Title: PROCEDURE FOR RGA FIELD CALIBRATION ON AN ISOLATABLE SECTION

PROCEDURE FOR RGA FIELD CALIBRATION FOR AN ISOLATABLE SECTION

LIGO VACUUM EQUIPMENT

Hanford, Washington and Livingston, Louisiana

JOB NO. V59049

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PROCESS SYSTEMS INTERNATIONAL, INC.			SPECIFICATION	
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OUTLINE

SPECIFICATION	
Number: V049-2-186 A	Rev.1

LIST OF DATA SHEETS

1.0 PURPOSE

The purpose of this procedure is to define the steps necessary to calibrate an RGA for determining partial pressures of the various gas species in the vacuum on a large volume (isolatable section).

2.0 GENERAL

This procedure is generally applicable for any RGA, but specific reference will made to the Balzers Quadstar software and for the Balzers QMS 200 PRISMA RGA.
Data acquisition and control of the RGA is done with a PC through the RS-232 interface using the software provided with the RGA.
Software should have been loaded on the computer to be used.

3.0 REFERENCE DOCUMENTS

Balzers QUADSTAR 421 SOFTWARE MANUAL
PSI Spec. # V049-2-113, V049-2-114, V049-2-115

4.0 RESPONSIBILITY

The procedure is applicable to PSI Personnel.

5.0 Partial Pressure Measurement in an Isolatable Section

5.1 OPTION 2: Calibrated Mixed Gas Leak with Fixed Orifice

An absolute calibration is required for the RGA to measure actual partial pressures of the residual gasses.

Outline of the calibration method
A mixed gas leak shall be calibrated against a NIST traceable standard for N_2. The leak should consist of H_2, N_2, Ar, and Xe. The calibration values from the vendor will be used without any corrections.

The calibrated Stabil-Ion gauge shall be mounted on the calibration chamber with a 1½-inch all-metal valve (C= 40 l/s).

The RGA shall be calibrated on the calibration chamber with a 1½-inch all-metal valve (C= 40 l/s).

Sensitivity shall be determined for the following gasses against the calibrated mixed leak with the fixed orifice: H_2, CH_4, H_2O, N_2, Ar, CO_2 and Xe. Adjustments using published ionization and transmission efficiency factors relative to nitrogen will be made for CH_4, H_2O, and CO_2.

Calibration shall be done in the $1x10^{-7}$ Torr range due to orifice size. Background pressure is expected to be about 10^{-8} Torr in the calibration chamber after baking pumping through the fixed orifice. The mixed gas leak of $6x10^{-6}$ Torr-L/s with about 1% Xe will be used to check RGA sensitivity in the 10^{-8} Torr Range at the higher AMU (Xe). Pump speed for a ¼-inch diameter orifice is about 3.7 l/s for N_2.

A data point shall be taken with the RGA and total pressure gauge to check the sensitivity for H_2O prior to bake out when the chamber is wet.

The chamber and instruments shall be baked to eliminate moisture. The baking will occur when the test chamber is attached to the BSC's 2½-inch RGA port (C=118 l/s). This port is located off the V049-4-045 or V049-4-046 manifold which is attached to the V049-4-142P1 flange.

Once calibrated, the RGA is then rebaked along with the system. The RGA is only exposed to the system when the system has reached high vacuum.

6.0 CALIBRATION METHOD

The calibration method used in the field station commissioning is Option 2 from the Doc. V049-PL-485 titled "Calibrated Mixed Leak + Orifice". This is the preferred method from LIGO due to its high level of repeatability. This method of calibration assumes a linear relationship between the sensitivities at different pressure ranges (10^{-6} to 10^{-9}), as long as the electron multiplier is turned on.

6.1 Calibration at $1x10^{-7}$ Torr

Determine sensitivities for the selected gas species by operating the 250 l/s turbomolecular pump with the fixed orifice and the calibrated mixed gas leak open. The fixed orifice will determine the pressure profile in the test chamber. This can be compared to the measured Stabil-ion gauge reading. RGA sensitivities and partial pressures can be calculated from this known pressure profile.

7.0 SETUP AND RGA CONDITION

See attached drawing on page 8 for reference.

7.1 Setup

RGA

The RGA will be located on the calibration vessel along with a hot ion gauge. If the RGA head is valved off to the calibration vessel with an angle valve then a 1½-inch all-metal valve should be used.

RGA should be located 90° from the hot ion gauge if the RGA is in the line of sight. The preferred orientation is horizontal if the RGA is to be turned on while warm. This will prevent hot air from convecting onto the electronics unit when it is mounted on the sensor head.

Connect the RGA electronics package to the RGA detector head and the communications cable to the computer.

Mixed Gas calibrated leak

The mixed gas calibrated leak should be supplied into the vacuum space at the far end of the calibration chamber. This will allow the leak to distribute into a uniform molecular flow and to allow the proper pressure profile to be established.

Hot Ion Gauge

The hot ion gauge used will be a Model 360 Granville-Phillips Stabil-Ion Gauge.

Data acquisition

Data will be taken by two methods: A complete 1-200 AMU Scan in BARGRAPH mode and one in ANALOG mode. Both these scans shall be made with the Electron Multiplier on.

7.2 Pump-down of Calibration Chamber

Rough the chamber down with the Auxiliary Turbo Cart with the turbomolecular pump operating. Start the Main 250 l/s turbomolecular pump.

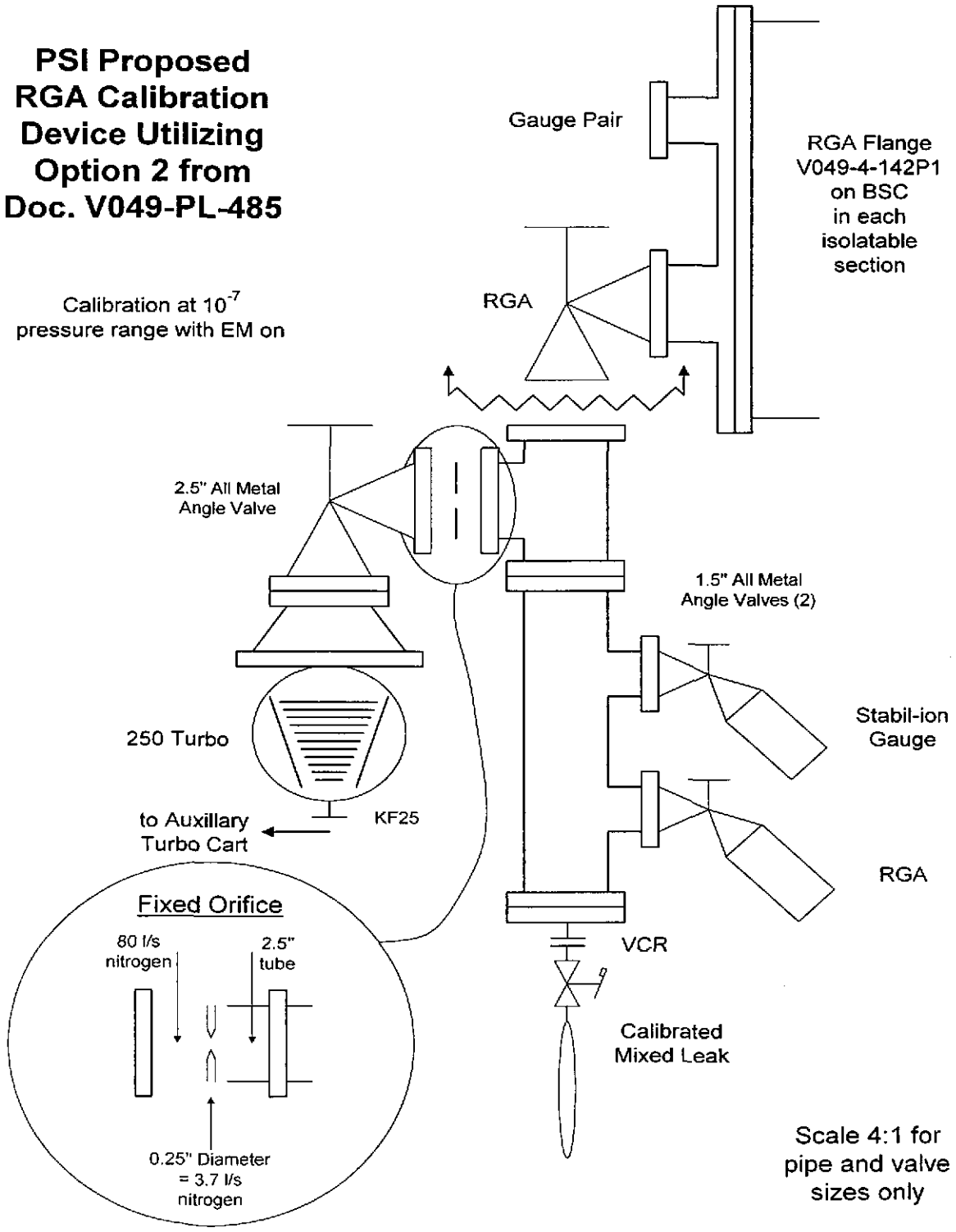
Record the pressure vs. time on the data sheet. This is done to have a history on roughing the calibration chamber. The operator can recognize a problem for subsequent calibrations in the event a valve was left partially open or a large leak develops.

Verify that the test chamber is leak tight ($<1x10^{-9}$ Torr-l/s) prior to bakeout.

7. 3 Bakeout

Prior to calibration, the RGA, Stabil-Ion Gauge, and calibration chamber must be baked. For the Balzers PRISMA RGA, the detector head can be baked to 200°C with the electronics package removed. Requirements for bakeout are that warm-up of the RGA head shall not occur until the pressure is below 10^{-4} Torr to prevent the bake-on of contaminants. Bake for 24-48 hours. Start calibration procedure when all components are at room temperature.

PSI Proposed RGA Calibration Device Utilizing Option 2 from Doc. V049-PL-485



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8.0 CALIBRATION PROCEDURES

Summary of Procedures

8.1 RGA Mass Scale Tuning, Ion Source Setup, and Detector Parameter Files Setup
8.2 RGA and Stabil-Ion Gauge Bakeout and Soak
8.3 RGA and Stabil-Ion Gauge Cooldown
8.4 RGA and Stabil-Ion Gauge Degas
8.5 Background (Baseline) Scan
  8.5.1 Bargraph Scan
  8.5.2 Pressure Readings
  8.5.3 Analog Scan
8.6 Mixed Gas Calibration
8.7 Shutting Down the Calibration System

8.1 RGA Mass Scale Tuning, Ion Source Setup, and Detector Parameter Files Setup

MASS SCALE TUNING

Mass scale tuning should be done only if the RGA has not been used for a long time, if a filament has been replaced, or the second filament chosen for use (there are two filaments available on each head). Mass scale tuning allows one to calibrate the detectors mass scaling against a known source.

Open the calibrated mixed gas leak.
Select Program Icon "TUNE-UP", submenu "Tune", and selection "QMS200 Tune mass scale".
To align the RGA mass scale with the peaks from the gas source, two parameters need to be adjusted: the offset and slope.
The offset shifts the mass scale axis left or right.
The slope adjust (stretches the axis) spacing between AMU tick marks relative to the actual calibration peaks. It may not always be possible to align the mass scale axis to the actual peaks perfectly. The calibration gas gives peaks for Hydrogen, Nitrogen, Argon, and Xenon.
Open the calibrated leak and align the Mass scale axis with the peaks, going back and forth between the higher AMU and lower AMU peaks.

Table 8.1 defines atomic mass number for each gas species of interest.

Table 8.1

Species	Mass No.
H_2	2.0
CH_4	16.0
N_2	28.0
Ar	40.0
CO_2	44.0
Xe	129 131 132 134 136

ION SOURCE

Ion source setup is located under Program Icon "TUNE-UP", submenu "Tune", and selection "Ion Source". The Ion source settings allow you to set the filament current, filament (#1 or #2), and the filament protection current. It also allows for setting of voltages, which are factory set and should not be changed without consulting the proper personnel.

Type	CH-TRON
Channel	0 ENABLE

IS-TYPE:	HS-THOR.

Detector	
Type	CH-TRON
SEM Volt.	<< 1700>>

Amplifier	
Range	
Offset	ON

RF-Polarity	inverse
IS-Voltages	[V]
IonRef	138
Cathode	90.0
Focus	9.38
Field Axis	5.75
Extract	12

Mass	
Mode	SCAN-N
First	0.00
Width	6
Speed	5s
Resolution	25
Threshold	

Ion Source	
Filament #	**Fil 1**
IS-Set	**SET 1**

IS-Emission	
Emiss [mA]	**0.50**
Protect [A]	3.5

Fil.Prot.	Thresh. [mbar]
ON below	
OFF above	

PARAMETER FILE SETUP

ANALOG SCAN PARAMETER FILE:
LIGO200.**SAP**

Load-Ch:00	CH-0
State	ENABLE
Det. Type	CH-TRON
Mass Mode	SCAN-F
First Mass	0.00

Detector

SEM Voltage	1700

Mass

Speed	5 s
Width	200
Resolution	25

Amplifier

Amp. Mode	AUTO
Amp. Range	----
Range-L	----
Pause - Cal	1.0
Offset	ON

BARGRAPH SCAN PARAMETER FILE:
LIGO200.**SBP**

Load-Ch:00	CH-0
State	ENABLE
Det. Type	CH-TRON
Mass Mode	SCAN-F
First Mass	0.00

Detector

SEM Voltage	1700

Mass

Speed	5 s
Width	200
Resolution	25
Threshold	1E-15

Amplifier

Amp. Mode	AUTO
Amp. Range	----
Range-L	----
Pause - Cal	1.0
Offset	ON

OUTPUT: User discretion
DISPLAY: User discretion

8.2 RGA and Stabil-Ion Gauge Bakeout and Soak

RGA Bakeout
The RGA head needs to be baked along with the isolatable section. The RGA shall be baked at a temperature of 160°C or higher.

Stabil-Ion Gauge Bakeout
The Stabil-ion gauge will be on during the bake-out to monitor the pressure. The Stabil-ion gauge will be baked at a temperature of 160°C or higher (same setpoint as RGA).

8.3 RGA and Stabil-Ion Gauge Cooldown

These components should soak for 2 hours longer than the chamber soak time. The ramp down should be staggered in order to maintain the gauge temperature 25°C above the chamber temperature.

8.4 RGA and Stabil-Ion Gauge Degas

Stabil-Ion Gauge Degas
Degas the hot ion gauge for 4 min at the end of the bake soak cycle, before the start of cool down.

RGA Degas
When the vacuum vessel temperature is below 70°C, the heat on the RGA head can be turned off and the RGA head allowed to cool. When the RGA head temperature drops below 100°C, the electronics unit can be mounted onto the head and the RGA can be turned on and degassed.

Execute the program icon **TUNE-UP** and select the "**connect**" option under "**Comm**" menu to connect to the RGA. Once communications is established, select "**degas**" option under the " **setup**" menu.
Select the following degas settings:

Degas Control QMA200

Degas	
Filament #	Fil 1 or Fil 2
Current [mA]	10.0
Protect [A]	3.50
Time [min]	4

8.5 Background (Baseline) Scan of main chamber volume

•The baseline scan of RGA calibration chamber is taken after cooldown.
•The RGA is openend to the main volume and a scan for the Main chamber volume is done first to ensure that the RGA is taking the scan with the RGA chamber at its cleanest state.
•A Rate of Rise test is then done by closing the ion pumps gate valves.
•The RGA is then isolated for calibration.
•An air leak is introduced to obtain a cracking pattern / AMU sensitivity ratios for the air components.

After cooldown of the chamber and instrumentation, a scan of the main volume can be taken by opening the RGA chamber to the main volume. If the RGA is baked with the main volume, then the isolation valve is already open.

8.5.1 Bargraph Scan

Although the bargraph scan gives the same information as the analog scan, the data is easily exported to a spreadsheet for calculation and data reduction.
Execute QUADSTAR Software " Measurement" icon and turn on filament and electron multiplier if not already on.
Select "Scan" and submenu "Bargraph".
Load the parameter file: LIGO200.sbp.
Verify settings according to Bargraph Scan settings sheet in Section 9. Enter any changes on the data sheet.
Save data to **WLERGA_1.sbc** where **WLE** stands for **W** (ashington), **L** (eft), and **E** (nd). Enter RGA serial #, SEM voltage, etc. in File Info section in the Save menu.

8.5.2 Analog Scan

Execute QUADSTAR Software " Measurement" icon and turn on filament and electron multiplier if not already on.
Select "Scan" and submenu "Analog".
Load the parameter file: LIGO200.sap
Verify settings according to Analog Scan settings sheet in Section 9, Page 21. Enter any changes on the data sheet.

Save data to **WLERGA_1.sac** where **WLE** stands for **W**(ashington), **L**(eft), and **E**(nd). Enter RGA serial #, SEM voltage, etc. in File Info section in the Save menu. The file name should be the same as the name used in the bargraph mode.

8.6 Rate of Rise measurement

Change the mass range for the scan from 200 AMU to 50 AMU.
Although it is more accurate to do the rate of rise scan at a smaller dwell time, the sensitivity/ noise level and therefore dynamic range may be affected by shortening the dwell time. The dwell time can be left at 5 seconds so that the calibration remains the same.
Start the analog scan.
Close the gate valves on the main ion pumps and allow the hydrogen pressure to go up about 2 decades. This will take about 1800 seconds. Each scan will take 250 seconds (5sec x 50 AMU).
Reopen the gate valves to the ion pumps after the rate of rise test.

8.7 Mixed Gas Calibration

8.7.1 RGA Chamber baseline scan

The baseline pressure is expected to be predominantly H_2. With an approximate surface area of 3000 cm^2, the gasload should be approximately $3x10^{-8}$ Torr-L/s. With a pumping speed of 13.8 l/s (H_2 corrected) the pressure should be mid 10^{-9} to low 10^{-8} Torr range.

Take a few analog scans and a bargraph scans to measure the RGA calibration chamber baseline. Bargraph scans are not necessary but are easily exported to a spreadsheet for analysis.

8.7.2 RGA Chamber calibrated leak scan

Open the mixed gas calibrated leak after the baseline is established.

Take a few analog scans and a bargraph scans to measure the RGA calibration chamber baseline. Bargraph scans are not necessary but are easily exported to a spreadsheet for analysis.

The time constant for the calibrated leak for this small volume is less than 1 minute. The time to complete one scan at a 5-second dwell time is 16 minutes, therefore, by taking two scans, equilibrium is ensured.

8.8 **Air ionization and pumping pattern.**

After calibrating the RGA using the mixed leak, close the valve to the turbopump on the calibration chamber and open the valve to the main volume to allow the RGA to measure the main volume. Open the air leak into the main volume, and adjust the air leak rate to obtain a large enough signal to get it one decade above the background outgassing of mass 28.
Take analog scans of this pattern after the pressure has been stabilized.

8.9 **Shutting Down the Calibration System**

The RGA can now be shut down. The filaments and electron multiplier must be turned off from the Setup menu; they do not shut off automatically. All other components (turbo pumps, gauges, etc.) should be left running until all calculations are complete and deemed valid. Once it is complete the 2½-inch valve above the 250 l/s turbo can be closed and the 2½-inch valve to the BSC can be opened, if and only if the BSC is under a high vacuum.

9.0 CALIBRATION OF RGA

Sensitivities at other AMU

To determine the pressures for species other than H_2, N_2, Ar, and Xe, previously determined sensitivities for that particular gas specie would be used. This utilizes published ionization efficiencies (E_{amu}) and transmission efficiency factors (F_{amu}). These values will be used without any corrections.

Actual orifice speed at other AMU

Determination of the orifice speed for other AMUs is dependent on the knowledge of the pumping speed for air as a reference point. The governing equation for an orifice size of ¼-inch diameter is

$$s_{orifice\_amu} = 11.6A\sqrt{\frac{28.78}{amu}} = 3.673\sqrt{\frac{28.78}{amu}}$$ where the units for A is cm^2.

Calculation of Partial Pressures

E_{amu}: Ionization efficiency for a specific AMU (-)

F_{amu}: Transmission efficiency for a specific AMU (-)
I_{amu}: Ion current at specific AMU of the background (Amp)
I_{leak}: Ion current at specific AMU with calibrated leak opened (Amp)
S_{p_amu}: Pressure sensitivity of specific AMU (Torr/Amp)
$s_{orifice\_amu}$: Pumping speed of specific AMU of that component through the orifice (l/s)
Q_{amu_leak}: Calibration load for this AMU with calibrated leak opened (Torr-l/s)
P_{amu}: Partial pressure of specific AMU

Sensitivities for the various gas species from the calibrated leak can be calculated from

$$S_{p\,amu} = \frac{Q_{amu\_leak}}{s_{orifice\_amu}\left(I_{leak} - I_{amu}\right)}$$

For species that are calibrated directly using the calibrated leak, the specie's system pressure is computed by

$$P_{amu} = I_{amu} \cdot S_{p\,amu}$$

Species that do not have a direct calibration will be calculated using the values for nitrogen with the ionization and transmission efficiency correction factors. The equation for the partial pressure of other AMUs is

$$P_{amu} = \frac{I_{amu} \cdot F_{amu} \cdot S_{p\,N_2}}{E_{amu}} \cdot \sqrt{\frac{28}{amu}}$$

For the "OTHER" category, we will add all relevant peaks and use the values for nitrogen to calculate partial pressure.

Refer to PSI Specifications V049-2-113, V049-2-114, and V049-2-115 for cleanliness level criteria.

TITLE	RGA CALIBRATION CHAMBER PUMPDOWN LOG
DATE:	
TIME:	
TEST I.D.: e.g. WBSC1_1	
PSI TEST ENGINEER:	

PHYSICAL DIMENSIONS				
SS SURFACE AREA		ft^2		cm^2
VOLUME		ft^3		liters
PUMPDOWN	TIME		PRESSURE	
Date:		hr:min		Torr
		hr:min		Torr
		hr:min		Torr
		hr:min		Torr
		hr:min		Torr
		hr:min		Torr
		hr:min		Torr
		hr:min		Torr
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		hr:min		Torr
		hr:min		Torr
		hr:min		Torr
		hr:min		Torr
		hr:min		Torr
		hr:min		Torr

TITLE	RGA CALIBRATION CHAMBER BAKEOUT TEMP. LOG
DATE:	
TIME:	
TEST I.D.: e.g. WBSC1_1	
PSI TEST ENGINEER:	

BAKEOUT LOG / DATE	TIME		TEMPERATURE	
		hr:min		°C
		hr:min		°C
		hr:min		°C
		hr:min		°C
		hr:min		°C
		hr:min		°C
		hr:min		°C
		hr:min		°C
		hr:min		°C
		hr:min		°C
		hr:min		°C
		hr:min		°C
		hr:min		°C
		hr:min		°C
		hr:min		°C
		hr:min		°C
		hr:min		°C
		hr:min		°C
		hr:min		°C

TITLE	RGA ION SOURCE SETTINGS SHEET
DATE:	
TIME:	
TEST I.D.: e.g. WBSC1_1	
PSI TEST ENGINEER:	

Type	CH-TRON
Channel	0 ENABLE

Detector	
Type	CH-TRON
SEM Volt.	<< >>

Amplifier	
Range	
Offset	ON

IS-TYPE:	HS-THOR.

RF-Polarity	inverse
IS-Voltages	[V]
IonRef	138
Cathode	90.0
Focus	9.38
Field Axis	5.75
Extract	12

Mass	
Mode	SCAN-N
First	
Width	
Speed	
Resolution	
Threshold	-

Ion Source	
Filament #	
IS-Set	

IS-Emission	
Emiss [mA]	
Protect [A]	3.5

Fil.Prot.	Thresh. [mbar]
ON below	
OFF above	

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TITLE	RGA SCAN PARAMETER FILE SETTINGS
DATE:	
TIME:	
TEST I.D.: e.g. WBSC1_1	
PSI TEST ENGINEER:	

PARAMETER FILE: LIGO200.SBP

		Actual
Load-Ch:00	CH-0	
State	ENABLE	
Det. Type	CH-TRON	
Mass Mode	SCAN-F	
First Mass	0.00	

Detector

SEM Voltage	1700	

Mass

Speed	5 s	
Width	200	
Resolution	25	
Threshold	1E-15	

Amplifier

Amp. Mode	AUTO	
Amp. Range	----	
Range-L	----	
Pause - Cal.	1.0	
Offset	ON	

PARAMETER FILE: LIGO200.SAP

		Actual
Load-Ch:00	CH-0	
State	ENABLE	
Det. Type	CH-TRON	
Mass Mode	SCAN-F	
First Mass	0.00	

Detector

SEM Voltage	1700	

Mass

Speed	5 s	
Width	200	
Resolution	25	

Amplifier

Amp. Mode	AUTO	
Amp. Range	----	
Range-L	----	
Pause - Cal.	1.0	
Offset	ON	

OUTPUT: User discretion
DISPLAY: User discretion

TITLE	RGA CAL. CHAMBER PARTIAL PRESSURE DATA SHEET
DATE:	
TIME:	
TEST I.D.: e.g. WBSC1_1	
PSI TEST ENGINEER:	

AMU	I_{amu} (Amp)	Q_{amu_leak} Leak rate (Torr-L/s)	F_{amu} Transmission Factor wrt N_2	E_{amu} Ionization efficiency wrt N_2*	I_{leak} (Amp)	S_{p_amu} (Torr/A)	P_{amu} (Torr)
H_2		4.8×10^{-6}		0.46			
He				0.18			
12			0.42				
14			0.5				
15			0.54				
CH_4			0.57	1.60			
17			0.6				
H_2O			0.64	1.12			
19			0.67				
26			0.71				
28		9.5×10^{-7}		1.00			
32			1.14	1.01			
38			1.36				
40		9.4×10^{-8}		1.29			
43			1.53				
44			1.57	1.42			
129		2.2×10^{-8}		2.87			
131		1.8×10^{-8}		2.87			
132		2.2×10^{-8}		2.87			
134		9.0×10^{-9}		2.87			
136		8.0×10^{-9}		2.87			
Other				1.00			

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

TITLE	RGA COMPUTER DATA FILE LOG
DATE:	
TIME:	
TEST I.D.: e.g. WBSC1_1	
PSI TEST ENGINEER:	

BARGRAPH DATA FILE NAME:

ANALOG SCAN DATA FILE NAME:

OTHER DATA FILES:

PRINTOUTS OF:

1. Baseline Analog scan with gauge on.
2. Baseline Analog scan with gauge off.
3. Calibration Analog scan with gauge on.
4. Calibration Analog scan with gauge off.
5. Baseline Bargraph scan with gauge on.
6. Baseline Bargraph scan with gauge off.
7. Calibration Bargraph scan with gauge on.
8. Calibration Bargraph scan with gauge off.