WASHINGTON SITE
LEFT ARM STATIONS
ACCEPTANCE TEST REVIEW DATA PACKAGE

CONTRACT NO:	**PC 175730**
PSI DOCUMENT NO:	**V049-1-169, Rev. 0**
PROGRAM I.D.:	**LIGO VACUUM EQUIPMENT**
ISSUE DATE:	**May 28, 1998**
CDRL NO:	**07-1**
APPROVAL STATUS:	**A**

SUBMITTED TO:

California Institute of Technology
391 South Holliston Avenue
Pasadena, CA 91125

SUBMITTED BY:

Process Systems International, Inc.
20 Walkup Drive
Westborough, MA 01581

Technical Director: N/A
David McWilliams

Project Manager: Richard Bagley
Richard Bagley, P.E.

LIGO-C981626-00-V

LIGO VACUUM EQUIPMENT

WASHINGTON SITE LEFT ARM STATIONS
ACCEPTANCE TEST REVIEW DATA PACKAGE

TABLE OF CONTENTS

ATTACHMENTS

1.0 INTRODUCTION/SCOPE

This data package details the material to be presented at the Acceptance Test Review Meeting for the LIGO Washington Site Left End and Left Mid Stations. The specific station test report should be reviewed for detailed information.

The data package is intended to meet the requirements of CDRL No. 7 for the Vacuum Equipment Contract (PC 175730).

Vacuum equipment design, installation and acceptance testing was documented in the Final Design Report (FDR) CDRL No. 3 dated November 16, 1996.

2.0 MEETING AGENDA

LIGO VACUUM EQUIPMENT (V.E.)
WASHINGTON SITE LEFT MID & END STATIONS
ACCEPTANCE TEST REVIEW MEETING
JUNE 18, 1998

***Location:** Marriott Hotel, Westborough, MA*

AGENDA

8:30 a.m. Start

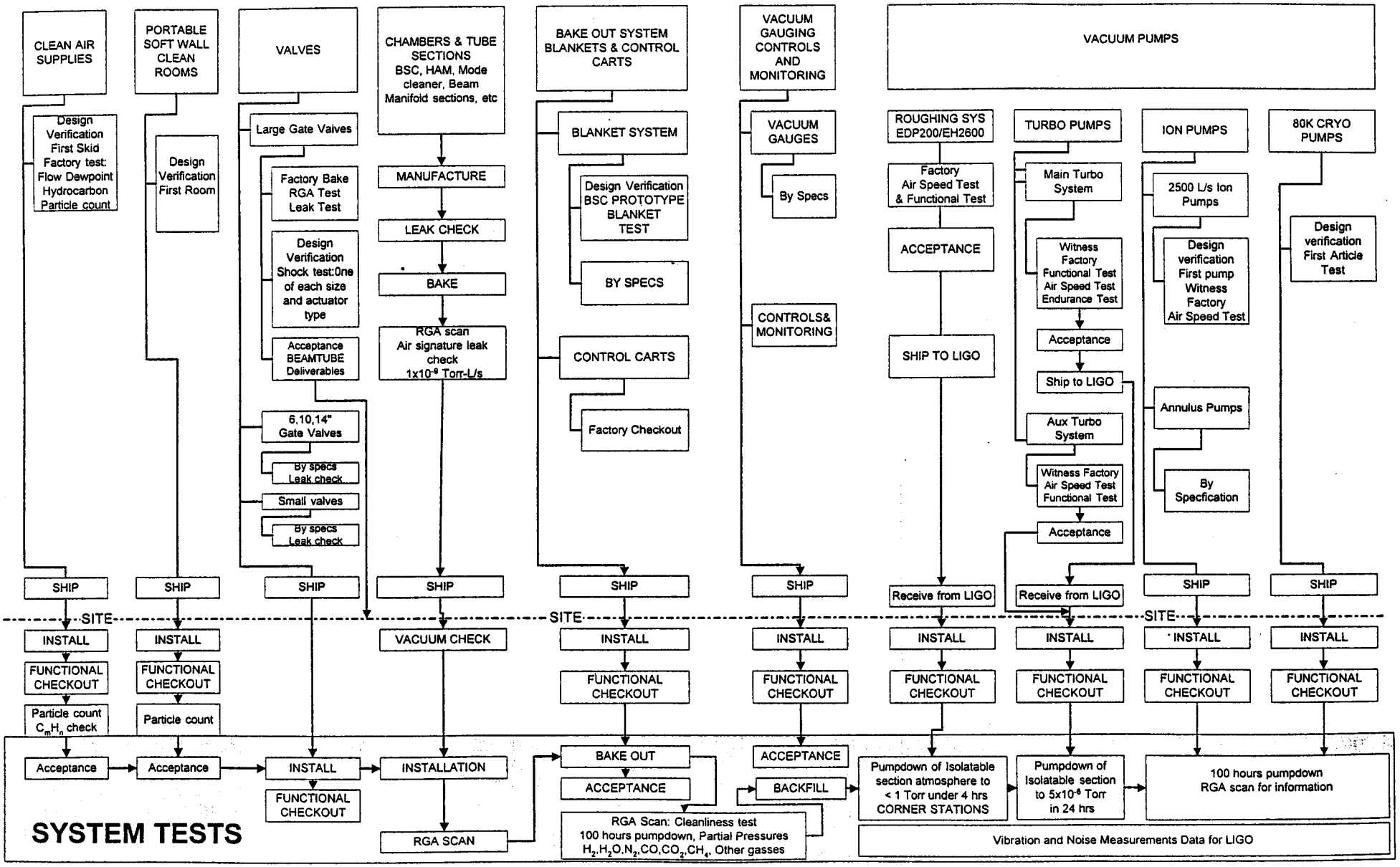
- Introduction
- General Acceptance Test Plan
- Component Fabrication
- Major Purchased Components
- Site Component Installation
- Component/Subsystem Testing
- System Testing
- Vacuum Equipment Performance Summary
- C.A.A. Noise/Shock/Vibration Testing
- Open Punch List Items
- GNB Valve Modification
- Equipment Warranty
- Operating and Maintenance Manuals
- Disposition of Equipment
- Closing

3.0 PROJECT ACCEPTANCE TEST PLAN

Vacuum equipment testing was planned to be split as follows:

- Component testing at PSI
- Vendor testing at major equipment vendors
- Equipment installation and alignment
- Equipment and subsystem testing
- Final system testing
- Noise/shock/vibration testing

LIGO VACUUM EQUIPMENT ACCEPTANCE TESTS PLAN



4.0 MAJOR COMPONENT FABRICATION (PSI)

- Component design was documented in the Final Design Report and approved by LIGO.

- Component fabrication was executed in accordance with procedures defined in the FDR.

- Components were inspected to the design documents. All deviations were identified to LIGO and were subsequently approved.

- Component QA documentation are summarized in the End Item Data Packages (Attachment II).

TYPICAL END ITEM
DATA PACKAGE CONTENTS – BSC

1. BSC (Ranor) Quality Plan/Shop Traveler/Documentation Package

2. Material Test Reports

3. Certificate of Conformance for nozzles, small parts, small flanges (under 60) and bolting

4. Heat Treat Charts

5. Final Cleaning Certification

6. Final Vacuum Leak Reports

7. RGA/Bake-out Certification

8. Nonconformance Reports (use as is)

9. Certificate of Conformance

5.0 MAJOR PURCHASED COMPONENTS

- Equipment procurement specifications were developed and approved by LIGO in the FDR.

- Equipment was purchased and tested to these specifications.

- Factory shop tests were conducted as specified in the FDR to verify critical system components (Edwards main turbo pump documents included as an example).

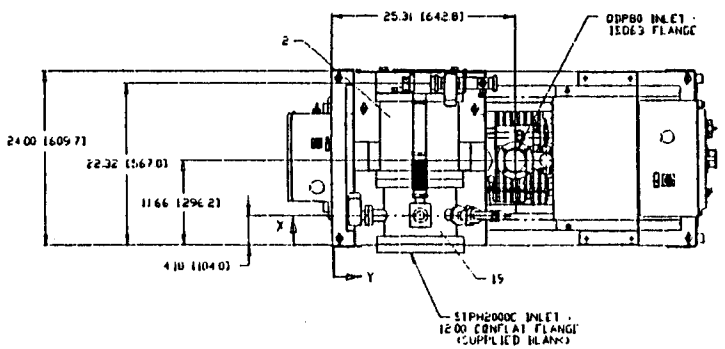
MAXIMUM SUPPLY PRESSURE	80 PSI
FLOWRATE	25 LPM
25 S/S SWAGELOK COMPRESSION	

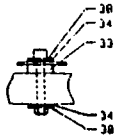
PNEUMATIC SUPPLY	
VALVE PNEUMATIC	40-60 PSI
1/8 NPT CONN	

PROCESS COOLING WATER	
MAXIMUM PRESSURE	100 PSI
MINIMUM PRESSURE DIFFERENTIAL	30 PSI
TYPICAL FLOWRATE AT 70°C	232 LPH
MAXIMUM FLOWRATE AT 55°C	397 LPH
RECOMMENDED SUPPLY TEMP	20-25°C
3/8 NPT CONNECTION	

ELECTRICAL	
SUPPLY	SEE ELECTRICAL SCHEMATIC DRAWING NO 1GB030210
FULL LOAD AMPERAGE	
RECOMMENDED SERVICE	

CONFLAT TORQUE SPEC		
SIZE	BOLT	TORQUE
2.75	1/4-28 x 1.25	16 FT LB MAX
1.230	5/16-24 x 3.00	26 FT LB MAX





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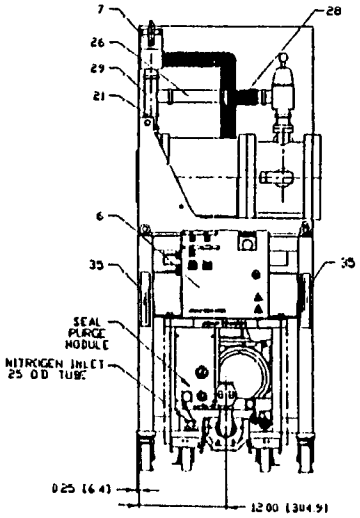
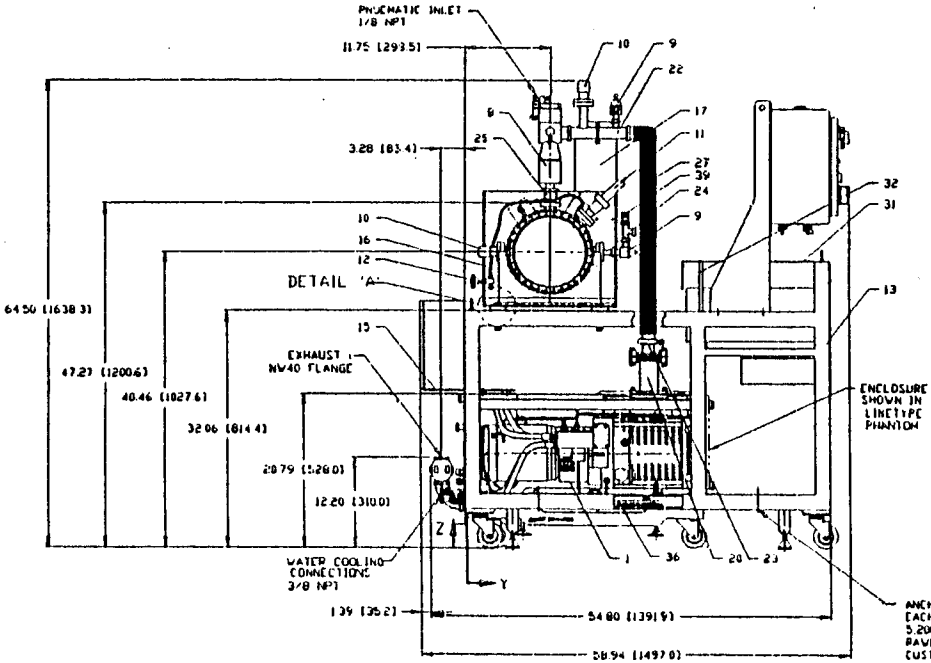
(TYP 4 PLACES)



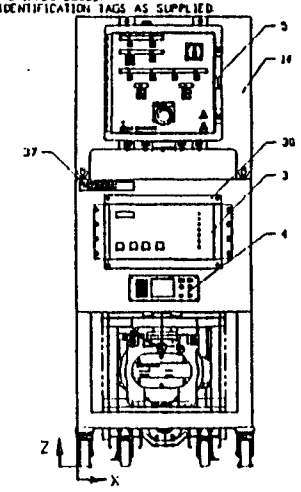


ANCHOR BOLTS ARE REQUIRED EACH BOLT SHALL HAVE A 5,200 POUND TENSILE MINIMUM RATING PAVL OR EQUIVALENT CUSTOMER SHALL SUPPLY BOLTS.

ESTIMATED CENTER OF GRAVITY				
DESCRIPTION	WT	x	y	z
ODP80	445 LBS	12.00	21.00	15.00
STP2000/CART	620 LBS	12.25	25.43	37.00
ODP80/STP2000/CART	1065 LBS	12.14	23.37	27.84

5	1	TURBOMOLECULAR PUMP CONTROLLER
4	1	GAUGE CONTROLLER
5	1	MAIN ELECTRICAL ENCLOSURE
6	1	LOCAL BOX
7	1	ISOLATION VALVE - PV40PKA
8	1	ISOLATION VALVE - PV40MV
9	2	ISOLATION VALVE - PV16MK
10	2	PIRANI GAUGE - 2.75 CONFLAT
11	1	COLD CATHODE - 2.75 CONFLAT
12	1	H2O KIT - 0100006G1	C3116
13	1	FRAME	D4523
14	1	BRACKET SUPPORT - MAIN ELECTRICAL ENCLOSURE	D3110
15	1	BRACKET SUPPORT - REMOTE BOX	C3113
16	1	MOUNTING BRACKET - STPH2000C TURBO PUMP	D4538
17	1	BRACKET - HOLDING UPPER PIPING	B2711
18	8	EYEBOLTS - M12	
19	1	SPOOL - 1.200 CONFLAT W/PORTS	C3118
20	1	SPOOL - NW63 x 1.5DN63 x 5.00 LONG	C3119
21	1	ADAPTER SPOOL - NW40 x NW40 x 1.60 LONG	A3531
22	1	SPOOL - NW40 x NW40 W/PORTS	C3123
23	1	ADAPTOR - NW40/1.5DN63	
24	1	ADAPTOR - NW16/2.75 CONFLAT	
25	1	ADAPTOR - NW40/2.75 CONFLAT	
26	1	SPOOL - NW40 x NW40 x 7.00 LONG	A1865
27	3	BELLOWS - NW40 x 100mm LONG	
28	1	BELLOWS - NW40 x 123mm LONG	
29	1	TEE - NW40 x NW40 x NW40	
30	1	COVER - CONTROL PANEL, FRONT	B2706
31	1	COVER - CONTROL PANEL, INSIDE	B2708
32	2	STANDOFF - INSIDE CONTROL PANEL COVER	A3539
33	4	POLYURETHENE SPACERS - .175 OD x .50 THICK	A3521
34	24	NEOPRENE WASHER - .375 OD x .125 THICK	A3531
35	1	LABEL - WARNING DO NOT LIFT	A3536
36	2	LABEL - WARNING	A2685
37	1	LABEL - RETURN/REPAIR	A3543
38	.50	FLAT WASHER - .63 x .375 OD	
39	1	AIR ADMITTANCE VALVE - AV10	

NOTE :
PART NO'S 28, 23, AND 27 ARE NOT SHOWN IN TOP VIEW, SO THAT ODP80 INLET LOCATION CAN BE SHOWN
EYEBOLTS (PART NO 18) TO BE PLACED IN THE FOUR (4) UPPER CORNERS OF THE MAIN FRAME AND FOUR (4) ARE TO BE PLACED ON THE TURBO MOUNTING BRACKET (PART NO16)
ONE BELLOWS (PART NO 27), INSTALLED AND TWO BELLOWS, (PART NO 27), TO BE SHIPPED LOOSE.
INSTALL IDENTIFICATION TAGS AS SUPPLIED



CUSTOMER SPEC. : V049-2-002

1	ECR21642	02-16-99	PMV

BOC EDWARDS
EDWARDS HIGH VACUUM INTERNATIONAL
A Division of The BOC Group, Inc.

MAIN TURBO CART
ODP80/STPH2000C COMBINATION WITH CONTROLLER AND ACCESSORIES

D-4507-1

A.V.S. Air speed test procedure on STPH2000C/QDP80 Turbomolecular Pump Cart carried out for Process Systems International

1. **Introductory Comments:**
   - 1.1. The purpose of this test is to confirm that the STPH2000C/QDP80 Turbomolecular pump cart as supplied by Edwards High Vacuum International, performs to inlet pump speed specification as per V-049-2-002 rev 2 section 3.0 of a minimum of $1400ls^{-1}$ at a pressure of $1x10^{-3}$ T and is capable of operating for extended periods of time at its maximum quoted inlet pressure of $1x10^{-1}$ T with water cooling of 2.0 $lmin^{-1}$
   - 1.2. The test performed will be following the American Vacuum Society AVS 4.1: Recommended procedure for measuring pumping speeds as revised in October 1986, see appendix 1
   - 1.3. The method Chosen will be Method 3.1, flowmeter method, see appendix 1.
   - 1.4. For the purpose of this test, N2 will be used as the test gas.

2. **Apparatus**

   - 2.1. Test dome see appendix 3
   - 2.2. Edwards Model 1605, 5 channel Display/controller
   - 2.3. Edwards Model 825 Mass flow controller 5 sccm calibrated for N_2
   - 2.4. Edwards Model 825 Mass flow controller 20 sccm calibrated for N_2
   - 2.5. Edwards Model 825 Mass flow controller 200 sccm calibrated for N_2
   - 2.6. Edwards Model 825 Mass flow controller 5lpm calibrated for N_2
   - 2.7. 4 branch MFC mounting manifold
   - 2.8. Gas inlet tube
   - 2.9. HPS model 937-120V60TR-CCTNA gauge system incorporating:
     - 2.9.1. HPS Series 937 system gauge controller
     - 2.9.2. 1 x SensaVac® Cold Cathode Gauge
     - 2.9.3. 2 x SensaVac® Pirani Gauge
     - 2.9.4. Calibrated HPS SensaVac® Cold Cathode Gauge, see appendix 6
   - 2.10. N2 test gas, regulated to 6-12 PSIG

   Note:
   The test dome will be fitted to the top of the measuring spool piece that is normally fitted to the Turbomolecular pump inlet. The test dome converts the spool piece to an AVS type test dome. see appendix 3 for details.
   The gas inlet tube shall be fitted into the port normally occupied by item 9 PV16K manually operated valve, which will be removed during the period of this test.
   The gauging is as supplied with the Turbomolecular pump cart, a specially calibrated gauge shall be fitted (per 2.9.4) and will be used to measure pressure lower than 1E-3 Torr. Its certificates of calibration and correction data against a spinning rotor gauges can be found in appendix 6.
   The mass flow controller will be mounted onto a 4 branch manifold, allowing any of the flow controllers to be operated, without dismantling the apparatus.
   See appendix 2 for GA of Main Turbo molecular pumping cart

3. **Pressure measurements and calibration**
   - 3.1. All Pressure measurements will be carried out using the Gauge heads normally fitted to the carts turbo inlet, see item 19, appendix 2. The gauge heads will be re-located on the test dome for the purposes of this test. A specially calibrated cold cathode gauge shall be used to take actual test data, see appendix 6 for certificate of calibration and corrction table.

4. **Test overview**

4.1. The speed test will be carried out across the normal working range of the Turbomolecular pump, from $1x10^{-5}$ T to $1x10^{-3}$ T (per V049-2-002), utilizing 5, 20 and 200 sccm mass flow controllers accordingly. etc. a stabilization time of approximately 10 minutes between pressure changes to ensure equilibrium is reached.

4.2. Three measurement points will be taken at each decade of measured pressure. Data points will additionally be taken for the purposes of demonstrating throughput capability

4.3. The continuous inlet pressure test will raise the inlet pressure up to $1x10^{-1}$ T, the pumps maximum continuos inlet pressure. Once this pressure is reached, the pump will be left running for a period, not to exceed 24hrs, running at this pressure in order to demonstrate its robustness running at high pressure.

5. **Procedure**

5.1. Base pressure measurement

5.1.1. The Pump shall be started, with the massflow controllers all in zero flow condition, and the system allowed to reach equilibrium. This pressure shall be at least 10 times lower than the lowest pressure for which speed is to be measured. This Pressure is recorded as P_0.

5.2. Speed test

5.2.1. The inlet pressure, as read by the cold cathode gauge, is increased by increasing the flow through the appropriate mass flow controller in steps to establish pressures over the test range according to table 1 below. Adjust the flows by adjusting the setpoint potentiometers accessible on the front panel of the 1605 MFC display/controller

5.2.2. The massflow indicated, actual inlet pressure, and foreline pressure shall be noted see appendix 4.
Between each pressure measurement change a period of at least 10 minutes shall be allowed for equilibrium to be reached.

5.3. Throughput test

5.3.1. Following the speed test, gas shall be inlet using the 5 LPM mass flow controller at pressures according to table 2 below to confirm the pumps throughput characteristics. These pressure readings shall be taken using the Pirani gauge only. Measurements shall be noted as per appendix 5
When the pump has reached an inlet pressure of approximately $1x10^{-1}$ T (maximum continuous inlet pressure), the test rig shall be left for a period not to exceed 24hrs to demonstrate its operating capability at high throughput/pressure.

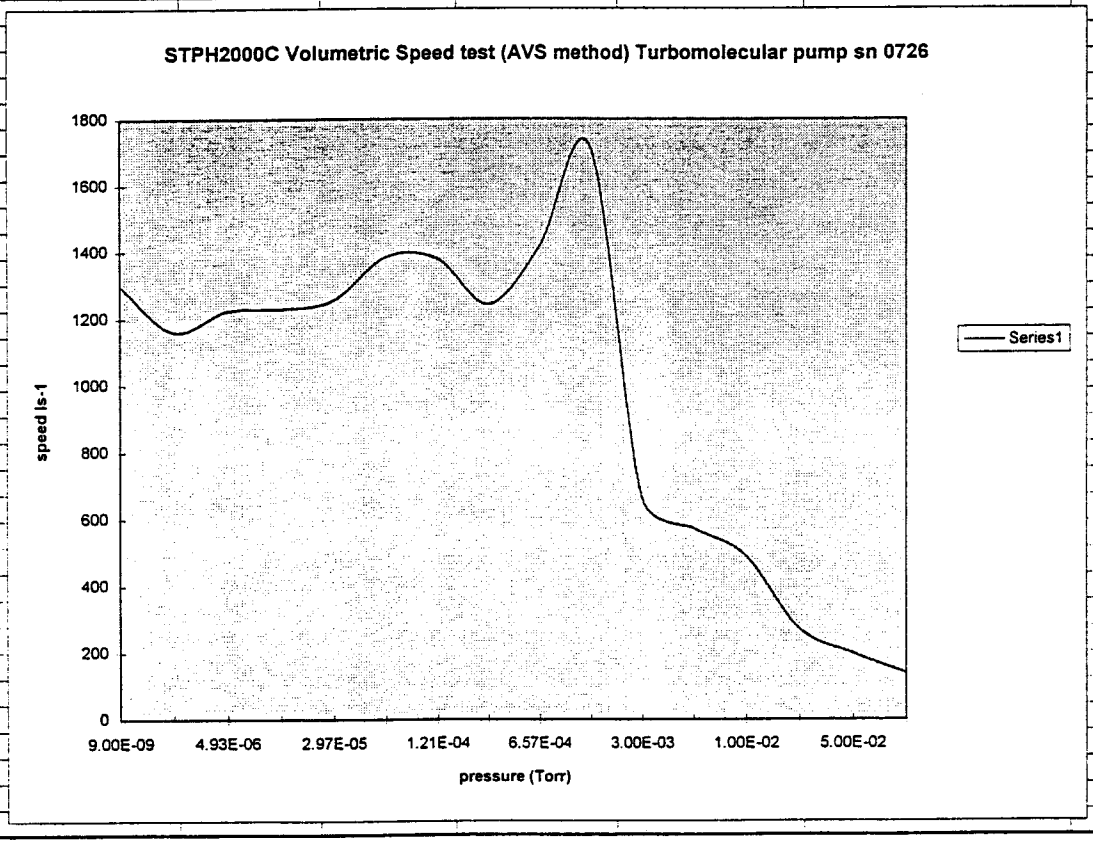
Reading #	Target Pressure (T)	Estimated massflow (sccm
1	3.00E-06	0.3
2	5.00E-06	0.5
3	1.00E-05	1.0
4	3.00E-05	2.8
5	5.00E-05	5.0
6	1.00E-04	11
7	3.00E-04	30
8	5.00E-04	50
9	1.00E-03	100

Table 1 target pressures for STPH2000C speed test

Reading #	Target Pressure (T)
1	3e-3
2	5e-3
3	1e-2
4	3e-2
5	5e-2
6	1e-1

Table 2 target pressures for STPH2000C throughput test

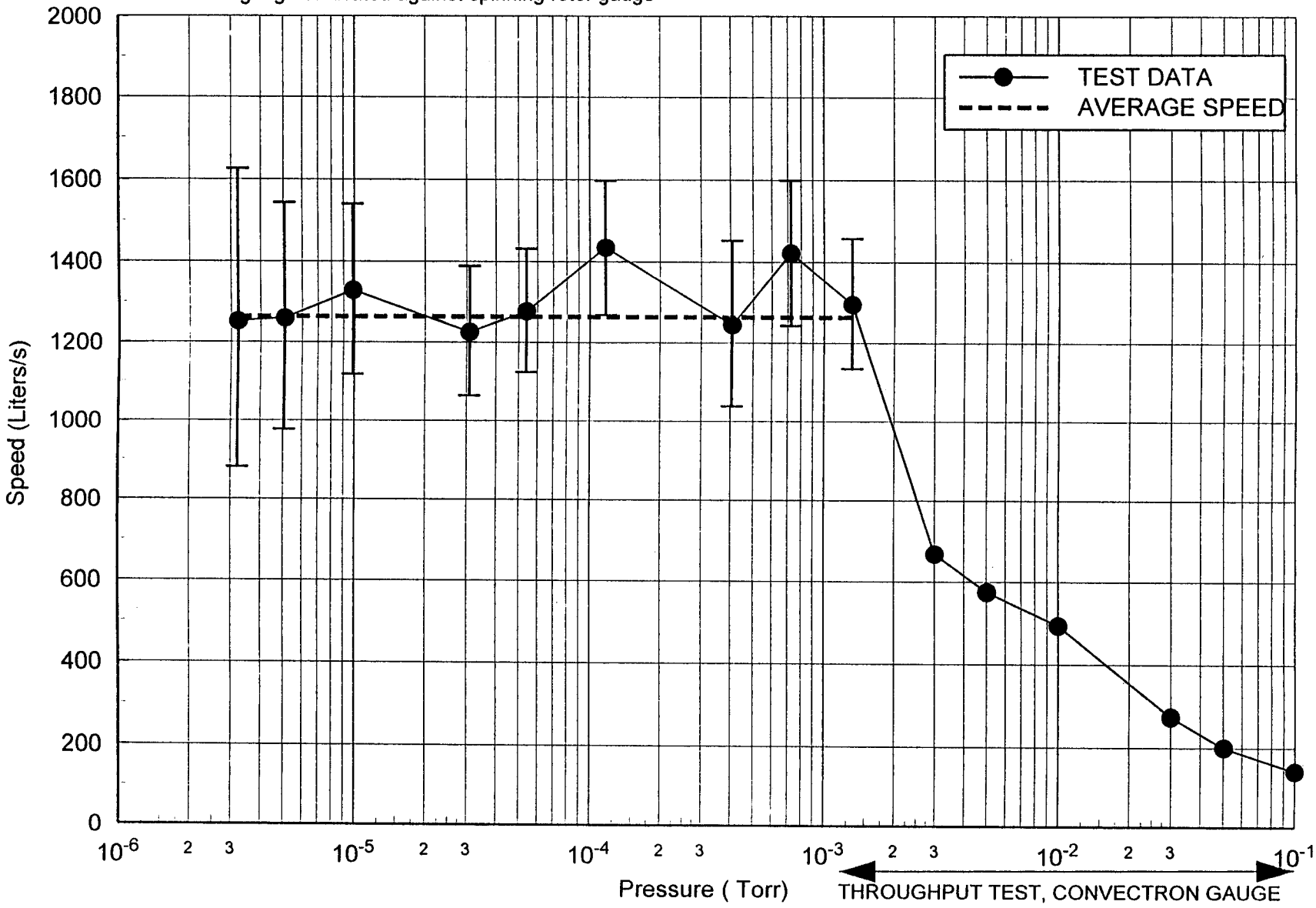
Reading #	Target Pressure (T)	Gauge type	Foreline (Torr)	Massflow (sccm)	Actual Pressure (T)	Corrected Pressure(T)	Pumpspeed (l/s)
1	Base Pressure	Cold Cathode	5.00E-03	0	9.00E-09	9.00E-09	1300
2	3.00E-06	Cold Cathode	6.40E-03	0.25	3.00E-06	2.96E-06	1161
3	5.00E-06	Cold Cathode	7.10E-03	0.44	5.00E-06	4.93E-06	1225
4	1.00E-05	Cold Cathode	8.25E-03	0.93	1.00E-05	1.04E-05	1229
5	3.00E-05	Cold Cathode	1.30E-02	2.72	3.00E-05	2.97E-05	1256
6	5.00E-05	Cold Cathode	1.70E-02	5	5.00E-05	4.95E-05	1385
7	1.00E-04	Cold Cathode	2.80E+00	12.2	1.00E-04	1.21E-04	1379
8	3.00E-04	Cold Cathode	5.50E-02	33	3.00E-04	3.64E-04	1243
9	5.00E-04	Cold Cathode	8.30E-02	68	5.00E-04	6.57E-04	1418
10	1.00E-03	Cold Cathode	1.30E-01	125	1.00E-03	1.00E-03	1712
11	3.00E-03	Pirani	1.40E-01	146	3.00E-03	3.00E-03	667
12	5.00E-03	Pirani	1.90E-01	210	5.00E-03	5.00E-03	575
13	1.00E-02	Pirani	2.80E-01	360	1.00E-02	1.00E-02	493
14	3.00E-02	Pirani	4.20E-01	600	3.00E-02	3.00E-02	274
15	5.00E-02	Pirani	5.00E-01	730	5.00E-02	5.00E-02	200
16	1.00E-01	Pirani	6.50E-01	1030	1.00E-01	1.00E-01	141



STPH2000C SN0726 SPEED TEST

Error bar includes accuracy of mass flow controller and ±10% error of pressure gauge

Pressure gauge calibrated against spinning rotor gauge



6.0 COMPONENT INSTALLATION

- Major equipment is set and aligned by PSI's site contractor.

  See Sample #1

- PSI verifies the alignment.

- LIGO checks critical component alignments.

- LIGO approves alignment and releases components for grouting.

  See Sample #2

- PSI conducts grout testing to verify grout strength.

  See Sample #3

COMPONENT CLOSE-OUT DATA SHEET

Component Tag Number: WBSC-6

Component Name: BEAM SPLITTER CHAMBER

Component S/N: S/N-07

Vacuum Sealing Surfaces Inspection

By: [signature] FOR FOREMAN ROCKWELL 12/10/97

Buyer: [signature] 10 DEC 97

Cleanliness Inspection

By: [signature] FOR FOREMAN ROCKWELL 12/10/97

Buyer: [signature] 10 DEC 97

O-Rings Installed

By: [signature] FOR FOREMAN ROCKWELL 12/10/97

Buyer: [signature] 10 DEC 97

Comments:

SAMPLE #1

Rework Required:

BSC ALIGNMENT Q.A.

PAGE 10 OF 6

Title COMPONENT ALIGNMENT PROCEDURE

ATTACHMENT B

COMPONENT INSTALLATION DATA SHEET

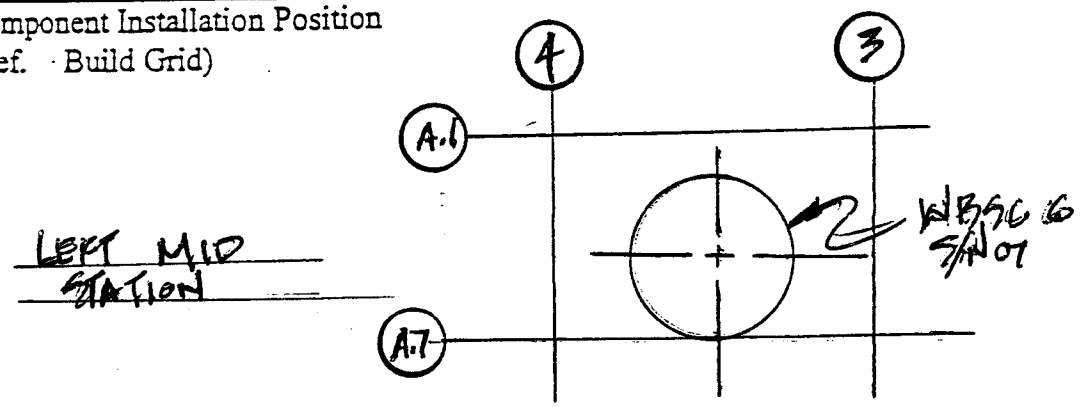
Component Tag Number: WBSC 6

Component Name: BEAM SPLITTER CHAMBER

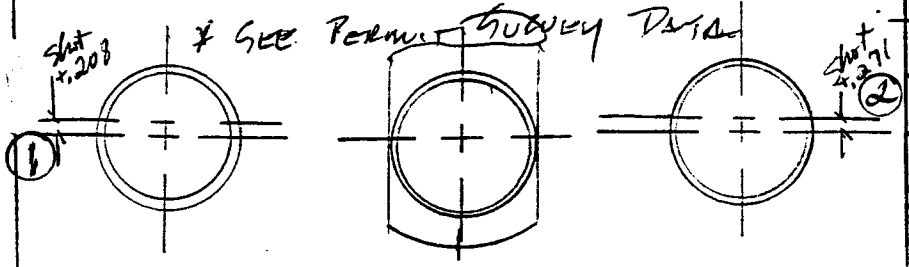
Component S/N: S/N 07

Component Installation Weight (lb.): 15,000 lb.

Component Installation Position (Ref. Build Grid)



	Signoffs (Contractor Unless Otherwise Noted)	By	Date
1.	Shipping Cover Cross Hairs Verified		10-30-97
2.	Component Located For Anchor Bolt Marking	Vern Coyne Bill Polster V.C.	10-30-97
	Buyer		300597
3.	Final Component Location Complete		11-4-97 *
	Buyer		



* See Permanent Survey Data

	1	2	△
WBSC 6			
calc	+.21	+.275	+.065
shot	+.208	+.271	.063

SPECIFICATION

Number A V049-2-174 Rev. 1

Page 1 of 1

Number Rev.

19

3 OF 5

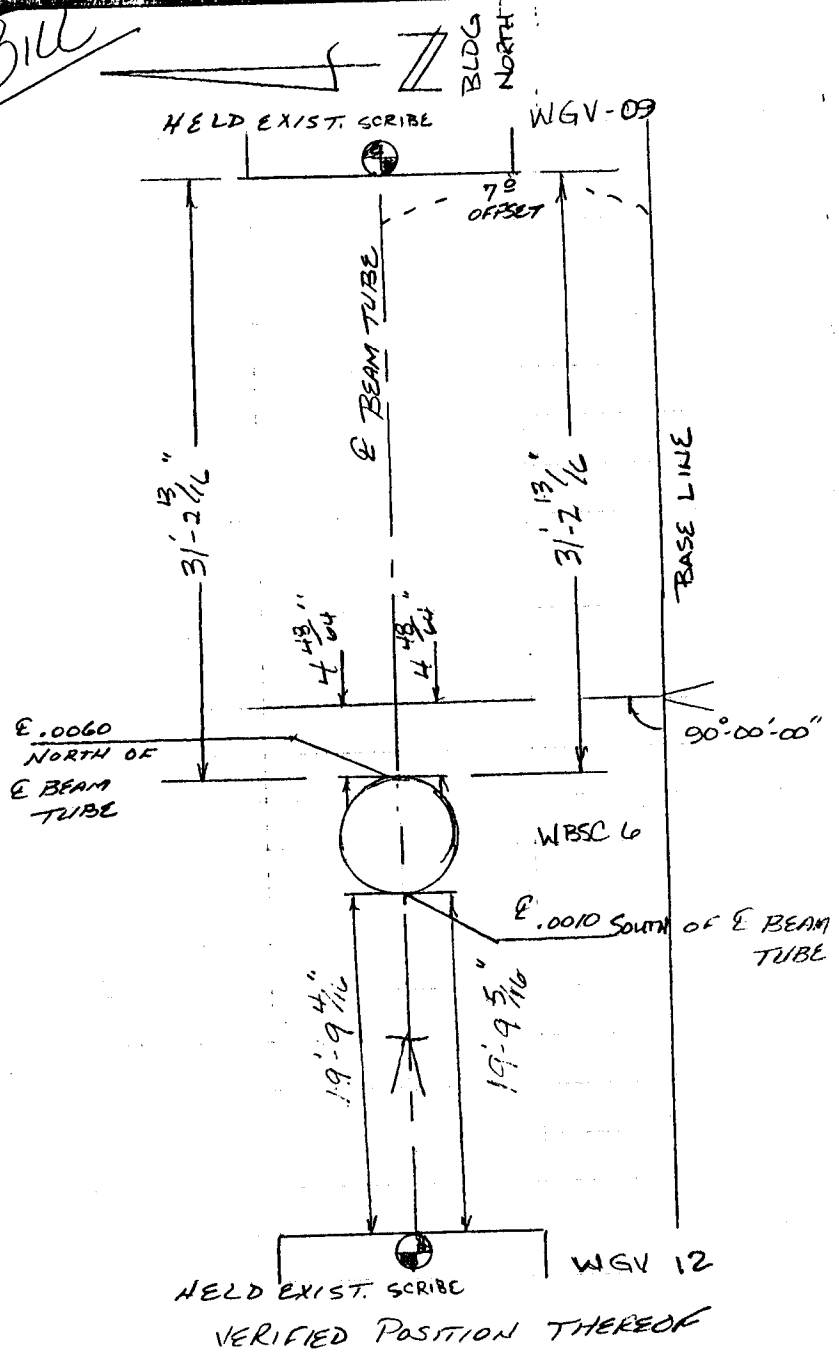
Bill

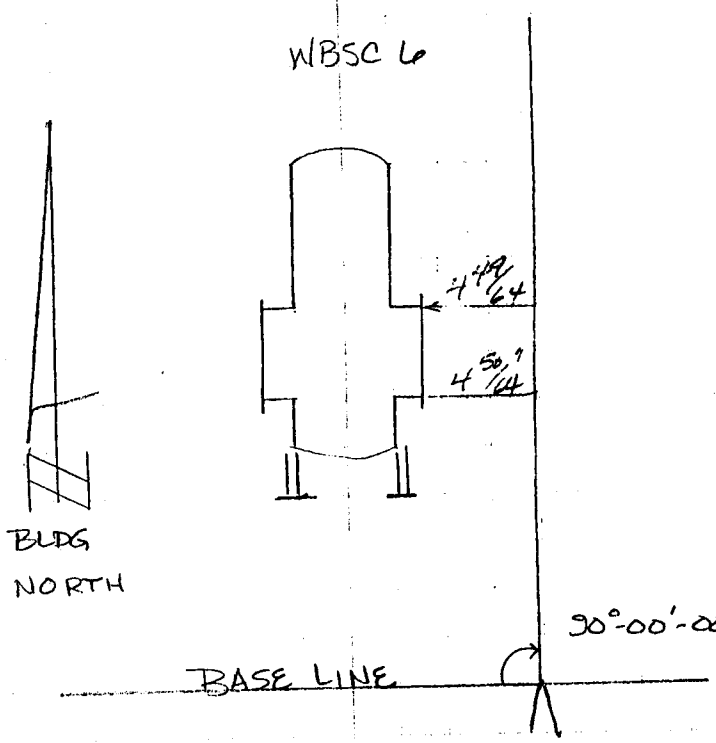
FROM VERN

LIGO LEFT MID STATION 10-30-97

V. COYNE

B. POLSTER





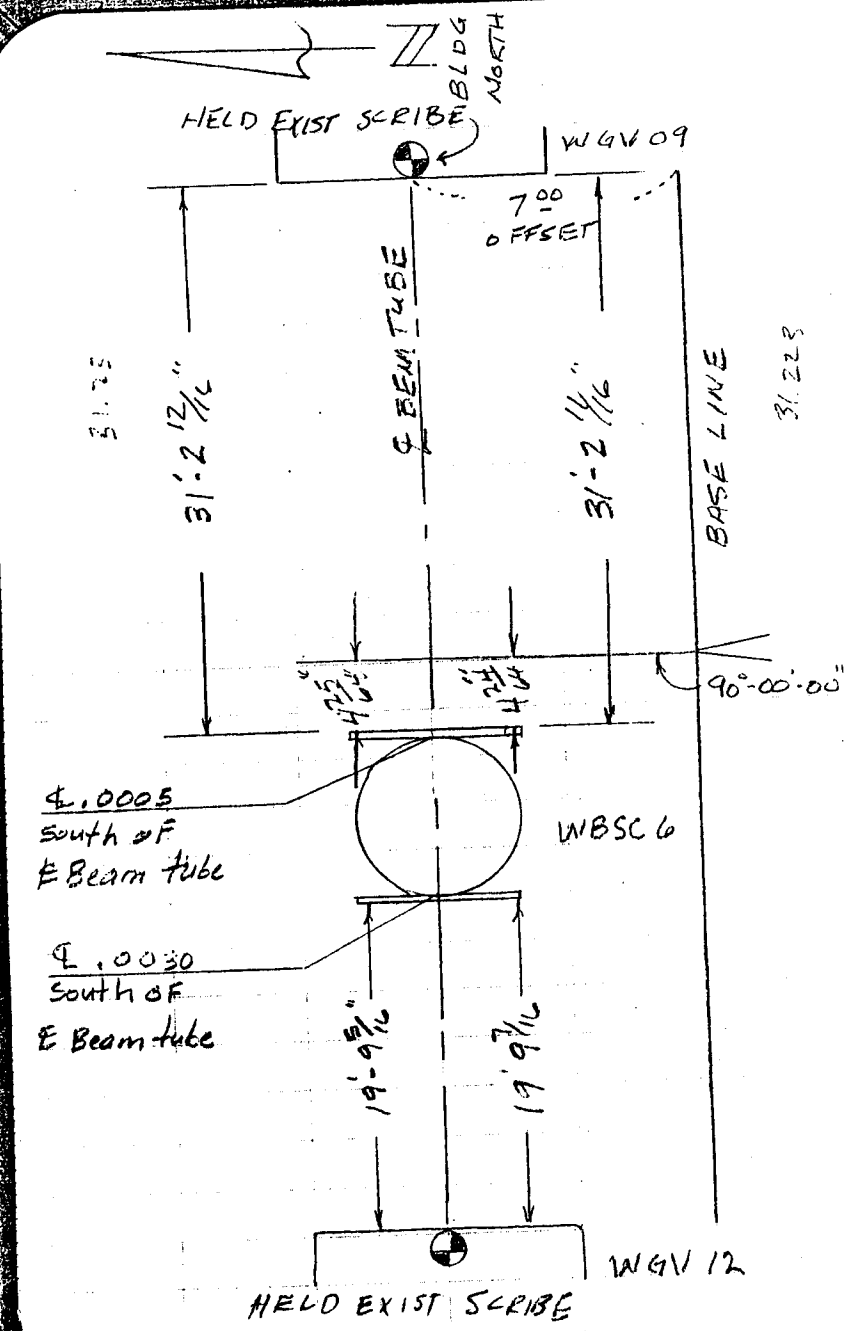
3 OF 5

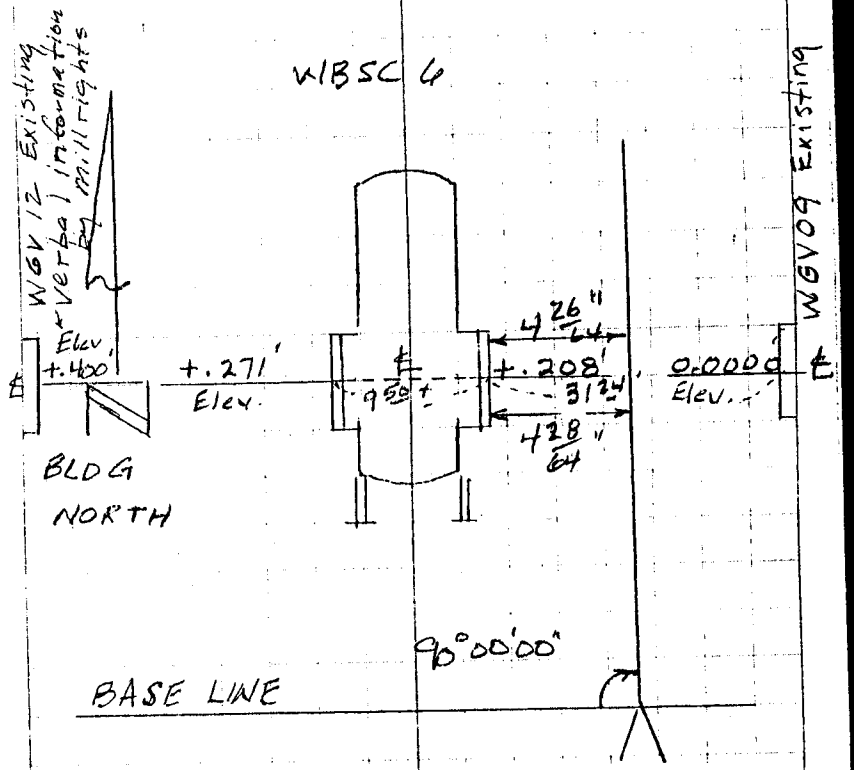
2/90

#9783 LIGO LEFT MID STATION 11-4-97

After Floor Anchor Bolts installed.

V. Coyne
K. Sarchett





9 of 9

3/90

+ H.I	− Rod	Elev.	
		0-0000	9783 L190 LEFT MID STATION 11-4-97 V. Coyne K. Sarchett
	-11.637	11-637	℄ W GV09 Gate valve
11.845		+ .208'	℄ WBSC6 East side
11.908		+ .271'	℄ WBSC6 West side

11.60 .208
6" 63

5 of 9

Apollo
Concrete Anchor Installation Report

Project: LIGO Vacuum Equipment Installation & Commissioning		Job No.: M-126	
Drawing: V049-5-006	Rev. 4	Date: 11/3/97	
Item Anchored: WBSC6	No. of Anchors 11/3/97 ~~12~~ 16	Size: 1 in.	Type: HVA

Attribute	a. Installer	b. Accepted	c. N/A	d. Date
Anchor Type (HAS Std or Super)		11/3/97		
Spacing & Location		11/3/97		
Anchor Size & Length		11/3/97		
Hole Size		11/3/97		
Hole & Core Condition (no voids, etc.)		11/3/97		
Embedment (minus 0 plus 1/8")		11/3/97		
Angle (90 deg. ± 1deg.)		11/3/97		
Floor Scarified		11/3/97		
Proper Nut Engagement		~~11/3/97~~		~~11/29/98~~
Tightening		~~11/3/97~~		~~11/29/98~~

Torque Device Identification: UNSI #10 11/20/96

Open Items

Item No.	Description	Corrective Action	Accept	Date

Comments:

Inspection by: Date

SAMPLE #2

PROCESS SYSTEMS INTERNATIONAL, INC.

LIGO Project

Doc.No.V049- PL - 511

Vacuum Equipment Grouting Request

Date: December 19,1997

Location: LIGO Washington Site

Subject: LIGO Vacuum Equipment Grouting Request

CC: R.Bagley Fax 508.898.0322

PSI requests permission from LIGO to grout all vacuum equipment in the Left Mid and Left End Stations.

By granting this request, LIGO agrees with the final alignment measurements and equipment sets performed by the Vacuum Equipment Contractor, Apollo Sheet Metal.

Request Approved John Worden – LIGO 12/19/97 Date

Northern, Inc.

- Consulting Engineers
- Environmental Scientists
- Special Structural Inspections
- Construction Materials Testing

SAMPLE #3
1 OF 3

722 N. 16th Ave. #31
Yakima, WA 98902
(509) 248-9798
Fax (509) 248-4220

6713 W. Clearwater #F
Kennewick, WA 99336
(509) 734-9320
Fax (509) 734-9321

1515 N. Miller Street
Wenatchee, WA 98801
(509) 664-8931
Fax (509) 665-0931

Sunnyridge Building #2
Rt. 2 Box 2555
Hermiston, OR 97838
(541) 564-0991
Fax (541) 564-0928

(800) 428-9798

PROCESS SYSTEMS INTERNATIONAL, INC
LIGO VACUUM EQUIPMENT INSTALLATION

INSPECTION SERVICES FOR GROUTING
FINAL REPORT

Northern, Inc.

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GROUT PRISM TEST REPORT

REPORT TO: PROCESS SYSTEMS INTERNATIONAL, INC
20 WALKUP DRIVE
WESTBOROUGH, MA 01581-5003

DATE: 01-19-98
JOB NO.: 97-734
W/ORDER NO.: 7290YM

PROJECT: LIGO VACUUM EQUIPMENT INSTALLATION
CONTRACTOR: APOLLO
STRUCTURE: VACUUM BASES
LOCATION: HANFORD/MID WEST STATION

MIX AND MATERIALS DATA

REPORTED BY APOLLO
MIX NUMBER: -
SACKS/CY.: -
CEMENT TYPE: CG200PC
ADMIXTURES: -

SPECIFICATIONS:
SLUMP, INCHES: -
AIR CONTENT, %: -

GROUT SUPPLIER: HILTI
MIXING METHOD: HAND MIX
AGGREGATE SOURCE: HILTI
WATER SOURCE: ON-SITE

REQUIRED STRENGTH, PSI:
7 DAY: -
28 DAY: 7000

FIELD TEST DATA

SLUMP, IN.: - (ASTM C143)
AIR CONT. %: - (ASTM C231)
GROUT TEMP: 70 (ASTM C1064)
AIR TEMP: 68
UNIT WT, PCF: N/R (ASTM C138)
YIELD: N/R (ASTM C138)
GROUT SAMPLED, (ASTM C172),
TESTED, & CYLINDERS CAST (ASTM C31)
DATE CAST: 12/22/97
TIME CAST: -
CAST BY: J. CAFFREY

TRUCK NO.: MIXED ON SITE
TIME BATCHED: -
TICKET NO.: -
NO. CY REP.: 1 SACK
WATER ADDED ON SITE,
GALLONS: -
CYLINDER CURING (ASTM C31)
FIELD CURE, DAYS: 1
AT TEMP RANGE: - TO -
LAB CURE FROM:
(DATE RECV'D): 12/23/97

LABORATORY TEST DATA

SAMPLE NUMBER: 5888-1

CYL. NUMBER	AGE/ DATE	DATE TESTED	X-SEC DIM.	AREA IN 2"	LOAD LBS.	COMP. STR.PSI
5888-1	7	12/29/97	2X2	4.0	22,940	5,740
5888-2	7	12/29/97	2X2	4.0	20,340	5,090
5888-3	7	12/29/97	2X2	4.0	24,480	6,120
5888-4	14	01/05/97	2X2	4.0	42,760	10,690
5888-5	28	01/19/97	2X2	4.0	53,720	13,430
5888-6	28	01/19/97	2X2	4.0	58,340	14,590

REVIEWED BY: Gerald Harper
Gerald Harper
Division Manager

7.0 COMPONENT MECHANICAL/ELECTRICAL INSPECTIONS/ TESTING

- P&ID/Piping Drawing Walkdowns
- Utility Systems Testing (Water, Class 100 Air, etc.)
  - Pressure tests
  - Particle count
  - Hydrocarbon level
  - Moisture level
- Electrical System Testing/Approvals

See Sample #1

SAMPLE #1

WIRING TEST DATA SHEET

Project No.: 97047
Megger:
M&TE:
Calibration Date:

Title: 1160
Test Voltage: CONTINUITY
Conducted By: RON GALPIN
Witnessed By: HARLAN BRADLY

VOM: FLUKE
M&TE: 97-22
Calibration Date: 4/22/97

CDS-17 MECHANICAL ROOM

WIRE RUN/CABLE # OR LOCATION	CONTINUITY		O TO O MEGGER READING			O TO GROUND MEGGER READING		
	CONDUCTORS	SH/GND	A-B	B-C	C-A	A	B	C
II-111	O.K.	O.K.						
II-115	O.K.	O.K.						
II-117	O.K.	O.K.						
II-121	O.K.	O.K						
II-125	O.K.	O.K.						
II-129	O.K.	O.K.						
II-131	O.K.	O.K.						
II-135	O.K.	O.K.						
II-139	O.K.	O.K.						
ZSC-109	O.K.	O.K.						
ZSO-109	O.K.	O.K.						
ZSC-145	O.K.	O.K.						
ZSO-145	O.K.	O.K.						
EI-1161A	O.K.	O.K.						
II-1161A	O.K.	O.K.						
EI-1161B	O.K.	O.K.						
II-1161B	O.K.	O.K.						
EI-1162A	O.K.	O.K.						
II-1162A	O.K.	O.K.						
EI-1162B	O.K.	O.K.						
II-1162B	O.K.	O.K.						
EI-1163A	O.K.	O.K.						
II-1163A	O.K.	O.K.						
EI-1163B	O.K.	O.K.						
II-1163B	O.K.	O.K.						
EI-1164A	O.K.	O.K.						
II-1164A	O.K.	O.K.						
EI-1164B	O.K.	O.K.						
II-1164B	O.K.	O.K.						
XA-1161A	O.K.	O.K.						
XA-1161B	O.K.	O.K						
XA-1162A	O.K.	O.K.						
XA-1162B	O.K.	O.K.						
XA-1163A	O.K.	O.K.						
XA-1163B	O.K.	O.K.						
XA-1164A	O.K.	O.K.						
XA-1164B	O.K.	O.K.						
HS-1161A	O.K.	O.K.						
HS-1161B	O.K.	O.K.						

8.0 VACUUM EQUIPMENT PERFORMANCE VERIFICATION

8A. LEFT END STATION

The left end vacuum performance data is detailed in Acceptance Test Report V049-1-168.

All test results met or exceeded the requirements.

The following is a summary of that report:

ACCEPTANCE TEST RESULTS SUMMARY

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

System Leak Check

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

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

System Bakeout

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

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

Ultimate Pressure Test

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

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

Backfill/100 Hour Pumpdown Test

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

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

LN2 Consumption

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

ACCEPTANCE TEST CRITERIA

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

LEFT END STATION

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

Partial Pressure Calculation

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

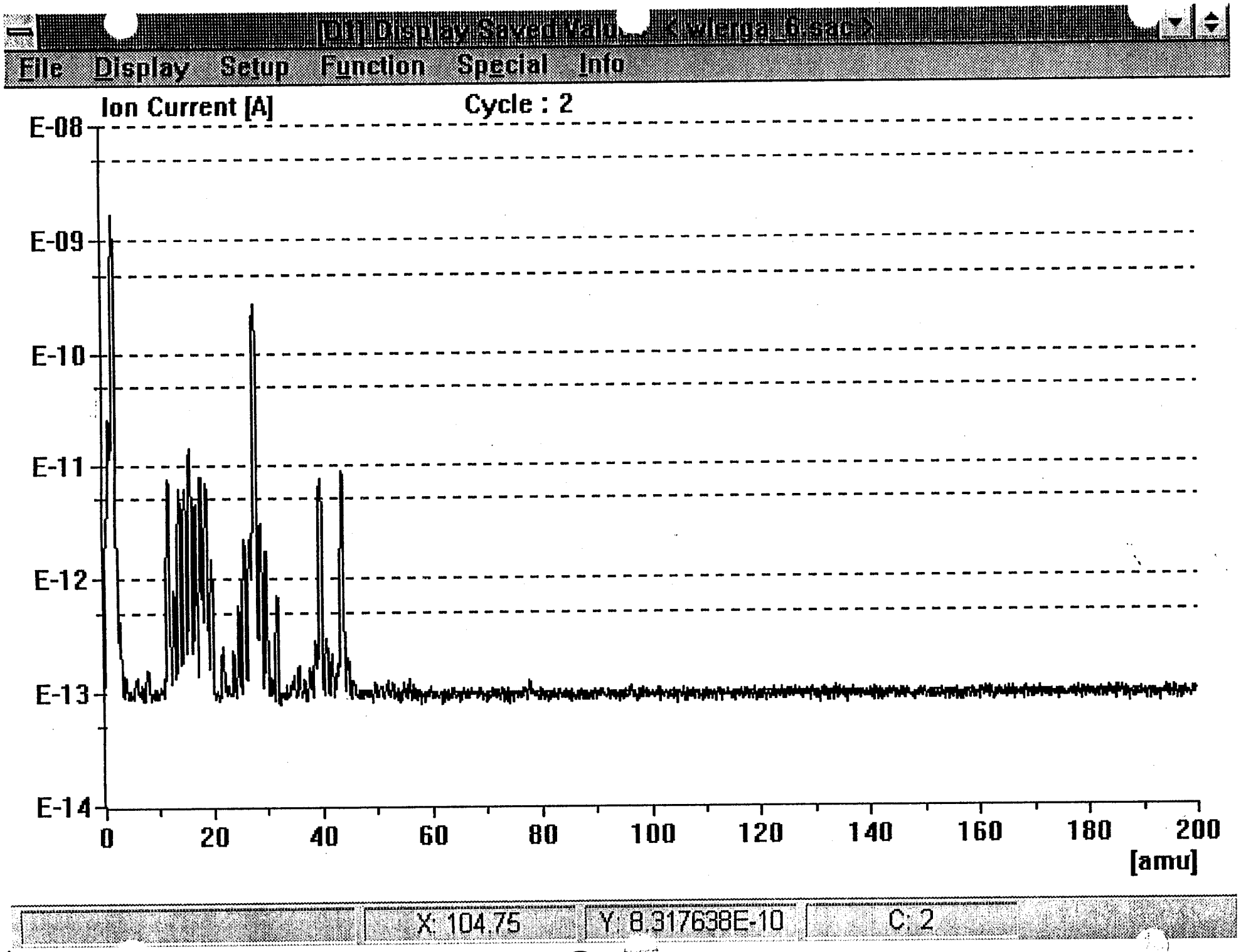
Date: 03/29/98
Test ID: WLERGA
PSI Engineer: S.MOTEW

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

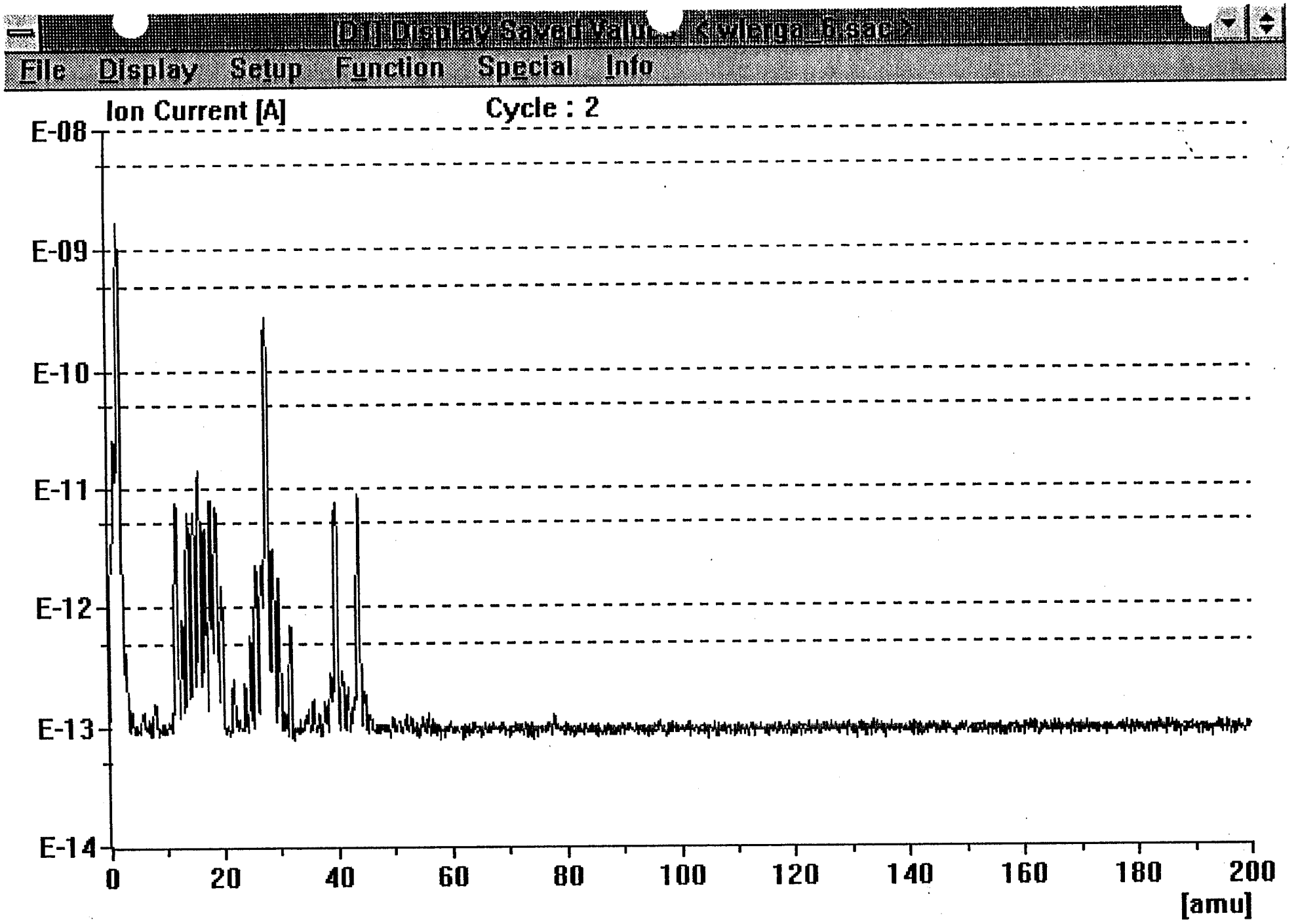
		LIGO Contract Limits	Actual	Pass
Primary Criteria -	Total Pressure:	2.00E-08 Torr	5.54E-09 Torr	Yes
Secondary Criteria -	Others except H_2 & H_2O:	3.00E-09 Torr	1.07E-09 Torr	N/A

LIGO: John Worden

PSI: Bruce Bagley



CRYOPUMP FULL 3-29-98 0810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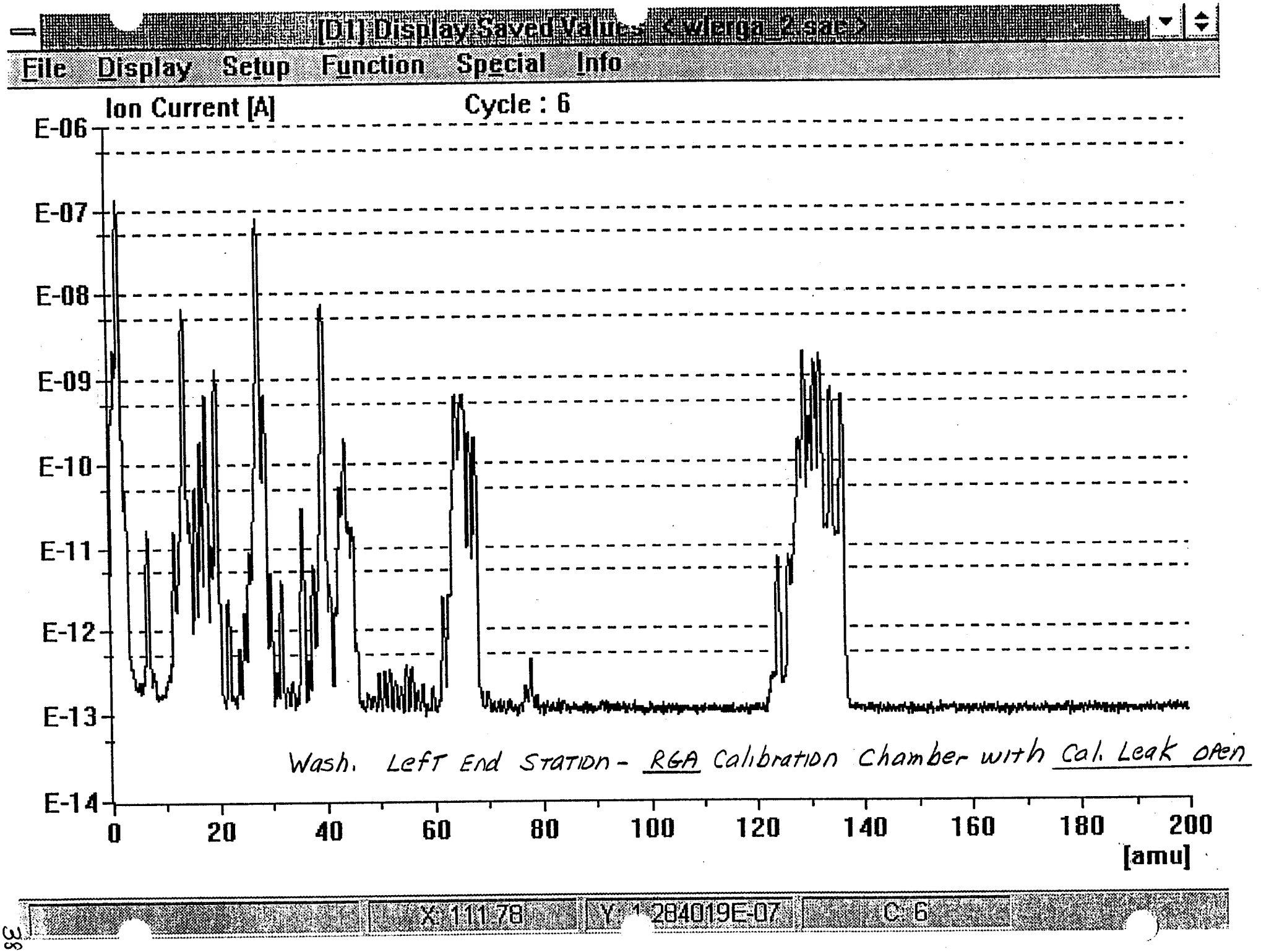
E-09
E-10
E-11
E-12
E-13
E-14
0
20
40
60
80
100
120
140
160
180
200
[amu]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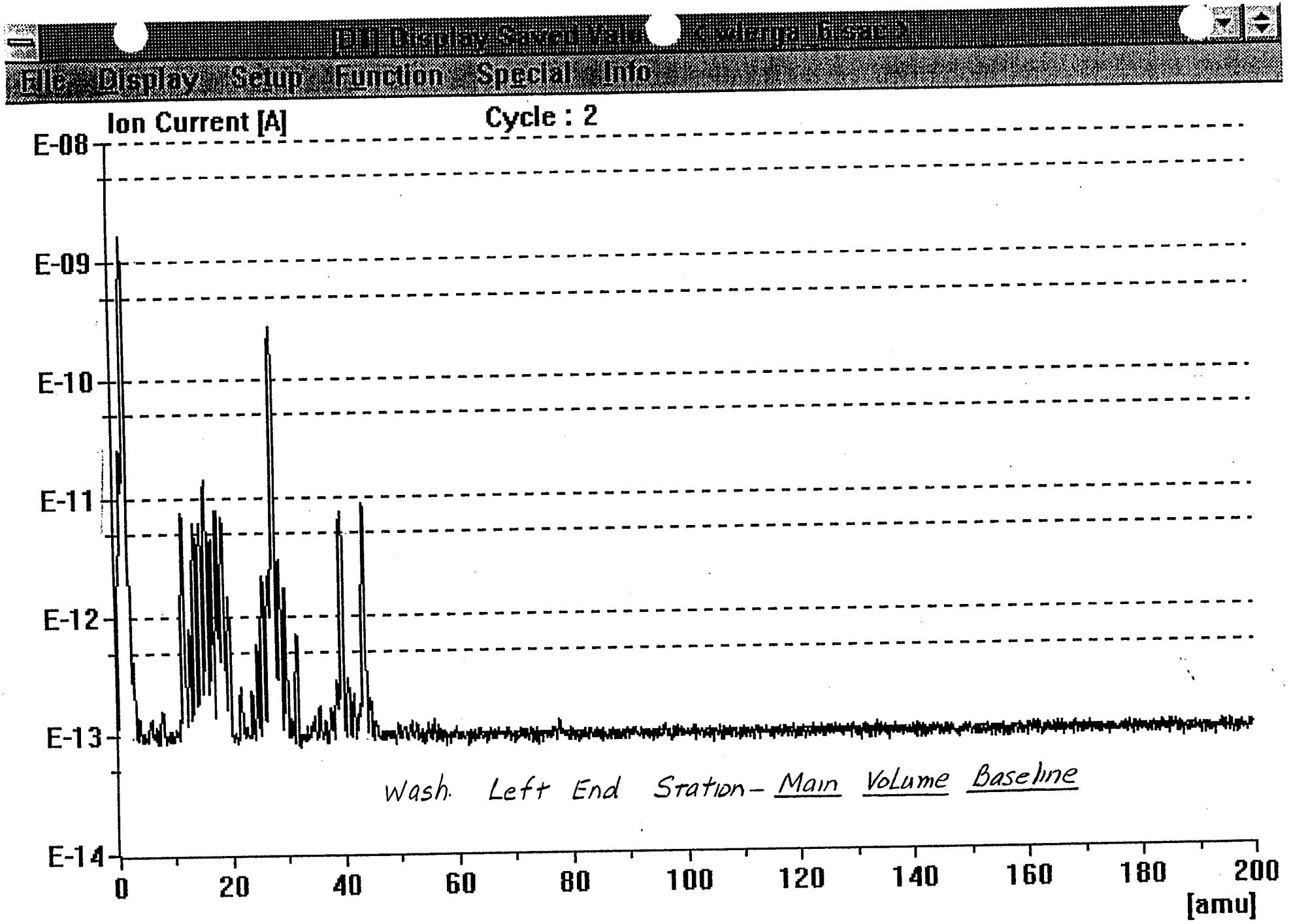
Cycle : 6
E-06
E-07
E-08
E-09
E-10
E-11
E-12
E-13
E-14
0
20
40
60
80
100
120
140
160
180
200
[amu]
Wash. Left End Station - RGA Calibration Chamber with Cal. Leak open
X 111.78
Y 1.284019E-07
C 6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Ion Current [A]
Cycle : 2
E-08
E-09
E-10
E-11
E-12
E-13
E-14
0
20
40
60
80
100
120
140
160
180
200
[amu]
Wash. Left End Station – Main Volume Baseline
X: 79.78
Y: 6.309573E-10
C: 2

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT SUMMARY

Backfill/100 Hr. Pumpdown Test – Left End Station

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.

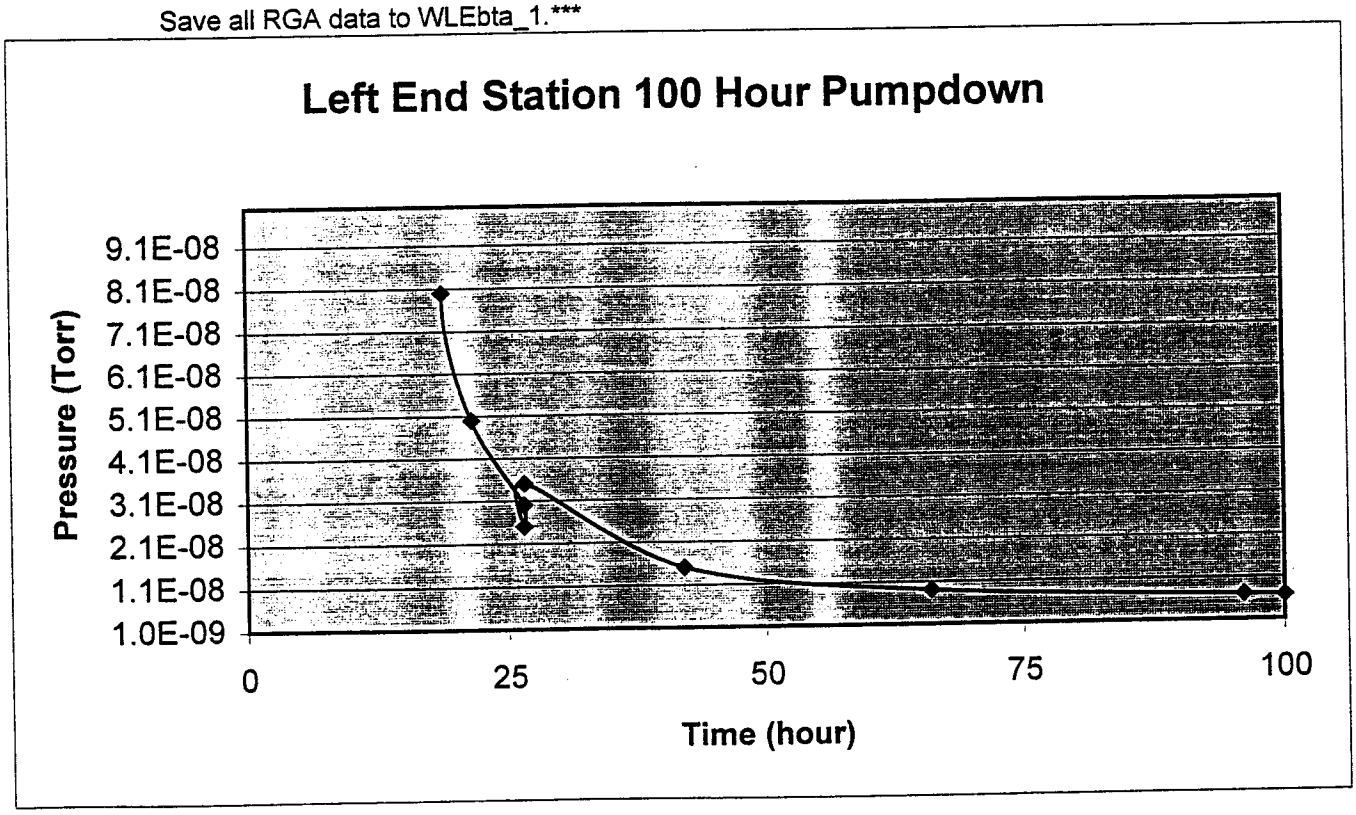
The ultimate pressure and partial pressure results are detailed herein. This test was for demonstration purposes only.

Left End Station Back-to-Air 100 Hour Pumpdown

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

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

Save all RGA data to WLEbta_1.***



Partial Pressure Calculation

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

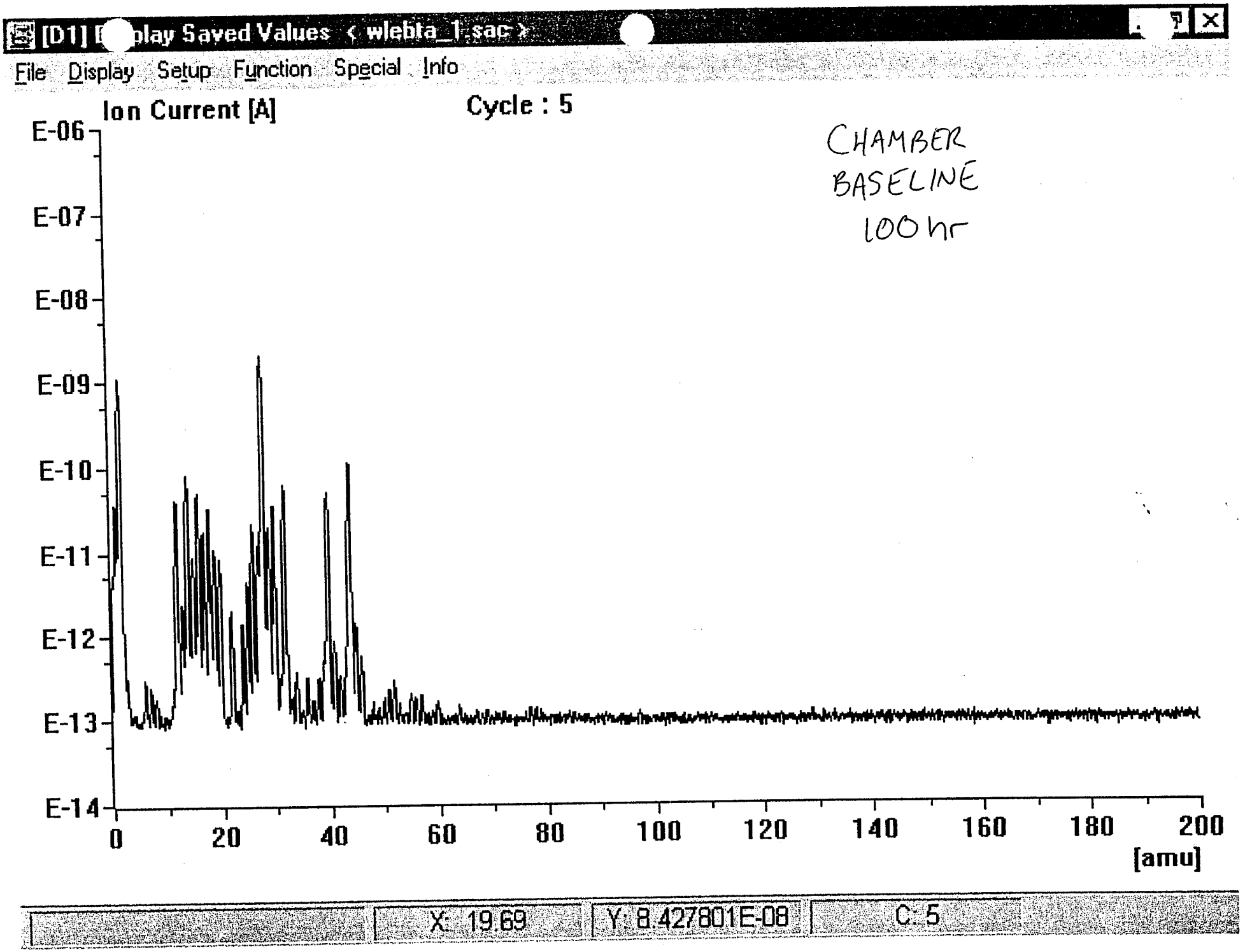
Date: 04/14/98
Test ID: WLEBTA (100 hr)
PSI Engineer: J. Flinn

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

Total Pressure =	1.25E-08

LIGO: _____

PSI: _____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CHAMBER
BASELINE
100 hr
E-06
E-07
E-08
E-09
E-10
E-11
E-12
E-13
E-14
0
20
40
60
80
100
120
140
160
180
200
[amu]
X: 19.69
Y: 8.427801E-08
C: 5

Partial Pressure Calculation

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

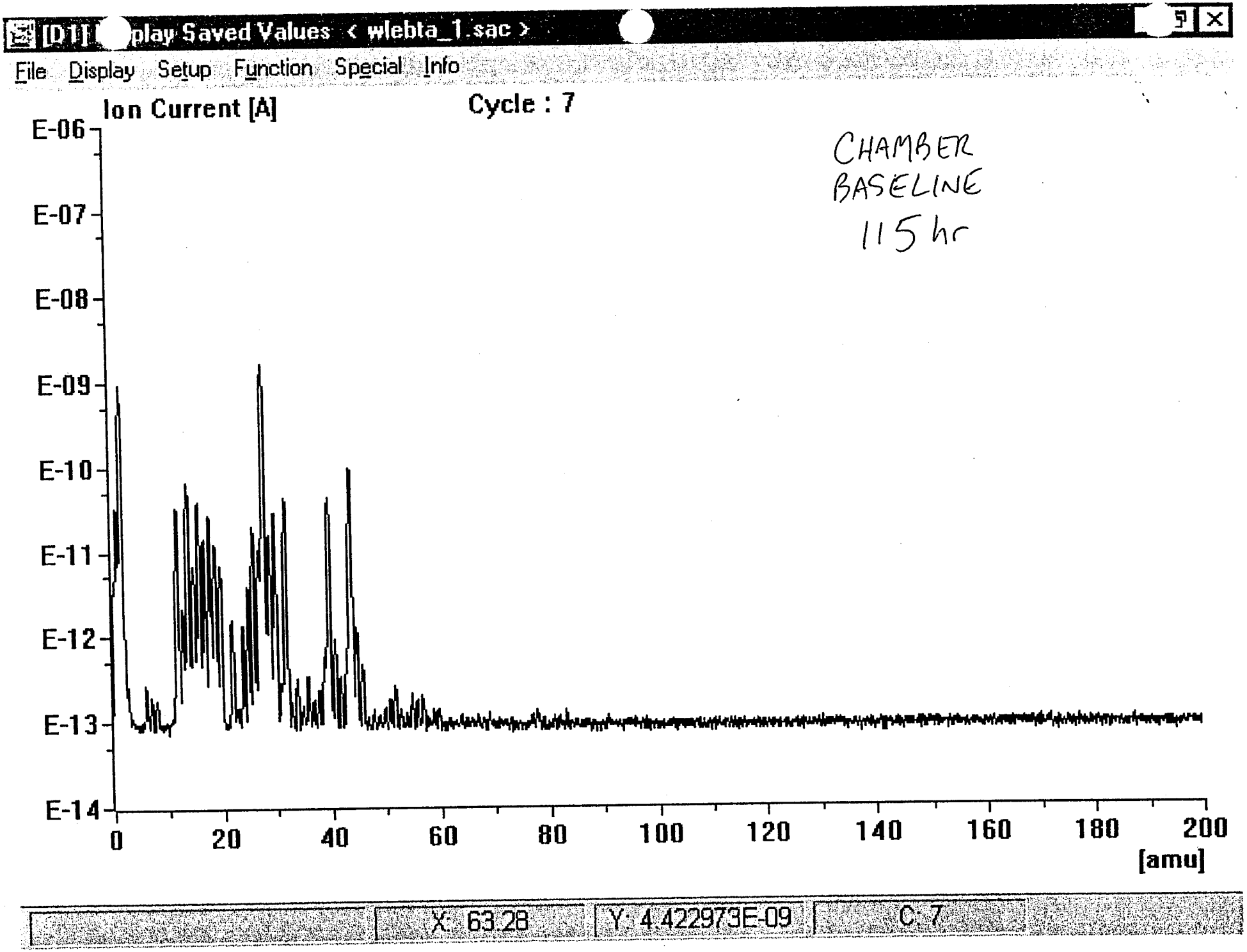
Date: 04/14/98
Test ID: WLEBTA (115 hr)
PSI Engineer: J. Flinn

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

Total Pressure =	1.01E-08

LIGO: _____

PSI: _____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BASELINE
115 hr
E-06
E-07
E-08
E-09
E-10
E-11
E-12
E-13
E-14
0
20
40
60
80
100
120
140
160
180
200
[amu]
X: 63.28
Y: 4.422973E-09
C: 7

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT SUMMARY

LN_2 Consumption Test – Left End Station

The LN_2 consumption test has been conducted per Acceptance Test Procedure V049-2-114. The duration between refills exceeded 100 days.

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

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

PSI [signature] 5/16/98

LIGO [signature]

8.0 VACUUM EQUIPMENT PERFORMANCE VERIFICATION

8B. LEFT MID STATION

The left end vacuum performance data is detailed in Acceptance Test Report V049-1-166.

All test results met or exceeded the requirements.

The following is a summary of that report:

ACCEPTANCE TEST RESULTS SUMMARY

As shown in Section 3 the WA Left Mid 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 $2x10^{-8}$ Torr-L/s Air.
The minimum detectable leak from the RGA scan with the sensitivity obtained during the scan for the Left Mid station is about $2x10^{-8}$ Torr-liter/s. This was deduced based on mass 32 ion current. The Argon signal is not used because the pumping speed is not known accurately for Argon.

The RGA scans of just the calibration chamber, indicates that there is a leak in the calibration chamber between $2 x10^{-10}$ to less than $1x10^{-9}$ Torr-liter/sec. The observed signal for mass 32 was almost $6x10^{-13}$ A with the RGA open to the main volume at an estimated conductance of 11 L/s (mass28). With the calibration chamber isolated the signal was $9x10^{-13}$ Amperes at an orifice speed of 3.7 L/s (mass28), with a calibrated sensitivity of 13 Torr/A the leak rate is estimated at $2x10^{-10}$ Torr-L/s. Helium leak checking of the RGA chamber indicates the chamber was tight to $1x10^{-9}$ Torr-L/s.

The RGA was subsequently moved to a 2.5 inch metal valve (back-to air) on the main volume and the mass 32 signal dropped to $1.5 x10^{-13}$ Amperes, just above the noise baseline. The corresponding detectable leak using the same RGA sensitivity is about $2x10^{-8}$ Torr liter/sec.

System Bakeout

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

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

Ultimate Pressure Test

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

AMU	LIGO Goals	Acceptance Test
	Partial Pressure	Partial Pressure
(Torr)	(Torr)	(Torr)
2	$5x10^{-9}$	6.2×10^{-9}
16	$2x10^{-10}$	1.0×10^{-10}
18	$5x10^{-9}$	5.2×10^{-10}
28	$1x10^{-9}$	9.7×10^{-10}
44	$2x10^{-10}$	2.6×10^{-11}
Other	$1.9x10^{-9}$	7.8×10^{-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. Negligible increases are shown for H_20 and CH_4 indicating that the clean air system is effective.

	After Bakeout	After Backfill & 100 hr Pumpdown
AMU	Partial Pressure	Partial Pressure
	(Torr)	(Torr)
2	6.2×10^{-9}	6.8×10^{-9}
16	1.0×10^{-10}	1.3×10^{-10}
18	5.2×10^{-10}	2.0×10^{-10}
28	9.7×10^{-10}	$5.7x 10^{-9}$
44	2.6×10^{-11}	3.9×10^{-10}
Other	7.8×10^{-11}	8.5×10^{-10}

LN2 Consumption

This test was not performed and will be completed as part of the punch list.

Noise/ Shock/Vibration

The vacuum requirement contract only has a requirement for shock levels. Noise and vibration testing were connected for information only.

The large gates exceeded the specification requirement (approximately .03g Vs .01g specification requirement.)

LEFT MID STATION

ACCEPTANCE TEST CRITERIA

Item	Acceptance Criteria	Acceptance Results
Interface to CDS	Functional Checkout per V049-2-163	Checkout completed on 1/16/98
Clean Air System Test	Functional Checkout per V049-2-109 Dewpoint:<-60 C Particle Count: Class 100 @ .5 micrometer. Hydrocarbon Check:	 Dewpoint: -75.3 C Particle Count: 0 Hydrocarbon Check: 0 PPM
Class 100 Cleanroom Test	Functional Checkout per V049-2-110 Particle Count: <100	 Particle Count: <80.6
System Leak Check	Individual leaks greater than $1x10^{-9}$ torr-L/s will be repaired. Vacuum Check: Annulus: P<3x10-4 torr 60 min for vessels and 30 min for spools and ate valves. Main Volume: by RGA air signature. Maximum rate to be consistent with system requirements and RGA sensitivity.	All components comprising the isolatable volume were helium leak checked via evacuation and spray prior to bakeout. All flange annuli checked and passed. Data recorded in site test logs. The station is leak tight to sensitivity of RGA air signature. For the Left Mid Station this $<2x10^{-8}$ Torr-l/s.
System Bake-out	Functional Checkout per V049-2-112 Rev1 Bakeout: Ramp Rate:<1C/hour Uniformity: 150 C+/-20C	The station was ramped from 19 C to 150 C over a period of 67 hours (2 C/hr) and held for 49 hours at 150C. Temperature data recorded in the bakeout cart data acquisition system was subsequently overwritten; therefore no temperature uniformity data is available. After the 48-hour hold, the temperature was ramped to 48 C over 48.5 hours (2.1C/hr) prior to shutting off the power.

LEFT MID STATION

Item	Acceptance Criteria	Acceptance Results
Ultimate Pressure Test (After Bake-out)	Total Pressure:<$2x10^{-8}$ torr Partial Pressure Measurements: Sum of all gasses other than H_2 and H_2O:<$3x10^{-9}$ torr	Total Pressure:$8.2x10^{-9}$ torr Partial Pressure Measurements: Sum of all gasses other than H_2 and H_2O:$1.4x10^{-9}$ torr
Backfill/100 Hr. Pumpdown Test	Roughing to < 0.2 torr in 15 hours Roughing to $5x10^{-6}$ torr in 24 hours RGA scan after 100 hours for information only	Roughing to 0.2 torr in 5 hours Roughing to $2x10^{-7}$ torr in 8 hours Partial pressures: AMU torr 2 $7x10^{-9}$ 16 $1x10^{-10}$ 18 $2x10^{-10}$ 28 $6x10^{-9}$ 44 $4x10^{-10}$ all others $8x10^{-10}$ Total $1.4x10^{-8}$
LN_2 Consumption Test	LN2 consumption per V049-2-208 90 days without refill.	LN2 consumption test not performed. Test will be performed later as part of the punch list.
Noise/Shock/Vibration Field Test	Per CAA Test Plan	See CAA Test Report in Section 5.9

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT SUMMARY

Backfill/100 Hr. Pumpdown Test – Left Mid Station

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

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

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

Partial Pressure Calculation

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

Date: 05/05/98
Test ID: WLMBTA (100 hr)
PSI Engineer: J. Flinn

AMU	*F (amu)* transmission efficiency wrt N_2	*E (amu)* ionization efficiency wrt N_2	*S (p_amu)* sensitivity (Torr/A)	*I (amu)* ion current (A)	*PP (amu)* (Torr)
2	-	-	4.66	1.45E-09	6.76E-09
16	0.57	1.60		4.85E-11	1.25E-10
18	0.64	1.12		5.25E-11	2.04E-10
28	-	-	5.45	1.05E-09	5.72E-09
44	1.57	1.42		8.10E-11	3.89E-10
all others	-	-	5.45	1.55E-10	8.45E-10

Total Pressure =	1.40E-08

LIGO: _____

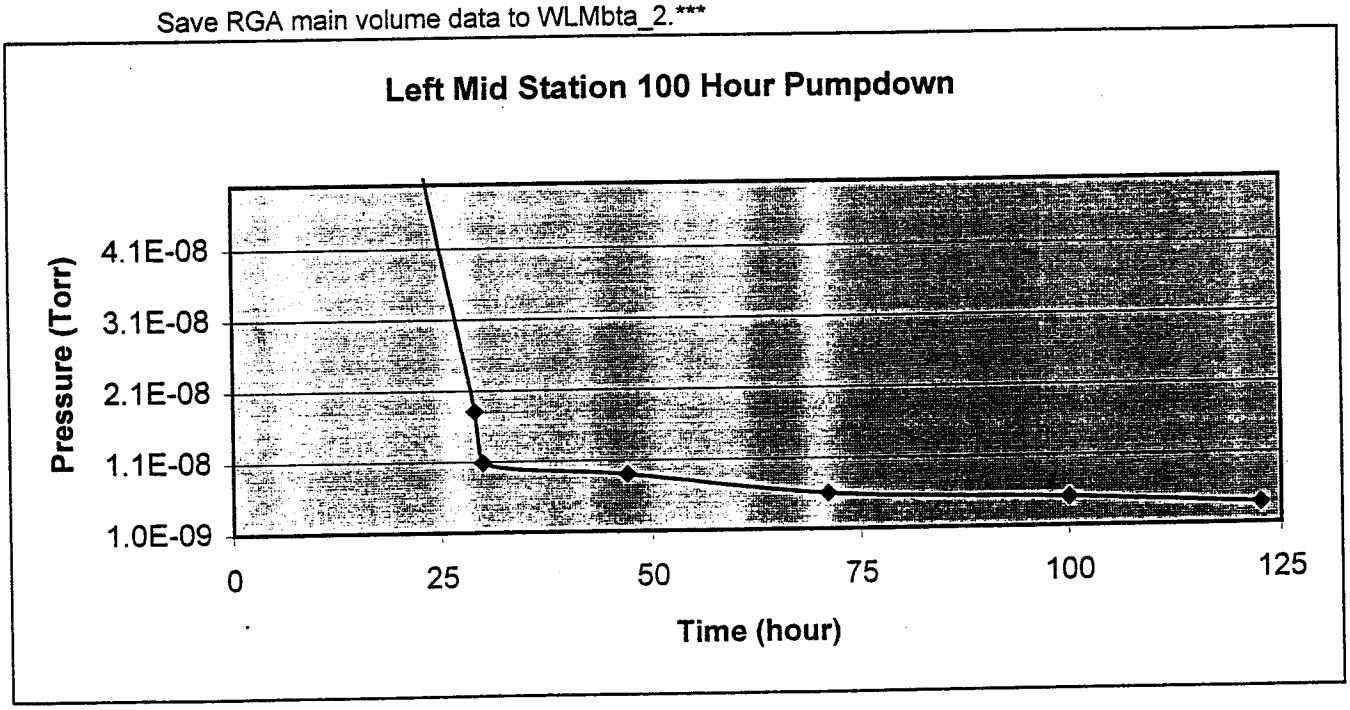
PSI: Rachel Bayer

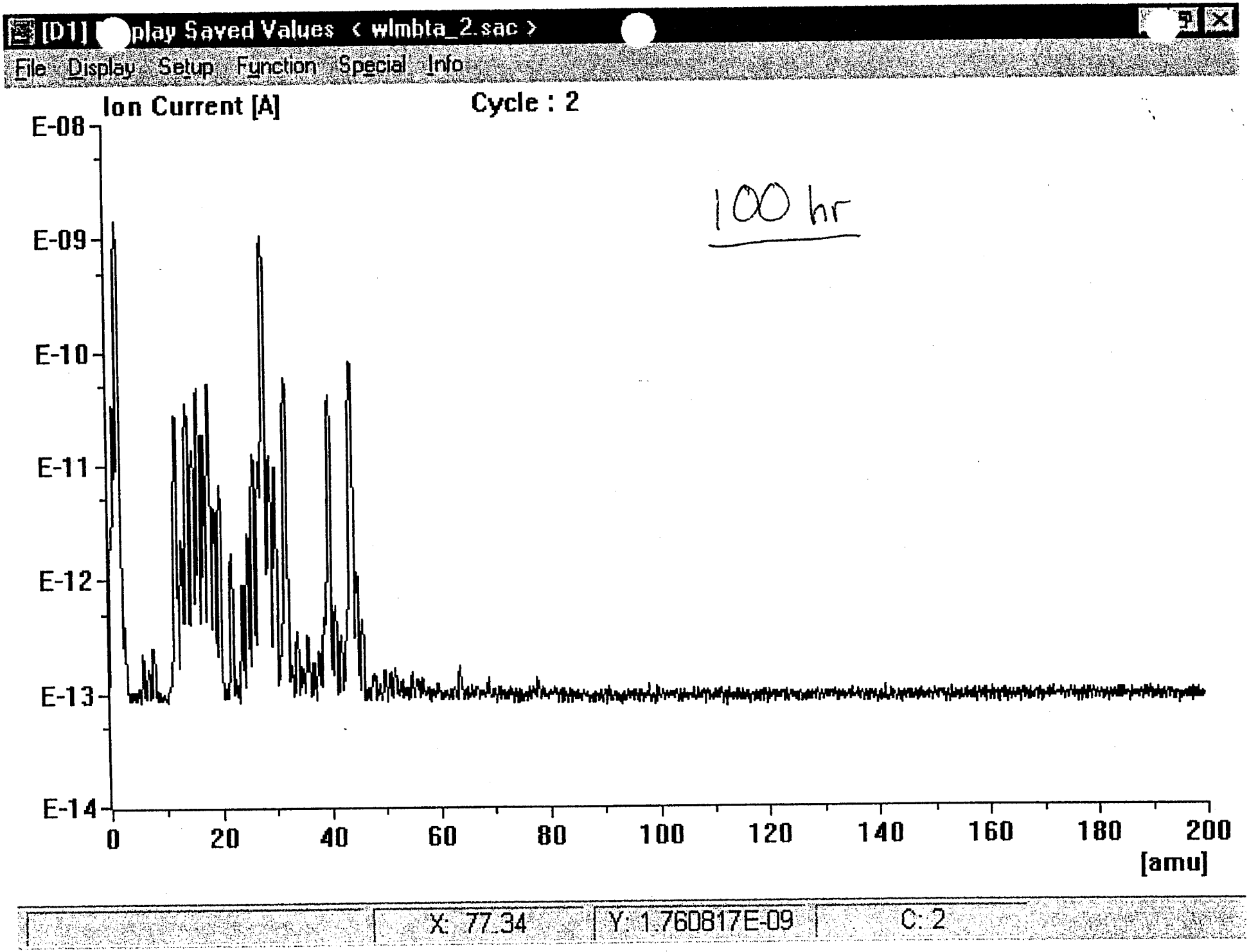
Left Mid Station Back-to-Air 100 Hour Pumpdown

04/28/98	800	Start clean air purge with cryopumps isolated by GV10,GV11
		Ion pump running and 14" valve closed
04/29/98	800	End clean air purge
	800	Start rough pumping system with QDP80
	1300	P=0.2 Torr
		Start turbo pumping system with STP2000C
	1600	P=2.0e-7 Torr - Turbo tripped out (Emergency Operation, 5 hour shutdown)
04/30/98	700	Restart turbopump
	830	Fill Cryopump WCP3 (WCP4 will remain isolated
		from the 100 hour pumpdown test)
		Open GV11 (44" gate valve) to WCP3
	1300	P=2.0E-8 Torr at turbo
		PT245= 1.8E-8 Torr
	1345	Ion Pump (Voltage=3000V, Amperage=1.8E-5A)
	1350	Open 14" gate valve
		Close 10" gate valve to isolate STP2000C
	1355	PT245=1.08E-8 Torr
		Ion Pump (Voltage=3000V, Amperage=1.6E-4A)
05/01/98	700	PT245=9.0E-9 Torr
05/02/98	700	PT245=6.0E-9 Torr
		Ion Pump (Voltage=3000V, Amperage=1.0E-4A)
05/03/98	1200	PT245=5.0E-9 Torr End of 100 hour test
		Ion Pump (Voltage=3000V, Amperage=9.0E-5A)
05/04/98	1030	PT245=3.9E-9 Torr
		Ion Pump (Voltage=3000V, Amperage=7.0E-5A)

Graphical Data	
Time (hr)	Press (torr)
0	760
5	0.2
8	2.00E-07
29	1.80E-08
29.92	1.08E-08
47	9.00E-09
71	6.00E-09
100	5.00E-09
122.5	3.90E-09

Save RGA calibration data to WLMbta_1.***
Save RGA main volume data to WLMbta_2.***

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File Display Setup Function Special Info
Ion Current [A]
Cycle : 2
100 hr
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: 77.34
Y: 1.760817E-09
C: 2

Partial Pressure Calculation

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

Date: 05/05/98
Test ID: WLMBTA (100 hr)
PSI Engineer: J. Flinn

AMU	*F (amu)* transmission efficiency wrt N_2	*E (amu)* ionization efficiency wrt N_2	*S (p_amu)* sensitivity (Torr/A)	*I (amu)* ion current (A)	*PP (amu)* (Torr)
2	-	-	4.66	1.45E-09	6.76E-09
16	0.57	1.60		4.85E-11	1.25E-10
18	0.64	1.12		5.25E-11	2.04E-10
28	-	-	5.45	1.05E-09	5.72E-09
44	1.57	1.42		8.10E-11	3.89E-10
all others	-	-	5.45	1.55E-10	8.45E-10

Total Pressure =	1.40E-08

LIGO: _____

PSI: _____

Partial Pressure Calculation

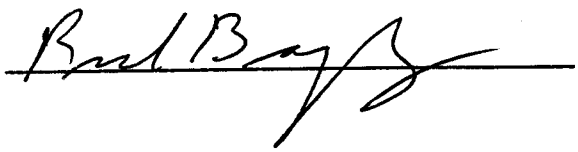
Demonstration of the Back-to-Air 100 hour pumpdown with respect to Partial Pressures

Date: 05/05/98
Test ID: WLMBTA (123 hr)
PSI Engineer: J. Flinn

AMU	*F (amu)* transmission efficiency wrt N_2	*E (amu)* ionization efficiency wrt N_2	*S (p_amu)* sensitivity (Torr/A)	*I (amu)* ion current (A)	*PP (amu)* (Torr)
2	-	-	4.66	1.14E-09	5.31E-09
16	0.57	1.60		3.40E-11	8.73E-11
18	0.64	1.12		3.68E-11	1.43E-10
28	-	-	5.45	8.00E-10	4.36E-09
44	1.57	1.42		5.00E-11	2.40E-10
all others	-	-	5.45	1.20E-10	6.54E-10

Total Pressure =	1.08E-08

LIGO: _____

PSI: 

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT SUMMARY

Ultimate Pressure Test (After Bake-out) – Left Mid Station

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

All test results met or exceeded the requirements.

Partial Pressure Calculation

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

Date: 03/18/98
Test ID: WLMRGA
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	-	-	9.75	6.39E-10	6.23E-09
16	0.57	1.60		1.69E-11	1.04E-10
18	0.64	1.12		5.64E-11	5.24E-10
28	-	-	13.03	7.44E-11	9.69E-10
44	1.57	1.42		2.27E-11	2.61E-10
all others	-	-	13.03	6.00E-12	7.82E-11

		LIGO Contract Limits	Actual	Pass
Primary Criteria -	Total Pressure:	2.00E-08 Torr	8.17E-09 Torr	Yes
Secondary Criteria -	Others except H_2 & H_2O:	3.00E-09 Torr	1.41E-09 Torr	N/A

LIGO: John Worden

PSI: Rick Bayle

Minimum Detectable Air Leak due to RGA Sensitivity at Left Mid Station

Ion current for mass 32 is 1.5×10^{-13}A. We will assume that no O_2 is consumed or produced and that the signal is due to an air leak.

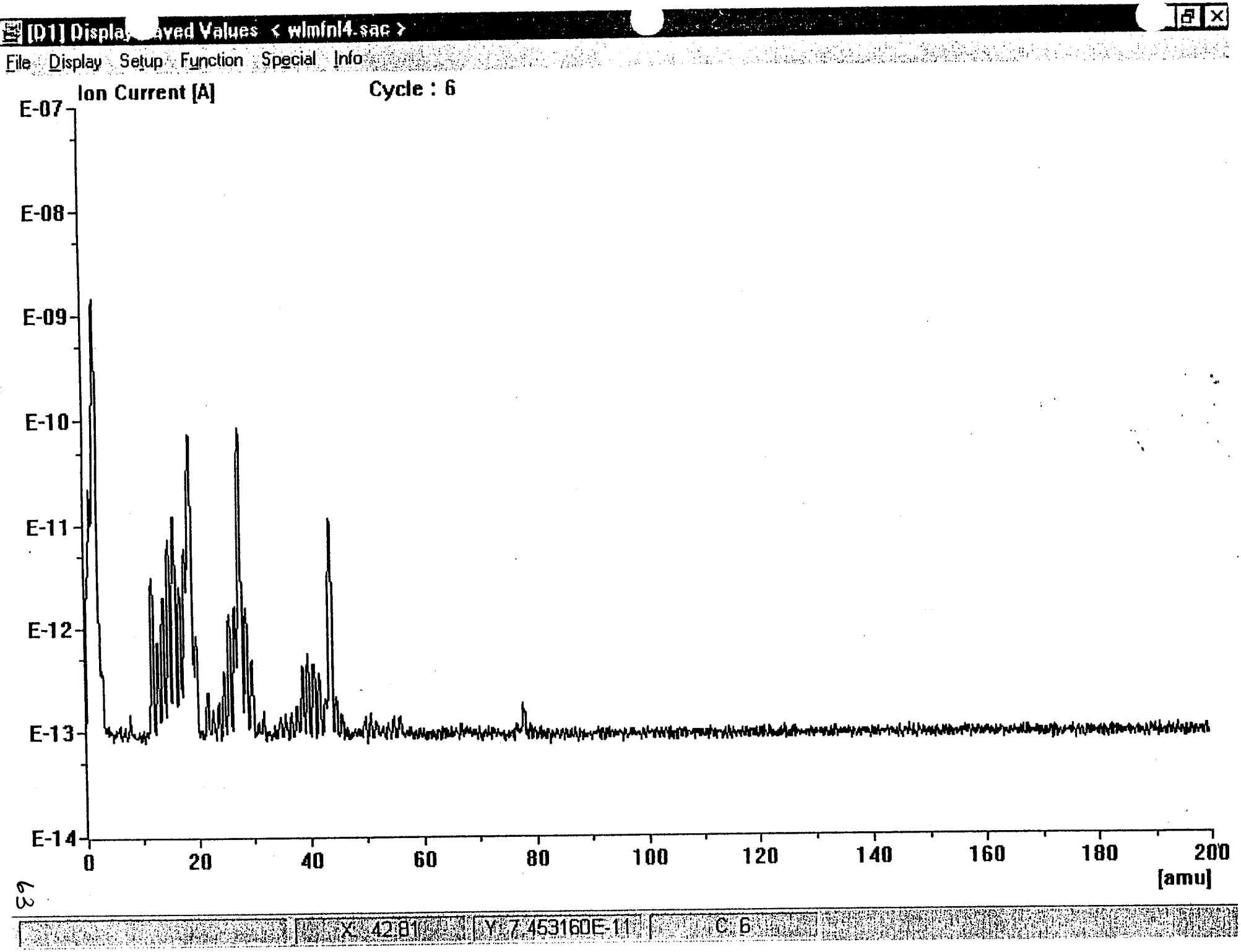
Use the standard composition of atmospheric air (~80% N_2, ~20% O_2). This concludes that the mass 28 ion current contribution is 6.0×10^{-13}A. The sum is then 7.5×10^{-13}A.

We also must assume that the calibration factors have not changed since the RGA was moved. The sensitivity for N_2 is 13 Torr/A. Therefore,

$$PP_{Air} = S_{N_2} \cdot IC_{N_2} = (13 Torr / A) \cdot (7.5 \times 10^{-13} A) = 9.75 \times 10^{-12} Torr$$

The published 2500l/s ion pump pumping speed for N_2 at 1×10^{-8} Torr is 2200l/s. This leads to the finding that the minimum detectable leak (*MDL*) is

$$MDL = (9.75 \times 10^{-12} Torr) \cdot (2200 l / s) = 2.1 \times 10^{-8} Torr - l / s$$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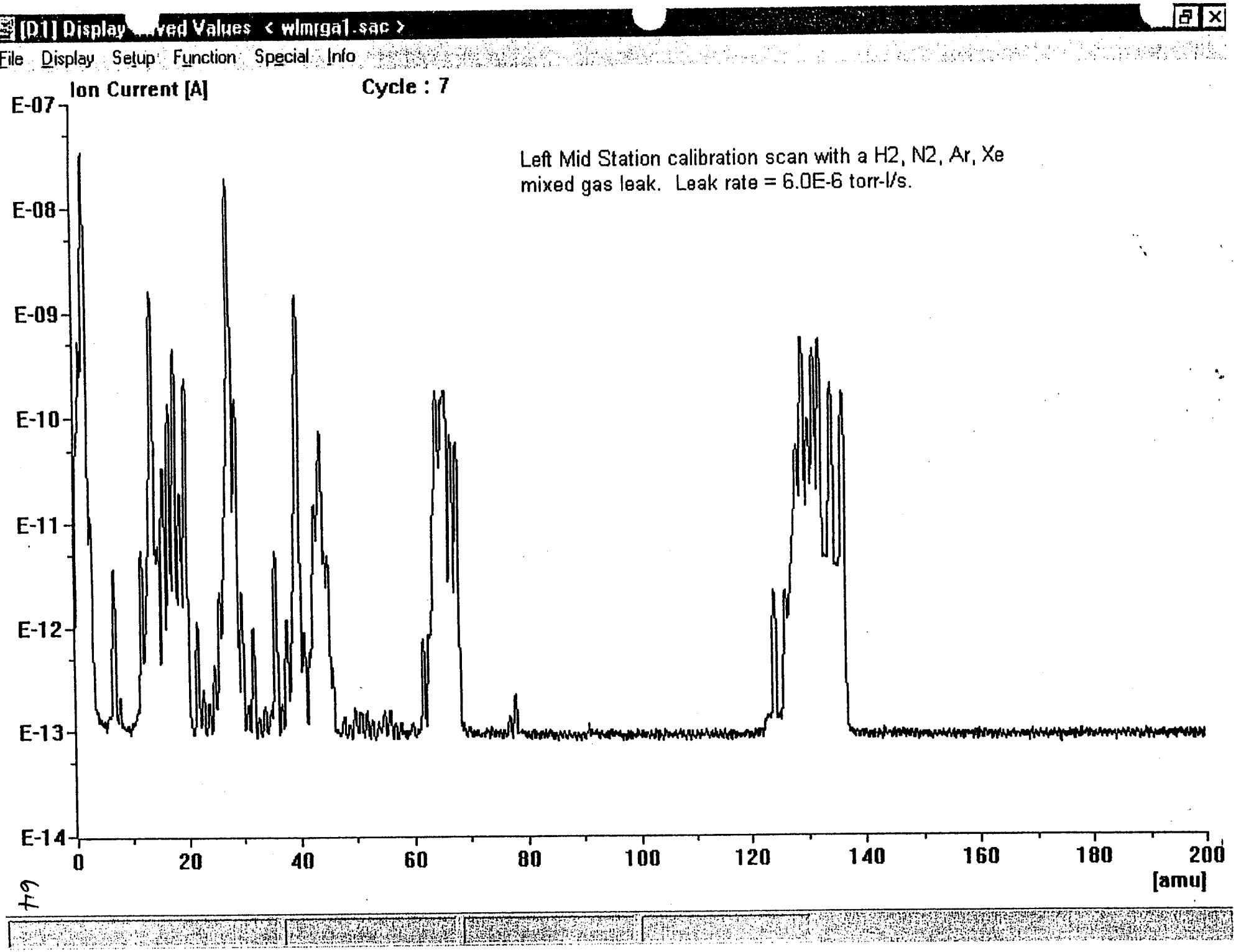
File Display Setup Function Special Info
Ion Current [A]
Cycle : 6
E-07
E-08
E-09
E-10
E-11
E-12
E-13
E-14
0
20
40
60
80
100
120
140
160
180
200
[amu]
X: 42.81
Y: 7.453160E-11
C: 6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File Display Setup Function Special Info
Ion Current [A]
Cycle : 7
Left Mid Station calibration scan with a H2, N2, Ar, Xe mixed gas leak. Leak rate = 6.0E-6 torr-l/s.
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]

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT SUMMARY

LN_2 Consumption Test – Left Mid Station

The LN_2 consumption test will be conducted per Acceptance Test Procedure V049-2-114.

It is presently a punch list item.

LIGO VACUUM EQUIPMENT

ACCEPTANCE TEST REPORT SUMMARY

Noise/Shock/Vibration Field Test – Left Mid Station

The noise/shock/vibration field testing was conducted by Cambridge Acoustical Associates (approximately .03g vs. .01g specification requirements).

SAMPLE
1 OF 8

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

Prepared By:

Kyle Martini

June 1998

Test Report

U-2379-8001

Prepared for:

Process Systems International, Inc.

20 Walkup Drive

Westborough, MA 01581-5003

PSI Purchase Order 554-386-00

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

I. INTRODUCTION AND SUMMARY

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

The results of the measurements are summarized as follows:

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

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

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

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

resonance response to the broadband excitation of cryopump as well as the background noise could be achieved by increasing the effective loss factor of the structure.

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

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

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

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

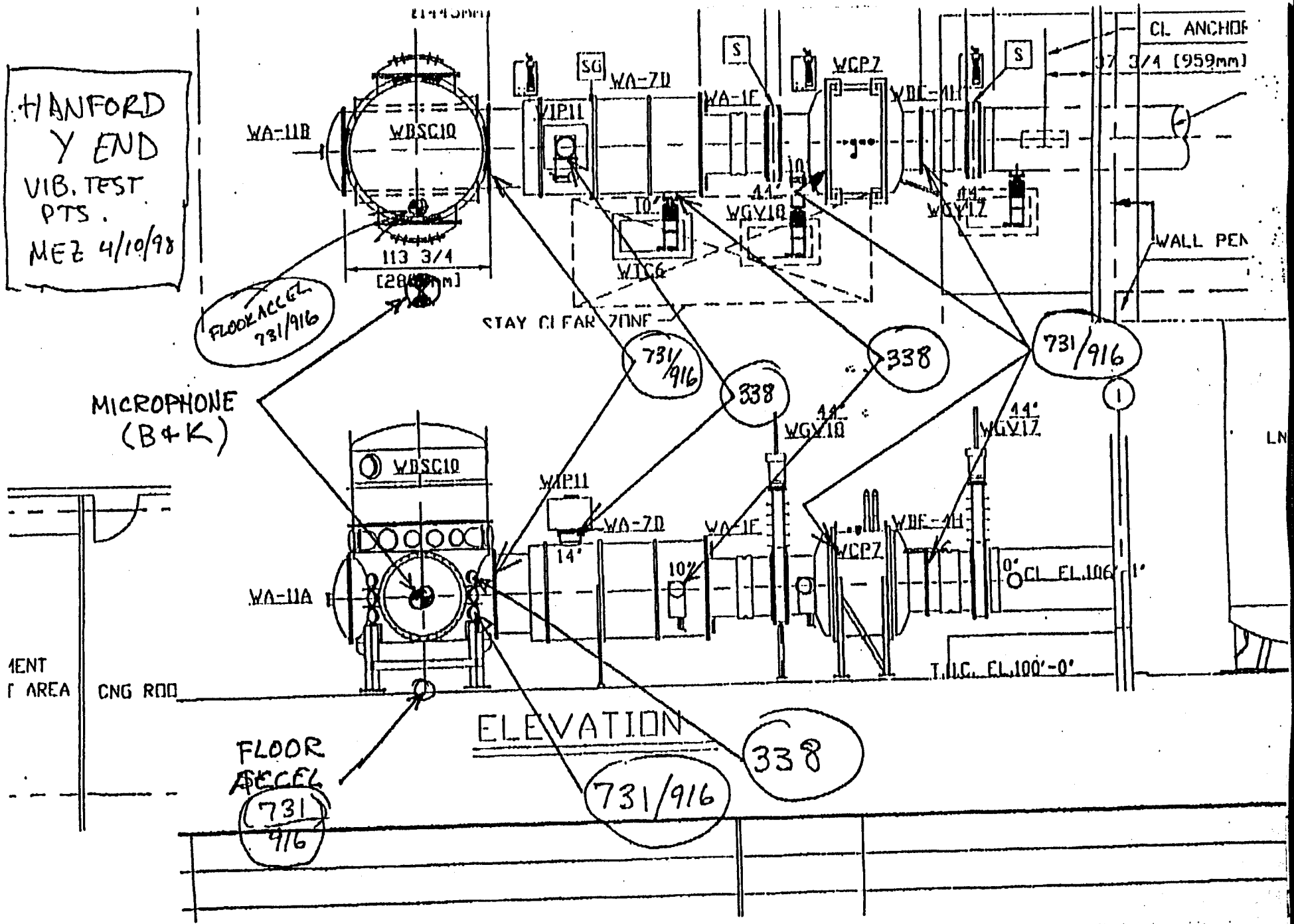


Fig. 3a End Station Measurement Locations.

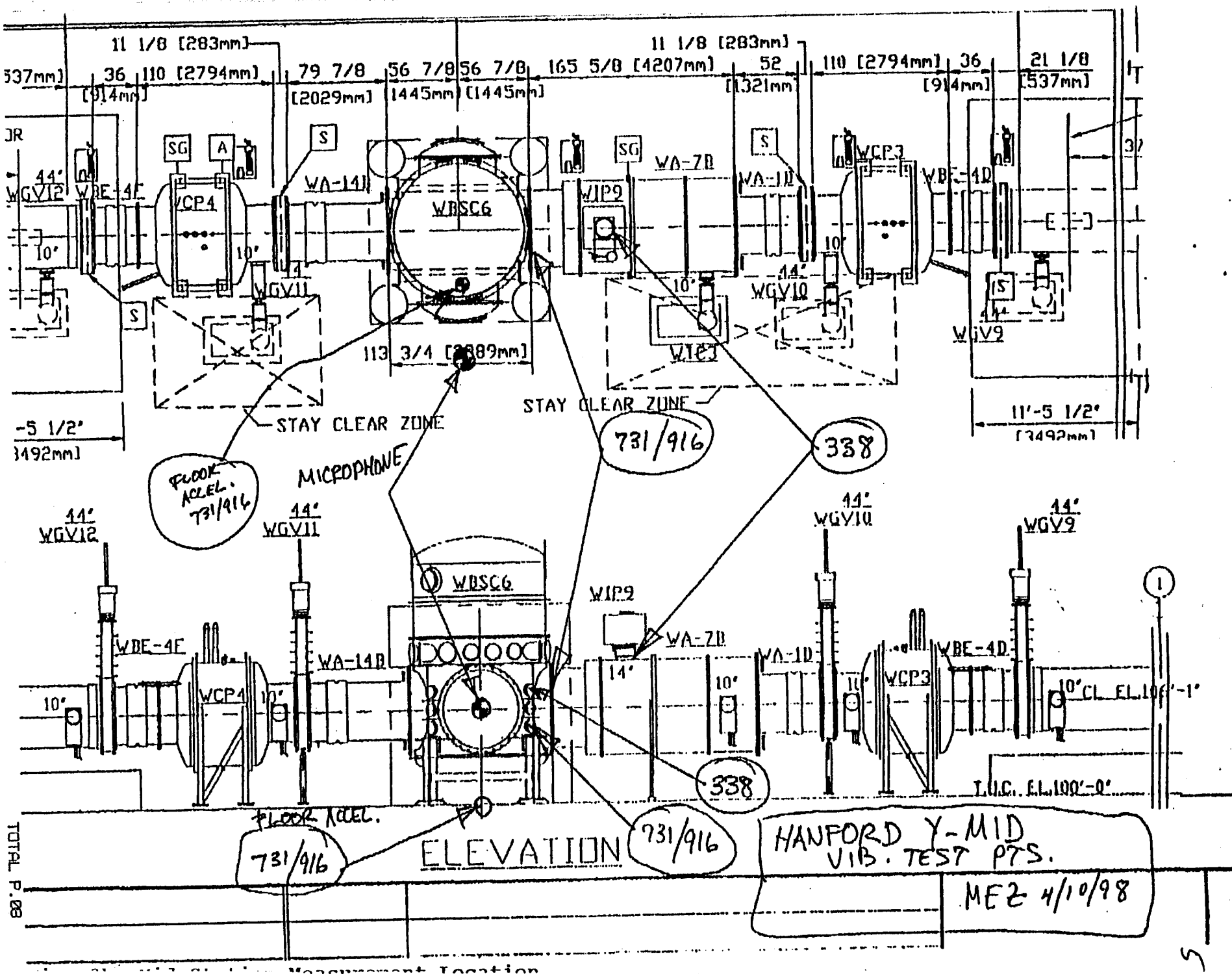

11 1/8 [283mm]
36 [914mm]
110 [2794mm]
79 7/8 [2029mm]
56 7/8 [1445mm]
56 7/8 [1445mm]
165 5/8 [4207mm]
52 [1321mm]
11 1/8 [283mm]
110 [2794mm]
36 [914mm]
21 1/8 [537mm]
WGV12
WBE-4E
VCP4
WA-14J
WBSC6
WIP9
WA-7B
WA-1D
VCP3
WBE-4D
WGV11
WGV10
WGV9
113 3/4 [2889mm]
STAY CLEAR ZONE
STAY CLEAR ZONE
11'-5 1/2" [3492mm]
FLOOR ACCEL. 731/916
MICROPHONE
731/916
338
WA-14B
WA-7B
WA-1D
WBE-4D
WCP4
WCP3
10" CL EL 100'-1"
T.O.C. EL 100'-0"
FLOOR ACCEL. 731/916
731/916
338
ELEVATION
HANFORD Y-MID VIB. TEST PTS.
ME2 4/10/98
TOTAL P.88
5 OF 8

Fig. 5

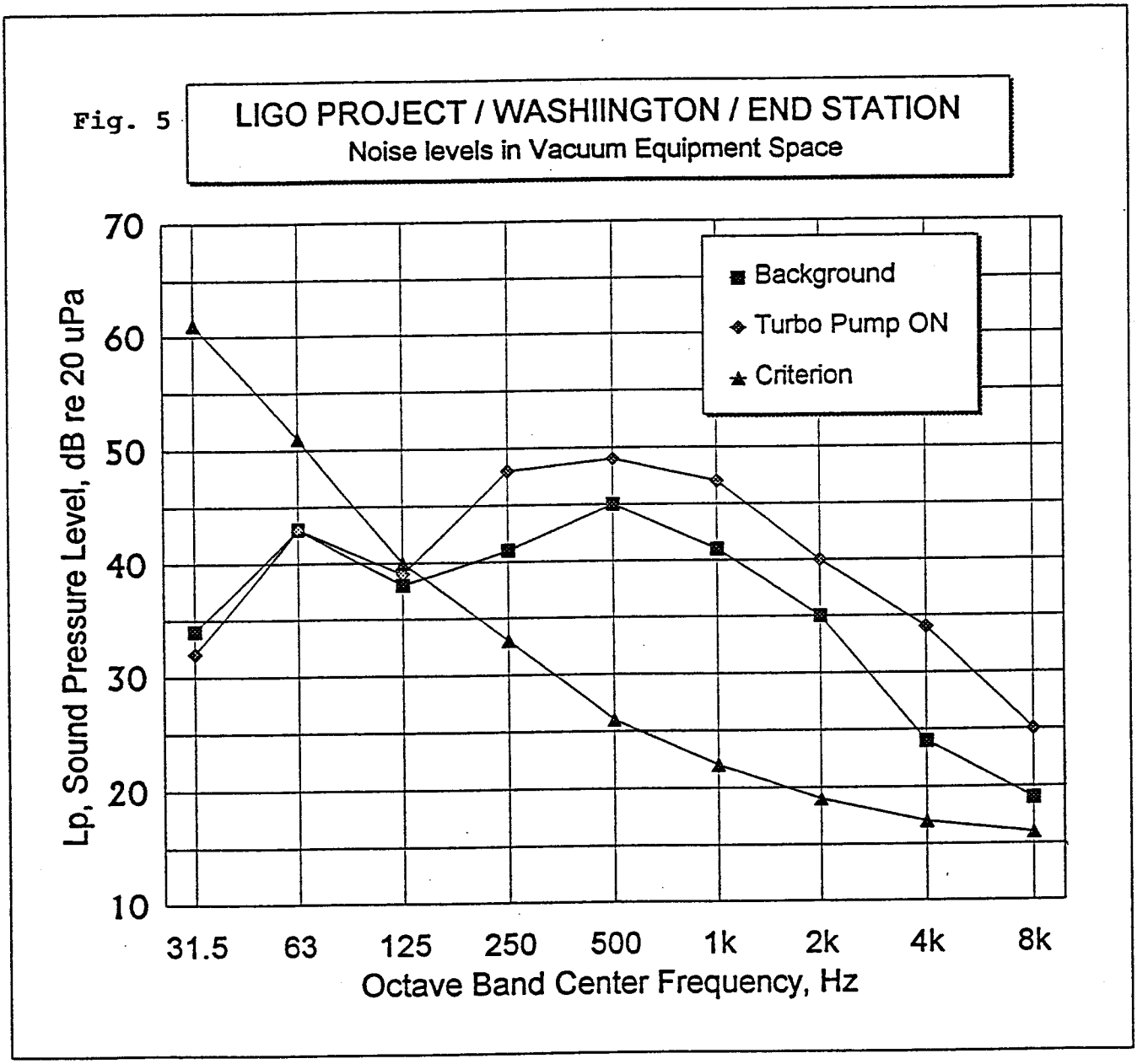
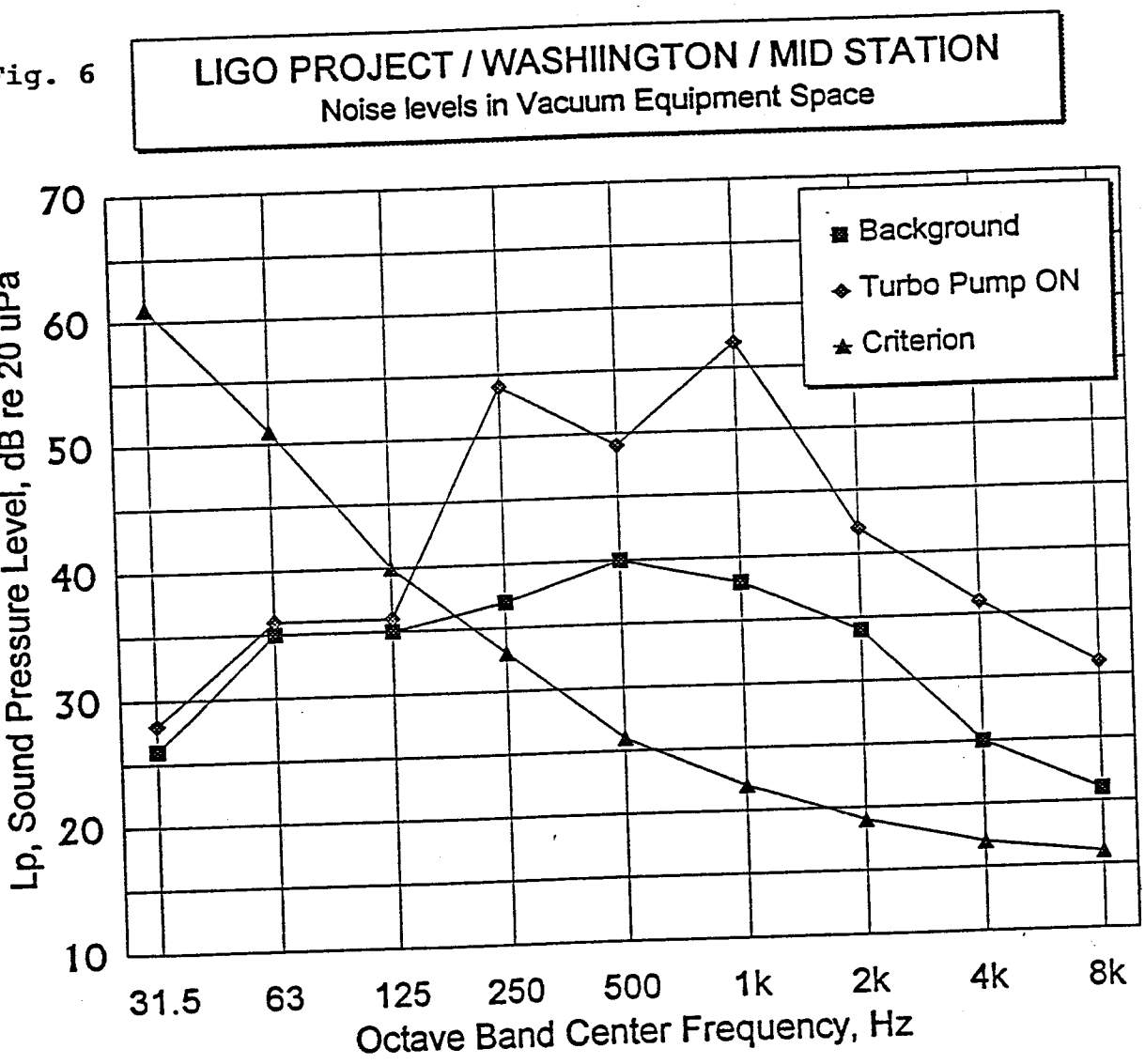
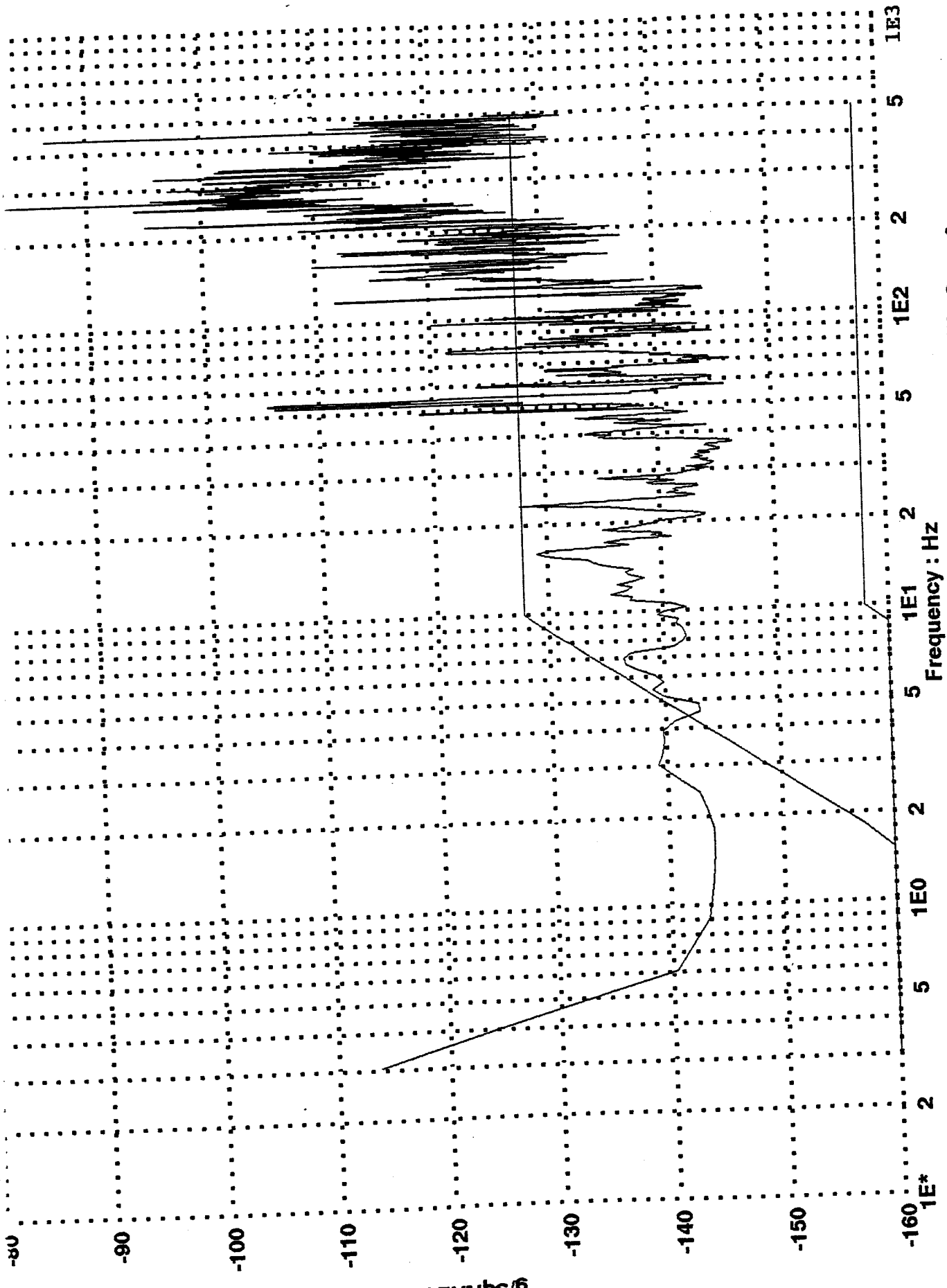

LIGO PROJECT / WASHIINGTON / END STATION
Noise levels in Vacuum Equipment Space
Background
Turbo Pump ON
Criterion
Lp, Sound Pressure Level, dB re 20 uPa
70
60
50
40
30
20
10
31.5
63
125
250
500
1k
2k
4k
8k
Octave Band Center Frequency, Hz

Fig. 6


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


g/sqrtHz : dB
-80
-90
-100
-110
-120
-130
-140
-150
-160
1E*
2
5
1E0
2
5
1E1
2
5
1E2
2
5
1E3
Frequency : Hz
DF: 0.31 Hz T-Lo: 0.ms T-Hi: 3277.ms FFT: 4096 Wind:HANN Sm: 0.
E1-14 4/20/98 End Station: BS noz G, circ. dir., turbo. source

9.0 SYSTEM DOCUMENTATION

The left end station vacuum equipment design and performance is detailed by the following documentation:

- As-built Drawings
- Quality Documentation
- Acceptance Test Reports
- Operating and Maintenance Manuals

10.0 DISPOSITION OF EQUIPMENT

All deliverable equipment will be installed in each station when it is accepted by LIGO.

The common equipment (bake-out blankets, cart, etc.) will be turned over to LIGO with the last LA site building.

Caltech did not furnish any equipment to PSI as part of this building installation and commissioning.

11.0 EQUIPMENT WARRANTY

Vacuum equipment warranty periods are based on when LIGO took possession of the equipment. The warranty period for the early deliverables (Washington beam tube valves, Washington beam tube pumps, etc.) has expired.

The warranty period for each piece of equipment in each building will be detailed in a separate document provided after LIGO accepts or takes possession of each building.

12.0 OPEN PUNCH LIST ITEMS

Meeting Handout

13.0 GNB VALVE MODIFICATIONS/STATUS

Meeting Handout

ATTACHMENT I

V049-1-169

As-built Drawings

[See Separate "B" Size Package]

ATTACHMENT II

V049-1-169

End Item Documentation Package

[Table of Contents Only]

LIGO PROJECT

MAJOR COMPONENT
END ITEM DOCUMENTATION PACKAGE
FOR WASHINGTON LEFT MID STATION

TAG NO.	*SER. NO.*
WBSC6	07
WCP3	01
WCP4	01
WA1A	01
WA7B1	01
WA14A	01
WBE4A	01
WBE4B	02

GNB GATE VALVES

WGV 12	003
WGV 09	004
WGV 10	010
WGV 18	016

PSI DOCUMENTATION NO. V049-1-171 Rev.0
VOLUME 1

LIGO PROJECT

MAJOR COMPONENT
END ITEM DOCUMENTATION PACKAGE
FOR WASHINGTON LEFT MID STATION

TAG NO.	*SER. NO.*
WBSC6	07
WCP3	01
WCP4	01
WA1A	01
WA7B1	01
WA14A	01
WBE4A	01
WBE4B	02

GNB GATE VALVES

WGV 12	003
WGV 09	004
WGV 10	010
WGV 18	016

PSI DOCUMENTATION NO. V049-1-171 Rev.0
VOLUME 2

LIGO PROJECT

MAJOR COMPONENT
END ITEM DOCUMENTATION PACKAGE
FOR WASHINGTON LEFT END STATION

TAG NO.	*SER. NO.*
WBSC10	01
WBE4C	03
WCP7	02
WA1B	02
WA7B	02

GNB GATE VALVES

WGV 17	008
WGV 11	009

PSI Documentation No. V049-1-170 Rev.0

VOLUME 1

LIGO PROJECT

MAJOR COMPONENT
END ITEM DOCUMENTATION PACKAGE
FOR WASHINGTON LEFT END STATION

TAG NO.	*SER. NO.*
WBSC10	01
WBE4C	03
WCP7	02
WA1B	02
WA7B	02

GNB GATE VALVES

WGV 17	008
WGV 11	009

PSI Documentation No. V049-1-170 Rev.0

VOLUME 2

ATTACHMENT III

V049-1-169

Washington Site Contractor QA Data

1. Left Arm Alignment
2. Left Arm Testing (Pressure Testing)
3. Left Arm Welding Inspection/X-ray

ATTACHMENT IV
V049-1-169

PROCESS SYSTEMS INTERNATIONAL, INC.
20 Walkup Drive, Westborough, MA 01581

LIGO PROJECT

SUB-VENDOR QA DOCUMENTATION DATA

TABLE OF CONTENTS

A&N CORP
EDWARDS HIGH VACUUM INTL.
Varian (conflats,ion pumps,small gate valves)
EDWARDS ENGINEERING (chillers)
FIBA Ambient Air Vaporizers
PROCESS ENGINEERING INC.(LN2 storage tanks)
BADGER METER CRYOVAVLES
J. ROYAL (viton o-rings)
MERIDEN (rotometers)
ROSEMONT (level & pressure trans.)
LINDCO (relief valves, burst disk)
CVI (vj piping)

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