@ GV2 3.4 $\times 10^{-5}$

RBMZ

6/18/98

$P_{TURBO} = 1.1 \times 10^{-5}$

$T_{sp} \sim 77°C$

CART 2 ZONE 90 (21°C higher than S.P.)
Shut down - running 0% anyway

0900 SP = 79 TURBO 1.1×10^{-5}
AUX @ GV4 4.2×10^{-6}
@ GV7 4.3×10^{-5}
@ GV8 1.5×10^{-4}
@ B1 5.2×10^{-5}
@ BSC8 6.9×10^{-5}
@ GV2 5.4×10^{-5}
REGEN HEATER ON

1330 SP = 88 TURBO 2.5×10^{-5}
AUX @ GV4 6.3×10^{-6}
@ GV7 4.8×10^{-5}
@ GV8 1.6×10^{-4}
@ B1 5.5×10^{-5}
@ BSC8 7.8×10^{-5}
@ GV2 6.6×10^{-5}
REGEN HEATER 195°C

RBM3

1600 SP = 94 TURBO 2.8×10^{-5}
AUX @GV4 8.1×10^{-6}
@GV7 5.1×10^{-5}
@GV8 1.6×10^{-4}
@B1 5.8×10^{-5}
@BSC8 8.3×10^{-5}
@GV2 7.2×10^{-5}
REGEN HEATER 152°C

6-19-98

0730 TURBO 1.4×10^{-5}
AUX @GV4 1.6×10^{-5}
@GV7 3.7×10^{-5}
@GV8 1.4×10^{-4}
@B1 4.5×10^{-5}
@BSC8 4.9×10^{-5}
@GV2 5.6×10^{-5}
REGEN HEATER 20°C (RESTART)

1100 TURBO 1.9×10^{-5}
AUX @GV4 1.8×10^{-5}
@GV7 3.8×10^{-5}
@GV8 1.3×10^{-4}
@B1 4.5×10^{-5}
@BSC8 5.8×10^{-5}
@GV2 5.7×10^{-5}
REGEN 170°C

RBM4

6-19-98
1600 144 TURBO 3.4 x10^-5
AUX @ GV4 2.6 x10^-5
@ GV7 4.7 x10^-5
@ GV8 1.4 x10^-4
@ B1 5.1 x10^-5
@ BSC8 7.8 x10^-5
@ GV2 6.7 x10^-5
REGEN HEATER 162°C

6-20-98
0900 150 TURBO 3.3 x10^-5
AUX @ GV4 2.2 x10^-5
@ GV7 1.6 x10^-5
@ GV8 1.1 x10^-4
@ B1 2.5 x10^-5
@ BSC8 4.6 x10^-5
@ GV2 3.4 x10^-5
REGEN 172°C

1330 150 TURBO 3.1 x10^-5
AUX @ GV4 2.1 x10^-5
@ GV7 1.4 x10^-5
@ GV8 1.0 x10^-4
@ B1 2.1 x10^-5
@ BSC8 4.2 x10^-5
@ GV2 2.9 x10^-5
REGEN 161°C

RBM5

1630 150 TURBO 3.0×10^{-5}
AUX @GU4 2.0×10^{-5}
@GU7 1.4×10^{-5}
@GV8 1.0×10^{-4}
@B1 1.9×10^{-5}
@BSC8 4.1×10^{-5}
@GU2 2.7×10^{-5}
REGEN 140°C

6/21

900 $P = 2.9 \times 10^{-6}$
HEATERS OFF!
THEY SHUT DOWN LAST NIGHT AT 8:00PM
ABOUT 24 HOURS AT TEMP

$T_{CART1} = 60-100°C$
$T_{CART2} = 45-60°C$
$T_{CART3} = <60°C - 80°C$
$T_{CART4} = <50-80°C$

10" GATE VALVE FAILURE

TRIPPED ON A MAJOR ALARM (50° Δ)

1000 RESTART TURBO 2.3×10^{-6}

6-21

RBM6 (2)

1500 TURBO 2.4×10^{-6}
AUX @GV4 1.5×10^{-6}
@GV7 1.2×10^{-6}
@GV8 OFF RESTART
@B1 1.1×10^{-6}
@BSC8 2.9×10^{-6}
@GV2 2.2×10^{-6}
6.21 REGEN 139°C

1800 150 TURBO 1.0×10^{-5}
AUX @GV4 37×10^{-6}
@GV7 2.5×10^{-6}
@GV8 9.2×10^{-5}
@B1 2.2×10^{-6}
@BSC8 9.1×10^{-6}
@GV2 5.7×10^{-6}
REGEN 156°C

2030 150 TURBO 2.3×10^{-5}
AUX @ GV4 8.3×10^{-6}
@ GV7 6.4×10^{-6}
@ GV8 9.2×10^{-5}
@ B1 4.5×10^{-6}
@ BSC8 2.1×10^{-5}
@GV2 1.1×10^{-5}
REGEN 133°C

RBM7 (3)

7-22

0730 150 TURBO 2.6×10^{-5}
AUX @ GV4 1.8×10^{-5}
@ GV 7 1.2×10^{-5}
@ GV 8 9.1×10^{-5}
@ B1 1.4×10^{-5}
@ BSC8 3.9×10^{-5}
@ GV2 2.1×10^{-5}
REGEN 138°C

1130 150 TURBO 2.6×10^{-5}
AUX @ GV4 1.8×10^{-5}
@ GV 7 1.2×10^{-5}
@ GV8 9.0×10^{-5}
@ B1 1.4×10^{-5}
@ BSC8 3.8×10^{-5}
@ GV2 2.1×10^{-5}
REGEN 164°C

1600 150 START RAMP DOWN
TURBO 2.6×10^{-5}
AUX @ GV4 1.8×10^{-5}
@ GV 7 1.2×10^{-5}
@ GV8 8.8×10^{-5}
@ B1 1.3×10^{-5}
@ BSC8 3.7×10^{-5}
@ GV2 2.1×10^{-5}
REGEN 162°C

RBM8 (4)

6-23-98

0630 121 TURBO 1.1×10^{-5}
AUX @GV4 8.7×10^{-6}
@GV ~~7~~ 6.1×10^{-6}
@GV8 8.1×10^{-5}
@B1 6.2×10^{-6}
@BSC8 1.7×10^{-5}
@GV2 1.2×10^{-5}
REGEN 137°C

1200 111 TURBO 7.7×10^{-6}
AUX @GV4 6.5×10^{-6}
@GV7 5.2×10^{-6}
@GV8 7.9×10^{-5}
@B1 4.5×10^{-6}
@BSC8 1.2×10^{-5}
@GV2 8.5×10^{-6}
REGEN 162°C

1530 107 TURBO 6.4×10^{-6}
AUX @GV4 5.4×10^{-6}
@GV7 4.0×10^{-6}
@GV8 7.7×10^{-5}
@B1 3.8×10^{-6}
@BSC8 1.1×10^{-5}
@GV2 7.3×10^{-5}
REGEN 166°C
REGEN OFF

RBM 9 (5)

6-24-98

0600 SP-63 SYSTEM OFF

TURBO	9.9×10^{-7}
AUX @GV4	1.1×10^{-6}
@GV7	9.0×10^{-7}
@GV8	7.3×10^{-5}
@B1	1.4×10^{-6}
@BSC8	2.7×10^{-6}
@GV2	2.2×10^{-6}

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT

7.6 Ultimate Pressure Test (After Bake-Out) – Right Beam Manifold

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

All test results met or exceeded the requirements.

Title: Partial Pressure Calculation for Right Beam Manifold Section
Date: 07/06/98
Test ID: WCRBM_6
PSI Engineer: J. Flinn

AMU	F (amu) transmission efficiency wrt N2	E (amu) ionization efficiency wrt N2	S (p_amu) sensitivity (Torr/A)	I (amu) ion current (A)	PP (amu) (Torr)
2	-	-	1.01	5.99E-09	6.05E-09
16	0.57	1.60		9.49E-11	6.93E-11
18	0.64	1.12		1.08E-11	1.19E-11
28	-	-	1.55	2.87E-10	4.45E-10
44	1.57	1.42		5.75E-12	7.86E-12
all others	-	-	1.55	1.81E-11	2.80E-11

Total Pressure =	6.61E-09

Partial Pressure and Air Signature Acceptance

LIGO: John Worden

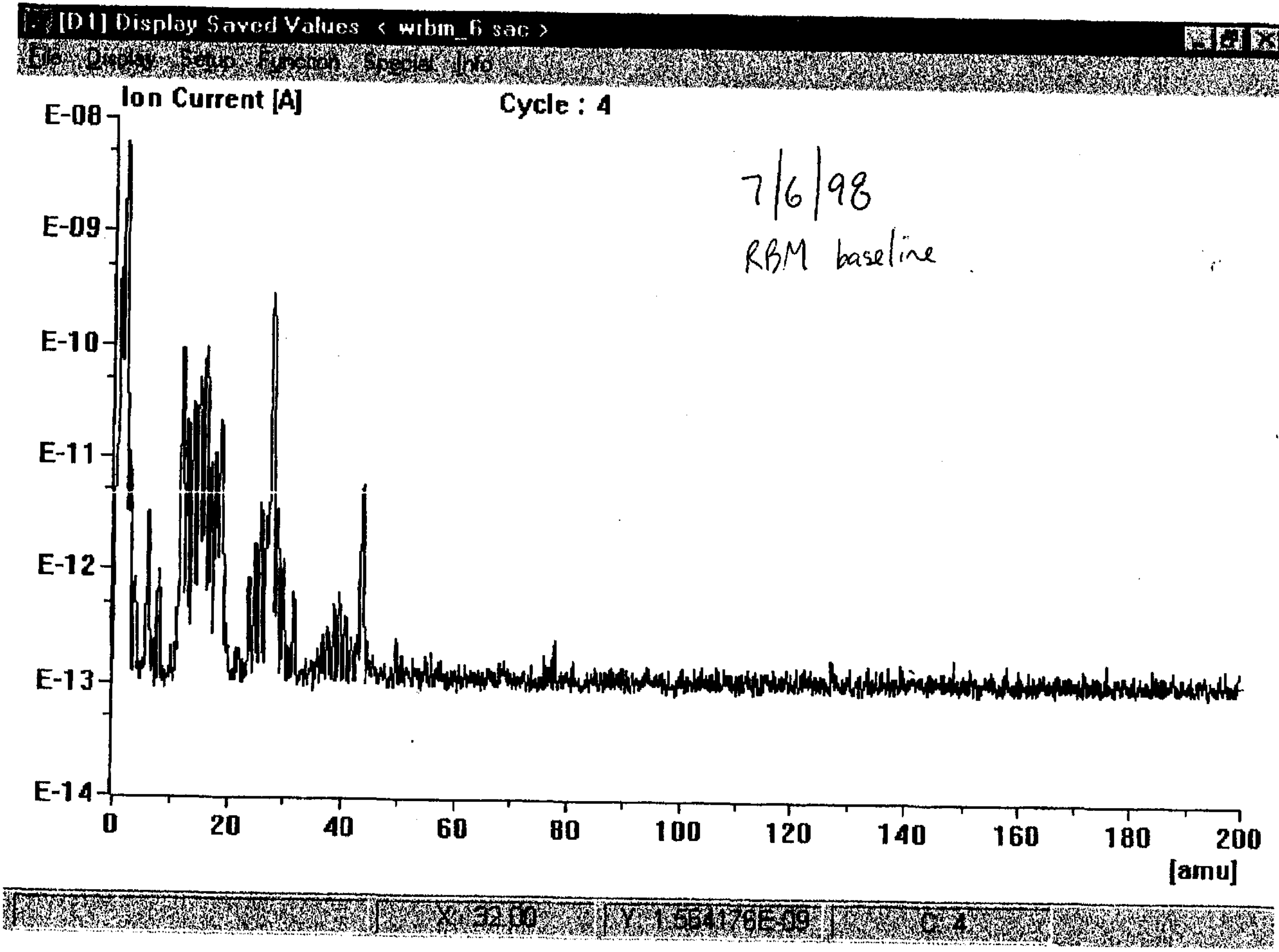
PSI: ______________________

WC RBM

7/6/98
WCRBM-6

"OTHERS"

24	8.3×10^{-13}
25	1.7×10^{-12}
26	3.9×10^{-12}
27	2.9×10^{-12}
29	3.4×10^{-12}
30	1.2×10^{-12}
32	6.4×10^{-13}
36	2.0×10^{-13}
37	2.6×10^{-13}
38	3.0×10^{-13}
39	5.0×10^{-13}
40	6.2×10^{-13}
41	3.9×10^{-13}
42	2.5×10^{-13}
43	2.6×10^{-13}
45	2.3×10^{-13}
50	2.5×10^{-13}
78	2.5×10^{-13}

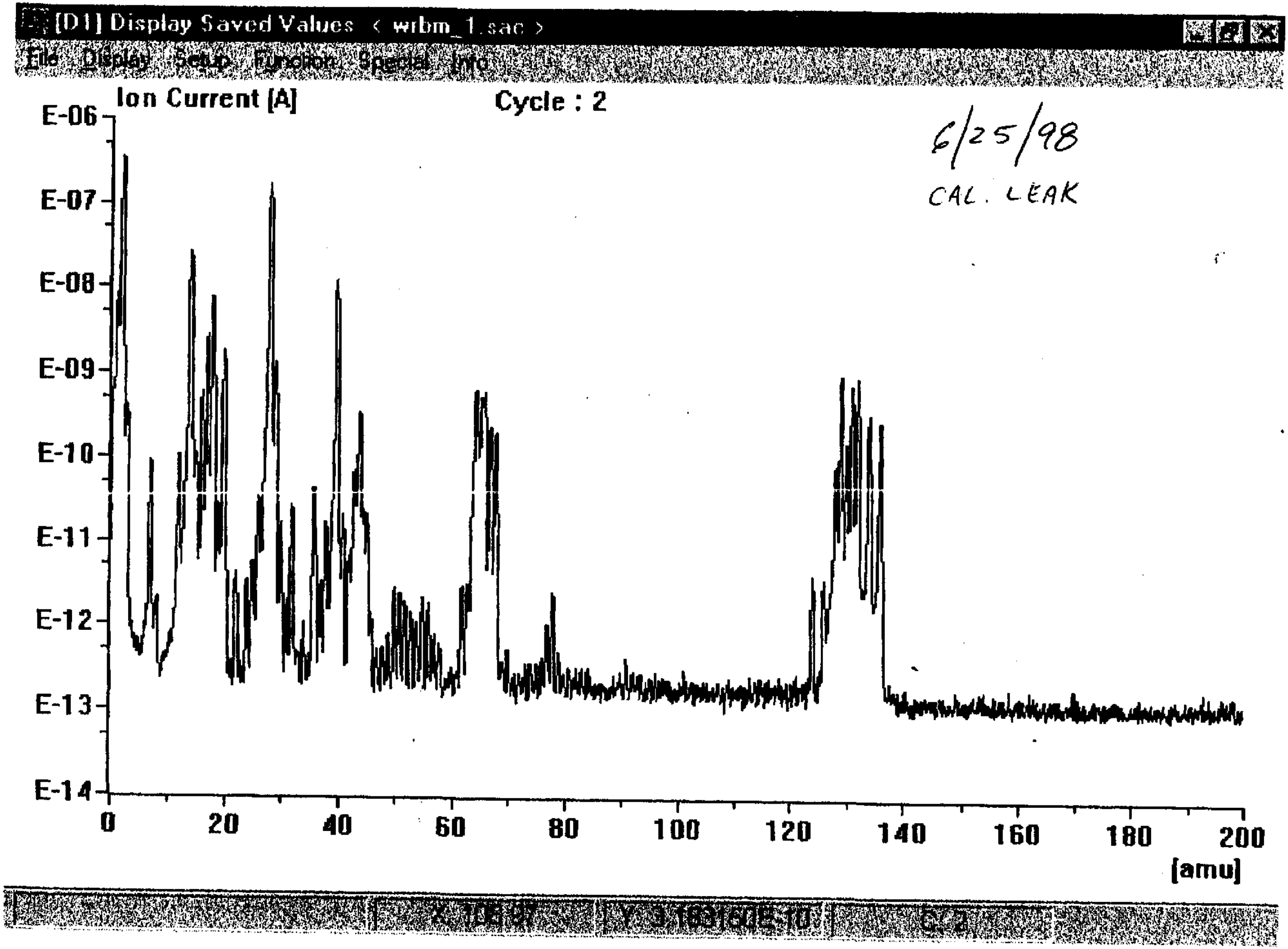

[D1] Display Saved Values < wrbm_6 sac >
File Display Setup Function Special Info
Ion Current [A]
Cycle : 4
E-08
E-09
E-10
E-11
E-12
E-13
E-14
0
20
40
60
80
100
120
140
160
180
200
[amu]
7/6/98
RBM baseline
X: 32.00
Y: 1.564176E-09
C: 4

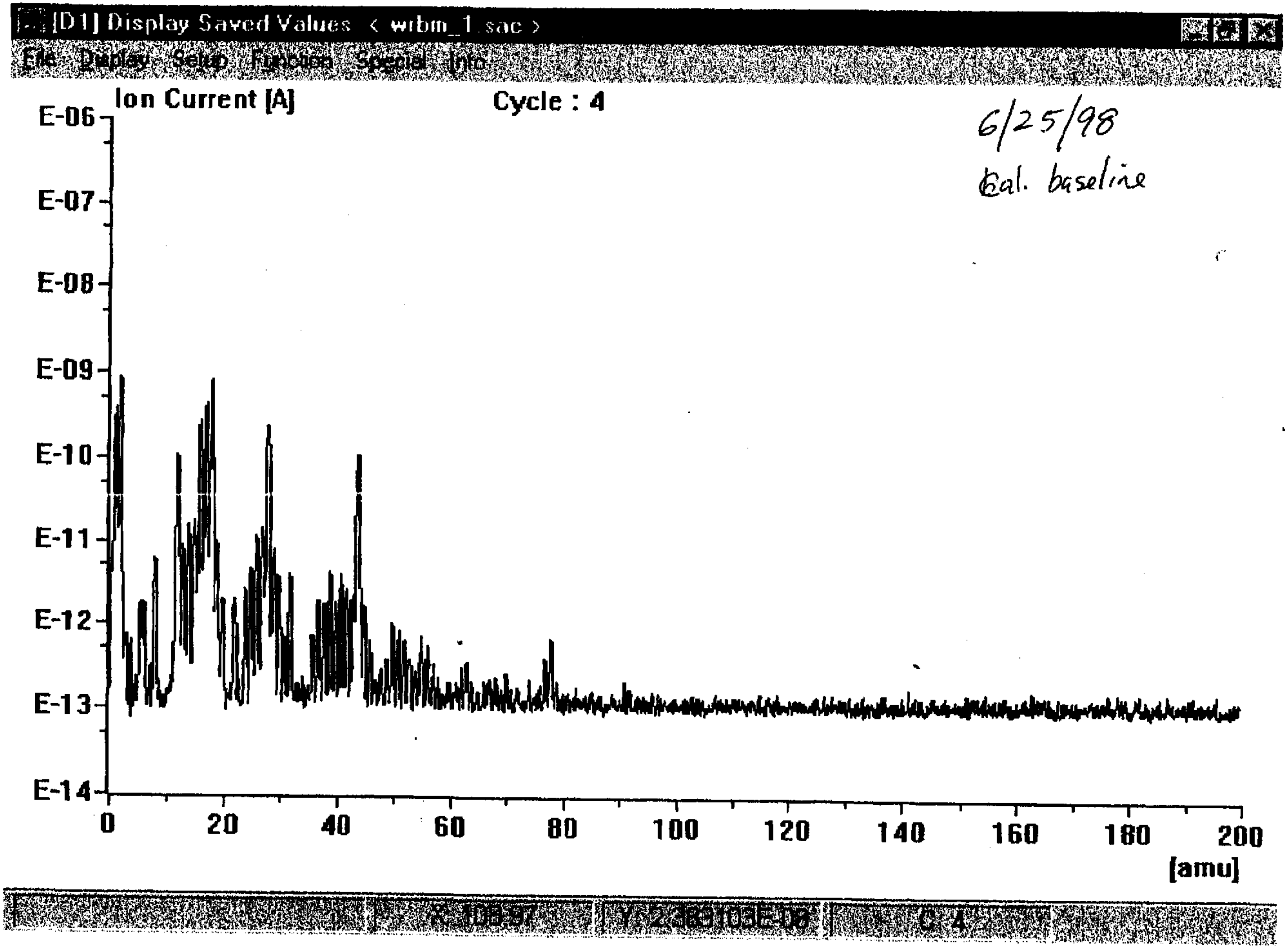
Title: RGA Sensitivity Calibration
Date: 6/25/98
Test ID: WCRBM_1
PSI Engineer: John Flinn

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	8.71E-10	3.44E-07			4.80E-06	13.9	1.01
16	-		0.57	1.6			0.73
18	-		0.64	1.12			1.10
28	2.23E-10	1.66E-07			9.50E-07	3.7	1.55
40	1.32E-12	1.20E-08			9.40E-08	3.1	2.53
44	-		1.57	1.42			1.37
129	1.10E-13	9.49E-10			2.20E-08	1.7	13.64
131	1.10E-13	7.49E-10			1.80E-08	1.7	14.14
132	1.10E-13	9.00E-10			2.20E-08	1.7	14.38
134	1.10E-13	3.31E-10			9.00E-09	1.7	16.00
136	1.10E-13	2.68E-10			8.00E-09	1.7	17.57

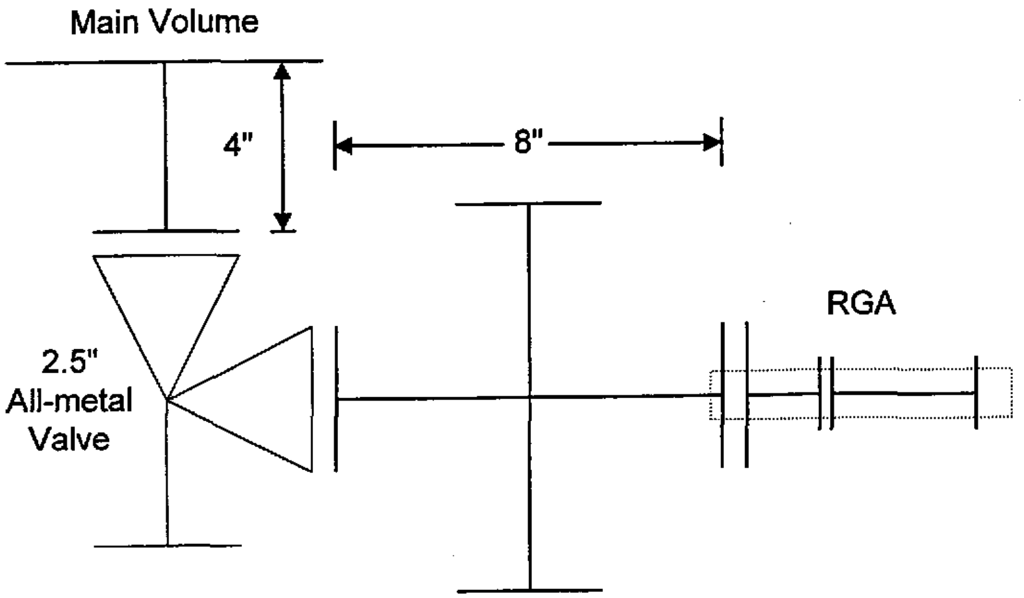
Title: RGA Sensitivity Calibration
Date: 7/7/98
Test ID: WCRBM_8
PSI Engineer: John Flinn

AMU	$I_{(amu)}$ (A)	$I_{(leak)}$ (A)	$F_{(amu)}$ (-)	$E_{(amu)}$ (-)	$Q_{(amu\_leak)}$ (Torr-l/s)	$S_{(orifice\_amu)}$ (l/s)	[redacted]	$S_{(p\_amu)}$ (Torr/A)
2	5.53E-10	3.44E-07			4.80E-06	13.9	[redacted]	1.01
16	-		0.57	1.6			[redacted]	0.72
18	-		0.64	1.12			[redacted]	1.09
28	6.11E-10	1.69E-07			9.50E-07	3.7	[redacted]	1.52
40	2.68E-13	1.22E-08			9.40E-08	3.1	[redacted]	2.49
44	-		1.57	1.42			[redacted]	1.34
129	1.10E-13	9.87E-10			2.20E-08	1.7	[redacted]	13.11
131	1.10E-13	7.59E-10			1.80E-08	1.7	[redacted]	13.95
132	1.10E-13	9.24E-10			2.20E-08	1.7	[redacted]	14.01
134	1.10E-13	3.36E-10			9.00E-09	1.7	[redacted]	15.76
136	1.10E-13	2.75E-10			8.00E-09	1.7	[redacted]	17.12


[D1] Display Saved Values < wrbm_1.sac >
File Display Setup Function Special Info
Ion Current [A]
Cycle : 2
6/25/98
CAL. LEAK
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]


[D1] Display Saved Values < wrbm_1.sac >
File Display Setup Function Special Info
Ion Current [A]
Cycle : 4
6/25/98
Cal. baseline
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]
C: 4

Conductance Calculation for RGA Calibration Chamber



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:

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

{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*).

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT

7.7 Backfill/100 Hr. Pumpdown Test – Right Beam Manifold

This section was tested with the Vertex Section – see Section 8.7 for test results.

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT

7.8 LN2 Consumption Test – Right Beam Manifold

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. CORNER		**Cryopump**	NCP2
Test	Start	Finish		
Date	7/10/98	7/15/98		
Time	1000	1130		

Storage Tank	WDW2	
17263	gallons total volume	
16440	gallons at full trycock	
16440 x 0.95 =	15618	usable gallons
360	in.H2O level indication at full trycock	
45.67	gallons / in.H2O	

Results

Starting level=	145	in.H2O		
Ending level=	131	in.H2O		
Duration=	145.5	Hours		
Liquid consumed=	639.3	gallons		
Tank pressure=	15-16	psig		
Ave.consumption for test duration=			4.39	gal/hour
Projected duration for usable gallons=			<u>148.1</u>	days
Projected duration to empty tank =			<u>155.9</u>	days

PSI ________________

LIGO John Worden

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

DATA SHEET

STATION	CORNER	ISO. SECT	RBM	WCP2			
OPER.							
DATE	7-10-98	7-11-98	7-13-98	7-14-98	7-15-98		
TIME	1000	950	800	1600	1130		
LN2							
PI	15 psig	15 psig	15 psig	16 psig	16 psig		
PI							
LI	145"	141"	136"	133"	131"	LN_2 tank	
LI						filled overnight	
PT 151	0.5 psig	0.5 psig	0.7 psig	0.6 psig	0.6 psig	test complete	
PT							
LIC	91.9%	92.2%	93.5%	91.9%	90.5%		
LIC							
LCV OP	60	60	60	60	60		
LCV OP							
LCV CL	10	10	10	10	10		
LCV CL							
MAIN V.							
PT 134	2.0×10^{-9}	2.0×10^{-9}	1.8×10^{-9}	1.74×10^{-9}	1.79×10^{-9}		
PI							
PI							
PI							
GH1							
GH2							
GH3							
ION P. #6							
EI	3000 V	3000	3000 V	3000 V	3000 V		
EI							
II	3.3×10^{-5}A	3.3×10^{-5}A	3.3×10^{-5}A	3.0×10^{-5}A	3.0×10^{-5}A		
II							

NOTES:

145 hour test

SPECIFICATION

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

8. ACCEPTANCE TEST RESULTS – VERTEX SECTION

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

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT

8.1 Interface To CDS – Vertex Section

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

8.2 Clean Air System Test – Vertex Section

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

All test results met or exceeded the requirements.

LIGO VACUUM EQUIPMENT ACCEPTANCE TEST DATA/TEST VERIFICATION

Equip. Tag____ S/N____________

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				
DEWPOINT	5.2	-60C / -69.C			Am 3/27/98
Particle Count	5.2	100. PART/FT3 REQ 0.0 PART/FT3 MEAS	0.5 μ		Am 3/27/98
HYDROCARBON CONTENT	5.2	0.0 PPM			Am 3/27/98

WASH. CORNER CLEAN AIR SYS.

185

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT

8.3 Class 100 Cleanroom Test – Vertex Section

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

All test results met or exceeded the requirements.

CORNERSTATION
HAM clean room

LIGO VACUUM EQUIPMENT ACCEPTANCE TEST DATA/TEST VERIFICATION

Equip. Tag____ S/N__________

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	ALL OPERATIONAL			[signature] 1/13/98
RGA Test	NA				
Particle Count	5.2	Class 100 FINAL COUNT - 2.8	EQUIPMENT - METONE LASER PARTICLE COUNTER	[signature] 1-15-98	[signature] 1/13/98
Pumpdown	NA				

CLEAN ROOM: Comer HAM DATE: 1/13/98 BY: John Flinn TEST NO.: 1
LIGO Witness: Kyle Ryan

MET ONE MODEL 227 FLOWRATE=0.1CFM PERIOD=2.0 MIN. START TIME: 1245
NO. LOC.=11 SAMP/LOC=1 HOLD=2.O MIN. STOP TIME: 1415
Samples= 20

MEAN =	2.8
SD=	7.0
SE=	1.6

READING	CONCENTRATION (PART/CUBIC FT)		(A-MEAN)^2
1	A1=	5	5.06
0	A2=	0	7.56
0	A3=	0	7.56
1	A4=	5	5.06
1	A5=	5	5.06
0	A6=	0	7.56
6	A7=	30	742.56
0	A8=	0	7.56
0	A9=	0	7.56
0	A10=	0	7.56
0	A11=	0	7.56
0	A12=	0	7.56
2	A13=	10	52.56
0	A14=	0	7.56
0	A15=	0	7.56
0	A16=	0	7.56
0	A17=	0	7.56
0	A18=	0	7.56
0	A19=	0	7.56
0	A20=	0	7.56

PRINTING 020 RECORD(S)
DATA WILL BE REMOVED FROM THE BUFFER

DATE = 01/13/98 TIME = 12:59:07 LOC
PERIOD = 00:02:00 LOCATION NUM. 11
0.3u = 3 0.5u = 1 1

DATE = 01/13/98 TIME = 13:03:07
PERIOD = 00:02:00 LOCATION NUM. 11
0.3u = 0 0.5u = 0 2

DATE = 01/13/98 TIME = 13:07:07
PERIOD = 00:02:00 LOCATION NUM. 11
0.3u = 1 0.5u = 0 3

DATE = 01/13/98 TIME = 13:11:07
PERIOD = 00:02:00 LOCATION NUM. 11
0.3u = 1 0.5u = 1 4

DATE = 01/13/98 TIME = 13:15:07
PERIOD = 00:02:00 LOCATION NUM. 11
0.3u = 1 0.5u = 1 5

DATE = 01/13/98 TIME = 13:19:07
PERIOD = 00:02:00 LOCATION NUM. 11
0.3u = 0 0.5u = 0 6

DATE = 01/13/98 TIME = 13:23:07
PERIOD = 00:02:00 LOCATION NUM. 11
0.3u = 10 0.5u = 6 7

DATE = 01/13/98 TIME = 13:27:07
PERIOD = 00:02:00 LOCATION NUM. 11
0.3u = 7 0.5u = 0 8

DATE = 01/13/98 TIME = 13:31:07
PERIOD = 00:02:00 LOCATION NUM. 11
0.3u = 1 0.5u = 0 9

DATE = 01/13/98 TIME = 13:35:07
PERIOD = 00:02:00 LOCATION NUM. 11
0.3u = 0 0.5u = 0 10

DATE = 01/13/98 TIME = 13:39:07
PERIOD = 00:02:00 LOCATION NUM. 11
0.3u = 0 0.5u = 0 11

DATE = 01/13/98 TIME = 13:43:07
PERIOD = 00:02:00 LOCATION NUM. 11

HAM

PRINTING 012 RECORD(S)
DATA WILL BE REMOVED FROM THE BUFFER

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DATE = 01/13/98 TIME = 13:36:22
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DATE = 01/13/98 TIME = 13:40:22
PERIOD = 00:02:00 LOCATION NUM. 11
0.3u = 0 0.5u = 0 11

DATE = 01/13/98 TIME = 13:44:22
PERIOD = 00:02:00 LOCATION NUM. 11
0.3u = 1 0.5u = 1 12

DATE = 01/13/98 TIME = 13:48:22
PERIOD = 00:02:00 LOCATION NUM. 11
0.3u = 1 0.5u = 0 13

DATE = 01/13/98 TIME = 13:52:22
PERIOD = 00:02:00 LOCATION NUM. 11
0.3u = 0 0.5u = 0 14

DATE = 01/13/98 TIME = 13:56:22
PERIOD = 00:02:00 LOCATION NUM. 11
0.3u = 0 0.5u = 0 15

DATE = 01/13/98 TIME = 14:00:22
PERIOD = 00:02:00 LOCATION NUM. 11

193

```
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PERIOD =  00:02:00  LOCATION NUM.  11
0.3u   =         5  0.5u   =        2   13

DATE   =  01/13/98  TIME   =  13:51:07
PERIOD =  00:02:00  LOCATION NUM.  11
0.3u   =         1  0.5u   =        0   14

DATE   =  01/13/98  TIME   =  13:55:07
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0.3u   =         1  0.5u   =        0   15

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0.3u   =         0  0.5u   =        0   16

DATE   =  01/13/98  TIME   =  14:03:07
PERIOD =  00:02:00  LOCATION NUM.  11
0.3u   =         0  0.5u   =        0   17

DATE   =  01/13/98  TIME   =  14:07:07
PERIOD =  00:02:00  LOCATION NUM.  11
0.3u   =         0  0.5u   =        0   18

DATE   =  01/13/98  TIME   =  14:11:07
PERIOD =  00:02:00  LOCATION NUM.  11
0.3u   =         0  0.5u   =        0   19

DATE   =  01/13/98  TIME   =  14:15:07
PERIOD =  00:02:00  LOCATION NUM.  11
0.3u   =         0  0.5u   =        0   20
```

CORNER STATION HAM CLEANROOM

LOCATION 11

PSI MET ONE PARTICLE COUNTER

11

```
DATE   =  01/13/98  TIME   =  14:04:22
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PERIOD =  00:02:00  LOCATION NUM.  11
0.3u   =         0  0.5u   =        0   18

DATE   =  01/13/98  TIME   =  14:12:22
PERIOD =  00:02:00  LOCATION NUM.  11
0.3u   =         0  0.5u   =        0   19

DATE   =  01/13/98  TIME   =  14:16:22
PERIOD =  00:02:00  LOCATION NUM.  11
0.3u   =         0  0.5u   =        0   20
```

CORNER STATION HAM CLEANROOM

LIGO MET ONE PARTICLE COUNTER

Title: ACCEPTANCE TEST PROCEDURE FOR PORTABLE SOFT-WALL CLEANROOMS

TABLE III - SAMPLE LOCATION GRID HAM CLEAN ROOM

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

CORNER STATION
HAM CLEANROOM
100 BUILDING

LOCATION - 11

SAMPLES - 20
PERIOD - 2.0min.
HOLD - 2.0min.

EMPTY ROOM
FLOOR WASHED
FLOW BALANCED

X- Elevation = ~ 4'

CORNER STATION
BSC II cleanroom

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

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			[signature] 1-16-98
RGA Test	NA				
Particle Count	5.2	Class 100 FINAL COUNT = 11.3	MET ONE LASER PARTICLE COUNTER	Data accepted by [signature] 1-16-98	[signature] 1-16-98
Pumpdown	NA				

CLEAN ROOM: Corner BSCII DATE: 1/16/98 BY: John Flinn TEST NO.: 1

MET ONE MODEL 227 FLOWRATE=0.1CFM PERIOD=2.0 MIN. START TIME: 1415
NO. LOC.=12 SAMP/LOC=1 HOLD=2.O MIN. STOP TIME: 1540
Samples= 19

MEAN =	11.3
SD=	18.1
SE=	4.3

READING	CONCENTRATION (PART/CUBIC FT)		(A-MEAN)^2
0	A1=	0	128.0
0	A2=	0	128.0
0	A3=	0	128.0
0	A4=	0	128.0
3	A5=	15	13.6
6	A6=	30	349.1
9	A7=	45	1134.6
4	A8=	20	75.4
0	A9=	0	128.0
13	A10=	65	2882.0
2	A11=	10	1.7
0	A12=	0	128.0
0	A13=	0	128.0
0	A14=	0	128.0
0	A15=	0	128.0
3	A16=	15	13.6
0	A17=	0	128.0
0	A18=	0	128.0
3	A19=	15	13.6

[redacted]

CORNER STATION

BSC II cleanroom

PRINTING 019 RECORD(S)
DATA WILL BE REMOVED FROM THE BUFFER

LOC

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DATE = 01/17/98 TIME = 14:27:14
PERIOD = 00:02:00 LOCATION NUM. 12
0.3u = 0 0.5u = 0 2

DATE = 01/17/98 TIME = 14:31:14
PERIOD = 00:02:00 LOCATION NUM. 12
0.3u = 0 0.5u = 0 3

DATE = 01/17/98 TIME = 14:35:14
PERIOD = 00:02:00 LOCATION NUM. 12
0.3u = 0 0.5u = 0 4

DATE = 01/17/98 TIME = 14:39:14
PERIOD = 00:02:00 LOCATION NUM. 12
0.3u = 10 0.5u = 3 5

DATE = 01/17/98 TIME = 14:43:14
PERIOD = 00:02:00 LOCATION NUM. 12
0.3u = 9 0.5u = 6 6

DATE = 01/17/98 TIME = 14:47:14
PERIOD = 00:02:00 LOCATION NUM. 12
0.3u = 11 0.5u = 9 7

DATE = 01/17/98 TIME = 14:51:14
PERIOD = 00:02:00 LOCATION NUM. 12
0.3u = 6 0.5u = 4 8

PERIOD = 00:02:00 LOCATION NUM [redacted]
0.3u = 0 0.5u = [redacted]

DATE = 01/17/98 TIME = [redacted]
PERIOD = 00:02:00 LOCATION NUM [redacted]
0.3u = 21 0.5u = [redacted]

DATE = 01/17/98 TIME = 15:03:14
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0.3u = 3 0.5u = 2

DATE = 01/17/98 TIME = 15:07:14
PERIOD = 00:02:00 LOCATION NUM. 12
0.3u = 0 0.5u = 0 12

DATE = 01/17/98 TIME = 15:11:14
PERIOD = 00:02:00 LOCATION NUM. 12
0.3u = 0 0.5u = 0 13

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

DATE = 01/17/98 TIME = 15:19:14
PERIOD = 00:02:00 LOCATION NUM. 12
0.3u = 0 0.5u = 0 15

DATE = 01/17/98 TIME = 15:23:14
PERIOD = 00:02:00 LOCATION NUM. 12
0.3u = 4 0.5u = 3 16

DATE = 01/17/98 TIME = 15:27:14
PERIOD = 00:02:00 LOCATION NUM. 12
0.3u = 0 0.5u = 0 17

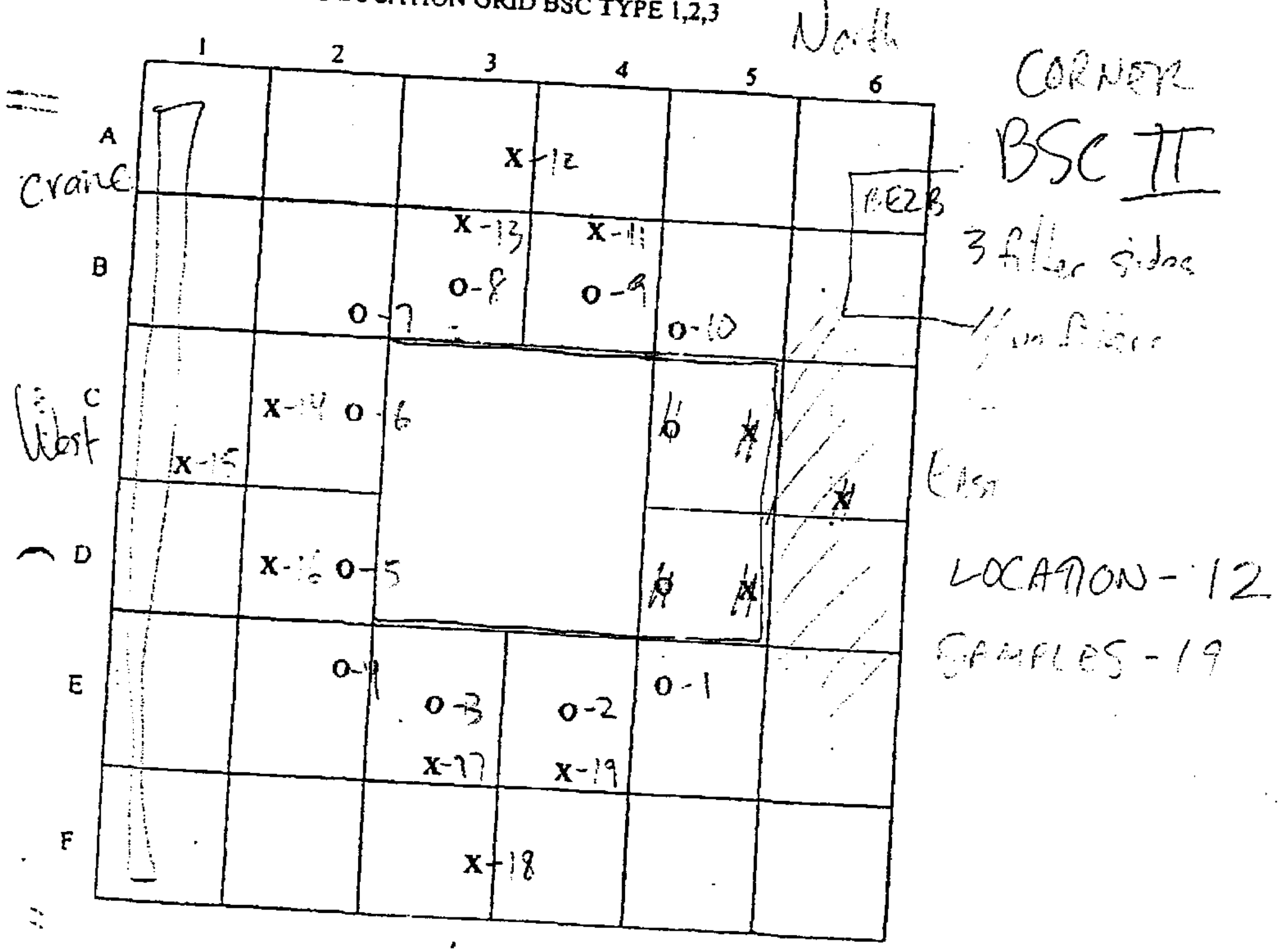
DATE = 01/17/98 TIME = 15:31:14
PERIOD = 00:02:00 LOCATION NUM. 12
0.3u = 0 0.5u = 0 18

DATE = 01/17/98 TIME = 15:35:14
PERIOD = 00:02:00 LOCATION NUM. 12
0.3u = 8 0.5u = 3 19

[redacted]

Title: ACCEPTANCE TEST PROCEDURE FOR PORTABLE SOFT-WALL CLEANROOMS

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



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

LOCATED OVER WBSC1

South

ATTACHMENT I V049-2-110

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT

8.4

(5.4) System Leak Check – VERTEX SECTION

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.

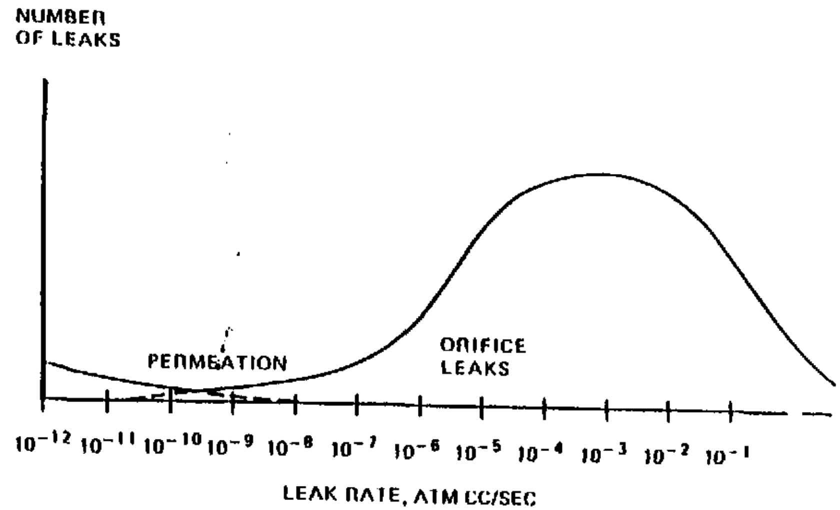


Figure 11.1 Typical distribution of leaks encountered in industrial products.

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

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT

8.4 System Leak Check – Vertex Section

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).

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Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

LEAK TEST DATA SHEET

	1	2	3
Component Name	WASH-VERTEX	ANNULAS PIPE	EQUIP.
Model Number			
Serial Number			
Drawing Number			
Detector Name	BALZERS	BALZERS	BSC 1,2,3
Model Number	HLT 160 DRY	HLT 160 DRY	HAM 1,2,3,4,5,6
Serial Number	03	07-03	A3A
SYS			A3B
~~Detector~~ Calibration			B3A
Expiration Date	1-12-98	INT CAL ONLY	B5A
Standard Leak Rate	4.53×10^{-9}		BE2A
Background			BE2B
Standard Response	4.5×10^{-9}	CF 1.2 CF 1.3	BE3A1
			BE3B
Leak Test Data			
Location /Date	WASH	5-98 / 6-98	
Tracer Gas	HE		
Pressure CC GA1	3.7×10^{-7}	$< 1 \times 10^{-5}$ PER ANNULAS	
Duration		SPACE	
Response	NDL EVAC + SPRAY	NDL EVAC + SPRAY	
	$\times 10^{-9}$ SCALE	$\times 10^{-9}$ SCALE	
Leak Rate			
Measured			
Calculated	NDL $\times 10^{-9}$ SCALE		
Allowable			
Performed By: D.H. & JF	Date :		
Witnessed By :	Date :		
Signature [signature]	Date : 6-9-98		
Title : PROD TECH III			

Remarks : LEAKS (1) 14" OD CFF W HAM 2 (2) 10" OD CFF W HAM 4 - REPAIRED

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

RBM & Vertex Rate of Rise (ROR) Accumulation Tests

1. RBM ROR Test#1. Total leak rate of 5E-9 torr-l/s
   (RBM accepted on Total Pressure and Air Signature)

2. RBM/Vertex ROR Test#1. Total leak rate of 1E-7 torr-l/s
   Tighten CF flanges on GV2 and retest.

3. RBM/Vertex ROR Test#2. Total leak rate of 1E-7 torr-l/s (no change)
   Find large weld leak on HAM2. Theorize an additional large UHV Oring leak in same annulus space. Backfill with Argon to repair leak and retest.

4. RBM/Vertex ROR Test#3. Total leak rate of 1E-7 torr-l/s (no change)
   UHV Oring is tight. Start turbo pumping at end of ROR test for a Helium mass spec. leak test. Burst in a calibrated leak, P=1E-4 Torr. Looking for a 2.6E-7 Helium signal, find a 2.1E-7 signal on 10" CF mechanical joint. Attempt to repair failed, opened leak to 5.7E-7. Purge leak with Helium, pump all annulus spaces and retest.

5. RBM/Vertex ROR Test#4. Total leak rate of 8E-8 to 1E-7 torr-l/s (no significant change) Isolate turbo and ion pump. Retest in AM.

6. RBM/Vertex ROR Test#5. Total leak rate of 8E-8 to 1E-7 torr-l/s (same as Test#4)
   Stumped. Recalibrate RGA. Close GV2 and retest RBM.

7. RBM ROR Test#2. Total leak rate 3E-8 torr-l/s.
   Expected to repeat 5E-9 torr-l/s from RBM ROR Test#1, now suspect cryo may be a source of air. Isolate cryo and retest.

8. RBM ROR Test#3. Total leak rate 3E-8 torr-l/s for Nitrogen (same as Test#2) but 8E-8 torr-l/s for Argon.
   Data is erratic. Only thing left to do is perform ROR on RGA calibration chamber.

9. RGA ROR Test on calibration chamber. Total leak rate is a max. of 2E-9 torr-l/s
   Calibration chamber not adding to overall leak rate significantly.

Vertex Total Leak Rate Summary

According the first Vertex test, the leak rate was 1E-7 torr-l/s. We believe that this was a single leak. We found this leak on a 10" CF mechanical joint, but it could not be repaired under vacuum. When completing RBM/Vertex ROR Test#4, we expected to see a high Helium signature and a lower air signature (≤1E-8 torr-l/s). Since this did not happen, we performed a rigorous Helium leak test. With the ease in finding a 2E-7 torr-l/s Helium leak, our experience would lead us to believe that we could, with the same technique, find a smaller leak. This leak would be on the order of 1E-8 → 5E-8 torr-l/s. Since the air signature was calculated to a larger value, we should have found the leak. We did not find any leaks beside the original 10" CF leak and we do not believe that there are any leaks on the system. We tried to prove this, and by analyzing the test results (Items 5-9 above) there is no proof either way of what is happening inside the clean UHV system. Our helium leak test techniques would find any substantial leaks in the system, and this is the final data on which we base our conclusions.

1. The weld leak on HAM2 annulus space saturated the UHV orings with air in HAM2 and HAM3, which share common annuli. This represents over 1600 lineal inches (4000 cm) of saturated orings. The backfill of Argon, to repair the leak, may have also added more air. The air signature that we continue to see is due to the degassing of these UHV orings.

2. If you subtract Vertex/RBM ROR Test #5 from Vertex/RBM Test #1, then you are left with a total leak rate (≤ 4E-8 Torr-l/s). The real total leak rate is probably less. Long term pumping should reduce the air signature that is due to this oring degassing.

AMU	Cycle 2 A	Torr/A	Torr	Cycle 40 A	Torr/A	Torr	ΔP	Volume liters	DTime s	T-L/s	FractionF	N2 Equiv T-L/s	T-L/s-cm2
2	5.80E-09	1	5.80E-09	4.70E-07	1	4.70E-07	4.64E-07	130000	10000	6.03E-06	1	6.03E-06	8.62E-12
3	2.90E-09	1	2.90E-09										
4		1	0.00E+00										
6	3.20E-12	1	3.20E-12										
7		1	0.00E+00										
8	1.00E-12	1	1.00E-12										
12	8.50E-11	1.5	1.28E-10	5.17E-11	1.5	7.76E-11							
13	4.80E-11	1.5	7.20E-11	1.92E-11	1.5	2.88E-11	-4.32E-11	130000	10000	-5.62E-10	0.07	-8.02E-09	
14 from CH4	1.78E-11	1.5	2.67E-11	1.78E-11	1.5	2.67E-11	0.00E+00	130000	10000	0.00E+00	0.156	0.00E+00	
14 from N2	3.00E-11	1.5	4.50E-11	4.74E-11	1.5	7.11E-11	2.61E-11	130000	10000	3.39E-10	0.072	4.71E-09	
15	8.80E-11	1.5	1.32E-10	9.20E-11	1.5	1.38E-10	6.00E-12	130000	10000	7.80E-11	0.85	9.18E-11	
16	1.60E-10	1.5	2.40E-10	1.10E-10	1.5	1.65E-10	-7.50E-11	130000	10000	-9.75E-10	1	-9.75E-10	
17		1.5	0.00E+00										
18		1.5	0.00E+00										
19		1.5	0.00E+00										
20	3.00E-13	1.5	4.50E-13	5.00E-13	1.5	7.50E-13	3.00E-13	130000	10000	3.90E-12	0.002	1.95E-09	
22		1.5	0.00E+00										
25		1.5	0.00E+00										
26		1.5	0.00E+00										
27		1.5	0.00E+00										
28	2.90E-10	1.5	4.35E-10	4.90E-10	1.5	7.35E-10	3.00E-10	130000	10000	3.90E-09	1	3.90E-09	
29	4.00E-12	1.5	6.00E-12	4.50E-12	1.5	6.75E-12	7.50E-13	130000	10000	9.75E-12	0.008	1.22E-09	
30		1.5	0.00E+00										
32	5.00E-13	1.5	7.50E-13										
[illegible]		[illegible]	[illegible]										
40	3.00E-13	2.5	7.50E-13	2.10E-12	2.5	5.26E-12	4.50E-12	130000	10000	5.85E-11	0.01	5.85E-09	
41		1.5	0.00E+00										
44	4.30E-12	1.5	6.45E-12	7.50E-12	1.5	1.13E-11							

BALZERS SPECTRA LIBRARY

	46	45	44	40	38	36	29	28	22	20	19	18	17	16	15	14	13	12
CO2	0.4	1.3	100					11.4	1.2					8.5				6
Ar				100	0.06					20		0.061						
CO							1.1	100						0.9		0.6		4.5
N2							0.8	100								7.2		
O2																		
H2O										0.3	0.1	100	23	1.1				
CH4													1.2	100	85.8	15.6	7.7	2.4

Using the change in signal of mass 28 and assigning it all to N2 leads to 4E-9 leak
Using the change in signal of mass 14 and assigning it all to N2 leads to 5E-9 leak
Using the change in signal of mass 40 and assigning it all to Ar leads to 6E-9 leak
Using the change in signal of mass 20 and assigning it all to Ar leads to 2E-9 leak using spectra library values
Using the change in signal of mass 29 and assigning it all to N2 leads to 2E-9 leak using spectra library values

RBM ROR Test#1
RGA file: WRBMROR1.sao
RBM_ROR_1.xls
7/6/98 PM

Oxygen is consumed to form CO2?
Carbon is consumed
Argon is not likely being pumped by cryopump
Entire change in mass 14 used in the calc. for leak rate, no seperation between CH4 and N

208

		Cycle 3 A	Torr/A	Torr	Cycle 50 A	Torr/A	Torr	Δ P	Volume liters	DTime s	T-L/s	FractionF	N2 Equiv T-L/s	T-L/s-cm2
	0													
	1													
	2	1.93E-08	1	1.93E-08	6.91E-07	1	6.91E-07	6.72E-07	300000	12180	1.65E-05	1	1.65E-05	5.01E-12
	3	8.10E-11	1	8.10E-11										
	4		1	0.00E+00										
	6	3.83E-12	1	3.83E-12										
	7		1	0.00E+00										
	8	1.56E-12	1	1.56E-12										
	12	1.78E-10	1.5	2.67E-10	9.49E-11	1.5	1.42E-10							
	13	1.11E-10	1.5	1.67E-10	4.79E-11	1.5	7.19E-11	-9.47E-11	300000	12180	-2.33E-09	0.07	-3.33E-08	
14 from CH4			1.5	#VALUE!		1.5	#VALUE!	#VALUE!	300000	12180	#VALUE!	0.156	#VALUE!	
14 from N2		1.88E-10	1.5	2.82E-10	3.73E-10	1.5	5.60E-10	2.78E-10	300000	12180	6.83E-09	0.072	9.49E-08	
	15	3.36E-10	1.5	5.04E-10	2.32E-10	1.5	3.48E-10	-1.56E-10	300000	12180	-3.84E-09	0.85	-4.52E-09	
	16	3.93E-10	1.5	5.90E-10	2.87E-10	1.5	4.31E-10	-1.59E-10	300000	12180	-3.92E-09	1	-3.92E-09	
	17		1.5	0.00E+00										
	18		1.5	0.00E+00										
	19		1.5	0.00E+00										
	20	1.34E-12	1.5	2.01E-12	3.44E-12	1.5	5.16E-12	3.15E-12	300000	12180	7.76E-11	0.002	3.88E-08	
	22		1.5	0.00E+00										
	25		1.5	0.00E+00										
	26		1.5	0.00E+00										
	27		1.5	0.00E+00										
	28	6.65E-10	1.5	9.98E-10	2.35E-09	1.5	3.53E-09	2.53E-09	300000	12180	6.23E-08	1	6.23E-08	
	29	5.53E-12	1.5	8.30E-12	2.41E-11	1.5	3.62E-11	2.79E-11	300000	12180	6.86E-10	0.008	8.58E-08	
	30		1.5	0.00E+00										
	32	8.77E-13	1.5	1.32E-12										
	39		1.5	0.00E+00										
	40	4.72E-12	2.5	1.18E-11	2.29E-11	2.5	5.73E-11	4.55E-11	300000	12180	1.12E-09	0.01	1.12E-07	
	41		1.5	0.00E+00										
	44	9.87E-12	1.5	1.48E-11	1.35E-11	1.5	2.03E-11							

BALZERS SPECTRA LIBRARY

	46	45	44	40	38	36	29	28	22	20	19	18	17	16	15	14	13	12
CO2	0.4	1.3	100					11.4	1.2					8.5				6
Ar				100	0.06					20		0.068						
CO							1.1	100						0.9		0.6		4.5
N2							0.8	100								7.2		
O2																		
H2O										0.3	0.1	100	23	1.1				
CH4													1.2	100	85.8	15.6	7.7	2.4

Using the change in signal of mass 28 and assigning it all to N2 leads to 6E-8 leak
Using the change in signal of mass 14 and assigning it all to N2 leads to 9E-8 leak
Using the change in signal of mass 40 and assigning it all to Ar leads to 1E-7 leak
Using the change in signal of mass 20 and assigning it all to Ar leads to 4E-8 leak using spectra library values
Using the change in signal of mass 29 and assigning it all to N2 leads to 9E-8 leak using spectra library values

Vertex/RBM ROR Test#1
RGA file: RBMVROR1.sac
RBM_Vertex_ROR_1.xls
7/9/98 PM

Oxygen is consumed to form CO2?
Carbon is consumed
Argon is not likely being pumped by cryopump
Entire change in mass 14 used in the calc. for leak rate, no separation between CH4 and N

209

		Cycle 3			Cycle 50				Volume	DTime			N2 Equiv	
	0	A	Torr/A	Torr	A	Torr/A	Torr	Δ P	liters	s	T-L/s	FractionF	T-L/s	T-L/s-cm2
	1													
	2	1.93E-08	1	1.93E-08	6.91E-07	1	6.91E-07	6.72E-07	300000	12180	1.65E-05	1	1.65E-05	5.01E-12
	3	8.10E-11	1	8.10E-11										
	4		1	0.00E+00										
	6	3.83E-12	1	3.83E-12										
	7		1	0.00E+00										
	8	1.56E-12	1	1.56E-12										
	12	1.78E-10	1.5	2.67E-10	9.49E-11	1.5	1.42E-10							
	13	1.11E-10	1.5	1.67E-10	4.79E-11	1.5	7.19E-11	-9.47E-11	300000	12180	-2.33E-09	0.07	-3.33E-08	
14 from CH4			1.5	#VALUE!		1.5	#VALUE!	#VALUE!	300400	12180	#VALUE!	0.156	#VALUE!	
14 from N2		1.45E-10	1.5	2.18E-10	3.54E-10	1.5	5.31E-10	3.14E-10	300000	12180	7.72E-09	0.072	1.07E-07	
	15	3.36E-10	1.5	5.04E-10	2.32E-10	1.5	3.48E-10	-1.56E-10	300000	12180	-3.84E-09	0.85	-4.52E-09	
	16	3.93E-10	1.5	5.90E-10	2.87E-10	1.5	4.31E-10	-1.59E-10	300000	12180	-3.92E-09	1	-3.92E-09	
	17		1.5	0.00E+00										
	18		1.5	0.00E+00										
	19		1.5	0.00E+00										
	20	2.04E-12	1.5	3.06E-12	4.04E-12	1.5	6.06E-12	3.00E-12	300000	12180	7.39E-11	0.002	3.69E-08	
	22		1.5	0.00E+00										
	25		1.5	0.00E+00										
	26		1.5	0.00E+00										
	27		1.5	0.00E+00										
	28	5.11E-10	1.5	7.67E-10	2.17E-09	1.5	3.26E-09	2.49E-09	300000	12180	6.13E-08	1	6.13E-08	
	29	4.98E-12	1.5	7.47E-12	2.41E-11	1.5	3.62E-11	2.87E-11	300000	12180	7.06E-10	0.008	8.83E-08	
	30		1.5	0.00E+00										
	32	8.77E-13	1.5	1.32E-12										
	39		1.5	0.00E+00										
	40	5.53E-12	2.5	1.38E-11	2.41E-11	2.5	6.03E-11	4.64E-11	300000	12180	1.14E-09	0.01	1.14E-07	
	41		1.5	0.00E+00										
	44	9.87E-12	1.5	1.48E-11	1.35E-11	1.5	2.03E-11							

BALZERS SPECTRA LIBRARY

	46	45	44	40	38	36	29	28	22	20	19	18	17	16	15	14	13	12
CO2	0.4	1.3	100					11.4	1.2					8.5				6
Ar				100	0.06					20		0.068						
CO							1.1	100						0.9		0.6		4.5
N2							0.8	100								7.2		
O2																		
H2O										0.3	0.1	100	23	1.1				
CH4													1.2	100	85.8	15.6	7.7	2.4

Using the change in signal of mass 28 and assigning it all to N2 leads to 6E-8 leak
Using the change in signal of mass 14 and assigning it all to N2 leads to 1E-7 leak
Using the change in signal of mass 40 and assigning it all to Ar leads to 1E-7 leak
Using the change in signal of mass 20 and assigning it all to Ar leads to 4E-8 leak using spectra library values
Using the change in signal of mass 29 and assigning it all to N2 leads to 9E-8 leak using spectra library values

Oxygen is consumed to form CO2?
Carbon is consumed
Argon is not likely being pumped by cryopump
Entire change in mass 14 used in the calc. for leak rate, no seperation between CH4 and N

<u>Vertex/RBM ROR Test#2</u>
tighten GV2 CF and retest (no change)
RGA file: RBMVROR2.sac
RBM_Vertex_ROR_2.xls
7/15/98 PM

AMU	Cycle 2 A	Torr/A	Torr	Cycle 38 A	Torr/A	Torr	ΔP	Volume liters	DTime s	T-L/s	FractionF	N2 Equiv T-L/s	T-L/s-cm2
2	1.93E-08	1	1.93E-08	6.91E-07	1	6.91E-07	6.72E-07	300000	7200	2.80E-05	1	2.80E-05	8.48E-12
3	8.10E-11	1	8.10E-11										
4		1	0.00E+00										
6	3.83E-12	1	3.83E-12										
7		1	0.00E+00										
8	1.56E-12	1	1.56E-12										
12	1.78E-10	1.5	2.67E-10	9.49E-11	1.5	1.42E-10							
13	1.11E-10	1.5	1.67E-10	4.79E-11	1.5	7.19E-11	-9.47E-11	300000	7200	-3.94E-09	0.07	-5.63E-08	
14 from CH4		1.5	#VALUE!		1.5	#VALUE!	#VALUE!	300000	7200	#VALUE!	0.156	#VALUE!	
14 from N2	9.49E-11	1.5	1.42E-10	2.32E-10	1.5	3.48E-10	2.06E-10	300000	7200	8.57E-09	0.072	1.19E-07	
15	3.36E-10	1.5	5.04E-10	2.32E-10	1.5	3.48E-10	-1.56E-10	300000	7200	-6.50E-09	0.85	-7.65E-09	
16	3.93E-10	1.5	5.90E-10	2.87E-10	1.5	4.31E-10	-1.59E-10	300000	7200	-6.63E-09	1	-6.63E-09	
17		1.5	0.00E+00										
18		1.5	0.00E+00										
19		1.5	0.00E+00										
20	2.51E-12	1.5	3.77E-12	3.83E-12	1.5	5.75E-12	1.98E-12	300000	7200	8.25E-11	0.002	4.13E-08	
22		1.5	0.00E+00										
25		1.5	0.00E+00										
26		1.5	0.00E+00										
27		1.5	0.00E+00										
28	5.99E-10	1.5	8.99E-10	1.63E-09	1.5	2.45E-09	1.55E-09	300000	7200	6.44E-08	1	6.44E-08	
29	5.53E-12	1.5	8.30E-12	1.76E-11	1.5	2.64E-11	1.81E-11	300000	7200	7.54E-10	0.008	9.43E-08	
30		1.5	0.00E+00										
32	8.77E-13	1.5	1.32E-12										
[illegible]		1.5	0.00E+00										
40	6.82E-12	2.5	1.71E-11	1.76E-11	2.5	4.40E-11	2.70E-11	300000	7200	1.12E-09	0.01	1.12E-07	
41		1.5	0.00E+00										
44	9.87E-12	1.5	1.48E-11	1.35E-11	1.5	2.03E-11							

BALZERS SPECTRA LIBRARY

	46	45	44	40	38	36	29	28	22	20	19	18	17	16	15	14	13	12
CO2	0.4	1.3	100					11.4	1.2					8.5				6
Ar				100	0.06					20		0.068						
CO							1.1	100						0.9		0.6		4.5
N2							0.8	100								7.2		
O2																		
H2O										0.3	0.1	100	23	1.1				
CH4													1.2	100	85.8	15.6	7.7	2.4

Using the change in signal of mass 28 and assigning it all to N2 leads to 6E-8 leak
Using the change in signal of mass 14 and assigning it all to N2 leads to 1E-7 leak
Using the change in signal of mass 40 and assigning it all to Ar leads to 1E-7 leak
Using the change in signal of mass 20 and assigning it all to Ar leads to 4E-8 leak using spectra library values
Using the change in signal of mass 29 and assigning it all to N2 leads to 9E-8 leak using spectra library values

Oxygen is consumed to form CO2?
Carbon is consumed
Argon is not likely being pumped by cryopump
Entire change in mass 14 used in the calc. for leak rate, no seperation between CH4 and N

<u>Vertex/RBM ROR Test#3</u>
Argon in HAM2,3 annulus space
RGA file: RBMVROR3.asc
RBM_Vertex_ROR_3.xls
7/17/98 PM

211

AMU	Cycle 2 A	Torr/A	Torr	Cycle 26 A	Torr/A	Torr	Δ P	Volume liters	DTime s	T-L/s	FractionF	N2 Equiv T-L/s	T-L/s-cm2
2	1.93E-08	1	1.93E-08	6.91E-07	1	6.91E-07	6.72E-07	300000	5100	3.95E-05	1	3.95E-05	1.20E-11
3		1											
4	7.68E-11	1	7.68E-11	9.61E-10	1	9.61E-10	8.84E-10	300000	5100	5.20E-08	2.6	2.00E-08	
6		1											
7		1											
8	1.56E-12	1	1.56E-12										
12	1.78E-10	1.5	2.67E-10	9.49E-11	1.5	1.42E-10							
13	1.11E-10	1.5	1.67E-10	4.79E-11	1.5	7.19E-11	-9.47E-11	300000	5100	-5.57E-09	0.07	-7.95E-08	
14 from CH4	0.00E+00	1.5			1.5			300000	5100		0.156		
14 from N2	2.09E-10	1.5	3.14E-10	3.53E-10	1.5	5.30E-10	2.16E-10	300000	5100	1.27E-08	0.072	1.76E-07	
15	3.36E-10	1.5	5.04E-10	2.32E-10	1.5	3.48E-10	-1.56E-10	300000	5100	-9.18E-09	0.85	-1.08E-08	
16	3.93E-10	1.5	5.90E-10	2.87E-10	1.5	4.31E-10	-1.59E-10	300000	5100	-9.35E-09	1	-9.35E-09	
17		1.5											
18		1.5											
19		1.5											
20	9.74E-13	1.5	1.46E-12	2.51E-12	1.5	3.77E-12	2.30E-12	300000	5100	1.36E-10	0.002	6.78E-08	
22		1.5											
25		1.5											
26		1.5											
27		1.5											
28	1.54E-09	1.5	2.31E-09	3.06E-09	1.5	4.59E-09	2.28E-09	300000	5100	1.34E-07	1	1.34E-07	
29	3.68E-11	1.5	5.52E-11	5.32E-11	1.5	7.98E-11	2.46E-11	300000	5100	1.45E-09	0.008	1.81E-07	
30		1.5											
32	8.77E-13	1.3	1.32E-12										
[illegible]		[illegible]											
40	4.03E-12	2.5	1.01E-11	9.36E-12	2.5	2.34E-11	1.33E-11	300000	5100	7.84E-10	0.01	7.84E-08	
41		1.5											
44	9.87E-12	1.5	1.48E-11	1.35E-11	1.5	2.03E-11							

BALZERS SPECTRA LIBRARY

	46	45	44	40	38	36	29	28	22	20	19	18	17	16	15	14	13	12
CO2	0.4	1.3	100					11.4	1.2					8.5				6
Ar				100	0.06					20		0.068						
CO							1.1	100						0.9		0.6		4.5
N2							0.8	100								7.2		
O2																		
H2O										0.3	0.1	100	23	1.1				
CH4													1.2	100	85.8	15.6	7.7	2.4

Using the change in signal of mass 14 and assigning it all to N2 leads to 1.8E-7 leak
Using the change in signal of mass 28 and assigning it all to N2 leads to 1.3E-7 leak
Using the change in signal of mass 29 and assigning it all to N2 leads to 1.3E-7 leak using spectra library values

Using the change in signal of mass 20 and assigning it all to Ar leads to 6.8E-8 leak using spectra library values
Using the change in signal of mass 40 and assigning it all to Ar leads to 7.8E-8 leak

Oxygen is consumed to form CO2?
Carbon is consumed
Argon is not likely being pumped by cryopump
Entire change in mass 14 used in the calc. for leak rate, no seperation between CH4 and N

<u>Vertex/RBM ROR Test#4</u>
Helium purging leak on HAM4 10" CF (5.7E-7mbar-l/s on HLT160#3)
All annulus spaces evacuated
Turbo pumping for leak testing (no ion pumping)
RGA file: RBMVROR4.sac
RBM_Vertex_ROR_4.xls
7/19/98 PM

AMU	Cycle 2 A	Torr/A	Torr	Cycle 41 A	Torr/A	Torr	Δ P	Volume liters	DTime s	T-L/s	FractionF	N2 Equiv T-L/s	T-L/s-cm2
2	7.49E-09	1	7.49E-09	1.86E-07	1	1.86E-07	1.79E-07	300000	10080	5.31E-06	1	5.31E-06	1.61E-12
3		1											
4	5.18E-11	1	5.18E-11	1.81E-09	1	1.81E-09	1.76E-09	300000	10080	5.23E-08	2.646	1.98E-08	
6		1											
7		1											
8	1.56E-12	1	1.56E-12										
12	1.78E-10	1.5	2.67E-10	9.49E-11	1.5	1.42E-10							
13	1.11E-10	1.5	1.67E-10	4.79E-11	1.5	7.19E-11	-9.47E-11	300000	10080	-2.82E-09	0.070	-4.02E-08	
14 from CH4	0.00E+00	1.5			1.5			300000	10080		0.156		
14 from N2	1.14E-10	1.5	1.71E-10	2.72E-10	1.5	4.08E-10	2.37E-10	300000	10080	7.05E-09	0.072	9.80E-08	
15	3.36E-10	1.5	5.04E-10	2.32E-10	1.5	3.48E-10	-1.56E-10	300000	10080	-4.64E-09	0.850	-5.46E-09	
16	3.93E-10	1.5	5.90E-10	2.87E-10	1.5	4.31E-10	-1.59E-10	300000	10080	-4.73E-09	1	-4.73E-09	
17		1.5											
18		1.5											
19		1.5											
20	2.48E-12	1.5	3.72E-12	3.83E-12	1.5	5.75E-12	2.03E-12	300000	10080	6.03E-11	0.002	3.01E-08	
22		1.5											
25		1.5											
26		1.5											
27		1.5											
28	2.20E-09	1.5	3.30E-09	4.20E-09	1.5	6.30E-09	3.00E-09	300000	10080	8.93E-08	1	8.93E-08	
29	2.98E-11	1.5	4.47E-11	5.91E-11	1.5	8.87E-11	4.40E-11	300000	10080	1.31E-09	0.008	1.64E-07	
30		1.5											
32	8.77E-13	1.5	1.32E-12										
39		1.5											
40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.01	[illegible]	
41		1.5											
44	9.87E-12	1.5	1.48E-11	1.35E-11	1.5	2.03E-11							

BALZERS SPECTRA LIBRARY

	46	45	44	40	38	36	29	28	22	20	19	18	17	16	15	14	13	12
CO2	0.4	1.3	100					11.4	1.2					8.5				6
Ar				100	0.06					20		0.068						
CO							1.1	100						0.9		0.6		4.5
N2							0.8	100								7.2		
O2																		
H2O										0.3	0.1	100	23	1.1				
CH4													1.2	100	85.8	15.6	7.7	2.4

Using the change in signal of mass 4 and assigning it all to He leads to 2E-8 leak

Using the change in signal of mass 14 and assigning it all to N2 leads to 9.8E-8 leak
Using the change in signal of mass 28 and assigning it all to N2 leads to 8.9E-8 leak
Using the change in signal of mass 29 and assigning it all to N2 leads to 1.6E-7 leak using spectra library values

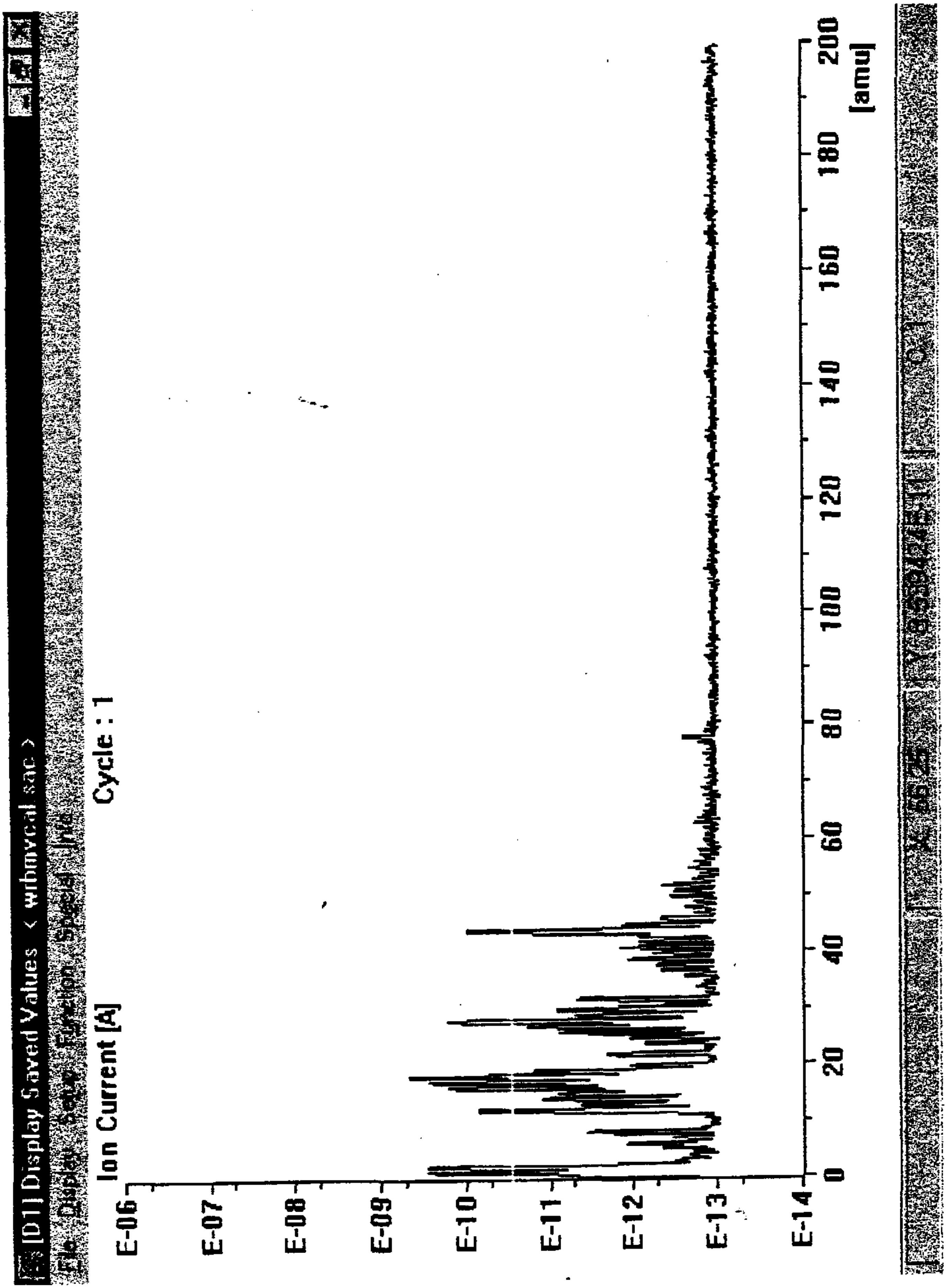
Using the change in signal of mass 20 and assigning it all to Ar leads to 3.0E-8 leak using spectra library values
Using the change in signal of mass 40 and assigning it all to Ar leads to 7.1E-8 leak

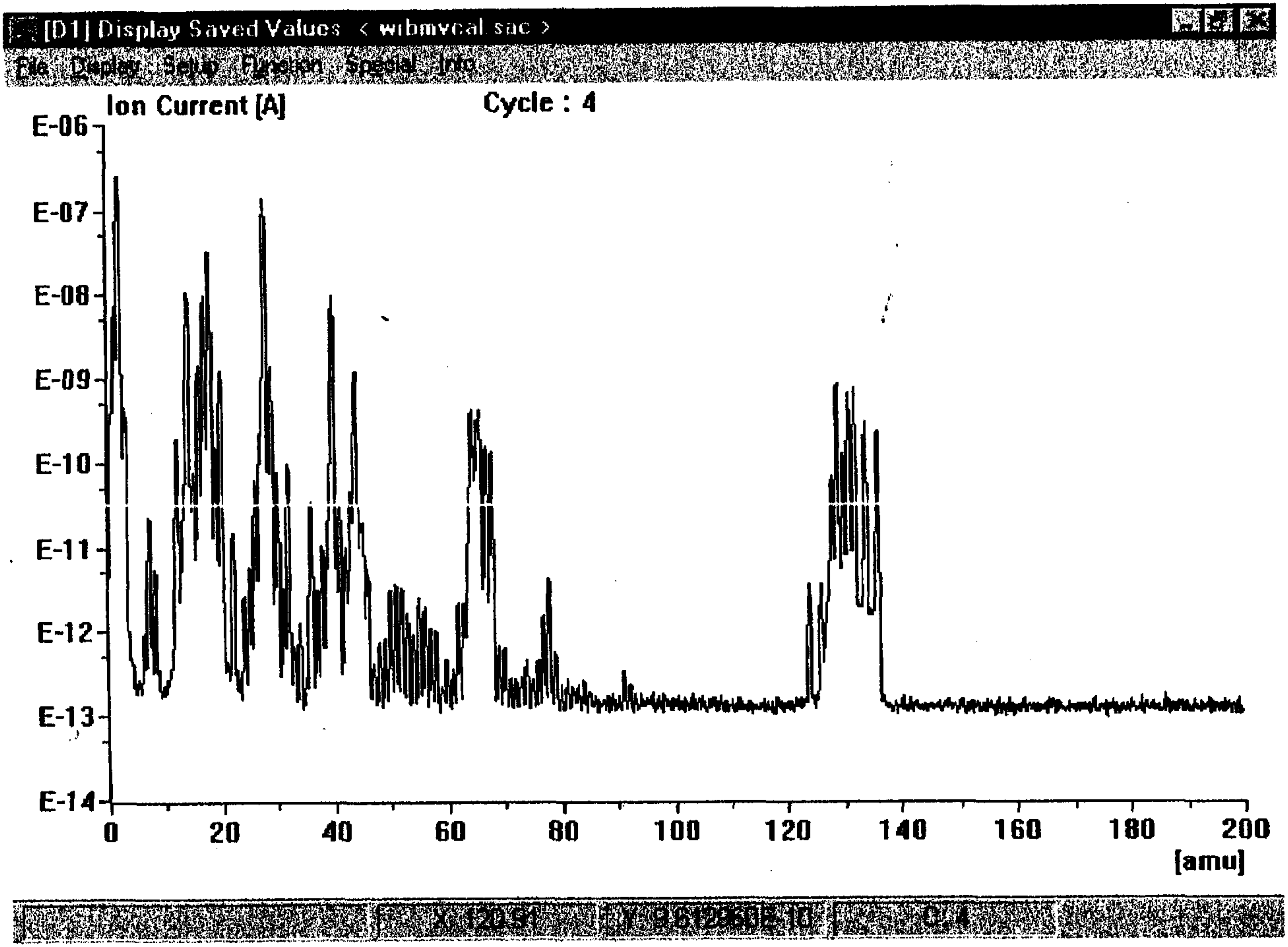
Oxygen is consumed to form CO2?
Carbon is consumed
Argon is not likely being pumped by cryopump
Entire change in mass 14 used in the calc. for leak rate, no separation between CH4 and N

Vertex/RBM ROR Test#5
Helium purging leak on HAM4 10" CF (5.7E-7mbar-l/s on HLT160#3
All annulus spaces evacuated
Ion pumping overnight
RGA file: RBMVROR5.sao
RBM_Vertex_ROR_5.xls
7/20/98 AM

Title:	RGA Sensitivity Calibration
Date:	7/21/98
Test ID:	WCRBM_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)	[redacted]	$S_{(p\_amu)}$ (Torr/A)
2	2.85E-10	2.55E-07			4.80E-06	13.9	[redacted]	1.36
16	-		0.57	1.6			[redacted]	0.90
18	-		0.64	1 12			[redacted]	1.36
28	1.53E-10	1.35E-07			9.50E-07	3.7	[redacted]	1.90
40	5.53E-13	9.74E-09			9.40E-08	3.1	[redacted]	3.11
44	-		1.57	1 42			[redacted]	1.68
129	1.00E-13	8.20E-10			2.20E-08	1.7	[redacted]	15.78
131	1.00E-13	6.31E-10			1.80E-08	1.7	[redacted]	16.78
132	1.00E-13	7.39E-10			2.20E-08	1.7	[redacted]	17.51
134	1.00E-13	2.87E-10			9.00E-09	1.7	[redacted]	18.45
136	1.00E-13	2.20E-10			8.00E-09	1.7	[redacted]	21.40


[D1] Display Saved Values < wrbmvcal.sac >
File Display Setup Function Special Info
Ion Current [A]
Cycle : 1
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]


[D1] Display Saved Values < wibmvcal.sac >
File Display Setup Function Special Info
Ion Current [A]
Cycle : 4
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: 120.91
C: 4

AMU	Cycle 1 A	Torr/A	Torr	Cycle 30 A	Torr/A	Torr	Δ P	Volume liters	DTime s	T-L/s	FractionP	N2 Equiv T-L/s	T-L/s-cm2
2	4.03E-08	1.3	5.24E-08	1.96E-07	1	1.96E-07	1.44E-07	130000	7440	2.51E-06	1	2.51E-06	3.58E-12
3	2.90E-09	1.3	3.77E-09										
4		1.3	0.00E+00										
6	3.20E-12	1.3	4.16E-12										
7		1.3	0.00E+00										
8	1.00E-12	1.3	1.30E-12										
12	8.50E-11	1.9	1.62E-10	5.17E-11	1.5	7.76E-11	-6.24E-11	130000	7440	-1.09E-09	0.07	-1.56E-08	
13	4.80E-11	1.9	9.12E-11	1.92E-11	1.5	2.88E-11	-7.12E-12	130000	7440	-1.24E-10	0.156	-7.97E-10	
14 from CH4	1.78E-11	1.9	3.38E-11	1.78E-11	1.5	2.67E-11	1.14E-10	130000	7440	2.00E-09	0.072	2.77E-08	
14 from N2	1.23E-10	1.9	2.34E-10	2.31E-10	1.5	3.48E-10	-2.92E-11	130000	7440	-5.10E-10	0.85	-6.00E-10	
15	8.80E-11	1.9	1.67E-10	9.20E-11	1.5	1.38E-10	-1.39E-10	130000	7440	-2.43E-09	1	-2.43E-09	
16	1.60E-10	1.9	3.04E-10	1.10E-10	1.5	1.65E-10							
17		1.9	0.00E+00										
18		1.9	0.00E+00										
19		1.9	0.00E+00										
20	1.34E-12	1.9	2.55E-12	2.51E-12	1.5	3.77E-12	1.22E-12	130000	7440	2.13E-11	0.002	1.06E-08	
22		1.9	0.00E+00										
25		1.9	0.00E+00										
26		1.9	0.00E+00										
27		1.9	0.00E+00										
28	9.12E-10	1.9	1.73E-09	2.35E-09	1.5	3.53E-09	1.79E-09	130000	7440	3.13E-08	1	3.13E-08	
29	1.50E-11	1.9	2.85E-11	3.49E-11	1.5	5.24E-11	2.39E-11	130000	7440	4.17E-10	0.008	5.21E-08	
30		1.9	0.00E+00										
32	5.00E-13	1.9	9.50E-13										
39		1.9	0.00E+00										
[illegible]	[illegible]	[illegible]	[illegible]	1.22E-11	2.5	3.05E-11	1.66E-11	130000	7440	2.90E-10	0.01	1.90E-08	
41		1.9	0.00E+00										
44	4.30E-12	1.9	8.17E-12	7.50E-12	1.5	1.13E-11							

BALZERS SPECTRA LIBRARY

	46	45	44	40	38	36	29	28	22	20	19	18	17	16	15	14	13	12
								11.4	1.2					8.5				6
CO2	0.4	1.3	100							20		0.068						
Ar				100	0.06									0.9		0.6		4.5
CO							1.1	100								7.2		
N2							0.8	100										
O2										0.3	0.1	100	23	1.1				
H2O													1.2	100	85.8	15.6	7.7	2.4
CH4																		

Using the change in signal of mass 28 and assigning it all to N2 leads to 4E-9 leak
Using the change in signal of mass 14 and assigning it all to N2 leads to 5E-9 leak
Using the change in signal of mass 40 and assigning it all to Ar leads to 6E-9 leak
Using the change in signal of mass 20 and assigning it all to Ar leads to 2E-9 leak using spectra library values
Using the change in signal of mass 29 and assigning it all to N2 leads to 2E-9 leak using spectra library values

RBM ROR Test #2
confirmation of vertex leak
recalibrated RGA in AM
RGA file: WRBMROR2.sao
RBM_ROR_2.xls
7/21/98 PM

Oxygen is consumed to form CO2?
Carbon is consumed
Argon is not likely being pumped by cryopump
Entire change in mass 14 used in the calc. for leak rate, no seperation between CH4 and N

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AMU	Cycle 2 A	Torr/A	Torr	Cycle 30 A	Torr/A	Torr	ΔP	Volume liters	DTime s	T-L/s	FractionF	N2 Equiv T-L/s	T-L/s-cm2
1													
2	6.39E-09	1.3	8.31E-09	1.22E-07	1	1.22E-07	1.14E-07	130000	7260	2.04E-06	1	2.04E-06	2.91E-12
3	2.90E-09	1.3	3.77E-09										
4		1.3	0.00E+00										
6	3.20E-12	1.3	4.16E-12										
7		1.3	0.00E+00										
8	1.00E-12	1.3	1.30E-12										
12	8.50E-11	1.9	1.62E-10	5.17E-11	1.5	7.76E-11							
13	4.80E-11	1.9	9.12E-11	1.92E-11	1.5	2.88E-11	-6.24E-11	130000	7260	-1.12E-09	0.07	-1.60E-08	
14 from CH4	1.78E-11	1.9	3.38E-11	1.78E-11	1.5	2.67E-11	-7.12E-12	130000	7260	-1.27E-10	0.156	-8.17E-10	
14 from N2	6.56E-11	1.9	1.25E-10	1.69E-10	1.5	2.54E-10	1.29E-10	130000	7260	2.31E-09	0.072	3.20E-08	
15	8.80E-11	1.9	1.67E-10	9.20E-11	1.5	1.38E-10	-2.92E-11	130000	7260	-5.23E-10	0.85	-6.15E-10	
16	1.60E-10	1.9	3.04E-10	1.10E-10	1.5	1.65E-10	-1.39E-10	130000	7260	-2.49E-09	1	-2.49E-09	
17		1.9	0.00E+00										
18		1.9	0.00E+00										
19		1.9	0.00E+00										
20	1.93E-12	1.9	3.67E-12	2.51E-12	1.5	3.77E-12	9.80E-14	130400	7260	1.75E-12	0.002	8.77E-10	
22		1.9	0.00E+00										
25		1.9	0.00E+00										
26		1.9	0.00E+00										
27		1.9	0.00E+00										
28	7.00E-10	1.9	1.33E-09	2.23E-09	1.5	3.35E-09	2.02E-09	130000	7260	3.61E-08	1	3.61E-08	
29	2.83E-11	1.9	5.38E-11	9.49E-11	1.5	1.42E-10	8.86E-11	130000	7260	1.59E-09	0.008	1.98E-07	
30		1.9	0.00E+00										
32	5.00E-13	1.9	9.50E-13										
39		1.9	0.00E+00										
40	7.20E-12	3.1	2.23E-11	2.83E-11	2.5	7.08E-11	4.84E-11	130000	7260	8.67E-10	0.01	8.67E-08	
41		1.9	0.00E+00										
44	4.30E-12	1.9	8.17E-12	7.50E-12	1.5	1.13E-11							

BALZERS SPECTRA LIBRARY

	46	45	44	40	38	36	29	28	22	20	19	18	17	16	15	14	13	12
CO2	0.4	1.3	100					11.4	1.2					8.5				6
Ar				100	0.06					20		0.061						
CO							1.1	100						0.9		0.6		4.5
N2							0.8	100								7.2		
O2																		
H2O										0.3	0.1	100	23	1.1				
CH4													1.2	100	85.8	15.6	7.7	2.4

Using the change in signal of mass 28 and assigning it all to N2 leads to 4E-9 leak
Using the change in signal of mass 14 and assigning it all to N2 leads to 3E-9 leak
Using the change in signal of mass 40 and assigning it all to Ar leads to 6E-9 leak
Using the change in signal of mass 20 and assigning it all to Ar leads to 2E-9 leak using spectra library values
Using the change in signal of mass 29 and assigning it all to N2 leads to 2E-9 leak using spectra library values

Oxygen is consumed to form CO2?
Carbon is consumed
Argon is not likely being pumped by cryopump
Entire change in mass 14 used in the calc. for leak rate, no seperation between CH4 and N

RBM ROR Test #3
confirmation of vertex leak
isolate cryopump on RBM (may actually pump Ar)
RGA file: WRBMROR3.sao
RBM_ROR_3.xls
7/22/98 AM

AMU	Cycle 2 A	Torr/A	Torr	Cycle 27 A	Torr/A	Torr	ΔP	Volume liters	DTime s	T-L/s	FractionF	N2 Equiv T-L/s	T-L/s-cm2
1													
2	2.26E-07	1.3	2.94E-07	6.96E-07	1.3	9.05E-07	6.11E-07	2	6480	1.89E-10	1	1.89E-10	6.29E-14
3		1.3			1.3								
4		1.3	#VALUE!		1.3	#VALUE!	#VALUE!	2	6480	#VALUE!	2.646	#VALUE!	
6		1.3			1.3								
7		1.3			1.3								
8	1.56E-12	1.3	2.03E-12		1.3								
12	1.78E-10	1.9	3.38E-10	9.49E-11	1.9	1.80E-10							
13	1.11E-10	1.9	2.11E-10	4.79E-11	1.9	9.10E-11	-1.20E-10	2	6480	-3.70E-14	0.070	-5.29E-13	
14 from CH4	0.00E+00	1.9			1.9			2	6480		0.156		
14 from N2	8.16E-10	1.9	1.55E-09	2.25E-08	1.9	4.28E-08	4.12E-08	2	6480	1.27E-11	0.072	1.77E-10	
15	3.36E-10	1.9	6.38E-10	2.32E-10	1.9	4.41E-10	-1.98E-10	2	6480	-6.10E-14	0.850	-7.18E-14	
16	3.93E-10	1.9	7.47E-10	2.87E-10	1.9	5.45E-10	-2.01E-10	2	6480	-6.22E-14	1	-6.22E-14	
17		1.9			1.9								
18		1.9			1.9								
19		1.9			1.9								
20	1.45E-12	1.9	2.76E-12	4.22E-11	1.9	8.02E-11	7.74E-11	2	6480	2.39E-14	0.002	1.19E-11	
22		1.9			1.9								
25		1.9			1.9								
26		1.9			1.9								
27		1.9			1.9								
28	4.57E-08	1.9	8.68E-08	2.56E-06	1.9	4.86E-06	4.78E-06	2	6480	1.47E-09	1	1.47E-09	
29	6.44E-10	1.9	1.21E-09	3.20E-08	1.9	6.08E-08	5.96E-08	2	6480	1.84E-11	0.008	2.30E-09	
30		1.9			1.9								
[illegible]	[illegible]	1.9	1.67E-12		1.9								
39		1.9			1.9								
40	8.54E-12	3.1	2.65E-11	3.36E-10	3.1	1.04E-09	1.02E-09	2	6480	3.13E-13	0.01	3.13E-11	
41		1.9			1.9								
44	9.87E-12	1.9	1.88E-11	1.35E-11	1.9	2.57E-11							

BALZERS SPECTRA LIBRARY

	46	45	44	40	38	36	29	28	22	20	19	18	17	16	15	14	13	12
CO2	0.4	1.3	100					11.4	1.2					8.5				6
Ar				100	0.06					20		0.068						
CO							1.1	100						0.9		0.6		4.5
N2							0.8	100								7.2		
O2																		
H2O										0.3	0.1	100	23	1.1				
CH4													1.2	100	85.8	15.6	7.7	2.4

Using the change in signal of mass 14 and assigning it all to N2 leads to 2E-10 leak
Using the change in signal of mass 28 and assigning it all to N2 leads to 1E-9 leak
Using the change in signal of mass 29 and assigning it all to N2 leads to 2E-9 leak using spectra library values

Using the change in signal of mass 20 and assigning it all to Ar leads to 1E-11 leak using spectra library values
Using the change in signal of mass 40 and assigning it all to Ar leads to 3E-11 leak

Oxygen is consumed to form CO2?
Carbon is consumed
Argon is not likely being pumped by cryopump
Entire change in mass 14 used in the calc. for leak rate, no seperation between CH4 and N

RGA Calibration Chamber ROR Test
last test to verify leak rate in calibration chamber
RGA file: RGAROR1.sac
RGA_ROR_1.xls
7/22/98 pm

AMU	Cycle 2 A	Torr/A	Torr	Cycle 41 A	Torr/A	Torr	Δ P	Volume liters	DTime s	T-L/s	FractionF	N2 Equiv T-L/s	T-L/s-cm2
2	7.49E-09	1	7.49E-09	1.86E-07	1	1.86E-07	1.79E-07	300000	10080	5.31E-06	1	5.31E-06	1.61E-12
3		1											
4	5.18E-11	1	5.18E-11	1.81E-09	1	1.81E-09	1.76E-09	300000	10080	5.23E-08	2.646	1.98E-08	
6		1											
7		1											
8	1.56E-12	1	1.56E-12										
12	1.78E-10	1.5	2.67E-10	9.49E-11	1.5	1.42E-10							
13	1.11E-10	1.5	1.67E-10	4.79E-11	1.5	7.19E-11	-9.47E-11	300000	10080	-2.82E-09	0.07	-4.02E-08	
14 from CH4	0.00E+00	1.5			1.5			300000	10080	#VALUE!	0.156	#VALUE!	
14 from N2	1.14E-10	1.5	1.71E-10	2.72E-10	1.5	4.08E-10	2.37E-10	300000	10080	7.05E-09	0.0593	1.19E-07	
15	3.36E-10	1.5	5.04E-10	2.32E-10	1.5	3.48E-10	-1.56E-10	300000	10080	-4.64E-09	0.85	-5.46E-09	
16	3.93E-10	1.5	5.90E-10	2.87E-10	1.5	4.31E-10	-1.59E-10	300000	10080	-4.73E-09	1	-4.73E-09	
17		1.5											
18		1.5											
19		1.5											
20	2.48E-12	1.5	3.72E-12	3.83E-12	1.5	5.75E-12	2.03E-12	300000	10080	6.03E-11	0.00148	4.07E-08	
22		1.5											
25		1.5											
26		1.5											
27		1.5											
28	2.20E-09	1.5	3.30E-09	4.20E-09	1.5	6.30E-09	3.00E-09	300000	10080	8.93E-08	1	8.93E-08	
29	2.98E-11	1.5	4.47E-11	5.91E-11	1.5	8.87E-11	4.40E-11	300000	10080	1.31E-09	0.01	1.31E-07	
30		1.5											
32	8.77E-13	1.5	1.32E-12										
39		1.5											
40	1.11E-11	2.5	2.78E-11	2.06E-11	2.5	5.15E-11	2.38E-11	300000	10080	7.07E-10	0.01	7.07E-08	
41		1.5											
44	9.87E-12	1.5	1.48E-11	1.35E-11	1.5	2.03E-11							

Data recalculated based on measured cracking pattern in situ

Using the change in signal of mass 4 and assigning it all to He leads to 1.98E-08 leak rate

Using the change in signal of mass 14 and assigning it all to N2 leads to 1.19E-07 leak rate
Using the change in signal of mass 28 and assigning it all to N2 leads to 8.93E-08 leak rate
Using the change in signal of mass 29 and assigning it all to N2 leads to 1.31E-07 leak rate

Using the change in signal of mass 20 and assigning it all to Ar leads to 4.07E-08 leak rate
Using the change in signal of mass 40 and assigning it all to Ar leads to 7.07E-08 leak rate

Vertex/RBM ROR Test#5A

Helium purging leak on HAM4 10" CF (5.7E-7mbar-l/s on HLT160#3) overnight
All annulus spaces evacuated
Ion pumping overnight
RGA file: RBMVROR5.sac
RBM_Vertex_ROR_5A.xls
7/20/98 AM

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Cracking Pattern 28AMU (nitrogen) and 40AMU (Argon) in the Vertex and RBM after bake with 5 ion pumps and 1 cryopump

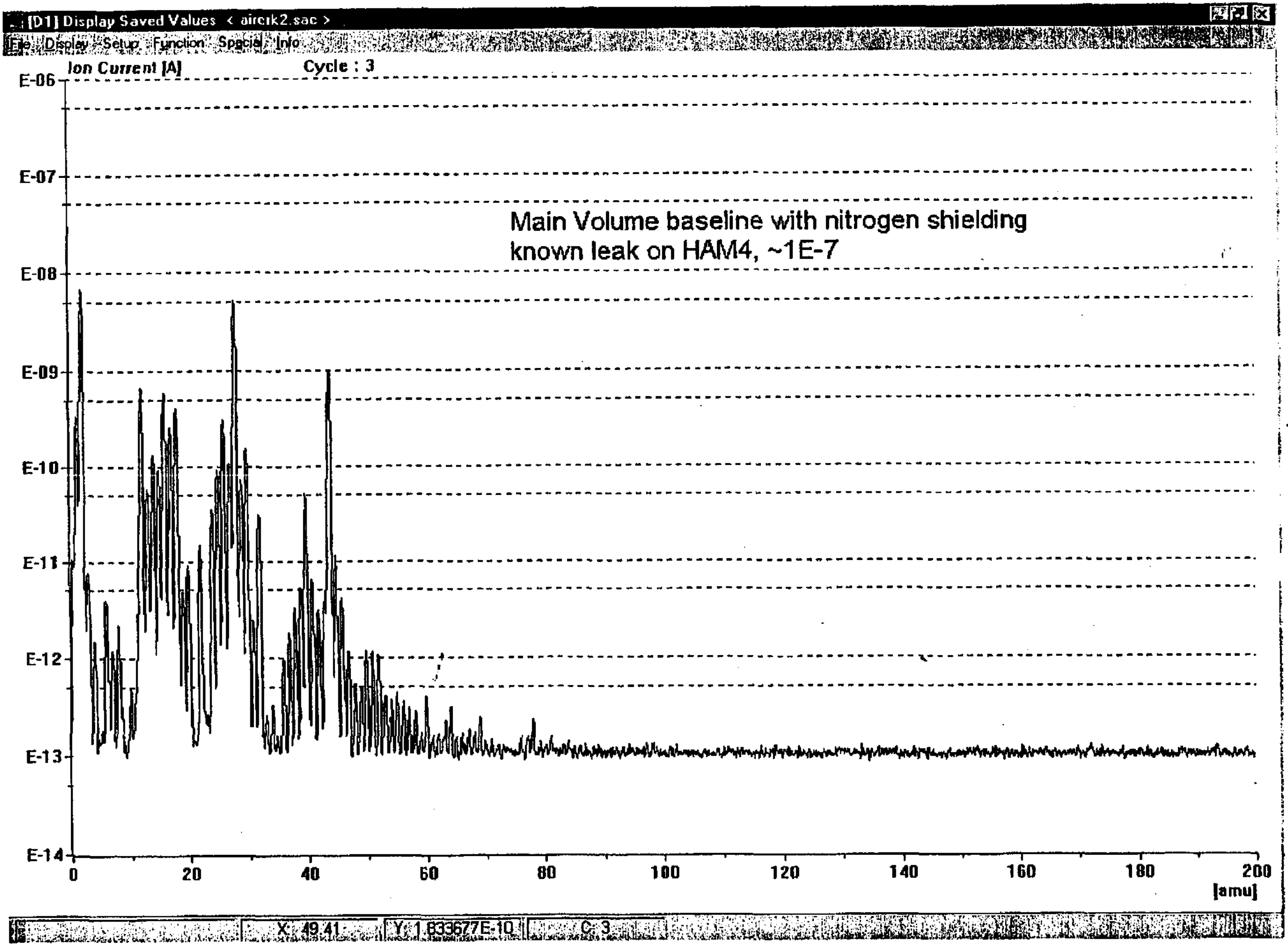
Variable Leak Valve open to increase the 14 and 28 baseline by a decade

	AMU		%	AMU		%
scan 6						
	14	4.55E-09	5.99	20	1.11E-10	14.61
	28	7.60E-08	100.00	40	7.60E-10	100.00
	29	7.38E-10	0.97			
				32	6.26E-09	8.24
scan 7						
	14	4.12E-09	5.83	20	1.11E-10	14.61
	28	7.07E-08	100.00	40	7.60E-10	100.00
	29	6.97E-10	0.99			
				32	5.26E-09	7.44
scan 8						
	14	3.94E-09	5.90	20	1.13E-10	14.66
	28	6.68E-08	100.00	40	7.71E-10	100.00
	29	6.57E-10	0.98			
				32	4.69E-09	7.02
scan 9						
	14	3.83E-09	5.90	20	1.18E-10	14.86
	28	6.49E-08	100.00	40	7.94E-10	100.00
	29	6.49E-10	1.00			
				32	4.36E-09	6.72
scan 10						
	14	3.72E-09	5.99	20	1.22E-10	15.16
	28	6.21E-08	100.00	40	8.05E-10	100.00
	29	6.12E-10	0.99			
				32	4.11E-09	6.62
scan 11						
	14	3.67E-09	6.00	20	1.23E-10	15.06
	28	6.12E-08	100.00	40	8.17E-10	100.00
	29	6.03E-10	0.99			
				32	3.94E-09	6.44

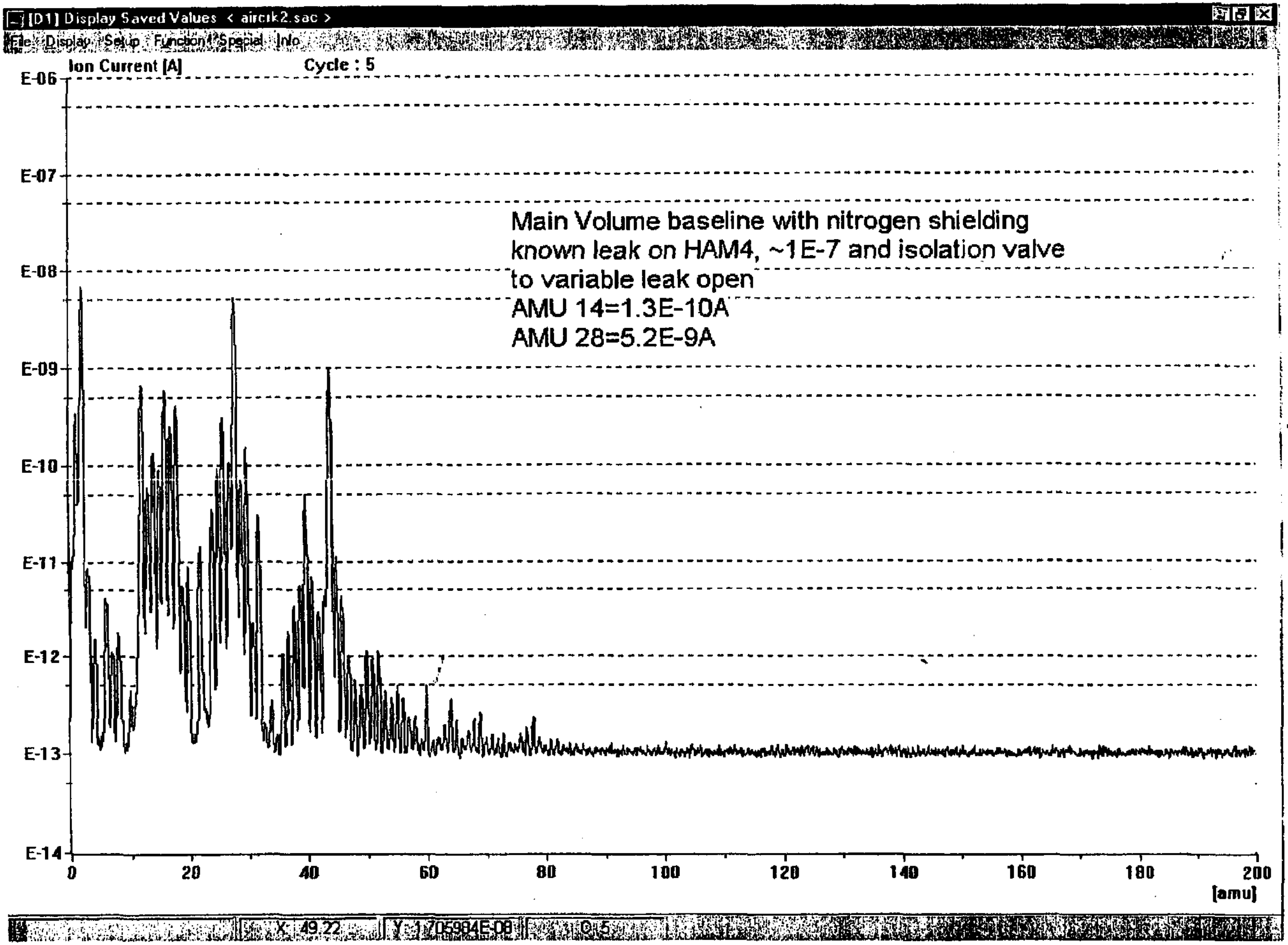
Note:
The 32AMU percentage is with respect to 100% of nitrogen.

Average	N2		Ar	
	14	5.93	20	14.82
	28	100.0	40	100.0
	29	0.99		

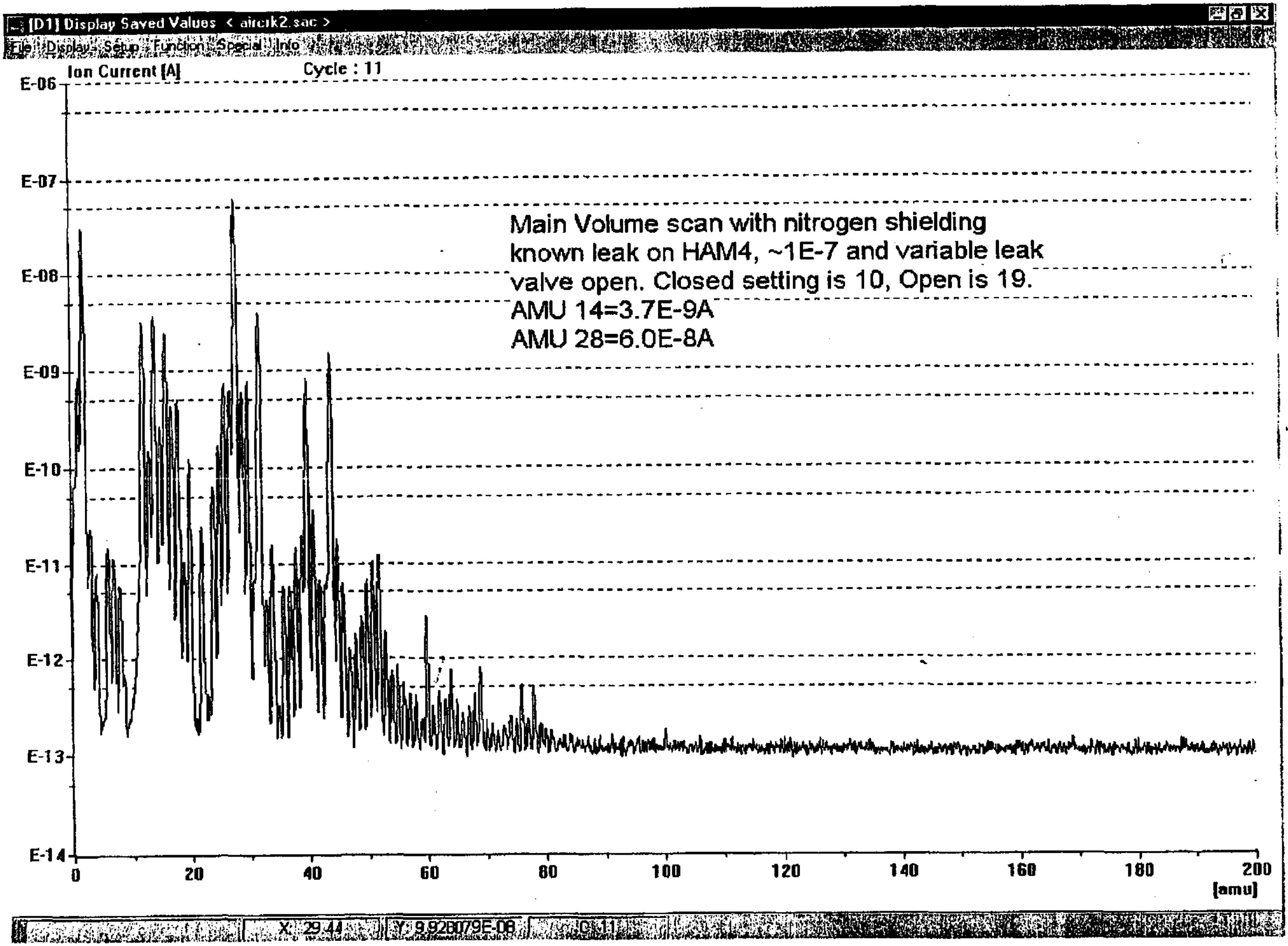
221


[D1] Display Saved Values < aircrk2.sac >
File Display Setup Function Special Info
Ion Current [A]
Cycle : 3
E-06
E-07
E-08
E-09
E-10
E-11
E-12
E-13
E-14
Main Volume baseline with nitrogen shielding
known leak on HAM4, ~1E-7
0
20
40
60
80
100
120
140
160
180
200
[amu]
X: 49.41
Y: 1.833677E-10
C: 3

222


[D1] Display Saved Values < aircık2.sac >
File Display Setup Function Special Info
Ion Current [A]
Cycle : 5
E-06
E-07
E-08
E-09
E-10
E-11
E-12
E-13
E-14
Main Volume baseline with nitrogen shielding
known leak on HAM4, ~1E-7 and isolation valve
to variable leak open
AMU 14=1.3E-10A
AMU 28=5.2E-9A
0
20
40
60
80
100
120
140
160
180
200
[amu]
X: 49.22
Y: 1.705984E-08
C: 5

223


[D1] Display Saved Values < aircrk2.sac >
File Display Setup Function Special Info
Ion Current [A]
Cycle : 11
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]
Main Volume scan with nitrogen shielding
known leak on HAM4, ~1E-7 and variable leak
valve open. Closed setting is 10, Open is 19.
AMU 14=3.7E-9A
AMU 28=6.0E-8A
X: 29.44
Y: 9.928079E-08
C: 11

Jul 28 98 07:20a David M. Evers 943-4429 p.2

7-26-98 AIRCRK2.SAC

CYCLE 6-13 with VAR LEAK

CYCLE 13 @ 80 AMU

CLOSE VALVE to MAIN VOLUME OPEN 250 TURBO

BURP IN MIX LEAK

CLOSE VAR. LEAK MANIFOLD

CYCLE 14-16 CAL MIX LEAK SCANS

CYCLE 1 BASELINE RGA

7-27-98 SAVE 1 CYCLE

AIRCRK2.SAC

7-26-98 Ag Piece on HAM #4 x10⁻⁷ LEAK

[CYCLE 1] BASELINE ON RGA ONLY

1:10 IP 1 4.5×10^{-4} AMP
2 4.6×10^{-4} AMP
3 4.5×10^{-4} AMP
4 4.6×10^{-4} AMP
6 4.7×10^{-4} AMP

Pcc Pt 120 1.7×10^{-8}
170 3.0×10^{-8}
134 3.0×10^{-8}

CP2 @ 88%

close 250 turbo open to main volume

[CYCLE 2+3] Main Volume Baseline

close Aux cart open VAR LEAK manifold setting .000

[CYCLE 4-5] BaseLine to closed VAR LEAK

Amu 14 @ 1×10^{-10}
Amu 28 @ 4×10^{-9} stable

2:40 STOP SCAN, change amu scale to 0-30 (.55sec) to add variable leak
start to open var leak of incr. of .002
var leak @ 19 looks like about 1 decade

[APPEND] to [redacted]. aircrk2.sac [10 SCANS]

4:40 IP 1 4.2×10^{-3} PRESS cc Pt 120 1.4×10^{-7}
2 4.2×10^{-3} Pt 170 2.6×10^{-7}
3 4.3×10^{-3} Pt 134 2.7×10^{-7}
4 4.2×10^{-3}
6 5.0×10^{-3}

WASHINGTON SITE CORNER STATION
PSI FACTORY LEAK TEST DATA SHEETS
VERTEX SECTION

Tag No.	*Serial No.*
WBSC 1	09
WBSC 2	02
WBSC 3	03
WHAM 1	01
WHAM 2	03
WHAM 3	04
WHAM 4	05
WHAM 5	07
WHAM 6	02
WA3A	01
WA3B	02
WB3A	01
WB5A	01
WBE2A	01
WBE2B	02
WBE3A1	01
WBE3B	01

VERTEX

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

LEAK TEST DATA SHEET

	1	2	3
Component Name	BSC	SPOOL	
Model Number	W BSC 1	A15	
Serial Number	09	02	
Drawing Number			
Detector Name	BALZERS		
Model Number	HLT 160 DRY		
Serial Number	02		
Detector Calib.Date	7-11-97		
Detector Calib.Factor	1.2		
Standard Leak Rate	4.8x10-9		
Std.Leak Expir.Date	6-3-98		
Standard Response	5.5x10-9		
Leak Test Data			
Location /Date	CLEAN ROOM / 7-11-97		
Tracer Gas	HE		
Pressure @ Turbo Inlet	6.8x10-7		
Duration	2 HRS		
Response	NDL X10-9 SCALE		
	EVAC + SPRAY		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : E.R.	Date : 7-11-97		
Witnessed By : D.H.	Date : 7-11-97		
Signature: [signature]	Date :		
Title :			

Remarks :

SPECIFICATION	
Number: V049-2-014 A	p2

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	BSC	SPOOL					
Model No.	WBSC1	A15					
Serial No.	09	02					
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
[redacted]		Torr	Torr				
	IV-V		$4x10^{-5}$	✓		[signature]	7-11-97
	II		NDL (108 Scale)	✓		[signature]	7-11-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments Pcc $1.7x10^{-5}$

Witnessed
Signature
Title
Date:

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	WBSC8		
Serial Number	02		
Drawing Number			
Detector Name	BALZERS		
Model Number	HL+ 160 DRY		
Serial Number	01		
Detector Calib.Date	4-19-98		
Detector Calib.Factor	1.1		
Standard Leak Rate	4.53×10^{-9} cc/sec		
Std.Leak Expir.Date	7-14-98		
Standard Response	4.9×10^{-9}		
Leak Test Data			
Location /Date	Clean Rm / 4-19-97		
Tracer Gas	HE		
Pressure @ Turbo Inlet	4.4×10^{-7}		
Duration	30 min Bag test		
Response	$<1 \times 10^{-9}$ cc/sec		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : D. H.	Date : 4-19-97		
Witnessed By : SM	Date : 4-19-97		
Signature [signature]	Date : 4-1997		
Title :			

Remarks :

SPECIFICATION

Number: V049-2-014 A p2

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	BSC						
Model No.	WBSC2						
Serial No.	02						
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
[redacted]		Torr	Torr				
	IV-V		$4x10^{-5}$	✓		[signature]	4-19-97
	II		NDL (10^{-9} Scale)	✓		[signature]	4-19-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments Pcc $6.8x10^{-6}$

Witnessed
Signature [signature]
Title
Date: 4-19-97

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

LEAK TEST DATA SHEET

	1	2	3
Component Name	BSC		
Model Number	WBSC3		
Serial Number	03		
Drawing Number			
Detector Name	BALZERS		
Model Number	HLT 160 DRY		
Serial Number	01		
Detector Calib.Date	6-12-97		
Detector Calib.Factor	1.2		
Standard Leak Rate	4.8x10-9		
Std.Leak Expir.Date	6-3-98		
Standard Response	5.3x10-9		
Leak Test Data			
Location /Date	CLEAN ROOM / 6-13-97		
Tracer Gas	HE		
Pressure @ Turbo Inlet	9.5x10-7		
Duration	2 HR		
Response	NDL x10-9 SCALE		
	EVAC + SPRAY		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : [signature]	Date :		
Witnessed By :	Date :		
Signature [signature]	Date : 6-13-97		
Title :			

Remarks :

SPECIFICATION

Number: V049-2-014 A p2

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	BSC						
Model No.	WBSC3						
Serial No.	03						
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		$4x10^{-5}$	✓		[signature]	6-13-97
	II		NDL (10^{-9} Scale)	✓		[signature]	6-13-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments PCC 4,0x10-5

Witnessed
Signature [signature]
Title
Date: 6-13-97

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	HAM		
Model Number	WHAM 1		
Serial Number	001		
Drawing Number			
Detector Name	BALZERS		
Model Number	HLT 160 #1		
Serial Number			
Detector Calib.Date	3-25-97		
Detector Calib.Factor	1.1		
Standard Leak Rate	4.4×10^{-9}		
Std.Leak Expir.Date	6-27-97		
Standard Response SYS	5.5×10^{-9}		
Leak Test Data			
Location /Date			
Tracer Gas	He		
Pressure @ Turbo Inlet			
Duration	15 min		
Response	1.5×10^{-9}		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : D. H.	Date : 3-25-97		
Witnessed By :	Date :		
Signature : [signature]	Date : 3-25-97		
Title :			

Remarks : LEAK RATE LESS than 1.5×10^{-9} AFTER 15 min BAG 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	HAM						
Model No.							
Serial No.	002						
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		$4x10^{-5}$	✓		[signature]	3-24-97
	II		NDL (10^{-9} Scale)	✓		[signature]	3-24-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				
Comments	LEAK RATE $< 1.5x10^{-9}$ AFTER 15 MIN BAG TEST						

Witnessed
Signature [signature]
Title
Date: 3-25-97

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	HAM		
Model Number	WHAM2		
Serial Number	003		
Drawing Number			
Detector Name	BALZERS		
Model Number	HLT 160		
Serial Number			
Detector Calib.Date			
Detector Calib.Factor			
Standard Leak Rate	4.4x10-9		
Std.Leak Expir.Date	6-27-97		
Standard Response	5.2x10-9		
Leak Test Data			
Location /Date			
Tracer Gas			
Pressure @ Turbo Inlet			
Duration	30 min		
Response	1x10-9		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : D. H.	Date : 5-5-97		
Witnessed By :	Date :		
Signature : [signature]	Date : 5-5-97		
Title :			

Remarks :

SPECIFICATION	
Number: V049-2-014 A	p2

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	HAM						
Model No.							
Serial No.	002						
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		$4x10^{-5}$	$5x10^{-5}$		[signature]	5-7-97
	II		NDL (10^{-9} Scale)	$x10^{-8}$		[signature]	5-7-97
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 $1x10^{-9}$ AFTER 30 min BAG-TEST

Witnessed
Signature [signature]
Title
Date: 5-5-97

SPECIFICATION

Number: V049-2-014 p2
A

FLANDERS

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

LEAK TEST DATA SHEET

	1	2	3
Component Name	HAM		
Model Number	INHAM3		
Serial Number	004		
Drawing Number			
Detector Name	Balzers		
Model Number	HLT 160		
Serial Number	313794w-003		
Detector Calib.Date	6-9-97		
Detector Calib.Factor	1.0		
Standard Leak Rate	N/A		
Std.Leak Expir.Date	N/A		
Standard Response	N/A		
Leak Test Data			
Location /Date			
Tracer Gas	HE		
Pressure @ Turbo Inlet			
Duration	N/A		
Response	N/A		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : P. TATRO	Date : 6-9-97		
Witnessed By :	Date :		
Signature [signature]	Date : 6-9-97		
Title :			

Remarks : Ham# 04 tested @ Flanders Rd Bake-out Station. Evac + Spray only NDL x10^{-9} scale

SPECIFICATION	
Number: V049-2-014 A	p2

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	HAM						
Model No.	WHAM 3						
Serial No.	004						
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		$4x10^{-5}$	✓		[signature]	6-9-97
	II		NDL (10^{-9} Scale)	✓		[signature]	6-9-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments EVAC + SPRAY ONLY NDL X 10^{-9} SCALE

Witnessed
Signature [signature]
Title
Date: 6-9-97

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	HAM	HAM	
Model Number	WHAM4	WHAM4	
Serial Number	005	005	
Drawing Number			
Detector Name	BALZERS	BALZERS	
Model Number	HLT 160	HLT 160	
Serial Number	313794W-002	313794W-002	
Detector Calib.Date	6-3-97	6-16-97	
Detector Calib.Factor	1.0	1.0	
Standard Leak Rate	N/A	N/A	
Std.Leak Expir.Date	N/A	N/A	
Standard Response	N/A	N/A	
Leak Test Data			
Location /Date			
Tracer Gas	HE	HE	
Pressure @ Turbo Inlet			
Duration	N/A	N/A	
Response	N/A	N/A	
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : D.H.	Date : 6-3-97	6-19-97	
Witnessed By :	Date :		
Signature [signature]	Date : 6-3-97	6-19-97	
Title :			

Remarks : HAM 005 EVAC + SPRAY ONLY NDL×10⁻⁹ SCALE
NO BAG TEST NO C.L. INSTALLED

SPECIFICATION	
Number: V049-2-014 A	p2

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	HAM						
Model No.	WHAM 4						
Serial No.	005						
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		$4x10^{-5}$	✓		[illegible]	6-3-97
	II		NDL (10^{-9} Scale)	$x10^{-8}$		[illegible]	6-3-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments: NDL $X10^{-9}$ SCALE EVAC X SPRAY ONLY OK 6-16-97 RE-EVAC + SPRAY NDL $X10^{-9}$ FAILED RGA TEST

Witnessed Signature: [illegible]
Title
Date: 6-3-97

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

LEAK TEST DATA SHEET

	1	2	3
Component Name	HAM		
Model Number	WHAM 5		
Serial Number	07		
Drawing Number			
Detector Name	BALZERS		
Model Number	HL+ 160 DRY		
Serial Number	02		
Detector Calib.Date	6-3-97		
Detector Calib.Factor	1.0		
Standard Leak Rate	NOT USED		
Std.Leak Expir.Date			
Standard Response			
Leak Test Data			
Location /Date	CLEAN ROOM / 6-3-97		
Tracer Gas	He		
Pressure @ Turbo Inlet	1.1×10^{-6}		
Duration	1 HR		
Response	NDL 4×10^{-9} SCALE		
	EVAC + SPRAY		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : D. H.	Date :		
Witnessed By :	Date :		
Signature [signature]	Date : 6-3-97		
Title :			

Remarks :

SPECIFICATION

Number: V049-2-014 A | p2

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	HAM						
Model No.	WHAM5						
Serial No.	07						
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		$4x10^{-5}$	✓		[signature]	6-3-97
	II		NDL (10^{-9} Scale)	✓		[signature]	6-3-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments PCC $1.8x10^{-5}$ HLT #3 CF 1.2

Witnessed
Signature
Title
Date:

SPECIFICATION

Number: V049-2-014 A | p2

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	HAM						
Model No.	WHAM6						
Serial No.	02						
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		$4x10^{-5}$	✓		[signature]	7-16-97
	II		NDL (10^{-9} Scale)	✓		[signature]	7-16-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments PCC $1.6x10^{-5}$

Witnessed
Signature [signature]
Title
Date: 7-16-97

SPECIFICATION

Number: V049-2-014 A | p2

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Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

LEAK TEST DATA SHEET

	1	2	3
Component Name	HAM		
Model Number	WHAM 6		
Serial Number	02		
Drawing Number			
Detector Name	BALZERS		
Model Number	HLT 160 DRY		
Serial Number	01		
Detector Calib.Date	7-16-97		
Detector Calib.Factor			
Standard Leak Rate	NONE		
Std.Leak Expir.Date			
Standard Response			
Leak Test Data			
Location /Date	Flanders / 7-16-97		
Tracer Gas	HE		
Pressure @ Turbo Inlet	1.5x10-7		
Duration	2.5 HRS		
Response	NDL x10-9 SCALE		
	EVAC + SPRAY		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : P.H	Date :		
Witnessed By : D. H	Date : 7-16-97		
Signature :	Date :		
Title :			

Remarks : REPAIRED LEAK 60" BELLOWS

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	SPool		
Model Number	BE2		
Serial Number	B		
Drawing Number			
Detector Name	BALZERS		
Model Number	HLT 160 DRY		
Serial Number	3		
Detector Calib.Date	8-29-97		
Detector Calib.Factor	1.3		
Standard Leak Rate	not used		
Std.Leak Expir.Date			
Standard Response			
Leak Test Data			
Location /Date	cryo room 8-29-97		
Tracer Gas	HE		
Pressure @ Turbo Inlet	1.6x10-7		
Duration	30 min		
Response	NDL EVAC + SPRAY		
	X10-9 scale		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : ER	Date :		
Witnessed By : DH	Date :		
Signature : [signature]	Date :		
Title :			

Remarks :

SPECIFICATION

Number: V049-2-014 A

2 of 2

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	SPOC						
Model No.	BE2B						
Serial No.	02						
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		$4x10^{-5}$	✓		[signature]	8-28-97
	II		NDL (10^{-9} Scale)	✓			
						[signature]	8-28-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments

Witnessed
Signature [signature]
Title
Date: 8-28-97

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	SPOOL		
Model Number	B5		
Serial Number	-A		
Drawing Number			
Detector Name	BALZERS		
Model Number	HLT 160 - DRY		
Serial Number	2		
Detector Calib.Date	7-2-97		
Detector Calib.Factor	1.0		
Standard Leak Rate	NOT USED		
Std.Leak Expir.Date			
Standard Response			
Leak Test Data			
Location /Date	CRYO ROOM / 7-2-97		
Tracer Gas	HE		
Pressure @ Turbo Inlet	1.8x10-7		
Duration	2 HRS		
Response	NDL [illegible] + SPRAY		
	x10-9 SCALE		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : D.H.	Date : 7-2-98		
Witnessed By :	Date :		
Signature [signature]	Date : 7-2-98		
Title :			

Remarks :

SPECIFICATION

Number: V049-2-014 A p2

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Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	SPOOL						
Model No.	B5						
Serial No.	A						
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		$2x10^{-5}$	✓		[signature]	7-2-97
	II		NDL (10^{-9} Scale)	✓		[signature]	7-2-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments HCT # 2 CF 1.0

Witnessed
Signature [signature]
Title
Date: 7-2-97

SPECIFICATION

Number: V049-2-014 A

p2

249

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

LEAK TEST DATA SHEET

	1	2	3
Component Name	SPOOL		
Model Number	A3		
Serial Number	B		
Drawing Number			
Detector Name	BALZERS		
Model Number	HLT 160 - DRY		
Serial Number	02		
Detector Calib.Date	7-25-97		
Detector Calib.Factor	1.2		
Standard Leak Rate	NOT USED		
Std.Leak Expir.Date			
Standard Response			
Leak Test Data			
Location /Date	CRYO ROOM / 7-25-97		
Tracer Gas	HE		
Pressure @ Turbo Inlet	1.0x10^-7		
Duration	1 HR		
Response	NDL EVAC + SPRAY x10^-9		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : P.H.	Date : 7-25-97		
Witnessed By :	Date :		
Signature [signature]	Date : 7-25-97		
Title :			

Remarks :

SPECIFICATION

Number: V049-2-014 A

p2

250

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	SPOOL						
Model No.	A3						
Serial No.	B						
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		$2x10^{-5}$	✓		[signature]	7-25-97
	II		NDL (10^{-9} Scale)	✓		[signature]	7-25-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments Pcc $1.9x10^{-5}$ torr

Witnessed Signature [signature]
Title
Date: 7-25-97

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	A3A w/ A3A ~2		
Model Number			
Serial Number	1		
Drawing Number			
Detector Name	Balzers		
Model Number	HLT160		
Serial Number	2		
Detector Calib.Date	7-23-97		
Detector Calib.Factor	1.0		
Standard Leak Rate			
Std.Leak Expir.Date			
Standard Response			
Leak Test Data			
Location /Date	clean weld room / 7-23-97		
Tracer Gas	He		
Pressure @ Turbo Inlet	2.3 × 10⁻⁷		
Duration	2 hours		
Response	NDL 10^{-9} range		
	2 vac. & spray		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : D. Hillier	Date : 7-23-97		
Witnessed By : (JF)	Date :		
Signature : Dan Hillier	Date : 7-23-97		
Title : (JF)			

Remarks :

SPECIFICATION	
Number: V049-2-014 A	p2

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Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	A3A						
Model No.							
Serial No.	1						
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		$4x10^{-5}$	✓		P. Hillier (JF)	7-24-97
	II		NDL (10^{-9} Scale)	✓		D Hillier (JF)	7-24-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments

Witnessed
Signature
Title
Date:

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	BE3A1 w/ BE3A2		
Model Number			
Serial Number	1		
Drawing Number			
Detector Name	Balzers		
Model Number	HLT160		
Serial Number	3		
Detector Calib.Date	8-16-97		
Detector Calib.Factor	1.2		
Standard Leak Rate			
Std.Leak Expir.Date			
Standard Response			
Leak Test Data			
Location /Date	Clean weld room / 8-16-97		
Tracer Gas	He		
Pressure @ Turbo Inlet	4.8 x 10⁻⁷		
Duration	2 hrs 20 min		
Response	NDL 10⁻⁹ range		
	evac. & spray		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : Paul Harris	Date : 8-16-97		
Witnessed By : Don Hillis	Date : 8-16-97		
Signature : Don Hillis	Date : 8-16-97		
Title : (TF)			

Remarks :

SPECIFICATION

Number: V049-2-014 A p2

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	BE3A1						
Model No.							
Serial No.	(						
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		$4x10^{-5}$	✓		D. Hillier	8-20-97
	II		NDL (10^{-9} Scale)	✓		(JF) D. Hillier	8-20-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments

Witnessed
Signature
Title
Date:

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	BE2A w/BE2B		
Model Number			
Serial Number	1		
Drawing Number			
Detector Name	Balzers		
Model Number	HLT160		
Serial Number	#3		
Detector Calib.Date	8-29-97		
Detector Calib.Factor	1.4		
Standard Leak Rate			
Std.Leak Expir.Date			
Standard Response			
Leak Test Data			
Location /Date	clean weld room / 8-29-97		
Tracer Gas	He		
Pressure @ Turbo Inlet	1.0×10^{-7}		
Duration	1		
Response	NDL 10^{-9} range		
	evac. + spray		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : Paul Tatro	Date : 8-29-97		
Witnessed By :	Date :		
Signature : Paul Tatro	Date : 8-29-97		
Title : (JF)			

Remarks :

SPECIFICATION	
Number: V049-2-014 A	p2

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	BEZA						
Model No.							
Serial No.							
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		$4x10^{-5}$	✓		Paul Tatro	8-29-97
	II		NDL (10^{-9} Scale)	✓		Paul Tatro	8-29-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments

Witnessed
Signature
Title
Date:

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	B3A		
Model Number			
Serial Number	1		
Drawing Number			
Detector Name	BALZERS		
Model Number	4LT160		
Serial Number	2		
Detector Calib.Date	6-25-97		
Detector Calib.Factor	0.9		
Standard Leak Rate			
Std.Leak Expir.Date			
Standard Response			
Leak Test Data			
Location /Date	clean weld room / 6-24-97		
Tracer Gas	He		
Pressure @ Turbo Inlet	1.4×10^{-7}		
Duration	1.5 hrs		
Response	NDL 10^{-9} range		
Leak Rate			
Measured			
Calculated			
Allowable			
Performed By : D. Hillier	Date : 6-25-97		
Witnessed By : (JF)	Date :		
Signature : Don Hillier	Date : 6-25-97		
Title :			

Remarks :

SPECIFICATION	
Number: V049-2-014 A	p2

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

VESSEL(BSC/HAM) LEAK TEST SUMMARY SHEET

Name	B3A						
Model No.							
Serial No.	\						
Drwg.No.							
Location	Category	Leak Rate	Allowable	Pass	Fail	Signature	Date
Annulus		Torr	Torr				
	IV-V		$4x10^{-5}$	✓		D. Hillier	8-27-97
	II		NDL (10^{-9} Scale)	✓		D. Hillier JF	6-27-97
Vessel		Torr-L/s	Torr-L/s				
Weld Joint	I		$1x10^{-9}$				
Weld Joint	II		$1x10^{-9}$				
Conflat	III		$1x10^{-9}$				

Comments

Witnessed
Signature
Title
Date:

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT

8.5 System Bake-Out – Vertex Section

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.

VERTEX BAKE

(VI)

6-27-98 1630 TURBO 8.5 x10^-5

6-28-98

0900 TURBO 4.6 x10^-6

1200 SYSTEM SHUTDOWN - TEMPSCAN COMM ERROR CART 4.
1600 RESTART

1930 TURBO 4.0 x10^-6 SP=45
AUX @ BSC1 3.1 x10^-5
@ HAM1 2.7 x10^-5
@ HAM 2 4.8 x10^-5
@ HAM 6 1.7 x10^-5
@ HAM 5 4.4 x10^-5
@ GV2 1.0 x10^-6

6-29-98
0630 SP=75 TURBO 2.6 x10^-5
AUX @ BSC1 1.3 x10^-4
@ HAM 1 8.9 x10^-5
@ HAM 2 1.7 x10^-4
@ HAM 6 8.6 x10^-5
@ HAM 5 3.5 x10^-6
@ GV2 2.1 x10^-6
0900 SYSTEM SHUTDOWN TEMPSCAN COMM ERROR CARTS 1 & 2

V2

1400 SP=100 TURBO 4.1 x10^-5
AUX @ BSC1 1.4 x10^-4
@ HAM 1 9.0 x10^-5
@ HAM 2 2.2 x10^-4
@ HAM 6 1.0 x10^-4
@ HAM 5 1.7 x10^-5
@ GV2 5.6 x10^-5

2100 SP=119 TURBO 4.3 x10^-5
AUX @ BSC1 1.3 x10^-4
@ HAM 1 9.1 x10^-5
@ HAM 2 2.0 x10^-4
@ HAM 6 9.6 x10^-5
@ HAM 5 3.6 x10^-5
@ GV2 1.5 x10^-5

6-30-98 SP=130 TURBO 2.1 x10^-5
AUX @ BSC1 6.0 x10^-5
@ HAM 1 4.4 x10^-5
@ HAM 2 8.1 x10^-5
@ HAM 6 4.8 x10^-5
@ HAM 5 5.7 x10^-5
@ GV2 1.7 x10^-5

1230 SP=142 TURBO 2.7 x10^-5
AUX @ BSC1 6.2 x10^-5
@ HAM 1 4.0 x10^-5
@ HAM 2 8.8 x10^-5
@ HAM 6 5.1 x10^-5
@ HAM 5 5.8 x10^-5
@ GV2 2.0 x10^-5

(V3)

1430 150 TURBO 3.2 x10^-5
AUX @ BSC1 6.9 x10^-5
@ HAM1 4.0 x10^-5
@ HAM2 9.1 x10^-5
@ HAM6 5.5 x10^-5
@ HAM5 6.2 x10^-5
@ GV2 2.2 x10^-5

7-1-98 0630 150 TURBO 2.4 x10^-5
AUX @ ~~HAM~~ BSC1 4.7 x10^-5
@ HAM1 2.5 x10^-5
@ HAM2 5.7 x10^-5
@ HAM6 3.6 x10^-5
@ HAM5 4.6 x10^-5
@ GV2 2.2 x10^-5

1330 150 TURBO 2.3 x10^-5
AUX @ BSC1 4.2 x10^-5
@ HAM1 2.3 x10^-5
@ HAM2 5.1 x10^-5
@ HAM6 2.3 x10^-5
@ HAM5 4.3 x10^-5
@ GV2 2.1 x10^-5

2000 150 TURBO 2.2 x10^-5
AUX @ BSC1 4.0 x10^-5
@ HAM1 2.2 x10^-5
@ HAM2 4.8 x10^-5
@ HAM6 2.5 x10^-5
@ HAM5 4.0 x10^-5
@ GV2 2.1 x10^-5

V4

7-2-98

0600 LSD TURBO 2.1 x10^-5
AUX @ BSC1 3.8 x10^-5
@ HAM1 2.0 x10^-5
@HAM2 4.5 x10^-5
@HAM6 1.8 x10^-5
@HAM5 3.7 x10^-5
@GV2 2.0 x10^-5

1230 LSD TURBO 2.0 x10^-5
AUX @BSC1 3.6 x10^-5
@HAM1 1.9 x10^-5
@HAM2 4.3 x10^-5
@HAM6 1.8 x10^-5
@HAM5 3.6 x10^-5
@GV2 1.9 x10^-5
START RAMP DOWN

7-3-98

1100 TURBO 1.6 x10^-6
AUX @BSC1 ~~[illegible]~~ 1.7 x10^-6
@HAM1 ~~[illegible]~~ 6.8 x10^-7
@HAM2 ~~[illegible]~~ 9.2x10^-6
@HAM6 7.8 x 10^-7
@HAM5 4.4 x10^-6
@GV2 3.3 x10^-6
PLC5 CHANNELL 14/1B QUEUE FULL

7/5 SYSTEM OKK

V5

7/6

830 $P_{GM} = 3.9 \times 10^{-8}$

940 Turn on IP4 & isolate. P↑ 5×10^{-6}

950 Turn on IP3 & isolate P↑ 4×10^{-6}

1025 " " IP2 " " P↑ 4×10^{-6}

1035 " " IP1 " " P↑ 6×10^{-6}

1245 $P_{GM} = 3.4 \times 10^{-8}$

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT

8.6 Ultimate Pressure Test (After Bake-Out) – Vertex Section

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

All test results met or exceeded the requirements.

Title: Partial Pressure Calculation for Right Beam Manifold and Vertex Sections
Date: 07/09/98
Test ID: WCRBM_V_1
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	-	-	1.01	3.58E-09	3.62E-09
16	0.57	1.60		8.10E-11	5.80E-11
18	0.64	1.12		2.20E-11	2.38E-11
28	-	-	1.52	4.25E-10	6.46E-10
44	1.57	1.42		1.17E-11	1.57E-11
all others	-	-	1.52	3.14E-11	4.77E-11

Total Pressure =	4.41E-09

Partial Pressure and Air Signature Acceptance

LIGO: John Worden

PSI: ______________________

Vertex & RBM 7/9/98

"others"

24	1.6×10^{-12}
25	2.9×10^{-12}
26	6.9×10^{-12}
27	4.4×10^{-12}
29	4.4×10^{-12}
30	1.6×10^{-12}
32	1.3×10^{-12}
36	2.2×10^{-13}
37	3.4×10^{-13}
38	4.5×10^{-13}
39	7.8×10^{-13}
40	4.5×10^{-12}
41	6.1×10^{-13}
42	3.6×10^{-13}
43	2.3×10^{-13}
45	3.5×10^{-13}
50	2.6×10^{-13}
78	2.0×10^{-13}

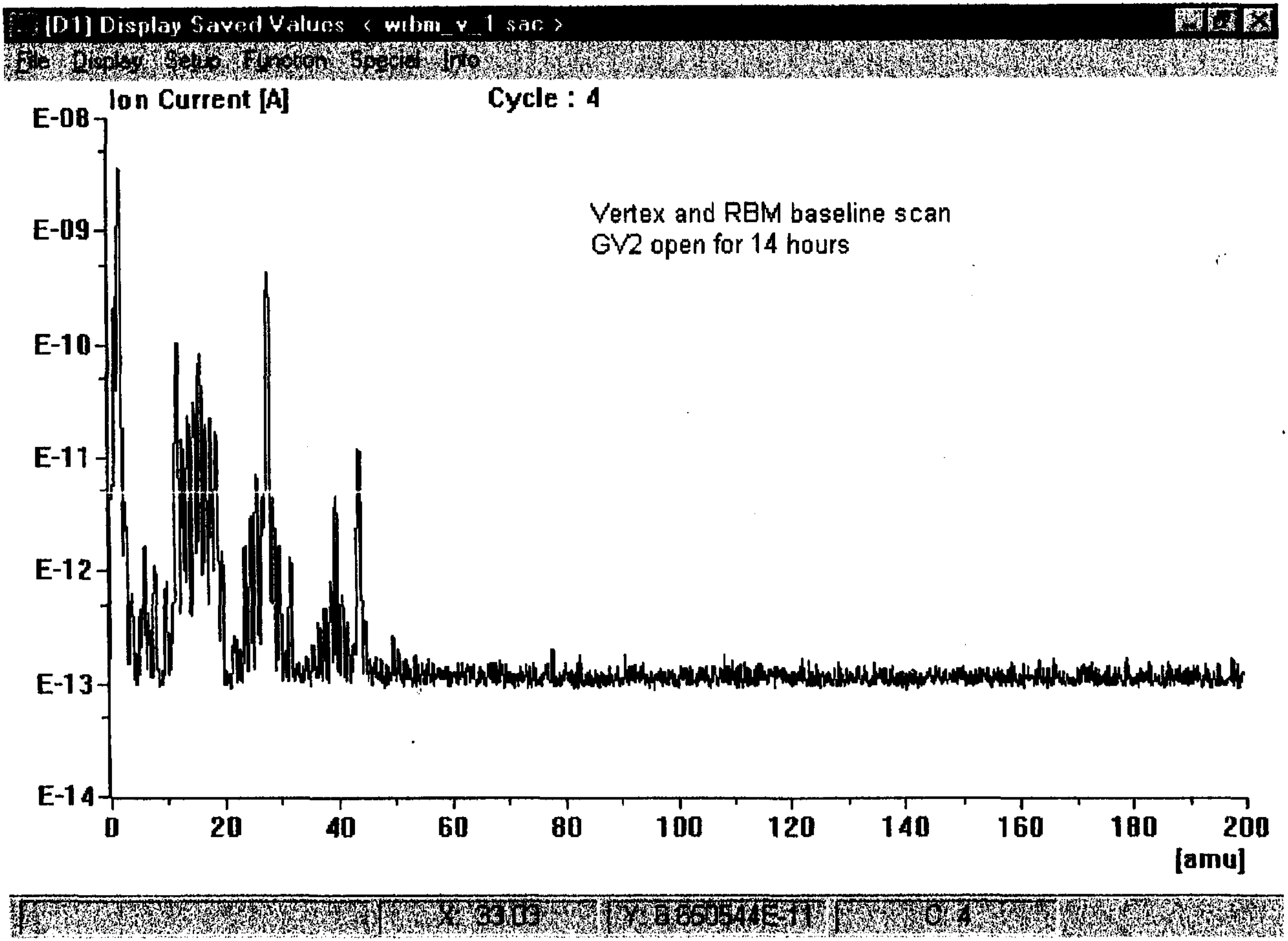
TOTAL

38.0×10^{-13}

$27.6 \cdot 10^{-12}$

31.4×10^{-12}

3.14×10^{-11} A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Ion Current [A]
Cycle : 4
Vertex and RBM baseline scan
GV2 open for 14 hours
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]
C: 4

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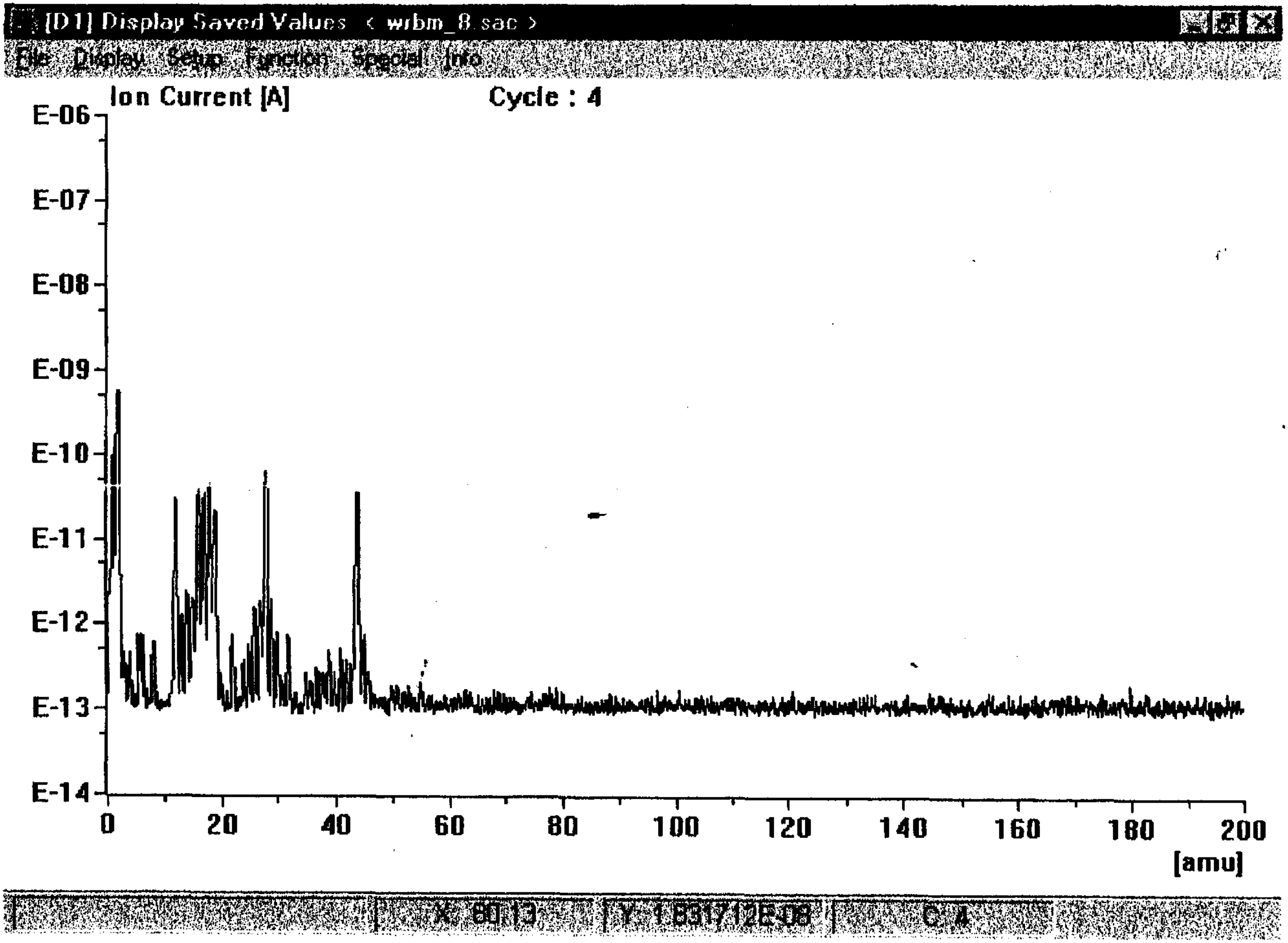
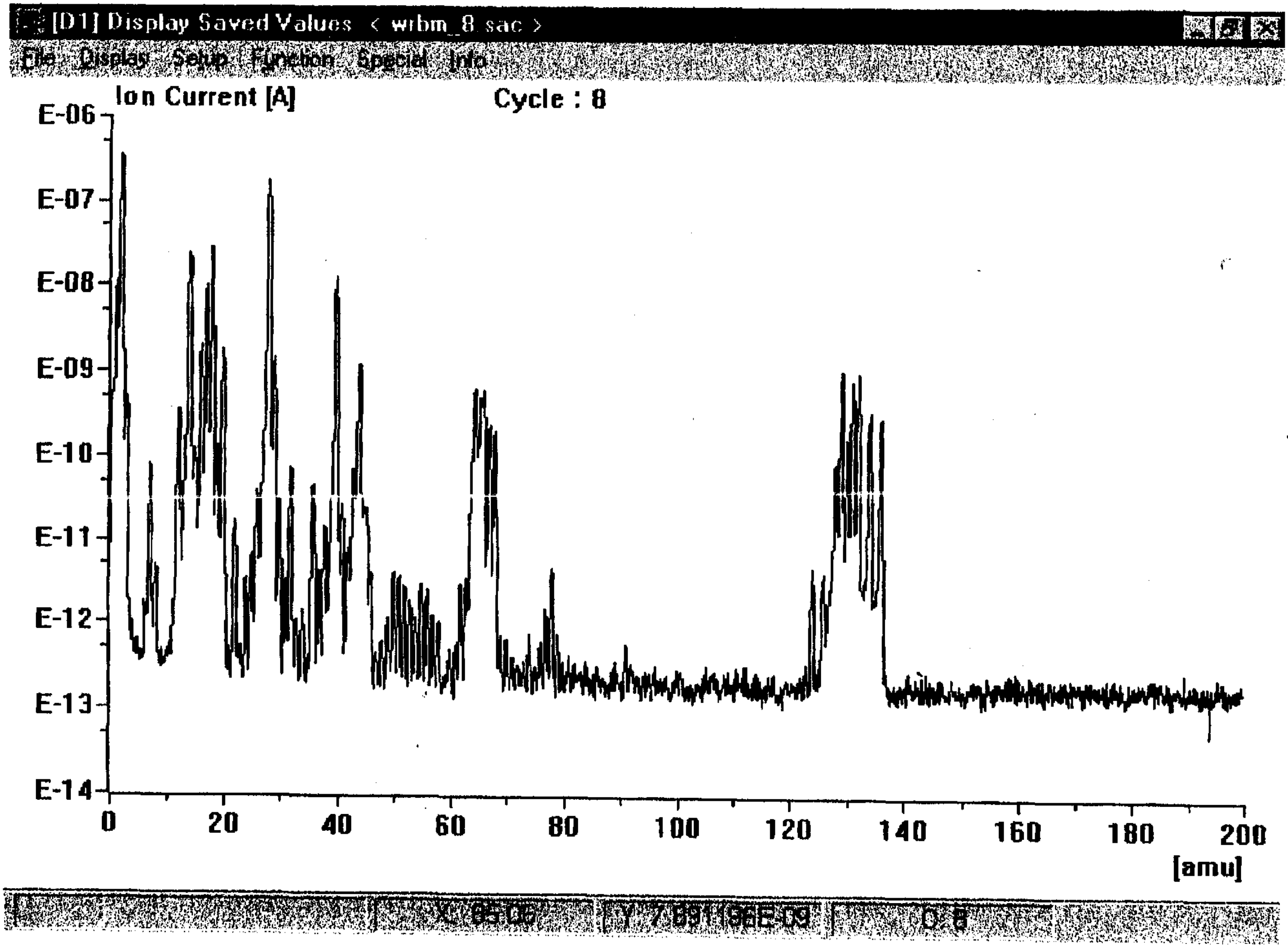
Title: RGA Sensitivity Calibration
Date: 7/7/98
Test ID: WCRBM_8
PSI Engineer: John Flinn

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	5.53E-10	3.44E-07			4.80E-06	13.9		1.01
16	-		0.57	1.6				0.72
18	-		0.64	1.12				1.09
28	6.11E-10	1.69E-07			9.50E-07	3.7		1.52
40	2.68E-13	1.22E-08			9.40E-08	3.1		2.49
44	-		1.57	1.42				1.34
129	1.10E-13	9.87E-10			2.20E-08	1.7		13.11
131	1.10E-13	7.59E-10			1.80E-08	1.7		13.95
132	1.10E-13	9.24E-10			2.20E-08	1.7		14.01
134	1.10E-13	3.36E-10			9.00E-09	1.7		15.76
136	1.10E-13	2.75E-10			8.00E-09	1.7		17.12



Jul 23 98 11:28a David H. Evers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Cycle : 8
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 65.06
Y 7.891196E-09
D 8

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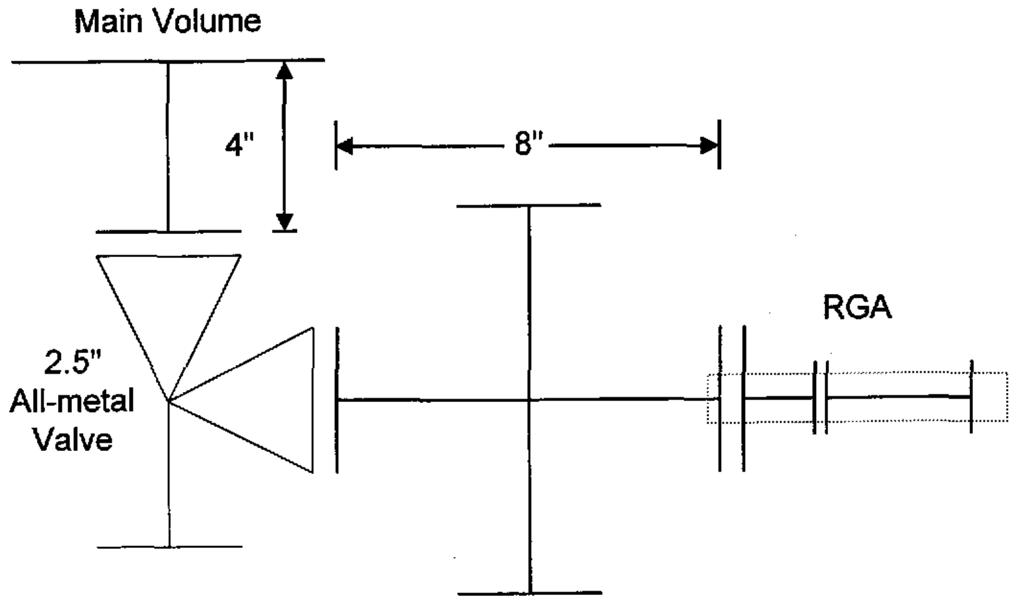
Conductance Calculation for RGA Calibration Chamber



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:

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

{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*).

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT

8.7 Backfill/100 Hr. Pumpdown Test – Vertex Section

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.

Title: Partial Pressure Calculation for Right Beam Manifold and Vertex Sections for the 100 hour pumpdown demonstration
Date: 08/04/98
Test ID: RBMV100
PSI Engineer: J. Flinn

Time = 100 hours

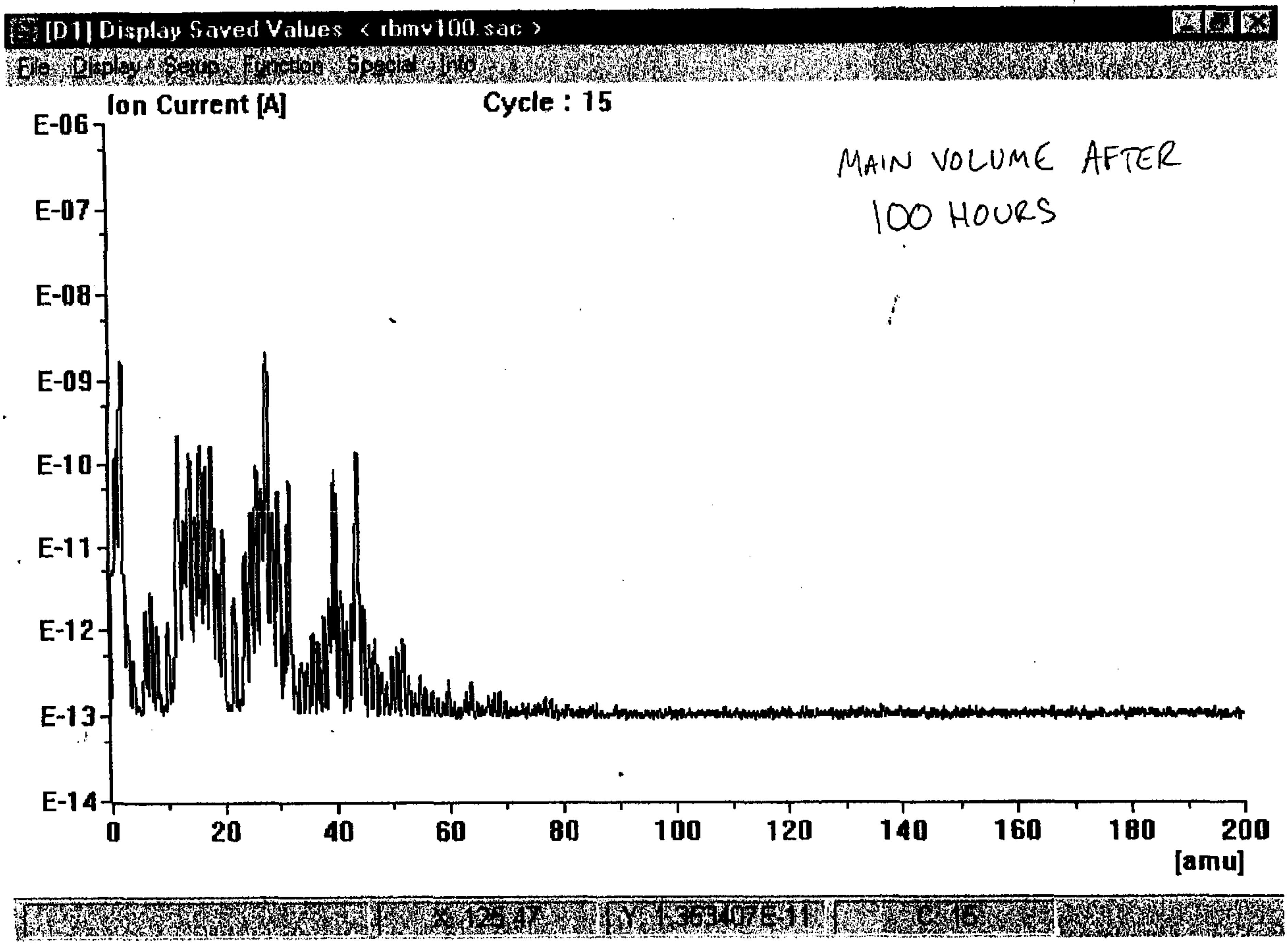
AMU	*F* (amu) transmission efficiency wrt N_2	*E* (amu) ionization efficiency wrt N_2	*S* (p_amu) sensitivity (Torr/A)	*I* (amu) ion current (A)	*PP* (amu) (Torr)
2	-	-	1.51	1.72E-09	2.60E-09
16	0.57	1.60		1.69E-10	1.98E-10
18	0.64	1.12		1.61E-10	2.85E-10
28	-	-	2.48	2.12E-09	5.26E-09
44	1.57	1.42		1.37E-10	3.00E-10
all others	-	-	2.48	4.00E-10	9.92E-10

Total Pressure =	9.63E-09

100 hour backfill and pumpdown demonstration acceptance

LIGO: ______________________

PSI: ______________________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File Display Setup Function Special Info
Ion Current [A]
Cycle : 15
MAIN VOLUME AFTER
100 HOURS
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]

Title: Partial Pressure Calculation for Right Beam Manifold and Vertex Sections for the 100 hour pumpdown demonstration
Date: 08/04/98
Test ID: RBMV100
PSI Engineer: J. Flinn

Time = 125 hours

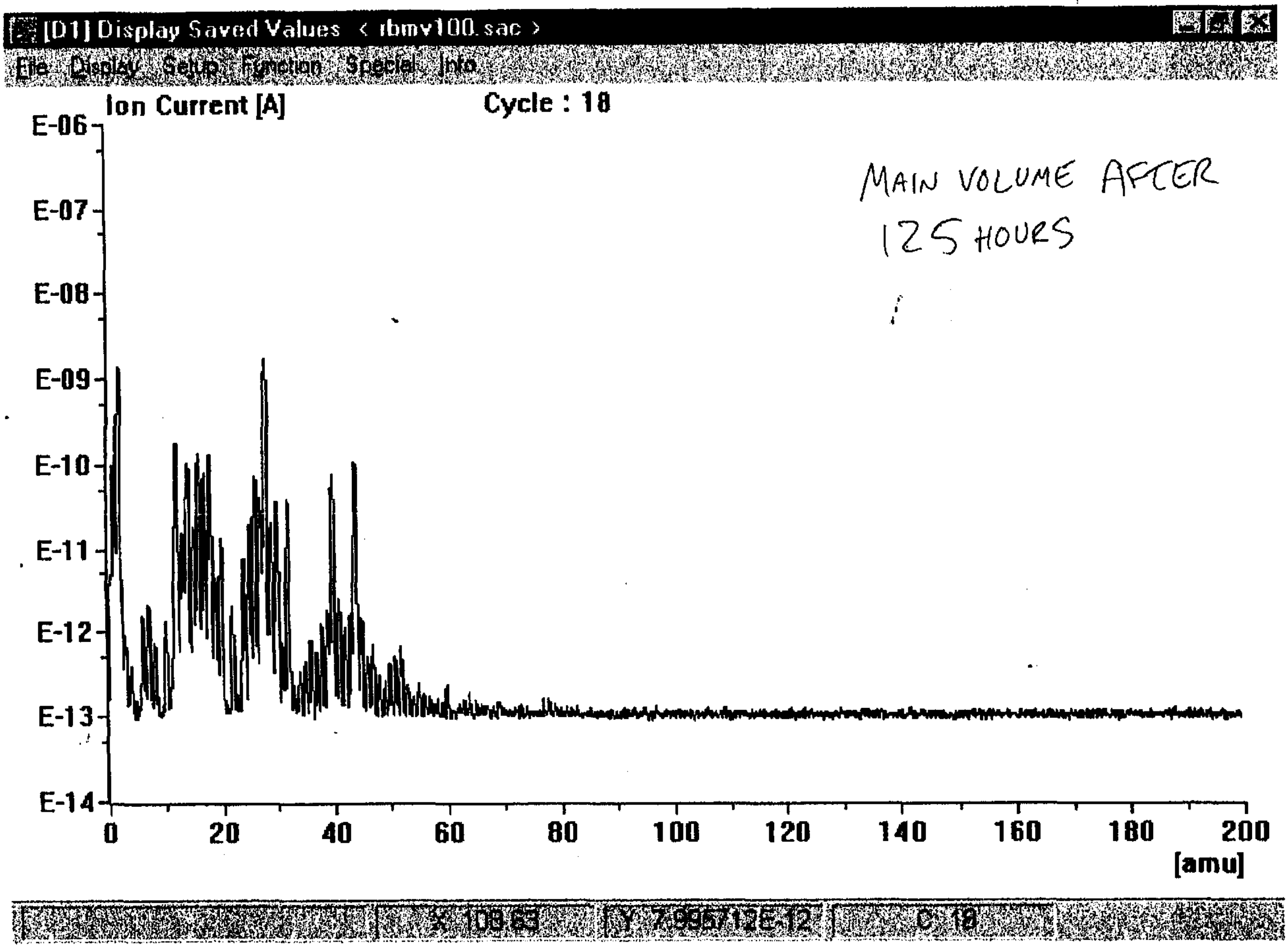
AMU	$F_{(amu)}$ transmission efficiency wrt N_2	$E_{(amu)}$ ionization efficiency wrt N_2	$S_{(p\_amu)}$ sensitivity (Torr/A)	$I_{(amu)}$ ion current (A)	$PP_{(amu)}$ (Torr)
2	-	-	1.51	1.39E-09	2.10E-09
16	0.57	1.60		1.37E-10	1.60E-10
18	0.64	1.12		1.30E-10	2.30E-10
28	-	-	2.48	1.72E-09	4.27E-09
44	1.57	1.42		1.05E-10	2.30E-10
all others	-	-	2.48	3.00E-10	7.44E-10

Total Pressure =	7.73E-09

100 hour backfill and pumpdown demonstration acceptance

LIGO: ______________________________

PSI: ______________________________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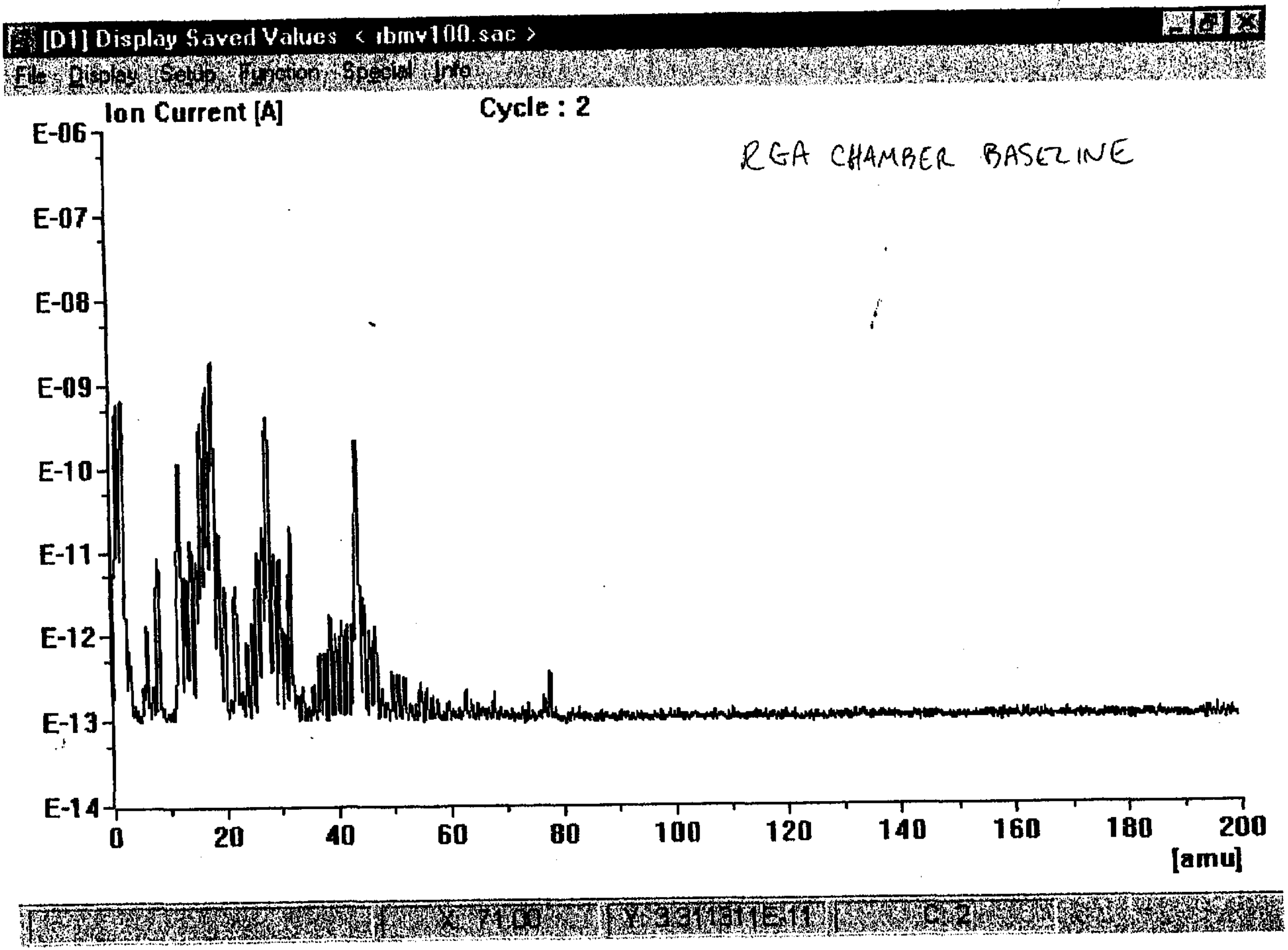
File Display Setup Function Special Info
Ion Current [A]
Cycle : 18
MAIN VOLUME AFTER 125 HOURS
E-06
E-07
E-08
E-09
E-10
E-11
E-12
E-13
E-14
0
20
40
60
80
100
120
140
160
180
200
[amu]
C: 18

Title: RGA Sensitivity Calibration
Date: 7/30/98
Test ID: RBMV100
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	6.65E-10	2.29E-07			4.80E-06	13.9	1.51
16	-		0.57	1.6			1.17
18	-		0.64	1.12			1.77
28	4.14E-10	1.04E-07			9.50E-07	3.7	2.48
40	1.03E-12	7.49E-09			9.40E-08	3.1	4.05
44	-		1.57	1.42			2.19
129	1.00E-13	5.68E-10			2.20E-08	1.7	22.79
131	1.00E-13	4.14E-10			1.80E-08	1.7	25.58
132	1.00E-13	5.11E-10			2.20E-08	1.7	25.33
134	1.00E-13	1.88E-10			9.00E-09	1.7	28.18
136	1.00E-13	1.44E-10			8.00E-09	1.7	32.70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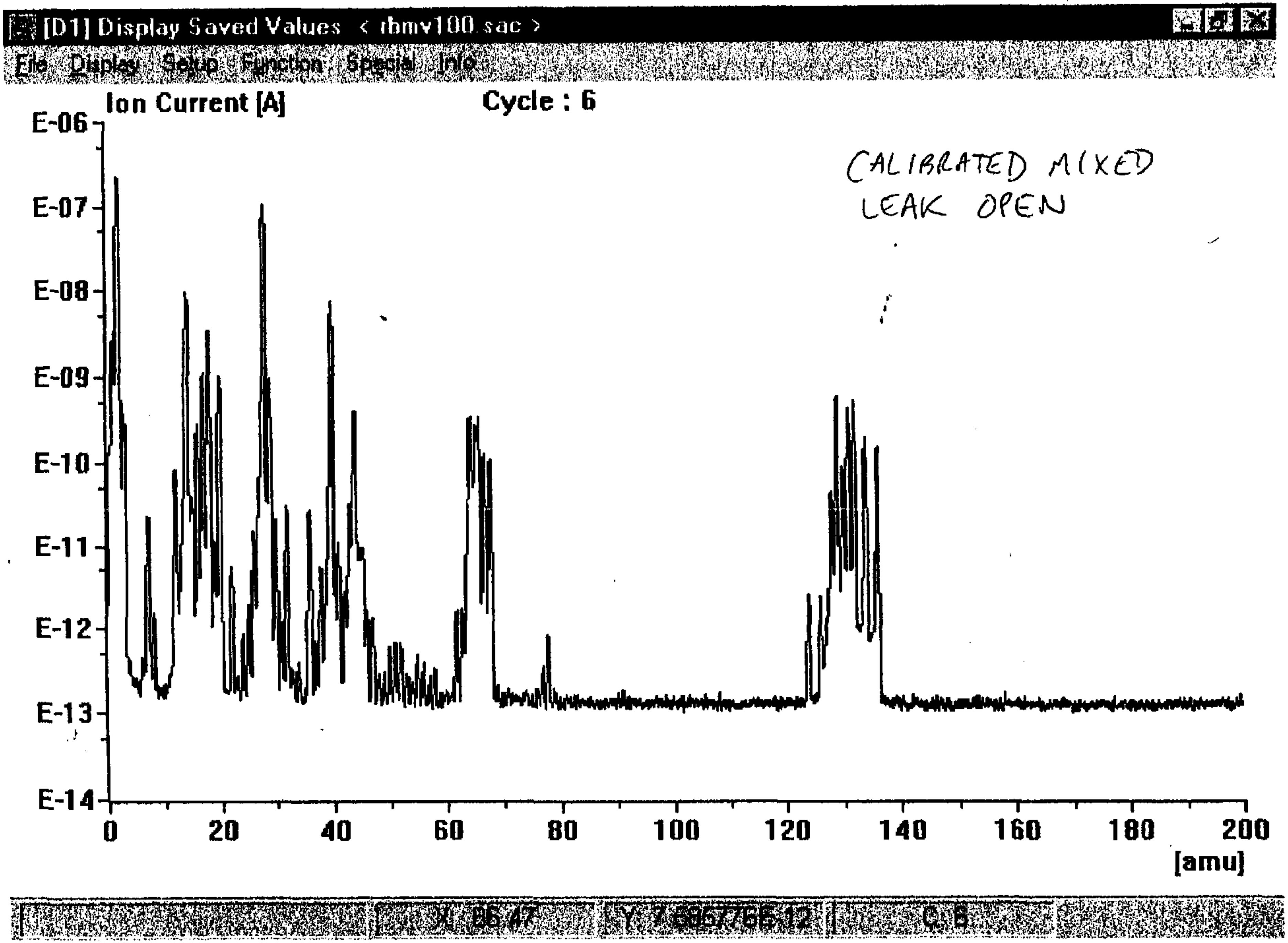
Cycle : 2
RGA CHAMBER BASELINE
E-06
E-07
E-08
E-09
E-10
E-11
E-12
E-13
E-14
0 20 40 60 80 100 120 140 160 180 200
[amu]
C: 2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File Display Setup Function Special Info
Ion Current [A]
Cycle : 6
E-06
E-07
E-08
E-09
E-10
E-11
E-12
E-13
E-14
0 20 40 60 80 100 120 140 160 180 200
[amu]
CALIBRATED MIXED
LEAK OPEN

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100 Hour Backfill Test in Vertex/ RBM 7/27/98 – 8/3/98

7-27-98

1000 Start 24 hour purge through mode cleaner in Vertex and out main turbo bypass line on RBM.

7-28-98

1000 Stop purge. Start roughing.
1025 P=470 Torr at main turbos.
1045 P=350 Torr
1115 P=270 Torr
1205 P=140 Torr
1250 P=90 Torr
1305 P=12 Torr
1315 – 1505 EDP200 problems (loose neutral wire problems)
1505 P=1.8 Torr
1600 P=1.3E-2 Torr. Start turbo pumps (2).
1615 Both turbos at full speed. Close 6" valve to EDP200.
1650 P_{Vertex_turbo}=4.8E-7 Torr
P_{RBM_turbo}=5.7E-7 Torr

7-29-98

0740 P_{Vertex_turbo}=1.3E-7 Torr
P_{RBM_turbo}=1.5E-7 Torr
CP2 isolated and is 90% full. P_{CP2}=2.0E-6 Torr
IP1 – Off, IP2 – 2.8E-5A, IP3 – 2.9E-5A, IP4 – 3.3E-5A, IP6 – 3.8E-5A
Pump IP#1 with Aux. Cart
0905 Open GV7 to CP2.
P_{CP2}=2.0E-6 Torr
P_{Vertex_turbo}=1.5E-7 Torr
0940 P_{RBM_turbo}=1.0 E-7 Torr
1000 Start IP1 on Aux. Cart.
P_{Vertex_turbo}=8.9E-8 Torr
P_{RBM_turbo}=8.6E-8 Torr
1125 IP1 running, $P_{Aux.\ Cart}$=7.8E-6 Torr
1130 P_{Vertex_turbo}=7.6E-8 Torr
P_{RBM_turbo}=8.0E-8 Torr
IP1 – CH1=750V,4.1E-2A – CH2=800V,3.6E-2A
1345 P_{Vertex_turbo}=7.0E-8 Torr
P_{RBM_turbo}=7.3E-8 Torr
Close AVUV15 on IP1 to Aux. Cart
1355 Crack open 14" GV on IP1
1415 14" GV full open on IP1
P_{Vertex_turbo}=4.0E-7 Torr
P_{RBM_turbo}=3.5E-7 Torr
IP1 – 2050V,8.9E-3A

1440 IP1 – 2500V

1515 P_{Vertex_turbo}=1.4E-7 Torr
P_{RBM_turbo}=1.9E-7 Torr
IP1=3000V,3.9E-3A, IP2=2.6E-5A, IP3=2.7E-5A, IP4=3.1E-5A, IP6=3.4e-5A
Isolate both turbos and open other four 14" GV to IP2,3,4,6
System now is only ion and cryo pumping.
Pressure now taken from CDS cold cathodes.

1540 PT120=3.0E-8 Torr
PT170=5.0E-8 Torr
PT134=6.0E-8 Torr

1800 PT120=2.5E-8 Torr
PT170=4.3E-8 Torr
PT134=5.0E-8 Torr

7-30-98

0700 PT120=1.8E-8 Torr
PT170=3.0E-8 Torr
PT134=3.2E-8 Torr

1300 PT120=1.5E-8 Torr
PT170=2.5E-8 Torr
PT134=2.7E-8 Torr
Calibrate RGA – save data to RBMV100.sac
Scan 1-3: RGA chamber baseline
Scan 4-7: Calibrated leak open
Scan 7-10: Close AVUV15 that isolates calibrated leak

1523 PT120=1.5E-8 Torr
PT170=2.5E-8 Torr
PT134=2.6E-8 Torr
IP1 – 4.5E-4A, IP2 – 4.1E-4A, IP3 – 4.0E-4A, IP4 – 4.1E-4A, IP6 – 4.2e-4A
Scan 11-12: isolate turbo, open AVUV25 to main volume

7-31-98

1100 PT120=1.05E-8 Torr
PT170=1.90E-8 Torr
PT134=1.84E-8 Torr
IP1 – 3.1E-4A, IP2 – 3.0E-4A, IP3 – 2.9E-4A, IP4 – 3.0E-4A, IP6 – 3.0e-4A

8-1-98

1145 PT120=8.0E-9 Torr
PT170=1.3E-8 Torr
PT134=1.3E-8 Torr
IP1 – 2.2E-4A, IP2 – 2.1E-4A, IP3 – 2.1E-4A, IP4 – 2.2E-4A, IP6 – 2.2e-4A

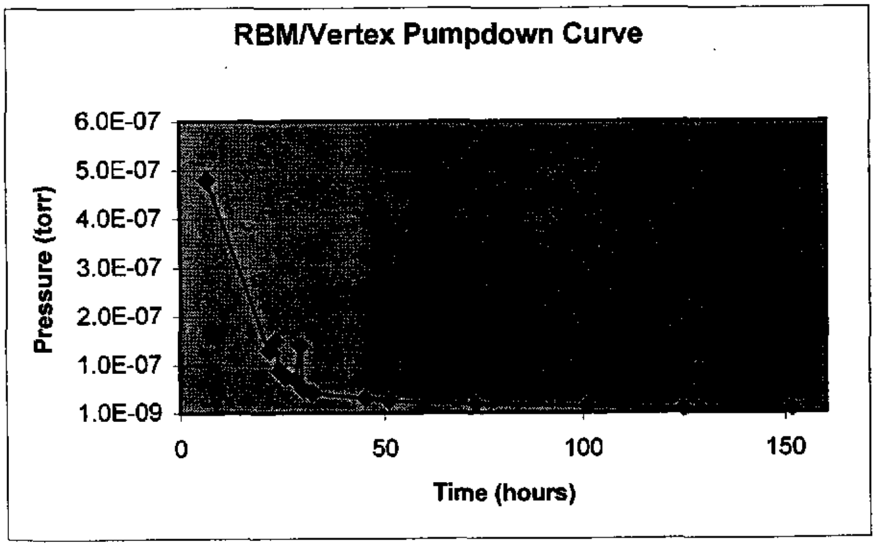
1500 PT120=7.6E-9 Torr
PT170=1.35E-8 Torr
PT134=1.33E-8 Torr
IP1 – 2.2E-4A, IP2 – 2.1E-4A, IP3 – 2.1E-4A, IP4 – 2.1E-4A, IP6 – 2.1e-4A

End 100 hour pumpdown demonstration test
Scan 13,14,15: Open to main volume

8-2-98
1500 PT120=6.18E-9 Torr
PT170=9.90E-9 Torr
PT134=9.90E-9 Torr
IP1 – 1.7E-4A, IP2 – 1.7E-4A, IP3 – 1.6E-4A, IP4 – 1.7E-4A, IP6 – 1.7e-4A
Cryopump is 91% full.
Scan 16,17,18: Open to main volume at 125 hour

8-3-98
0745 PT120=5.4E-9 Torr
PT170=9.5E-9 Torr
PT134=8.2E-9 Torr
Cryopump is 88% full. Shut down and start backfill

6.5	4.8E-07
21.5	1.3E-07
23	1.5E-07
24	8.9E-08
25.5	7.6E-08
27.75	7.0E-08
29.25	1.4E-07
29.75	5.0E-08
32	4.3E-08
45	3.0E-08
51	2.5E-08
73	1.9E-08
101	1.4E-08
125	9.9E-09
151.75	9.5E-09



LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT

9. NOISE/SHOCK/VIBRATION FIELD TEST

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

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

Prepared by:
Kyle Martini

October 1998

Test Report U-2484-8001

Prepared for:
Process Systems International, Inc.
20 Walkup Drive
Westborough, MA 01581-5003
PSI Purchase Order 554-386-00

Cambridge Acoustical Associates/ETC
A Department of Engineering Technologies
84 Sherman Street
Cambridge, MA 12140-3261

C1

VIBRATION, NOISE, SHOCK MEASUREMENTS OF THE PSI VACUUM EQUIPMENT AT THE LIGO CORNER STATION HANFORD, WA

Prepared by:

Kyle Martini

October 1998

Test Report U-2484-8001

Prepared for:

Process Systems International, Inc.

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84 Sherman Street
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C2

I. INTRODUCTION AND SUMMARY

The second phase of the LIGO commission test for vibration, noise, and shock has been completed at the Hanford, WA corner 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" (see Section IIA-4). 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, which are similar to those at the end- and mid-stations[1], are summarized as follows:

A. The background vibration levels in the corner station ("quiet mode"), 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. The molecular turbopump was located near HAM 6 during its measurements. Excitation frequencies of the pump are 48 and 54 Hz due to the pump's controller and its spin frequency of 450 Hz and higher harmonics. Measurement locations nearest the source show responses similar to what were observed in the mid- and end-station. At locations further away, only responses at the spin frequency and higher harmonics were above the background level. The vibration isolation system designed for the turbopump was not installed.

C. The excitation caused by boiling in the cryopump (WCP2) is broadband and tends to increase the overall level of vibration. As with our previous measurements, we varied the operation of the cryopump and significantly changed the levels of vibration. At

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a steady fill rate of 10% or 60% (normal operating conditions), the measurement locations away from the cryopump are not affected by the boiling process. When the flow rate is suddenly changed or is at a 100% flow, the cryopump's isolator frequencies become evident in these measurements. On the cryopump, normal boiling increases the overall level by 5-10 dB and violent boiling (either in the pump or the fill line), increases the level by 10-20 dB. Controlling the boil process is essential in minimizing vibration. Modification of the cryopump level control loop to continuous level control (versus the present two step 10%/60%) may reduce cryopump vibration.

D. The noise measured during the operation of the turbopump was similar to that measured in the mid- and end- stations. The measurement nearest the turbopump, ten feet behind HAM 6, had a higher narrow band level at 900 Hz than was measured at the further location near BS 7. Operation of the cryopump did not increase the background noise level when measured near BS 7.

E. The operation of the ion pump power supply does not raise the level of vibration in the LVEA above its ambient level.

F. The turbo-backing pump produces narrow band excitation at 59 Hz and harmonics of that frequency. There is also a broadband contribution above 50 Hz. Between the mechanical room floor and the LVEA floor there is a 10-20 dB transmission loss above 60 Hz. Below 60 Hz, there was not enough source strength to determine if there is any transmission loss between the floor slabs. The chambers in the LVEA are not significantly excited by the broadband vibration. However, the 59 Hz excitation and its harmonic are evident in the measurements.

G. The vent and purge system produces a loud noise during blowdown. Although no acoustic measurement was performed, the vibration measurements indicate a short burst of 150 Hz tones. This produces a 30-40 dB increase in vibration level at 150 Hz. There is also a 10-15 dB increase in the broadband level above 50 Hz, that is not

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attributed to the blowdown event.

H. Several measurements were recorded while the facility was not completely in its quiet mode. In particular, a set of measurements was performed while the site's chill water pumps were operating and another during a hard rain (no wind). Vibrations caused by these events were greater than those produced by the vacuum equipment except for the vent and purge system (above 100 Hz).

I. Shock measurements on the nearest chamber, when the manual valves were opened or closed, met or slightly exceeded LIGO's revised shock specification. The max-min combined levels ranged from 0.010 to 0.024 g's. Levels on the valve body were higher.

J. When operating the large gate valves, the combined max-min levels ranged from 0.016 to 0.045 g's. Levels on the valve's body were comparable.

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 operated alone. Background measurements, without any vacuum equipment operating, were recorded for comparison.

Observation or receiver locations were selected based on proximity to the source. Typically the measurements were performed in one or two perpendicular directions using a low frequency accelerometer. During measurements of the turbomolecular pump, a high frequency accelerometer was used for several measurements. For all low frequency measurements, four accelerometers were recorded simultaneously with one, located on

C6

the floor near BS 7, used as a reference channel.

2. Instrumentation

The two vibration sensors are 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. Recommended manufacturer's battery power units were used with the accelerometers.

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^2 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. Figure 1 indicates the locations of all vibration, noise, and shock measurements in the corner station. In this report, the locations shown in Figure 1 will be designated as follows:

Position 0-	Floor near Beamsplitter BS7	Vertical Direction
		Acoustic
Position 1-	Section WBE-4	Axial Direction
		Radial Direction
Position 2-	Cryopump WCP-2	Axial Direction

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		Radial Direction
Position 3-	Section WBE-5	Axial Direction
		Radial Direction
Position 4-	BS-7 Flange	Axial Direction
		Radial Direction
Position 5-	BS-7 Nozzle G	Radial Direction
Position 6-	BS-3 Nozzle G	Radial Direction
Position 7-	Section WBE-2	Axial Direction
		Radial Direction
Position 8-	HAM-4 Nozzle	Axial Direction
		Radial Direction
Position 9-	HAM-6 Flange	Axial Direction
		Radial Direction
Position 10-	HAM-6 Nozzle	Radial Direction
Position 11-	Floor LVEA near Mechanical room	Vertical Direction
Position 12-	Floor Mechanical room Near LVEA	Vertical Direction
Position 13-	Inlet line to Cryopump CP2	Vertical Direction
Position 14-	Behind HAM-6	Acoustic

4. Operating Conditions During Measurements

Vibration measurements were recorded for the following 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. The data acquisition system was located in the Equipment washdown room behind closed doors.

A reference accelerometer, located on the floor of the building at position "0" was used to monitor changes in background levels during the measurements. Wind, rain, traffic, and other source of external vibration could be observed.

b. **Turbo Source** - The turbomolecular pump at section WB-5, near HAM 6, was operated. 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 0,5,8,9 and 10 with the low frequency accelerometer and at position 5,8 and 10 with the high frequency accelerometer.

c. **Cryopump Source** - Cryopump measurements were performed at receiver positions 0,2,3,4,5 and 13. The cryopump has a low and high level set point. At the low point the fill rate is operated at 60% which adds more liquid to the reservoir than is evaporated. At the high point, the flow rate is reduced to 10% to decrease the level. Measurements were performed at flow rates of 10%, 60%, transitioning from 10-60% and at a 100%.

d. **Mechanical Room Source** - Measurements were recorded while the large ion pump power supply, the turbo-backing pump, or the vent and purge system was operating. Two reference accelerometers were utilized during these tests, at position 0 in the LVEA area and position 12 in the mechanical room. Vibration was monitored at position 5,8,10, and 11. Measurements at position 11 and 12, only three feet apart but on different foundations, were used to evaluate transmission loss between the slabs.

e. **Miscellaneous Sources**- Several measurements were recorded where there were sources other than the vacuum equipment. During the sensing equipment check out, a measurement was recorded at position 0,2 and 5 before all the equipment was shutdown. Another measurement was recorded during the quiet mode with the facility chill water pumps operating at position 0,1,2,4,and 5 and during a hard rain (without wind) at position 0,2, and 4.

B. Noise Measurements

Background, cryopump, and turbo source noise measurements were recorded. A Bruel and Kjaer Model 2236 Precision Sound Level Meter measured the overall sound pressure level at the microphone locations shown in Figure 1. Octave band measurements were read directly from the sound level meter and compared with the LIGO noise specification. Narrow band 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. Valves tested include one 10" manual turbopump valve (near HAM6), four 14" manual ion pump valves (IP1,3,4,and6), two motorize 48" gate valves (WGV2 and 3), and one pneumatic 48" gate valve (WGV5).

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 nearest chamber. Locations of the accelerometers are indicated in Figure 1 by a "v".

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.

III. MEASUREMENT RESULTS

A. <u>Vibration Results</u>

Thirty-one tests and some 123 vibration measurements were recorded and analyzed. Acceleration power spectral density curves are plotted in Appendix A. As a 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.

For diagnostic purposes, the measured acceleration time histories are plotted in Appendix B. Transients, produced either by the vacuum equipment or other sources, can be observed. To accentuate the transients, the average (over 0.125 second intervals) rms acceleration as a function of time is computed and plotted. The test date, number and channel number on the plots are described in Appendix A.

B. <u>Noise Results</u>

Both octave and narrow band noise measurements can be found at the end of Appendix A.

C. Valve Shock Results

A tri-axial accelerometer was located on the chamber nearest the valve to monitor the shock during opening and closing of the valve. Accelerometer #1 sensed the shock in the radial direction of the chamber, #2 sensed the vertical direction, and #3 the circumferential direction. In addition a fourth accelerometer, #4, was located on the valve body for diagnostic purposes. Maximum and minimum acceleration shock levels recorded when the valves open and closed are listed in Tables I for both sets of filtered data.

IV. REFERENCES

1 - Kyle Martini, Vibration, Noise, Shock Measurements of the PSI Vacuum Equipment at the LIGO End and Mid Station, Hanford, WA,CAA Test Report U-2379-8001, June 1998.

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

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Table I - LIGO CORNER STATION VALVE MEASUREMENT RESULTS

	500 Hz Filter		100 Hz Filter	
Accel #	Max(g)	Min(g)	Max(g)	Min(g)
1 48" WGV2 motorize gate valve background				
1	0.0042	-0.0040	0.0035	-0.0029
2	0.0043	-0.0042	0.0037	-0.0036
3	0.0048	-0.0056	0.0040	-0.0045
4	0.0053	-0.0051	0.0044	-0.0040
2 48" WGV2 motorize gate valve closing				
1	0.1173	-0.0278	0.0777	-0.0130
2	0.0316	-0.0369	0.0189	-0.0265
3	0.0269	-0.0311	0.0215	-0.0228
4	0.0390	-0.0510	0.0116	-0.0104
3 48" WGV2 motorize gate valve opening				
1	0.0080	-0.0080	0.0049	-0.0057
2	0.0226	-0.0265	0.0079	-0.0080
3	0.0173	-0.0218	0.0139	-0.0191
4	0.0229	-0.0199	0.0065	-0.0062
4 14" IP3 valve background				
1	0.0047	-0.0046	0.0042	-0.0045
2	0.0050	-0.0038	0.0042	-0.0032
3	0.0052	-0.0061	0.0041	-0.0046
4	0.0048	-0.0041	0.0048	-0.0036

	500 Hz Filter		100 Hz Filter	
Accel #	Max(g)	Min(g)	Max(g)	Min(g)
5 14" IP3 valve opening				
1	0.0891	-0.0784	0.0347	-0.0313
2	0.0079	-0.0074	0.0063	-0.0068
3	0.0064	-0.0068	0.0046	-0.0055
4	0.0083	-0.0087	0.0077	-0.0077
6 14" IP3 valve closing				
1	0.1058	-0.0337	0.0517	-0.0174
2	0.0075	-0.0070	0.0069	-0.0063
3	0.0060	-0.0054	0.0053	-0.0043
4	0.0082	-0.0094	0.0077	-0.0090
7 14" IP4 valve background				
1	0.0069	-0.0071	0.0058	-0.0064
2	0.0039	-0.0039	0.0034	-0.0033
3	0.0051	-0.0046	0.0036	-0.0031
4	0.0032	-0.0038	0.0027	-0.0031
8 14" IP3 valve opening				
1	0.1262	-0.1237	0.1311	-0.1298
2	0.0055	-0.0062	0.0047	-0.0054
3	0.0065	-0.0055	0.0055	-0.0042
4	0.0071	-0.0058	0.0064	-0.0052
9 14" IP3 valve closing				
1	0.1260	-0.1239	0.1262	-0.1325
2	0.0041	-0.0050	0.0037	-0.0042
3	0.0052	-0.0058	0.0036	-0.0049

Accel #	500 Hz Filter Max(g)	500 Hz Filter Min(g)	100 Hz Filter Max(g)	100 Hz Filter Min(g)
4	0.0062	-0.0055	0.0055	-0.0053

	500 Hz Filter		100 Hz Filter	
Accel #	Max(g)	Min(g)	Max(g)	Min(g)
10 10" Turbopump valve near HAM6 background				
1	0.0032	-0.0043	0.0027	-0.0034
2	0.0046	-0.0036	0.0041	-0.0032
3	0.0044	-0.0044	0.0036	-0.0038
4	0.0005	-0.0005	0.0004	-0.0004
11 10" Turbopump valve near HAM6 opening				
1	0.0960	-0.0617	0.0100	-0.0093
2	0.0054	-0.0065	0.0048	-0.0056
3	0.0075	-0.0079	0.0054	-0.0072
4	0.0008	-0.0007	0.0008	-0.0006
12 10" Turbopump valve near HAM6 closing				
1	0.0332	-0.0308	0.0061	-0.0044
2	0.0055	-0.0062	0.0049	-0.0056
3	0.0067	-0.0062	0.0047	-0.0057
4	0.0007	-0.0010	0.0006	-0.0009
13 14" IP2 valve background				
1	0.0040	-0.0043	0.0039	-0.0031
2	0.0050	-0.0040	0.0043	-0.0035
3	0.0035	-0.0039	0.0028	-0.0031
4	0.0039	-0.0046	0.0033	-0.0034
14 14" IP2 valve closing				
1	0.0998	-0.0664	0.0842	-0.0693
2	0.0076	-0.0093	0.0067	-0.0091

C15

3	0.0064	-0.0051	0.0058	-0.0043
4	0.0188	-0.0070	0.0180	-0.0058
	500 Hz Filter		100 Hz Filter	
Accel #	Max(g)	Min(g)	Max(g)	Min(g)
	15 14" IP2 valve opening			
1	0.0693	-0.0397	0.0532	-0.0074
2	0.0093	-0.0080	0.0079	-0.0073
3	0.0075	-0.0094	0.0061	-0.0073
4	0.0100	-0.0130	0.0062	-0.0076
	16 14" IP6 valve background			
1	0.0045	-0.0041	0.0039	-0.0034
2	0.0048	-0.0043	0.0042	-0.0038
3	0.0044	-0.0048	0.0037	-0.0046
4	0.0057	-0.0043	0.0051	-0.0034
	17 14" IP6 valve closing			
1	0.1238	-0.0888	0.0866	-0.0311
2	0.0072	-0.0112	0.0057	-0.0050
3	0.0109	-0.0156	0.0041	-0.0054
4	0.0214	-0.0198	0.0042	-0.0039
	18 14" IP6 valve opening			
1	0.1251	-0.1248	0.1075	-0.0797
2	0.0244	-0.0258	0.0079	-0.0081
3	0.0304	-0.0323	0.0043	-0.0056
4	0.0875	-0.0818	0.0048	-0.0052

C16

	19 48" WGV3 motorize gate valve background			
1	0.0039	-0.0043	0.0031	-0.0036
2	0.0042	-0.0036	0.0040	-0.0029
3	0.0062	-0.0053	0.0058	-0.0041
4	0.0045	-0.0047	0.0034	-0.0039

	500 Hz Filter		100 Hz Filter	
Accel #	Max(g)	Min(g)	Max(g)	Min(g)
	20 48" WGV3 motorize gate valve closing			
1	0.0072	-0.0090	0.0064	-0.0079
2	0.0081	-0.0084	0.0071	-0.0073
3	0.0112	-0.0100	0.0064	-0.0078
4	0.0146	-0.0104	0.0088	-0.0071
	21 48" WGV3 motorize gate valve opening			
1	0.0074	-0.0082	0.0066	-0.0075
2	0.0084	-0.0080	0.0079	-0.0072
3	0.0107	-0.0100	0.0060	-0.0064
4	0.0119	-0.0191	0.0065	-0.0071
	22 48" WGV5 pneumatic gate valve background			
2	0.0053	-0.0047	0.0042	-0.0040
3	0.0070	-0.0063	0.0031	-0.0033
4	0.0073	-0.0062	0.0033	-0.0034
	23 48" WGV5 pneumatic gate valve closing			
2	0.0064	-0.0076	0.0057	-0.0071
3	0.0109	-0.0100	0.0103	-0.0090
4	0.0060	-0.0067	0.0056	-0.0060

C17

APPENDIX A
PSI EQUIPMENT VIBRATION MEASUREMENTS
AT LIGO CORNER STATION
HANFORD, WA

LIGO/PSI VIBRATION MEASUREMENT LOG

Corner Station at Hanford, WA

A. Background Measurements

B1 9/24/98 Test 1, 0-Floor nr. BS 7, Bkg. before equip shutdown
B2 9/24/98 Test 1, 5-BS-7 nozzle radial, Bkg. before equip shutdown
B3 9/24/98 Test 1, 2-Cryopump axial, Bkg. before equip shutdown
B4 9/24/98 Test 1, 2-Cryopump radial, Bkg. before equip shutdown

B5 9/24/98 Test 2, 0-Floor nr. BS 7, Bkg. w/ chill water on
B6 9/24/98 Test 2, 4-BS-7 nozzle radial, Bkg. w/ chill water on
B7 9/24/98 Test 2, 2-axial on cryopump, Bkg. w/ chill water on
B8 9/24/98 Test 2, 2-radial on cryopump, Bkg. w/ chill water on

B9 9/24/98 Test 3, 0-Floor nr. BS 7, Bkg. w/ chill water on
B10 9/24/98 Test 3, 4-BS-7 flange radial, Bkg. w/ chill water on
B11 9/24/98 Test 3, 4-BS-7 flange axial, Bkg. w/ chill water on
B12 9/24/98 Test 3, 1-radial on WBE-4, Bkg. w/ chill water on

B13 9/25/98 Test 1, 0-Floor nr. BS 7, Bkg. heavy rain
B14 9/25/98 Test 1, 4-BS-7 flange axial, Bkg. heavy rain

B37 9/25/98 Test 7, 0-Floor nr. BS 7, Bkg.

B38 9/25/98 Test 7, 10-Ham 6 nozzle radial, Bkg.

B39 9/25/98 Test 7, 11-Floor VEA nr. Mech. Rm., Bkg.

B40 9/25/98 Test 7, 12-Floor Mech. Rm.nr. VEA, Bkg.

B41 9/25/98 Test 15, 0-Floor nr. BS 7, Bkg.

B42 9/25/98 Test 15, 8-Ham 4 nozzle radial, Bkg.

B43 9/25/98 Test 15, 5-BS-7 nozzle radial, Bkg.

B44 9/25/98 Test 15, 8-Ham 4 nozzle axial, Bkg.

B. **Cryopump Measurements**

C1 9/26/98 Test 1, 0-Floor nr. BS 7, Cryopump, fill rate 10%

C2 9/26/98 Test 1, 4-BS-7 flange axial, Cryopump, fill rate 10%

C3 9/26/98 Test 1, 2-Cryopump axial, Cryopump, fill rate 10%

C4 9/26/98 Test 1, 2-Cryopump radial, Cryopump, fill rate 10%

C5 9/26/98 Test 2, 0-Floor nr. BS 7, Cryopump, fill rate 10%

C6 9/26/98 Test 2, 4-BS-7 flange axial, Cryopump, fill rate 10%

C7 9/26/98 Test 2, 2-Cryopump axial, Cryopump, fill rate 10%

C8 9/26/98 Test 2, 2-Cryopump radial, Cryopump, fill rate 10%

C9 9/26/98 Test 3, 0-Floor nr. BS 7, Cryopump, fill rate 100%

C10 9/26/98 Test 3, 4-BS-7 flange axial, Cryopump, fill rate 100%

C11 9/26/98 Test 3, 2-Cryopump axial, Cryopump, fill rate 100%

C12 9/26/98 Test 3, 2-Cryopump radial, Cryopump, fill rate 100%

C13 9/26/98 Test 4, 0-Floor nr. BS 7, Cryopump, fill rate 10%-60%

C14 9/26/98 Test 4, 4-BS-7 flange axial, Cryopump, fill rate 10%-60%

C15 9/26/98 Test 4, 2-Cryopump axial, Cryopump, fill rate 10%-60%

C16 9/26/98 Test 4, 2-Cryopump radial, Cryopump, fill rate 10%-60%

C17 9/26/98 Test 5, 0-Floor nr. BS 7, Cryopump, fill rate -60%
C18 9/26/98 Test 5, 4-BS-7 flange axial, Cryopump, fill rate -60%
C19 9/26/98 Test 5, 2-Cryopump axial, Cryopump, fill rate -60%
C20 9/26/98 Test 5, 2-Cryopump radial, Cryopump, fill rate -60%

C21 9/26/98 Test 6, 0-Floor nr. BS 7, Cryopump, fill rate 10%
C22 9/26/98 Test 6, 4-Cryo inlet pipe, Cryopump, fill rate 10%
C23 9/26/98 Test 6, 2-Cryopump axial, Cryopump, fill rate 10%
C24 9/26/98 Test 6, 2-Cryopump radial, Cryopump, fill rate 10%

C25 9/26/98 Test 6, 0-Floor nr. BS 7, Cryopump, fill rate ? no IA
C26 9/26/98 Test 7, 4-Cryo inlet pipe, Cryopump, fill rate ? no IA
C27 9/26/98 Test 7, 2-Cryopump axial, Cryopump, fill rate ? no IA
C28 9/26/98 Test 7, 2-Cryopump radial, Cryopump, fill rate? no IA

C29 9/26/98 Test 8, 0-Floor nr. BS 7, Cryopump, fill rate 10%
C30 9/26/98 Test 8, 4-Cryo inlet pipe, Cryopump, fill rate 10%
C31 9/26/98 Test 8, 2-Cryopump axial, Cryopump, fill rate 10%
C32 9/26/98 Test 8, 2-Cryopump radial, Cryopump, fill rate 10%

C33 9/26/98 Test 9, 0-Floor nr. BS 7, Cryopump, fill rate 60%
C34 9/26/98 Test 9, 4-Cryo inlet pipe, Cryopump, fill rate 60%
C35 9/26/98 Test 9, 2-Cryopump axial, Cryopump, fill rate 60%
C36 9/26/98 Test 9, 2-Cryopump radial, Cryopump, fill rate 60%

C37 9/26/98 Test 10, 0-Floor nr. BS 7, Cryopump, fill rate 10%

C38 9/26/98 Test 10, 4-BS 7 nozzle, Cryopump, fill rate 10%

C39 9/26/98 Test 10, 2-WBE-5 axial, Cryopump, fill rate 10%

C40 9/26/98 Test 10, 2-WBE-5 radial, Cryopump, fill rate 10%

C. Turbomolecular Pump Measurements

T1 9/25/98 Test 18, 0-Floor nr. BS 7, Turbo on nr. Ham 6

T2 9/25/98 Test 18, 8-Ham 4 noz. radial, Turbo on nr. HAM 6

T3 9/25/98 Test 18, 5-BS-7 nozzle, Turbo on nr HAM 6

T4 9/25/98 Test 19, 5-BS-7 noz. radial, Turbo on nr. HAM 6

T5 9/25/98 Test 19, 5-HAM-4 noz. radial, Turbo on nr HAM 6

T6 9/25/98 Test 19, 10-Ham 6 noz. axial, Turbo on nr. HAM 6

T7 9/25/98 Test 20, 0-Floor nr. BS 7, Turbo on nr. Ham 6

T8 9/25/98 Test 20, 9-Ham 6 flange axial, Turbo on nr. HAM 6

T9 9/25/98 Test 20, 9-Ham 6 flange radial, Turbo on nr HAM 6

T10 9/25/98 Test 20, 10-Ham 6 noz. radial, Turbo on nr. HAM 6

D. Mechanical Room Vacuum Equipment Sources

mr1 9/25/98 Test 8, 0-Floor nr. BS 7, Ion Pump Power Supply

mr2 9/25/98 Test 8, 10-Ham 6 nozzle radial, Ion Pump Power Supply

mr3 9/25/98 Test 8, 11-Floor VEA nr. Mech. Rm., Ion Pump Power Supply

mr4 9/25/98 Test 8, 12-Floor Mech. Rm.nr. VEA, Ion Pump Power Supply

mr5 9/25/98 Test 9, 0-Floor nr. BS 7, Backing Pump

mr6 9/25/98 Test 9, 10-Ham 6 nozzle radial, Backing Pump

mr7 9/25/98 Test 9, 11-Floor VEA nr. Mech. Rm., Backing Pump

mr8 9/25/98 Test 9, 12-Floor Mech. Rm.nr. VEA, Backing Pump

mr9 9/25/98 Test 10, 0-Floor nr. BS 7, Vent and Purge

mr10 9/25/98 Test 10, 10-Ham 6 nozzle radial, Vent & Purge

C24

mr11 9/25/98 Test 10, 11-Floor VEA nr. Mech. Rm., Vent and Purge

mr12 9/25/98 Test 10, 12-Floor Mech. Rm.nr. VEA, Vent and Purge

mr13 9/25/98 Test 11, 0-Floor nr. BS 7, Ion Pump Power Supply

mr14 9/25/98 Test 11, 8-Ham 4 nozzle radial, Ion Pump Power Supply

mr15 9/25/98 Test 11, 5-BS 7 Noz. radial, Ion Pump Power Supply

mr16 9/25/98 Test 11, 12-Floor Mech. Rm.nr. VEA, Ion Pump Power Supply

mr17 9/25/98 Test 12, 0-Floor nr. BS 7, Backing Pump

mr18 9/25/98 Test 12, 8-Ham 4 nozzle radial, Backing Pump

mr19 9/25/98 Test 12, 5-BS 7 Noz. radial, Backing Pump

mr20 9/25/98 Test 12, 12-Floor Mech. Rm.nr. VEA, Backing Pump

mr21 9/25/98 Test 13, 0-Floor nr. BS 7, Vent and Purge

mr22 9/25/98 Test 13, 8-Ham 4 nozzle radial, Vent & Purge

mr23 9/25/98 Test 13, 5-BS 7 Noz. radial., Vent and Purge

mr24 9/25/98 Test 13, 12-Floor Mech. Rm.nr. VEA, Vent and Purge

mr25 9/25/98 Test 13, 0-Floor nr. BS 7, Vent and Purge Modified Op.

mr26 9/25/98 Test 13, 8-Ham 4 nozzle radial, Vent & Purge Modified Op.

mr27 9/25/98 Test 13, 5-BS 7 Noz. radial., Vent and Purge Modified Op.

mr28 9/25/98 Test 13, 12-Floor Mech. Rm.nr. VEA, Vent and Purge Mod. Op.

E. **Acoustic Measurements (Octave band and narrow band)**

A1 9/25/98 Test 16, Floor nr. BS 7, Acoustic bkg.

A2 9/25/98 Test 16, 10 feet behind Ham 6, Acoustic bkg.

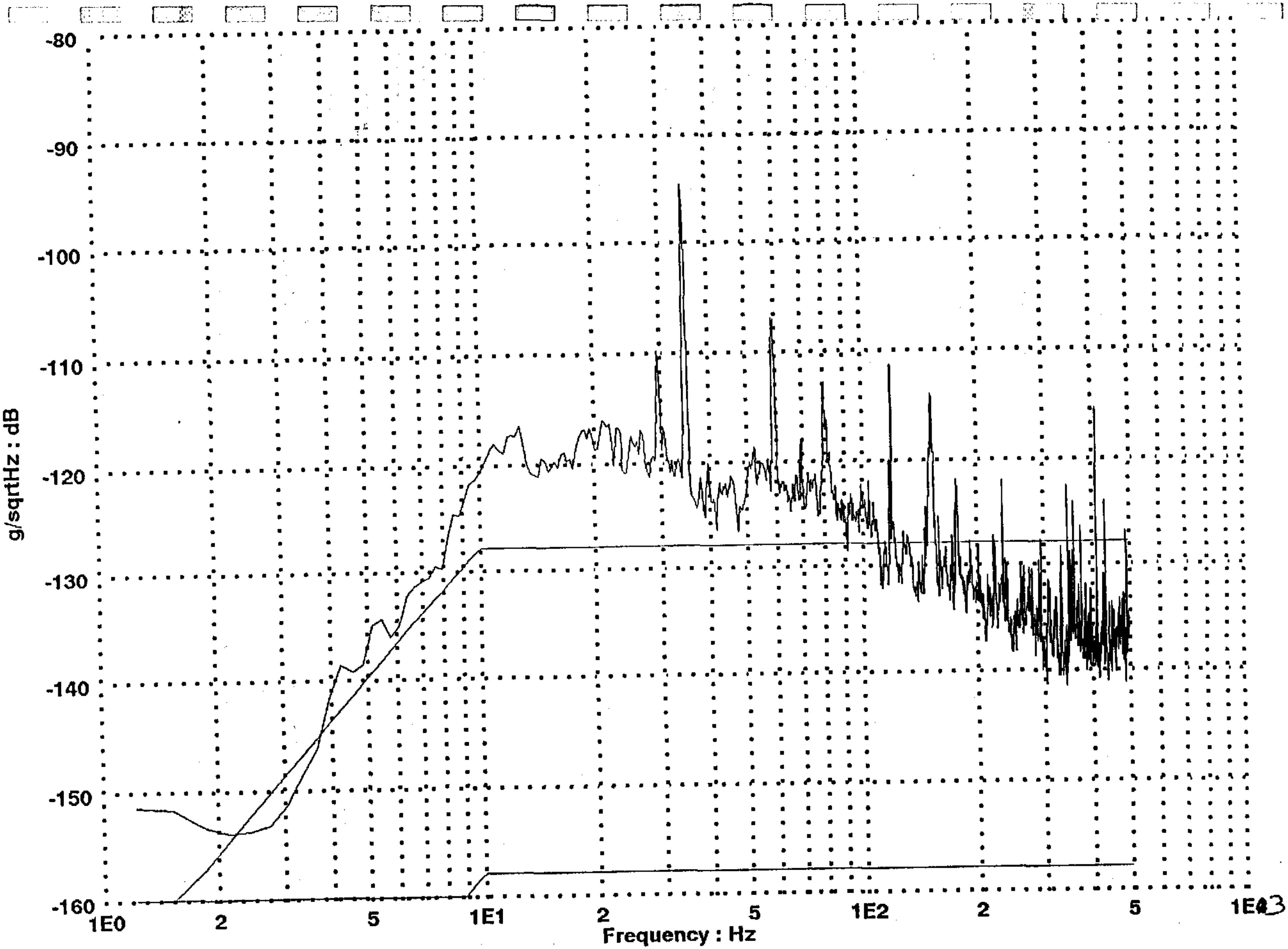
A3 9/25/98 Test 17, Floor nr. BS 7, Acoustic, Turbo nr. Ham 6

A4 9/25/98 Test 17, 10 feet behind Ham 6, Acoustic, Turbo nr. Ham 6

A5 9/26/98 Test 11, Floor nr. BS 7, Acoustic, Cryopump

A6 Octave band Measurements nr BS 7, Bkg., Turbo and Cryopump

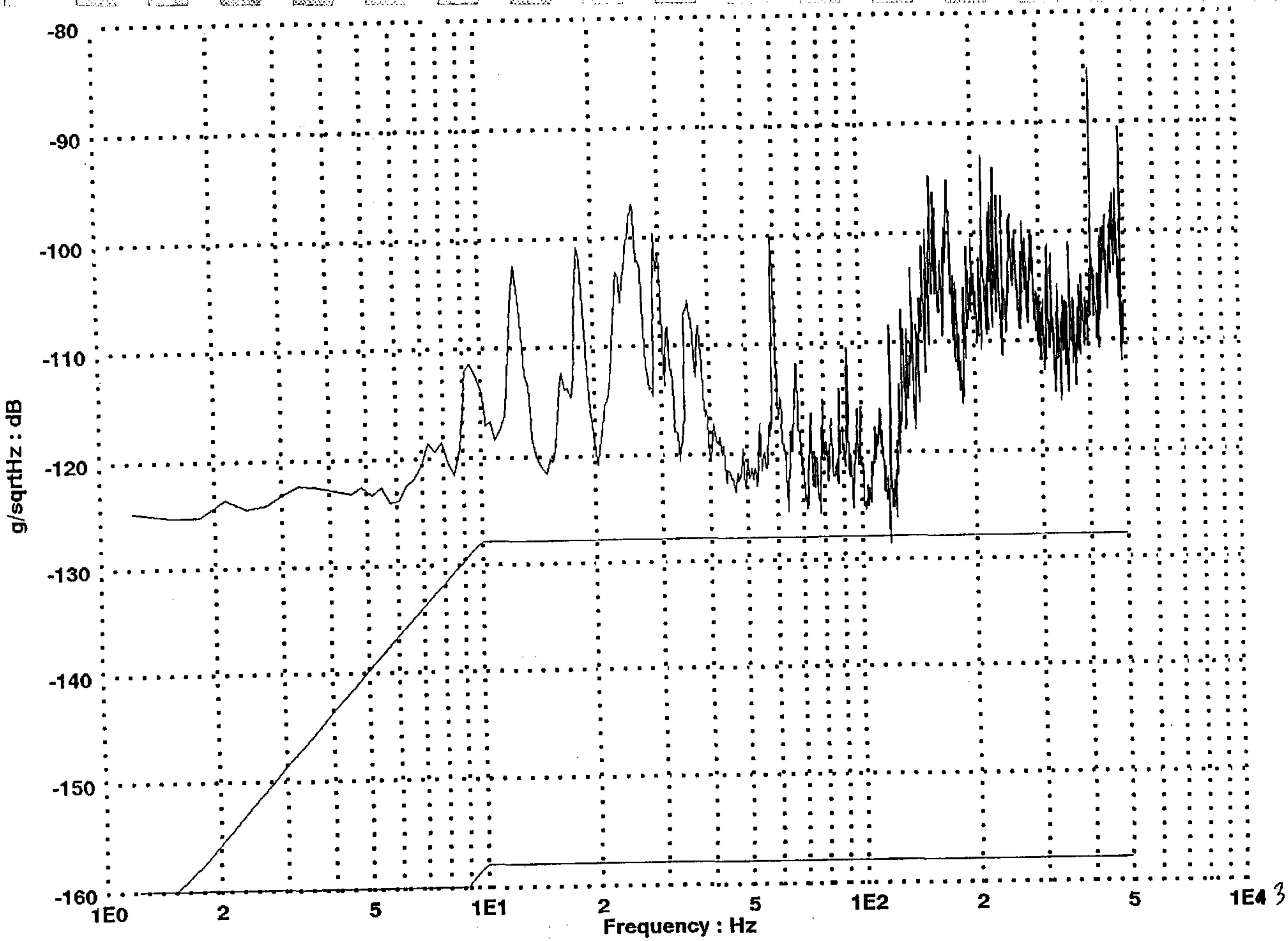
A7 Octave band Measurements nr Ham 6, Bkg. And Turbo



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

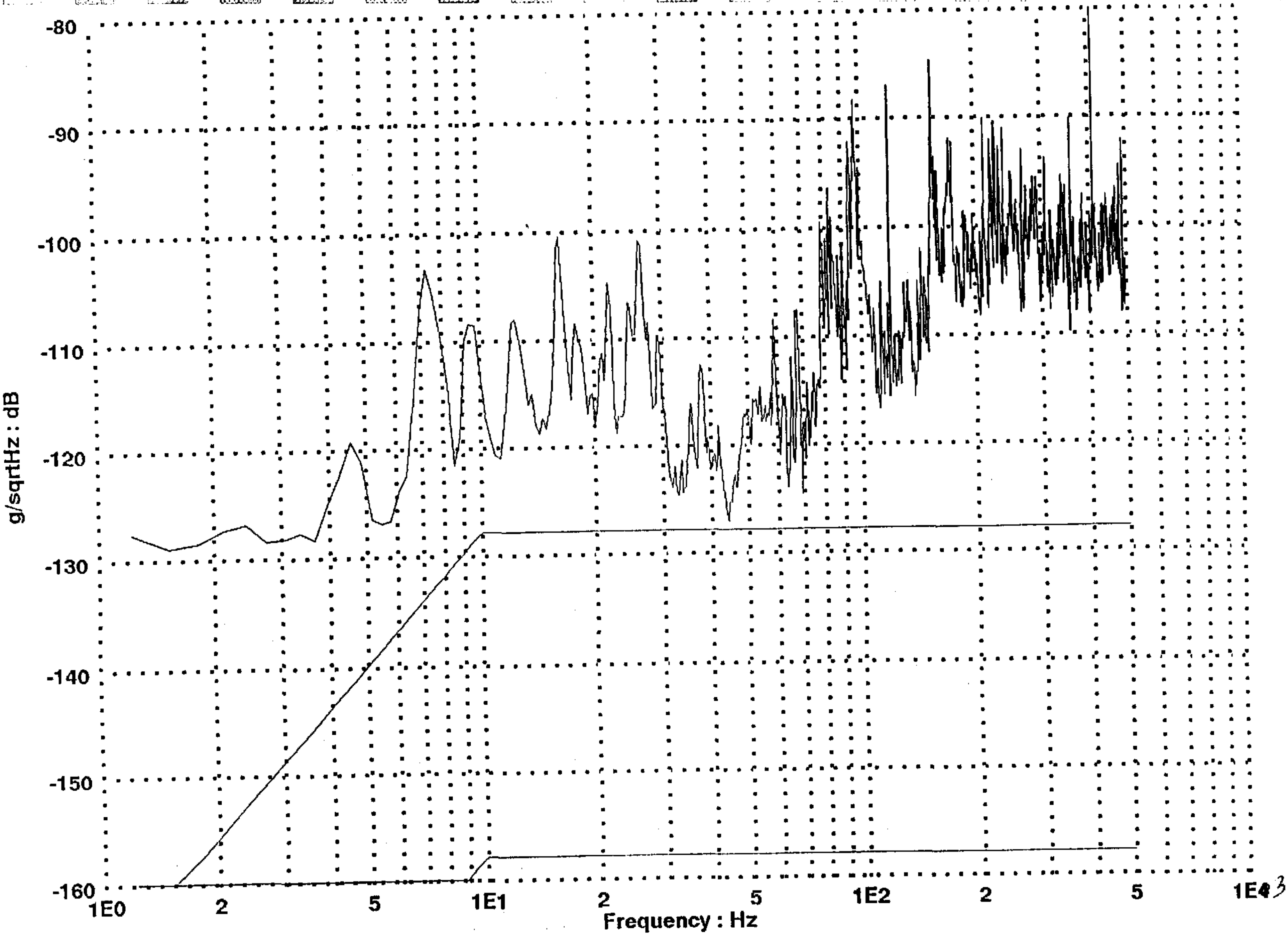
B1 9/24/98 Test 1, 0-Floor nr. BS 7, Bkg. before equip shutdown

C27



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

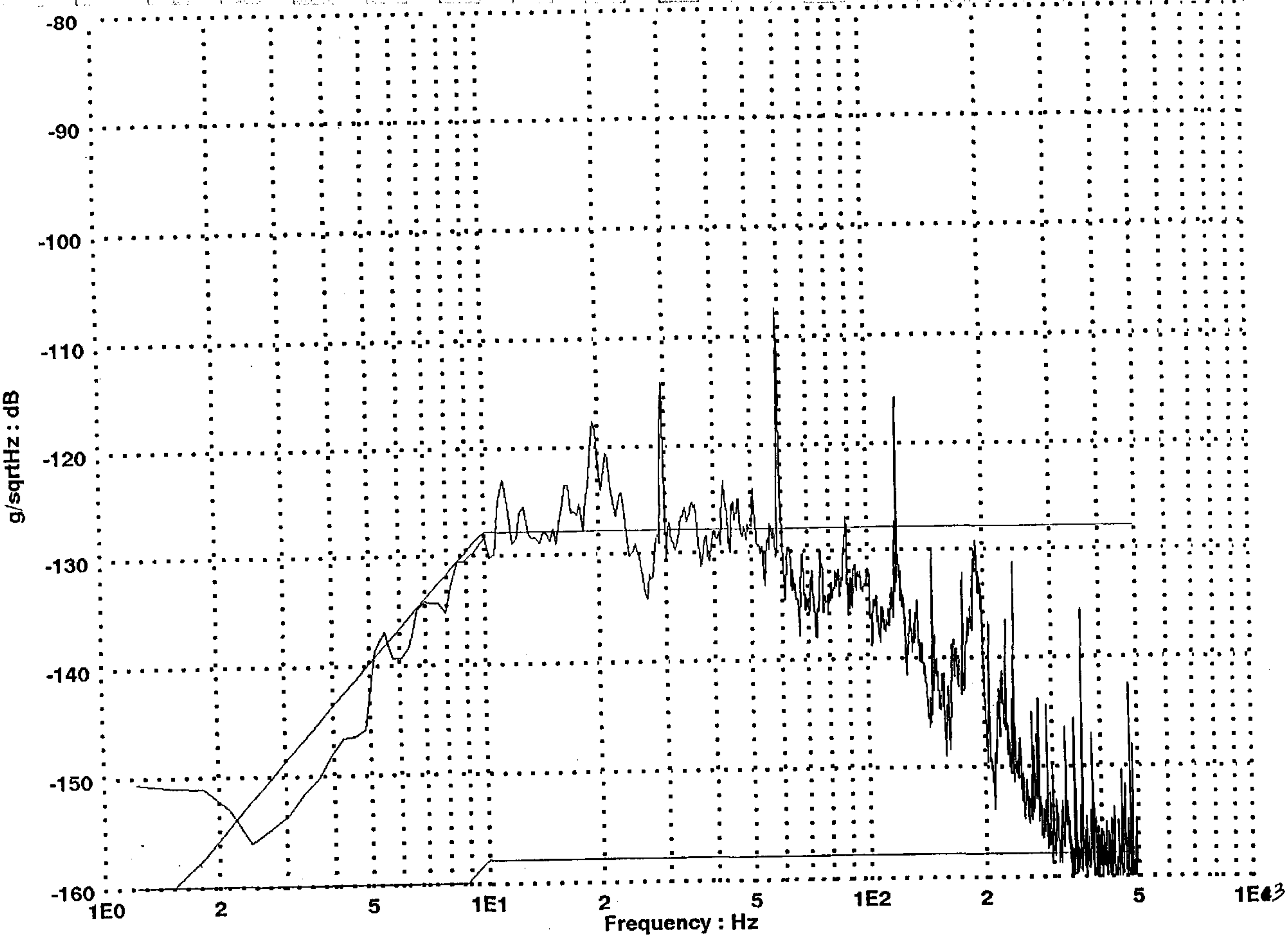
B3 9/24/98 Test 1, 2-Cryopump axial, Bkg. before equip shutdown



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

B4 9/24/98 Test 1, 2-Cryopump radial, Bkg. before equip shutdown

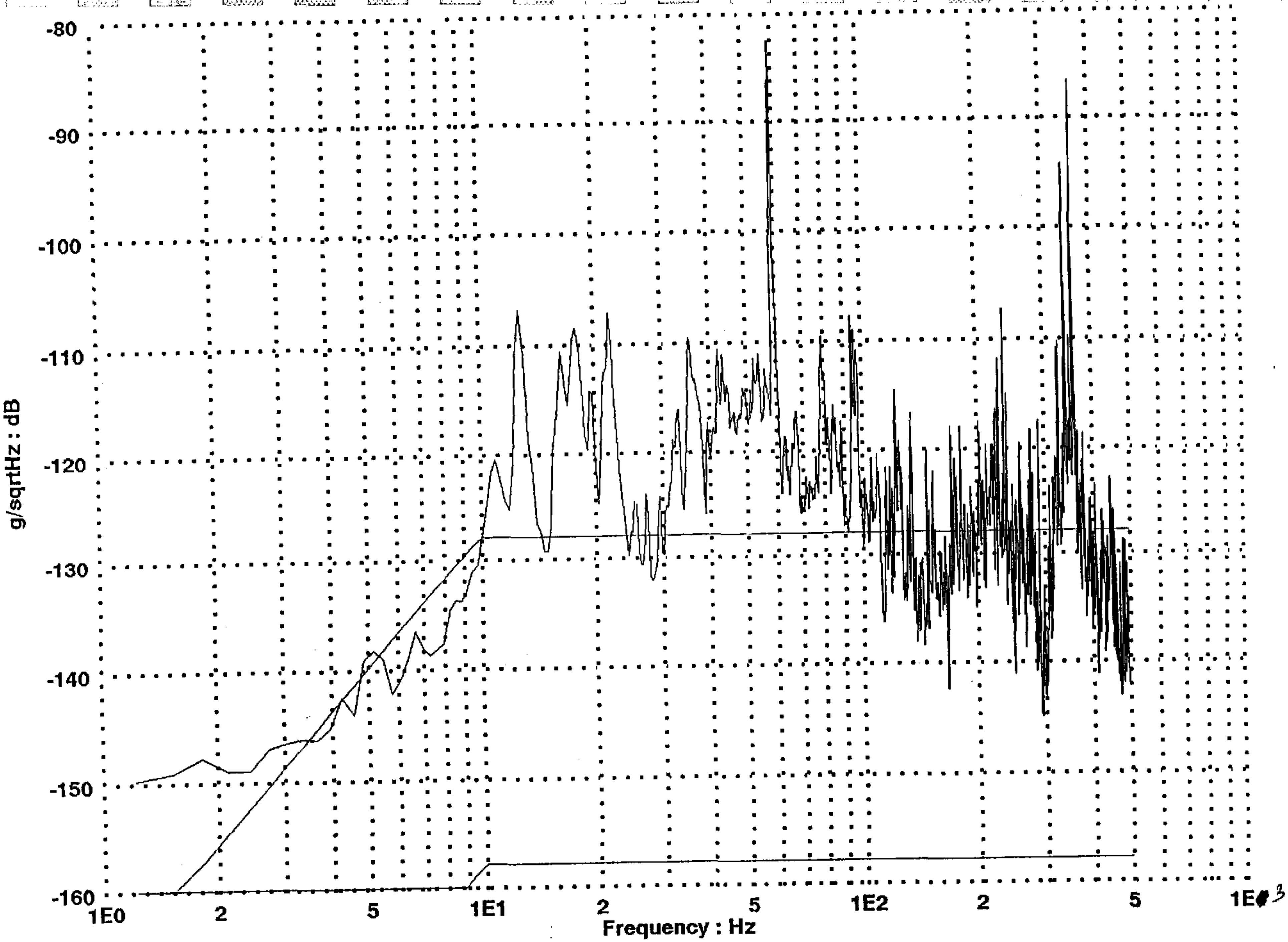
C30



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

B5 9/24/98 Test 2, 0-Floor nr. BS 7, Bkg. w/ chill water on

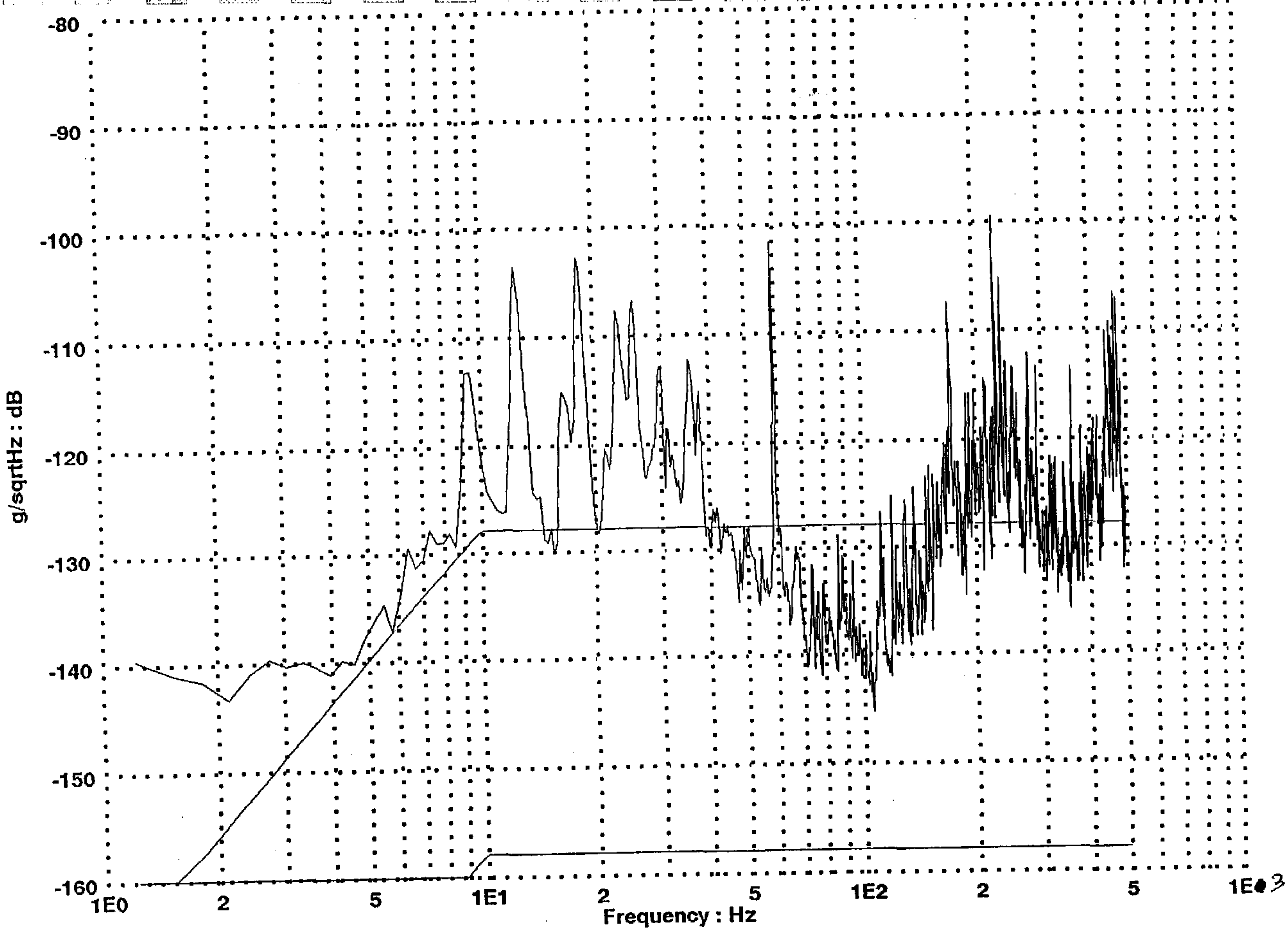
C31



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

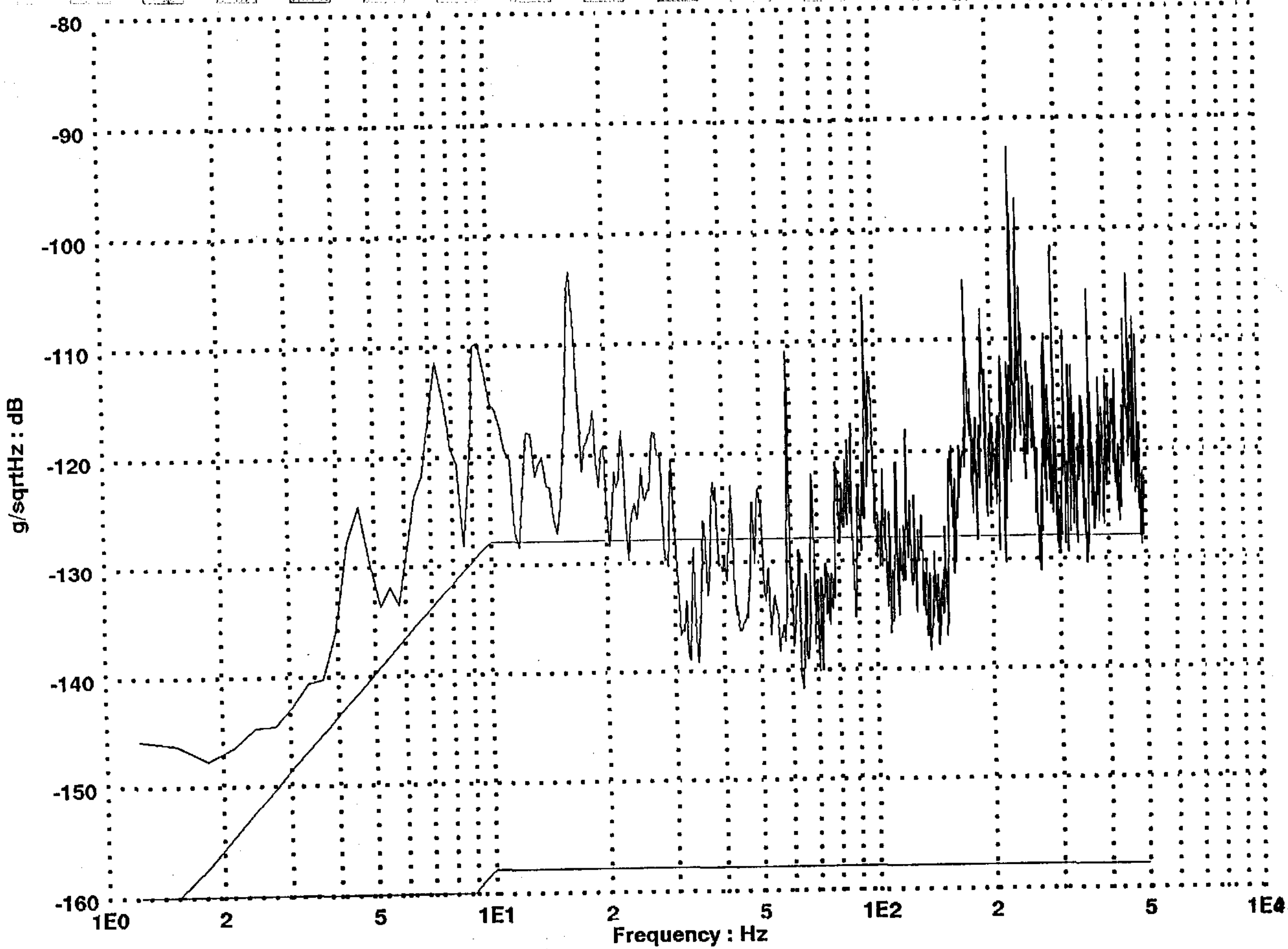
B6 9/24/98 Test 2, 4-BS-7 nozzle radial, Bkg. w/ chill water on

232



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

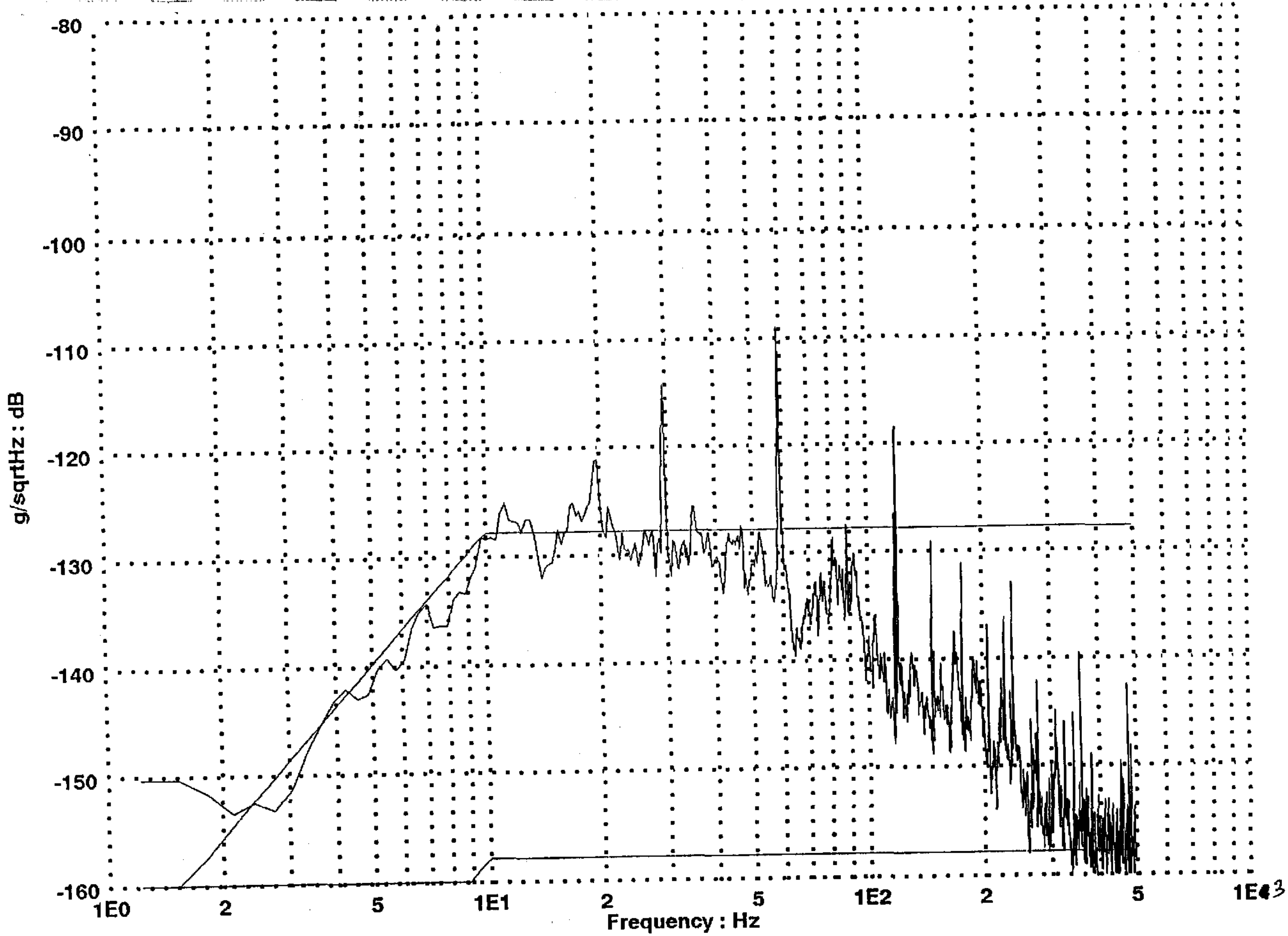
B7 9/24/98 Test 2, 2-axial on cryopump, Bkg. w/ chill water on



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

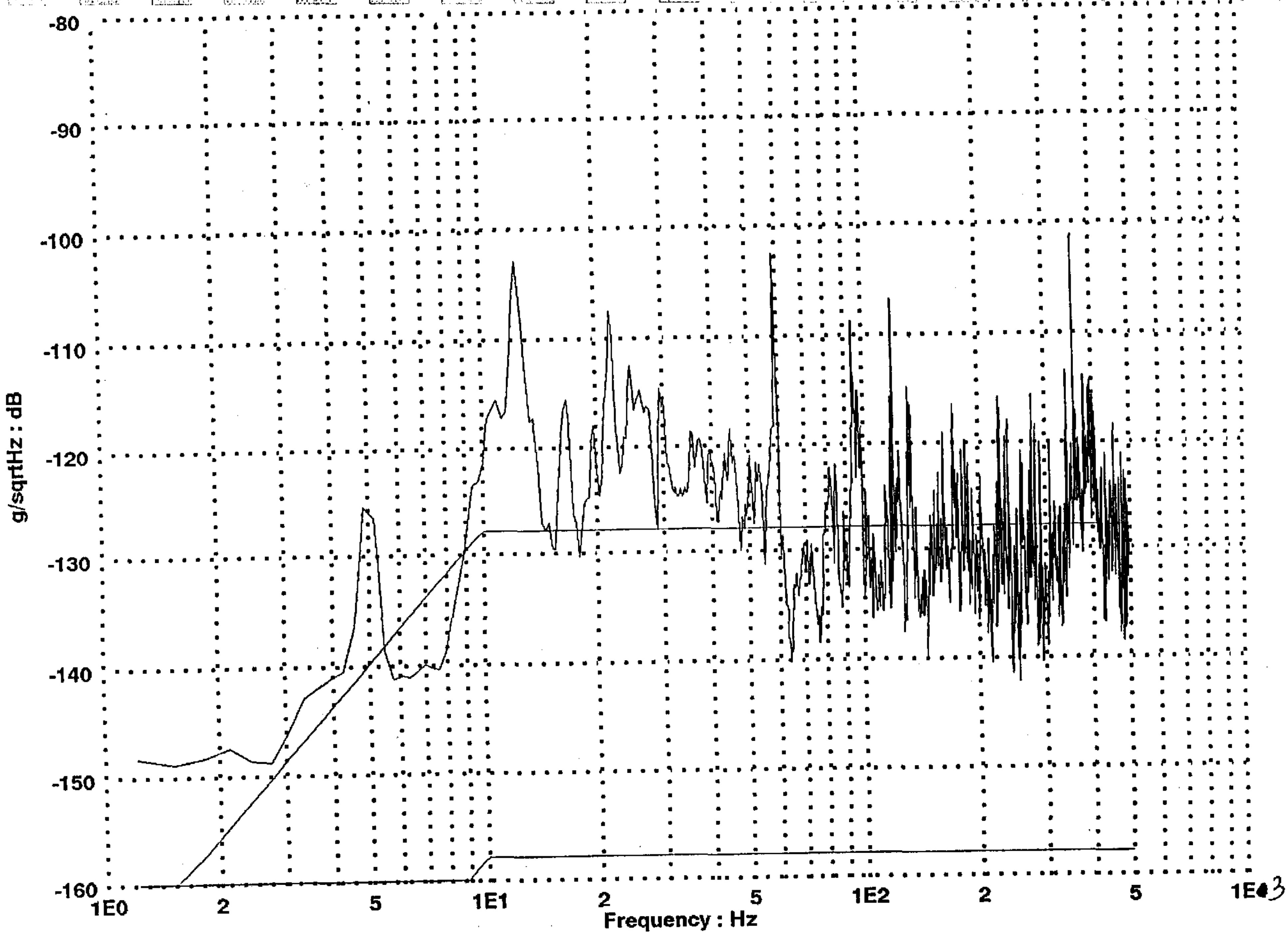
B8 9/24/98 Test 2, 2-radial on cryopump, Bkg. w/ chill water on

C34



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

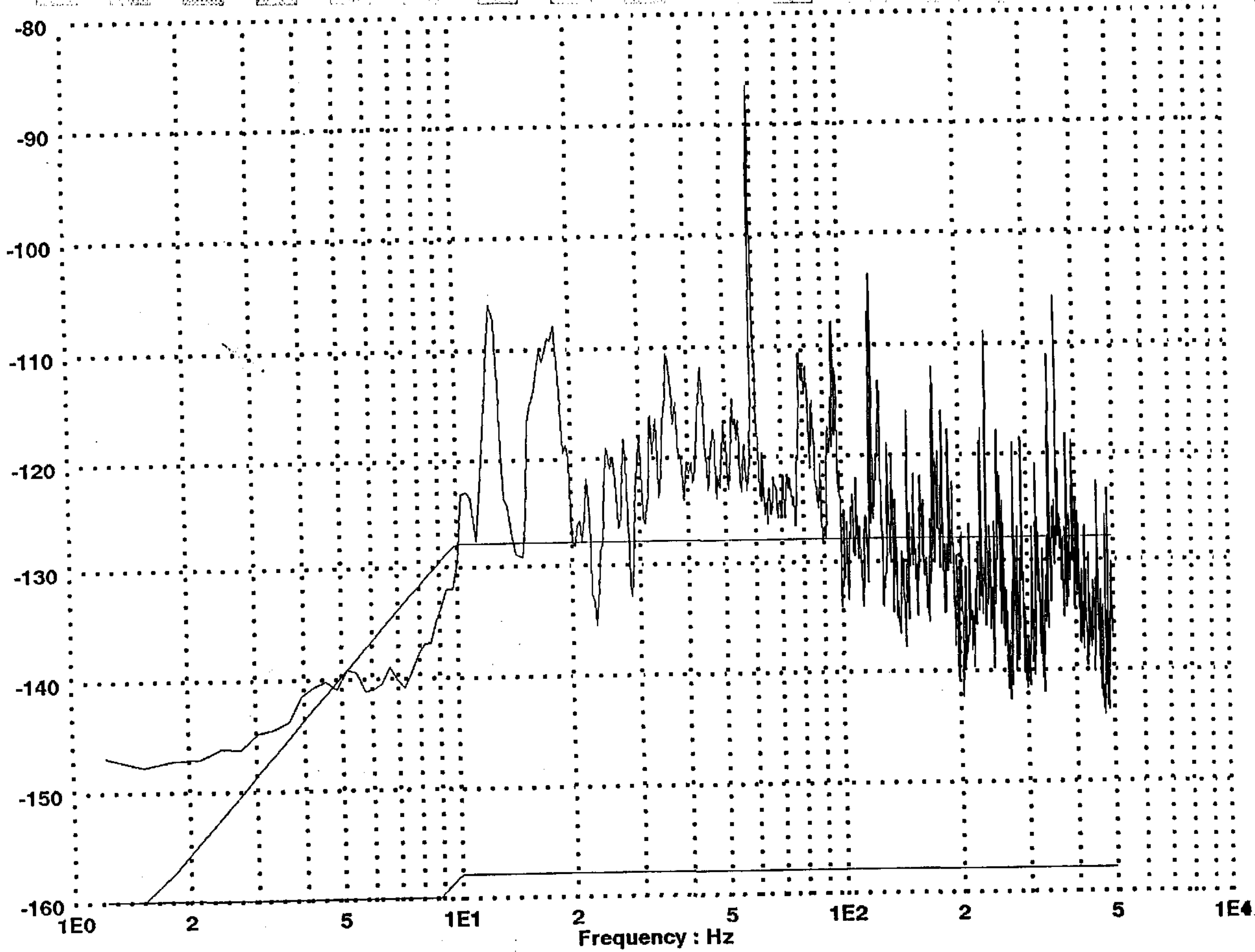
B9 9/24/98 Test 3, 0-Floor nr. BS 7, Bkg. w/ chill water on



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

B10 9/24/98 Test 3, 4-BS-7 flange radial, Bkg. w/ chill water on

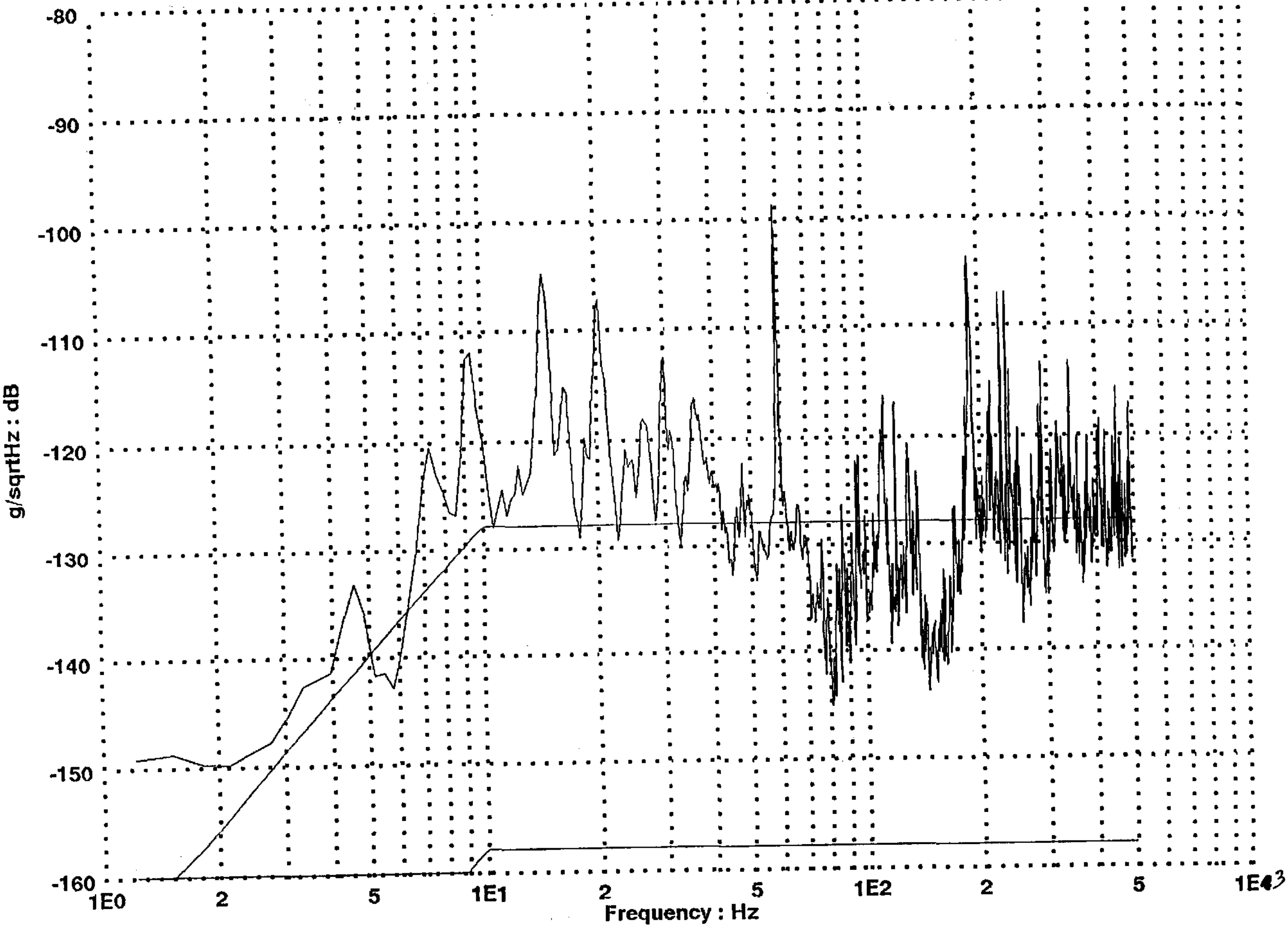
C36



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

B11 9/24/98 Test 3, 4-BS-7 flange axial, Bkg. w/ chill water on

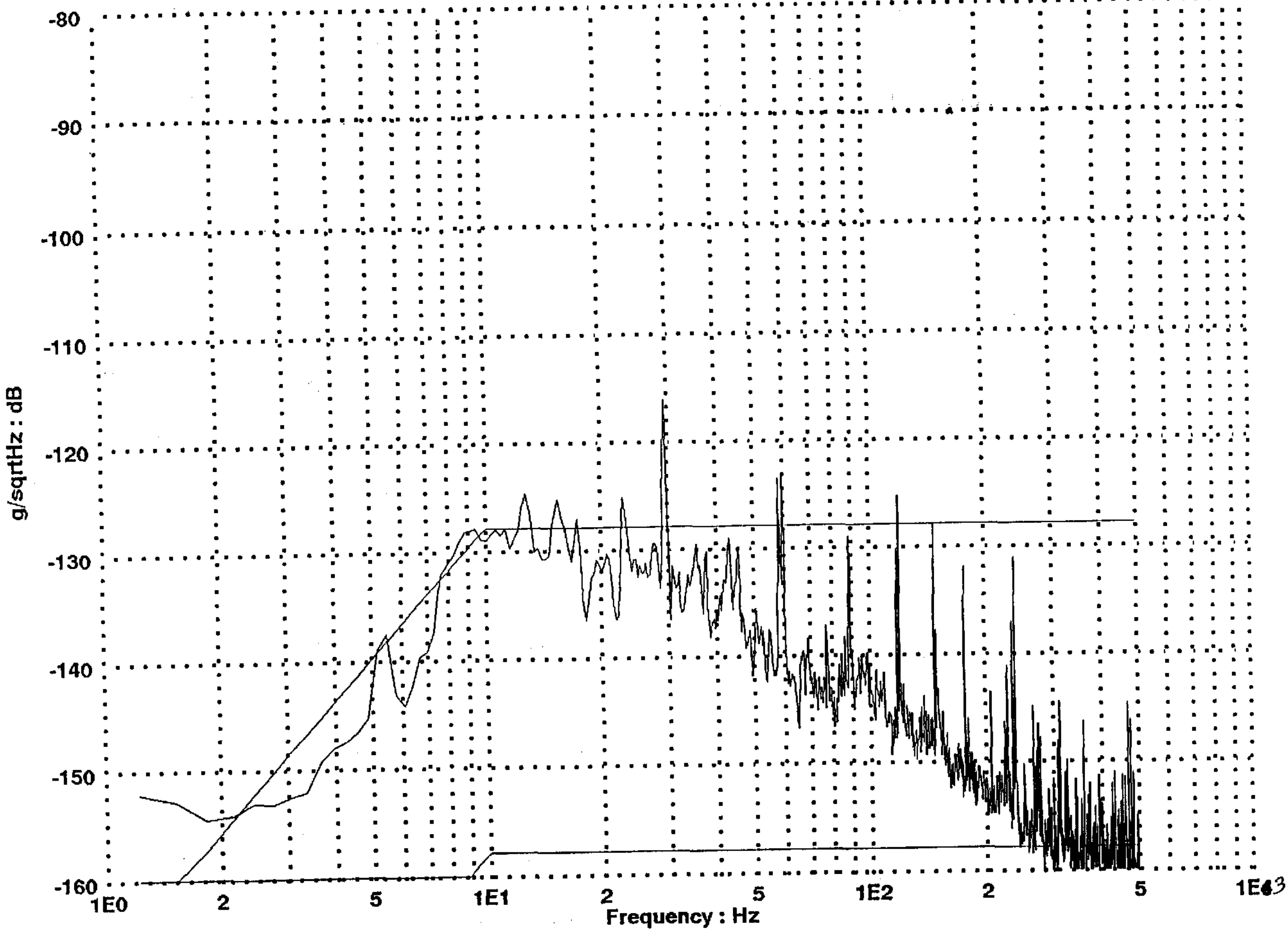
C37



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

B12 9/24/98 Test 3, 1-radial on WBE-4, Bkg. w/ chill water on

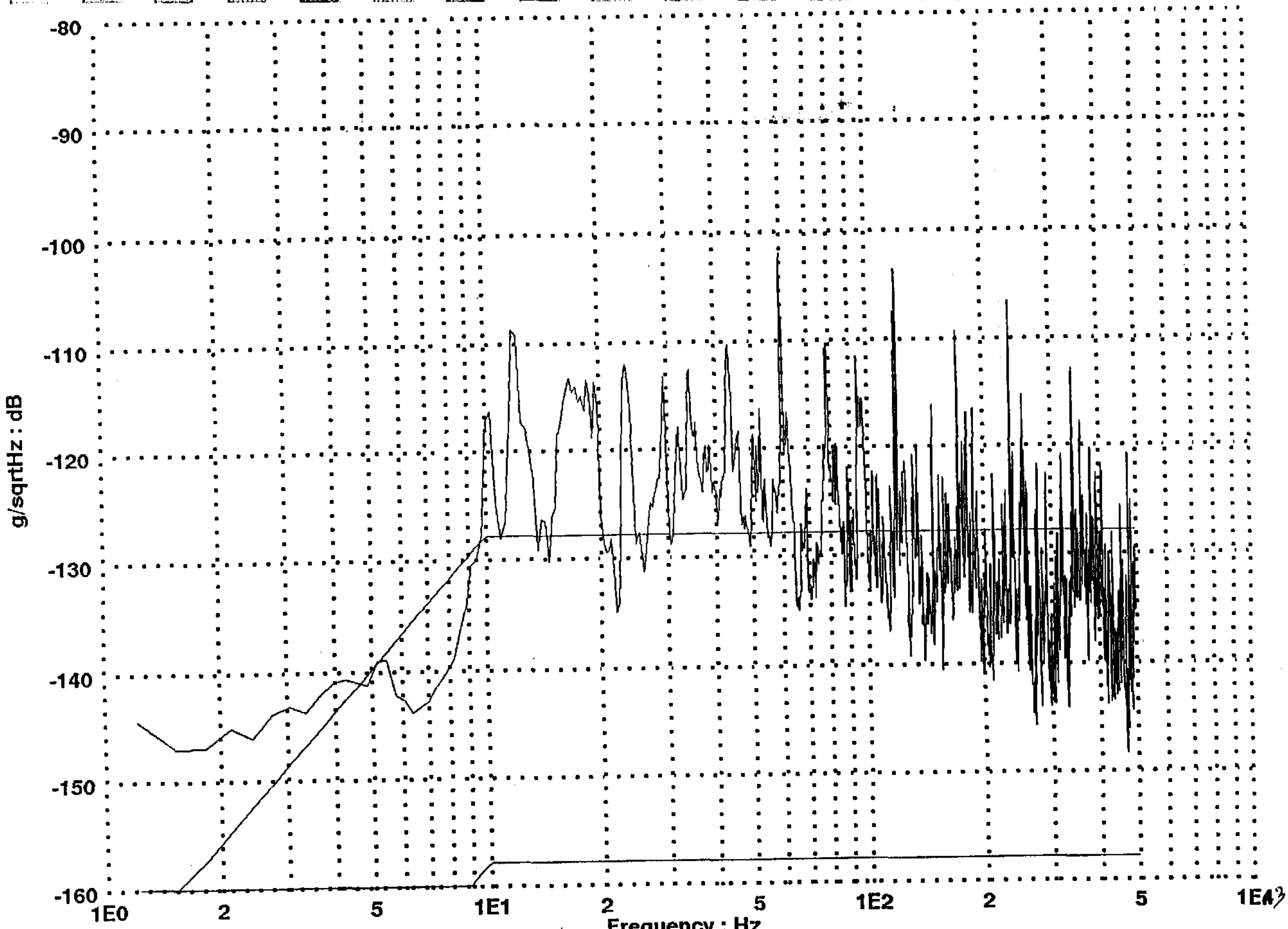
238



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

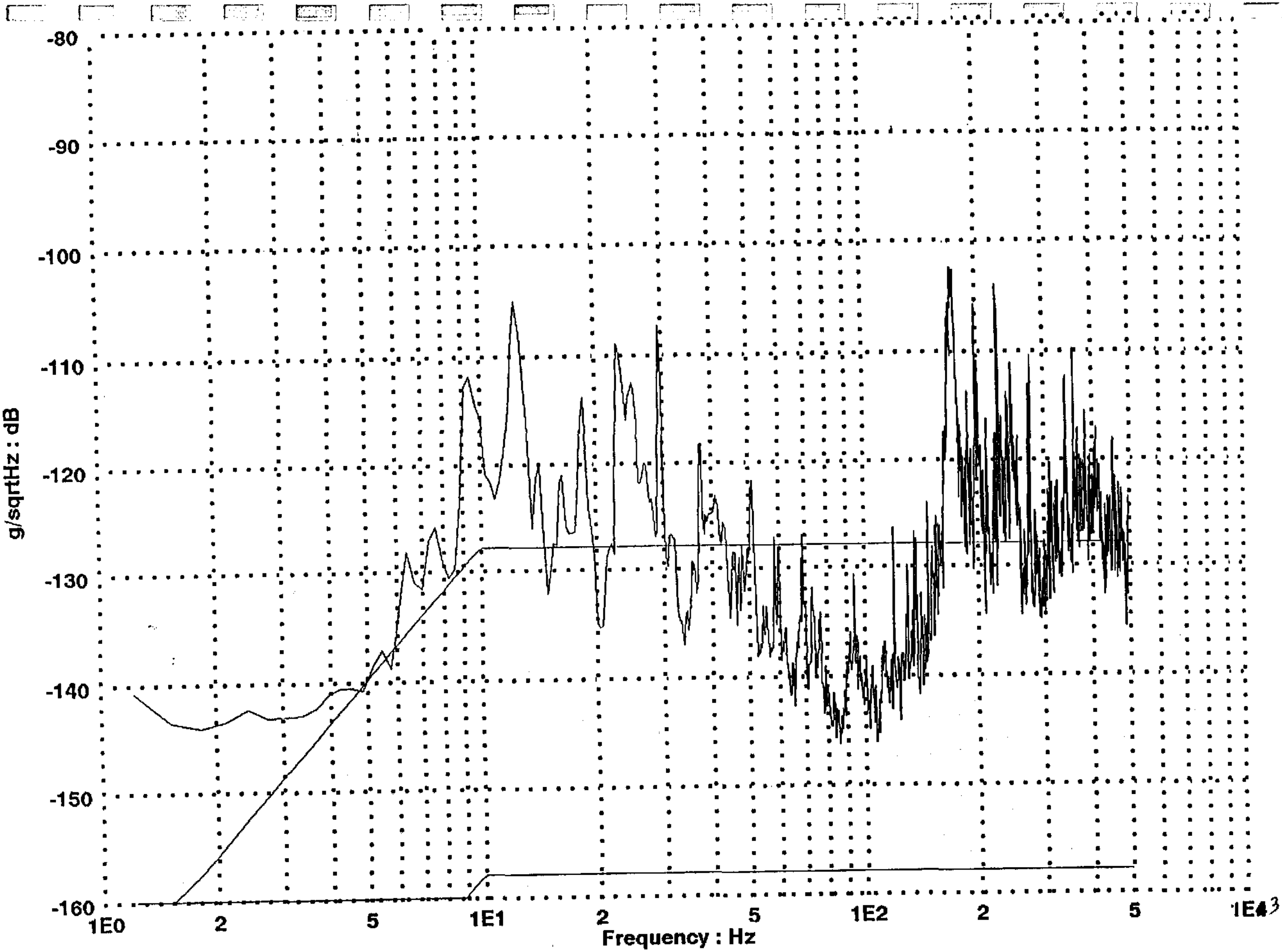
B13 9/25/98 Test 1, 0-Floor nr. BS 7, Bkg. heavy rain

C35



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

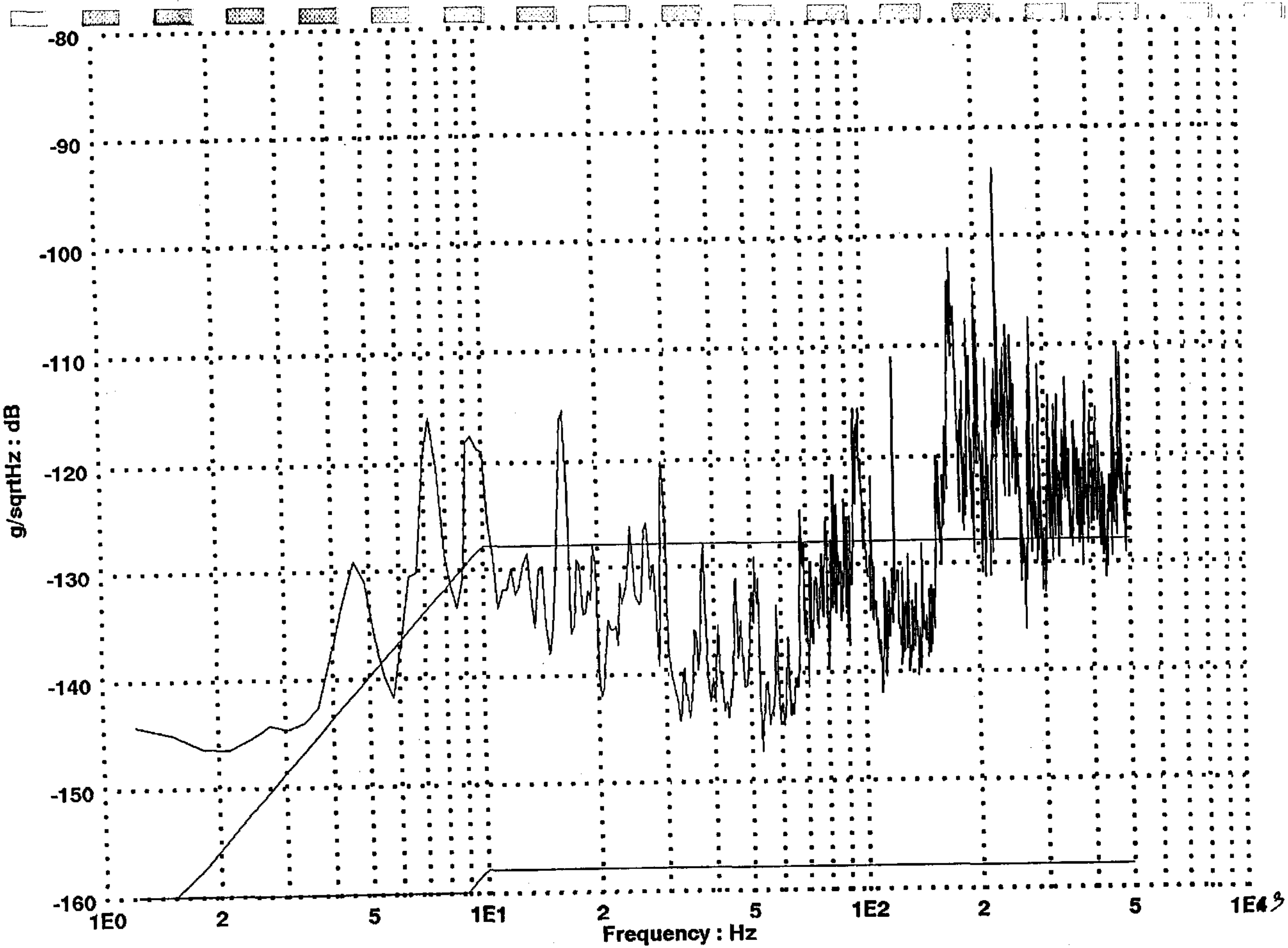
B14 9/25/98 Test 1, 4-BS-7 flange axial, Bkg. heavy rain



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

B16 9/25/98 Test 1, 2-Cryopump axial, Bkg. heavy rain

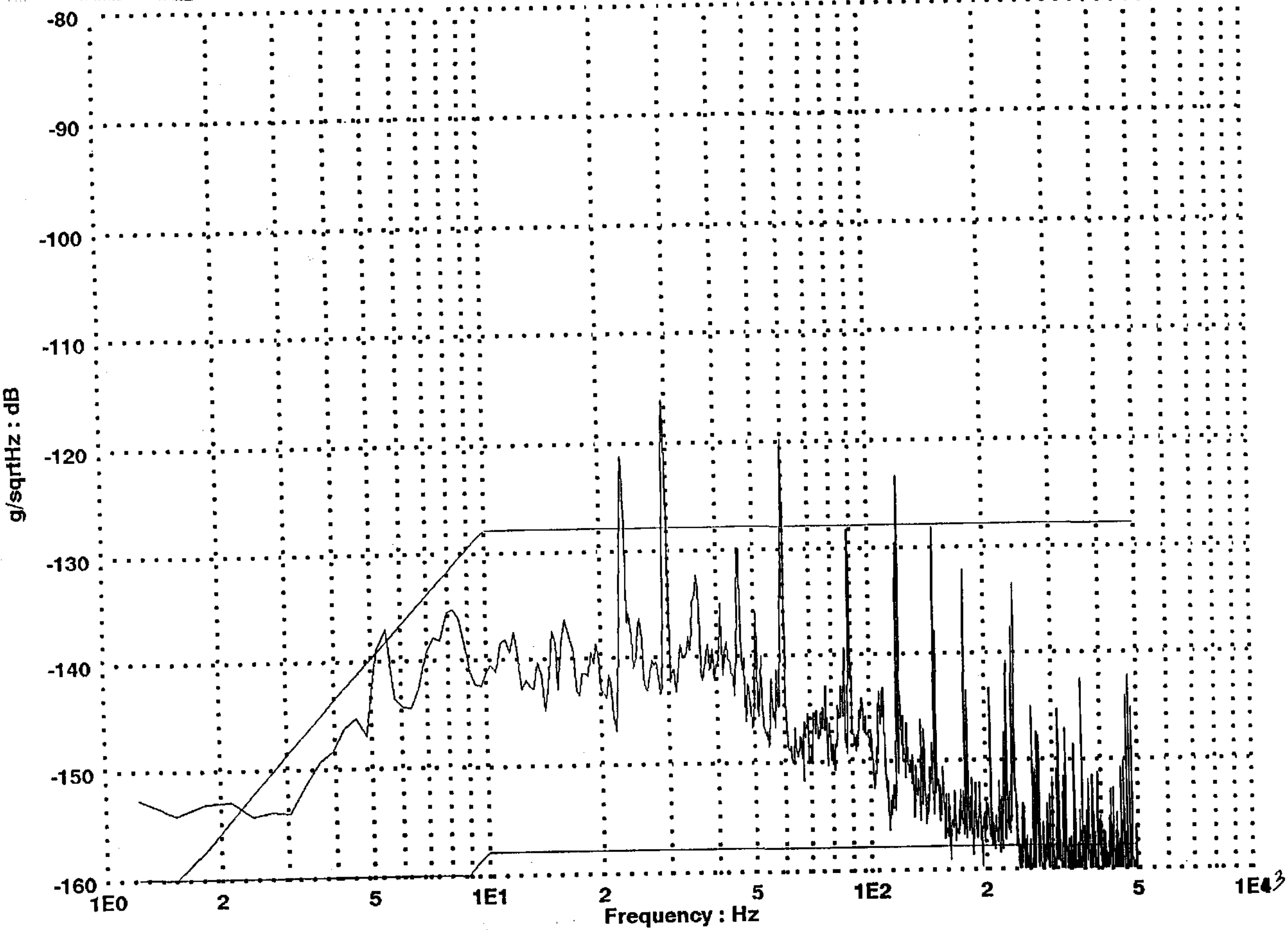
242



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

B19 9/25/98 Test 2, 2-Cryopump radial, Bkg. light rain

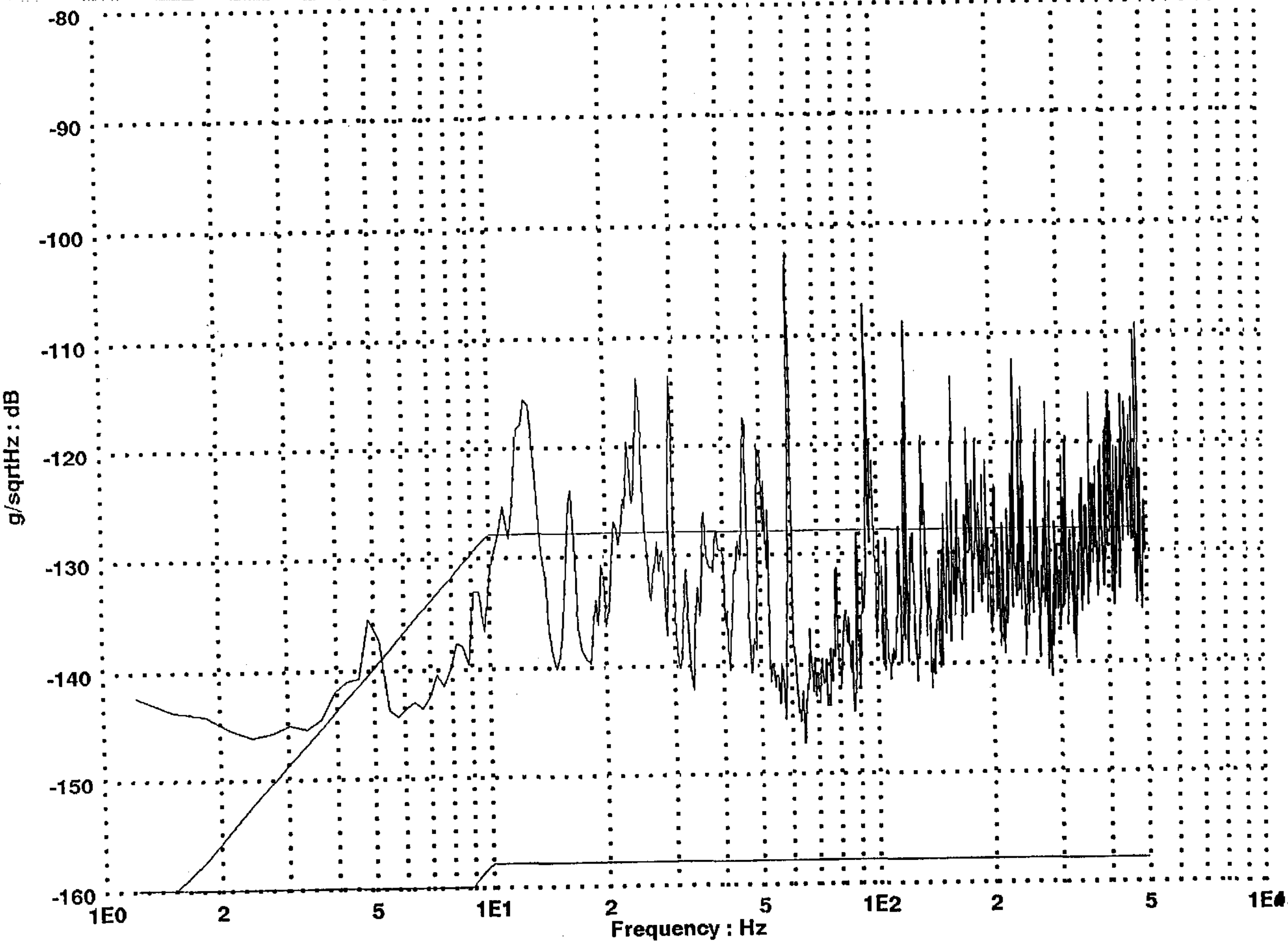
C45



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

B21 9/25/98 Test 3, 0-Floor nr. BS 7, Bkg.

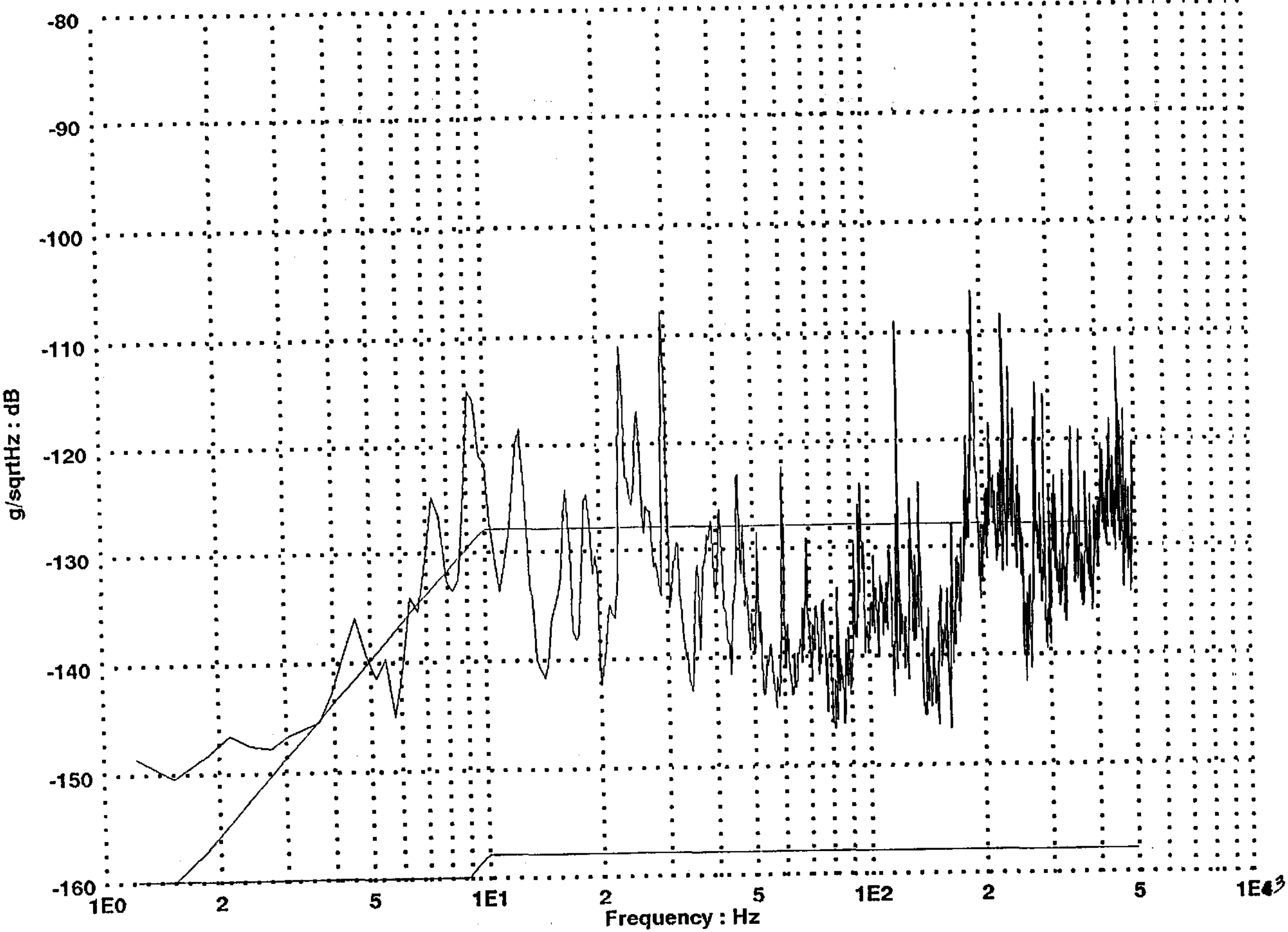
C47



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

B22 9/25/98 Test 3, 4-BS-7 flange radial, Bkg.

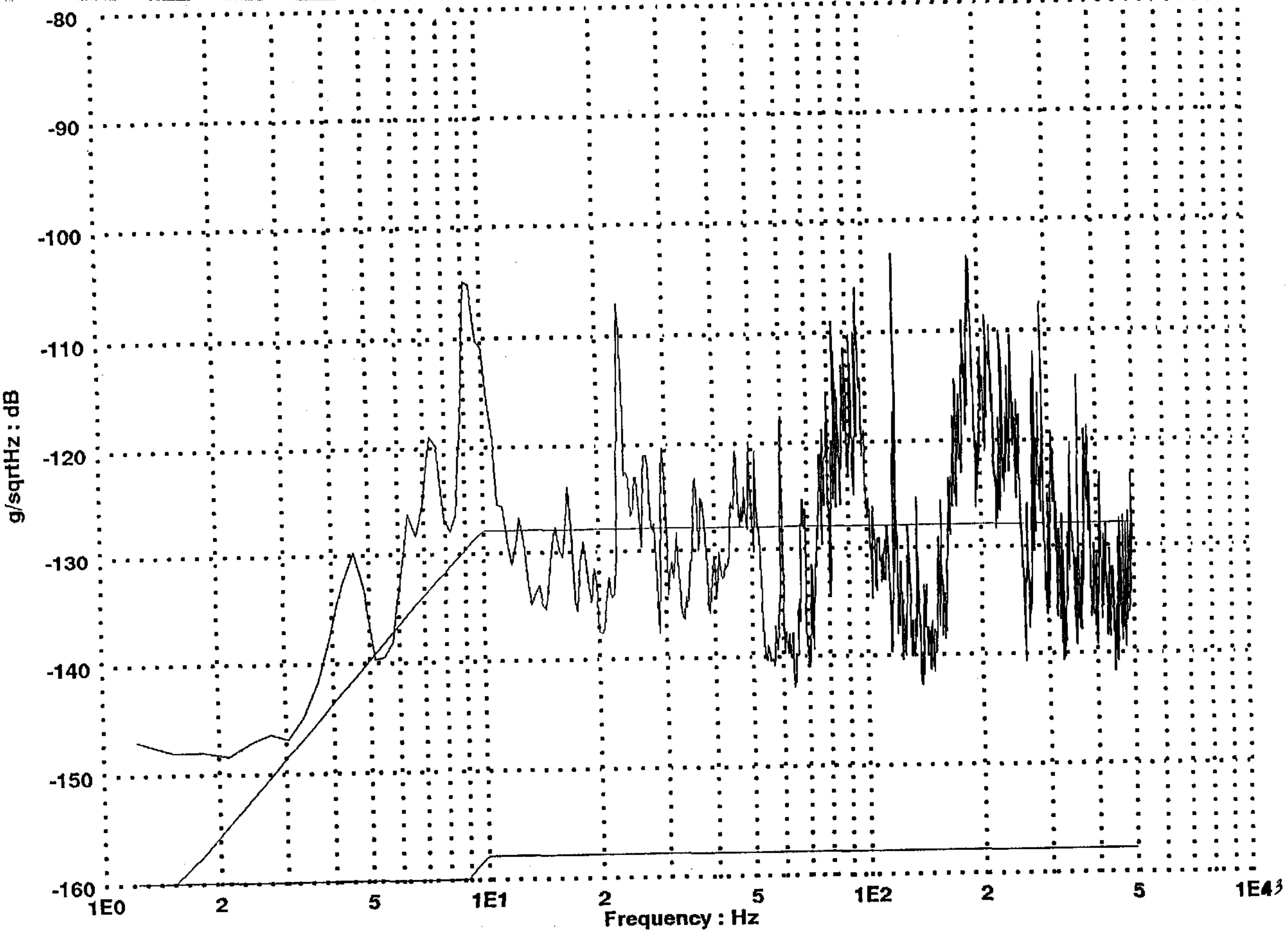
C48



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

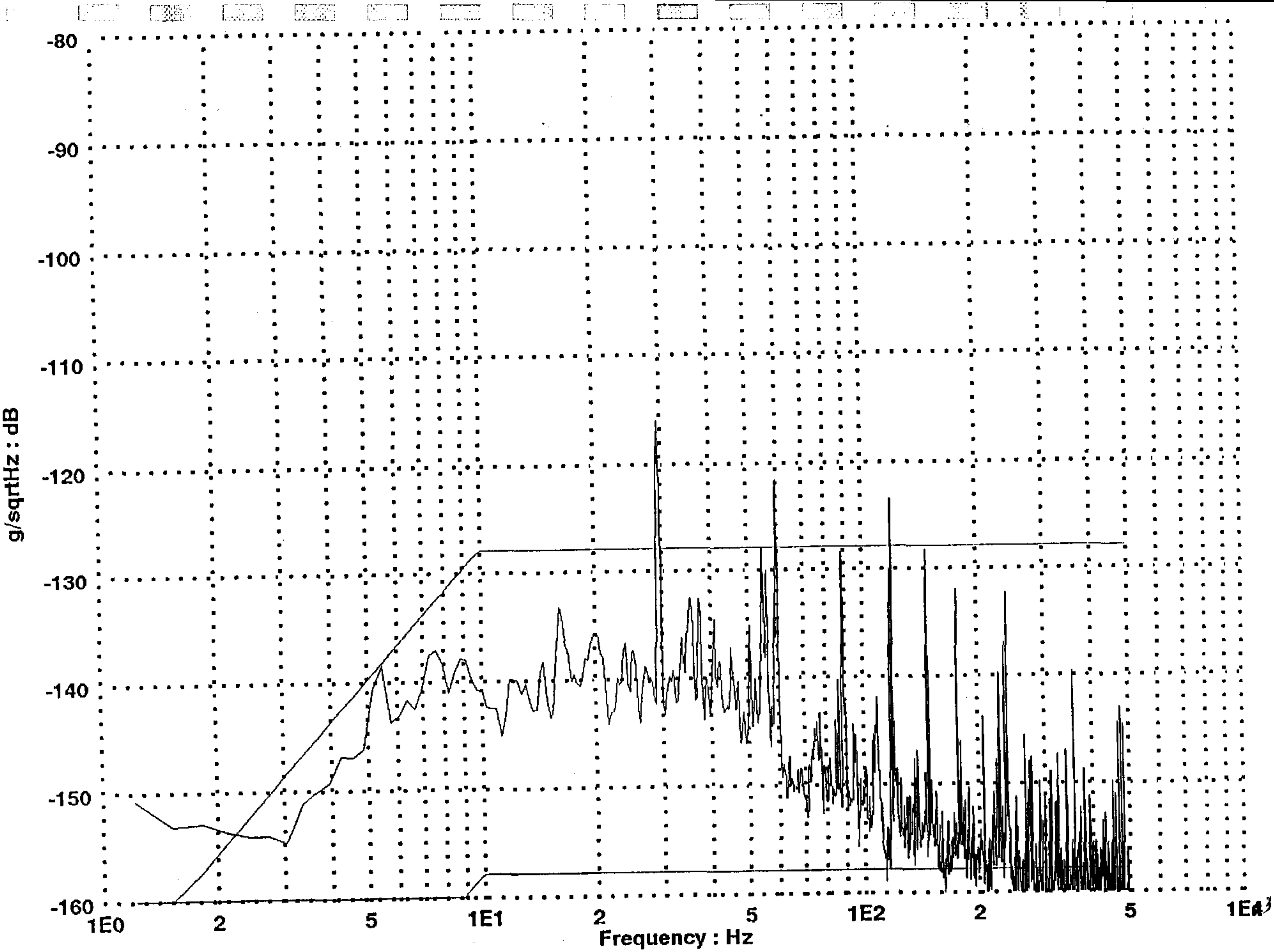
B23 9/25/98 Test 3, 1-WBE-4 axial, Bkg.

C47



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

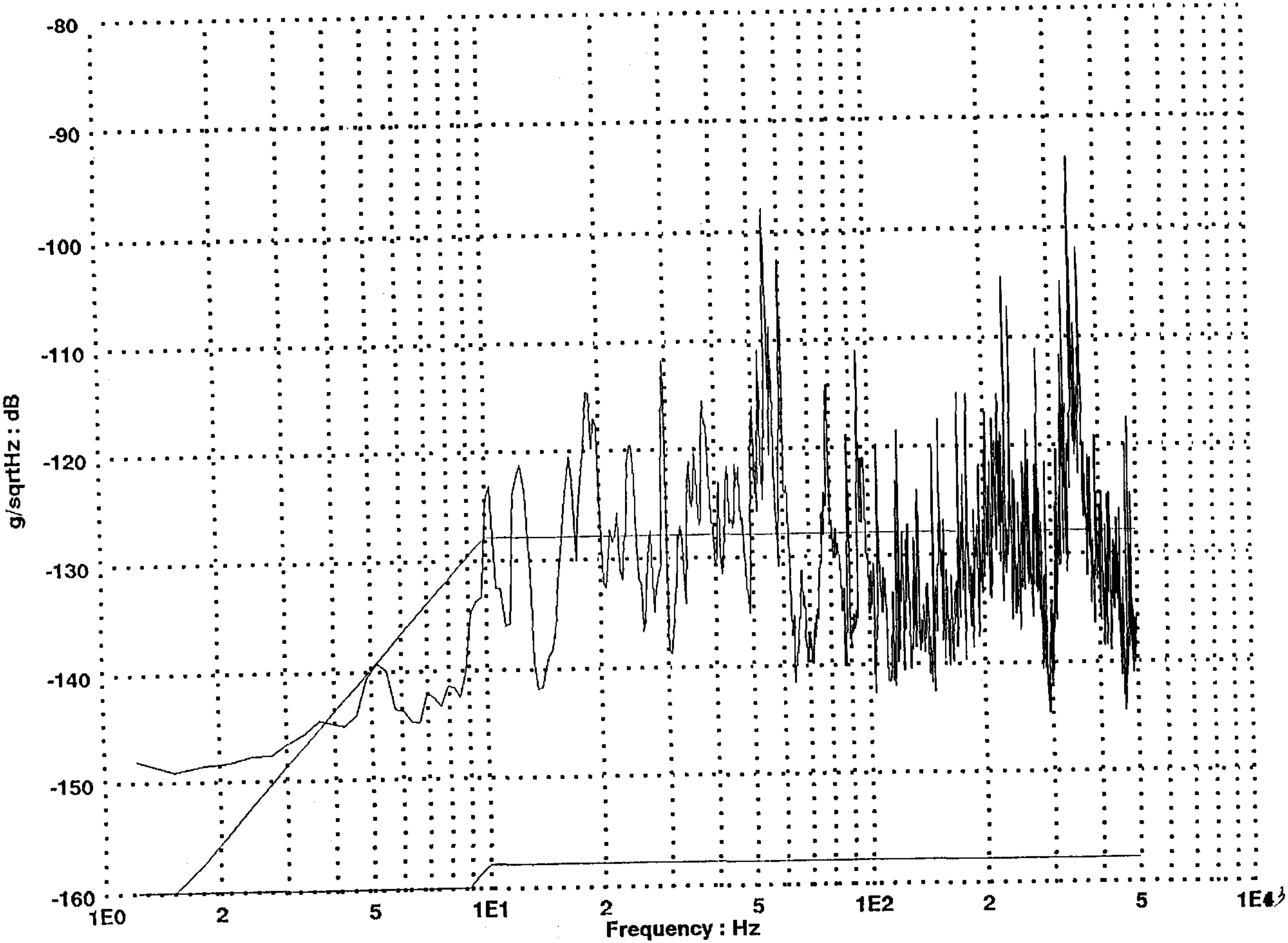
B24 9/25/98 Test 3, 1-WBE-4 radial, Bkg.



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

B25 9/25/98 Test 4, 0-Floor nr. BS 7, Bkg.

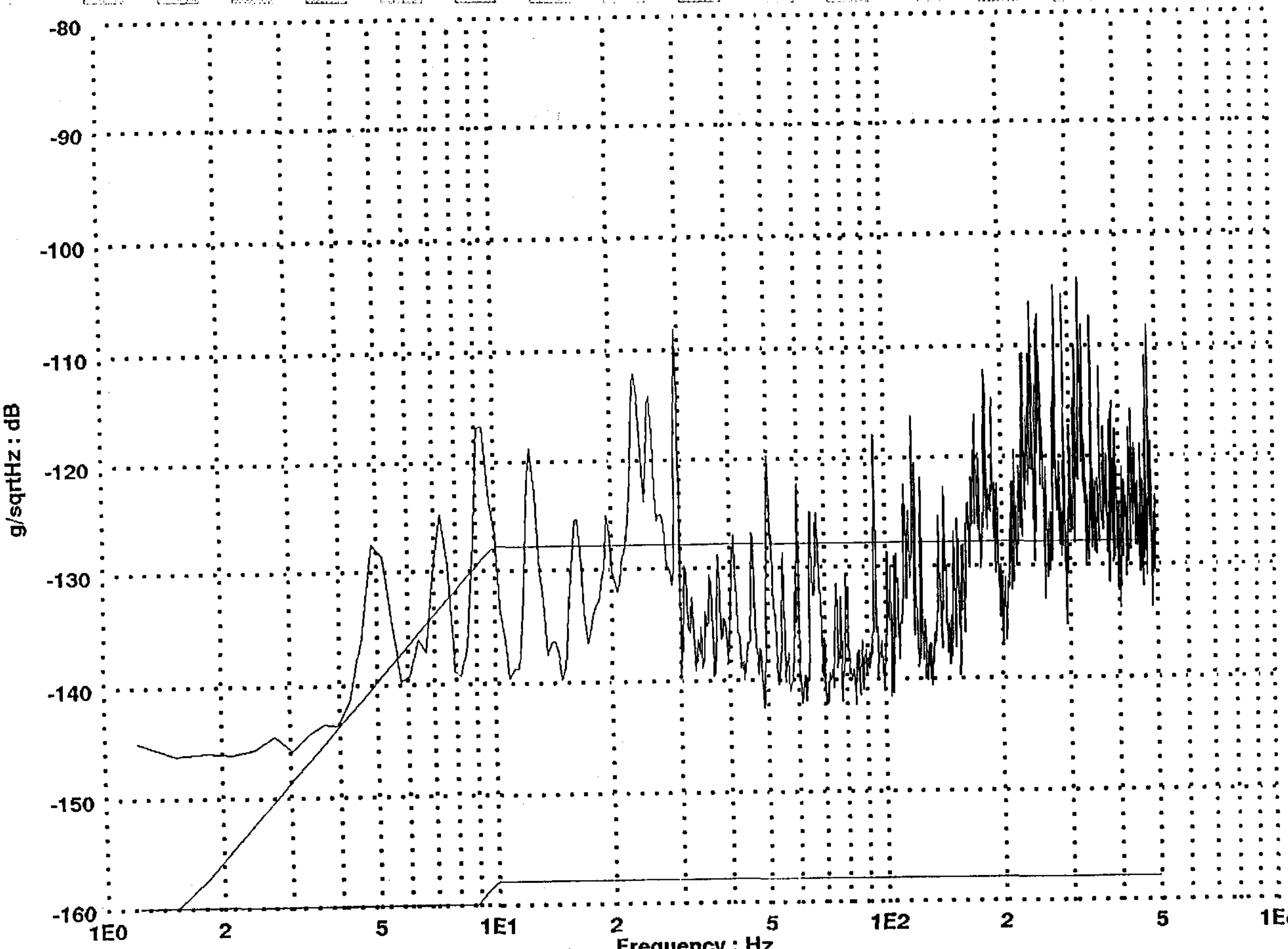
157



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

B26 9/25/98 Test 4, 5-BS-7 nozzle radial, Bkg.

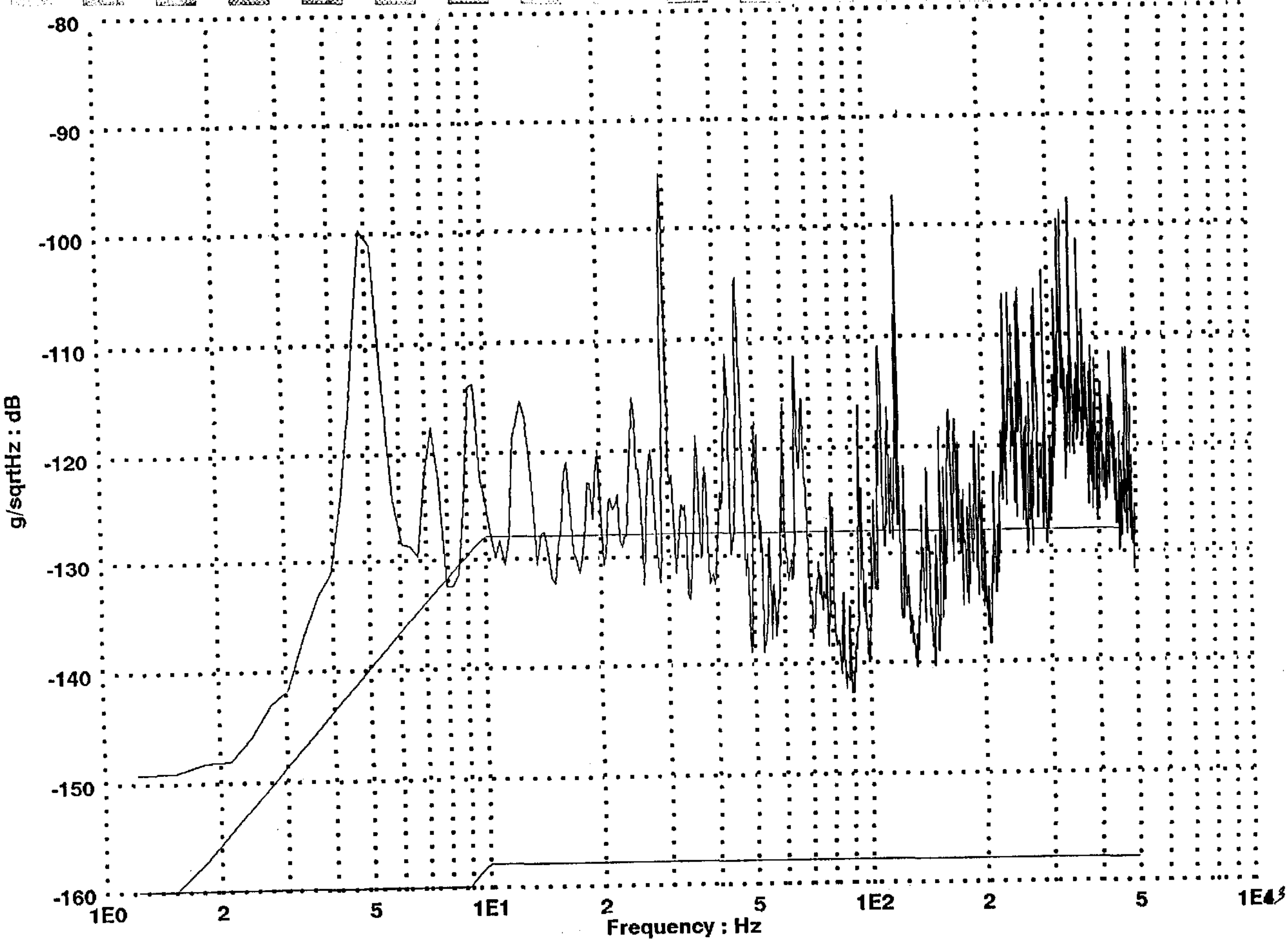
252



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

B27 9/25/98 Test 4, 3 axial WBE-5, Bkg.

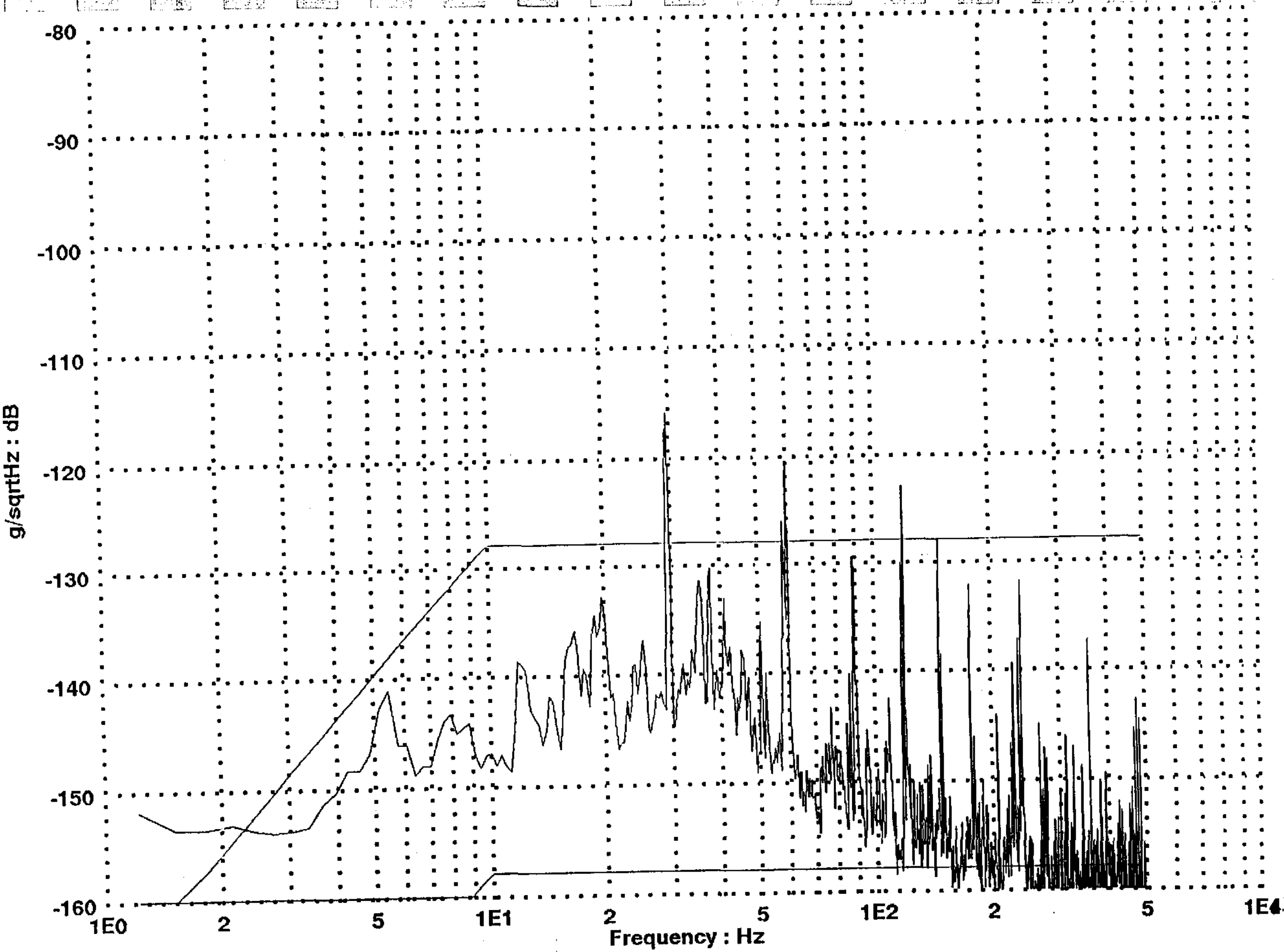
253



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

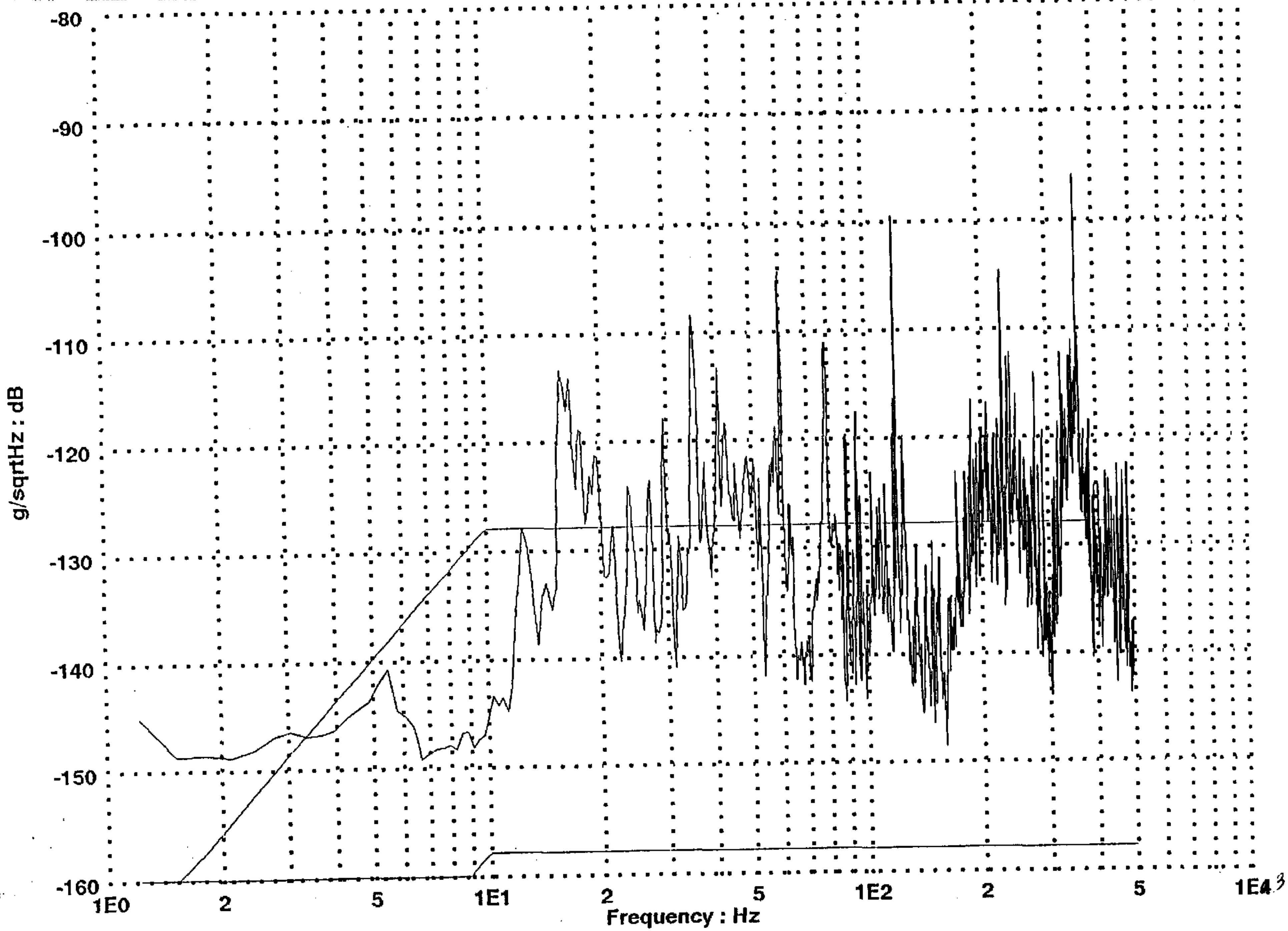
B28 9/25/98 Test 4, 3 radial WBE-5, Bkg.

C54



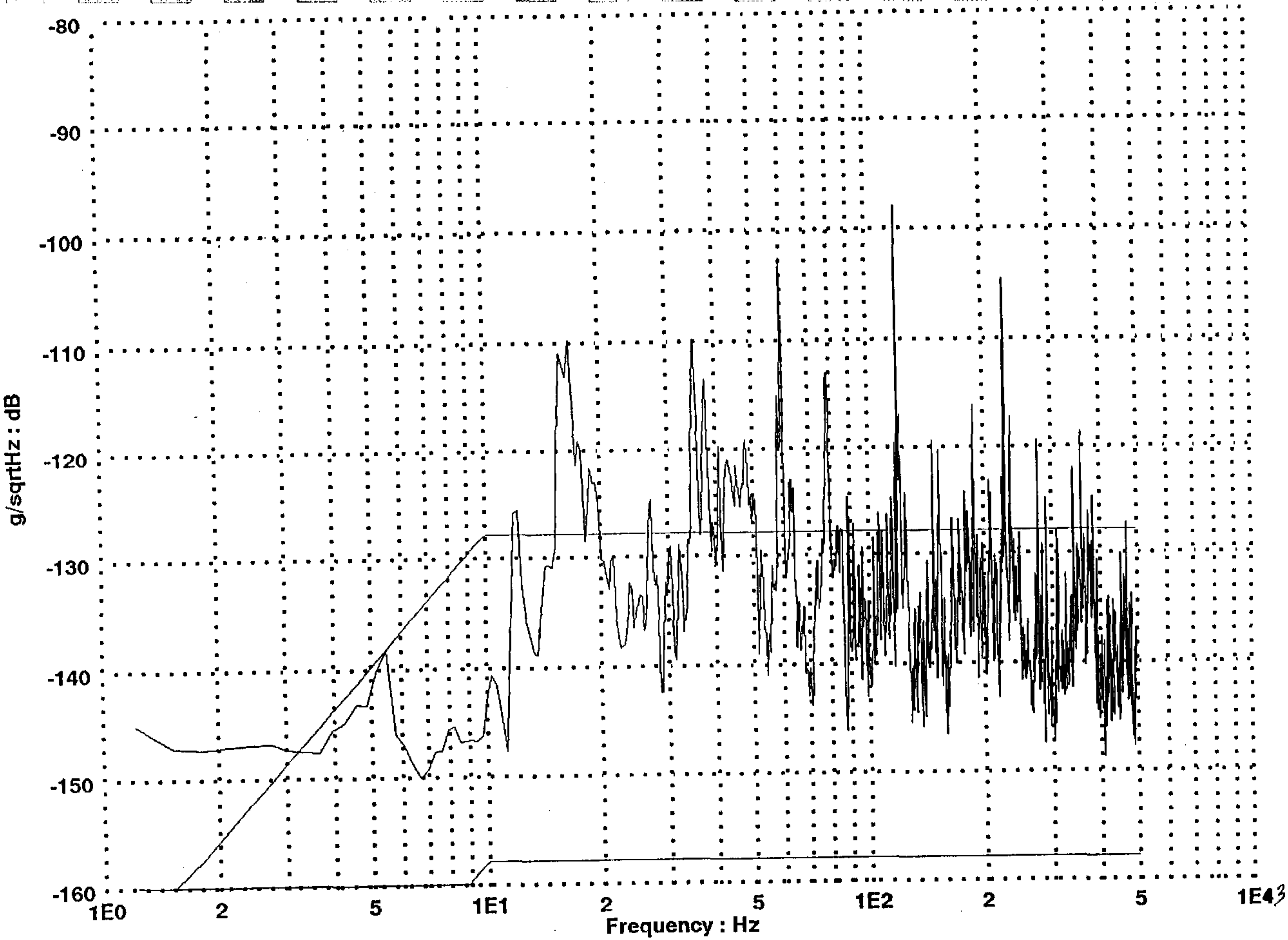
DF: 0.31 Hz T-Lo: 0.ms T-Hi: 3277.ms FFT: 4096 Wind:HANN Sm: 0.

B29 9/25/98 Test 5, 0-Floor nr. BS 7, Bkg.



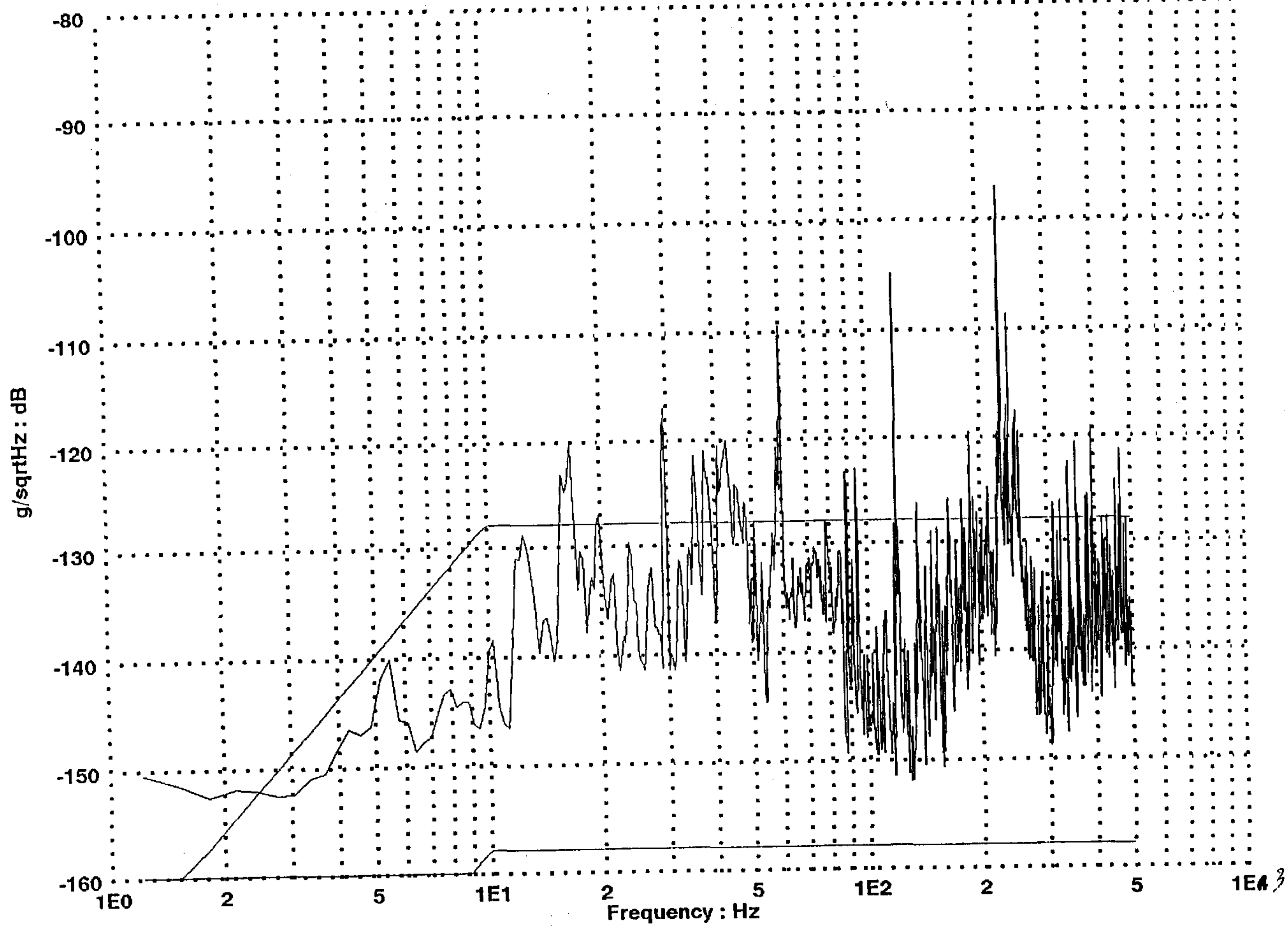
DF: 0.31 Hz T-Lo: 0.ms T-Hi: 3277.ms FFT: 4096 Wind:HANN Sm: 0.

B30 9/25/98 Test 5, 6-BS 3 nozzle radial, Bkg.



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

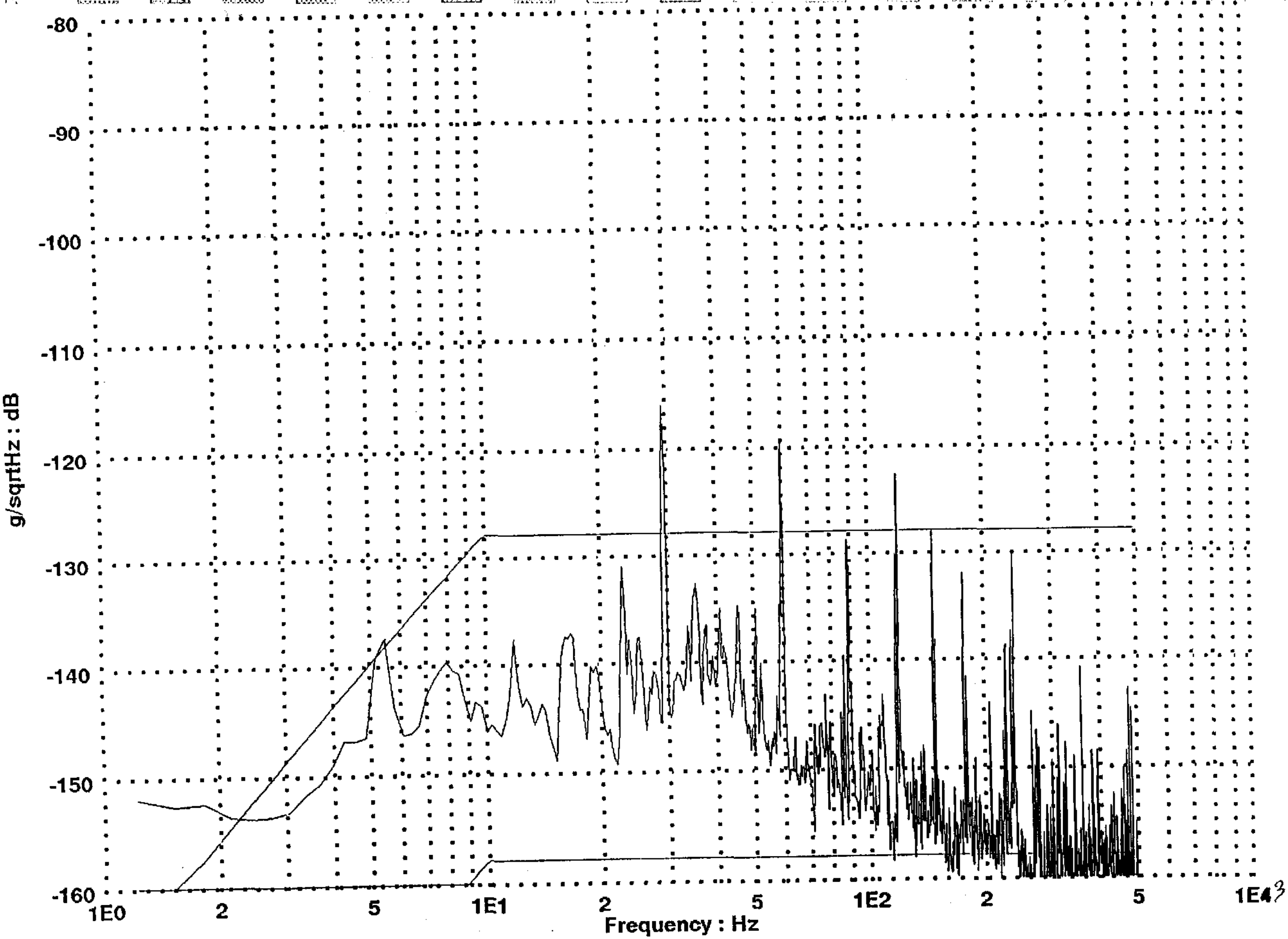
B31 9/25/98 Test 5, 7-WBE-2 vertical, Bkg.



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

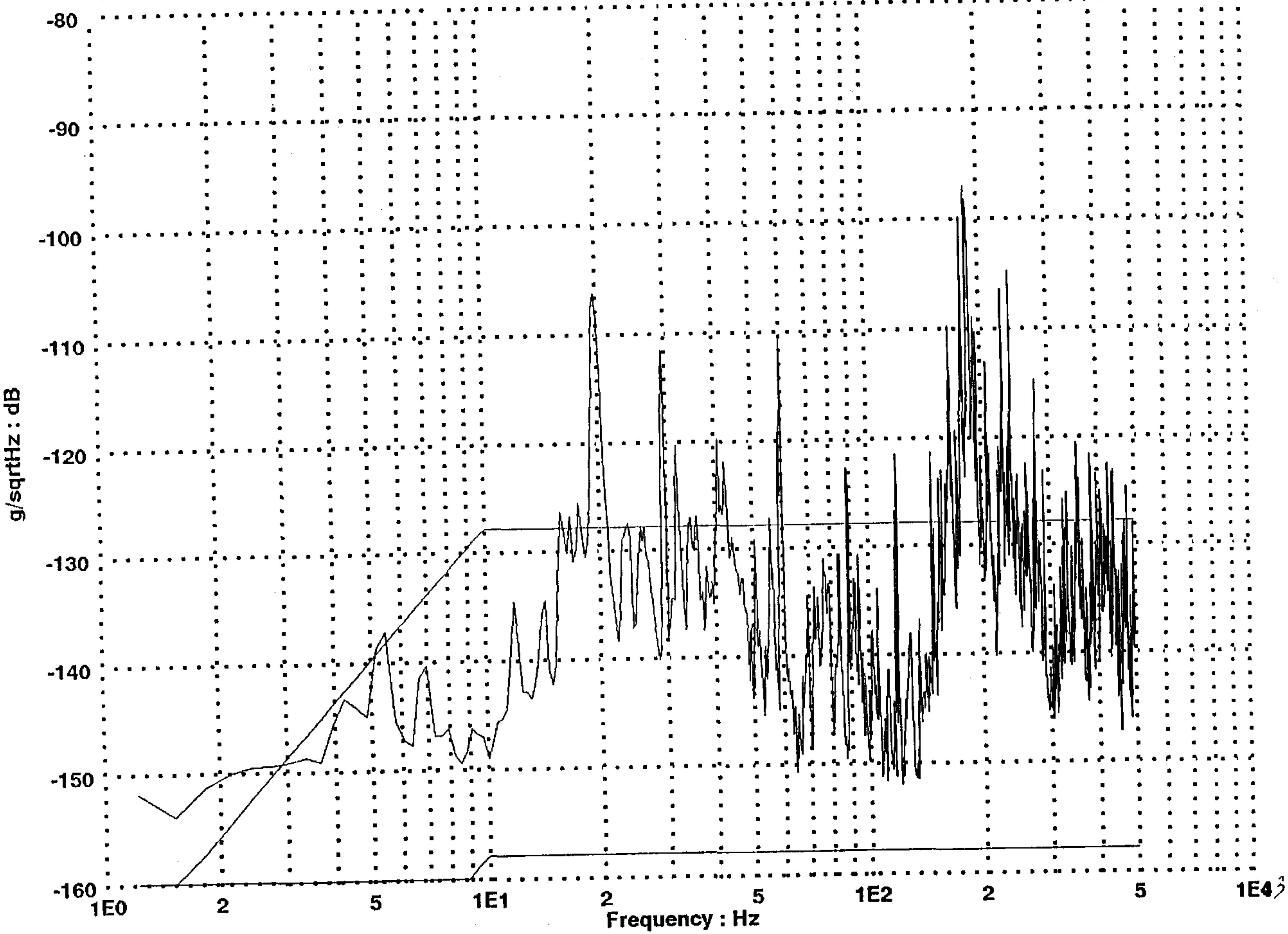
B32 9/25/98 Test 5, 7-WBE-2 radial, Bkg.

258



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

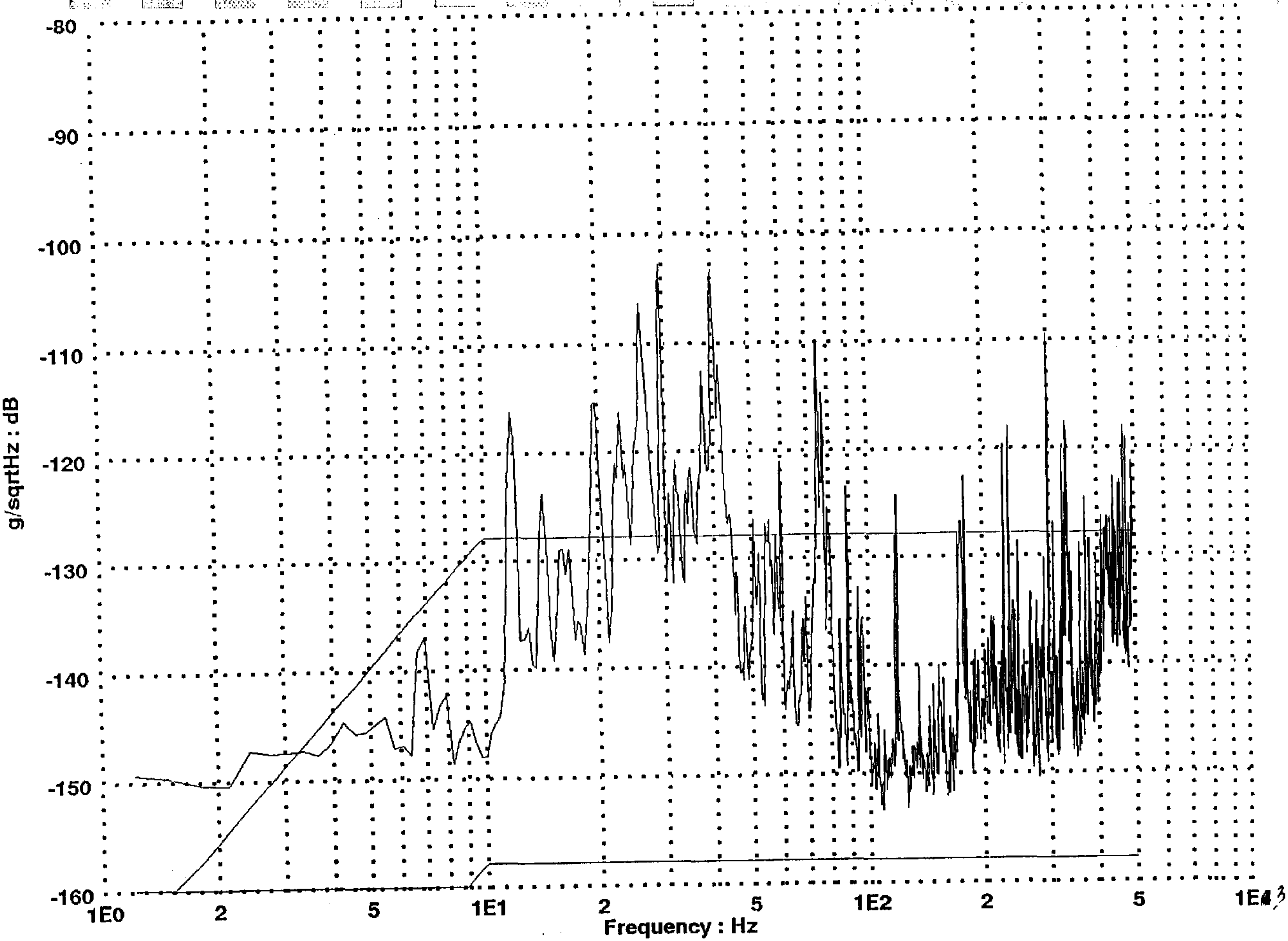
B33 9/25/98 Test 6, 0-Floor nr. BS 7, Bkg.



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

B34 9/25/98 Test 6, 8-Ham 4 nozzle radial, Bkg.

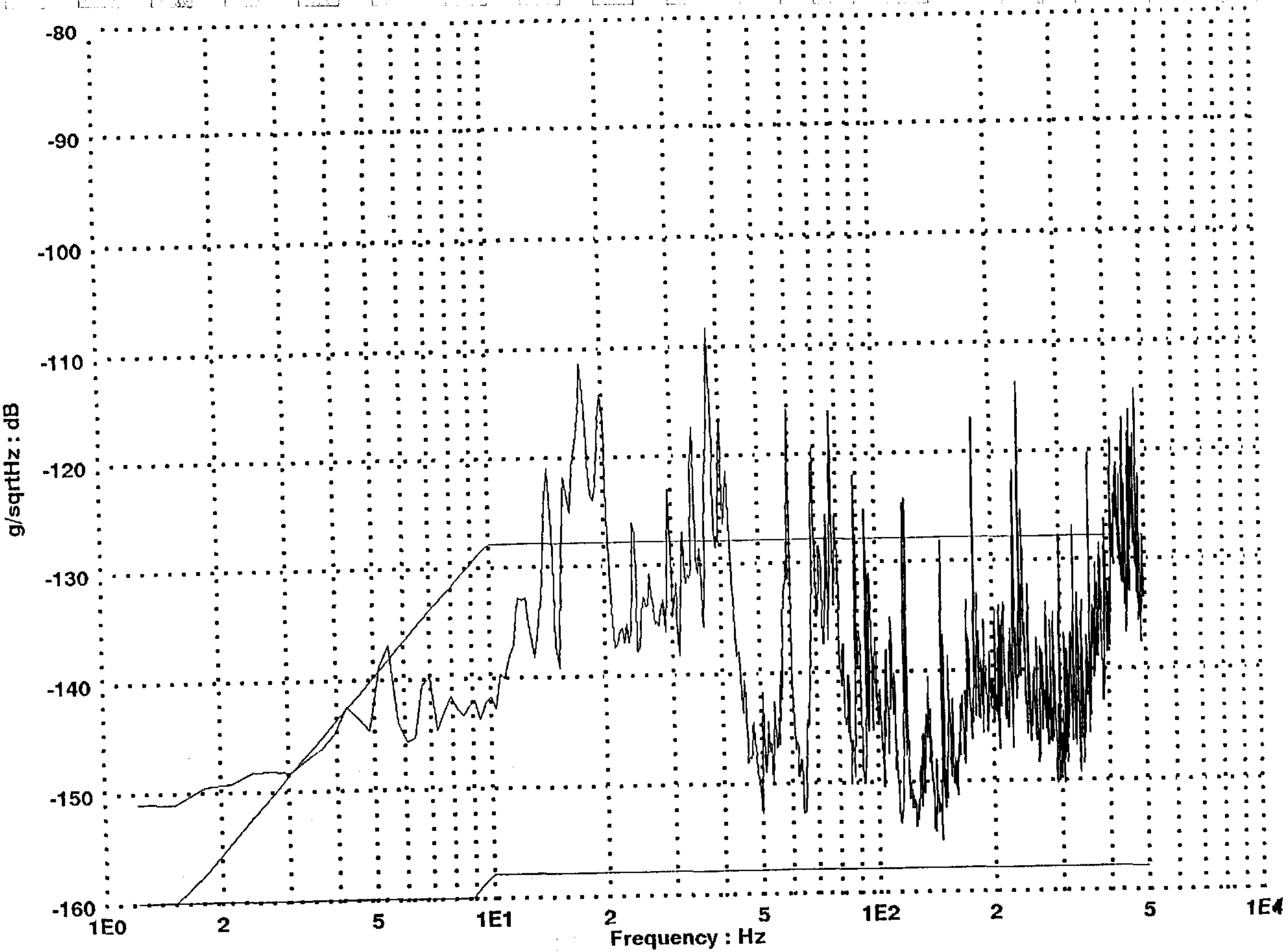
C 66



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

B35 9/25/98 Test 6, 9-Ham 6 flange axial, Bkg.

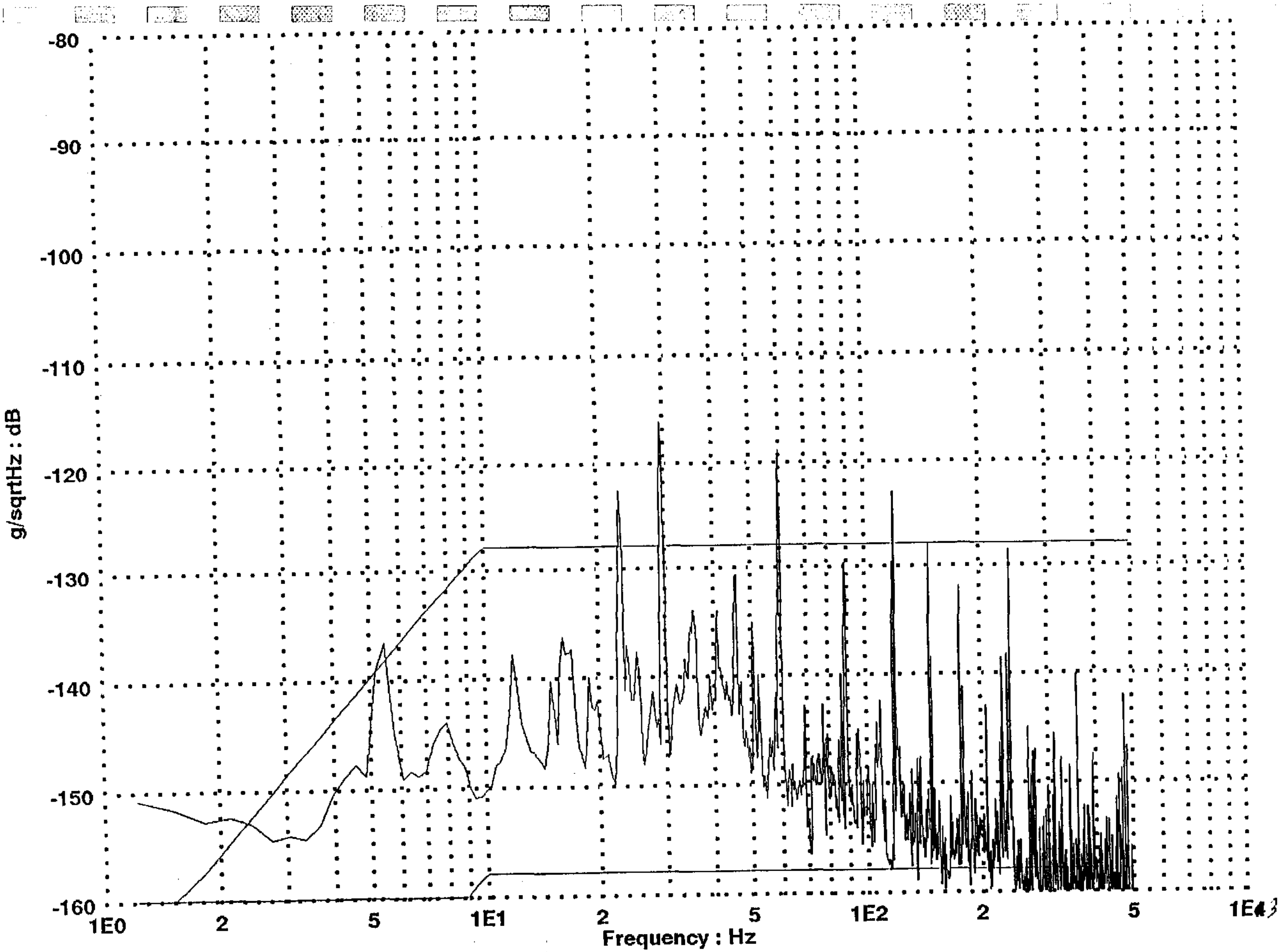
192



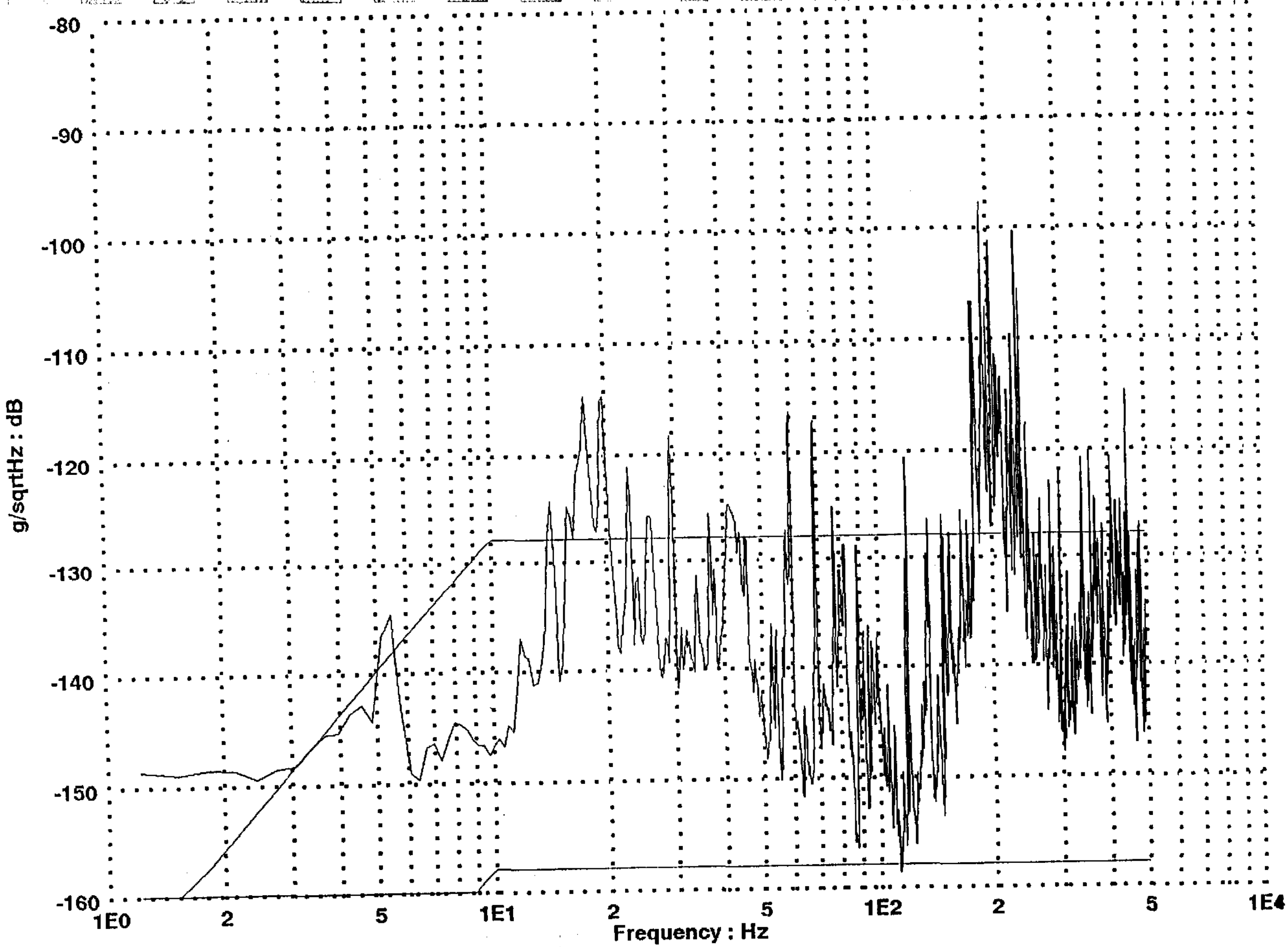
DF: 0.31 Hz T-Lo: 0.ms T-Hi: 3277.ms FFT: 4096 Wind:HANN Sm: 0.

B36 9/25/98 Test 6, 9-Ham 6 flange radial, Bkg.

262



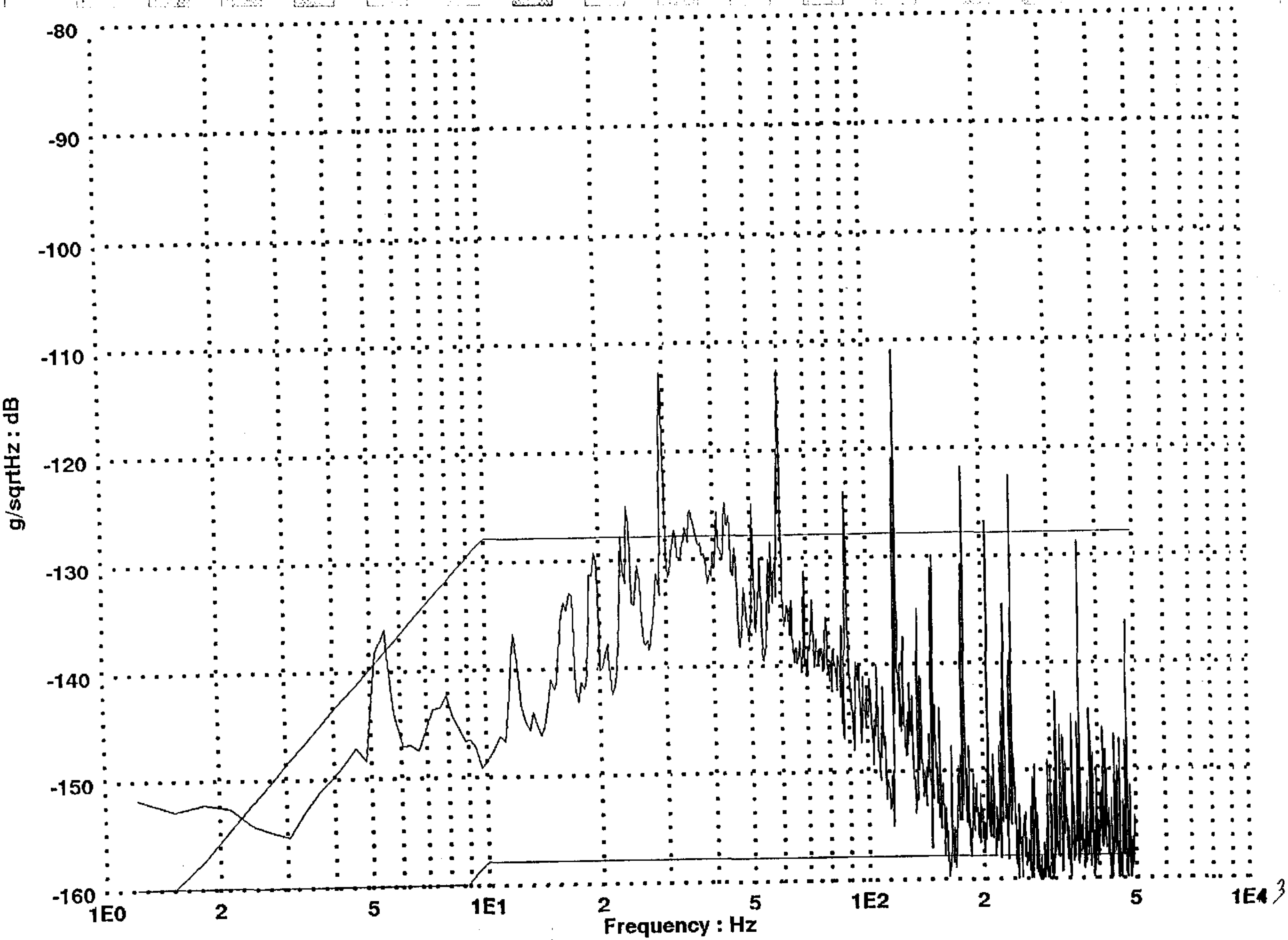
B37 9/25/98 Test 7, 0-Floor nr. BS 7, Bkg.



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

B38 9/25/98 Test 7, 10-Ham 6 nozzle radial, Bkg.

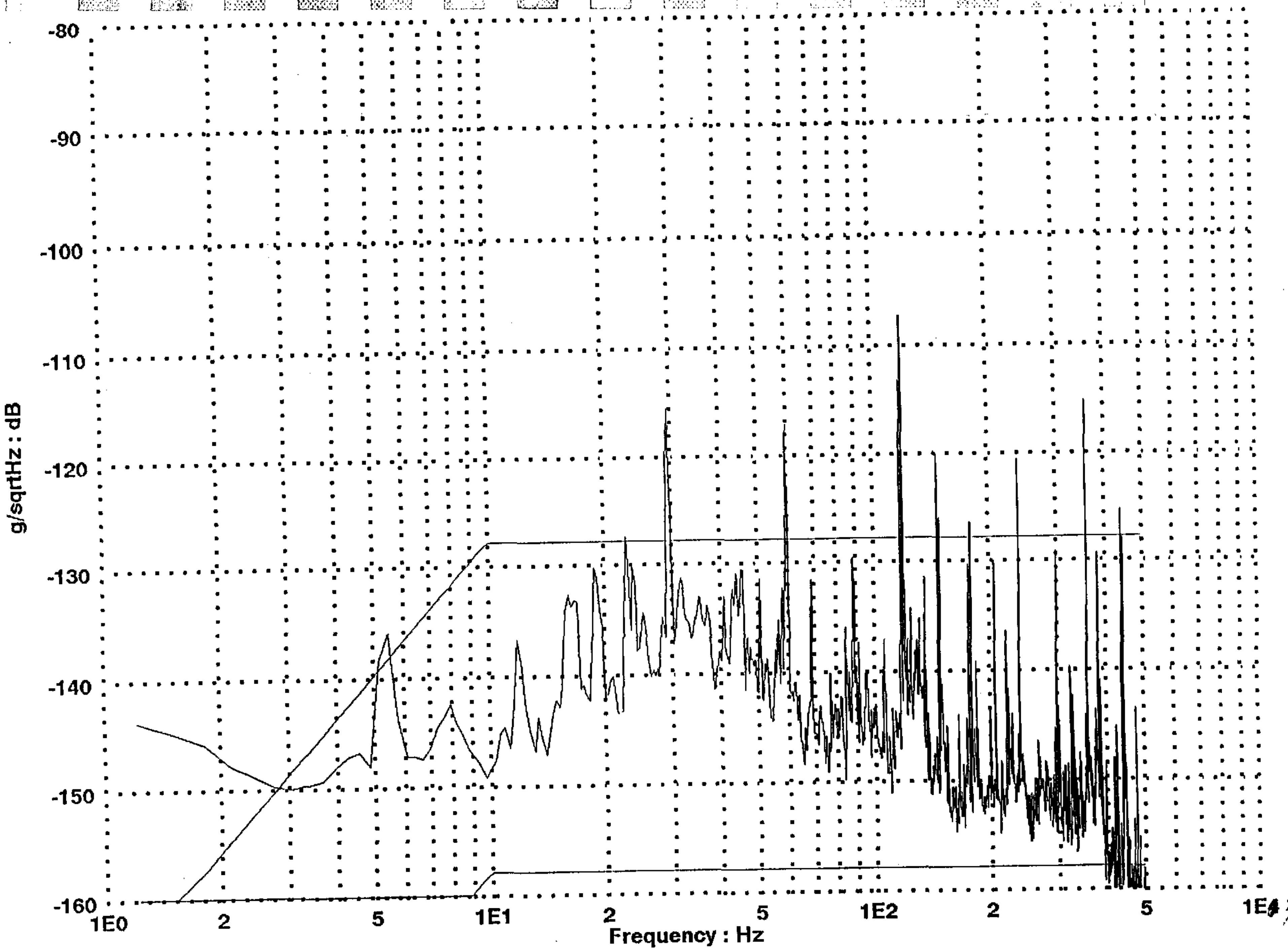
C64



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

B39 9/25/98 Test 7, 11-Floor VEA nr. Mech. Rm., Bkg.

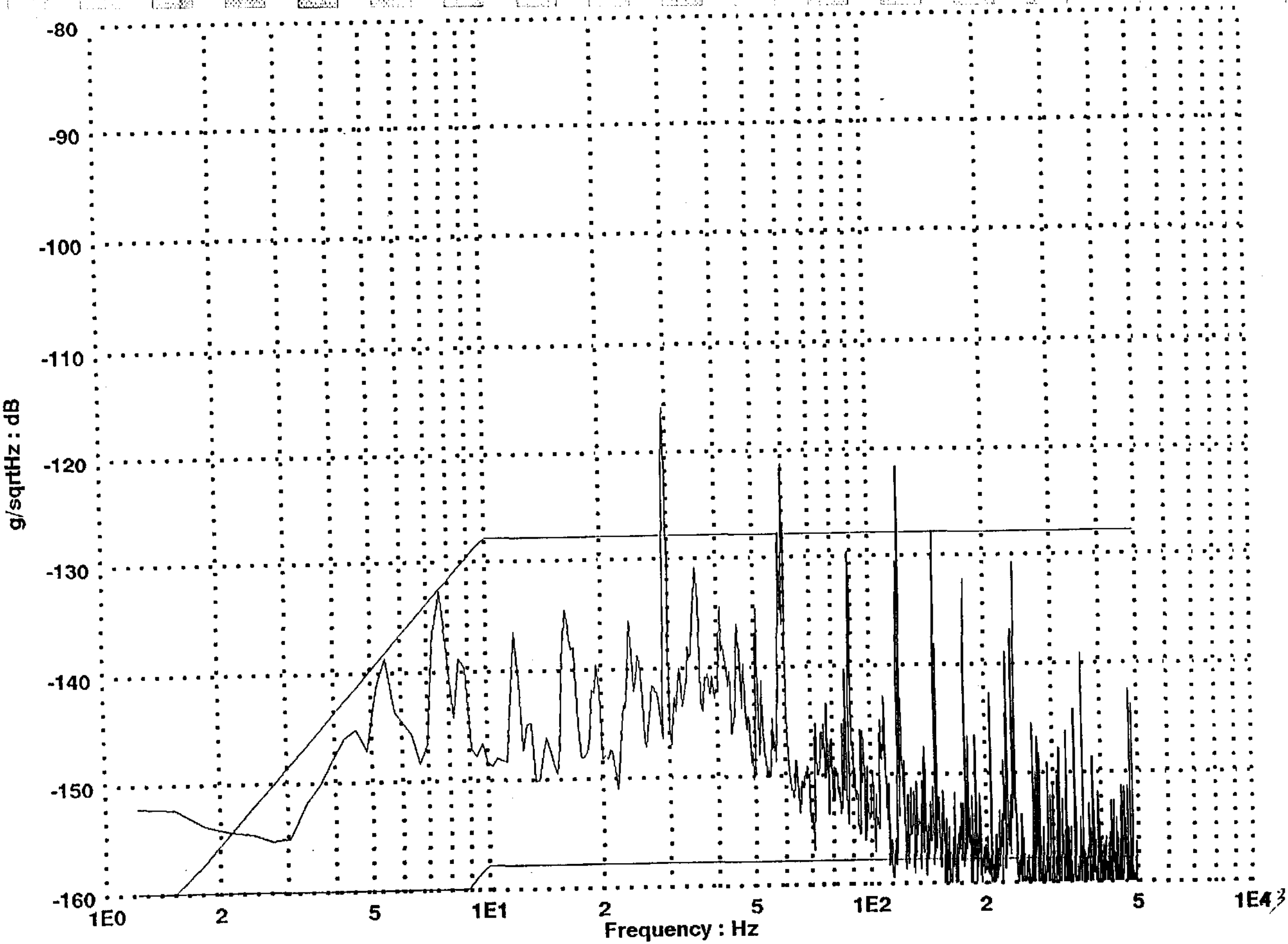
C65



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

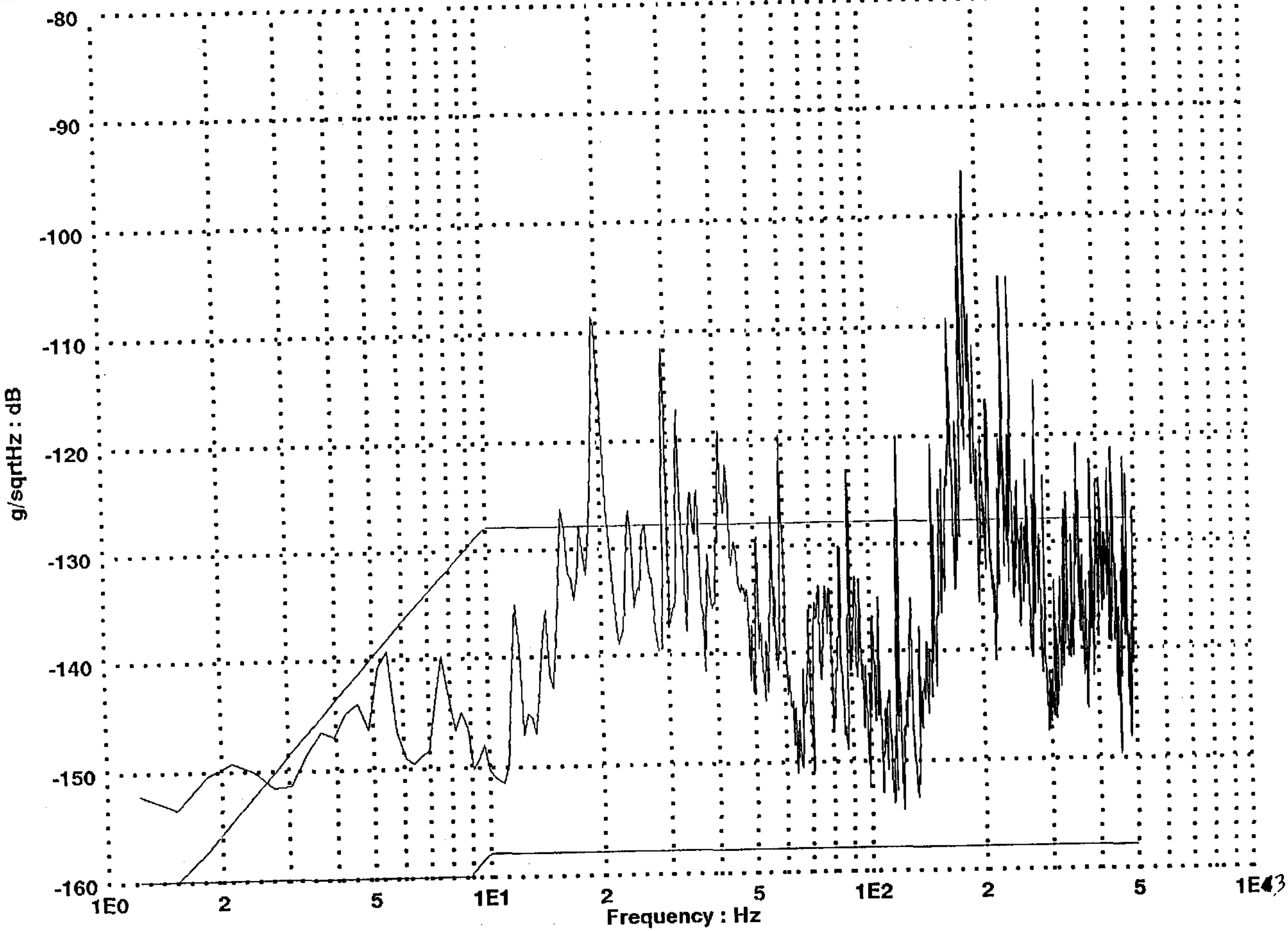
B40 9/25/98 Test 7, 12-Floor Mech. Rm.nr. VEA, Bkg.

C66



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

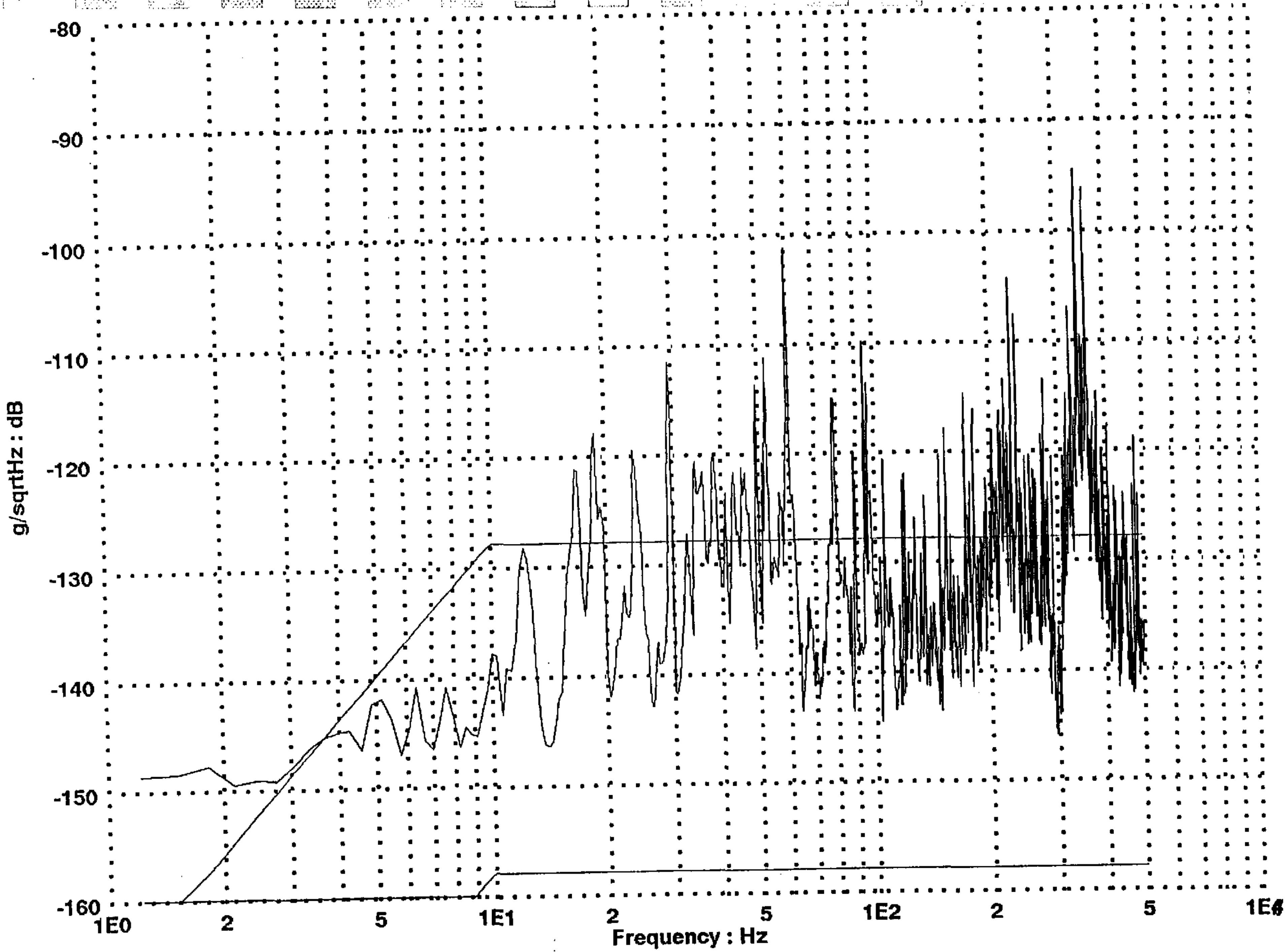
B41 9/25/98 Test 15, 0-Floor nr. BS 7, Bkg.



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

B42 9/25/98 Test 15, 8-Ham 4 nozzle radial, Bkg.

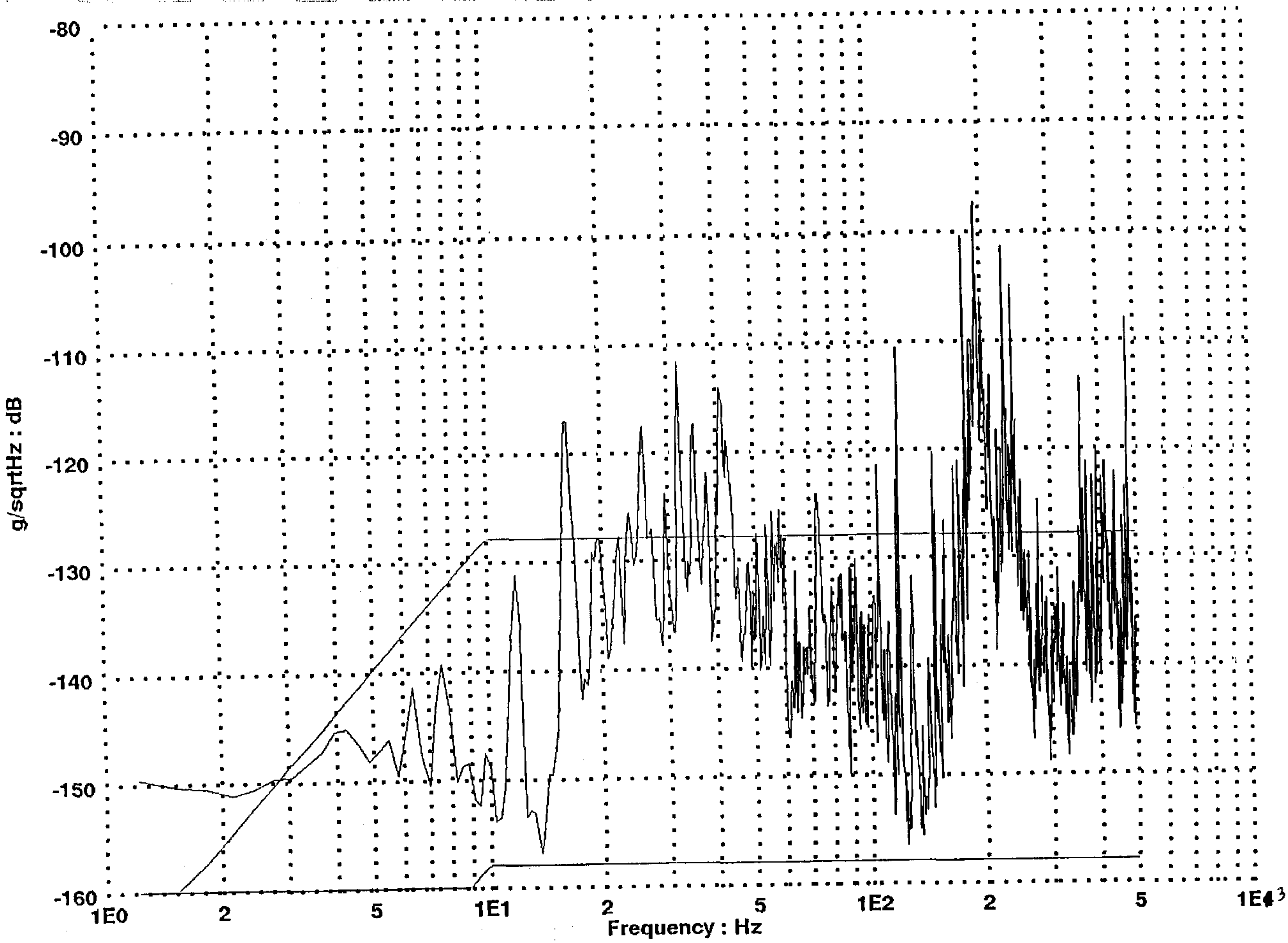
C68



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

B43 9/25/98 Test 15, 5-BS-7 nozzle radial, Bkg.

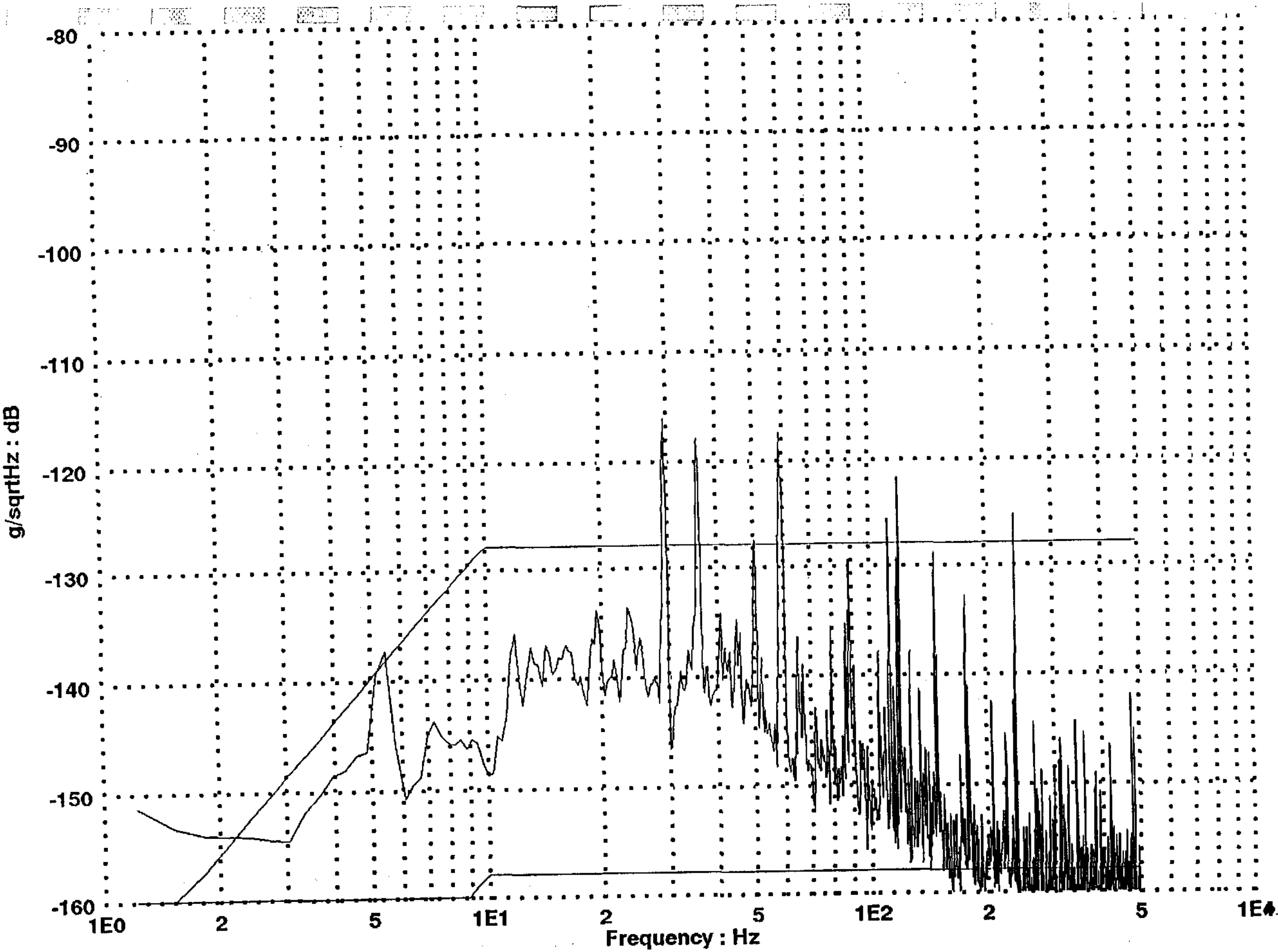
C69



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

B44 9/25/98 Test 15, 8-Ham 4 nozzle axial, Bkg.

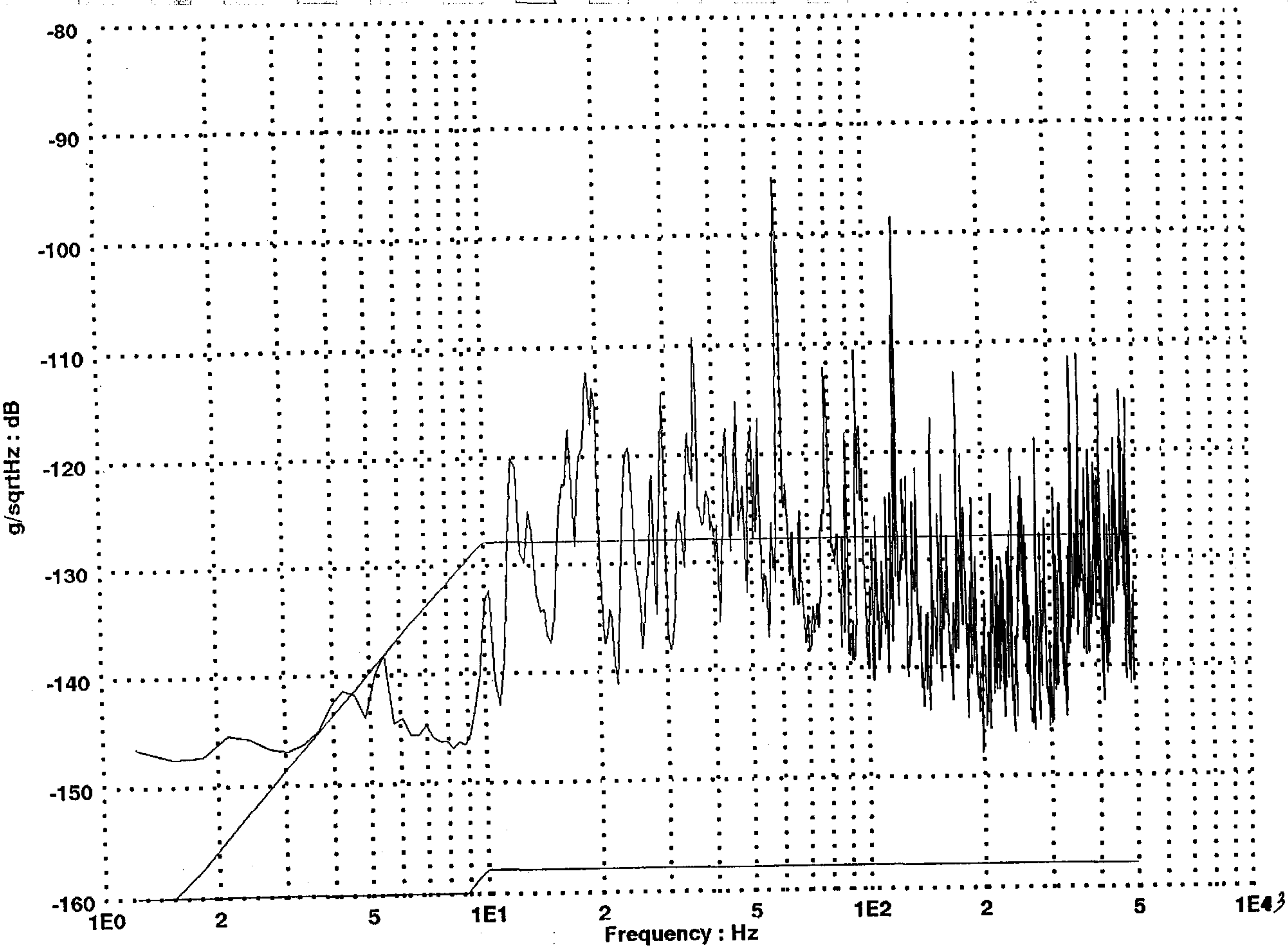
C70



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

C1 9/26/98 Test 1, 0-Floor nr. BS 7, Cryopump, fill rate 10%

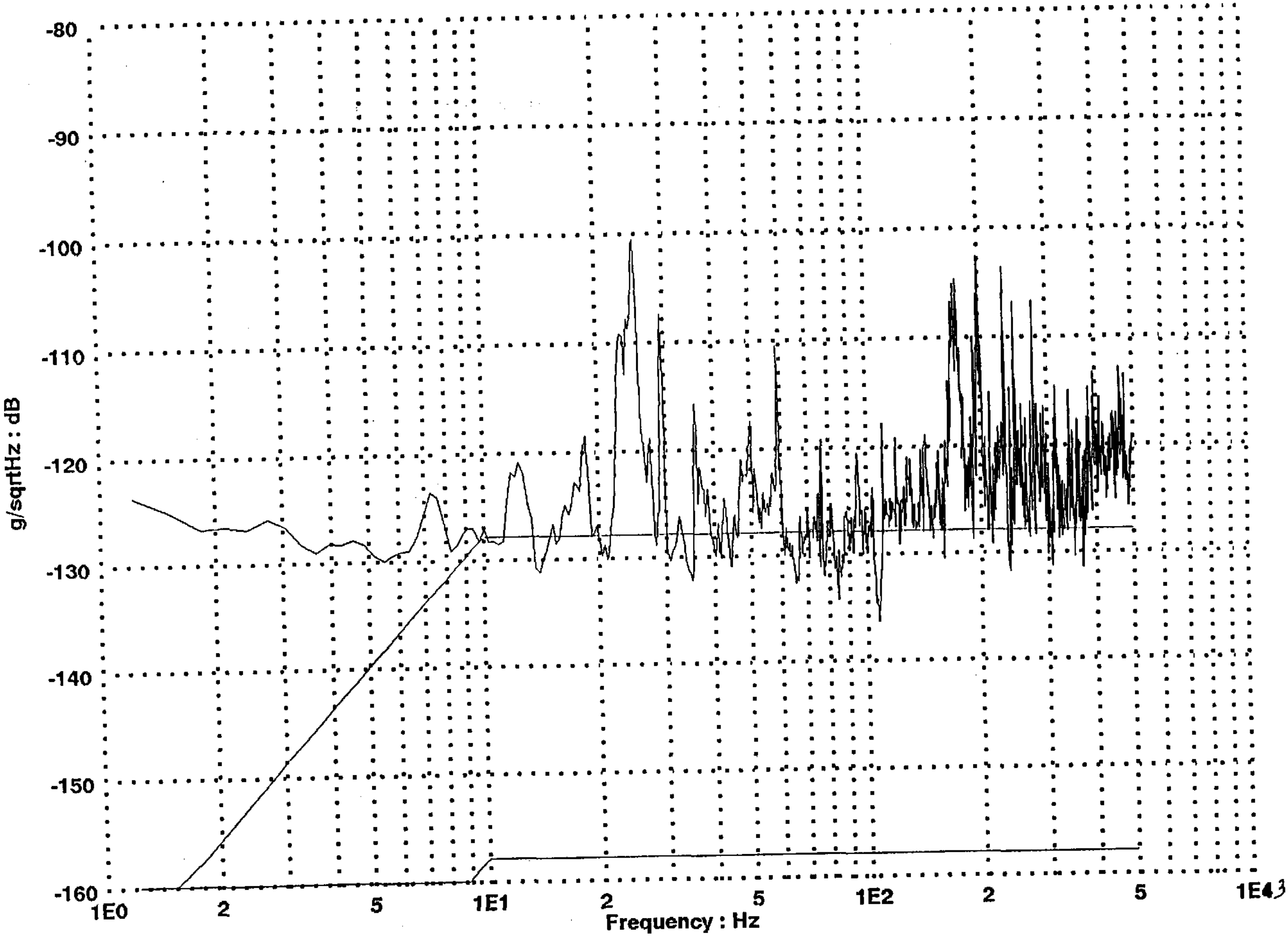
ILC



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

C2 9/26/98 Test 1, 4-BS-7 flange axial, Cryopump, fill rate 10%

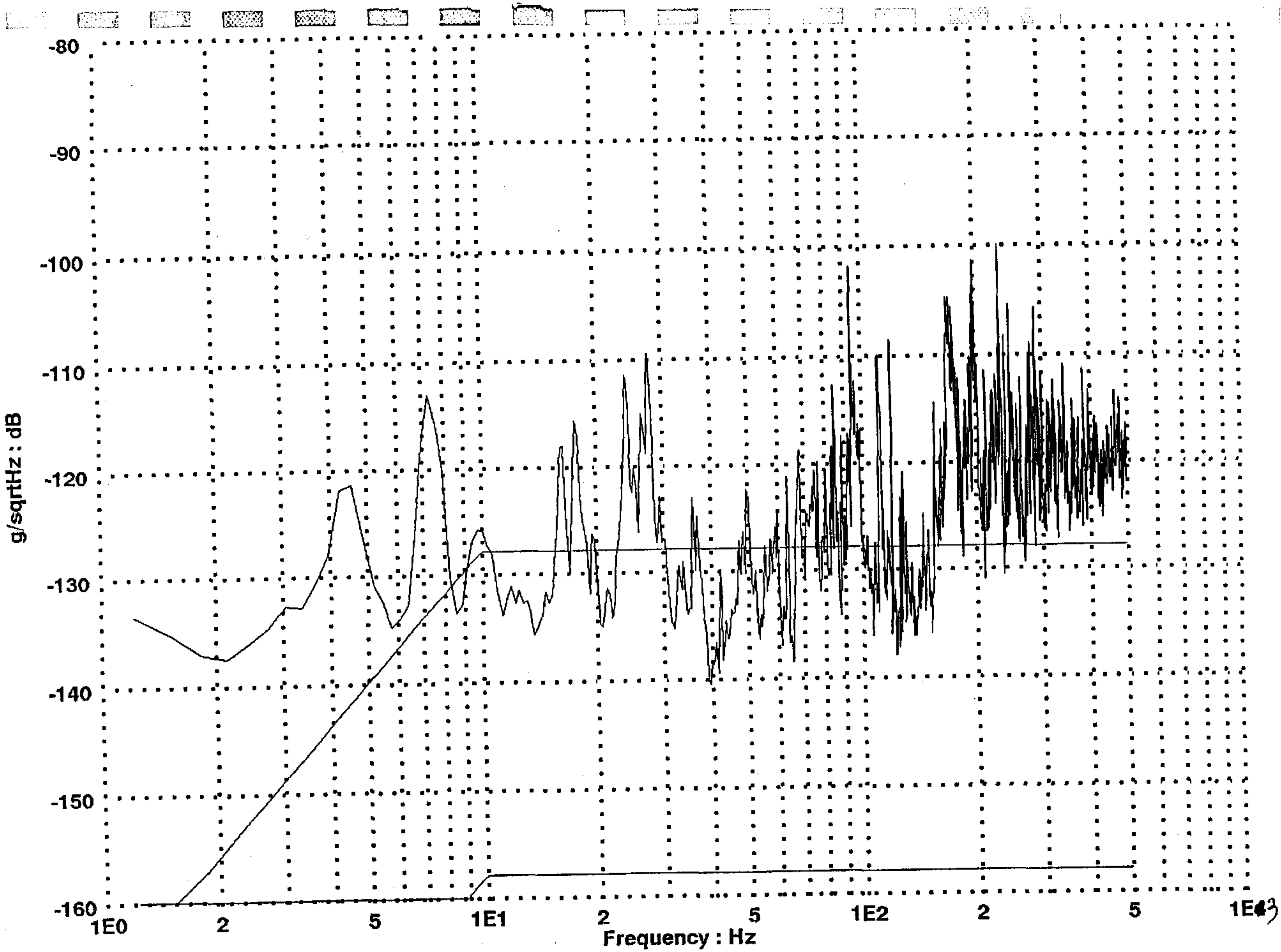
C72



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

C3 9/26/98 Test 1, 2-Cryopump axial, Cryopump, fill rate 10%

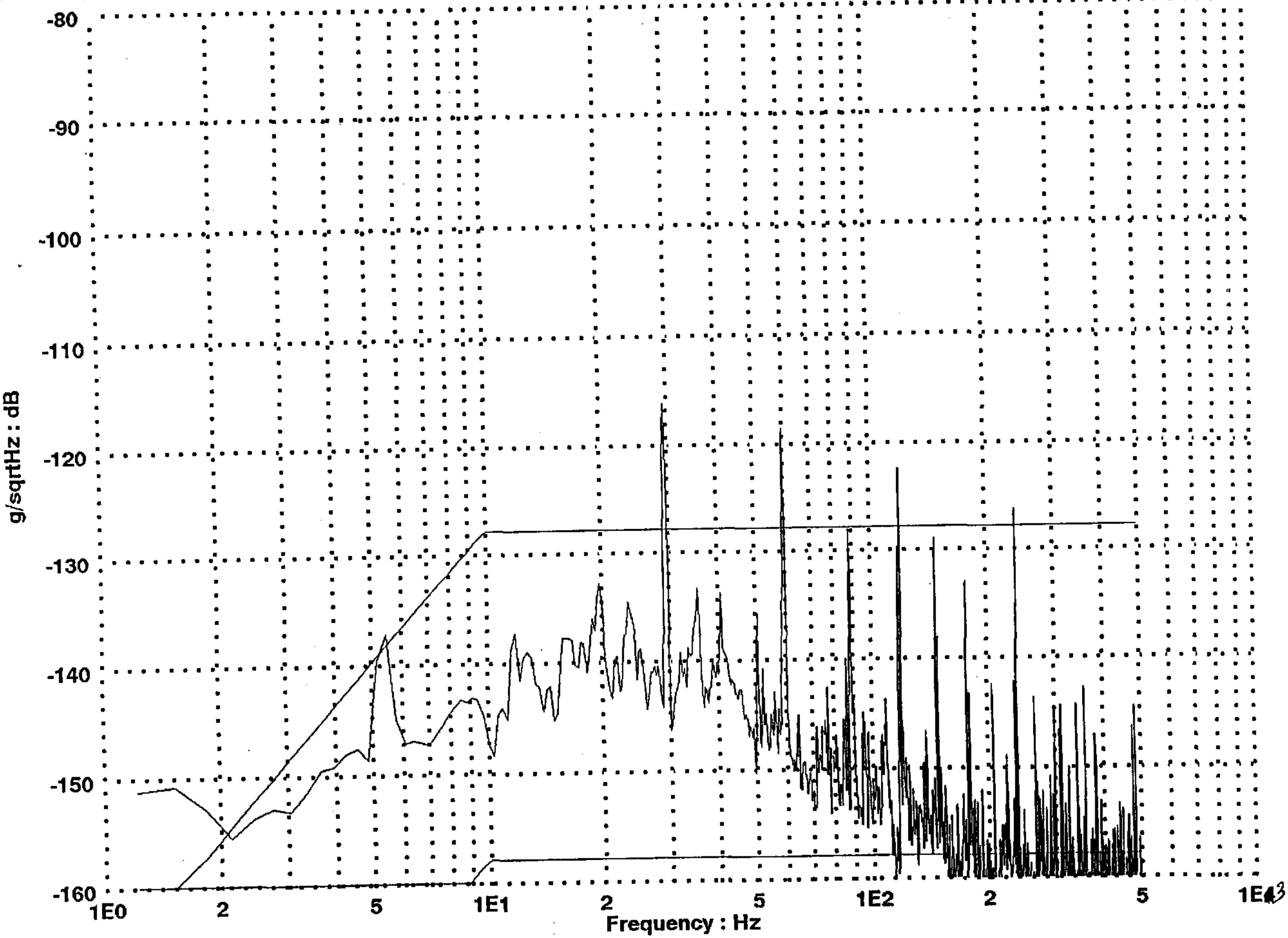
273



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

C4 9/26/98 Test 1, 2-Cryopump radial, Cryopump, fill rate 10%

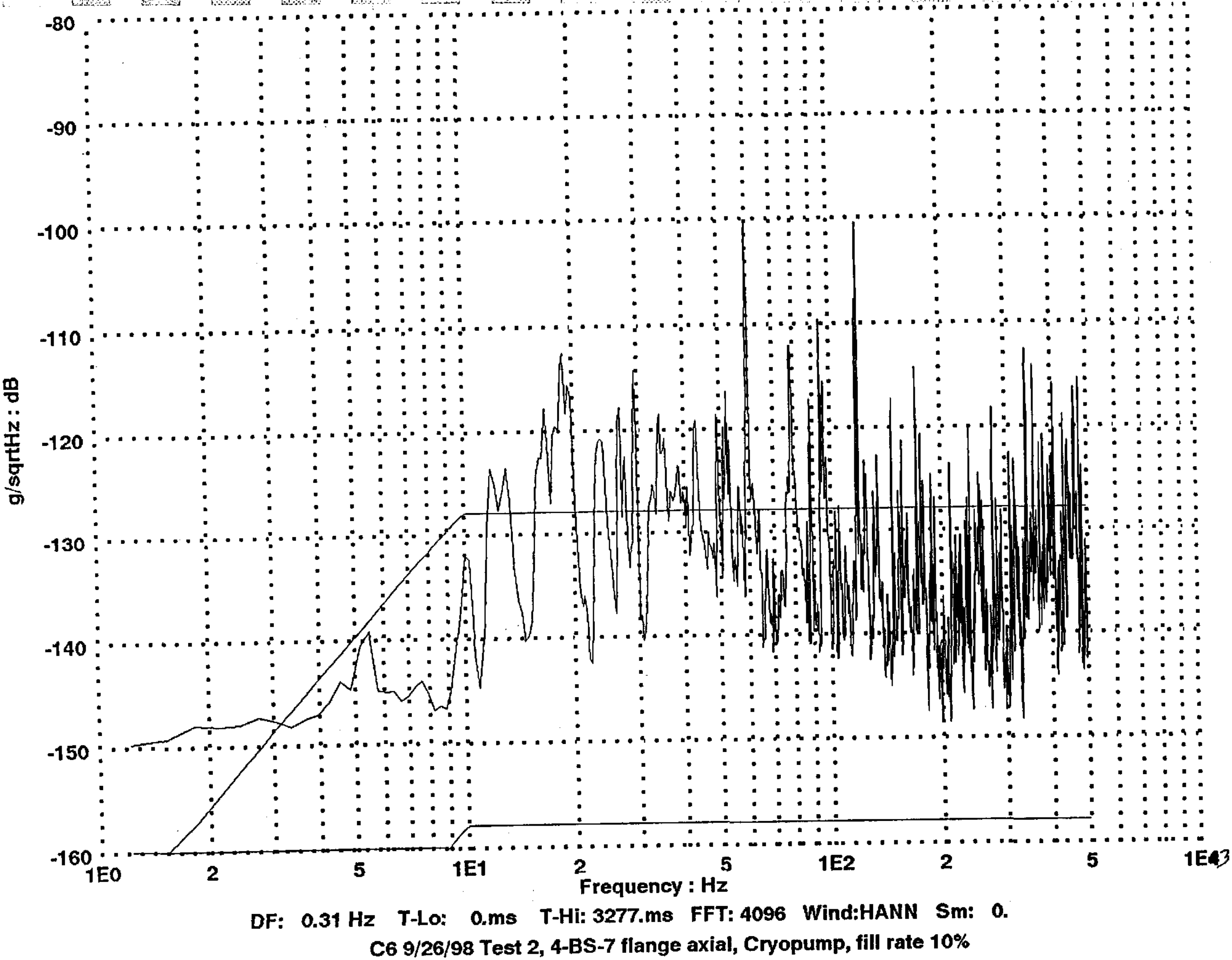
C74



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

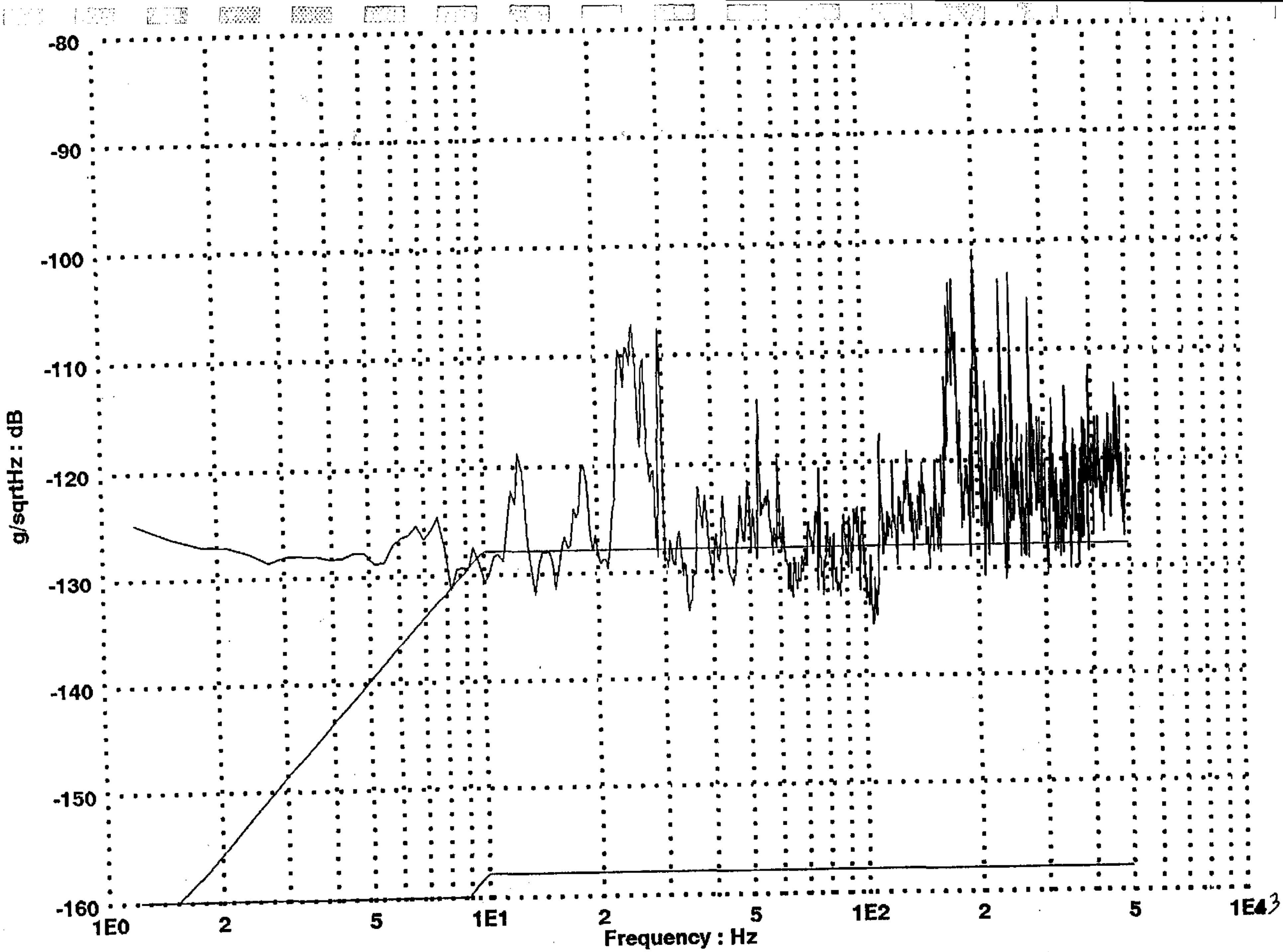
C5 9/26/98 Test 2, 0-Floor nr. BS 7, Cryopump, fill rate 10%

C25



-80
-90
-100
-110
-120
-130
-140
-150
-160
g/sqrtHz : dB
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.
C6 9/26/98 Test 2, 4-BS-7 flange axial, Cryopump, fill rate 10%

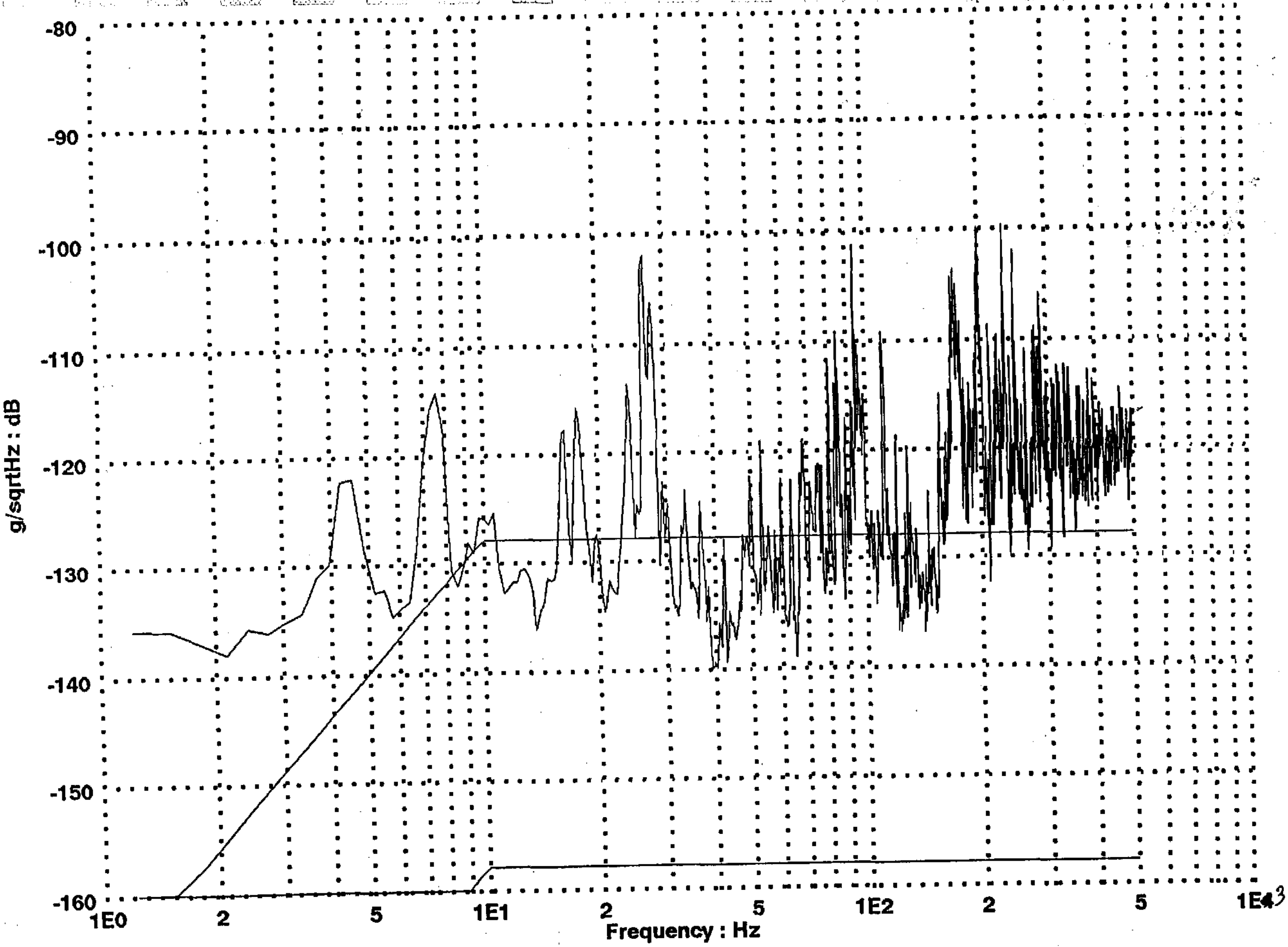
C76



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

C7 9/26/98 Test 2, 2-Cryopump axial, Cryopump, fill rate 10%

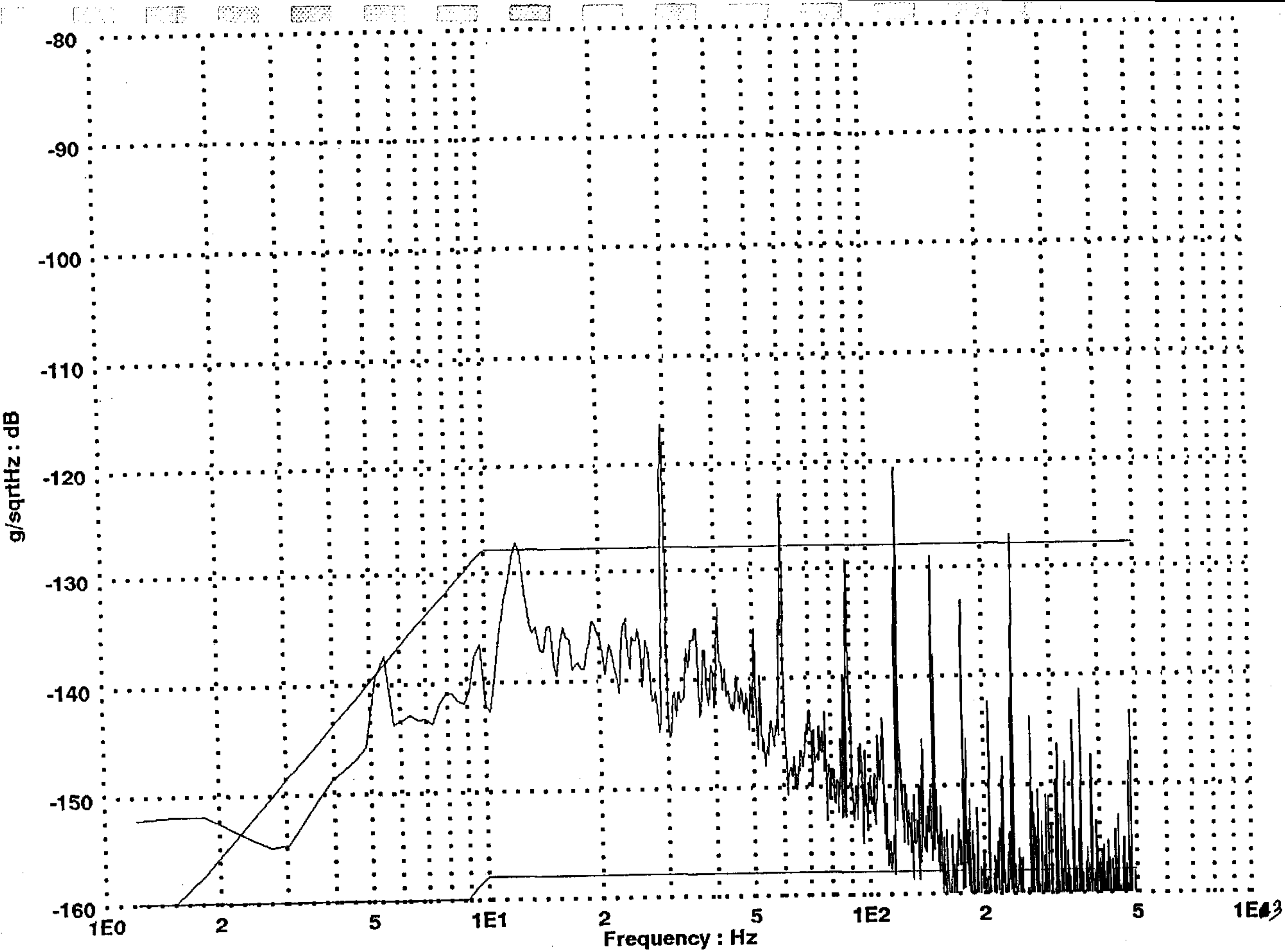
C-77



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

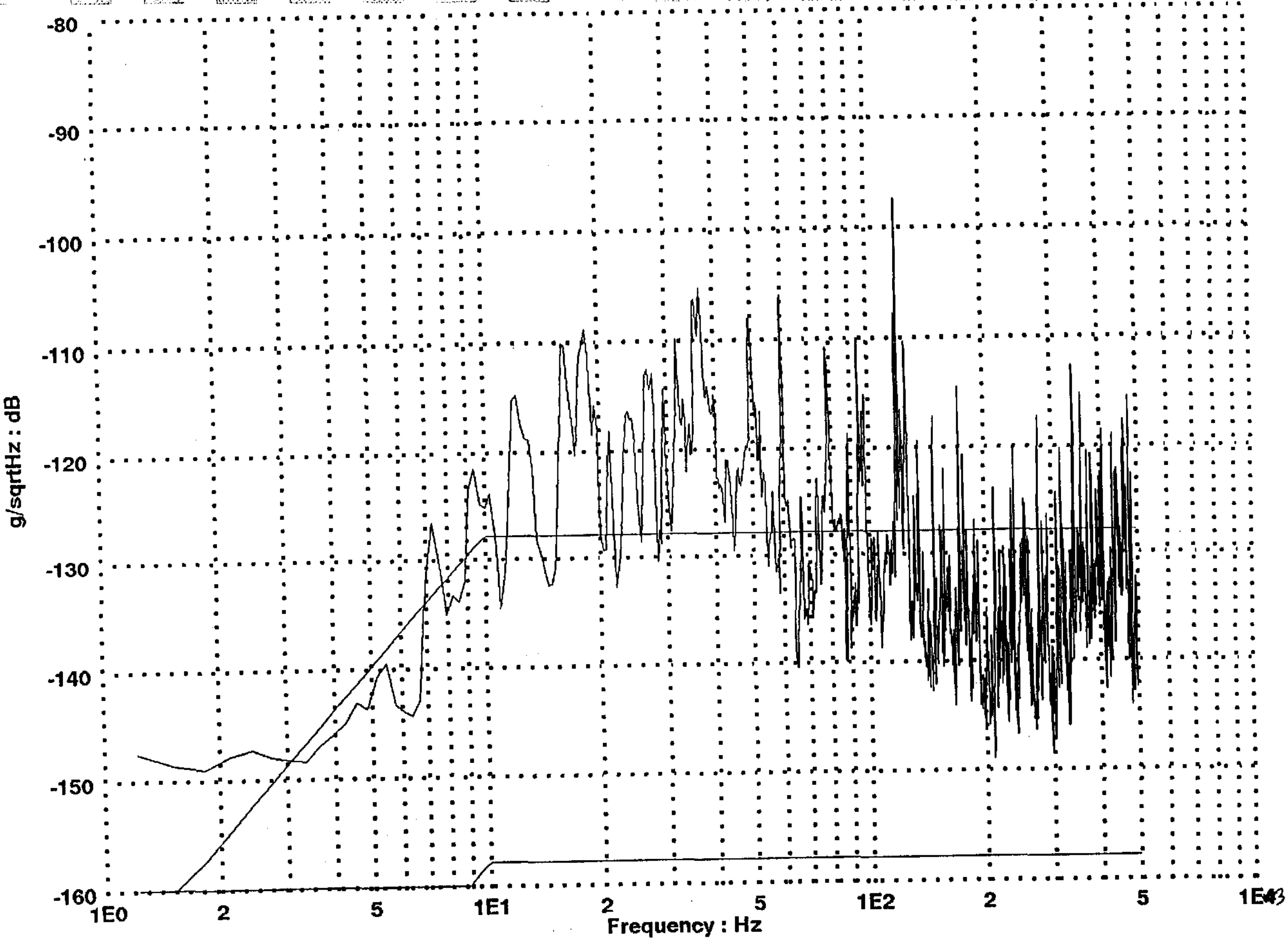
C8 9/26/98 Test 2, 2-Cryopump radial, Cryopump, fill rate 10%

C-78



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

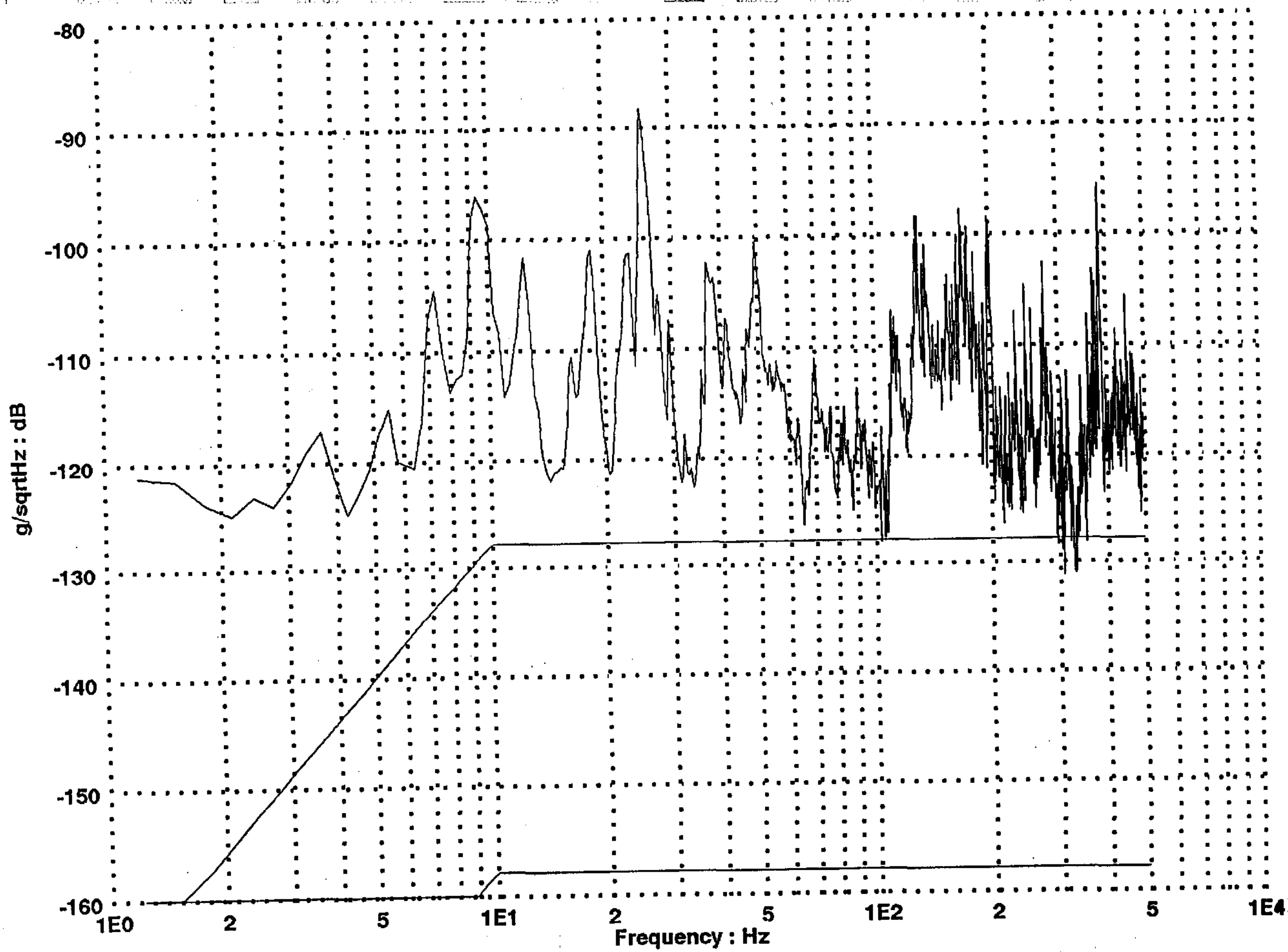
C9 9/26/98 Test 3, 0-Floor nr. BS 7, Cryopump, fill rate 100%



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

C10 9/26/98 Test 3, 4-BS-7 flange axial, Cryopump, fill rate 100%

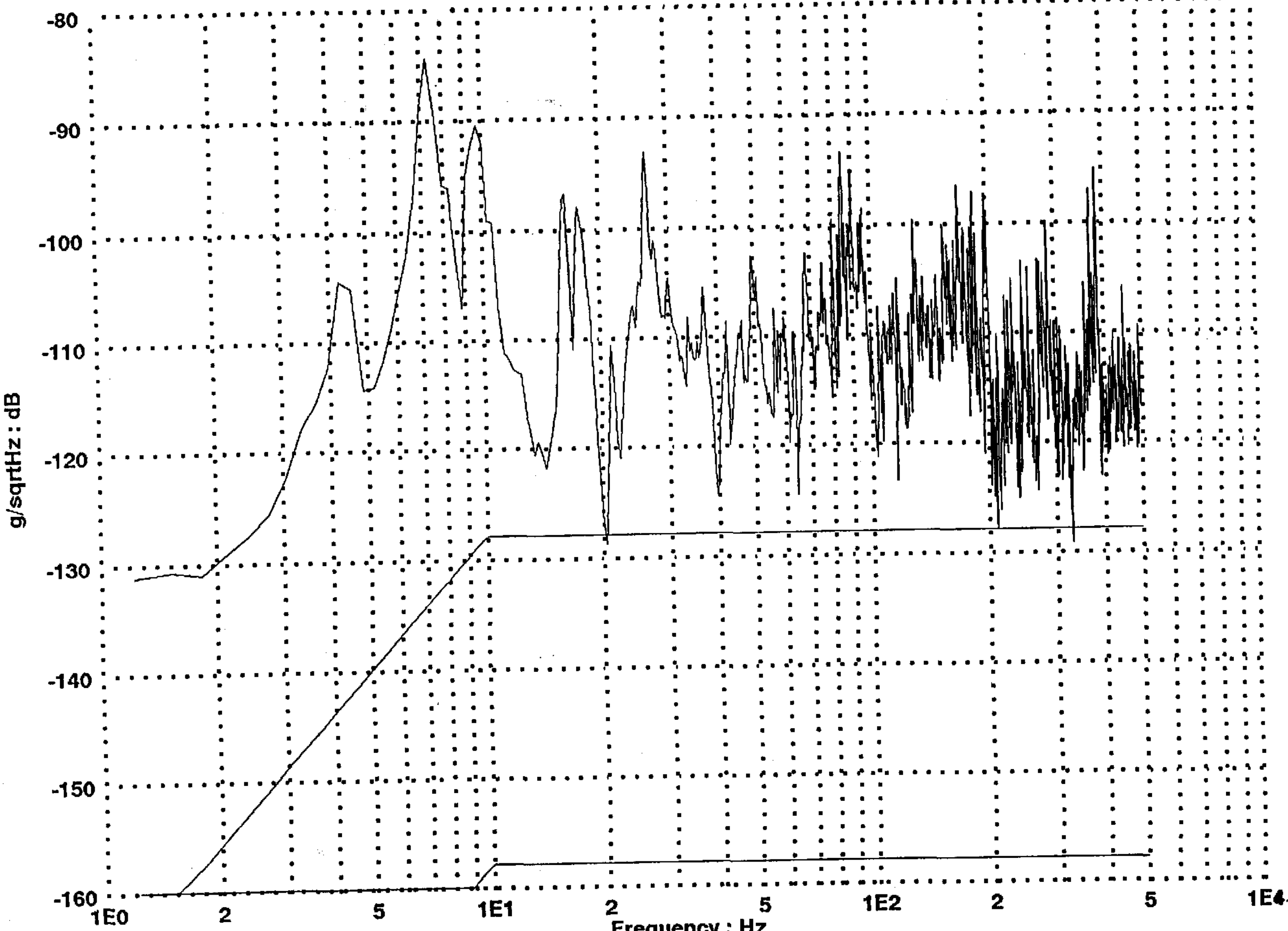
C-80



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

C11 9/26/98 Test 3, 2-Cryopump axial, Cryopump, fill rate 100%

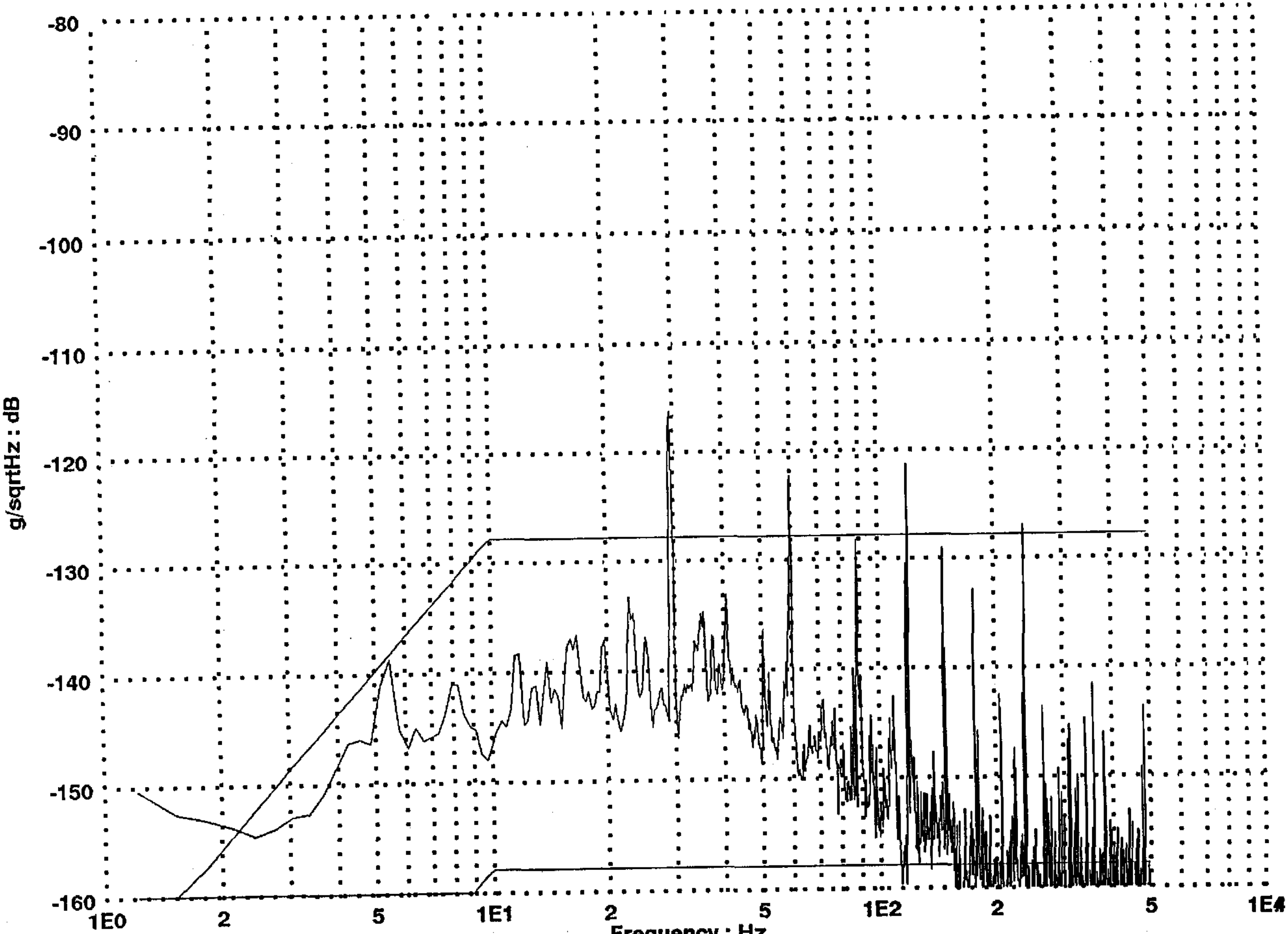
C-81



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

C12 9/26/98 Test 3, 2-Cryopump radial, Cryopump, fill rate 100%

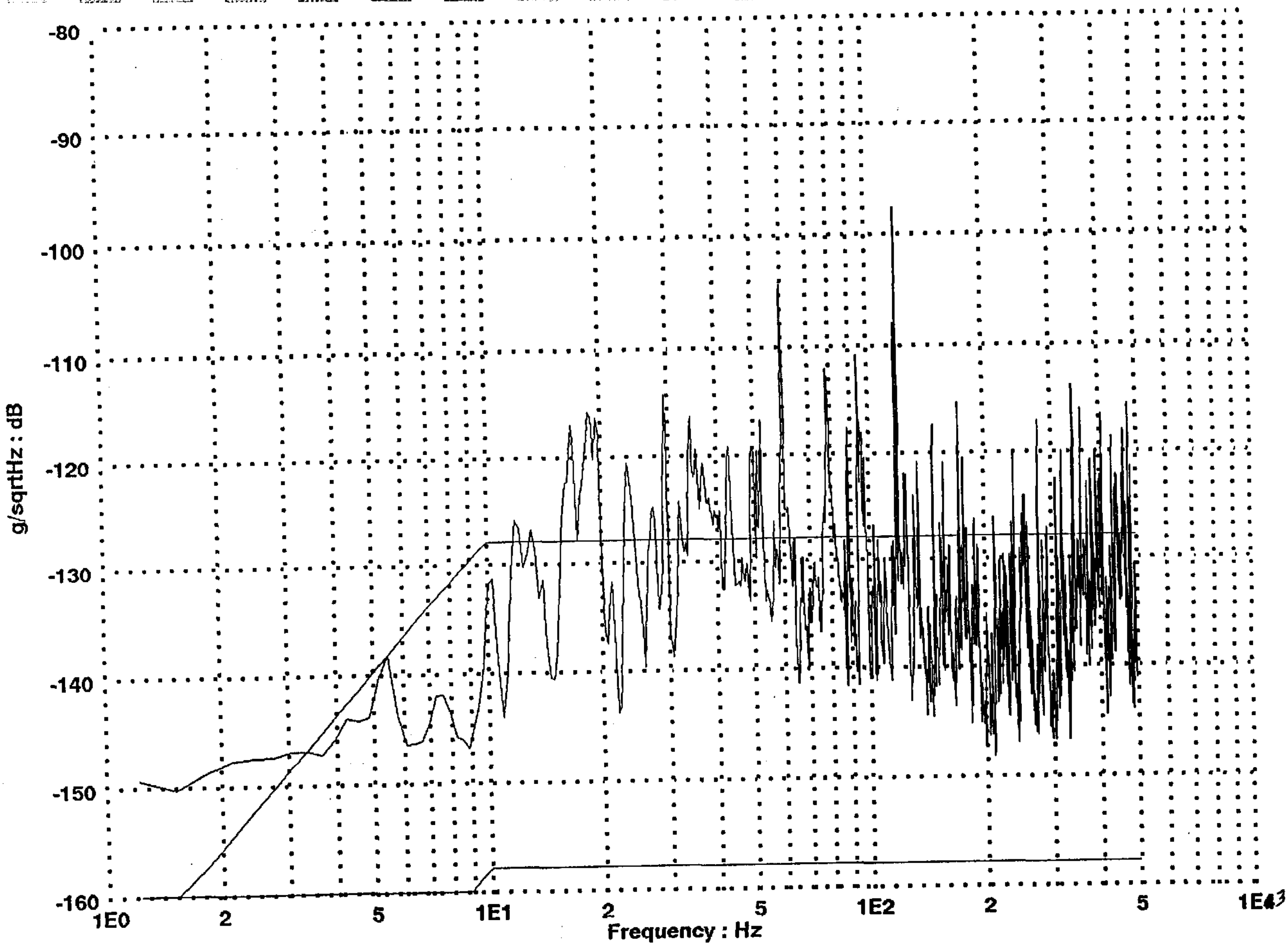
C82



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

C13 9/26/98 Test 4, 0-Floor nr. BS 7, Cryopump, fill rate 10%-60%

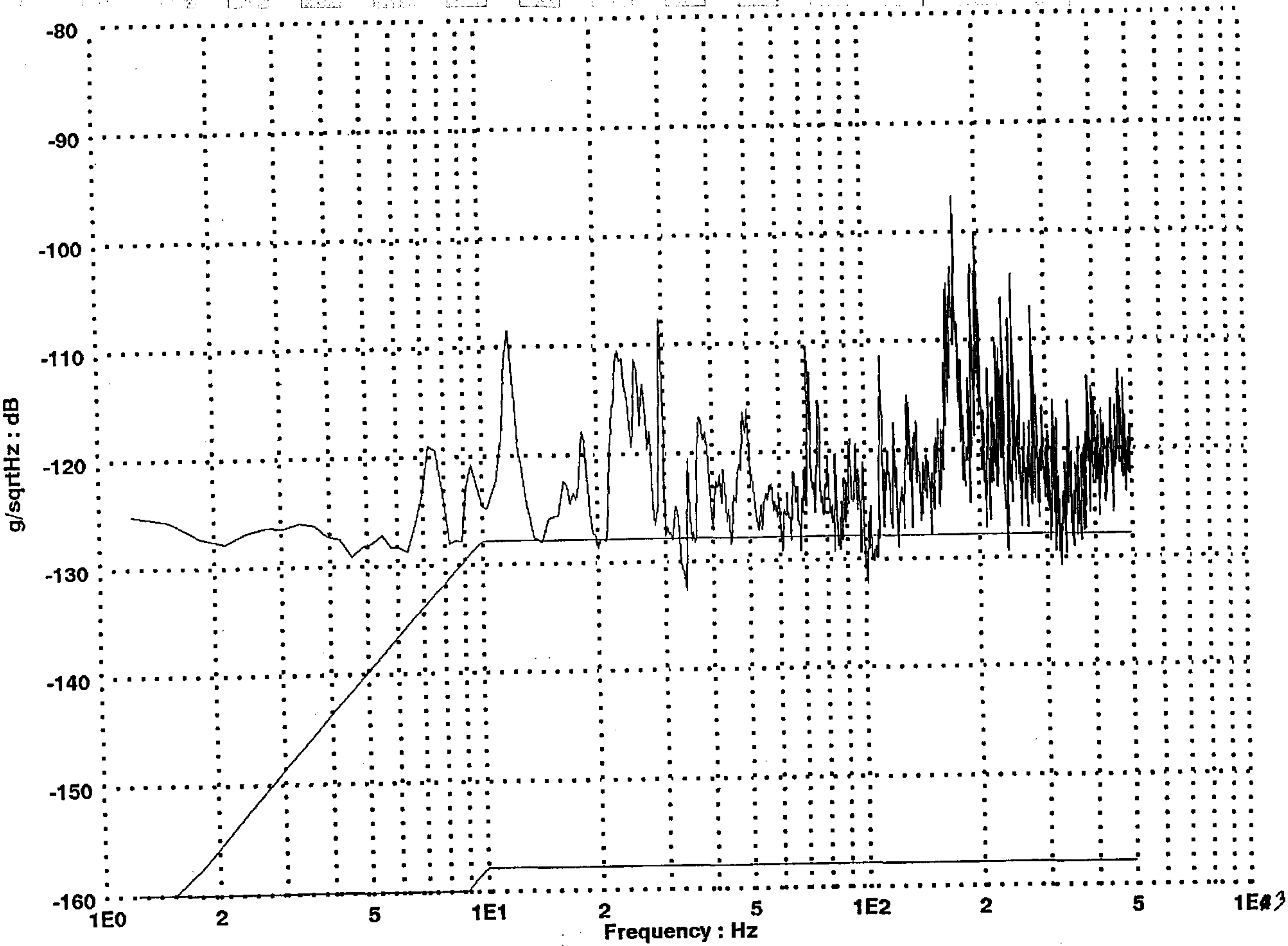
C83



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

C14 9/26/98 Test 4, 4-BS-7 flange axial, Cryopump, fill rate 10%-60%

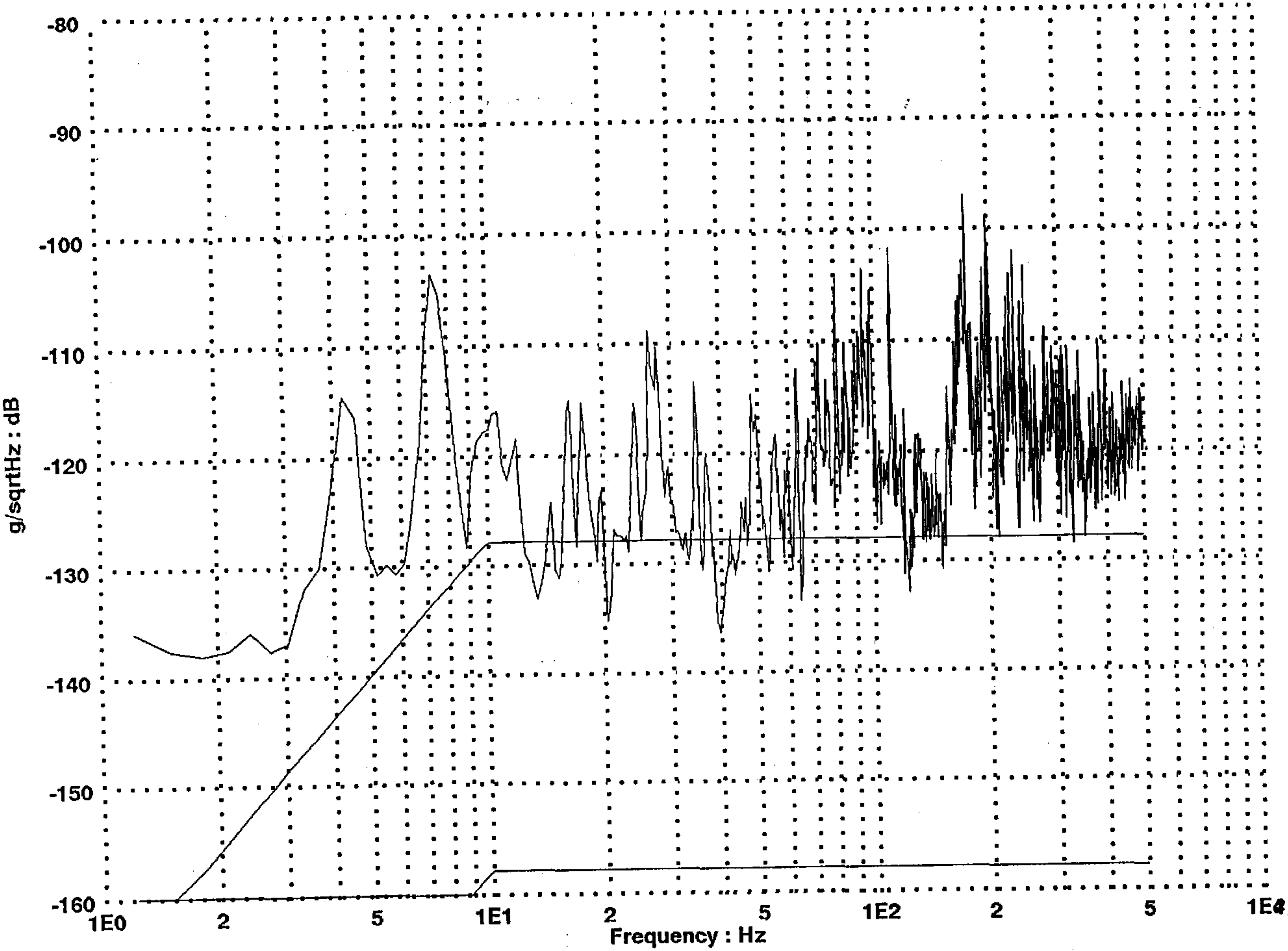
C 84



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

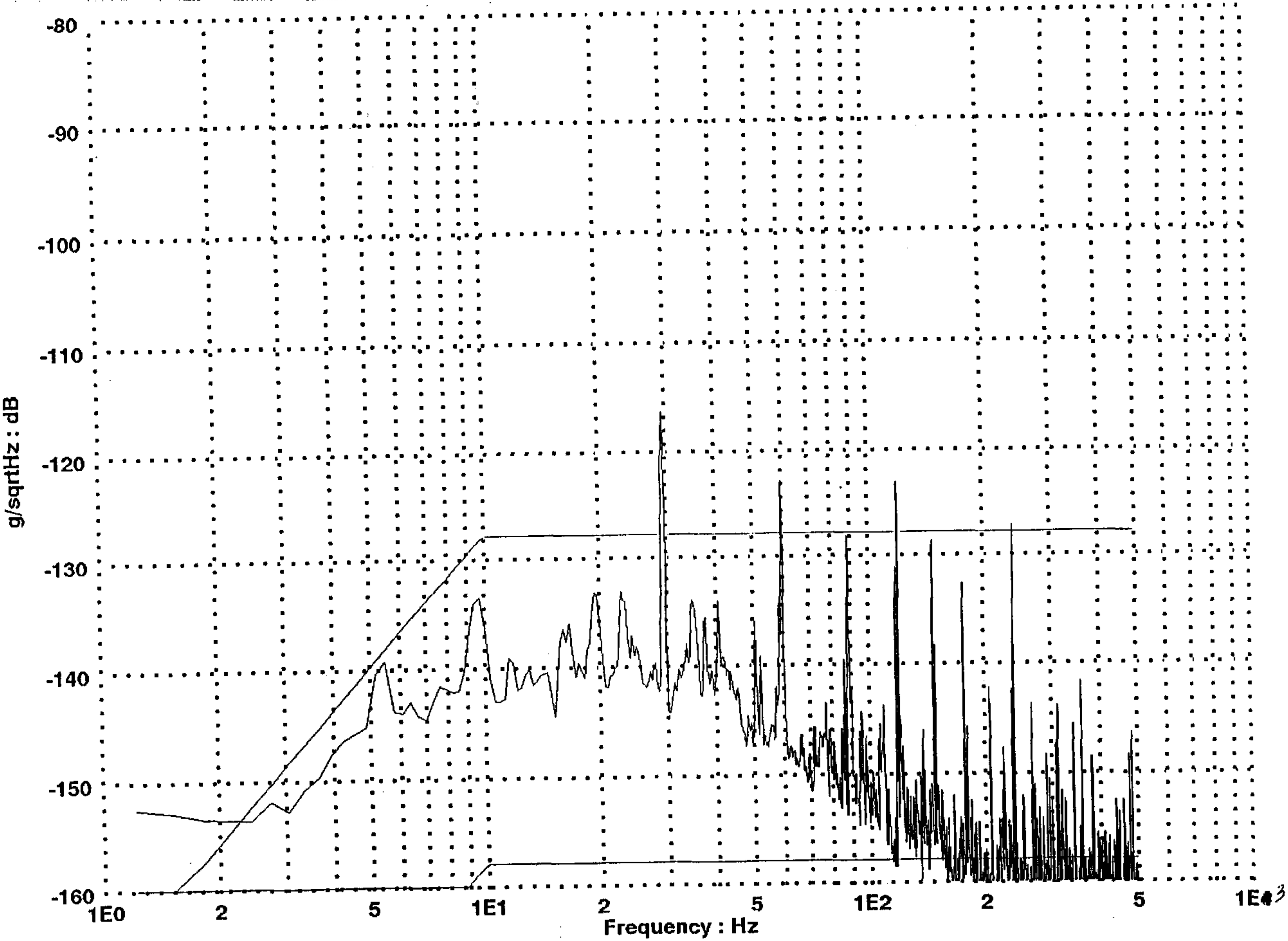
C15 9/26/98 Test 4, 2-Cryopump axial, Cryopump, fill rate 10%-60%

C85



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

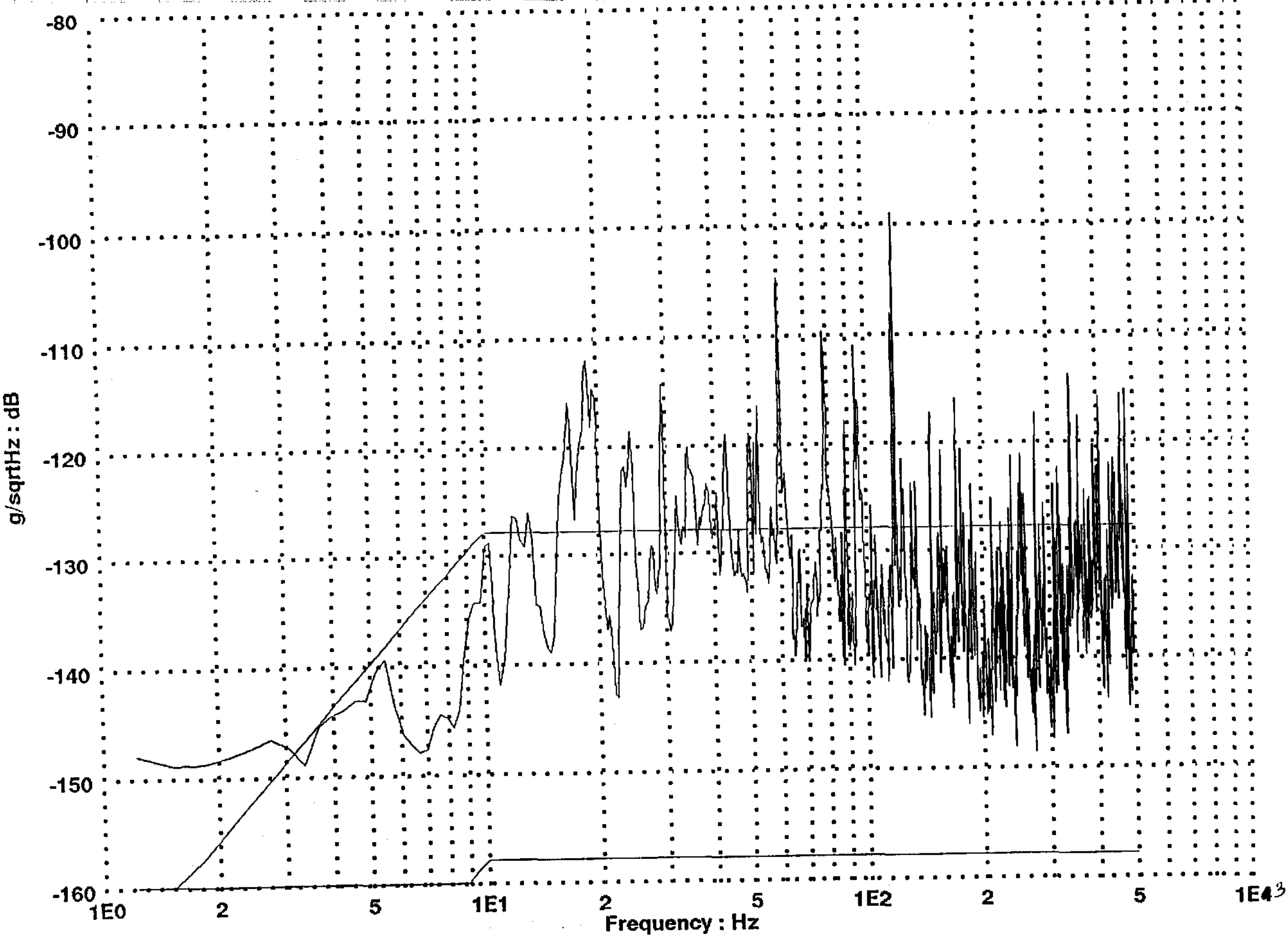
C16 9/26/98 Test 4, 2-Cryopump radial, Cryopump, fill rate 10%-60%



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

C17 9/26/98 Test 5, 0-Floor nr. BS 7, Cryopump, fill rate -60%

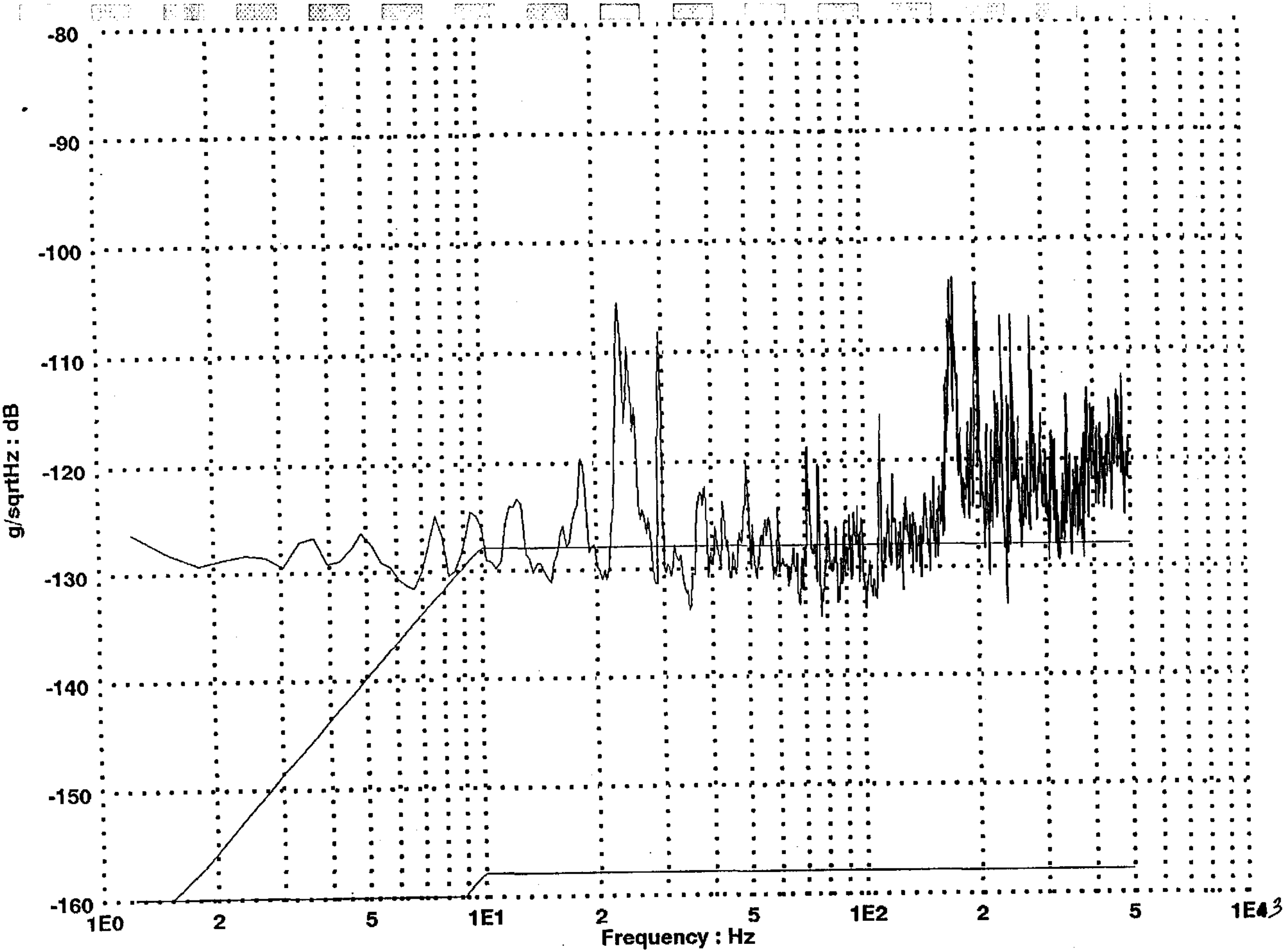
687



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

C18 9/26/98 Test 5, 4-BS-7 flange axial, Cryopump, fill rate -60%

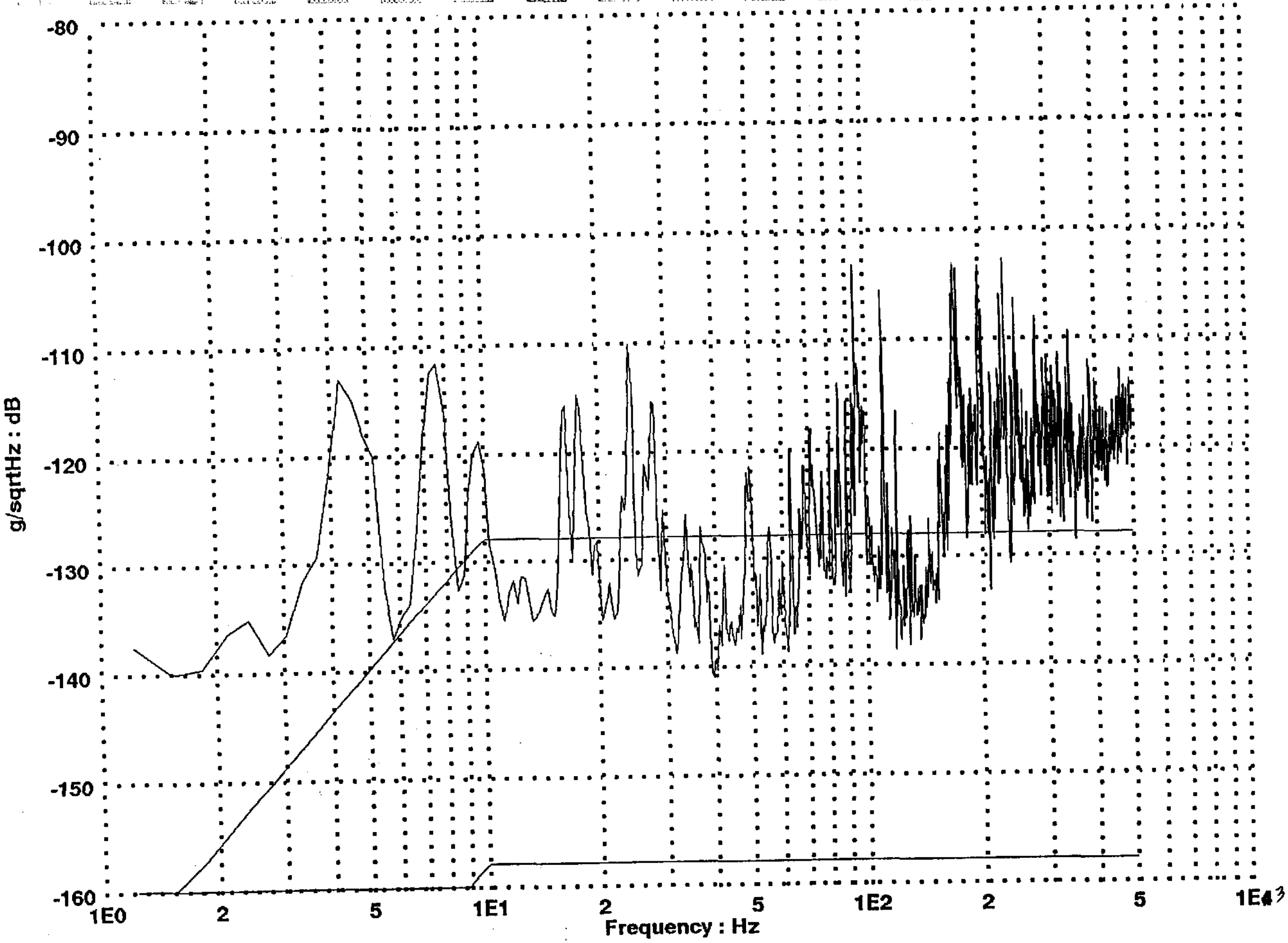
887



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

C19 9/26/98 Test 5, 2-Cryopump axial, Cryopump, fill rate -60%

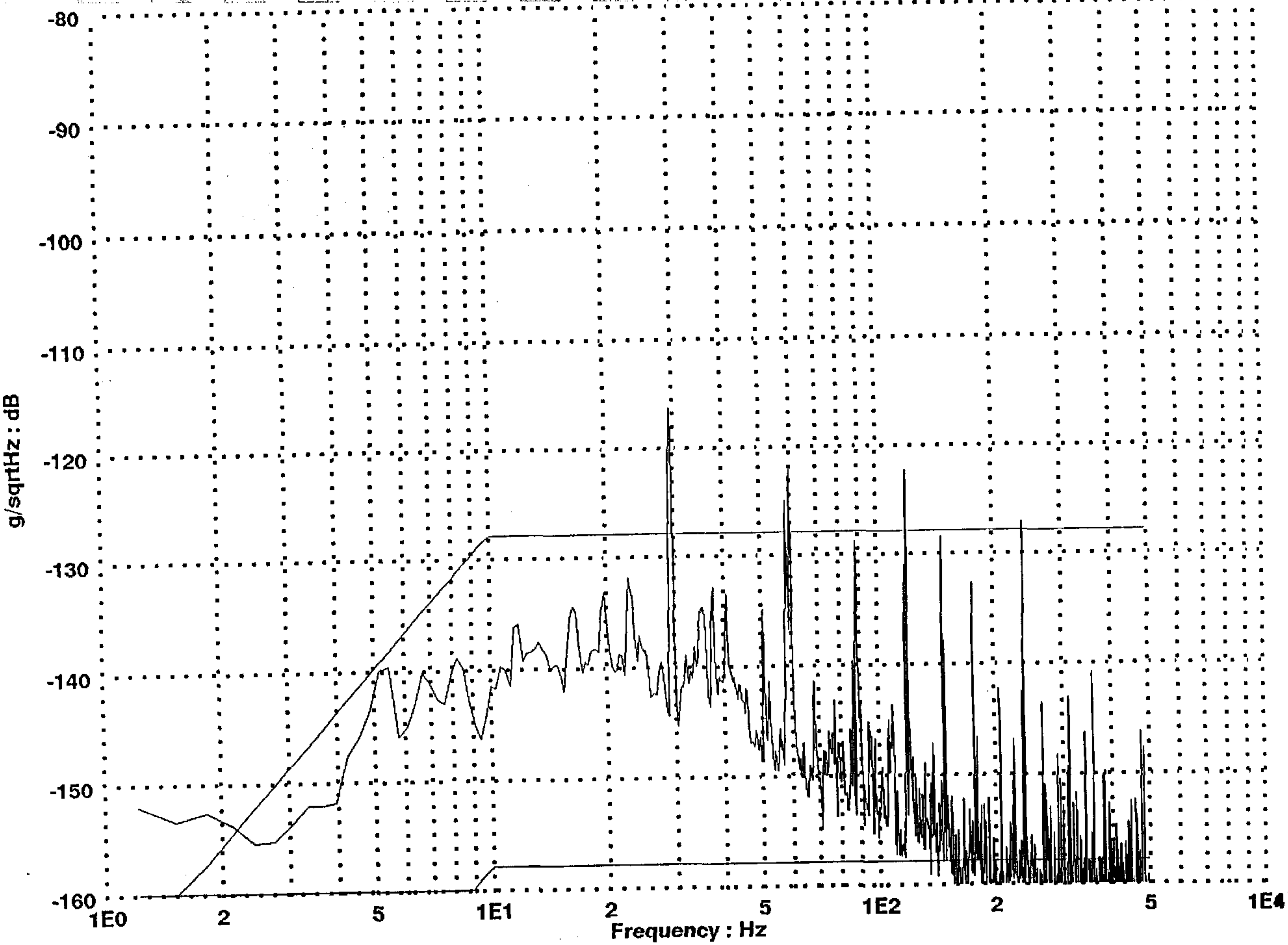
687



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

C20 9/26/98 Test 5, 2-Cryopump radial, Cryopump, fill rate -60%

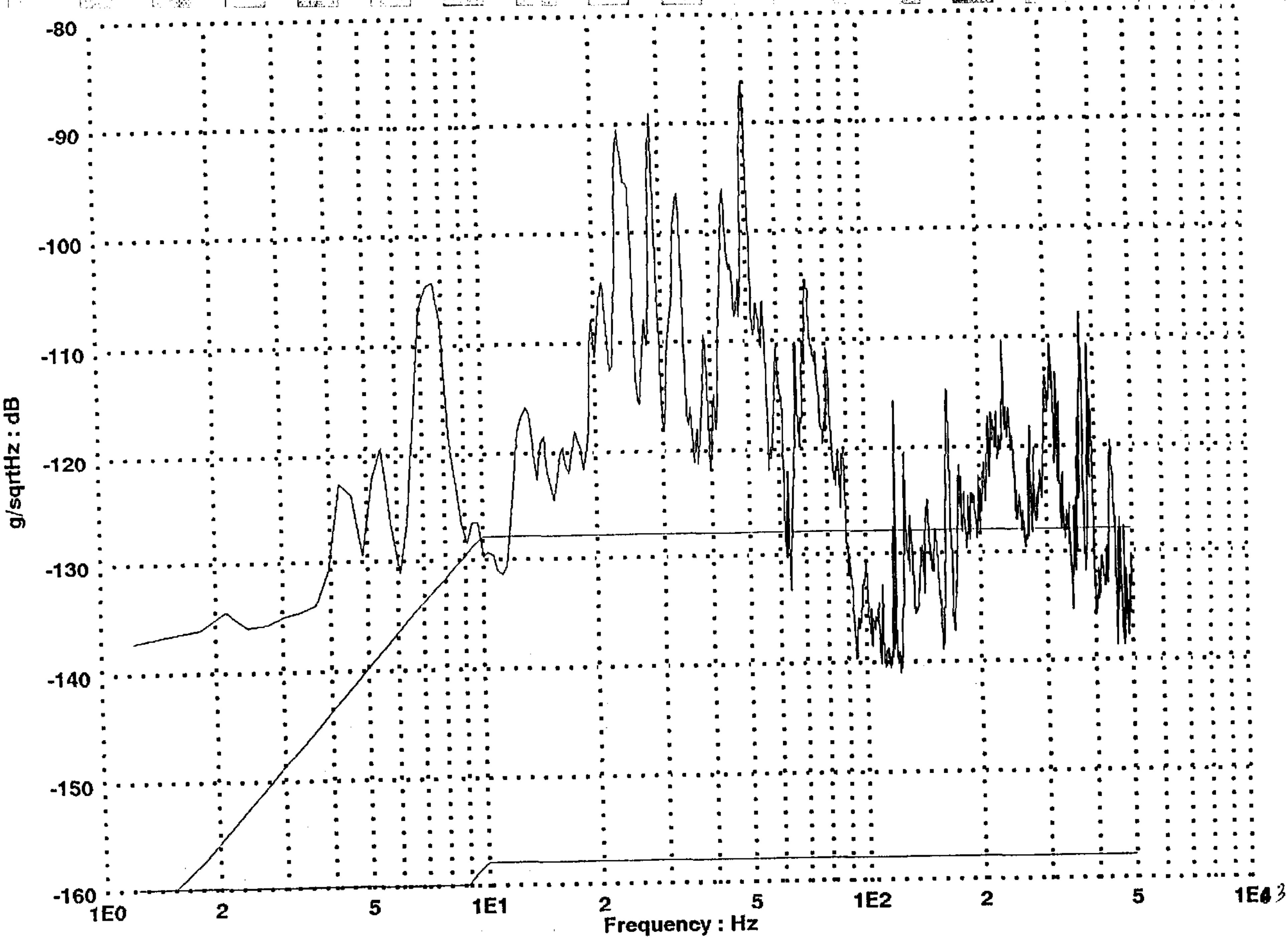
C90



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

C21 9/26/98 Test 6, 0-Floor nr. BS 7, Cryopump, fill rate 10%

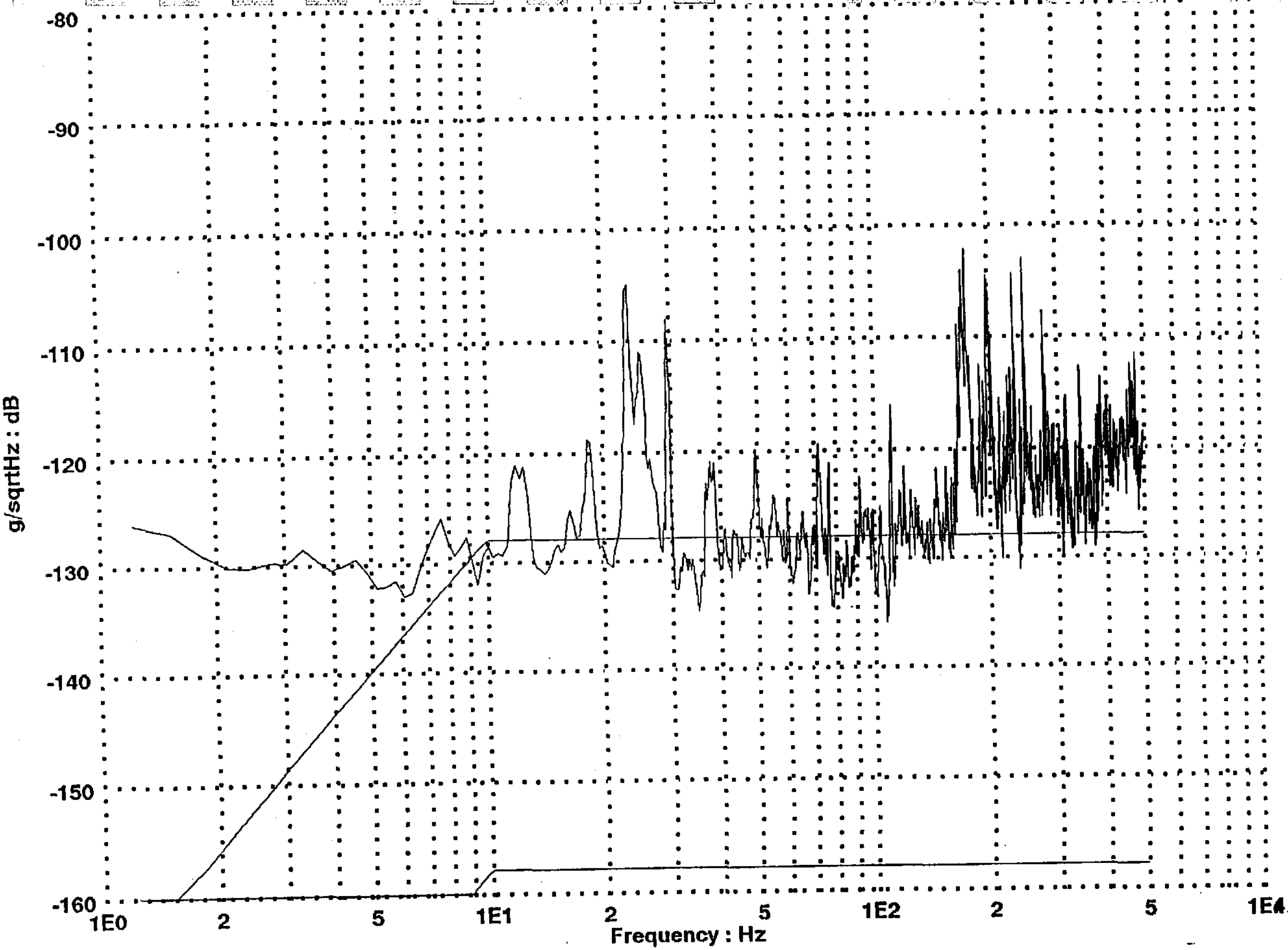
167



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

C22 9/26/98 Test 6, 4-Cryo inlet pipe, Cryopump, fill rate 10%

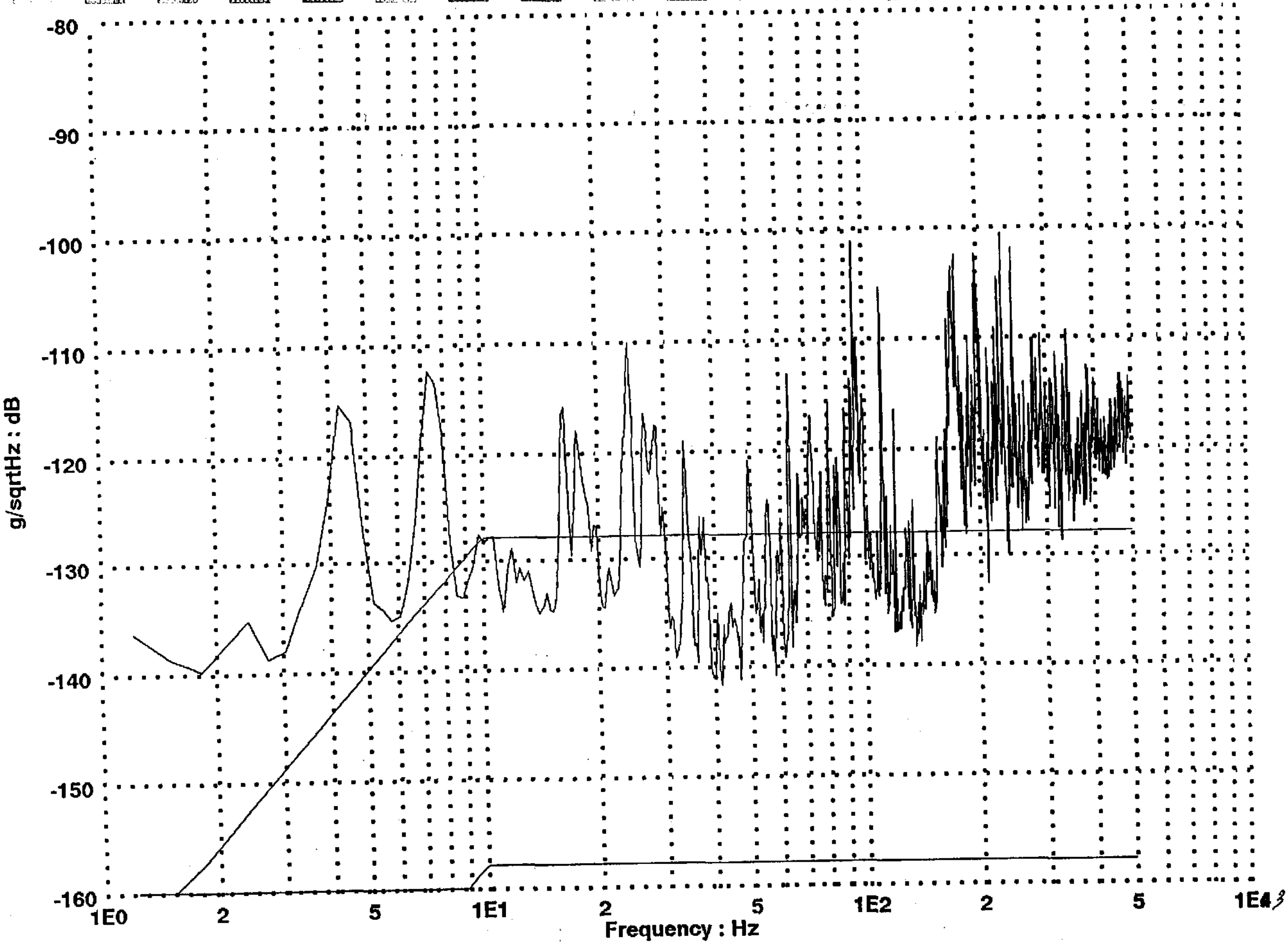
C92



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

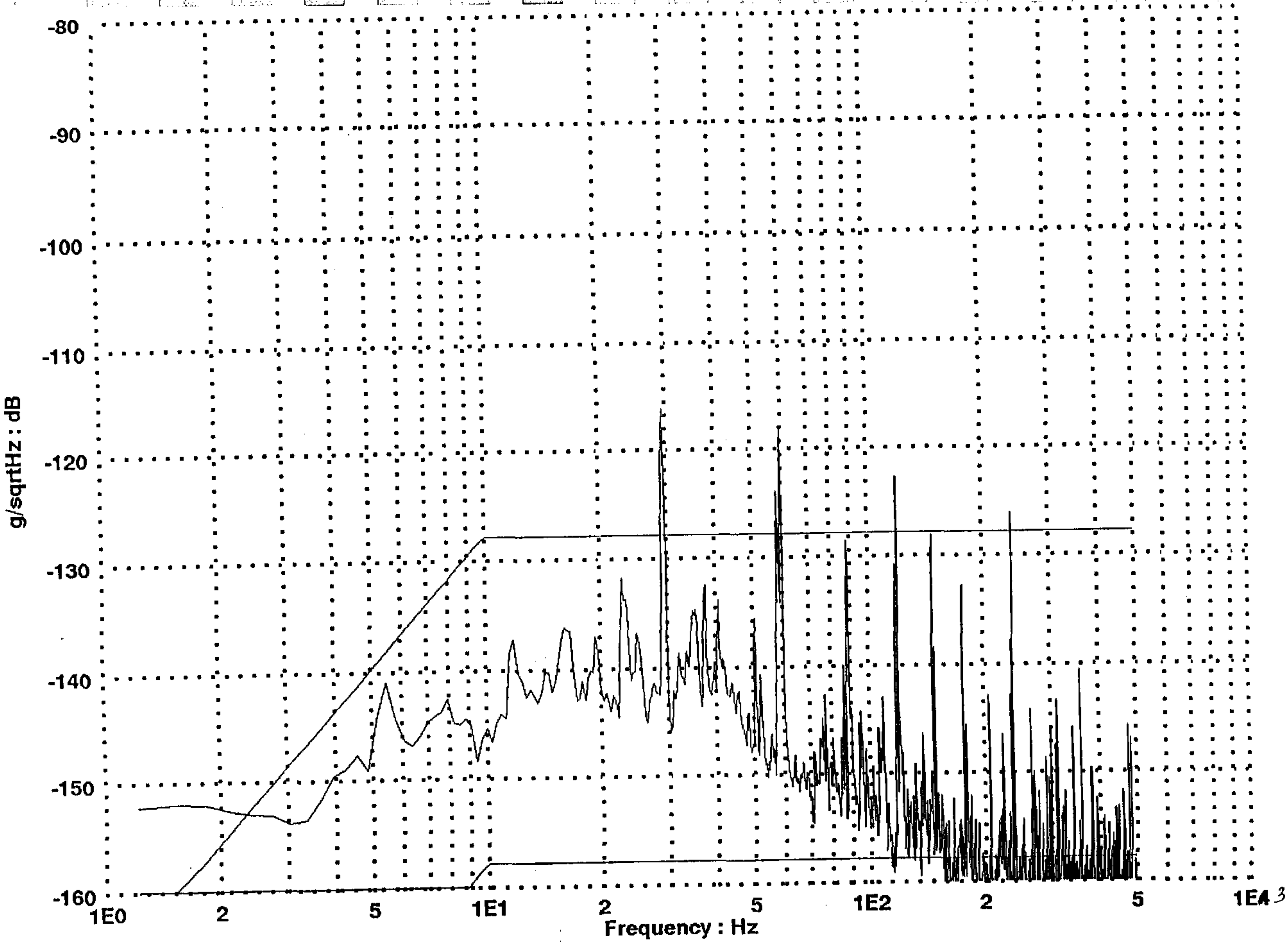
C23 9/26/98 Test 6, 2-Cryopump axial, Cryopump, fill rate 10%

C93



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

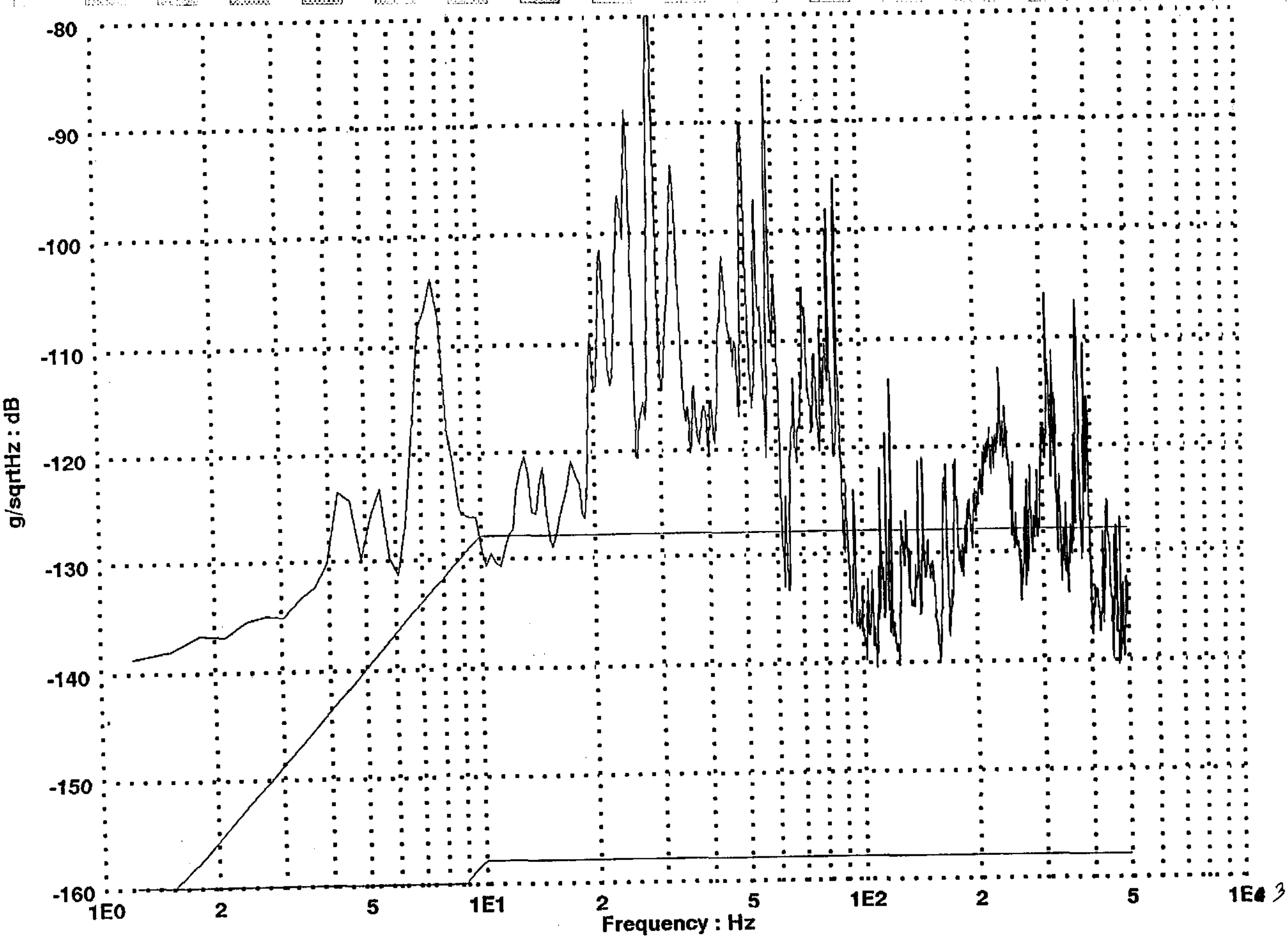
C24 9/26/98 Test 6, 2-Cryopump radial, Cryopump, fill rate 10%



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

C25 9/26/98 Test 6, 0-Floor nr. BS 7, Cryopump, fill rate ? no IA

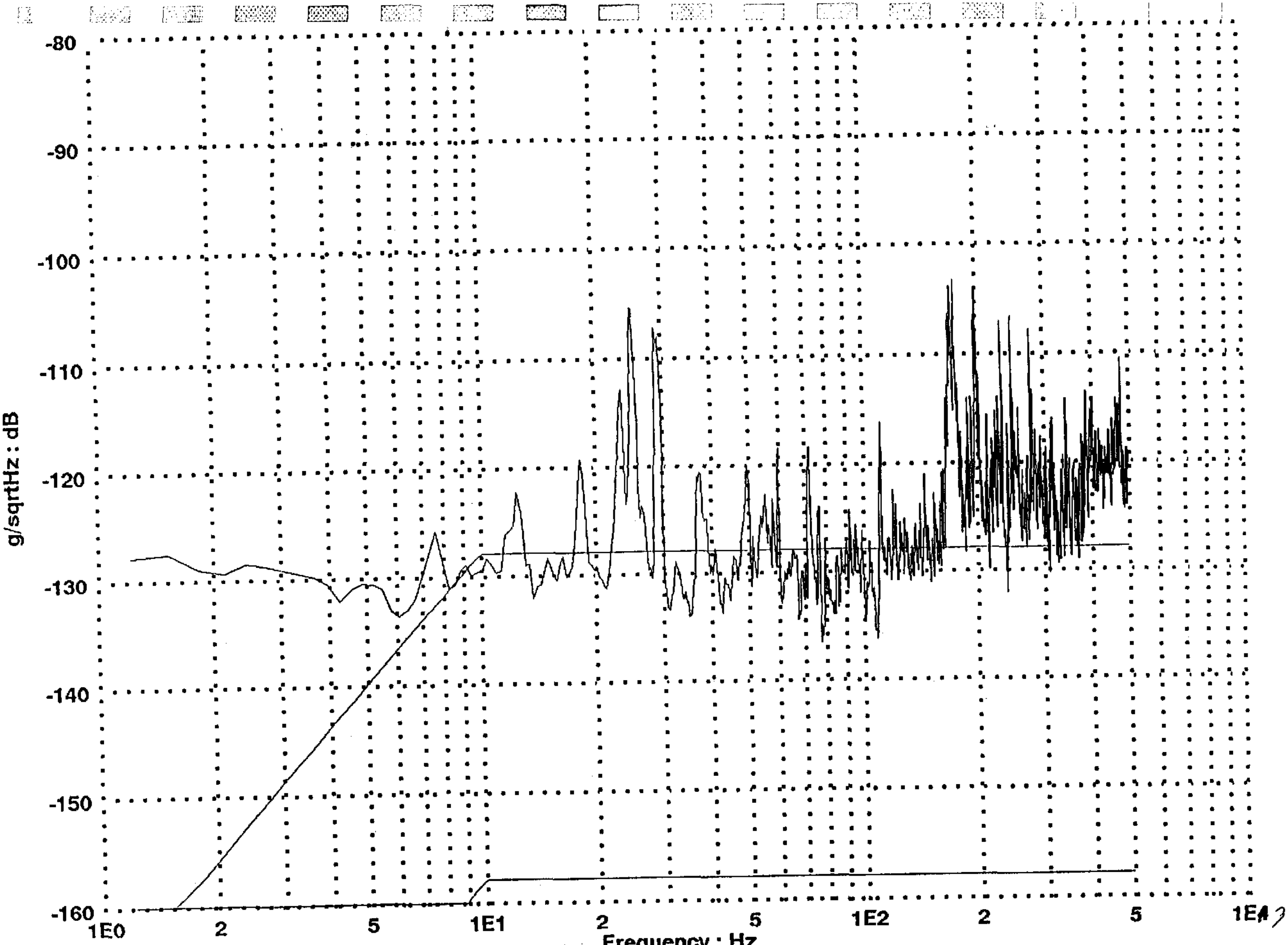
C95



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

C26 9/26/98 Test 7, 4-Cryo inlet pipe, Cryopump, fill rate ? no IA

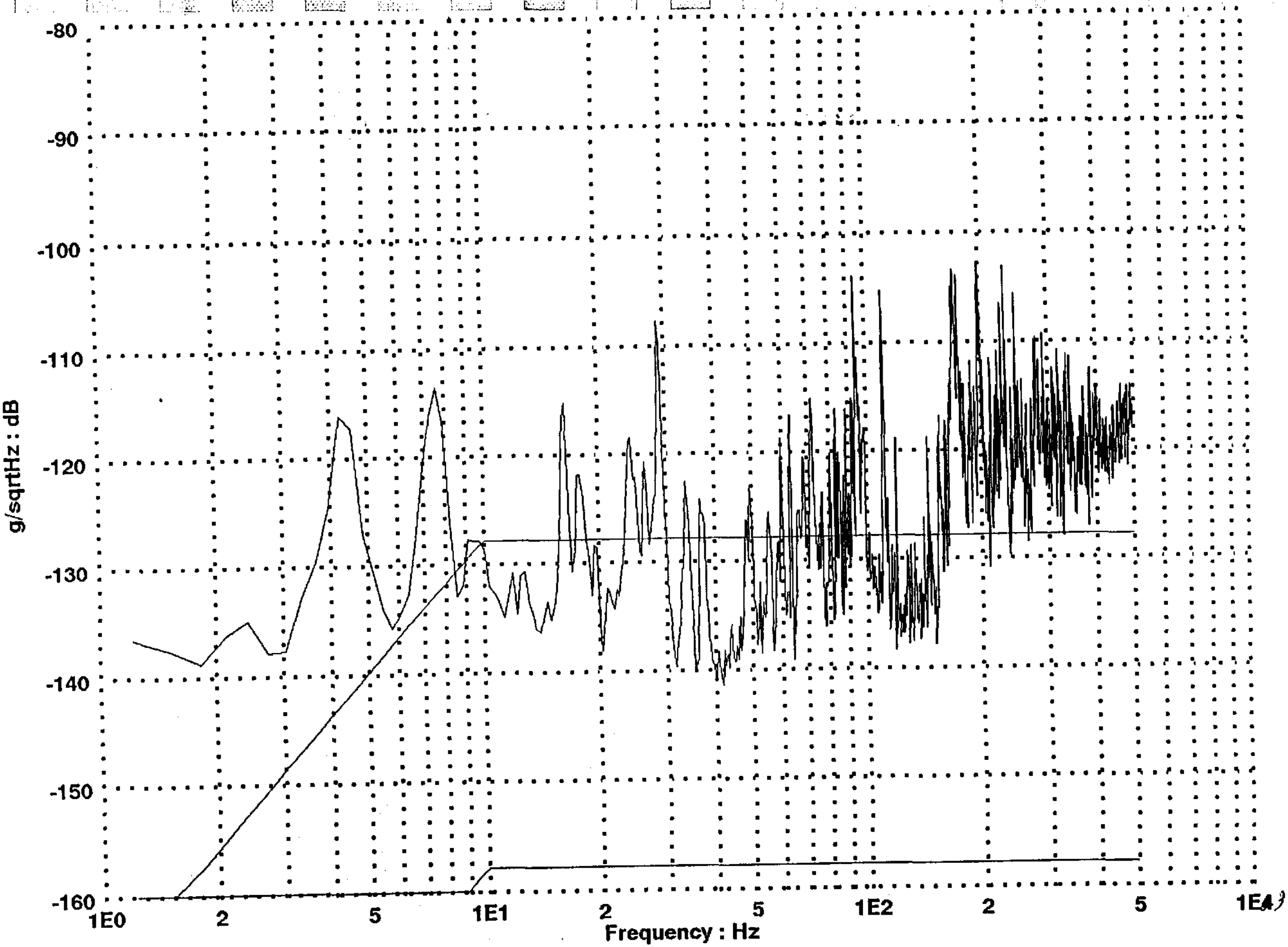
C96



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

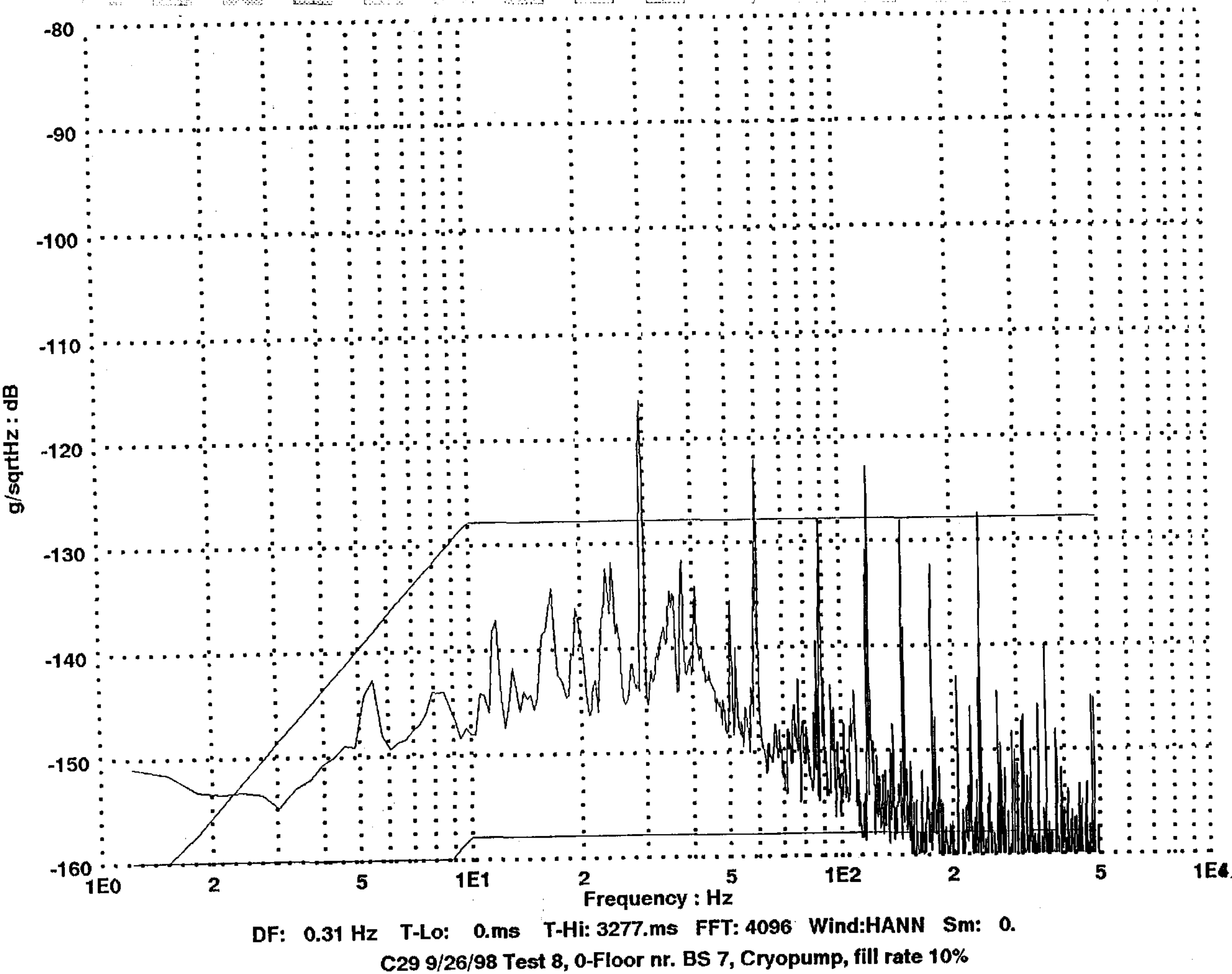
C27 9/26/98 Test 7, 2-Cryopump axial, Cryopump, fill rate ? no IA

C97

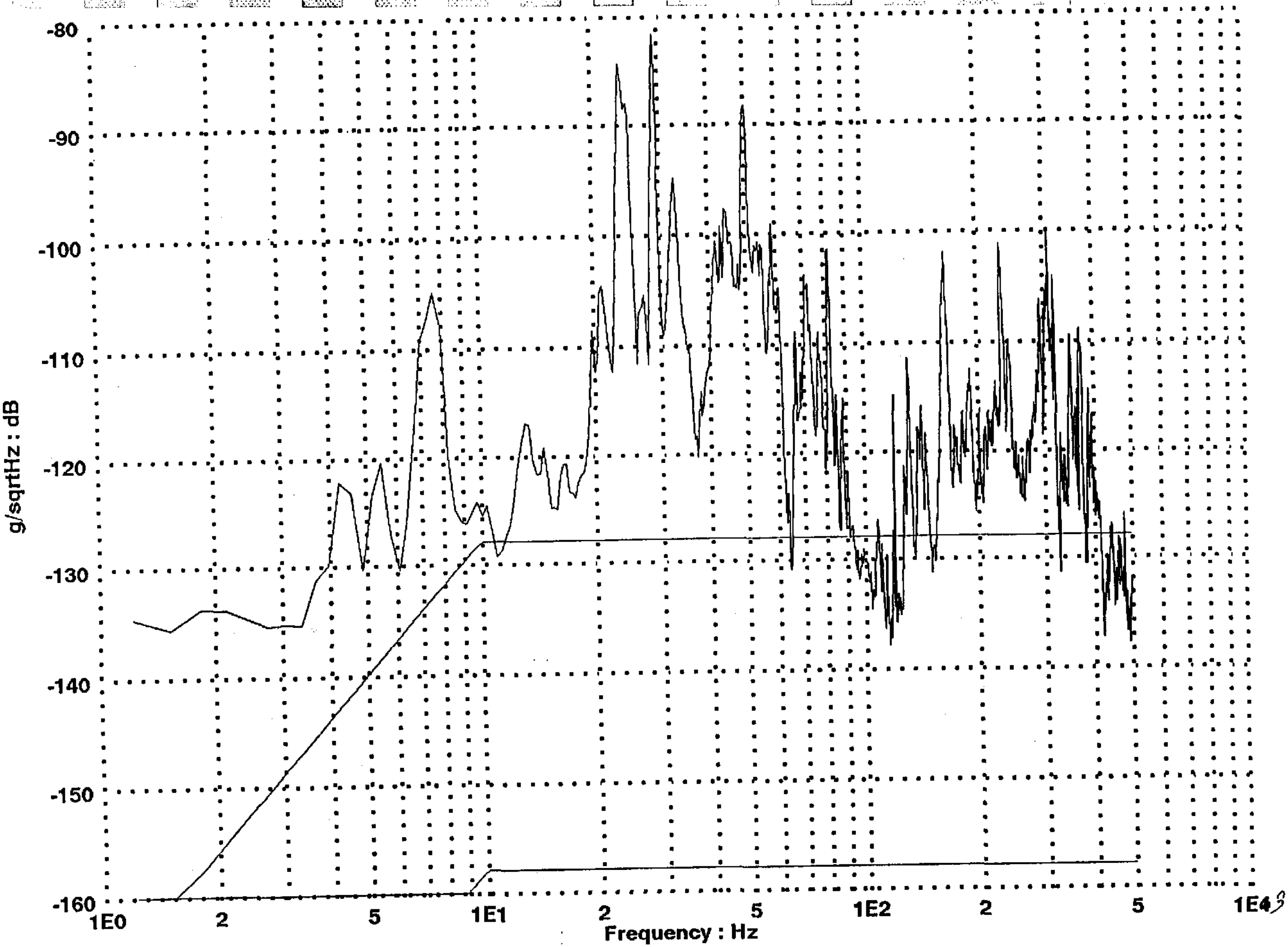


DF: 0.31 Hz T-Lo: 0.ms T-Hi: 3277.ms FFT: 4096 Wind:HANN Sm: 0.

C28 9/26/98 Test 7, 2-Cryopump radial, Cryopump, fill rate? no IA

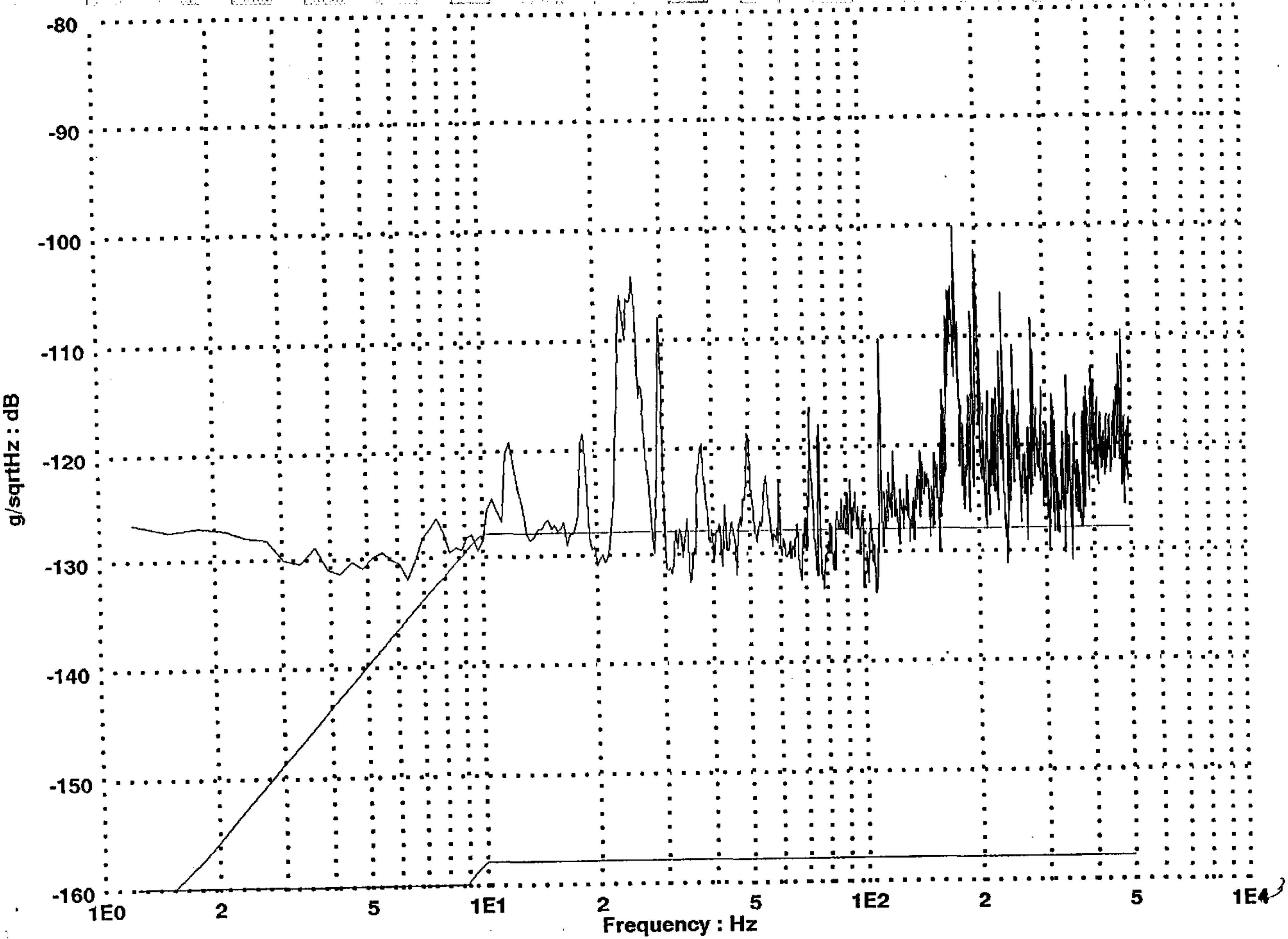

-80
-90
-100
-110
-120
-130
-140
-150
-160
g/sqrtHz : dB
1E0
2
5
1E1
2
5
1E2
2
5
1E3
Frequency : Hz
DF: 0.31 Hz T-Lo: 0.ms T-Hi: 3277.ms FFT: 4096 Wind:HANN Sm: 0.
C29 9/26/98 Test 8, 0-Floor nr. BS 7, Cryopump, fill rate 10%

C99



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

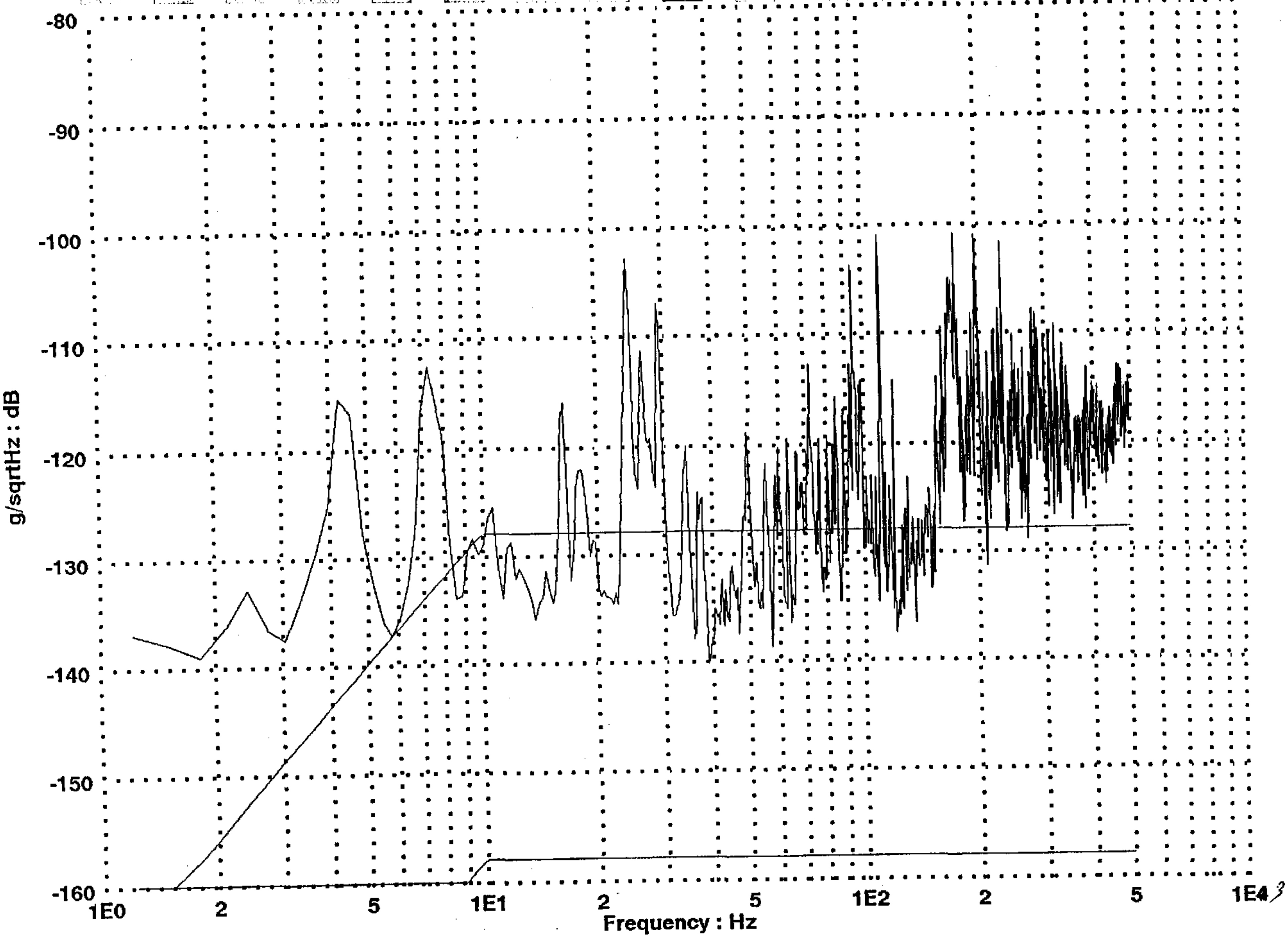
C30 9/26/98 Test 8, 4-Cryo inlet pipe, Cryopump, fill rate 10%



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

C31 9/26/98 Test 8, 2-Cryopump axial, Cryopump, fill rate 10%

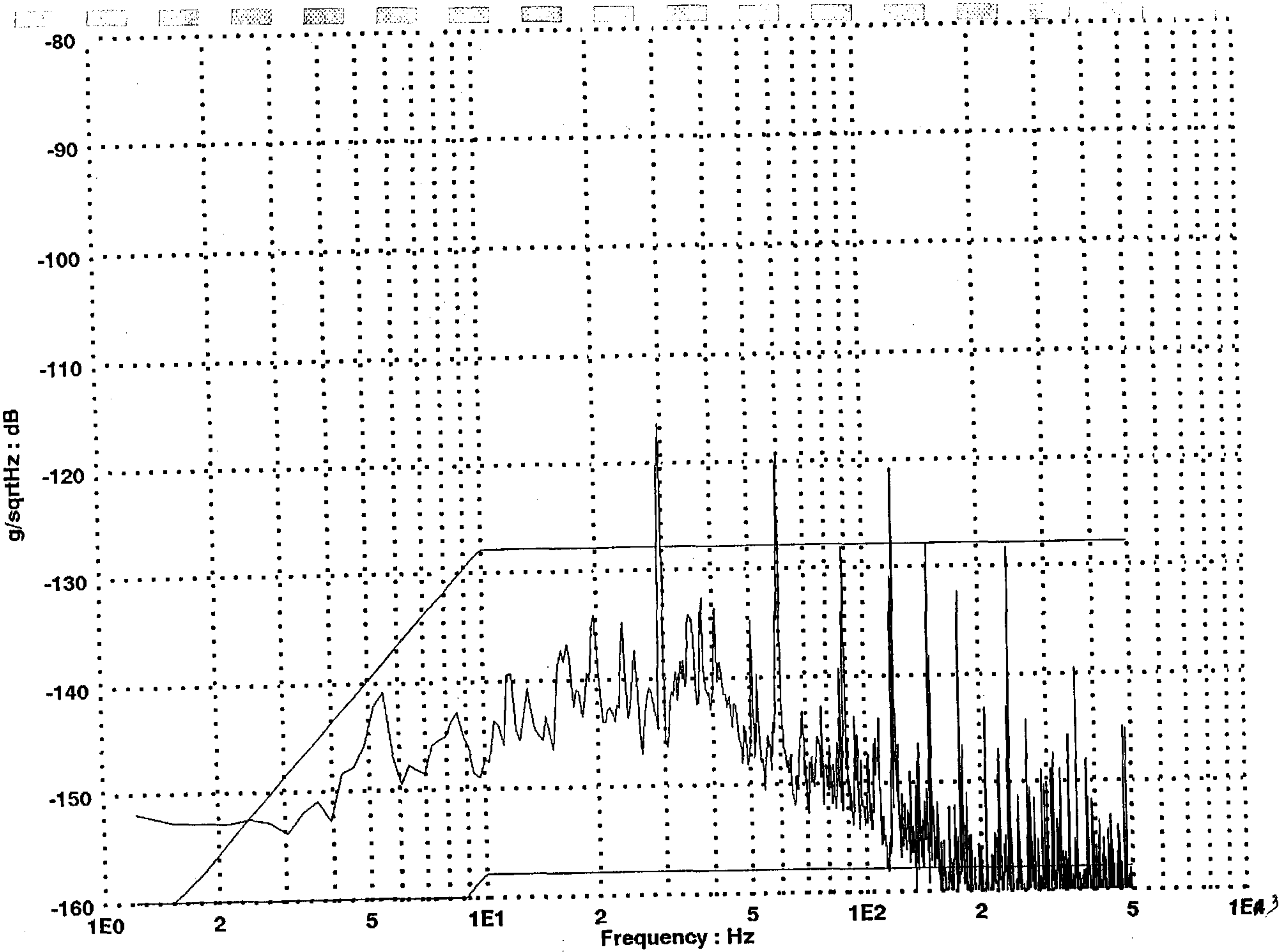
C/01



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

C32 9/26/98 Test 8, 2-Cryopump radial, Cryopump, fill rate 10%

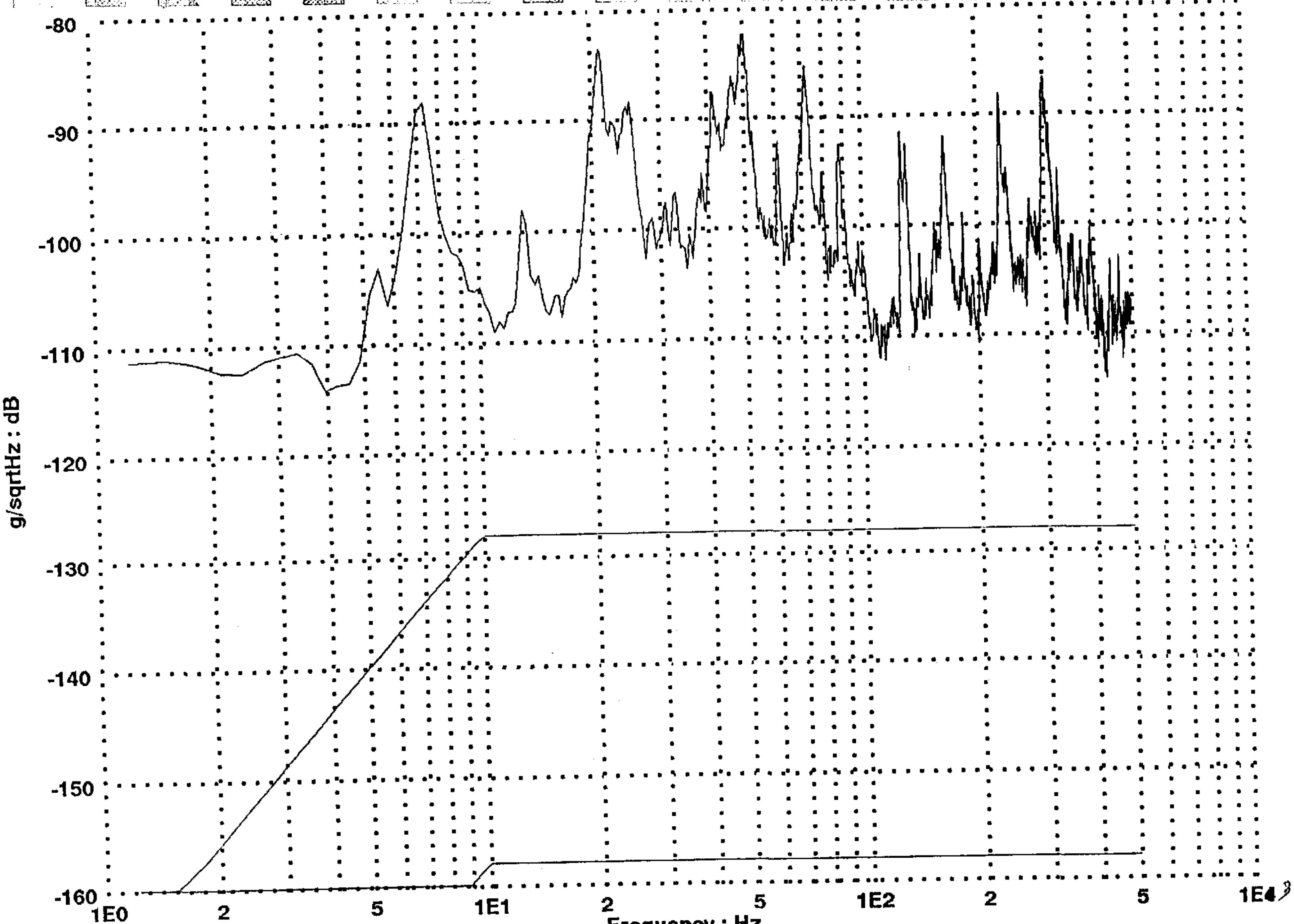
C102



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

C33 9/26/98 Test 9, 0-Floor nr. BS 7, Cryopump, fill rate 60%

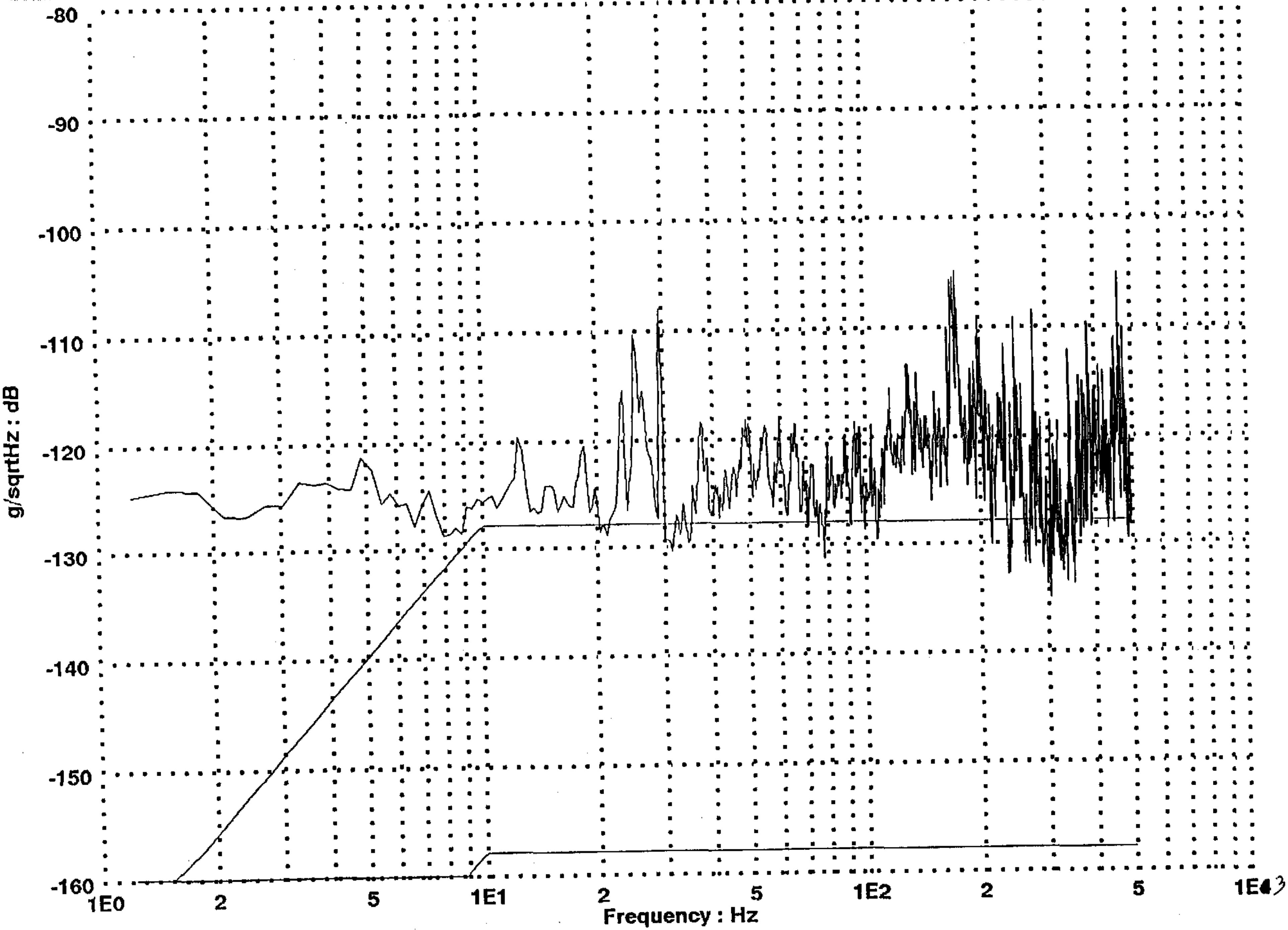
C/o3



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

C34 9/26/98 Test 9, 4-Cryo inlet pipe, Cryopump, fill rate 60%

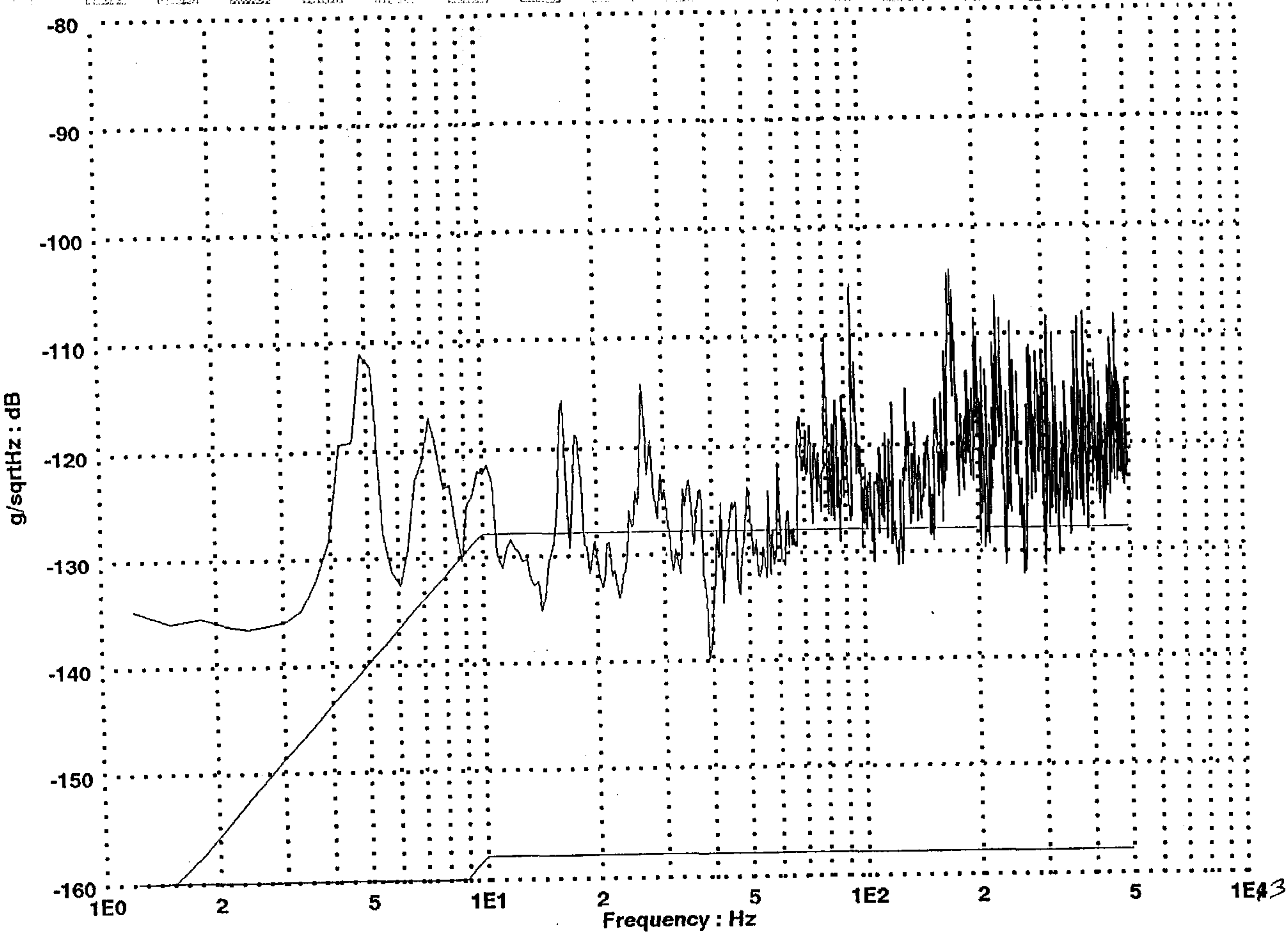
C104



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

C35 9/26/98 Test 9, 2-Cryopump axial, Cryopump, fill rate 60%

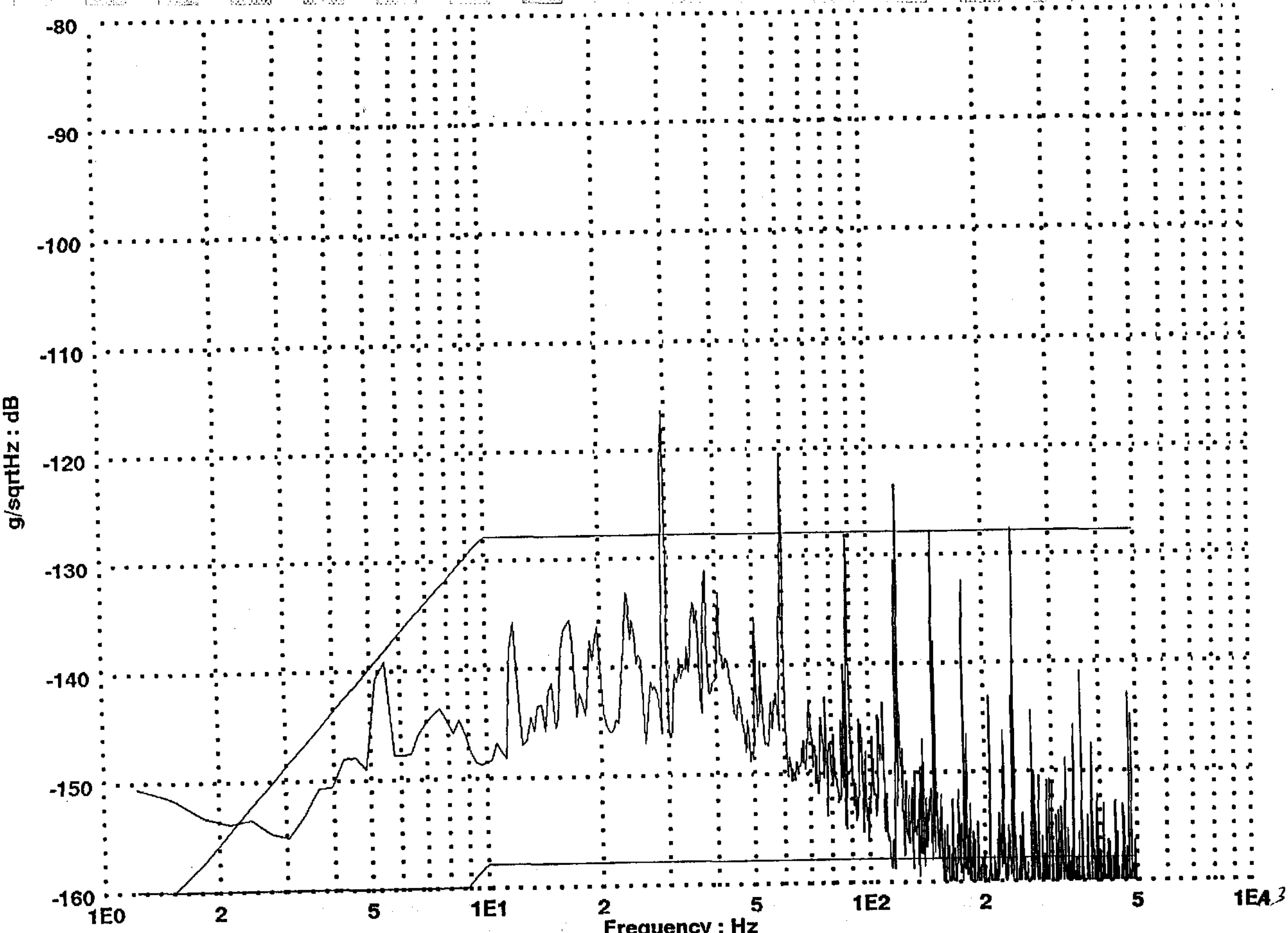
C105



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

C36 9/26/98 Test 9, 2-Cryopump radial, Cryopump, fill rate 60%

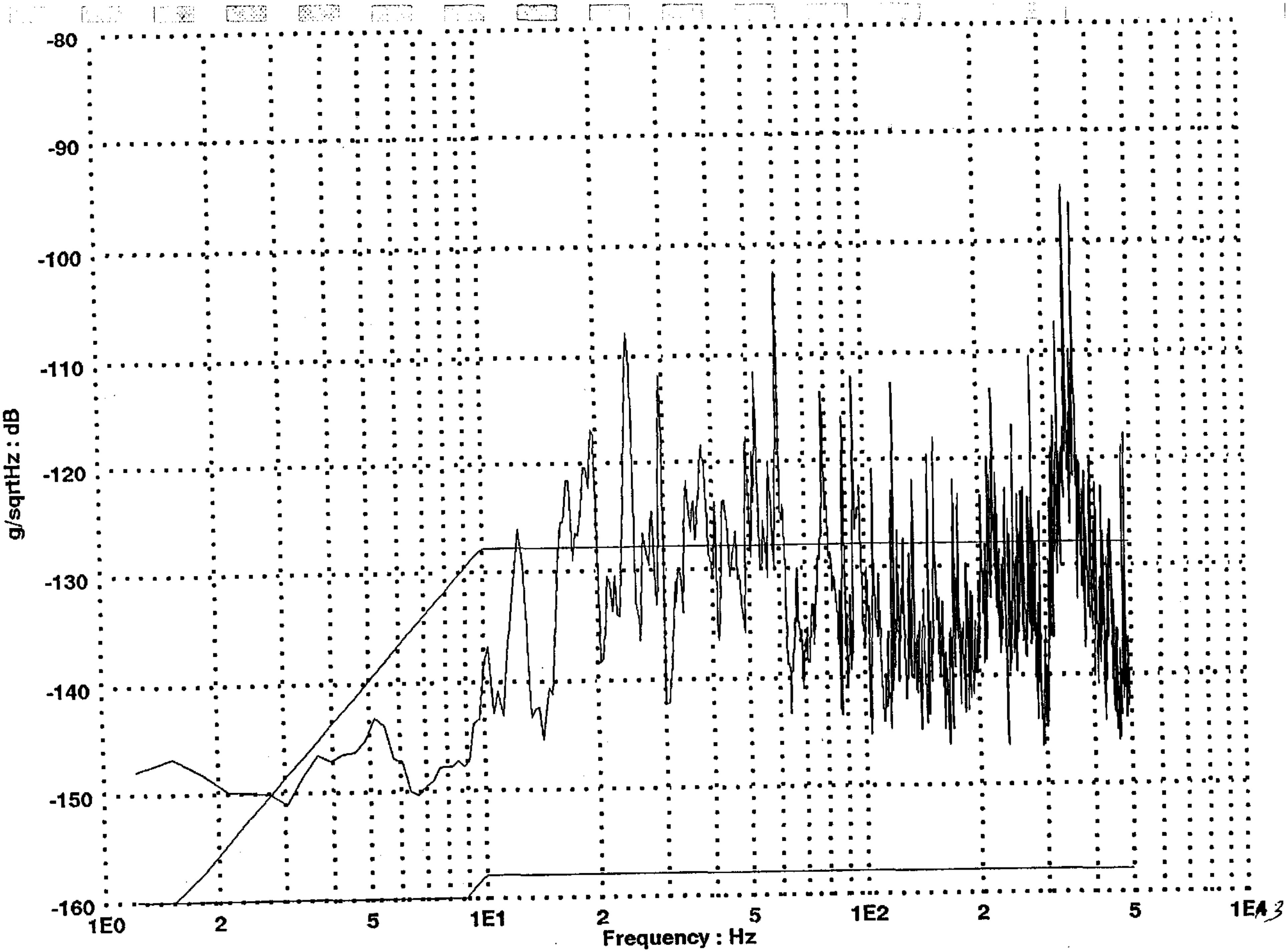
C 106



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

C37 9/26/98 Test 10, 0-Floor nr. BS 7, Cryopump, fill rate 10%

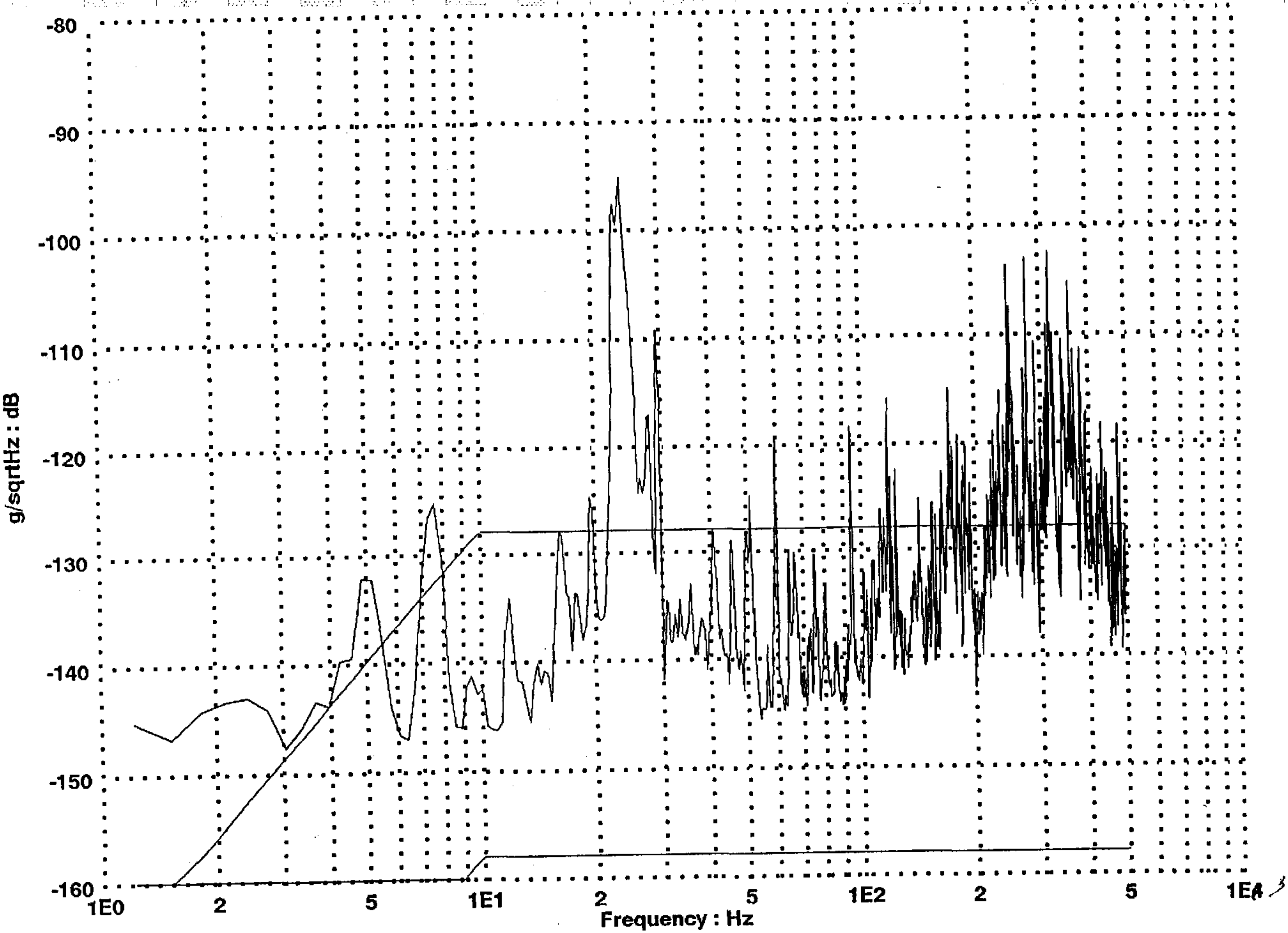
C107



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

C38 9/26/98 Test 10, 4-BS 7 nozzle, Cryopump, fill rate 10%

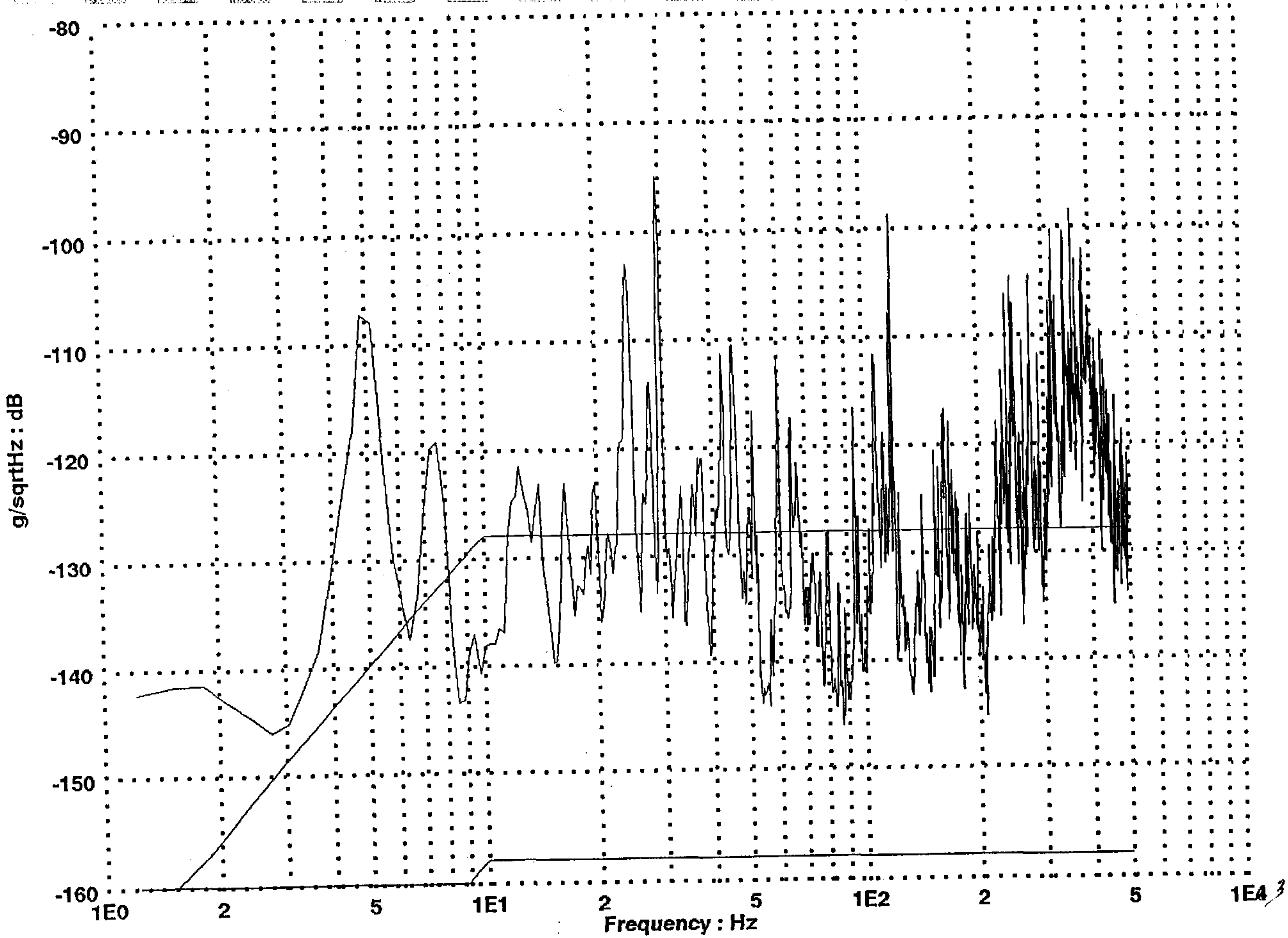
C108



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

C39 9/26/98 Test 10, 2-WBE-7 axial, Cryopump, fill rate 10%

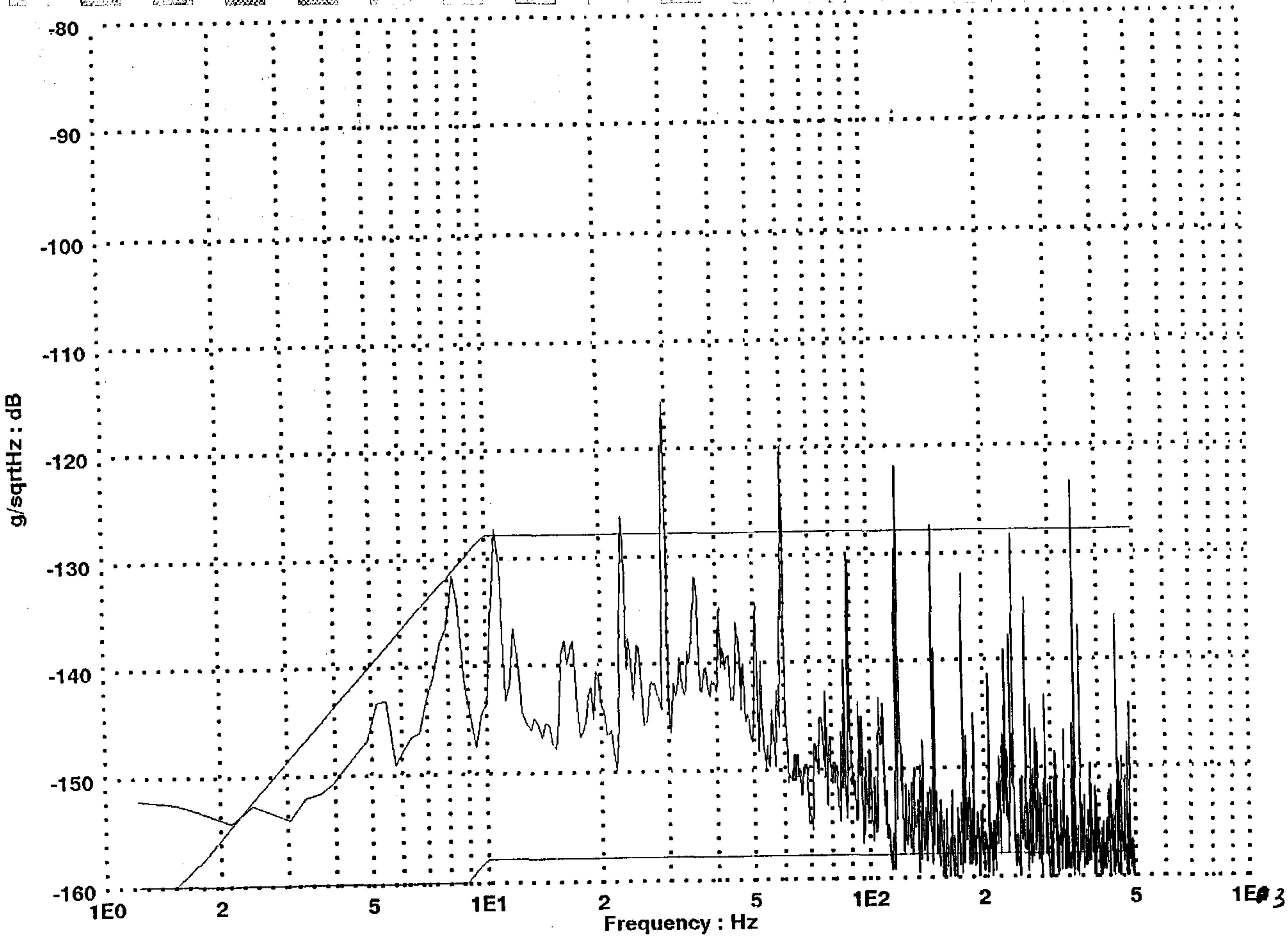
C109



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

C40 9/26/98 Test 10, 2-WBE-7 radial, Cryopump, fill rate 10%

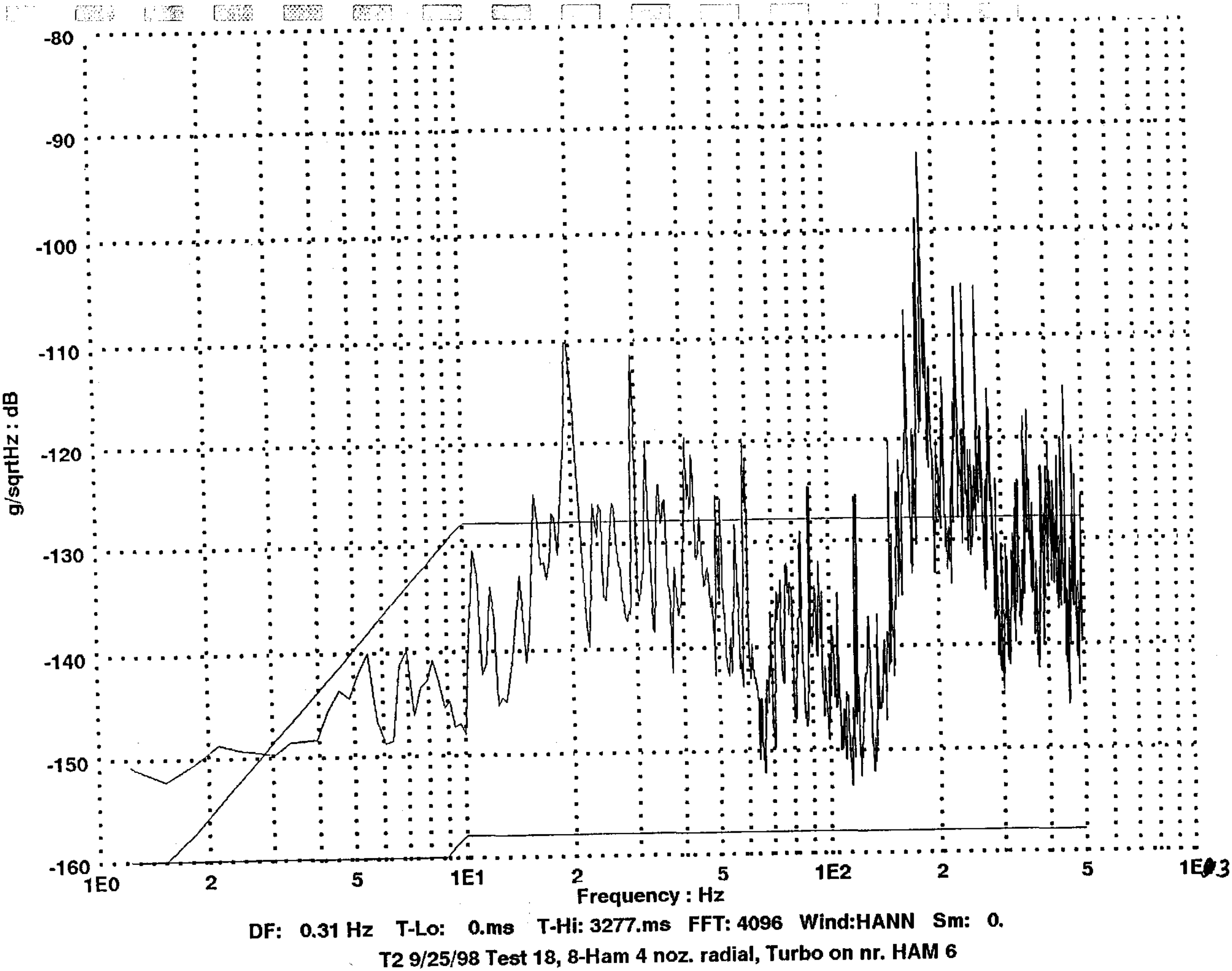
C 110



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

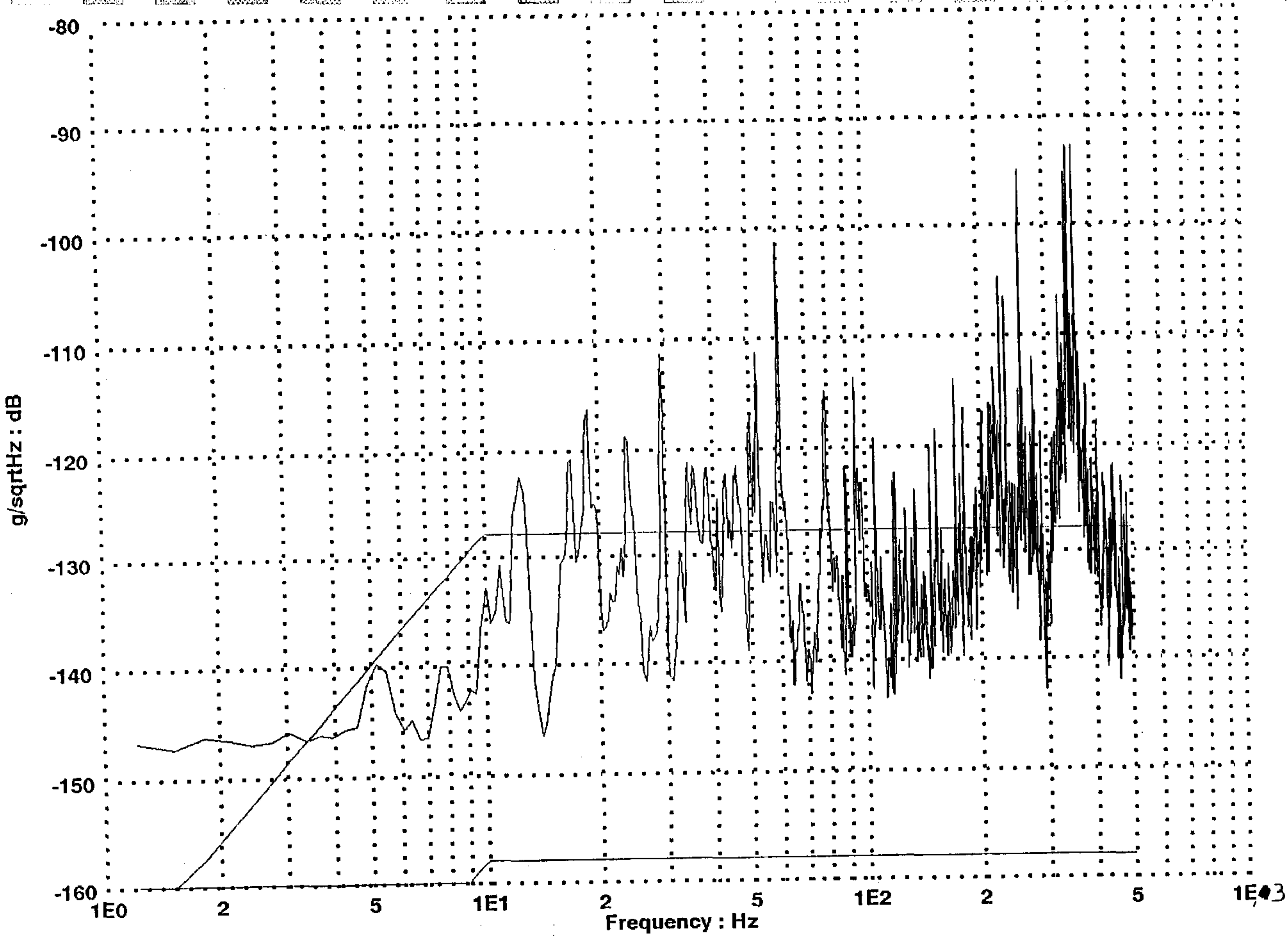
T1 9/25/98 Test 18, 0-Floor nr. BS 7, Turbo on nr. Ham 6

111



-80
-90
-100
-110
-120
-130
-140
-150
-160
g/sqrtHz : dB
1E0
2
5
1E1
2
5
1E2
2
5
1E#3
Frequency : Hz
DF: 0.31 Hz T-Lo: 0.ms T-Hi: 3277.ms FFT: 4096 Wind:HANN Sm: 0.
T2 9/25/98 Test 18, 8-Ham 4 noz. radial, Turbo on nr. HAM 6

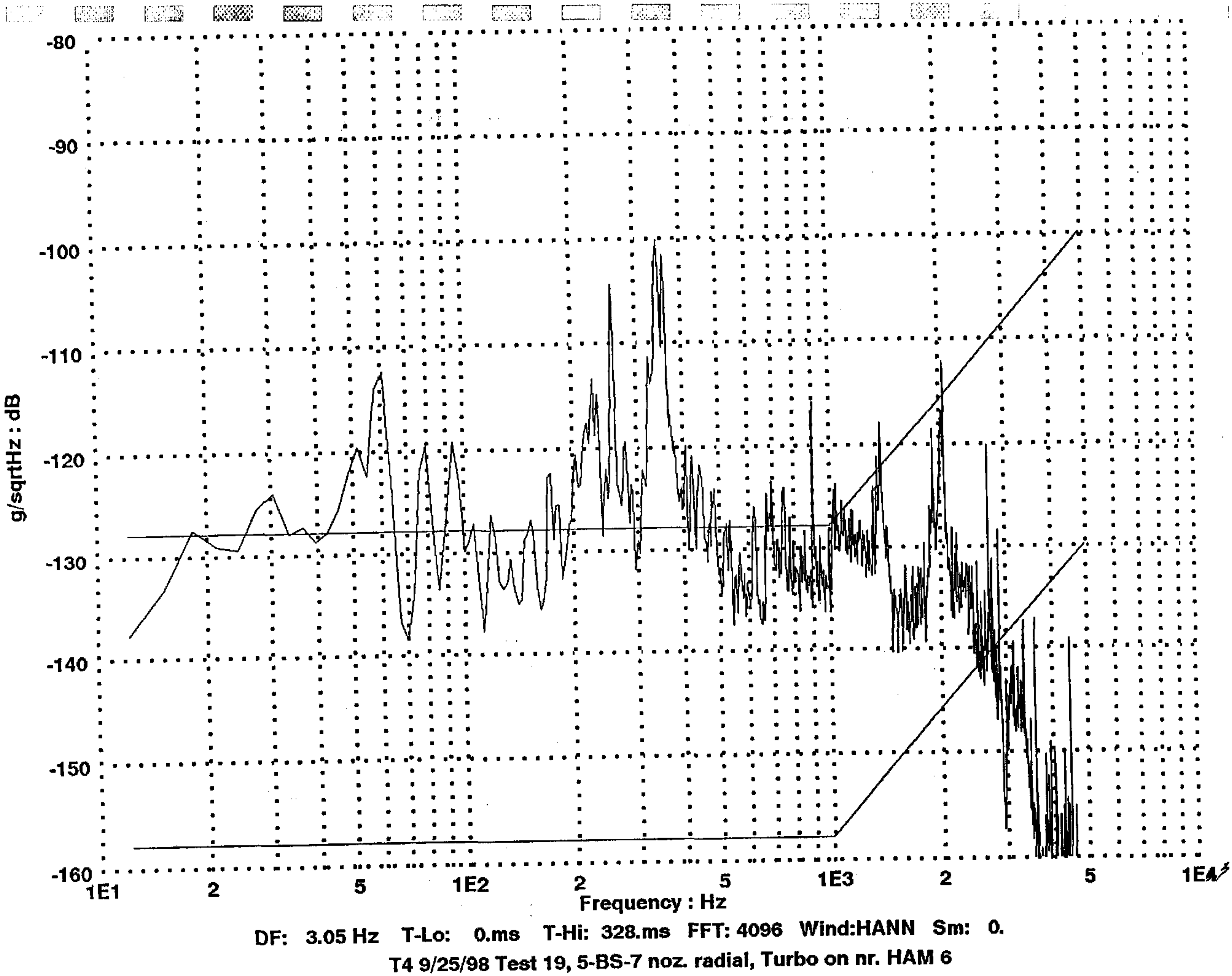
2112



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

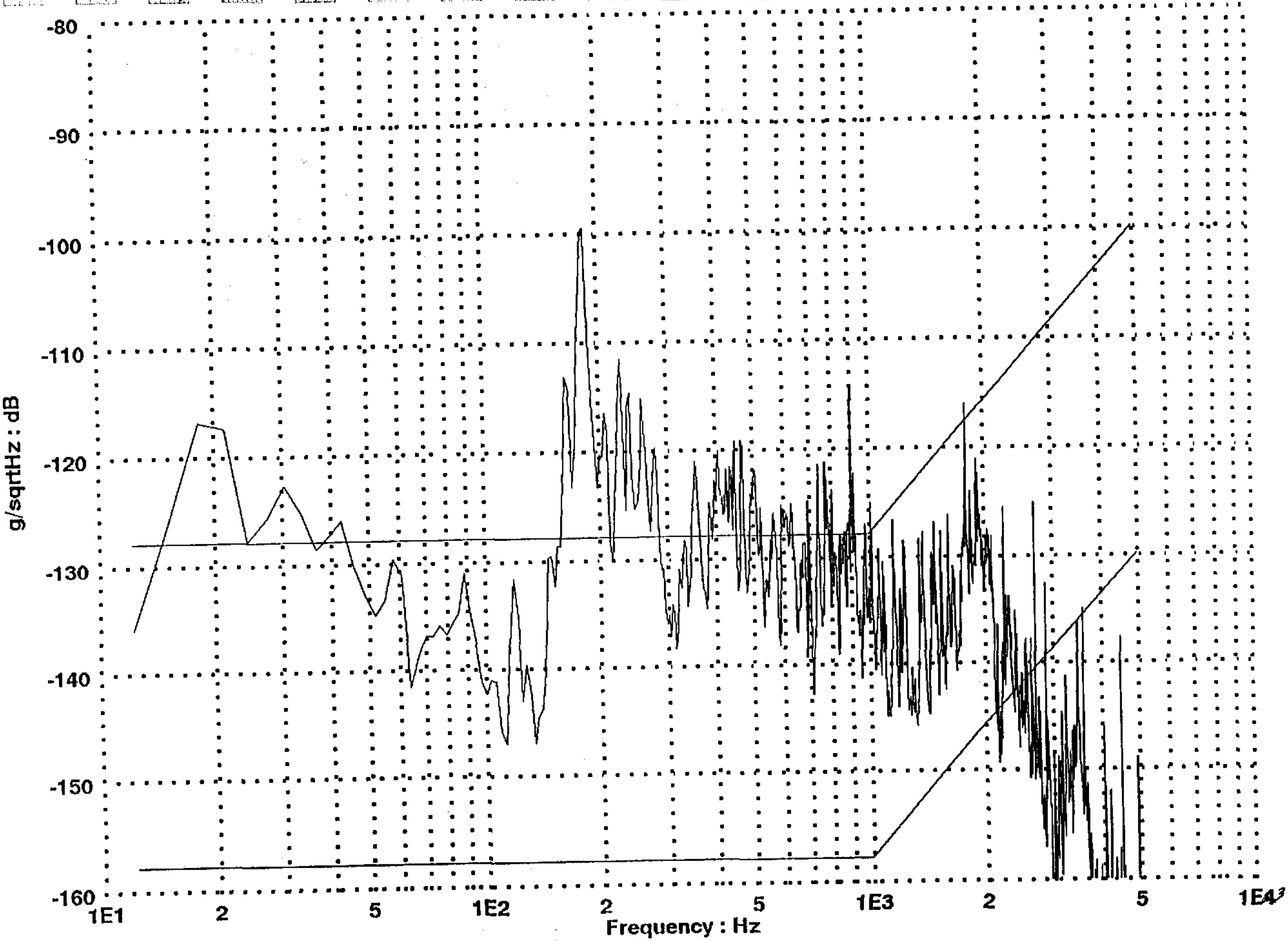
T3 9/25/98 Test 18, 5-BS-7 nozzle, Turbo on nr HAM 6

C113



-80
-90
-100
-110
-120
-130
-140
-150
-160
g/sqrtHz : dB
1E1
2
5
1E2
2
5
1E3
2
5
1E4
Frequency : Hz
DF: 3.05 Hz T-Lo: 0.ms T-Hi: 328.ms FFT: 4096 Wind:HANN Sm: 0.
T4 9/25/98 Test 19, 5-BS-7 noz. radial, Turbo on nr. HAM 6

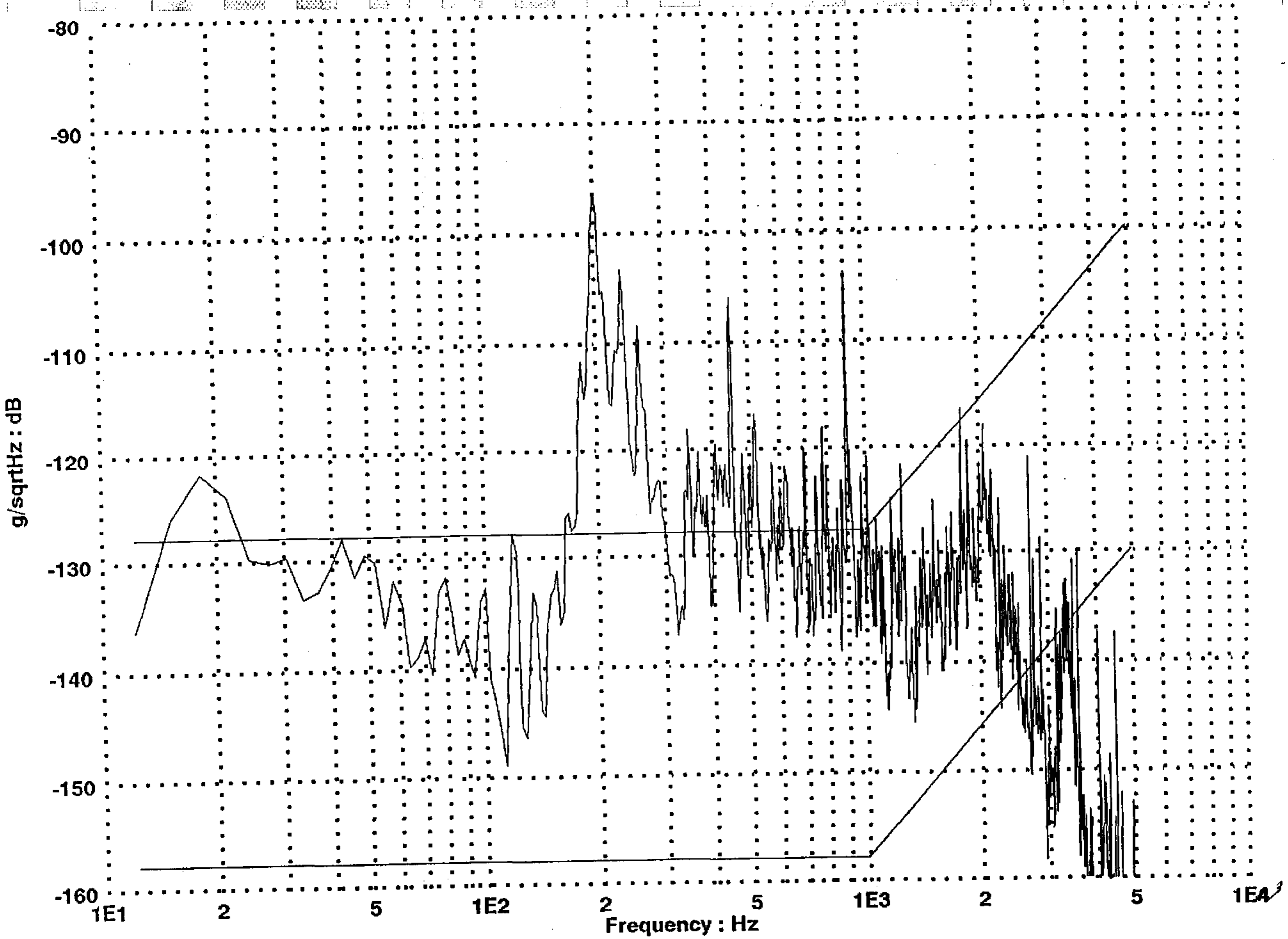
C114



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

T5 9/25/98 Test 19, 5-HAM-4 noz. radial, Turbo on nr HAM 6

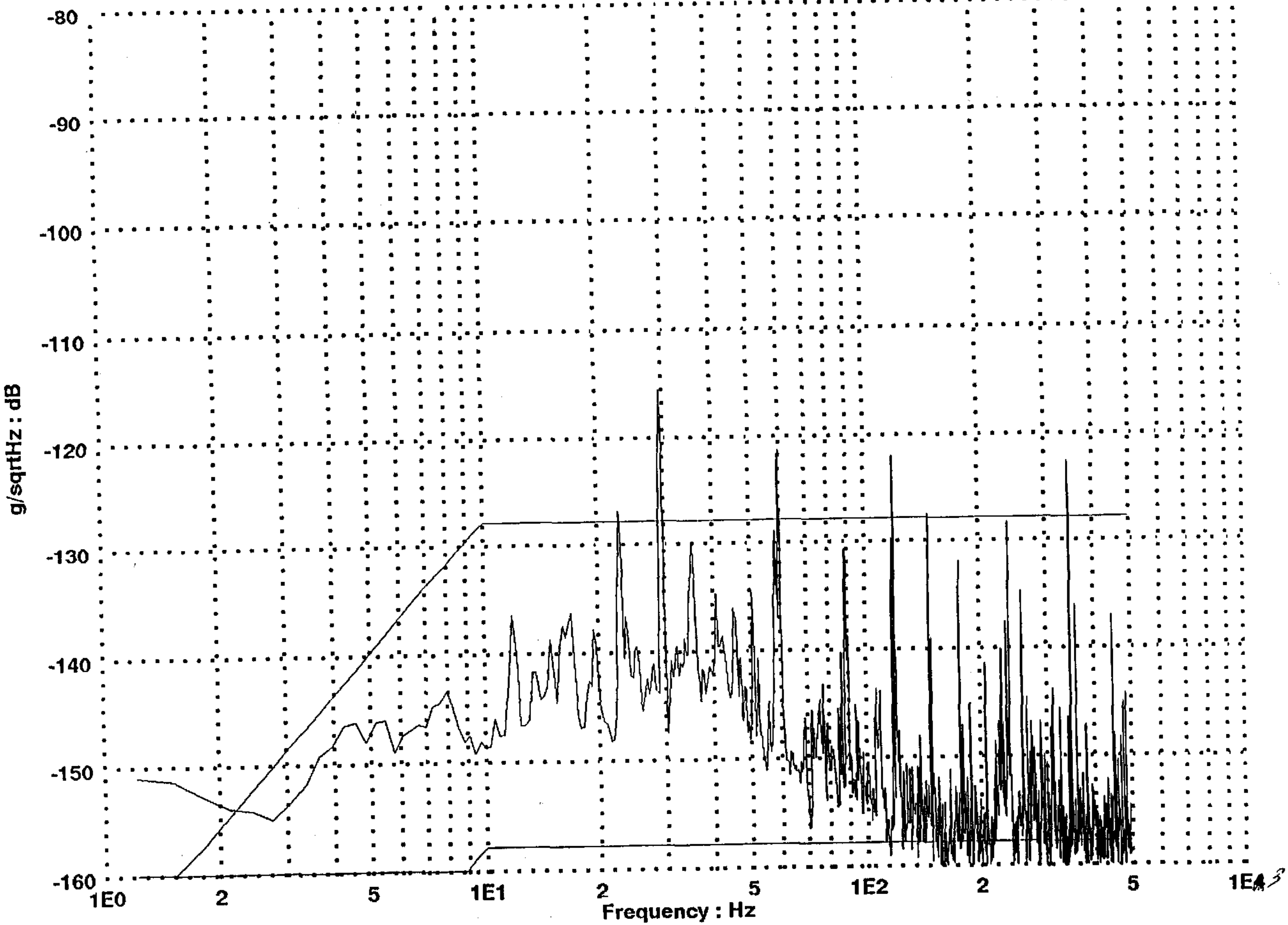
C115



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

T6 9/25/98 Test 19, 10-Ham 6 noz. axial, Turbo on nr. HAM 6

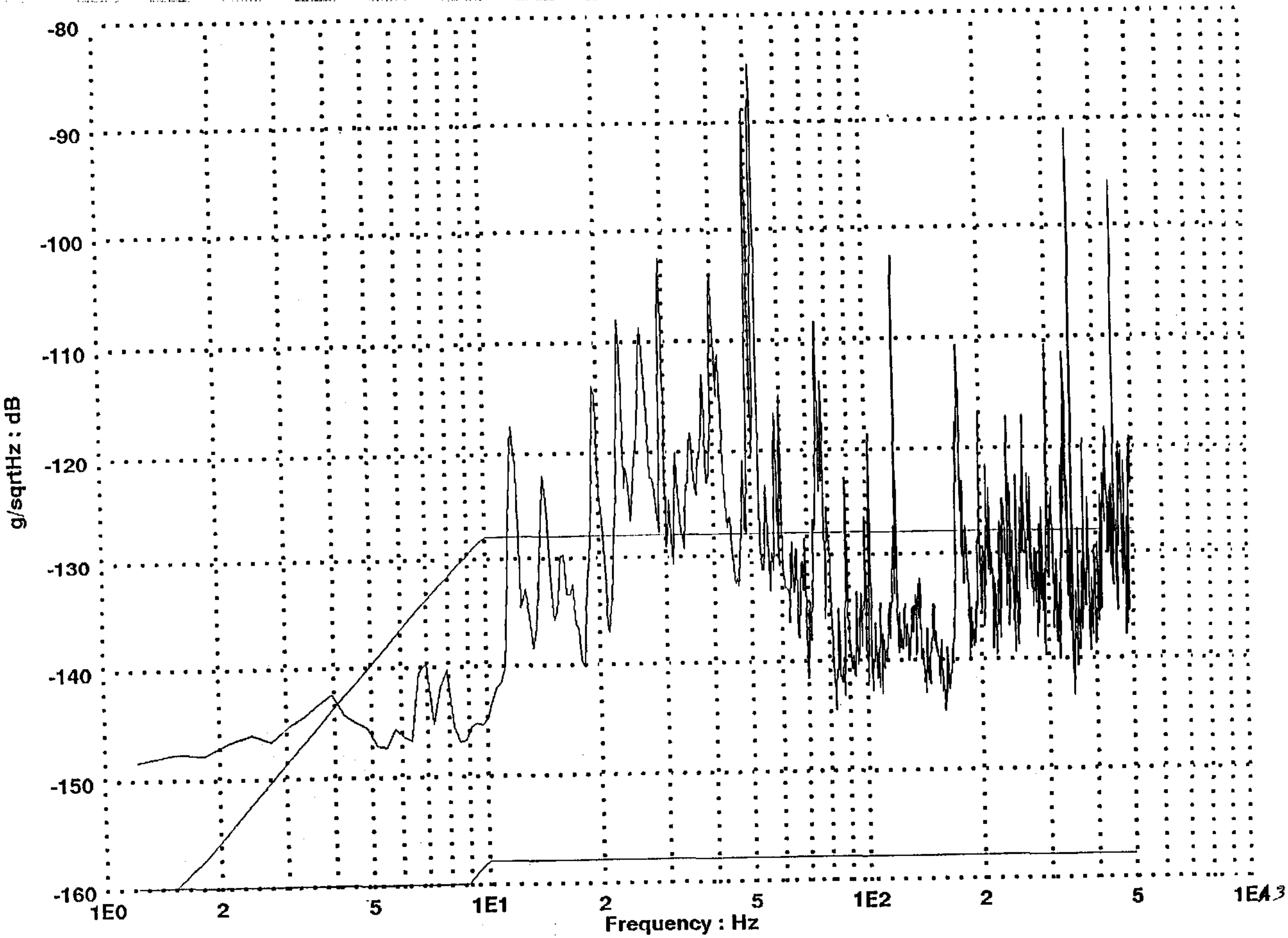
C-116



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

T7 9/25/98 Test 20, 0-Floor nr. BS 7, Turbo on nr. Ham 6

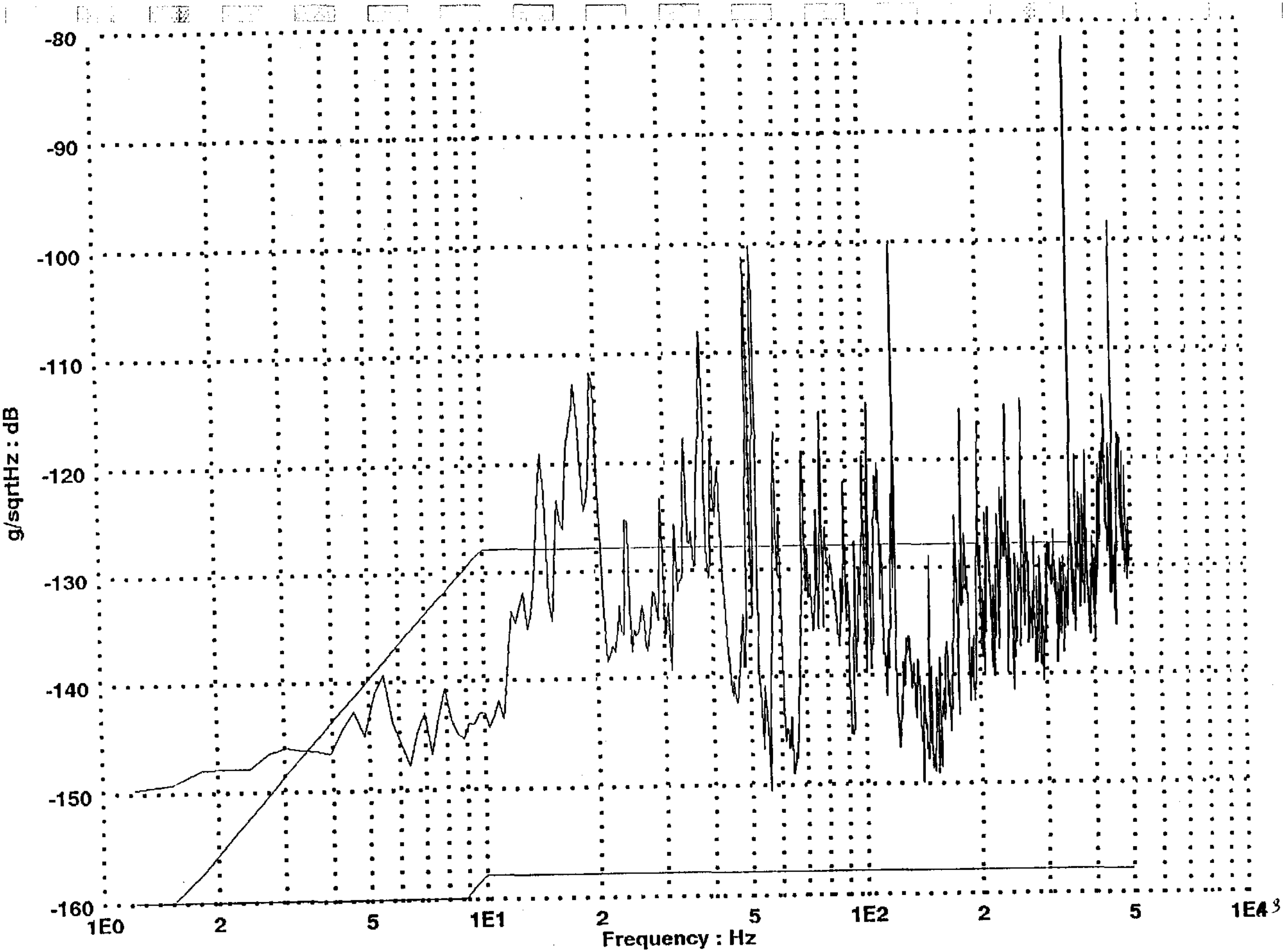
C-117



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

T8 9/25/98 Test 20, 9-Ham 6 flange axial, Turbo on nr. HAM 6

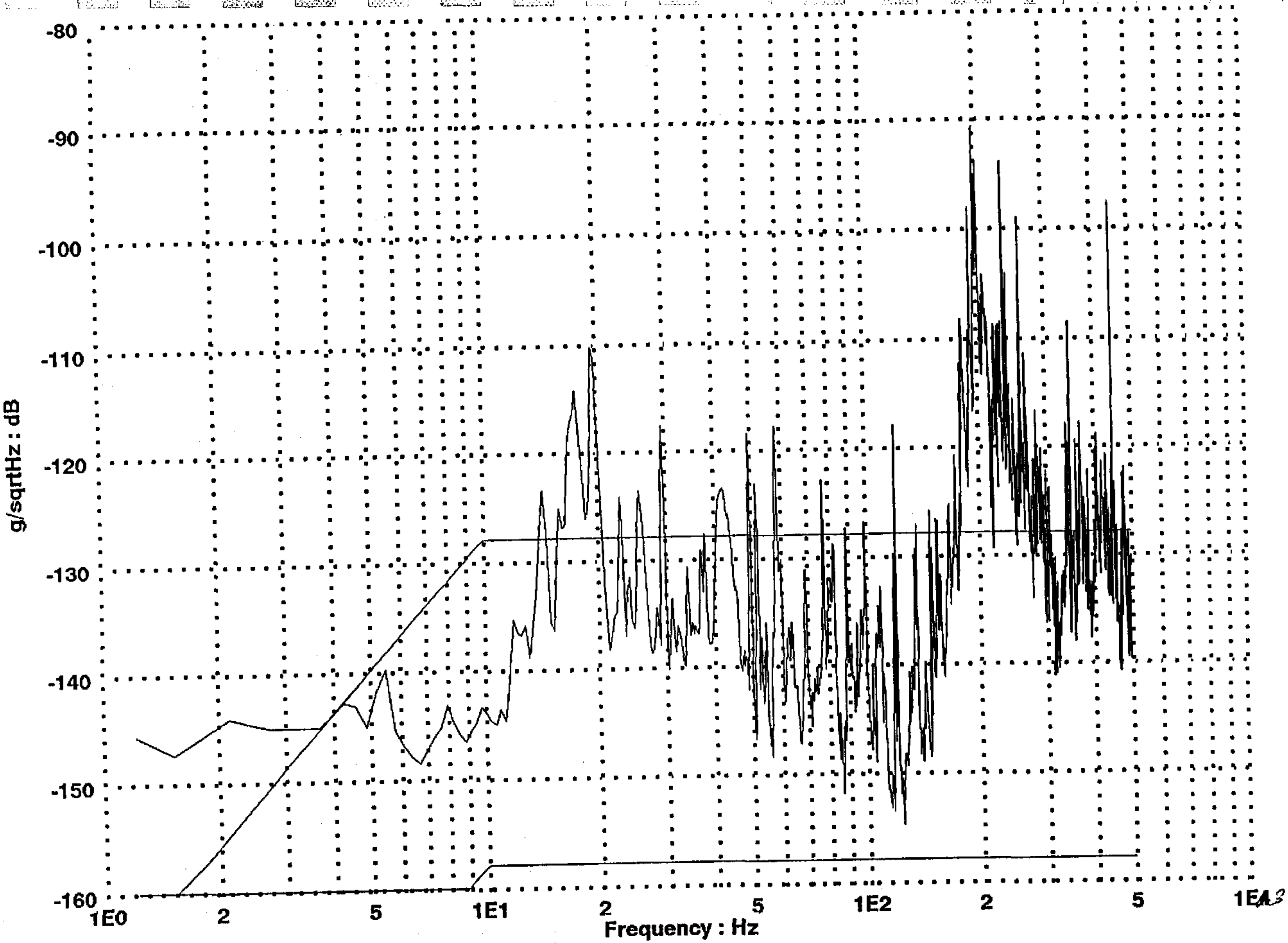
8/17



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

T9 9/25/98 Test 20, 9-Ham 6 flange radial, Turbo on nr HAM 6

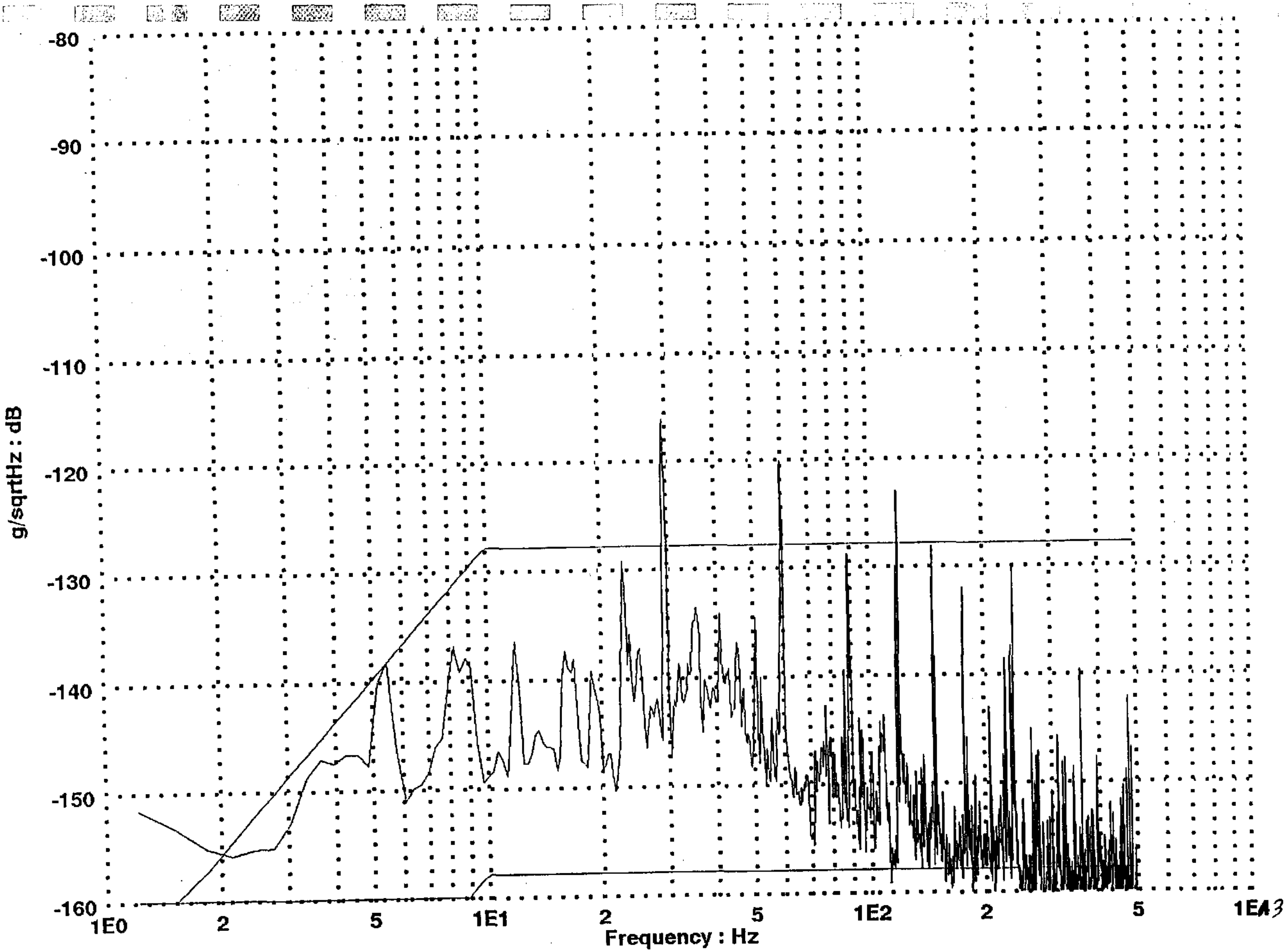
C/19



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

T10 9/25/98 Test 20, 10-Ham 6 noz. radial, Turbo on nr. HAM 6

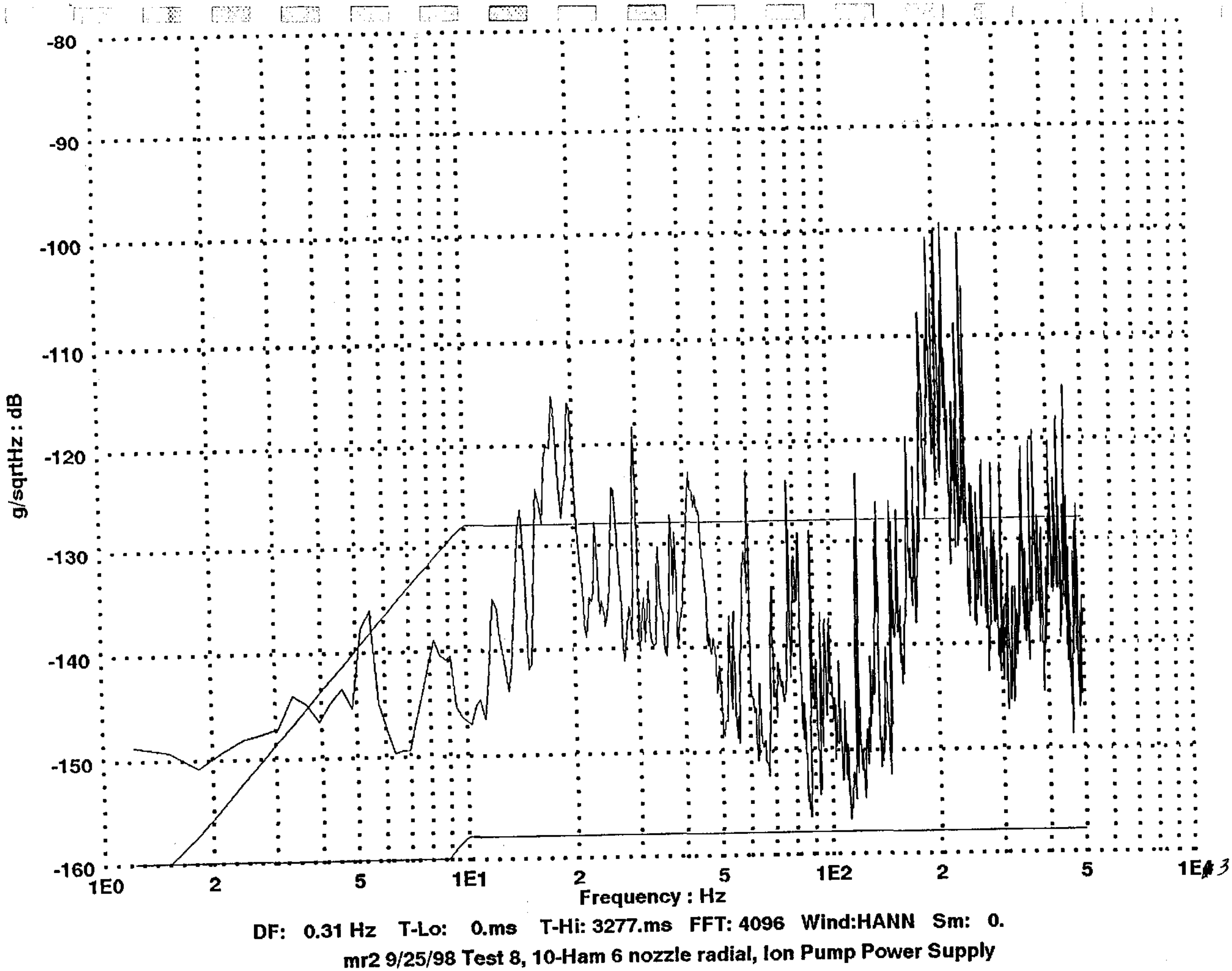
C/20



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

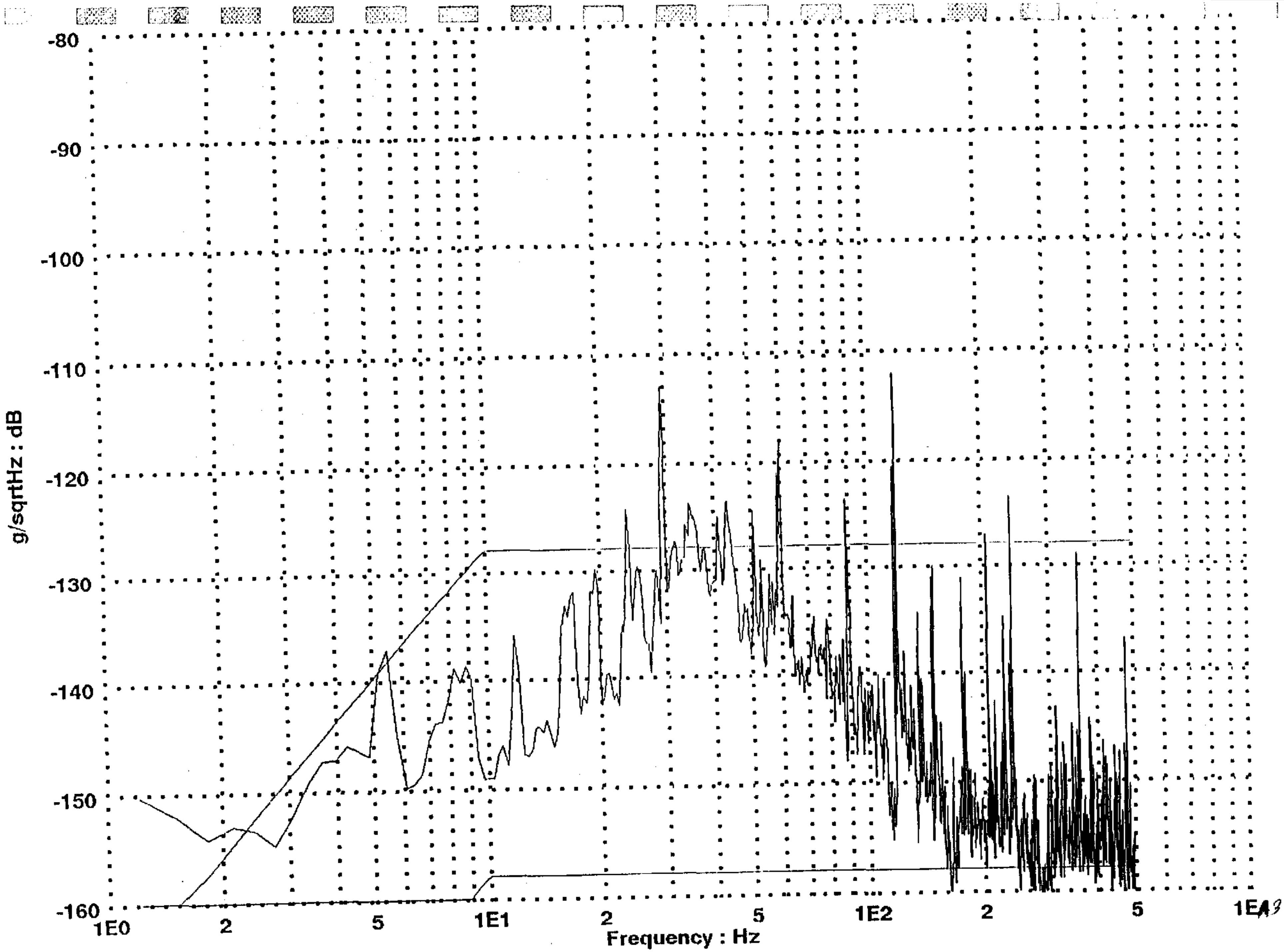
mr1 9/25/98 Test 8, 0-Floor nr. BS 7, Ion Pump Power Supply

C121



-80
-90
-100
-110
-120
-130
-140
-150
-160
g/sqrtHz : dB
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.
mr2 9/25/98 Test 8, 10-Ham 6 nozzle radial, Ion Pump Power Supply

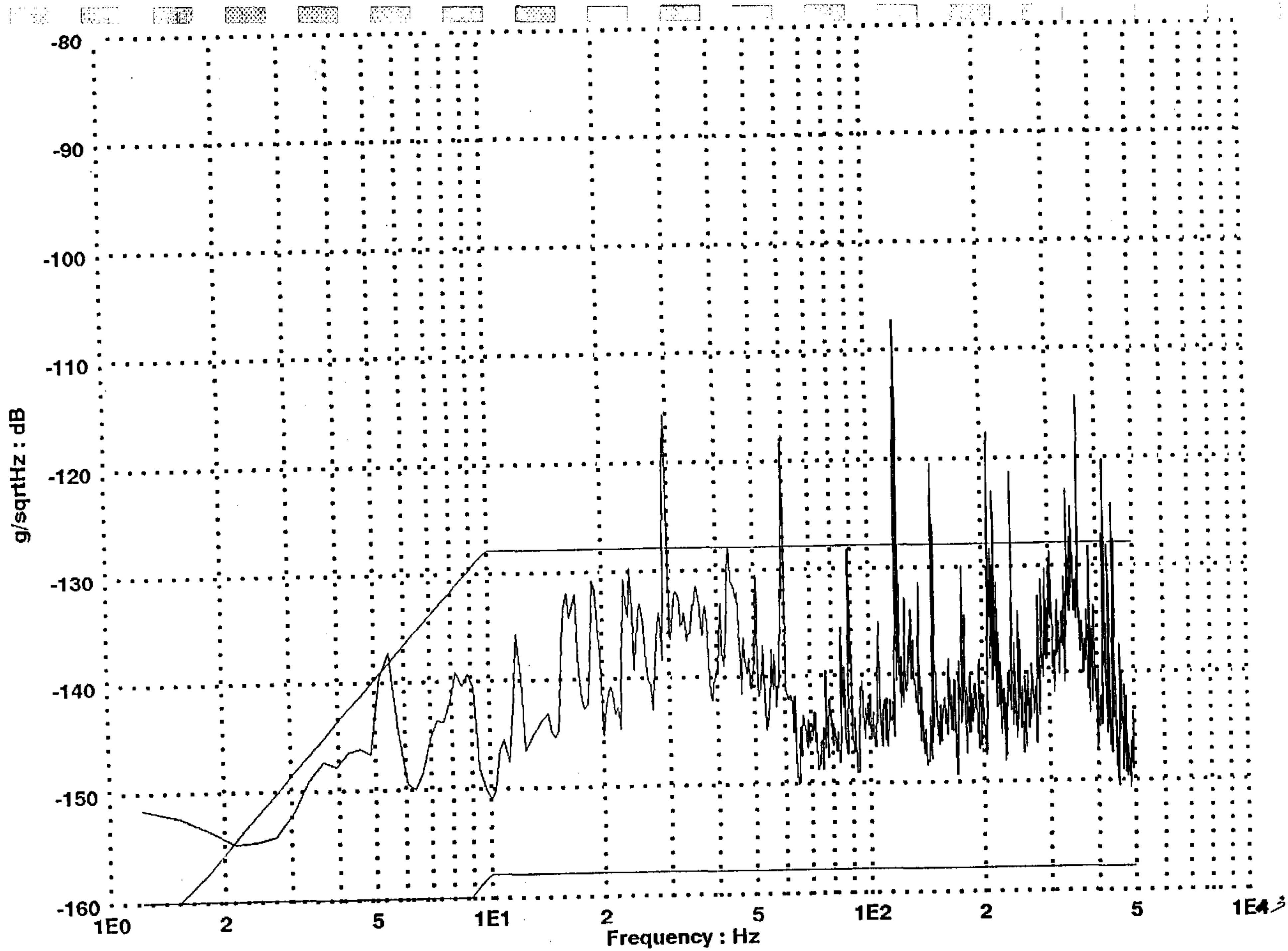
C122



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

mr3 9/25/98 Test 8, 11-Floor VEA nr. Mech. Rm., Ion Pump Power Supply

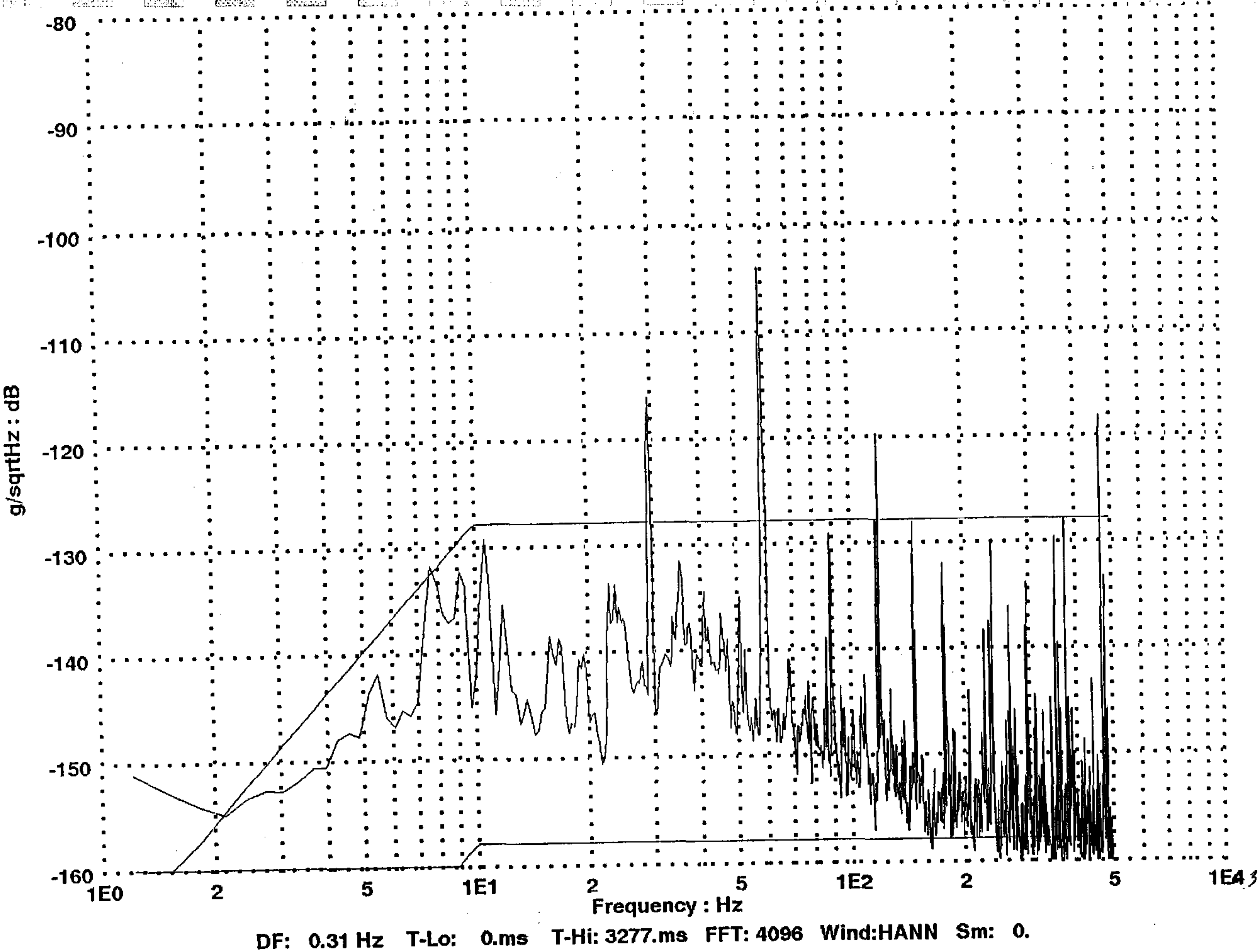
C123



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

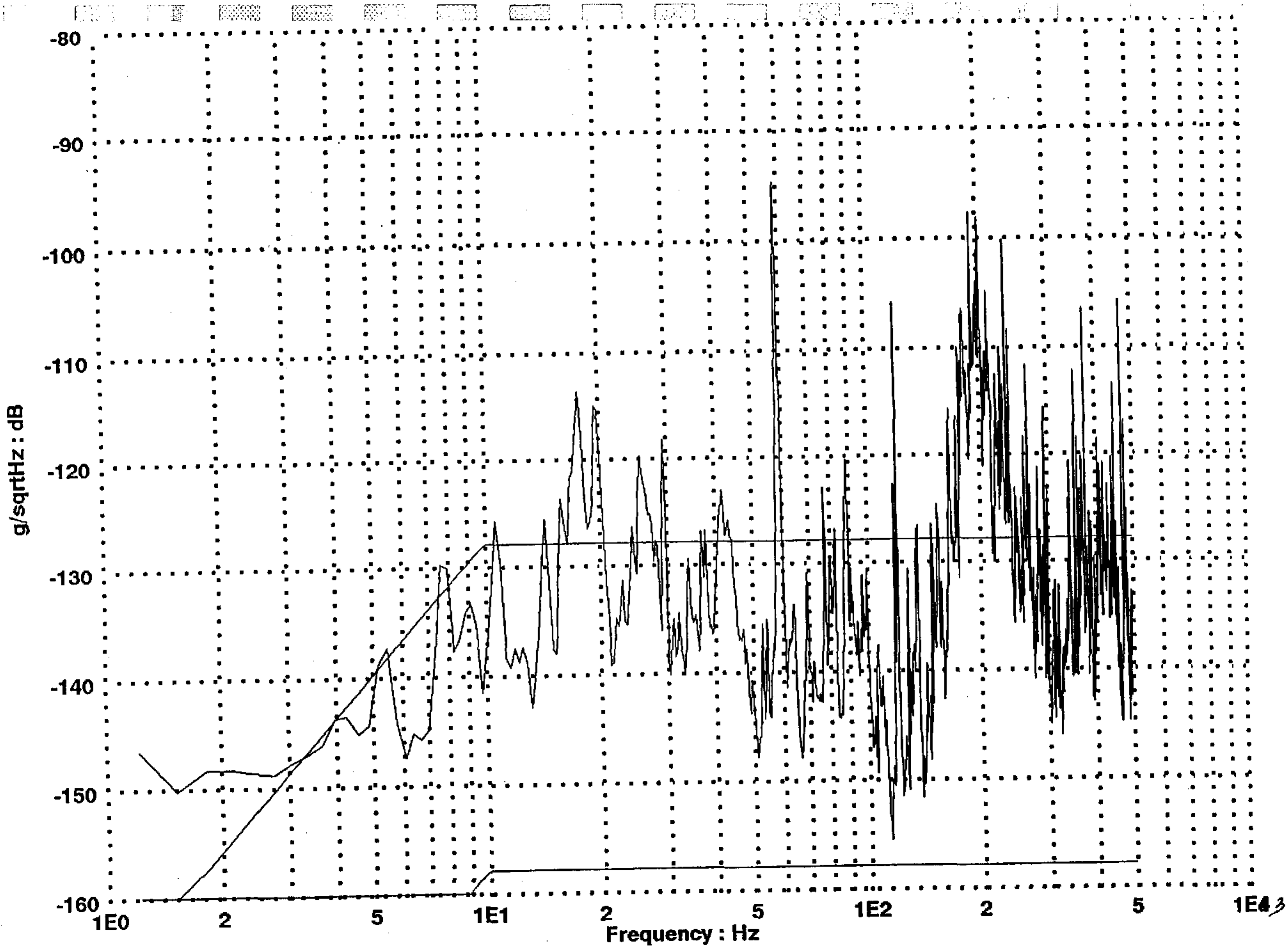
mr4 9/25/98 Test 8, 12-Floor Mech. Rm.nr. VEA, Ion Pump Power Supply

C124



mr5 9/25/98 Test 9, 0-Floor nr. BS 7, Backing Pump

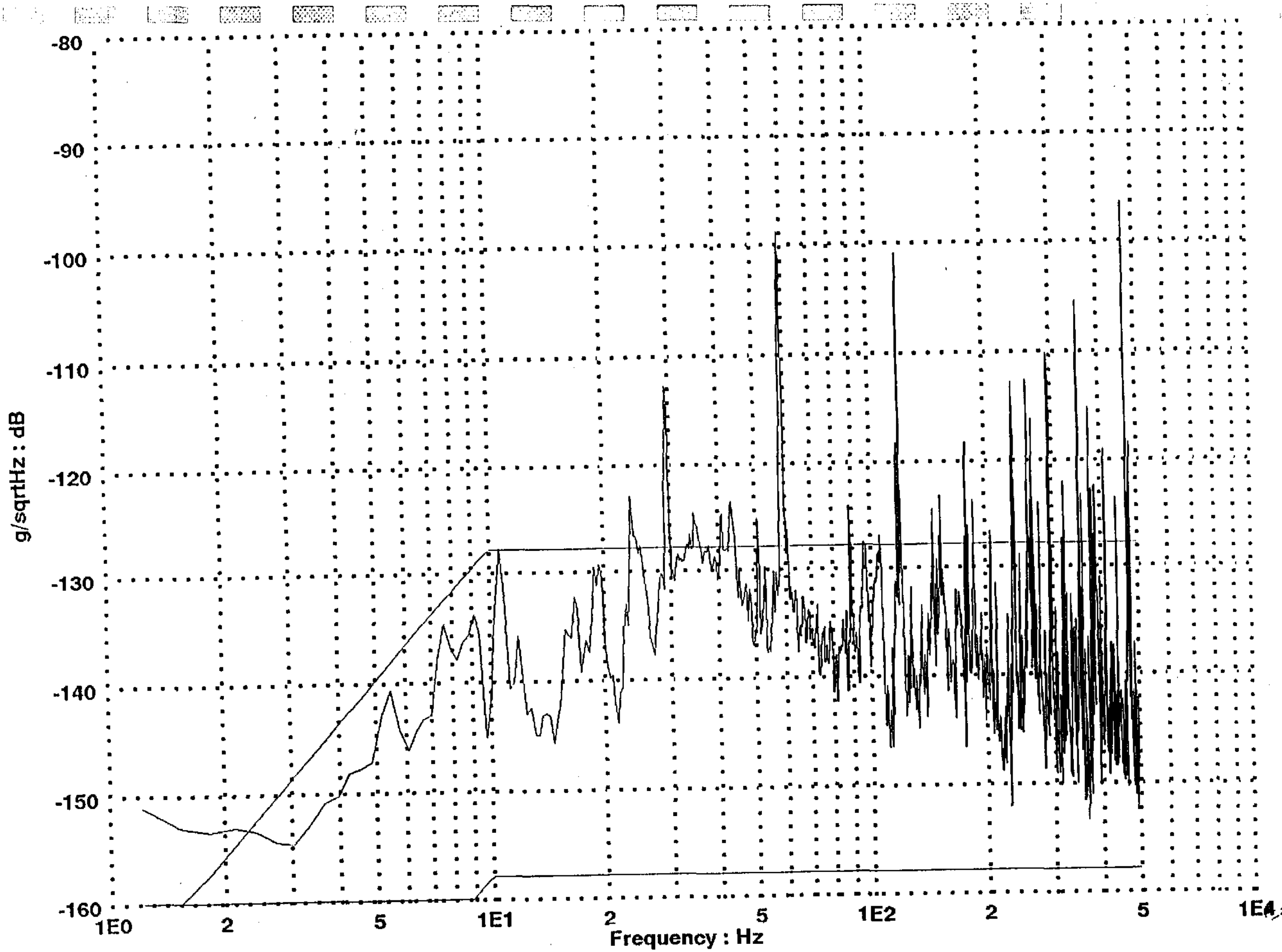
C-125



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

mr6 9/25/98 Test 9, 10-Ham 6 nozzle radial, Backing Pump

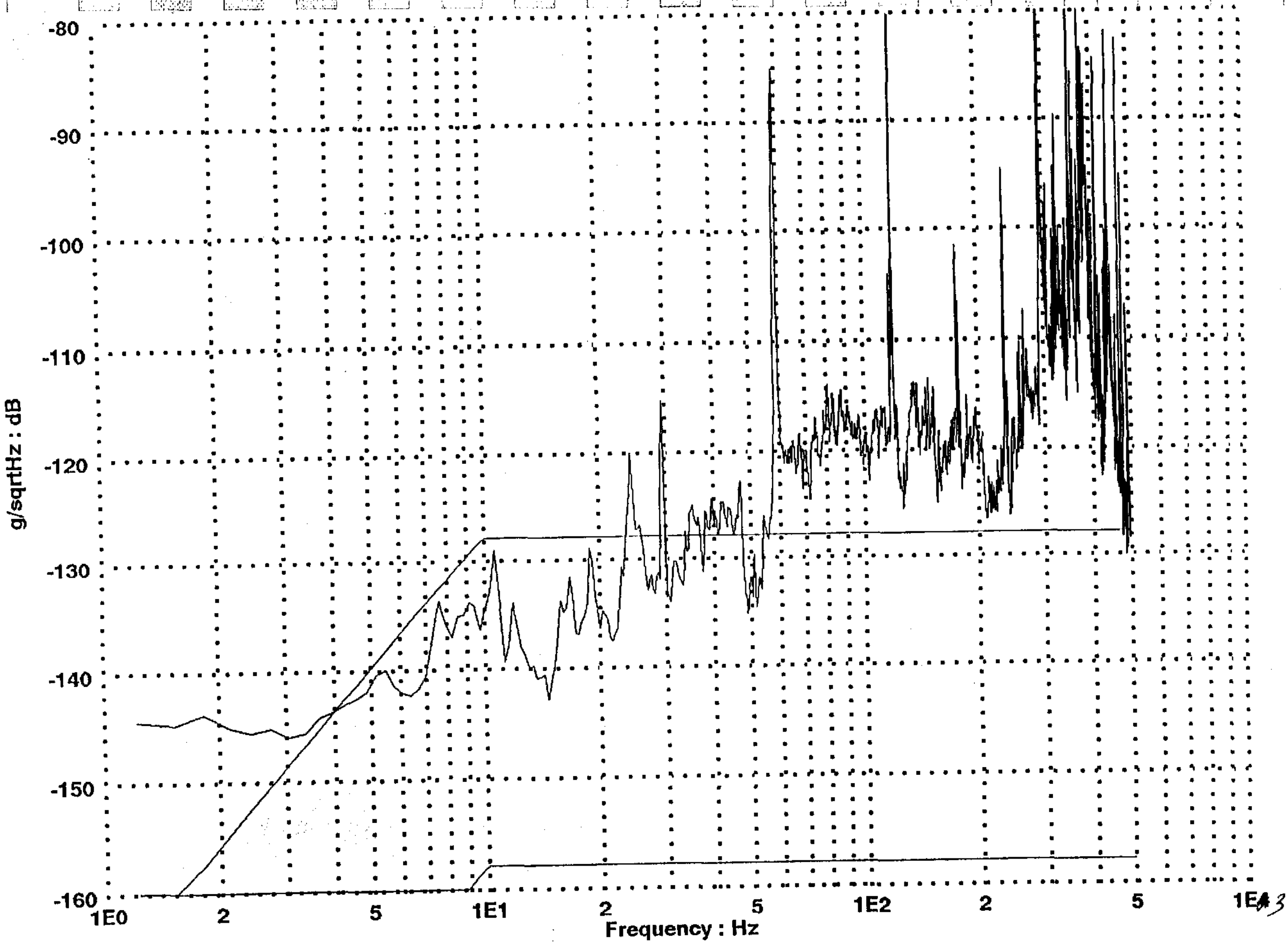
C-126



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

mr7 9/25/98 Test 9, 11-Floor VEA nr. Mech. Rm., Backing Pump

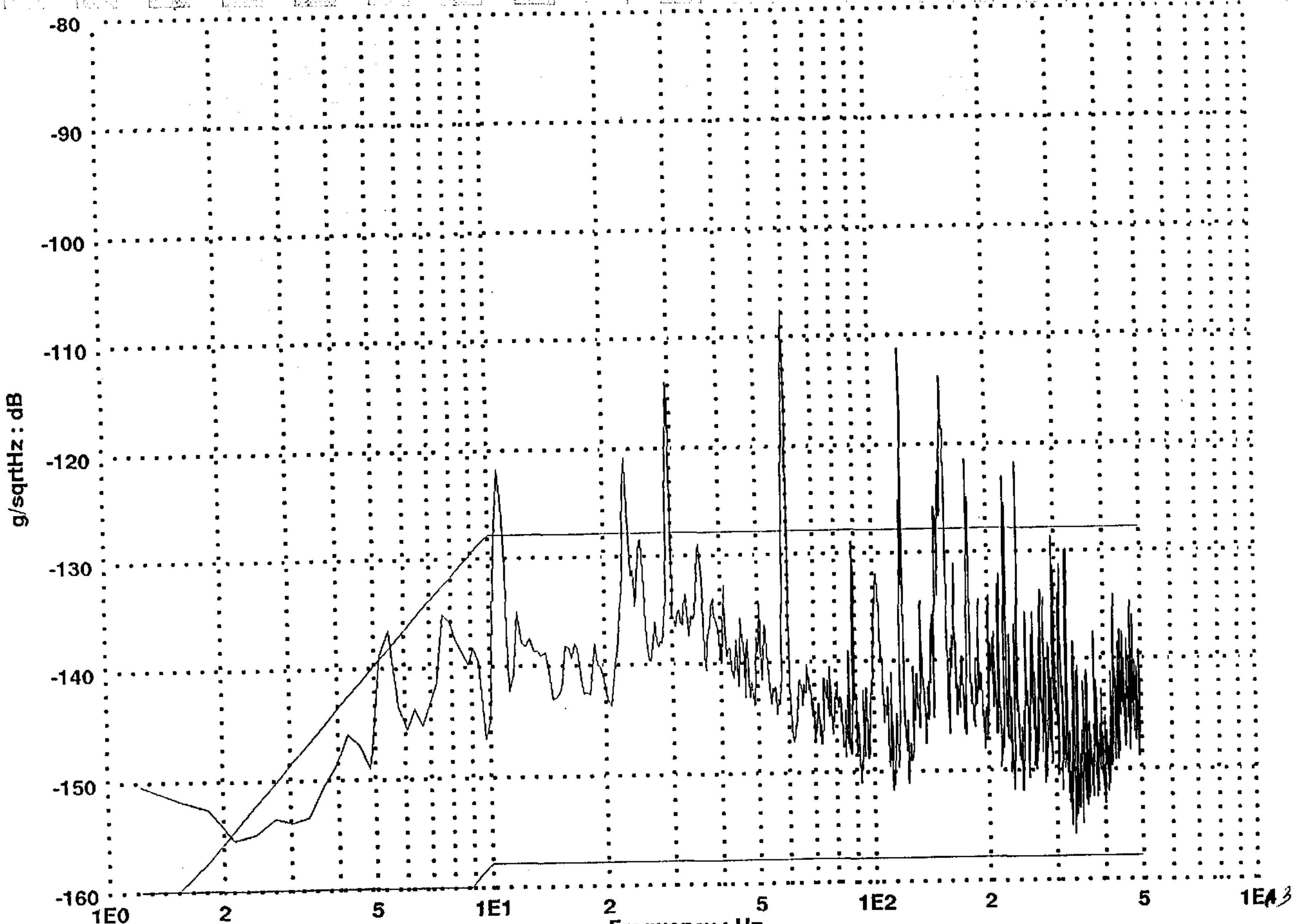
C127



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

mr8 9/25/98 Test 9, 12-Floor Mech. Rm.nr. VEA, Backing Pump

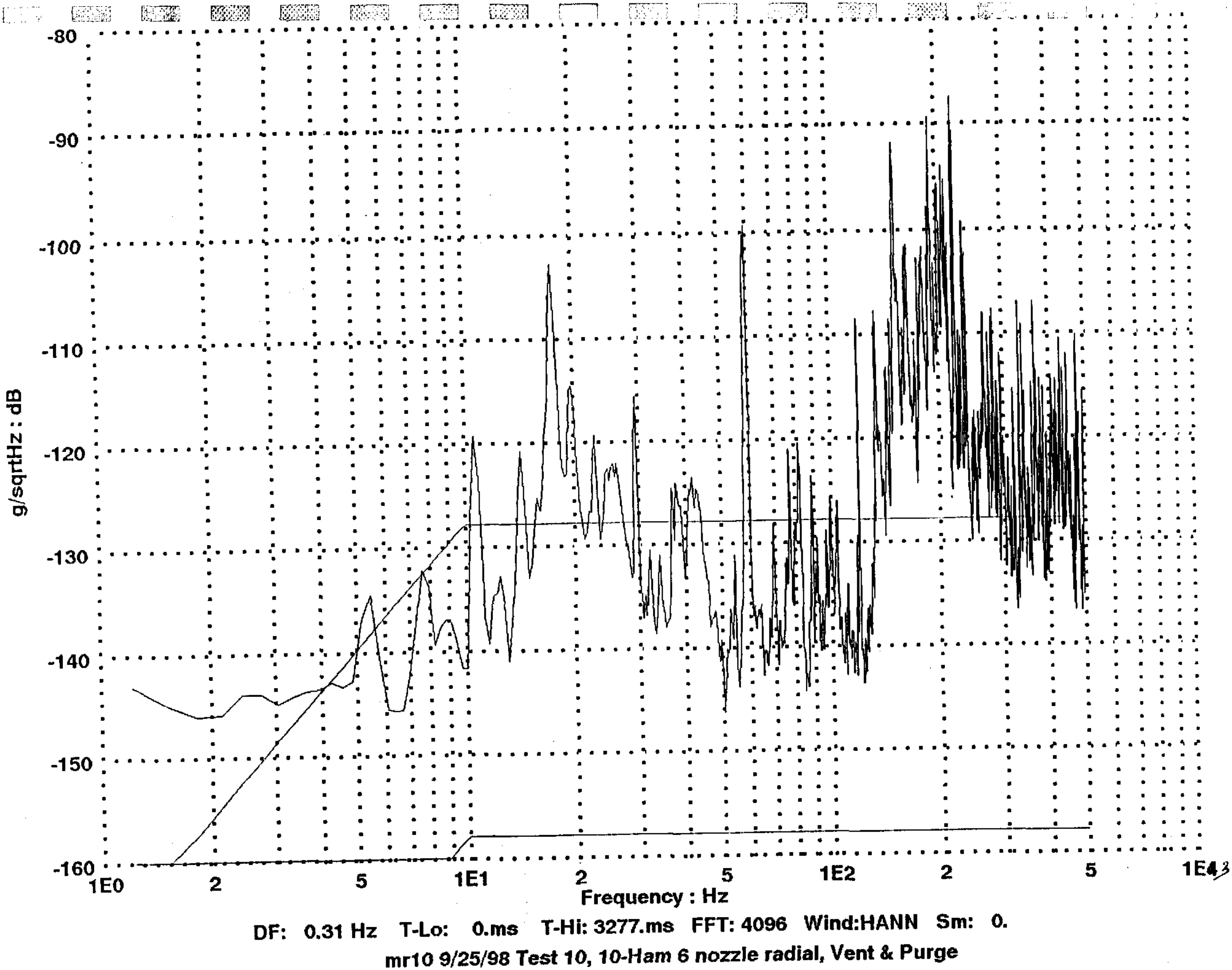
C128



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

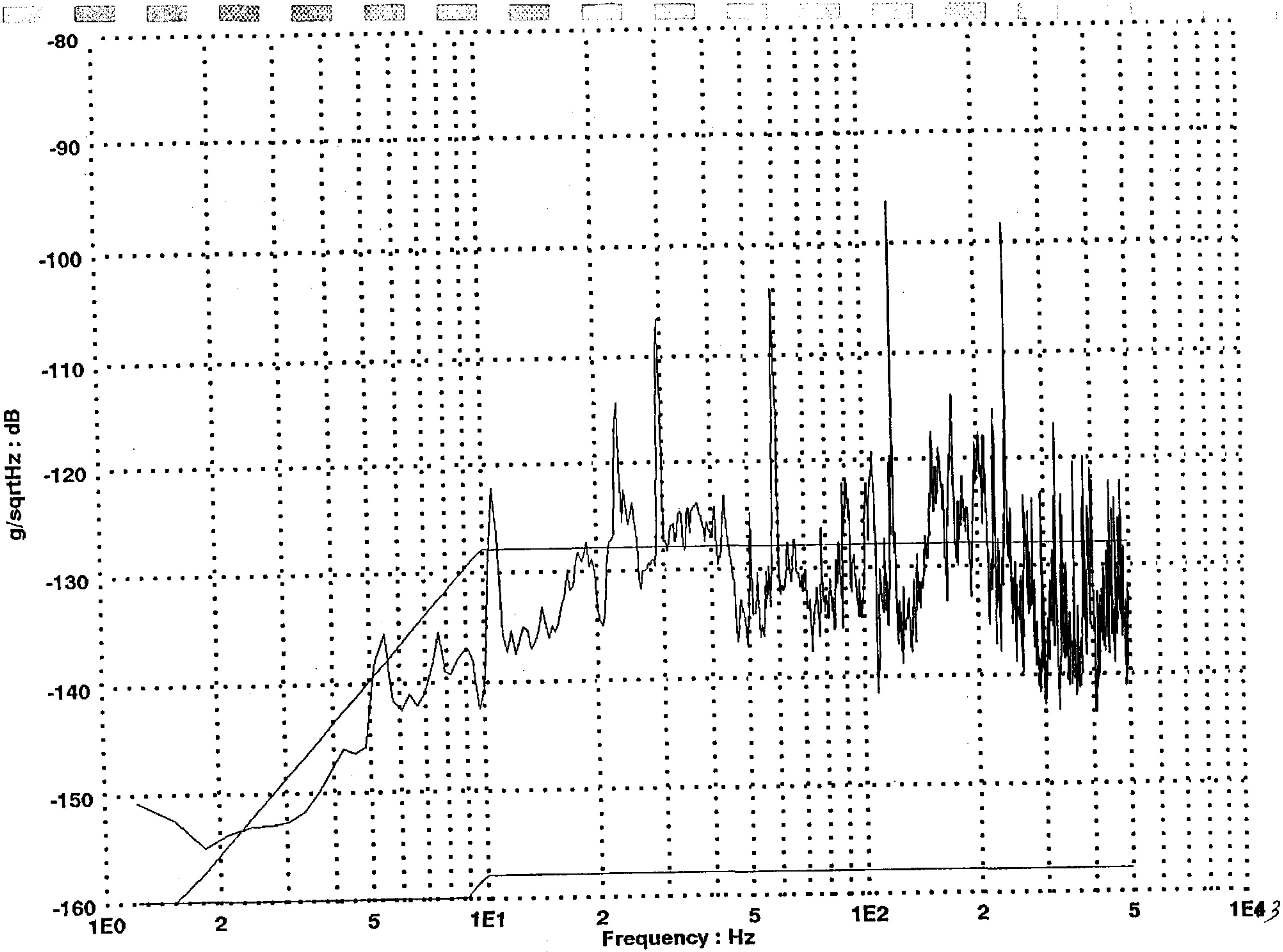
mr9 9/25/98 Test 10, 0-Floor nr. BS 7, Vent and Purge

C129



-80
-90
-100
-110
-120
-130
-140
-150
-160
g/sqrtHz : dB
1E0
2
5
1E1
2
5
1E2
2
5
1E4
Frequency : Hz
DF: 0.31 Hz T-Lo: 0.ms T-Hi: 3277.ms FFT: 4096 Wind:HANN Sm: 0.
mr10 9/25/98 Test 10, 10-Ham 6 nozzle radial, Vent & Purge

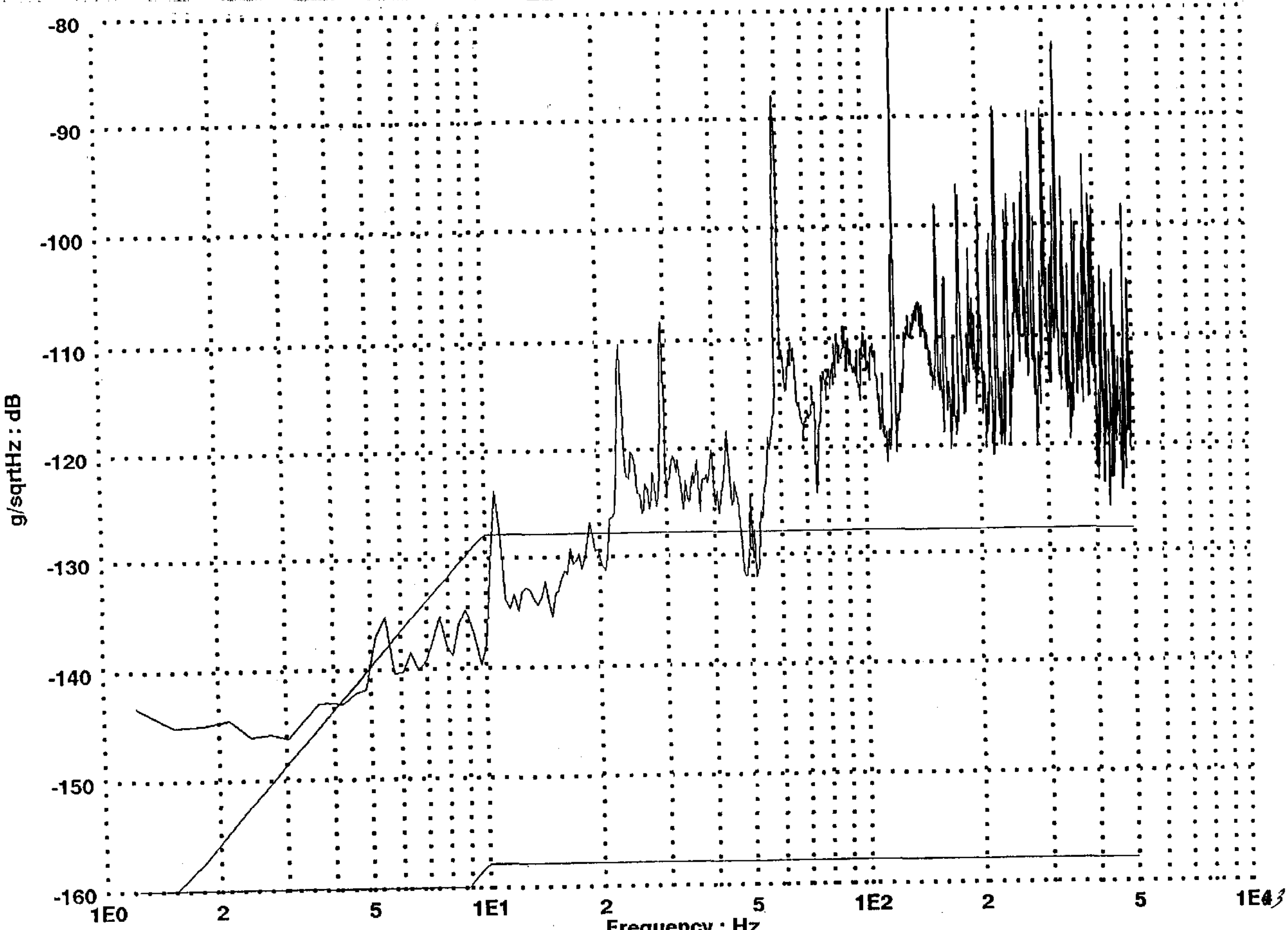
C130



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

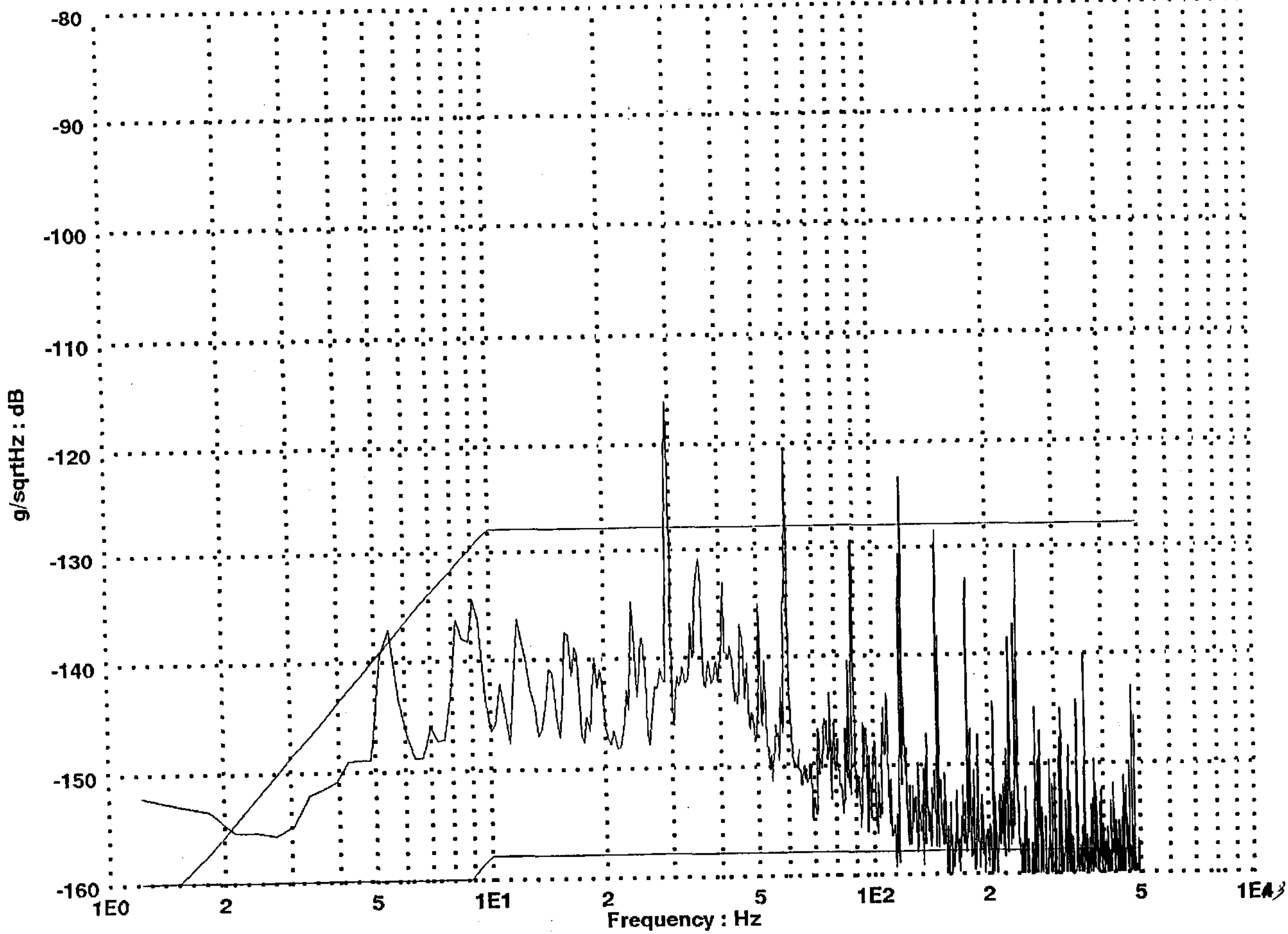
mr11 9/25/98 Test 10, 11-Floor VEA nr. Mech. Rm., Vent and Purge

C131



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

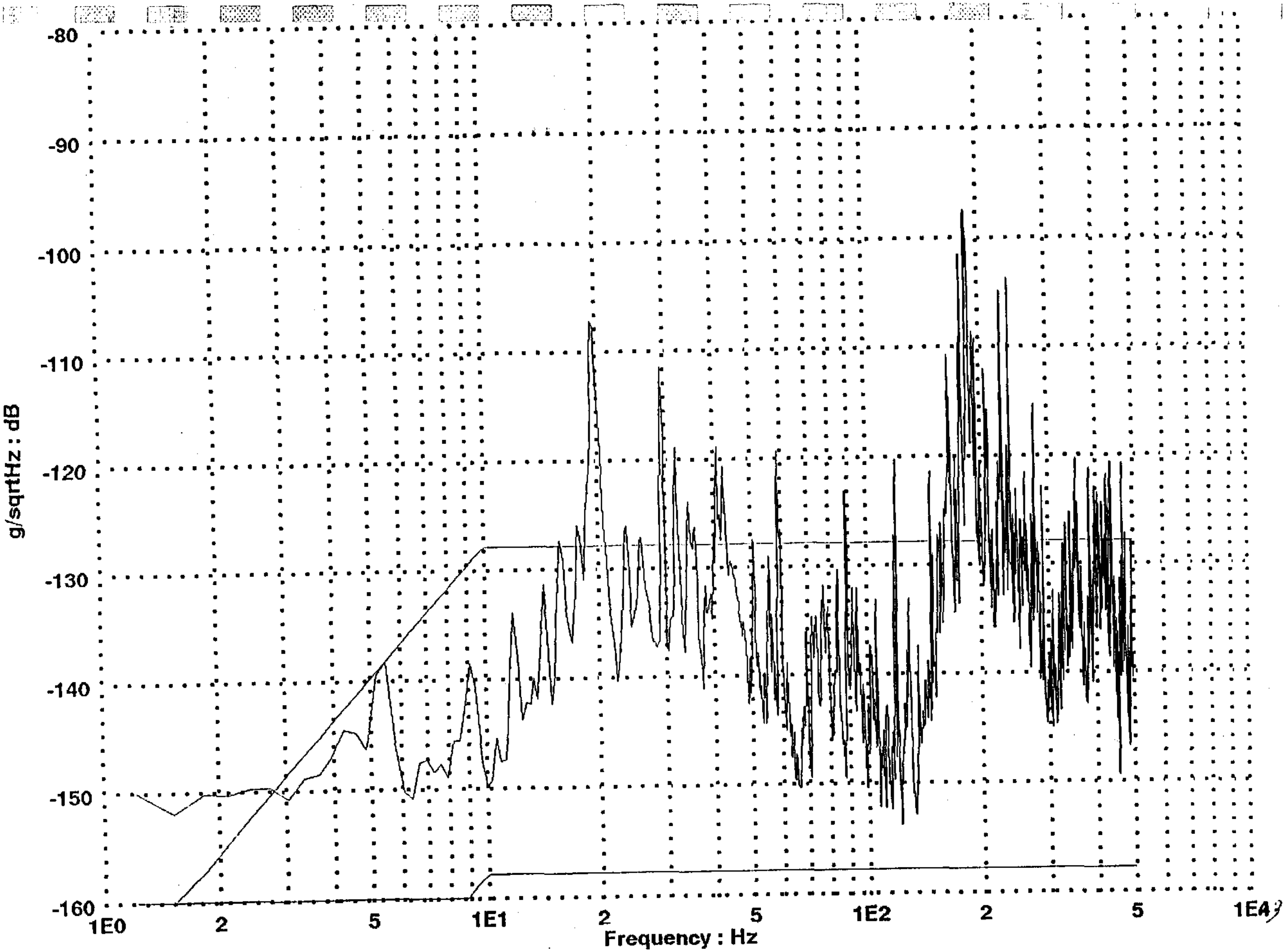
mr12 9/25/98 Test 10, 12-Floor Mech. Rm.nr. VEA, Vent and Purge



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

mr13 9/25/98 Test 11, 0-Floor nr. BS 7, Ion Pump Power Supply

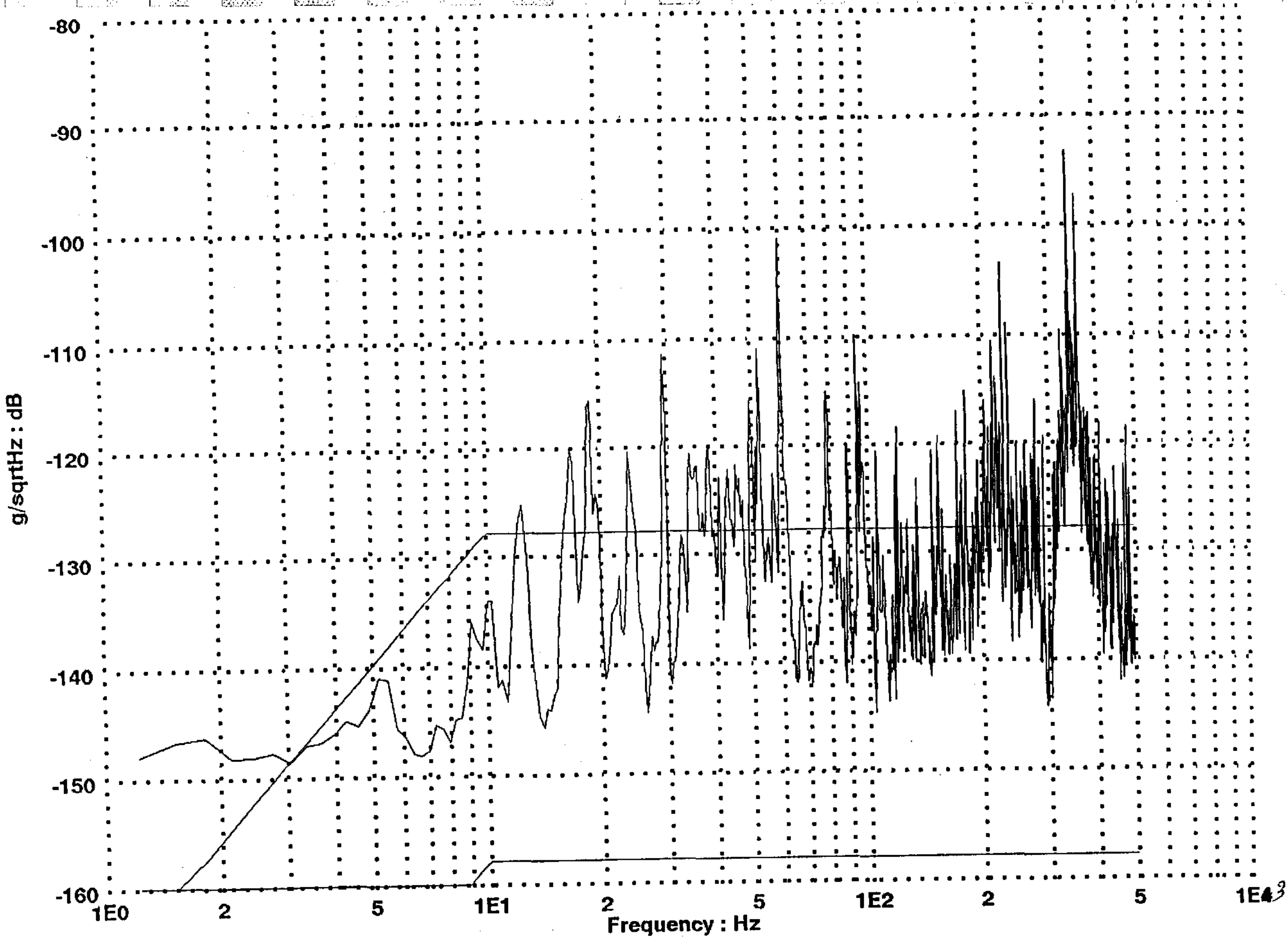
C133



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

mr14 9/25/98 Test 11, 8-Ham 4 nozzle radial, Ion Pump Power Supply

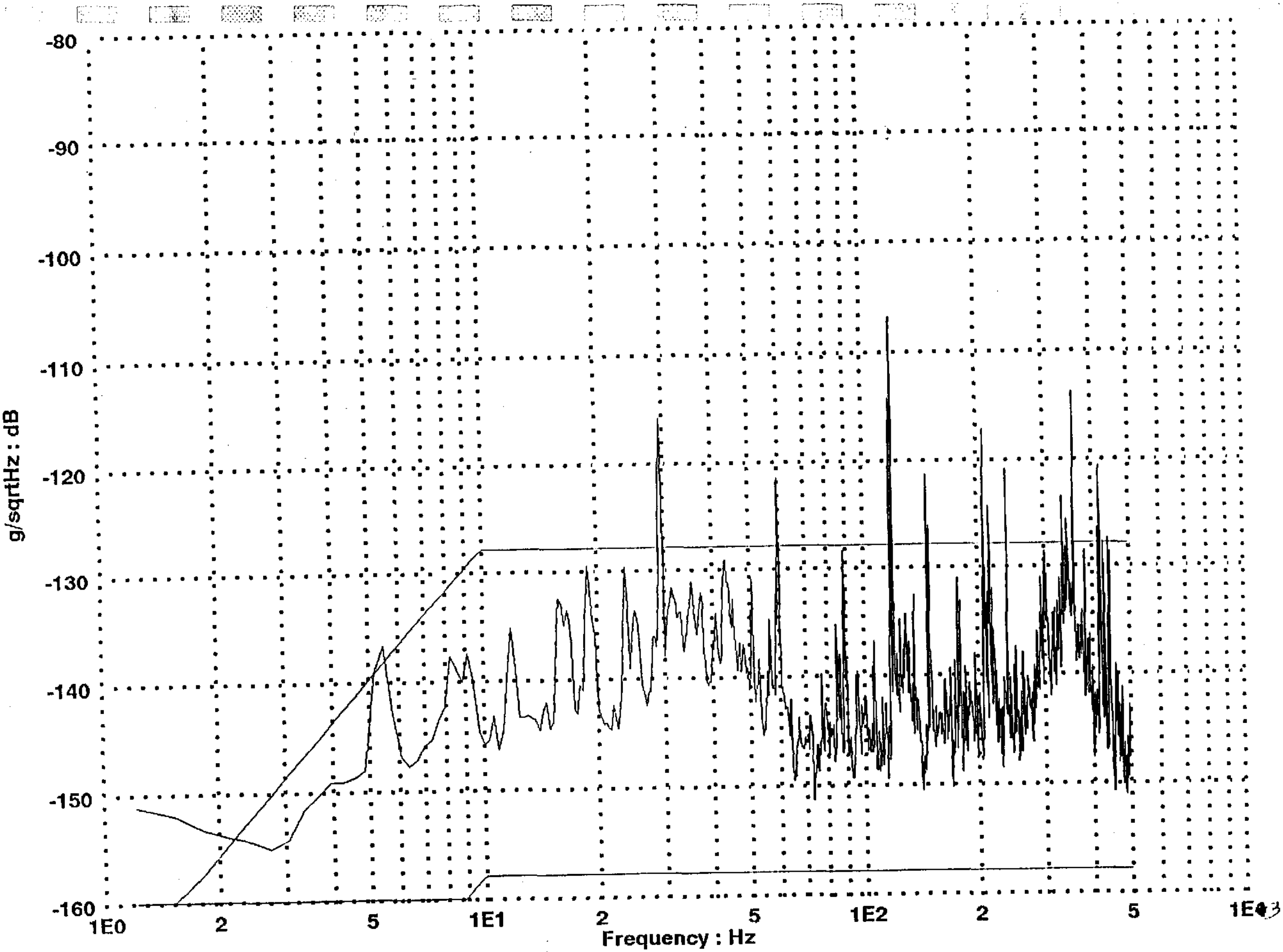
C134



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

mr15 9/25/98 Test 11, 5-BS 7 Noz. radial, Ion Pump Power Supply

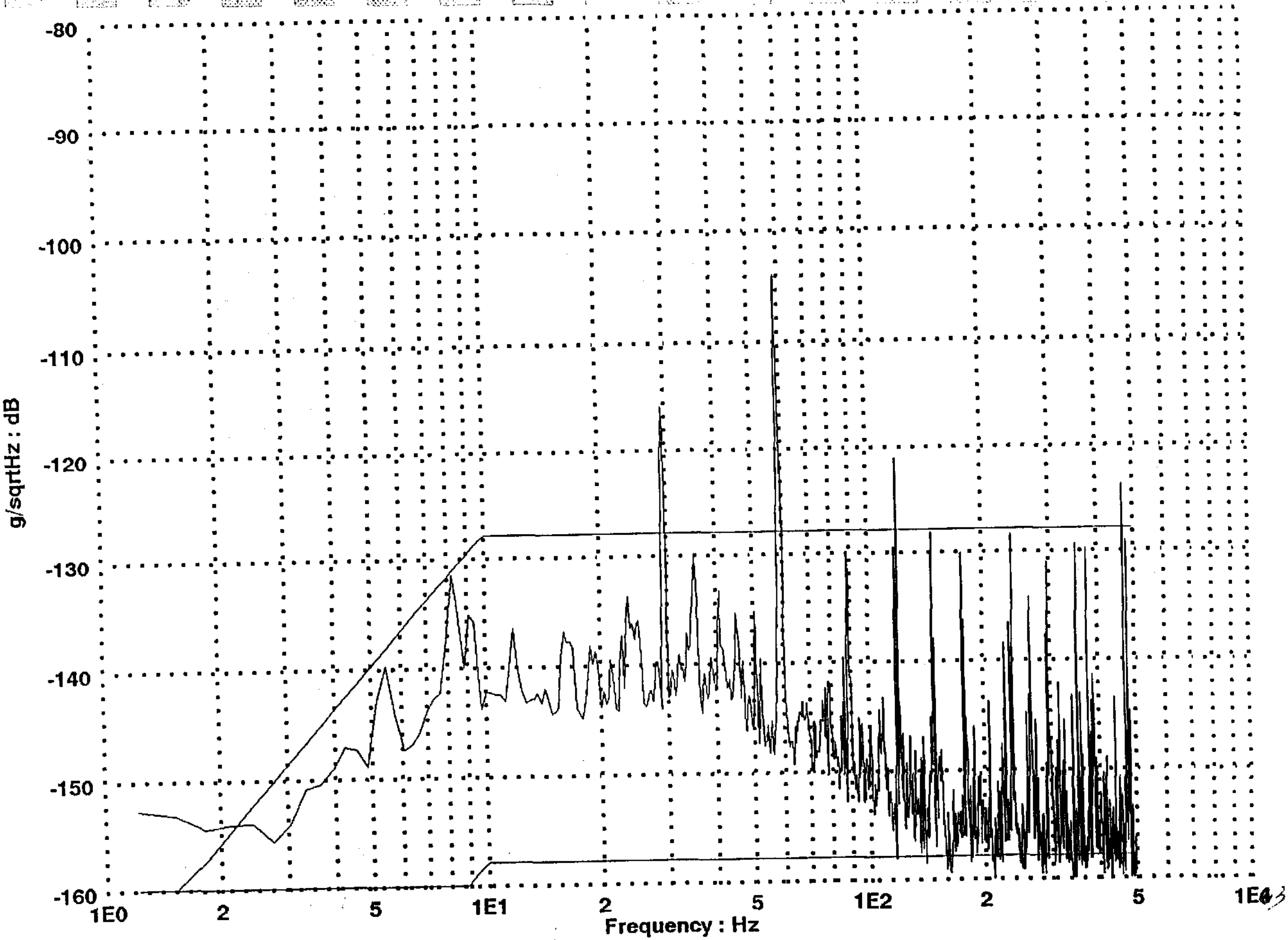
C135



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

mr16 9/25/98 Test 11, 12-Floor Mech. Rm.nr. VEA, Ion Pump Power Supply

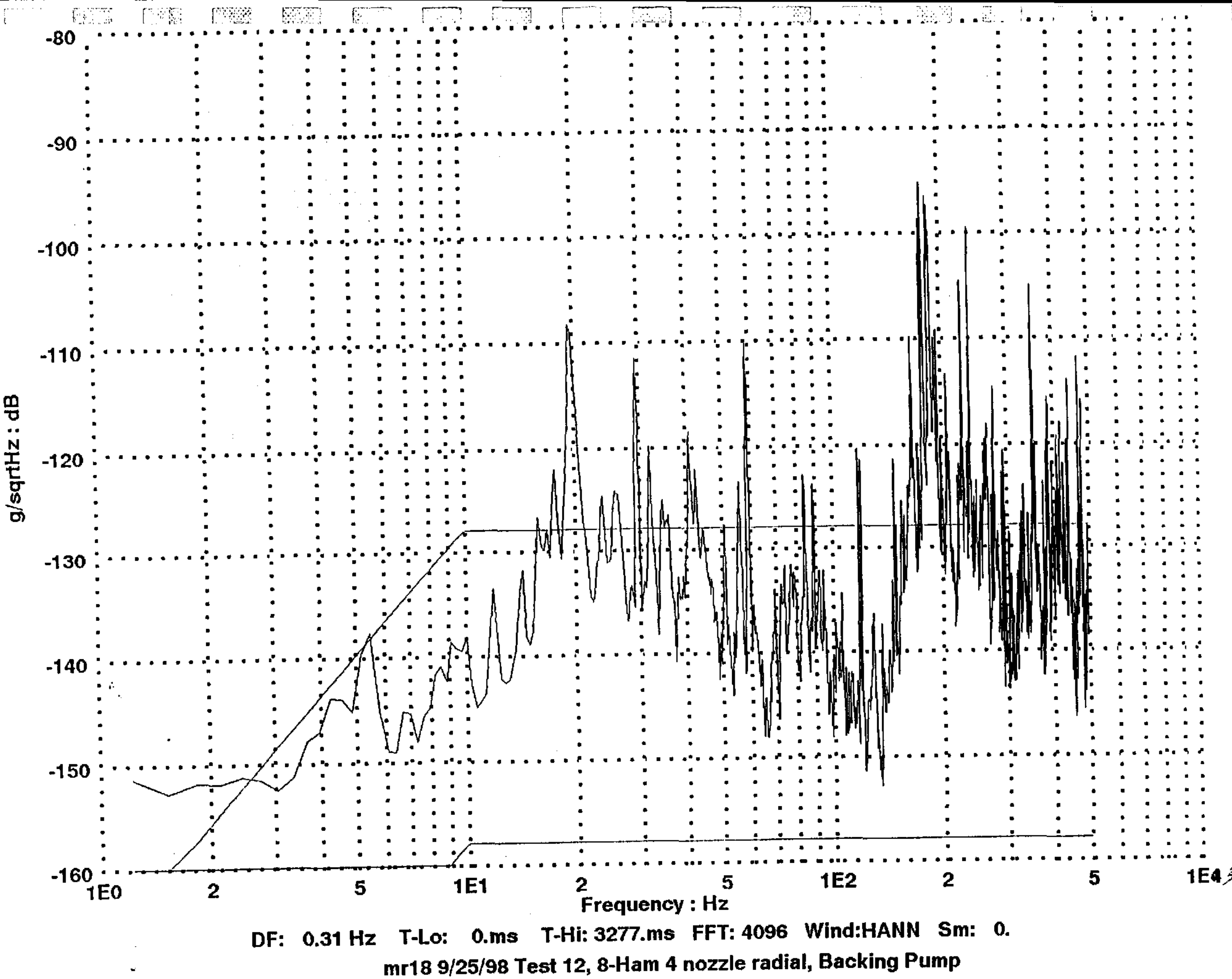
C136



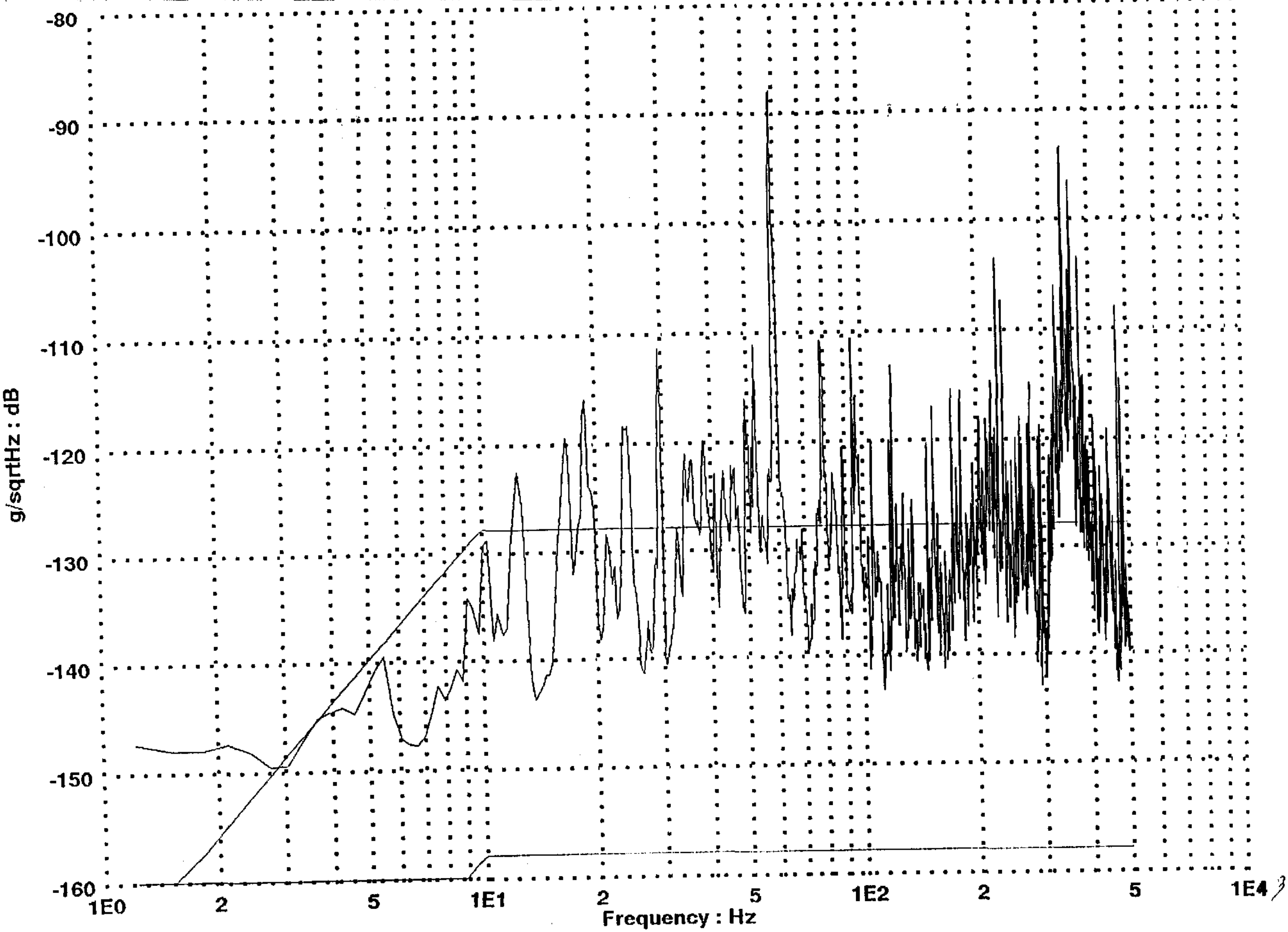
DF: 0.31 Hz T-Lo: 0.ms T-Hi: 3277.ms FFT: 4096 Wind:HANN Sm: 0.

mr17 9/25/98 Test 12, 0-Floor nr. BS 7, Backing Pump

C137


-80
-90
-100
-110
-120
-130
-140
-150
-160
g/sqrtHz : dB
1E0
2
5
1E1
2
5
1E2
2
5
1E4
Frequency : Hz
DF: 0.31 Hz T-Lo: 0.ms T-Hi: 3277.ms FFT: 4096 Wind:HANN Sm: 0.
mr18 9/25/98 Test 12, 8-Ham 4 nozzle radial, Backing Pump

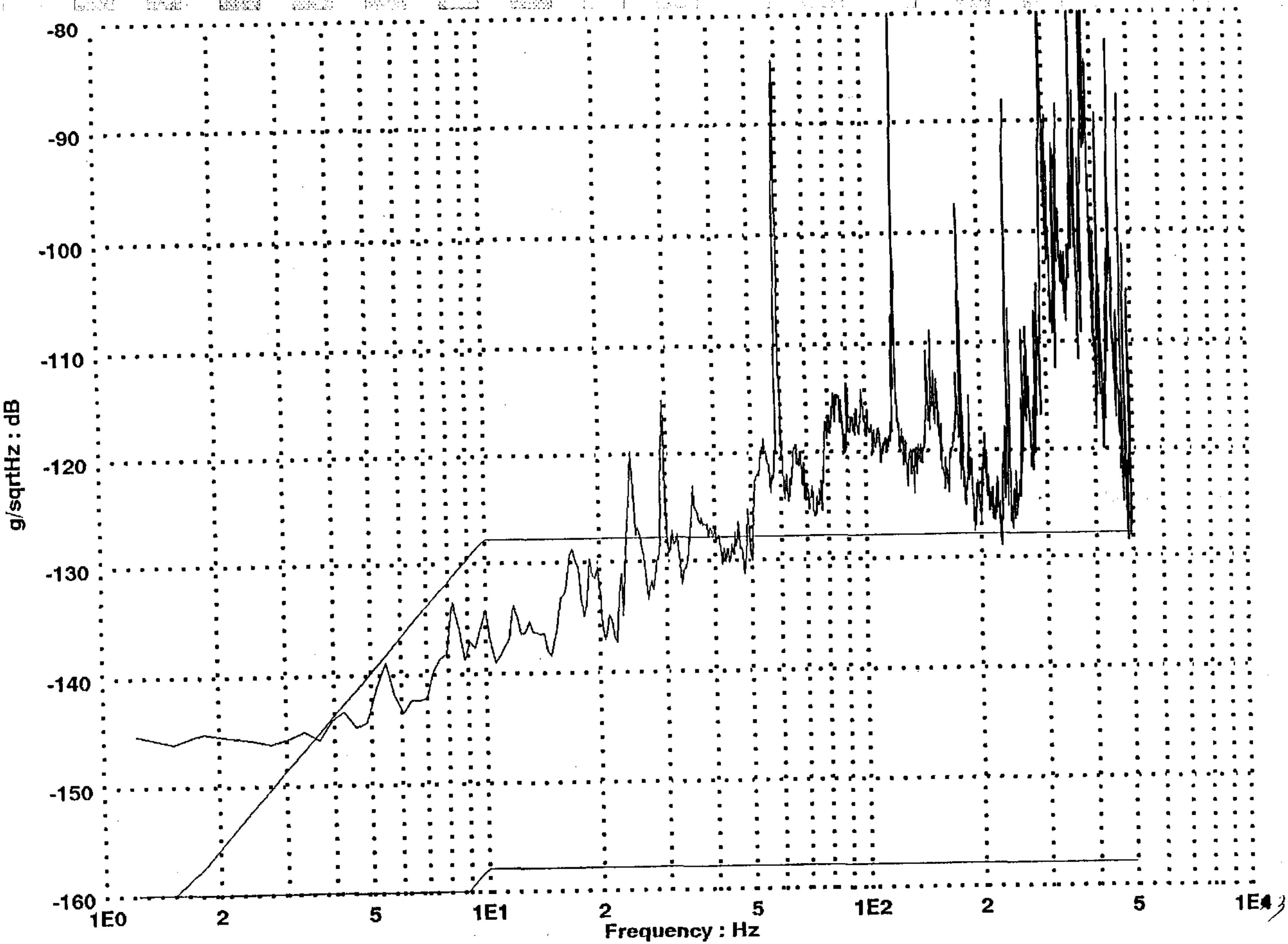
C138



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

mr19 9/25/98 Test 12, 5-BS 7 Noz. radial, Backing Pump

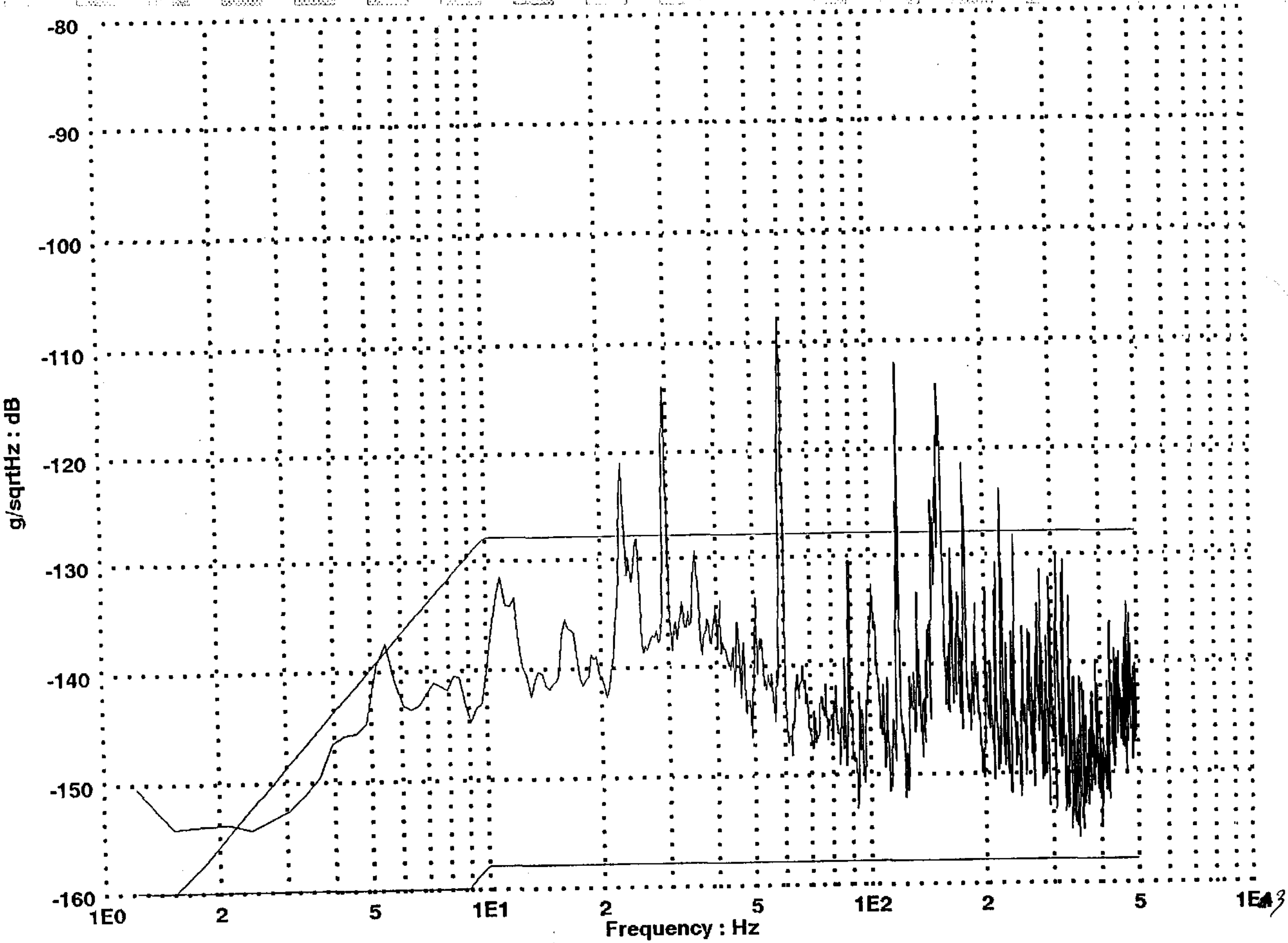
C135



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

mr20 9/25/98 Test 12, 12-Floor Mech. Rm.nr. VEA, Backing Pump

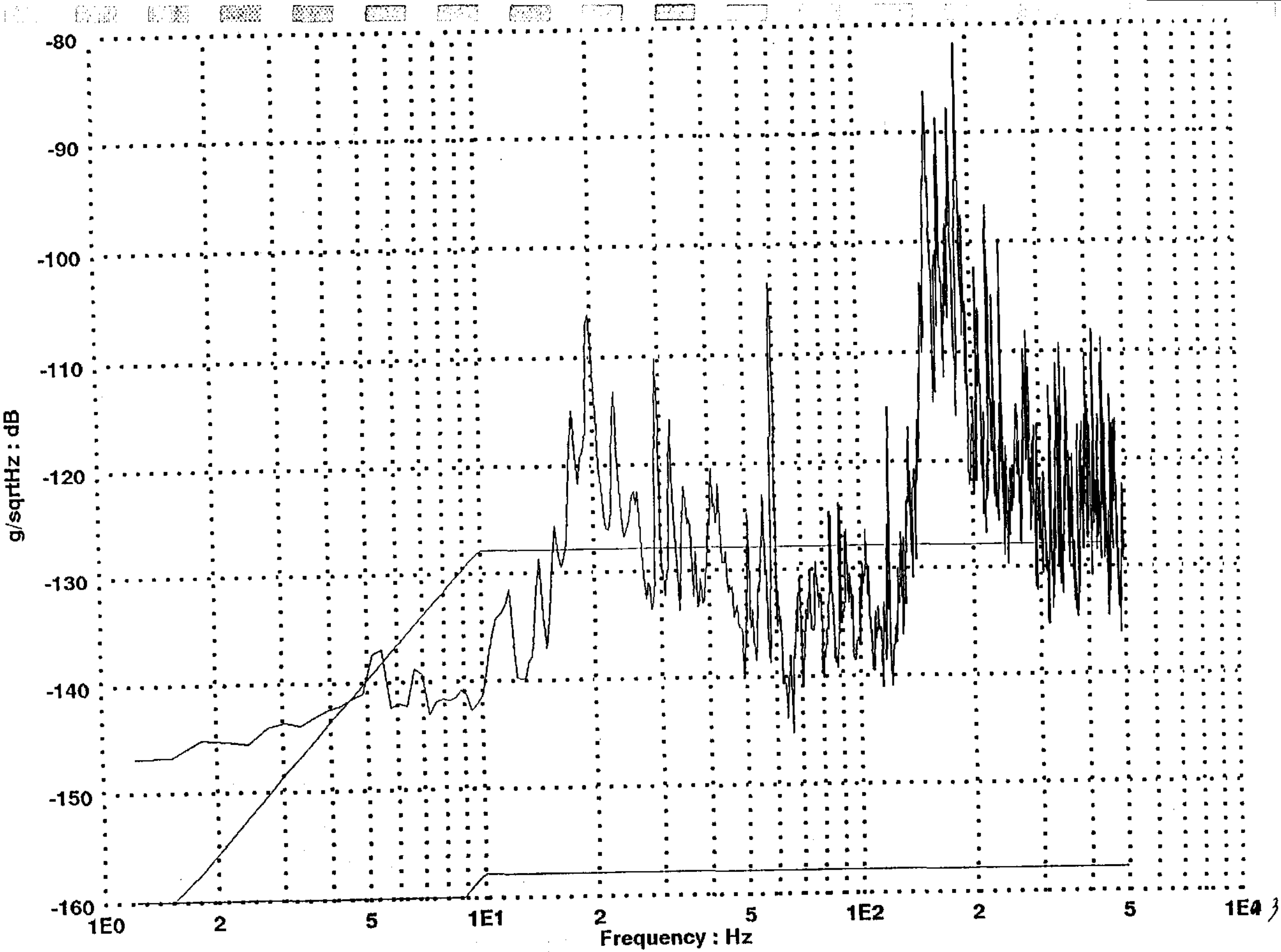
C140



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

mr21 9/25/98 Test 13, 0-Floor nr. BS 7, Vent and Purge

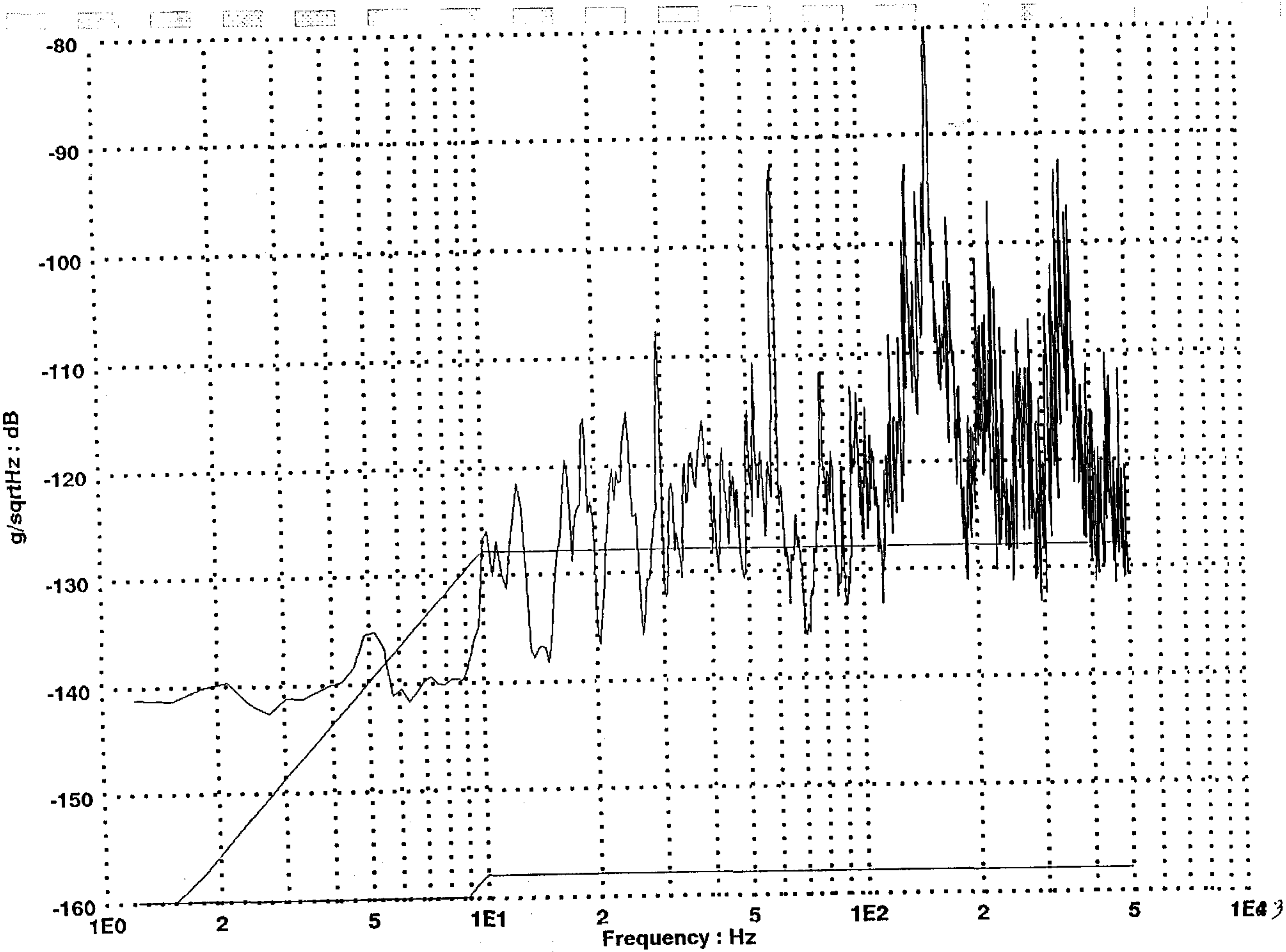
C141



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

mr22 9/25/98 Test 13, 8-Ham 4 nozzle radial, Vent & Purge

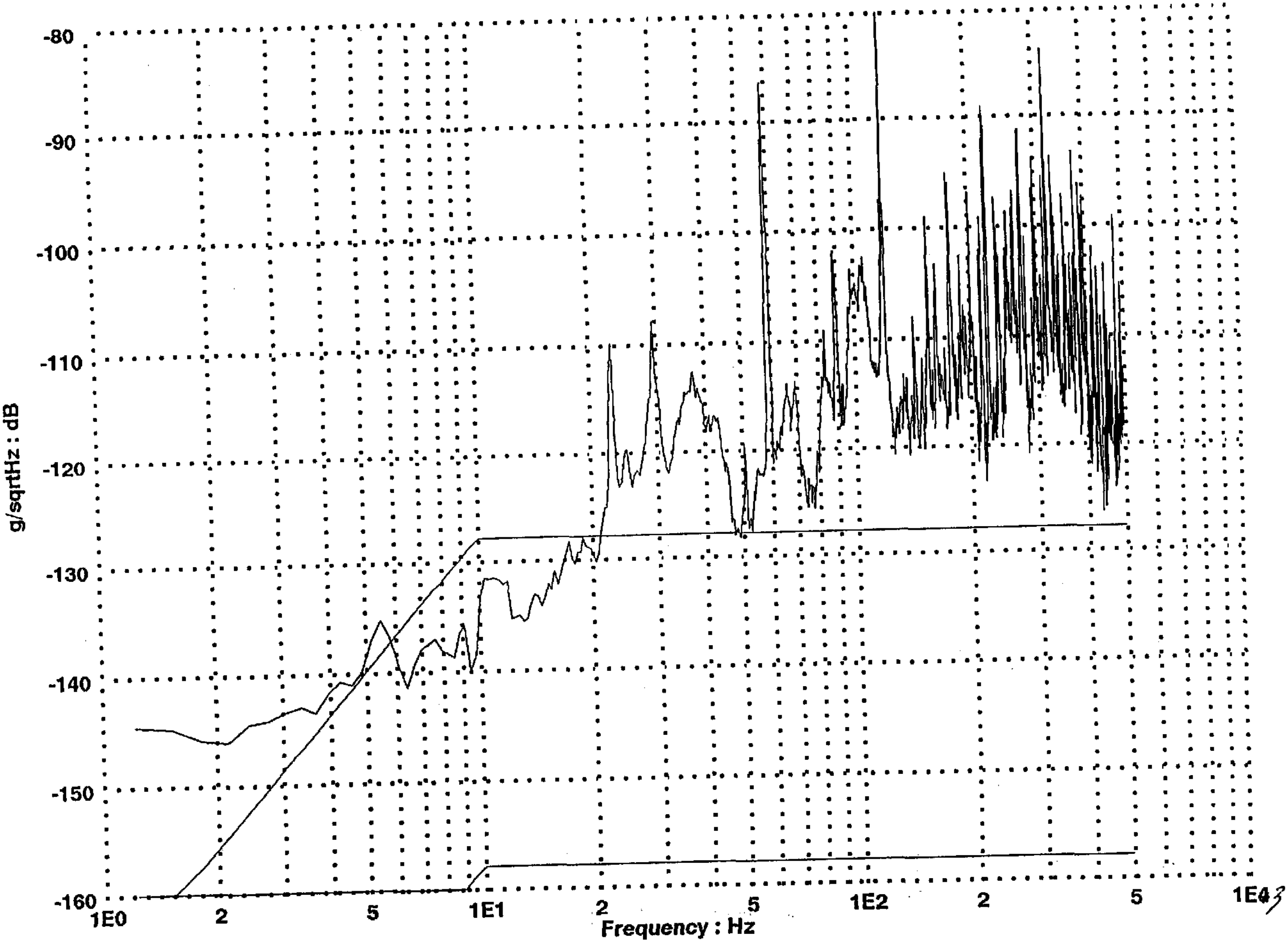
C142



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

mr23 9/25/98 Test 13, 5-BS 7 Noz. radial., Vent and Purge

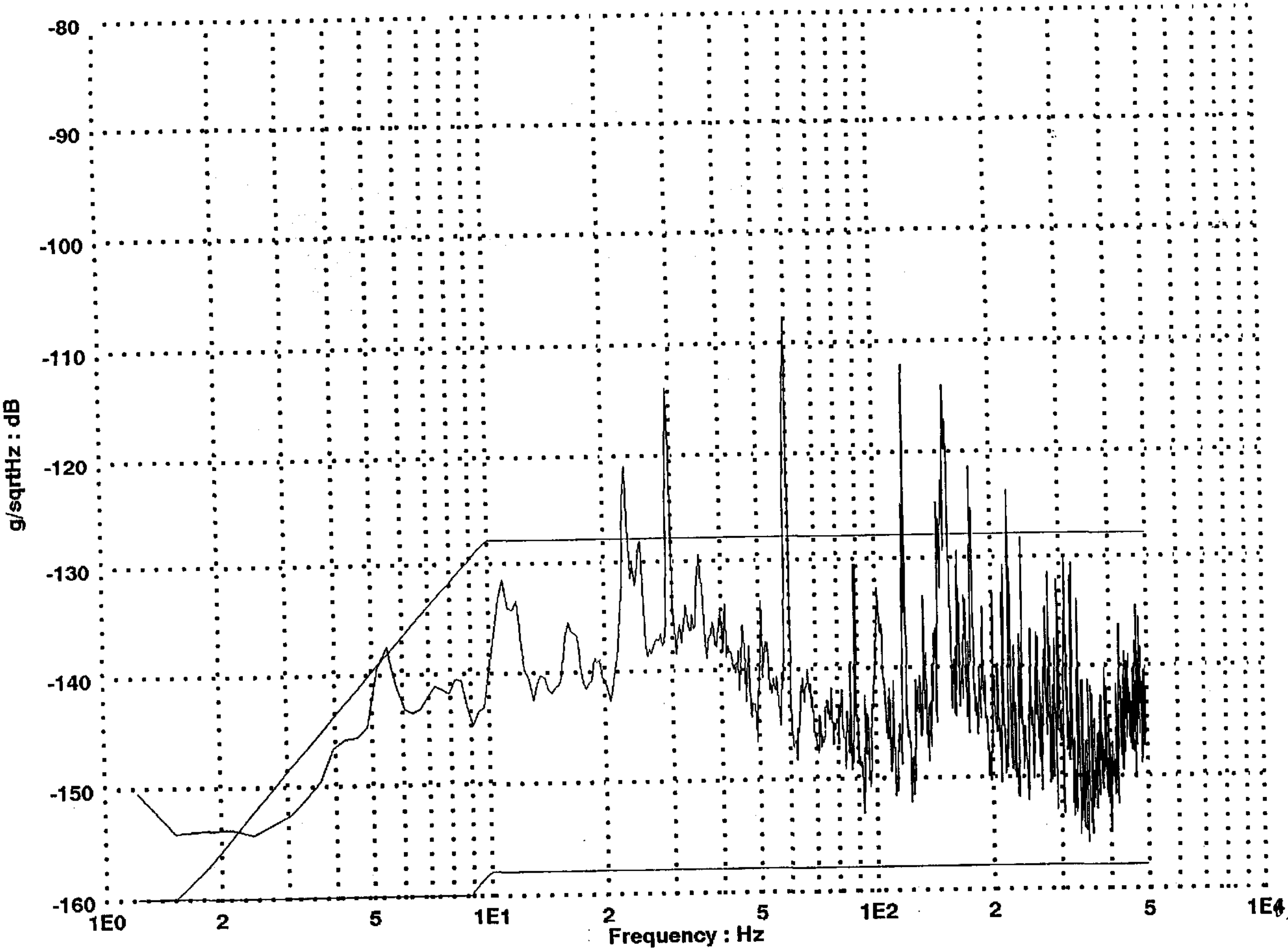
C/43



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

mr24 9/25/98 Test 13, 12-Floor Mech. Rm.nr. VEA, Vent and Purge

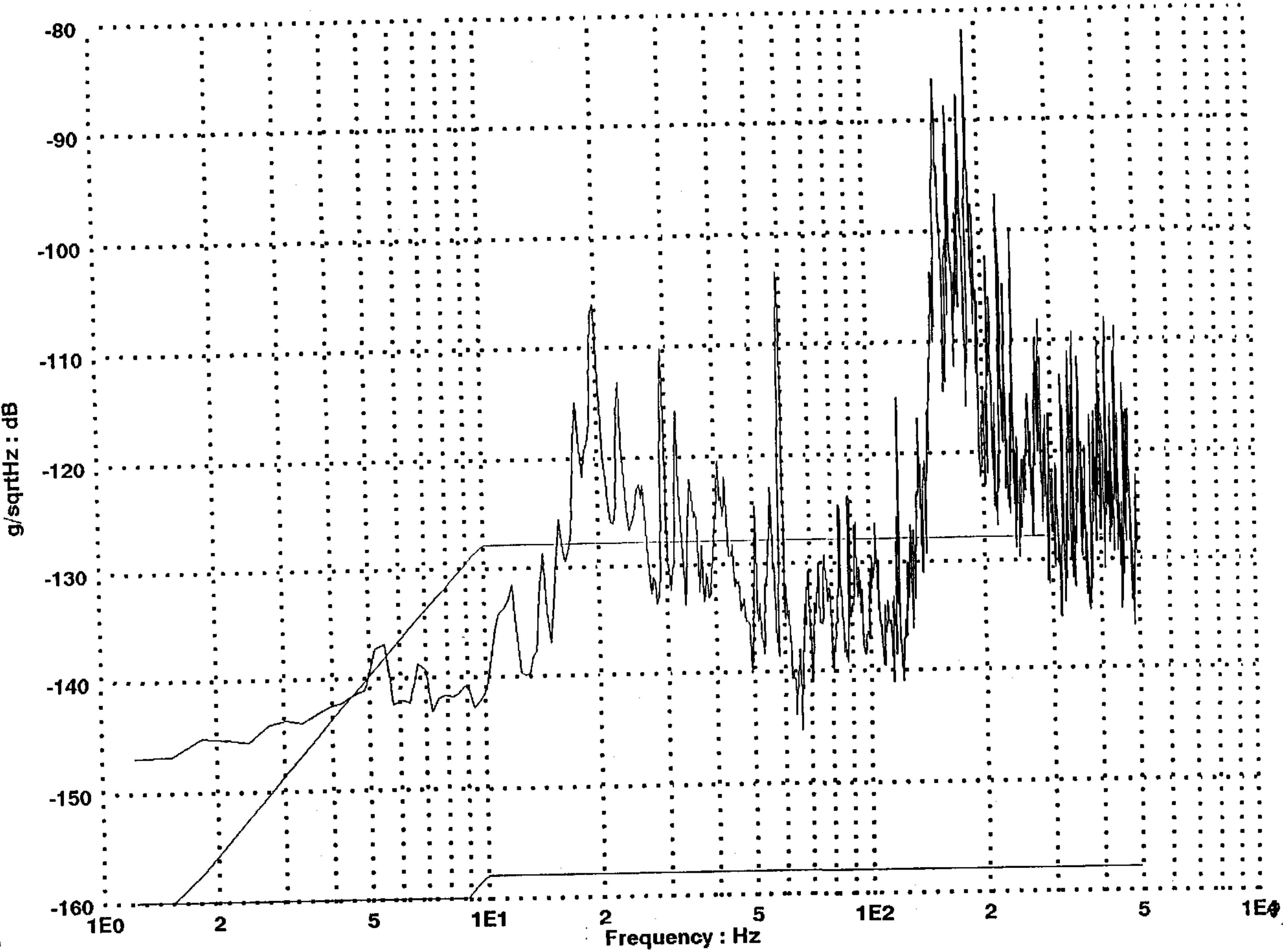
C-144



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

mr25 9/25/98 Test 13, 0-Floor nr. BS 7, Vent and Purge Modified Op.

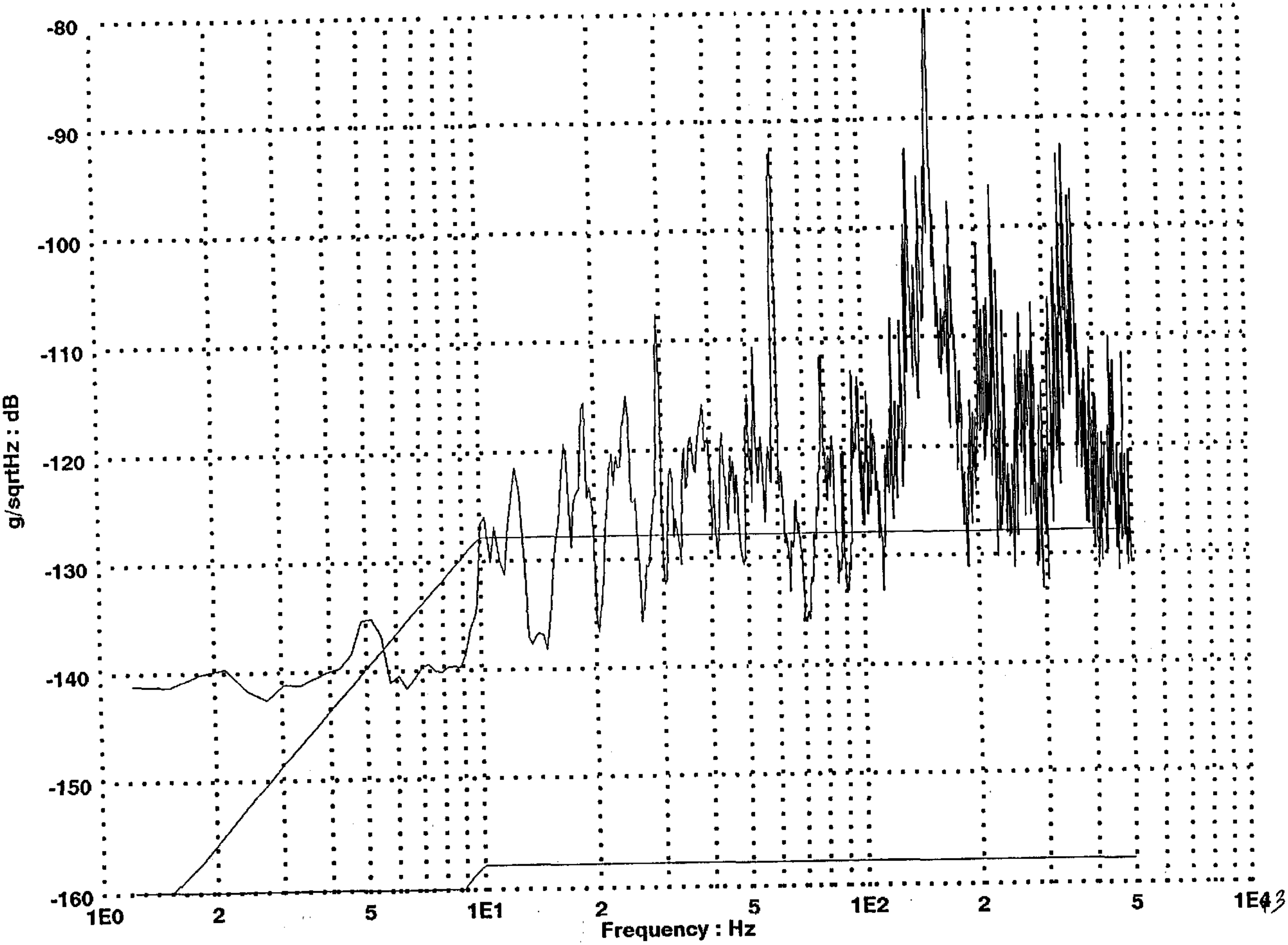
C-145



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

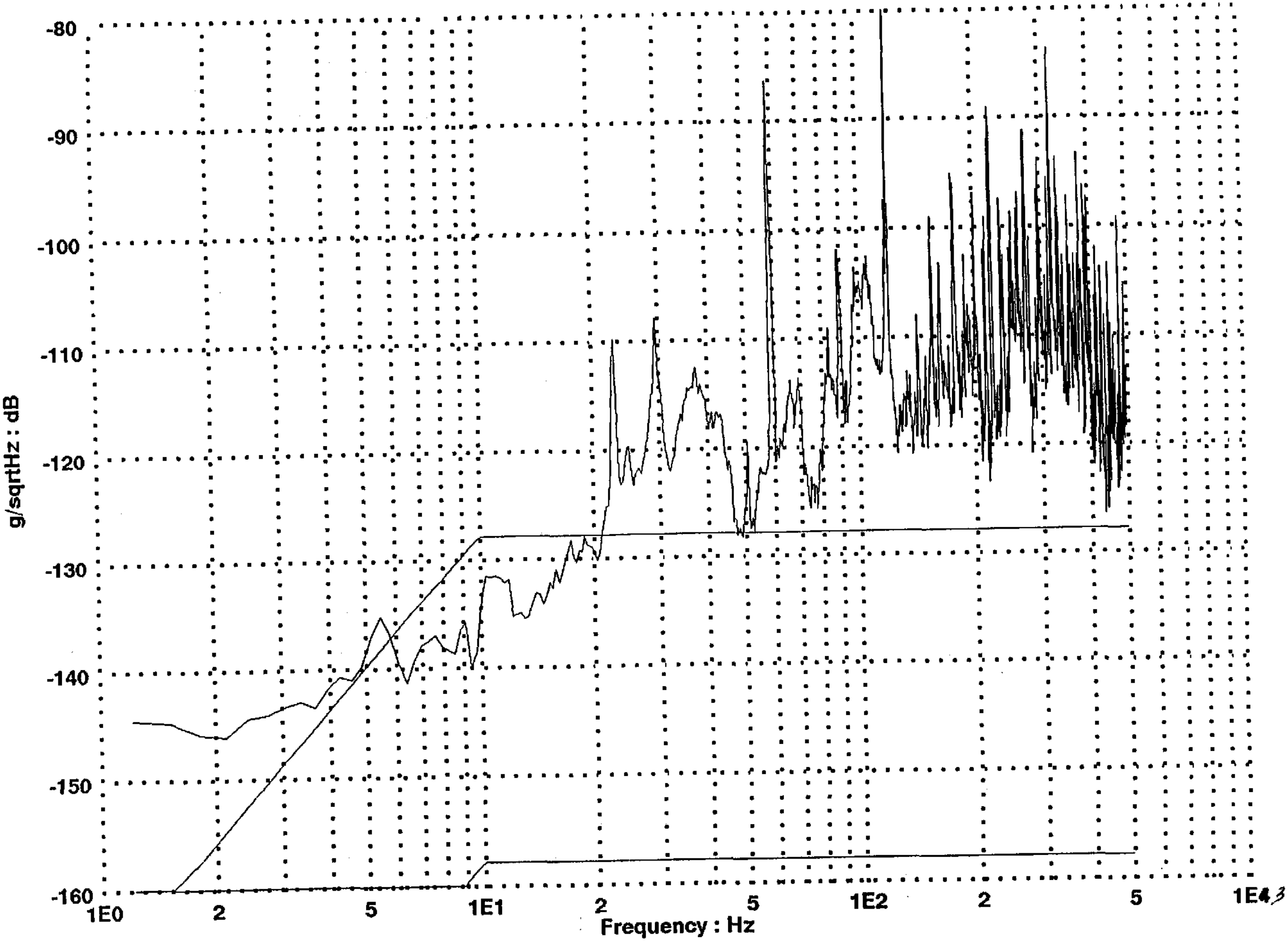
mr26 9/25/98 Test 13, 8-Ham 4 nozzle radial, Vent & Purge Modified Op.

C-146



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

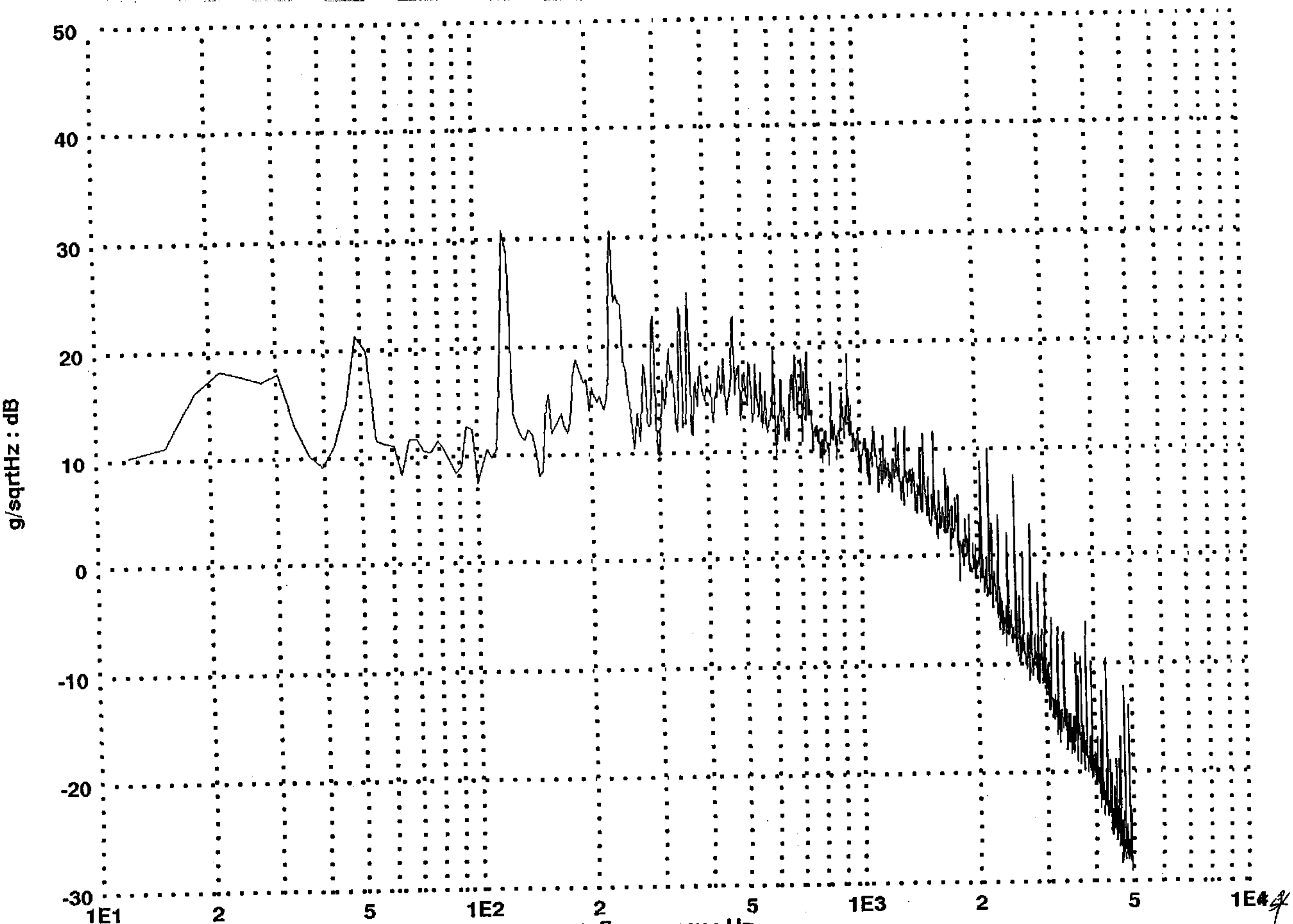
mr27 9/25/98 Test 13, 5-BS 7 Noz. radial., Vent and Purge Modified Op.



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

mr28 9/25/98 Test 13, 12-Floor Mech. Rm.nr. VEA, Vent and Purge Mod. Op.

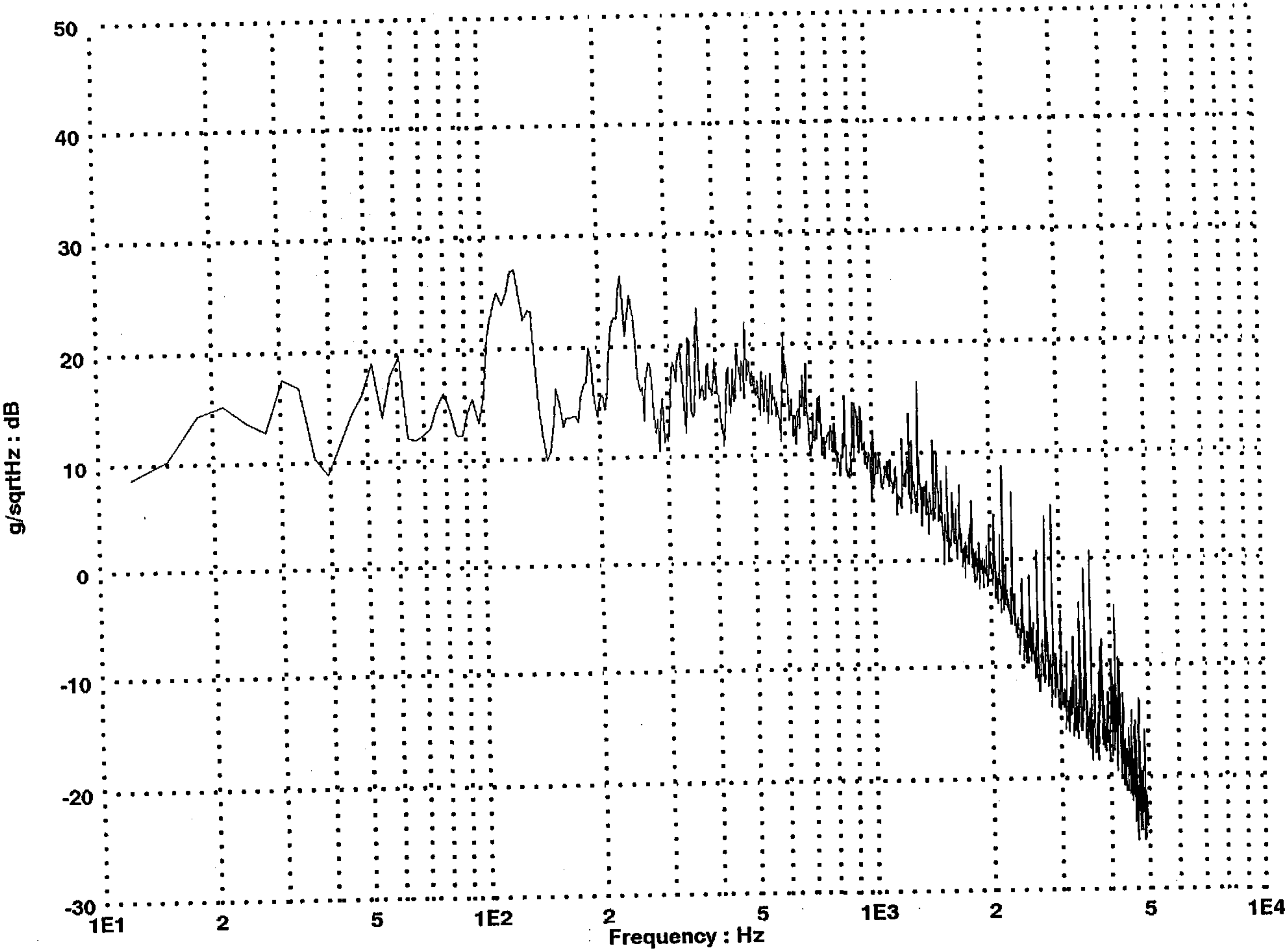
C1148



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

A1 9/25/98 Test 16, Floor nr. BS 7, Acoustic bkg.

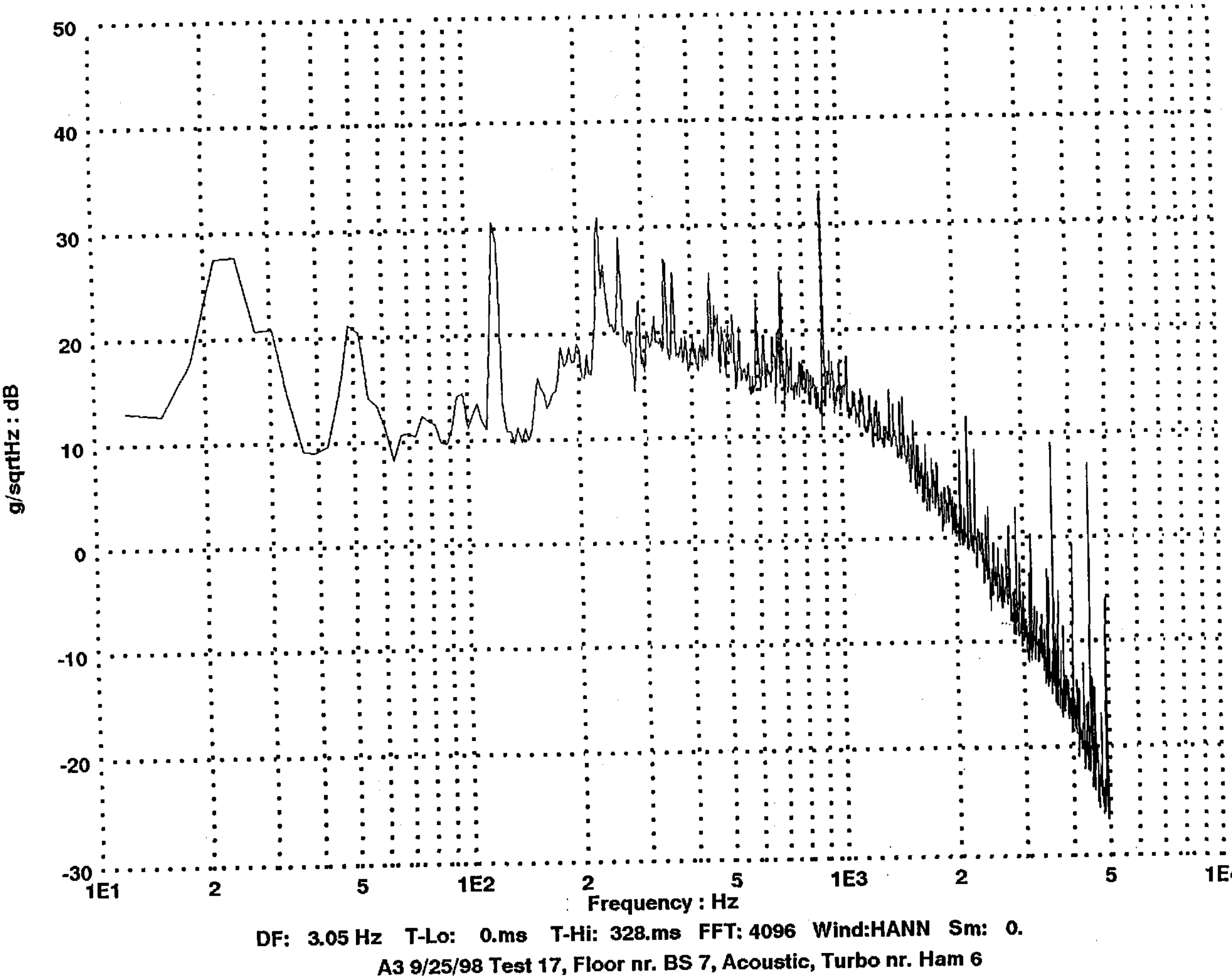
C149



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

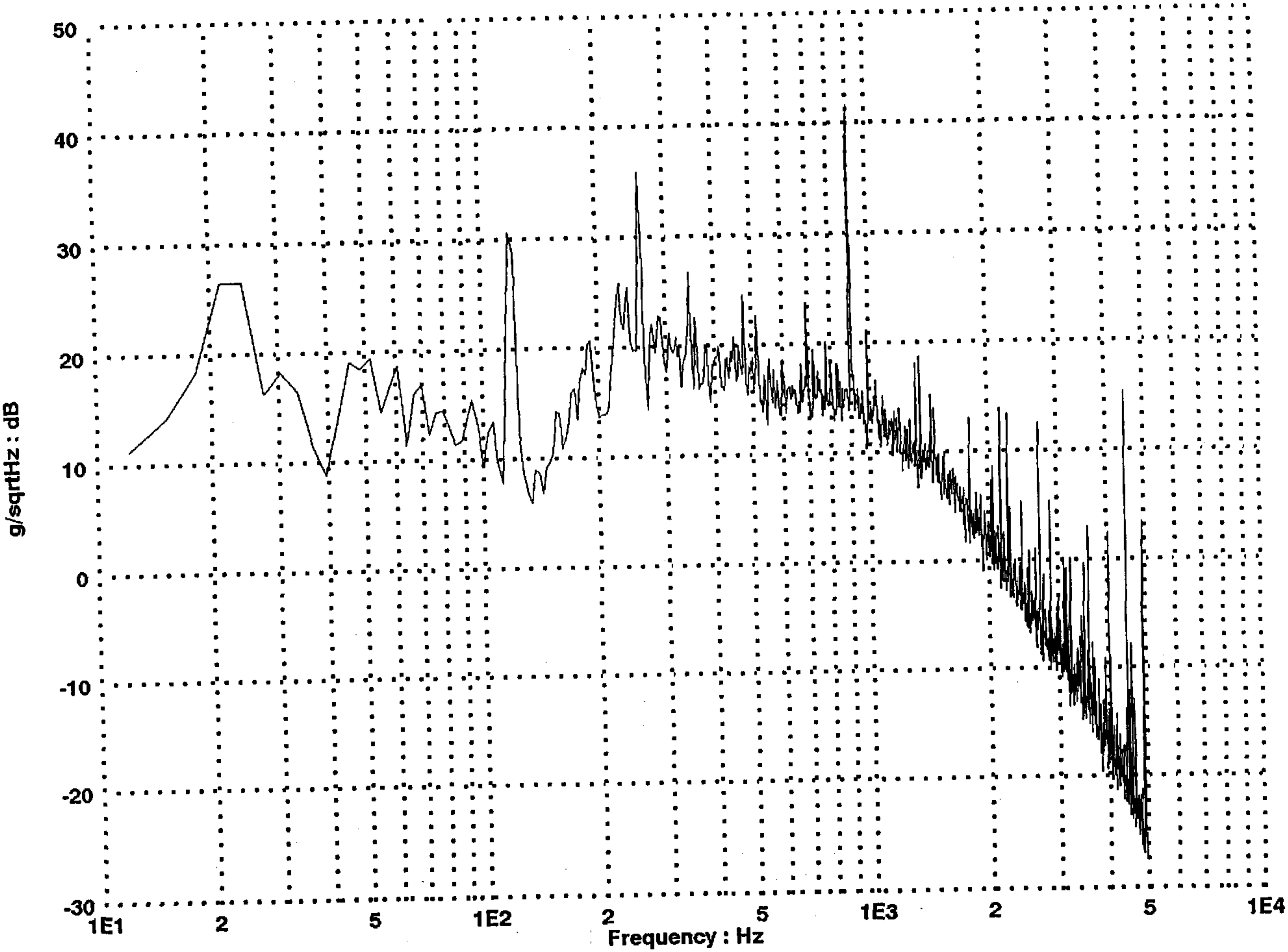
A2 9/25/98 Test 16, 10 feet behind Ham 6, Acoustic bkg.

C156



50
40
30
20
10
0
-10
-20
-30
g/sqrtHz : dB
1E1
2
5
1E2
2
5
1E3
2
5
1E4
Frequency : Hz
DF: 3.05 Hz T-Lo: 0.ms T-Hi: 328.ms FFT: 4096 Wind:HANN Sm: 0.
A3 9/25/98 Test 17, Floor nr. BS 7, Acoustic, Turbo nr. Ham 6

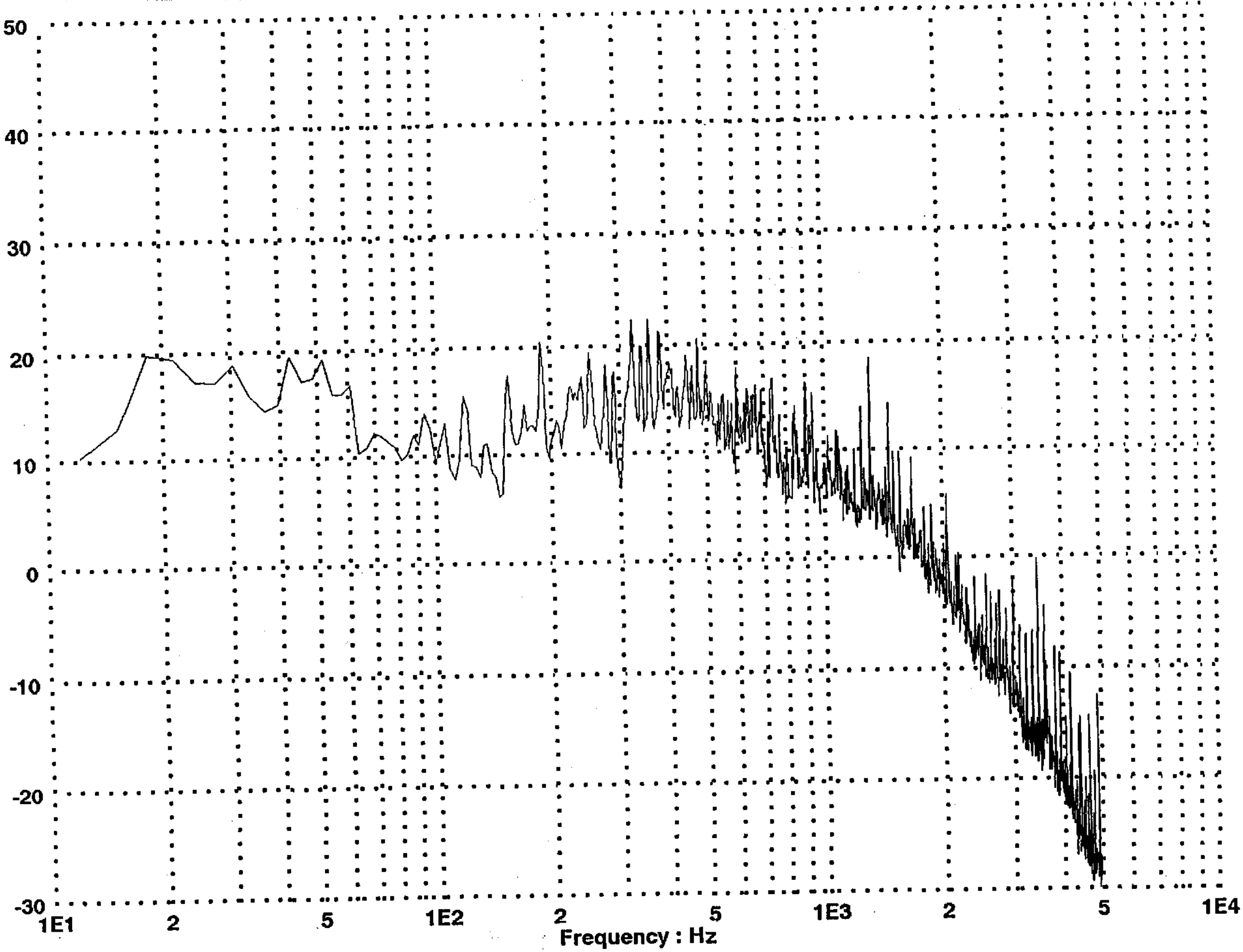
C151



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

A4 9/25/98 Test 17, 10 feet behind Ham 6, Acoustic, Turbo nr. Ham 6

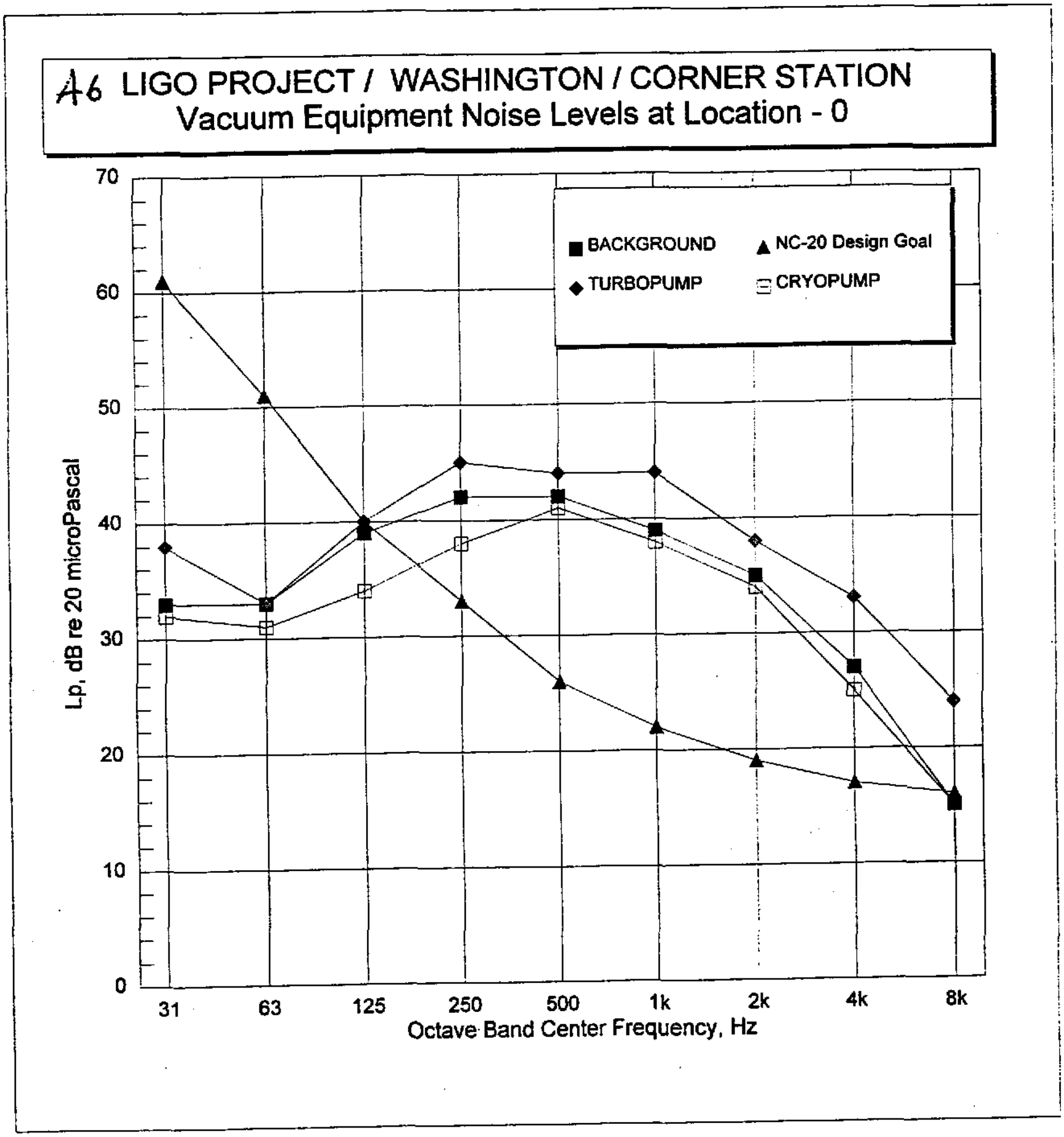
C152



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

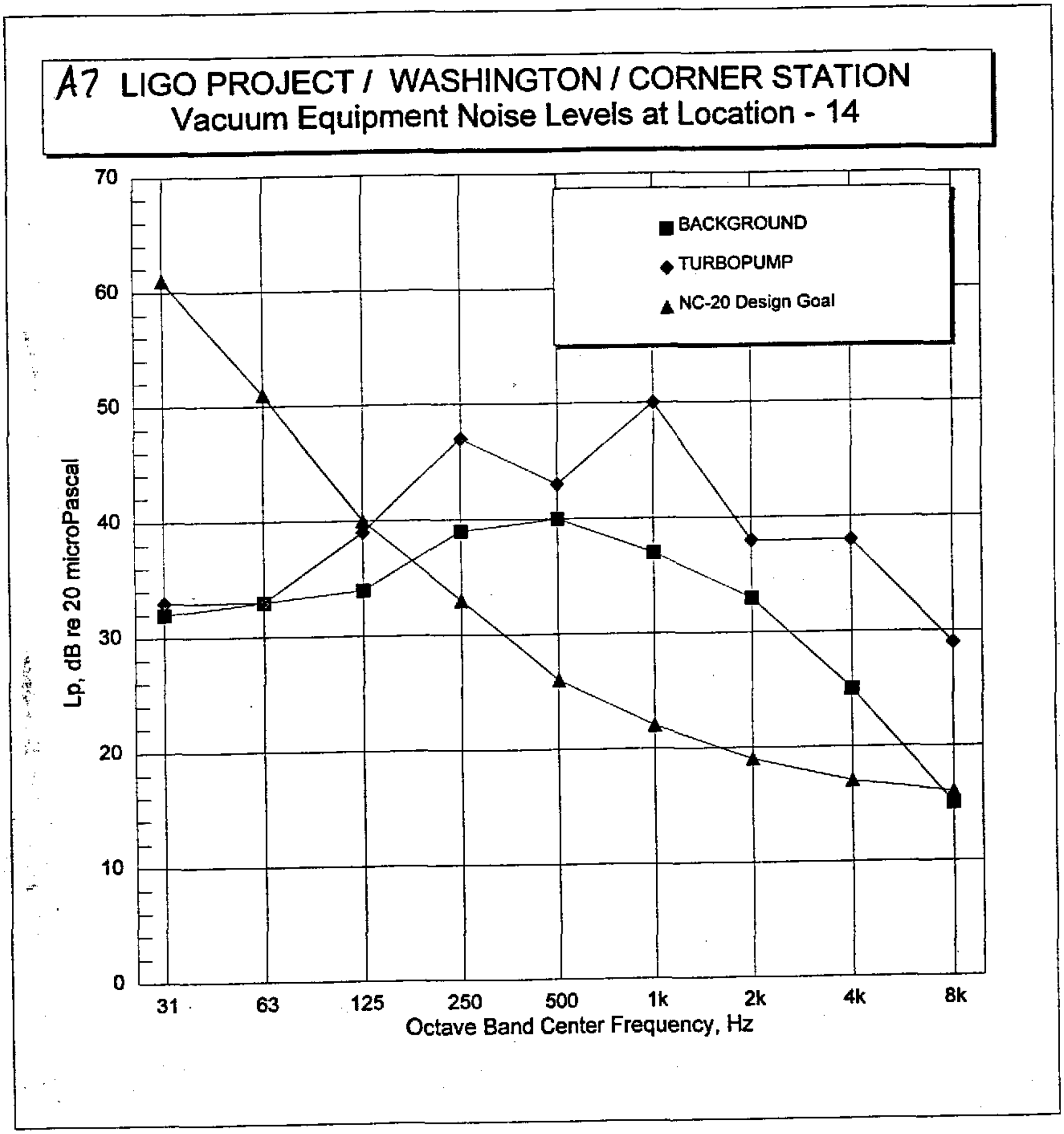
A5 9/26/98 Test 11, Floor nr. BS 7, Acoustic, Cryopump

C153



A6 LIGO PROJECT / WASHINGTON / CORNER STATION
Vacuum Equipment Noise Levels at Location - 0
BACKGROUND
NC-20 Design Goal
TURBOPUMP
CRYOPUMP
Lp, dB re 20 microPascal
70
60
50
40
30
20
10
0
31
63
125
250
500
1k
2k
4k
8k
Octave Band Center Frequency, Hz

C154


A7 LIGO PROJECT / WASHINGTON / CORNER STATION
Vacuum Equipment Noise Levels at Location - 14
BACKGROUND
TURBOPUMP
NC-20 Design Goal
Lp, dB re 20 microPascal
70
60
50
40
30
20
10
0
31
63
125
250
500
1k
2k
4k
8k
Octave Band Center Frequency, Hz

C155

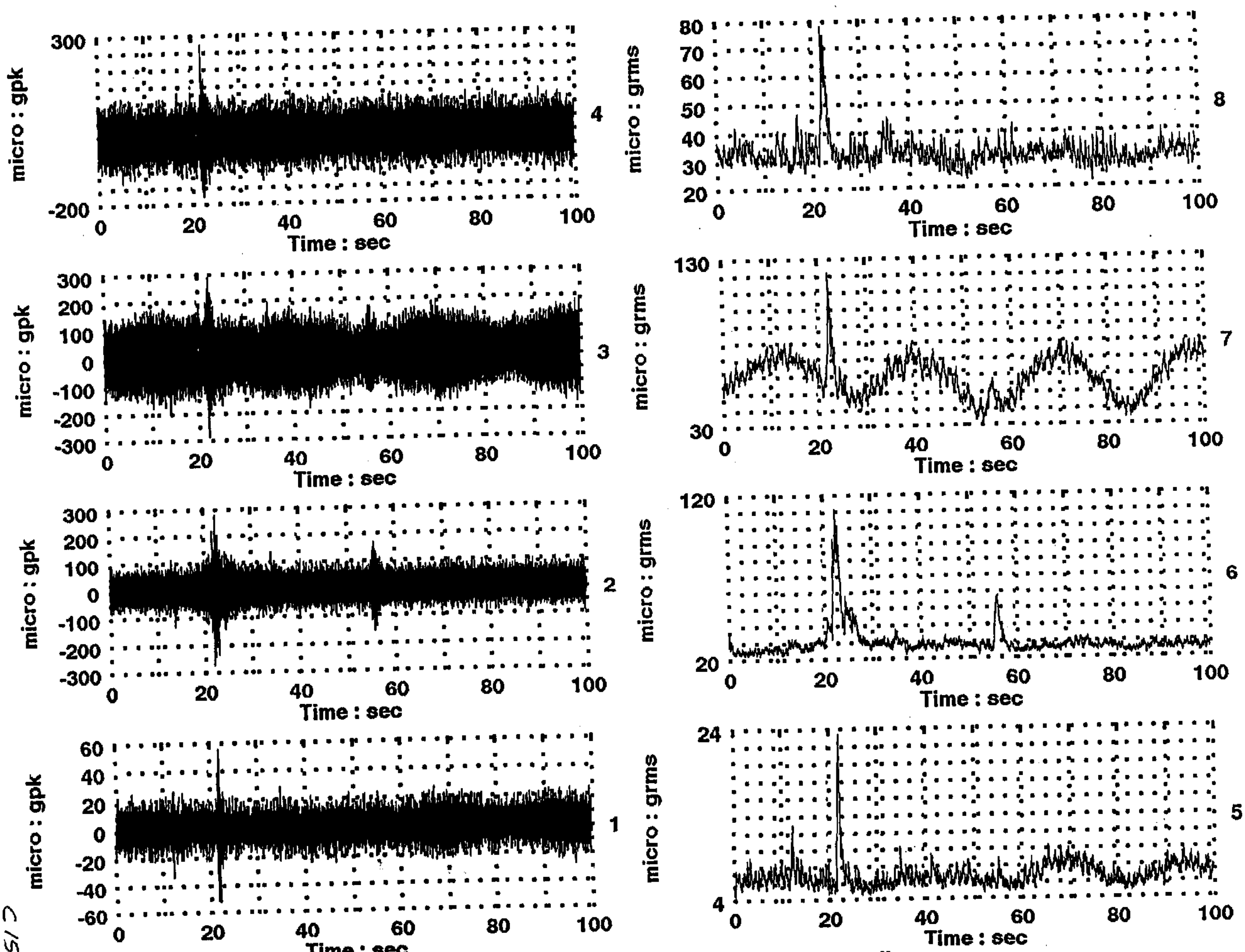
APPENDIX B

PSI EQUIPMENT TIME HISTORY MEASUREMENTS

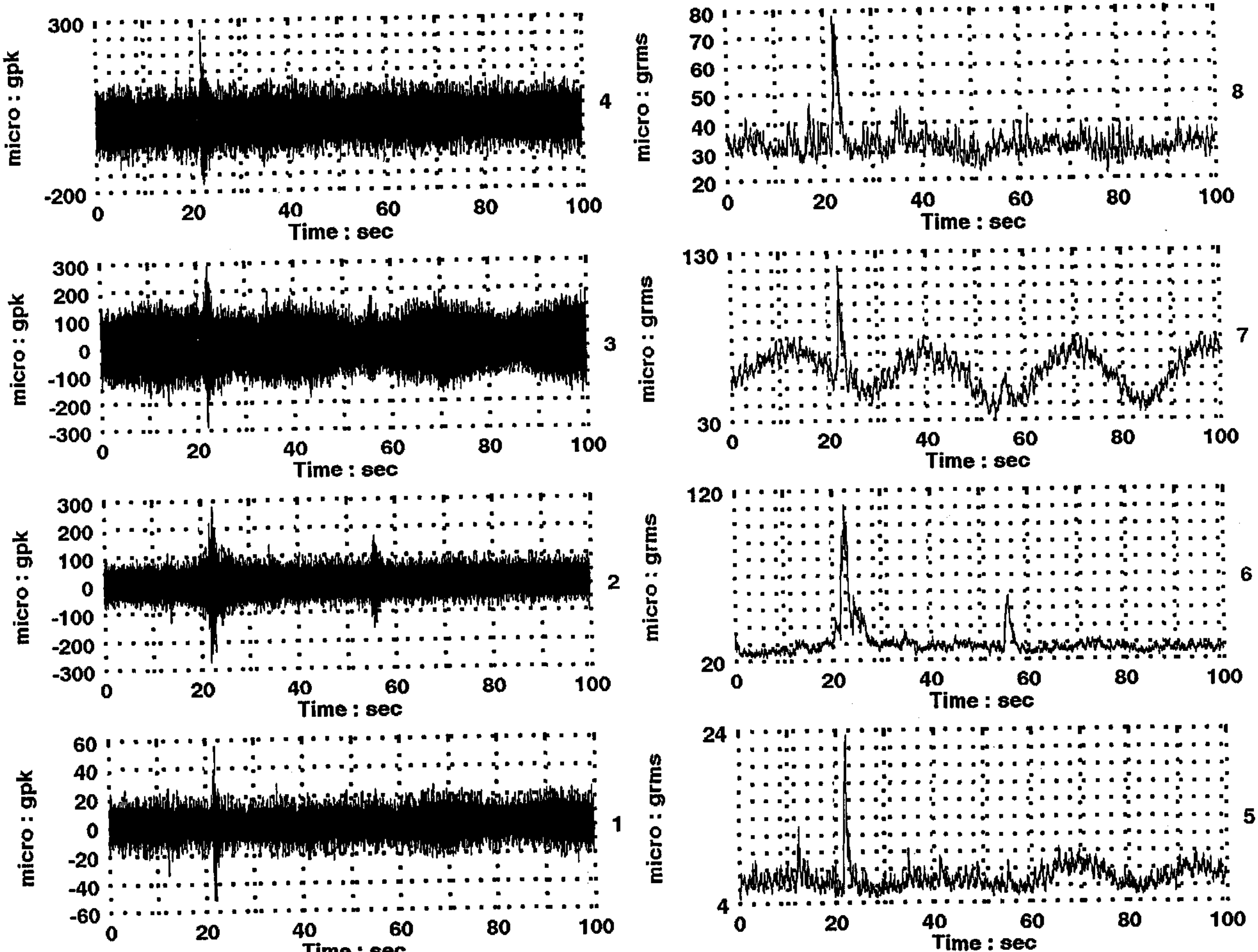
AT LIGO CORNER STATION

HANFORD, WA

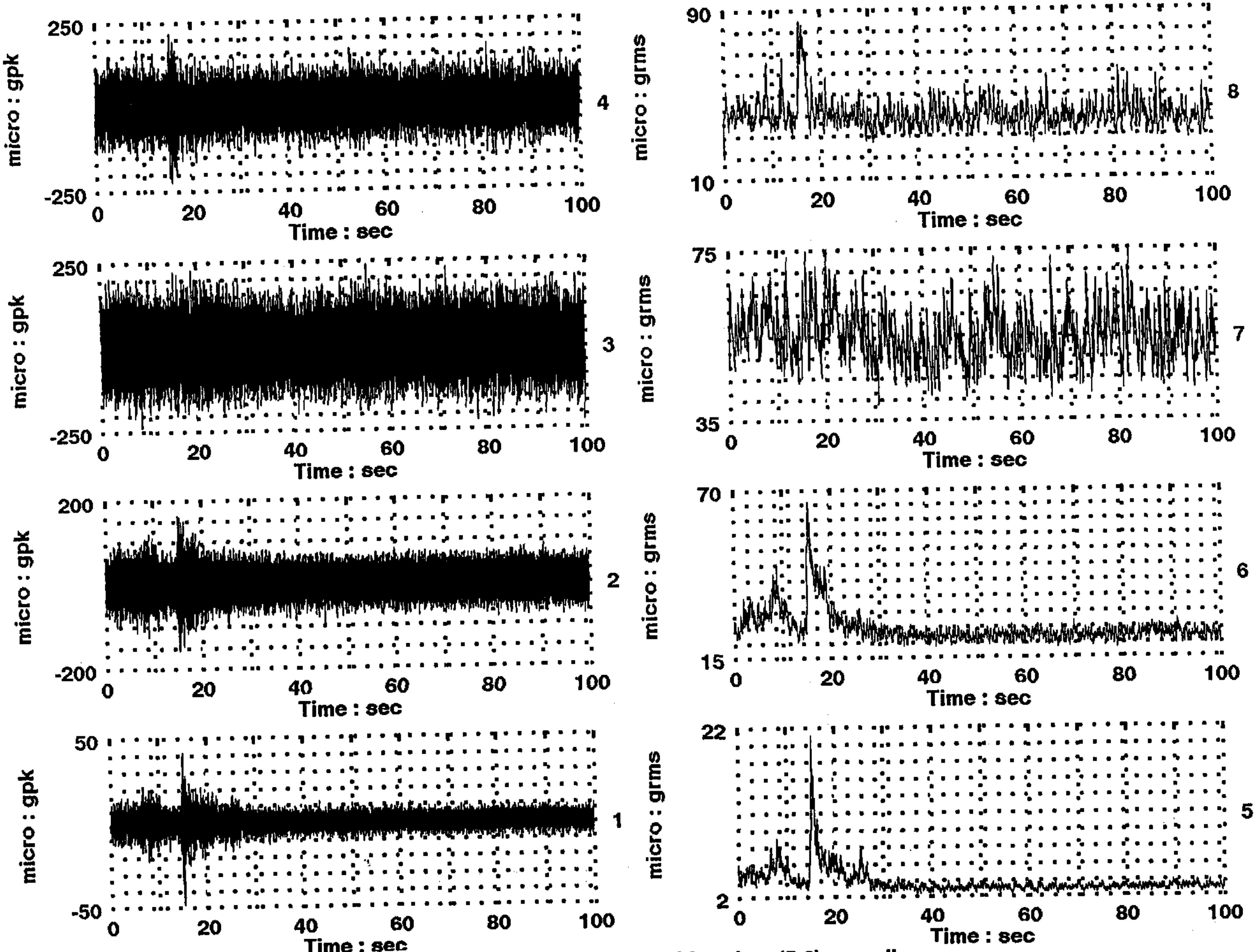
C156



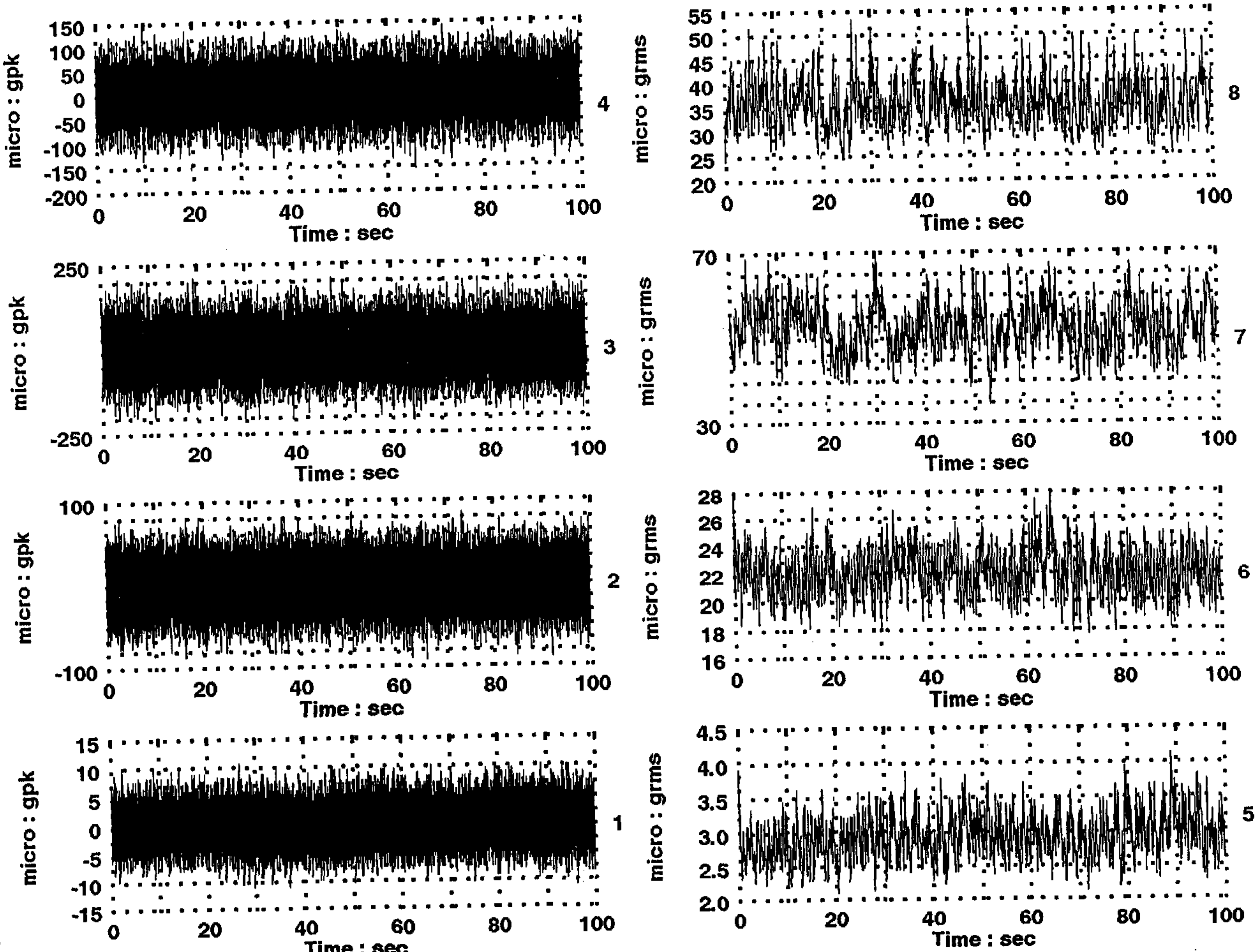
9/24/98 Test 3 (Bkg), (1-4)time histories, (5-8) overall rms



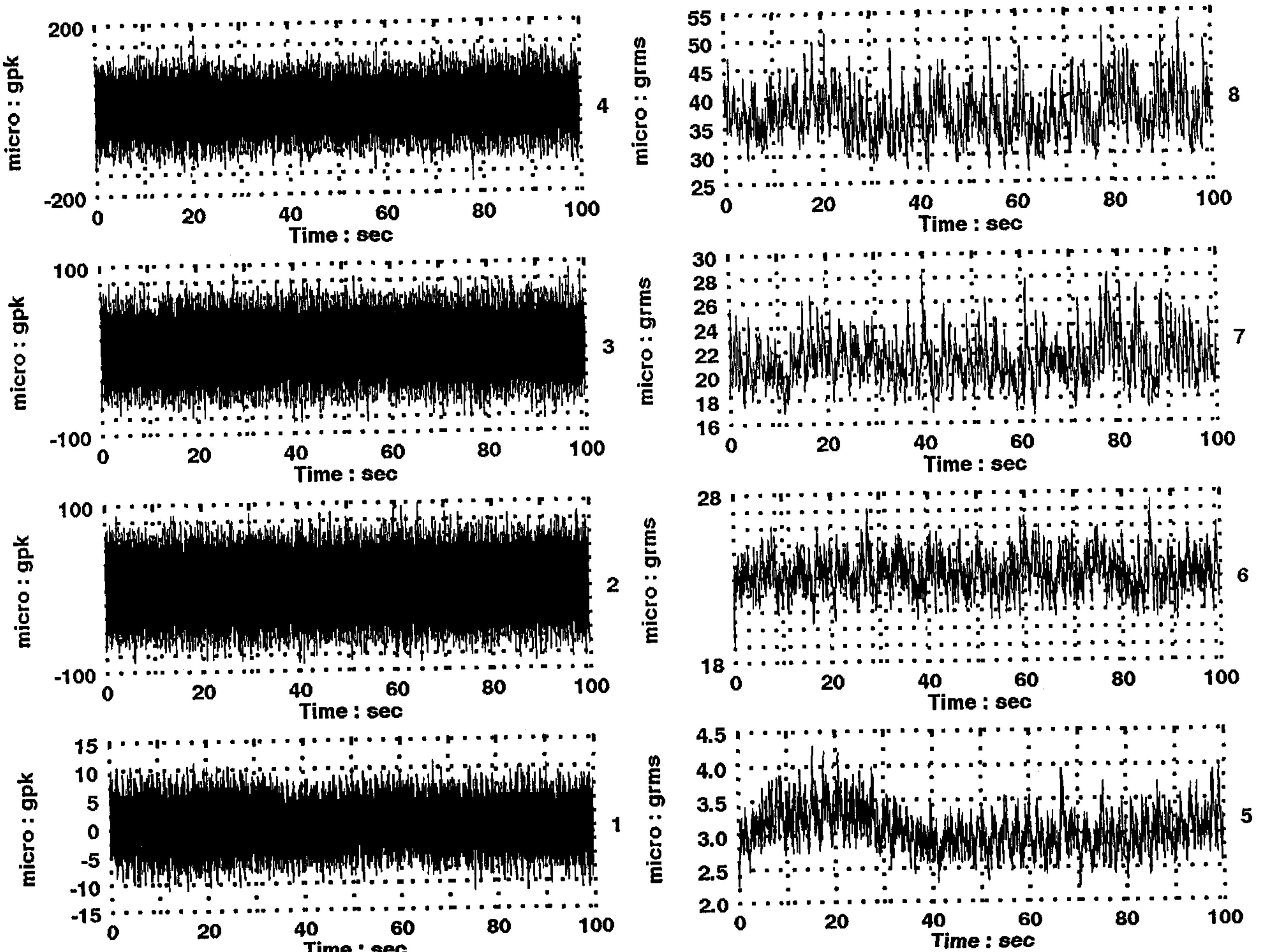
9/24/98 Test 3 (Bkg), (1-4)time histories, (5-8) overall rms



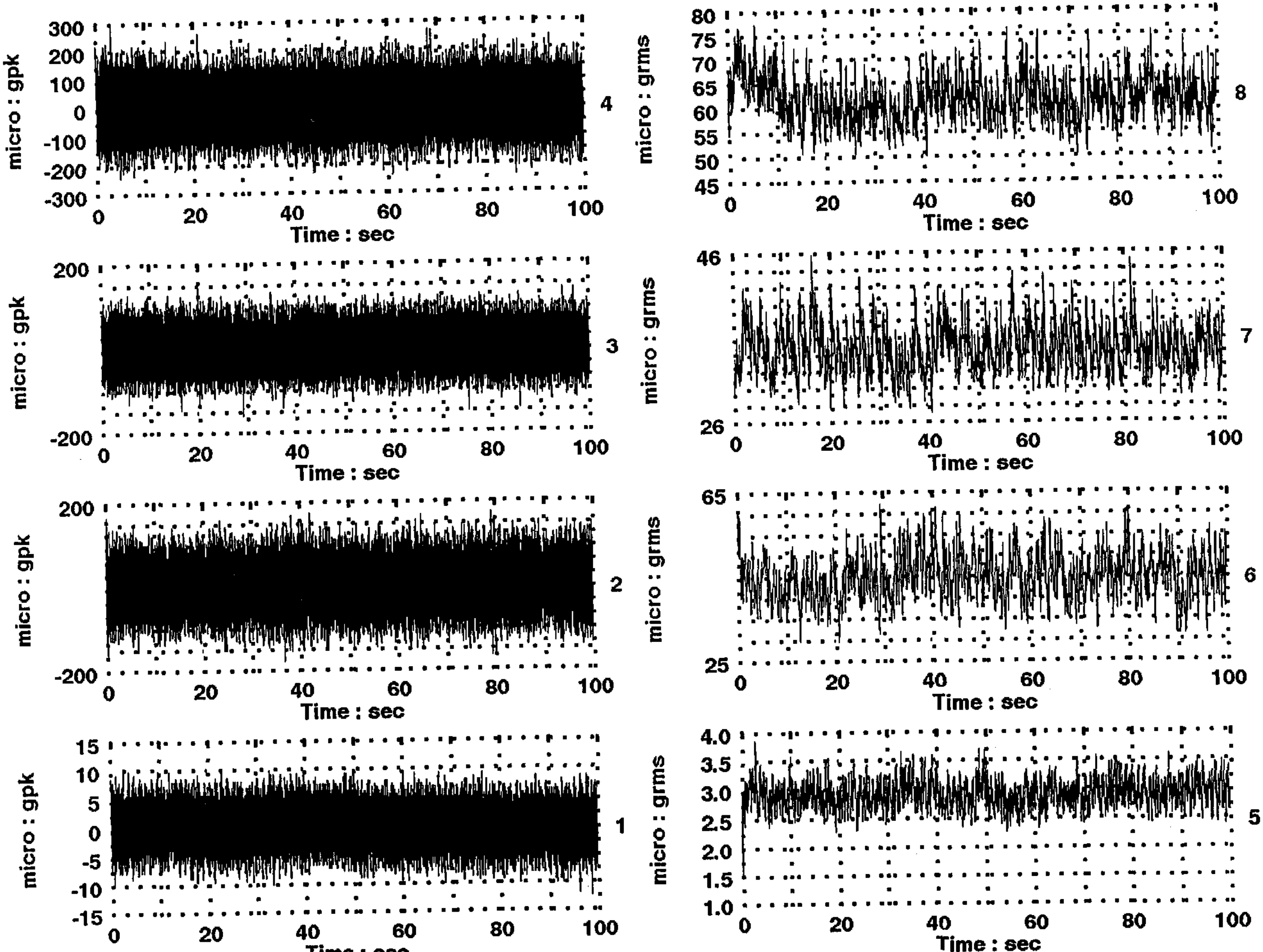
9/25/98 Test 1 (Bkg), (1-4)time histories, (5-8) overall rms



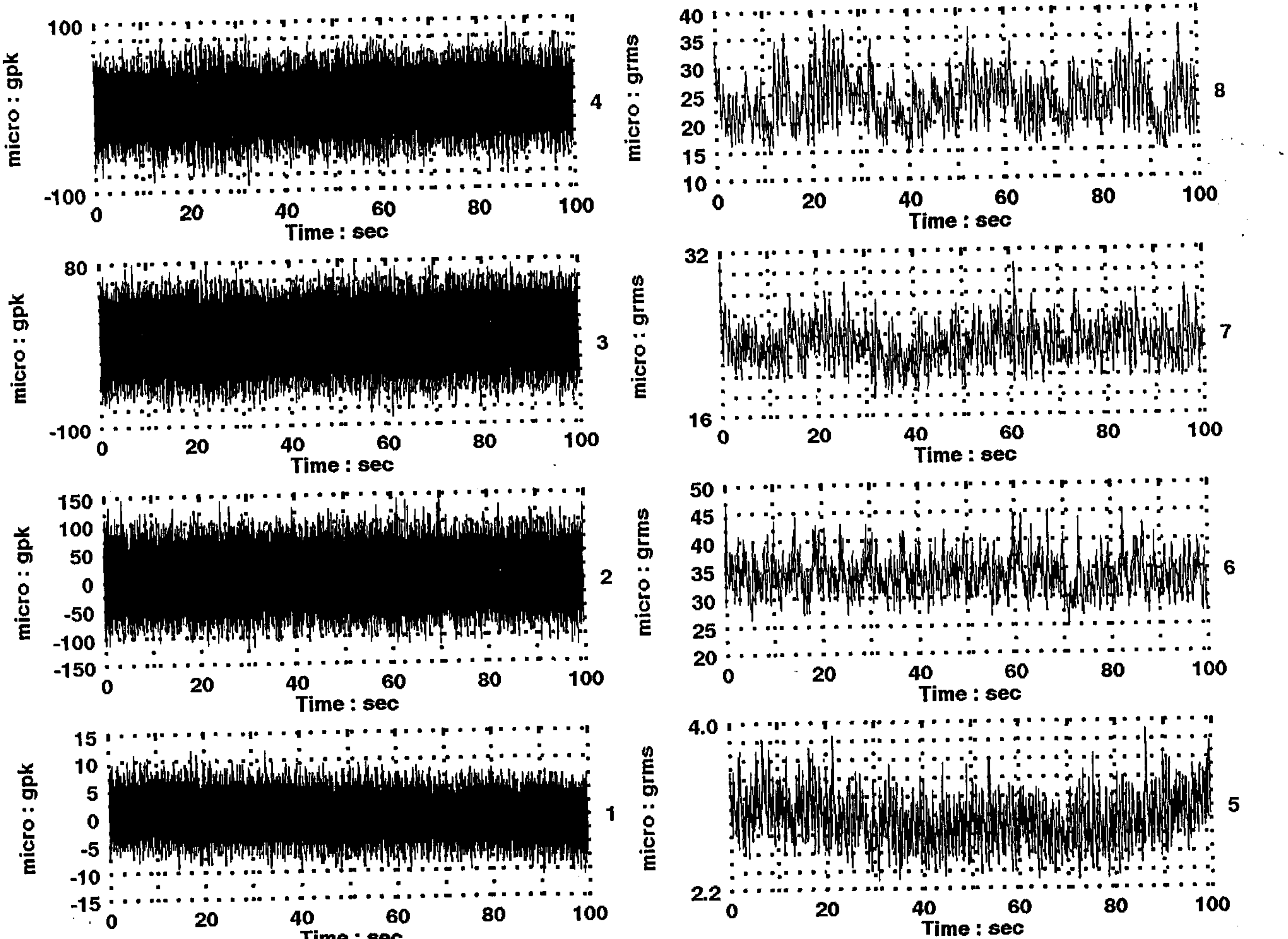
9/25/98 Test 2 (Bkg), (1-4)time histories, (5-8) overall rms



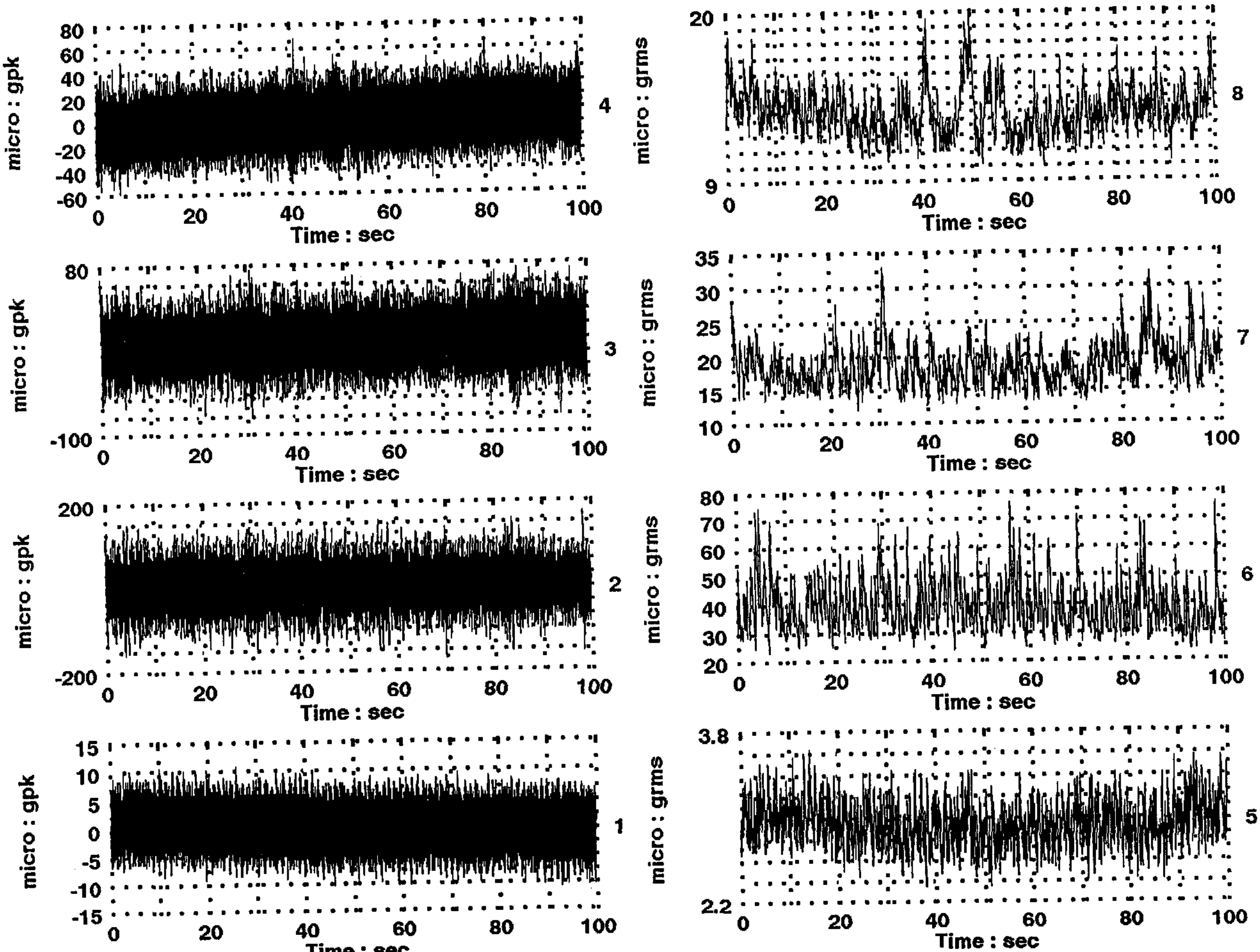
9/25/98 Test 3 (Bkg), (1-4)time histories, (5-8) overall rms



9/25/98 Test 4 (Bkg), (1-4)time histories, (5-8) overall rms

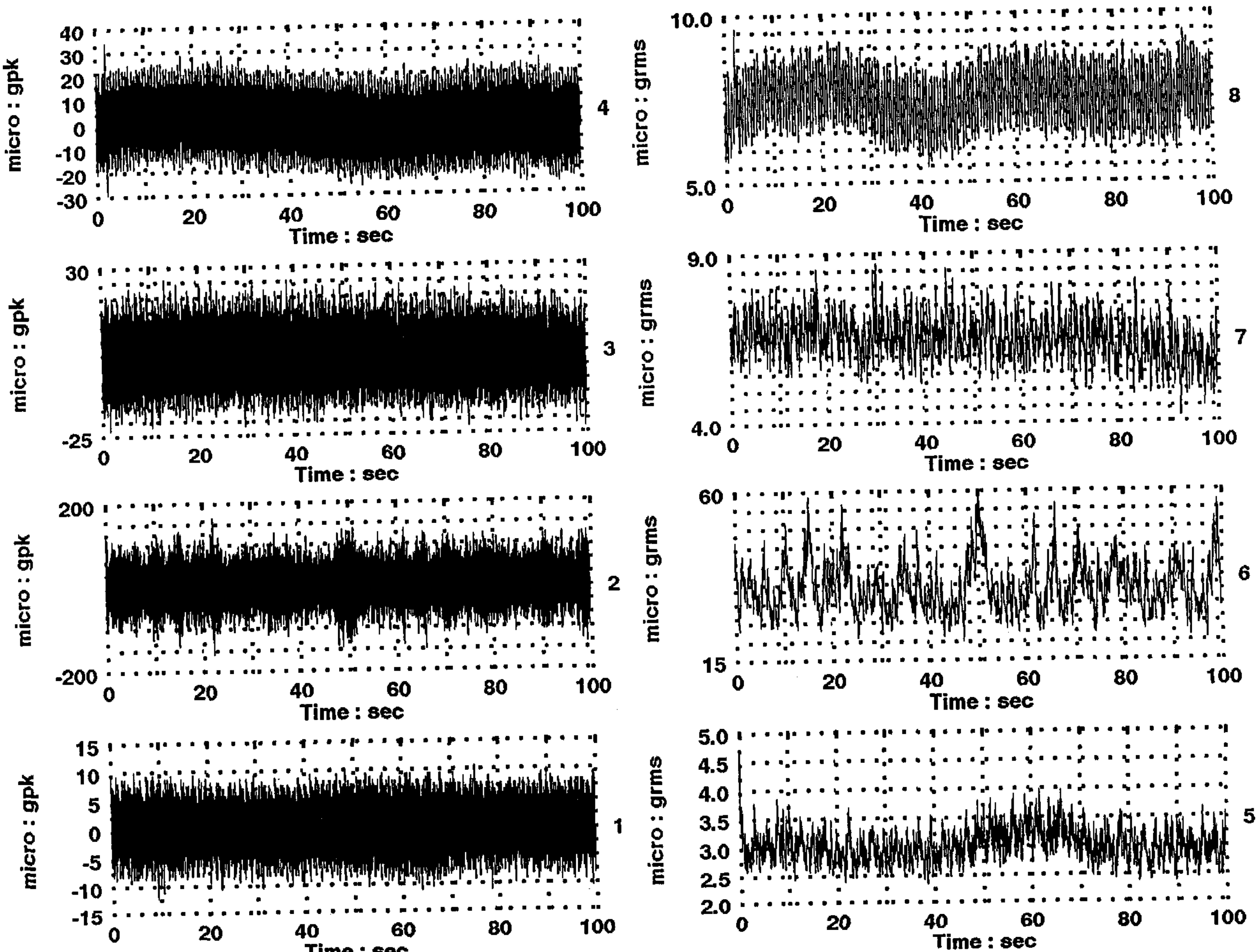


9/25/98 Test 5 (Bkg), (1-4)time histories, (5-8) overall rms

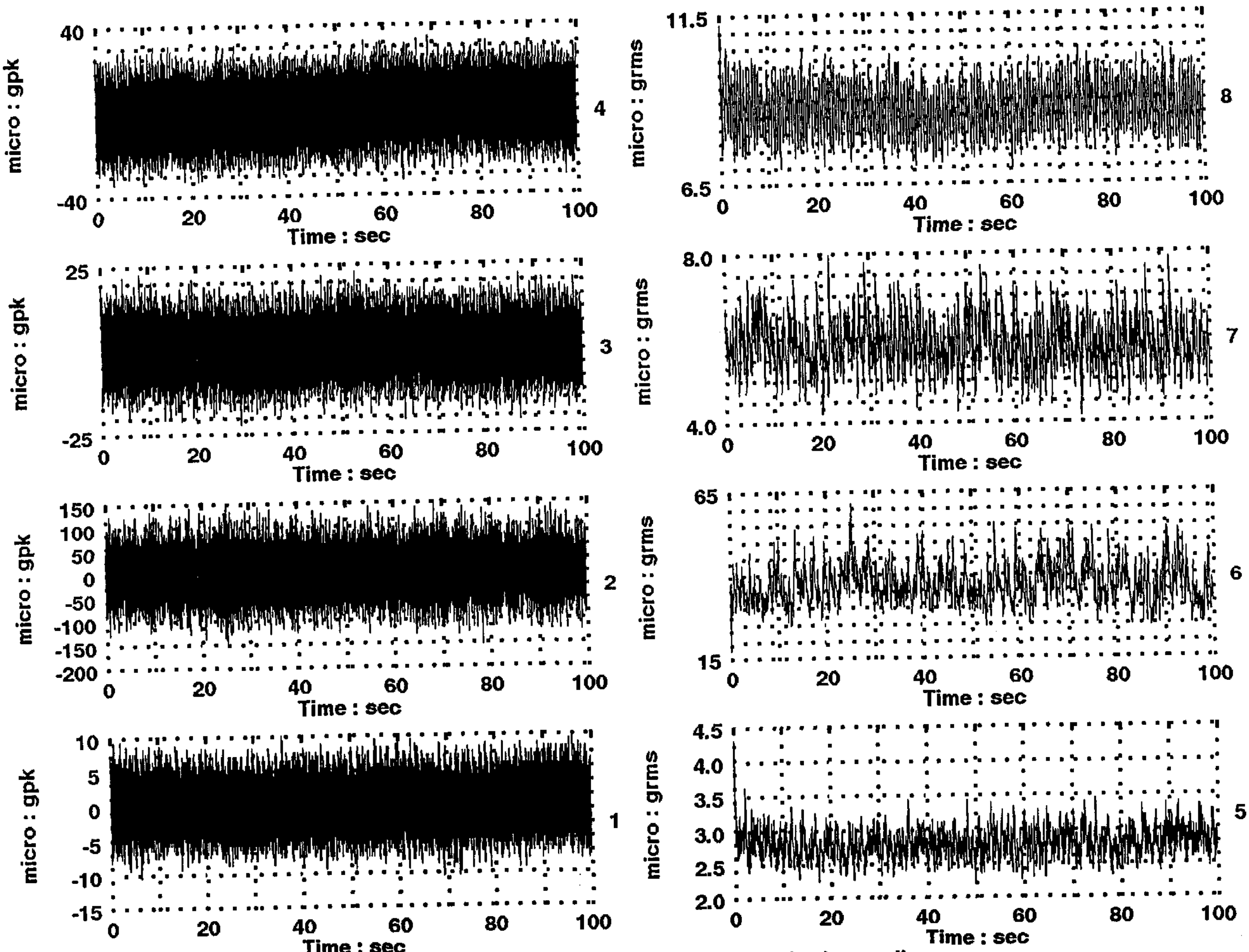


9/25/98 Test 6 (Bkg), (1-4)time histories, (5-8) overall rms

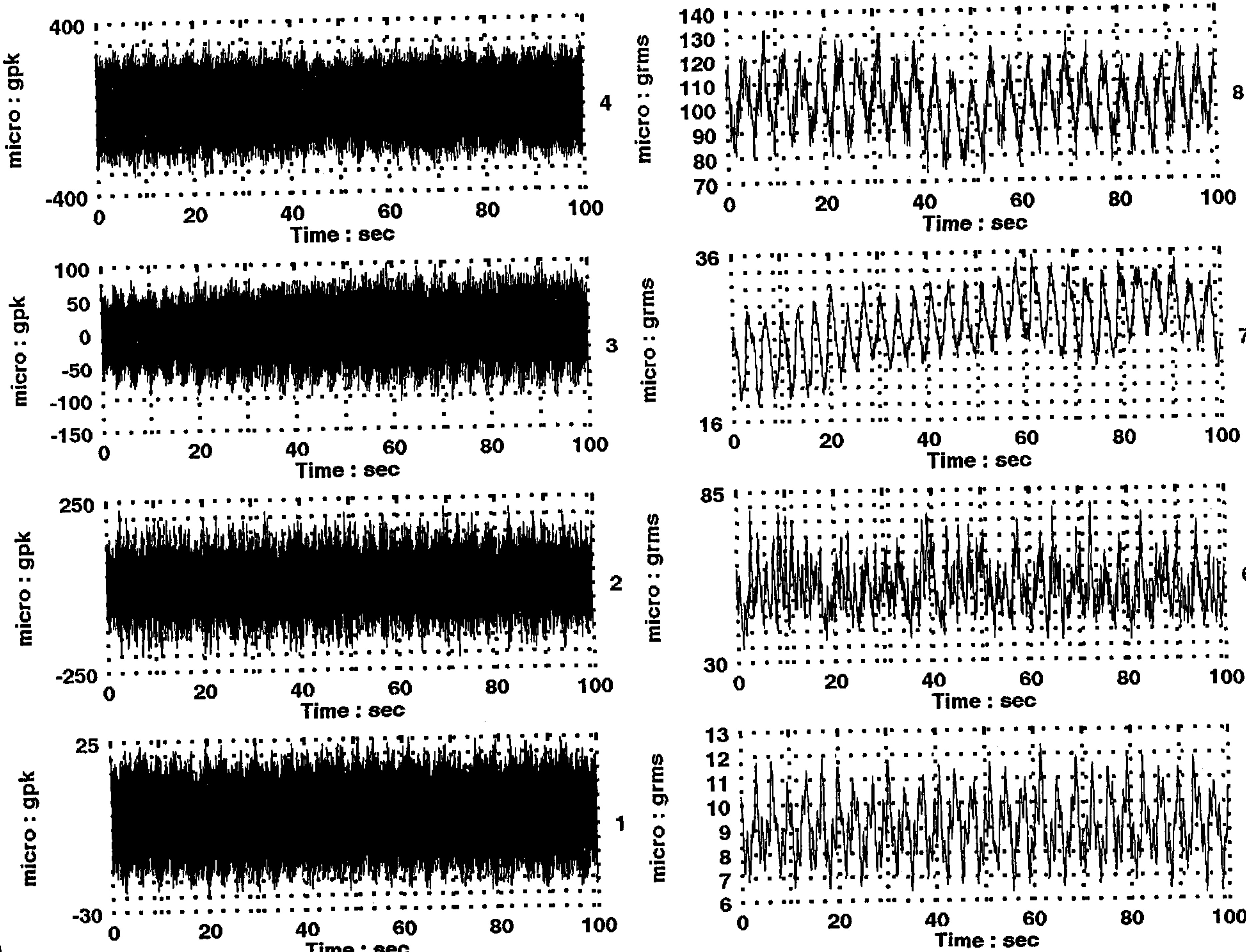
C164



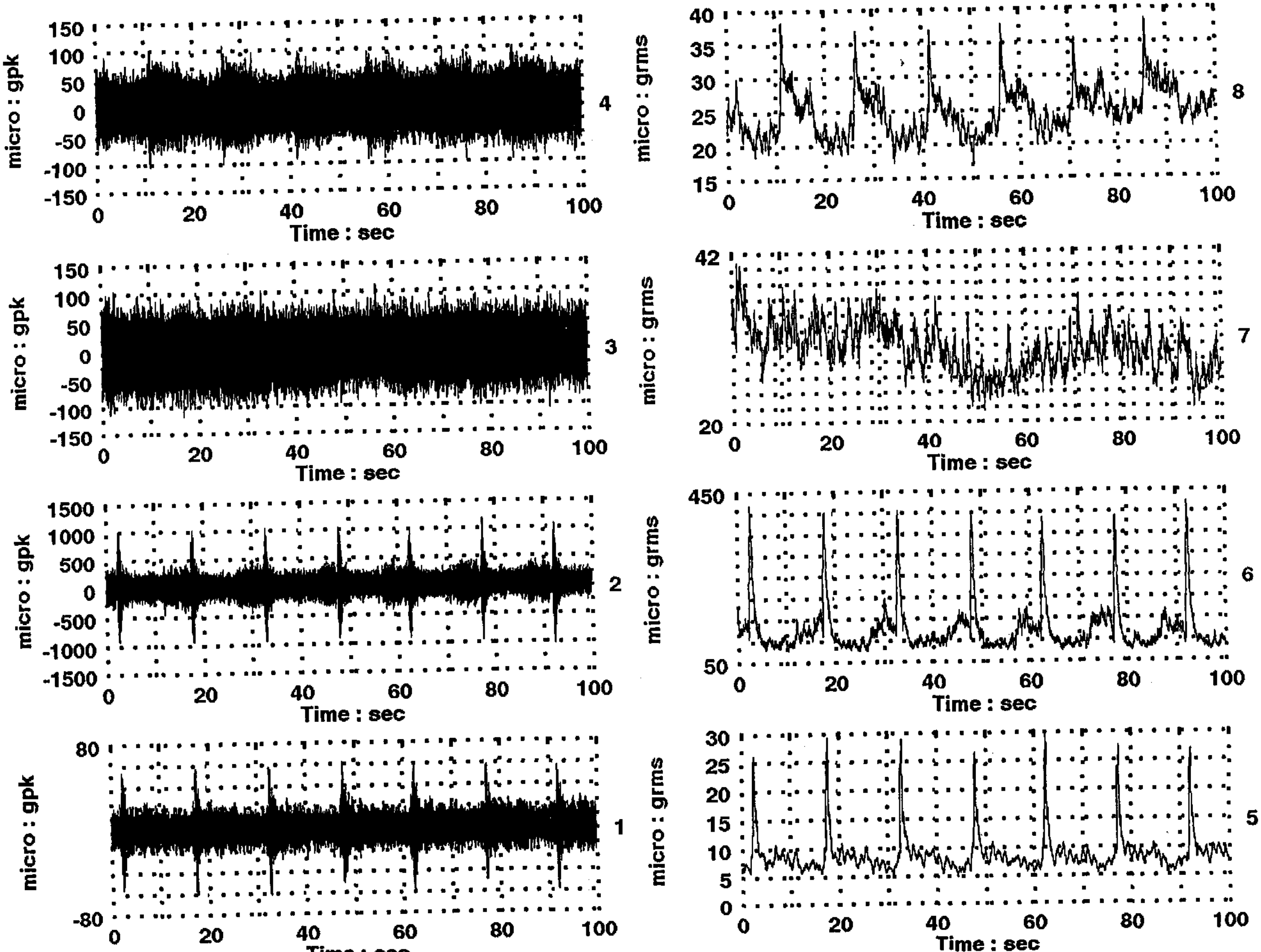
9/25/98 Test 7 (Bkg), (1-4)time histories, (5-8) overall rms



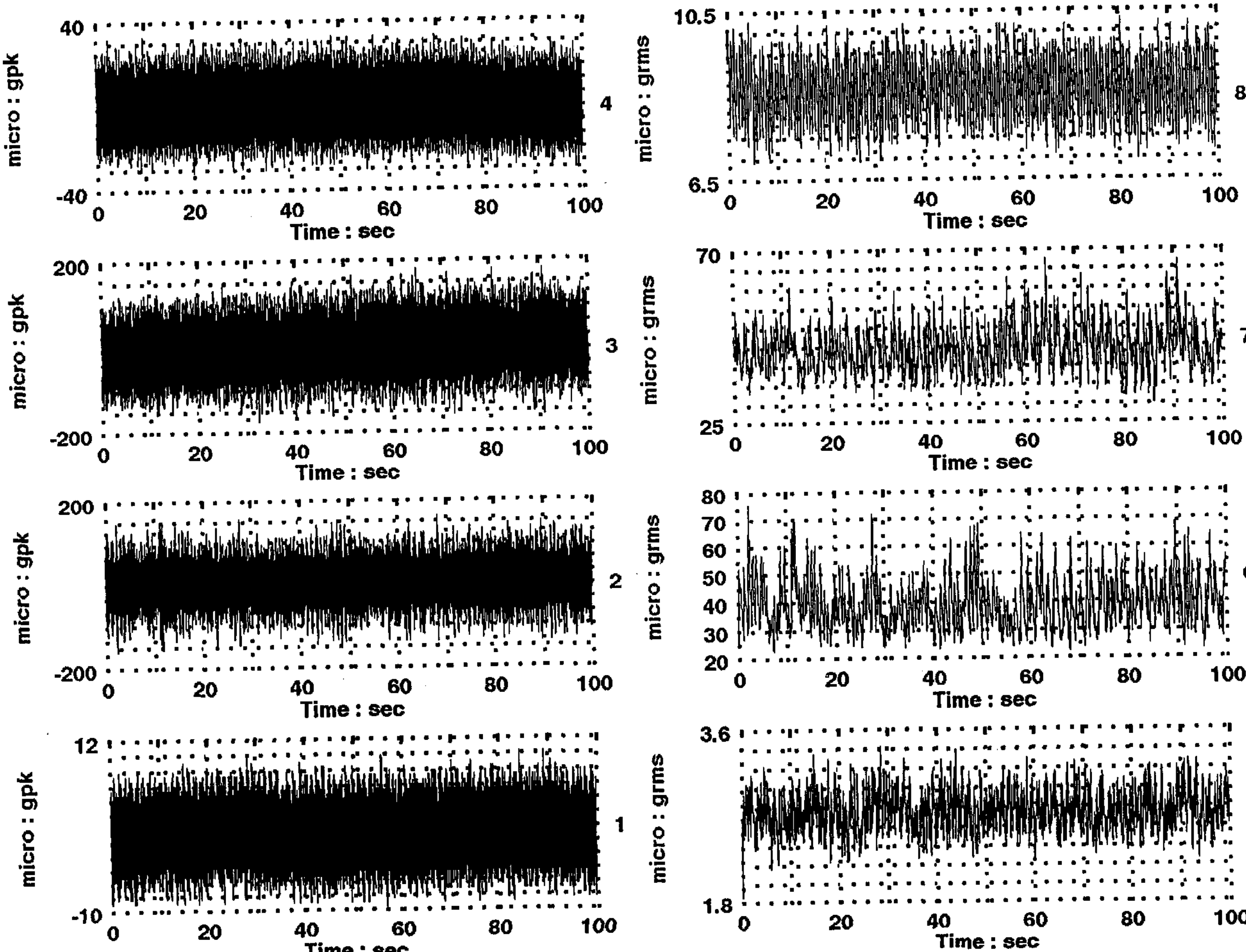
9/25/98 Test 8 (Ion PS), (1-4)time histories, (5-8) overall rms



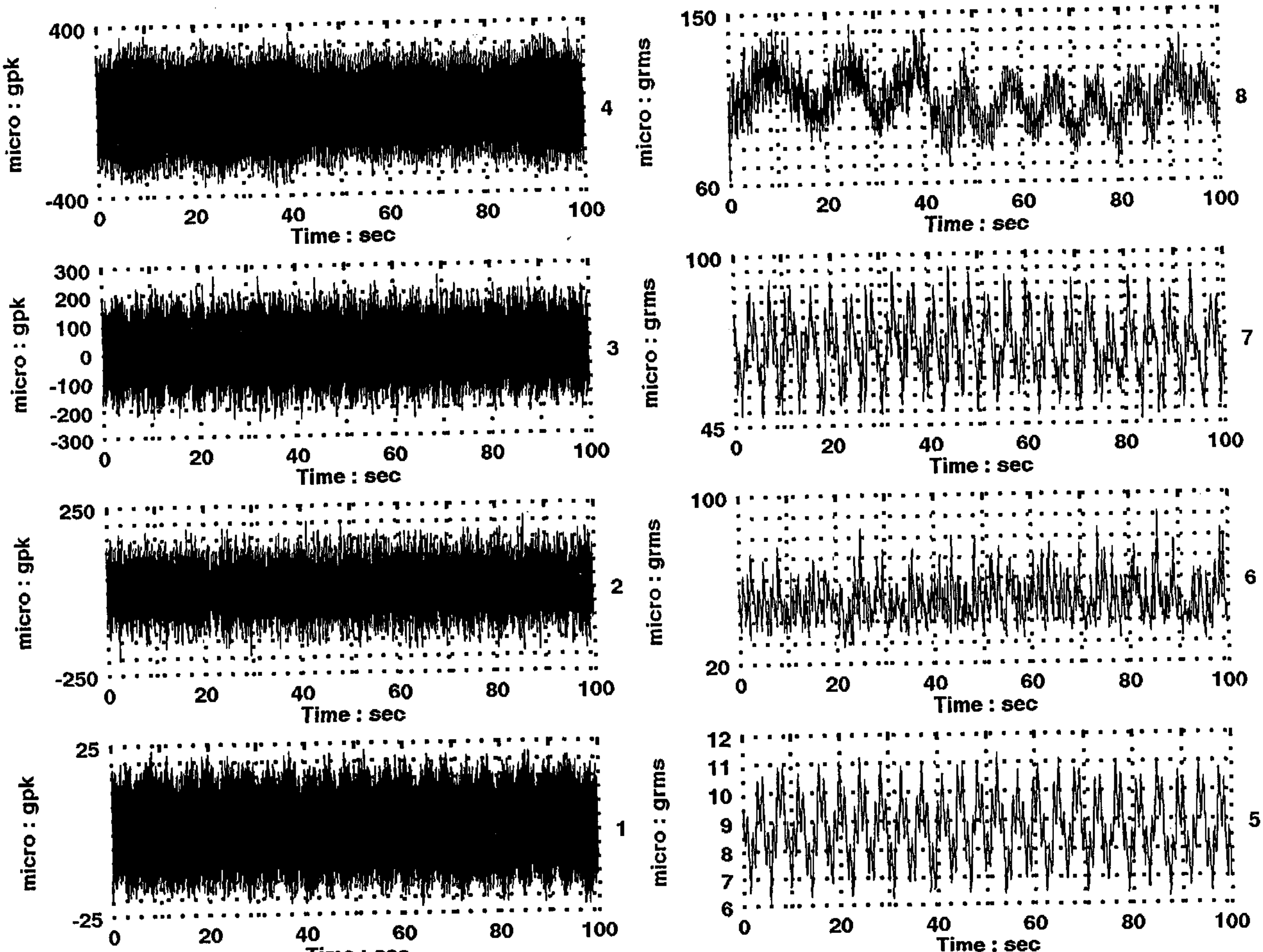
9/25/98 Test 9 (B. Pump) (1-4)time histories, (5-8) overall rms



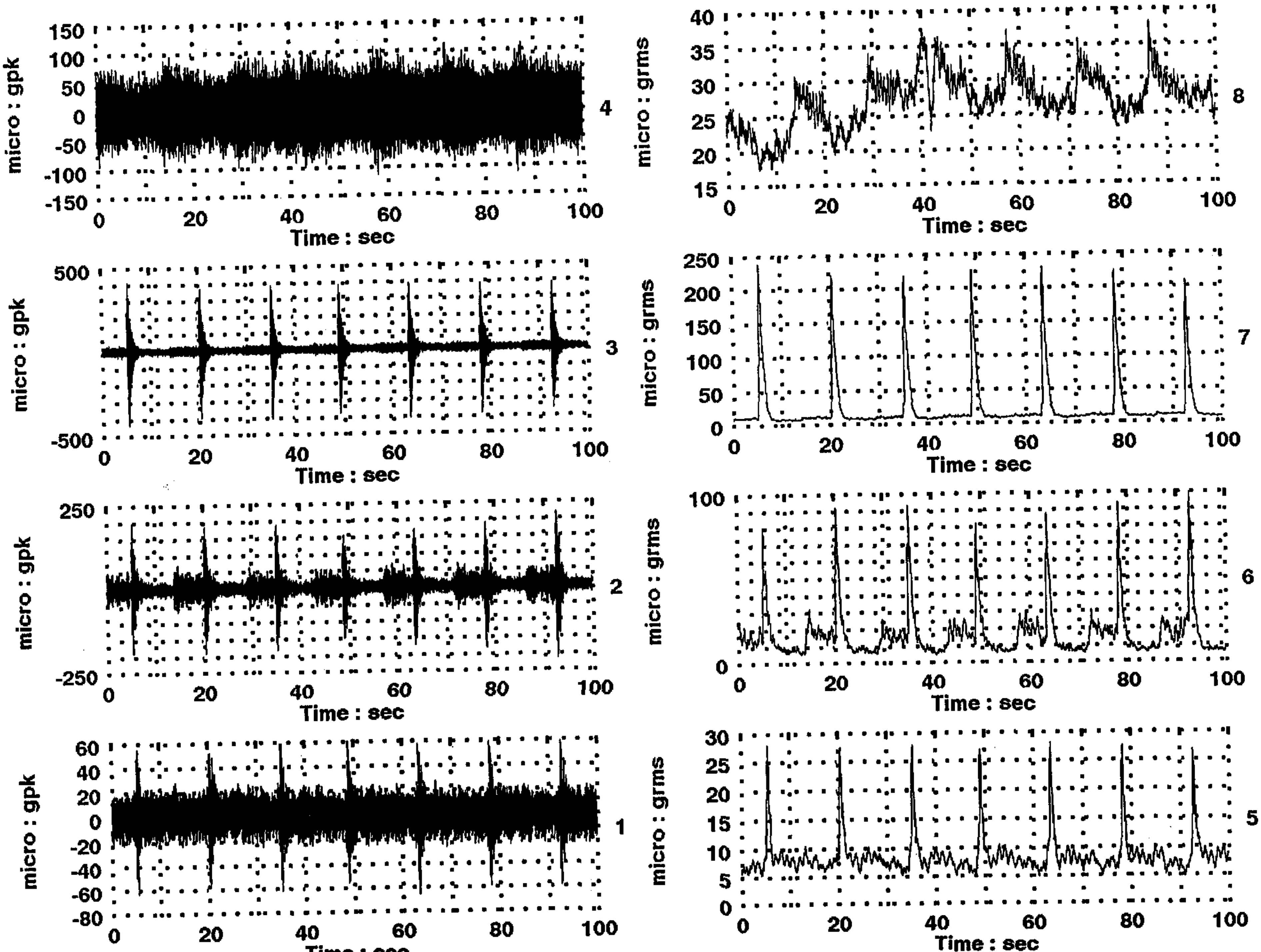
9/25/98 Test 10 (V&P), (1-4)time histories, (5-8) overall rms



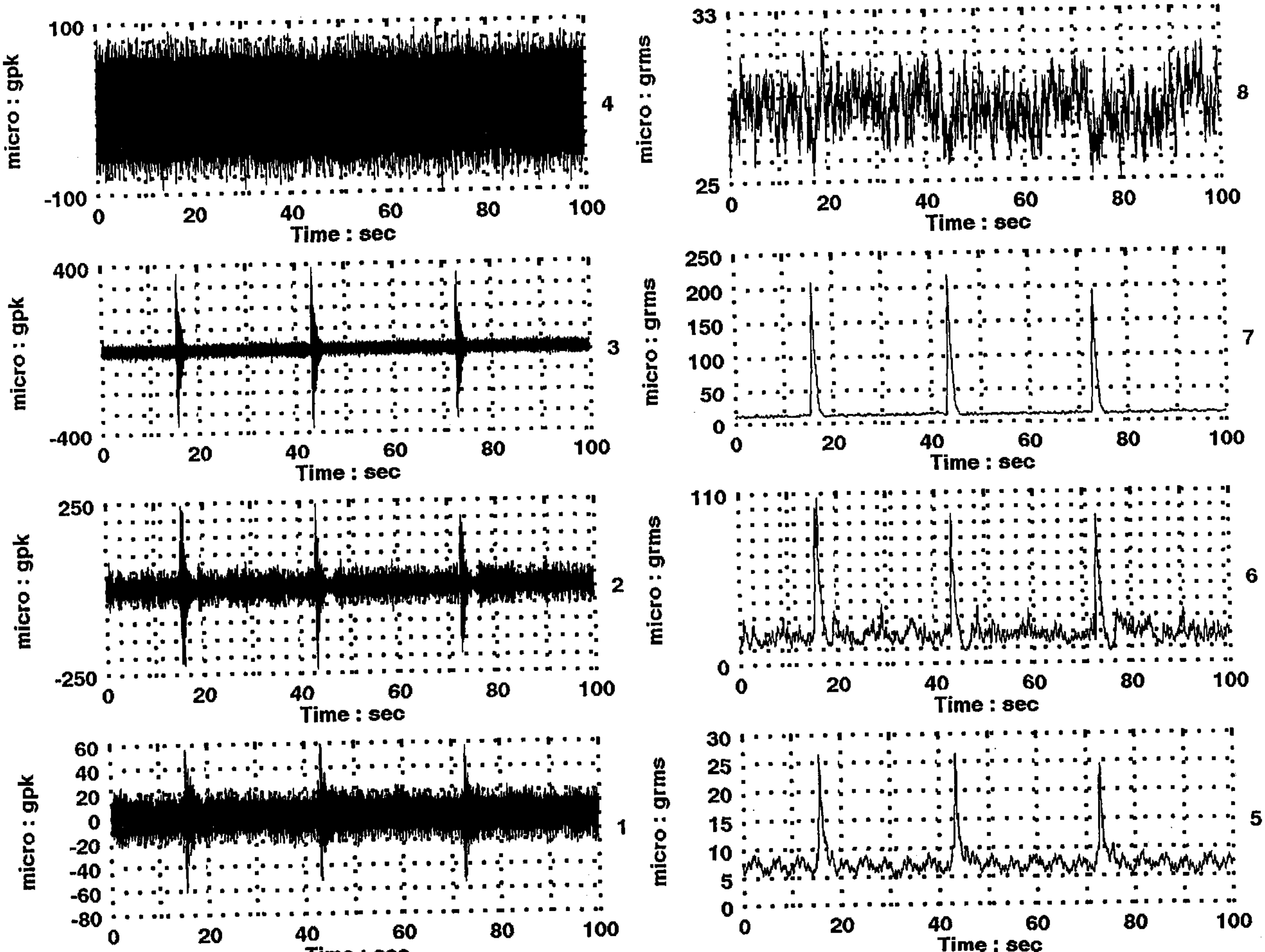
9/25/98 Test 11 (Ion PS), (1-4)time histories, (5-8) overall rms



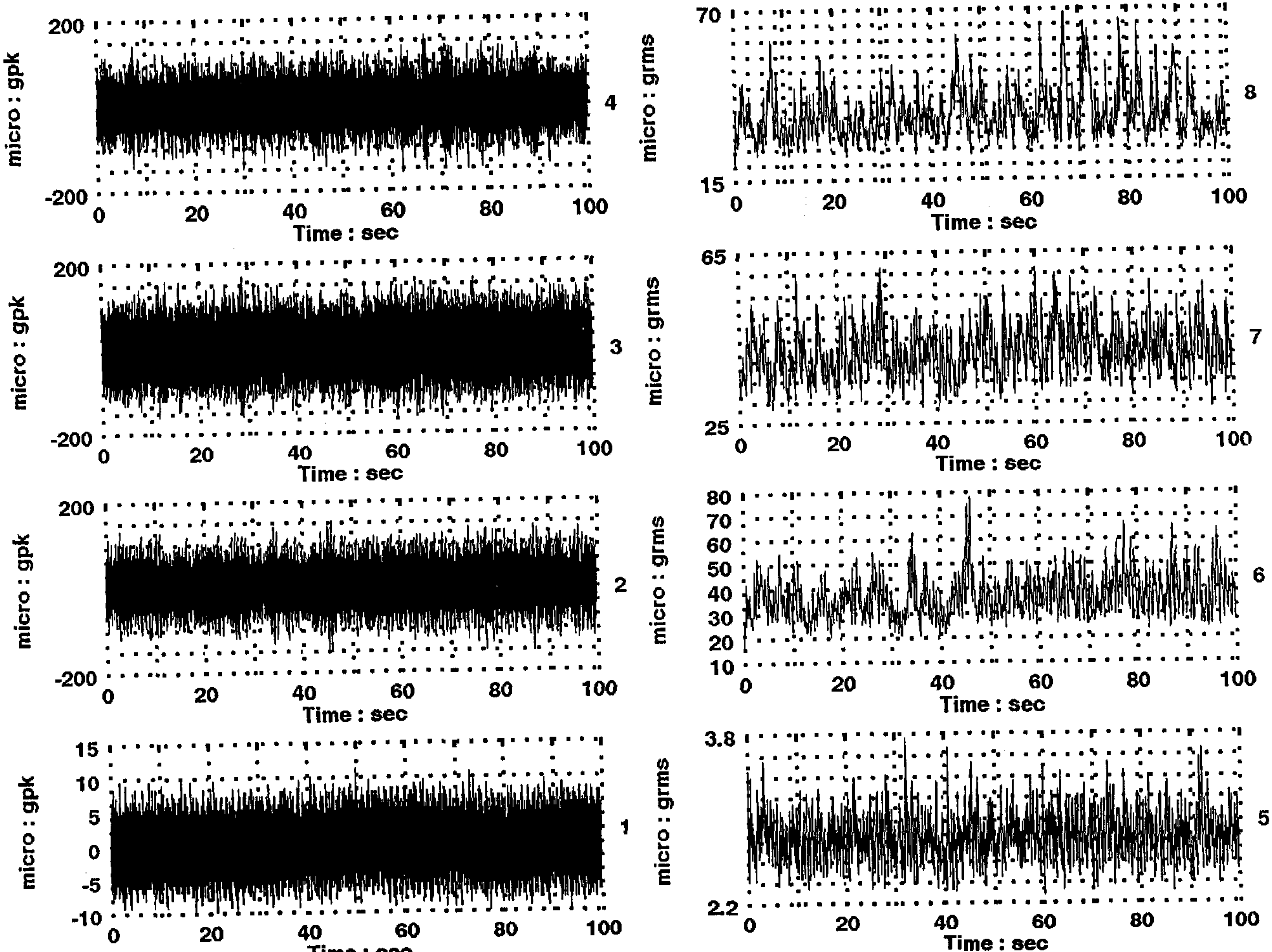
9/25/98 Test 12 (B. pump), (1-4)time histories, (5-8) overall rms



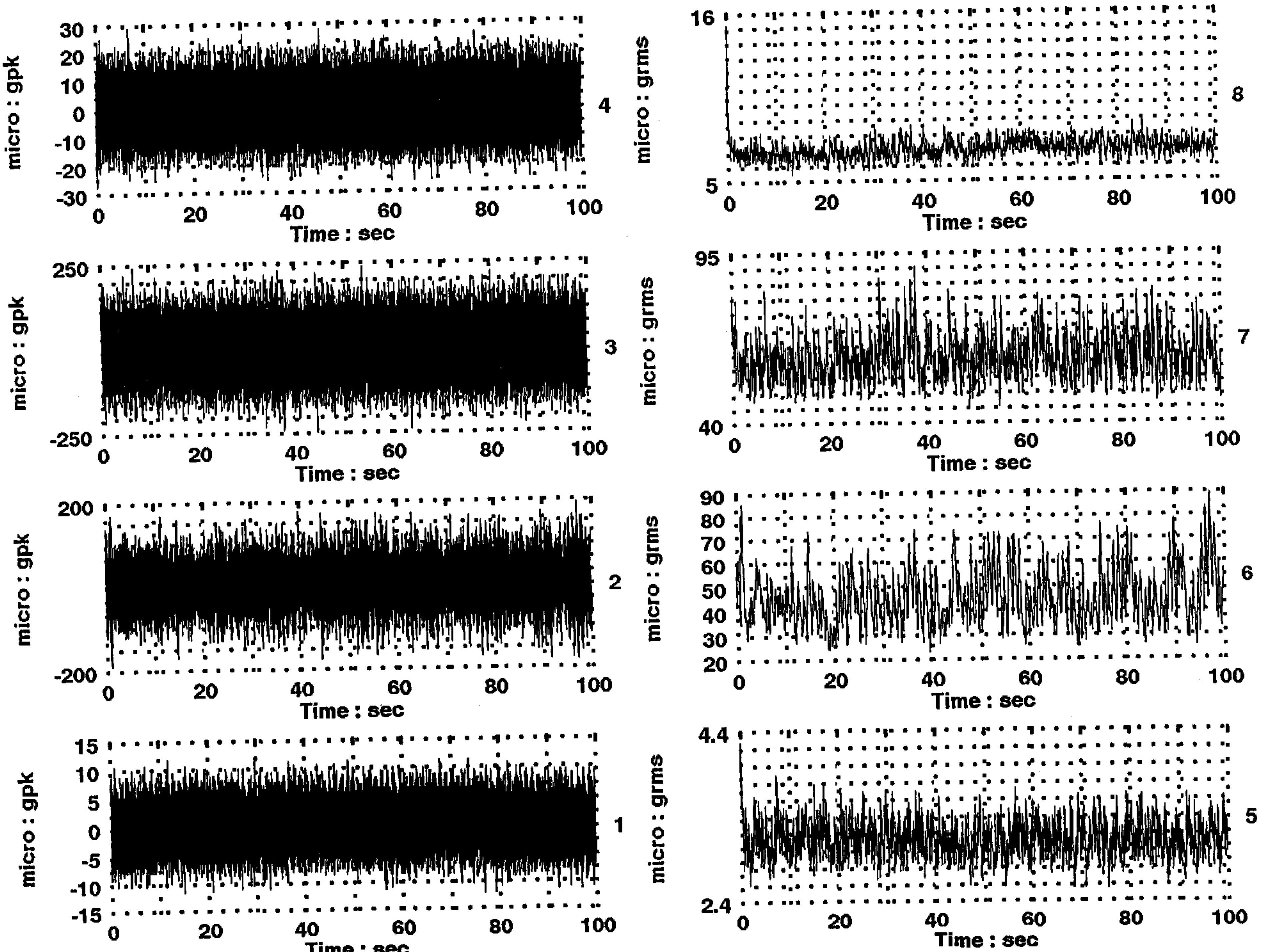
9/25/98 Test 13 (V&P), (1-4)time histories, (5-8) overall rms



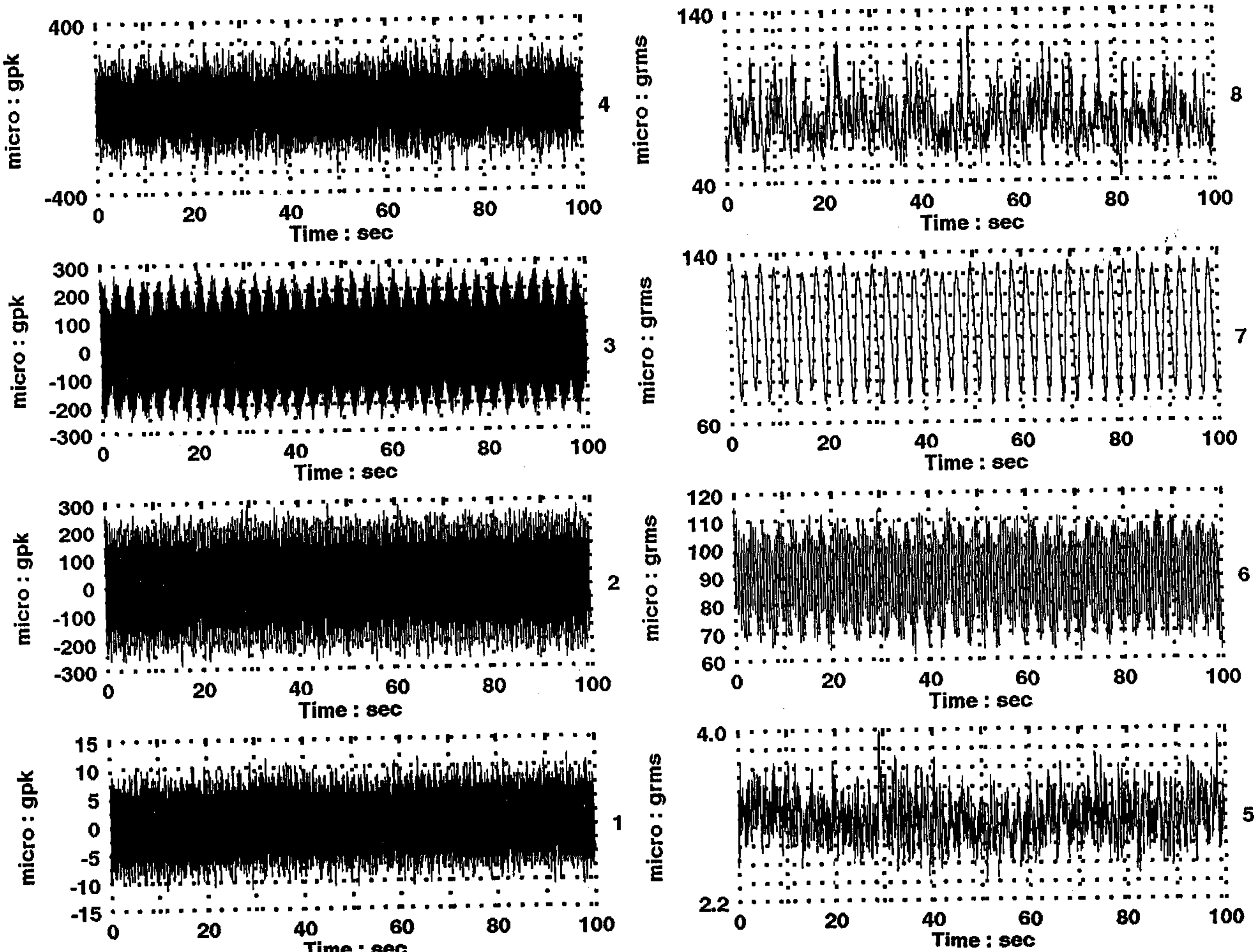
9/25/98 Test 14 (V&P mod), (1-4)time histories, (5-8) overall rms



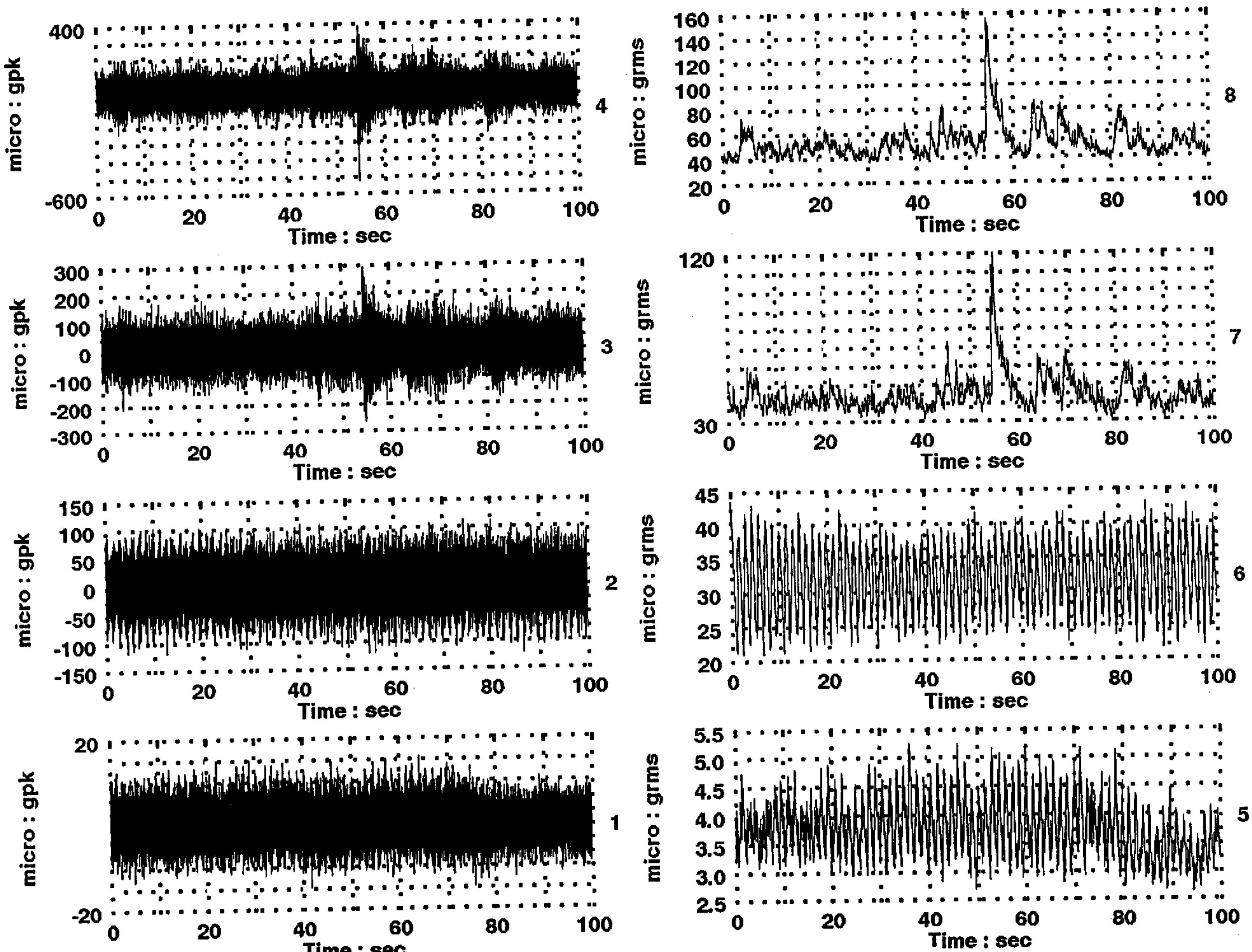
9/25/98 Test 15 (bkg.), (1-4)time histories, (5-8) overall rms



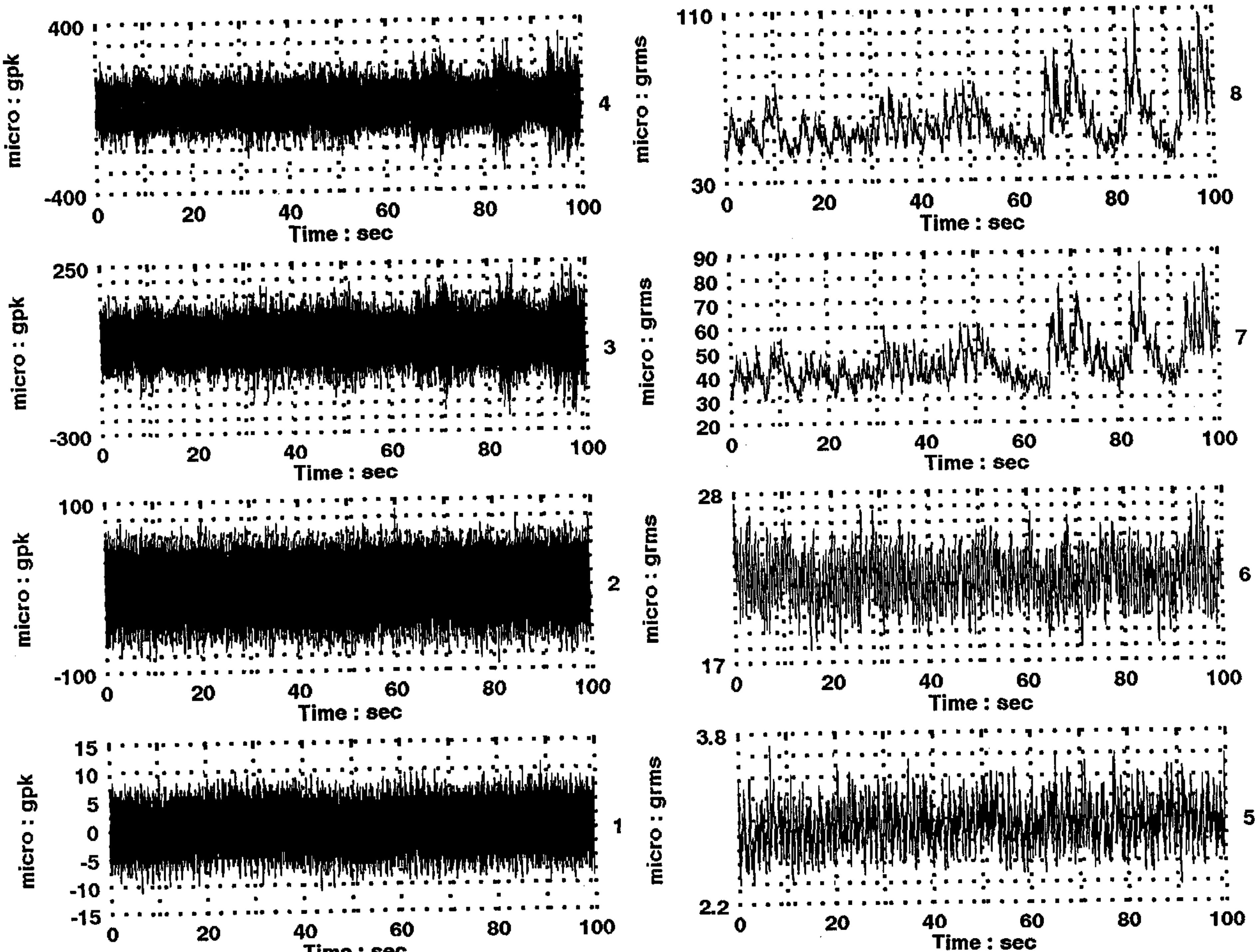
9/25/98 Test 18 (turbo), (1-4)time histories, (5-8) overall rms



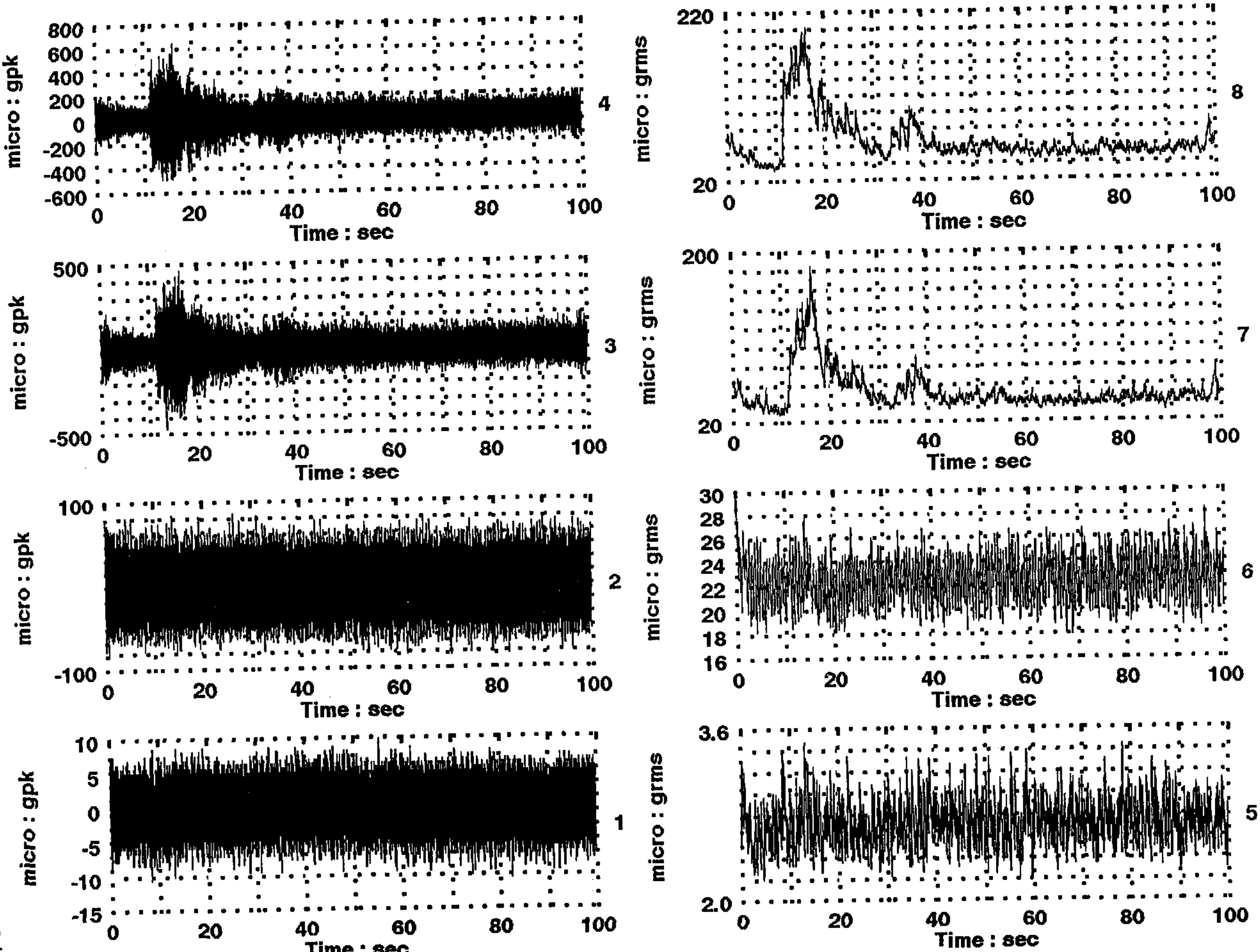
9/25/98 Test 20 (turbo), (1-4)time histories, (5-8) overall rms



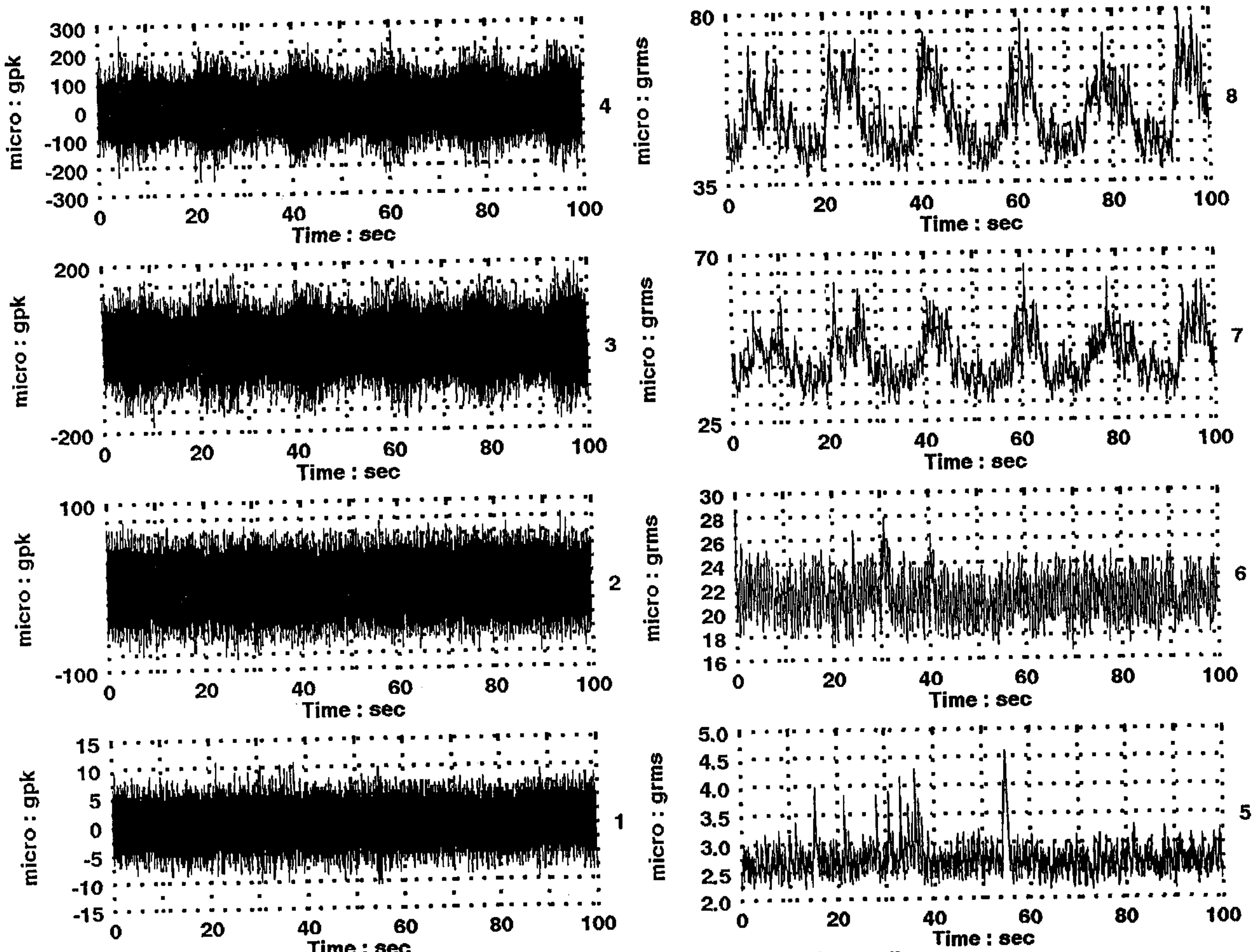
9/26/98 Test 1 (cryo), (1-4)time histories, (5-8) overall rms



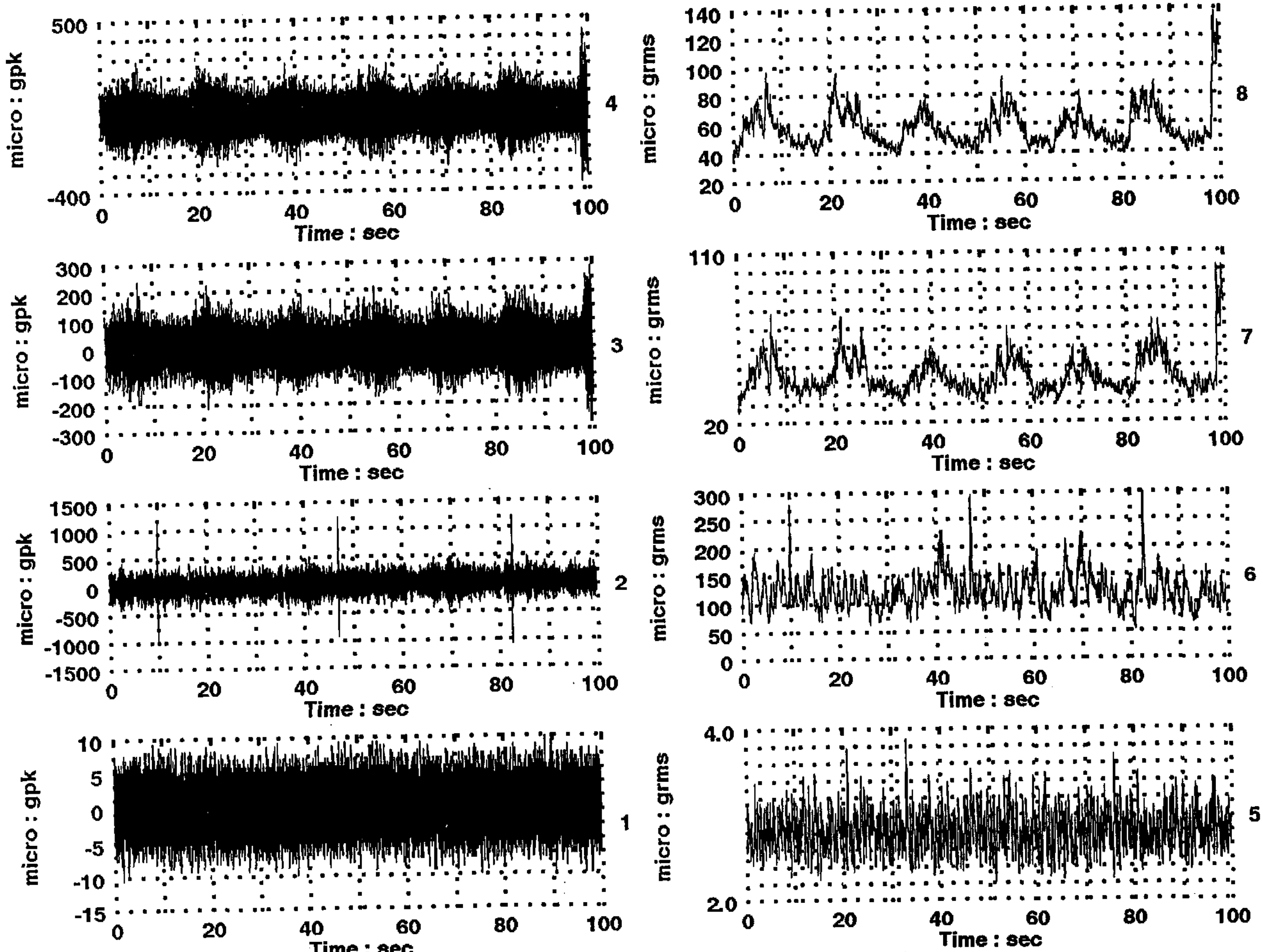
9/26/98 Test 2 (cryo), (1-4)time histories, (5-8) overall rms



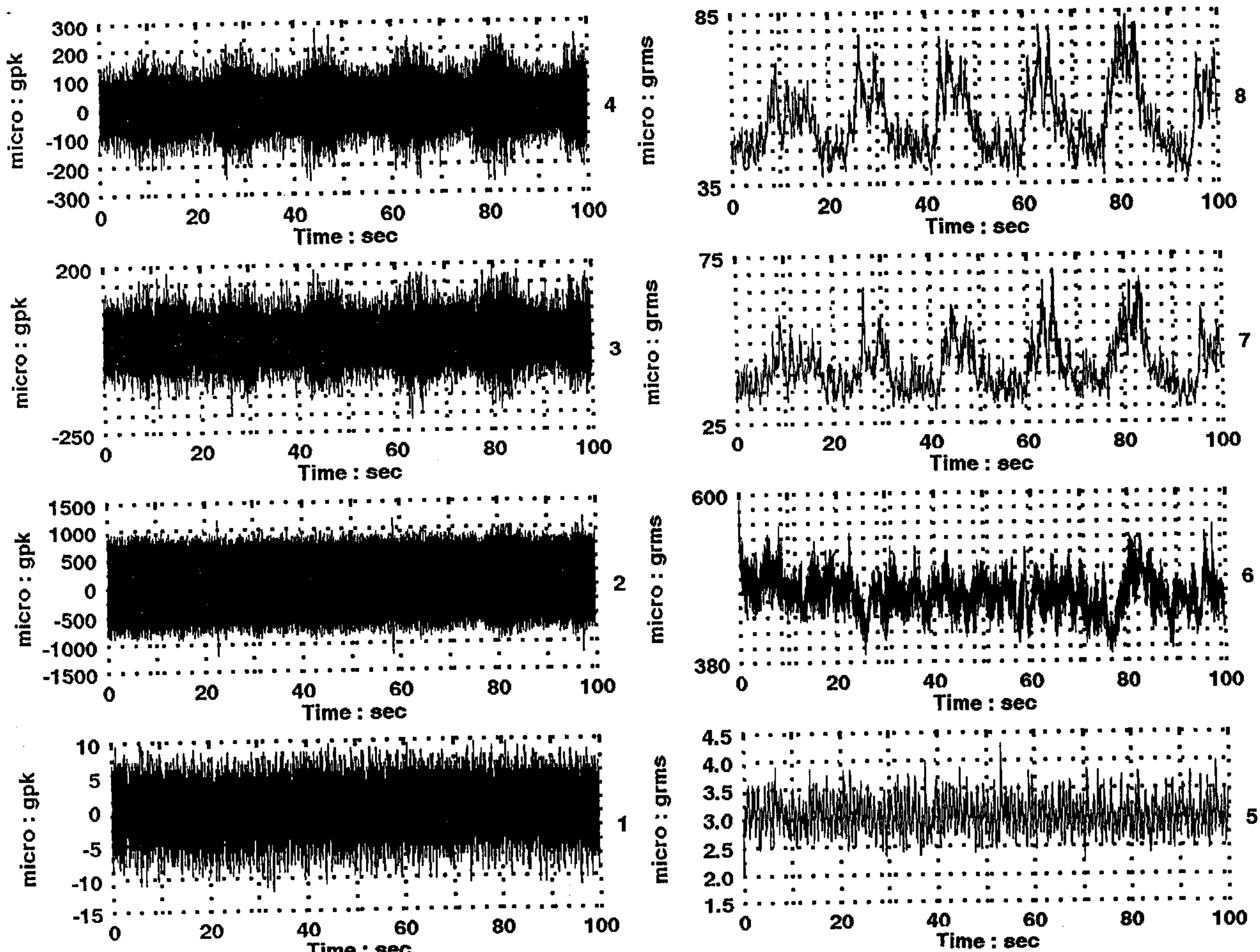
9/26/98 Test 4 (cryo), (1-4)time histories, (5-8) overall rms



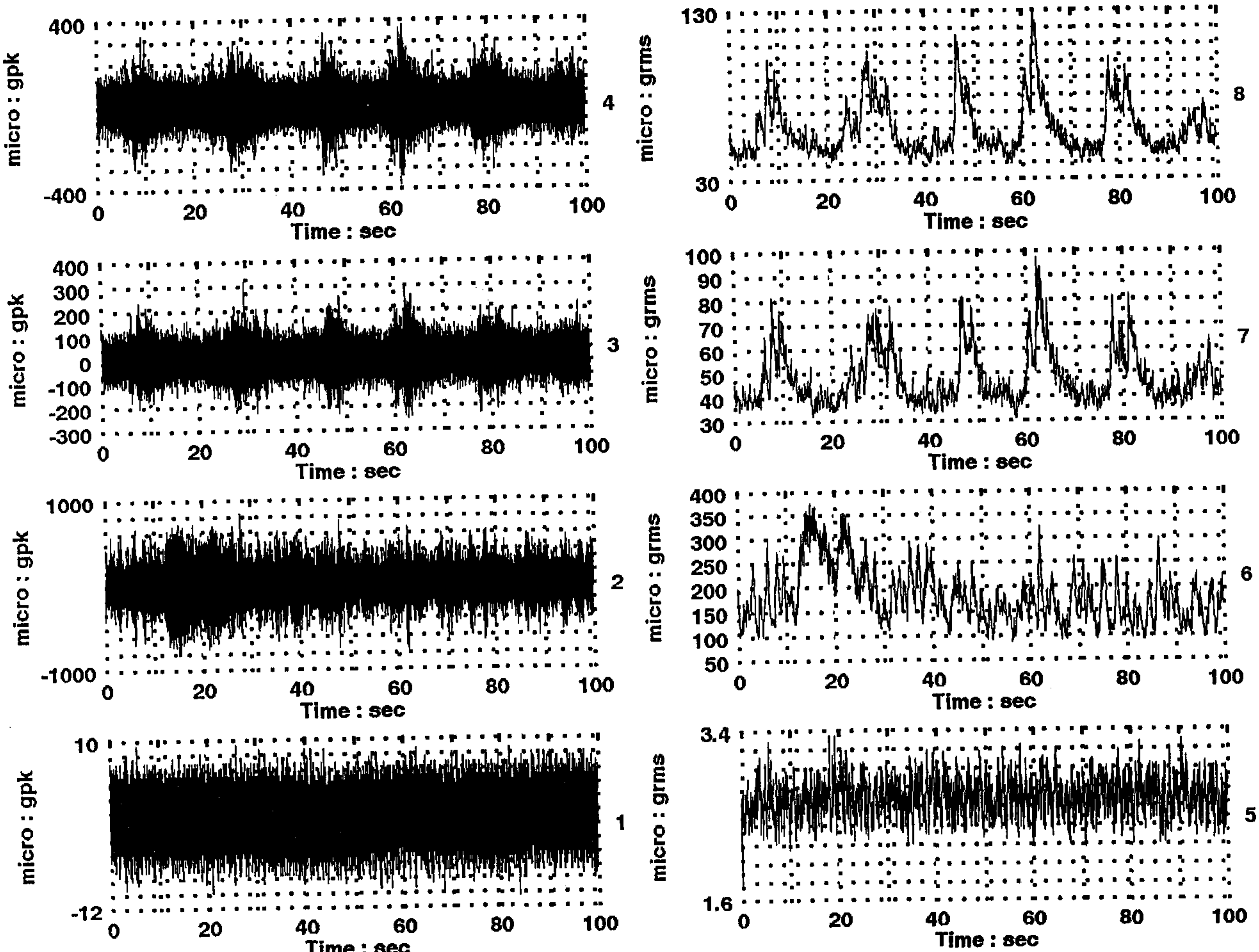
9/26/98 Test 5 (cryo), (1-4)time histories, (5-8) overall rms



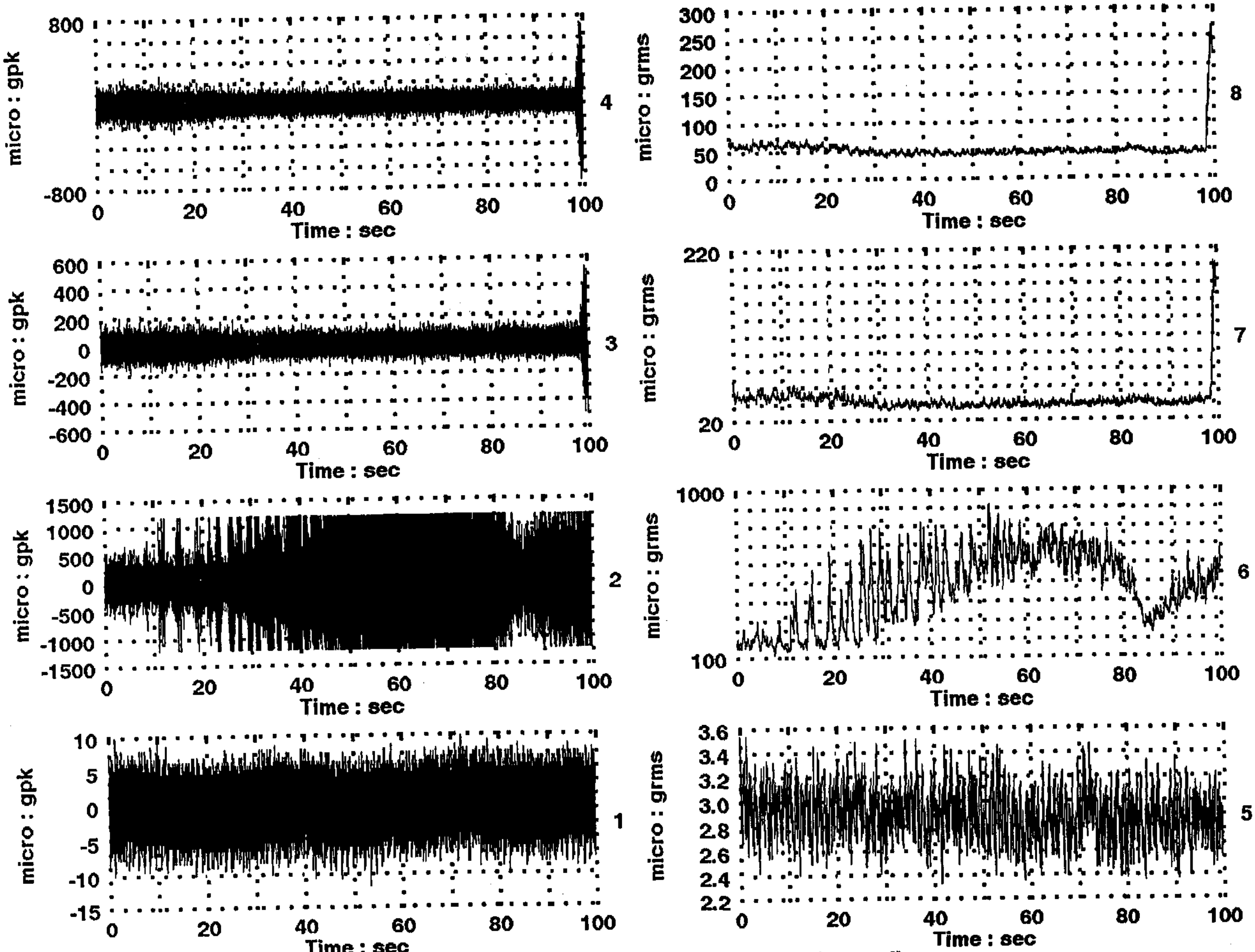
9/26/98 Test 6 (cryo), (1-4)time histories, (5-8) overall rms



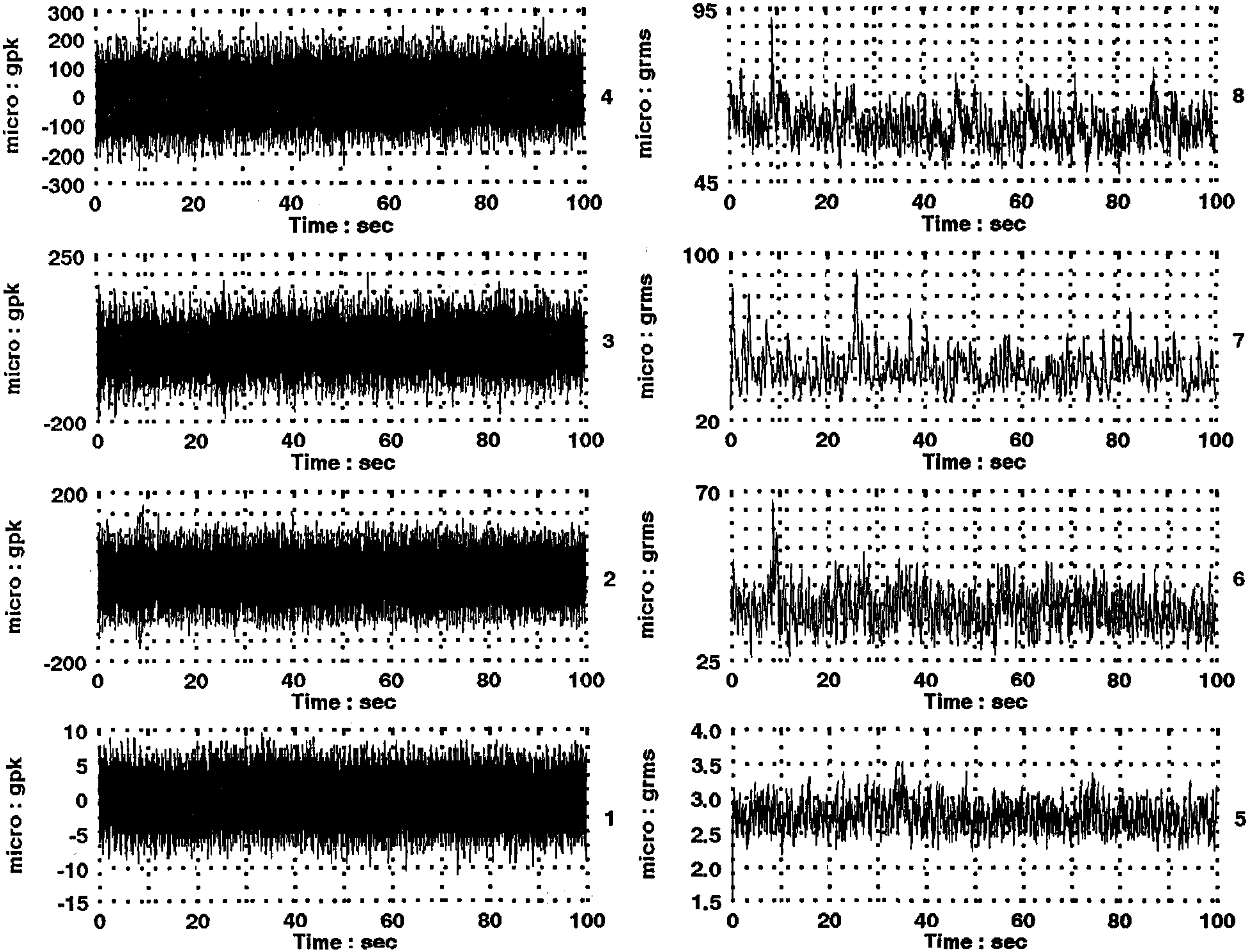
9/26/98 Test 7 (cryo), (1-4)time histories, (5-8) overall rms



9/26/98 Test 8 (cryo), (1-4)time histories, (5-8) overall rms



9/26/98 Test 9 (cryo), (1-4)time histories, (5-8) overall rms



9/26/98 Test 10 (cryo), (1-4)time histories, (5-8) overall rms

C-LAST

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT

10. STATION ACCEPTANCE TEST SUMMARY AND SIGN-OFF SHEET

ATTACHMENT II

LIGO PROJECT – PROCESS SYSTEMS INTERNATIONAL

CORNER STATION ACCEPTANCE TESTING AND INSPECTION SUMMARY

	By	Date Complete	Comments
1. LN_2 Tank Inspection Tank S/N ______ (per V049-2-102)	SM	2-19-98	
2. LN_2 Tank Inspection Tank S/N ______ (per V049-2-102)	SM	2-19-98	
3. Regeneration Heater Inspection HTR # ______ (per V049-2-102)	RW	5-10-98	
4. Regeneration Heater Inspection HTR # ______ (per V049-2-102)	RW	5-10-98	
5. Cryopump Instrumentation Calibration & Functional Test (per)	RW	5-13-98	
6. Vacuum Instrumentation Checkout	RW	5-14-98	
7. Fill LN_2 Tank	SM	2-20-98	
8. Instrument/Electrical Wiring Checkout (per V049-1-163)	RW/JF	5-14-98	
9. Clean Air Compressor Checkout (per V049-2-109)	SM	3-27-98	
10. Clean Room Testing (per V049-2-110)	JF	1/13/98 1/16/98	

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ATTACHMENT II

LIGO PROJECT – PROCESS SYSTEMS INTERNATIONAL

CORNER STATION ACCEPTANCE TESTING AND INSPECTION SUMMARY
(continued)

	By	Date Complete	Comments
11. Gate Valve Operational Test (per V049-2-107)	RW/DE	3-27-98	
12. Roughing Pump Skid Operational Test (per V049-2-104)	SM/JF	5-14-98	LBM Diagonal Vertex RBM
13. Turbopump Skid Operational Test (per V049-2-105)	JF	5-14-98	LBM Diagonal Vertex RBM
14. 10 & 14 In. Manual Valves (per V049-2-108)	JF	5-5-98	
15. Auxiliary Turbopump Test (per V049-2-105)	JF	5-8-98	
16. Main Ion Pump Testing (per V049-2-106)	JF	5-7-98	LBM Diagonal Vertex RBM
17. Bake-out Cart/System (per V049-2-112)	RW	3-13-98	
18. Annulus Ion Pump Functional Test (per V049-2-106)	DH/JF	5-9-98	LBM Diagonal Vertex RBM
19. Flange Annulus Leak Test (per V049-2-113)	DH	5-9-98	LBM Diagonal Vertex RBM

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ATTACHMENT II

LIGO PROJECT – PROCESS SYSTEMS INTERNATIONAL

CORNER STATION ACCEPTANCE TESTING AND INSPECTION SUMMARY
(continued)

	By	Date Complete	Comments	
20. Main Volume Leak Check (per V049-2-113)	DH JF	→	LBM	4/10/98
			Diagonal	4/28/98
			Vertex	5/22/98
			RBM	5/7/98
21. Ultimate Pressure Test/RGA/ Rate of Rise (per V049-2-113)	JF	→	LBM/Diagonal	6/13/98
			RBM/Vertex	7/9/98
22. 10 Day LN_2 Usage Test	JF	→	LBM	6/26/98
			RBM	7/17/98
23. 100 Hour Pumpdown Demonstration Test	JF	→	LBM/Diagonal	N/A
			RBM/Vertex	7/16/98

Acceptance Testing Complete

Signed [signature]

Date 10/7/98

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

Signed [signature]

Date 10/7/98

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Title: SYSTEM ACCEPTANCE TEST PLAN, CORNER STATIONS

SYSTEMS ACCEPTANCE TEST PROCEDURE

LIGO VACUUM EQUIPMENT

CORNER STATIONS

Hanford, Washington and Livingston, Louisiana

JOB NO. V59049

PREPARED BY:	Robert Thon
QUALITY ASSURANCE:	Alan R Bradbrook
TECHNICAL DIRECTOR:	D.C. McWilliams
PROJECT MANAGER:	[signature]

4		D.McW 6-24-98	REVISED PER DEO 0621 TO INCLUDE RATE OF RISE TEST
3	RB 11/13/97	KSS 11/13/97	Revised per DEO 0564
2	D.McW 4-25-97	RES 9/7/96	REVISED PER DEO 0475
1	DM 5/7/96	RES 5/7/96	Revised per DEO # 0178
ϕ	R.T. 5/1/96	RES 5/2/96	INITIAL RELEASE PER DEO 0157 FOR FDR
REV LTR	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.			SPECIFICATION	
INITIAL APPROVALS	PREPARED R.T. DATE 5/1/96	Approved RES DATE 5/2/96	Number: V049-2-113 A	Rev. 4

Title: SYSTEM ACCEPTANCE TEST PLAN, CORNER STATIONS

SYSTEM ACCEPTANCE TEST PLAN

LIGO VACUUM EQUIPMENT

CORNER STATIONS

Hanford, Washington and Livingston, Louisiana

JOB NO. V59049

PREPARED BY: ______________________

QUALITY ASSURANCE: ______________________

TECHNICAL DIRECTOR: ______________________

PROJECT MANAGER: ______________________

			INITIAL RELEASE
REV LTR	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.			**SPECIFICATION**	
INITIAL APPROVALS	PREPARED DATE	Approved DATE	Number: V049-2-113 A	Rev.4

TABLE OF CONTENTS

1.0 PURPOSE

2.0 GENERAL

3.0 REFERENCES

4.0 RESPONSIBILITIES

5.0 FIELD TEST PROCEDURES

ATTACHMENTS

I. CAA Test Plan for Vibration, Noise and Test

II. Corner Station Acceptance Testing and Inspection Summary

III. Authorization to Vacuum Test Form

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 general apply to the corner stations. Slight differences among each station will be due to different vacuum equipment, size of the isolatable section sizes, surfaces, volumes, and quantities involved relating to instrumentation, equipment, etc.

Corner station WA	Vertex Section
	Diagonal Section
	Left Beam Manifold Section
	Right Beam Manifold Section

Corner station LA	Vertex Section
	Left Beam Manifold
	Right Beam Manifold

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

5.2 Bakeout and Ultimate Pressure Test: Corner 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 largest isolatable section with an 80K pump. In the case of the Washington corner station the isolatable sections would be: 1. The Vertex section with the Right Beam Manifold, and 2. The Diagonal section with the Left Beam Manifold. In the case of the Louisiana corner station the isolatable section would be the Vertex section with one of the Beam Manifolds. Before a pumpdown and ultimate pressure test is performed, the sections that make up the largest 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 and HAM'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 be 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°.

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.

Since the pumpdown tests will be carried out on a isolatable section with a 80K cryopump, the beam manifold section will also need to be baked prior to vacuum pumpdown tests in the case of the corner stations.

Because there are only enough bakeout blankets and carts to bake one isolatable section at a time, the Beam Manifolds must be baked independently of the Vertex or Diagonal sections. To minimize the time required to bake the combination of Beam Manifold and Vertex or Diagonal, the Beam Manifold should be baked first in order to allow it to cool so that the 80 K pump may be cooled down and is operational while the Vertex or Diagonal is being baked.

5.2.2.4.1 Beam Manifold Bakeout

Install bakeout blankets on Beam Manifold, Beam Manifold ion pump, and adjacent 80K Cryopump.

Install roughing and turbo pumps.

Evacuate volume to be baked plus the two adjoining isolatable sections to 0.1 torr using roughing pump prior to starting blankets or turbo pump. This is required to minimize convective heat losses at the gate valves. 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 pump may be started.

When the section reaches ambient temperature (~ 20 C) the 80 K pump can be cooled down in accordance with its operating procedures.

5.2.2.4.2 Vertex or Diagonal Bakeout

Install bakeout blankets on Vertex or Diagonal, 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 may be connected to the adjacent Beam Manifold 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.

Four sets of measurements shall be made using the RGA: steady state, rate of rise, RGA calibration, and ionization/pumping pattern. Detailed procedures for performing these tests may be found in the RGA Calibration Procedure, V049-2-186.

The first test is made under steady state conditions with the cryopump and ion pumps operating. The purpose of the first test is to determine the minimum detectable leak (MDL) based on the O_2 pressure. The O_2 pressure provides the most sensitive value for determining the MDL in this mode, but is subject to potential errors from gettering effects and uncertainity in the ion pump speed.

The second test is performed with the ion pump isolated. This test allows the argon and N_2 pressures to be considered in determining the MDL. This test shall be performed immediately after completion of the steady state test without changing any RGA settings. The test shall be run long enough to allow the H_2 pressure to increase by approximately two decades.

Upon completion of the rate of rise test the RGA shall be calibrated.

After completion of the RGA calibration and prior to backfilling a small air leak shall be introduced to measure the ionization/pumping pattern for air.

5.2.2.6 Ultimate Pressures after 100 hours.

The isolatable section shall attain a total pressure of $2x10^{-8}$ 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 $3x10^{-9}$ 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 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 will be done only on the largest isolatable volume in each station, and is for information only.

5.3.1 Pumpdown of isolatable section with 80K cryopump

Corner station: Vertex & Right Beam manifold or Diagonal and Left Beam Manifold
Once two isolatable sections, a vertex section and beam manifold section have been baked and backed 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.

After completion of the partial pressure measurements, the rate of rise test shall be performed with the ion pumps isolated.

5.3.2 Pumpdown from atmosphere to 0.1 Torr using the roughing system

Corner stations:
The isolatable section will be pumped using one main roughing system to a pressure below 0.1 Torr. The requirement is to be able to turn off the roughing pump in less than four hours. Acceptance will be when the pressure of 0.1 Torr is reached in less than 4 hours and the roughing system can be turned off and the turbo pump can be turned on.

5.3.3 Pumpdown from 0.1 Torr to 10^{-6} Torr using the main turbomolecular system

Corner *stations:* The isolatable section will be pumped using two 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 CO_2, 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). Measurements are taken for data only, there is no acceptance criteria

No tests will be conducted in LA.

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:

V049-3-123 (5 sheets)

V049-3-623 (4 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

ACCEPTANCE TEST: PUMPDOWN ISOLATED SECTION, CORNER STATION

STATION:			
SECTION:		TIME	DATE
		24 hr clock hour : min	mm/dd/yy
ROUGHING 760 Torr to 0.1 Torr			
PUMPS TURNED ON, ELAPSED TIME	HR, MIN		
at PRESSURE	Torr		
TURNED OFF, ELAPSED TIME	HR, MIN		
at PRESSURE	Torr		
ACCEPTANCE			
PUMPDOWN from 0.1 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		

RGA DATA

RESULTS OF THE RGA TEST	
RGA TEST :	AFTER 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 :	AFTER 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		

NOISE / VIBRATION MEASUREMENTS

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

	VIBRATION MEASUREMENTS	COMPLETED
1	a. Single -axis at on floor , 1m from one BSC, Corner Station without equipment operating b. Idim, with equipment operating c. Tri axis two locations on BSC	
2	a. Single -axis at on floor , 1m from one BSC, Corner Station without equipment operating b. Idim, with equipment operating c. Tri axis two locations on BSC	
3	Tri-axis measurements, BSC (WBSC2) during operation of 15 cm, 35cm, 122 cm gate valves	
4		
	NOISE MEASUREMENTS	
	Sound pressure levels measurements each chamber	

	ENGINEER NAME & TITLE	SIGNATURE
PSI		
PSI		
LIGO		
LIGO		

Equipment summary

Corner Station, WA

	Component	Quantity
Vacuum Envelope	BSC	5
	HAM	12
	Interconnecting Spools	various
	Long 80K Pump Chamber	2
Vacuum Pumps	Main Ion Pump	8
	Main Turbo Pumpcart	2
	Aux. Turbo Cart	2
	Annulus Pumps	
Cryopumps	Long 80K Pump	2
	LN2 Dewar	2
Valves	44" Gate Valves	4
	48" Gate Valves	4
	14" Gate Valves	8
	10" Gate Valves	6
Clean Air System	Clean Air Compressor System 200 CFM	1
	Back to Air Valve Systems	4
	Back to Air Portable Controller Box	1
Bakeout System	Blankets	Isolatable section
	Control Cart	7
Vacuum Gauging	Cold Cathode / Pirani Gauge Pair	6

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
Corner Station, LA

	Component	Quantity
Vacuum Envelope	BSC	3
	HAM	6
	Interconnecting Spools	various
	Long 80K Pump Chamber	2
Vacuum Pumps	Main Ion Pump	4
	Main Turbo Pumpcart	2
	Aux. Turbo Cart	2
	Annulus Pumps	
Cryopumps	Long 80K Pump	2
	LN2 Dewar	2
Valves	44" Gate Valves	4
	48" Gate Valves	2
	14" Gate Valves	4
	10" Gate Valves	5
Clean Air System	Clean Air Compressor System 200 CFM	1
	Back to Air Valve Systems	1
	Back to Air Portable Controller Box	1
Bakeout System	Blankets	Isolatable section
	Control Cart	7
Vacuum Gauging	Cold Cathode / Pirani Gauge Pair	5