

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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1.0 PURPOSE

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

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

2.0 GENERAL

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

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

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

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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.

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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 3×10^{-4} torr is within the limits of Table 5.1.1.2.1.

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Table 5.1.1.2.1

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

5.1.1.2.2 Main Volume Leak Check

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

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

5.2 Bakeout and Ultimate Pressure Test: End Station

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

5.2.1 Annuli pumpdown

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

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

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5.2.2 Vacuum equipment

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

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

5.2.2.3 Deleted

5.2.2.4 System/Isolatable section bakeout.

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

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

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

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

Install roughing and turbo pumps.

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

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

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

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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 O₂ pressure. The O₂ pressure provides the most sensitive value for determining the MDL in this mode, but is subject to potential errors from gettering effects and uncertainty in the ion pump speed.

The second test is performed with the ion pump isolated. This test allows the argon and N₂ 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 H₂ 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 2×10^{-8} torr or less (N₂ 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 H₂ and H₂O, shall not exceed 3×10^{-9} torr. Only the main ion pumps and 80K cryopumps are permitted to operate during this test.

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

Table 5.2.2.6

Gas Species	LIGO Partial Pressure Goals Torr	Acceptance Partial Pressures Torr
H ₂	5x10 ⁻⁹	
H ₂ O	5x10 ⁻⁹	
Total H ₂ O, 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 H₂O 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.

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

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

5.3.1 Pumpdown of isolatable section with 80K cryopump

End station:

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

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 0.2 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 5×10^{-6} Torr. Acceptance will be when the pressure of less than 5×10^{-6} Torr is reached in 24 hours.

5.3.4 80K Cryopump

The cryopump will be turned on when a pressure of less than 5×10^{-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.

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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.

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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.

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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.

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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

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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 <math>5 \times 10^{-6}</math>			
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		

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RG A DATA

RESULTS OF THE RGA TEST	
RG A 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		

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RG A DATA

RESULTS OF THE RGA TEST	
RG A 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		

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RG A DATA / ULTIMATE PRESSURES

RESULTS OF THE RGA TEST	
RG A 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 ₂ O		
CO		
CO ₂		
CH ₄		
N ₂		
Others		

	ENGINEER NAME & TITLE	SIGNATURE
PSI		
PSI		
LIGO		
LIGO		

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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		

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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		

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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

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