Transpector® CPM
Compact Process Monitor

PN 074–641–P1B

INFICON

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INFICON Inc.
Two Technology Place
East Syracuse, NY 13057
USA

meets the essential safety requirements of the European Union and is placed on the market accordingly. It has been constructed in accordance with good engineering practice in safety matters in force in the Community and does not endanger the safety of persons, domestic animals or property when properly installed and maintained and used in applications for which it was made.

Equipment Description: Transpector® CPM
Gas Analysis System

Applicable Directives: 2014/35/EU (LVD)

2014/30/EU (EMC)

2011/65/EU (RoHS)

Applicable Standards:

Safety: EN 61010-1:2010 Safety Requirements for Electrical Equipment For Measurement,
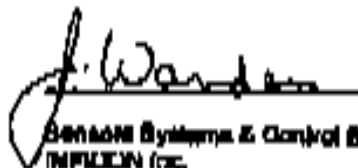Control, and Laboratory Use.
Part 1: General Requirements

Emissions: EN 61326-1:2013 (Radiated & Conducted Emissions)
CISPR 11/EN Group 1, Class A;
(EMC – Measurement, Control & Laboratory Equipment)

FCC 47 CFR Part 15 Class A emission requirements (USA)

Immunity: EN 61326-1:2013 (General EMC)
Class A: Immunity
(EMC – Measurement, Control & Laboratory Equipment)

RoHS: Fully compliant

CE Implementation Date: January 5, 2016

Authorized Representative:

Sensors Systems & Control Business Line Manager
INFICON Inc.

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NOTE: These instructions do not provide for every contingency that may arise in connection with the installation, operation or maintenance of this equipment. Should you require further assistance, please contact INFICON.

1 INFICON

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Chapter 1
Getting Started

1.1 General Safety Information

⚠️ **WARNING**

Transpector CPM is not for use in a manner not specified by INFICON.

⚡ **WARNING - Risk Of Electric Shock**

There are no user serviceable components within the Transpector CPM case.

⚡ **WARNING - Risk Of Electric Shock**

Potentially lethal voltages are present when the line cord is connected to Transpector CPM.

⚡ **WARNING - Risk Of Electric Shock**

Refer all Transpector CPM maintenance to qualified personnel.

1.2 Purpose of Transpector CPM

Transpector CPM samples a representative fraction of a process environment and directs the gas sample to a Residual Gas Analyzer (RGA). The CPM can detect levels of impurities in process gases at sub-ppm levels.

1.2.1 Description of the Transpector CPM

Transpector CPM is comprised of:

◆ **FabGuard® or FabGuard Explorer™** software provides automatic or manual control and status information. It includes a full array of basic residual gas analyzer (RGA) features, including Spectrum or Selected Peaks scanning, Leak Detection and Recipe Generation.

◆ **Quadrupole Sensor** analyzes gases by: (1) ionizing the gas molecules, (2) separating the ions by their mass-to-charge ratio, and (3) measuring the quantity of ions at each mass. The sensor can indicate the partial pressures of gases characteristic of processes occurring within a vacuum or other vessel, and is used to investigate the nature of a process or to monitor process conditions.

◆ **Electronics Module (Transpector®)** controls the sensor. The electronics module and quadrupole sensor are a matched set. The electronics module attaches to and is supported by the sensor.

◆ **CPM Controller** consolidates control functions into a single device. The CPM controller works in conjunction with the Transpector electronics module to control valve activation, heaters, pumps, and power to all elements of the system.

◆ **Pumping System** provides process sampling from 1.5 atmospheres to high vacuum.

◆ **Inlet Valves**, a HexBlock™ inlet provides several sampling ranges, a calibration reference, and a process pressure gauge.

1.3 Using this Operating Manual

Before using this manual, please take a moment to understand the Cautions and Warnings used throughout. They provide pertinent information that is useful in achieving maximum instrument efficiency while ensuring personal safety.

NOTE: Notes provide additional information about the current topic.

HINT: Hints provide insight into product usage.

CAUTION

Failure to obey these messages could result in damage to the sensor.

WARNING

Failure to obey these messages could result in personal injury.

WARNING - Risk Of Electric Shock

Potentially lethal voltages are present.

1.4 How to Contact INFICON

To contact INFICON regarding Transpector CPM, please use the following contact information:

> INFICON, Inc.
> Two Technology Place
> East Syracuse, NY 13057
> USA
> Tel: +315.434.1100
> Fax: +315.437.3803
> E-mail: reachus@inficon.com

Worldwide customer support information is also available at www.inficon.com under **Contact >> Support Worldwide**

◆   Sales and Customer Service

◆   Technical Support

◆   Repair Service

If experiencing a problem with Transpector CPM, please have the following information readily available:

◆   The Transpector CPM serial number

◆   A description of the problem

◆   An explanation of any attempts at corrective action

◆   The exact wording of any error messages received

1.4.1 Returning Transpector CPM to INFICON

Do not return any component of the Transpector CPM to INFICON without first speaking with a Customer Support Representative. A Return Material Authorization (RMA) number must be obtained from the Customer Support Representative.

If a package is delivered to INFICON without an RMA number, the package will be held and customer contact will be made. This will result in delays in servicing Transpector CPM.

Prior to being given an RMA number, a Declaration Of Contamination (DOC) form may need to be completed if the sensor has been exposed to process materials. DOC forms must be approved by INFICON before an RMA number is issued. INFICON may require that the sensor be sent to a designated decontamination facility, not to the factory.

1.5 Transpector CPM Performance Specifications

1.5.1 General Specifications

Table 1-1 General specifications

Mass Range (AMU)	1 – 100	1 – 200	1 – 300
Resolution	<1 AMU wide @ 10% peak height over entire mass range (per AVS 1993 recommended practice)		
Total Pressure Range[1]	$5\times10^{-7}-1\times10^{-3}$ Torr ($6.6\times10^{-7}-1.3\times10^{-3}$ mbar)		
Total Pressure Accuracy[2]	±25% $1\times10^{-6}-1\times10^{-3}$ Torr ($1.3\times10^{-6}-1.3\times10^{-3}$ mbar)		
Maximum Ion Source Operating Pressure[3]	1×10^{-3} Torr (1.3×10^{-3} mbar)		
Nominal Operating Pressure[4]	2×10^{-4} Torr (2.6×10^{-4} mbar)		
System Operating Pressure	1×10^{-8} Torr (1.3×10^{-8} mbar)-1.2 atmospheres (with proper inlet configuration)		
Sensitivity @ Low Emission @ High Emission	Amps/Torr (Amps/mbar) >4×10^{-6} (>3×10^{-6}) >2×10^{-5} (>1.5×10^{-5})	Amps/Torr (Amps/mbar) >2×10^{-6} (>1.5×10^{-6}) >1×10^{-5} (>7.6×10^{-6})	Amps/Torr (Amps/mbar) >1×10^{-6} (>7.6×10^{-7}) >5×10^{-6} (>3.8×10^{-6})
Minimum Detectable Partial Pressure[5]	1×10^{-13} Torr (1.3×10^{-13} mbar)	2×10^{-13} Torr (2.6×10^{-13} mbar)	4×10^{-13} Torr (5.3×10^{-13} mbar)
Maximum Data Rate (analog scans OR selected peaks)	1.8 ms per point (555 data points per second)		
Abundance Sensitivity[6]	<5 ppm	<10 ppm	<100 ppm
Zero Blast[7]	<2 ppm	<25 ppm	<200 ppm
Detection Limit[8]	<1 ppm	<2 ppm	<4 ppm
Linearity[9]	±20%		

Table 1-1 General specifications (continued)

Mass Range (AMU)	1 – 100	1 – 200	1 – 300
Minimum Background Pressure	1×10^{-8} Torr (1.3×10^{-8} mbar)		
Maximum Sensor and Inlet Temperature	150°C		

[1] Ion source pressure reading @ low emission using total pressure lens
[2] Total pressure accuracy @ low emission
[3] Maximum ion source operating pressure @ low emission
[4] 2×10^{-4} Torr in the ion source will produce about 1×10^{-5} Torr in the quadrupole region
[5] MDPP at the ion source with EM on and 1 s dwell time
[6] Mass 40 contribution onto 41 AMU
[7] Zero blast contribution onto 2 AMU
[8] Minimal detectable concentration with Krypton in air @ a 1 s dwell time
[9] For 1 Torr orifices and lower. Linearity @ low emission at 0.1 to 2 times the nominal orifice pressure

1.5.2 Hex Block Orifice Sampling Inlets

Table 1-2 HexBlock inlets and available orifices (maximum nominal pressure for orifice)

Inlet	Orifices
V1 (LP)	3 mTorr (no orifice) 10 mTorr 15 mTorr 100 mTorr 360 mTorr 1 Torr
V2 (HP)	3 mTorr (no orifice) 10 mTorr 15 mTorr 100 mTorr 360 mTorr 1 Torr (bypass) 3 Torr (bypass) 10 Torr (bypass) 30 Torr (bypass) 1 Torr Sniffer (bypass) 3 Torr Sniffer (bypass) 7 Torr Sniffer (bypass) 10 Torr Sniffer (bypass 30 Torr Sniffer (bypass) 100 Torr Sniffer (bypass)
V3 (HC)	1 mTorr (High Conductance)

1.5.3 Atmospheric Pressure (Capillary) Sampling

Table 1-3 Capillary sampling option

Process Pressure Range (23°C ambient, no purge)	300 to 900 Torr (400 to 1199 mbar)
Capillary Size and Lengths	1/16 in. OD x 1.5 m SS capillary 1/16 in. OD x 3.0 m SS capillary
Process Gas Consumption	2.6 sccm @ 300 Torr (400 mbar) 17 sccm @ 760 Torr (1013 mbar) 30 sccm @ 900 Torr (1199 mbar)
Response Time for Composition Changes (response to normal inert gases)	Capillary Delay: t(1.5m) = 0.3 s t(3.0m) = 1 s Intermediate Volume Tau = 0.7 s CPM Isolation time constant = 75 s

1.6 Physical Requirements

1.6.1 Physical Dimensions

Figure 1-1 Pumping system dimensions
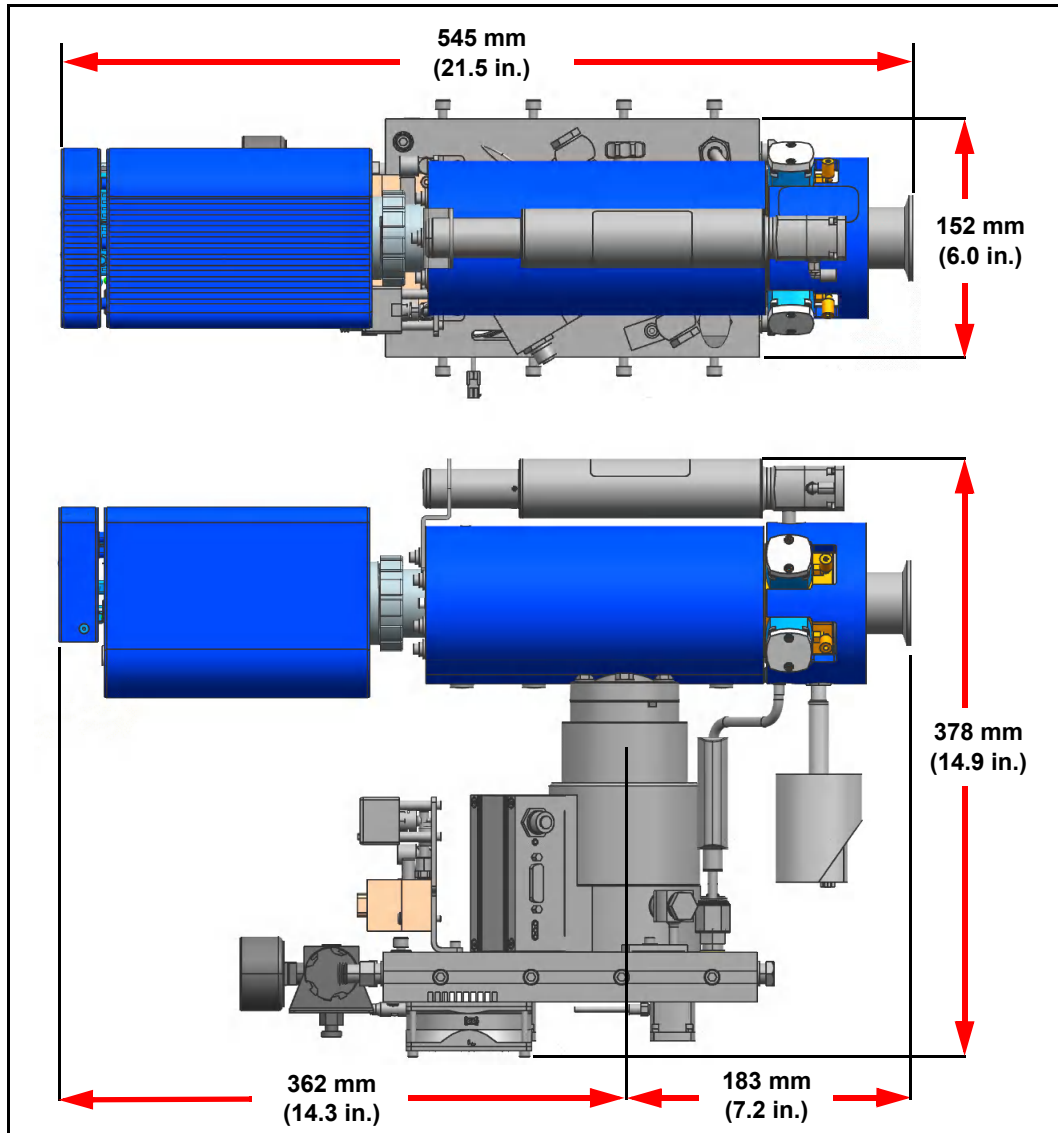
Pumping System dimensions

545 x 152 x 378 mm (21.5 x 6.0 x 14.9 in.)

CPM Controller dimensions

195 x 207 x 89 mm (7.7 x 8.1 x 3.5 in.)

Foreline Pump dimensions

218 x 150 x 147 mm (8.6 x 5.9 x 5.8 in.)

NOTE: See for cable connections.

1.6.2 Weight

The approximate weight of Transpector CPM (without the Foreline Pump and the CPM controller) is 15.5 kg (34 lb.).

NOTE: This weight does not include connecting cables.

1.6.3 Ventilation Requirements

⚠️ **CAUTION**

> **For adequate ventilation, maintain at least 25.4 mm (1 in.) clearance around the Transpector electronics module, the CPM heaters and the pumping system.**

If enclosing Transpector CPM, the enclosure must be large enough or ventilated to provide adequate cooling airflow to the fan on the Transpector CPM pumping system and the fan in the Transpector CPM controller.

1.7 Electrical Power Requirements

The CPM system components that require AC power input are:

CPM controller . . . . Universal input, any voltage in the range specified in section 1.7.1.1 is acceptable.

Personal computer . . . . Universal input, any voltage in the range specified in section 1.7.1.1 is acceptable.

1.7.1 Required Supply Voltage

Except for the AC power input, the CPM controller supplies all required voltages.

1.7.1.1 Acceptable Supply Voltage Range

The AC power input must be 100, 120, or 230 V∼, ±10%

NOTE: If the input power is less than 100 V∼, the time required for the heaters to reach their nominal temperature will be increased.

1.7.1.2 Required Frequency

50 or 60 Hz, ±5%

1.7.1.3 Power Rating

CPM controller—500 VA

1.7.1.4 Fuse Rating

- 3.15 A @ 250 V~

- Interrupt Current 35 A @ 250 V~

- Type T (5 x 20 mm)

1.7.1.5 Overvoltage Category

Overvoltage Category II (per EN61010-1:2010)

- Short Term: 1440 V < 2 seconds

- Long Term: 490 V < 5 seconds

1.7.1.6 Electrical Connections

One of the following:

- 110 V ~, three-pronged, grounded plug

- 230 V ~, European style, two-pronged plug with ground contact

NOTE: Do not replace power cord with an inadequately rated cord. Cord must be rated 10 A or higher.

1.8 Nitrogen Purge Gas (Corrosive System Only)

The corrosive service Turbo Molecular Pump requires 10 to 25 sccm nitrogen purge gas flow through its bearings to protect the bearings from corrosion and loss of lubricant by evaporation. The CPM nitrogen regulator range is 10–15 psi (gauge). It is set for 10 sccm flow at the factory.

⚠️ **CAUTION**

> **The corrosive service Turbo Molecular Pump (CVD/Etch), requires nitrogen purge gas flow whenever the system is operational.**

Normally, dry nitrogen is supplied at the acceptable pressure range for the air pressure. (See). In this manner, dry nitrogen can be supplied directly to the solenoid valve block and to the pressure regulator via the supplied 6.35 mm (1/4 in.) tee. The regulator supplies dry nitrogen at a reduced pressure for the purge.

Figure 1-2 Compressed air supply connection

**Dry Compressed Air
58 – 100 psi (gauge)
Recommended Setting
is 75-80 psi (gauge)**

**Dry nitrogen
58 – 100 psi (gauge)
Bearing Purge
Corrosive System Only**
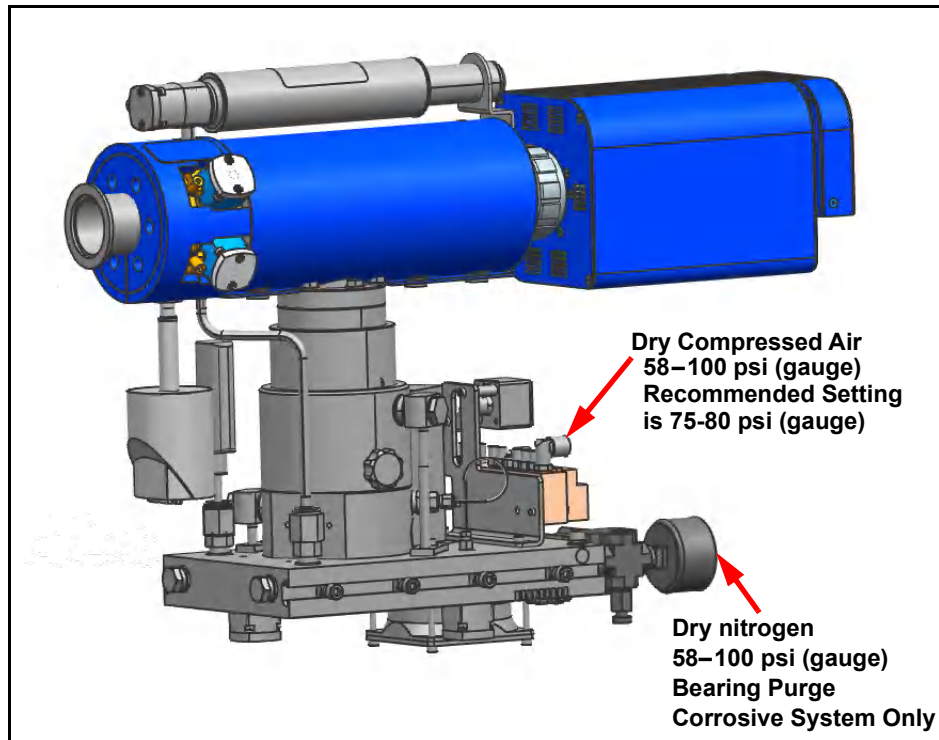
The pressure range is 58–100 psi (gauge) (4–6.9 bar) [400–690 kPa].
Recommended setting is 75-80 psi (gauge) (5.17 to 5.52 bar) [517 kPa to
552 kPa].

⚠️ **WARNING**

**Nitrogen pressure must not exceed 100 psi (gauge)
(6.9 bar) [690 kPa].**

⚠️ **CAUTION**

**Nitrogen pressure must be at least 58 psi (gauge)
(4 bar) [400 kPa].**

1.9 Exhaust Gas

Exhausting gas from the Turbo Molecular Pump is required for corrosive
applications. With non-corrosive applications, exhaust the Turbo Molecular Pump
in accordance with the facility's requirements. The dry Foreline Pump has a
6.35 mm (1/4 in.) Swagelok® tube adapter for an exhaust fitting.

1.10 Air Pressure Requirements

1.10.1 Required Air Pressure

Dry compressed air (or dry nitrogen) is used to operate the electro-pneumatic inlet valves. The minimum air pressure required to operate the inlet valves is 58 psi (gauge) (4 bar) [400 kPa]. Recommended setting is 75-80 psi (gauge) (5.17 to 5.52 bar) [517 kPa to 552 kPa].

1.10.2 Air Pressure Range

The air pressure range is 58–100 psi (gauge) (4–6.9 bar) [400–690 kPa]. Recommended setting is 75-80 psi (gauge) (5.17 to 5.52 bar) [517 kPa to 552 kPa].

⚠️ **WARNING**

Air pressure must not exceed 100 psi (gauge) (6.9 bar) [690 kPa].

⚠️ **CAUTION**

Air pressure must be at least 58 psi (gauge) (4 bar) [400 kPa].

1.10.3 Moisture Content of Compressed Air Supply

The compressed air supply used for inlet valve operation must be dried to the extent that changes in compressed air pressure during operation will not produce condensation in lines, solenoids or valve actuators.

⚠️ **CAUTION**

Moisture condensation can cause corrosion.

1.10.4 Air Pressure Connections

The compressed air supply connects to the CPM solenoid with 6.35 mm (1/4 in.) polymer hose. The 6.35 mm (1/4 in.) connector is a friction-lock, right-angle fitting to adapt the supply hose to the solenoid base.

1.11 Vacuum Requirements

1.11.1 Required Vacuum

The Turbo Molecular Pump and Foreline Pump create vacuum. The Foreline Pump must provide <10 Torr (13 mbar) when there is up to 30 sccm of nitrogen purge plus process gas bypass flow.

⚠️ **CAUTION**

Do not exceed 10 Torr (13 mbar) Foreline Pump pressure.

1.11.2 Acceptable Range Of Vacuum

The CPM manifold can achieve <1×10^{-8} Torr (1.33×10^{-8} mbar) of base pressure (no sample flow) after bakeout and cool down. This level of vacuum requires a foreline pressure of <10 Torr (13 mbar).

1.12 Environmental Requirements

1.12.1 Use

Indoor use only.

1.12.2 Altitude Range

Up to an altitude of 2000 m (6561 ft.)

Contact INFICON for operation at higher altitudes.

1.12.3 Maximum Humidity

80% relative humidity (no condensation)

1.12.4 Pollution Degree

Pollution Degree 2 (per EN61010-1:2001)

1.12.5 Maximum Operating Temperature

50°C (122°F) Transpector Electronics Module

35°C (95 °F) for the turbo pump under maximum gas load

1.12.6 Minimum Operating Temperatures

20°C (68°F)

1.12.7 Clean Room Requirements

The CPM is clean room compatible (including silicone rubber heaters).

1.12.8 Anti-Static Conditions

CPM passes standard EN 61326-1:2013.

1.13 Computer System Requirements

The minimum system requirements for FabGuard® Explorer Operating Software are listed in Table 1-4:

Table 1-4 Minimum computer requirements for FabGuard Explorer

Parameters	FabGuard Explorer Requirements
Processor	2.4+ GHz Dual Core
Memory	4+ GB
Hard Drive	SATA 80 GB to 1 TB 7200+ RPM
Resolution	1024 X 768 16-bit color or greater
Ethernet Port	One free Ethernet port for connection to Transpector CPM
Operating System	Windows 7® or Windows 8®

INFICON can supply a controller to run the software that operates Transpector CPM System. (Refer to section 1.4 on page 1-4.)

1.13.1 Operating System

FabGuard Explorer software requires either Windows 7 or Windows 8 for proper operation.

See Chapter 10 or the FabGuard Explorer CD for FabGuard Explorer software operation.

Chapter 2
Installation

2.1 Installation Overview

The Transpector CPM system is partially disassembled for shipping and must be re-assembled prior to operation. The Transpector sensor is shipped inside the CPM manifold tee, but the remaining components such as the Transpector electronics module, cable box, CPM controller, diaphragm foreline pump and all connecting cables will need to be installed per the instructions in this chapter:

1 Install the Transpector electronics module, heat guard, and cable box. (See section 2.2 on page 2-2.)

2 Install sniffers, if applicable. (See section 2.2 on page 2-2.)

3 Mount CPM to process tool, if applicable. (See section 2.4 on page 2-5.)

4 Install the CPM controller and connect communications cables from the CPM controller to the Transpector cable box (See Figure 2-6 on page 2-8.)

5 Connect cables on the Transpector cable box to the various CPM sub systems, and the control computer. (See Figure 2-8 on page 2-10.)

6 Install the CPM Foreline Pump. (See section 2.7 on page 2-11.)

7 Install the software. (See section 2.8, Software Installation, on page 2-11.)

2.2 Transpector Electronics Module, Heat Guard, and Cable Box Installation

The Transpector electronics module and cable box must be mounted in an area where the ambient temperature does not exceed 50°C (122°F) and there is ample air flow. Best performance is achieved when the electronics module is not exposed to wide temperature variations.

2.2.1 Attach Transpector Electronics Module

The Transpector sensor is typically already installed inside the CPM Manifold Tee. The Transpector electronics module must be mounted onto the sensor:

1 The Transpector sensor mounting connector assembly includes a mounting nut and an O-ring. Place the nut over the end of the sensor and roll the O-ring back to the groove on the sensor. When the mounting nut is tightened, the O-ring compresses making a tight fit on the sensor housing.

2 Note the recessed area on the sensor feedthrough and the ground tab on the Transpector electronics module. Match the recessed area of the feedthrough to the ground tab and carefully slide the Transpector electronics module fully onto the sensor.

3 Finger tighten the mounting nut on the Transpector sensor.

Figure 2-1 Transpector electronics module dimensions
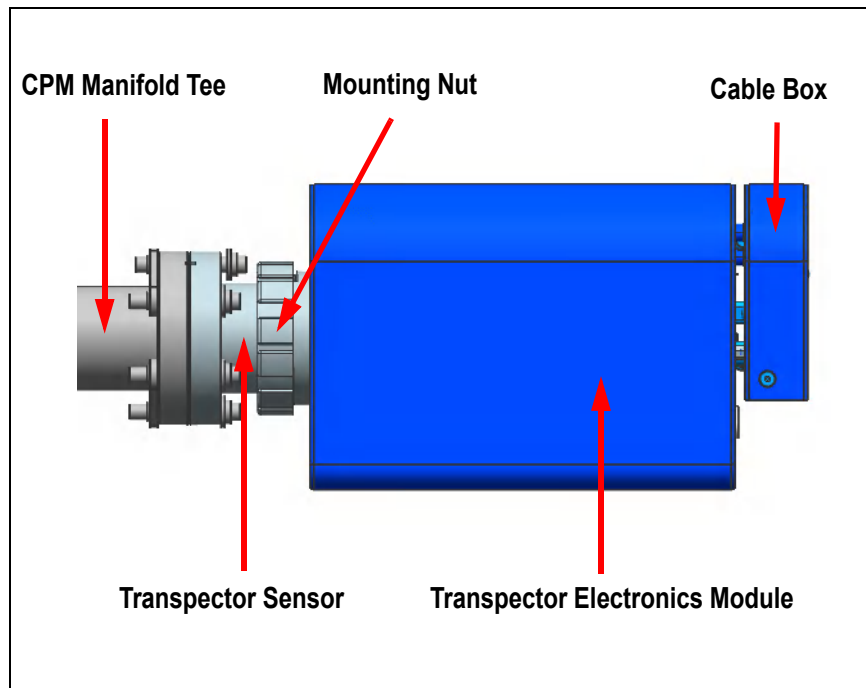
2.2.2 Attach Heat Guard

To decrease the risk of burns when the heating jacket is on, a heat guard is provided for the metal surfaces between the Transpector electronics box and the CPM manifold tee.

1 Loosen the single screw that attaches the calibration reference shipping bracket to remove the bracket. Replace the screw.

2 Attach heat guard between the Transpector electronics module and the mounting nut using the two screws provided.

3 Attach calibration reference standard bracket to the heat guard and secure the bracket to the heat guard with the provided screw.

Figure 2-2 Heat Guard and Calibration Reference Bracket
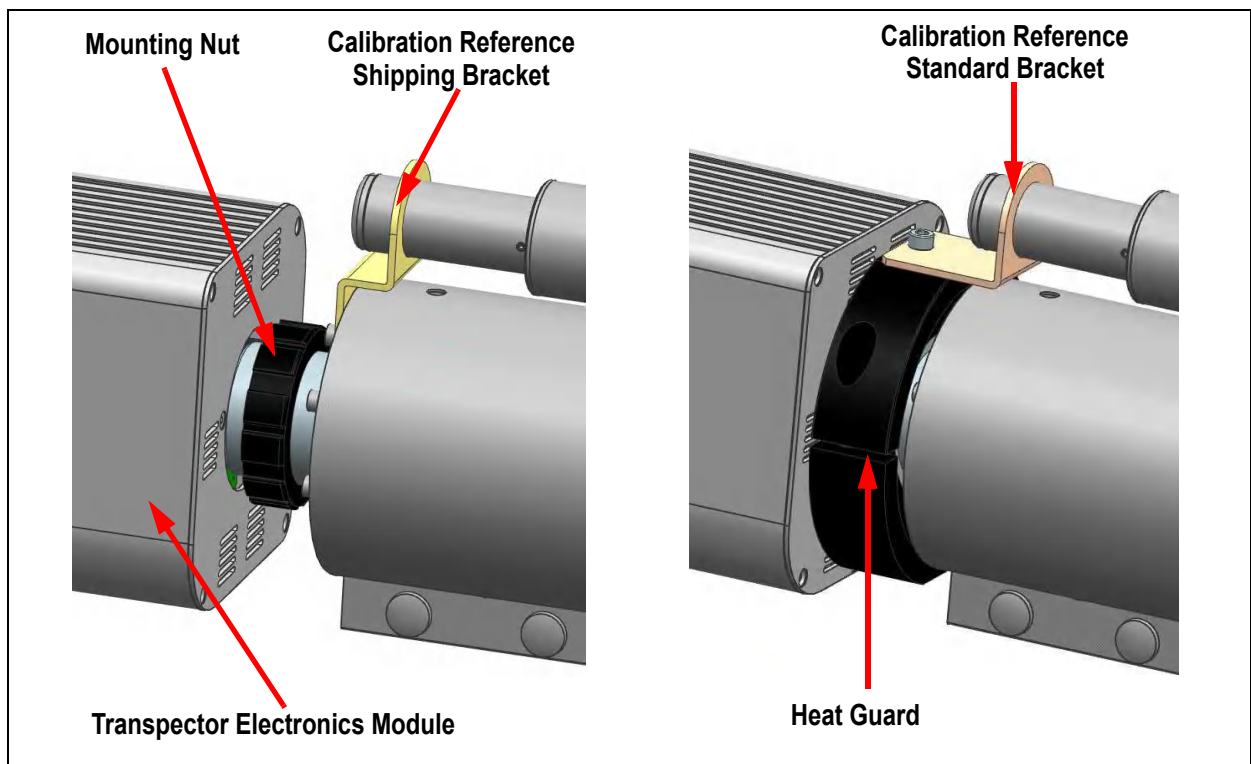
⚠ WARNING - High Temperature

Metal surfaces will be hot when heating jacket is on. Attach heat guard to avoid risk of burns from metal surfaces between Transpector electronics module and CPM manifold tee.

2.2.3 Attach Cable Box

The cable box and Transpector electronics module are connected via an Ethernet connection, a 15-pin Aux I/O connection, and a 62-pin extended I/O connection. Three screws are used to stabilize the cable box on the electronics module. (See Figure 2-3.)

To connect the cable box to the electronics module:

1 Insert the Ethernet jack on the cable box into the Ethernet port on the electronics module.

2 Carefully insert the 15-pin Aux I/O and 62-pin extended I/O connectors until they are secure and the Ethernet connector snaps into place.

3 Secure the cable box on the electronics module with the three provided screws.

Figure 2-3 Transpector electronics module and cable box
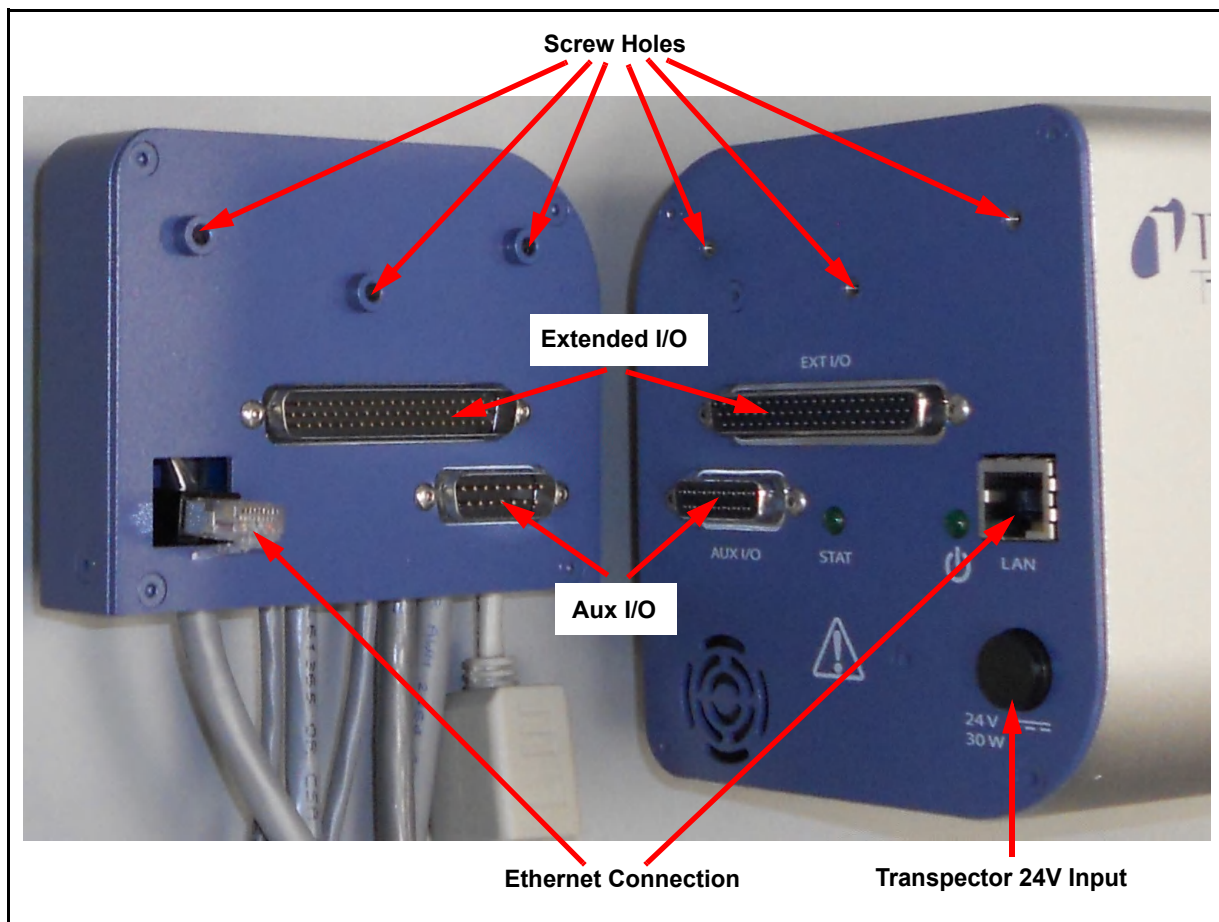
⚠️ **WARNING - Risk Of Electric Shock**

**DO NOT remove the cover from the Transpector 24 V
input. 24V is supplied to the Transpector electronics box
from the controller.**

2.3 Sniffer Installation

Install the sniffer into the Swagelok® fitting on the hexblock using the 1/4 in.
(6.35 mm) nut and vespel ferrule supplied with the sniffer.

2.4 Mounting the Pumping System

The Transpector CPM system typically mounts directly to a process chamber via
the CF or KF process connection at the end of the Hexblock inlet. Normally there
is no need to use an additional isolation valve between the Hexblock and the
process chamber.

If an isolation valve is needed and the CPM does not have a CDG interlock for the
Hexblock inlet, it is essential to pump down the volume between the Hexblock and
isolation valve from the process side before the CPM is turned on. If this volume is
not pumped down properly filament failure can be the result.

⚠️ **CAUTION**

**If an isolation valve is used ensure and trapped volumes
are pumped out in order to avoid filament failure.**

A support kit is supplied for CPM configurations with a standard process
connection. The support kit, PN 922-209-G1, consists of two 1.22 m (4 ft.) support
legs, two adjustable feet and mounting hardware.

2.4.1 Installing the Support Kit

1 Measure the support leg to make sure there is ample room for installation. The leg may be cut to size.

NOTE: One end of the support leg has a threaded hole for the adjustable foot. When cutting the leg, make sure that the threaded hole end is used for the support.

2 Screw the adjustable foot fully into the bottom of the support leg. (See Figure 2-4.)

3 Install the right angle bracket onto the support leg using the T-nut and bolts provided. Finger tighten.

4 Install the second bolt and T-nut into the bracket, leaving it loose.

5 Slide the T-nut into the CPM foreline block groove and adjust the position of the leg so that it is perpendicular to the floor with the adjustable foot about 12.7 mm (1/2 in.) from the floor.

6 Tighten all hardware.

7 Install the safety cap.

Figure 2-4 Adjusting leg position
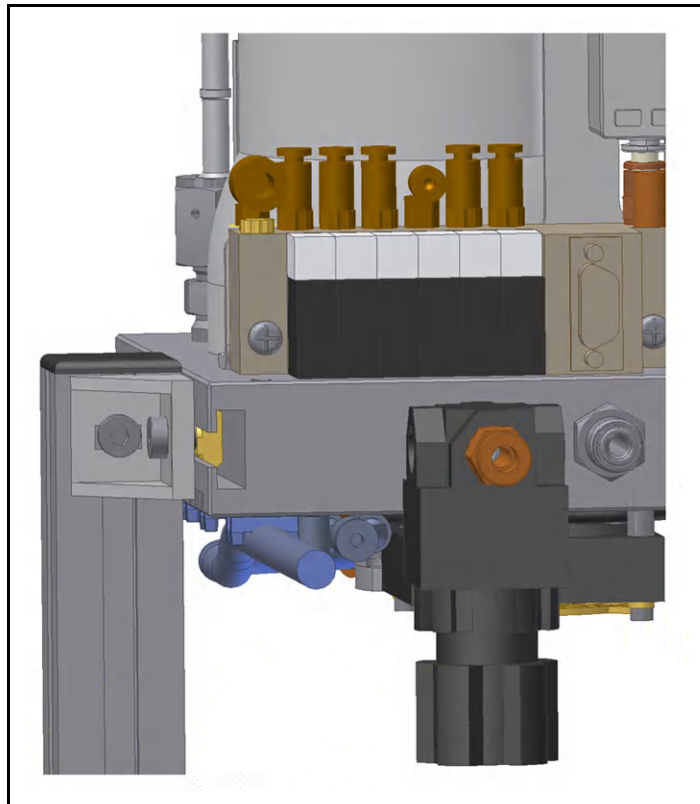
8 Unscrew the adjustable foot until it supports Transpector CPM and relieve pressure from the flange.

9 Tighten the lock nut on the adjustable foot against the support leg.

2.4.2 Atmospheric Support Frame

Atmospheric Transpector CPMsystems do not need the standard support legs. An atmospheric system is mounted to a support frame, which also houses the CPM controller. (See Figure 2-5.)

Figure 2-5 CPM configured with support frame for atmospheric sampling
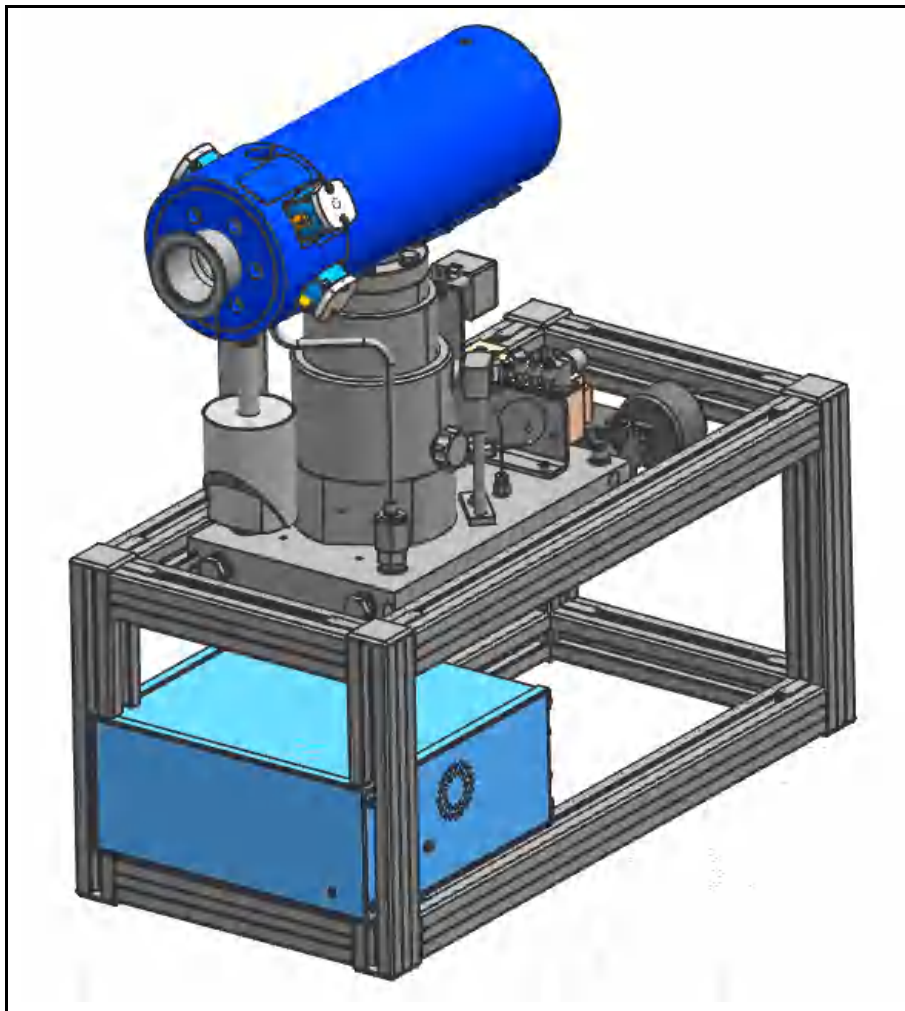
2.5 CPM Controller Installation

The CPM controller is standard 1/2 rack, 2U height rack mountable. The CPM controller is provided with feet and can sit on the floor or table.

Cable connections on the CPM controller are:

◆ Cable bundle that includes the CPM interface cable (connects to the cable box on the back of the Transpector electronics module), heater cable, and ground strap

◆ Foreline pump power cable

◆ CPM Controller power cable

The back panel of the CPM controller is shown in Figure 2-6. Connections are shown in Figure 2-8.

Figure 2-6 CPM controller rear panel
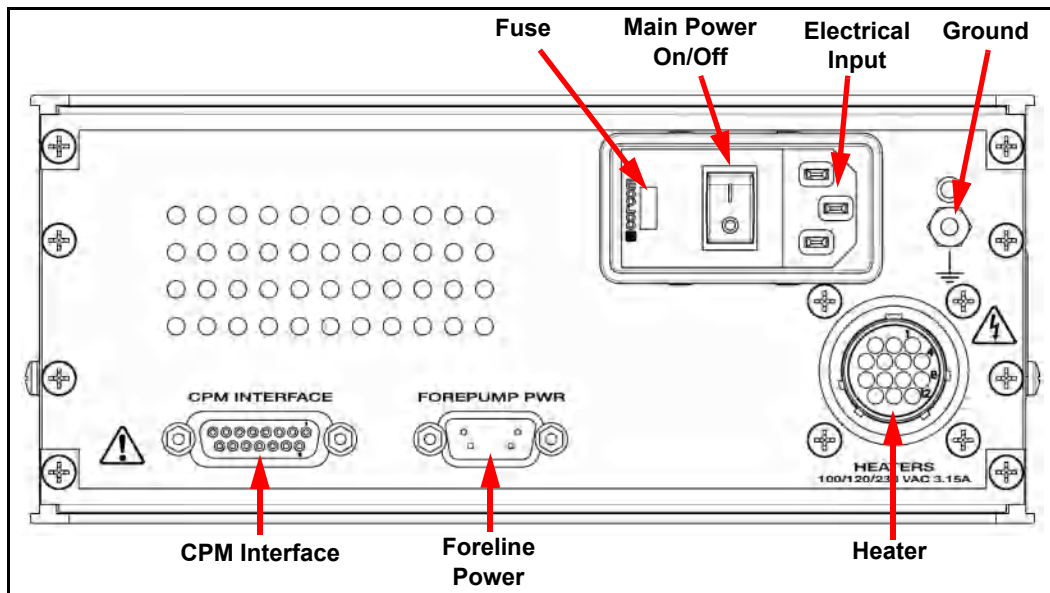
2.6 Transpector Cable Box Connections

The cable box mounted on the back of the Transpector electronics module makes cable connections to most of the subcomponents of the CPM System. (See Figure 2-7. Cable connections for the entire CPM system are shown in Figure 2-8.)

◆ Short Ethernet cable with port (600-1485-P1) attaches to the supplied RJ45, Cat5e Ethernet cable, which then connects to the control computer. For networking information, see Chapter 3, Connecting Transpector CPM.

◆ Aux I/O cable (600-1486-P1) is available for User I/O. See section 4.3.1.1 on page 4-3 for additional information about Aux I/O.

◆ Turbo pump cable (600-1475-P1) connects to the turbo pump controller.

◆ Pirani cable (600-1474-P1) connects to the foreline Pirani gauge.

◆ Solenoid cable (600-1476-P1) connects to the solenoid valve block as well as the digital pressure switch.

◆ CDG cable (600-1473-P1) connects to the CDG gauge.

◆ CPM cable (600-1472-P1) connects to the CPM interface cable in the cable bundle from the CPM controller.

Figure 2-7 Cable box and cables
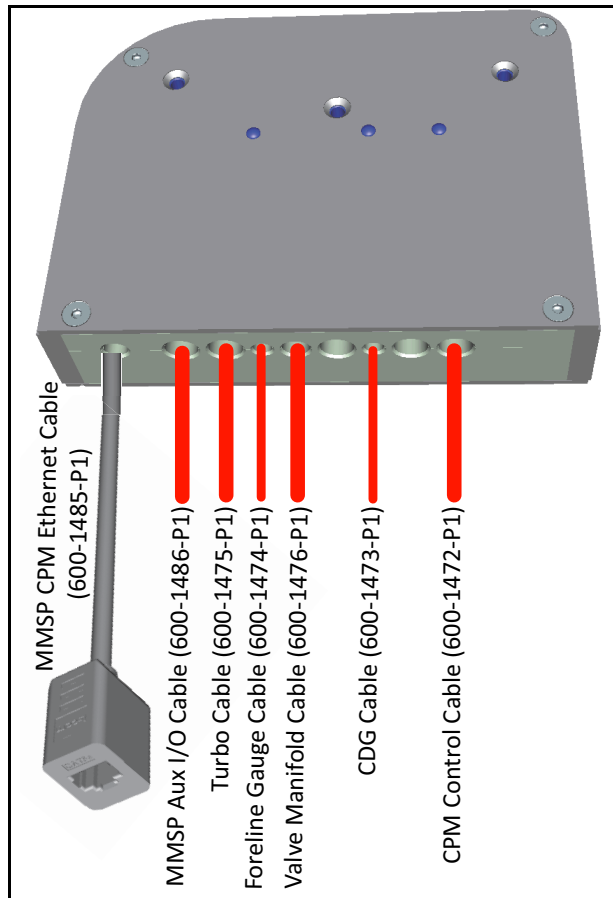
Figure 2-8 CPM cable connections
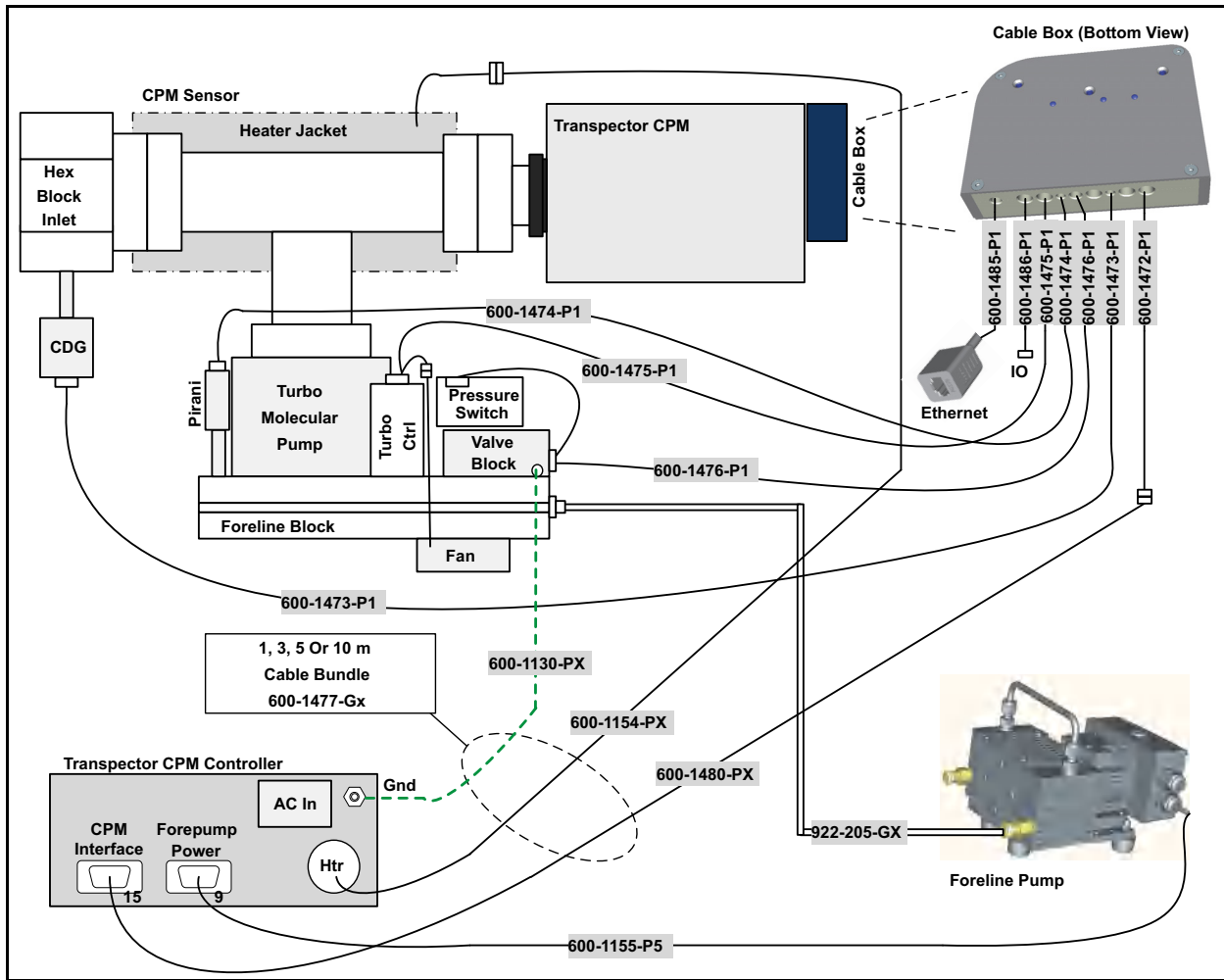
2.7 CPM Foreline Pump Installation

The 24 V (dc) dry Foreline Pump has the following connections:

◆ Electrical connection to the CPM controller

◆ Foreline hose connection from the UHV Turbo Molecular Pump foreline block

◆ Exhaust port connection—required for corrosive or toxic gas sampling. Refer to appropriate standards such as SEMI S6-0707E for exhaust gas guidelines.

⚠ **WARNING**

Proper exhaust connections must be installed when sampling toxic, corrosive or any hazardous gases to protect the environment from lethal levels of gas.

⚠ **CAUTION**

If a customer-supplied foreline pump is used, it must provide a continuous pressure below 10 Torr.

Figure 2-9 Two-stage foreline pump components
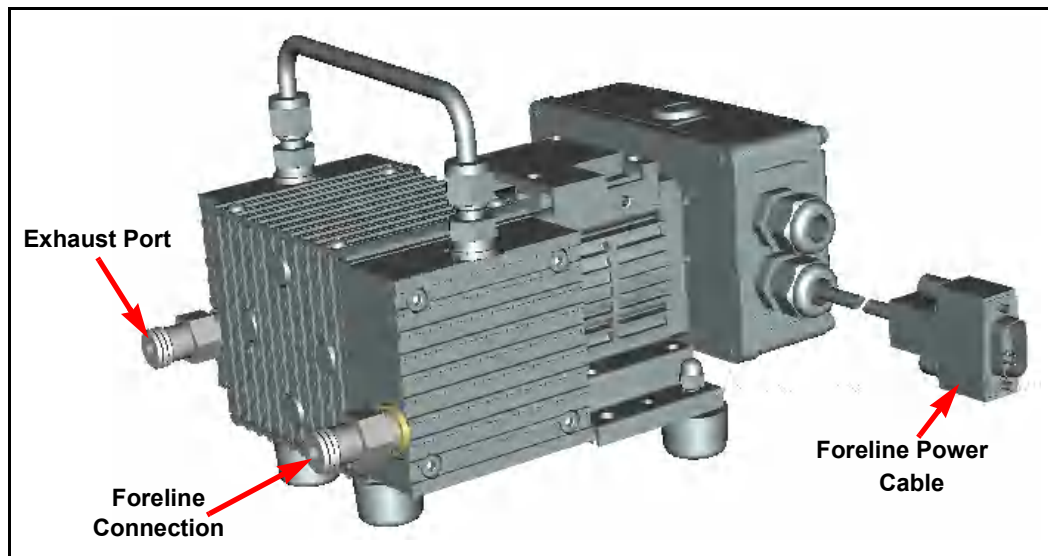
2.8 Software Installation

Refer to the FabGuard Explorer Operating Manual for information regarding software installation.

Chapter 3
Connecting Transpector CPM

3.1 Introduction

Transpector CPM communicates via Ethernet. Devices on an Ethernet network have two identifying addresses: an IP address and a MAC address.

- IP addresses are assigned to identify individual devices on a network. Each device on an Ethernet network must have a unique IP address.
  IP addresses can be reassigned to other devices on the network as long as each device has a unique IP address.

- MAC addresses are unique for each device. MAC addresses are never duplicated.

3.2 General Networking Information
3.2.1 IP Addresses

IP addresses can be either static or dynamic.

- Static (manual) IP addresses are set by the user and are changeable by the user. Static IP addresses are preferred.

- Dynamic (automatic) IP addresses are automatically set by a host or by a server on a network. Dynamic IP addresses can be set through Dynamic Host Communication Protocol (DHCP).

NOTE: When using Static IP addresses on a large network (e.g., on a company network), a block of addresses should be reserved for static IP address use and prohibited from being assigned by the DHCP server (host). This will avoid duplicate IP address conflicts.

> ⚠️ **CAUTION**
>
> **Use static IP addresses with Transpector CPM. Using DHCP, the host server may generate a new IP address if Transpector CPM is taken offline and then returned online or if there is an IP address conflict on the network.**
>
> **If the Transpector CPM IP address is randomly changed during data acquisition, FabGuard will not reconnect to the new sensor IP address, which will result in a loss of communication and loss of data.**

Transpector CPM follows the IPv4 IP address convention. An example IP address is `192.168.1.100`. Each of the four parts is referred to as an "octet". The IP address consists of a Network Prefix and a Host Protocol.

3.2.2 Subnetworking

An IP network can be split into multiple subnets. Subnetting sets a region of the IP address as a Network Prefix for all IP addresses inside the subnet through a subnet mask. The subnet mask determines which octets of the IP address are used as the network prefix. (See Table 3-1.)

In order for two network devices to communicate, they must be on the same subnet, be connected to the same internet network and have the same network prefix.

NOTE: If two devices have different network prefixes, the two devices are on different subnets.

Table 3-1 Subnetting

	Example 1	**Example 2**	**Example 3**
IP address	192.168.1.104	192.168.1.105	192.168.1.150
Subnet mask	255.255.255.0	255.255.0.0	255.255.255.192
Network prefix	192.168.1.0	192.168.0.0	192.168.1.128
Host Protocol	0.0.0.104	0.0.1.105	0.0.0.22

3.3 Transpector CPM IP Address

The default Transpector CPM IP address is `192.168.1.100` with a subnet mask of `255.255.0.0`.

NOTE: When connecting to an existing local network, there must be a static IP address for each Transpector RGA. Contact the network administrator for IP address assignments.

Two methods of changing the Transpector CPM IP address are available.

◆ INFICON Mass Spectrometer Search Utility. (See section 3.3.1.)

◆ Transpector Web UI. (See section 3.3.1.2 on page 3-5.)

3.3.1 Using the INFICON Mass Spectrometer Search Utility to Change the Transpector CPM IP Address

The INFICON Mass Spectrometer Search Utility (IMSSU) is located on the software installation disk and the RGA Manuals CD. The IMSSU does not need to be installed. Double-click **INFICONMassSpecSearch.exe**. The IMSSU will display. (See Figure 3-1.)

Figure 3-1 INFICON mass spectrometer search utility
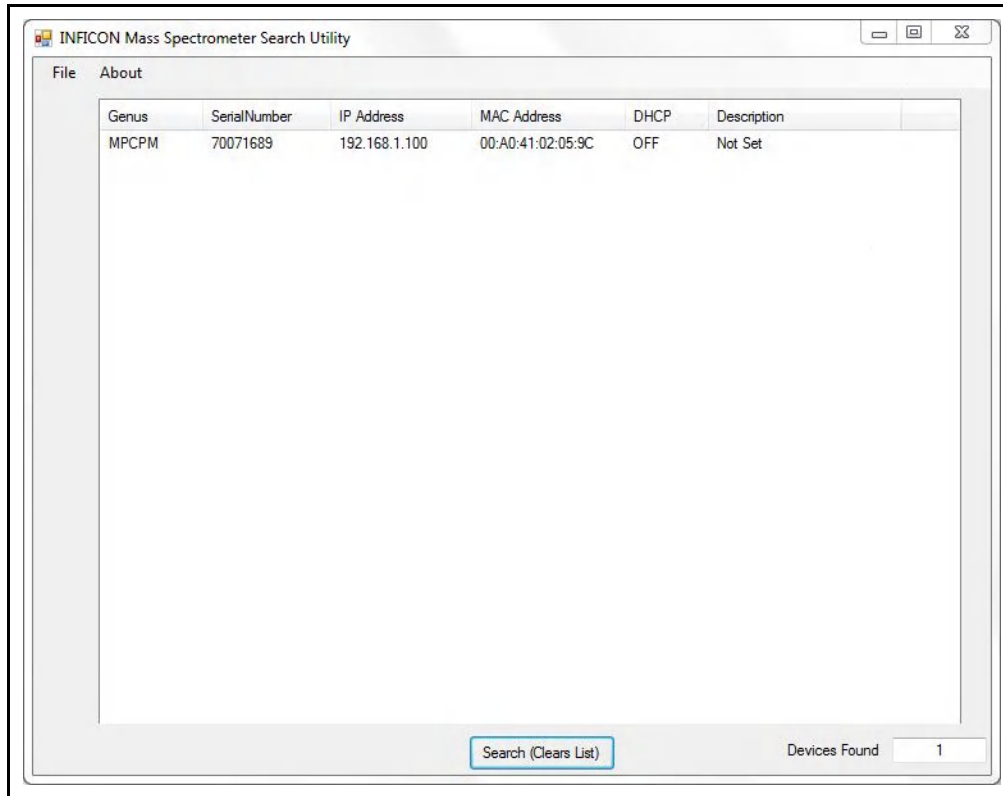
The IMSSU detects every Transpector RGA installed on the network regardless of IP address. The IMSSU will run automatically, or it can be manually started by clicking **Search (Clears List)**. The display shows:

- Genus (MPCPM for Transpector CPM sensors)
- Serial Number
- Current IP address
- MAC address
- DHCP status (On or Off)
- Description (user editable)

Right-click on a sensor to display the menu shown in Figure 3-2.

Figure 3-2 IMSSU right-click menu
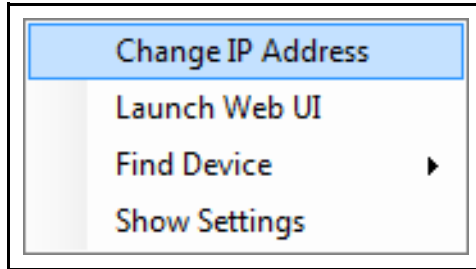
3.3.1.1 Change IP Address

1 Right-click on the sensor and select **Change IP Address**. The **TCP/IP Properties** window will display. (See Figure 3-3.)

Figure 3-3 TCP/IP Properties window
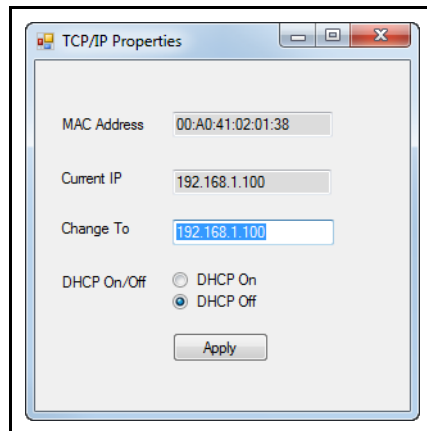
The **TCP/IP Properties** window displays the:

 ◆ Transpector CPM MAC Address

 ◆ Transpector CPM IP address

 ◆ **Change To** text box, to enter a new Transpector CPM IP address

 ◆ **DHCP On** or **DHCP Off** selection

⚠️ **CAUTION**

Set DHCP Off so the IP address cannot be automatically assigned.

2 Type the new IP address in the **Change To** text box.

3 Click **Apply**. Transpector CPM will automatically reboot and will return online with the new IP address.

4 Launch Web UI.

3.3.1.2 Launch Web UI

Transpector Web UI can be launched from inside of the IMSSU. (Refer to the 074-581-P1 Transpector Web UI Operating Manual.)

3.3.1.3 Find Device

Find Device On will flash the power indicator on the device. The indicator will flash for up to 60 seconds and then illuminate.

Find Device Off selected within 60 seconds after selecting **Find Device On** will stop the search.

3.3.1.4 Show Settings

Click **Show Settings** to display multiple settings useful for troubleshooting.
The display shows:

- Serial Number
- Gateway
- IP Address
- DHCP Status
- MAC Address
- Description
- Subnet Mask
- Name
- Description
- Structure Version
- Name
- Box Type
- Port
- Firmware Version
- TCP/IP Source

3.4 Connecting Transpector CPM

Before connecting Transpector CPM, decide:

◆ Is Transpector CPM going to be on:

   ◆ a private network (installed directly on either a computer or a router that is not hooked up to the internet), or

   ◆ an internal network where multiple computers are connected with access to the internet?

◆ Is more than one Transpector CPM sensor being installed at the same time?

3.4.1 Connecting a Single Transpector CPM

3.4.1.1 Single Transpector CPM Direct Connection Installation

When installing a single Transpector CPM on a private network or directly connected to a computer, changing the IP address of Transpector CPM is necessary only if the computer being used to connect to Transpector CPM has a different network prefix than Transpector CPM.

The network prefix of Transpector CPM is `192.168.x.x`. The IP address of the host computer used to control Transpector CPM must have a subnet mask of `255.255.0.0` and a network prefix of `192.168.x.x`.

If this is not the case, change the computer IP address to match the network prefix of Transpector CPM. For example, giving the computer an IP address of `192.168.1.101` will allow Transpector CPM to communicate directly with the computer. (See section 3.5, Changing the Computer IP Address, on page 3-8.)

3.4.1.2 Installing a Single Transpector CPM on an Existing Local Network

When installing a single Transpector CPM on an existing local network, the default IP address of Transpector CPM may not be compatible with the network.

Transpector CPM can have either a Static IP address (*recommended*) or a Dynamic IP address set by DHCP (*not recommended*).

Contact the network administrator for information regarding valid IP addresses and ask the administrator to assign an IP address for Transpector CPM. (Refer to section 3.3.1, Using the INFICON Mass Spectrometer Search Utility to Change the Transpector CPM IP Address, on page 3-3.)

3.4.2 *Installing Multiple Transpector CPM Sensors*

Each Transpector CPM is shipped with an identical default IP address. When installing multiple Transpector CPM, the IP address of each Transpector CPM must be changed one at a time so that each Transpector CPM has a unique IP address. (Refer to section 3.3.1, Using the INFICON Mass Spectrometer Search Utility to Change the Transpector CPM IP Address, on page 3-3.)

⚠️ **CAUTION**

> **Do not connect multiple Transpector CPM to a network without first changing the IP addresses. Otherwise, there will be IP address conflicts on the network.**

3.4.2.1 *Installing Multiple Transpector CPM Directly to a Host Computer*

A private local network must be created when multiple Transpector CPM sensors are connected to a single host computer instead of an existing local area network. Transpector CPM must be installed on either a router or Ethernet switch. The router or switch is connected to the host computer through the LAN port of the router/switch.

3.4.2.2 *Installing Multiple Transpector CPM on an Existing Local Network*

Use an Ethernet switch instead of a router when multiple Transpector CPM sensors are connected to an existing local network.

⚠️ **CAUTION**

> **Routers can cause conflicts with local networks because the router will attempt to set IP addresses for all network connected devices.**

Since Transpector CPM sensors are network connected devices, each sensor must have an IP address assigned to it by a network administrator. After changing each IP address manually, connect all of the sensors to the Ethernet switch and connect the switch to the local network.

3.5 Changing the Computer IP Address

An alternative to changing the Transpector CPM IP address is to change the host computer's IP address to allow for communication between the host computer and Transpector CPM.

3.5.1 Windows 7

NOTE: Changing the IP address of the host computer requires administrator rights.

1 Click **Start**, then click **Control Panel**. (See Figure 3-4.)

Figure 3-4 Start menu
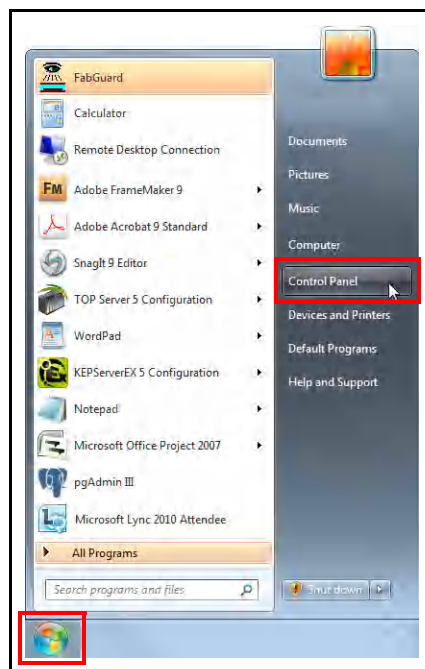
2 In the **Network and Internet** group. click **View network status and tasks**. (See Figure 3-5.)

Figure 3-5 View network status and tasks
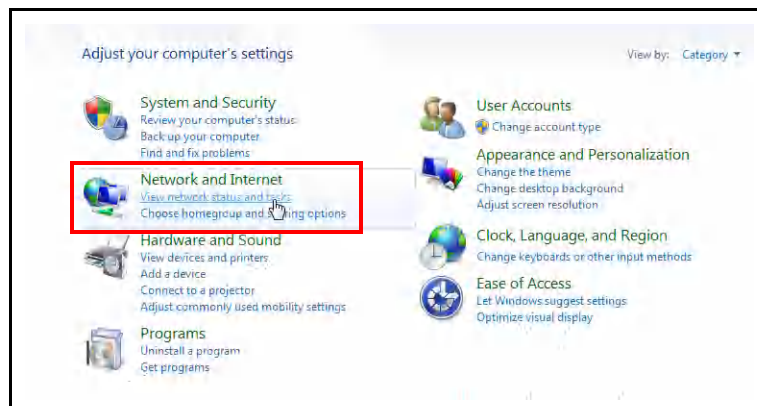
3 On the network status and tasks window, click **Change adapter settings**. (See Figure 3-6.)

Figure 3-6 Change adapter settings
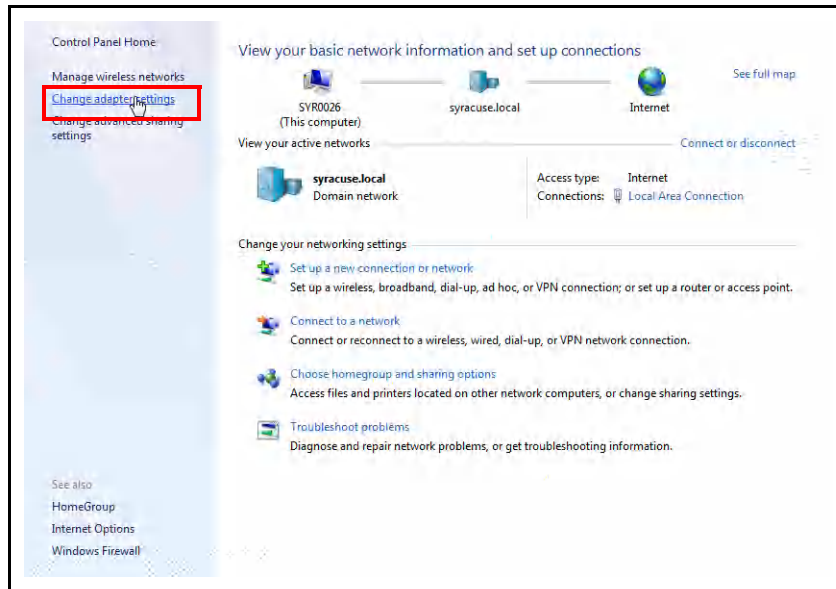
4 If the host computer is connected directly to Transpector CPM through the Ethernet port of the computer, right-click **Local Area Connection** and select **Properties**. (See Figure 3-7.)

Figure 3-7 Changing adapter settings
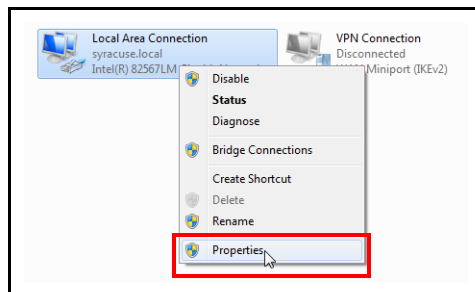
5 Click **Internet Protocol Version 4 (TCP/IPv4)**.

6 Click **Properties**. (See Figure 3-8.)

Figure 3-8 TCP/IPv4
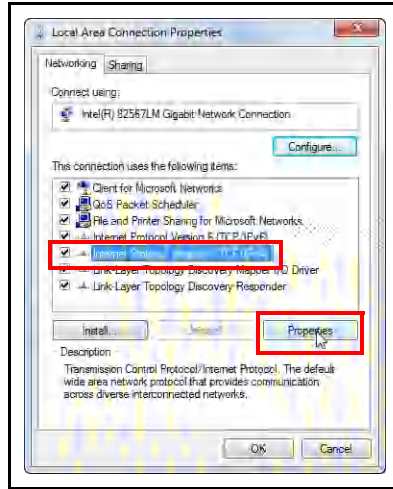
7 On the TCP/IPv4 properties window, click **Use the following IP address**. (See Figure 3-9.)

Figure 3-9 Use the following IP address
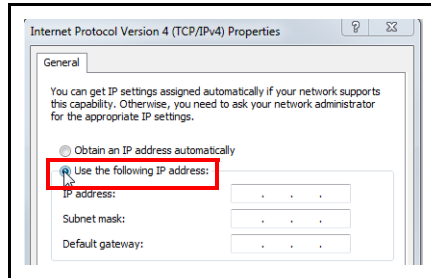
8 In **IP address**, type `192.168.1.xxx`. The last octet can be any number as long as it is unique to the network and is not the same as the Transpector CPM IP address. (See Figure 3-10.)

9 In **Subnet mask**, type `255.255.0.0`.

10 Click **OK**.

Figure 3-10 Changing the computer IP address
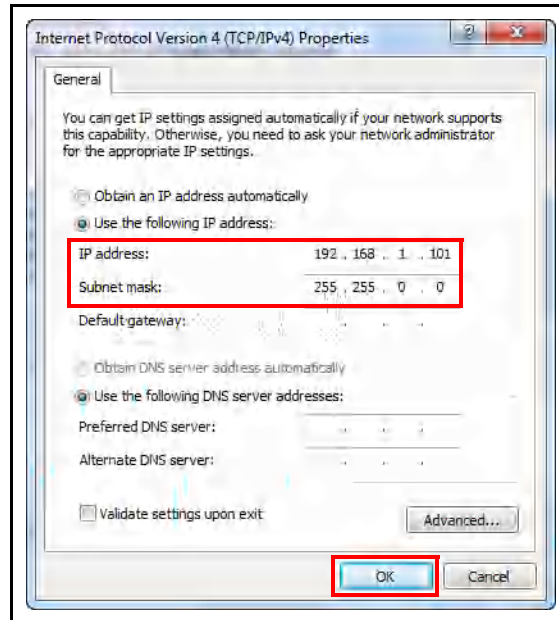
11 The IP address will now be set to the manual IP address chosen in step 7.

12 Exit all menus.

13 Connect to Transpector CPM.

14 To change the IP address back to its default settings, follow steps 1 through 6 and reset the properties to their original settings.

Chapter 4
How the CPM System Works

4.1 CPM Components

A fully configured CPM corrosive pumping system is illustrated in Figure 4-1. (The CPM controller and foreline diaphragm pump are not shown.)

Figure 4-1 CPM pumping system components

1	Process Pressure Gauge
2	Process Connection (CF40, KF40 or KF25)
3	HexBlock™ Inlet
4	Optional Calibration Reference
5	CPM Sensor (inside manifold)
6	Sensor Manifold and Heater
7	CPM Transpector Electronics Module
8	Pressure Switch
9	Valve Solenoids
10	Nitrogen Regulator (for nitrogen purge and valve operation)
11	Integrated Foreline Block
12	UHV Turbo Molecular Pump
13	Foreline Pirani Gauge
14	Bypass Connection for High Pressure Applications

4.2 Theory of Operation

Many gas analysis applications involving pressures too high for direct exposure to the quadrupole sensor (pressures greater than 1.0E-4 Torr/mbar) require a pressure converter to reduce the pressure and keep the sensor at high vacuum. With a pressure converter, a quadrupole sensor may be used for high pressure applications such as sputtering, Chemical Vapor Deposition (CVD), etch, vacuum furnace analysis, and laser gas analysis.

Transpector CPM pressure is the pressure inside the closed ion source (CIS). The nominal operating pressure inside the closed ion source is approximately 2E-4 Torr. Since the conductance between the closed source and the sensor manifold is 0.7 L/s and given the effective pumping achieved using the turbo molecular pump attached to this manifold, the pressure in the mass analyzer region is approximately 23 times lower than in the closed source. Thus, with the source at ~2E-4 Torr, the pressure in the manifold is approximately 1.0E-5 Torr.

Pressure converters use orifices and/or capillaries to reduce the partial pressure of the gas-mixture, typically by a fixed proportion, with minimum mass discrimination. An orifice, a small disk with a defined hole, acts as a conductance limitation. When both the volume and the high vacuum pump speed are constant, the orifice hole size determines the pressure at the sensor. Orifices are available in various sizes to cover various pressure ranges.

⚠️ **CAUTION**

FabGuard Explorer and FabGuard display total pressure inside the closed ion source.

Optimum performance is obtained when the total pressure display reads ~2x10^{-4} Torr measured in low energy mode (40 eV, 200 μA).

Operation in high energy mode (70eV, 2000 μA) will give an inaccurate total pressure reading.

4.3 Instrument Overview
4.3.1 Input/Output (Aux I/O)

This section describes the available input and output (I/O) for Transpector CPM. See for a pinout diagram.

Transpector CPM has two digital inputs for manual emission control, one digital relay output for emission status, and one analog input.

4.3.1.1 CPM Aux I/O Connector

User I/O is through a 15 pin DSUB connector on the cable box attached to the back of the Transpector electronics module. (See Figure 2-8 on page 2-10.)

A mating DB15 Male connector is supplied in the ship kit for connecting to the Transpector CPM Aux I/O connections.

4.3.1.2 Two Digital Inputs

Logic Inputs 1 and 2 are by default set to remotely control emission status. (See Table 4-1.)

◆ Connecting Pin 14 (Logic Input 1) to Pin 15 (Ground) will turn on the emission.

◆ Connecting Pin 13 (Logic Input 2) to Pin 15 (Ground) will turn off the emission.

Table 4-1 Digital inputs

Emission ON	PIN 14
Emission OFF	PIN 13
Ground	PIN 15

⚠️ **CAUTION**

Controlling emission through digital inputs bypasses all software and hardware interlocks. When using digital inputs for controlling Transpector CPM emission, develop an interlock that will not allow the emission to turn on if the pressure is too high for operation of Transpector CPM.

4.3.1.3 One Status Relay Output

One status relay output is active (closed) when the emission is on. See Table 4-2.

Table 4-2 Status relay output

EMISSION ON	Relay closed. PIN 2 and PIN 1 connected
EMISSION OFF	Relay open
CONTACT RATING	24 V (dc) at 0.5 A

NOTE: The status relay is not available when HPR or calibration reference options are selected.

4.3.1.4 One Analog Input

One analog input is differential and can handle inputs between 0 to +10 volts and common mode voltages of 100 volts. See Table 4-3.

Table 4-3 2 analog inputs

ANALOG INPUT 1	(+)	PIN 9
ANALOG INPUT 1	(-)	PIN 10

NOTE: The analog input is supported through FabGuard software.

Figure 4-2 CPM Aux I/O pinout diagram


```
PIN 1   RELAY COMMON
PIN 2   RELAY NORMALLY OPEN
PIN 3   RELAY NORMALLY CLOSED
PIN 4   RESERVED
PIN 5   RESERVED
PIN 6   RESERVED
PIN 7   +24V AUX RET
PIN 8   +24V AUX VS
PIN 9   ANALOG IN+
PIN 10  ANALOG IN-
PIN 11  RESERVED
PIN 12  RESERVED
PIN 13  REMOTE LOGIC 2  ( EMISSION OFF)
PIN 14  REMOTE LOGIC 1  ( EMISSION ON)
PIN 15  GROUND
```
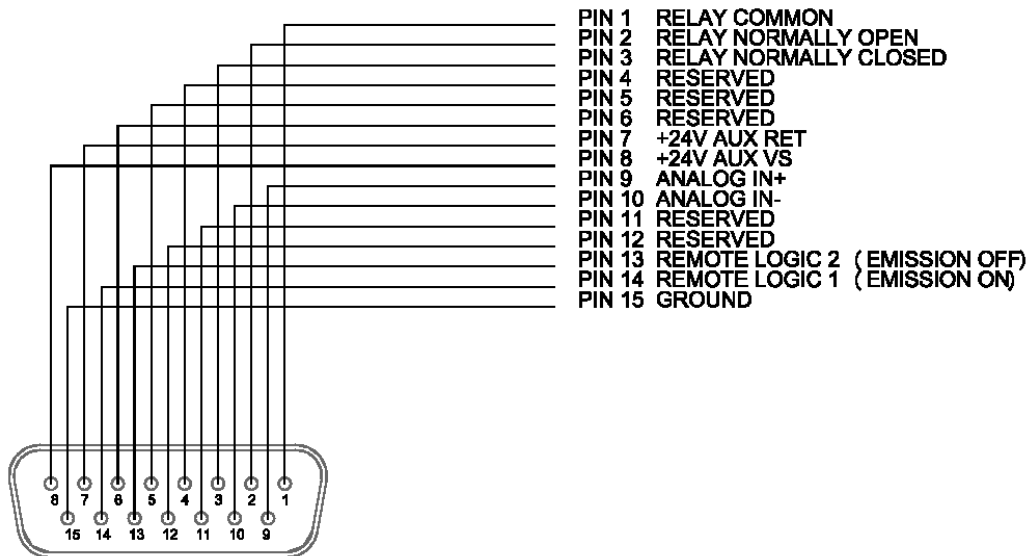
4.3.2 Ultra-High Vacuum System

The vacuum system provides low pressure to:

◆   establish a sample flow from the process by pressure difference.

◆   provide low pressure for optimum operation of the sensor.

A dry pumping system comprised of a Turbo Molecular Pump and Foreline Pump is used to minimize hydrocarbons in the residual gas background.

The Turbo Molecular Pump provides a high compression ratio between the high vacuum side and the Foreline Pump side for all gases, including hydrogen. Hydrogen is the major residual gas component in ultra-high vacuum. The high compression ratio for hydrogen is important for producing a low base pressure.

4.3.2.1 Foreline Subsystem

The foreline subsystem components include a flexible foreline hose of various lengths (≤10 m), a foreline Pirani gauge, and a diaphragm foreline pump.

The Foreline Pump produces base pressures (no gas flow) of 2 Torr, significantly less than the 10 Torr needed for the Turbo Molecular Pump operation. The 2 Torr operating pressure for the foreline is in the viscous gas flow regime such that the foreline does not require a large diameter. The inside diameter of the foreline is 6 mm (1/4 in.) which produces a 2 Torr pressure drop across a 10 m length of foreline at 20 sccm of gas flow.

The foreline Pirani gauge can be used to troubleshoot pumping system problems and to verify that the turbo pump is being backed properly.

4.3.3 Heater(s) Subsystem

The heaters are dual temperature (150°C and 90°C), dual element silicone rubber pad heaters with silicone rubber foam insulation.

The CPM controller supplies power to the heaters.

Heaters are software controlled at low temperature (90°C) or high temperature (150°C).

⚠ WARNING - High Temperature

During or immediately after bakeout, the heating jacket and metal surfaces in the vicinity of the heating jacket are hot. These surfaces exceed 100°C at the maximum ambient operating temperature (50°C), and will cause burns if touched.

4.3.4 CPM Controller Subsystem

The CPM controller contains all of the AC components, the AC-DC converter which supplies the +24 V (dc) for the Transpector, the Foreline Pump, the Turbo Molecular Pump controller, and valve solenoids.

The AC-DC converter accepts input voltages ranging 90-240V (ac). The output is 24 V (dc) @ 12A. The output is supplied through the CPM controller interface cable to the Transpector electronics.

The heater drive circuit controls the AC voltage to the heaters. The heaters are interlocked and will not turn on if the pump is not up to speed or if there are any faults.

4.3.5 Solenoid Valves

The solenoid-controlled valves are a group of valves joined together as one manifold assembly which is mounted to a bracket on the Turbo Molecular Pump foreline block. The valves are controlled either by the CPM controller rocker switches or the Valves Aux I/O connector.

When solenoid valves are activated, compressed air from the input air supply (ranging 58–100 psi (gauge) (4–6.9 bar) [400–690 kPa]) will open the appropriate valve. The recommended setting is 75-80 psi (gauge) (5.17 to 5.52 bar) [517 kPa to 552 kPa]. All valves are electropneumatically operated. There are six solenoid valves: (See Figure 4-3.)

V0—Foreline isolation valve and nitrogen purge valve on corrosive systems. Automatically opened and closed by the start/stop of the pumping system.

V1—Low pressure orifice valve for the HexBlock or the capillary sampling option. Configured depending on the application. Typically used for background monitoring.

V2—High pressure orifice valve for the HexBlock or the capillary sampling option. Typically used for process pressure sampling. User configured depending on the application.

V3—High conductance valve (1 mT maximum nominal pressure)

V4—Bypass valve used in conjunction with the high pressure bypass option or the capillary sampling option

V5—Calibration reference

For more details about the function of each valve, see section 6.1.1 on page 6-2.

NOTE: Each solenoid has a red indicator that illuminates when the solenoid is activated.

Figure 4-3 Solenoid valve block
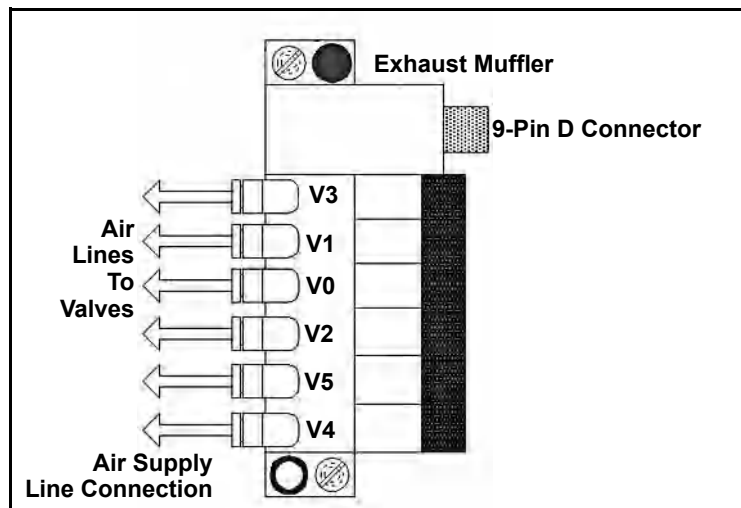
4.3.6 Sensor and Transpector Electronics Module Subsystem

The sensor is a quadrupole partial pressure analyzer that analyzes gases by:

1 Ionizing some of the gas molecules.

2 Separating the ions by mass.

3 Measuring the quantity of ions at each mass.

The masses, unique for each substance, allow the identification of the gas molecules from which the ions were created. The magnitudes of these signals are used to determine the partial pressures (i.e., amounts) of the respective gases.

The Transpector electronics module mounts to the sensor and provides all of the requirements for operating the sensor, making the appropriate ion current measurements, communicating to a computer, and sending the resulting output to the computer.

The Transpector electronics module cable box contains all the cable connections to the various components of the CPM pumping system, including turbo pump, gauges and solenoid valves. See Figure 2-8 on page 2-10 for a schematic of cable connections.

4.4 Application

The pumping system reduces the pressure of process gas to a pressure at the ion source which optimizes partial pressure measurements. The pressure reduction orifices produce 2×10^{-4} Torr pressure in the closed ion source (CIS). The flow rate of gas that produces this pressure is:

$$Q(\text{T-L/s}) = P_{CIS}\, S_{CIS}$$

$$= 2\times10^{-4}\,(\text{Torr}) \times 0.7\,(\text{L/s})$$

$$= 1.4\times10^{-4}\,(\text{T-L/s})$$

P_{CIS} = the pressure at the CIS ion source within the CPM tee region
S_{CIS} = the pumping speed of the closed ion source
Q = throughput of the CIS ion source

This flow rate produced by process gas flowing through the process gas orifice is:

$$Q(\text{T-L/s}) = (P_{Process} - P_{CIS})\times C_{Process\ Orifice} \sim 1.4\times10^{-4}\,(\text{T-L/s})$$

where the conductance $C_{Process\ Orifice}$ determines the orifice diameters needed to produce this flow for each process pressure.

A selection of orifice diameters are available for reducing pressure for a multi-decade range of (maximum) process pressures ranging 0.001–100 Torr. For example, a 10 Torr orifice has a 20 micron diameter hole to produce approximately 2×10^{-4} Torr at the CIS when the process has 10 Torr of nitrogen. Since process pressures can vary within the operating range of the process, different pressure reductions may be needed. The CPM system has a variety of inlet orifices that allow pressure range sampling which typically covers measurement of the base pressure of the process chamber (for leak detection and base vacuum analysis) with a high conductance port and two orifices for process pressures. Various inlet systems are described with their typical use in section 4.5.

4.5 Sample Inlet Systems and Examples of Use
4.5.1 Inlet System

Figure 4-4 shows the HexBlock inlet.

Figure 4-4 HexBlock inlet

Table 4-4 Inlet system

Hex Block Inlets	Part Number
Hex Block Inlet with one orifice (V1) and high vacuum (V3)	923-604-G11
Hex Block Inlet with one orifice (V2) with high pressure by-pass (V4) and high vacuum (V3)	923-604-G12
Hex Block Inlet with two orifices (V1) and (V2)	923-604-G13
Hex Block Inlet with two orifices (V1) and (V2) with high pressure by-pass (V4)	923-604-G14
Hex Block Inlet with two orifices (V1), (V2), and high vacuum (V3)	923-604-G15
Hex Block Inlet with two orifices (V1), (V2) with high pressure by-pass (V4), and high vacuum (V3)	923-604-G16

When both volume and high vacuum pump speed are constant, the orifice hole size determines the pressure at the sensor. Orifices are available in various sizes to cover several pressure ranges. Table 4-5 and Table 4-6 show different orifices for low and high pressure range application. Figure 4-5 shows pressure ranges for sampling which will assist in choosing the proper orifice for the application.

Table 4-5 Hex block orifices (V1 for low pressure, typically background)

HexBlock Orifices	Part Number
10 mTorr orifice	923-706-G6
15 mTorr orifice	923-706-G8
100 mTorr orifice	923-706-G5
360 mTorr orifice	923-706-G7
1 Torr orifice	923-706-G4
3 Torr orifice	923-706-G9
10 Torr orifice	923-706-G3

Table 4-6 Hex Block orifices, sniffers and capillaries
(V2 for high pressure, typically process pressure)

Size of Orifices, Sniffers and Capillaries	Part Number
10 mTorr orifice	923-706-G6
15 mTorr orifice	923-706-G8
100 mTorr orifice	923-706-G5
360 mTorr orifice	923-706-G7
1 Torr orifice	923-706-G4
3 Torr orifice	923-706-G9
10 Torr orifice	923-706-G3
30 Torr orifice (requires high pressure by-pass)	923-706-G10
7 Torr sniffer (requires high pressure by-pass, 30.5 cm length)	923-707-G3
10 Torr sniffer (requires high pressure by-pass, 5 cm length)	923-707-G1
100 Torr sniffer (requires high pressure by-pass, 5 cm length)	923-707-G2

Table 4-6 Hex Block orifices, sniffers and capillaries
(V2 for high pressure, typically process pressure)

Size of Orifices, Sniffers and Capillaries	Part Number
30 Torr sniffer (requires high pressure by-pass, 10 cm length)	923-707-G4
300 Torr sniffer (requires high pressure by-pass, 5 cm length)	923-707-G5
30 Torr sniffer (requires high pressure by-pass, 30.5 cm length)	923-707-G6
10 Torr sniffer (requires high pressure by-pass, 30.5 cm length)	923-707-G7

Figure 4-5 Pressure Ranges for Sampling for CPM Inlet Orifices and Sniffers
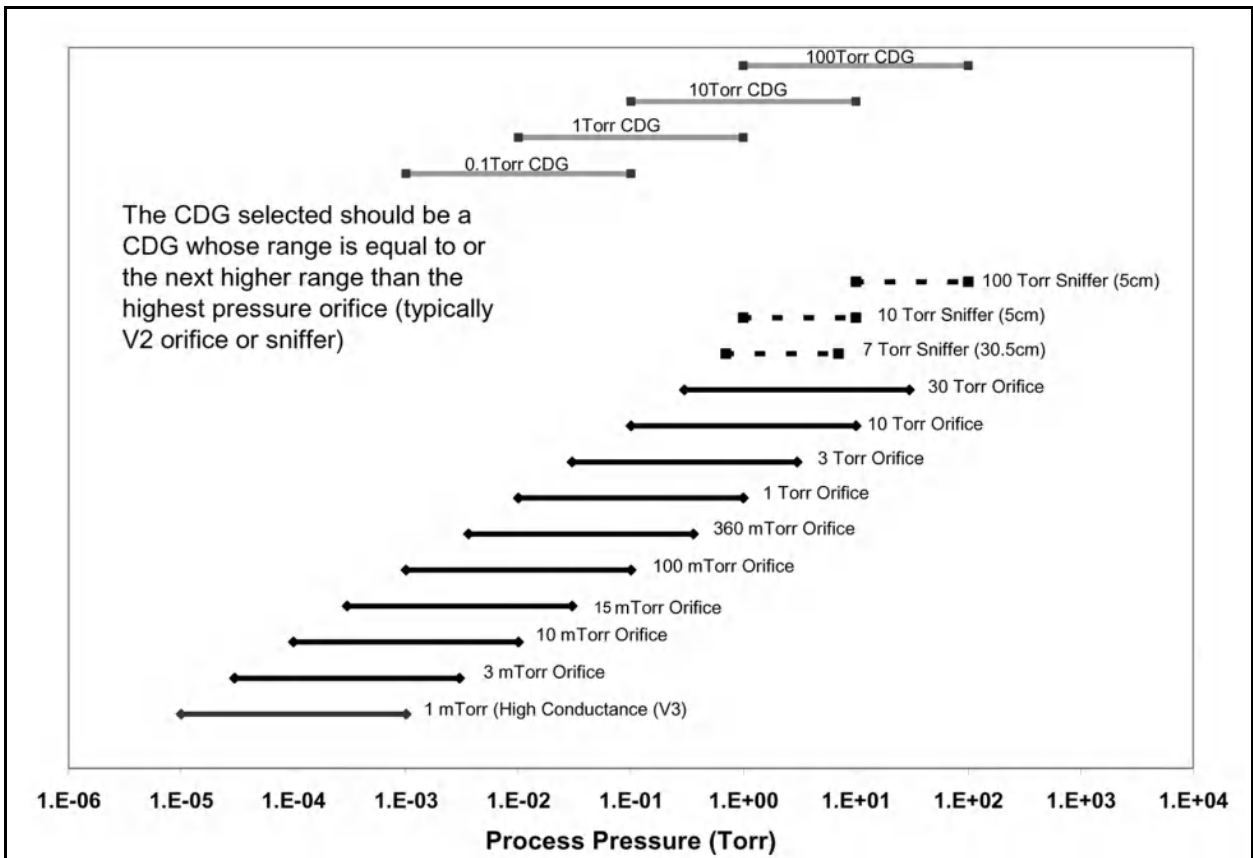
4.5.2 High Pressure Sampling: Orifice Bypass (V4)

When process pressures exceed 10 Torr, the process gas is dense enough that the gas molecules collide with each other more often than with the walls of the sampling system. In this transition or viscous flow regime, the time constant for detecting changes in process gas composition becomes dominated by the time it takes for the gas species that changes in the process to diffuse through the gas matrix and arrive at the sampling orifice. This diffusion time is proportional to the process pressure and the square of the distance from the process to orifice. This sampling method effectively shortens the diffusion distance from process change to the sampling orifice by drawing a small quantity (10 sccm) of the process gas through the sampling valve and bypass valve to the interstage port of the Turbo Molecular Pump. When the process gas flows in this manner, the diffusion distance of the gas is reduced to about 2 cm and the response time for changes in the process gas is significantly reduced.

4.5.3 Dual-Capillary Sampling Option

The Dual-Capillary Sampling option reduces the pressure of a process atmosphere ranging 300–1400 Torr to an intermediate pressure that is <10 Torr at the closed ion source. (See Figure 4-6.) The exit orifice to the pumping line limits the flow to the Turbo Molecular Pump and establishes the interstage pressure. The capillary is inserted through the Swagelok® connection fitting. It is locked in place and sealed by tightening the Swagelok nut with a re-usable ferrule.

Figure 4-6 Dual-Capillary sampling option (shown with calibration reference)
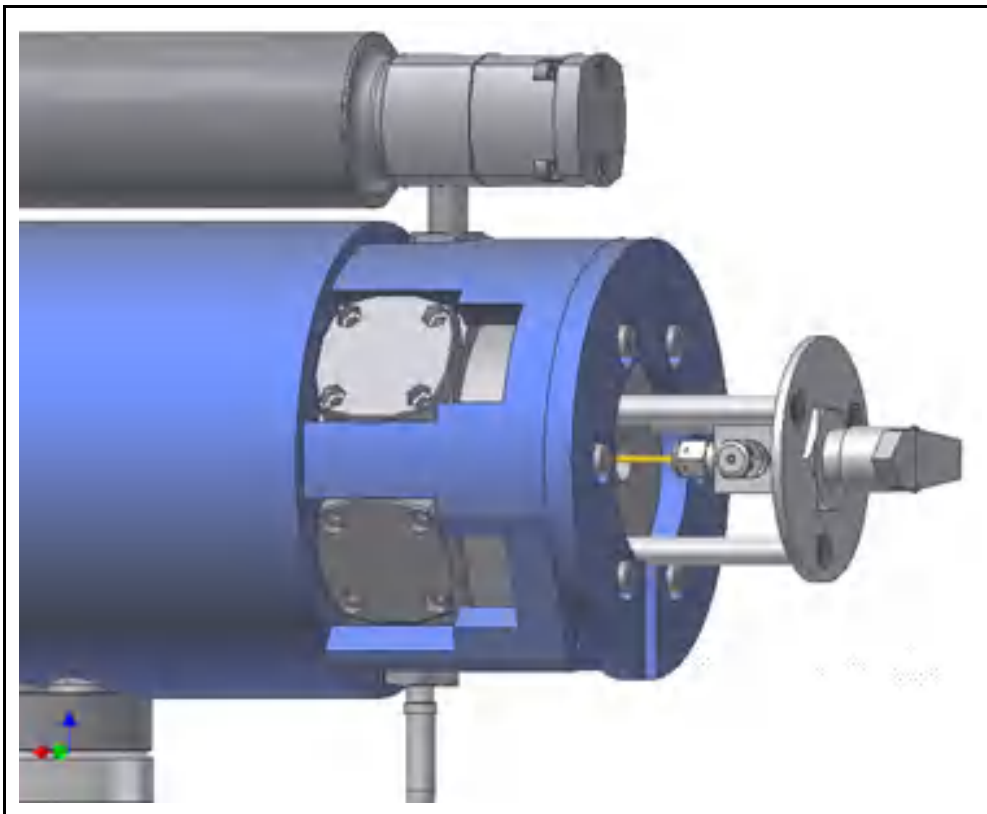
4.6 Advice and Tips

4.6.1 Achieving Good Base Pressure in the CPM

The CPM vacuum manifold must be baked out after initial installation or whenever the RGA sensor is exposed to air. After an eight hour bakeout and cool down, the base pressure must be less than 5E-7 Torr at 40 eV, 200 μA. If not, examine the background mass spectrum to look for the largest peak. If the spectrum is dominated by mass 18, continued bakeout is required to reduce water vapor.

4.6.2 Avoiding Trapped Gas when Sampling Valves are Closed

When V2 is closed, the sampled process pressure is trapped between V2 and O2. This gas will pump out in a few minutes. It is best to keep V2 open until the process pressure is evacuated. Then open V1 to scan the background spectrum of the process vacuum system.

⚠ **CAUTION**

Close the sampling valves when finished with measurements to avoid pressure bursts to the RGA if the process is vented.

NOTE: CPM will turn off emission and the electron multiplier and close all sampling valves when a pressure burst occurs.

Chapter 5
Theory and Application Guide

5.1 Theory of Operation

A Closed Ion Source (CIS) analyzer takes a representative process gas sample and directs it to the ionization region of a Residual Gas Analyzer (RGA). The sampling and flow of the gas sample is accomplished by successive reduction of pressure from the process to the Turbo Molecular Pump through fixed geometry pump-in channels. Transpector CPM detects levels of impurities in process gases that are significantly lower—at sub-ppm levels for many components—than those detected by open-ion source RGA analyzers.

5.2 Sensors

The three main components of the Transpector CPM sensor are:

◆ ion source (ionizer)

◆ quadrupole mass filter

◆ detector/electron multiplier

These components are mounted on an electrical feedthrough flange bolted to the vacuum manifold. (See Figure 5-1.)

The sensor works only in a high-vacuum environment because the ions, once created, must not collide with other gas molecules as they move through the sensor.

Figure 5-1 CPM sensor

Ion Source   Mass Filter   Detector / Electron Multiplier
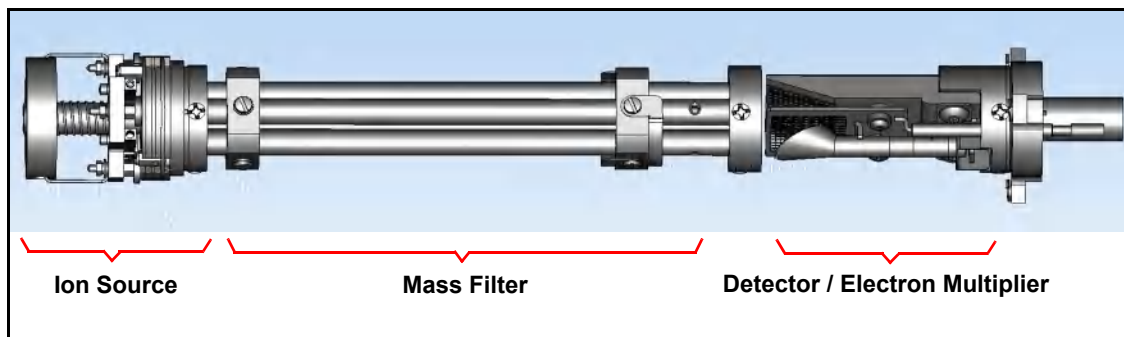
5.2.1 The Ion Source

The Transpector CPM sensor closed ion source requires a pressure reducing orifice because process pressures are typically far greater than the maximum at which the closed ion source can operate. (See Figure 5-2.)

Figure 5-2 Closed ion source

Sealing Disk

Anode Cylinder

Filament Block

Anode Plate

Focus Plates

Filament

Spring

Shield Washer

Insulator Rings

Upper Tube Ring

(Electron Repeller not shown)
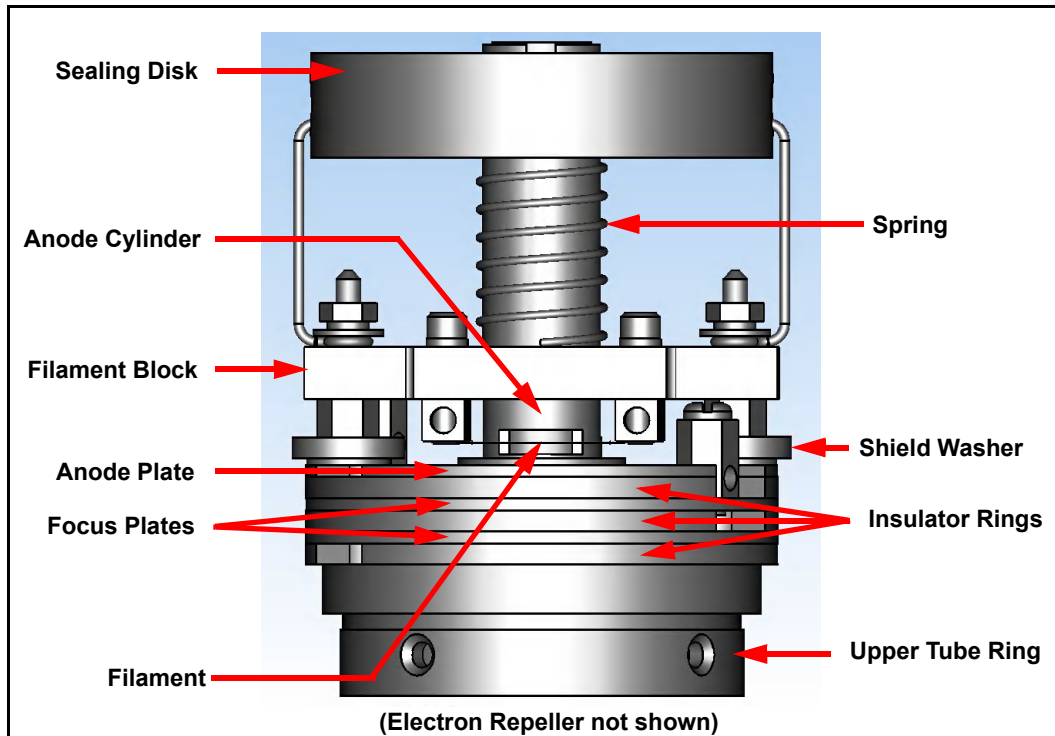
Inside the closed ion source, a heated filament emits electrons which bombard the incoming gas molecules giving them an electrical charge. While this charge may be either positive or negative, Transpector CPM detects only positive ions. Once a molecule is charged (ionized), electric fields can be used to manipulate the molecule.

The default filament is made of tungsten. Tungsten offers the best resistance to aggressive gases, particularly those containing fluorine and chlorine. A yttria coated iridium filament can be used in oxygen or water vapor heavy environments (that will quickly oxidize the tungsten filament).

⚠️ **CAUTION**

Tungsten filaments will be destroyed when operated at high pressure because they react with oxygen and water vapor at operating temperature.

The term *emission current* refers to the stream of electrons emitted by the filament. Emission current is controlled by the temperature of the filament.

The filament is centered over a hole in the anode cylinder. The potential (voltage) on the anode is positive with respect to the filament. The electron repeller, a flat plate, is located behind the filament and is electrically connected to the negative side of the filament. The potential difference between the filament and the anode determines the kinetic energy (*electron energy*) of the emitted electrons. The electron energy determines how gas molecules will ionize when struck by electrons.

Electron energy can range from 70 eV down to 10 eV. Operation below 70 eV is restricted to emission currents of no greater than 200 µA. At 70 eV or above, an emission current of 2 mA will maximize sensitivity for background monitoring and leak checking.

The ions formed within the anode cylinder are pulled away by the potential on the focus lens and formed into an ion beam. (The focus lens is also called an extractor, since it extracts the ions from the region in which they are created.) The focus lens focuses the ion beam into the hole in the source exit lens. To attract positive ions, the focus lens is biased negatively with respect to the anode.

The potential on the source exit lens is negative with respect to the anode and the focus lens. The ion beam passes through the hole in the exit lens and is injected into the mass filter.

The closed ion source pumping speed is approximately 0.7 L/s. This will create a pressure differential between the ion source and the quadrupole region. The closed ion source will operate with a maximum process pressure up to about 2 mTorr (2.7E-3 mbar). This ion source is used with an orifice to reduce the high pressure down to approximately 2E-4 Torr (2.7E-4 mbar). The pressure in the closed ion source will be about 23 times higher than the pressure in the quadrupole (e.g., 2.3E-4 Torr in the ion source will produce 1E-5 Torr in the quadrupole region).

See for more ion source information.

5.2.2 The Quadrupole Mass Filter

The ions produced in the ion source are injected into the mass filter, which rejects all ions except those with a specific mass-to-charge ratio. Most ions contain only one unit of charge. The mass filter is a quadrupole, to which is applied a combination of RF and DC potentials. The RF frequency and amplitude determine the mass. The RF/DC ratio determines the filter selectivity. (See Figure 5-3.)

Figure 5-3 The sensor's quadrupole mass filter
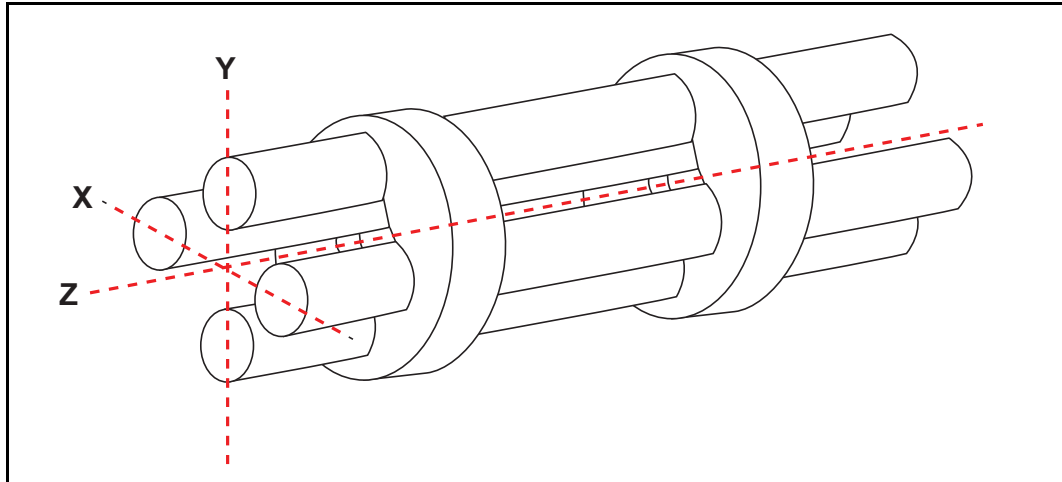
The mass filter's four rods (hence the term *quadrupole*) are alternately charged to direct ions of specific masses down through the center, deflecting all larger and smaller masses (hence the term *mass filter*).

The mass filter consists of four parallel rods, or poles, in a square array. The rods, and the insulators in which they are mounted, form an extremely precise mechanical assembly. The distance between the center of the square array and the closest rod surface is known as the quadrupole radius, r_0. Ideally, the rod should have a hyperbolic shape (towards the center of the assembly) rather than round. If the ratio of the round rod radius to r_0 is equal to 1.148, the resulting electric field is a reasonably good approximation of the desired hyperbolic shape.

Opposite rods are electrically connected together. The ions are directed into the space between the poles in a direction nominally parallel to the length of the rods. There the ions are separated according to their mass-to-charge ratios by the lateral forces resulting from the potentials applied to the poles.

The applied potentials consist of an RF component and a DC component. The RF potential on one set of rods is out of phase by 180° with respect to the RF potential on the other set of rods, but all are the same amplitude. For one pair of rods, the "X" pair, the DC potential is positive. For the other, the "Y" pair, the DC potential is of the same magnitude but negative. The DC and RF potentials are referenced to a *center voltage* (*pole zero*).

The following equations summarize the potentials applied to the rods:

$$X = V\cos(2\pi ft) + U + PZ \qquad\qquad [1]$$

$$Y = V\cos(2\pi ft + \pi) - U + PZ \qquad\qquad [2]$$

V = RF amplitude

f = RF frequency

t = time

U = DC potential

PZ = pole zero.

The RF component removes the low-mass ions from the beam. Ions of sufficiently low mass have their motions remain in phase with the applied RF. These ions will gain energy from the field and oscillate with increasingly large amplitudes. Eventually, as they travel along the length of the rods, they will strike one of the rods and be neutralized. High mass ions are focused by the RF component to an area close to the quadrupole's long axis, the Z axis.

The DC component is superimposed on the RF to remove high mass ions from the beam. The DC field deflects the high mass ions toward the negative poles, opposing the focusing effects of the RF field. Eventually, these high mass ions strike the negative rods and are neutralized. By a suitable choice of DC-to-RF ratio, the mass filter can be made to discriminate against both high and low mass ions.

The ion energy directed along the Z axis of the mass filter is dependent on the difference between the potential at which the ions were formed (the anode voltage) and the pole zero. The ion energy is usually only slightly modified by the electric field (the *fringing* field) between the source exit aperture and the quadrupole. Imbalances in the amplitude of the two phases of RF applied to the rod pairs, and DC voltages are also applied, resulting in a further modification of the ion energy.

The mass of the ions passed by the filter is determined by the RF amplitude, the RF frequency, and the quadrupole radius. (See equation [6].)

$$V = 14.438 M f^2 r_0^2 \qquad\qquad [3]$$

V = peak-to-peak RF amplitude in Volts

M = mass of the ion in atomic mass units (AMU) per electron charge

f = RF frequency in megahertz

r_0 = quadrupole radius in centimeters.

For example, a 200 AMU singly-charged ion would pass through a quadrupole with nominal 6.35 mm (1/4 in.) diameter rods (an r_0 of 0.277 cm), operating at 1.78 MHz, at a peak-to-peak RF amplitude of approximately 700 Volts.

The mass of ions transmitted (M) is directly proportional to the RF amplitude (provided f is constant). As the RF amplitude is increased, progressively higher mass ions will be made to oscillate in phase with the RF field and thus gain sufficient energy to strike the poles. The DC voltage must be increased to maintain the high mass rejection properties of the filter. A mass spectrum is generated by sweeping the RF amplitude along with the DC voltage.

The next section (Scanning Characteristics) discusses the variation in the efficiency of transmission of ions through the filter with mass. Following that, section 5.2.2.2, The Zero Blast, discusses the behavior of the filter at very low masses where the applied voltages approach zero.

5.2.2.1 Scanning Characteristics

The quadrupole acts as a mass filter for a mixed beam of ions, rejecting those of both high and low mass, while passing those of an intermediate mass. The selectivity of the mass filter is expressed in terms of resolution, R, which is numerically given by the ratio of the center mass, M, to the width, ΔM (both in AMU), of the pass band. Since the number of the ions passed by the filter falls off gradually as the edge of the pass band is approached, the width is defined at the point where the ion current falls to some specified fraction (usually 1/2 or 1/10) of the maximum value. The width of the pass band is determined by the DC-to-RF ratio.

The quadrupole can be designed so that R varies in any desired manner with M. However, keeping ΔM constant ensures adequate separation of masses that are 1 AMU apart. This mode of scanning is called Constant ΔM. As a result, R is proportional to M, and therefore the efficiency with which ions of mass M are transmitted through the quadrupole decreases with M. Therefore, the sensitivity of the sensor decreases as M increases.

5.2.2.2 The Zero Blast

When the RGA scans over the very low end of the mass spectrum, the RF and DC voltages applied to the rods approach zero. The quadrupole then ceases to act as a filter and a large current of unseparated ions is detected, called the *zero blast*. (See Figure 5-4.)

Zero blast will interfere with the observation of masses 1 and 2 in the higher pressure range of the RGA (i.e., 1E-6 Torr to 5E-4 Torr) when significant quantities of higher-mass ions are present. The zero blast contribution to the mass 2 signal intensity can be between 5 ppm and 100 ppm depending on the mass range of the RGA.

Figure 5-4 The zero blast
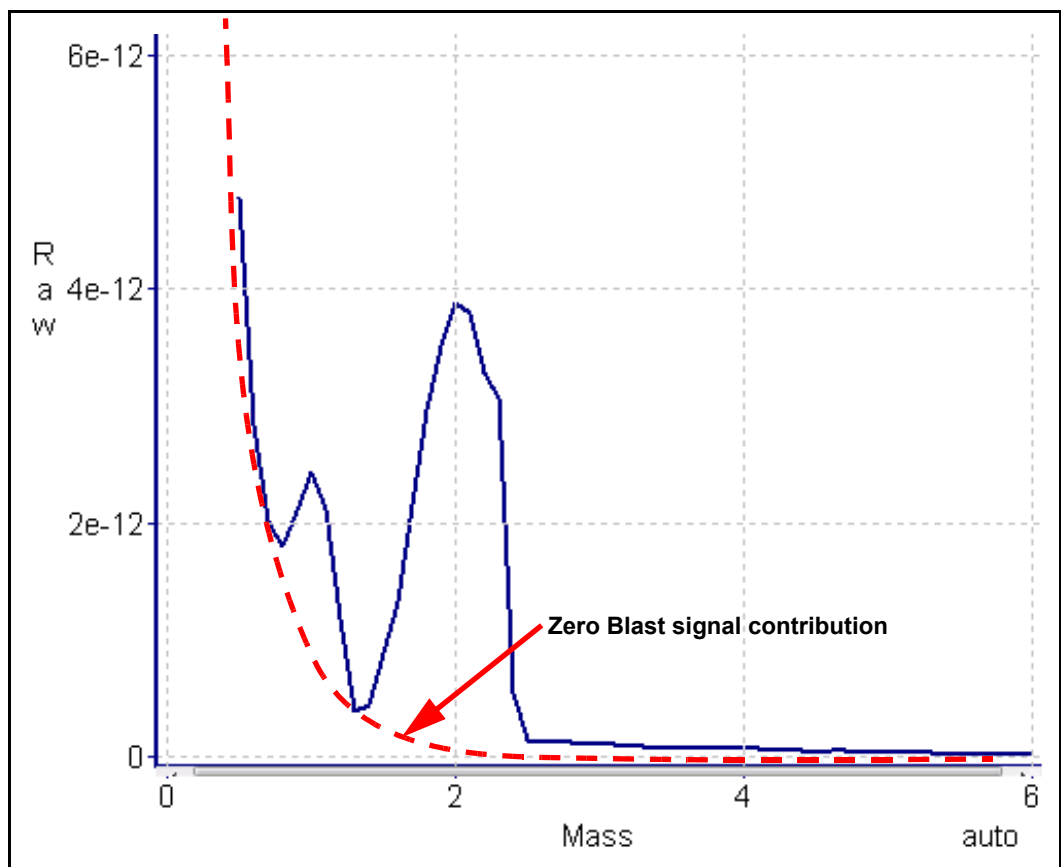
5.2.3 The Ion Detector

The ion detector region of the sensor consists of the quadrupole exit lens, the electron multiplier and the detector itself. The quadrupole exit aperture is biased negatively with respect to the anode, focusing ions that have been transmitted through the quadrupole into the electron multiplier and detector.

5.2.3.1 The Electron Multiplier (EM) Detector

The Electron Multiplier (EM) acts as an *in situ* preamplifier for improved sensitivity. Incoming ions are accelerated into the EM by a high negative voltage (usually -1.0 kV or more). When an ion strikes the surface of the EM, one or more secondary electrons are emitted. These electrons are accelerated to a second surface which is at a more positive potential, where additional electrons are generated.

This process repeats itself until a pulse of electrons emerges from the output of the EM and is collected on a Faraday Cup. The result is that as many as a million electrons or more can be produced by each incident ion. The current output from an EM detector is negative due to this pulse of electrons.

The ratio of the electron output current to the incident ion current is the EM gain. The gain primarily depends on the EM type, the voltage applied to the EM input, the voltage applied across the EM, the condition of the EM, and to a lesser extent the mass and chemical nature of the incident ion. In general, EM gain decreases as the ion mass increases.

The advantage of the EM detector sensor is it's high sensitivity (as much as 500 A/Torr), making it possible to measure partial pressures as low as 1×10^{-15} Torr for a 100 AMU sensor.

5.2.3.2 The Continuous Dynode Electron Multiplier/Faraday Cup Detector

The Continuous Dynode Electron Multiplier/Faraday Cup (CDEM/FC) detector amplifies the electron *pulse*, significantly increasing the analyzer's sensitivity.

Figure 5-5 CDEM/FC detector
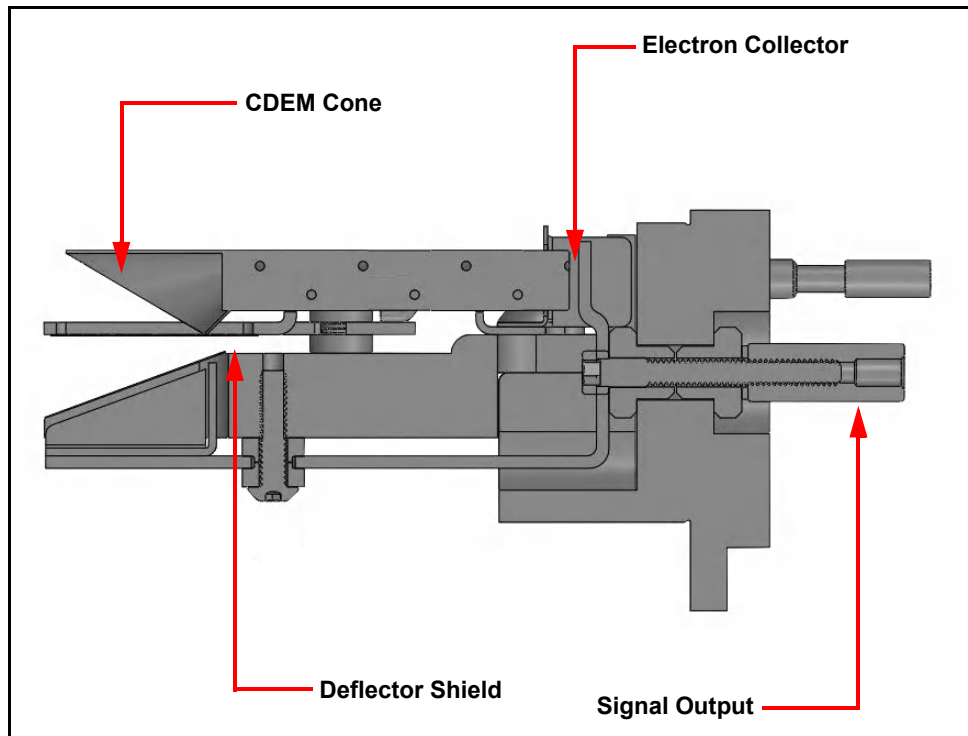
The CDEM/FC detector continuous dynode element is a special type of glass, rather than a discrete dynode EM which is a copper-beryllium alloy. The advantage of the CDEM/FC detector over a discrete dynode EM detector is that CDEM/FC performance does not degrade when exposed to air and does not need to be stored under vacuum.

The maximum operating temperature for the CDEM/FC detector is 150°C. It can be baked out at 300°C with the high voltage off.

The CDEM/FC detector is slightly slower to recover after exposure to excessive input or output currents. It may take a bit longer to stabilize its gain after the high voltage is changed.

The CDEM/FC detector is operated at high voltages between -0.6 and -2.0 kV. A new CDEM/FC detector will typically have a gain between 10 and 1,000 at -0.8 kV. The gain at -3.0 kV typically exceeds 1×10^6. The Transspector CPM default EM voltage is -0.8 kV.

⚠️ **CAUTION**

> **Do not operate the CDEM/FC detector at temperatures above 150°C. Permanent damage may result.**

⚠️ **CAUTION**

> **Avoid output currents in excess of 1 x 10^{-6} amps. Either decrease the high voltage or decrease the pressure.**

Use the minimum CDEM/FC detector voltage required to obtain the necessary peak amplitudes and/or signal-to-noise ratio. Operating at higher voltages than necessary will result in premature aging of the EM. As the CDEM/FC detector ages, the voltage needed to obtain a specific EM gain will increase.

Since EM performance depends on the condition of its interior surfaces, prevent hydrocarbon or other contamination:

◆ Make sure diffusion-pumped vacuum systems are properly trapped to reduce oil back-streaming.

◆ Make sure turbomolecular pumped systems are interlocked to eliminate mechanical pump oil back-streaming through a nonspinning turbo pump.

EM gain reduction from these kinds of problems can range from 50% to more than 90%. The initial gain of the EM is generally high enough to accommodate some degradation and yet still be usable. With repeated instances of contamination, the EM will eventually require replacement.

⚠️ **CAUTION**

> **In addition to hydrocarbon contamination, an EM can be adversely affected by exposure to highly reactive chemicals. Avoid any substance that will either cause the deposition of a surface film on the EM or etch its surface. Avoid high levels of reactive fluorides, such as tungsten hexafluoride, hydrogen fluoride, and nitrogen trifluoride.**

5.3 How to Interpret The Result

◆ Qualitative Interpretation Of Mass Spectra explains how to determine which substances are present in the gas sample being analyzed. (See section 5.3.1.)

◆ Quantitative Interpretation of Mass Spectra (Calculating Partial Pressures) explains how to estimate how much of each substance is present. (See section 5.3.2 on page 5-26.)

◆ Additional Information For Interpreting Mass Spectra provides additional information regarding interpreting mass spectra. (See section 5.3.3 on page 5-32.)

Software packages for Transpector instruments include routines which serve as aids in the interpretation of spectra and the calculation of partial pressures and relative concentrations.

For a discussion of how the Transpector produces its measurements, see Chapter 4, How the CPM System Works.

5.3.1 Qualitative Interpretation Of Mass Spectra

The graphical output of a partial pressure analyzer is a mass spectrum. A mass spectrum is a pattern of peaks on a plot of ion intensity as a function of ion mass-to-charge ratio. Each chemical substance has a characteristic mass spectrum. Different instruments will give slightly different spectra for the same substance. The particular characteristics of the ionizer, mass filter, detector, and the manner in which the sample is introduced into the mass spectrometer all influence the spectrum that is produced.

Rarely will a mass spectrum be obtained for a pure substance. Most of the time (especially for residual gas analyzers), the spectrum obtained will be a composite of the individual substances which together comprise the actual sample present.

Figure 5-6 shows the mass spectrum of air. The top graph shows the mass spectrum of a single scan during the data run with the raw signal data on the y-axis and the mass data on the x-axis. The prominent peaks for air are mass 28 (N_2), mass 32 (O_2), mass 40 (Ar) and mass 18 (H_2O). Also notice the N and O peaks at masses 14 and 16 respectively. These are created when N_2 and O_2 are broken apart in the ion source. The bottom graph is a trend analysis showing a few selected mass signals versus time.

Figure 5-6 Air mass spectrum
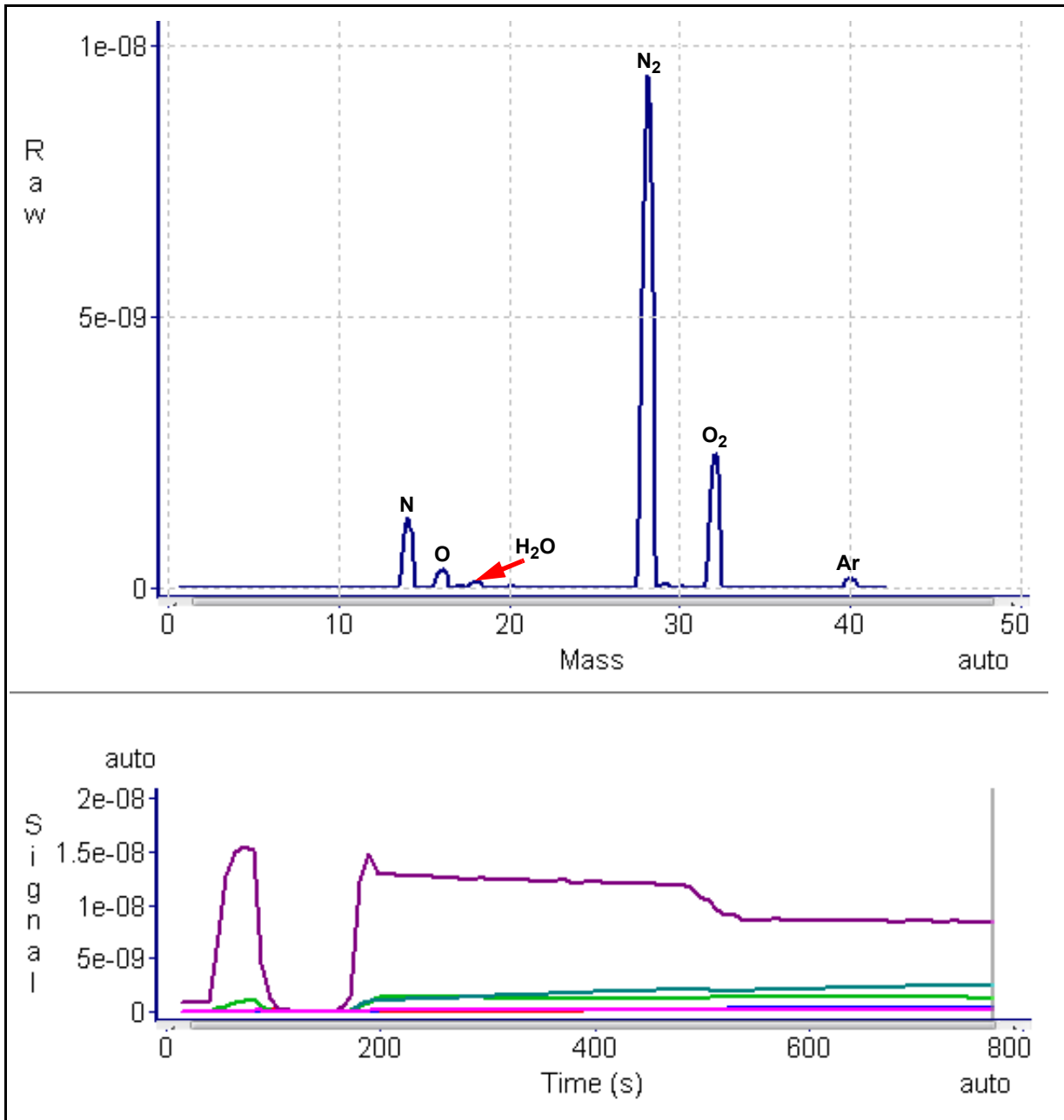
5.3.1.1 Ionization Process

When a sufficiently energetic electron strikes a gas molecule, there are many processes that can occur, some of which are summarized in Table 5-1.

Table 5-1 Electron Impact Ionization Processes

$XYZ + e^- \rightarrow$

$XYZ^+ + 2e^-$	(1)
$XYZ^{2+} + 3e^-$	(2)
$XY + Z^+ + 2e^-$	(3)
$XY^+ + Z + 2e^-$	(4)
$X^+ + YZ + 2e^-$	(5)
$X + YZ^+ + 2e^-$	(6)
$XZ + Y^+ + 2e^-$	(7)
$XZ^+ + Y + 2e^-$	(8)
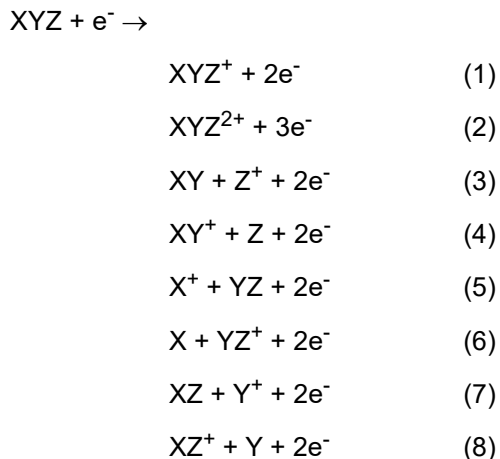
In all cases, the reactants are a high energy electron (e^-) and a gas molecule (XYZ). The products of the first reaction are the molecule with a single electron removed (the parent ion) and two low energy electrons. In the second reaction, two electrons are removed from the gas molecule, resulting a doubly charged ion. Triply (or even more highly) charged ions are possible, provided the incident electron has enough energy.

Reactions 3 through 8 are examples where the original molecule is broken into fragments, at least one of which is positively charged (negative ions can also be produced in this manner). Only the positive ion fragments are observed; the neutral (uncharged) fragments are not detected. The mass spectrum obtained when the parent molecule breaks apart under electron impact is commonly referred to as the *fragmentation pattern* (or *cracking pattern*). The fragmentation pattern for nitrogen at an electron energy of 70 eV is displayed in Figure 5-7.

Figure 5-7 A nitrogen fragmentation pattern
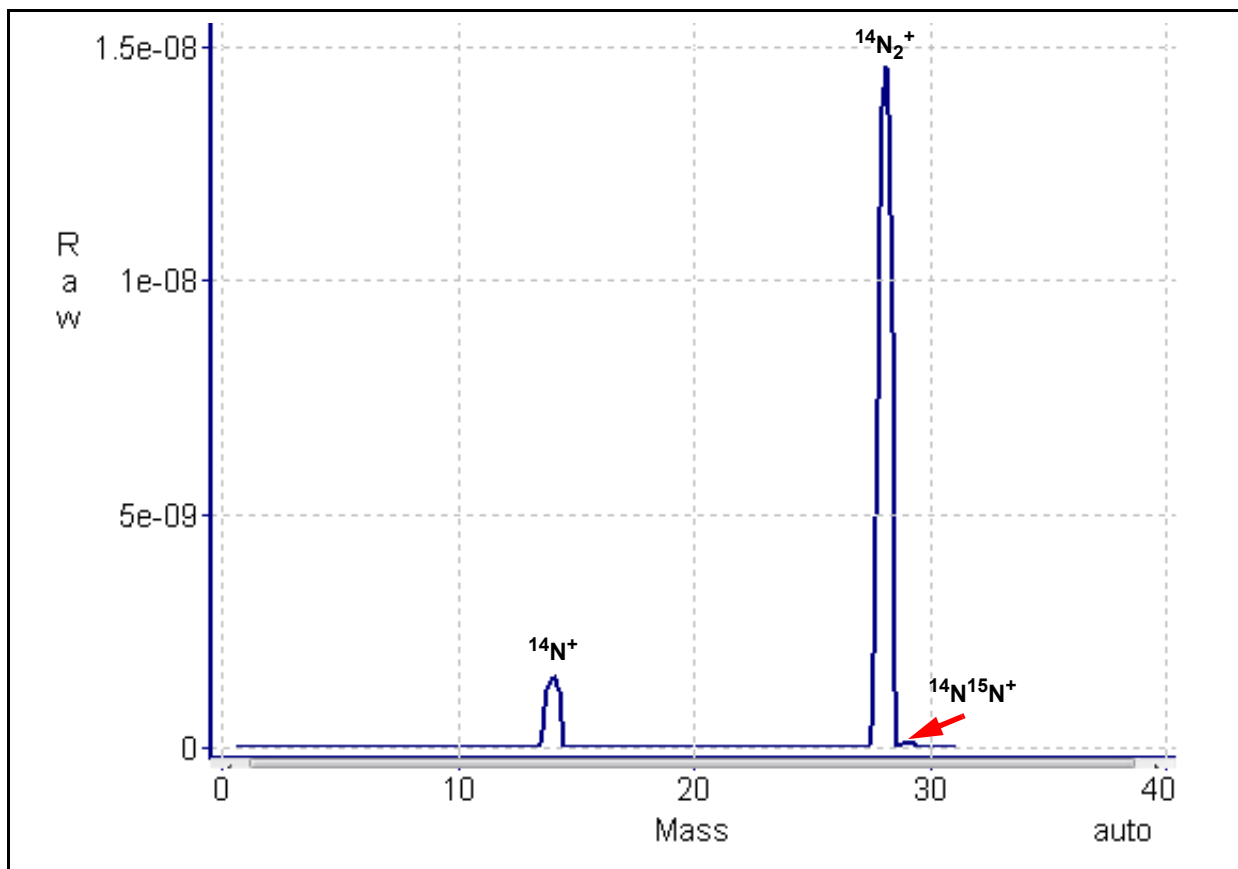
This nitrogen fragmentation pattern shows $^{14}N^+$ (14 AMU), $^{14}N_2^+$ (28 AMU), and $^{14}N^{15}N^+$ (29 AMU).

In general, peaks from multiple charged species will be less intense than those for the corresponding singly charged ion. For example, the doubly charged peak for argon is typically less than one fifth as intense as the singly charged peak (this intensity ratio is sensitive to the incident electron energy).

There are some situations when it is difficult to determine whether the ion is singly or multiply charged. When a molecule is comprised of two atoms of the same element, the typical partial pressure analyzer cannot distinguish between the singly charged one-atom fragment ion and the doubly charged two-atom molecular ion, which will both have the same mass-to-charge ratio. Refer to Figure 5-7. The peak at 28 AMU is the parent ion, N_2^+. It is not discernible from this spectrum if the peak at 14 AMU is from N^+ or N_2^{2+}. The 14 AMU peak in the nitrogen spectrum is from the singly charged fragment ion.

Most ions (with the important exception of complex hydrocarbons) have masses very close to integer values. When the mass of an ion is not evenly divisible by the number of charges on it, the mass-to-charge ratio will not be an integer. Thus, Ar^{3+} will appear at 13.33 AMU, while F^{2+} will appear at 9.5 AMU.

5.3.1.2 Isotope Ratios

An additional cause of multiple peaks in the mass spectrum of a pure substance is that most elements are comprised of more than one isotope. For example, 99.63% of all nitrogen atoms in nature have a mass of 14 AMU; only 0.37% have a mass of 15 AMU. Examine the nitrogen spectrum in Figure 5-7. The largest peak at 28 AMU is the parent ion, N_2^+. The peak at 29 AMU is the isotope peak, $^{14}N^{15}N^+$, and is 0.74% (two times 0.37%) as high as the parent peak since there are two nitrogen atoms in the ion, each one of which has a 0.37% chance of being 15 AMU.

Some elements have many intense isotopes. For example, xenon is 0.096% mass 124, 0.090% mass 126, 1.92% mass 128, 26.44% mass 129, 4.08% mass 130, 21.18% mass 131, 26.89% mass 132, 10.44% mass 134, and 8.87% mass 136.

Isotope ratios, like fragmentation patterns, aid in recognizing specific materials. Under normal partial pressure analyzer ionization conditions, the peak height ratios for the various isotopes of an element will be the same as the ratios of their natural abundance's. For example, the probability of ionizing the mass 35 isotope of chlorine (^{35}Cl) is the same as the probability of ionizing the mass 37 isotope (^{37}Cl). Thus, the peak height ratio of mass 35 to 37 from HCl will be 3.07 to 1 (75.4% / 24.6%).

Table 5-2 lists the isotopic ratios for lighter elements. For a complete listing of the natural abundances for the isotopes of all the elements, see the *Handbook of Chemistry and Physics* from CRC Press.

Table 5-2 Isotope ratios

Isotope Ratios		
Element	Mass No.	Relative Abundance
H	1	99.985
	2	0.015
He	3	0.00013
	4	~100.0
B	10	19.78
	11	80.22
C	12	98.892
	13	1.108
N	14	99.63
	15	0.37

Table 5-2 Isotope ratios (continued)

Isotope Ratios		
Element	**Mass No.**	**Relative Abundance**
O	16	99.759
	17	0.0374
	18	0.2039
F	19	100.0
Ne	20	90.92
	21	0.257
	22	8.82
Na	23	100.0
Al	27	100.0
Si	28	92.27
	29	4.68
	30	3.05
P	31	100.0
S	32	95.06
	33	0.74
	34	4.18
	36	0.016
Cl	35	75.4
	37	24.6
Ar	36	0.337
	38	0.063
	40	99.600

5.3.1.3 Electron Energy Effects

The exact fragmentation pattern will depend on the energy of the bombarding electrons. Figure 5-8 graphs the number of argon ions (of different charge states) produced per incident electron per Torr of gas pressure as a function of electron energy.

Figure 5-8 Electron energy effects

From a paper by W. Bleakney, Physical Review, 36, p. 1303, published in 1930.
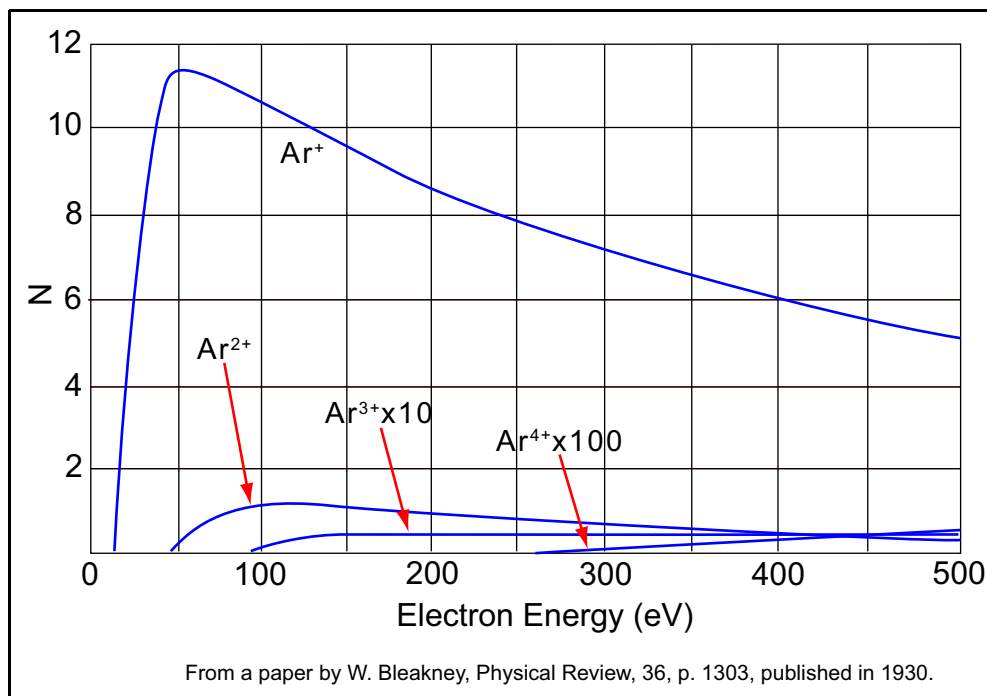
This graph shows the number or argon ions, N, formed per electron per Torr at 0°C versus electron energy.

The appearance potential—the minimum electron energy required to produce a specific ion—for Ar^+ is 15.7 eV. The number of argon ions produced rises steeply with energy until a maximum is reached at about 55 eV. As the electron energy rises above this level, the rate of Ar^+ production slowly decreases.

Typically in mass spectrometry, electron impact ionization is carried out at an electron energy of 70 eV for two reasons:

◆ 70 eV is above the minimum energy required to produce at least some positive ions from any sufficiently volatile chemical species.

◆ 70 eV is near the energy at which the rate of ion production is at its maximum for most of the common gases.

Operating at 70 eV provides a universal detector with good sensitivity for gases typically encountered.

Sometimes there is a problem with mass spectral overlap—ions with differing chemical composition form chemically distinct source molecules, but with the same mass. For example, there is a problem with detecting small amounts of water vapor in argon, as is often desired when monitoring a PVD process. Normally, water vapor is monitored at 18 AMU (H_2O^+). Overlap from the doubly charged argon[36] isotope also shows up at mass-to-charge ratio 18 (most mass filters, including quadrupoles, are really mass-to-charge ratio filters and not true mass filters). Approximately 3,400 parts per million of all argon atoms are the mass 36 isotope. Also, at 70 eV, the doubly-charged argon ion, Ar^{2+}, has about 15% of the intensity of the singly charged Ar^+ ion. Therefore, there will be approximately 510 ppm (3,400 ppm times 15%) of $^{36}Ar^{2+}$ at 18 AMU, making it impossible to detect several ppm of water vapor at the same mass. Another ion from water vapor, the OH^+ at 17 AMU, could be used instead. Unfortunately, OH^+ at 17 AMU from water vapor has an intensity of only 25% of that of the parent ion H_2O^+. To detect several ppm of water vapor would require the detection of less than one ppm of current at 17 AMU. This is difficult because there will be some tailing of the 510 ppm $^{36}Ar^{2+}$ peak at 18 AMU onto 17 AMU.

The best solution to this argon/water vapor problem is to make use of a property of ions known as *appearance potential*. The appearance potential for an ion from a given substance is the minimum electron energy required to produce that particular type of ion from the specified substance. Table 5-3 lists appearance potentials for various ions from common gases.

Table 5-3 Appearance potentials for various ions from common gases

Ion	Gas	Mass-to-Charge	Appearance Potential (eV)
Ar^+	argon	40	15.7
Ar^{2+}	argon	20	43.5
Ar^{3+}	argon	13.3	>70
N_2^+	nitrogen	28	15.6
N^+	nitrogen	14	24.3
O_2^+	oxygen	32	12
O^+	oxygen	16	14.01
CO_2^+	carbon dioxide	44	13.8
CO^+	carbon dioxide	28	19.4
O^+	carbon dioxide	16	19.4
C^+	carbon dioxide	12	22.7
CO^+	carbon monoxide	28	14.1
O^+	carbon monoxide	16	20.9
C^+	carbon monoxide	12	20.9

Table 5-3 Appearance potentials for various ions from common gases

Ion	Gas	Mass-to-Charge	Appearance Potential (eV)
H_2O^+	water vapor	18	12.6
OH^+	water vapor	17	13.5
H_2^+	hydrogen	2	15.5
HF^+	hydrogen fluoride	20	16.1

Table 5-3 shows that the appearance potential for Ar^{2+} is 43.5 eV, while that for H_2O^+ is 13.5 eV. Therefore, by choosing an electron energy below 43.5 but above 13.5 eV, it is possible to produce the water vapor ion without producing doubly charged argon ions, permitting the detection of water vapor at 18 AMU.

The Transpector CPM sensor and electronics can operate at electron energies below 70 eV, with reduced electron emission (200 µA, max.). When monitoring PVD processes, the CPM should be operated at 40 eV with an electron emission current of 200 µA to reduce power to the filament. The software has the capability to switch the CPM between 70 eV, 2.0 mA (CIS high) for background monitoring and 40 eV, 200 µA (CIS low) for process monitoring.

With FabGuard Explorer, electron energy can be changed to a voltage ranging 10–100 eV.

⚠ CAUTION

Below 70 eV it is necessary to limit the electron emission current to no more than 200 µA, in order to not overpower the filament. Overpowering the filament will result in shortened filament life.

5.3.1.4 A Qualitative Interpretation Guide

A partial pressure analyzer identifies unknown substances by interpreting three characteristics: fragmentation patterns, multiply charged ions, and isotope ratios. Simple spectra are easy to interpret. The analysis of complicated mixtures is more difficult.

Table 5-4 is a spectrum interpretation guide for examining an unknown spectrum. It lists the masses of peaks, possible ion identities for each of these masses, and common sources for each of these ions. This guide is by no means all-inclusive, and only goes up to 50 AMU. Processes such as CVD and Etch often involve fairly complex chemicals which provide very complicated spectra that extends to masses well beyond 50 AMU.

Table 5-4 Spectrum interpretation guide

AMU #	Chemical Symbol	Sources
1	H	water F or hydrogen F
2	H_2, D	hydrogen, deuterium (^{2}H)
3	HD, ^{3}H	hydrogen-deuterium, tritium (^{3}H)
4	He	helium
5	No known elements	
6	C	Doubly Ionized ^{12}C (Rare)
7	N	DI ^{14}N (Rare)
8	O	DI ^{16}O (Rare)
9	No known elements	
10	Ne, ^{10}B	DI ^{20}Ne (Rare), BF_3, BCl_3
11	Ne, ^{11}B	DI ^{22}Ne (Rare), $^{11}BF_3$, BCl_3
12	C	carbon, carbon monoxide F, carbon dioxide F
13	CH, ^{13}C	methane F, carbon isotope
14	N, CH_2	nitrogen, methane F or Note 1
15	CH_3	methane F or Note 1
16	O, CH_4, NH_2	oxygen or carbon monoxide F, ammonia
17	OH, NH_3	water F, ammonia F
18	H_2O	water
19	F	fluorine or freon F
20	Ar^{2+}, Ne, HF	argon DI, neon, hydrofluoric acid
21		
22	^{22}Ne, CO_2	neon, DI CO_2
23		
24	C_2	See Note 1
25	C_2H	See Note 1
26	C_2H_2 CN	See Note 1, hydrogen cyanide F
27	C_2H_3, Al, HCN	See Note 1, aluminum, hydrogen cyanide
28	N_2, CO, C_2H_4, Si	nitrogen, carbon monoxide, ethylene P, silicon

Table 5-4 Spectrum interpretation guide (continued)

AMU #	Chemical Symbol	Sources
29	CH_3CH_2	ethane F or ethanol F or isopropyl alcohol
30	C_2H_6, NO	ethane P, nitric oxide
31	P, CH_2OH,	phosphorus, methanol F,
32	O_2, S	oxygen, sulfur, methanol P
33	HS	hydrogen sulfide F
34	H_2S, ^{34}S, O_2	hydrogen sulfide P, sulfur isotope, oxygen isotope
35	^{35}Cl	chlorine isotope, See Note 2
36	HCl, ^{36}Ar, C_3	hydrochloric acid, argon isotope, hydrocarbons
37	^{37}Cl, C_3H	chlorine isotope, See Note 2, hydrocarbons
38	^{37}HCl, C_3H_2	hydrochloric acid or see Note 2, hydrocarbons
39	C_3H_3	See Note 3, hydrocarbons
40	Ar, C_3H_4	argon, See Note 1, hydrocarbons
41	C_3H_5	See Note 1, hydrocarbons
42	C_3H_6	See Note 1, hydrocarbons
43	C_3H_7, CH_3CO	Note 1, acetone F or methyl ethyl ketone F
44	CO_2, C_3H_8	Carbon dioxide, See Note 3
45	CH_3CH_2O	ethanol F or isopropyl alcohol F
46	CH_3CH_2OH	ethanol P
47	$C^{35}Cl$	See Note 2
48	$HC^{35}Cl$, SO	See Note 2, sulfur dioxide F
49	$C^{37}Cl$	See Note 2
50	$C^{37}Cl$, CF_2, C_4H_2	See Note 2, freon F, Note 3
NOTE:	(1) Fragments of several hydrocarbons, such as mechanical pump oil, diffusion pump oil, vacuum grease, cutting oil, and organic solvents. (2) Fragments of several chlorinated hydrocarbons, such as carbon tetrachloride, tichloroethylene, and many freons. (3) Fragments from both straight chain hydrocarbons and benzene ring hydrocarbons. (4) F = Fragment ion; P = Parent ion; DI = Doubly ionized	

5.3.1.5 Dry Etching Chemistries

Table 5-5 lists materials to be etched, the typical chemistries used, the chemical species that are important, and a list of masses used to monitor each specie.

Many different chemistries exist for etching any given film. Only a few of the more common etch processes are listed in Table 5-5. The important species listed for each process were picked for the list on the basis of their either being reagent gases for the listed process, known reaction product gases, potentially troublesome impurities (e.g., H_2O), or probable by-product gases.

Table 5-5 is not an all-inclusive list. There may be other important species, such as highly reactive intermediates, which are not included. The list of monitored masses for each process is a general guide.

Significant spectral overlap exists (for example, COF_2 and SiF_4 or CO, CO_2 and N_2), which must be considered when interpreting the data. Furthermore, many cracking patterns for the important species are very complicated because of the molecule's complexity and because of multiple isotope peaks. Only a few of the more intense or unique masses are listed.

Table 5-5 Dry etching chemistries

Etched Material	Typical Reagents	Important Species	Monitored Masses
Al (and alloys)	BCl_3/Cl_2 (+N_2)	BCl_3	81, 83, 116, 118, 46, 48
		Cl_2	70, 72, 74
		N_2	28, 14
		O_2	32, 16
		$AlCl_3$	134, 97, 62, 27
		Al_2Cl_6	266, 231, 196, 161, 134, 97, 62
		HCl	36, 38
		H_2O	18, 17

Table 5-5 Dry etching chemistries (continued)

Etched Material	Typical Reagents	Important Species	Monitored Masses
W (and alloys)	SF_6	SF_6	127, 89, 108
		WF_6	279, 281
		F_2	38
		HF	20
		H_2O	18, 17
		O_2	32, 16
		N_2	28, 14
		WOF_4	257, 259
(TiN liner)		TiF_4	86, 67, 105, 48
W (and alloys)	NF_3	NF_3	52, 33, 71
		WF_6	279, 281
		F_2	38
		HF	20
		H_2O	18, 17
		N_2	28, 14
		O_2	32, 16
		WOF_4	257, 259
(TiN liner)		TiF_4	86, 67, 105, 48
SiO2 (and boro-phospho-silicate glass)	$CHF_3/CF_4,$ CHF_3/O_2	CHF_3	51, 69
		CF_4	69, 50
		O_2	32, 16
		SiF_4	85, 66, 47
		CO_2	44, 28, 16, 12
		HF	20
		H_2O	18, 17
		COF_2	47, 66
		C_2F_6	119

Table 5-5 Dry etching chemistries (continued)

Etched Material	Typical Reagents	Important Species	Monitored Masses
Si3N4	CF_4/O_2	CF_4	69, 50, 31
		O_2	32, 16
		SiF_4	85, 66, 47
		NF_3	52, 33, 71
		CO_2	44
		HF	20
		H_2O	18, 17
		COF_2	47, 66
		N_2	28, 14
		CO	28, 12
Poly-Si	BCl_3/Cl_2	BCl_3	81, 83, 116, 118, 46, 48
		Cl_2	70, 72, 74
		$SiCl_4$	133, 135, 170
		HCl	36, 38
		H_2O	18, 17
	$HBr/Cl_2/O_2$	HBr	80, 82
		Cl_2	70, 72, 74
		O_2	32, 16
		$SiCl_4$	170, 133, 135
		$SiBr_4$	348, 267, 269
		$SiBr_XCl_{(1-X)}$	many peaks
		H_2O	18, 17
		HCl	36, 38

5.3.1.6 Tungsten CVD

Table 5-6 lists some of the materials of interest and the masses at which to monitor them for blanket tungsten or tungsten silicide deposition. Oxygen and water vapor are unwanted contaminants during tungsten deposition because they react with the tungsten hexafluoride to produce tungsten oxyfluorides and oxides, which, except for WOF_4, are nonvolatile and can result in particle generation. The presence of

WOF$_4$ may be the only indication that water vapor or oxygen are also present, but not detected by the mass spectrometer because of rapid reaction with the tungsten hexafluoride.

Table 5-6 Tungsten CVD materials of interest

Chemical	Type	Monitoring Mass
WF6	reagent	279
H2	reagent	2
SiH4	reagent	30, 31, 32
Ar	reagent	40
N2	reagent	28 (interference from SiH4)
HF	product	20 (at 35 eV)
O2	contaminant	32 (interference from SiH4)
H2O	contaminant	18 (at 35 eV)
WOF4	by-product	257

5.3.1.7 Copper MOCVD

Table 5-7 lists some of the materials of interest and the masses for monitoring them for the deposition of copper using Cu^I(hfac)(tmvs). Oxygen and water vapor are unwanted contaminants.

Table 5-7 Copper MOCVD materials of interest

Chemical	Types	Monitoring Mass
CuI(hfac)(tmvs)	reagent	201, 63
H2	reagent	2
Ar	reagent	40
tmvs	product	100, 85
H(hfac)	product	139
O2	contaminant	32
H2O	contaminant	18 (if Ar present, use 35 eV)

5.3.2 *Quantitative Interpretation of Mass Spectra (Calculating Partial Pressures)*

Partial pressure is defined as the pressure of a designated component in a gas mixture. By Dalton's Law, the sum of all the partial pressures is the total pressure. The partial pressure analyzer is designed so that the height of a peak in a mass spectrum is proportional to the number of ions giving rise to that peak. The number of ions is more or less proportional to the partial pressure of the substance giving rise to that peak (over some specified operating pressure range). Therefore, the height of a peak is proportional to the partial pressure of the substance giving rise to that peak.

Equation [4] shows the relationship between the partial pressure of substance a determined by measuring the ion current at mass b:

$$PP_a = K_{ab} \times I_{ab} \qquad [4]$$

PP_a = the partial pressure of substance a

K_{ab} = the proportionality constant for the peak at mass b from substance a

I_{ab} = the ion current at mass b from substance a

The proportionality constant (K_{ab}) depends on the nature of the substance being detected and on the characteristics of the partial pressure analyzer. The substance dependent part is called the material factor (M_{ab}). The instrument dependent part is called the analyzer factor (A_b) and depends primarily on the ion mass (b). Therefore, the original equation [4] can therefore be rewritten as follows:

$$PP_a = (M_{ab} \times A_b) \times I_{ab} \qquad [5]$$

The material factor (M_{ab}) depends on the fragmentation pattern for the particular substance, the fragmentation pattern for a reference gas (usually nitrogen), and the ease with which the substance can be ionized relative to the same reference gas. The relationship is shown in equation [6]:

$$M_{ab} = \frac{1}{FF_{ab} \times XF_a} \qquad [6]$$

The fragmentation factor for substance (a) at mass (b) is (FF_{ab}). It is equal to the fraction of the total current of all ions from substance (a) which have a mass (b).

The ionization probability of substance (a), relative to nitrogen (i.e., $XF_N = 1$) is (XF_a). That is, it is the ratio of total ion current (for all masses) from substance (a) to the total ion current from nitrogen (N), both measured at the same true partial pressure. Both fragmentation factors and ionization probabilities depend strongly on the energy of the ionizing electrons. If the correct values of these factors are not known for the exact conditions of the particular analyzer being used, they can be approximated using published values for other conditions with, generally, only a small loss in accuracy.

Fragmentation factors can be calculated from fragmentation patterns given in the general references cited in Chapter 12, Bibliography. Other valuable references include the Index of Mass Spectral Data from ASTM, and EPA/NIH Mass Spectral Data Base by Heller and Milne and an extensive library of spectra is available from the National Institute of Standards and Technology.

Table 5-8 lists the fragmentation factors (FF) for the major peaks for selected substances.

NOTE: Actual fragmentation factors vary significantly depending especially on the ionizer, electron energy, and mass filter turning. For best accuracy, measure fragmentation factors with the same instrument used for the analysis, under the same tuning conditions.

*Table 5-8 Typical fragmentation factors for the major peaks of some common substances
(at 70eV electron energy)*

Mass	FF	Mass	FF	Mass	FF
acetone: $(CH_3)_2CO$		helium: He		oxygen: O_2	
43	.46	4	1.00	32	.82
58	.11			16	.18
42	.03	hydrogen: H_2			
27	.05	2	1.00	toulene: $C_6H_5CH_3$	
				91	.33
argon: Ar				92	.24
40	.87	krypton: Kr		39	.07
20	.13	84	.45	65	.04
		86	.13	63	.03
benzene: C_6H_6		82	.10		
78	.43	83	.10	trichlorethylene: C_2HCl_3	
51	.09			130	.17
52	.09	methane: CH_4		95	.16
50	.08	16	.44	132	.16
		15	.39	97	.10
carbon dioxide: CO_2		14	.09	60	.08
44	.86	13	.05		
28	.06	12	.02	water: H_2O	
16	.05	17	.01	18	.77
12	.01			17	.21
		methanol: CH_3OH		16	.02
carbon monoxide: CO		31	.31		
28	.87	32	.21	xenon: Xe	
12	.08	29	.07	132	.26
16	.04	28	.04	129	.26
29	.01			131	.22
		neon: Ne		134	.11
ethanol: C_2H_5OH		20	.91	136	.09
31	.45	22	.09		
45	.22				
46	.08	nitrogen: N_2			
27	.07	28	.87		
29	.05	14	.12		
		29	.01		

Ionization probability factors can be approximated by substituting the relative ion gauge sensitivities for various gases. Table 5-9 lists relative ion gauge sensitivities for some common gases.

NOTE: Table 5-9 lists relative ionization gauge sensitivities for selected molecules. The data was compiled from *Empirical Observations on the Sensitivity of Hot Cathode Ionization Type Vacuum Gauges* by R. L. Summers (NASA Technical Note NASA TN D5285, published in 1969). Similar, although more limited, lists of ionization sensitivities can be found in the books by O'Hanlon, and Drinkwine and Lichtman. (See Chapter 12, Bibliography.)

HINT: Actual ionization probabilities vary significantly depending especially on the ionizer and the electron energy. For best accuracy, measure the relative ionization probability using a hot cathode ionization gauge (calibrated for nitrogen) to monitor a known pressure of the substance of interest. The ratio of the gauge reading to the known true pressure is the relative ionization probability. To determine the true pressure, use a gauge which is gas species independent (e.g., a capacitance manometer) or a gauge with a known sensitivity factor (e.g., a spinning rotor gauge).

Table 5-9 Ionization Probabilities For Some Common Substances

Substance	Formula	Relative Ionization Gauge Sensitivity	Substance	Formula	Relative Ionization Gauge Sensitivity
acetone	$(CH_3)_2CO$	3.6	hydrogen chloride	HCl	1.6
air		1.0	hydrogen fluoride	HF	1.4
ammonia	NH_3	1.3	hydrogen iodide	HI	3.1
argon	Ar	1.2	hydrogen sulfide	H_2S	2.2
benzene	C_6H_6	5.9	krypton	Kr	1.7
benzoic acid	C_6H_5COOH	5.5	lithium	Li	1.9
bromine	Br_2	3.8	methane	CH_4	1.6
butane	C_4H_{10}	4.9	methanol	CH_3OH	1.8
carbon dioxide	CO_2	1.4	neon	Ne	0.23
carbon disulfide	CS_2	4.8	nitrogen	N_2	1.0
carbon monoxide	CO	1.05	nitric oxide	NO	1.2
carbon tetrachloride	CCl_4	6.0	nitrous oxide	N_2O	1.7
chlorobenzene	C_6H_5Cl	7.0	oxygen	O_2	1.0
chloroethane	C_2H_5Cl	4.0	n-pentane	C_5H_{12}	6.0
chloroform	$CHCl_3$	4.8	phenol	C_6H_5OH	6.2
chloromethane	CH_3Cl	3.1	phosphine	PH_3	2.6

Table 5-9 Ionization Probabilities For Some Common Substances (continued)

Substance	Formula	Relative Ionization Gauge Sensitivity	Substance	Formula	Relative Ionization Gauge Sensitivity
cyclohexane	C_6H_{12}	6.4	propane	C_3H_8	3.7
deuterium	D_2	0.35	silver perchlorate	$AgClO_4$	3.6
dichlorodifluormethane	CCl_2F_2	2.7	stannic iodide	SnI_4	6.7
dichloromethane	CH_2Cl_2	7.8	sulfur dioxide	SO_2	2.1
dintrobenzene	$C_6H_4(NO_2)_2$	7.8	sulfur hexafluoride	SF_6	2.3
ethane	C_2H_6	2.6	toluene	$C_6H_5CH_3$	6.8
ethanol	C_2H_5OH	3.6	trinitrobenzene	$C_6H_3(NO_2)_3$	9.0
ethylene oxide	$(CH_2)_2O$	2.5	water	H_2O	1.0
helium	He	0.14	xenon	Xe	3.0
hexane	C_6H_{14}	6.6	xylene	$C_6H_4(CH_3)_2$	7.8
hydrogen	H_2	0.44			

The analyzer factor, A_b, depends on the transmission and detection characteristics of the analyzer, the EM gain (if the analyzer is so equipped), and the basic sensitivity. (See equation [7].)

$$A_a = \frac{1}{TF_b \times DF_{ab} \times G \times S} \qquad [7]$$

The transmission factor of the mass filter at mass (b) is (TF_b). The transmission factor is the fraction of ions at mass (b) which pass through the mass filter, relative to nitrogen ions at mass 28. Nominally, the transmission factor is equal to 28 divided by the mass of the ion (b).

The detection factor (DF_{ab}) is equal to 1 for a Faraday Cup detector. For an EM, the detection factor is a function of the mass of the ion and its chemical nature, and is measured relative to that of a reference gas, typically nitrogen. In general, as the mass ion increases, the EM detection factor decreases.

The gain of the EM (G) measured at mass 28 for nitrogen, is the EM output current divided by the Faraday mode output current, under otherwise identical conditions. The multiplier gain is a strong function of the high voltage applied.

The sensitivity of the instrument (S) is the Faraday mode ion current from a given pressure of pure nitrogen measured at mass 28, and is typically expressed in A/Torr.

The overall relation between partial pressure and ion current, given in equation [8], is quite general. The constants for this equation can be obtained from various tables, but for the best accuracy, they should be measured for each instrument.

$$PP_a = \left\{ \frac{FF_{N28}}{FF_{ab} \times XF_{ab} \times TF_b \times DF_{ab} \times G \times S} \right\} \times I_{ab} \qquad [8]$$

PP_a = partial pressure of substance a (usually in Torr).

FF_{ab} = fragmentation factor, or fraction of total ion current from substance a having mass b (dimensionless; see Table 5-8 on page 5-28).

FF_{N28} = fragmentation factor for N_{2+} ions at 28 AMU from nitrogen (dimensionless; typically around 0.9).

XF_a = ionization probability of substance a relative to nitrogen; approximately the same as the relative ion gauge sensitivity as shown in (dimensionless).

TF_b = transmission factor, the fraction of total ions at mass b which pass through the mass filter, relative to ions with a mass of 28 AMU; nominally,
T_{FM} = 28 / M (dimensionless).

DF_{ab} = detection factor for mass (b) ions from substance (a), relative to nitrogen at 28 AMU; assumed to be 1.00 for Faraday detectors, but varies for EM detectors (dimensionless).

G = EM gain for nitrogen ions at 28 AMU (dimensionless; set equal to 1 for a Faraday Cup detector).

S = sensitivity of instrument to nitrogen, the ion current at 28 AMU per unit of nitrogen partial pressure (usually in A/Torr).

I_{ab} = ion current of mass peak (b) resulting from substance (a)
In amps; assumes that there are no other substances present which contribute significantly to the total current at mass peak (b).

5.3.3 Additional Information For Interpreting Mass Spectra
5.3.3.1 Ion Source Characteristics

A closed ion source, and the particular inlet system selected, can have an effect on the mass spectrum obtained.

The analyzer itself is a source of gas molecules because of outgassing from its surfaces. Usually, outgassing levels can be reduced by baking the analyzer in vacuum and by using the degas function (wherein the ion source surfaces are bombarded by high energy electrons). Overnight bakeouts at the maximum allowable temperature is the best way to minimize the effects of outgassing of the sensor, manifold, and inlet system.

NOTE: It can take more than three hours for all parts of the sensor to reach maximum temperature during a bakeout, and more than six hours to cool down.

⚠️ **CAUTION**

> **Make sure EM high voltage is off if the bakeout temperature exceeds 150°C. Otherwise, permanent damage to the EM may result.**

It is possible that the opposite of outgassing can occur, that is, gas molecules can be captured by the surfaces of the sensor. This effect is called *pumping*. The magnitude of the signals of the gases pumped will be lower than is properly representative of the composition of the gas in the vacuum chamber. Significant temporary pumping effects will frequently occur following degassing the ion source.

Reactions involving gas molecules on surfaces of the analyzer can result in a change of composition. Gases can either be consumed by the surfaces, or produced by the surfaces. One example of gas consumption is the reaction of oxygen with a hot filament, particularly when tungsten filaments are used. The typical result is an anomalously low concentration of oxygen detected. See O'Hanlon's book for more information on filament materials and their interactions with the gas being analyzed. (See Chapter 12, Bibliography.) An example of gases being produced from surfaces is the liberation of carbon monoxide molecules from a thorium oxide coated iridium filament by a sputtering mechanism in the presence of significant quantities of argon. It is for this reason that the PVD version of the CIS uses tungsten filaments.

There are cases where at least some of the ions detected are emitted from surfaces in the ion source under electron bombardment and are not generated in the gas phase from neutral molecules. This process is known as electron stimulated desorption (ESD), or sometimes as electron induced desorption (EID). When the sensor has been exposed to fluorine containing substances (e.g., sulfur hexafluoride, chlorofluorocarbons, perfluorotributylamine, or perfluorokerosene)

for extended periods of time, it is not uncommon for a strong F^+ peak at 19 AMU to remain even after the fluorine containing substance has been removed. When operating in the UHV region, ESD/EID of H^+, C^+, O^+, and CO^+ (and other ions) is not uncommon. The clue to diagnosing this problem is that the observed fragmentation patterns do not match known gas phase patterns. See pages five and six, and typical spectra TS2 through 5, 16, 28, and 30, of Partial Pressure Analyzers and Analysis by Drinkwine and Lichtman for more information on ESD/EID.

Partial pressure analyzers are also characterized by varying degrees of mass discrimination, that is, the sensitivity of the instrument is a function of mass. Ion sources show mass discrimination because various substances offer different degrees of difficulty of ionization. Generally, heavy, large molecules are ionized more readily than light, small molecules. There is a rough correlation between the number of electrons in a molecule and its ease of ionization. Although the total ion yield (that is, the sum of ions of all masses) is electron energy and ionizer dependent, a reasonable estimate for the number of ions produced (relative to a standard, usually nitrogen) in a partial pressure analyzer is the relative ionization gauge sensitivity.

5.3.3.2 Scanning Characteristics

Quadrupole mass filters can also exhibit mass discrimination characteristics depending on how the control voltages are varied during the sweep through the mass range. Most instruments are designed to operate with a constant peak width (constant ∆M) which results in a resolution which is proportional to the mass. This characteristic provides a good degree of peak separation throughout the mass spectrum, but results in an ion transmission efficiency (i.e., the fraction of all ions of the selected mass entering the mass filter which are transmitted through it) which decreases as mass increases.

The way the mass scale is calibrated (tuned)—the way the peak positions and widths are adjusted—can have a significant effect on the transmission efficiency of the mass filter across the mass spectrum. If the adjustments are not made properly, the ratios of peak heights across the mass range will not be correct.

5.3.3.3 Fragmentation Factors

The fragmentation factor is the fraction of the total ion current contributed by ions of the chosen mass. Only peaks contributing at least one percent to the total ion current are included in the list. The sum of the factors for all the peaks in a mass spectrum cannot exceed 1.00. The sum can be less than 1.00 if only some of the peaks are listed (either there are many peaks, or some of the ions produced lie outside the mass range of the particular instrument used).

The data presented in Table 5-8 on page 5-28 are typical fragmentation factors for some common gases at an electron energy of 70 eV. These fragmentation factors can vary considerably with electron energy. For instance, at 35 eV the only significant peak in argon is Ar^+ at 40 AMU.

Chapter 6
Operation

6.1 HexBlock

The HexBlock provides several inlets, a process pressure gauge (CDG) and a calibration reference. It allows for up to three pressure ranges, including a high conductance inlet that covers various applications such as High Density Plasma Etch (HDP), TiN Deposition such as TDMAT, W CVD, or any other semiconductor process. Advantages include:

◆ small vacuum path lengths

◆ minimum surface area

◆ interchangeable orifices

◆ multiple process connection options (CF40, KF40 and KF25)

◆ multiple sniffer (capillary) inlet options for sampling the process

The orifices mounted in the HexBlock valves are replaceable.

Pressure ranges for the two main sampling valves are:

V1 . . . 3 mTorr–10 Torr

V2 . . . 3 mTorr–Atmosphere

⚠️ **CAUTION**

The tool and the CPM must be vented before changing orifices, except when a tool isolation valve is installed.

6.1.1 HexBlock Inlet

- ◆ **V1**—Low pressure sampling (LP). Indicates background pressures for some etch or CVD process. (No bypass available.)

- ◆ **V2**—High pressure sampling (HP). Indicates process pressures for etch, CVD and 300 mm degas sampling. Bypass is optional.

- ◆ **V3**—High Conductance. Similar to a wide open position. Used for any high vacuum condition lower than 1 mTorr.

- ◆ **V4**—Bypass. Used in conjunction with V2 in high pressure applications (above 1 Torr). V4 connects to the interstage of the Turbo Molecular Pump via a bypass tube which pulls gas from the process directly to V2. This can cut the response time down from several minutes to less than ten seconds for a 100 Torr process. The V4 bypass inlet typically consumes approximately 17 sccms of process gas.

  NOTE: When sampling lighter gases such as hydrogen and helium, it may be necessary to connect the V4 bypass tube to the foreline pump port rather than the turbo pump interstage port to improve pumping efficiency.

⚠️ **CAUTION**

> **To prevent pressure bursts to the RGA, V4 should open before V2 to ensure the pressure is correct for the V2 orifice. When V2 is closed, V4 should remain open for several seconds to pump out residuals left from sampling the process.**

- ◆ **V5—**Calibration Reference. Used for mass tuning and as a sensitivity reference, providing:

  - ◆ a means to tune the RGA
  - ◆ a reference for adjusting the EM voltage
  - ◆ a way to check whether the orifices are getting dirty or clogged
  - ◆ a reference for tracking the performance of the RGA

  The Calibration Valve refers to the option of adding a Calibration Reference to the CPM system. The Calibration Reference is located near the ion source.

  NOTE: The Transpector emission and EM are turned off prior to opening Calibration Valve (V5). This is due to trapped gas in the calibration reference.

- ◆ **Sniffer or Capillary**—The sniffer or capillary option allows sampling closer to the actual process reactions and it gives a faster response time and better signal (uses valve V2). Capillaries also provide part of the necessary pressure drop to sample from atmospheric pressure.

- ◆ **CDG Gauge**—The CDG gauge measures process pressure. It helps to prevent accidental or erroneous inlet valves from being opened.

6.1.1.1 Hex Block Process Connections

Table 6-1 Hex block process connections

Types of connections	Part Number
KF25 In-line connection	923-700-G1
KF40 In-line connection	923-701-G1
CF40 In-line connection	923-702-G1
KF25 90 degree elbow connection	923-703-G1
KF40 90 degree elbow connection	923-704-G1
CF40 90 degree elbow connection	923-705-G1

6.1.2 Calibration Option

A single source of gas mixture will accomplish two calibration functions:

◆   Mass scale calibration

◆   Partial pressure reference levels

NOTE: Selection of the appropriate gas mixture components is dictated by the mass range desired.

Test Mix 1 composition is listed in Table 6-2. The method of delivery is a flow reference with a remote on/off valve (V5). The gas flow rate is calibrated at the factory and is kept small (typically $1x10^{-4}$ Torr-L/s) by a sintered leak. Flow through the leak element is viscous, therefore the gas composition in the reservoir is not altered by sampling. The pumping system does not allow other valves to be opened with the calibration reference to ensure that no calibration mix enters the tool.

Table 6-2 Mix 1: Calibration mixture of selected impurities in argon

	Component (Composition)	Calibration Masses
Mix 1	H_2 (1%)	2
	He (1%)	4
	N_2 (1%)	28
	Ar (Balance)	36, 38, 40
	Kr (1%)	84
	Xe (1%)	134, 136

NOTE: Refer to the software operating manual for more information regarding Mass Tuning. Results using FabGuard Explorer or FabGuard with this calibration mixture may be different than shown above due to the programming of the ionization probability and material factors.

6.1.2.1 High Mass FC5311 Tuning Reference

The FC5311 Tuning Reference Gas option is available for adjusting peak position for 300 AMU CPMs. It is controlled via a manual valve. FC5311 Tuning Reference Gas is a volatile liquid. It is located at the inlet of the high vacuum pump.

⚠️ **CAUTION**

A bakeout must be performed if FC5311 Tuning Reference Gas is sampled. Up to 24 hours of pumping may be required to remove all trace levels.

The perfluorophenanthrene liquid in the FC5311 Tuning Reference has a high molecular weight and a vapor pressure of 100 Pa (1 Torr) at 22°C (71.6°F). The mass spectrum is given as mass and characteristic peak intensity in Table 6-3. The masses of abundant peaks can be used with the Tune option of FabGuard Explorer to calibrate the mass scale, particularly for 200 AMU and 300 AMU sensors.

Table 6-3 Mix 2: FC5311 reference mass spectrum
70 eV, peak intensity ranging 1–100%

Mass	Intensity	Mass	Intensity
55	1.83	219	2.66
56	1.09	231	4.06
57	2.97	243	7.66
69	100	255	2.09
70	1.17	267	2.55
93	5.97	286	2.09
94	1.27	293	7.65
100	11.09	305	1.14
112	1.50	317	2.27
119	16.80	331	1.12
124	1.49	343	1.17
131	47.08	367	1.88
143	5.26	405	4.23
155	3.05	455	18.30
162	5.64	505	4.41
169	7.66	517	1.17
181	11.23	555	4.62

*Table 6-3 Mix 2: FC5311 reference mass spectrum
70 eV, peak intensity ranging 1–100%*

Mass	Intensity	Mass	Intensity
193	6.73	605	1.64
205	2.82	624	1.00
217	2.05		

6.1.3 Process Gauge (CDG)

The Capacitance Diaphragm Gauge (CDG) measures the pressure based on the elastic deformation of a ceramic diaphragm. The capacitance change caused by the deflection is converted into a linear output signal proportional to pressure. The CDG is resistant to high pressure surges.

The CDG type is selected based on process conditions. (See Table 6-4.) Select a gauge based on maximum pressure orifice. The CDG range must be equal to or the next higher range than the highest pressure orifice (typically V2 or the sniffer).

Table 6-4 Hex block process pressure gauge

Process Range	Part Number
1 Torr range	964-208-G11
10 Torr range	964-208-G12
100 Torr range	964-208-G13
1000 Torr range	964-208-G14

6.2 Heaters

A Transspector CPM software interlock will turn on the heater only when the Turbo Molecular Pump is at normal speed (72,000 RPM). There are two temperature settings: low (90°C); high (150°C).

6.3 Pumping System

The pumping system is preconfigured at the factory. The pumping system can be reconfigured with a different:

◆ Foreline Pump, either System Controlled or customer supplied

◆ Turbo Molecular Pump, either standard or corrosive

◆ Inlet arrangement, the type of inlet and/or orifices

◆ Calibration reference

6.3.1 Foreline Pump

The system controlled Foreline Pump configuration is selected when there is a INFICON supplied Foreline Pump. If a customer supplied foreline pump is used to back other vacuum equipment, a check valve can be used to temporarily isolate the CPM from any short (<10 seconds) pressure bursts that would damage the CPM. See Table 9-3 for the check valve part number.

⚠ **CAUTION**

A customer supplied pump must supply a continuous foreline pressure between 10^{-2} and 10 Torr.

6.3.1.1 Foreline Pirani Gauge

A Pirani gauge mounted to the CPM foreline block monitors the pressure in the foreline. In the event of a pumping system malfunction, the foreline Pirani gauge can be used to verify the foreline pressure is <10 Torr. For optimal pumping system performance, the foreline pressure should be <2.25 Torr.

6.3.2 Turbo Molecular Pump

There are two types of pumping systems: Standard (non-corrosive) and corrosive. The standard Turbo Molecular Pump is used in both applications.

The corrosive pump configuration is selected for applications such as CVD or Etch or whenever corrosive gases are being sampled. The purge valve is automatically opened when the CPM Turbo Molecular Pump is operating.

The corrosive service high vacuum pump requires 10 to 25 sccm of purge gas flow through the bearing region to protect the bearings from corrosion and loss of bearing lubricant by evaporation. The regulator is preset at the factory using a MFC to produce 10 sccm of nitrogen purge. To produce 10 sccm, the nitrogen regulator should be set between 10 and 15 psi (gauge).

⚠ **CAUTION**

For the corrosive service Turbo Molecular Pump (CVD/Etch), nitrogen purge gas is required whenever the system is operational.

⚠ **WARNING - Risk Of Electric Shock**

The Turbo Molecular Pump must be completely at rest and the controller power supply must be disconnected before removing the Turbo Molecular Pump connecting cable.

6.3.2.1 Turbo Molecular Pump Status

Pump rotational speed is the RPM at which the Turbo Molecular Pump is operating. Normal speed is 80% of full speed (72,000 RPM). Full speed is 90,000 RPM.

> ⚠️ **CAUTION**
>
> **With the corrosive Turbo Molecular Pumping system, the nitrogen purge valve with regulator is connected to the purge port of the pump. The nitrogen purge valve is always open when the corrosive Turbo Molecular Pump is running. This protects the bearings from corrosive gas attack and evaporation of bearing lubricant.**

6.4 Nitrogen Purge Valve for the Turbo Molecular Pump on Corrosive Pumping Systems

On corrosive pumping systems, the nitrogen purge valve provides a continuous flow of dry nitrogen to the bearings of the Turbo Molecular Pump.

The nitrogen purge valve opens when the Turbo Molecular Pump is turned on, and closes when the pump is shut down. Over-pressurization is avoided by pressure relief of the Foreline Pump valves. Over-pressure exits the exhaust. There is no software control of the nitrogen purge valve; it is coupled with Foreline Pump operation.

6.5 Filament Control

6.5.1 Interlock

On pump down, emission will automatically turn on when the Turbo Molecular Pump reaches full speed (90,000 RPM). The emission will automatically turn off if the pump speed is below 72,000 RPM.

6.5.2 Total Pressure Calibration

To protect the filament, Transpector CPM has a factory-calibrated total pressure lens that measures the total pressure in the closed ion source. The filament will turn off (within 50 ms) after the pressure in the ion source rises above the total pressure setpoint, typically 1E-3 Torr @ 40 eV 200 μA for a CVD closed ion source.

The total pressure reading is calibrated with the ionizer set to the default low emission settings (200 μA emission; 40 eV electron energy). The default value for the over-pressure setpoint is 1 to 3 mTorr.

When operating at high emission (2 mA at 70 eV), the pressure will read approximately 20 times high. Therefore, the over-pressure will trip at a pressure about 20 times lower. Typically, this is not an issue since high emission should only be used when high sensitivity is needed, such as when leak checking a system.

When sampling at a process pressures, running at high emission will result in poor linearity if the over-pressure does not trip. If 70 eV is desired for monitoring process gas, run FabGuard Explorer, enter **Sensor Configuration** and change the electron energy to 70 eV, leaving the emission current at 200 μA.

Re-calibration requires calculation of the pressure in the CIS when Process Gas is introduced at a known pressure. The relationship is:

$$P_{CIS} = C_{Orifice} P_{Process} / C_{CIS} \qquad [1]$$

Table 6-5 lists the values for the exit conductance for CIS and for different orifices used in CPM sampling systems. Equation [1] can be used to infer the target gas pressure in the CIS that produces the total pressure measurement. Using the process gas pressure (measured by the CDG or other gauge) and the conductance of the orifice in use, the P_{CIS} (Hi-P) and P_{CIS} (Lo-P) values can be calculated to use the automatic TW-32 Total Pressure Calibration software.

Table 6-5 CIS and Orifice Conductances for use with Equation 1

Orifice Designation	Orifice Diameter (microns)	Conductance (L/s)	PCIS (Torr) [@ Design P$_{Process}$]
CVD – CIS Exit	-------	1.0	
10 mT	750	3.9E-2	3.9E-4
100 mT	200	2.8E-3	2.8E-4
1 Torr	62	2.7E-4	2.7E-4
3 Torr	35	8.6E-5	2.6E-4
6 Torr	25	4.4E-5	2.6E-4
10 Torr	20	2.8E-5	2.8E-4

6.5.3 Filament Lifetime

Tungsten filament material is used in corrosive applications. The melting point of tungsten is 3410°C; its boiling point is 5660°C. At normal operating temperatures (approximately 2200°C), tungsten vapor pressure is approximately 1E-7 Torr, which normally results in a reasonable lifetime. Various oxides of tungsten are known.

The lowest oxide, WO_2, is brown in color and has a sublimation temperature of around 800°C. The intermediate oxides, W_2O_5 and W_4O_{11}, which are blue-violet in color, and sublimes between 800°C and 900°C.

The highest oxide, WO_3 is yellow in color and has a melting point of $1473°C$. No boiling point or sublimation temperature is reported, but presumably it is far more volatile than the pure metal itself.

At normal filament operating temperature, tungsten will readily react with oxygen or water vapor to form oxides.

◆   If the oxygen (or water vapor) is very high, WO_3 is formed. This would be observed if an attempt had been made to turn on the filament in air at 760 Torr.

◆   At lower oxygen (or water vapor) partial pressures, lower tungsten oxides are formed, giving rise to the blue color observed on the electron repeller. Since the tungsten oxides are far more volatile than the pure tungsten, when they form on the filament surface, they evaporate away, depositing on the nearest relatively cool surface.

Figure 6-1 depicts a graph correlating tungsten filament mean time between failure (MTBF) in seconds with oxygen or water vapor partial pressure in Torr. The graph predicts a filament lifetime of approximately 200 seconds at 1 Torr, the maximum pressure at which Transpector can maintain electron emission.

Figure 6-1 Tungsten Filament MTBF
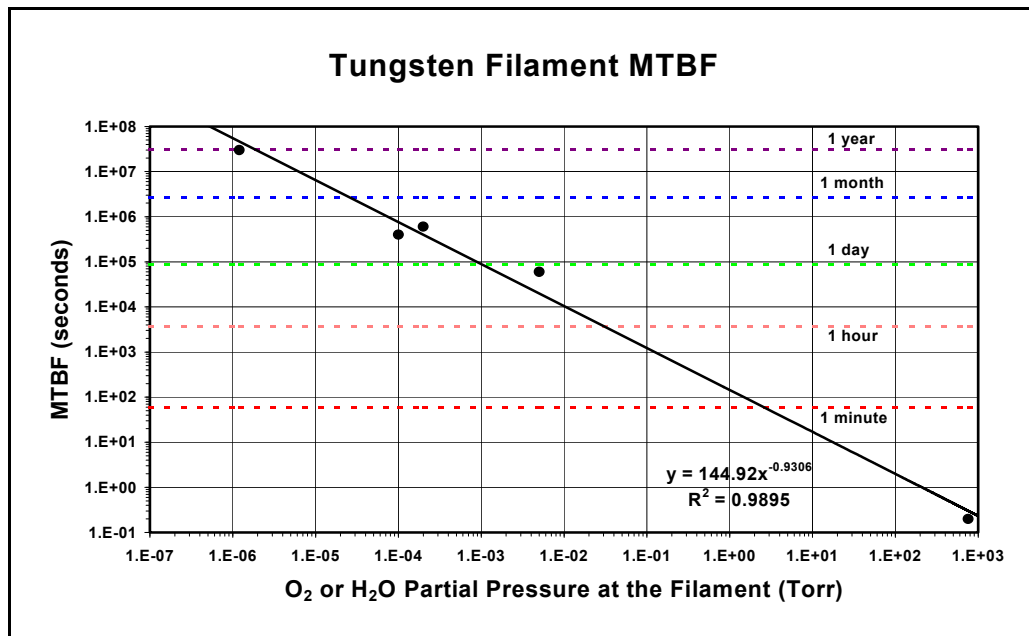
At 1 Torr at the filament, the pressure inside the anode cylinder will be approximately five times higher (assuming the bulk of the gas load is entering the CPM manifold through the closed ion source).

At 5 Torr, the collisional mean-free-path for ions will be less than 0.01 mm. The distance from the ion creation region to the total pressure collector electrode is about 4 mm, or approximately 400 mean-free-paths away. At this pressure, the scattering losses may sufficiently reduce the total pressure ion current so that it remains less than the over-pressure trip current. Under these conditions, the

filament would stay on and react with the oxygen, producing relatively volatile tungsten oxides, until the filament diameter had been reduced to the point where the tension on the wire was sufficient to cause the wire to pull apart.

Figure 6-2 depicts a CPM over-pressure trip calculation. The total pressure current curve after 5E-1 is due to the pure collisional scattering. Without collisional scattering, it would be linear. The point where the CIS total pressure current and DAC line meet is called the over-pressure trip point. When the total pressure current exceeds the DAC line (Region II) the filament is turned off.

NOTE: In Region II, there is a six second delay in turning emission on and off.

At 5 Torr in Region III, there is no overpressure and no emission error, but the filament would last only hours. At 100 Torr, the filament would be destroyed instantly.

Figure 6-2 CPM over-pressure trip calculations
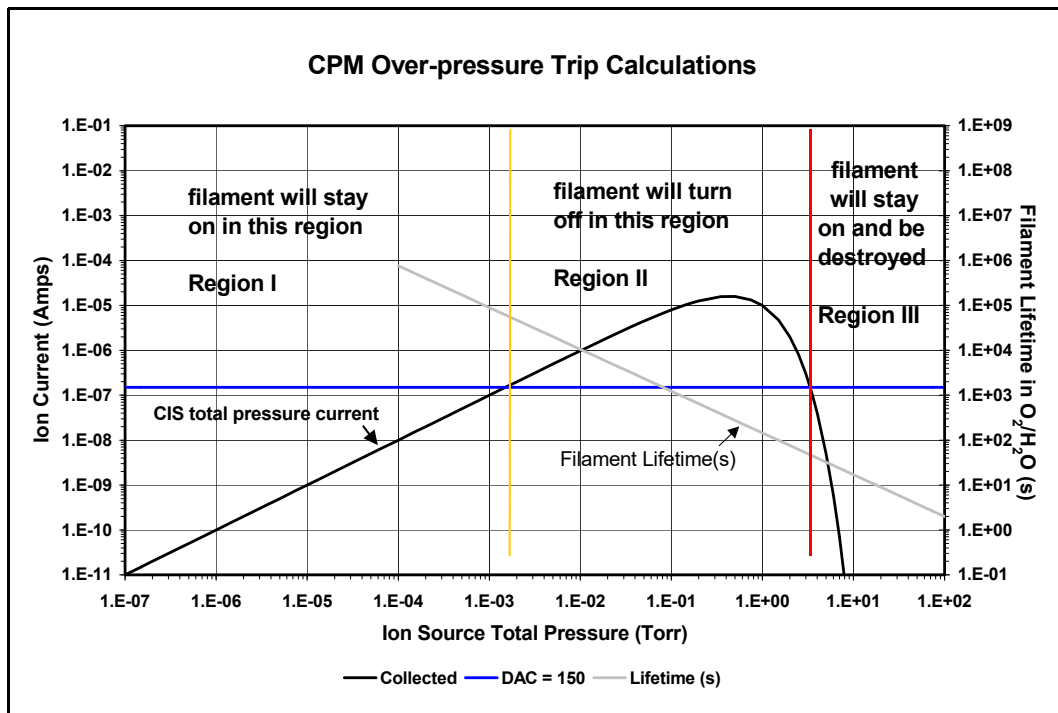
6.6 Pneumatic Digital Pressure Switch and Pressure Gauge

The Pneumatic Digital Pressure Switch and Pressure Gauge:

◆ provide a visual display of the air (or nitrogen) pressure provided to the pneumatic block

◆ ensure proper pressure for the CPM to function. If the pressure has decreased below 58 psi (3.999 bar) [399.9 kPa] or exceeds 100 psi (6.895 bar) [689.5 kPa], the CPM system will shut itself down

Figure 6-3 Location of pneumatic digital pressure switch and gauge
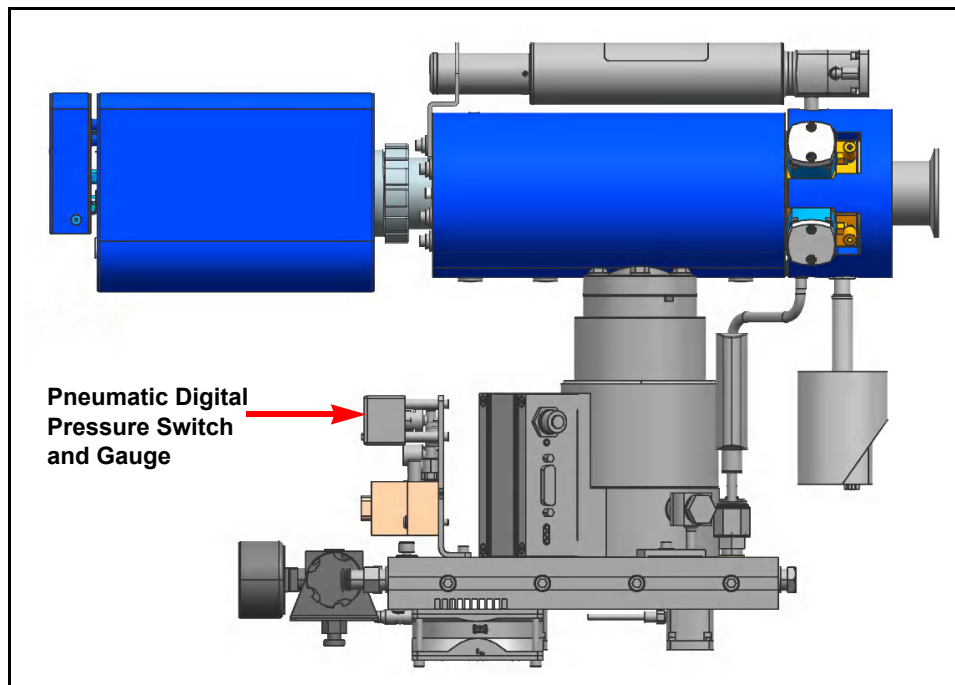
6.6.1 Setup Procedure

This setup procedure assumes:

◆ no pressure is applied

◆ psi is the pressure unit

Figure 6-4 depicts the location of the display and controls.

Figure 6-4 Location of display and controls

LCD Display

SMC PRESSURE

OUT

△ Button   ▽ Button

Operation Indicator Lamp   SET Button
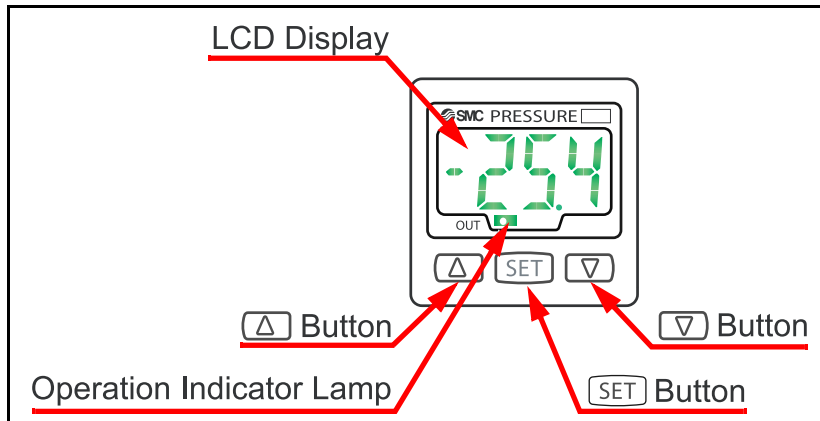
Pressure Unit Setup

1   Press and hold SET for 5 seconds. The display will show **LoC** (locked condition).

2   Press ▽ to display **UnL** (unlock).

3   Press SET. The CPM will return to Measure Mode.

4   Press and hold SET for 2 seconds. The display will show the current Pressure Unit. The default is **psi**.

5   Change to the desired Pressure Unit by pressing △ or ▽.

Display Color

6   Press SET. The display will show the Display Color Mode.
The default is **Sor** (Red/on).

7   To change the Display Color Mode, press △ or ▽.

Operating Mode

8   Press SET. The display will show the current operating mode. The default is **und**.

9   To change the Window Mode, press △ or ▽ to select **und (**Window Mode).

Output Mode

10   Press SET. The display will show the current Output Mode. The default is **nC** (normally closed).

11   Press △ or ▽ to change the Output Mode.

NOTE: The **no** (normally open) mode is not available.

Response Time Mode

12   Press ⎡SET⎤. The display will show the current Response Time. The default is **20**, at which the display color will change to red.

13   Change the setting by pressing ⎡△⎤ or ⎡▽⎤.

14   Press ⎡SET⎤ to return to Measure Mode.

Upper And Lower Pressure Limits

15   Press ⎡SET⎤. The current lower limit is displayed. The display will alternately flash **n_1** and a number representing the lower pressure limit.

16   Press ⎡▽⎤ to change the lower limit to 58 psi.

   16a   The least significant digit will flash and can be changed using ⎡△⎤ or ⎡▽⎤.

   16b   Press ⎡SET⎤ to set the digit to the desired number.

   16c   The next digit will flash.

   16d   Change the digit using either ⎡△⎤ or ⎡▽⎤, then press ⎡SET⎤.

   16e   Continue this process until 58.0 is achieved.

   16f   Press ⎡SET⎤. The display will flash 58.0 with a vertical bar showing to the left of the 58.0.

17   Press ⎡SET⎤. The current upper limit is displayed. The display will alternately flash between **n_2** and some number representing the upper pressure limit. Follow the same procedure (refer to step 16) to set the upper limit to 100 psi.

6.6.2 How to Test for Proper Settings

With zero pressure applied, the display will show 0 pressure (small negative numbers are acceptable) and the display will be colored red.

NOTE: The following test assumes the pressure unit is psi.

Apply a pressure of slightly greater than 58 psi and the display color should illuminate in green. Increase the pressure slightly greater than 100 psi and the display color should illuminate in red. Set pressure to a nominal 80 psi operating condition and the display color should illuminate green.

In normal operating conditions, the display is red when the pressure is below 58 psi or above 100 psi.

Interlocks ensure that the system will not be damaged by an air pressure failure and the CPM will shut itself safely down after ten seconds.

6.6.3 How to Lock and Unlock the Settings

To lock the settings to protect them from accidental change.

1 In Measurement Mode, press ⎡SET⎤ for five seconds. **UnL** (unlocked) is displayed.

2 Press ⎡△⎤ or ⎡▽⎤ to change **UnL** to **LoC**.

3 Press ⎡SET⎤ to return to Measurement Mode.

To unlock the settings so that they can be changed:

1 In the Measurement Mode press ⎡SET⎤ for five seconds. **LoC** (locked) will display.

2 Press ⎡△⎤ or ⎡▽⎤ to change **LoC** to **UnL**.

3 Press ⎡SET⎤ to return to Measurement Mode.

Chapter 7
Maintenance

7.1 Introduction

The sensor, Turbo Molecular Pump, Foreline Pump, and HexBlock are subject to aging and will eventually require repair or replacement.

NOTE: The Transpector electronics module and CPM controller modules rarely require repair or maintenance.

INFICON provides complete service for both sensors and electronics modules. (Refer to section 1.4, How to Contact INFICON, on page 1-4.)

7.2 Safety Considerations

⚠ **WARNING**

If Transpector CPM is used in a manner not specified by the manufacturer, the protection provided by Transpector CPM may be impaired.

⚠ **WARNING**

Transpector CPM maintenance should only be performed by qualified personnel.

⚠ **WARNING**

There are no user serviceable parts inside the Transpector electronics or the CPM controller modules.

⚠ **WARNING - Risk Of Electric Shock**

Before any maintenance is performed, Transpector CPM must be disconnected or isolated from its power source (AC mains) and the Turbo Molecular Pump must be at rest.

7.2.1 Toxic Material

⚠️ **WARNING**

> Sensors, pumps, Hexblock components and connecting tubing used in applications where toxic materials are employed or generated are likely to carry residues of these materials. Appropriate safety precautions must be obeyed when handling contaminated sensors to assure safety of maintenance personnel.

7.2.2 Radiation

Transpector CPM does not produce harmful radiation.

7.2.3 Electrical Voltages

The Transpector CPM does not present electrical hazards when enclosed and grounded according to the specifications given in the installation instructions.

⚠️ **WARNING - Risk Of Electric Shock**

> The Transpector electronics and CPM controller modules should never be operated with their covers removed. Hazardous electrical voltages present a shock hazard. Such operation should not be attempted, except by qualified service personnel.

⚠️ **WARNING - Risk Of Electric Shock**

> Before any maintenance is performed, the CPM system must be disconnected or isolated from its power source (AC mains) and the Turbo Molecular Pump must be at rest.

7.3 Maintenance Procedures

7.3.1 Bakeout of Quadrupole

If the CPM Symptom—Cause—Remedy Chart on page 8-2 suggest that the sensor is contaminated, try first to restore normal performance by baking the sensor under a high vacuum—at least 1 x 10^{-5} Torr (1.333 x 10^{-5} mbar) [1.333 x 10^{-3} Pa]—for several hours, preferably overnight. Table 7-1 represents the maximum bakeout temperatures.

If baking the sensor doesn't increase sensor performance, do section 7.7.2, Transpector Sensor Filament Replacement, on page 7-18 and do section 7.7.3, Transpector Sensor Ion Source Replacement, on page 7-20.

If the problem remains, contact INFICON. (Refer to section 1.4, How to Contact INFICON, on page 1-4.)

Table 7-1 Maximum bakeout temperatures

		While Operating	With Electronics Removed
Faraday Cup Sensors		200°C	300°C
Electron Multiplier Faraday Cup Combination	**EM Mode** **FC Mode**	150°C 200°C	300°C 300°C

⚠️ **CAUTION**

When heating the sensor above 200°C, the electronics module and the signal contact must be removed from the sensor.

7.3.2 Spare Heating Jacket

INFICON offers several heating jackets to help in baking a sensor. These heating jackets operate at a maximum temperature of 150°C. (Refer to section 1.4 on page 1-4.)

7.4 General Instructions For All Repair Procedures

⚠ **CAUTION**

Do servicing in a clean, well illuminated area.

⚠ **WARNING**

Obey all cautions and warnings.

⚠ **CAUTION**

Wear clean nylon, lint free lab gloves or finger cots. Do not touch the vacuum side of any component with unprotected fingers.

⚠ **CAUTION**

Use clean tools for sensor disassembly and assembly.

7.5 Required Tools, Materials, or Parts
7.5.1 Tools for Replacing the Filament Kit

- 3 mm nut driver

- 1/16 in. flat blade screwdriver

7.5.2 Tools for Replacing the Ion Source

- 1/16 in. flat blade screwdriver

- #2 Phillips head screwdriver

- Precision pliers

7.5.3 Tools for Replacing the Electron Multiplier

- 1/16 in. flat blade screwdriver

- Phillips head screwdriver

- 1.5 x 50 mm hex driver

- 2.0 x 75 mm hex driver

- Precision pliers

- Non-Metallic tweezers

7.5.4 Parts Required For Maintenance

- filament kit

- ion source kit

- diaphragm kit

- replacement valves

- orifice gaskets

- VCR gaskets

- copper gaskets

7.6 Changing Diaphragms in the Foreline Pump
7.6.1 Replacement Interval

The foreline pump diaphragm disks, valve seals, valve disks, and O-rings must be replaced every 8000 hours of operation.

7.6.2 Diaphragm kit PN 923-418-G1

Figure 7-1 Diaphragm kit contents
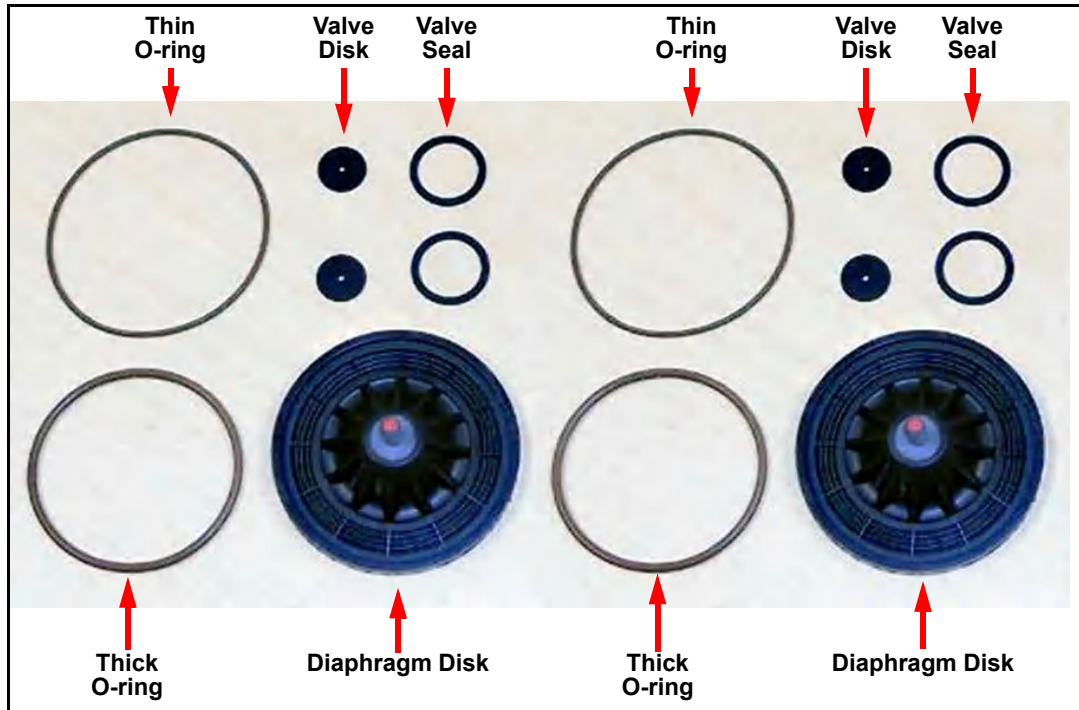
7.6.3 Procedure

⚠️ **CAUTION**

Wear safety glasses and latex gloves during this procedure.

1 Using two 9/16 in. open-end wrenches, remove the interstage tubing between the two pump heads. (See Figure 7-2.)

Figure 7-2 Removing the interstage tubing
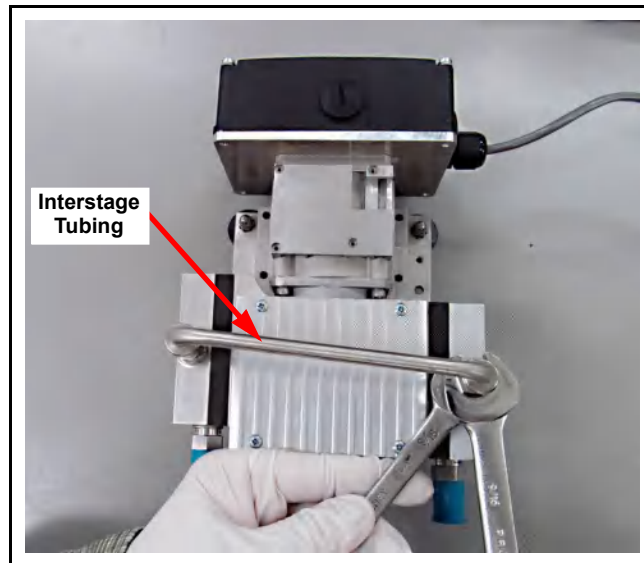
2 Using a #1 Phillips screw driver, remove the cam cover from the top side of the foreline pump. (See Figure 7-3.)

Figure 7-3 Removing the cam cover
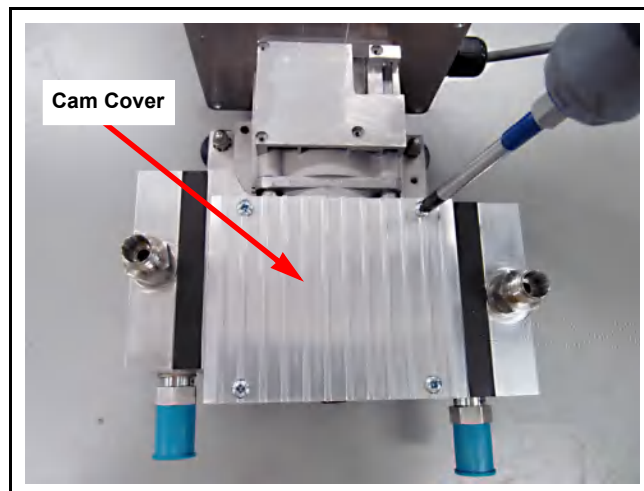
3 Inspect the inside of the pump for cleanliness. A buildup of a black, powdery substance indicates bearing wear requiring pump replacement.

4 The diaphragm disks are screwed into the cams. (See Figure 7-4.)

Figure 7-4 Foreline pump cams
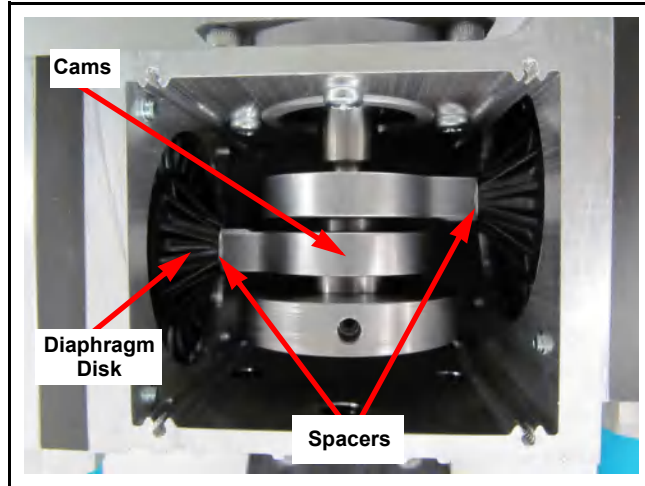
5 Unscrew the head covers of the foreline pump using a 3 mm hex key. (See Figure 7-5.)

Figure 7-5 Removing the head cover
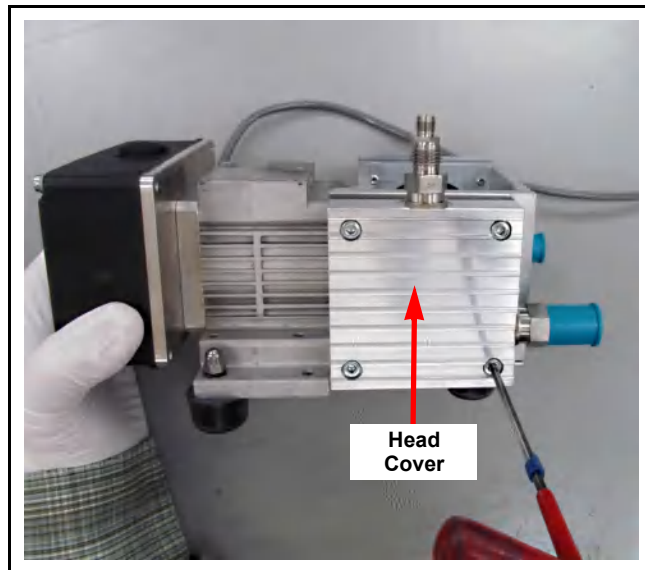
6 Remove the foreline pump head cover and diaphragm plate. (See Figure 7-6.)

Figure 7-6 Diaphragm and diaphragm plate
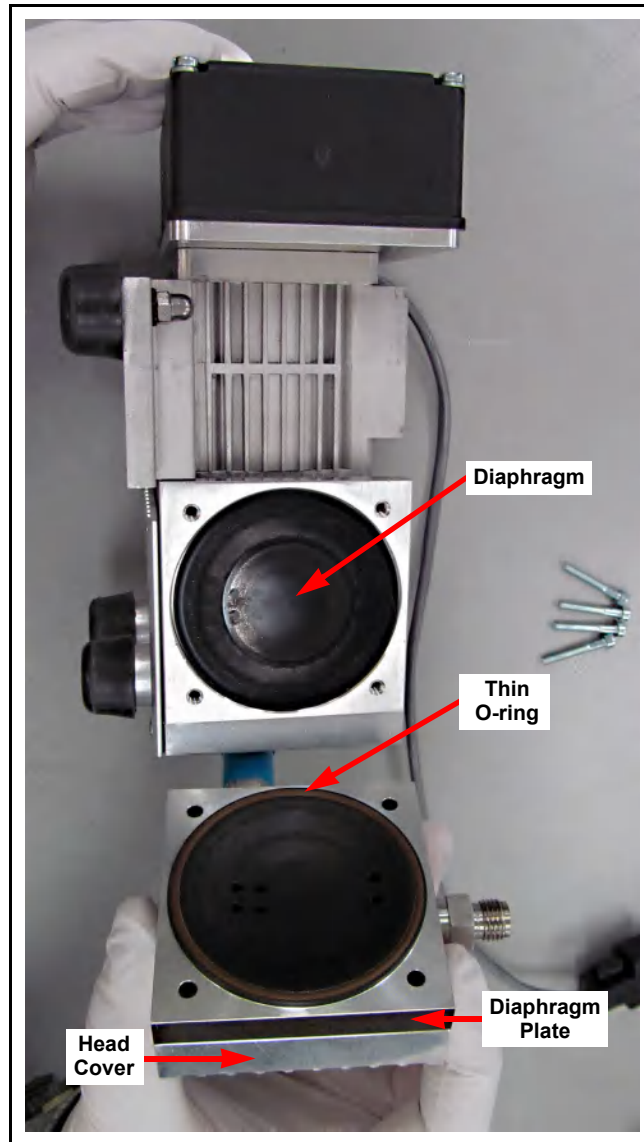
7 Separate the diaphragm plate from the head cover. (See Figure 7-7.)

NOTE: Take note of the orientation of the valves in the head cover and diaphragm plate. They must be reassembled in exactly the same orientation.

Figure 7-7 Diaphragm plate separated from head cover
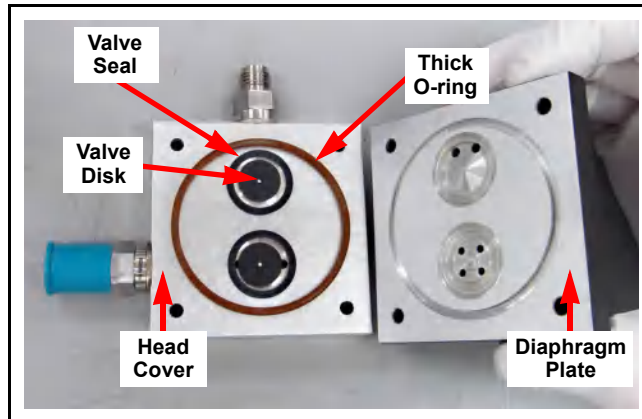
8 Remove the old valve disks, valve seals and O-rings from both sides of the diaphragm plate. (See Figure 7-8.)

Figure 7-8 Removed valve seals, valve disks, and O-rings

Diaphragm Plate
(Valve Side)

Diaphragm Plate
(Diaphragm Side)
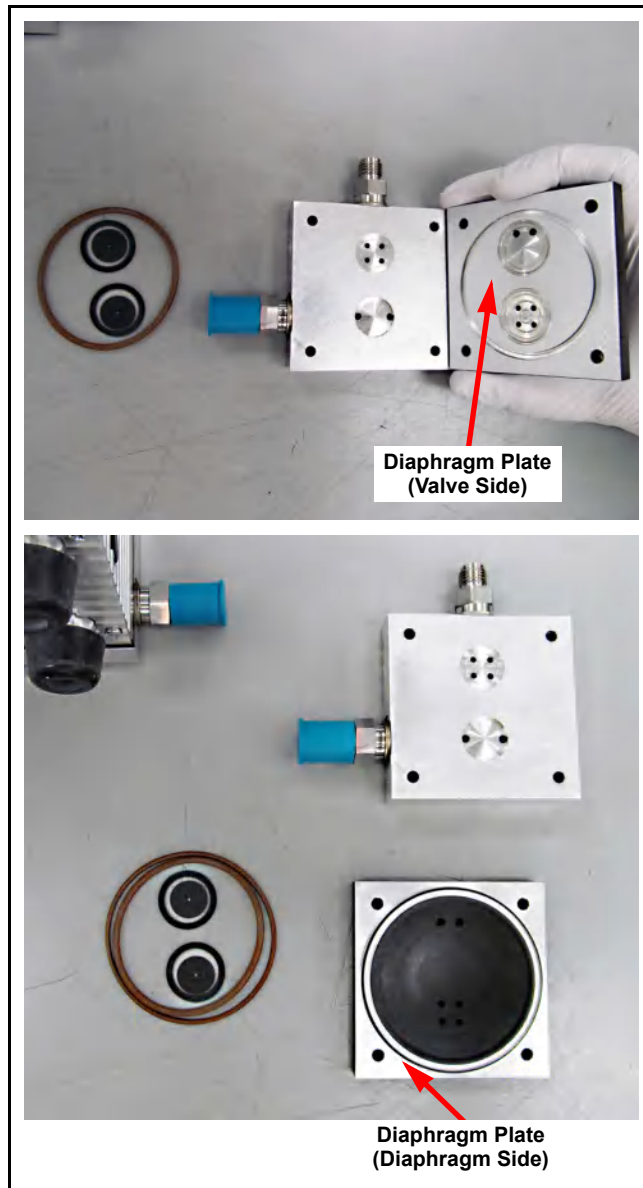
9 Clean both sides of the diaphragm plate and the foreline pump head cover with methanol and lint free wipes. Pay special attention to the sealing surfaces (grooves) inside of the head cover and on either side of the diaphragm plate.

⚠️ **CAUTION**

Read and understand the entire Methanol Material Safety Data Sheet. Follow the precautions specified in the MSDS.

10 Rotate the diaphragm disk counterclockwise to unscrew the diaphragm disk from the cam. If necessary, carefully use a flat head screwdriver to pry up the diaphragm disk. (See Figure 7-9.)

Figure 7-9 Unscrew diaphragm disk

Rotate Counterclockwise
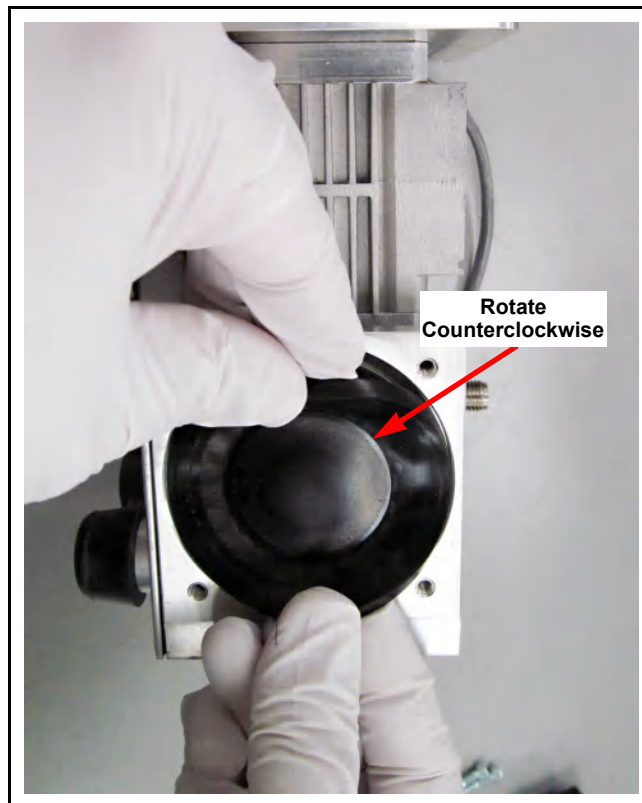
11 There are spacers between the diaphragm disks and the cam. Note the position of the spacers when removing the diaphragm disks. The spacers must be reassembled on the new diaphragm disks in exactly the same position. (See Figure 7-10.)

Figure 7-10 Spacers
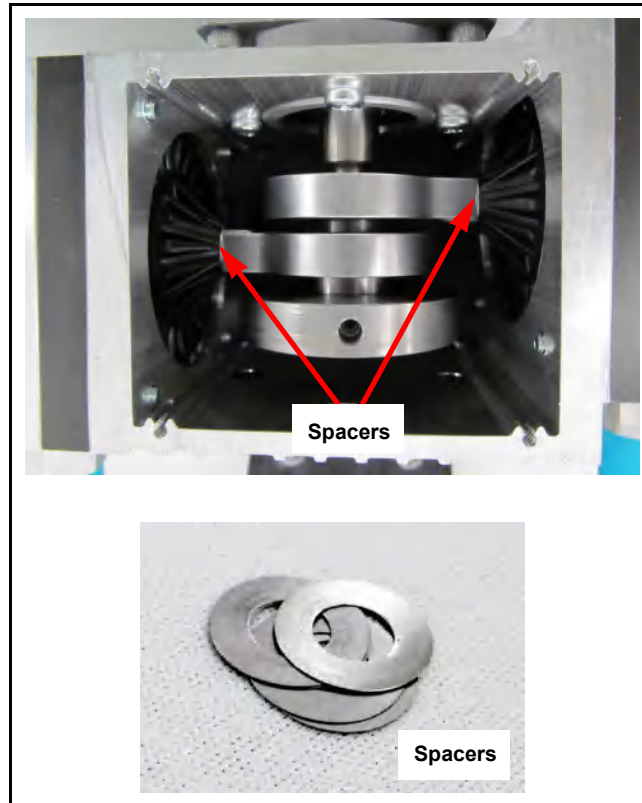
12 Place the original spacers on the new replacement diaphragm in exactly the same order as they were on the old diaphragm. (See Figure 7-11.)

⚠️ **CAUTION**

The spacers, cam, diaphragm disks and electric motor are balanced at the manufacturer for optimal performance. Therefore, one side of the diaphragm may have a different number of spacers than the other in order to achieve balance. To maintain the balance, the original spacers must be transferred to the new diaphragm in exactly the same position as they were when removed from the old diaphragm.

Figure 7-11 Placing original spacers on new diaphragm

13   Clean the channel that the diaphragm disk is seated in with methanol and lint free wipes. (See Figure 7-12.)

14   Screw the diaphragm disk, with original spacers, into the cam screw hole. (See Figure 7-12.)

⚠ **CAUTION**

> **Screw in the diaphragm disk tightly.**
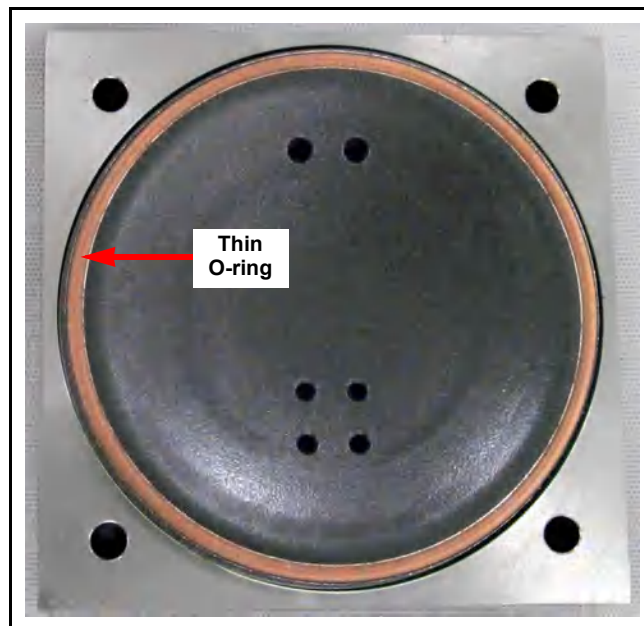> **A loose disk can damage the pump.**

Figure 7-12 Installing the new diaphragm disk
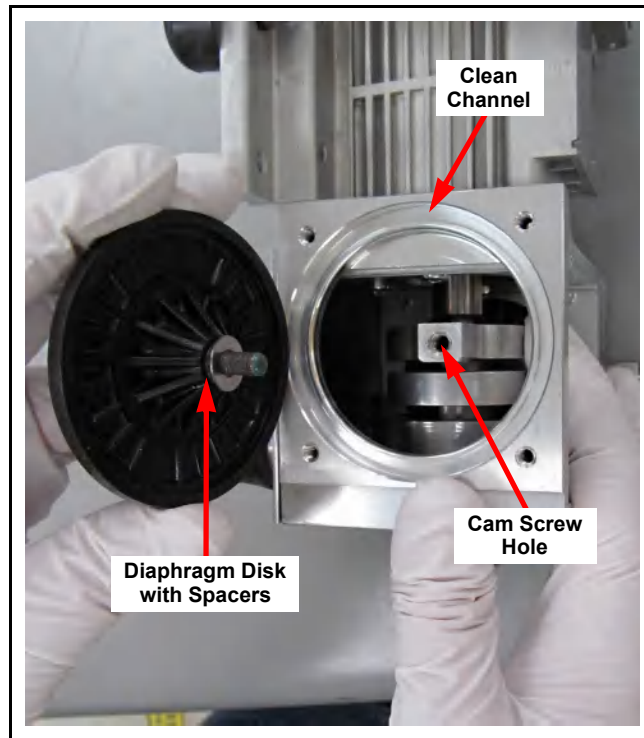
15 Place the thin O-ring into the groove on the diaphragm side of the diaphragm plate. (See Figure 7-13.)

Figure 7-13 Thin O-ring

16 Carefully place the diaphragm plate over the diaphragm head so that the screw holes line up. (See Figure 7-14.)

17 Install the new valve disks, valve seals and thick O-ring onto the diaphragm plate.

18 Install the head cover on the diaphragm plate.

Figure 7-14 Assembling valve disks, valve seals and thick O-ring
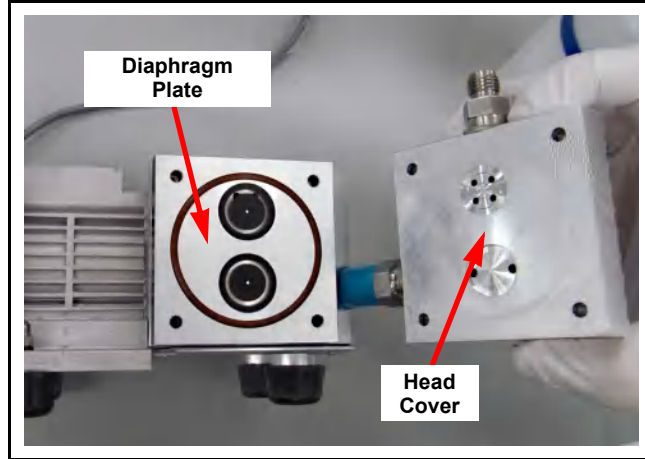
19 Replace four hex screws to secure the head cover.

20 Perform steps 5-19 again for second pump head.

21 Replace the cam cover.

22 Replace the interstage tubing. (See Figure 7-15.)

Figure 7-15 Reassembled interstage tubing
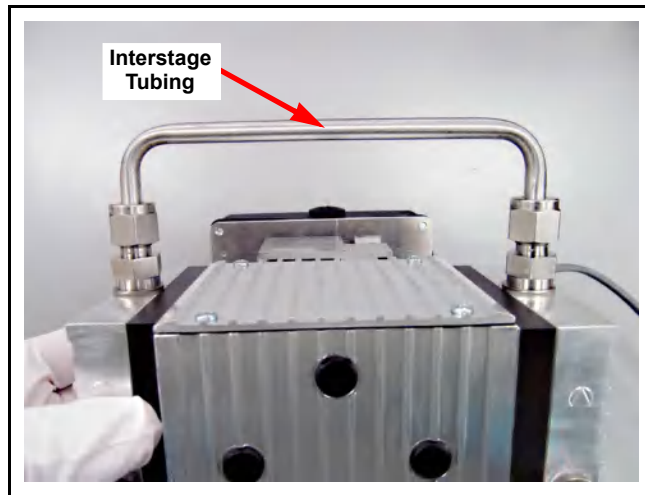
7.7 Transpector Sensor Maintenance

Sensors must be cleaned only by qualified factory personnel. Refer to section 1.4, How to Contact INFICON, on page 1-4 for assistance.

Maintenance of the Transpector CPM sensor is limited to filament, ion source and electron multiplier replacement.

7.7.1 How to Determine if a Filament Kit Replacement is Required

Do these steps to determine if a filament replacement is required.

1 Measure the resistance of the filament while the sensor is under vacuum by measuring the resistance between pins **3** and **10.** (See Figure 7-16). A failed filament will measure open while an intact filament will measure 0.8 Ω.
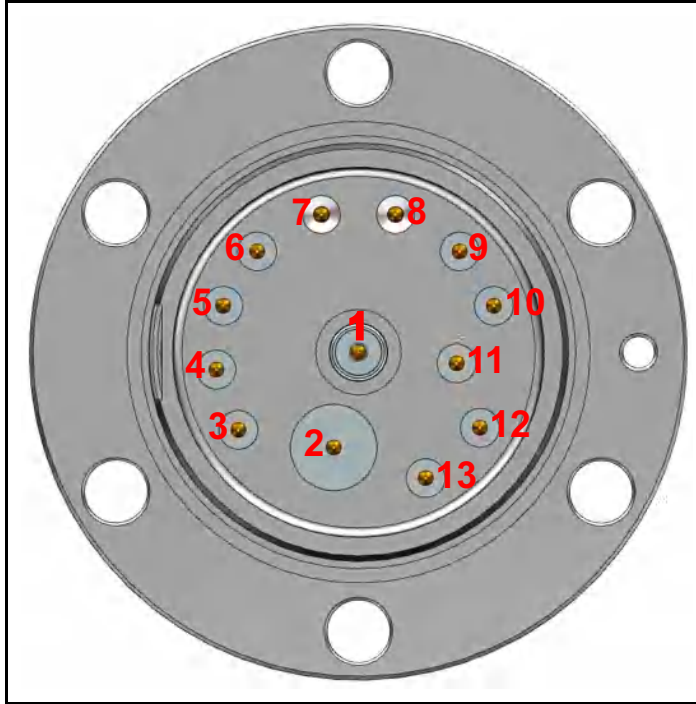
Figure 7-16 Sensor pinout

Table 7-2 Pin assignment

Pin	Assignment	Pin	Assignment
1	PP	8	GND
2	EM HV	9	RF+
3	Filament	10	Filament
4	Reserved	11	Reserved
5	Anode	12	Focus
6	RF-	13	TP
7	GND		

NOTE: Although the following measurements may measure below 30 MΩ with the filament assembly and ceramic shield in place, they must be above 30 MΩ when measured with the filament assembly and ceramic shield removed.

2 Measure the resistance of each of the pins with respect to ground
(pin **7** and **8**). These measurements must be above 30 MΩ.

3 Measure the resistance of each of the pins with respect to each other. All of
these measurements must be above 30 MΩ, with the exception of the
measurement between the filament pins if the filament has not failed.

7.7.2 Transpector Sensor Filament Replacement

1 Remove the ceramic sealing disk (A) by carefully pulling the wire hold downs
(B) away from the edges of the disk and pulling off the sealing disk.

2 Remove spring (C).

3 Remove the filament lead screw (D1), loosen the filament lead screw (D2) and
remove the filament leads (E) from the filament. (See Figure 7-17.)
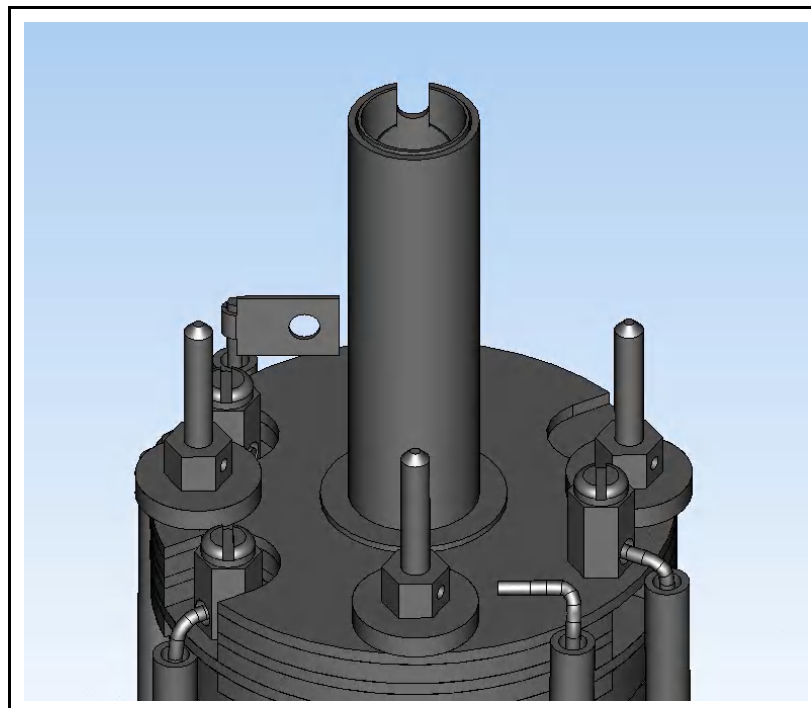
Figure 7-17 Sensor head
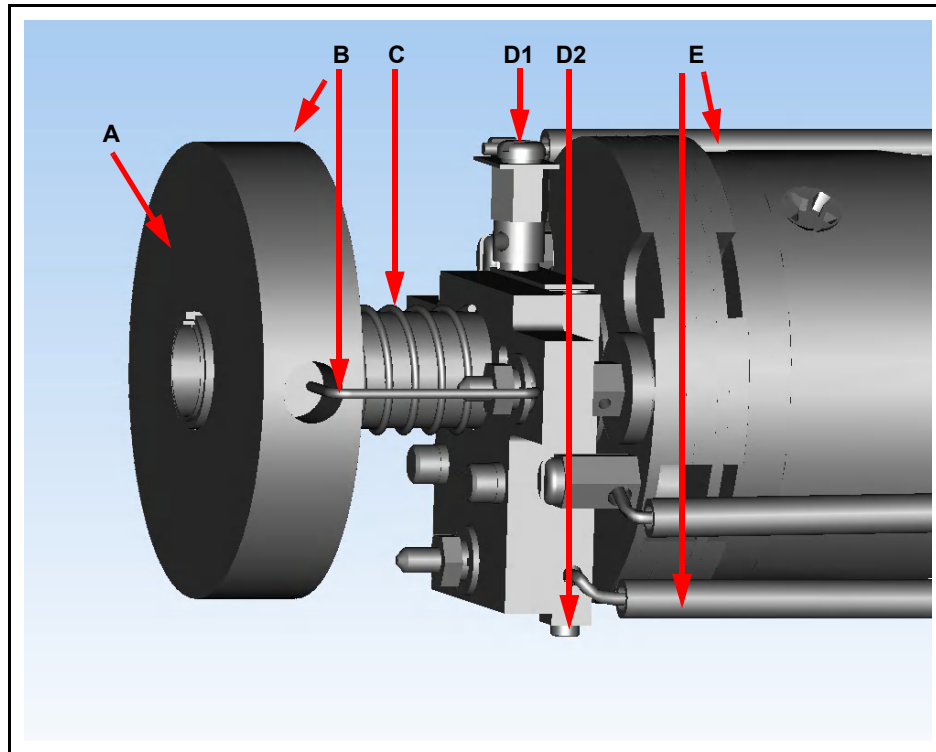
4 Remove three nuts (F) and the washers holding the filament assembly in place. Be careful; do not to lose the two ceramic sealing disk wire hold downs. (See Figure 7-18.)

Figure 7-18 Removing sensor filament assembly
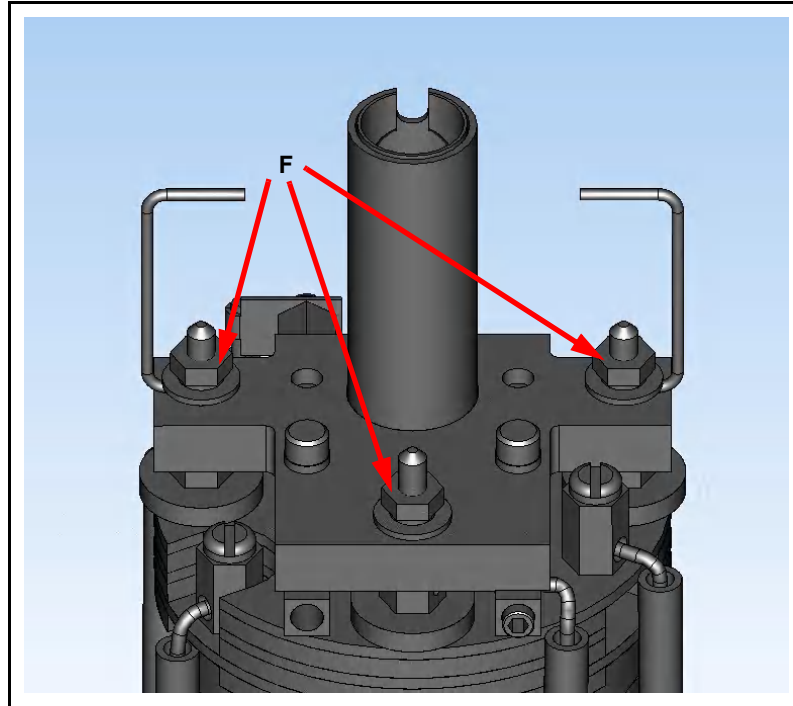
5 Carefully remove the filament assembly. (See Figure 7-19.)

Figure 7-19 Filament assembly removed

6 Remove the three screws holding the filament assembly on the shipping fixture.

7 Carefully remove the new filament from its fixture and place it on the ion source posts.

8 Replace the three filament assembly nuts and washers. Be sure to install the wire hold downs.

> ⚠️ **CAUTION**
>
> **To avoid cracking the ceramic plate, do not overtighten the three nuts.**

9 Reattach the filament leads and tighten the filament lead screws.

10 Reinstall spring and ceramic sealing disk.

7.7.3 Transpector Sensor Ion Source Replacement

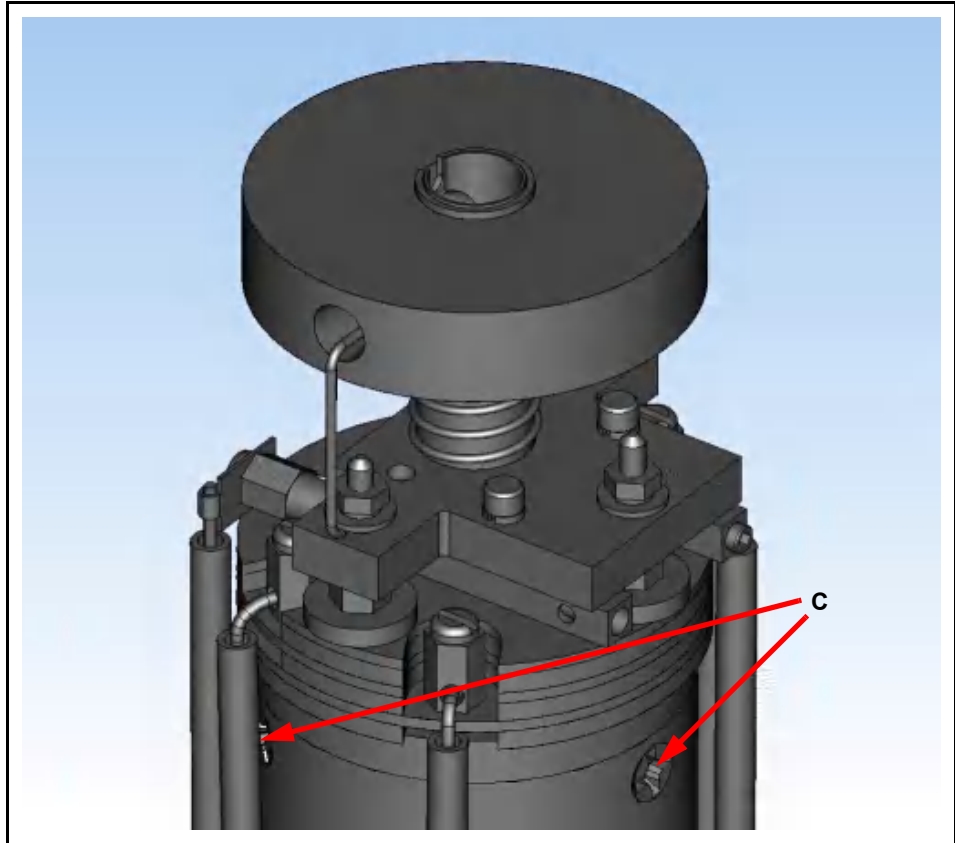**1** Remove filament lead screw (A1), loosen filament lead screw (A2), and loosen the three screws (B) in the ion source lead connectors. (See Figure 7-20.)

Figure 7-20 Filament lead screws (A1, A2) and ion source lead connectors (B)
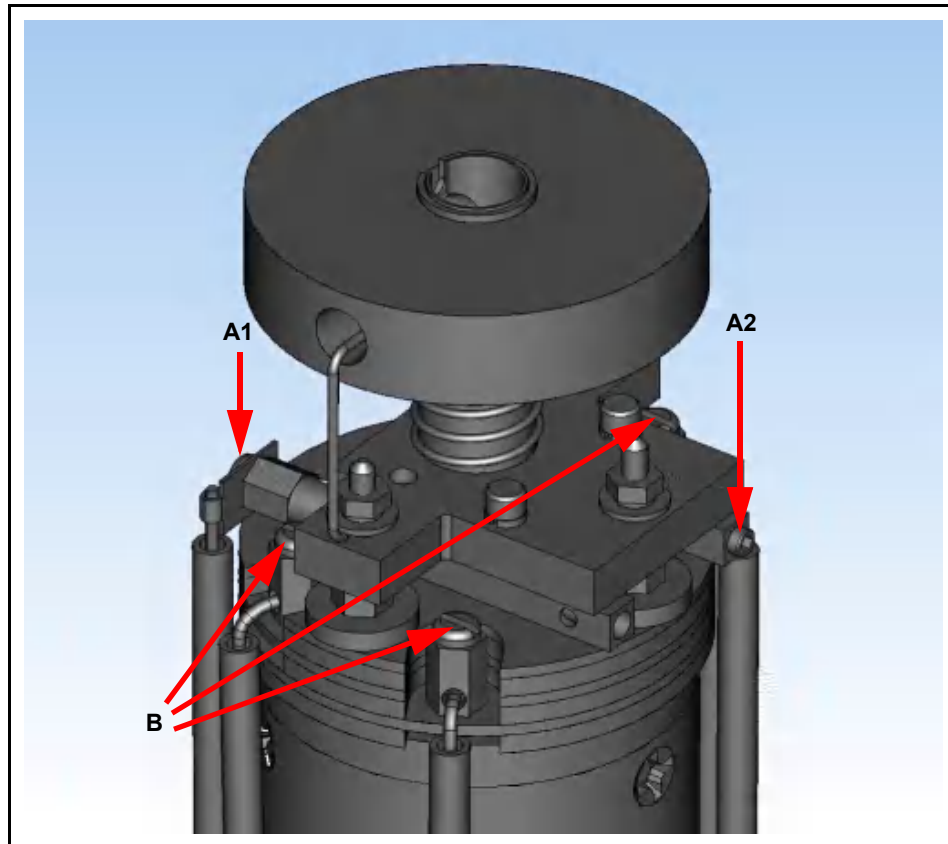
**2** Pull the electrical leads away from the sensor.

3 Remove the three ion source retaining screws (C) around the bottom of the ion source assembly. (See Figure 7-21; one screw is not visible in the figure). They hold the ion source onto the quadrupole assembly.

Figure 7-21 Ion source retaining screws

4 The ion source can now be removed by lifting it off the quadrupole assembly. Install a new ion source by reversing the above steps. (See Figure 7-22.)

Figure 7-22 Ion Source and quadrupole assembly
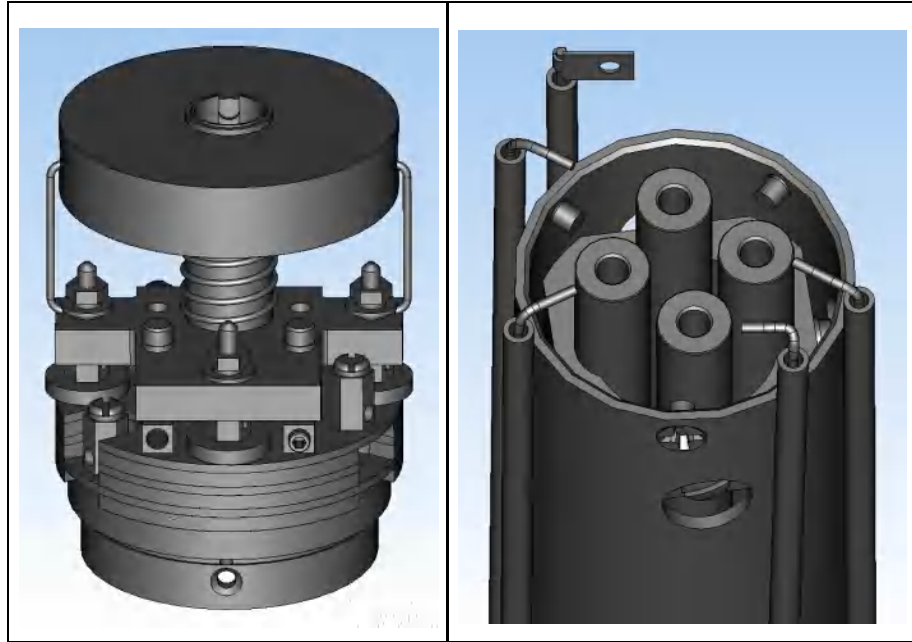
5 Using an ohm meter, check that the filament is not shorted to ground or to any of the ion source plates and that the two filament leads show a filament resistance of approximately 1 Ω at the feed-through (approximately 0.5 Ω at the lead connectors).

7.7.4 Electron Multiplier Replacement

> **NOTE:** Refer to section 7.5.3, Tools for Replacing the Electron Multiplier, on page 7-5 before continuing.

1 Remove filament lead screw (**A1**), loosen filament lead screw (**A2**), and loosen the three screws (**B**) in the ion source lead connectors. Using the 1.5 x 50 mm hex driver, unscrew the screws (**C**) that secure the two RF leads. Make sure to remove the lock washers as well. There are a total of seven leads that must to be loosened. (See Figure 7-23.)

Figure 7-23 Detach leads
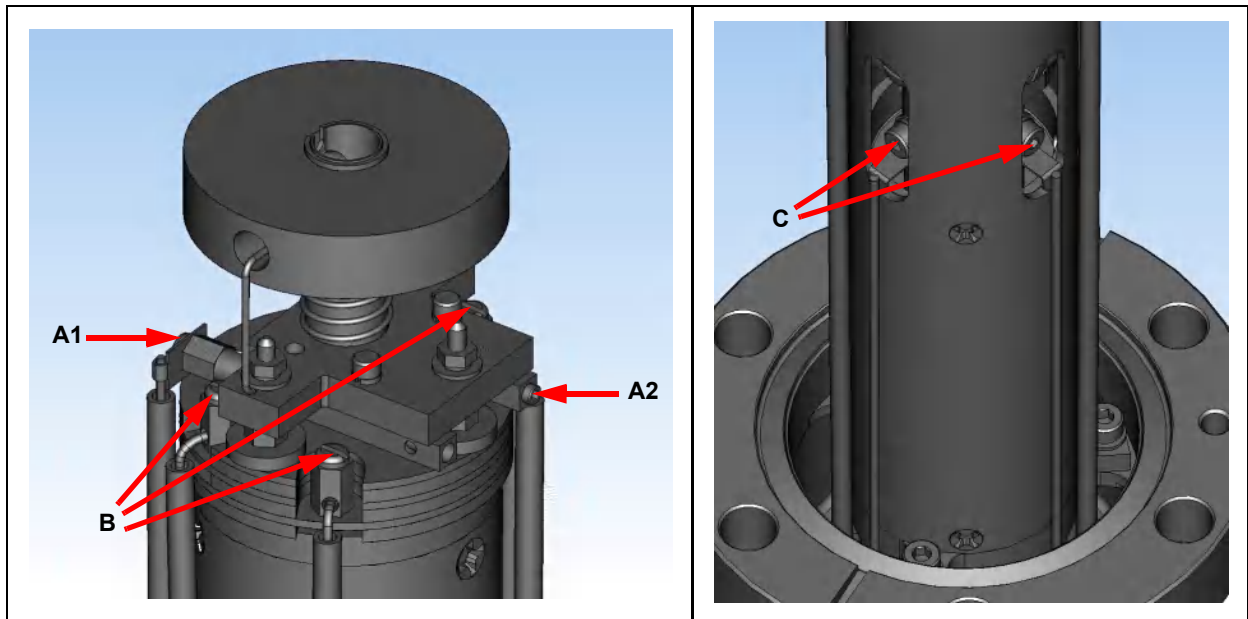
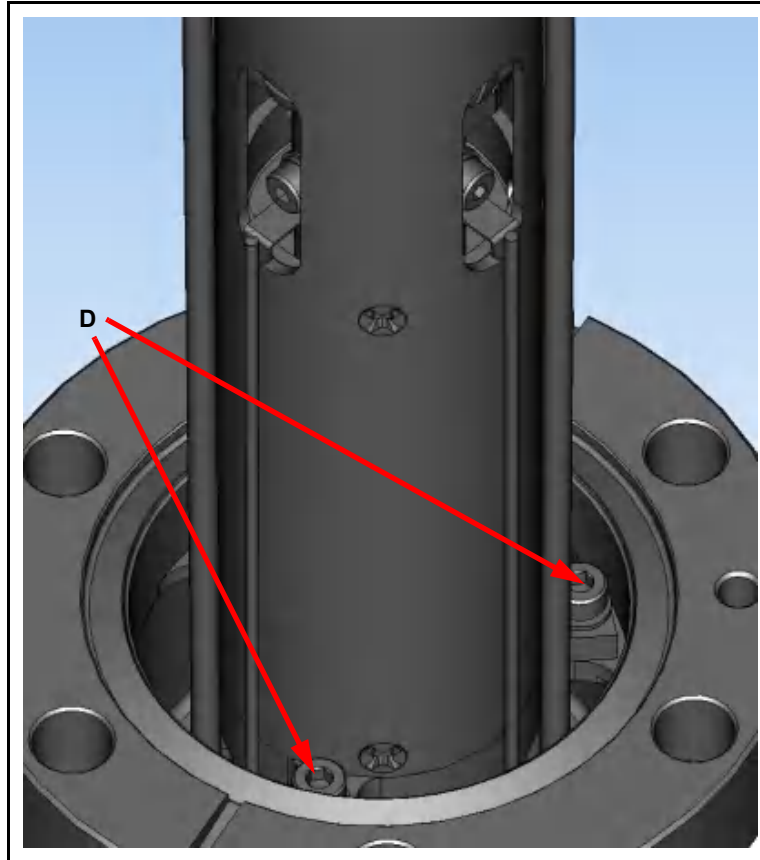**2** Gently pull the electrical leads away from the sensor.

> ⚠️ **CAUTION**
>
> **Do not bend the leads.**

3 Using the 2.0 x 75 mm hex driver, unscrew three screws (**D**; one is hidden in the figure) holding the sensor assembly to the feedthrough. Gently remove the sensor assembly from the feedthrough. (See Figure 7-24.)
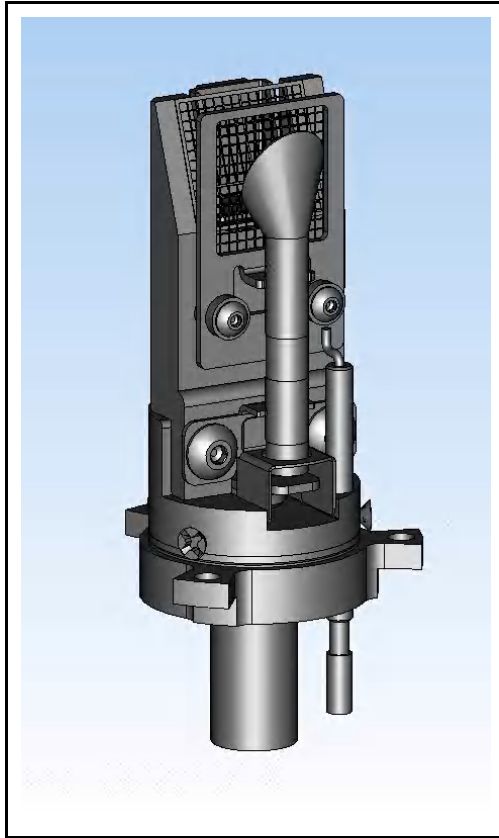
Figure 7-24 Removing the sensor assembly

4 Using the Phillips head screwdriver, remove three gold screws (**E**; one is hidden in the figure) holding the EM assembly inside of the sensor assembly. (See Figure 7-25)

Figure 7-25 Removing the screws holding the EM
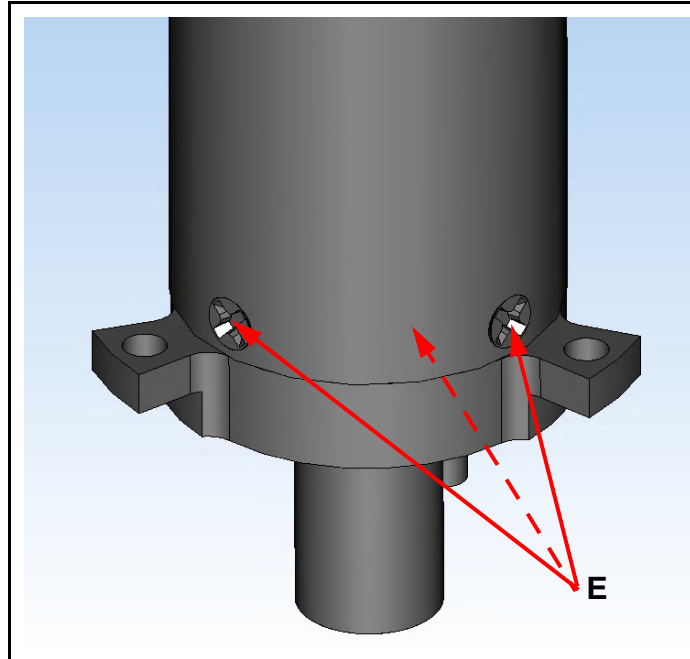
5 Gripping the bottom of the EM assembly, gently remove the EM assembly from the sensor assembly. (See Figure 7-26.)
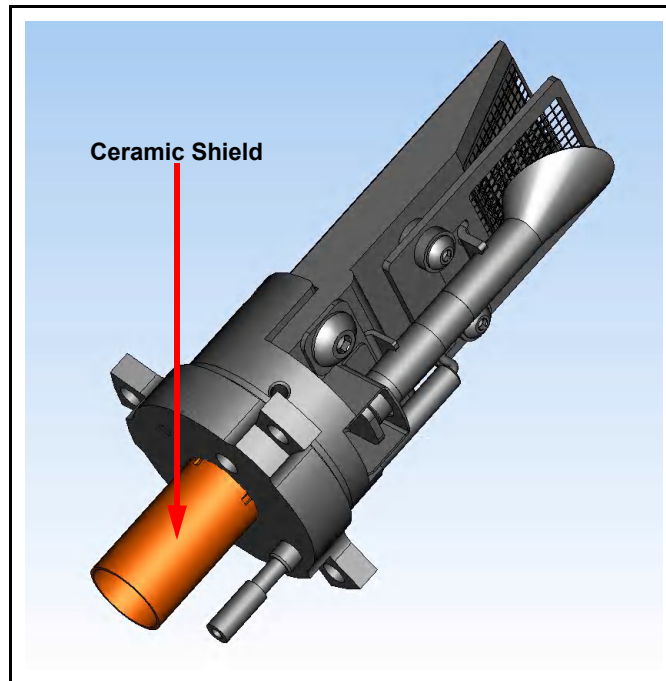
Figure 7-26 EM assembly

6 Remove the ceramic shield on the bottom of the old detector assembly. (See Figure 7-27.)

Figure 7-27 Removing the ceramic shield

7 Install the ceramic shield removed in step 6 onto the new Electron Multiplier assembly.

8 Install the new Electron Multiplier assembly into the sensor can.

9 When installing the sensor back into the feedthrough, ensure that the two pins on the bottom of the detector align with the two pins on the feedthrough. (See Figure 7-28.)

Figure 7-28 Pin location
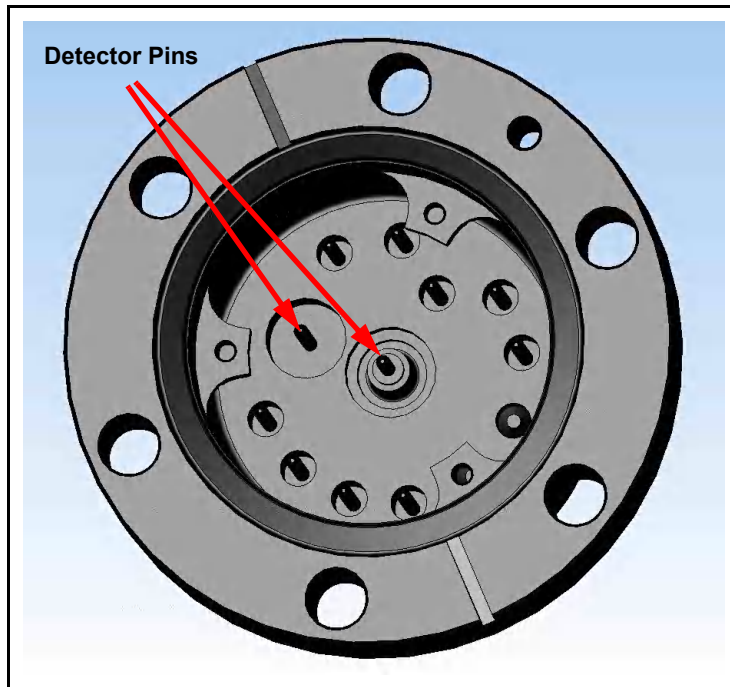
**10** Reverse steps 1-4 to reassemble the Transpector CPM sensor.

7.8 HexBlock Inlet Maintenance
7.8.1 Valve and Orifice Replacement

Under clean operating conditions, the HexBlock valves can operate 1,500,000 cycles before requiring maintenance. Depending on the application and the gases processed, valve and/or orifice replacement may be necessary.

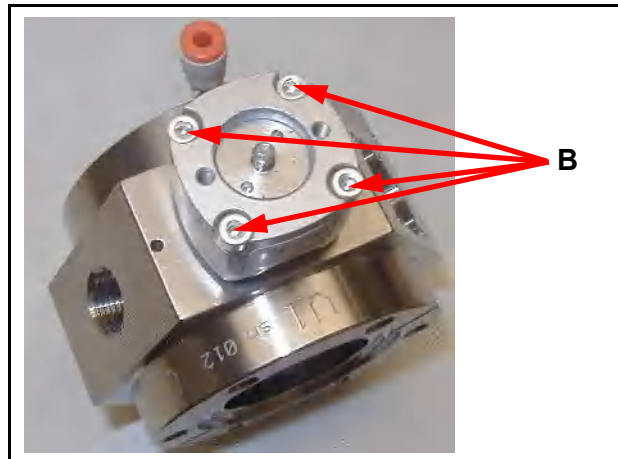**1**   Remove valve cover by loosening two screws (A) with 2.5 mm allen wrench. (See Figure 7-29.)

Figure 7-29 Removal/installation of valve cover
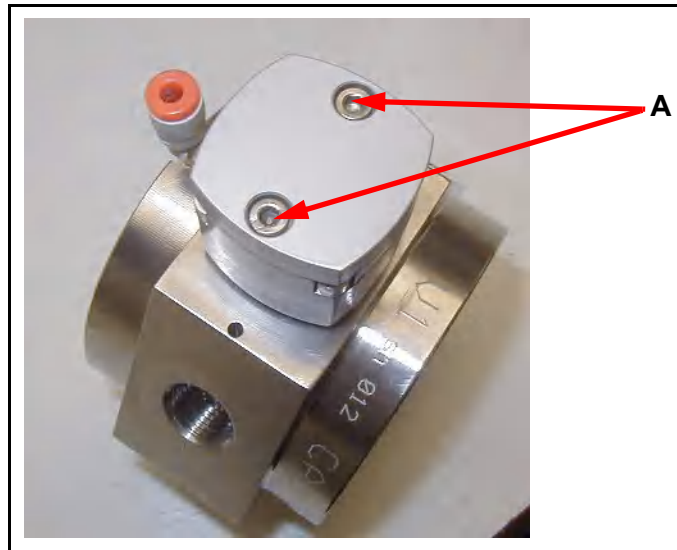
2   Loosen four silver plated screws (B). (See Figure 7-30.)

Figure 7-30 Removal/installation of four silver plated screws

3   Remove the valve.

4   Carefully remove the old C-ring (for HexBlock) or viton O-ring (for foreline block). (See Figure 7-31.)

⚠️ **CAUTION**

Do not scratch the seal surface. The seal surface can be easily damaged by a metal tweezer. Use a nonmetallic tweezer.

Figure 7-31 Removal/installation of C-ring

5 Carefully remove (by turning counterclockwise) the old orifice using the 2 mm allen wrench. (See Figure 7-32.)

⚠️ **CAUTION**

Use only the provided 2 mm allen wrench or similar particle free tool. Other allen wrenches can produce particles that can plug the orifice.

*Figure 7-32 Removal/installation of orifice*

6 Carefully press in place a new orifice gasket onto the new orifice.

7 Install the new orifice using a 2 mm allen wrench. Tighten the orifice to a torque of 3-4 in-lbs (0.34 to 0.45 Nm), or approximately 1/4 turn (clockwise) past finger tight. (See Figure 7-33.)

⚠️ **CAUTION**

Overtightening the orifice may cause damage.

Figure 7-33 Installing a new orifice with orifice gasket
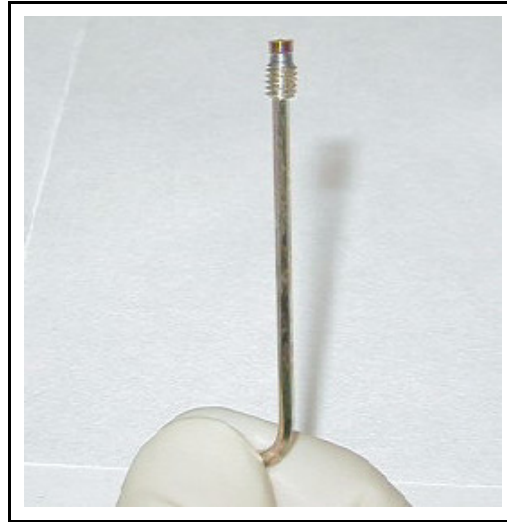
8 Install a new C-ring (HexBlock) or a new O-ring (Foreline Block). (Refer to Figure 7-31.)

9 Install the valve and four silver plated screws. (Refer to Figure 7-30.) The screws must be tightened:

9a Using two fingers, lightly turn one screw until resistance is felt, then back the screw out 1/8 turn. Repeat on the other three screws.

9b Using fingers, evenly tighten all four screws.

9c In 5 in-lb. (0.6 Nm) increments, tighten all four screws to a torque of 20 in-lb. (2.26 Nm).

10 Install valve cover and tighten its retaining screws with 2.5 mm allen wrench. (Refer to Figure 7-29.)

Chapter 8
Diagnosing Problems

8.1 Introduction

Downtime can be reduced by diagnosing problems from observations related to the failure, examining the FabGuard Event Logs, and checking hardware status.

8.2 Communication Problems

To correct communication problems, do the following:

◆ Is the Ethernet cable connected to the Transpector electronics module and the host computer (either directly or through a router/switch)?

◆ Does the Transpector sensor IP address have the same network prefix as the host computer?

◆ Is Port 80 open on the host computer?

◆ Is there an IP address conflict between the Transpector sensor and another network device?

NOTE: Refer to Chapter 3, Connecting Transpector CPM for more information on communications problems.

8.3 CPM Symptom—Cause—Remedy Chart

Before proceeding, make sure that the insulation on all cables is intact. There must be no damage to the insulating material. If there is, replace the cable.

Table 8-1 Symptom—Cause—Remedy Chart

SYMPTOM	CAUSE	REMEDY
CPM will not pump down	Forepump not plugged in	Connect cable to controller
	Control cable missing or bad connection	Check control cable
	Foreline isolation valve not opening	Check valve actuation
	Digital Pressure Switch defective or not within required pressure range	Replace the Digital Pressure Switch
		Verify incoming pneumatic pressure is between 58 and 100 psi
Turbo Molecular Pump does not reach operating speed	Foreline pressure too high due to gas leak or forepump diaphragm failure	Find Leak(s).
		Replace diaphragm. (refer to section 7.6 on page 7-6)
	Turbo Molecular Pump bearing drag excessive	Replace pump
	Foreline pressure too high due to water vapor in foreline hose	Run pumpdown and purge with dry gas
	No pneumatic pressure applied to the foreline valve	Check supply and connections to the foreline block valves
Turbo Molecular Pump is noisy	Bearing failure	Replace pump
Diaphragm Pump is noisy	Loose Diaphragm	Tighten Diaphragm
Analyzer pressure high with sampling valves closed	Leaks in manifold or orifices	Tighten or replace gaskets
	Seat leaks to process gas	Replace seat or valve

Table 8-1 Symptom—Cause—Remedy Chart (continued)

SYMPTOM	CAUSE	REMEDY
Process valve(s) don't open	Low air pressure	Check air pressure
	Leaks in air lines	Listen/check for leaks
Water vapor high in background mass spectrum	Exposure to air or water in process	Bake out manifold and Inlet to 150 °C for 8 hours. Check for water after cool down
Power indicator on controller does not illuminate	+24 V controller internal power supply	Check input AC line voltage to external power supply
		Check +24 V input, verify input range 20–30 V
		Replace power supply
	Controller electronics failure	Return controller to INFICON for repair
Power Indicator on Transpector cable box does not illuminate	Controller is not on	Refer to section 2.2.1, Attach Transpector Electronics Module, on page 2-2
	CPM control cable is disconnected	Check control cable at controller end and at cable box end
No communication to HOST computer	Sensor IP address not compatible with network	Refer to Chapter 3, Connecting Transpector CPM
	Transpector Communications port (port 80) is not open on the host computer	Open port 80 on the host computer or change the communications port of Transpector CPM
	Cable connections	Make sure cables are connected to proper connectors
	Host computer Ethernet malfunction	Replace Ethernet Card on host computer

Table 8-1 Symptom — Cause — Remedy Chart (continued)

SYMPTOM	CAUSE	REMEDY
EMISSION error (Cold Start, Warm Start)	Defective sensor filament open, or shorted	Check sensor with OHM meter
		Replace sensor or filament
	Electronics failure	Return to INFICON for repair
	Pressure too high at ion source	Verify ion source pressure is less than 5E-4 Torr
	Sensor Operating voltages incorrect	Verify correct settings. Contact INFICON for assistance
	Transpector CPM electronics module not fully engaged on sensor	Make sure that the Transpector CPM electronics module is pushed completely on sensor
	Cable box not fully seated on Transpector electronics module	Ensure cable box is fully seated on Transpector electronics module
ANODE error	Defective sensor, anode shorted	Check sensor with Ohm meter for shorts. See sensor pin-out diagram
		Fix or replace sensor
	Electronics failure	Return to INFICON for repair
RF error	Defective sensor, RF leads open	Fix or replace sensor
	Electronics failure, RF/DC card fault	Return to INFICON for repair

Table 8-1 Symptom—Cause—Remedy Chart (continued)

SYMPTOM	CAUSE	REMEDY
Electron Multiplier error	Defective sensor, EM shorted	Check sensor with Ohm meter. See sensor pin-out diagram
		Fix or replace sensor
	EM just replaced	Verify that EM is plugged into the HV pin properly
	Electronics failure	Return to INFICON for repair
Temperature error	Transpector CPM internal ambient temp >70°C	Verify unit is installed properly, ambient temp <50°C
		Verify that there are no heat sources in local proximity
		Verify that the internal fan is providing adequate airflow
	Electronics failure	Return to INFICON for repair
Overpressure	Total Pressure Plate current exceeded trip threshold	Reduce pressure at the ion source to less than 5E-4 Torr
	Total Pressure plate is contaminated	Replace ion source
	Process pressure too high for sampling orifice	Reduce process pressure
		Install proper orifice for process pressure
Electrometer error	Excessive current (>2E-6 Amps)	Reduce Pressure at the ion source
		Reduce EM voltage
	Electronics failure	Return to INFICON for repair.

Table 8-1 Symptom—Cause—Remedy Chart (continued)

SYMPTOM	CAUSE	REMEDY
Mass filter error	Bad tune file	Retune RGA
	Contaminated quadrupole	Return to INFICON for repair
Ion source error	Incorrect ion source settings	Load original configuration file
	Ion source contaminated	Replace ion source
Detector error	EM voltage set too high	Reduce EM voltage
	Detector not working correctly	Replace EM detector
DSP communications error	Incorrect DSP response detected	Reset electronics module
		Return electronics module to INFICON for repair.
DEC Communications Error	Incorrect DEC response detected	Reset electronics module
		Return electronics module to INFICON for repair
Peakfind Error	No peak at target mass	Upload original configuration file
		Return electronics module to INFICON for repair
Filament potential error	Insufficient vacuum	Verify pressure is less than 5E-4 Torr at the ion source
	Filament broken	Verify integrity of filament
	Filament shorted	Verify that filament is not shorted to ground
	Cable box not fully seated on Transpector electronics module	Ensure Cable box is fully seated on Transpector electronics module

Table 8-1 Symptom—Cause—Remedy Chart (continued)

SYMPTOM	CAUSE	REMEDY
Filament current error	Insufficient vacuum	Verify pressure is less than 5E-4 Torr at the ion source
	Filament broken	Verify integrity of filament
	Filament shorted	Verify that filament is not shorted to ground
	Cable box not fully seated on Transpector electronics module	Ensure Cable box is fully seated on Transpector electronics module
Focus error	Unable to start or maintain focus voltage	Reset Electronics module
		Return electronics module to INFICON for repair
No spectra	Emission is OFF	Turn Emission ON
	EM is ON, when operating	Turn EM OFF
	Contaminated sensor	Degas, or service sensor
		Replace sensor
	Electronics Failure	Return to INFICON for repair
	Pressure too low for FC	Use EM detector
	EM voltage too low	Increase voltage
	Transpector CPM electronics module not fully engaged on sensor	Make sure that the Transpector CPM electronics module is pushed completely on sensor
	Mass calibration	Adjust mass calibration

Table 8-1 Symptom—Cause—Remedy Chart (continued)

SYMPTOM	CAUSE	REMEDY
Poor sensitivity	Sensor contaminated	Degas sensor
		Bake-out sensor
		Replace ion source
	Ion source pressure too low	Increase process pressure, if possible
		Verify orifice is not blocked and replace orifice if necessary
	Mass calibration (resolution)	Adjust Mass Calibration, increase peak width
	Sensor operating parameters set wrong	Check settings of: electron energy, ion energy, focus emission current
	Improper calibration	Ensure that the total pressure gauge used for sensitivity calibration was properly calibrated
	Electronics failure	Return to INFICON for repair
	EM has low gain	Replace sensor or EM
Poor peak shape	Sensor contaminated	Degas sensor
		Bake-out sensor
		Service sensor
	Ion source pressure too high	Verify pressure is less than 5E-4 Torr at the ion source
	Mass calibration required	Perform mass calibration
	Electronics failure	Return to INFICON for repair

Table 8-1 Symptom—Cause—Remedy Chart (continued)

SYMPTOM	CAUSE	REMEDY
High noise level	System grounding	Verify that vacuum system is grounded
	Electronics failure	Return to INFICON for repair
	Transpector CPM electronics module not mounted properly on sensor	Ensure the Transpector CPM electronics module is fully seated on sensor
	EM defective.	Replace EM assembly or sensor.
	Scan speed too fast for gain setting.	Increase dwell time.

8.4 If You Cannot Resolve Your Problem

Contact INFICON. (Refer to .)

8.5 Event Log Files

FabGuard Explorer software records Errors and Events with time of occurrence for each day of operation, providing a chronology of operations that can be useful in diagnosing problems. See FabGuard Explorer Operating Manual (PN 074-528-P1) for additional information.

Chapter 9
Recommended Parts List

9.1 Ordering Information

To contact INFICON order services regarding Transpector CPM, please use the following contact information:

INFICON, Inc.
Two Technology Place
East Syracuse, NY 13057
USA
Tel: +315.434.1100
E-mail: reachus@inficon.com

9.2 CPM Consumable Parts

The following consumable parts should be readily available.

Table 9-1 Consumables

Part Number	Description
059-196	4-VCR gasket
059-0400	Replacement c-ring
070-1042	Viton O-ring (V4 only)
923-706-G6	10 mTorr HexBlock orifice with gasket
923-706-G8	15 mTorr HexBlock orifice with gasket
923-706-G5	100 mTorr HexBlock orifice with gasket
923-706-G7	360 mTorr HexBlock orifice with gasket
923-706-G4	1 Torr HexBlock orifice with gasket
923-706-G9	3 Torr HexBlock orifice with gasket
923-706-G3	10 Torr HexBlock orifice with gasket
923-706-G10	30 Torr HexBlock orifice with gasket
923-707-G3	7 Torr HexBlock sniffer kit (30.5 cm length)
923-707-G1	10 Torr HexBlock sniffer kit (5 cm length)
923-707-G2	100 Torr HexBlock sniffer kit (5 cm length)

Table 9-1 Consumables

Part Number	Description
922-204-G1	1.5 m capillary assembly kit
922-204-G3	3 m capillary assembly kit
923-706-G8	Bypass orifice kit

9.3 Preventative Maintenance Parts

The following preventative maintenance kits should be readily available.

Table 9-2 Preventative maintenance kits

INFICON Part Number	Description
923-712-G1	Spare HexBlock Orifice Gaskets (pack of five)
923-711-G1	HexBlock Valve Replacement Kit
923-710-G1	HexBlock Orifice Replacement Tools
964-710-G1	CPM Tungsten Filament Kit
964-710-G2	CPM Coated Filament Kit
964-711-G1	CPM Tungsten Ion Source Kit
964-711-G2	CPM Tungsten Ion Source Kit with Anode Liner
964-712-G1	CPM Coated Ion Source Kit
964-712-G2	CPM Coated Ion Source Kit with Anode Liner
923-418-G1	Replacement Diaphragm Kit for Two-Stage Pump

9.4 Replacement Spare Parts

The following spare parts should be readily available.

Table 9-3 Replacement spare parts

INFICON Part Number	Description
964-403-P1	CPM Manifold Heater
059-0400	Replacement C-ring
032-0079	Turbo Molecular Pump (with CF40 flange)
923-403-P2	CPM Valve Block
964-208-G11	1 Torr CPM CDG
964-208-G12	10 Torr CPM CDG
964-208-G13	100 Torr CPM CDG
964-208-G14	1000 Torr CPM CDG
964-230-G1	CPM Cable Box Assembly
923-417-G1	Foreline Check Valve Kit

Chapter 10
FabGuard Explorer Operation

10.1 Operation (FabGuard Explorer)

Transpector CPM can be operated by any version of FabGuard gas analysis software. This chapter provides information on how to use FabGuard Explorer to operate the Transpector CPM Gas Analysis System.

FabGuard Explorer uses a bin to collect a specific piece of data. Bins collect selected masses (e.g., 2, 4, 18, 28) as opposed to collecting an entire range of masses (e.g., analog scan from 2 to 28, where each mass is collected for every scan).

10.2 Introduction

FabGuard Explorer software operates under Windows 7 and Windows 8.

FabGuard Explorer provides valve control through recipes, manual control of components, and status information. It provides basic residual gas analyzer features, including trend analysis, bar graph, leak check, and analog/selected peak modes. Process monitoring includes recipe generation, automated data collection, norm generation, and process deviation.

NOTE: Additional information concerning FabGuard Explorer is located in the *FabGuard Explorer Operating Manual*, PN 074-528-P1.

This chapter assumes that the Transpector CPM Gas Analysis System is properly installed, and FabGuard Explorer software is installed and running on the computer intended to control the Transpector CPM Gas Analysis System.

10.3 Connecting to Transpector CPM

1 Click **Start** and select **FabGuard Explorer**.

2 When FabGuard Explorer is opened for the first time, the message shown in Figure 10-1 will display.

Figure 10-1 Transpector connection prompt
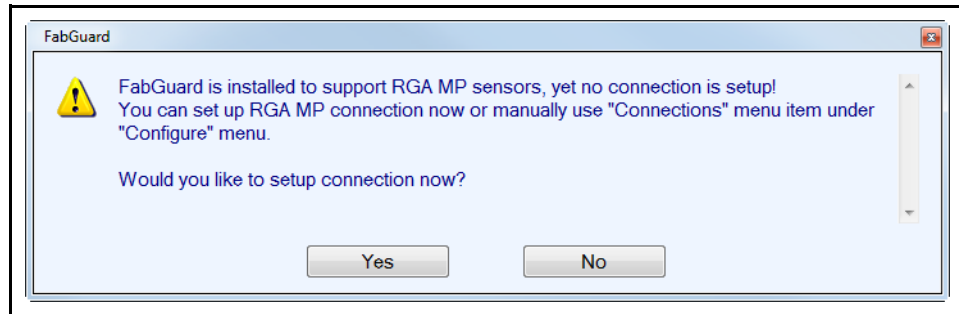
3 Click **Yes**.

4 The **Connection Type** message is displayed. Select MP RGA HTTP as the connection type and Click **OK.** (See Figure 10-2.)

Figure 10-2 Transpector connection type
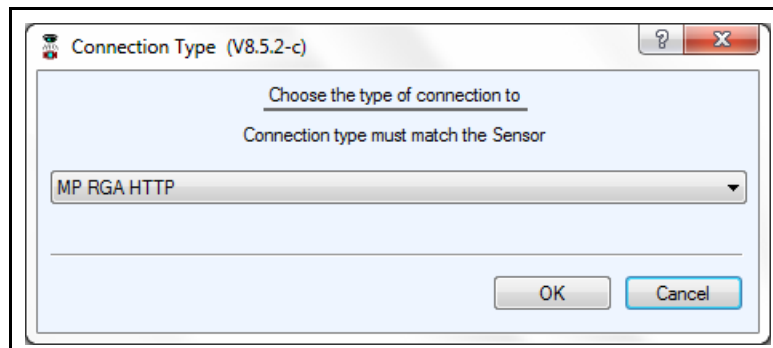
5 The **TCP/IP** dialog box will open. To add a sensor, click **Add** and select **RGA MPx**.(See Figure 10-3.)

Figure 10-3 Transpector connections menu
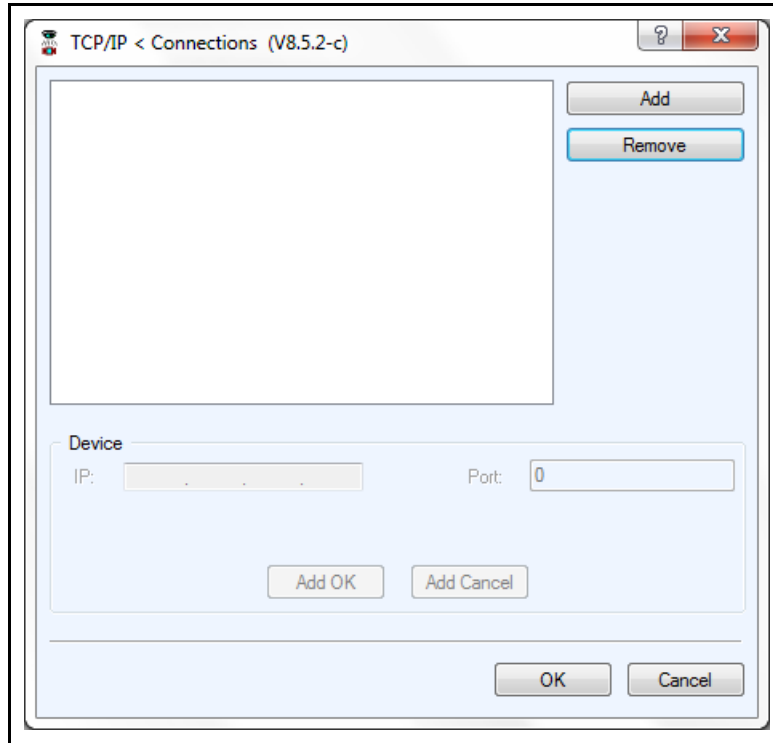
6 In the **Device** pane, Type the Transpector IP address in the **IP** box. (See Figure 10-4.)

7 Type the port number in the **Port** box

8 Click **Add OK**.

Figure 10-4 Device IP address
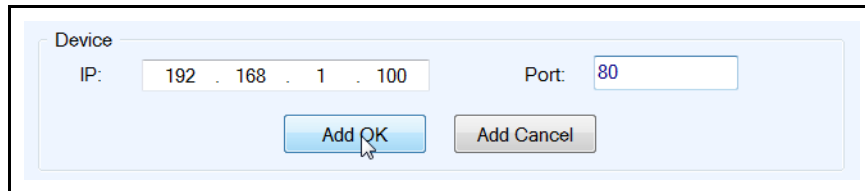
NOTE: Transpector MP sensors ship with a default IP address of **192.168.1.100** and a default Port of **80**. If this IP address is not compatible with your network, the IP address can be changed using the INFICON Mass Spectrometer Search Utility.

9 Click **Add OK**.

10.4 RGA Configuration—CPM tab

The Transpector CPM system must be configured before use. This section explains the **CPM** tab in detail (See Figure 10-5.), but not the additional tabs in the **RGA Configuration** window. Additional information is located in the *FabGuard Explorer Operating Manual* (PN 074-528-P1).

Figure 10-5 RGA Configuration: CPM tab
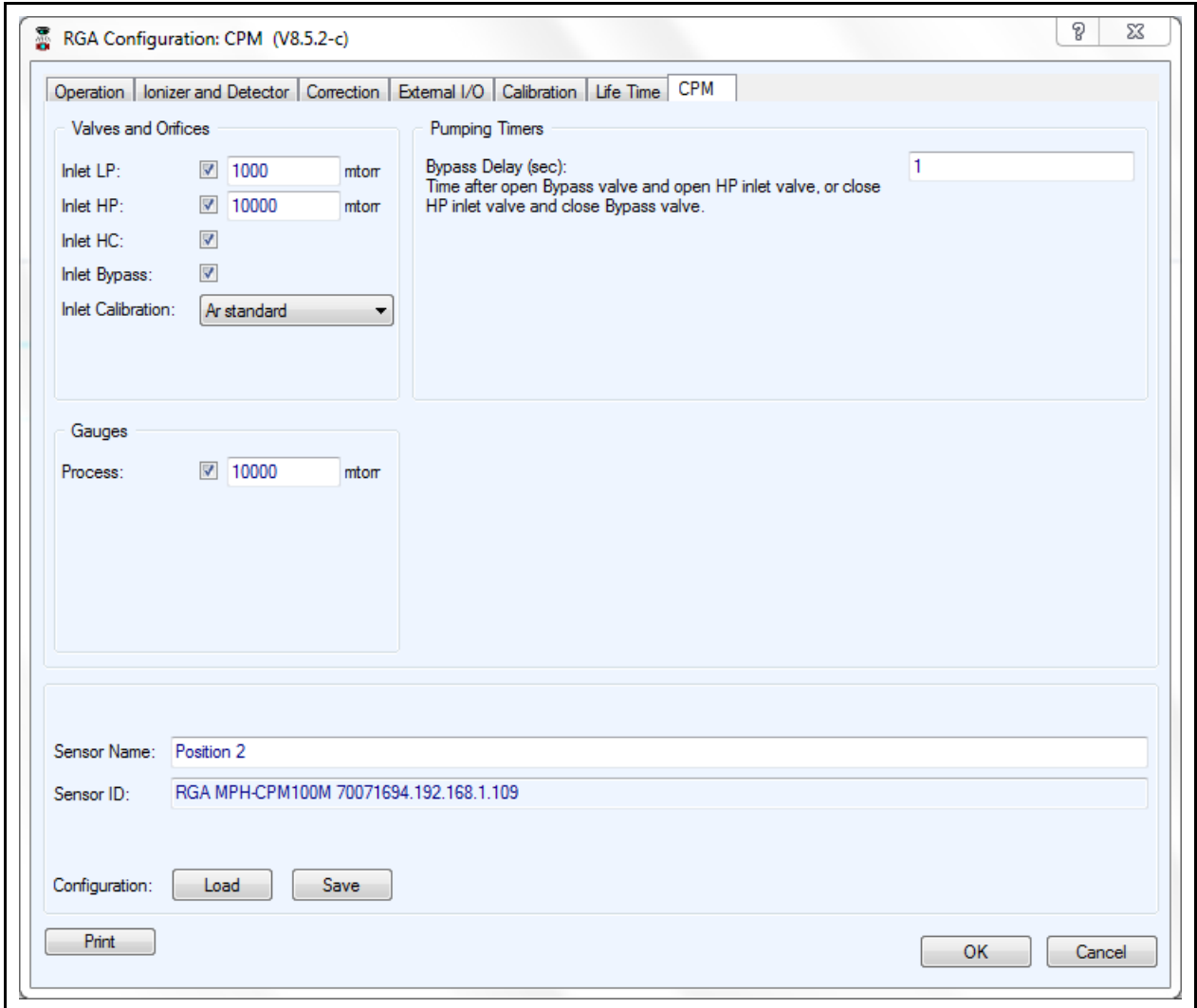
10.4.1 Valves and Orifices pane

Orifices in the HexBlock inlet system are replaceable. Transpector CPM is set up in the factory with the correct valve and orifice values. However, if a valve or orifice is changed, the new configuration must be entered in the RGA Configuration.

10.4.1.1 Inlet LP

Defines the size of the orifice in the V1 Low Pressure (LP) valve. (See Figure 10-6.)

◆ Enter the pressure for the orifice currently installed in V1. Note that the scale is in millitorr.

◆ If no orifice is installed in V1, clear the check box.

Figure 10-6 Inlet LP

| Inlet LP: | ☑ | 1000 | mtorr |

10.4.1.2 Inlet HP

Defines the size of the orifice in the V2 High Pressure (HP) valve.

◆ Enter the pressure for the orifice currently installed in V2. Note that the scale is in millitorr.

   ◆ If using a sniffer, enter the appropriate sniffer pressure range.

   ◆ If using an atmospheric CPM, enter 760000 millitorr.

◆ If no orifice is installed in V2, clear the check box.

Figure 10-7 Inlet HP
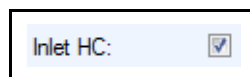
| Inlet HP: | ☑ | 10000 | mtorr |

10.4.1.2.1 Inlet HC

If the V3 High Conductance (HC) valve is installed, select the box check.

Figure 10-8 Inlet HC
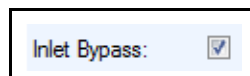
| Inlet HC: | ☑ |

10.4.1.2.2 Inlet Bypass

If the V4 Bypass valve is installed, select the check box.

Figure 10-9 Inlet Bypass

| Inlet Bypass: | ☑ |

10.4.1.2.3 Inlet Calibration

Defines the V5 Calibration valve.

- ◆ If a standard calibration gas is installed, select **Ar standard**.

- ◆ If a high mass tuning reference gas is installed, select **FC5311 standard**.

- ◆ If V5 is not installed, select **No Valve**.
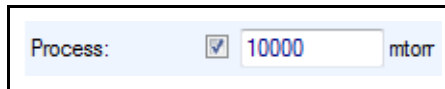
Figure 10-10 Inlet Calibration

10.4.2 Gauges pane

10.4.2.1 Process Gauge

The Transspector CPM includes an optional CDG (capacitance diaphragm gauge).

- ◆ If the CDG is installed, enter its appropriate pressure range. Note that the scale is in millitorr.

- ◆ If the CDG is not installed, clear the check box.

Figure 10-11 Process gauge

10.4.3 Bypass Delay - Interlock between V2 and V4

Bypass Delay defines the interlock between V2 (HP) and V4 (Bypass) valves. The time entered (in seconds) determines:

1 How long the V4 (Bypass) valve will be open before the V2 (HP) valve will be opened

2 How long the V4 (Bypass) valve will remain open after the V2 (HP) valve has been closed.

This interlock between V4 (Bypass) and V2 (HP) is only active when using V2 (HP) in recipes. When opening V2 (HP) in Configuration monitor, this interlock is not active.

Figure 10-12 Pumping Timers pane
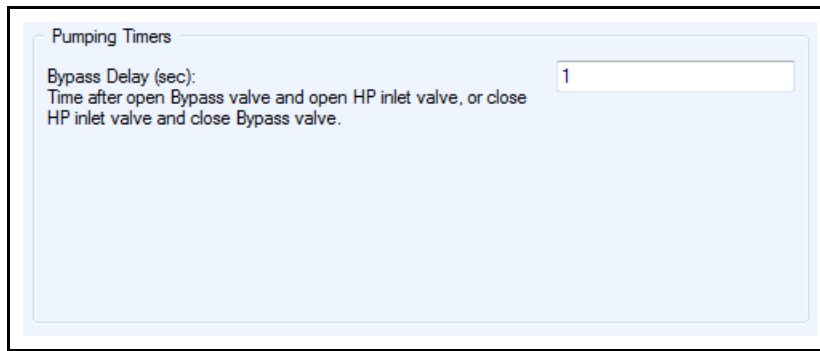
10.5 CPM Configuration Monitor

The **Configuration Monitor** allows experimentation to determine the combination of data acquisition parameters that provide the most appropriate runs. Data acquisition parameters can be changed and the effect of the change is displayed.

NOTE: The CPM **Configuration Monitor** window is different from the open ion source instruments' **Sensor** window because of the pumping and inlet systems on the CPM.

Figure 10-13 Transpector CPM configuration monitor
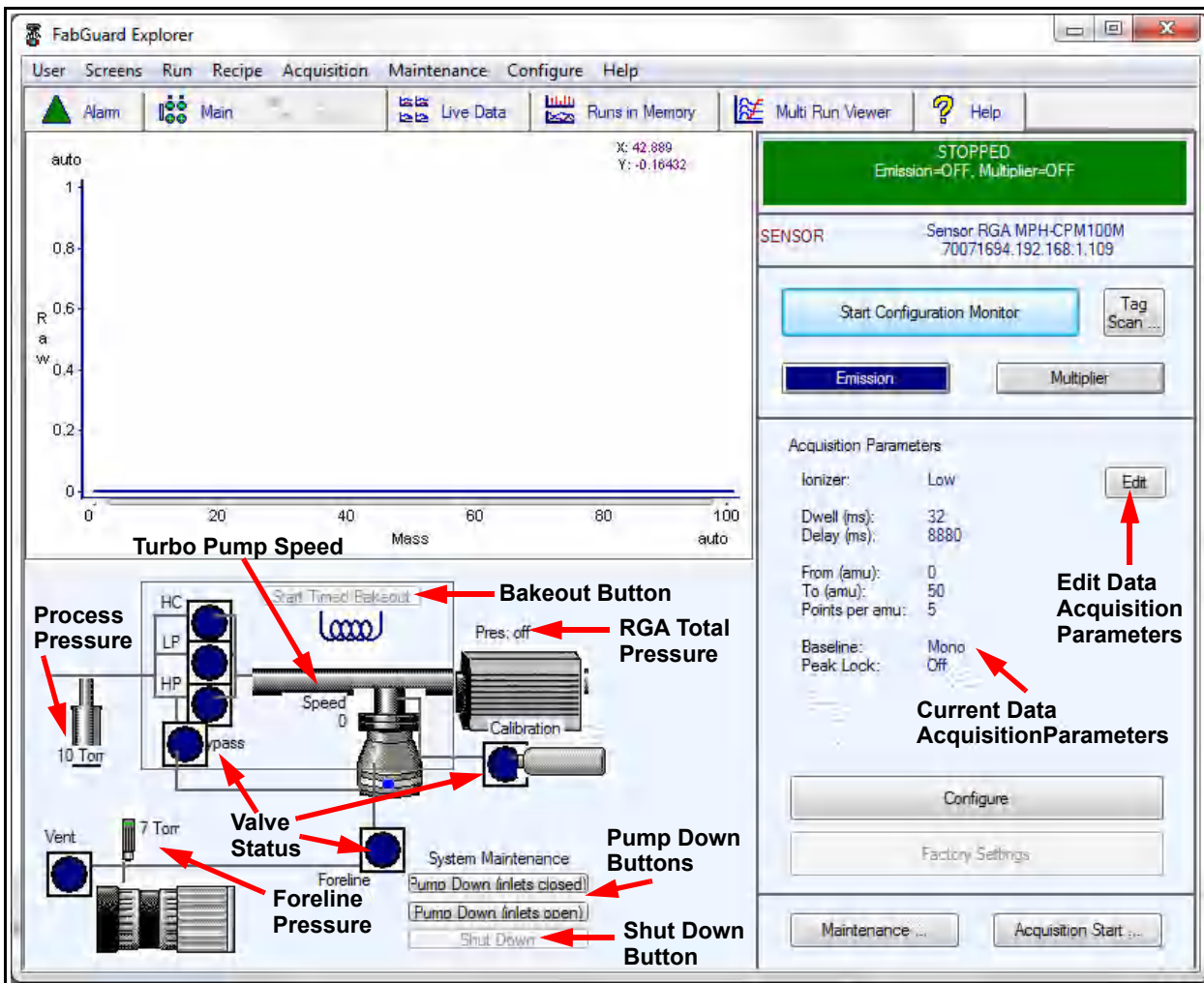
1 Pump down the system.

1a Click **Pump Down (inlets closed)** to start the foreline and turbo pumps and open the foreline valve. Select **Pump Down (inlets open)** if there is an additional isolation valve in front of the Hexblock and the volume between the isolation valve and the Hexblock needs to be pumped down. See Figure 10-14 on page 10-9 for approximate times to pump down trapped volumes.

Figure 10-14 Pumpout time for trapped volumes
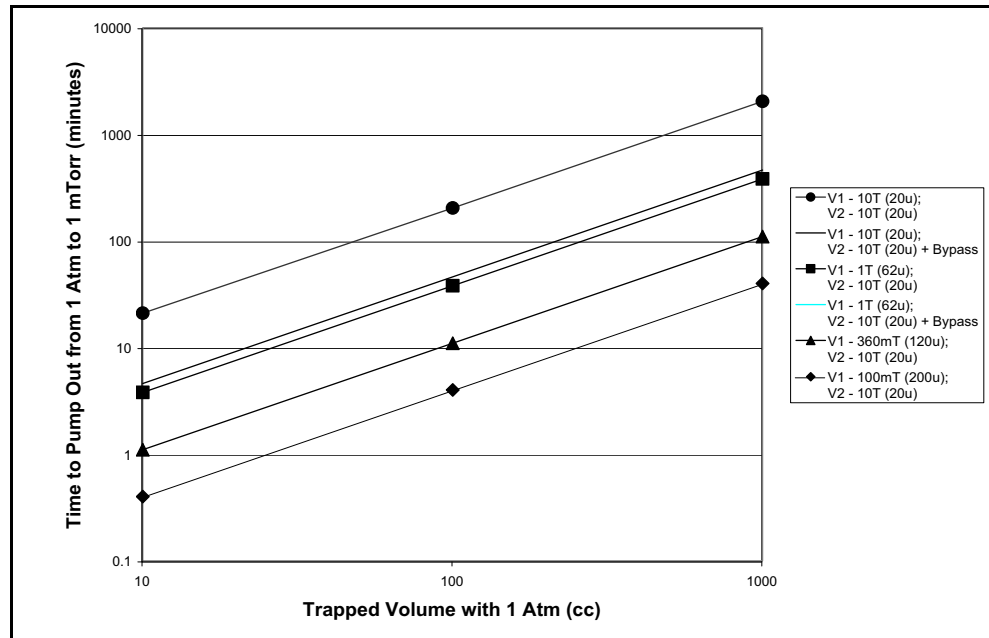
1b The foreline **Valve Status** indicator will change color from dark blue to green.

1c The **Turbo Pump Speed** will increase to 90,000 rpm.

1d Once the turbo pump reaches normal speed, a pumpdown delay occurs before data can be collected. The default pumpdown delay is 300 seconds (five minutes).

2 Bake out the CPM.

2a Click **Start Timed Bakeout.**

2b Select a bakeout time. A normal bakeout is eight hours.

3 Click **Configure** to change CPM Hardware Configuration settings.

4 Click **Emission**. The sensor filament is off the first time **Configuration Monitor** is run. The **Emission** button will be dark blue. It will progress to yellow and finally green to signify that the EM is on. (See Figure 10-15.)

Figure 10-15 Emission status
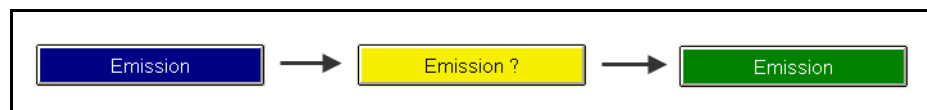
5 Click **Multiplier** to turn on the electron multiplier. The **Multiplier** button will be colored dark blue. It will progress to yellow and finally green to signify that the EM is on. (See Figure 10-16.)

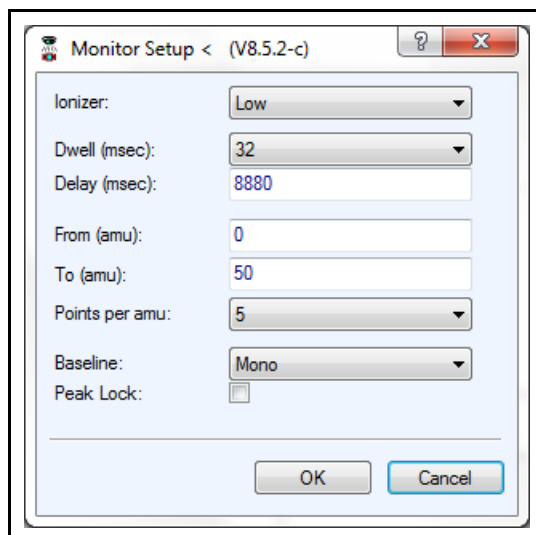*Figure 10-16 Multiplier status*
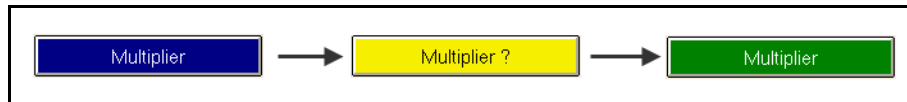
6 Click **Edit** to alter the sensor's data acquisition parameters (see Figure 10-18 on page 10-11). For more information on data acquisition parameters, refer to the *FabGuard Explorer Operating Manual*.

> **NOTE:** Maintain a detailed log of the changes to the sensor's data acquisition parameters.

Figure 10-17 Monitor Setup

7 Choose which (if any) inlets to open to monitor the sensor configuration.

◆ Do not open an inlet when monitoring the residual gas inside of the CPM to obtain a background scan of the CPM sensor.

◆ The illustration in the bottom pane of the **Configuration Monitor** window is representative of the CPM. Installed valves are represented. In Figure 10-18, a CPM with V1, V2, V3, V4 and V5 installed is depicted.

Figure 10-18 Configuration monitor window illustration
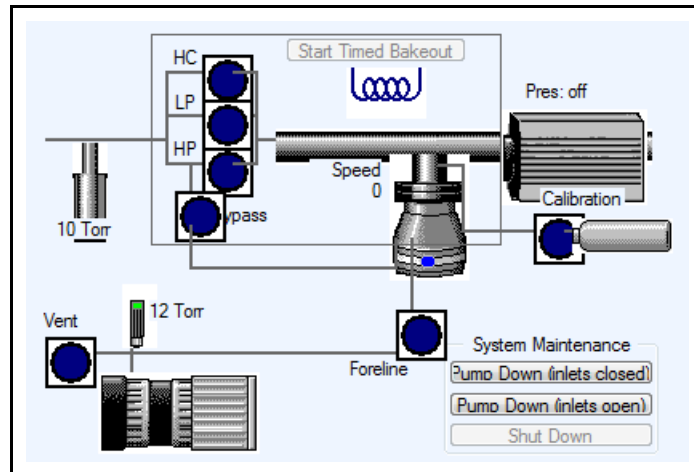
- ◆ Determine which valve to open.

  - ◆ **V1 (LP)** —low pressure valve

  - ◆ **V2 (HP)** —high pressure valve (tied to V4, the bypass valve)

  - ◆ **V3 (HC)** —high conductance valve (used if the sensor's process connection is under high vacuum)

  - ◆ **V4 (Bypass)**—bypass valve (used in conjunction with V2)

  - ◆ **V5 (Calibration)**—calibration valve (available if a calibration gas is installed)

- ◆ To open the valve, click on the **Valve Status** indicator in the CPM figure at the bottom of the screen. The **Valve Status** indicator will switch from dark blue to green.

8 Click **Start Configuration Monitor**. The sensor will begin collecting data with the configuration set up using the chosen data acquisition parameters.

9 If the data is satisfactory, log the parameters and save the configuration. Use these data acquisition parameters in any data collection method.

10 If the data is unsatisfactory, repeat this procedure with different parameters.

⚠️ **CAUTION**

CIS Pressure (Torr) is calibrated in the factory at 40 eV electron energy at 200 µA emission current. Changing electron energy and/or emission current will cause incorrect CIS pressure readings.

10.6 CPM Sensor Acquisition Defaults
10.6.1 What to Acquire (RGAs)

The **What to Acquire** parameters decide the data that the Transpector CPM will collect. This menu is very similar for both CPMs and Open Ion Source RGAs.
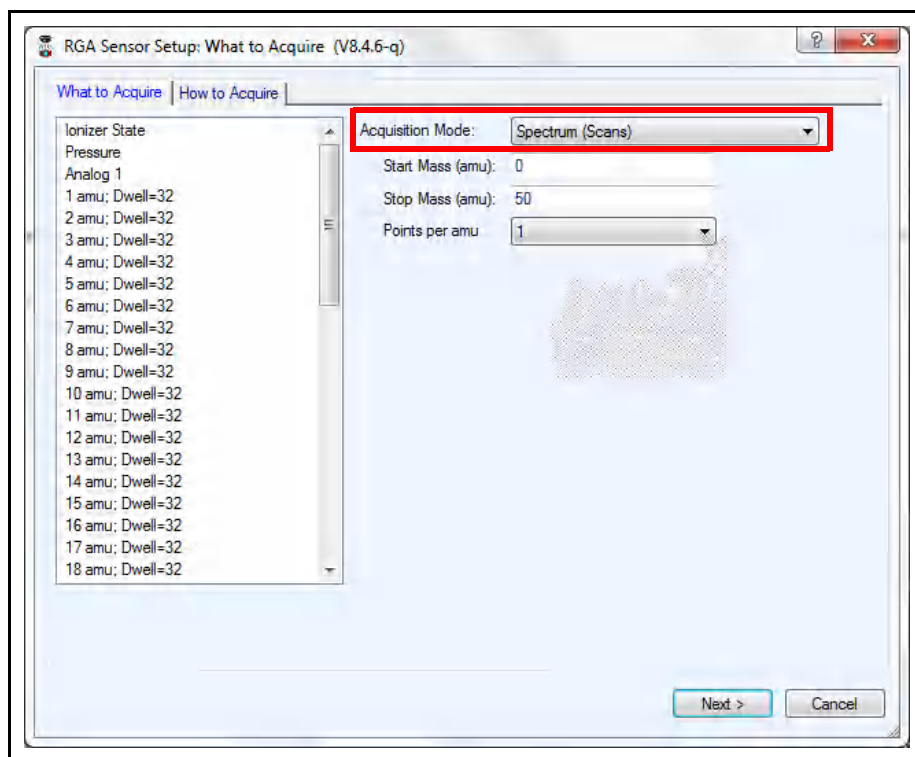
10.6.1.1 Acquisition Modes

There are two different acquisition modes: **Spectrum (Scans)** and **Selected Masses (Bins)**. (See Figure 10-19.)
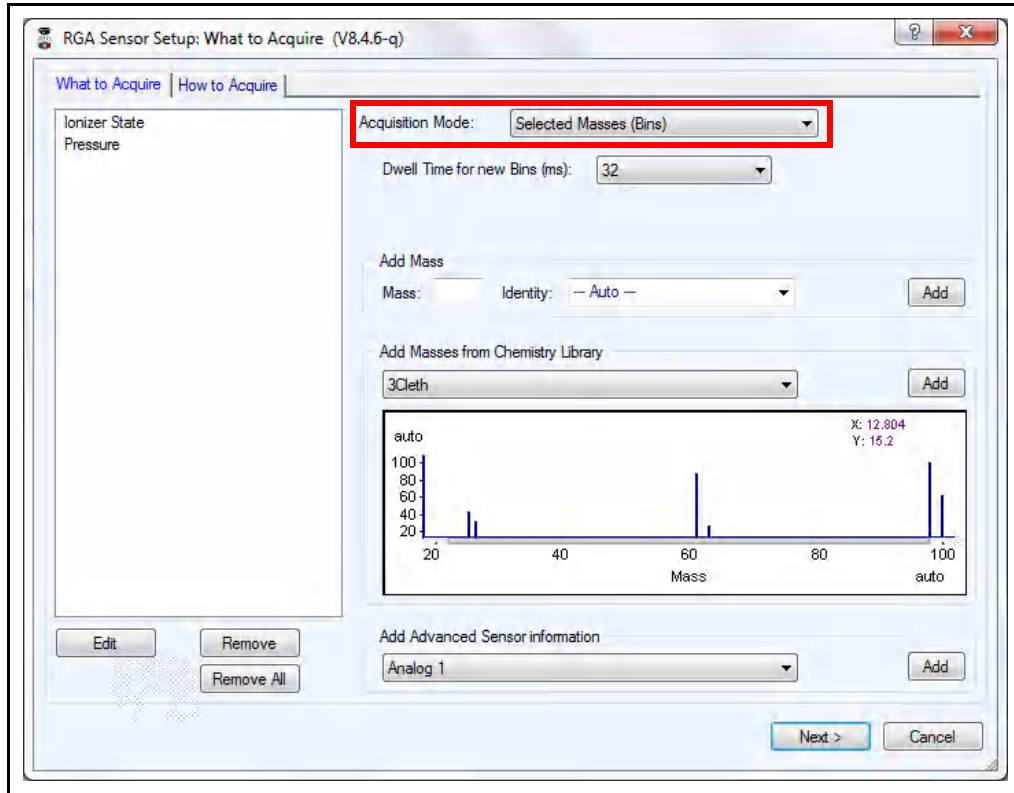
Figure 10-19 Acquisition modes
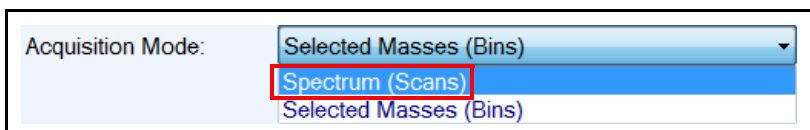
- ◆ **Spectrum (Scans)** is the default mode of data acquisition in FabGuard Explorer. This mode will take data across a user-defined mass range. (See Figure 10-20.)

Figure 10-20 What to Acquire—Spectrum

Selected Masses (Bins) mode allows data collection of specific masses.

Figure 10-21 What to Acquire—Selected Masses

10.6.1.1.1 Spectrum Mode Acquisition Parameters

Figure 10-22 Spectrum mode acquisition parameters

Start Mass (amu):	0
Stop Mass (amu):	50
Points per amu	1

1
2
5
10

Start Mass (amu) . . . . The amu at which the RGA will begin scanning.

Stop Mass (amu). . . . . The amu at which the RGA will stop scanning.

Points per amu . . . . The number of points per amu (ppamu) that the RGA will monitor.

Setting a **Stop Mass** value outside of the sensor's 2222range will create an error. For example, if a 200 amu sensor is installed, FabGuard Explorer will not allow a 250 amu **Stop Mass**.

Increasing the number of ppamu will increase the total time it takes to perform a full scan. In FabGuard Explorer, there are four different options for ppamu values: 1, 2, 5 and 10 ppamu.

10.6.1.2 Selected Masses Mode

It is possible to define specific masses of interest in **Selected Masses Mode**. Transpector CPM advanced sensor functions can be tracked as individual bins in this data acquisition mode. (See Figure 10-23.)

Figure 10-23 Selected masses mode
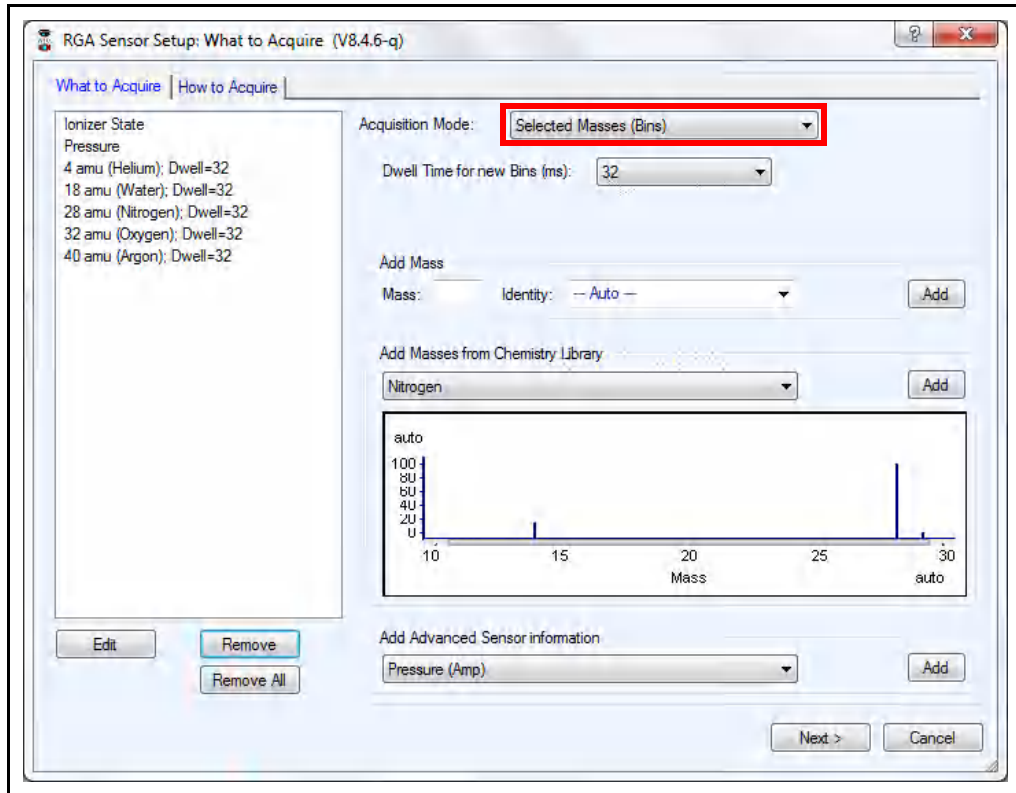
#### 10.6.1.2.1 Existing Masses

Editing Masses

If a mass has already been added but the mass has the wrong identity for the process, click **Edit** to open the **Mass Properties** window and change the identity. (See Figure 10-24.)

For example, a process may require monitoring of carbon monoxide. Since carbon monoxide has the same mass as nitrogen (28 amu), the identity of mass 28 must be changed from nitrogen to carbon monoxide in the **Identity** list.

Dwell time can be changed in the **Dwell** list.

In the **Relay** list, thresholds can be set up to open or close relays based on the signal of the mass bin. (See Figure 10-24.)

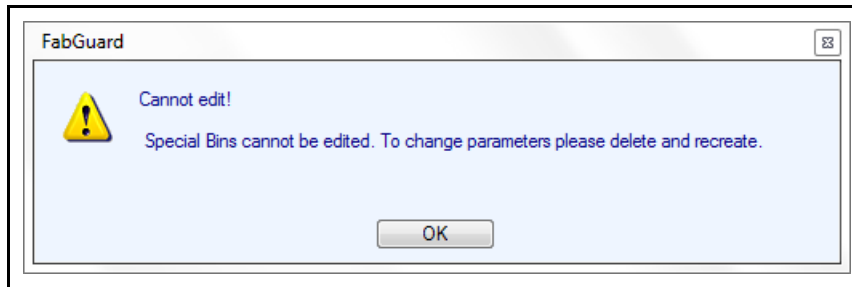*Figure 10-24 Mass properties*
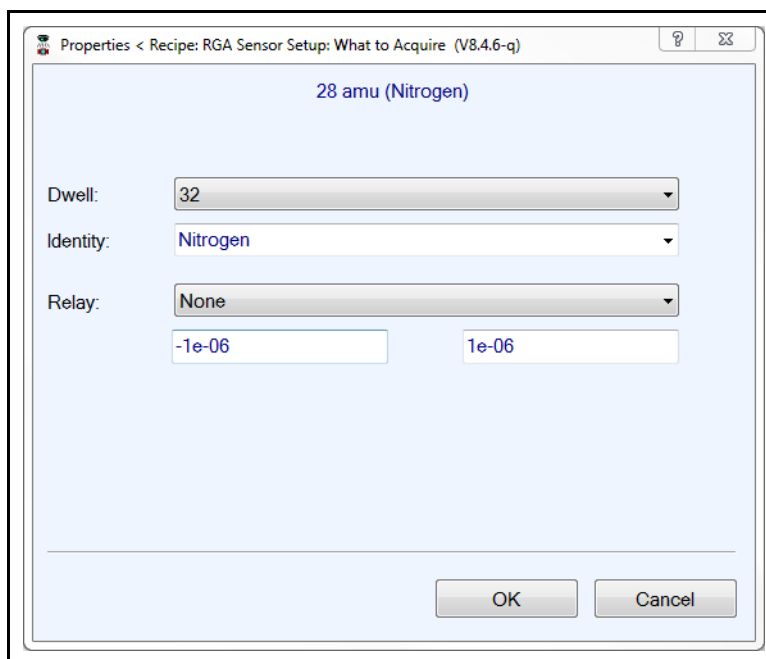
> ⚠️ **CAUTION**
>
> **Editing a special bin, such as Ionizer State, will display an error message. (See Figure 10-25.)**

Figure 10-25 Editing special bins not allowed

Removing Masses

Click **Remove** to remove an individual mass. (See Figure 10-26.)
Click **Remove All** to remove all of the masses. (See Figure 10-27.)
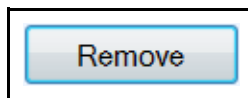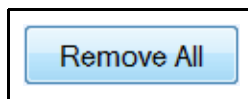
Figure 10-26 Remove

*Figure 10-27 Remove All*

10.6.1.2.2 Adding Masses

FabGuard Explorer allows masses to be added to the mass list for the sensor.

Dwell Time for New Bins

When collecting data with **Bin Independent** dwell times, the **Dwell Time for New Bins** can be set to any value.

NOTE: The dwell time for each mass can be changed by editing the mass. This new dwell time will be used for all newly created masses.

Figure 10-28 Dwell time for new bins
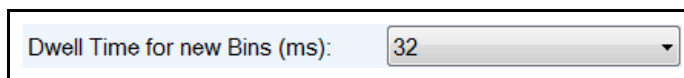
Add Mass

Adds a mass to monitor by identifying a specific mass in amu, either defining it manually or using the auto select function to name the mass. After entering the mass value in the **Mass:** box and selecting the **Identity**, click **Add**.

Figure 10-29 Add mass

Add Masses from Chemistry Library

Allows the selection of peaks based on chemicals that are present in a process. A compound is selected to monitor. The mass spectrum for the specific compound will be displayed in the graph. After clicking **Add**, the masses in the spectrum will be added to the active bin list.

Figure 10-30 Add masses from chemistry library
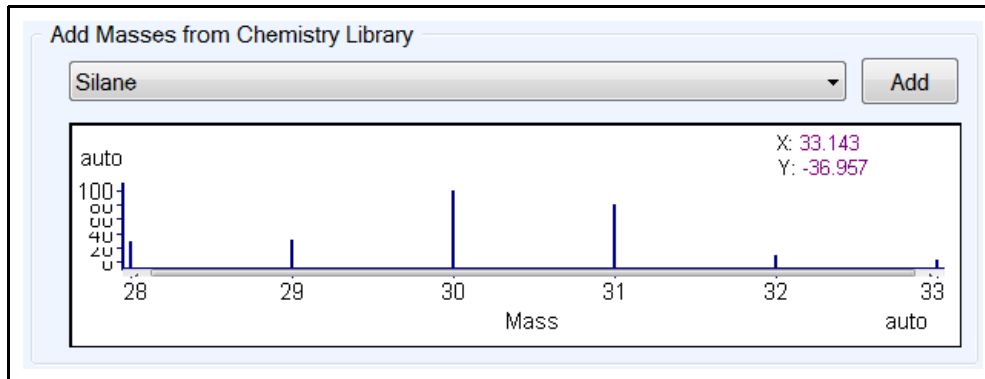
NOTE: An error message will be displayed if a compound is added that shares a mass with a compound that has previously been added.
FabGuard Explorer can only associate each mass with one chemical compound. For instance, if air is added to the active mass list and then nitrogen added afterwards, an error will display because two masses have already been assigned 14 amu and 28 amu.

Figure 10-31 Sensor bin already exists
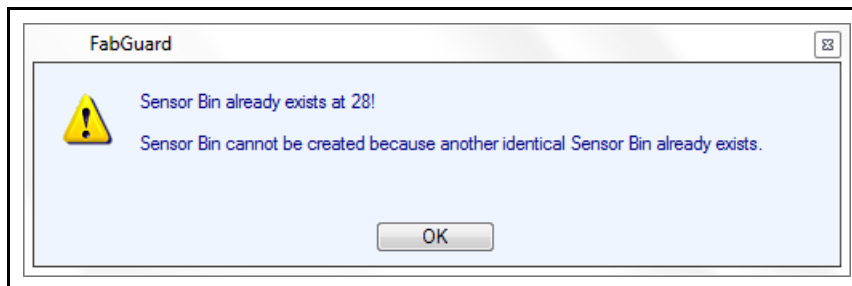
Add Advanced Sensor Information

Adds bins that measure advanced sensor functions. The most commonly used bins are the **Analog Input(s)** bin(s) and the **Pressure** bin. Once the bin of interest has been selected, click **Add** and the bin will be added to the list of active bins.

Figure 10-32 Advanced sensor information
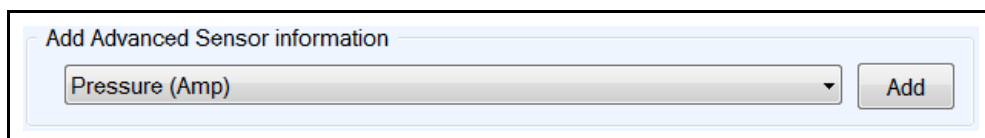
10.6.2 How to Acquire (CPM)

The **How to Acquire** menu for the CPM (see Figure 10-33) is similar to the Open Ion Source RGAs. However, there are a number of differences due to the additional valve assembly and pumping system of the CPM.

Figure 10-33 How to acquire CPM

10.6.2.1 Ionizer Presets

Determines the ionization energy with which the sensor collects data.

Figure 10-34 Ionizer presets

- ◆ **Low** selects the sensor's low ionization energy for the run.
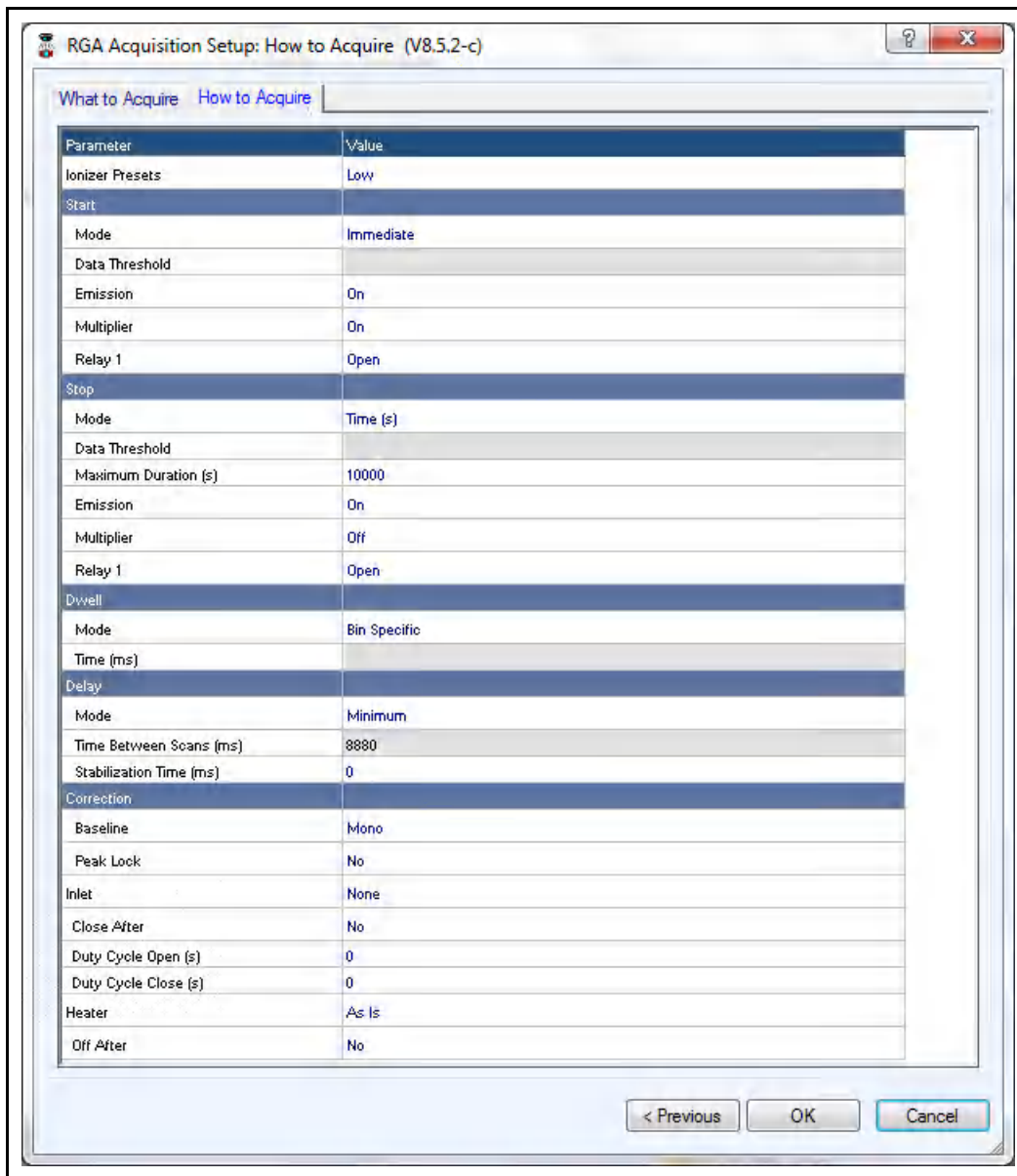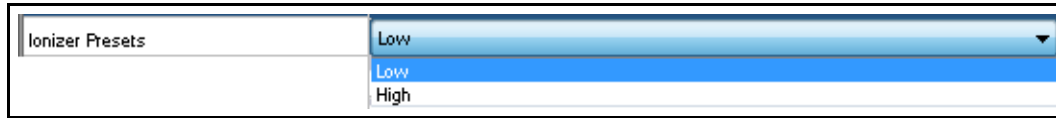
- ◆ **High** selects the sensor's high ionization energy for the run.

10.6.2.2 Start Parameters

The **Start Parameters** define how and when the sensor starts acquiring data.

10.6.2.2.1 Start Mode Type

The **Start Mode Type** defines when the sensor starts collecting data. (See Figure 10-35.)

Figure 10-35 Start mode type
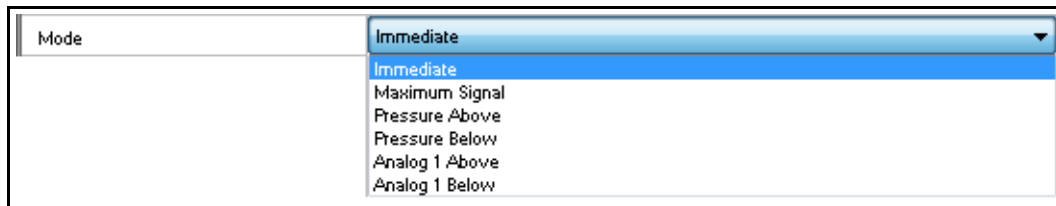
- ◆ **Immediate** starts the run immediately after the run is started.

- ◆ **Maximum Signal** starts the run after the sensor sees a defined maximum signal. The signal is set by the **Data Threshold.** (See section 10.6.2.2.2)

- ◆ **Pressure Above** starts the run immediately after an increase in the internal RGA total pressure above the user-defined **Data Threshold**. Emission must be ON prior to recipe start for this mode to function.

- ◆ **Pressure Below** starts the run immediately after a decrease in the internal RGA total pressure below the user-defined **Data Threshold**. Emission must be ON prior to recipe start for this mode to function.

- ◆ **Analog 1 Above** starts the run after an increase in voltage above the user-defined **Data Threshold**.

- ◆ **Analog 1 Below** starts the run after a decrease in voltage below the user-defined **Data Threshold**.

10.6.2.2.2 Data Threshold

Defines the threshold that the **Start Mode Type** utilizes to determine when the run will start. The **Data Threshold** is set in units corresponding to the **Start Mode Type** selected. **Maximum Signal** is in units of current, **Pressure Above/Below** is in units of pressure, and **Analog 1 Above/Below** is in units of volts. (See Figure 10-36.)

Figure 10-36 Data Threshold

Data Threshold	0.075

10.6.2.2.3 Emission

Defines the mode of the filament when the run starts. (See Figure 10-37.) If **Emission** is not turned on, data will not be collected.

Figure 10-37 Emission

Emission	On
	As Is
	Off
	On

- ◆ **As Is** uses the current status of the filament.

- ◆ **Off** starts the data acquisition with the filament off.

- ◆ **On** starts the data acquisition with the filament on.

10.6.2.2.4 Multiplier

Defines the mode of the electron multiplier when the run starts. (See Figure 10-38.)

Figure 10-38 Multiplier

Multiplier	On
	As Is
	Off
	On

- ◆ **As Is** uses the current status of the EM.

- ◆ **Off** starts the data acquisition with the EM off.

- ◆ **On** starts the data acquisition with the EM on.

10.6.2.2.5 Relay 1

Defines the state of **Relay 1** when the run starts

- ◆ **As Is** leaves the relay in its current state at the beginning of the run.

- ◆ **Open** opens the relay at the beginning of the run.

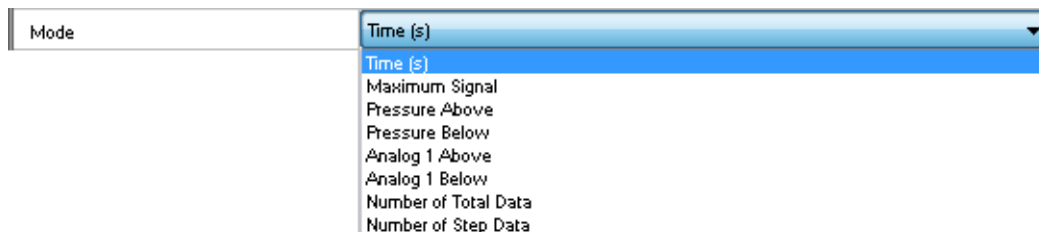- ◆ **Close** closes the relay at the beginning of the run.

10.6.2.3 Stop Parameters

Defines how and when the data acquisition stops.

10.6.2.3.1 Stop Mode Type

Defines when the data acquisition stops. (See Figure 10-39.)

Figure 10-39 Stop mode CPM

- ◆ **Time (s)** stops the acquisition after a set period of time.

- ◆ **Maximum Signal** stops the run after the sensor sees a defined maximum signal. The signal is set by the Data Threshold. (See section 10.6.2.3.2.)

- ◆ **Pressure Above** stops the run immediately after an increase in the internal RGA total pressure above the user-defined **Data Threshold**.

- ◆ **Pressure Below** stops the run immediately after a decrease in the internal RGA total pressure below the user-defined **Data Threshold**.

- ◆ **Analog 1 Above** stops the run after an increase in voltage above the user-defined Data Threshold.

- ◆ **Analog 1 Below** stops the run after a decrease in voltage above the user-defined Data Threshold.

- ◆ **Number of Points** stops the run after collecting a user-defined number of scans.

10.6.2.3.2 Data Threshold

Defines the threshold that the **Stop Mode Type** utilizes to determine when the run will stop. The **Data Threshold** is set in units corresponding to the **Start Mode Type** selected. **Maximum Signal** is in units of current, **Pressure Above/Below** is in units of pressure, and **Analog 1 Above/Below** is in units of voltage. (See Figure 10-40.)

Figure 10-40 Data threshold (stop mode)
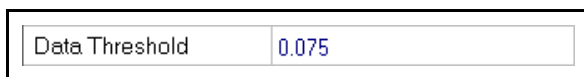
10.6.2.3.3 Maximum Duration

Defines the length of time in seconds that the RGA will collect data if using **Time** as a stop mode. If using a different stop mode, **Maximum Duration** defines the maximum amount of time that the RGA will collect data. (See Figure 10-41.)

Figure 10-41 Maximum duration

Maximum Duration (s)	10000

NOTE: If the data acquisition ends due to the **Maximum Duration** when its **Stop Mode Type** is not set to **Time**, an alarm will occur. For more information on alarms, refer to Chapter 8.

10.6.2.3.4 Emission

Defines the mode of the filament when the run stops. It is recommended to turn off the filament if the sensor will be exposed to high pressures following a run. (See Figure 10-42.)

Figure 10-42 Emission

Emission	On
	As Is
	Off
	On

- ◆ **As Is** uses the current status of the filament.

- ◆ **Off** stops the data acquisition with the filament off.

- ◆ **On** stops the data acquisition with the filament on.

10.6.2.3.5 Multiplier

Defines the mode of the electron multiplier when the run stops. It is recommended to turn off the EM if the sensor will be exposed to high pressures following a run. (See Figure 10-43.)

Figure 10-43 Multiplier

Multiplier	On
	As Is
	Off
	On

- ◆ **As Is** uses the current status of the EM.

- ◆ **Off** starts the data acquisition with the EM off.

- ◆ **On** starts the data acquisition with the EM on.

10.6.2.3.6 Relay 1

Defines the state of **Relay 1** when the run stops.

- **As Is** leaves the relay in its current state at the end of the run.

- **Open** opens the relay at the end of the run.

- **Close** closes the relay at the end of the run.

10.6.2.4 Dwell

Determines how and for how long the RGA collects data at each point.

10.6.2.4.1 Dwell Mode

Determines how the dwell is chosen for each data point. This option is changeable only when in **Selected Masses** mode. (See Figure 10-44.)

Figure 10-44 Dwell mode
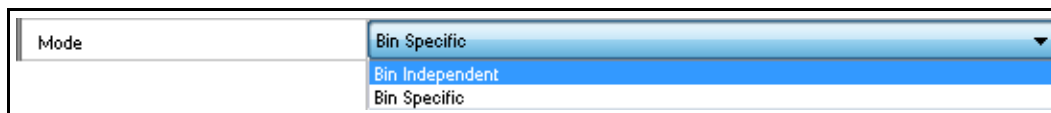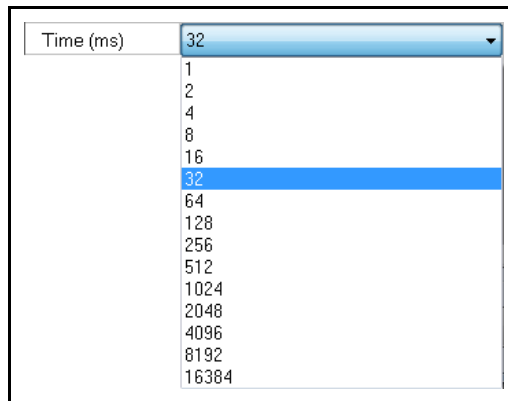
- **Bin Independent** uses the same dwell time for each data point.

- **Bin Specific** is only available when running in Selected Masses mode. This choice allows for each mass to have a specific dwell time. This methodology is desirable if a peak of interest has an unusually noisy response. FabGuard Explorer can be set to dwell at that peak for a longer time period, which will decrease the noise and increase the signal-to-noise ratio.

10.6.2.4.2 Dwell Time

Defines the amount of time in milliseconds (ms) that FabGuard Explorer will collect data at every data point. In general, the longer the dwell time, the lower the noise of the signal. Longer dwell times at each point will result in longer overall scan times. **Dwell Time** is only selectable when **Bin Independent** is chosen as the **Dwell Mode**. (See Figure 10-45.)

Figure 10-45 Dwell time
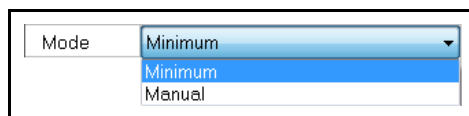
10.6.2.5 Delay

Defines whether FabGuard Explorer will add additional wait time after the sensor has completed a full scan.

10.6.2.5.1 Delay Mode

Figure 10-46 Delay mode
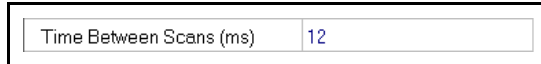
◆ **Minimum** sets the **Time Between Scans** to its minimum value. After the sensor has completed a scan, no additional wait time will be added to the scan by FabGuard Explorer.

◆ **Manual** allows the operator to set an additional delay time after the sensor completes the scan.

10.6.2.5.2 Time Between Scans

Time Between Scans can be set to a value greater than the minimum scan time if additional wait time is desired. This field can only be set if **Manual** is chosen as the **Delay Mode**.

Figure 10-47 Time between scans

Time Between Scans (ms)	12

NOTE: Time Between Scans cannot be set lower than the minimum scan time.

10.6.2.5.3 Stabilization Time

Stabilization Time is the amount of time FabGuard Explorer waits after the **Start Mode** condition has been met before setting the Emission and EM to their specified Start states and beginning data acquisition. For example, if the recipe starts based on an analog input and an additional wait time is desired before the Emission is turned on.
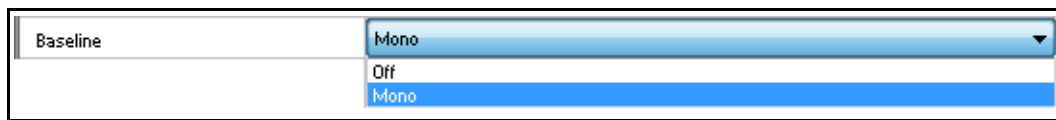
10.6.2.6 Correction

Defines the type of **Baseline** correction used by FabGuard Explorer (if any correction at all) and whether or not **Peak Lock** is turned on.

10.6.2.6.1 Baseline

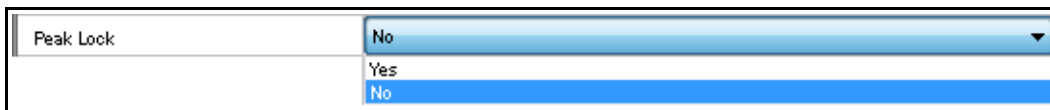Sets the **Baseline** to **Off** or **Mono**. For more information, refer to the FabGuard Explorer Operating Manual.

Figure 10-48 Baseline

Baseline	Mono ▼
	Off
	Mono

10.6.2.6.2 Peak Lock

Figure 10-49 Peak lock

Peak Lock is a method of fine tuning the sensor while it is collecting data. Peak Lock is only available when running at 1 ppamu (either in spectrum mode or selected masses mode). Peak Lock collects data around the peak while looking for the maximum signal. Peak Lock then defines the maximum signal as being the true location of the mass of interest. This is helpful because peaks can drift as a sensor runs, but retuning constantly can be too time consuming.

It is recommended that **Peak Lock** be turned **On**. **Peak Lock** should only be disabled if extremely fast data acquisition is needed and the peak position is carefully set.

10.6.2.7 Inlet

Defines the inlet that is opened for the run, and whether it is closed after the data acquisition is over. (See Figure 10-50.)

Figure 10-50 Inlet
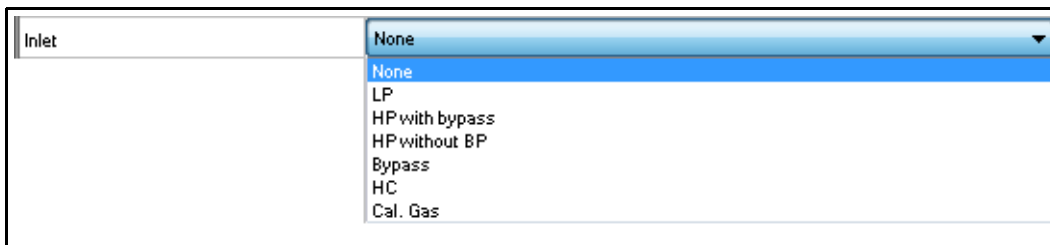
- **None** does not open any valves for the data acquisition. This would give data that is only representative of the background of the CPM.

- **LP** opens the V1, low pressure valve.

- **HP with bypass** opens the V2, high pressure valve, with the bypass valve, V4.

- **HP without BP** opens the V2, high pressure valve, without the bypass valve. This is not recommended because the response time of the CPM can be much slower without the bypass.

- **Bypass** opens the V4, bypass valve.

- **HC** opens the V3, high conductance valve. This valve is used primarily to monitor process chamber background and should not be used for higher pressures.

- **Cal Gas** opens the V5, calibration gas valve. With this valve open, the sensor will only monitor the calibration gas. This is useful when tuning and calibrating the sensor.

10.6.2.7.1 Close After

Figure 10-51 Close after

Defines the status of the selected valve after data collection is over. If Yes is chosen, the valve will be closed at the end of the data acquisition.

10.6.2.7.2 Duty Cycle

When sampling aggressive gases, do not expose Transpector CPM to the aggressive gas for long periods of time. The CPM Inlet can be automatically opened and closed in a duty cycle. To use the duty cycle feature, the Open time and Close time must be defined. (See Figure 10-52.)

Figure 10-52 Duty cycle

10.6.2.8 Heater

The **Heater** parameter controls the CPM heating jacket while the RGA is acquiring data. The heater can be set to **As Is, Off**, **Low** (90ºC), or **High** (150ºC).

Figure 10-53 Heater

10.6.2.8.1 Off After

Selecting **Yes** from the **Off After** list will turn the heater off at the end of the data acquisition.

Figure 10-54 Off after

Chapter 11
Glossary

Anode

The anode is the structure in the ion source in which ions are created by electron impact. It can be formed from a mesh, such as in the open ion source, or from a solid tube, such as in the closed ion source. Its electrical potential is positive with respect to the filament, focus lens, total pressure plate, pole zero, exit aperture and Faraday cup.

Appearance Potential

The minimum electron energy required to produce, by electron bombardment, a given ion in its lowest energy state.

Atomic Mass Unit (AMU)

An atomic mass unit is a unit of measurement for the mass of a molecule or ion. It is based on the definition that the mass of an atom of the carbon-12 isotope is exactly 12.

Background

The background is the residual atmosphere in a vacuum apparatus when no gases are being deliberately introduced.

Bakeout

A bakeout is the process of heating a vacuum chamber above the ambient temperature in order to accelerate the desorption of species such as water vapor and hydrocarbons which are adsorbed onto the inner surfaces of the vacuum chamber.

Center Voltage

The center voltage is the DC potential to which the quadrupole rod RF and differential DC potentials are referenced.

Closed Ion Source (CIS)

The closed ion source is an ion source in which the pressure in the ionization region is higher than in the rest of the analyzer sensor. This is usually accomplished by fabricating the anode from a solid walled tube instead of an open mesh. This type of source is usually employed to measure trace contaminant levels in a process gas.

Conductance

The conductance of a gas flow channel is the ratio of the gas quantity flowing through the channel to the pressure drop across that channel.

Cracking Pattern

See **Fragmentation Pattern**.

Detection Factor

The detection factor is the ratio of the detected signal for a given ion current from a certain substance to the detected signal for the same ion current of nitrogen ions as measured at mass 28. For Faraday cup detectors, the detection factor is usually 1. For electron multiplier detectors, this factor depends on the mass and chemical nature of the ion.

Detector

The detector is that part of the mass spectrometer sensor which converts a beam of ions into an electrical signal.

Doubly Charged Ion

For positive ions, a doubly charged ion is a parent or fragment ion where two electrons have been removed.

Electron Energy

The electron energy is the kinetic energy of the ionizing electrons in an electron bombardment ion source and is typically measured in units of electron volts (eV). The electron energy is approximately equal to the difference between the bias voltage on the filament and the anode potential, times the electron charge.

Electron Multiplier

An electron multiplier is a *in situ* amplifier which is used to increase the sensitivity of a mass spectrometer. When a high voltage is applied to an electron multiplier, positive ions are accelerated into the multiplier, causing the release of a large number of electrons per incident ion at the output.

Emission Current

The emission current is the current of electrons leaving the surface of a heated filament.

Exit Aperture (Quadrupole)

The exit aperture is a focus lens at the ion exit (detector) end of a quadrupole mass spectrometer. This lens is often biased by a potential that is negative with respect to the quadrupole center voltage such that ions are extracted from the exit end of the quadrupole and focused into the detector.

Extractor

See **Focus Lens**.

Faraday Cup

The Faraday Cup is a detector for ions and/or electrons consisting of a cup shaped, conductive electrode.

Filament

The filament is a fine wire or ribbon, which, when heated by means of electrical current, emits electrons. The filament typically made of iridium with a thorium or yttrium oxide coating, or of tungsten or a tungsten alloy.

Focus Lens

The focus lens is a conductive aperture located next to, and usually biased negatively with respect to, the anode. Its purpose is to draw the ions out of the anode, form them into a beam, and focus them into the next lens element.

Fragment Ion

A fragment ion is an ion with fewer atoms than the parent gas molecule from which the ion is produced. The mass of the fragment ion is always less than that of the parent ion.

Fragmentation Factor

The fragmentation factor is the fraction of the total ions produced from a specified substance which have a given mass. The sum of the fragmentation factors for all of the ions produced from a specified substance is equal to one.

Fragmentation Pattern

The fragmentation pattern is the pattern of ion masses and intensities produced by electron bombardment of a specified gas species as transmitted by the mass filter, detected and recorded.

Gain (Electron Multiplier)

The gain of an electron multiplier is the ratio of incident ion current to electron current output. The gain of the multiplier is a strong function of the bias potential applied across it.

Ion

An ion is a molecule or atom which has either lost or added one or more electrons. Those molecules which have lost electrons are positive ions. Those molecules which have added electrons are negative ions.

Ion Current

An ion current is the rate of flow of electrical charge associated with the flow of ions.

Ion Energy

The ion energy is the kinetic energy associated with a beam of ions. It is equal to the potential difference across which the ion beam is accelerated (or decelerated) times the charge on the ion, and is typically measured in electron volts (eV). Specifically, in a quadrupole mass spectrometer, it is the kinetic energy, along the axis, of the ions as they pass through the mass filter. The ion energy is approximately equal to the anode potential minus the quadrupole center voltage time the ionic charge.

Ion Source

The ion source is that part of a mass spectrometer in which neutral gas molecules or atoms are ionized by electron bombardment.

Ionization Probability

The ionization probability for a chemical substance is the ratio of the total ion current (at all masses) produced from a given partial pressure of that substance, to the total ion current produced from nitrogen at the same partial pressure.

Isotope

The atom is composed of nucleus protons and neutrons surrounded by an electron cloud. The chemical properties of an element are determined by the number and arrangement of electrons (with -1 charge) in an atom. The number of electrons in a neutral atom in turn depends on the number of protons (with +1 charge) within the nucleus of that atom. Atomic nuclei also contain neutrons which, being uncharged, do not affect the chemistry of an element. Protons and neutrons have approximately the same mass, which is approximately 1,800 times the mass of an electron. All atoms of a given element have the same number of protons but not necessarily the same number of neutrons. Atoms of the same element which have a different number of neutrons are called isotopes. See **Natural Abundance**.

Linearity

Linearity is the mathematical relationship between an ion current and the total or partial pressure giving rise to that current. A mass spectrometer is said to have good linearity when the ion current is proportional to the pressure over a specified pressure range within a specified tolerance. Typically (but not always), the ion current will be linear with pressure at the low end of an instrument's pressure range. At some pressure near the high pressure end of an instrument's range, the ion current will be less than proportional to the pressure.

Mass to Charge Ratio

The mass to charge ratio is ratio of the mass of an ion to its charge, usually expressed in atomic mass units per unit electron charge.

Mass Filter

The mass filter is that part of the mass spectrometer which separates a beam of ions by their mass to charge ratios.

Mass Spectrometer

A mass spectrometer is an instrument which ionizes a gas sample, separates the resulting beam of ions by mass to charge ratio, and detects the filtered ions as an electrical signal.

Mass Spectrum

A mass spectrum is a record of ion current as a function of mass to charge ratio obtained with a mass spectrometer. The spectrum can be presented as a graph with mass to charge ratio on the X-axis and ion current on the Y-axis, or as a tabular listing of ion currents and the associated mass to charge ratios.

Material Factor

The material factor for a chemical substance is that part of the proportionality constant between the partial pressure of that substance and the resulting mass filtered ion current which depends on the chemical nature of that substance but not the particular instrument used for that measurement. The material factor is a function of the ionization probability and fragmentation factor for the specified substance.

Mean Free Path

The mean free path is the average distance an ion, electron, atom, or molecule can travel before colliding with an ambient gas molecule. The mean free path is inversely proportional to the pressure.

Molecular Flow

Molecular flow is that motion of gas molecules wherein the collisional mean free path is greater than the critical dimension of a flow constraining element such as an orifice of tube diameter. The gas flow characteristics are dominated by collisions between the gas molecules and the appropriate surfaces of the vacuum system.

Natural Abundance

The natural abundance of an isotope is the average percentage of all atoms of a given element which have the same number of neutrons. For example, 99.985% of all naturally occurring hydrogen atoms have no neutrons, giving an atomic mass of approximately 1, while 0.015% have one neutron, giving an atomic mass of approximately 2. There is a third isotope of hydrogen which contains two neutrons, giving an atomic mass of 3, but this isotope is unstable with such a short radioactive half life that it is not normally naturally occurring in any significant quantity on earth.

There are occasions when observed an isotopic abundance will not reflect the natural abundance. For instance, in semiconductor processing tools know as ion implanters, it is not unusual for the BF_3 boron dopant source to be isotopically enriched to 99%+ of the boron-11 isotope (instead of the naturally occurring 80.22%).

Open Ion Source (OIS)

An open ion source is an ion source constructed with an open grid structure with high conductance between the ionization region and the vacuum region surrounding it. Residual gas analyzers are typically equipped with this type of ion source.

Outgassing

Outgassing is the evolution of gas which was dissolved in or adsorbed on solid surfaces inside a vacuum chamber.

Parent Ion

A parent ion is an ion made by removing a single electron from the original, or parent, gas molecule, and therefore has the same mass.

Partial Pressure

The partial pressure is the pressure of a specific chemical component of a gas mixture. The sum of all the partial pressures is the total pressure.

Pole Zero

See **Center Voltage**.

Quadrupole

A quadrupole is a mass filter consisting of four parallel electrodes or poles (hence quadrupole) arranged in a square array. Opposite poles are connected together electrically such that an electric field of hyperbolic geometry is produced. The potentials applied to these poles are a superposition of variable DC and RF voltages, generally of fixed RF frequency.

Repeller (Electron)

The electron repeller is an electrode located on the opposite side of the filament than the anode. The repeller is usually biased at the same potential as the negative side of the filament, or a more negative potential.

Residual Gas Analyzer

A residual gas analyzer is an instrument which is used to determine the quantities and chemical nature of gases present in a vacuum system. The instrument is typically a mass spectrometer equipped with an open ion source.

Resolution

Resolution is the ability of a mass filter to select between nearby masses. It is typically measured as the mass of the peak divided by the width of a given mass peak at 10% or 50% of the peak maximum intensity.

Secondary Electron

A secondary electron is an electron emitted from a surface when that surface is struck by a sufficiently energetic ion, electron, neutral molecule or photon.

Sensitivity

The sensitivity of a mass spectrometer is the ratio of ion current at a specified mass from a specified gas to the partial pressure of that gas, suitably corrected for background. The specified gas is typically nitrogen, measured at 28 AMU, although argon at 40 AMU is sometimes used instead, depending on the instrument.

Total Pressure

The total pressure is the force per unit area exerted by a gas on the walls of its container. It is equal to the sum of all the partial pressures of the different chemical species which comprise that gas.

Total Pressure Plate

The total pressure plate, or collector, is an electrode in the ion source on which at least a part of the ion beam impinges. The current striking this plate is a function of the total pressure in the ion source.

Transition Flow

Transition flow is that motion of gas molecules wherein the collisional mean free path is approximately the same as the critical dimension of a flow constraining element such as an orifice of tube diameter.

Transmission Factor

The transmission factor is the ratio of ion current detected at the exit end of the mass filter (set to transmit a given mass) to the current of ions of the same mass entering the filter from the ion source. Typically, the transmission factor for nitrogen ions at 28 AMU is set equal to 1. The transmission factor at other masses is given relative to that for nitrogen.

Viscous Flow

Viscous flow is that motion of gas molecules wherein the collisional mean free path is less than the critical dimension of a flow constraining element, such as an orifice of tube diameter. The gas flow characteristics are dominated by collisions between gas molecules.

Zero Blast

Zero blast is the ion current which is not mass filtered and is detected when the mass spectrometer is scanning near mass zero.

Chapter 12
Bibliography

For further information on partial pressure analyzers, see *Partial Pressure Analyzers and Analysis*, M. J. Drinkwine and D. Lichtman, American Vacuum Society Monograph Series, or *A User's Guide to Vacuum Technology*, J. F. O'Hanlon, John Wiley and Sons (1989). The latter book also contains a wealth of information on related topics including gas flow, pressure gauges, pumps, materials, and the design of vacuum systems.

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