O P E R A T I N G   M A N U A L

Transpector® XPR3

Gas Analysis System

PN 074-378-P1D

INFICON

Trademarks

The trademarks of the products mentioned in this manual are held by the companies that produce them.

INFICON®, Transpector®, XPR® and FabGuard® are registered trademarks of INFICON GmbH.

This product contains embedded software protected under the following copyrights:

Copyright INFICON Inc.

Copyright Greenleaf Software, Inc.

Contains licensed program materials of Metagraphics Software Corporation:

Copyright Metagraphics Software Corporation, Scotts Valley, CA 95066

Copyright Microsoft Corp., All Rights Reserved.

Copyright Application Techniques Inc.

All other brand names, product names or trademarks belong to their respective holders.

Disclaimer

The information contained in this Operating Manual is believed to be accurate and reliable. However, INFICON assumes no responsibility for its use and shall not be liable for any special, incidental, or consequential damages related to the use of this product.

Due to our continuing program of product improvements, specifications are subject to change without notice.

Copyright

Table Of Contents

Chapter 1

Getting Started

Chapter 3

Applications Guide

Chapter 4

Transpector XPR3 Installation

Chapter 1
Getting Started

1.1 Introduction

This chapter provides an overview of the Transpector XPR3 Gas Analysis System. Topics include the purpose of the Transpector XPR3 Gas Analysis System, its specifications, an inventory of items you should receive, installation instructions, recommendations for operation, and information on how to contact Customer Support.

This Operating Manual provides information concerning:

- Sensor Models X3M / X3MH
- Electronics Module
- Pirani Interlock

Information concerning the software is located in the TWare 32 Operating Manual or your FabGuard® help files, included with your Transpector XPR3 Gas Analysis System.

1.2 Using This Manual

Please read this Operating Manual before operating Transpector XPR3.

1.2.1 Note and Hint Paragraphs

NOTE: This is a note paragraph. Notes provide additional information about the current topic.

HINT: This is a hint paragraph. Hints provide insight into product usage.

1.2.2 Warning and Caution Paragraphs

The following Caution and Warning paragraphs are used to alert the reader of actions which may cause either damage to the instrument or bodily injury.

CAUTION

This is an example of a Caution paragraph. It cautions against actions which may cause an instrument malfunction or the loss of data.

WARNING

This is an example of a General Warning paragraph. It warns against actions which may cause bodily injury.

WARNING - Risk Of Electric Shock

This is an example of an Electrical Warning paragraph. It warns of the presence of electrical voltages which may cause bodily injury.

1.2.3 Usage of the Modern Metric System

In many places throughout this manual, American measurement units are given along with their International System of Units eqivalences. However, providing all measurement units in all discussions becomes cumbersome to the reader. Therefore, equivalences are not given in all cases. You may perform the conversion as follows:

- To convert from psig to bar:

  psig x 0.069 = bar

- To convert from psig to kPa:

  psig x 6.8947 = kPa

- To convert from Torr to mbar:

  Torr x 1.3332 = mbar

- To convert from Torr to Pascals (Pa)

  Torr x 133.32 = Pascals

- To convert from inches (in.) to millimeter (mm)

  in. x 25.4 = mm

- To convert from feet (ft.) to meters (m)

  ft. x 0.3048 = m

- To convert from pounds (lb.) to kilograms (kg):

  lb. x 0.453593 = kg

1.3 How To Contact Customer Support

If you need assistance with your instrument, please read this Operating Manual before contacting Customer Support.

Worldwide support information regarding:

- Technical Support, to contact an applications engineer with questions regarding INFICON products and applications,
- Sales and Customer Service, to contact the INFICON Sales office nearest you,
- Repair Service, to contact the INFICON Service Center nearest you,

is available at www.inficon.com.

If you are experiencing a problem with your instrument, please have the following information readily available:

- the serial number for your instrument
- a description of your problem
- an explanation of any corrective action that you may have already attempted
- and the exact wording of any error messages that you may have received

To contact Customer Support, see Support at www.inficon.com.

1.3.1 Returning Your Instrument to INFICON

Do not return any component of your instrument to INFICON without first speaking with a Customer Support Representative. You must obtain a Return Material Authorization (RMA) number from the Customer Support Representative.

If you deliver a package to INFICON without an RMA number, your package will be held and you will be contacted. This will result in delays in servicing your instrument.

Prior to being given an RMA number, you may be required to complete a Declaration Of Contamination (DOC) form if your instrument has been exposed to process materials. DOC forms must be approved by INFICON before an RMA number is issued. INFICON may require that the instrument be sent to a designated decontamination facility, not to the factory. Failure to follow these procedures will delay the repair of your instrument.

1.4 Transpector XPR3 Filament Precautions

Sampling atmosphere or oxygen above $1x10^{-4}$ Torr ($1.3x10^{-4}$ mbar) [$1.3x10^{-2}$ Pascals] using the Transpector XPR3 is not recommended. To obtain maximum useful life from Transpector XPR3 filaments observe the following caution:

CAUTION

Attempting to turn on the emission above 20 milliTorr may result in premature failure of filaments.

Utilize the Pirani Interlock to operate Transpector XPR3 within a safe pressure range.

Failure to observe these cautions will result in premature failure of filaments. Filament replacement is not covered by warranty under these conditions. Please read Chapter 5, Transpector XPR3 Operation, before using your Transpector XPR3 filament and follow the recommendations in Chapter 6, Transpector XPR3 Best Known Methods.

1.5 Quick Start

Before using your new Transpector XPR3, please read this entire manual. However, to quickly put your Transpector XPR3 Gas Analysis System to work, you need only perform the following tasks.

1. Check to ensure that you received everything.
   See section 1.9, Supplied Items, on page 1-9.
2. Install the Hardware. See Chapter 4, Transpector XPR3 Installation.
3. Install the Software. Refer to the TWare32 Operating Manual or FabGuard Operating Manual for information on installing the software.
4. Review Chapter 6, Transpector XPR3 Best Known Methods, before using your Transpector XPR3 instrument.

1.6 Transpector XPR3 Gas Analysis System

Transpector XPR3 Gas Analysis System is a quadrupole-based residual gas analyzer that operates at PVD process pressures and has an Electron Multiplier that can operate at 10 mTorr operating pressures. The miniature quadrupole sensor analyzes gases by:

- ionizing some of the gas molecules
- separating the ions by mass
- 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 (amounts) of the respective gases. Transpector XPR3 measures major components and impurities common in a process with a 10-ppm detection limit.

Transpector XPR3 is an important aid in the efficient use of a high-vacuum system, detecting leaks, and contaminants. It can indicate the partial pressures of gases in processes occurring within a vacuum or other vessel, and therefore, can be used to investigate the nature of a process or monitor process conditions.

1.7 General Description of the Transpector XPR3 Gas Analysis System

The Transpector XPR3 Gas Analysis System is comprised of these parts:

Sensor

The sensor, which functions only in a high-vacuum environment with pressures below $2x10^{-2}$ Torr ($2.66x10^{-2}$ mbar) [2.66 Pascals].

The sensor itself is comprised of three parts:

- ion source (ionizer)
- quadrupole mass filter
- ion detector

The sensor is mounted on an electrical feed-through flange, which is bolted to the vacuum space where the gas analysis measurements are made.

Electronics Module

The electronics module, which controls the sensor. The electronic module and sensor are matched and sold in sets. The electronics module attaches to and is supported by the sensor.

Pirani Interlock

The Pirani Interlock, which controls emission to the sensor.

Software

The software, which controls the electronics module.

1.8 Specifications for the Transpector XPR3 Gas Analysis System

The following section details the specifications for the Transpector XPR3 Gas Analysis System. As a result of INFICON's continuing product improvement and quality assurance programs, these specifications are subject to change without notice or obligation.

Table 1-1 Transpector XPR3 specifications

Mass Range (amu)	1-100
Resolution (per 1993 AVS Recommended Practice)	< 1 @ 10% measured at mass 4, 20, 28 and 40
Mass Filter Type	Quadrupole
Detector Type	Off-axis FC and microchannel plate EM
Temperature Coefficient (FC signal at 1E-4 Torr of Argon)	< 1% of peak height per ^{o}C
Mass Position Stability (FC signal at 1E-4 Torr of Argon with constant STP)	< 0.1 amu over 24 hours
Peak Ratio Stability (2/40, 4/40, 20/40, 28/40)	< 2% over 24 hours
Sensitivity (nominal) **As FC at 40 eV / 200 uA** **As EM at 40 eV / 200 uA**	 ≥ 4E-7 amps/Torr (3E-7 amps/mbar) ≥ 4E-3 amps/Torr (3E-3 amps/mbar)
Minimum Detectable Partial Pressure **As FC at 40 eV / 200 uA** **As EM at 40 eV / 200 uA**	 ≤ 1E-9 Torr (1.3E-9 mbar) ≤ 6E-12 Torr (8E-12 mbar)
Maximum Operating Pressure **As FC or EM** **As FC or EM (linear operation)**	 20 mTorr (2.6E-2 mbar) 10 mTorr (1.3E-2 mbar)
Maximum Sensor Operating Temperature	150 ^{o}C
Maximum Bakeout Temperature (electronics removed)	200 ^{o}C
PPM Detectable Limit (at 1-5 mTorr process pressure)	10 ppm
Operating Temperature	20-50 ^{o}C
Power Input	20-30 V(dc), 1.25 amps, 9-pin male "D" connector, internally isolated from system ground
RS232 Serial Communications Interface	Non isolated, baud selection 1200 through 9600, 9-pin female "D" connector

Table 1-1 Transpector XPR3 specifications (continued)

RS485 Addressable Communications Interface	Isolated, 57600 fixed baud, half duplex, fixed address of 1-31, 9-pin female "D" connector
Relay Outputs	4 relays, 24 V at 0.5 A (1 for operational status, 3 for setpoint limits)
Inputs	2 non isolated TTL inputs, contact closure; 2 differential analog inputs, 0-10 V(dc)

NOTE: All specifications after a 30 minute warm up.

NOTE: MDPP (Minimum Detectable Partial Pressure) is calculated as the standard deviation of the noise (minimum detectable signal) divided by the sensitivity of the sensor measured at a four-second dwell time.

1.9 Supplied Items

You should receive the following:

- A Ship Kit. See section 1.9.1 on page 1-10.
- An Electronics Module. See section 1.9.2 on page 1-10.
- A Power Supply. See section 1.9.3 on page 1-10.
- A Transpector XPR3 Pirani Interlock and Heater. See section 1.9.5 on page 1-11.
- A Sensor. See section 1.9.4 on page 1-10.
- Software. See section 1.9.6 on page 1-11.
- A Computer Cable. See section 1.9.8, Computer Cables for Single Sensor Operation, on page 1-11 or section 1.9.9, Computer Cables for Multiple Sensor Operation, on page 1-12.
- If required, a Computer Communications Module Option For Multiple Sensor Operation. See section 1.9.10 on page 1-12.

1.9.1 Ship Kit

Part Number	Description
911-203-G6	Ship Kit
Includes:	
051-032	D Connector
051-1082	Cable Clamp for D connector
062-058	Fuse 2A 250V
074-378-P1	Manual
911-089-P3	Configurable switch cover plate

1.9.2 Electronics Module

Part Number	Description
918-214-G1	Transpector XPR3 -100 AMU EM/FC

1.9.3 Power Supply

(one of the following)	
Part Number	**Description**
911-039-G1	Power Supply Kit - 85-250 V(ac) 4 ft (1.2 m) standard cable - 120V (optional)
911-039-G2	Power Supply Kit - 85-250 V(ac) 4 ft (1.2 m) standard cable - 230V (optional)
600-1008-P15	Power Supply Cable - 15 ft (4.6 m) (optional)
600-1008-P30	Power Supply Cable - 30 ft (9.2 m) (optional)

1.9.4 Sensor

Part Number	Description
918-208-G1	Transpector XPR3 with High pressure EM (X3MH)

1.9.5 Transpector XPR3 Pirani Interlock Protection and Heater

Part Number	Description
914-416-G1	Pirani Interlock Weldment
918-401-P1	Pirani Gauge
600-1109-P1	Pirani Interlock Cable
914-415-P1	Pirani Interlock Weldment Heater
600-1487-P1 068-0433	Heater Power Cable (120V) AC Power Cord (120V)
or	
600-1487-P2 068-0434	Heater Power Cable (230V) AC Power Cord (230V)

1.9.6 Software

Software packages are available for Windows only.

one of the following (optional)	
Part Number	**Description**
911-339-G3	TWare32 Single Sensor Version - CD
911-339-G4	TWare32 Multi-Sensor Version - CD
911-275-G1	Transpector DDE Software (stand alone)
911-275-G2	TWare 32 DDE Software

1.9.7 FabGuard Software

Please call your local INFICON Sales Representative for information on FabGuard Integration and Analysis Software.

1.9.8 Computer Cables for Single Sensor Operation

(one of the following) (optional)	
Part Number	**Description**
600-1001-P15	RS232 Cable - 15 ft (4.6 m)
600-1001-P30	RS232 Cable - 30 ft (9.2 m)

1.9.9 Computer Cables for Multiple Sensor Operation

Part Number	Description
911-040-G30	RS485 Cable Kit - 30 ft (9.2 m)
Includes:	
600-1003-P1	"Y" Cable

1.9.10 Computer Communications Module Options for Multiple Sensor Operation

Part Number	Description
916-600-G2	TCA485 Communications Kit - US
916-600-G3	TCA485 Communications Kit - German
916-600-G4	TCA485 Communications Kit - Japan
916-600-G5	TCA485 Communications Kit - UK
Includes:	
600-1118-P1	RS232 to TCA485 Cable
074-304	TCA485 Installation Instructions
916-200-G1	TCA485 Assembly
054-513	TCA485 Power Supply - US
054-515	TCA485 Power Supply - German
054-516	TCA485 Power Supply - Japan
054-517	TCA485 Power Supply - UK

1.10 Physical Requirements

The following sections show the Transpector XPR3's physical dimensions, weight, mounting requirements, ventilation requirements, and perimeter required for maintenance access.

1.10.1 Physical Dimensions

Figure 1-2 shows the overall physical dimensions of Transpector XPR3 in inches [millimeters].

Figure 1-1 Sensor dimensions

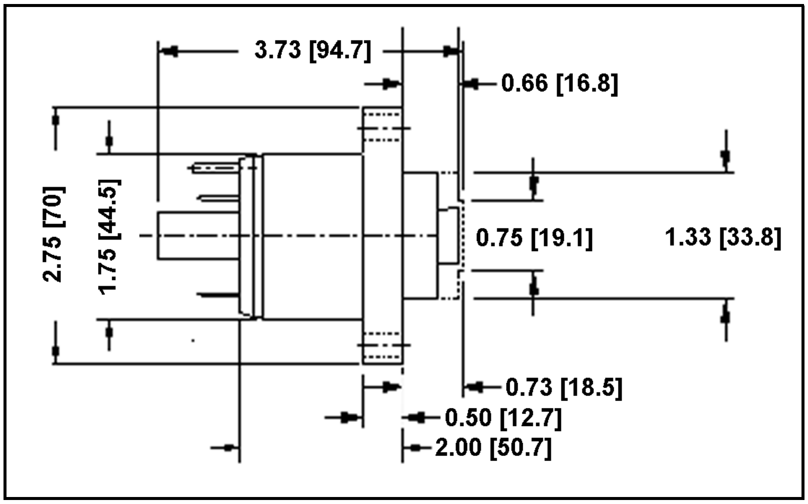
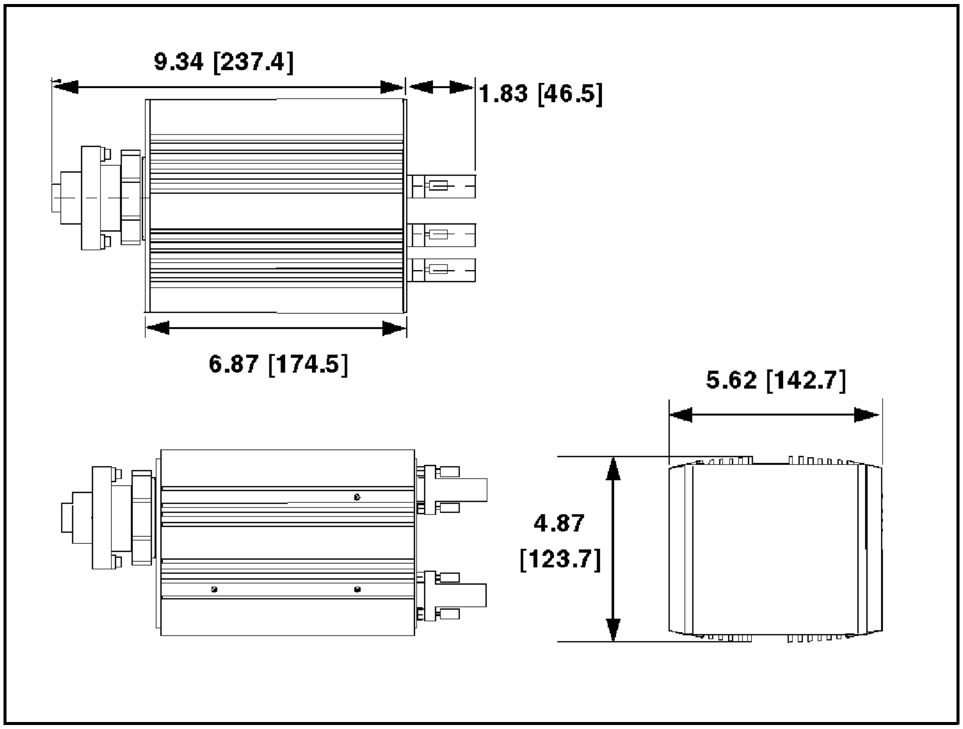


Figure 1-2 Physical dimensions of the Transpector XPR3



1.10.2 Weight

The Transpector XPR3 Electronics Module weighs 5 lb. (2.25 kg).

1.10.3 Mounting Requirements

The sensor is mounted to a high-vacuum chamber with a standard 2.75 inch (69.9 mm) O.D. ConFlat flange.

The electronics module attaches to and is supported by the sensor. Transpector XPR3 can be mounted in any position. See Chapter 4, Transpector XPR3 Installation, for information on installing the Transpector XPR3 system.

1.10.4 Ventilation Requirements

Approximately 1 inch (25.4 mm) clearance all around the Transpector XPR3 Electronics Module should be maintained.

1.10.5 Perimeter for Maintenance Access

Easy access to the Transpector XPR3 should be maintained for installation and maintenance activities.

1.11 Electrical Power Requirements

Transpector XPR3 must be connected to a source of power as specified in the following sections.

1.11.1 Required Supply Voltage

20 to 30 V(dc)

Recommended Power Supply . . . . . +24 V(dc) ±5% Total Regulation

Power Continuous . . . . 40 Watts

1.11.2 Current Rating

1.25 A @ 24 V(dc)

Recommended Power Supply . . . . . 1.8 A maximum sustained load

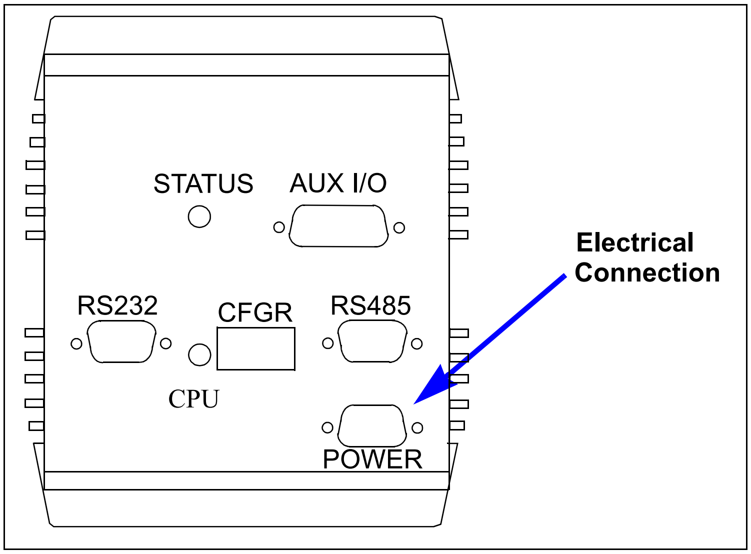
Hot Start . . . . 20 A (< 1 ms duration)

Peak Current . . . . 1.5 x Continuous (100 ms max. duration)

1.11.3 Electrical Connection

9-pin male “D” connector, internally isolated from system ground.
See Figure 1-3. Pin connections are given in Table 1-6 on page 1-19

Figure 1-3 Transpector XPR3 Electronics Module connections



1.12 Overvoltage Category

Overvoltage Category II (per EN61010-1).

1.13 Required Vacuum

Transpector XPR3: < 2.0x10^{-2} Torr (2.66x10^{-2} mbar) [2.66 Pascals]

1.14 Environmental Requirements

The following paragraphs explain the use, altitude range, humidity, pollution degree, and operating temperature for Transpector XPR3.

1.14.1 Use

Indoor use only.

1.14.2 Altitude Range

Maximum altitude range of 6561 feet (2000 meters).

1.14.3 Pollution Degree

Pollution Degree 2 (per EN61010-1).

1.14.4 Operating Temperature

The Transpector XPR3 is designed to operate within a temperature range of 20 °C (68 °F) to 50 °C (122 °F).

1.14.5 Humidity

Up to 98% relative humidity at operating temperature.

1.15 Computer System Requirements

Refer to the TWare32 Operating Manual or the FabGuard Operating Manual for the computer system requirements.

1.16 Communications

This section describes the Transpector XPR3's output and input features. It also discusses the Transpector XPR3 configuration switches, as well as the optional TCA485 Communications Adapter for the host computer.

1.16.1 RS-232C Link

This interface connector allows the user to interface Transpector XPR3 to a host computer via RS-232C.

The RS-232C link is full duplex, meets a subset of EIA-232-D standards, and supports 4 baud rates (1200, 2400, 4800, 9600). The baud is selected by configuration switch 6 and 7. The frame size is 10 bits, consisting of 1 start, 8 data, and 1 stop bits.

There are two modes of RS-232C communication: an ASCII Diagnostic Mode and a Primary Mode. The mode of operation is selected by configuration switch 8.

1.16.1.1 Diagnostic Link (SW8 - OFF)

When switch 8 is OFF, the RS-232C port communicates in an ASCII mode. This facilitates service diagnostics. For more information, see section 8.4 on page 8-6.

1.16.1.2 Primary Link (SW8 - ON)

If switch 8 is ON, the Transpector XPR3 runs in a binary mode, using the RS-232C serial link as the primary source of communication. Data is exchanged with the host computer in binary format. The host computer must be operating with the proper INFICON software (or user written software) to use this communication mode.

1.16.2 RS-485 Link (SW8 - OFF)

When switch 8 is OFF, Transpector XPR3 operates using RS-485 for the primary source of communication. Data is exchanged with the host computer in binary format. The host computer must be operating with the proper INFICON software (or user written software) to use this communication mode.

The RS-485 link implements a ninth bit protocol allowing a single computer to operate up to thirty-one Transpector Electronics Modules. This link is full duplex, meets EIA-485 standards, and operates at 57600 baud. The frame size is 11 bits, with 1 start, 8 data, 1 address/data flag, and 1 stop bit.

The host computer must be equipped with a TCA485 Communications Adapter. See section 4.9.2 on page 4-14 for information on installing the TCA485 Communications Adapter.

To select this mode configuration switch 8 must be in the OFF position. The Transpector XPR3 Electronics Module must have a unique address between 1 and 8 selected by configuration switches 1 through 5.

NOTE: Address 0 is reserved. Address 0 is used as a GLOBAL address by the application program.

1.16.3 Auxiliary I/O

The Transpector XPR3 Electronics Module supports the following I/O functions through the AUX I/O connector on the back panel.

1.16.3.1 Two Digital Inputs

The emission can remotely be controlled with these inputs. The Emission ON requires a HIGH to LOW transition, while the Emission OFF is level sensitive, causing the emission to TURN OFF or remain OFF when ever this line is LOW. These inputs are pulled high internal to the Transpector Electronics Module, allowing a simple contact closure or TTL input to activate them. A contact closure is preferred to maintain ground isolation. See Table 1-2.

Table 1-2 Digital inputs

Emission ON	PIN 11 high to low transition
Emission OFF	PIN 10 level ACTIVE LOW
GND	PIN 9

1.16.3.1.1 One Status Relay Output

This relay is active (closed) when the emission is on. See Table 1-3.

Table 1-3 Status relay output

EMISSION ON	Relay closed. PIN 1 and PIN 2 connected
EMISSION OFF	Relay open
CONTACT RATING	24V at .5 A

1.16.3.1.2 Three Setpoint Relays

These relays work in conjunction with the UPPER and LOWER limits established in the application software. See the appropriate software manual for detailed programming instructions. If the data are within the LOWER and UPPER limits and the relay is programmed for normal operation, the relay is open; otherwise it is closed. If the relay is programmed for reverse operation it is closed if the data are within limits; otherwise it is open. See Table 1-4.

Table 1-4 Setpoint relay outputs

SPT1	PIN 3 and PIN 4 connected
SPT2	PIN 5 and PIN 6 connected
SPT3	PIN 7 and PIN 8 connected
CONTACT RATING	24V at .5 A

1.16.3.1.3 Two Analog Inputs

These inputs are differential and can handle inputs between 0 to +10 volts and common mode voltages of 100 volts. See Table 1-5.

Table 1-5 Two analog inputs

ANALOG INPUT 1	(+)	PIN 14
ANALOG INPUT 1	(-)	PIN 15
ANALOG INPUT 2	(+)	PIN 12
ANALOG INPUT 2	(-)	PIN 13

NOTE: Analog inputs are supported through TWare32 software.

1.16.3.1.4 Power Supply

The power supply input is internally isolated from ground. It is protected by a 2 amp fuse, which is located in the power supply. See Table 1-6.

Table 1-6 Power supply voltage

Pins	1, 2, 3	+24 volt return
Pins	4, 5	No connection
Pins	6, 7, 8	+24 volts
Pin	9	Shield Drain
20-30 V(dc), 1.25 amps		

1.16.3.1.5 Analog Outputs (Optional)

The optional analog output accessory provides four external connections which carry voltages that vary in proportion to the abundance of the specified ions. The software provides a means for the user to assign a mass to each of the four channels along with a scaling factor and offset. The analog output accessory is available in one of two voltage ranges: 0 to 5.0 V and 0 to 10 V.

In addition to the analog signals there is a normally open relay which is closed when the analog outputs are updating. The outputs are updating when in selected peaks mode *and* one or more channels are enabled *and* the emission is on *and* the EM is on (if selected). There is an LED on the back panel of the Transpector which reflects the status of this relay. Table 1-7 lists the connector pins and their corresponding signals.

Table 1-7 Pinouts for analog output connector

Pin #	Signal Name	Pin #	Signal Name
1	Channel 1 output	9	Ground Reference
2	Channel 2 output	10	Ground Reference
3	Channel 3 output	11	Ground Reference
4	Channel 4 output	12	Ground Reference
5	Unused	13	Unused
6	Status Relay Common	14	Unused
7	Status Relay (NO)	15	Cable Shield
8	Unused		

Chapter 2
How The Instrument Works

2.1 Introduction

This section explains how Transpector XPR3 produces its measurements. For a discussion of how to interpret those measurements, see section 3.1 on page 3-1.

2.2 Overview

The Transpector XPR3 Gas Analysis System is a miniature quadrupole partial pressure analyzer which measures the partial pressures of gases in a mixture. It is controlled by an external computer. The Transpector XPR3 Gas Analysis System consists of these parts: a sensor that functions only in a high-vacuum environment, an electronics module which operates the sensor, and the software which resides on an external computer and controls the electronics module.

NOTE: The high-vacuum environment means pressures below 2.6 Pascals, or approximately $2x10^{-2}$ Torr [approx. $2.6x10^{-2}$ mbar].

2.3 Patents

The following patents are applicable to the design and operation of Transpector XPR3 system.

"Method of manufacturing a miniature quadrupole using electrode-discharge machining" [US 5,852,270]

Abstract

A method for manufacturing a miniature quadrupole from a single blank includes fastening four lengthwise insulating strips into parallel slots formed in the blank. A lengthwise axial hole is cut through the blank for the guide wire used in the EDM process. The blank is machined lengthwise into four electrodes using the EDM process so that the electrodes are spaced apart in a width-wise direction and each electrode is connected to an adjacent electrode by one of the insulating strips. During the cutting, the electrodes are held in place by the insulating strips.

"Method for linearization of ion currents in a quadrupole mass analyzer" [US 5,889,281]

Abstract

A method of linearizing the sensitivity of a quadrupole mass spectrometric system to allow the sensor to more accurately report partial pressures of a gas in high pressure areas in which the reported data is effected by a number of loss mechanisms. According to the invention, correction factors can be applied empirically or software in a quadrupole mass analyzer system can be equipped with correcting software to expand the useful range of the mass spectrometer.

"Ion collector assembly" [US 6,091,068]

Abstract

An ion collector includes a Faraday Cup collector having a conductive surface disposed substantially parallel to and spaced from the axis of an entering particle beam containing charged and uncharged particles. A grounded plate disposed in the path of the particle beam allows incoming uncharged particles to impinge thereupon. Preferably, the application of a suitable potential to the conductive plate manipulates incoming charged ions to impinge upon either the electron multiplier or the Faraday collector. The ion collector can further include an electron multiplier used in conjunction with the Faraday collector to allow separate modes of operations. Application of a suitable first potential to the electron multiplier can cause charged particles to be deflected directly to the Faraday collector in one mode, and application of a second potential can cause deflection of charged particles to the electron multiplier, with the effects of the uncharged particles on the output of the detector being minimized.

"Apparatus of measuring total pressure and partial pressure with common electron beam" [US Patent Application 20020153820]

Abstract

An apparatus for determining both total and partial pressures of a gas using one common electron beam includes a partial pressure ionization region and a total pressure ionization region separated by a grid or aperture. A filament produces a plurality of electrons which are focused into an electron beam by a repeller and an aperture or an anode. The interactions between the electron beam and molecules of said gas within the partial pressure and total pressure regions produces first and second ion streams. A focus plate is biased such that the first ion stream is directed to an analyzer which calculates the partial pressure of the gas. An ion collector collects the ions from the second ion stream, where the resulting reference current is used to determine the total pressure of the gas.

2.4 The Sensor

The Transpector XPR3 Sensor (see Figure 2-2) analyzes gases by ionizing some of the gas molecules (in the ion source), separating the ions by mass (in the mass filter), and measuring the quantity of ions at each mass (in the detector). The masses, unique for each substance, identify the gas molecules from which the ions were created. The magnitudes of these signals are used to determine the partial pressures (amounts) of the respective gases.

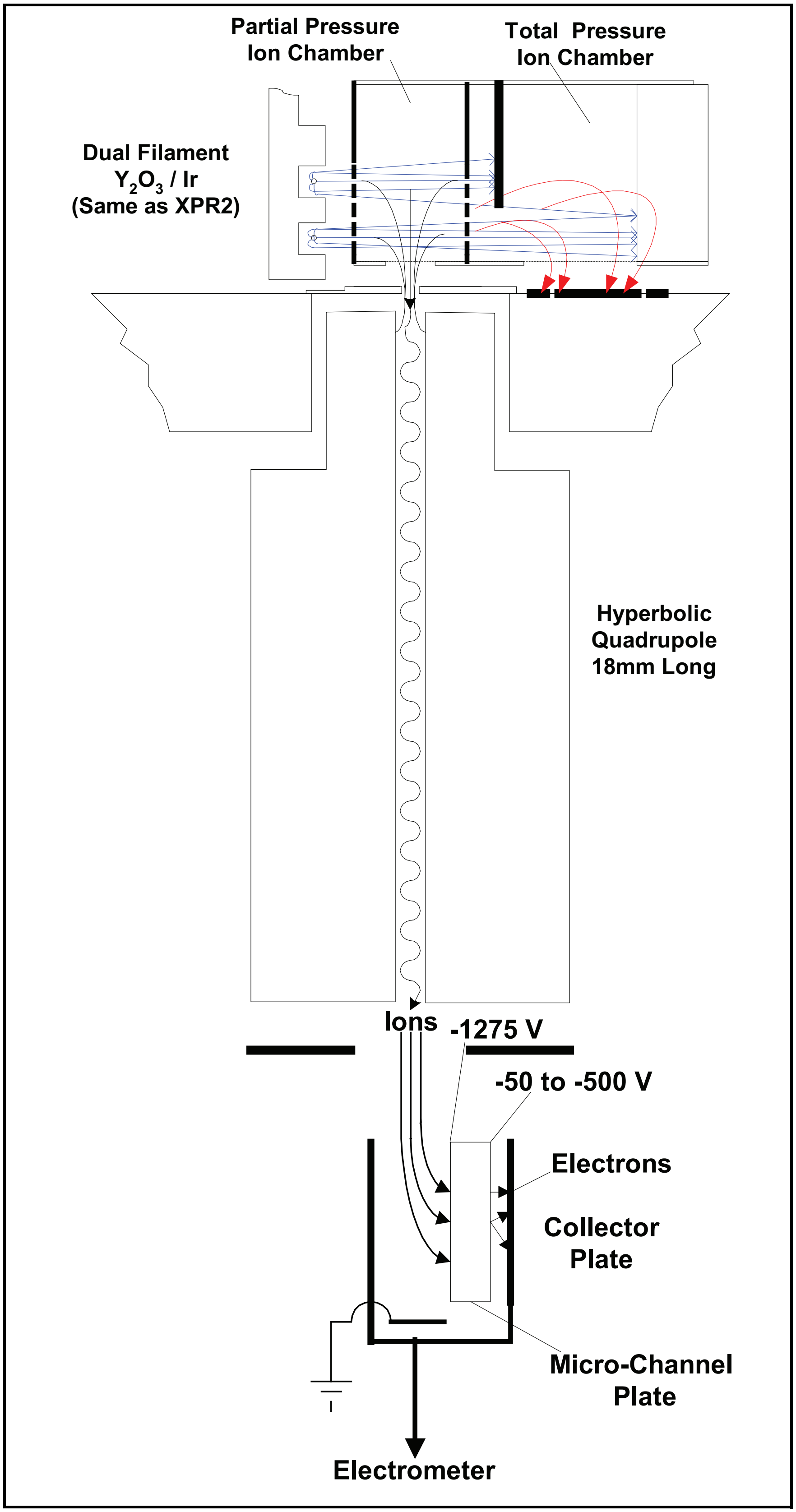
The Sensor consists of three main parts:

- ion source (ionizer)
- quadrupole mass filter
- ion detector

All of these parts are mounted on an electrical feed-through flange, which is bolted to the vacuum space where the gas analysis measurements are made.

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; otherwise, they might not be detected. The miniature design of Transpector XPR3 allows it to operate at pressures higher than those necessary for traditional open ion source sensors.

Figure 2-1 Transpector XPR3 sensor



2.4.1 The Ion Source

The Transpector XPR3 Sensor's ion source, optimized for detecting residual gases in a vacuum system, has a fairly open construction that facilitates the flow of gas molecules into the ionizing region.

The ion source of Transpector XPR3 operates on the same principles as the larger ion sources of standard open ion source sensors. However, Transpector XPR3 is built with a dual ion source which supplies one ion stream to the quadrupole filter and a second ion stream to a total pressure collector. This design allows the total pressure collector to be well isolated from other electrodes in the ion source so that the small ion currents from the Transpector XPR3 source can be measured accurately.

Inside the ion source, a heated filament emits electrons, which bombard the gas molecules, giving them an electrical charge. While this charge may be either positive or negative, Transpector XPR3 detects only positive ions. (Except for certain specialized applications, negative ion capability does not add sufficient utility to justify the considerable added complexity and cost.) Once a molecule is charged, or ionized, electric fields can be used to manipulate it.

The filament is an iridium wire with yttrium-oxide coating. The Transpector XPR3 filament is protected by the Pirani Interlock, which controls emission within safe operating parameters.

The term "emission current" refers to the stream of electrons emitted by the filament. The filament is heated with a DC current from the emission regulator circuit, with the resulting temperature of the filament used as the means of controlling the emission current.

The potential (voltage) on the anode is positive with respect to the potential on the filament. The potential difference between the filament and the anode determines the kinetic energy (usually called the electron energy) of the emitted electrons. The electron energy in turn determines how gas molecules will ionize when struck by the electrons.

A three-sided repeller is centered around the filament and is connected to the low voltage side of the filament. This geometry and potential focuses the electrons through the partial pressure region and on into the total pressure ion region as shown in Figure 2-2. The ions formed within the cage on the anode are pulled away by the potential on the focus lens and formed into a beam. (The focus lens is sometimes called an extractor, since it extracts the ions from the region in which they are created.) The focus lens also serves to focus the ion beam into the quadrupole. To attract positive ions, the focus lens is biased negatively with respect to the anode.

The ion beam generated in the partial pressure chamber passes through the hole in the focus lens and is injected into the mass filter. The ion beam generated in the total pressure chamber strikes the exit lens and is neutralized, resulting in a current flow. The magnitude of this current is related to the pressure in the ion source, and can therefore, be used as a measure of the total pressure. When this current exceeds a preset level, the voltages operating the sensor are turned off, thus helping to protect the sensor from damage due to an over-pressure condition.

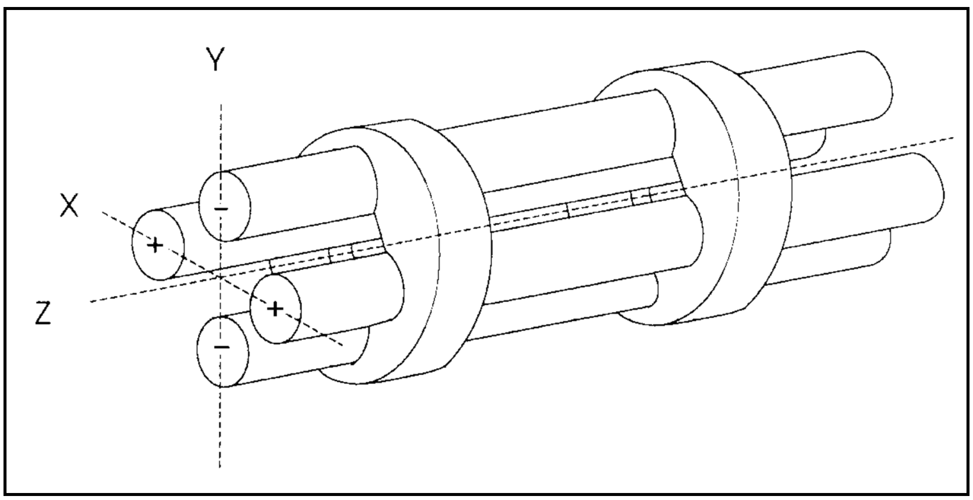
CAUTION

Although this over-pressure protection feature using the internally measured total pressure is available in Transpector XPR3, it is recommended to use only the Pirani Interlock for controlling emission to the sensor. Exposing the Transpector XPR3 sensor to over-pressure or trying to turn the emission on at high pressures exceeding the Transpector XPR3 operating specifications will cause the filaments to prematurely fail.

2.4.2 The Quadrupole Mass Filter

The ions produced in the ion source are injected into the mass filter, which rejects all ions except those of a specific mass-to-charge ratio. Most ions contain only one unit of charge. In Transpector XPR3, the mass filter is a quadrupole type, to which is applied a combination of RF and DC potentials. The RF frequency and amplitude determine the mass, and the RF/DC ratio determines the filter selectivity. See Figure 2-2.

Figure 2-2 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, with the symbol r_0. Ideally, the rod should have a hyperbolic shape (towards the center of the assembly) rather than round. The Transpector XPR3 quadrupole is machined to have the hyperbolic shape and thus has an optimum electric field for mass filtering ions.

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 of 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” (sometimes called the “pole zero”). The following equations summarize the potentials applied to the rods:

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

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

where:

V is the RF amplitude,

f is the RF frequency,

t is time,

U is the DC potential,

PZ is the 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 that of 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. On the other hand, 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 to the desired degree.

The kinetic energy directed along the Z axis of the mass filter (usually called the ion energy) is primarily dependent on the difference between the potential at which the ions were formed (approximately 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 of the DC voltages also applied, result 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, as shown by the following equation:

$$V = 14.438Mf^2r_0^2 \quad [3]$$

where:

V is the peak-to-peak RF amplitude in Volts,

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

f the RF frequency in megahertz,

r_0 the quadrupole radius in centimeters.

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. Of course, the DC voltage must also be increased to maintain the high-mass rejection properties of the filter. A mass spectrum can therefore be obtained by sweeping the RF amplitude, along with the DC voltage.

The variation in the efficiency of transmission of ions through the filter with mass is discussed in section 2.5 on page 2-10. Following that, section 2.6 on page 2-11 discusses the behavior of the filter at very low masses where the applied voltages approach zero.

2.4.3 The Ion Detector

The ion detector region of the sensor consists of the quadrupole exit lens and the detector itself. Often, the quadrupole exit aperture is biased negatively with respect to the anode, focusing ions that have been transmitted through the quadrupole into the detector element. The detector can be a simple Faraday Cup (FC), an Electron Multiplier (EM), or a combination of both. Transpector XPR3 is a combination of Faraday Cup and Electron Multiplier.

2.4.3.1 The Faraday Cup Detector

The Faraday Cup detector is typically a metal plate or a cup-shaped electrode, on which the ion beam impinges. Ions strike the detector and are neutralized, thus drawing a current from the circuitry connected to the electrode. Usually, the current flow that results is exactly equal to the incident ion current. In the Transpector family of instruments, the Faraday Cup is at ground potential.

The sensitivity for Transpector XPR3 instruments operating in Faraday Cup mode is typically > $4x10^{-7}$ amps per Torr. The minimum detectable partial pressures, therefore, can be as small as $1x10^{-9}$ Torr in Faraday Cup mode.

2.4.3.2 The Electron Multiplier (EM) Detector

The Electron Multiplier (EM) acts as an in situ preamplifier for improved sensitivity. Although there are several different types of EM, their operating principals are the same. Incoming ions are accelerated into the input of the EM by a high negative voltage. 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 from a Faraday detector is positive (for positive ions) while an EM detector puts out a negative signal.

The ratio of the electron output current to the incident ion current is known as 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, the EM gain decreases as the ion mass increases.

The advantage of the EM Sensor is its higher sensitivity, thus making it possible to measure lower partial pressures. A typical Transpector XPR3 has an FC sensitivity of about $4x10^{-7}$ amps/Torr, resulting in a minimum detectable partial pressure of $1x10^{-9}$ Torr. Operating in EM mode, the Transpector XPR3 Sensor has a sensitivity of greater than $4x10^{-3}$ amps/Torr, resulting in a minimum detectable partial pressure of $6x10^{-12}$ Torr.

The main disadvantage of the EM Sensor is that the EM gain is less stable and is less precisely known for quantitative measurements.

2.4.3.3 The Transpector XPR3 Microchannel Plate, High Pressure Electron Multiplier

Transpector XPR3 uses a Microchannel plate (MCP) High Pressure Electron Multiplier (HPEM)/Faraday Cup detector. The MCP is a small plate (approximately 1/2" (12.7 mm) square by 1/16" (1.6 mm) thick) consisting of an array of over 10,000 very small continuous dynode multipliers, each with a 0.001" (0.03 mm) inside diameter. Refer to Figure 2-2 on page 2-6.

The main advantage of the MCP over other multiplier designs is its smaller size. Also, the required operating voltage is lower.

The MCP does not have to be kept under a vacuum. However, because of the large surface area, the MCP can absorb water vapor and should be protected from exposure to high levels of moisture over extended periods.

When the MCP is grounded, the ions exiting the quadrupole through the exit lens are collected on the Faraday Cup. The resulting current is conducted through the signal output to the detection amplifier. When -1275 V is applied to the front of the MCP, and between -500 and -50 V is applied to the back of the MCP, the ions impinge on the front side of the MCP. The resulting electron current is collected by the same Faraday electrode.

The front of the MCP is fixed at -1275 V in the EM mode for two reasons. First, the ion beam exiting the quadrupole can be strongly divergent, -1275 V ensures that the entire ion beam is deflected into the MCP. Second, if the ion's kinetic energy as it strikes the entrance of the EM is too low, severe mass discrimination effects can occur. The -1275 V avoids both issues.

Since the MCP gain is determined by the voltage across it, the voltage on the input side must be varied to control the gain. The MCP gain is at its lowest with -775 V on the input side. With -1225 V on the MCP output, the MCP gain is maximized. The Transpector XPR3 voltage is factory adjusted to produce a gain of 300.

Use the minimum MCP voltage required to obtain the necessary peak amplitudes and/or signal-to-noise ratio—a gain of 300 is recommended. Operating at higher voltages than necessary will result in premature aging of the Electron Multiplier, requiring early replacement. As the MCP ages, the voltage needed to get a specific EM gain will increase. Refer to Chapter 6, Transpector XPR3 Best Known Methods.

2.5 Scanning Characteristics

As described above, 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.

While the quadrupole drive circuits can be designed so that R varies in any desired manner with M, it is usually most convenient to keep ΔM constant at a value, which 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. Thus, the sensitivity of the Sensor decreases as M increases.

2.6 The Zero Blast

When the mass filter is tuned to very low masses, 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. This current is called the “zero blast."

The zero blast, present in all quadrupole-based sensors, can interfere with the observation of masses 1 and 2 when significant quantities of higher-mass ions are present. In some instruments, the magnitude of the zero blast is concealed by preventing the voltages from reaching zero.

The "zero blast" (the large current of unseparated ions that enters the mass filter when it is turned to very low masses) can interfere with the observation of masses 1 and 2 when significant quantities of higher-mass ions are present.

2.7 High Pressure Effects

Since Transpector XPR3 is designed to operate at pressures in the milliTorr range, it has some special operating features. The principal difference is that the interaction of ions with the neutral gas molecules in the sensor cannot be neglected.

The interaction of ions with ambient gas molecules is described by the mean-free-path property of the gas environment. The mean-free-path is the average distance that an ion travels before interacting with a gas molecule. The numerical value of the mean-free-path is dependent on the type of ion, the type of gas atmosphere and the gas pressure (i.e. the concentration of gas molecules).

$$\lambda = \frac{K}{P} \qquad [1]$$

where:

λ is the mean-free-path,

K is a constant depending on the ion and gas species,

P is the pressure of the gas

The mean-free-path grows proportionally shorter as the gas pressure in the sensor increases. The effect of collisions of ions with the gas molecules is to prevent the ions from reaching the collector and being measured. Thus the sensor output is no longer directly proportional to the concentration of the gas species being measured.

The fraction of ions that are able to travel a distance X in a gas is given as:

$$\frac{n}{n_0} = \exp\left(-\frac{X}{\lambda}\right) \qquad [2]$$

where:

n is the remaining number of ions after travelling distance X,

n_0 is the original number of ions.

Therefore:

$$\frac{n}{n_0} = \exp\left(-P\left(\frac{X}{K}\right)\right) \qquad [3]$$

That is, the fraction of ions in the beam traveling from the ion source decreases with increasing pressure, P, and increasing length, X, of the ion path. This relationship indicates that a high pressure sensor must be made small in order to avoid the loss of ions.

Since the fraction of ion current that is lost is predictable, the data can be linearized by mathematically compensating for the current loss, provided that the current output I of the ion source is proportional to the partial pressure of the ion of interest. An additional linearization term, (1+AP), is used to compensate for the effects of ion space charge in the ion source. Transpector XPR3 is equipped to make this linearizing calculation using the total pressure reading of the ion source. The linearization factors $F=X/K$ and A, the ionizer constant, are empirically determined for each Transpector XPR3 Sensor for the gas being measured and the electron energy used. The linearized ion current (I_0) is proportional to the original ions in the source, n_0, is displayed using the equation:

$$I_0 = I\ \exp(FP) \times (1 + AP) \qquad [4]$$

where:

I is the measured raw ion current,

P is the Transpector XPR3 total pressure,

A is the ionizer constant,

F is the linearization factor.

Chapter 3
Applications Guide

3.1 How to Interpret the Result

This section explains how to interpret the measurements Transpector XPR3 produces. It is divided into three main parts:

- section 3.1.1, Qualitative Interpretation of Mass Spectra, on page 3-1, explains how to determine which substances are present in the gas sample being analyzed.
- section 3.1.2, Quantitative Interpretation of Mass Spectra (Calculating Partial Pressures), on page 3-9, shows how to estimate how much of each substance is present.
- section 3.1.3, Additional Information for Interpreting Mass Spectra, on page 3-15, provides additional information that may help you interpret mass spectra.

For a discussion of how the Transpector XPR3 produces its measurements, refer to Chapter 2, How The Instrument Works.

3.1.1 Qualitative Interpretation of Mass Spectra

The basic graphical output of a partial pressure analyzer is the 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, and detector, not to mention 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. (See Figure 3-1.)

Figure 3-1 Mass spectrum

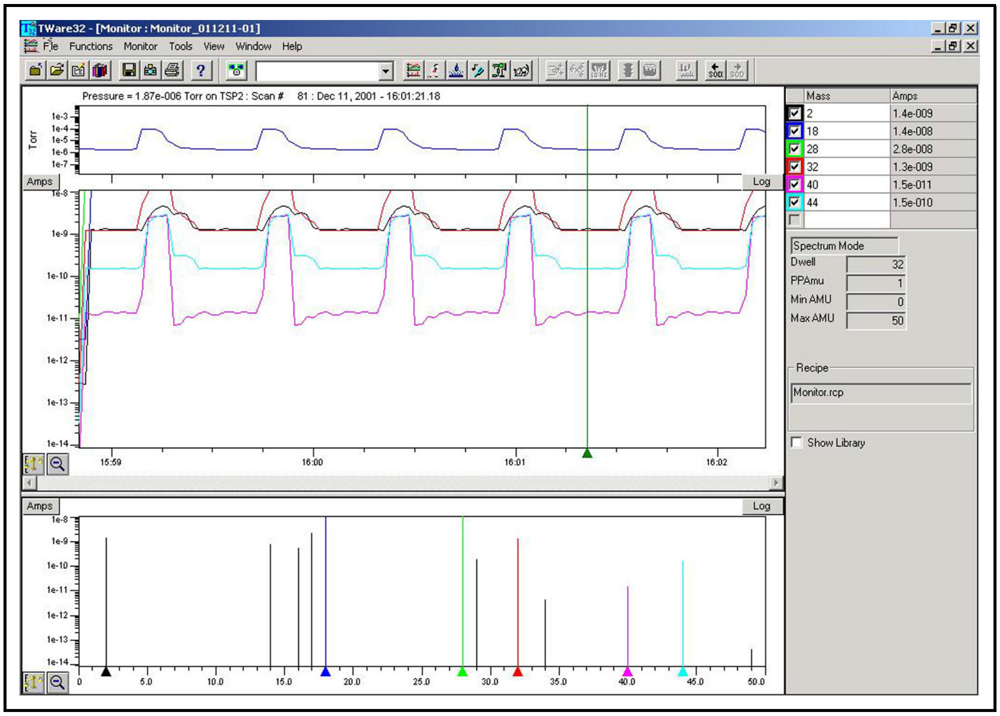


Figure 3-1 is an example of a mass spectrum. The top graph is a trend analysis showing the most important masses verses time. The bottom graph shows the data taken during the 81 scan and shows the air spectra over a six decade y-axis. The prominent peaks for air are mass 28 from Nitrogen, mass 32 from Oxygen, mass 40 from Argon, and mass 18 from water vapor.

3.1.1.1 Ionization Process

When a sufficiently energetic electron strikes a gas molecule, there are many processes that can occur, just some of which are summarized in Table 3-1.

Table 3-1 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 so-called 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 also possible, provided the incident electron has enough energy.

Reactions 3 through 8 are all 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 (i.e., 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, sometimes, the cracking pattern). The fragmentation pattern for nitrogen is given in Figure 3-2.

Figure 3-2 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 multiply 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 (it should be noted that 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 composed 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 3-2 on page 3-3; 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+}. It has been demonstrated, by other means, that 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 show up at 9.5 AMU.

3.1.1.2 Isotope Ratios

An additional cause of multiple peaks in the mass spectrum of a pure substance is that most (but not all) elements are composed 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. Carefully examine the nitrogen spectrum in Figure 3-2 on page 3-3. 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 (e.g., 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, are a very useful 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. That is, the probability of ionizing, for example, 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%).

For a listing of the isotopic ratios for the lighter elements, see Table 3-2. 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.

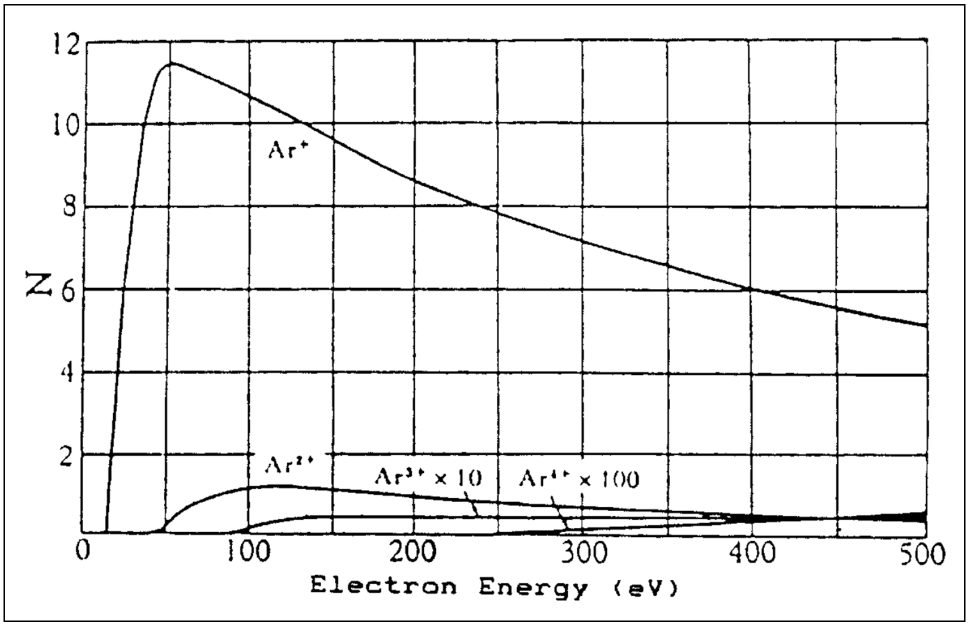
Table 3-2 Isotope ratios

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
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

3.1.1.3 Electron Energy Effects

As was previously mentioned, the exact fragmentation pattern observed will depend on the energy of the bombarding electrons. Figure 3-3 (from a paper by W. Bleakney, *Physical Review*, 36, p. 1303, published in 1930) 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 3-3 Electron energy effects



This graph shows the number of argon ions, N, formed per electron per Torr at 0 °C versus electron energy.

The appearance potential (i.e., 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.

The appearance potential for Ar^{2+} is 43.5 eV, and the ion production rate does not maximize until the electron energy exceeds 100 eV. The appearance potential for Ar^{3+} is approximately 85 eV, while the appearance potential for Ar^{4+} is over 200 eV. Transpector XPR3 normally is set for 40 eV (Low Emission) setting to produce Ar^+ ions. The low electron energy (40 eV) model of Transpector XPR3 operation suppresses production of $^{36}Ar^{2+}$ ions at mass 18, resulting in the mass 18 current being principally a measure of H_20.

3.1.1.4 A Qualitative Interpretation Guide

To use a partial pressure analyzer to identify unknown substances, you must recognize three characteristics: fragmentation patterns, multiply charged ions, and isotope ratios. Simple spectra are, in general, relatively easy to interpret and will yield useful identifications. The analysis of complicated mixtures of substances is much more difficult.

Table 3-3 is intended as a spectrum interpretation guide which may be of use when first examining an unknown spectrum. The guide lists the masses of peaks, possible ion identities for each of these masses, and common sources for each of these ions.

NOTE: This list is by no means all-inclusive.

Table 3-3 Spectrum Interpretation Guide

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

Table 3-3 Spectrum Interpretation Guide (continued)

Spectrum Interpretation Guide		
AMU #	**Chemical Symbol**	**Sources**
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
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,	Oxygen, 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	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

Table 3-3 Spectrum Interpretation Guide (continued)

Spectrum Interpretation Guide		
AMU #	**Chemical Symbol**	**Sources**
49	$C^{37}Cl$	See Note 2
50	$C^{37}Cl$, CF_2, C_4H_2	See Note 2, Freon F, Note 3
NOTES:	(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	

3.1.2 *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. Also by design, 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.

The following equation shows the relationship between the partial pressure of substance determined by measuring the ion current at mass b:

$$PP_a = K_{ab} \times I_{ab} \quad [1]$$

The partial pressure of substance a is symbolized by PP_a, while K_{ab} is the proportionality constant for the peak at mass b from substance a, and I_{ab} is 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 [1] can therefore be rewritten as follows:

$$PP_a = (M_{ab} \times A_b) \times I_{ab} \quad [2]$$

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 involved is shown in equation [3]:

$$M_{ab} = \frac{1}{FF_{ab} \times XF_{a}} \quad [3]$$

The term FF_{ab} is the fragmentation factor for substance a at mass b. It is equal to the fraction of the total current of all ions from substance a which have a mass b. Finally, XF_a is the ionization probability of substance a, relative to nitrogen (i.e., $XF_N = 1$). That is, it is the ratio of total ion current (for all masses) from substance a to the total ion current from nitrogen, 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 10. 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 (formerly the National Bureau of Standards).

Table 3-4 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 3-4 Typical fragmentation factors for the major peaks of some common substances

Mass	FF	Mass	FF	Mass	FF
Acetone $(CH_3)_2CO$		Helium He		Oxygen O_2	
43	.63	4	1.00	32	.95
58	.23			16	.05
42	.04	Hydrogen H_2			
27	.03	2	1.00	Toulene $C_2H_5CH_3$	
				91	.46
Argon Ar				92	.34
40	.83	Krypton Kr		60	.07
20	.17	84	.45	65	.05
		86	.13		
Benzene C_6H_6		82	.10	Trichlorethylene C_2HCl_3	
78	.53	83	.10	95	.22
51	.11			130	.22
52	.11	Methane CH_4		132	.21
50	.10	16	.46	97	.14
		15	.40	60	.13
Carbon Dioxide CO_2		14	.07		
44	.70	13	.04	Water H_2O	
28	.11			18	.75
16	.06	Methanol CH_3OH		17	.19
12	.01	31	.43	1	.05
		32	.23	16	.02
Carbon Monoxide CO		29	.18		
28	.91	28	.03	Xenon Xe	
12	.05			132	.26
16	.03	Neon Ne		129	.26
		20	.90	131	.22
Ethanol C_2H_5OH		22	.10	134	.11
31	.49			136	.09
45	.21	Nitrogen N_2			
27	.09	28	1.00		
29	.07	14	.12		
		29	.01		

Ionization probability factors can be approximated by substituting the relative ion gauge sensitivities for various gases. Table 3-5 gives relative ion gauge sensitivities for some common gases.

NOTE: This table 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 (Chapter 8, Section 1.1) and Drinkwine and Lichtman (Table I, page 5).

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 (for example, a capacitance manometer) or a gauge with a known sensitivity factor (for example, a spinning rotor gauge).

Table 3-5 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
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 Electron Multiplier gain (if the analyzer is so equipped), and the basic sensitivity, as indicated in equation [4]:

$$A_a = \frac{1}{TF_b \times DF_{ab} \times G \times S} \qquad [4]$$

Here, TF_b is the transmission factor of the mass filter at mass 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 Electron Multiplier, 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 Electron Multiplier detection factor decreases.

The gain of the Electron Multiplier, G, measured at mass 28 for nitrogen, is the Electron Multiplier 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 ratio of Faraday mode ion current for a given pressure of pure nitrogen measured at mass 28, and is typically expressed in amps/Torr.

The overall relation between partial pressure and ion current, given in equation [5], 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.

$$PP_a = \left\{ \frac{FF_{N28}}{FF_{ab} \times XF_{ab} \times TF_b \times DF_{ab} \times G \times S} \right\} \times I_{ab} \qquad [5]$$

A brief discussion of each of the terms follows:

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 3-4 on page 3-11).

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 Electron Multiplier detectors (dimensionless).

G . . . . Electron Multiplier 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 amps/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).

3.1.3 Additional Information for Interpreting Mass Spectra

The following paragraphs contain additional information which may be of use when interpreting mass spectra.

3.1.3.1 Ion source Characteristics

It is important to recognize that the partial pressure analyzer (especially the ion source) and the vacuum system configuration can both have an effect on the relative concentrations of the gases detected. In order to minimize these effects, it is necessary to have the right type of ionizer, the right type of filament, and the right configuration of the vacuum system. This is particularly true when a differential pumping arrangement is used because the pressure of the gas to be sampled is too high for the Sensor to operate. J. O'Hanlon's book, *A User's Guide to Vacuum Technology*, has a brief discussion (in Chapter 8, Section 2) of some of these concerns.

There are four classes of interactions between the sensor and the immediate vacuum environment which can have a significant effect on the detected gas composition.

First, the analyzer itself is a source of gas molecules because of outgassing from its surfaces. Usually, the outgassing levels can be reduced by baking the analyzer in vacuum. When operating in the ultrahigh vacuum (UHV) region, it is best to bake the sensor overnight at the maximum permissible temperature with the electronics removed. See the bakeout temperature specifications for the Transpector XPR3 sensor. A second overnight bakeout should be performed at the maximum sensor operating temperature. (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 back down.)

CAUTION

Make sure that the Electron Multiplier high voltage is turned off for this (second) bakeout temperature, otherwise, permanent damage to the EM may result.

Second, 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.” In such cases, 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.

Third, 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 (Chapter 8, Section 2) for more information on filament materials and their interactions with the gas being analyzed. 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. This latter mechanism makes the combination of a pressure reduction system and an RGA Sensor unsuitable for measuring nitrogen contamination in argon at the low parts-per-million (PPM) level from a sputter deposition process. A special type of inlet system and ion source (often referred to as a Closed Ion Source [CIS]) should be used for this type of application.

Fourth, 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 (such as 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, EID/ESD 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 EID/ESD.

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 (i.e., the sum of ions of all masses) is electron energy and ionizer dependent, a reasonable estimate for the number of ions produced (relative to some standard, usually nitrogen) in a partial pressure analyzer is the relative ionization gauge sensitivity.

3.1.3.2 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 ΔM) 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) that decreases as mass increases.

The way the mass scale is “calibrated” or “tuned” (i.e., 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.

3.1.3.3 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 earlier in Table 3-4 on page 3-11, Typical fragmentation factors for the major peaks of some common substances, is compiled from more than one source and is for illustrative purposes only. For maximum accuracy in determining partial pressures, the fragmentation factors for the substances of interest should be measured with the same instrument, and the same adjustments, as the samples to be analyzed.

3.1.3.4 High Pressure Effects

As described in section 2.7, High Pressure Effects, on page 2-11, when approaching the high pressure limit of operation the ion current does not increase linearly with pressure because of ion losses that are pressure dependent. The degree of ion loss depends on the nature of the ion in question and the nature of the total gas environment in the sensor. If conditions are sufficiently defined, i.e. the type of major gases and the interaction with the ion of interest, it is possible to compensate mathematically for the non-linear behavior at the high pressure end of the range. The Transpector XPR3 permits the user to make such a compensation using the total pressure sensed by the ion source and an empirically determined factor for specific gases. Even when the exact factor is not known, the compensated results are typically more nearly accurate than the raw data.

Chapter 4
Transpector XPR3 Installation

4.1 Installation Steps

The following steps must be performed to install the Transpector XPR3 Gas Analysis System.

1. Install the Isolation Valve, see section 4.4 on page 4-4.
2. Mount the Pirani Interlock Weldment Assembly, section 4.5 on page 4-8.
3. Mount the Pirani Gauge, see section 4.6 on page 4-9.
4. Install the Transpector XPR3 Sensor, see section 4.7 on page 4-10.
5. Install the Transpector Electronics Module, see section 4.8 on page 4-11.
6. Install the Communications cables, see section 4.9 on page 4-12.
7. Install the 24 V DC Power Supply, see section 4.10 on page 4-15.
8. Install the Transpector XPR3 Interlock Cable, see section 4.11 on page 4-18.
9. Attach the Heating Jackets, see section 4.12 on page 4-20.
10. Install the Software, see section 4.13 on page 4-20.

CAUTION

Avoid mounting the sensor near any magnetic fields greater than 2 gauss.

CAUTION

It is important that the connection between the sensor and the vacuum chamber does not interfere with gas exchange to ensure that the gas composition accurately reflects that existing in the vacuum chamber.

4.2 ConFlat® Flanges - General information

The sensor is installed on your vacuum system with a 2.75 inch (69.9 mm) O.D. ConFlat flange. ConFlat flanges, and similar compatible types made by other manufacturers, are widely used for attaching devices to ports on high vacuum systems. If you are familiar with the installation of this type of flange go on to section 4.7 on page 4-10.

NOTE: If your system does not have a port with a compatible mating flange, an adapter will be necessary.

In order to install these flanges without leaks, it is important to follow the proper operating procedures. These flanges are sealed with a metal gasket and can be heated for bakeout to temperatures of 350 °C. For bakeout temperatures when a Transpector XPR3 Sensor is installed, see Table 5-1 on page 5-1.

4.2.1 Assembling ConFlat Flanges

To assemble a pair of ConFlat flanges, follow these steps:

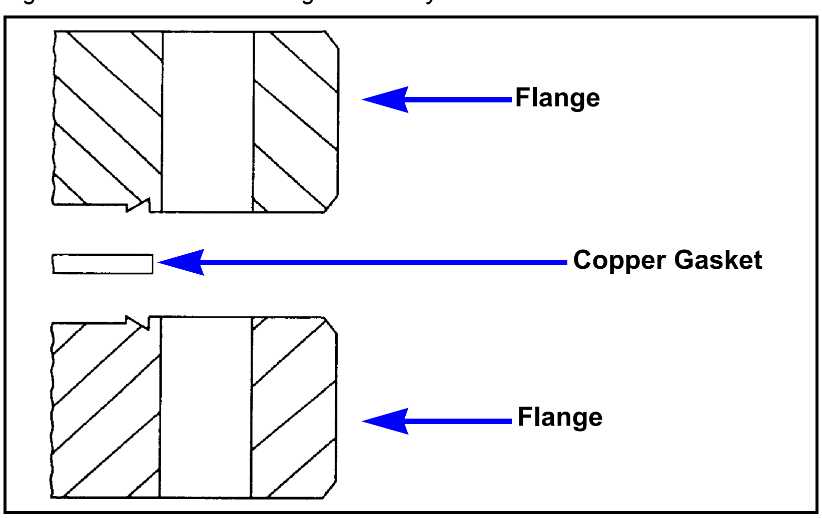
1. Wipe the sealing areas of the flanges with a laboratory towel using a clean solvent, such as water free alcohol. These areas must be clean and free of particulate matter. Also clean the copper gasket between the flanges in the same manner.

CAUTION

Do not touch the gasket and flange faces with your fingers during the installation process.

2. Install the copper gasket between the two flanges. See Figure 4-1. Always use a new gasket. *Do not attempt to use gaskets more than once.*

Figure 4-1 Gasket and Flange Assembly



3 Bring the two flanges together making sure that the gasket fits in the recess in both flanges. Flange faces should be parallel. If the gasket is properly seated, it should not be possible to slide the two flanges laterally with respect to each other.

4 Install stainless steel bolts in the bolt holes of the flanges and finger tighten only. If the flanges are to be baked, coat the bolt threads with an anti-seize compound (FelPro C 100 or equivalent).

CAUTION

Do not get any of the anti-seize compound on the gaskets or the vacuum parts of the flange.

5 After the bolts have been finger tightened and the flange faces are parallel, tighten the bolts gradually and evenly in a criss-cross pattern until the flange faces are brought into even contact with each other.

4.3 Avoiding Process Metal Deposition

CAUTION

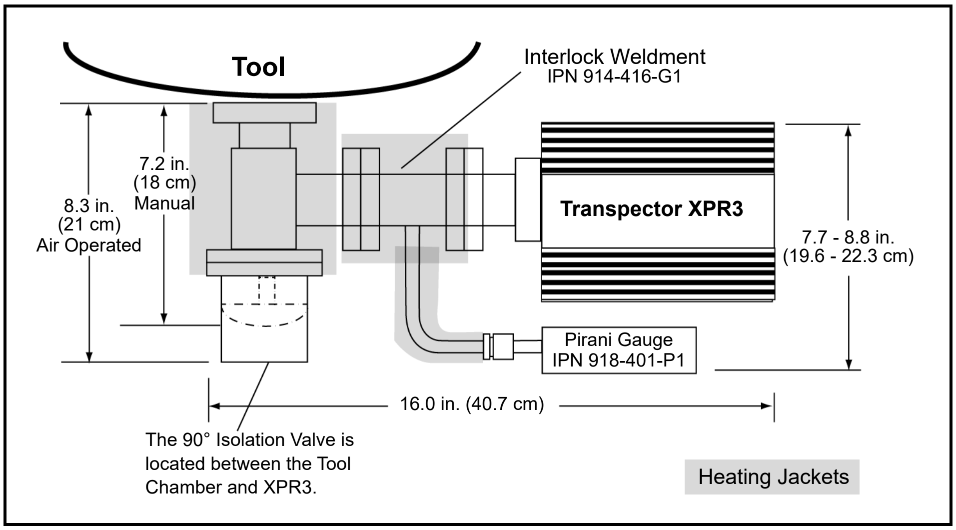
Conductive deposits on the ceramic ion source plate from the process can cause electrical short circuits and a general failure of the Transpector XPR3. The use of a 90^{o} valve between the process and the sensor will alleviate this condition. The installation of a 90^{o} valve is described in section 4.4 on page 4-4.

4.4 Installing the Isolation Valve

Transpector XPR3 should be installed on a 90° high-conductance isolation valve (1.5" [38 mm] outer diameter) mounted on the process chamber (see Figure 4-2). This prevents line-of-sight deposits, from the plasma, from reaching the Transpector XPR3 Sensor. The isolation valve may be provided by the user, or purchased from INFICON (see below). The isolation valve needs to be bakeable and needs to be fitted with a heating jacket designed for baking the valve.

- 1½" Right Angle Valve Hand Operated with Heating Jacket: IPN 914-024-G1
- 1½" Right Angle Valve Air Operated with 24 V(dc) Solenoid and Heating Jacket: IPN 914-025-G1
- Valve Heating Jacket (150 °C; 120/230 V(ac) Operation): IPN 914-407-P1

Figure 4-2 Typical Connection of a Transpector XPR3 to the process chamber



4.4.1 Notes for Air Operated Valve

The INFICON supplied air operated valve is a 1/8" ported, 3-way, single solenoid, 2-position spring return, Normally Open (NO) or Normally Closed (NC), general purpose air valve. It is configured for 2-way, NC use, whereby the EXH port is plugged and the air supply (60 - 100 psig) must be connected to the port labelled IN. See Figure 4-3.

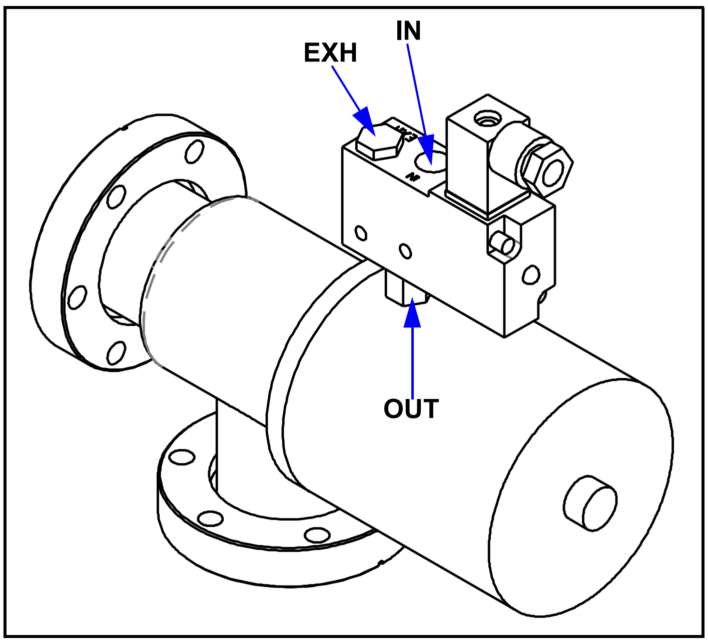
WARNING

The air pressure supplied to the valve must not exceed 100 psig.

CAUTION

The air pressure supplied to the valve must be at least 60 psig.

Figure 4-3 INFICON supplied air valve

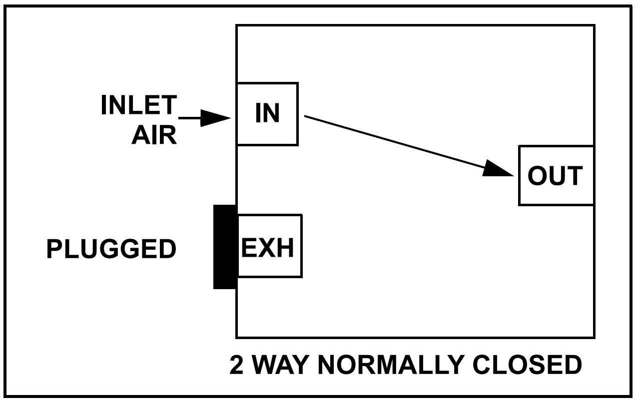


4.4.1.1 Port Identification for 2-Way, Normally Closed Use

See Figure 4-4.

IN . . . . Pressure supply port
OUT . . . . Delivery port to valve
EXH . . . . Exhaust port, plugged

Figure 4-4 Port identification



4.4.1.2 Valve Parts List

Figure 4-5 shows the Valve Parts List

4.4.1.3 Wiring Instructions

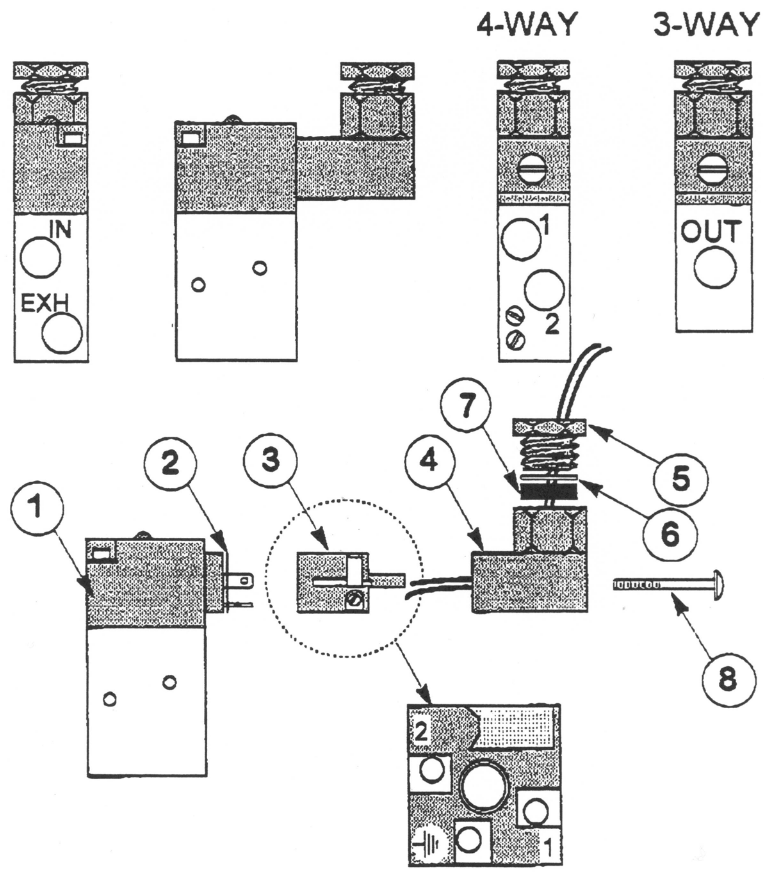
See Figure 4-5.

1. Remove screw (item 8) and pull off connector elbow (item 4).
2. Unscrew nut (item 5); washer (item 6) and compression ring (item 7) may remain in place.
3. Remove connector (item 3) from elbow by inserting a narrow blade screwdriver in the rectangular slot near the edge of the elbow and gently prying the connector out from the elbow.
4. Thread wire through nut, washer, compression ring and elbow.
5. Connect "Positive" and "Negative" to terminals "1" and "2" in any order; connect "Ground" to Ground. Either solder or screw wires into connections.
6. Press connector back into elbow at any 90° position; screw nut securely into washer / compression ring fitting.
7. Note alignment of pins and press connector elbow back onto solenoid coil; replace screw.

WARNING

This valve has an operational voltage rating of 24 V(dc) +10% to -15%.

Figure 4-5 Valve parts list



Item	Description
1	Solenoid Coil
2	Connector Gasket
3	Connector
4	Connector Elbow
5	Nut
6	Washer
7	Compression Ring
8	Screw

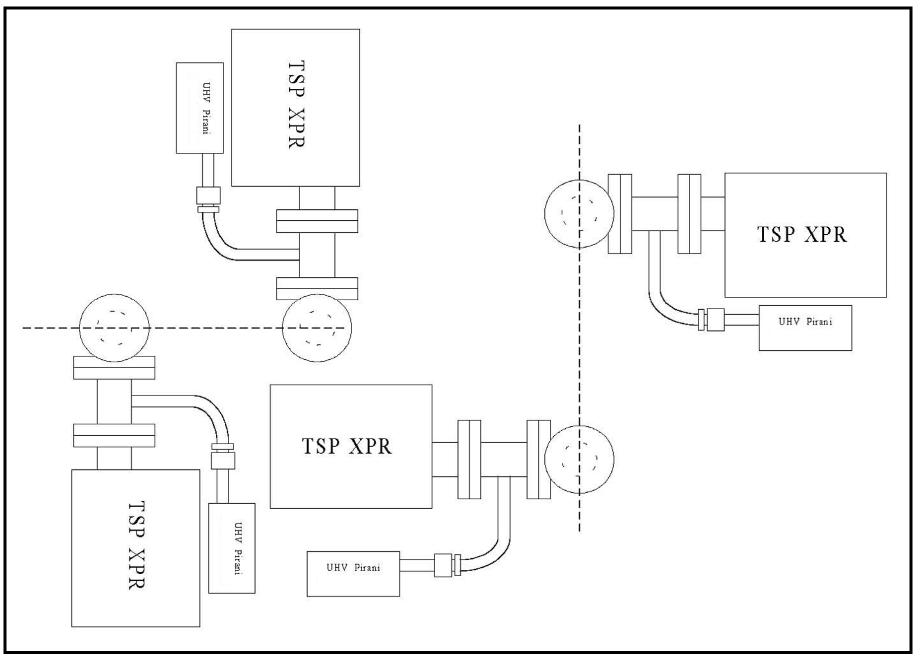
4.5 Mounting the Pirani Interlock Weldment Assembly

The Transpector XPR3 Interlock Weldment Assembly with a Pirani gauge port has a 1.5 in. (38 mm) inner diameter for the Transpector XPR3 Sensor. Both CF-40 flanges rotate to provide flexibility in orientation of the Pirani gauge with respect to the Transpector electronics module, the isolation valve, and the tool.

1 Evaluate, or pre-fit, Transpector XPR3 on the tool port to determine the orientation of the Transpector electronics module with respect to the tool, and the Pirani gauge with respect to a side of the Transpector electronics module. Typically, the Pirani gauge is placed under the Transpector electronics module if the axis of the Transpector XPR3 is horizontal, as shown in Figure 4-6.

NOTE: For measurements of $2x10^{-2}$ Torr or less, that are involved in protection of the Transpector XPR3 filament, the Pirani gauge retains its accuracy in any orientation.

Figure 4-6 Orientations for mounting an Transpector XPR3 on a tool



2 Attach the Interlock Weldment Assembly to the 1½" Right Angle Valve with a Cu gasket using ¼-28 x 1¼" 12 pt SS silver plated bolts, with the nut plates on the Valve side. Tighten the bolts finger tight.

3 Check for orientation and alignment: the Pirani gauge tube should be oriented so that the VCR fitting is facing away from the valve.

4 Tighten all the bolts evenly and gradually in a crisscross pattern until the flange faces come into contact.

4.6 Mounting the Pirani Gauge

The Pirani gauge is UHV compatible with a SS body, ceramic electrical feed-through and a 8-VCR female mounting flange.

1 Connect the Pirani gauge flange to the port on the Interlock Weldment Assembly using a Ni-8-VCR -2 silver plated Ni gasket.

2 Adjust the orientation of the Pirani gauge and tighten the gland finger tight. Use a 1-1/16" open end wrench for the female nut and a 15/16" open end for the male nut.

NOTE: For Ni gaskets, tighten 1/8 beyond finger tight with the wrenches to seal the Pirani gauge fitting. Rotation of the Pirani gauge can be inhibited by rotating the male nut and keeping the female nut wrench fixed.

4.7 Sensor Installation

When you are installing a sensor, follow these general rules.

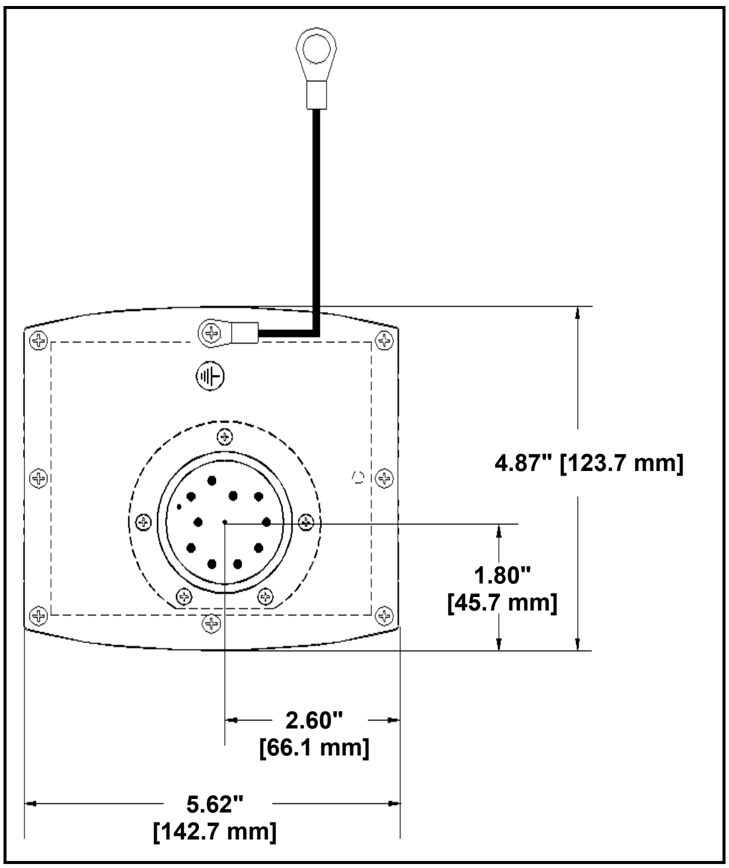
CAUTION

Do not touch any surface on the vacuum side of the sensor with your fingers. If it is necessary to touch any of these parts, always wear clean linen or nylon laboratory gloves.

Before installing the sensor on your system, check for any signs of loose or broken parts.

Do not attempt to clean the sensor in any kind of solvent. Cleaning the sensor requires its disassembly. If the sensor is contaminated and needs cleaning, contact the INFICON Service Department for specific instructions. Refer to section 1.3 on page 1-4.

Figure 4-7 Transpector sensor connector diagram



4.7.1 Attaching the Sensor

Transpector XPR3 may be mounted in any position when attaching it to the vacuum vessel or chamber.

1. Attach the Transpector XPR3 Sensor Flange to the Pirani Interlock Weldment Assembly CF-40 Flange with a Cu gasket using ¼-28 x 1¼" 12pt SS silver plated bolts, with the nut plates on the Transpector XPR3 side of the Flange. Tighten the bolts finger tight.
2. Tighten all the bolts evenly and gradually in a crisscross pattern until the flange faces come into contact.

4.8 Electronics Module Installation

NOTE: The Transpector Electronics Module was calibrated at the factory to a specific Transpector XPR3 Sensor. If mounted to a different sensor, the Transpector Electronics Module may have to be recalibrated.

The Transpector Electronics Module should be mounted in an area where the ambient temperature does not exceed 50 °C, and where there is free air circulation around the unit. Best performance will be achieved if the unit is not located close to major heat sources where it is subjected to wide temperature variations.

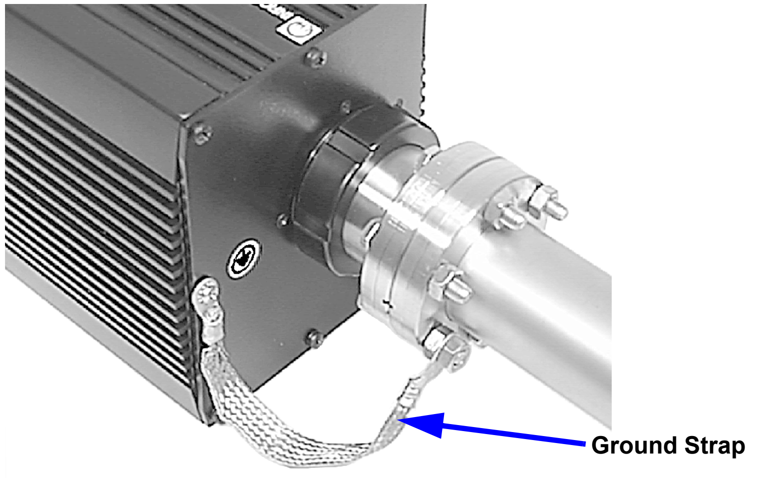
After the Pirani Interlock hardware and Transpector XPR3 Sensor have been installed on the vacuum system, the Transpector Electronics Module should be mounted on to the sensor. Follow these steps to install the Transpector Electronics Module on the sensor:

1. The Transpector Sensor mounting connector assembly has an O-ring in it. When the mounting nut is tightened the O-ring compresses making a tight fit on the sensor housing. Before attempting to mount the sensor, make sure the mounting nut on Transpector Electronics Module is loose so the O-ring is not compressed.
2. Note the alignment pin on the sensor feed-through and the Transpector mounting connector. Carefully slide the Transpector Electronics Module onto the sensor. Make sure the Transpector Electronics Module slides on all the way.
3. Hand tighten the mounting nut on the Transpector Electronics Module.
4. Tightly fasten the 6" ground strap from the Transpector Electronics Module to the sensor ConFlat flange mounting bolt. See Figure 4-8.

WARNING - Risk Of Electric Shock

You must install the ground strap to ensure a good safety ground. Failure to make this connection could result in a shock hazard and/or personal injury.

Figure 4-8 Properly installed ground strap



- Continue with section 4.9 and install the communication cables.

4.9 Installing Communications Cables

Communication cables are required to connect the Transpector Electronics Module to the computer which will operate it. There are two communication systems; the correct option must be chosen.

- If you purchased a single Transpector system, you will use RS-232C communications. See section section 4.9.1 below.
- If you purchased multiple Transpector systems to network from a single computer, you will use RS-485 communications. See section 4.9.2 on page 4-14.

See section Figure 4-9 on page 4-16 for a diagram of communications connections.

4.9.1 RS-232C Communication

RS-232C Communication is used by the single-sensor version of TWare32. The configuration DIP switches on the Transpector Electronics Module must be set correctly for RS-232C communication:

- SWITCH 8 must be ON.
- SWITCH 6 and 7 must be set to select the proper baud rate as selected in the application software. The software default is 9600 baud. See Table 4-1.

Table 4-1 RS-232C communications baud rates

SW6	SW7	Baud
OFF	OFF	9600
ON	OFF	4800
OFF	ON	2400
ON	ON	1200

Connect the RS-232C communications interface cable, from the Transpector Electronics Module to the proper serial channel on the host computer, e.g., COM1 or COM2.

NOTE: The application software may be configured to the COM channel used for communication to the Transpector Electronics Module. Make sure the RS-232C interface cable is connected to the COM port that is selected in the application program. (Refer to the TWare32 Operating Manual for more information.)

4.9.2 RS-485 Communication

RS-485 Communication is used by the Multi-Sensor version of TWare32. The configuration DIP switches on the Transpector Electronics Module must be set correctly for RS-485 communication:

- RS-485 baud is fixed at 57600
- SWITCH 8 must be OFF
- SWITCHES 1-5 must be set for a unique address as shown below

Each Transpector Electronics Module on the network must have a unique address between 1-31. See Table 4-2.

Table 4-2 Network addresses 1 through 8

SW1	SW2	SW3	SW4	SW5	ADDRESS
OFF	OFF	OFF	OFF	ON	1
OFF	OFF	OFF	ON	OFF	2
OFF	OFF	OFF	ON	ON	3
OFF	OFF	ON	OFF	OFF	4
OFF	OFF	ON	OFF	ON	5
OFF	OFF	ON	ON	OFF	6
OFF	OFF	ON	ON	ON	7
OFF	ON	OFF	OFF	OFF	8

1. Connect the RS-485 center connector on the RS-485 “Y” cable to the RS-485 connector on the back of the Transpector.
2. Connect the female end of the RS-485 interface cable to the male end of the “Y” cable.
3. If this is a multiple Transpector installation, connect the RS-485 interface cable from the next Transpector. See Figure 4-9 on page 4-16.

   If the RS-485 interface is to be used, the host computer must have the TCA485 Communication Adapter installed. See the TCA instruction sheet (IPN 074-304) for installation details.
4. Connect the RS-232/TCA485 cable from the TCA485 adapter to the COM port of choice on the host computer.
5. Connect the power transformer to the TCA485 adapter.

4.10 Connecting the 24 V(dc) Power Supply

1 Connect the +24 V(dc) power supply cable to the POWER connector on the Transpector Electronics Module.

2 Plug the AC line cord into the mating IEC320 connector on the power supply module.

NOTE: The AC Line Input for the +24 V(dc) Power Supply is: 90-260 V(ac), 40 watts max, 47-63 Hz.

3 Plug the AC line cord into an appropriate AC outlet.

4 Verify that the green LED labeled CPU on the Transpector back panel is on. If the LED is not on, check the power connections. If the LED flashes, see Chapter 8 to determine the problem.

NOTE: Recommendations for user provided 24 V(dc) power supply are given in section 1.11, Electrical Power Requirements, on page 1-14.

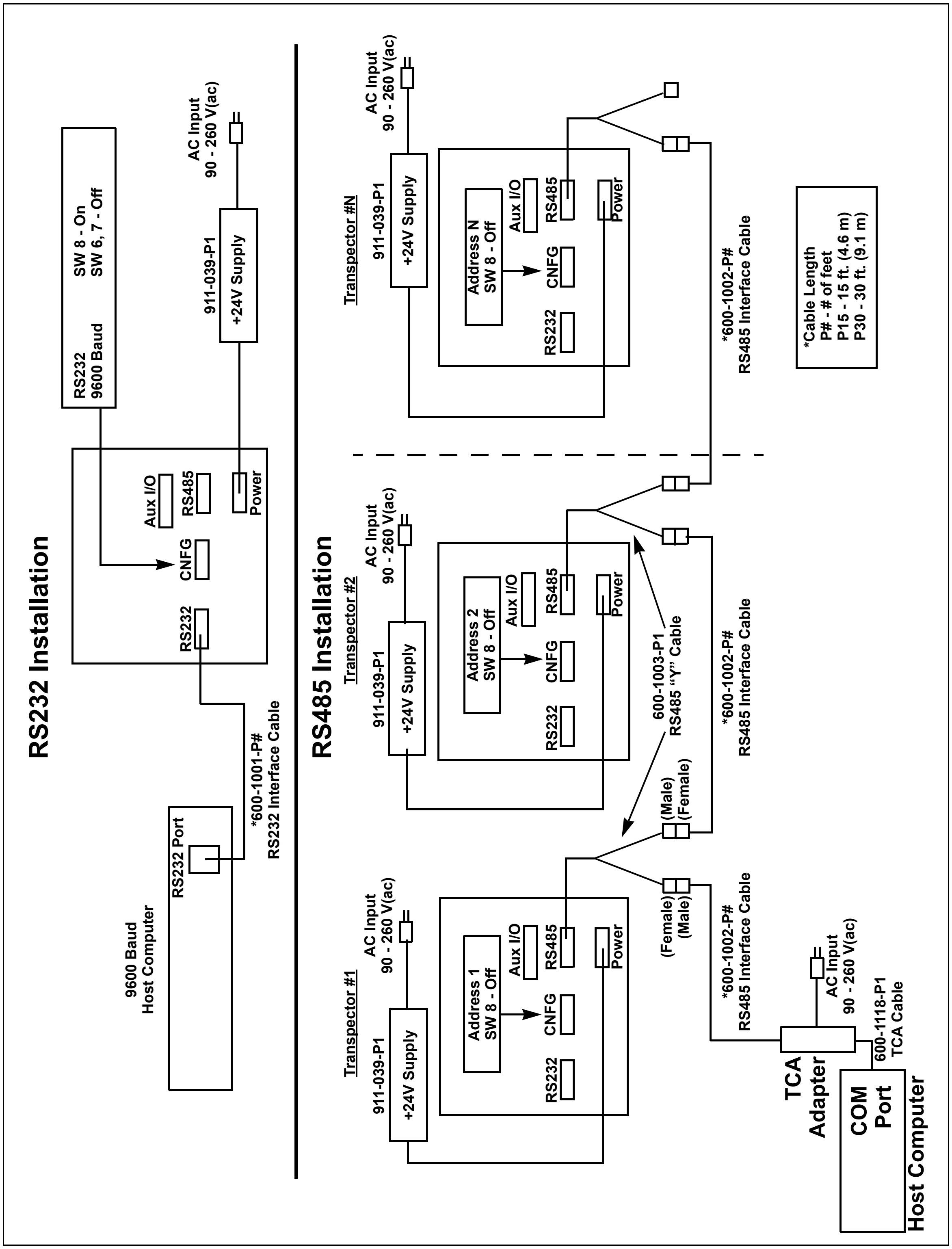


Figure 4-9 Cable connections

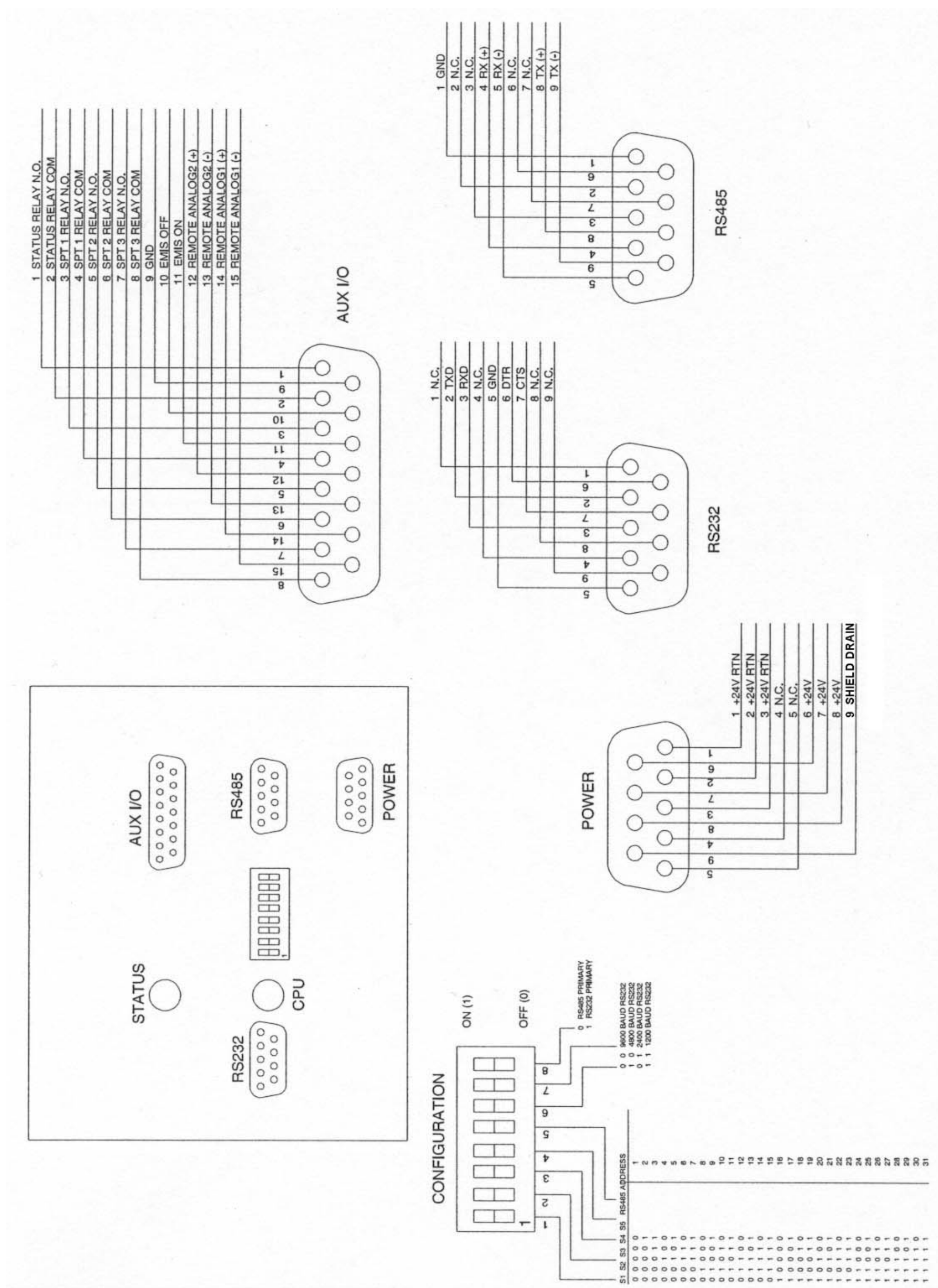


Figure 4-10 Pinout connectors for RS-232C link

4.11 Installing the Pirani Interlock Cable

The Transpector XPR3 Pirani Interlock Cable (IPN 600-1109-P1) has three functions:

- it provides 24 V(dc) power to the Transpector Electronics Module and the Pirani Gauge,
- it connects the Pirani output voltage to Analog Input #2 of the Transpector Electronics module, and
- it provides parallel access to the Auxiliary I/O port for other User applications.

Connect the cable as indicated in Figure 4-11.

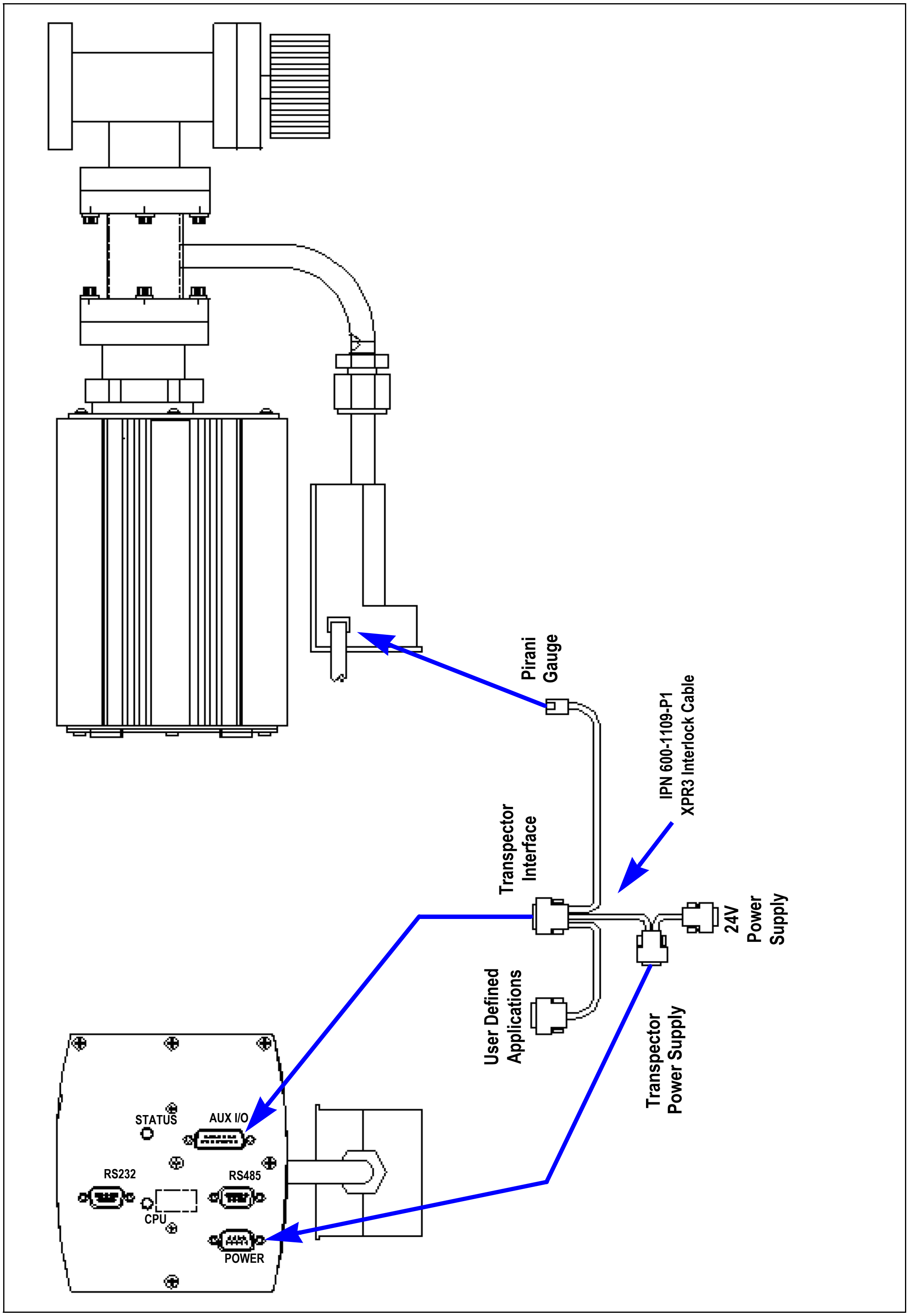


Figure 4-11 Interlock cable connections

4.12 Attaching Heating Jackets

Heating Jackets for the Transpector XPR3 Pirani Interlock Weldment and the Isolation Valve are installed separately but share a common power cord, as shown in Figure 4-12.

The dual element heater can be operated with 120/230 V(ac) by choosing the power cord with the appropriate power source connector. Part numbers for the heaters and power cords are:

- Dual element heater for Interlock Weldment
  IPN 914-415-P1
- Dual element heater for Isolation Valve
  IPN 914-407-P1
- Power cord for 120 V(AC) operation
  IPN 600-1487-P1 and 068-0433
- Power cord for 230 V(AC) operation
  IPN 600-1487-P2 and 068-0434

The operating temperature of the heater is nominally 150 ^{o}C. Thermal over-temperature protection is built into the heater.

WARNING

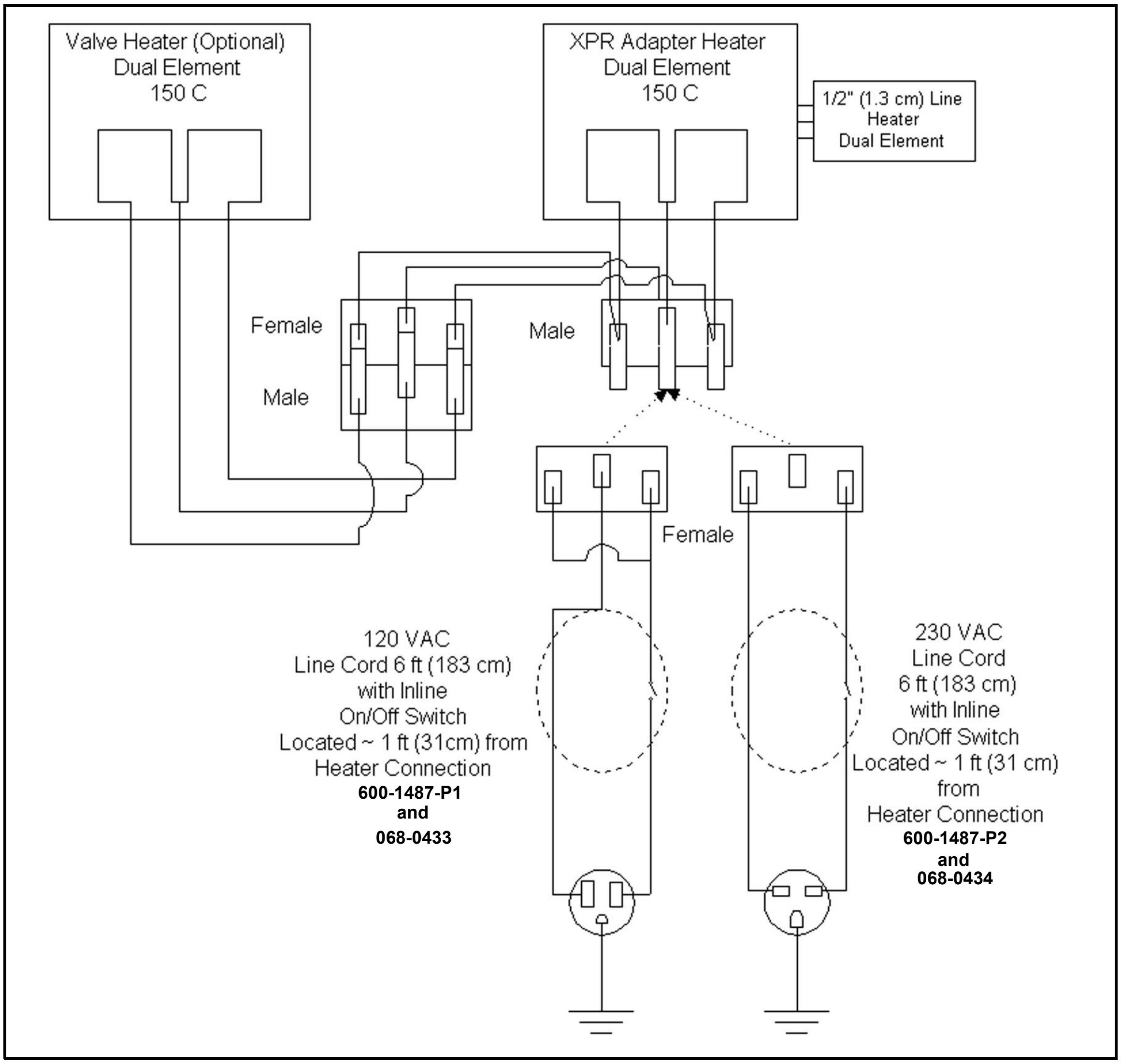
During or immediately after bakeout, the heating jacket and metal surfaces in the vicinity of the heating jacket may be hot. These surfaces may exceed 100 °C at the maximum ambient operating temperature (i.e., 50 °C), which will cause burns if touched directly without using the proper personal protection equipment.

4.13 Installing the Software

Refer to the TWare 32 Operating Manual, INFICON part number 074-334, for specific information on installing TWare32 software.

Refer to the FabGuard Operating Manual or Help files for information concerning FabGuard software.

Figure 4-12 Heaters for the Transpector XPR3 mounting housing and the isolation valve



4.14 Optional Digital I/O

TWare32, through the use of a PCI-bus Digital I/O board installed in the PC (IPNs 911-261-G2 and 911-261-G3), will start and stop recipes based on an external signal. This use of external inputs as a recipe trigger allows the data collection to be more closely synchronized with the process. TWare32 also provides external outputs (relays) for use as signals to indicate when a mass has crossed a recipe-based mass setpoint.

Data collection may be isolated to specific steps in the process by programming one recipe to run during wafer processing, another during the inter-wafer period and a third for the pump down cycle. Specifically isolating the data ultimately enhances the data recall and report generation features in TWare32 by synchronizing RGA data collection with process steps.

The Digital I/O board supplied for use with your PC and TWare32 provides eight or 16 channels of optically isolated digital input and eight or 16 channels of electromechanical relay output (the software handles 16 of each). Inputs can be driven by control voltages of 5 to 28 V(dc) (not TTL compatible) and are isolated to 500V. Input response time is typically 5 milliseconds. The outputs are reed relays configured as five form C and three form A with the default setting of normally open for each. The contacts are rated for 6.0 amps at 120 V(ac) or 28 V(dc) resistive load. Operation time is typically 20 milliseconds.

There are two kit IPNs for the TWare32 Digital I/O Board:

- IPN 911-261-G2 (8 channels), includes the items listed in Table 4-3 on page 4-23 and shown in Figure 4-13 on page 4-23.
- IPN 911-261-G3 (16 channels), includes the items listed in Table 4-4 on page 4-23 and shown in Figure 4-14 on page 4-24.

Table 4-3 Kit IPN 911-261-G2 (8 Channels)

Qty.	Description	IPN
1	Digital Input Board for PCI Bus (PCI-PDISO8)	911-429-P1
1	37 pin screw terminal board (CIO-MINI37)	911-430-P1
1	Plastic enclosure for screw terminal board (ENC-MINI37)	911-431-P1
1	3 ft. (0.9 m), 37 pin cable, female D connector each end (C37FF-3)	911-432-P1
1	PCI-PDISO8 User's Manual	
1	CD with software driver	

Figure 4-13 Kit IPN 911-261-G2 8 Input, 8 Output Board and accessories

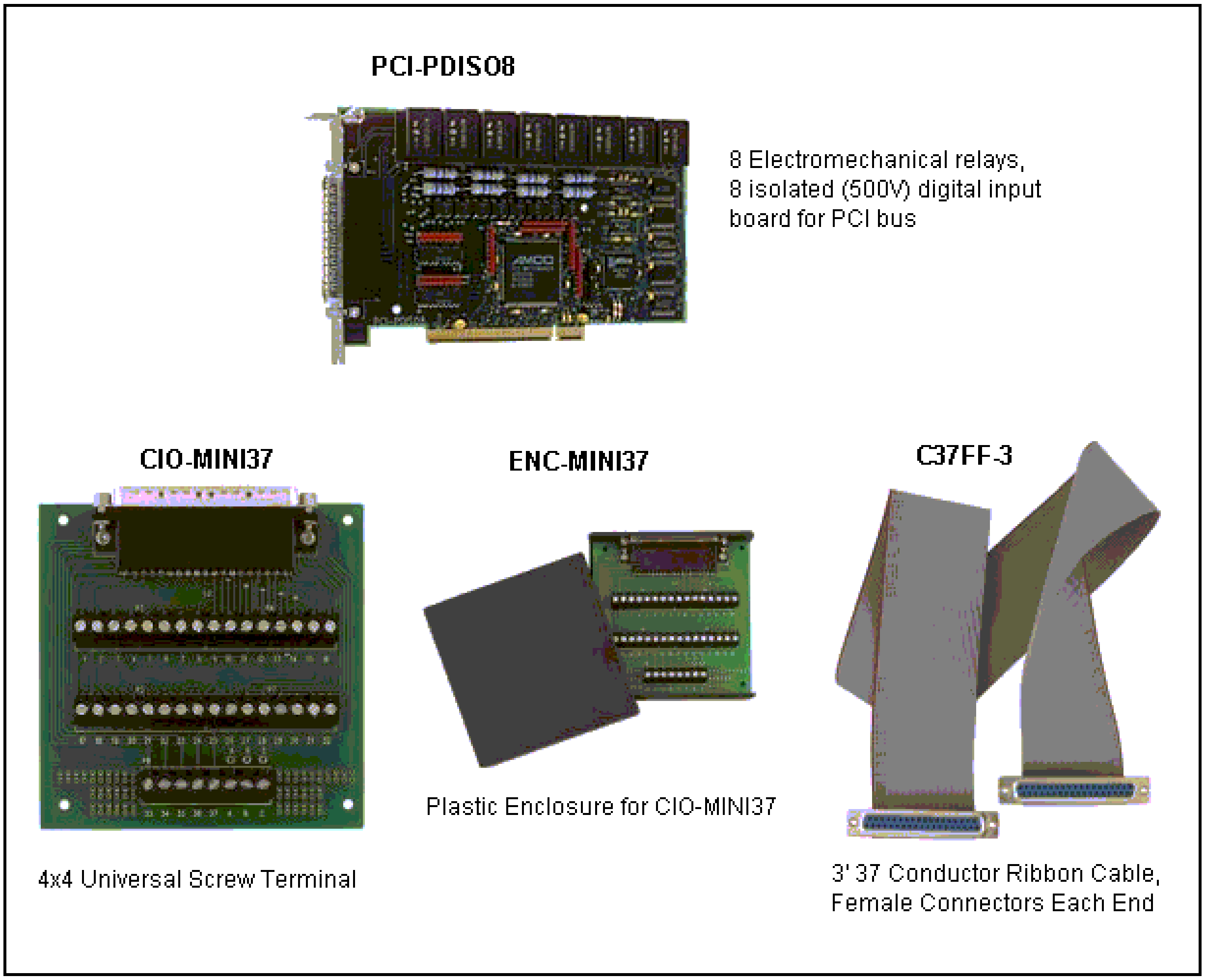


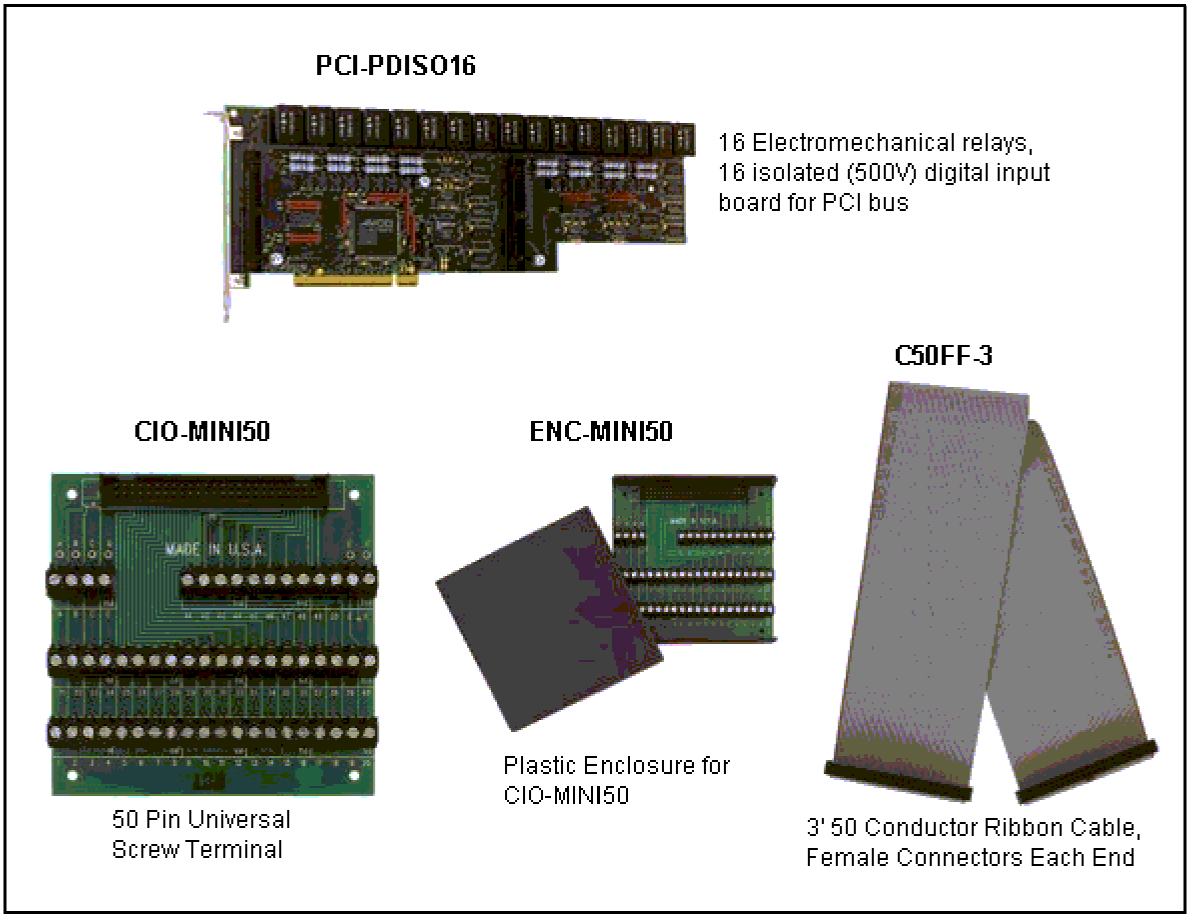
Table 4-4 Kit IPN 911-261-G3 (16 Channels)

Qty.	Description	IPN
1	Digital Input Board for PCI Bus	911-433-P1
2	50 pin universal screw terminal accessory	911-434-P1
2	Plastic enclosure for screw terminal accessory	911-435-P1

Table 4-4 Kit IPN 911-261-G3 (16 Channels)

Qty.	Description	IPN
2	3 ft., 50 conductor ribbon cable, female connectors each end	911-436-P1
1	PCI-PDISO16 User's Manual	
1	CD with software driver	

Figure 4-14 Kit IPN 911-261-G3 16 Input, 16 Output Board and accessories



4.14.1 Basic Installation Instructions for the Digital I/O Board

Refer to the User's Guide supplied with the Digital I/O board for the manufacturer's instructions and precautions on how to install the board in your computer. Detailed installation instructions are provided in section 4.14.2 of this Operating Manual.

CAUTION

Anti-static precautions should be taken prior to handling the Digital I/O board and computer.

The Digital I/O board is a PCI-bus board and should be recognized as a plug and play device, by the operating system, after the board is installed. The basic installation procedure is to remove power from the computer, install the Digital I/O cables and board, reapply power and start the computer. The operating system will recognize the Digital I/O board and request that a driver be installed. A CD is supplied with the board to provide the necessary driver.

4.14.2 Detailed Installation Instructions for the Digital I/O Board

Refer to the User's Guide supplied with the Digital I/O board for the manufacturer's instructions and precautions on how to install the board in your computer.

CAUTION

Anti-static precautions should be taken prior to handling the Digital I/O board and computer.

The installation procedure is as follows:

1. Install TWare32, version 2.50 or greater, on your computer.
2. Shut down the operating system and computer.
3. Remove power from the computer.
4. Remove the access cover from the computer.
5. Locate a PCI slot and remove the cover plate for the slot to provide an opening for the cable to pass through.
6. If installing the 8 input, 8 output board (911-261-G2), go to step 7. If installing the 16 input, 16 output board (911-261-G3) then these extra steps are required. First, feed the proper end of each ribbon cable through the opening in the computer. Next, feed each ribbon cable through the opening in the metal plate attached to the board. Now plug each connector into the

appropriate receptacle on the board. Finally, label each cable, at a point outside the computer, to distinguish between the upper and lower 8 channels.

7. Install the Digital I/O board. Ensure that it is properly seated.
8. For the 8 input, 8 output board (911-261-G2) connect the cable to the 37 pin D connector at the back of the board.
9. Put the computer cover on, reapply power and start the computer.
10. Upon restart, the operating system should recognize that new hardware has been installed in the computer. If the Digital I/O board is not recognized then shut down the operating system and computer and check that the board is properly inserted in the PCI slot.
11. When the Digital I/O board is recognized, the operating system will ask to locate and install the software driver for the board. Insert the CD supplied with the board and respond to all prompts provided. In the rare case that the operating system cannot locate the driver then the program **Setup.exe** must be run from the CD.
12. After successful installation of the driver, start TWare32.

4.14.3 Setup and Test of the Digital I/O

Refer to the TWare32 Operating Manual (IPN 074-334) for detailed information on setting up and testing the Digital I/O.

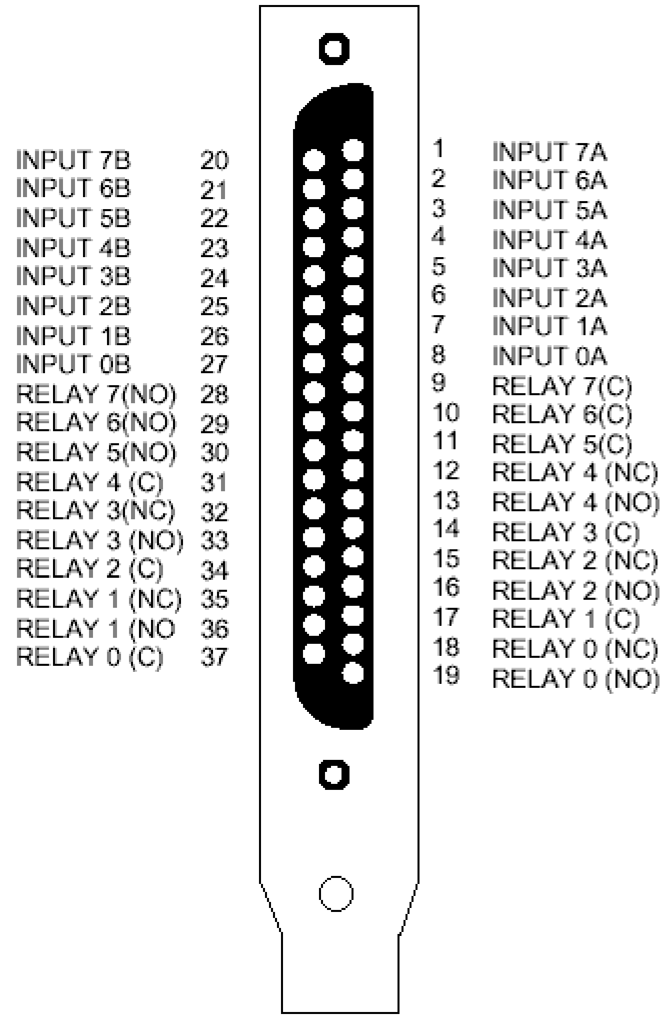
4.14.4 Hard Wiring the I/O Board

The following information is provided to assist in hard wiring the Digital I/O board to the external signal source.

Before making any wiring connections, the computer power should be turned off and the source of electrical power should be disconnected from the computer.

The 8 channel card, model PCI-PDISO8, uses a single 37 pin connector. The pinout of the 37 pin connector is shown in Figure 4-15 on page 4-27.

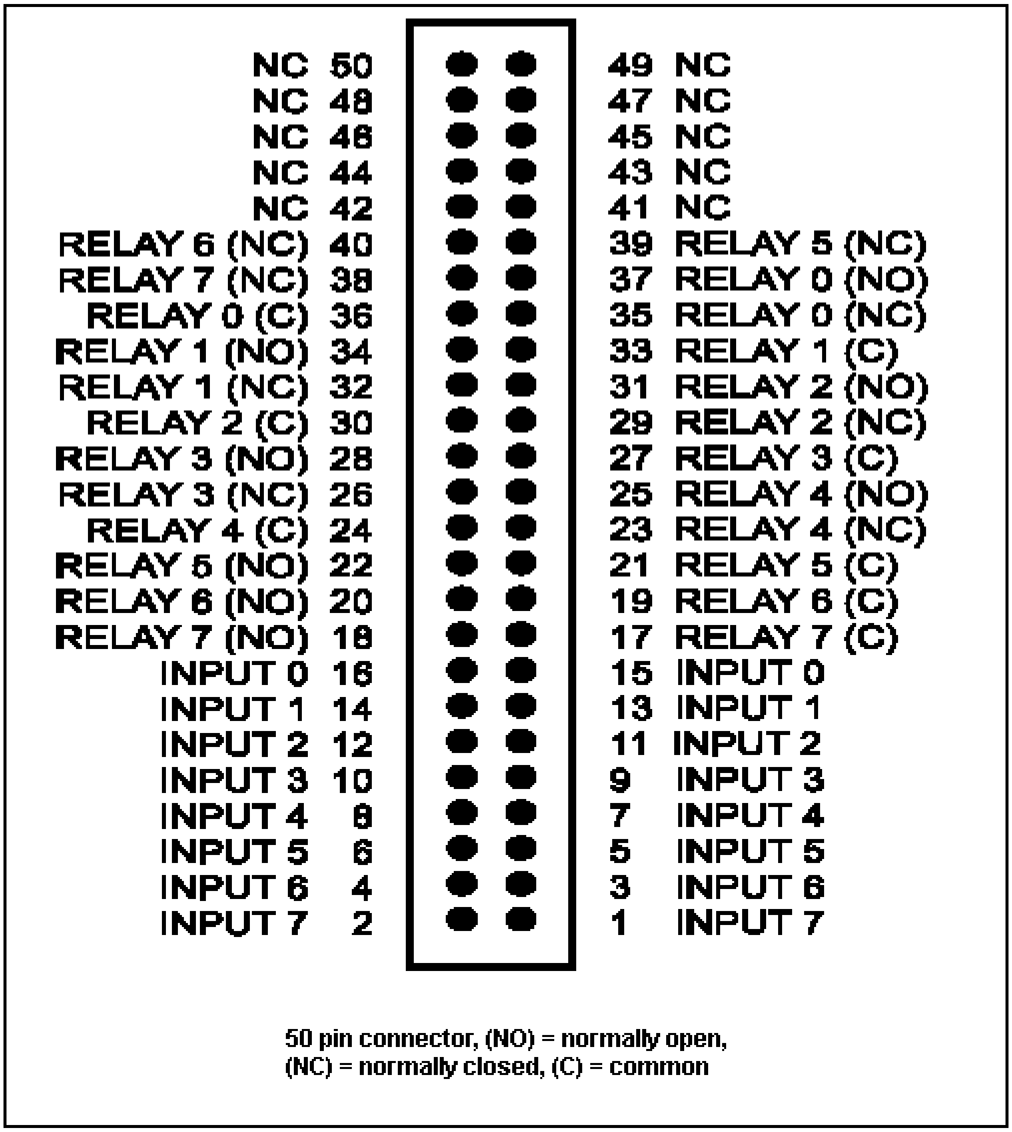
Figure 4-15 Pinout for 37 pin connector



37 pin connector, (NO) = normally open, (NC) = normally closed, (C) = common

The 16 channel card, model PCI-PDISO16, uses two 50 pin connectors. The pinout of the 50 pin connector is shown in Figure 4-16 on page 4-28.

Figure 4-16 Pinout for 50 pin connector



NOTE: The upper 8 inputs and outputs use the same pin configuration as shown in Figure 4-16 with Input 8 in the location of Input 0, Input 9 in the location of Input 1, and so on. Relay 8 uses the pins designated by Relay 0.

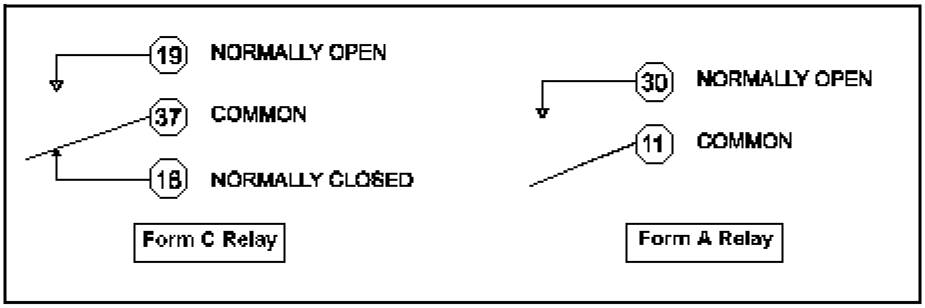
NOTE: Before making any wiring connections to the screw terminals be sure to route all wiring through the opening in the plastic enclosure.

NOTE: Some modifications may be required, to the plastic enclosure, to mount the board or secure the cabling.

Make the appropriate connections for the system to the screw terminals on the CIO-MINI37 (or CIO-MINI50) Terminal Board. Secure the Terminal Board into the enclosure using either the slot (provided in the case) or the standoffs and screws. Attach the C37FF-3 (or C50FF-3) cable(s) so that it connects the Terminal board and the Digital I/O board in the computer.

When using the output relays, refer to Figure 4-17 for relay contact information.

Figure 4-17 Form A and C Relay examples



Chapter 5
Transpector XPR3 Operation

5.1 Introduction

Once the Transpector XPR3 Sensor, Electronics Module, Isolation Valve, and Pirani Interlock are installed, the isolation valve should be opened to allow the Transpector XPR3 to obtain high vacuum. It is strongly recommended that the Transpector XPR3 be kept under high vacuum conditions for at least eight hours before the filament is turned on. It is also recommended that the Transpector XPR3 be baked out with the supplied heating jacket (which operates at 150 °C), for a period of at least eight hours. This eight hour minimum bakeout is required to reduce residual water vapor levels that may be higher due to local surface outgassing effects. These recommendations should be followed whenever the Transpector XPR3 Sensor is exposed to atmosphere for long periods of time and will serve to increase sensor life.

Table 5-1 Transpector XPR3 Sensor maximum bakeout temperature

Sensor	Maximum Operating Temperature	Maximum Bakeout Temperature Electronics Removed
XPR3	150 °C	200 °C

CAUTION

Do not turn on Electron Multiplier high voltage at sensor temperatures above 150 °C. Permanent damage to the Electron Multiplier could result.

WARNING

During or immediately after bakeout, the heating jacket and metal surfaces in the vicinity of the heating jacket may be hot. These surfaces may exceed 100 °C at the maximum ambient operating temperature (i.e., 50 °C), which will cause burns if touched directly without using the proper personal protection equipment.

5.2 Precautions for Operation

There are some precautions that the operator should take to maintain sensor performance and extend filament life. It is recommended that the Transpector XPR3 filament emission be turned off manually, before maintenance, to allow cooling before exposure to the vent gas. If manual shutdown does not happen, the interlock will turn off the filament when the vent gas is introduced.

If the **Pirani Auto Emission ON** is check marked (enabled) during process operation, it is recommended that it be disabled (unchecked) during maintenance operations. This assures a manual restart after maintenance.

The point of greatest risk to air exposure is after maintenance where the process chamber has been exposed to air. Recommended operation after maintenance is to pump down the chamber and Transpector XPR3 Sensor followed by a bakeout with the Transpector XPR3 Sensor heater (and isolation valve heater, if present). Following bakeout and cool down, the base pressure should be < 10^{-6} Torr for safe turn on of the filament.

See Chapter 7 for specific Maintenance Procedures.

5.3 Pirani Interlock Protection

Filament interlock protection for the Transpector XPR3 allows the XPR3 filament emission to operate at safe pressures (< $2x10^{-2}$ Torr) by action of the Pirani Emission OFF Interlock function. Protection is provided by a Pirani gauge, which directly monitors pressure at the XPR3. Interlock protection turns off the XPR3 filament if the pressure increases above a maximum operating limit (< $2x10^{-2}$ Torr) and does not allow the filament to be turned on when pressures exceed this limit. This chapter describes the interlock apparatus and its operation.

If TWare32’s **Pirani Auto-Emission ON** is check marked, the filament will be turned on when the ON Trip Level setting is reached (≤ $3x10^{-3}$ Torr). The default for this function is disabled (unchecked), in which case the operator must turn on the filament when the pressure is sufficiently low. See section 5.4 on page 5-3 for more information on TWare32.

Interlock Protection:

- prevents inadvertent turn on of the XPR3 emission at high pressures,
- safely turns off the XPR3 filament when process pressures exceed a selected pressure (the default / maximum value is 20 mTorr), and
- (optionally) turns the XPR3 emission on at a different safe pressure (the default for this option is OFF).

5.3.1 Detection of the Pirani Gauge

To assure that a gauge is present for the interlock, the firmware detects the output voltage of the Pirani gauge on analog input #2, on the back of the Electronics Module. If this voltage is greater than 0.5 volts, the firmware assumes that the Pirani gauge is present. If the voltage is zero, the firmware presumes that the Pirani protection is not present and TWare32 displays the **Pirani not detected or in error. Emission is OFF.** error message. If the Pirani gauge sensing element fails, typically a rare event, the voltage goes to 10.5 volts and the **Pirani interlock high limit exceeded. Emission is OFF.** error message is displayed.

5.3.2 High Pressure Shut Off of Transpector XPR3 Filament

Based on the **OFF Trip Level** set using TWare32, the software downloads a Pirani voltage level corresponding to the upper pressure limit of operation. This pressure is 20 mTorr ($2x10^{-2}$ Torr), which is the XPR3's operating specification limit and is the default value in the XPR3 firmware. If the pressure measured by the Pirani exceeds this setpoint, the XPR3 filament emission is turned off, and turning on the emission is inhibited.

5.3.3 Automatic Restart/Filament Turn On of the Transpector XPR3

The factory default for the **Pirani Auto Emission ON** option is disabled (not check marked). The **ON Trip Level** pressure should be less than or equal to 3.0 mTorr.

5.4 TWare32 Control

Figure 5-1 shows the TWare32 **Sensor Setup/TSP User Settings** screen.

Clicking first on the **XPR3** icon from the TWare 32 main screen to reach the **Sensor Properties** and then selecting the **TSP User Settings** tab can display the sensor properties shown below.

For an XPR3 with the High Pressure Electron Multiplier, be sure that the **Detector Type** indicates **High Pressure Electron Multiplier**. This box should be greyed out and unable to be changed by the user.

The **Total Pressure Reading** should be set to **Internal - Transpector**.

In the **Pressure Interlock Functions** section of the screen:

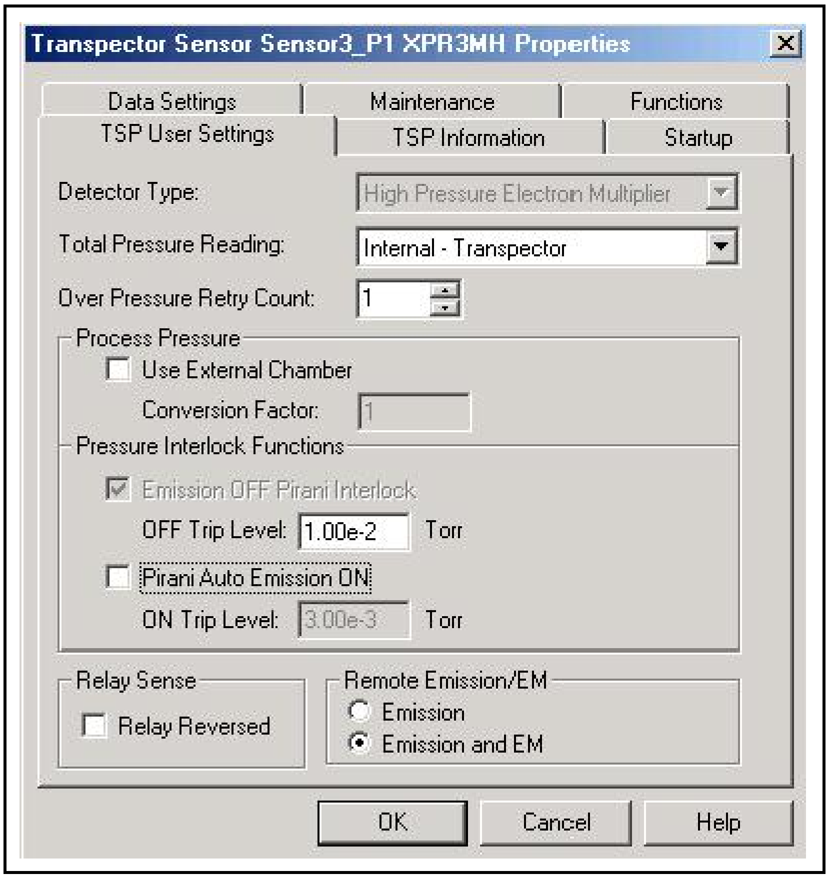
- **Emission OFF Pirani Interlock** is enabled (check marked) with the **OFF Trip Level:** shown as 1.0x10^{-2} Torr. The default value (and maximum value allowed) is 2x10^{-2} Torr.

  NOTE: The **Emission OFF Pirani Interlock** is always enabled for XPR3 and can not be disabled.

- **Pirani Auto Emission On** is shown disabled (unchecked). The **ON Trip Level:** shown is at the default value (and maximum value allowed) of 3.0x10^{-3} Torr.

  NOTE: The pressure units shown throughout this chapter are in Torr. In TWare32, the pressure units can be changed to either Millibar or Pascal by selecting **System Properties >> Miscellaneous**.

Figure 5-1 TWare32 setup sensor screen



5.4.1 TWare32 Error Messages

Errors displayed related to the Pirani Interlock are shown in Table 5-2. Refer to the TWare 32 Operating Manual for a complete list of Software related Error Messages. See Chapter 8 for a complete list of Hardware related Error Messages.

Table 5-2 Pirani Interlock Errors

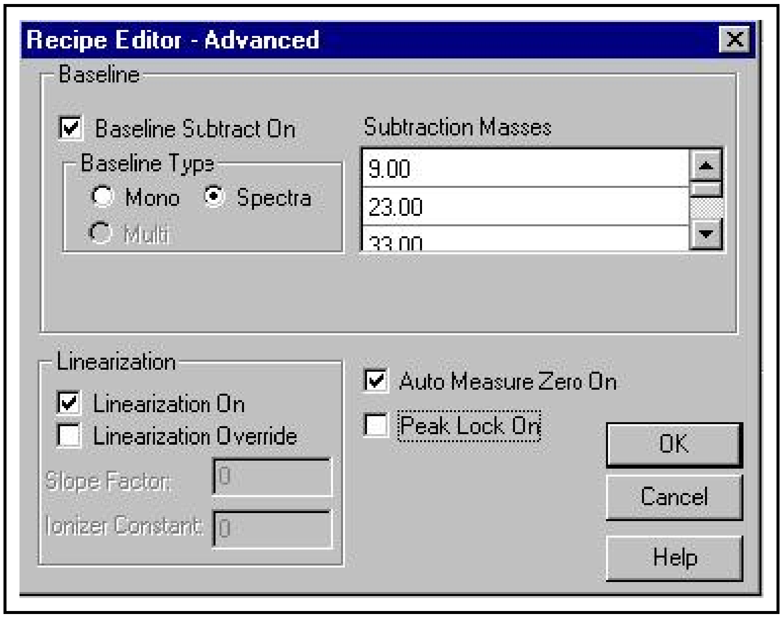
Condition	Error Reported
XPR3 is turned off due to overpressure	Pirani interlock high limit exceeded. Emission is OFF.
Pirani element fails	Pirani interlock high limit exceeded. Emission is OFF.
No Pirani or not connected	Pirani not detected or in error. Emission is OFF.

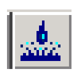
5.4.2 Using Transpector XPR3

Once the sensor has been conditioned, by baking it out and then keeping it under vacuum, the emission can be turned on. At this point, typical uses for the Transpector XPR3 would be leak detection, background monitoring, and process monitoring. The following are recommended parameters when operating the Transpector XPR3 in any of these applications. These are reached from the Recipe Editor by choosing **Recipe Editor >> Sensor State >> Advanced Functions** (see Figure 5-2)**.**

- **Baseline** should be enabled by checking the box **Baseline Subtract On** and choosing **Spectra** as the **Baseline Type.** Use the default **Subtraction Masses** of **9**, **23**, **33, 47.**
- **Linearization** should always be **On**, by checking the box**.**
- **Peak Lock** should always be **Off**, by not checking the box.

Figure 5-2 Recipe Editor - Advanced dialog



5.4.3 Leak Detection 

Using TWare32, there is no recipe required for operating in Leak Mode. Select the Leak Mode icon to default to sampling Helium (mass 4) over time. When leak checking a vacuum system that has a pressure of $1x10^{-5}$ Torr or lower, the High Pressure Electron Multiplier should be used. The HPEM voltage that is necessary is based on the level of the leak that you are searching for. Adjust the HPEM voltage so that the Helium (Mass 4) signal can be observed, but do not exceed an intensity of 1E-7 amps.

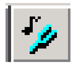
Refer to the TWare 32 Operating Manual for complete information on Leak Detection Mode.

5.4.4 Recipe Generation 

Using the Transpector XPR3 for background monitoring or process monitoring is accomplished by creating and running a recipe. The Transpector XPR3 user can generate these recipes or sample recipes can be obtained from INFICON. The recipe file sizes are rather small (about 1 Kb) and can be easily e-mailed. Please contact INFICON by phone at (315) 434-1128 or by e-mail at reachus@inficon.com.

Refer to the TWare 32 Operating Manual for complete information on Recipe Generation.

Refer to Chapter 6, Transpector XPR3 Best Known Methods, for sample recipes.

5.4.5 Mass Scale Tuning 

Another part of preventive maintenance is checking the functional operation of the Transpector XPR3. This includes the mass position and mass resolution of the instrument.

Refer to section 6.1.15, Mass Scale Tuning, on page 6-11 for information on Tuning the Transpector XPR3.

Chapter 6
Transpector XPR3 Best Known Methods

6.1 Best Known Methods

Transpector XPR3 is a third-generation, quadrupole-based residual gas analyzer that operates at PVD process pressures and is the first process monitor with an Electron Multiplier (EM) that can operate at 10 mTorr operating pressures. Transpector XPR3 does not require the large differential pumping system normally required for PVD process monitoring. Transpector XPR3 can operate up to 20 mTorr, and it is linear at pressures up to 10 mTorr. Transpector XPR3 measures major components and impurities common in a process with a 10 ppm detection limit.

Using these recommended Best Known Methods will provide you with a reliable Transpector XPR3 for process monitoring of a high pressure application.

6.1.1 Transpector XPR3 Applications

Transpector XPR3 utilizes a High Pressure Micro Channel Plate Electron Multiplier (HPEM). The HPEM can be used at both lower pressures, such as background pressures, and at higher pressures, such as process pressures.

Transpector XPR3 is typically used for process monitoring of PVD applications. These applications normally operate in the mTorr range with backgrounds from 10^{-6} to 10^{-9} Torr. While Transpector XPR3 can be used for other applications where the process pressure is less than 10 mTorr, precautions should be used. Applications that have high levels of hydrocarbon contamination or a significant amount of fluorines, chlorines, or halogens are inappropriate for the Transpector XPR3.

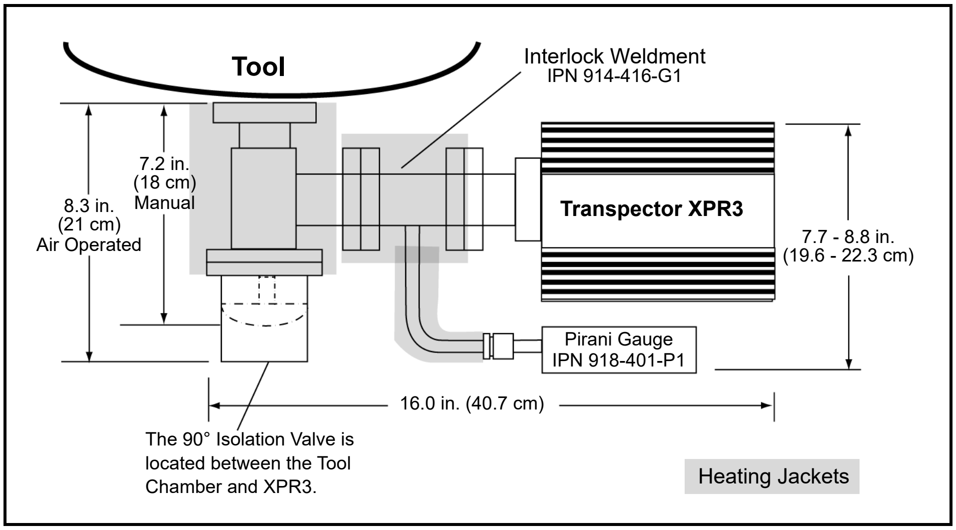
6.1.2 Physical Installation

Transpector XPR3 package includes an interlock weldment approximately 3.6" (91.44 mm) long with a VCR connection tube for the Pirani gauge. The Pirani gauge is used for turning the Transpector XPR3 filament off for pressure up to 20 mTorr and optionally turning the filament back on at pressures below the turn off point.

The Transpector XPR3 Sensor mounts within the interlock weldment. The weldment must be mounted to the process chamber via a 90° valve (or mitered elbow). This prevents any line of sight plasma from reaching the ion source plate, which prevents any material from depositing onto the Transpector XPR3 Sensor. A heating jacket is provided with the Transpector XPR3 package and should be installed over the interlock weldment such that the cable is oriented as seen in Figure 6-1.

Once the Transpector XPR3 Sensor, electronics, valve and Pirani are installed, the valve should be opened to allow the Transpector XPR3 to obtain high vacuum. It is strongly recommended that the Transpector XPR3 be kept under high vacuum conditions for at least eight hours before the filament is turned on. It is also recommended that the Transpector XPR3 be baked out with the supplied heating jacket (which operates at 150 °C), for a period of at least eight hours. This eight hour minimum bakeout is required to reduce residual water vapor levels that may be higher due to local surface outgassing effects. These recommendations should be followed whenever the Transpector XPR3 Sensor is exposed to atmosphere for long periods of time and will serve to increase sensor life.

Figure 6-1 Transpector XPR3 installation



6.1.3 Pirani Gauge Set-up

Clicking first on the **XPR3** icon from the TWare 32 main screen to reach the **Sensor Properties** and then selecting the **TSP User Settings** tab will display the Pirani gauge set points.The **Pressure Interlock Functions** dialog is shown in Figure 6-2. The **Emission OFF Pirani Interlock** function is automatically enabled and cannot be disabled. The default (and maximum) value for emission off is 20 mTorr. The **Pirani Auto Emission ON** is disabled by default, but can be enabled by checking the box and assigning a value less than or equal to 3.00e-3 Torr.

Figure 6-2 Pressure interlock functions

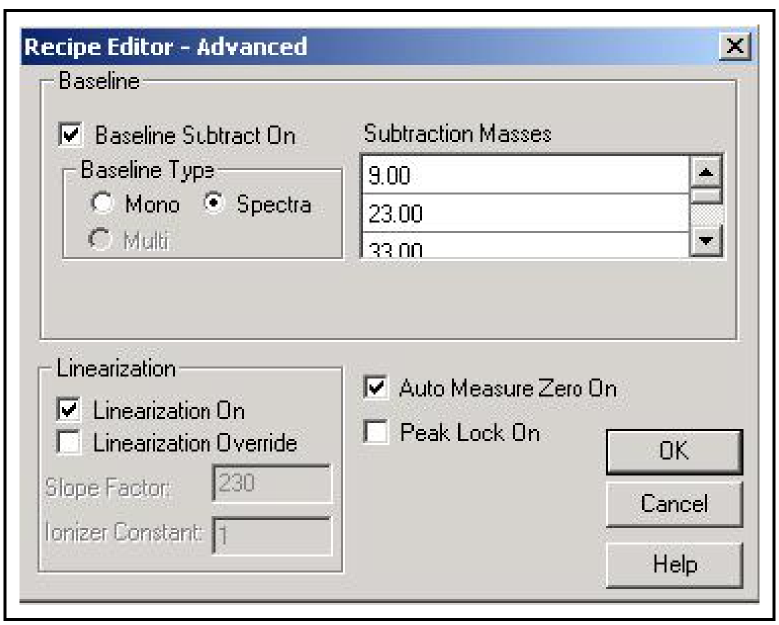
6.1.4 Using Transpector XPR3

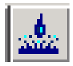
Once the sensor has been conditioned, by baking it out and then keeping it under vacuum, the emission can be safely turned on. At this point, typical uses for the XPR3 would be leak detection, background monitoring and process monitoring. The following are recommended parameters when operating the XPR3 in any of these applications:

- **Baseline** should be enabled by checking the box **Baseline Subtract On** and choosing **Spectra** as the **Baseline Type.** Use the default **Subtraction Masses** of **9**, **23**, **33, 47.**
- **Linearization** should always be **On**, by checking the box. Use the factory determined values that have been programmed into the Transpector firmware.
- **Peak Lock** should always be **Off**, by not checking the box.

These are reached from the Recipe Editor by choosing **Recipe Editor >> Sensor State >> Advanced Functions** (Figure 6-3)**.**

Figure 6-3 Recipe Editor - Advanced dialog



6.1.5 Leak Detection 

Using TWare32, there is no recipe required for operating in Leak Mode. Select the Leak Mode icon to default to sampling Helium (Mass 4) over time. When leak checking a vacuum system that has a pressure of $1x10^{-5}$ Torr or lower, the HPEM should be used. The HPEM voltage that is necessary is based on the level of the leak that you are searching for. Adjust the HPEM voltage so that the Helium (Mass 4) signal can be observed, but do not exceed an intensity of 1e-7 amps.

6.1.6 Recipe Generation 

Using Transpector XPR3 for background monitoring or process monitoring is accomplished by creating and running a recipe. Transpector XPR3 user can generate these recipes or sample recipes can be obtained from INFICON. The recipe file sizes are rather small (about 1 Kb) and can be easily e-mailed if desired. Please contact INFICON by phone at (315) 434-1128 or by e-mail at reachus@inficon.com.

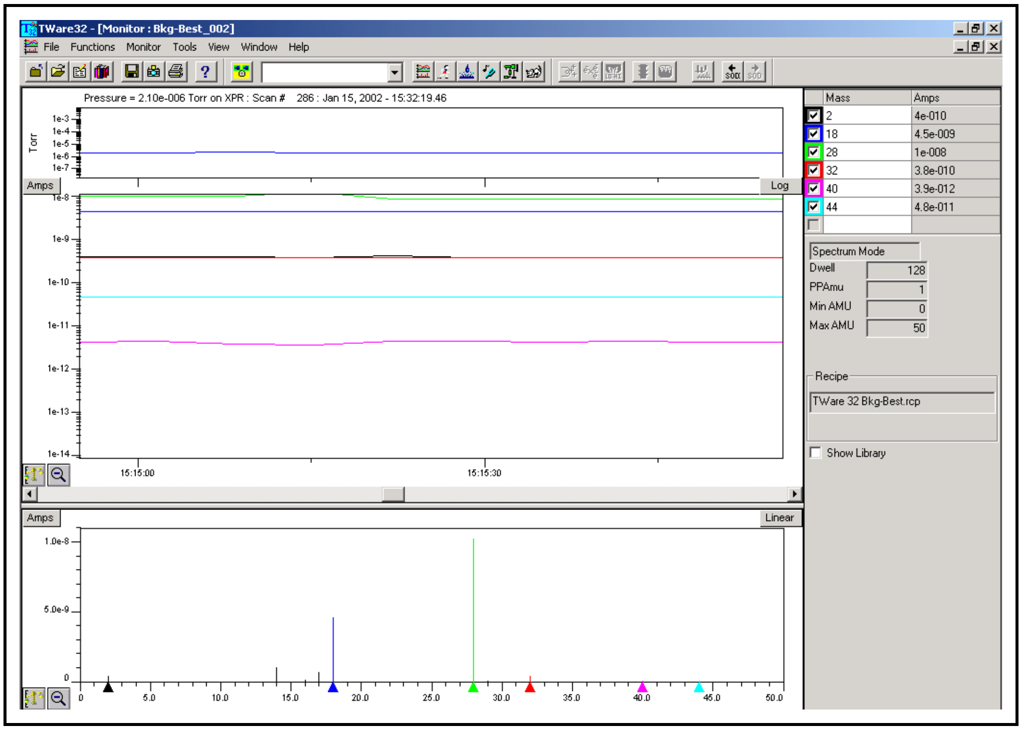
6.1.7 Background Monitoring: Best Practical Detection Limits — bkg.best.rcp

For acquiring a spectrum where the full mass range is desired, the recipe parameters should be:

- **Spectrum Scanning**
- **Mass Range 0-50**
- **1 point per AMU**
- **Dwell time** = **128 ms**
- **EM ON**
- **EM voltage set for 300 gain.** The EM voltage is set for 300 gain at the Factory, and may require periodic adjustment depending on the current levels delivered to the EM.
- **Electron Energy** = **40 ev**

The above recipe will provide the best results for background monitoring, but it will take approximately 11 seconds for one scan. See Figure 6-4 for typical background results.

Figure 6-4 Typical background results



6.1.8 Background Monitoring: Fast Results — bkg-fast.rcp

Faster scanning can be accomplished, but detection limit and accuracy will be sacrificed. For faster scanning, the dwell time can be reduced to 32 ms. This will lower the scan time to about 4 seconds.

6.1.9 PVD Process Monitoring with Argon Process Gas: Best Results — pro-best.rcp

Since it is assumed that speed is very important in monitoring various gases during the process, **Selected Peaks** should be used instead of Spectrum Scanning. The recipe parameters should be:

- **Electron Energy** = **40 ev**
- **EM On with a gain set to 300.** The EM voltage is set for 300 gain at the Factory, and may require periodic adjustment depending on the current levels delivered to the EM.

While the masses to be sampled are customer selectable, the following masses and dwell times are recommended for a typical PVD application involving Argon process gas:

Table 6-1 Recommended masses and dwell times for typical PVD applications

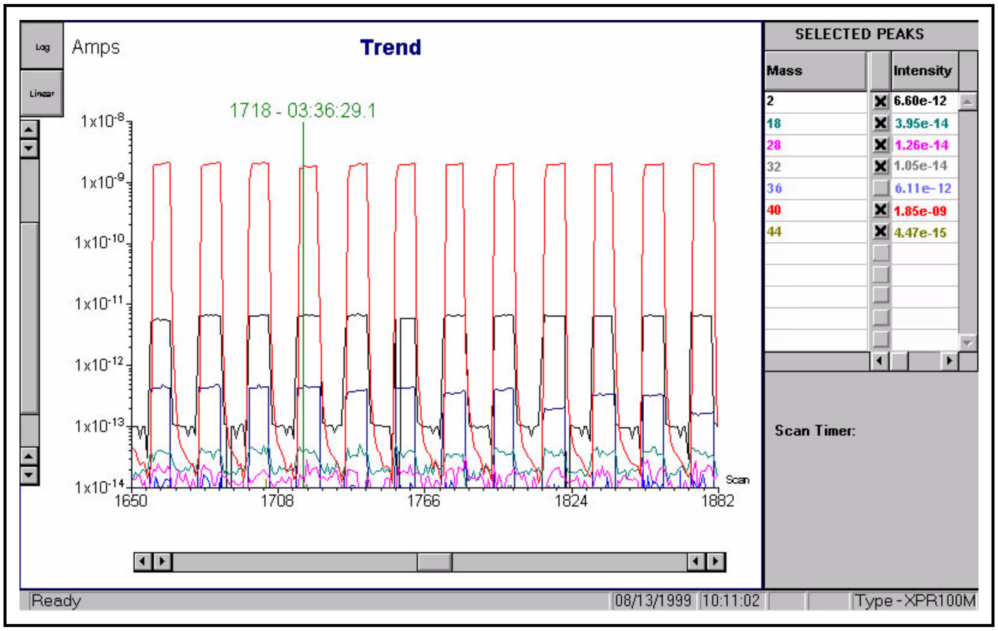
Mass	**Species**	**Dwell**	Multiplier
2	H_2	32 ms	1
18	H_20	128 ms	1
28	N_2/CO	128 ms	1
32	O_2	128 ms	1
36	Ar^{36}	32 ms	297 *
44	CO_2	128 ms	1
Optional: 15 or 42	Hydrocarbons	128 ms	1
* Multiplier is derived from the natural abundance of Ar^{36} in Argon gas: 100/.0337 = 297			

CAUTION

Do not scan over any peak with the EM ON that produces ion currents in excess of 1e-7 amps. For example, do not scan over Mass 40 Argon in a PVD process involving Argon gas since this mass will produce large peaks. Use Mass 36 Argon isotope as a safe alternative. Scanning over any large ion currents for extended periods of time will damage the Electron Multiplier and substantially shorten its lifetime.

This recipe will take about 3 seconds per scan and will produce results similar to those shown in Figure 6-5. Peaks for hydrocarbons can be added at mass 15 and/or 42.

Figure 6-5 Example of recipe results



6.1.10 PVD Process Monitoring with Argon-Nitrogen Process Gas

For metal-nitride processes, the presence of nitrogen can also generate high ion currents at Mass 28. For these processes, alternate recipes are recommended with peaks that are listed in Table 6-2.

Table 6-2 Recommended peaks for Metal-Nitride PVD process using Argon-Nitrogen gases

Mass	**Species**	**Dwell**	Multiplier
2	H_2	32 ms	1
14	N_2 / CO	128 ms	25 **
18	H_20	128 ms	1
32	O_2	128 ms	1
36	Ar^{36}	32 ms	297
44	CO_2	128 ms	1
Optional: 15 or 42	Hydrocarbons	128 ms	1
** Default value. Sensor specific value can be found by FC measurement of N_2: Multiplier = I(28)/I(14)			

CAUTION

Do not scan over any peak with the EM ON that produces ion currents in excess of 1E-7 amps. For example, do not scan over Mass 28 Nitrogen in a PVD process involving Argon-Nitrogen gas since this mass will produce large peaks. Use Mass 14 Nitrogen isotope as a safe alternative. Scanning over any large ion currents for extended periods of time will damage the Electron Multiplier and substantially shorten its lifetime.

6.1.11 PVD Process Monitoring with Argon-Oxygen Process Gas

For metal-oxide processes, the presence of oxygen can also generate high ion currents at Mass 32. For these processes, alternate recipes are recommended with peaks that are listed in Table 6-3.

Table 6-3 Recommended peaks for Metal-Oxide PVD processes using Argon-Oxygen gases

Mass	**Species**	**Dwell**	Multiplier
2	H_2	32 ms	1
16	O_2	128 ms	15 ***
18	H_20	128 ms	1
28	N_2 / CO	128 ms	1
36	Ar^{36}	32 ms	297
44	CO_2	128 ms	1
Optional: 15 or 42	Hydrocarbons	128 ms	1
*** Default value. Sensor specific value can be found by FC measurement of O_2: Multiplier = I(32)/I(16)			

CAUTION

Do not scan over any peak with the EM ON that produces ion currents in excess of 1E-7 amps. For example, do not scan over Mass 32 Oxygen in a PVD process involving Argon-Oxygen gas since this mass will produce large peaks. Use Mass 16 Oxygen isotope as a safe alternative. Scanning over any large ion currents for extended periods of time will damage the Electron Multiplier and substantially shorten its lifetime.

6.1.12 Preventive Maintenance

The XPR3 Sensor has yttria-coated iridium filaments with a defined lifetime, as well as a high pressure electron multiplier that may degrade over time.

6.1.13 Transpector XPR3 Filament

The XPR3 filaments should last a minimum of 4000 hours when following these Best Known Methods. It is strongly recommended that the filaments be replaced after 4000 hours of operation (approximately six months of continuous operation).

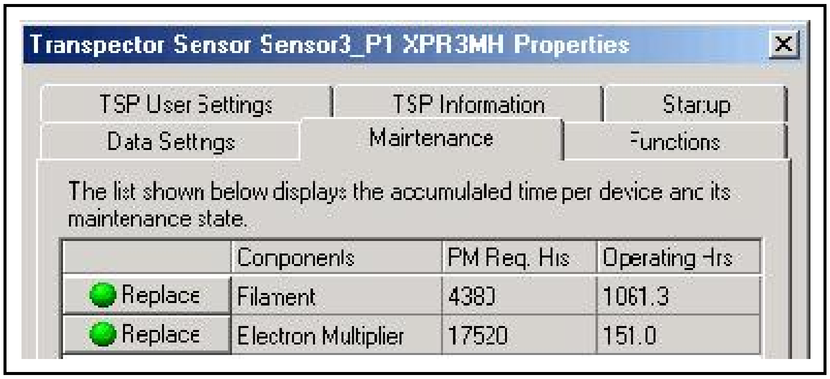
CAUTION

If the filaments are not replaced and are allowed to burn out, coating from the filament could contaminate the ion source plate and create electrical shorts preventing operation with a new set of filaments.

The yttria-coated filament (part number 914-022-G2) is field replaceable. Replacement instructions are included in the filament kit and are also found at section 7.6 on page 7-5 in this manual.

To determine how many hours the filaments have been operational, click on the **XPR3** icon from the TWare 32 main screen to reach the **Sensor Properties** screen and then select the **Maintenance** tab. The information displayed is shown in Figure 6-6.

Figure 6-6 Transpector Sensor Properties dialog

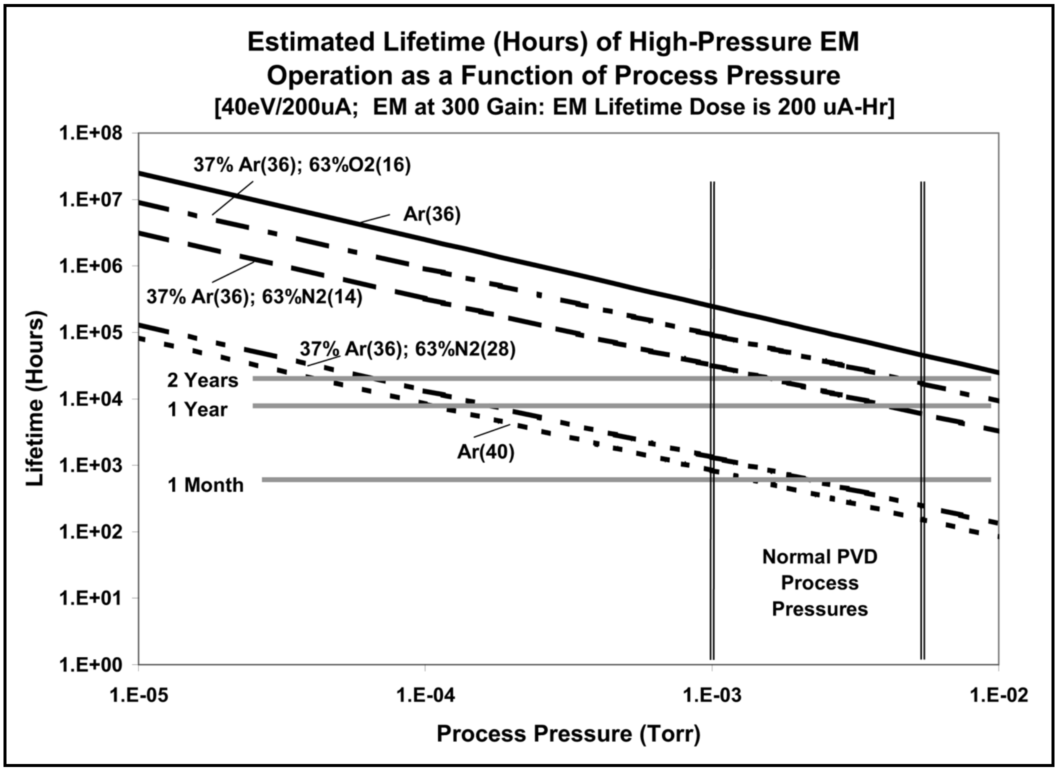


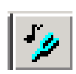
6.1.14 High Pressure Electron Multiplier

Since the HPEM is used at background and process pressure, the EM hours will mirror those of the emission hours. The HPEM gain may degrade over time and it is recommended to replace the EM when the EM voltage can no longer be adjusted to achieve a 300 gain. It is expected that the HPEM will last greater than 1 year, when used continuously.

The HPEM degrades from monitoring high ion currents. Figure 6-7 shows estimated age for the EM as a function of process pressure for common gas mixtures and for monitoring different peaks. The plot highlights the increased lifetime advantage of measuring the recommended mass peaks. [These are estimates based on test data. Individual HPEMs may have different lifetimes depending on usage history.]

Figure 6-7 Estimated Lifetime of High-Pressure EM

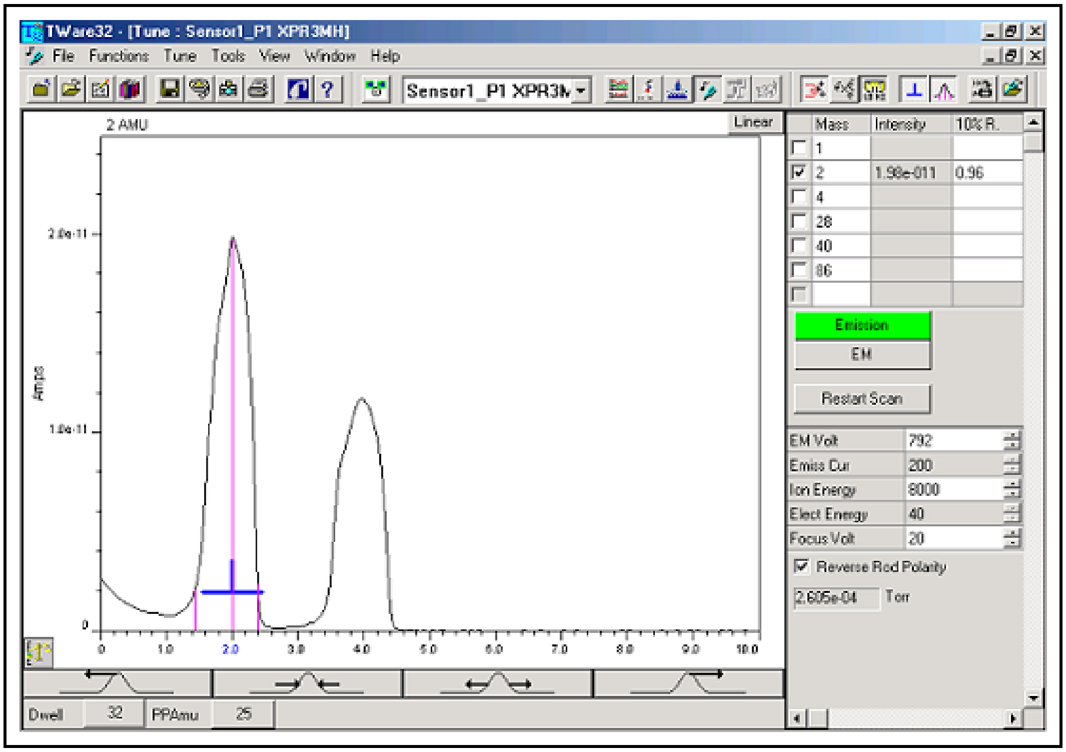


6.1.15 Mass Scale Tuning 

Another part of preventive maintenance is checking the functional operation of the Transpector XPR3. This includes the mass position and mass resolution of the instrument. While this mass scale tuning is accomplished in a similar fashion to any other Transpector, the Transpector XPR3 does have some slightly different values for peak width adjustment.

The grid on the right of the screen shown in Figure 6-8 shows the typical masses from a factory calibration gas mixture. The TWare32 Operating Manual (INFICON part number 074-334) provides details on how to tune the resolution and mass position for any Transpector and the following sections are to be used for mass scale tuning in the field.

Figure 6-8 Typical widths of various masses



6.1.15.1 Mass Scale Tuning at Base Pressure

Mass scale tuning can be done at base pressure using the background peaks of water vapor (18 AMU) and Nitrogen (28 AMU). The following procedure should be used to check peak location and peak widths at mass 18 and mass 28 and to make adjustments as needed.

CAUTION

Do not attempt to remove masses 1, 2, 4, or 86 AMU from the Tune Table or adjust the resolution at these masses.

1. Open the Tune window and set the points per AMU to 25 for all Tune masses.
2. If necessary, enable the Low energy setting: 40 eV (200 µA emission).
3. Delete mass 40 from the Tune Table and insert mass 18 AMU into the Tune Table.
4. Turn on the Electron Multiplier so that the mass 18 and 28 peaks are visible in the 5E-11 amp range (or greater). It might be necessary to increase the dwell time so that the amount of noise on the peaks is reduced.

5. Adjust the peak width and peak position of mass 18 and/or 28 AMU as needed. Set the peak width of these masses to 1.00 ± 0.04 AMU wide at 10% of the peak height. Also set the peak position to nominal mass.
6. Save the mass calibration upon exiting Tune mode.

NOTE: Do not attempt to add or delete Tune masses prior to exiting Tune mode.

6.1.15.2 Mass Scale Tuning with Process Gas

For mass scale tuning at process pressures, the following procedure should be used to adjust the Argon (40 AMU) and/or Nitrogen (28 AMU). This tuning procedure can be used for Argon, Argon-Nitrogen, or Argon-Oxygen processes.

NOTE: For this mass scale tuning procedure, the Tune Mass Table should be the default Tune list, which is masses 1, 2, 4, 28, 40, and 86. If this list is not present when the Tune window is opened, modify the Tune Mass Table as necessary to show only masses 1, 2, 4, 28, 40, and 86.

CAUTION

Do not attempt to remove masses 1, 2, 4, or 86 AMU from the Tune Table or adjust the resolution at these masses.

1. Open the Tune window and set the points per AMU to 25 for all Tune masses.
2. If necessary, enable the Low energy setting: 40 eV (200 µA emission). Turn off the EM so that the XPR3 is operating in the FC mode.
3. Adjust the dwell time as needed to reduce the amount of noise on the peaks.
4. Adjust the peak width and peak position of mass 28 and/or 40 AMU as needed. Set the peak width of these masses to 1.00 +/- 0.04 AMU wide at 10% of the peak height. Also set the peak position to nominal mass.
5. Save the mass calibration upon exiting Tune mode.

NOTE: Do not attempt to add or delete Tune masses prior to exiting Tune mode.

Chapter 7
Maintenance

7.1 Introduction

The Transpector XPR3 Sensor is subject to aging in normal use and will eventually require repair or replacement. The Transpector Electronics Module does not normally require repair or maintenance.

WARNING - Risk Of Electric Shock

Removal of the Transpector Electronics Module covers should only be done by qualified service personnel. There are no user-serviceable parts inside the unit. Removal of these covers could result in a shock hazard and/or personal injury.

INFICON maintains complete maintenance service for both Sensors and Electronic Modules. Refer to section 1.3, How To Contact Customer Support, on page 1-4.

7.2 Safety Considerations

WARNING

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

7.2.1 Toxic Material

WARNING

Sensors which have been used on applications where toxic materials are used or generated are likely to carry residues of these materials. Appropriate safety precautions must be taken when handling contaminated Sensors in order to assure safety of maintenance personnel.

7.2.2 Radiation

Transpector XPR3 is not known to produce harmful radiation.

7.2.3 Electrical Voltages

Transpector XPR3 does not present electrical hazards when enclosed and grounded according to the specifications given in the installation instructions.

WARNING - Risk Of Electric Shock

If the Transpector Electronics Module is operated with its cover removed, hazardous electrical voltages may be present. Such operation should not be attempted, except by qualified service personnel.

7.3 Transpector XPR3 Spare Parts

See Table 7-1 for a list of Transpector XPR3 spare parts.

Table 7-1 Transpector XPR3 spare parts

Part Number	Description
914-022-G2	Filament kit (Yttria)
918-401-P1	Pirani Gauge
914-408-P1	Spare Pirani Interlock Heating Jacket
600-1487-P1 068-0433	Spare Heater Power Cable 120 V AC Power Cord 120 V
or	
600-1487-P2 068-0434	Spare Heater Power Cable 230 V AC Power Cord 230 V

7.4 General Instructions for All Repair Procedures

CAUTION

Perform any servicing in a clean, well illuminated area.

Wear clean nylon, lint free lab gloves or finger cots.

Do not touch the vacuum side of the sensor with unprotected fingers.

Use clean tools for sensor disassembly (and assembly).

7.5 Repair Procedures

The following repair procedures are discussed:

- section 7.5.1, Bakeout of Quadrupole, on page 7-3.
- section 7.6, Transpector XPR3 Filament Installation, on page 7-5.

7.5.1 Bakeout of Quadrupole

If the symptoms in section 8.2, Symptom-Cause-Remedy Chart, on page 8-1 suggest that the sensor is contaminated, try first to restore normal performance by baking the sensor under a high vacuum of at least 1×10^{-5} Torr (1.333×10^{-5} mbar) [1.333×10^{-3} Pa] for several hours or preferably overnight. Table 7-2 represents the maximum bakeout temperatures.

If baking the sensor does not increase the sensor performance, it may be necessary to perform the tasks described in section 7.6.4 on page 7-8.

If the procedures explained above do not solve the problem, contact Customer Support. Refer to section 1.3, How To Contact Customer Support, on page 1-4.

Table 7-2 Transpector XPR3 maximum bakeout temperatures

		While Operating	With Electronics Removed
Transpector XPR3			
Electron Multiplier Faraday Cup Combination	EM Mode FC Mode	150 °C 150 °C	200 °C 200 °C

7.5.2 Spare Heating Jackets

INFICON offers several heating jackets to help in baking a Transpector XPR3 System. The heating jacket for the Pirani Interlock Weldment is included with the Transpector XPR3 Gas Analysis System.

Pirani Interlock Heating Jacket

- Transpector XPR3 Pirani Interlock Heating Jacket - IPN 914-415-P1

Heating Jacket for optional Right-Angle Valve

- Valve Heating Jacket - IPN 914-407-P1

Power Cables Required for Heating Jackets

- 120 V(ac)—IPN 600-1487-P1 and 068-0433
- 230 V(ac)—IPN 600-1487-P2 and 068-0434

7.6 Transpector XPR3 Filament Installation

These instructions cover the yttria-coated filament kit IPN 914-022-G2.

These instructions are intended for Transpector XPR3 Sensors having serial numbers 1500 and greater. These Transpector XPR3 Sensors have filaments that are mounted with screws.

CAUTION

Installation of the filament assembly requires the handling of small and fragile parts. If you are unsure about installing the filament assembly, please contact your nearest INFICON Service Center for assistance.

CAUTION

Do not, under any circumstances, remove the quadrupole assembly from the ion source base plate. Doing so will require factory realignment.

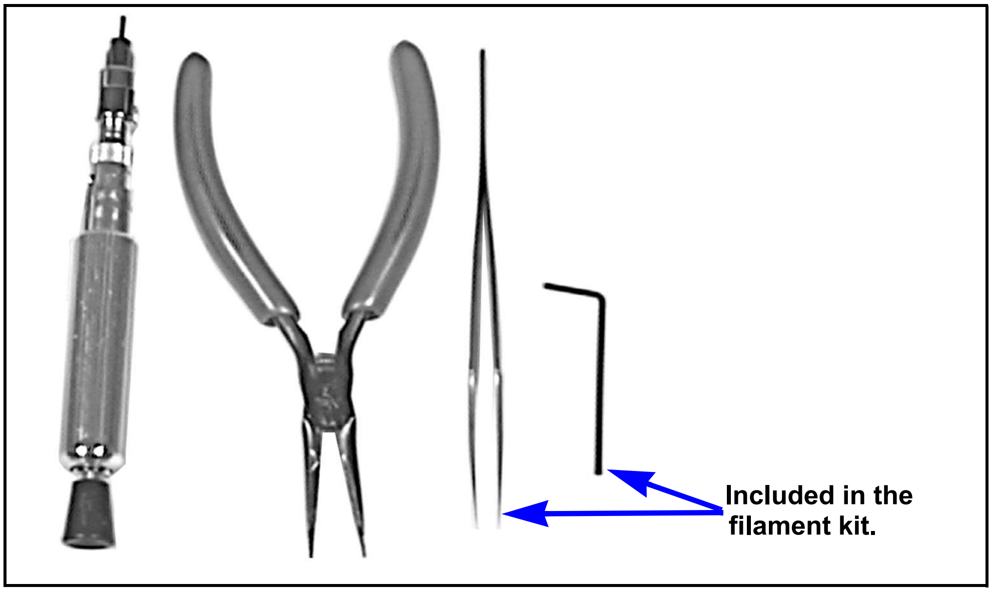
Use finger cots or talc free latex gloves when changing the filament assembly. Do not use nylon gloves when handling an Transpector XPR3 Sensor.

The Total Pressure circuit must be recalibrated after changing the filament. The new sensitivity should be determined and saved to the Transpector's nonvolatile RAM (NVRAM) using TWare32. Instructions on calibration are provided at the end of the filament installation procedure.

7.6.1 Tools Required

- The hand tools shown in Figure 7-1.
- A DMM capable of measuring 30MΩ or above.

Figure 7-1 Tools required

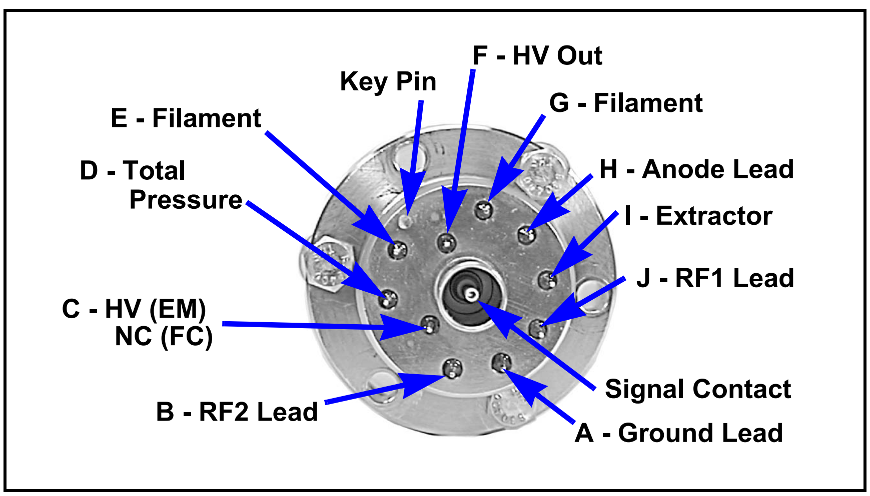


7.6.2 How to Determine if a Filament Replacement is Required

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

1. Measure the filament resistance. This can be accomplished while the sensor is under vacuum by measuring the resistance between pins **G** and **E**. (See Figure 7-2.) A failed filament will measure open.

Figure 7-2 Transpector XPR3 sensor pin location



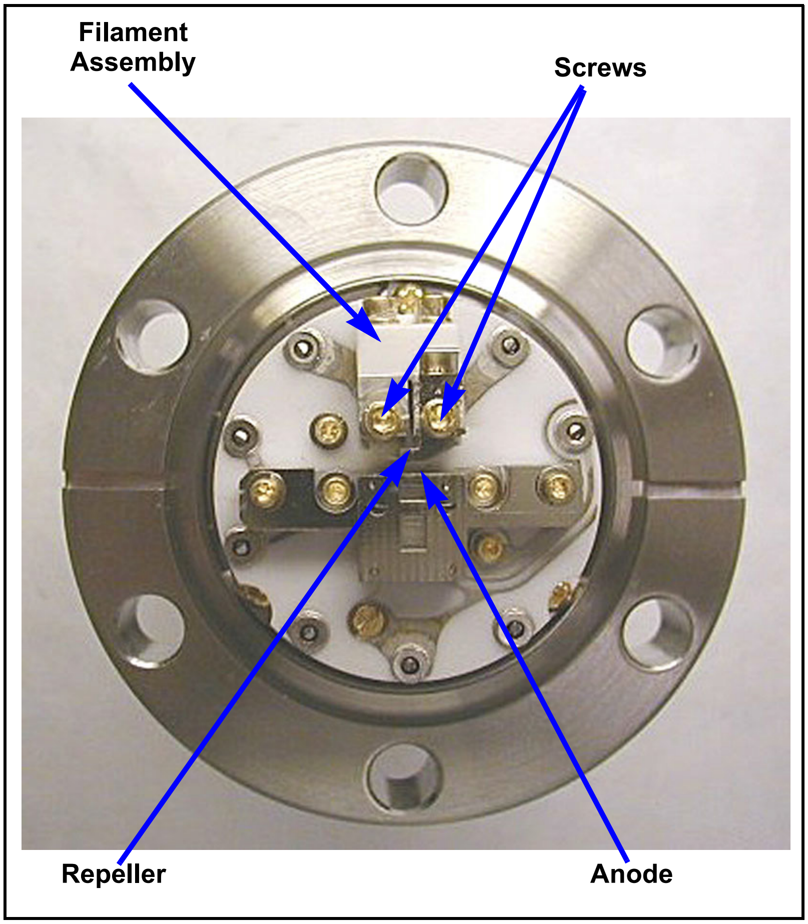
NOTE: Although the following measurements may measure below 30MΩ with the filament assembly in place, they must be above 30MΩ when measured with the filament assembly removed.

2. Measure the resistance of each of the pins with respect to ground (pin **A**). These measurements should be above 30MΩ.
3. Measure the resistance of each of the pins with respect to each other. All of these measurements should also be above 30MΩ, with the exception of across the filament if the filament has not failed.

7.6.3 How to Determine the Condition of the Ion Source

1. Remove the Transpector XPR3 Sensor from the vacuum system.
2. Completely loosen the two 1-72 x 0.31" long gold plated cap head screws that hold the filament assembly to the ion source plate. Remove the filament assembly and screws. See Figure 7-3.

Figure 7-3 Top view of the Transpector XPR3 Sensor



3 Measure the resistance of each of the pins with respect to ground (refer to pin **A** in Figure 7-2). These measurements should be above 30MΩ.

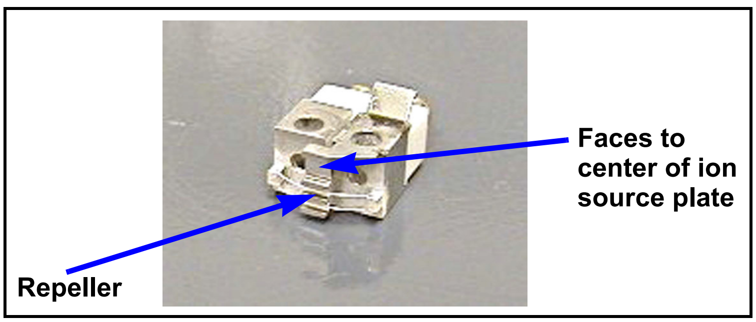
4 Measure the resistance of each of the pins with respect to each other. All of these measurements should also be above 30MΩ.

- If any of the measurements in steps 3 and 4 are less than 30MΩ the ion source is contaminated and requires cleaning or replacement before the new filament is installed. Contact the nearest INFICON Service Center for assistance with returning the unit to the factory for repair. Refer to section 1.3, How To Contact Customer Support, on page 1-4.
- If the resistance measurements in steps 3 and 4 above are greater than 30 MΩ proceed with section 7.6.4, How to Replace the Filament.

7.6.4 How to Replace the Filament

1 Install the filament so that the face of the repeller is parallel to the face of the anode and the filament is approximately centered to the two mounting screws (per steps 2 and 3 below). See Figure 7-4.

Figure 7-4 Filament assembly

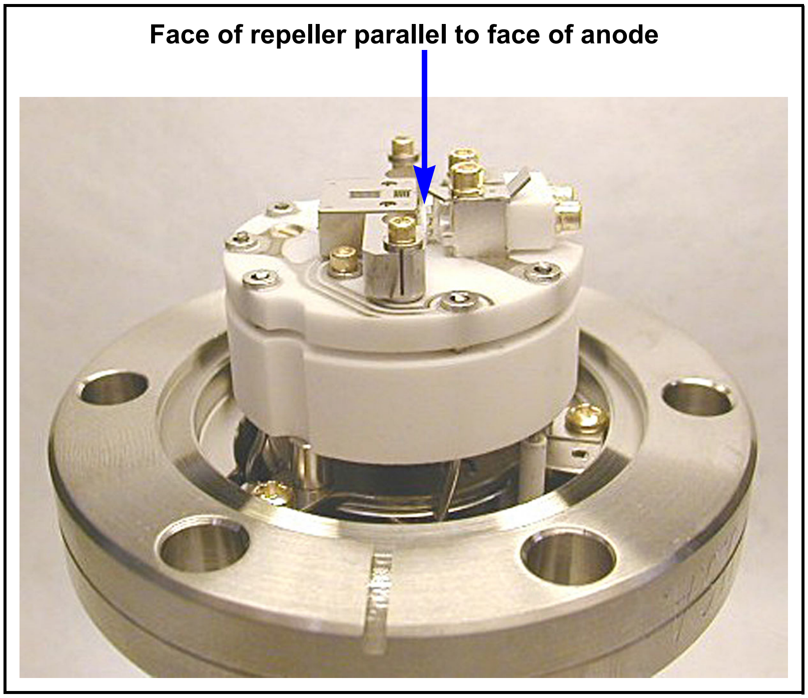


2 Align the holes in the filament blocks with those on the base plate.

3 Place the lock washers on the screws, and then insert the screws through the filament assembly and into the holes in the ion source base plate. Alternately tighten the screws until the screw heads just touch the lock washers. See Figure 7-5.

NOTE: Both screws must have lock washers to maintain mechanical connection and therefore electrical connection from the traces to the filament assembly.

Figure 7-5 Filament in place on sensor



4 While holding the short end of the hex wrench, alternately tighten the screws until the hex wrench begins to flex. Alternately use a torque-limiting screwdriver (IPN 02-389-P1 or equivalent), torque the screws to 10-12 oz In. (0.0384 Nm to 0.0461 Nm).

CAUTION

Do not touch the filament wires.

7.7 Total Pressure Calibration

See the TWare32 Operating Manual for detailed information on how to calibrate the Total Pressure.

CAUTION

Enable the Lo Emission (40eV, 200µA) icon in TWare32.

Do not use the High and Low pressures indicated in the TWare32 software. Perform the Total Pressure calibration at the following pressures.

Low Pressure: $1x10^{-5}$ Torr argon ($1.333x10^{-5}$ mbar) [$1.333x10^{-3}$ Pa]

High Pressure: $3x10^{-3}$ Torr argon ($4x10^{-3}$ mbar) [$4x10^{-1}$ Pa]

7.8 How to Determine Sensitivity

Introduce argon to provide a pressure of $1x10^{-4}$ Torr ($1.333x10^{-4}$ mbar) $1.333x10^{-2}$ Pa] with the sensor set to 40eV, 200µA emission (Lo Emission). Measure the current for mass 40 and divide that by the actual pressure to obtain the sensitivity in amps/Torr.

Example

1. Introduce argon to provide a pressure of $1x10^{-4}$ Torr with the sensor set to 40eV, 200µA emission (Lo Emission).
2. Measure the current for Mass 40 and the actual pressure.
   - current: $2.5x10^{-11}$ amps
   - actual pressure: $1x10^{-4}$ Torr
3. Divide the current by the actual pressure to determine the sensitivity in amps/Torr.

$$\frac{2.5 \times 10^{-11}}{1 \times 10^{-4}} = 2.5 \times 10^{-7} \text{amps/Torr} \quad [1]$$

4. In TWare32, go to: **Tune >> Advanced >> Set Sensitivity...**.
5. Enter the sensitivity ($2.5x10^{-7}$ amps/Torr in this example.)

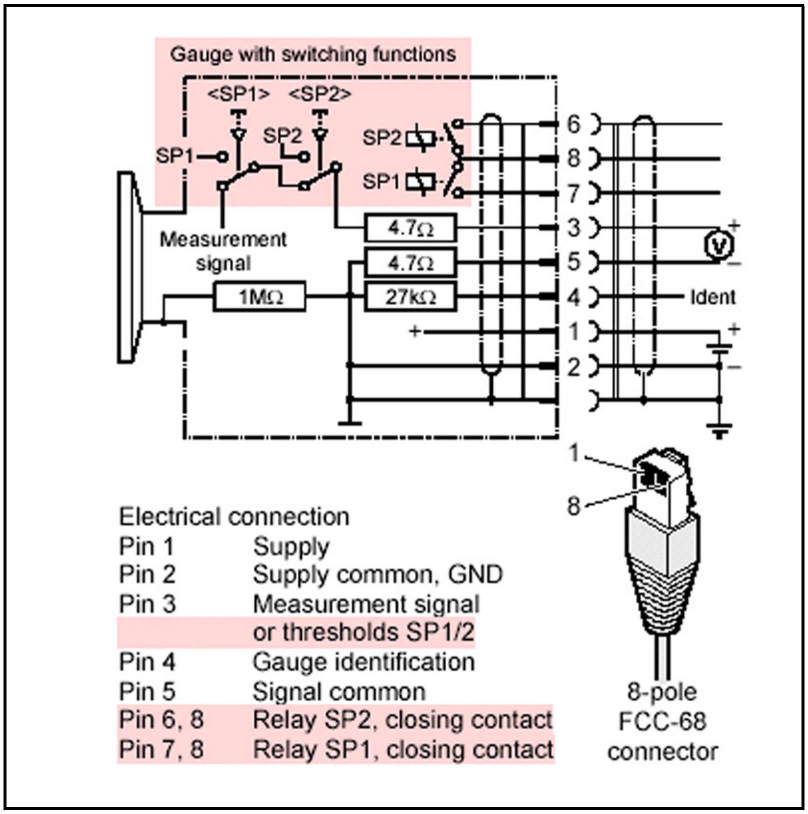
7.9 Pirani Interlock Adjustment Procedures

Follow these procedures for adjusting the Pirani Interlock on XPR3, XPR2, Preclude, and XPR Transpectors.

7.9.1 INFICON PSG500 Adjustment Instructions

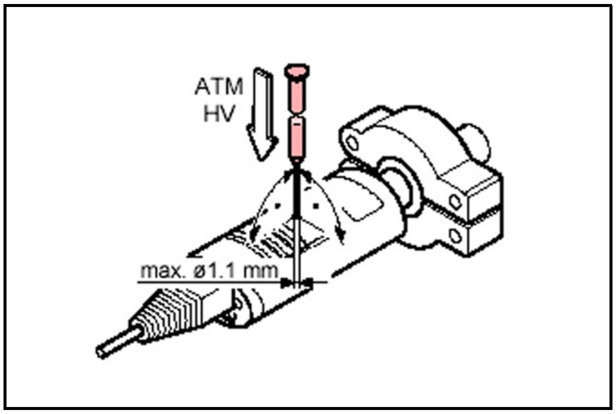
1. Mount the Pirani gauge on the vacuum system.
2. Apply power to the gauge, 24 V(dc). See Figure 7-6.

Figure 7-6 PSG500 electrical connections



3. Allow the Pirani gauge to warm-up for a minimum of 10 minutes.
4. While at atmosphere (air or nitrogen), press the button on the back of the gauge (see Figure 7-7) with the supplied tool to make the ATM (atmosphere) adjustment. The gauge is automatically adjusted to 750 Torr (1000 mbar) [99,991.78 Pa], which is a Pirani voltage of 10 V(dc) (± 0.1V).

Figure 7-7 PSG500 adjustment button



5 Evacuate the vacuum system to a pressure of less than $7.5x10^{-6}$ Torr ($1x10^{-5}$ mbar) [$1x10^{-3}$ Pa] and wait at least 2 minutes.

6 While at high vacuum, press the button on the back of the gauge to adjust the HV (high vacuum) setting. The gauge is automatically set to 1.0 V(dc) by default. Press the button for > 5 seconds until the voltage increases to 1.9 ± 0.1 V(dc).

7 Vent the system to atmosphere (air or nitrogen) and verify that the Pirani voltage is 10.0 ± 0.1 V(dc). Repeat the ATM adjustment if the setting at atmosphere has changed.

8 Evacuate the system to a pressure of less than $7.5x10^{-6}$ Torr ($1x10^{-5}$ mbar) [$1x10^{-3}$ Pa] and wait at least 2 minutes.

9 Verify that the Pirani voltage at high vacuum is still 1.9 ± 0.1 V(dc). If the Pirani voltage has changed, repeat the HV adjustment to read 1.9 ± 0.1 V(dc).

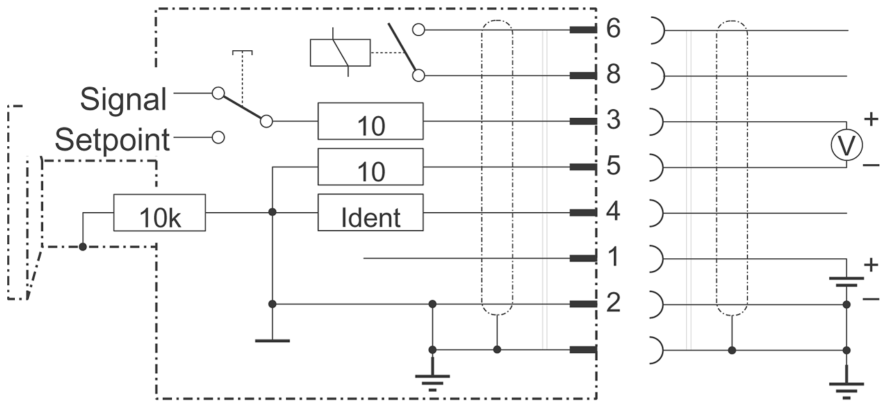
10 If a readjustment of the HV setting was done in step 9, repeat steps 7-10 of this procedure until valid readings are obtained at atmosphere and high vacuum.

7.9.2 INFICON PSG400 Adjustment Instructions

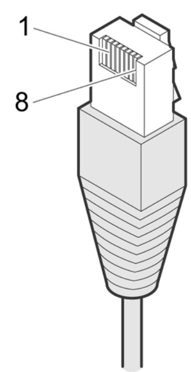
1 Mount the Pirani gauge on the vacuum system.

2 Apply power to the gauge, 24 V(dc). (See Figure 7-8.)

Figure 7-8 PSG400 electrical connections



Pin	Assignment
Pin 1	Supply voltage (+14 ... +32 Vdc)
Pin 2	Supply Common
Pin 3	Signal output (measurement signal)
Pin 4	Identification
Pin 5	Signal Common
Pin 6, 8	Switching Contacts



8 pole FCC-68 plug

3 Allow the Pirani gauge to warm-up for a minimum of 5 minutes.

4 While at atmosphere (air or nitrogen), adjust the ATM (atmosphere) potentiometer so the Pirani voltage (measuring signal) is set to 10.0 ± 0.1 V(dc).

5 Evacuate the vacuum system to a pressure of less than $7.5x10^{-6}$ Torr ($1x10^{-5}$ mbar) [$1x10^{-3}$ Pa].

6 While at high vacuum, adjust the HV (high vacuum) potentiometer to 1.9 ± 0.1 V(dc).

7 Vent the system to atmosphere (air or nitrogen) and verify that the Pirani voltage is 10.0 ± 0.1 V(dc). Readjust the ATM potentiometer if the setting at atmosphere changed.

8 Evacuate the system to a pressure of less than 7.5x10^{-6} Torr (1x10^{-5} mbar) [1x10^{-3} Pa].

9 Verify that the Pirani voltage at high vacuum is still 1.9 ± 0.1 V(dc). If the Pirani voltage changed, readjust the HV potentiometer to 1.9 ± 0.1 V(dc).

10 If a readjustment of the HV potentiometer was done in step 9, repeat steps 7 - 10 of this procedure until valid readings are obtained at atmosphere and high vacuum.

7.9.3 INFICON TR090 Adjustment Instructions

1 Orient the Pirani gauge in the horizontal position on the vacuum system.

2 Apply power to the gauge, 24 V(dc). (Refer to Figure 7-8.)

3 Allow the Pirani gauge to warm-up for a minimum of 5 minutes.

4 While at atmosphere (air or nitrogen), adjust the ATM potentiometer so the Pirani voltage (measuring signal) is set to 10.0 ± 0.1 V(dc).

5 Evacuate the vacuum system to a pressure of less than 7.5x10^{-6} Torr (1x10^{-5} mbar) [1x10^{-3} Pa].

6 While at high vacuum, adjust the HV potentiometer to 1.9 ± 0.1 V(dc).

7 Vent the system to an atmosphere of air or nitrogen and verify that the Pirani voltage is 10.0 ± 0.1 V(dc). Readjust the ATM potentiometer if the setting at atmosphere changed.

8 Evacuate the system to a pressure of less than (7.5x10^{-6} Torr) (1x10^{-5} mbar) [1x10^{-3} Pa].

9 Verify that the Pirani voltage at high vacuum is still 1.9 ± 0.1 V(dc). If the Pirani voltage changed, readjust the HV potentiometer to 1.9 ± 0.1 V(dc).

10 If a readjustment of the HV potentiometer was done in step 9, repeat steps 7 - 10 of this procedure until valid readings are obtained at atmosphere and high vacuum.

Chapter 8
Diagnosing Problems

8.1 Introduction

If you are having trouble with your Transpector XPR3, first look at Table 8-1 and see if your problem is listed there. If not, contact Customer Support (refer to section 1.3, How To Contact Customer Support, on page 1-4).

8.2 Symptom-Cause-Remedy Chart

Make sure that the insulation on all cables is intact (that is, there is no damage on the insulating material) before using Table 8-1.

NOTE: An X in the last column denotes that the REMEDY should be performed by qualified service personnel only.
A Y denotes that the Transpector XPR3's power should be turned off for 5 seconds to effect the REMEDY.

WARNING - Risk Of Electric Shock

Removal of the Transpector Electronics Module covers should only be done by qualified service personnel. There are no user-serviceable parts inside the unit. Removal of these covers could result in a shock hazard an/or personal injury.

Table 8-1 Symptom—Cause—Remedy Chart

SYMPTOM	CAUSE	REMEDY	
CPU LED does not turn on.	+24V external power supply	Check input AC line voltage to external power supply.	
		Check +24V input, verify input between 20 - 30 volts.	
		Replace external supply.	
	Transpector internal fuse blown	Replace fuse on Power Supply card.	X
	CPU card failure	Replace CPU card.	X
	Power Supply card failure	Replace Power Supply card.	X
CPU LED flashes			
1 flash	Invalid interrupt, possible CPU fault	Reset Transpector.	Y
		If problem persists, replace CPU card.	X
2 flashes	NMI (Non-maskable interrupt)	Check +24V input voltage. Verify input voltage is between 20 -30V.	
	Power Supply card failure	Replace Power Supply card.	X
3 flashes	Unimplemented OPcode CPU card failure	Reset Transpector.	Y
		If problem persists, replace CPU card.	X
4 flashes	DUART failed to initialize	Reset Transpector.	Y
		If problem persists, replace CPU card.	X
5 flashes	CPU card RAM corrupted or bad	Reset Transpector.	Y
		If problem persists, replace CPU card.	

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

SYMPTOM	CAUSE	REMEDY	
No communication to HOST computer	Configuration of DIP switches incorrect	Refer to installation.	
	Baud rate incorrect	Check baud rate selection on both Transpector and Computer.	
	Cable connections	Make sure cables are connected to proper connectors.	
	Incorrect COM port selected	Select correct COM port on computer.	
		Reset Transpector.	Y
		Reset HOST computer.	
	Computer interface card RS-232C or RS-485	Replace interface card in computer or TCA485 adapter, if available.	
EMISSION error	Defective sensor filament open, shorted	Check sensor with OHM meter.	
		Replace sensor or filament.	
	Power supply card defective	Replace power supply card.	X
	Insufficient vacuum	Verify pressure is less than 2E-2 Torr for Transpector XPR3.	
	Sensor operating voltages incorrect	Verify correct settings See Service Diagnostics for nominal sensor settings.	
	Transpector not fully engaged on sensor	Make sure Transpector Electronics Module is pushed all the way on sensor.	
ANODE error	Defective sensor, anode shorted	Check Sensor with OHM meter for shorts. See sensor pin-out diagram.	
		Fix or replace sensor.	
	Power supply card failure	Replace power supply card.	X

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

SYMPTOM	CAUSE	REMEDY	
RF error	Defective sensor, RF leads open RF/DC card fault	Fix or replace sensor.	
		Replace RF/DC card.	X
EMULT error	Defective sensor or EM shorted	Check Sensor with Ohm meter. See sensor pin-out diagram.	
		Fix or replace sensor.	
	Power supply card	Replace power supply card.	X
Temperature error	Transpector internal ambient temp > 75 °C	Make sure unit is installed properly, ambient temp < 50 °C.	
		Verify that there are no heat sources in local proximity.	
	CPU card malfunction	Replace CPU card.	X
No spectra	Emission is OFF	Turn Emission ON.	
	Contaminated sensor	Service sensor.	
		Replace sensor.	
	Measurement card failure	Replace measurement card.	X
	Pressure too low for FC	Use EM detector.	
	EM voltage to low	Increase voltage.	
	Transpector not fully engaged on sensor	Push Transpector Electronics Module completely onto sensor.	
	Mass calibration	Adjust MASS calibration.	

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

SYMPTOM	CAUSE	REMEDY	
Poor sensitivity	Sensor contaminated	Bake-out sensor.	
		Service sensor.	
	System pressure too low	Increase sample pressure, if possible.	
	Mass calibration (resolution)	Adjust Mass Calibration, increase peak width.	
	Sensor Operating parameters set wrong	Check settings of: electron energy, ion energy, focus emission current.	
	Measurement card defective	Replace measurement card.	X
	EM has low gain	Bake-out sensor.	
		Replace sensor.	
Poor peak shape	Sensor contaminated	Bake-out sensor.	
		Service EM or sensor.	
	System pressure too high	Verify pressure less than 2E-2 Torr.	
	Mass calibration required	Perform Mass calibration.	
	RF/DC card defective	Replace RF/DC card.	
	Power Supply card defective	Replace Power Supply card.	
High noise level	System grounding	Verify that vacuum system is grounded.	
	Damaged signal input	Replace Measurement card.	X
	Output spring contact on Sensor damaged or shorted	Fix or replace.	
	Transpector not mounted properly on sensor	Push Transpector all the way on to the sensor.	
	EM defective	Replace EM assembly or sensor.	X
	Scan speed too fast for gain setting	Reduce Scan speed.	

8.3 Communication Problems

If there are any communication problems, check the following:

- Ensure that the COM port that the Transpector is installed on is the same as the COM port selected in the application software configuration.
- Ensure that the Transpector baud rate is the same as the application software configuration.
- If you are running RS-232C, make sure that the Transpector Electronics Module SWITCH 8 is on.
- If running RS-485, ensure that the Transpector Electronics Module SWITCH 8 is off, and a valid, unique Sensor number has been assigned.

8.4 Service Diagnostics via RS-232C Serial Port

Using a PC computer or any other computer equipped with an RS-232C serial port and a terminal emulation program, service personnel can obtain information about internal operations of the Transpector. This information may also be useful when calling INFICON's Service Department with a problem.

In order to configure the Transpector for the diagnostic mode, follow the steps below:

1 Set configuration switch 8 on the Transpector to the OFF position. The Transpector will now communicate in an ASCII format over the RS-232C serial port.

2 Set switch 6 and 7 on the Transpector to obtain the same BAUD that the terminal program is configured for. (e.g.,. SW6 - OFF, SW7 - OFF = 9600 baud.)

NOTE: When switches 6 and 7 are changed, the Transpector must be RESET, since these switches are only read on power up.

3 Verify terminal program is configured for the following:

- NO Parity
- 8 Data Bits
- 1 Stop BIT

4 Select the appropriate COMM channel on the computer.

When the Transpector receives an ASCII "DS," status and diagnostic information is sent out the RS-232C serial link. This diagnostic mode can operate simultaneously with the RS-485 link.

A typical Transpector status and diagnostic information display is shown on the following page.

```
**** Transpector Ver 2.00, C+C Tst 1.50, Meas Rev 2.09 ****

**** SENSOR ****

Type = TSP, Range = 100, Det = FC/MCP, RF Board = 1, RF = 1989300
Hz Measuring 39.75 amu, delay = 1 mS, dwell = 16 mS Emission 2000
uA, focus 10 V, ion energy 8000 meV, electron energy 102 eV
CEM/MCP front set at 0 V, MCP back set at 0 V, rod polarity 0

**** POSSIBLE PROBLEMS ****

# of Warnings: anode = 0, em = 0, emis = 0, rf lock = 0

Anomaly ID: anode = 0, C+C = 0, emis = 0, tune = 0, peakfind = 1

**** AtoD ****

Temp = 3.003 V, 27.3 C, DtoA = 0.649 V, Emis = 2.300 V, Anode =
2.075 V TPP high = 0.000 V, TPP low = 1.826 V, RMT1 = 0.000 V,
RMT2 = 0.000 V

**** MISC ****

DIP switches = EF, Relays in = 0, DUART resets = 0, Task P1S2 max
= 162 Hardware ID function = D480, error = 0, warning = 0 Meas RX
= 2531917, Errors (line = 0, ID = 0), Retries = 0, Resets = 0 232
RX = 129, Errors (line = 0, protocol = 0, ID = 0), CTS = 0 485 RX
= 16671382, Errors (line = 0, protocol = 0, ID = 0), Address = 1
RF delta = 0 camu, fo = 1988600, xtal = 16012 KHz, Tic = 16279
Baseline added = 0.00e+00, measured = 1.71e-16, press_lin_mult =
1.00e+00
```

A brief description of the diagnostic information follows:

Line 1 . . . . Current version level of the Control Card and Measurement Card firmware.

SENSOR . . . . Sensor related information

TYPE XPR3

RANGE . . . . Mass range 100

DETECTOR . . . . FC/MCP (XPR3)

RF. . . . . RF measured frequency,
XPR3-13.0MHz nominal

MEASURING . . . . Mass that is currently being measured

DELAY . . . . Delay after control voltages are set

DWELL. Measurement time

EMISSION . . . . Current emission current set point
XPR3: 70 ev/400 µa; 40 eV/200 µa (default)

FOCUS. Current focus voltage set point
XPR3: 10-30V; 20V default

ION ENERGY. . . . . Current ion energy set point
XPR3: 8V nominal; 5-15V

ELECTRON ENERGY . . . . Current electron energy set point.
102 eV nominal
XPR3: Hi = 70 eV; Lo = 40 eV (default)

CEM/MCP. . . . . Voltage on front side of MCP
XPR3 MCP -775 - 1225

MCP . . . . Adjustable voltage on back of MCP
50 - 500 (XPR3)

POSSIBLE PROBLEMS . . . . Warnings and error codes

# of warnings—each of these warnings are accumulated in a counter and displayed. The count is only reset when the Transpector is reset (powered down and back up)

ANODE . . . . Anode voltage is too low or too high

EM. . . . . Electron Multiplier error

EMIS . . . . Emission regulator unable to achieve emission

RF LOCK. . . . . Measured RF Frequency out of specification, or failure to achieve set RF amplitude value.

ANOMALY ID. . . . . These one byte codes help to identify the cause of the warnings, when a bit is set the condition has been observed.

ANODE . . . . bit 7 - voltage too low
bit 6 - voltage too high
bits 5-0 reserved (0)

C&C . . . . Control Card
bit 7 - reserved (0)
bit 6 - User database corrupt
bit 5 - D/A test failed
bit 4 - RAM battery low
bit 3 - corrupt RAM data base
bit 2 - Duart Fail
bit 1 - Last power down fail
bit 0 - reserved (0)

TUNE . . . . Calibration
bit 7 - Lower RF DAC limit exceeded
bit 6 - Upper RF DAC limit exceeded
bit 5 - Lower DC DAC limit exceeded
bit 4 - Upper DC DAC limit exceeded
bit 3 - Position limit
bit 2 - Resolution limit
bit 1 - Min RF limit
bit 0 - reserved (0)

EMISSION . . . . bit 7 - low emission control integrator (voltage less than 0.5 volts)
bit 6 - high emission control integrator (voltage greater than 3.0 volts)
bit 5 - cold start fail
bit 4 - warm start fail
bits 3-0 reserve (0)

A to D Group . . . . Analog signals measured by the control card

TEMP . . . . Internal ambient temperature of box in °C. Maximum allowable 75 °C.

D to A . . . . Resolution set point voltage /2

EMIS . . . . Emission control integrator output. Allowable limits: 0.5 minimum, 3.0 maximum

ANODE . . . . Anode voltage /100
Allowable limits: 202 minimum, 220 maximum

TPP high . . . . HIGH Total pressure amplifier output

TPP low . . . . LOW Total pressure amplifier output

RMT1 . . . . Remote analog input 1

RMT2 . . . . Remote analog input 2

MISC GROUP . . . . This group displays the read value of the configuration switches, Remote I/O inputs, and diagnostic information on each of the three serial ports.

8.4.1 RS-232C Interface Cable

The RS-232C interface cable connections are shown in the figure below. This cable is available from INFICON as part number 600-1001-P15 (15 ft. (4.6 m) length) or 600-1001-P30 (30 ft. (9.1 m) length). You can also make your own cable by using the drawing in Figure 8-1.

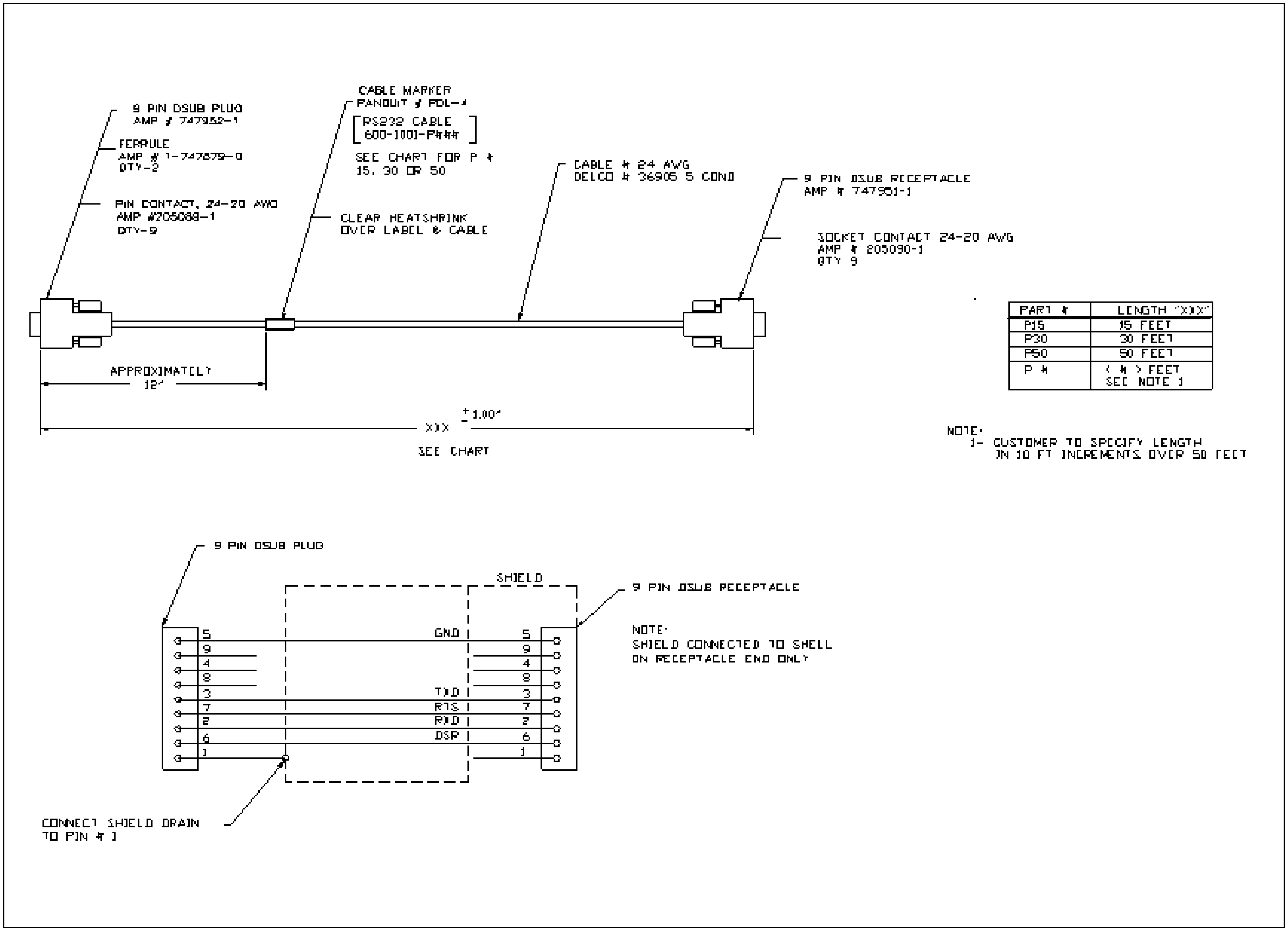


Figure 8-1 RS-232C Interface Cable

Chapter 9
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 also **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**, above.

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 10
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.

Index

N

O

P

Q

R

S

PN 074-378-P1D