Title: SPECIFICATION FOR SYSTEM ACCEPTANCE TESTS PLAN, END STATIONS

SYSTEMS ACCEPTANCE TEST PROCEDURE

LIGO VACUUM EQUIPMENT

END STATIONS

Hanford, Washington and Livingston, Louisiana

JOB NO. V59049

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PROCESS SYSTEMS INTERNATIONAL, INC.			SPECIFICATION	
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1.0 PURPOSE

The purpose of this Acceptance Test Procedure (ATP) is to define the overall plan for systems acceptance testing of the vacuum envelope and vacuum pumping system in order to demonstrate that it meets the requirements of the LIGO Vacuum Equipment Specification, LIGO-E940002-02-V, Revision 2, dated August 31, 1995.
This document will be part of the Acceptance Test Report as required by CDRL No.06.

2.0 GENERAL

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

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

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 1×10^{-9} torr-l/s of helium to be repaired in accordance with LIGO approved procedures. Leak checking shall conform to ASTM E498 "Standard Test Methods for Leaks using the Mass Spectrometer Leak Detector". (Ref. Specification V049-2-014, Leak Test Procedure). The following is a summary of the field leak testing plan.

5.1.1.1 Prerequisites

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

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

5.1.1.2 Isolated Sections

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

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

5.1.1.2.1 Annulus Leak Check

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

Table 5.1.1.2.1	
Component	**Max Allowable Pumpdown TimeMinutes**
BSC	60
Spools	30
Gate valves	30

5.1.1.2.2 Main Volume Leak Check

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

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

5.2 Bakeout and Ultimate Pressure Test: Mid Station

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

5.2.1 **Annuli pumpdown**

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

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

5.2.2 Vacuum equipment

The roughing carts, and main turbomolecular pumping system and main ion pump system will have been tested already. A functional test may be required prior to start of the bakeout to ensure proper operation of the equipment.
The main ion pumps will be evacuated and baked after installation onto the vacuum envelope. The main ion pumps will then started to ensure proper operation.

5.2.2.3 Deleted

5.2.2.4 System/Isolatable section bakeout.

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

The isolatable section will be heated to 150°C 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. This is done by ramping down the setpoints to ambient temperature.

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

Install roughing and turbo pumps.

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

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

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

5.2.2.5 Residual gas analysis after bakeout and cooldown

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

5.2.2.6 Ultimate Pressures after 100 hours

The isolatable section shall attain a total pressure of $2x10^{-8}$ 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 is for information only.

5.3.1 Pumpdown of isolatable section with 80K cryopump

End station:
Once the isolatable section has 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.

5.3.2 Pumpdown from atmosphere to 0.2 Torr using the roughing system

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

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

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

5.3.4 80K Cryopump

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

5.3.5 Main Ion pumps.

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

5.4 Noise, Shock, and Vibration

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

5.5 Interface to the CDS

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

V049-3-408 (2 sheets)

V049-3-508 (2 sheets)

V049-3-708 (2 sheets)

V049-3-808 (2 sheets)

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

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

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

5.6 Liquid Nitrogen Consumption

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

Acceptance Criteria:

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

5.7 Clean Air System Commissioning

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

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

Acceptance Criteria:

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

ACCEPTANCE TEST: LEAKAGE ISOLATED SECTION

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

	ENGINEER NAME & TITLE	SIGNATURE
PSI		
PSI		
LIGO		
LIGO		

INCLUDE ALL RAW DATA AND CALCULATION SHEETS

Title: SYSTEM ACCEPTANCE TEST PLAN, END

ACCEPTANCE TEST: PUMPDOWN ISOLATED SECTION, END STATION

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

	ENGINEER NAME & TITLE	SIGNATURE
PSI		
PSI		
LIGO		
LIGO		

SPECIFICATION

Number: V049-2-115 A	Rev.2

RGA DATA

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

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

RGA DATA

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

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

RGA DATA / ULTIMATE PRESSURES

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

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

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

NOISE / VIBRATION MEASUREMENTS

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

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

	ENGINEER NAME & TITLE	SIGNATURE
PSI		
PSI		
LIGO		
LIGO		

ELECTRICAL / INSTRUMENTS CHECK OUT & INTERFACE TO CDS

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

	ENGINEER NAME & TITLE	SIGNATURE
PSI		
PSI		
LIGO		
LIGO		

Equipment summary

End Stations

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

ATTACHMENT I

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

LIGO COMMISSION TEST PLAN FOR VIBRATION, NOISE, AND SHOCK

I. INTRODUCTION

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

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

II. TEST PROCEDURE

A. VIBRATION AND NOISE

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

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

b. right mid-station- BSC5 and CP6

c. left mid-station- BSC6 and CP4

d. right end-station- BSC9 and CP8

e. left end-station- BSC10 and CP7

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

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comparison, a background measurement will be performed with PSI's equipment "turn off" and the LIGO equipment in its "quiet mode".

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

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

B. NOISE

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

C. SHOCK

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

<u>corner station</u>-

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

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

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

left mid-station-

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

right end-station-

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

left end-station-

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

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