Vacuum Technology

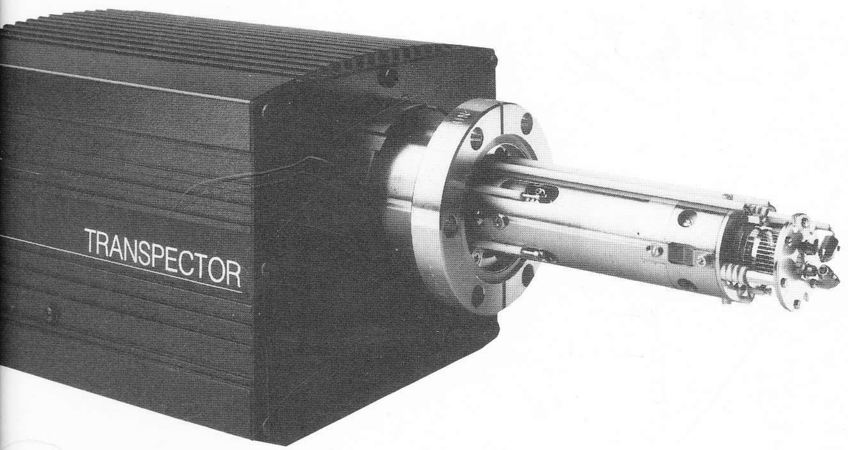
Vacuum Process Engineering

Measuring and Analytical Technology

LEYBOLD

LEYBOLD INFICON INC.

Part Number 074-201



TRANSPECTOR® Gas Analysis System

MANUAL

Vacuum Technology

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TRANSPECTOR® Gas Analysis System

MANUAL

JUNE 1996

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1.1 About Section 1

Section 1 of the Transpector Manual provides you with the necessary information to verify that your system is complete, connected correctly, and will perform basic operations.

> ***CAUTION:*** *DO NOT attempt to install the Transpector without reading this section. FAILURE TO FOLLOW THESE INSTALLATION INSTRUCTIONS MAY RESULT IN DAMAGE NOT COVERED BY WARRANTY.*

a. If you haven't removed the Transpector from its shipping containers, do so now.

b. Carefully examine the unit for damage that may have occurred during shipping. This is especially important if you notice obvious rough handling on the outside of the cartons. IMMEDIATELY REPORT ANY DAMAGE TO THE CARRIER AND TO INFICON.

c. Keep the packing materials until you have taken inventory and completed the check procedures.

d. Now that the unit is unpacked and inspected, you are ready to take inventory.

1.2 Inventory

Make sure that you have received all of the parts that belong to your system.

Part Number	Description
Transpector Electronics Unit (one of the following):	
911-202-G1	Compact 100 AMU FC and EM/FC (C100F, C100M)
911-210-G1	High Performance 100 AMU FC and EM/FC (H100F, H100M)
911-212-G1	High Performance 200 AMU FC and EM/FC (H200F, H200M)
911-214-G1	High Performance 300 AMU FC and EMFC (H300F, H300M)
Sensor (one of the following):	
912-350-G1	Compact 100 AMU FC (C100F)
912-350-G2	Compact 100 AMU EM/FC (C100M)
912-402-G2	High Performance 100 AMU FC (H100F)
912-403-G2	High Performance 100 AMU EM/FC (H100M)
912-402-G1	High Performance 200 AMU FC (H200F)
912-403-G1	High Performance 200 AMU EM/FC (H200M)
912-412-G1	High Performance 300 AMU FC (H300F)
912-411-G1	High Performance 300 AMU EMFC (H300M)

Part Number	Description
Extension Kit	
900-041-G3	100, 200, 300 EM High Performance Sensor Extension Kit
900-041-G1	100, 200, 300 FC High Performance Sensor Extension Kit
900-041-G4	100 EM/FC Compact Sensor Extension Kit (C100 F/M)
Software (one of the following)	
911-005-G1	MasterQuad Software (Single sensor software)
911-008-G1	SQX (Single sensor software)
911-006-G1	MQX Software (Multiplexing software)
Ship Kit	
911-203-G1	Ship Kit - includes:
051-032	"D" Connector
051-1082	Cable Clamp for "D" connector
062-058	Fuse 2A 250V
074-201	Manual
Power Supply (optional)	
911-039-G1	Power Supply Kit - 90-260 VAC 4 ft. standard cable - 120V
911-039-G2	Power Supply Kit - 90-260 VAC 4 ft. standard cable - 230V
600-1008-P15	Power Supply Cable - 15 ft. (optional)
600-1008-P30	Power Supply Cable - 30 ft. (optional)
For Single Sensor Operation: (one of the following)	
600-1001-P15	RS232 Cable - 15 ft.
600-1001-P30	RS232 Cable - 30 ft.
For Multiple Sensor Operation: (one of the following)	
911-040-G15	RS485 Cable Kit - 15 ft.
911-040-G30	RS485 Cable Kit - 30 ft.
	Included in above part numbers:
600-10C3-P1	"Y" Cable
Computer Communications Module (optional)	
911-045-G1	RS485 Communication Kit
	Includes:
911-041-P1	Terminator Plug
911-042-P1	RS485 Card

1.3 Setup And Installation (Hardware)

1.3.1 Sensor Installation

GENERAL NOTES

- Do not touch any surface on the vacuum side of the sensor with the fingers. If it is necessary to touch any of these parts, always wear clean linen or nylon laboratory gloves.
- Before installing the device 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 of the sensor requires disassembly. If you feel that the sensor is contaminated and needs cleaning, contact the Leybold Inficon Service Department for specific instructions.

1.3.1.1 ConFlat® Flanges

The sensor is installed on your vacuum system with a 2¾" 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 the section on "Attaching the Sensor to the Vacuum Chamber." 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 400°C or more without incurring leaks in the seal. For bakeout temperatures when a sensor is installed, refer to Section 1.2.1.3.

1.3.1.2 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.

   NOTE: DO NOT TOUCH the gasket and flange faces with your fingers during the installation process.

2. Install the copper gasket between the two flanges (Figure 1.1). *ALWAYS USE A NEW GASKET*. Do not attempt to use gaskets more than once.

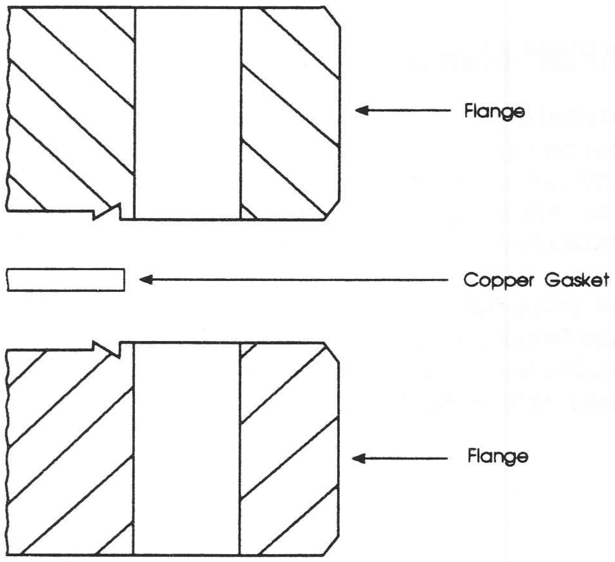


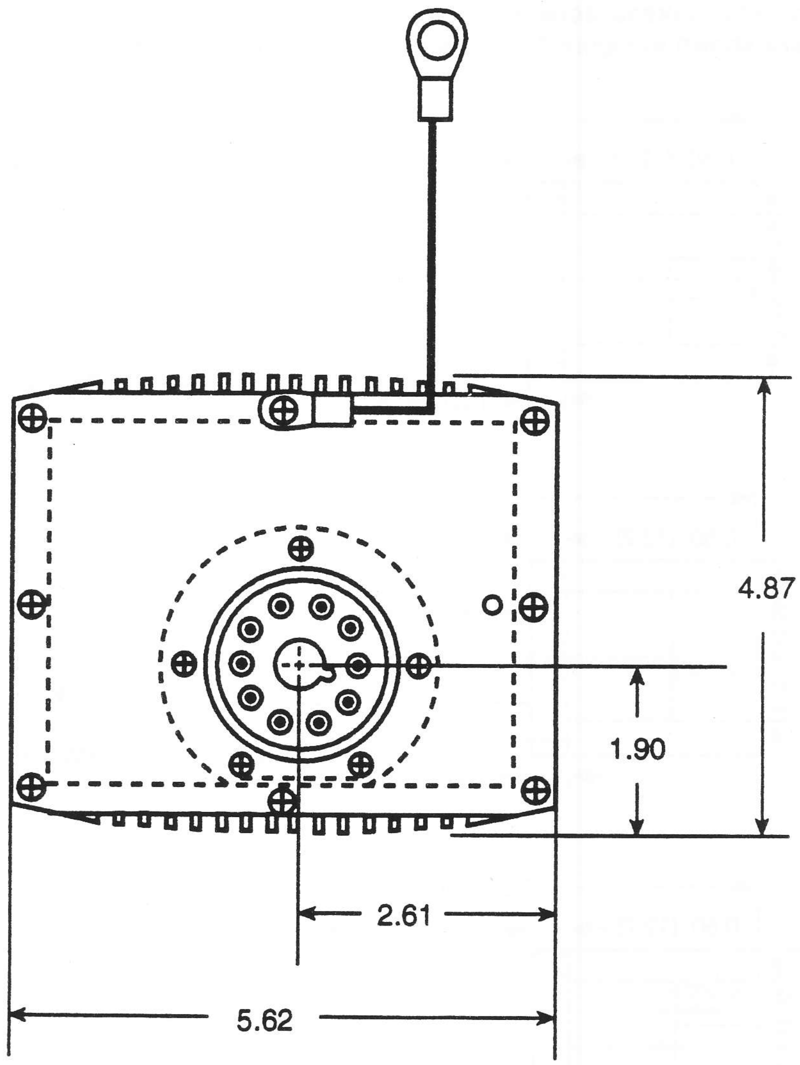
Figure 1.1 Gasket and Flange Assembly

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, prelubricate the bolt threads with an anti-seize compound (FelPro® C 100 or equivalent).

CAUTION: *Be careful not to 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 contact all the way around.



Transpector/Sensor Connector Diagram

1.3.1.3 Attaching the Sensor to the Vacuum Chamber

The sensor may be mounted in any position for convenience when attaching it to the vacuum vessel or chamber within which the measurements are to be made. However, you should avoid any magnetic fields greater than 2 gauss. 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. If materials are evaporated or coatings are deposited in the vacuum chamber, you must protect the sensor against the deposition of these materials on its surfaces by installing a baffle or deflector. In systems which are baked, include the sensor in the bakeout zone or provide it with separate heaters. Dimensions of the quadrupole sensors are shown in Figure 1.2 to assist in the planning of the installation.

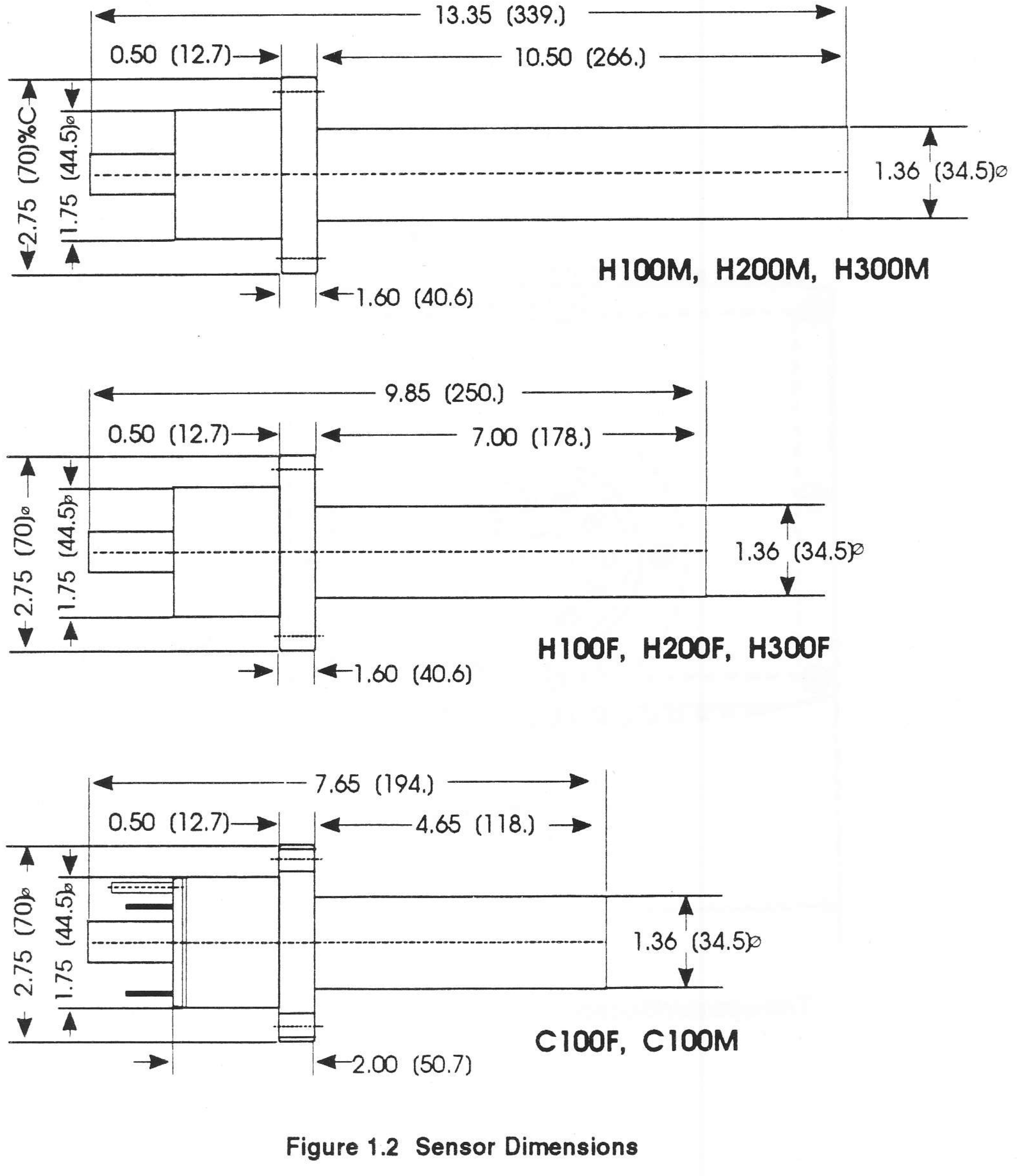


Figure 1.2 Sensor Dimensions

Design of the sensor may not allow installation into a standard 2¾" ConFlat port with a 1.5" tube diameter. An optional extension tube with 1.62" tube diameter is provided if it is needed to attach the sensor to your vacuum chamber. The part number for an Electron Multiplier (H100M or H200M) 9.75" tube is 900-041-G3; the part number for a Faraday Cup (H100F or H200F) 6.25" tube is 900-041-G1 and 904-041-G4 for a compact H100C tube.

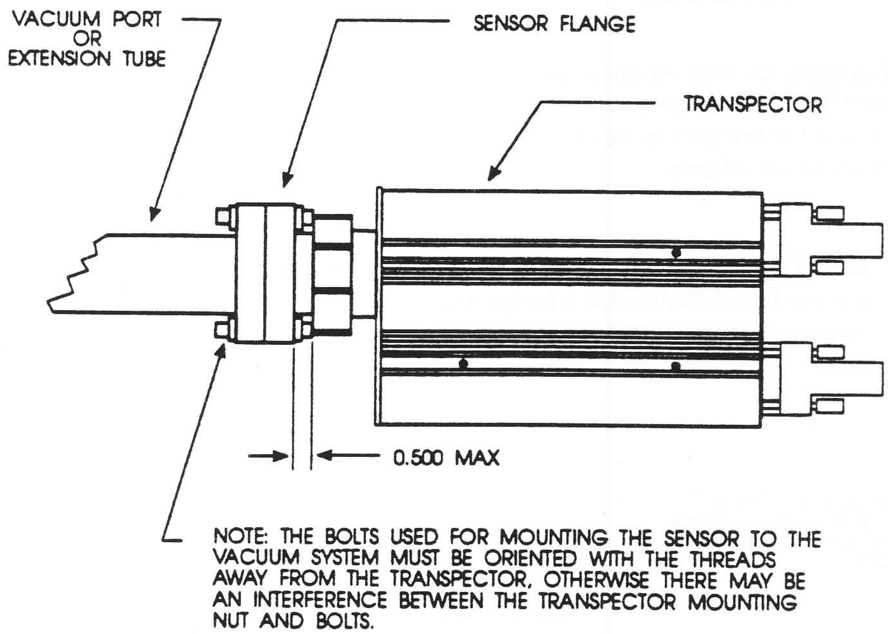


Figure 1.3 Sensor and Transpector Mounting (911-090 A)

CAUTION: *Maximum bakeout temperature for sensors is:*

Sensor	**Operating Temp.**	**Not Operating - Electronics Removed**
C100F	100°C	200°C
C100M	100°C	200°C
H100F, H200F, H300F	250°C	350°C
H100M, H200M, H300M	100°C	400°C

When baking out the system, the Transpector Unit and the signal contact pin on the sensor must be removed prior to bakeout at jacket temperatures greater than 250°C (FC). See Figure 1.3.

CAUTION: *Do not turn on multiplier high voltage at sensor temperatures above 100°C. Otherwise permanent damage to the multiplier could result.*

1.3.2 Transpector Installation

NOTE: The Transpector module was calibrated at the factory to a specific sensor. If mounted to a different sensor of the same type, the Transpector may have to be recalibrated. (Refer to Section 6 for MasterQuad calibration and Section 7 for MQX and SQX calibration.)

The Transpector module should be mounted in an area where the ambient temperature does not exceed 122°F (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.

CAUTION: *The sensor output contact for the Transpector unit is a gold plated spring. If the sensor that the Transpector module is being installed on does not have this type of contact, the old connector must be removed and the new spring contact added: IPN 912-401.*

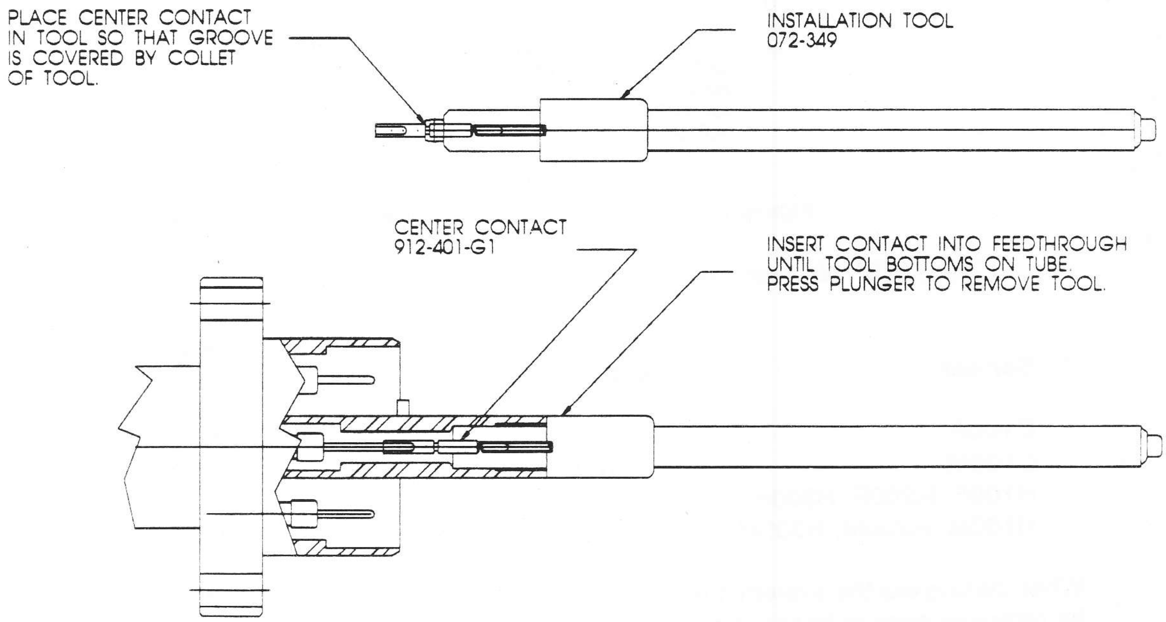


Figure 1.4 Sensor Contact (912-401 C)

After the sensor has been installed on the vacuum system, the Transpector module may be mounted on to the sensor. To install the Transpector on the sensor follow these steps:

1. Look at the contact in the center of the sensor; verify that it is a gold spring (IPN 912-401). (See Figure 1.4)

2. 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 mounting nut on Transpector is loose so the O-ring is not compressed.

3. Note alignment pin on the sensor feed-through and mating notch in the Transpector mounting connector. Carefully align the pin and notch and slide the Transpector onto the sensor. Make sure the Transpector module slides on all the way.

4. Hand tighten the mounting nut on the Transpector unit.

5. Tightly fasten the 6" ground strap from the Transpector unit to the sensor ConFlat flange mounting bolt.

WARNING!!

THE 6" GROUND STRAP IS A PROTECTIVE CONDUCTOR SAFETY GROUND. IT MUST BE CONNECTED PRIOR TO ANY USE OF THE INSTRUMENT.

6. Install communication cables for the Transpector

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

   See Figure 1.5 for a diagram of communications connections.

RS232 Communications: (Default for the MasterQuad and SQX)

- SWITCH 8 must be ON

- SWITCH 6 and 7 must be set to select the proper baud rate as selected in the application software.

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

NOTE: If running SQX software with RS232 the baud rate is fixed at 9600, therefore SW6 and SW7 must be OFF.

Connect the other end of the communications interface cable, to the proper serial channel on the host computer, e.g., COM1 or COM2.

NOTE: The application software is configurable for which COM channel is used for communication to the Transpector unit. Make sure the interface cable is connected to the COM port that is selected in the application program. (Refer to appropriate sections for details: Section 6 - MasterQuad, and Section 7 for SQX and MQX.)

If using SQX software, default parameters are

communication type	= RS232
communication port	= COM1
mouse port	= COM2

RS485 Communications: (Required for MQX and optional for MasterQuad and SQX)

- RS485 baud rate is fixed at 57600.
- SWITCH 8 must be OFF
- SWITCHES 1-5 must be set for a unique address as shown below.

NOTE: For MasterQuad and SQX address must be set to:
1 (SW 1-4 OFF, SW 5 ON)

For MQX each Transpector unit on the network must have a unique address between 1-8.

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

Connect the RS485 center connector on the RS485 "Y" cable (IPN 600-1003-P1) to the RS485 connector on the back of the Transpector. Connect the female end of the RS485 interface cable (IPN 600-1002-P#) to the male end of the "Y" cable. If this is a single Transpector installation, plug the Terminator Plug (IPN 911-041-P1) onto the remaining female end of the "Y" cable. If this is a multiple Transpector installation, connect the RS485 interface cable from the next Transpector. (See Figure 1.5).

Each Transpector unit on the RS485 link must have an RS485 “Y” cable terminated with the TERMINATOR PLUG (IPN 911-041-P1), or connected to another sensor.

If the RS485 interface is to be used, the HOST computer must have the RS485 option card (IPN 911-042) installed. Refer to your computer manual for option board installation.

NOTE: The RS485 option card configuration switches were set at the factory as shown in Section 2, Figure 2.2.

Connect the main RS485 cable to the host computer. Be sure to use port 1 (the upper connector).

7. Connect the +24v power supply cable to the POWER connector on the Transpector unit.

8. Plug the AC line cord into the mating IEC320 connector on the power supply module IPN 911-038.

NOTE: AC LINE INPUT for +24V POWER SUPPLY
90 - 260 VAC 40 watts max
47 - 67 HZ

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

10. 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 Section 8: Troubleshooting to determine the problem.

Now turn to the appropriate section (Section 6 for MasterQuad or Section 7 for MQX and SQX) to run or install the specific application software. If there are any communication problems, check the following:

- COM port that Transpector is installed on is the same as the COM port selected in the application software configuration.
- Transpector baud is the same as the application software configuration.
- If running RS232, Transpector SWITCH 8 is on.
- If running RS485, Transpector SWITCH 8 is off, and a valid, unique sensor number has been assigned (sensor #1 for SQX and sensor #1-8 for MQX).

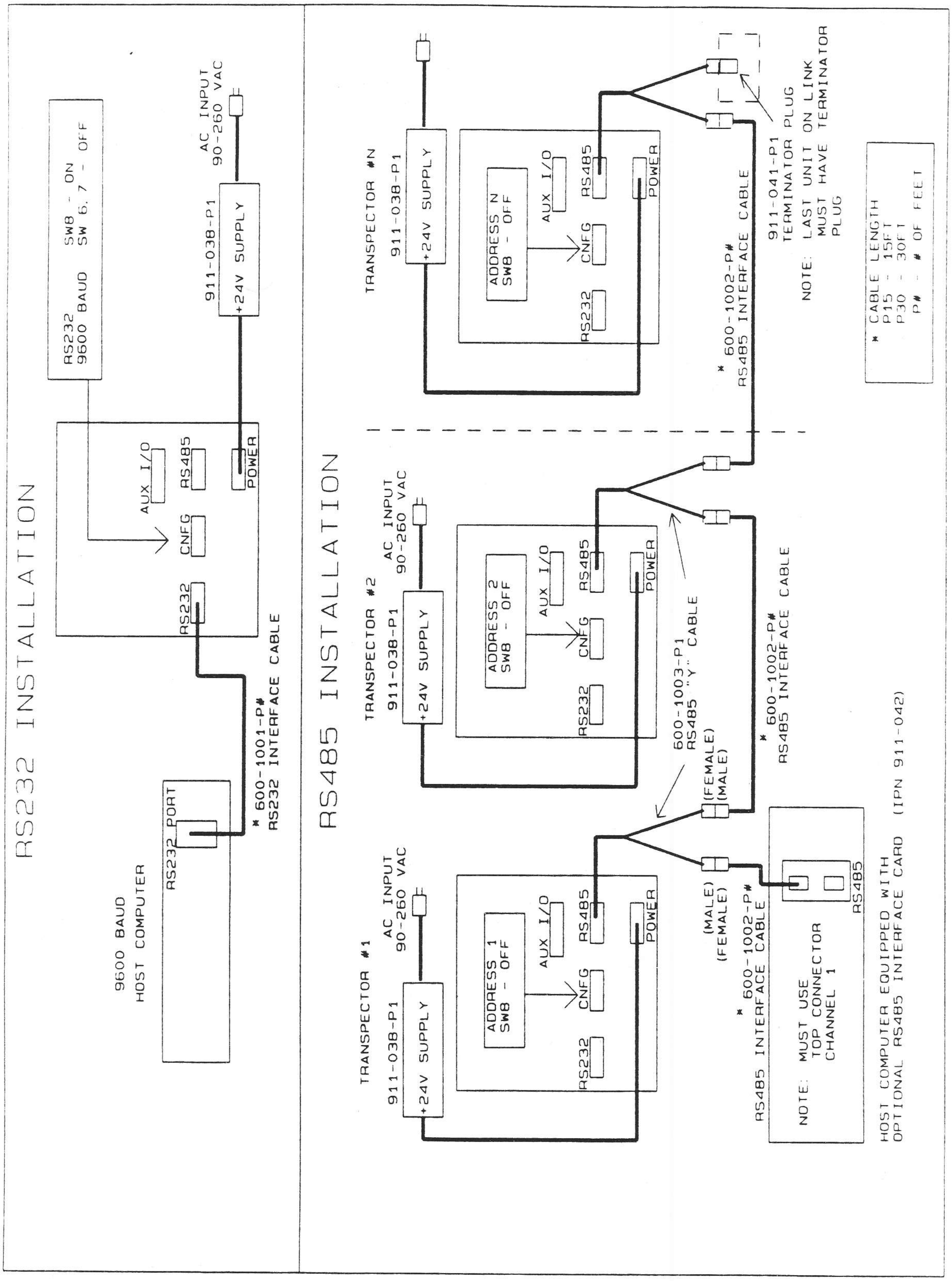


Figure 1.5 Cable Connections

Section 2
Input-Output Features

Contents

2.1 About Section 2

This section describes the Transpector's output and input features. It also defines the Transpector configuration switches, as well as the optional RS485 card for the host computer.

2.2 RS232 Link

This interface connector allows the user to interface the Transpector to a host computer via RS232. The connector pinout is shown in Figure 2.1. The RS232 link is full duplex, meets a subset of EIA-232-D standards, and supports 4 bauds (1200, 2400, 4800, 9600). The baud is selected by configuration switch 6 and 7 as specified in Figure 2.1. The frame size is 10 bits, consisting of 1 start, 8 data and 1 stop bits.

There are two modes of RS232 communication: an ASCII Diagnostic Mode and a Primary Mode. The mode of operation is selected by configuration switch 8.

2.2.1 Diagnostic Link (SW8 - OFF)

When switch 8 is OFF, the RS232 port communicates in an ASCII mode. If an ASCII "?" is sent to the Transpector a screen-full of status and diagnostic information is sent across the RS232 serial link. (See Section 8 for more detail). Any terminal program such as PROCOMM® can be used to obtain this information. This mode runs simultaneously with the RS485 link.

2.2.2 Primary Link (SW8 - ON)

If switch 8 is ON, the Transpector runs in a binary mode, using the RS232 serial link as the primary source of communication. All three of Leybold Inficon's DOS application programs or a user written program using the Transpector command protocols communicate in this mode.

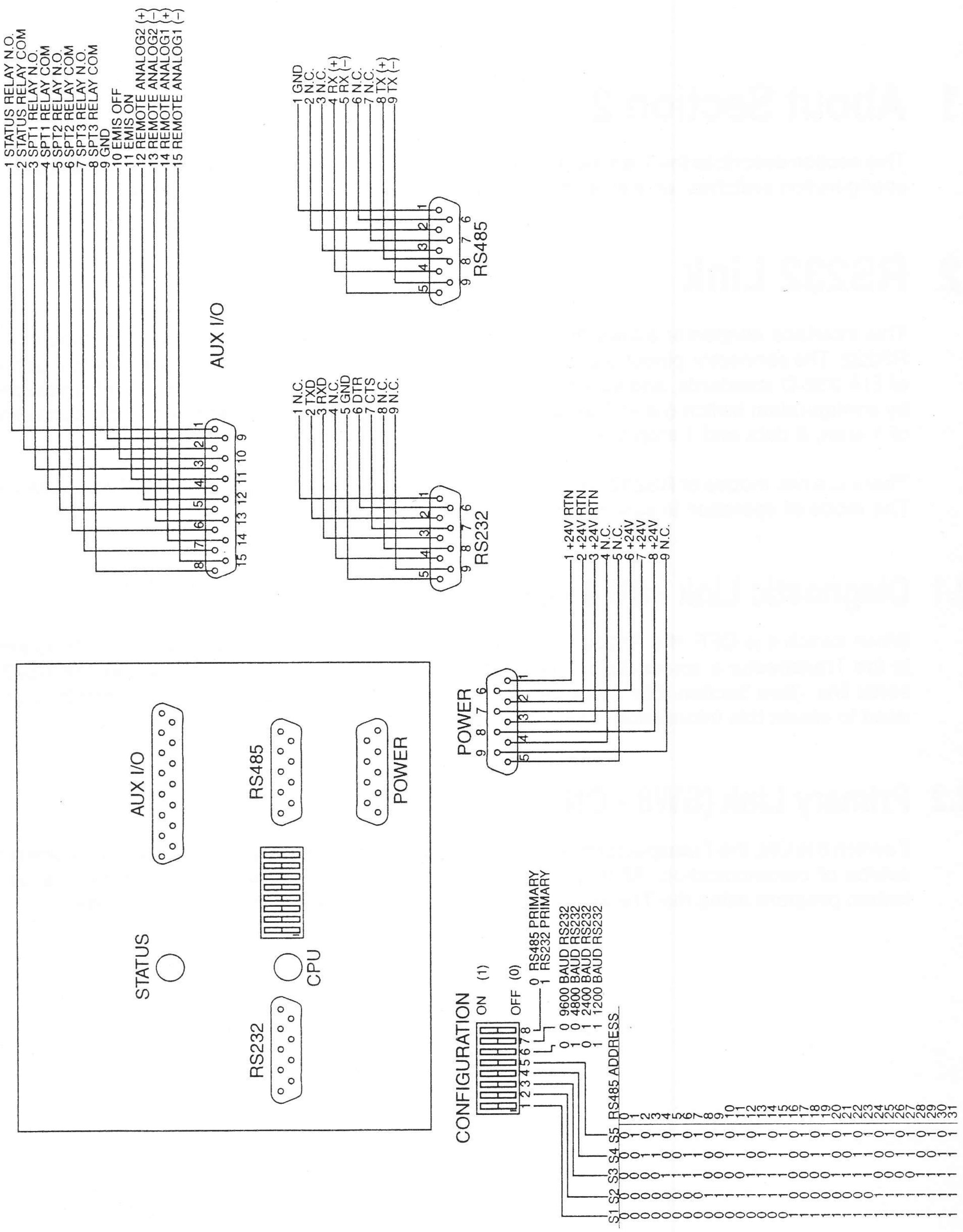


Figure 2.1 Pinout Connectors for RS232 Link

2.3 RS485 Link (SW8 - OFF)

When switch 8 if OFF, the Transpector operates using the RS485 port 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 RS485 link implements a ninth bit protocol allowing a single computer to operate up to thirty-one Transpector 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 485 serial interface card (IPN 911-042) or equivalent. This card is configured at the factory for Channel 1 to communicate via I/O address 280 HEX and interrupt line IRQ5. Channel 2 is disabled. See Figure 2.2 showing proper switch settings.

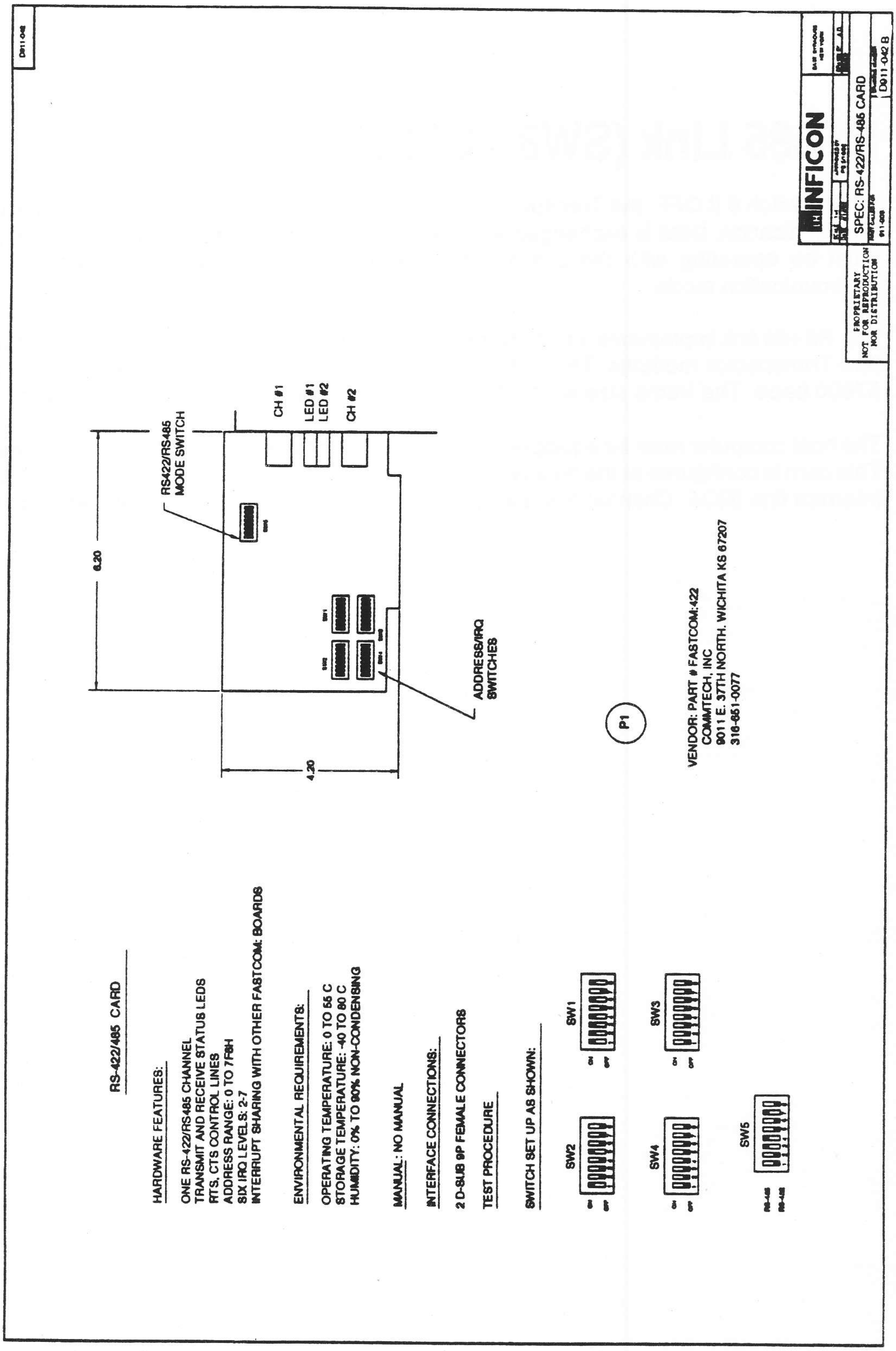


Figure 2.2 - Switch Settings for 485 Option Card

To select this mode configuration switch 8 must be in the OFF position. The Transpector module MUST have a unique address between 1 and 31 selected by configuration switches 1 - 5. Refer to Figure 2.1 for address selection.

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

NOTE: If operating the Transpector unit with MQX software, the Transpector unit must have a unique address between 1 and 8.

2.4 Auxiliary I/O

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

2.4.1 2 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 module, allowing a simple contact closure or TTL input to activate them. A contact closure is preferred to maintain ground isolation.

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

2.4.2 1 Status Relay Output

This relay is active (closed) when the emission is on.

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

2.4.3 3 Setpoint Relay

These relays work in conjunction with the TABLE mode UPPER and LOWER limits in MQX/SQX application software. See Section 7 for detailed programming instructions. If the TABLE channel data is within limits (between lower and upper limits) the relay is open; otherwise it is closed.

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 amp

2.4.4 2 Analog Inputs

These inputs are differential and can handle inputs between 0 to +10 volts and common mode voltages of 100 volts.

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

NOTE: This information is supplied for reference only. Analog inputs are not supported by MQX, SQX or MasterQuad software.

2.4.5 Power Supply

20-30 Volts DC, 24 watts

Pins	1, 2, 3	+24 volt return
	6, 7, 8	+24 volts

NOTE: a) input is isolated from ground

b) internally fused @ 2 amps

Section 3
How the Transpector Works
(Theory of Operation)

Contents

3.1 About Section 3

This section tells how the Transpector produces its measurements.

For a discussion of how to interpret those measurements, see Section 4, "Interpreting the Mass Spectra."

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.

3.2 Overview

The Transpector, a quadrupole partial pressure analyzer, measures the partial pressures of gases in a mixture. Controlled by an external computer, the instrument consists of a sensor that functions only in a high-vacuum environment (pressures below 1.0E-2 Pascals or approximately 1.0E-4 torr) and the electronics that operate the sensor.

The Transpector 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 characteristic of processes occurring within a vacuum or other vessel, and therefore can be used to investigate the nature of a process or to monitor process conditions. You may develop many other uses.

By attaching the sensor to a small vacuum system with a suitable controlled leak or other gas-inlet device, the Transpector can measure gases or volatile materials at pressures higher than those at which the sensor itself can operate. It can then be used as a medical instrument, an air pollution monitor, a chemical process monitor, or a leak detector.

The Transpector sensor analyzes gases by ionizing some of the gas molecules, separating the ions by mass and measuring the quantity of ions at each mass. The masses, unique for each substance, allow you to 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: the ion source (ionizer), the quadrupole mass filter, and the ion detector. All of these parts are mounted on an electrical feedthrough flange, which is bolted to the vacuum space where the gas analysis measurements are made.

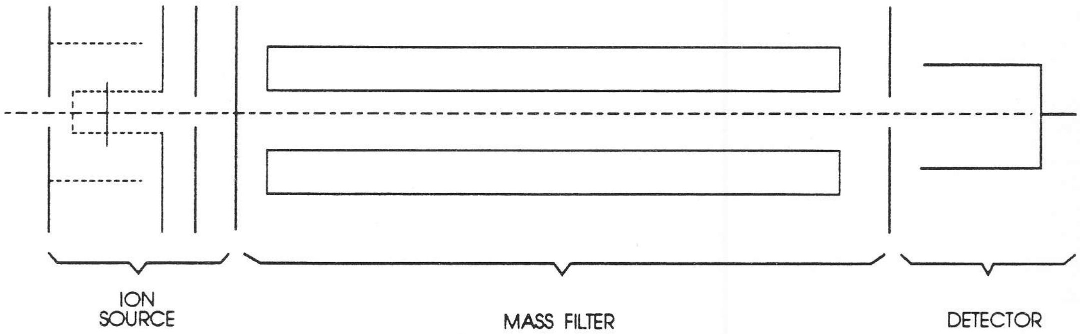


Figure 3.1 The Transpector Sensor

The sensor analyzes gases by ionizing some of the gas molecules (in the ion source), separating the ions by mass (in the mass filter), then measuring the quantity of ions at each mass (in the detector).

3.3 The Ion Source

The Transpector 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.

Inside the ion source, a heated filament emits electrons, which bombard the incoming gas molecules, giving them an electrical charge. (While this charge may be either positive or negative, the Transpector 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.

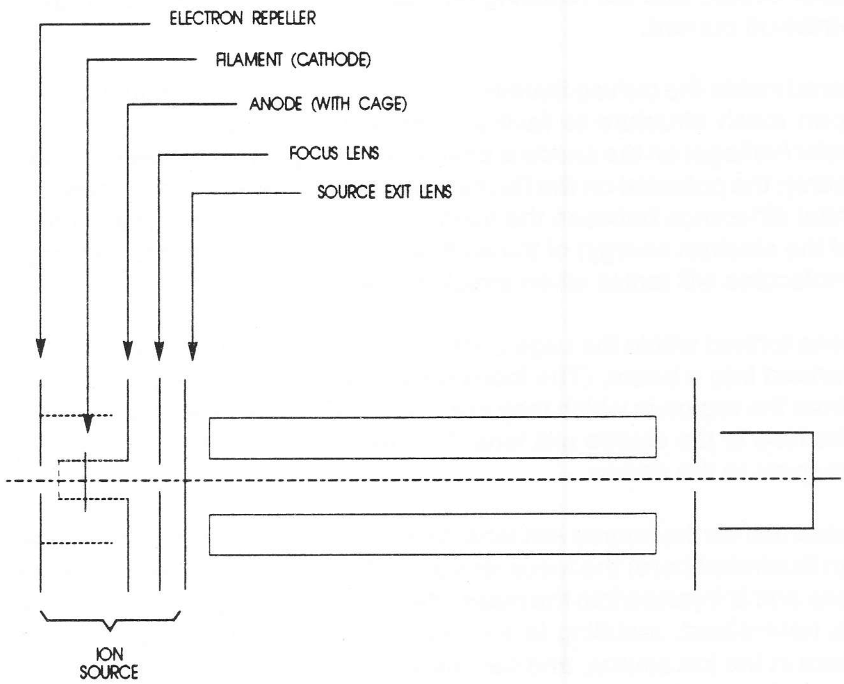


Figure 3.2 The Sensor's Ion Source

Once heated, the filament inside the ion source emits electrons, which bombard the incoming gas molecules, giving them an electrical charge. These charged molecules, or ions, then move through the instrument in response to varying electrical fields.

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 curved filament is usually an iridium wire with a thorium-oxide coating. This type is often chosen because it can be turned on in air without undergoing almost instantaneous destruction.

NOTE: When certain chemicals are present, like fluorine- or chlorine-containing species, or when thorium-oxide might introduce undesirable artifacts into the analysis, the optional tungsten or rhenium filaments are preferable. Both options, however, have their own drawbacks. For example, they can be destroyed if operated at too high a pressure, because they react with oxygen at the filament operating temperature.

The filament emits the electrons used to ionize the gas molecules. The term "emission current" refers to this stream of electrons. 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.

Centered inside the curved filament is the ion cage, which is mounted to the anode. The cage has an open mesh structure to facilitate the flow of gas molecules into the ionizing region. The potential (voltage) on the anode is positive with respect to the electron repeller (also an open mesh structure); the potential on the filament lies somewhere between these other two electrodes. 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.

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 hole in the source exit lens. To attract positive ions, the focus lens is biased negatively with respect to the anode.

The potential on the source exit lens is negative with respect to the anode, and (for the particular design illustrated here) the focus lens as well. Part of the ion beam passes through the hole in the exit lens and is injected into the mass filter. The remaining portion of the beam 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 overpressure condition.

NOTE: This protection feature works only after the filament has been operating for a short period of time. Therefore, a tungsten or rhenium filament may not be protected from excessive pressure if the sensor is turned on too early in a pump-down cycle.

3.4 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. (Multiply charged ions are discussed in Section 4.) In the Transpector family, 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.

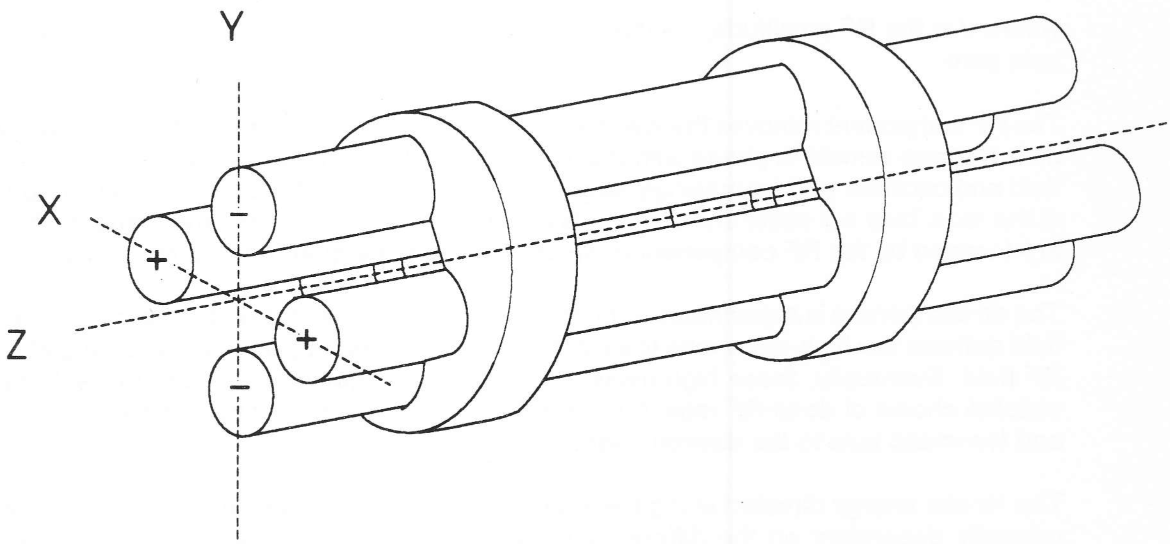


Figure 3.3 The Sensor's Quadrupole Mass Filter

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

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

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

The applied potentials consist of an RF component and a dc component. The RF potential on one set of rods is out of phase by 180° with respect to the RF potential on the other set of rods, but 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:

$$X = V \cos(2\Pi\, ft) + U + PZ$$

$$Y = V \cos(2\Pi\, ft + \Pi) - U + PZ$$

where V is the RF amplitude, f is the RF frequency, t is time, U is the dc potential, and 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:

$$V = 14.438\, M\, f^2\, r_0^2$$

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, and r_0 the quadrupole radius in centimeters.

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

The mass of ions transmitted (M) is directly proportional to the RF amplitude (provided f is constant). As the RF amplitude is increased, progressively higher mass ions will be made to oscillate in phase with the RF field and thus gain sufficient energy to strike the poles. 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 next subsection, "Scanning Characteristics," discusses the variation in the efficiency of transmission of ions through the filter with mass. Following that, the subsection "Zero Blast" discusses the behavior of the filter at very low masses where the applied voltages approach zero.

3.4.1 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.

3.4.2 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.

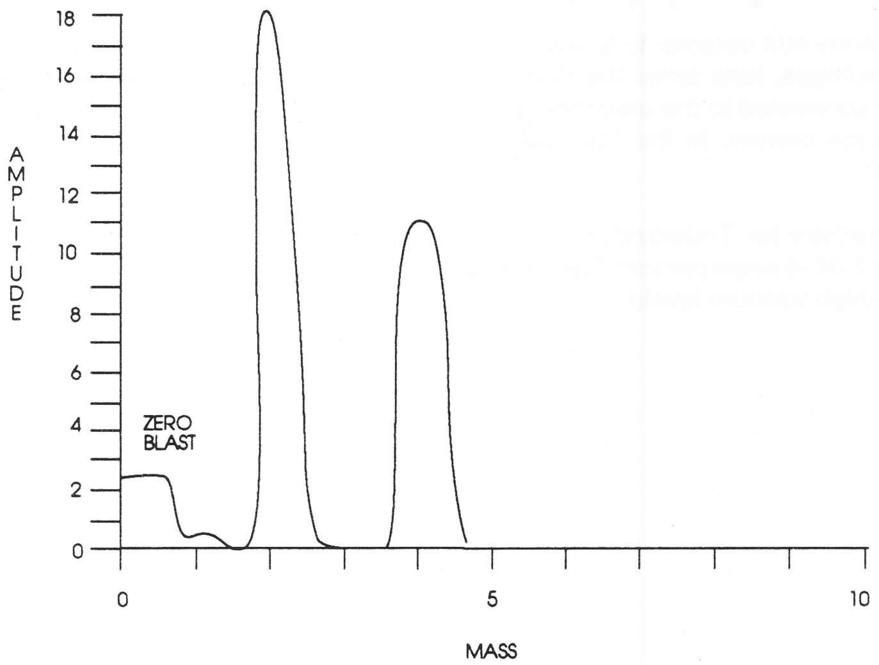


Figure 3.4 The Zero Blast

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

3.5 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.

3.5.1 The Faraday Cup (FC) 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 instruments equipped with a simple Faraday cup detector is typically 2.0E-4 amps per torr. The detected currents, therefore, can be as small as 1.0E-15 amps for ultra-high vacuum levels.

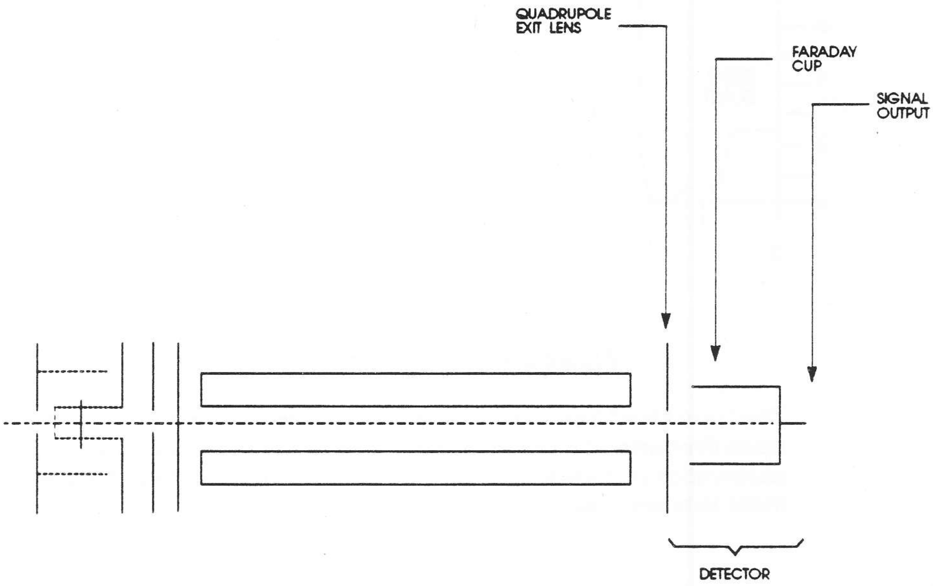


Figure 3.5 An FC Detector

Ions striking the Faraday cup detector are neutralized, drawing a current that equals the incident ion current.

3.5.2 The Electron Multiplier (EM) Detector

The electron multiplier (EM) acts as an *in vacuuo* preamplifier for improved sensitivity. Although there 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 (usually -1.0 kV or more). When an ion strikes the surface of the EM, one or more secondary electrons are emitted. These electrons are accelerated to a second surface which is at a more positive potential, where additional electrons are generated.

This process repeats itself until a pulse of electrons emerges from the output of the EM and is collected on a Faraday cup. The result is that as many as a million electrons or more can be produced by each incident ion. The current 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 detector sensor is its high sensitivity (as much as 100 amps/torr), thus making it possible to measure partial pressures as low as 2.0E-14 torr for some instruments in the Transpector family. A typical FC sensor would have a sensitivity of only 2.0E-4 amps/torr, resulting in a minimum detectable partial pressure of 5.0E-12 amps/torr. (Again, this value depends on the particular Transpector model.)

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

3.5.3 The Channel Electron Multiplier/Faraday Cup (CEM/FC) Detector

The channel electron multiplier/Faraday cup (CEM/FC), used for H100M, H200M and H300M High Performance models of the Transpector, offers the advantages of both the FC and EM detectors combined in one unit.

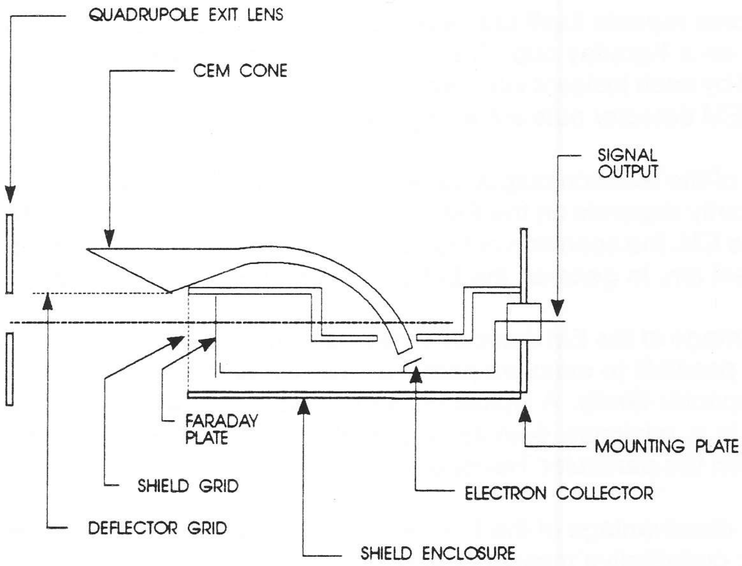


Figure 3.6 A CEM/FC Detector

In channel electron multiplier/Faraday cup (CEM/FC) detectors, the electron multiplier cone amplifies the electron "pulse," significantly increasing the analyzer's sensitivity.

The Transpector CEM/FC detector uses a continuous dynode element made of a special type of glass, rather than the traditional discrete dynode EM, which is made from a copper-beryllium alloy. The principal advantage of the CEM is that its performance does not degrade when exposed to air. In order to prolong its useful life, a copper-beryllium dynode multiplier must be stored under vacuum; exposure to air for more than a brief period can result in a significant decrease in the maximum available gain.

Not surprisingly, the CEM has some disadvantages. The maximum operating temperature for the CEM is only 100°C. (It can still be baked out at 400°C, provided that the high voltage is off.) Also, the CEM is slightly slower to recover after exposure to excessive input or output currents, and it may take a bit longer to stabilize its gain after the high voltage is changed.

When the deflector grid and the CEM input cone are held at ground potential, ions exiting the quadrupole through the exit lens pass through the shield grid and impinge on the Faraday plate. The resulting current flow is conducted through the signal output to the detection amplifier circuit. When negative high voltage is applied to the deflector grid and CEM cone, positive ions are deflected into the CEM cone, where the electron multiplying process takes place.

The resulting electron current impinges on the electron collector, which is connected parallel to the Faraday plate. To minimize electrical interference, the low level signal path's components (the Faraday plate, electron collector, and signal output) are housed within a grounded shield.

The CEM is operated at high voltages between -1.0 and -3.0 kV. A new CEM will typically have a gain of between 10 and 1,000 at 1.0 kV. The gain at -3.0 kV typically exceeds 1.0E+6. For a new sensor, the EM mode sensitivity of 100 amps/torr is typically achieved at around -2.3 kV.

> ***CAUTION:*** *Do not operate the CEM at pressures above $1x10^{-5}$ torr, or temperatures above 100°C. Permanent damage may result. Also, avoid output currents in excess of $1x10^{-6}$ amps; either decrease the high voltage or, if possible, decrease the pressure.*

Use the minimum CEM voltage required to obtain the necessary peak amplitudes and/or signal-to-noise ratio. Operating at higher voltages than necessary will result in premature aging of the electron multiplier, requiring early replacement. As the CEM ages, the voltage needed to get a specific EM gain will increase.

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

- Make sure diffusion-pumped vacuum systems are properly trapped to reduce oil backstreaming.
- Make sure turbomolecular pumped systems are interlocked to eliminate mechanical pump-oil backstreaming through a nonspinning turbo pump.

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

> **NOTE:** In addition to hydrocarbon contamination, multipliers can be adversely affected by exposure to highly reactive chemicals. Avoid any substance that will either cause the deposition of a surface film on the EM or etch its surface. For example, avoid high levels of reactive fluorides, such as tungsten hexa-fluoride and hydrogen fluoride.

3.5.4 The Microchannel Plate/Faraday Cup (MCP/FC) Detector

The Compact (C100M) Transpector model uses a microchannel plate/Faraday cup (MCP/FC) detector. The MCP works much like the CEM, described above. The main difference is that the MCP is a small plate (approximately 1/2" square by 1/16" thick) consisting of an array of over 10,000 very small continuous dynode multipliers, each with a .001" inside diameter.

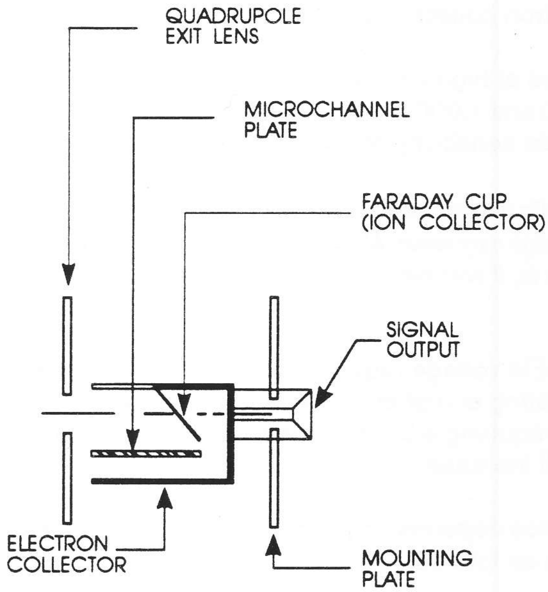


Figure 3.7 An MCP/FC Detector

The microchannel plate/Faraday cup (MCP/FC) detector, which works much like the CEM/FC detector, is smaller and needs less voltage.

The main advantage of the MCP over the CEM is its smaller size. Sensor models using the MCP/FC detector are considerably shorter than those using the CEM/FC (approximately 4-1/2" from ion source to vacuum sealing surface, as opposed to 10-1/2"). Also, the required operating voltage is lower.

The main disadvantage of the MCP is that the maximum gain is between 1.0E+3 and 1.0E+4. Like the CEM, the MCP does not have to be kept under a vacuum. However, because of the large surface area, the MCP can absorb more water vapor than the CEM and should be protected from exposure to high levels of moisture over extended periods. The MCP may also exhibit higher outgassing levels than the CEM.

The MCP operates in essentially the same manner as the CEM. 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 -1.15 kV 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 maintained at approximately -1.15 kV in the EM mode for two reasons. First, the ion beam exiting the quadrupole can be strongly divergent, requiring -1.15 kV to ensure 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 less than 1.0 kV (approximately), severe mass discrimination effects can occur.

Since the MCP gain is determined by the voltage across it, the voltage on the output side must be varied to control the gain. The MCP gain is at its lowest with -500 on the output side. With -50 volts on the MCP output, the MCP gain is maximized. A minimum voltage of -50 V (during EM operation) is maintained to ensure that the FC collects the entire electron current leaving the MCP.

> ***CAUTION:*** *Do not operate the MCP at pressures above $1x10^{-5}$ torr, or temperatures above 100°C. Permanent damage may result. Also, avoid output currents in excess of $1x10^{-6}$ amps; either decrease the high voltage or, if possible, decrease the pressure.*

Use the minimum MCP voltage required to obtain the necessary peak amplitudes and/or signal-to-noise ratio. Operating at higher voltages than necessary will result in premature aging of the electron multiplier, requiring early replacement. As the MCP ages, the voltage needed to get a specific EM gain will increase.

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

- Make sure diffusion-pumped vacuum systems are properly trapped to reduce oil back-streaming.
- Make sure turbomolecular pumped systems are interlocked to eliminate mechanical pump-oil backstreaming through a nonspinning turbo pump.

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

> **NOTE:** In addition to hydrocarbon contamination, multipliers can be adversely affected by exposure to highly reactive chemicals. Avoid any substance that will either cause the deposition of a surface film on the EM or etch its surface. For example, avoid high levels of reactive fluorides, such as tungsten hexa-fluoride and hydrogen fluoride.

Section 4
Interpreting the Mass Spectra

Contents

4.1 About Section 4

This section, which tells how to interpret the measurements the Transpector produces, is divided into three main parts.

- The first part—qualitative interpretation of mass spectra (4.2)—tells you how to determine **which substances** are present in the gas sample being analyzed.
- The second part—quantitative interpretation of mass spectra (4.3)—tells you how to estimate **how much of each substance** is present.
- The third part (4.4) gives you **additional information** that may help you interpret mass spectra.

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

For a discussion of how the Transpector produces its measurements, see Section 3, "How the Transpector Works (Theory of Operation)."

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.

4.2 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, as seen below.

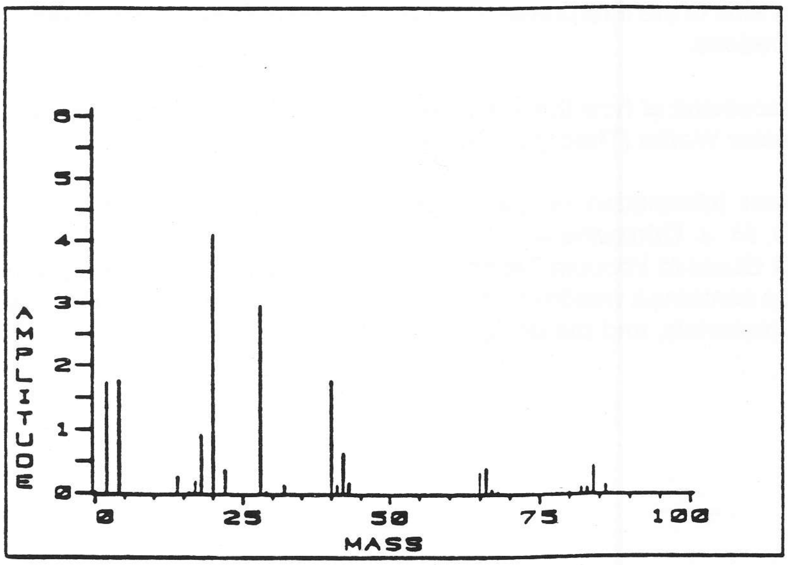


Figure 4.1 A Mass Spectrum

This is the mass spectrum of a gas mixture containing hydrogen, helium, water vapor, neon, nitrogen, argon, krypton, and parts of xenon.

4.2.1 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 the table below.

Table 4.1

Electron Impact Ionization Processes

$XYZ + e^- \longrightarrow$

$XYZ^+ + 2e^-$	(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 at an electron energy of 102 eV is given in Figure 4.2, following.

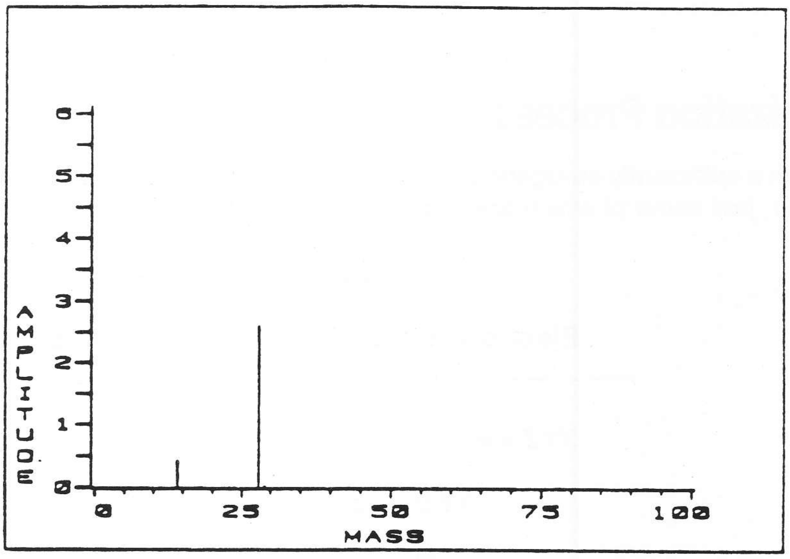


Figure 4.2 A Nitrogen Fragmentation Pattern

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

In general, peaks from 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 ration. Refer to the figure above; 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.

4.2.2 Isotope Ratios

An additional cause of multiple peaks in the mass spectrum of a pure substance is that the fact 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 4.2. 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 abundances. 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 4.2, following. 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 4.2

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

4.2.3 Electron Energy Effects

As was previously mentioned, the exact fragmentation pattern observed will depend on the energy of the bombarding electrons. The following figure (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.

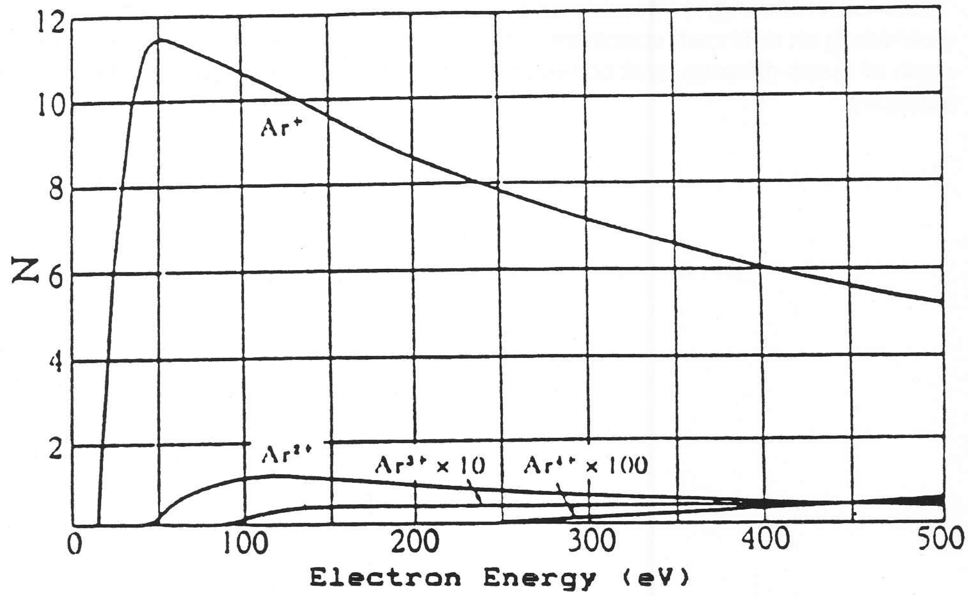


Figure 4.3 Electron Energy Effects

This graph shows the number or 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. In the Transpector family, the electron energy is set at 102 eV.

4.2.4 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 4.3, following, 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. This list is by no means all-inclusive.

Table 4.3

Spectrum Interpretation Guide

AMU NO.	CHEMICAL SYMBOL	SOURCES	F = Fragment P = Parent Ion DI = Doubly Ionized
1	H	Water F or Hydrogen F	
2	H_2, D	Hydrogen, Deuterium (H^2)	
3	HD, H^3	Hydrogen-Deuterium, Tritium (H^3)	
4	He	Helium	
5		No known elements	
6	C^{++}	Doubly Ionized C^{12}	Rare
7	N^{++}	DI N^{14}	Rare
8	O^{++}	DI O^{16}	Rare
9		No known elements	
10	Ne^{++}	DI Ne^{20}	Rare
11	Ne^{++}	DI Ne^{22}	Rare
12	C	Carbon, Carbon Monoxide F. Carbon Dioxide F	
13	CH, C^{13}	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,	
17	OH, NH_3	Water F, Ammonia F	
18	H_2O	Water P	
19	F	Fluorine or Freon F	
20	Ar^{++}, Ne, HF	Argon DI, Neon, Hydrofluoric acid	
21			
22	Ne^{22}		
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, S	Oxygen, Methanol P, Sulfur	
33	HS	Hydrogen Sulfide F	
34	*H_2S, S^{34}	Hydrogen Sulfide P, Sulfur isotope	
35	*Cl	Chlorine isotope, See Note 2	
36	*HCl, Ar^{36}	Hydrochloric acid, Argon isotope	
37	*Cl^{37}	Chlorine isotope, See Note 2	
38	HCl^{37}	Hydrochloric acid or See Note 2	
39	C_3H_3	See Note 3	
40	Ar, C_3H_4	Argon, See Note 1	
41	C_3H_5	See Note 1	
42	C_3H_6	See Note 1	
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	CCl^{35}	See Note 2	
48	$HCCl^{35}$, SO	See Note 2, Sulfur Dioxide F	
49	CCl^{37}, SiOH	See Note 2, pump oil F	
50	CCl^{37}, CF_2, C_4H_2	See Note 2, Freon F, Note 3	

NOTE 1
Fragments of several hydrocarbons, such as mechanical pump oil, diffusion pump oil, vacuum grease, cutting oil, and organic solvents.

NOTE 2
Fragments of several chlorindated hydrocarbons, such as carbon tetrachloride, trichloroethylene and many Freons.

NOTE 3
Fragments from both straight chain hydrocarbons and benzene ring hydrocarbons.

4.3 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 **a** as determined measuring the ion current at mass **b**:

$$PP_a = K_{ab} \times I_{ab}$$

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**. The original equation (above) can therefore be rewritten as follows:

$$PP_a = (M_{ab} \times A_b) \times I_{ab}$$

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. This equation shows the relationship involved:

$$M_{ab} = FF_{N28} / (FF_{ab} \times XF_a)$$

The term FF_{N28} is the fragmentation factor for nitrogen at mass 28. That is, it is the fraction of the total current of ions from nitrogen which have a mass of 28 atomic mass units. The term FF_{ab} is the fraction of all ions from substance **a** with mass **b**. Finally, XF_a is the ionization probability of substance **a**, relative to nitrogen. 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 at the beginning of this section (O'Hanlon and Drinkwine and Lichtman). 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 on IBM™ compatible floppy disks is available from the National Institute of Standards and Technology (formerly the National Bureau of Standards).

The following table 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 4.4

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	Toluene $C_2H_5CH_3$	
				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_6OH		22	.10	134	.11
31	.49			136	.09
45	.21	Nitrogen N_2			
27	.09	28	1.00		
29	.07	14	.12		
		29	.01		

FF© fraction of total ions that occur at the indicated mass

Ionization probability factors can be approximated by substituting the relative ion gauge sensitivities for various gases. The following table gives relative ion gauge sensitivities for some common gases.[1]

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

Table 4.5
Ionization Probabilities
for Some Common Substances

Substance	Formula	Relative Ionization Gauge Sensitivity, S/S_{N_2}	Substance	Formula	Relative Ionization Gauge Sensitivity S/S_{N_2}
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	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_3Cl	4.0	n-Pentane	C_5H_{17}	6.0
Chloroform	$CHCl_3$	4.8	Phenol	C_6H_5OH	6.2
Chloromethane	CH_3Cl	3.1	Phosphine	PH_3	2.6
Cyclohexylene	C_6H_{12}	6.4	Propane	C_3H_8	3.7
Deuterium	D_2	0.35	Silver perchlorate	$AgClO_4$	3.6
Dichlorodifluormethane	$CC_{l2}F_2$	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			

[1]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).

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 this equation:

$$A_a = 1 / (TF_b \times DF_{ab} \times G \times S)$$

Here, TF_{ab} 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 overall relation between partial pressure and ion current, given in the following equation, 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.

$$PP_a = \{ FF_{N28} / (FF_{ab} \times XF_a \times TF_b \times DF_{ab} \times G \times S) \} \times I_{ab}$$

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 4.4).

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 Table 4.5 (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, TF_M = 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).

4.4 Additional Information for Interpreting Mass Spectra

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

4.4.1 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 of some of these concerns (Chapter 8, Section 2).

When using the Transpector as a residual gas analyzer, the sensor should be installed such that the conductance between the ion source and the vacuum region to be analyzed is maximized. If possible, install the sensor without any intervening valves or vacuum hardware. If the sensor is equipped with a residual gas analyzer ion source, 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 and by using the DEGAS function (wherein the ion source surfaces are bombarded by high energy electrons). 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 specifications for your particular Transpector sensor model. 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 if this (second) bakeout temperature exceeds maximum EM operating temperature specified for your sensor. 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. Significant temporary pumping effects will frequently occur following degassing of the ion source.

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 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) 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.

4.4.2 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.

4.4.3 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 the table of typical fragmentation factors, compiled from more than one source, is for illustrative purposes. 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.

Section 5
Electronic Circuitry

Contents

5.1 About Section 5

This section describes the electronic circuitry of the Transpector and of its components.

5.2 Transpector

The Transpector module contains all the electronics required to drive the RGA sensor, digitize the data, and communicate this data back to a host computer via RS232 or RS485. There are five circuit boards in the Transpector unit: the power supply, CPU, amplifier, RF/DC generator, and the mother board. The mother board contains the control bus, which connects the other four boards to each other, as well as providing the RGA sensor contacts. (See individual card description for details on each board.)

The Transpector input power requirement is 20 - 30 VDC @ 1.25 amps.

The Transpector unit has a molded plastic connector with a twist lock mounting system which provides the mechanical as well as the electrical connections to the RGA sensor head.

All user interface connections are on the back panel. (See Section 2 for contact definitions.) The configuration switch on the back panel allows the user to select a communication interface and baud rate. Two green LEDs on the back panel display the status of the Transpector module. The CPU LED when active (on) signifies that the unit has power and the CPU is running. If a hardware error occurs, this LED will flash an error code to assist in diagnosing the problem. (See Section 8: Troubleshooting.) The status LED indicates that the emission is on and there are no errors.

WARNING!!

LINE VOLTAGE IS PRESENT ON THE PRIMARY CIRCUITS OF THE OPTIONAL 24VDC POWER SUPPLY AND DC VOLTAGE IS PRESENT IN THE INSTRUMENT WHENEVER IT IS PLUGGED INTO A MAIN POWER SOURCE. NEVER REMOVE THE COVERS FROM THE INSTRUMENT DURING NORMAL OPERATION. THERE ARE NO OPERATOR SERVICEABLE ITEMS WITHIN THIS INSTRUMENT.

REMOVAL OF THE TOP OR BOTTOM COVERS MUST BE DONE ONLY BY A TECHNICALLY QUALIFIED PERSON.

IN ORDER TO COMPLY WITH ACCEPTED SAFETY STANDARDS, THE POWER SOURCE MUST BE INSTALLED INTO A RACK OR SYSTEM WHICH CONTAINS A MAINS SWITCH. THIS SWITCH MUST BREAK BOTH SIDES OF THE LINE WHEN IT IS OPEN AND IT MUST NOT INTERFERE WITH THE SAFETY GROUND.

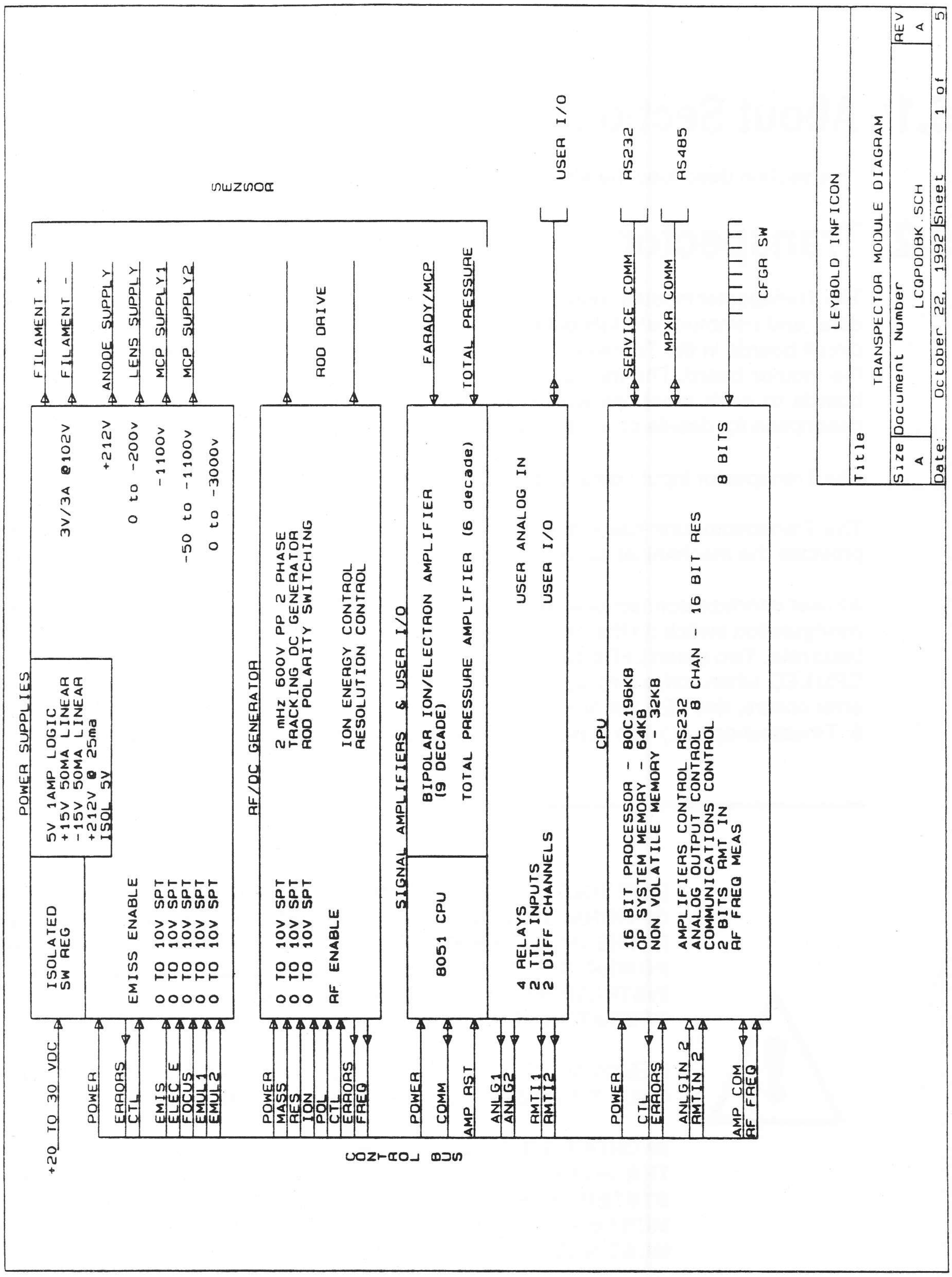


Figure 5.1 Transpector Block Diagram

5.3 CPU Card

The CPU card is the brain of the Transpector module. This card contains the firmware which controls all functions of the Transpector as well as the communication interface and control circuitry that operates the other boards in the Transpector module.

The heart of the CPU card is an embedded 16 bit microcontroller which contains an 8 channel 10 bit ADC, serial port and counters on chip.

A battery backed static RAM stores all operating and calibration parameters for the Transpector.

Analog signals remote input, total pressure, anode, emission and ambient box temperature are conditioned and constantly monitored by the 10 bit ADC on the microcontroller.

The RS232 service link is handled through the serial port on the microcontroller, while the RS485 multidrop and measurement serial links are handled through a DUART. The RS485 drivers are isolated from the system ground by opto-isolators.

The CPU card communicates measurement commands to and results from the amplifier card through the second serial port on the DUART. The actual digital processing and calculated current value is done on the amplifier card. This allows for parallel processing of Transpector tasks.

Eight 0 - 10V analog control signals are generated by a 16 bit DAC, 8 channel analog multiplexer, and sample and hold circuitry. The control signals are set points for mass, resolution, lens, emission, cathode, ion energy, and electron multiplier supplies.

Configuration switches which are accessible at the back panel allow the user to select the baud, RS485 address, and type of serial interface.

Analog and digital remote inputs, RF generator and MCP errors are monitored on a regular basis by the microcontroller. Control signals for emission, MCP supply and rod polarity are generated by the microcontroller. At power-up the CPU reads the mass range and sensor type from the RF generator card.

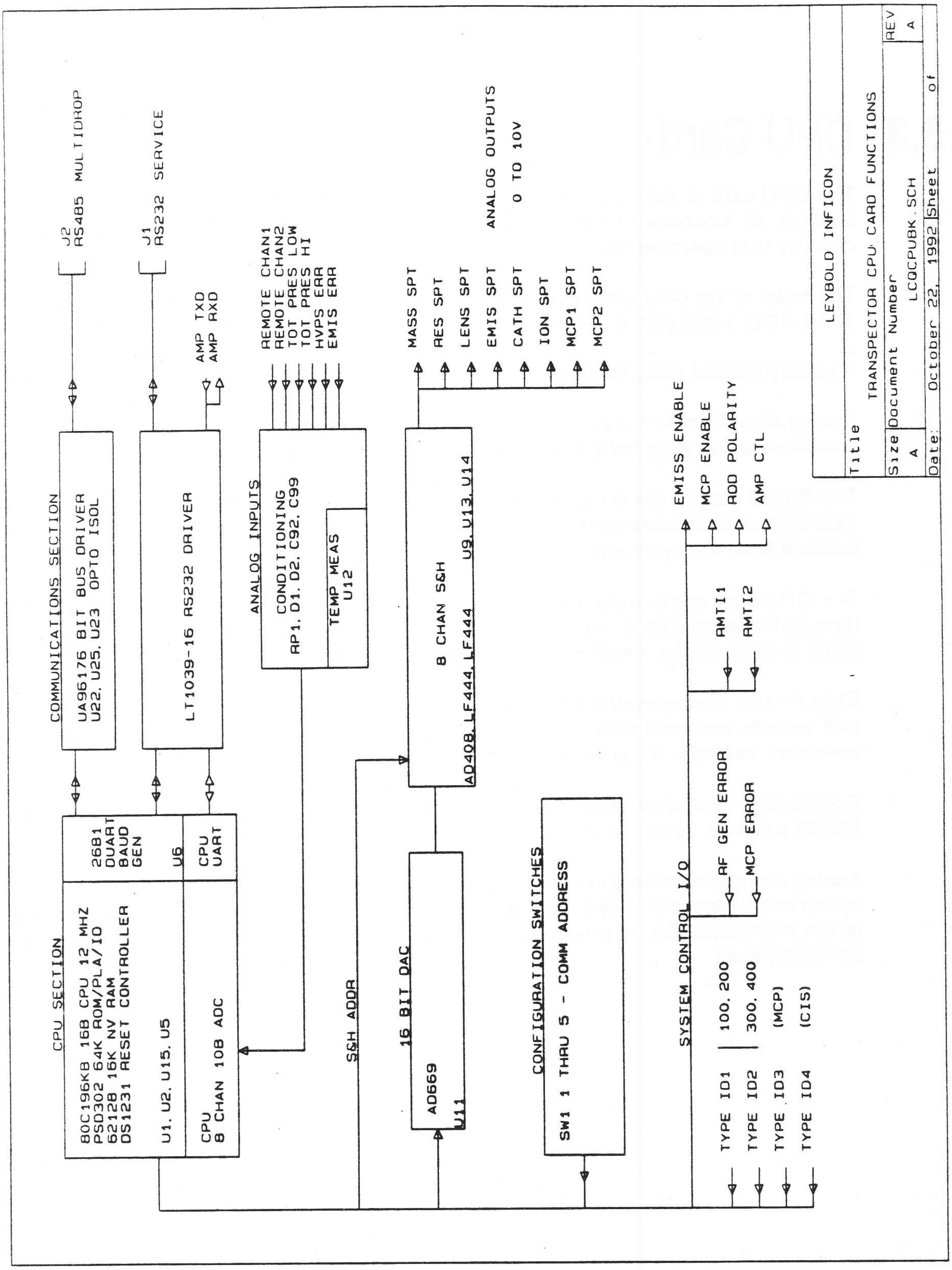


Figure 5.2 CPU Card Block Diagram

5.4 Power Supply Card

The power supply card generates all the required voltages needed to operate the Transpector electronics and RGA sensor family. There are two different cards: 911-142, used for the compact (C) sensor line; and 911-172 which is used in conjunction with the high performance (HP) sensor line. The two boards are identical except for the high voltage section, which is described later. The CPU reads the board I.D. to determine which board is present. The power supply is a switching type that runs at approximately 45 kHz. The specified input is 20 - 30 VDC at approximately 24 watts. The input is isolated from system ground by the switching power transformer.

The following voltages are generated:

5V @ 1 amp	Logic
+18V @ 500 m amp	RF/DC generator
+15V/-15V @ 50ma	Linear circuits
+212 @ 25ma	Emission, lens bias
Isolated +5V @ 70 ma	RS485 drivers
1150 V	MCP supplies (911-142)
50-500V	MCP supplies
1kV - 3kV	EM supply (911-172)

The input voltage is passed through a 2 amp fuse. A diode on the input prevents damage to the electronics in case input polarity is accidentally reversed. The input voltage is then filtered and preregulated to 18 volts by a stepdown switching regulator. This preregulated voltage then is used as the primary voltage on the switching transformer. The primary push-pull drive is generated by a switching regulator, synchronized to the preregulator and operated open loop.

The dc outputs of +18V,-18V, +10V (isolated 5V for RS485 drivers), +250V, and filament drive input voltage are produced by the four secondaries of the power transformer along with full-wave rectifiers and filtering circuits.

The +5 Vdc for the digital circuits is produced by a step-down switching regulator operating from the +18V. Linear circuits get +15V and -15V power from linear regulators operating from the +18V and -18V, respectively. The isolated 5V supply operates the RS485 drivers on the CPU card, and is generated from a linear regulator.

The +250V is regulated down to +212Vdc (anode) by a series-pass regulator. The +212Vdc current limited to approximately 30 milliamps. The +212 is active only when emission is turned on, which is controlled by the EMIS CTL\ (emission control) signal from the CPU board. The +212 voltage is attenuated and buffered to the CPU board for monitoring purposes. The lens bias voltage is generated by a regulator which also runs off the +212 and is controlled by the CPU card via the LENS SPT (lens setpoint).

The emission regulator circuitry consists of filament drive, emission current control, and electron energy circuitry. The filament drive is generated from a secondary on the power transformer which is down regulated to approximately 2-3 volts (maximum 5V) by a switching regulator. The filament switching regulator is controlled via an opto-coupler from emission control integrator. The input to the emission control integrator is the difference between the actual emission current and the emission set point, which is set by a current sink controlled by the CPU card via EMIS SPT (emission setpoint). The electron energy is set by the bias transistor which has its base voltage set by a high voltage regulator controlled by the CPU card via the EENG SPT (_______ setpoint). The bias transistor biases the filament drive circuitry to the set voltage while also providing the return and sense path for the emission current.

The high voltages needed to run the compact sensor microchannel plate (MCP) and high performance sensor (electron multiplier - EM) is generated by a DC-to-AC inverter module operating from the +5VDC supply . The output is regulated by a series-pass regulator which is controlled by the CPU card via the MCP SPT1 signal. On the 911-142 assembly (compact power supply card), the AC output is doubled by a multiplier circuit to provide an output voltage of minus 1100Vdc. On the 911-172 assembly. (high performance power supply card) the output is quadrupled by a multiplier circuit in order to obtain an output voltage of minus 1kV - 3kV. On the 911-142 assembly a second MCP voltage is generated by a regulator which runs off the minus 1150Vdc and reduces the voltage down to minus 650 - 50 Vdc which is controlled by the CPU via MCP2 setpoint.

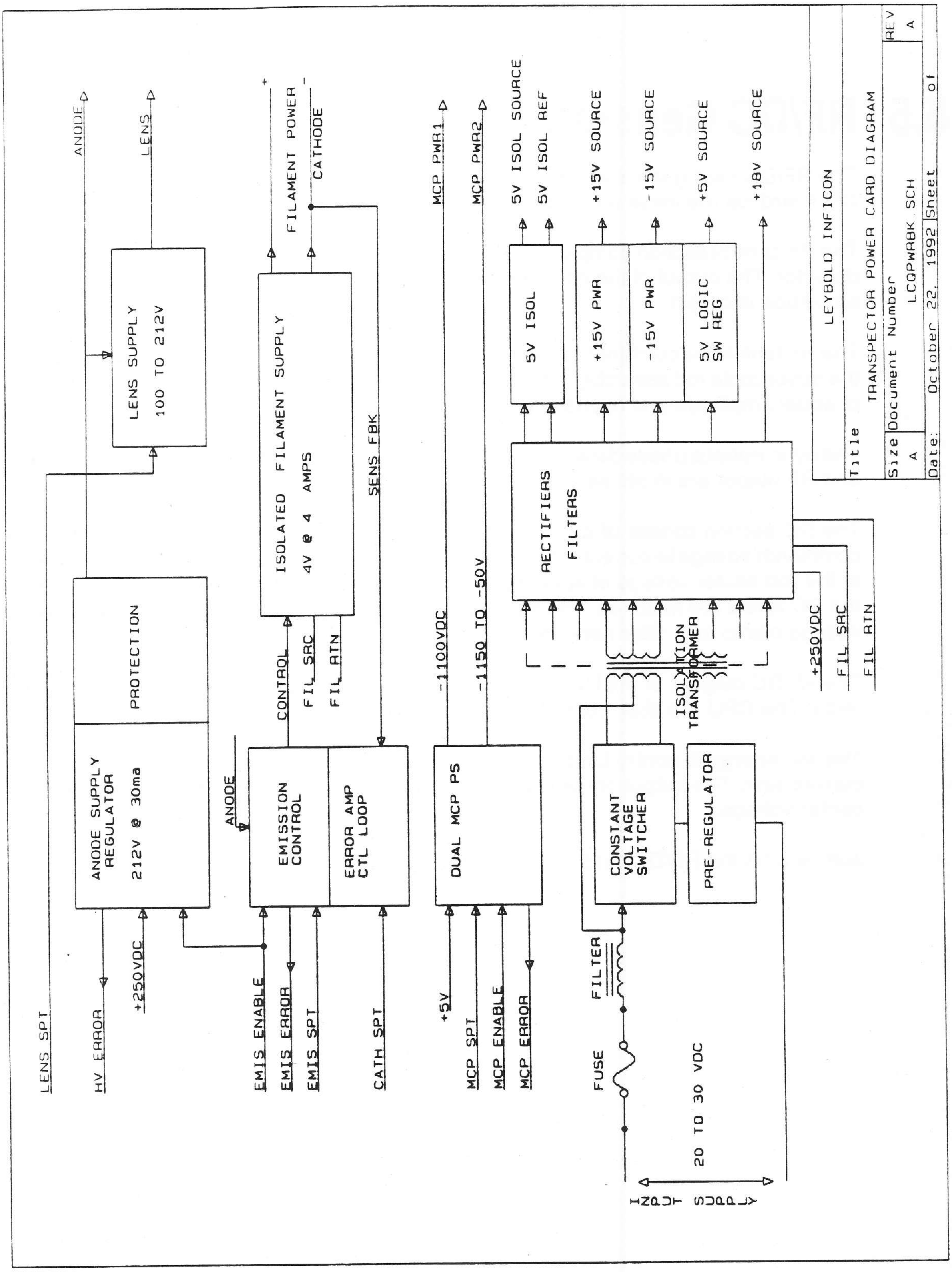


Figure 5.3 Power Supply Block Diagram

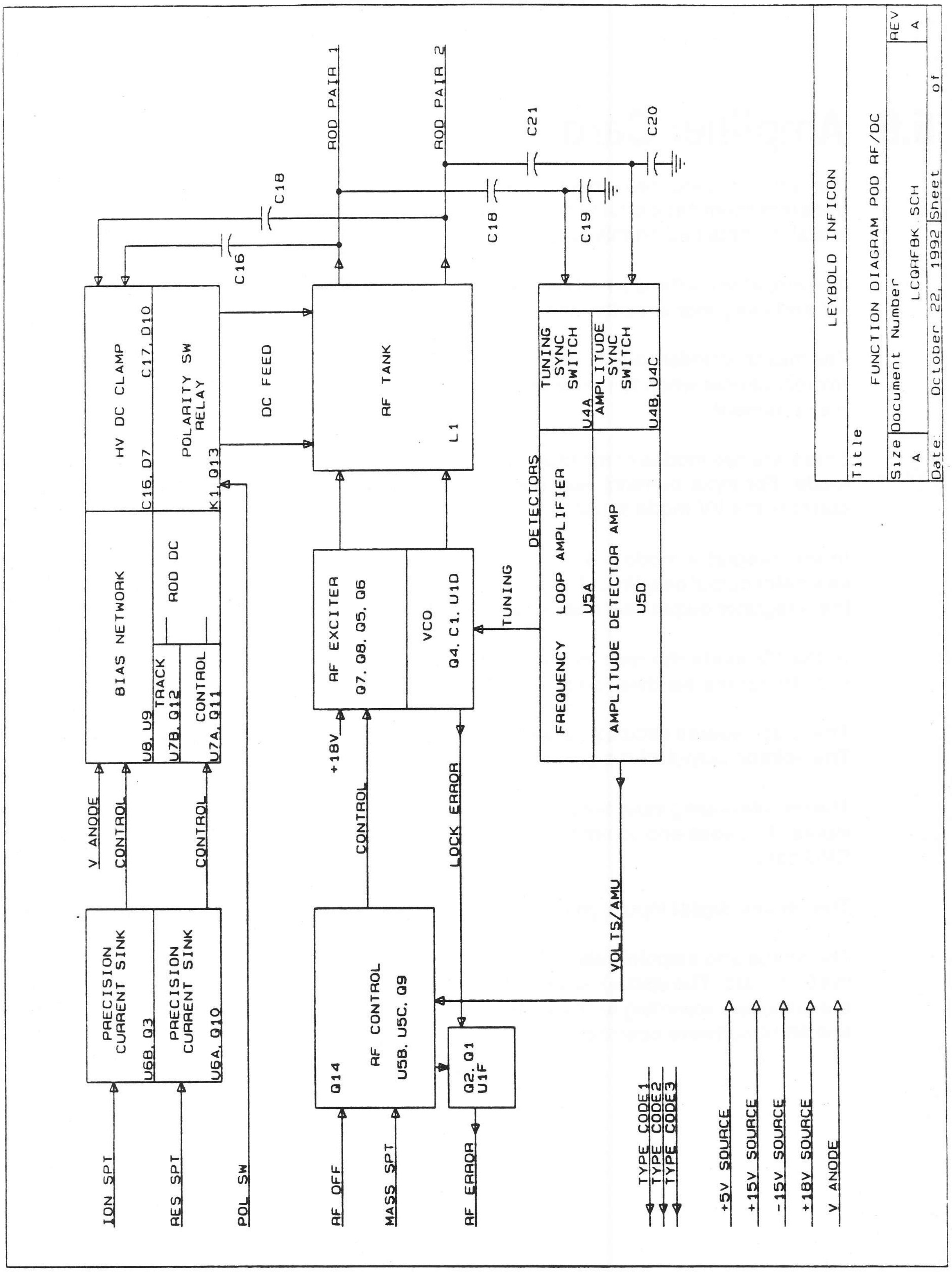


Figure 5.4 RF/DC Generator Card Block Diagram

5.6 Amplifier Card

The amplifier card measures the ion current from the quadrupole head, digitizes the results, and transmits them back to CPU card. The total pressure, remote analog and digital input, and relays are also contained on this card.

The amplifier card is a smart card which contains an 8 bit embedded microcontroller, 12 bit ADC, I/V and integrator circuitry, and a very low noise input amplifier.

The microcontroller communicates to the CPU via an RS232 serial link. The CPU tells the amplifier microcontroller when to measure and at what dwell time. The microcontroller then performs the measurement.

There are two modes of measurement which are a current-to-voltage (I/V) mode and integrator mode. For input currents less than 10 E-9 amps, the integrator mode is used, and for larger currents the I/V mode is used.

In the integrator mode the microcontroller and the ADC measure the voltage change of the integrator output over time. The microcontroller calculates the current from this information. When the integrator output reaches its rail, the microcontroller resets it through the reset circuitry.

In the I/V mode the microcontroller constantly measures and averages the output of the I/V circuitry for the set dwell time. This average voltage is then converted to a current.

The total pressure circuitry consists of an I/V low noise input stage, followed by a dual gain stage. The voltage output of the gain stage is fed directly back to the CPU card.

The remote analog input circuitry consists of a differential input stage which can handle differential inputs of 10 volts and common mode voltages of 100V. The output of this stage is fed back to the CPU card.

The remote digital inputs go through a buffer stage and are then fed to the CPU card.

The status and setpoint relays are controlled by the amplifier microcontroller under direction of the CPU card. The status relay is active (closed) whenever the emission is on, the setpoint relays are activated according to the limits set in the table mode. (See Sections 6 and 7 - MasterQuad and MQX software operation).

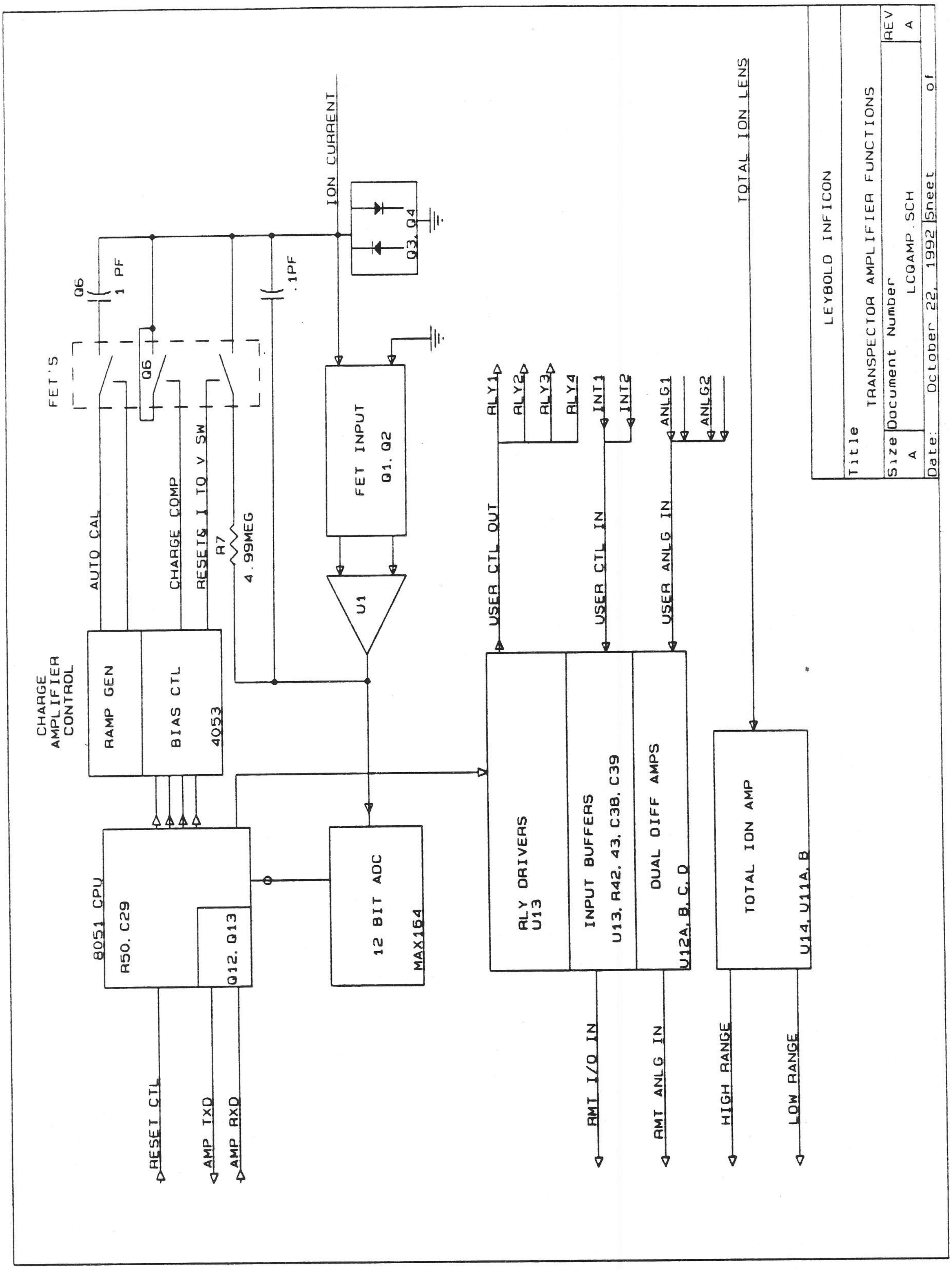


Figure 5.5 Amplifier Card Block Diagram

Section 8
Troubleshooting and Maintenance

Contents

8.1 About Section 8

This section is designed to help you recognize and correct operational problems that could occur with the Transpector system.

In Section 8.2 you will find a list of symptoms and a corresponding list of possible causes for the failure.

Section 8.3 shows how to use the Transpector RS232 serial port to obtain status and diagnostic information in a text format on the computer screen.

Section 8.4 describes vacuum bakeout requirements for contaminated sensors.

Section 8.5 contains a list of field-replaceable spare parts for quadrupole sensors.

Section 8.6 explains how to replace the filament on a quadrupole sensor.

Section 8.7 explains how to remove and replace the ion source of a quadrupole sensor.

Section 8.8 describes the removal of an electron multiplier on the H100, H200 and H300 sensors.

Section 8.9 describes how to replace the electron multiplier on compact C100M sensors.

WARNING!!

HIGH VOLTAGE EXISTS IN THE TRANSPECTOR UNIT.

DO NOT OPERATE THE UNIT WITH SIDE COVERS REMOVED.

8.2 Symptom Check List

NOTE: X - These operations to be done by qualified service personnel only.
Y - Reset the Transpector by turning power off for 4 - 5 seconds.

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 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. If problem persists, replace CPU card	Y X
2 flashes	NMI (Non-maskable interrupt)	Check +24V input voltage. Verify input voltage between 20 -30V.	
	Power Supply card failure	Replace Power Supply card	X
3 flashes	Unimplemented OPcode CPU card failure	Reset Transpector. If problem persists, replace CPU card	Y X
4 flashes	DUART failed to initialize.	Reset Transpector. If problem persists, replace CPU card	Y X
5 flashes	CPU card RAM corrupted or bad.	Reset Transpector. If problem persists, replace CPU card	Y X

SYMPTOM	CAUSE	REMEDY	
No communication to HOST computer	Configuration of DIP switches incorrect	Refer to Section 1 (Installation)	
	Baud rate incorrect	Check Baud rate selection on both Transpector and Computer.	
	Cable connections	Make sure cables are connected to proper connectors. See Section 1 (Installation)	
	Incorrect COM port selected	Select correct COM port on computer See Sections 6,7 Reset Transpector Reset HOST computer	Y
	Computer Interface card. RS232 or RS485	Replace interface card in computer.	
EMISSION error	Defective sensor filament open, shorted	Check sensor with OHM meter. See Figs. 8.2, 8.3, and 8.4 for pin-out information. Replace sensor or filament.	
	Power Supply card defective	Replace power supply card	X
	Insufficient vacuum	Verify pressure is less than 1E-4 torr	
	Sensor Operating voltages incorrect	Verify correct settings See Section 8.3, Service Diagnostics for nominal sensor settings.	
	Transpector not fully engaged on sensor.	Make sure Transpector unit is pushed all the way on sensor.	
ANODE error	Defective sensor, anode shorted	Check sensor with OHM meter for shorts. See Figs. 8.2, 8.3, and 8.4 for sensor pin-out diagram. Fix or replace sensor.	
	• Power Supply card failure.	Replace power supply card.	X

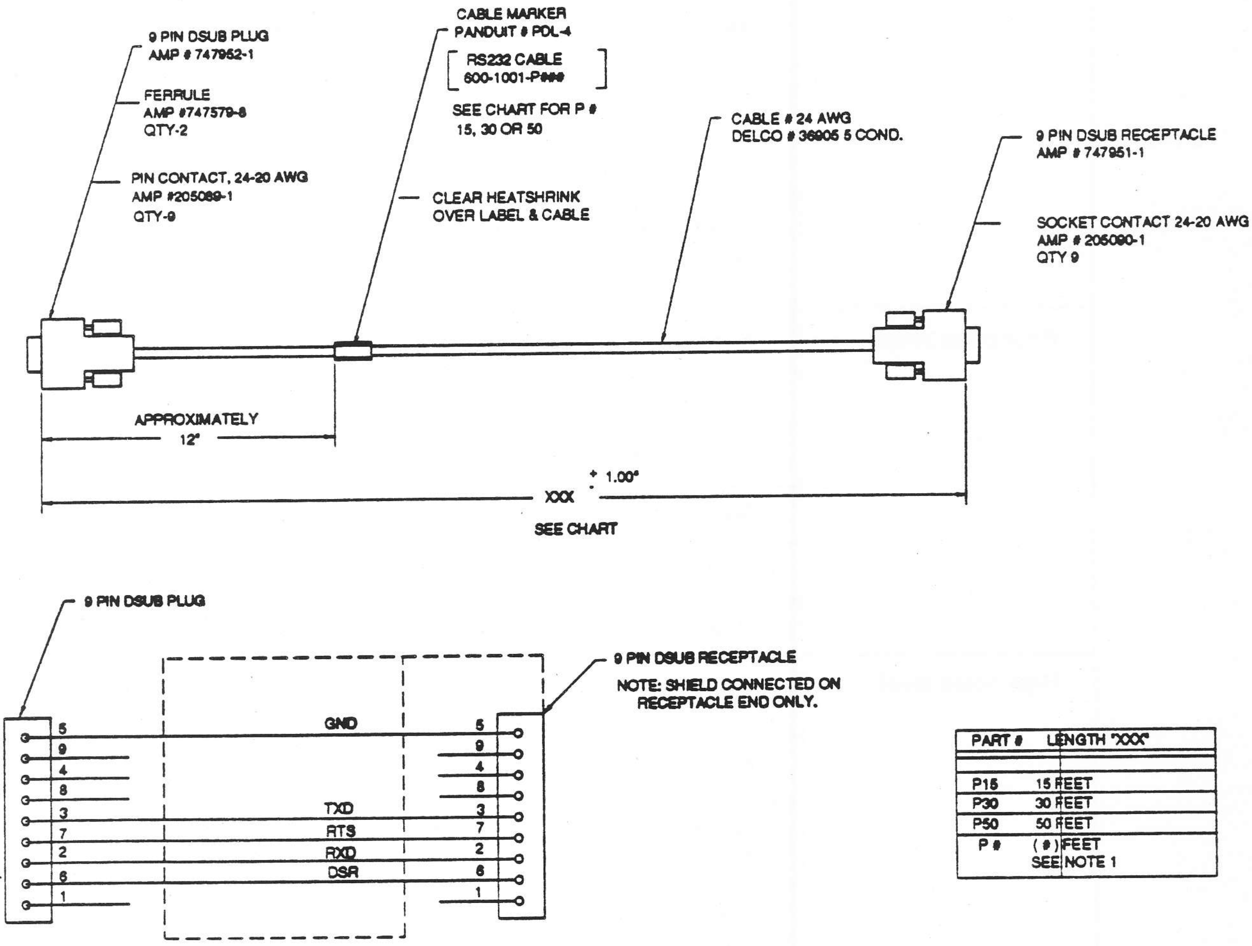
SYMPTOM	CAUSE	REMEDY
RF error	Defective sensor, RF leads open RF/DC card fault	Fix or replace sensor. Replace RF/DC card. X
EMULT error	Defective sensor, MCP or EM shorted.	Check sensor with Ohm meter. See Figs. 8.2, 8.3 and 8.4 for sensor pin-out diagram. Fix or replace sensor.
	Power Supply card	Replace 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
	Degas is ON	Turn Degas OFF
	EM is ON, when operating an FC sensor.	Turn EM OFF
	Sensor output SIGNAL contact missing or damaged.(gold plated spring)	Replace or repair contact. See Section 1.
	Contaminated sensor	Degas, or service sensor Replace sensor
	Measurement card failure	Replace Measurement card. X
	Pressure too low for FC	Use EM detector
	EM or MCP voltage to low	Increase voltage
	Transpector not fully engaged on sensor. Mass calibration	Push Transpector unit completely onto sensor. Adjust MASS calibration.

SYMPTOM	CAUSE	REMEDY
Poor sensitivity	Sensor contaminated	Degas sensor 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 See section 8.3 Service diagnostics for nominal settings.
	Measurement card defective MCP or EM has low gain	Replace Measurement card X Bake-out sensor Replace sensor
Poor peak shape	Sensor contaminated	Degas sensor Bake-out sensor Service sensor
	System pressure too high	Verify pressure less than 1E-4
	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. See Section 1.
	Transpector not mounted properly on sensor	Push Transpector all the way on to the sensor
	MCP or EM defective	Replace MCP or EM X assembly or sensor
	Scan speed too fast for gain setting.	Reduce Scan speed

8.3 Service Diagnostics via RS232 Serial Port

To assist in servicing the Transpector unit, DIAGNOSTIC INFORMATION was designed into the Transpector firmware. Using a PC computer or any other computer equipped with an RS232 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 Leybold Inficon's Service Department with a problem.

The RS232 interface cable connections are shown in the figure below. This cable is available from Leybold Inficon as part number 600-1001-P15 (15'length) or 600-1001-P30 (30' length). You can also make your own cable by using the following drawing.



PART #	LENGTH "XXX"
P15	15 FEET
P30	30 FEET
P50	50 FEET
P #	(#) FEET SEE NOTE 1

NOTE:
1- CUSTOMER TO SPECIFY LENGTH IN 10 FT INCREMENTS OVER 50 FEET.

Figure 8.1 (RS232 Interface cable) Dwg. 600-1001

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 RS232 serial port.

2. Set switch 6 and 7 on the Transpector as shown in Section 2 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 "?", status and diagnostic information is sent out the RS232 serial link. This diagnostic mode can operate simultaneously with the RS485 link.
A typical Transpector status and diagnostic information display is shown below:

```
        **** Transpector Ver 1.00, C+C Ver 1.00, Meas Rev 1.01 ****
          **** SENSOR ****
Type = Compact, Range = 100 AMU, Detector =FC/MCP, RF = 1977332 Hz
Measuring  9.45 amu, delay = 1 mS, dwell = 32 mS
Emission 2000 µA, focus 27 V, ion energy 8000 meV, electron energy 102 eV
CEM/MCP front set at 0 V, MCP back set at 0 V
          **** POSSIBLE PROBLEMS ****
# of Warnings:  anode = 0, em =     0, emiss =  0, rf lock =   0
Anomaly ID:anode = 0,    C+C = 0, emis = 0, tune = 0
          **** A to D ****
Temp = 3.022 V, 292. c, DtoA = 0.347 V, Emis = 2.061 V, Anode = 2.114 V
TPP high = 0.127 V, TPP low = 4.995 V, RMT1 = 0.049 V, RMT2 = 0.000 V
          **** MISC ****
DIP switches = 6F, Relays in = 2, DUART resets = 0, Task max = 84
Hardware ID function = D080, error = 0, warning = 0
Meas RX = 1019232, Errors (line = 0, ID = 0), Retries = 0, Resets = 0
232 RX = 12708, Errors (line = 0, protocol = 0, ID = 0), CTS = 0
485 RX = 524684, Errors (line = 0, protocol = 0, ID = 0), Address = 1
         Timeouts = 0, Length = 0, Checksum = 0
Baseline added = 0.00e+00, measured = 8.24e-14
```

NOTE: Reference Figure 8-7 for your RS485 interface cable connections.

A brief description of the diagnostic information follows:

Line 1 - Current version level of the CONTROL CARD and MEASUREMENT CARD firmware.

SENSOR GROUP - Sensor related information

- TYPE - Compact or High Performance
- RANGE- Mass range, 100, 200, or 300
- DETECTOR - FC/MCP (compact) or FC/CEM (High Performance)
- RF - RF measured frequency,
  - 100 AMU - 2.00 MHz nominal
  - 200 AMU - 1.60 MHz nominal
  - 300 AMU - 1.50 MHz nominal
- MEASURING - Mass that is currently being measured
- DELAY - Delay after control voltages are set
- DWELL - Measurement time
- EMISSION - Current emission current set point
  - 50 - 15000 ua
  - 2000 ua nominal (2 ma)
- FOCUS - Current focus voltage set point
  - 0-100V
  - 27 nominal
- ION ENERGY - Current ion energy set point
  - COMPACT 8V nominal
  - HIGH Performance 10V nominal
- ELECTRON ENERGY - Current electron energy set point.
  - 102 volts nominal
- CEM/MCP - Current voltage on Electron Multiplier or front side of MCP if sensor is COMPACT type.
  - CEM - 1000 - 3000 (High Performance)
  - MCP - 1150 (Compact)
- MCP - Current voltage on back of MCP
  - 50 - 650 (Compact)

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 spec, 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 to low
bit 6 - voltage to high
bits 5-0 reserved (0)

C&C: - Control Card
bits 7-6 reserved (0)
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
bits 3-0 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)

AtoD Group - Analog signals measured by the control card
TEMP - Internal ambient temperature of box in °C. Maximum allowable 75°C.
DtoA - 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 Bakeout of Quadrupole Sensor

If the symptoms in Section 8.2 suggest that the sensor is contaminated, try first to restore normal performance by baking the sensor under a high vacuum of at least $1x10^{-5}$ torr for several hours or preferably overnight. The following is a table representing the maximum bakeout temperatures.

		While Operating	With Electronics Removed
High Performance			
Faraday Cup Sensors		250°C	* 350°C
Electron Multiplier/	FC Mode	250°C	
Faraday Cup Combination	EM Mode	100°C	* 400°C
Compact			
Faraday Cup		100°C	200°C
Electron Multiplier/ Faraday Cup Combination		100°C	200°C

NOTE: *When heating the sensor above 250°C, the electronics unit and the signal contact (IPN 904-048) must be removed from the sensor.

Inficon offers several heating jackets to help in baking a sensor. These jackets are sized for the appropriate sensor in use.

High Performance Sensor

Faraday Cup Sensor Heating Jacket - IPN 900-065-P2
Electron Multiplier Heating Jacket - IPN 900-066-P2

Compact Sensor

FC-FC/MCP - IPN 912-322-P3 117VAC
- IPN 912-323-P3 220 VAC

If an IPC-2 Pressure Converter system is used, a heating jacket system can be purchased. It includes the sensor heater, an IPC-2 heater and an insulator for the tee.

IPC-2 Heating Jacket system for the FC - IPN 900-003-G1
IPC-2 Heating Jacket system for the EM - IPN 900-003-G2

If baking the sensor doesn't increase the sensor performance, it may be necessary to perform the service operations listed on the following pages.

WARNING!!

PRECAUTIONS MUST BE USED WHEN PERFORMING ANY SERVICE OPERATIONS ON THE SENSOR. THEY ARE:

1. **PERFORM ANY SERVICING IN A CLEAN AREA.**
2. **WEAR CLEAN NYLON, LINT FREE LAB GLOVES OR FINGER COTS**
3. **AVOID TOUCHING ANY PART OF THE SENSOR WITH UNPROTECTED FINGERS**
4. **USE CLEAN TOOLS FOR SENSOR DISASSEMBLY (AND ASSEMBLY)**

If the routine procedures outlined above do not solve the problem, contact the appropriate Leybold Inficon Service Department. In the U.S. (East coast) at (315) 434-1167; or (West coast), San Jose (408) 436-2828 Outside the U.S., contact your Inficon sales and service representative. They will make arrangements to have the sensor returned for refurbishment.

8.5 Sensor Spare Parts List

8.5.1 H100, H200 Models & H300

Part Number	Description	Qty used per sensor
019-071-G1	Ion source assembly kit	1
019-070-G1	Filament kit	1
073-054	Lead wire (high performance only)	approx. 4'
073-059	Filament lead wire (high perform. only)	approx. 2'
912-401-G1	Center contact (high performance only)	1
	Electron Multiplier (Channeltron)	1

FC Sensor Only (H100F, H200F)

019-132-P1	6.7" Lead ceramics	2
019-132-P2	6.0" " "	1
019-132-P3	5.9" " "	1
019-132-P4	5.8" " "	1
019-132-P5	1.8" " "	1
019-132-P6	1.5" " "	2

EM/FC Sensor Only (H100M, H200M)

019-172-P1	10.0" Lead ceramics	2
019-172-P2	9.4" " "	1
019-172-P3	9.3 " "	1
019-172-P4	9.2" " "	1
019-172-P5	5.0" " "	1
019-172-P6	4.9" " "	1
019-172-P7	2.6" " "	1

600-1008-P15	Power Supply Cable - 15 ft.
600-1008-P30	Power Supply Cable - 30 ft.
600-1001-P15	RS232 Cable - 15 ft.
600-1001-P30	RS232 Cable - 30 ft.
911-040-G15	RS485 Cable Kit - 15 ft.
911-040-G30	RS485 Cable Kit - 30 ft.
911-041-P1	Terminator Plug
911-042-P1	RS485 Card

8.5.2 C100F & C200M Models

Part Number	Description	Qty used per sensor
019-071-G1	Ion source assembly kit	1
019-070-G1	Filament kit	1
019-078-P1	Electron Multiplier (Channeltron)	1

8.6 Filament Replacement (for all RGA source sensors)

A filament replacement kit (IPN 019-070-G1) can be purchased. This kit contains a new filament assembly mounted on a shipping fixture and a small Allen wrench. Perform the following steps to replace the filament:

> ***CAUTION:*** *The filament can't be cleaned. The filament, which is thoria-coated iridium, will be damaged if cleaned with cleaning solutions such as acetone.*

1. Loosen the Allen screws in the barrel connectors which hold the two filament leads in place.

> ***CAUTION:*** *Make sure to hold the barrel connectors with needle-nosed pliers so that the filament post doesn't move.*

2. Remove the two filament leads from the barrel connectors.
3. Loosen the other Allen screws in the barrel connectors and remove the barrel connectors from the old filament assembly.
4. Remove the three pan head screws which are holding the old filament assembly onto the three posts.
5. Carefully remove the filament assembly.
6. Remove the three screws which are holding the new filament assembly onto the shipping fixture.
7. Carefully remove the new filament assembly from its fixture and place it on the ion source posts.

> ***CAUTION:*** *The new filament assembly must be carefully placed onto the ion source. Any excessive horizontal movement will cause the filament to hit the ion cage and cause damage.*

8. Replace the three filament assembly screws without moving the filament in the horizontal direction.
9. Replace the barrel connectors onto the filament post and tighten.
10. Replace the filament leads into the barrel connectors and tighten.
11. Using an ohmmeter, check that the filament is not shorted to ground or to any of these lenses and that the two filament leads show a filament resistance of approximately .5 ohms at the barrel connectors (approx. 1.0 ohms at the feedthrough). (See Figures 8.2 and 8.3 for pin-outs.)

8.7 Ion Source Removal

The following steps should be performed to remove the ion source:

1. Remove all electrical leads form the ion source assembly loosening the Allen screws in the filament barrel connectors and the screws in the lead connectors.

2. Pull the electrical leads away from the sensor.

3. Remove the four hex head screws (#2-56) around the bottom of the ion source assembly. They hold the ion source onto the quadrupole assembly.

4. The ion source can now be removed by lifting it off the quadrupole assembly. A new ion source assembly (IPN 019-071-G1) can now be installed by reversing the above steps.

8.8 Replacing the Electron Multiplier (H100M, H200M, H300M)

> ***CAUTION:*** *The electron multiplier can't be cleaned. If excessive degradation of the EM is noted, it should be replaced. Unless you are familiar with electron multipliers, send the sensor to the Leybold Inficon Service Department for replacement.*

Figure 8.4 is an assembly drawing of the electron multiplier assembly.

The following steps should be performed for replacing the EM: (Refer to Figures 8.4 and 8.5.)

> **NOTE:** A spot welder will be needed to replace the EM.

1. Disconnect all the electrical leads from the ion source as described in Section 8.7 Ion Source Removal. Also disconnect the RF leads (the shorter leads) by unscrewing them from the rods or (in older version sensors) by breaking the spot weld.
2. Remove the ion source, quadrupole assembly and EM housing in one piece by removing the three #4-40 Phillips head screws from the bottom of the sensor.
3. Carefully break the spot weld on the high voltage electrical lead (Item #19 on Figure 8.4) to the EM ceramic housing. This lead is spot welded to a screw near the top of the EM.
4. Remove the two #2-56 Allen head screws (Item #16) holding the EM to the base.
5. Loosen the Allen head screw that connects the signal lead from the EM to the signal lead feedthrough. This screw is in a barrel connector (Item #17) located in the base, underneath the EM. It can be loosened by putting the Allen head wrench into the hole in the EM base.
6. Carefully lift the EM off the base, over the electrical lead.
7. Remove the barrel connector from the old EM and attach it to the new EM noting the space position and the orientation.
8. Install the new EM by placing it back on the base with the electrical lead going through the appropriate hole and the signal lead going into the barrel connector.
9. Tighten the Allen screw in the barrel connector.
10. Replace the two Allen screws and carefully spot weld the electrical lead back onto the top screws.
11. Use an ohmmeter to check for any shorts and good connections.
12. Replace the sensor and electrical leads using the reverse procedure from above.

8.9 Replacing the Electron Multiplier (C100M)

CAUTION: *The electron multiplier can't be cleaned. If excessive degradation of the EM is noted, it should be replaced. Unless you are familiar with electron multipliers, send the sensor to the Leybold Inficon Service Department for replacement.*

Figure 8.6 is an assembly drawing of the electron multiplier version of the compact sensor. Refer to this drawing for the steps to be performed in replacing the electron multiplier assembly. Before going any further, put the black plastic pin protector/straightener (which came with the sensor) on the feedthrough.

1. Disconnect the two filament leads from from the ion source by loosening the #1-72 X .125" long set screws using a .035 inch allen wrench. It is not necessary to remove the screws completely.

2. Disconnect the three remaining leads from the ion source by loosening the three #0-80 X .188 long pan head set screws with a jeweler's flat blade screwdriver. It is not necessary to remove the screws completely.

3. Disconnect the two RF leads from the mass filter assembly by removing the two #0-80 X .125" long socket head cap screws with a .050" allen wrench. Do not lose the two #0 split lock washers. If the hex posts have started to loosen, retighten them now.

4. Remove the three #2-26 X .188" long pan head screws that fasten the sensor assembly to the feedthrough flange. Gently pull the ion source and RF leads back from the sensor; do not use excessive force or you will break the ceramic insulator tubes. Carefully lift the sensor assembly out of the feedthrough flange. Do not pull with excessive force. If the sensor seems to be sticking, one (or more) of the lead wires is probably hung up on the sensor. Gently pull the offending lead back and continue to remove the sensor.

5. Remove the two #0-80 X .188" long socket head set screws from the bottom of the electron multiplier assembly. Do not lose the two #0 split lock washers. Remove the electron multiplier assembly from the sensor and lay the multiplier aside.

6. Remove the new electron multiplier assembly from its protective bag. Orient the multiplier assembly according to Figure 8.6 and insert it into the bottom of the sensor assembly. Install the two #0-80 X .188" long socket head set screws along with their lock washers. Tighten the screws until all slack is removed from the lock washers. When properly oriented, the multiplier bottom plate should be fairly well centered on the outer shield. If the multiplier is off to one side, it is probably installed 180° out of alignment.

7. Note the alignment pin on one of the sensor assembly mounting tabs. Position the sensor so that it lines up properly above the feedthrough flange. Gently lower the sensor into the flange. Pull back gently on the leads if they get in the way. Rotate the sensor slightly until the alignment pin drops into the smooth sided hole (not one of the tapped holes). Gently push down on the sensor until it seats itself into the flange. Install the three #2-56 X .188" long pan head screws; do not over-tighten the screws.

8. Place a lock washer on each of the two #0-80 X .125" long socket head cap screws. Insert the screws through the tabs on the RF leads in into the holes in the hex posts. Tighten the screws until the slack is removed in the lock washers.

9. Insert the three leads into their respective positions in the ion source. If the leads do not want to go all the way into the terminal posts, loosen the #0-80 X .188" long pan head screws slightly. When the leads are fully inserted (the the ceramic tubes should be flush against the mass filter housing), tighten the three screws.

10. Insert the two filament leads into the barrel connectors at the top of the ion source. If the leads do not go in all the way, loosen the two set screws a bit. When the ceramic tubes are flush with the mass filter housing, tighten the two set screws.

11. Before reinstalling the sensor on your vacuum chamber, it is a good idea to check for proper electrical continuity. Refer to Figure 8.2 for the pin-out diagram. The resistance between the two filament pins should be much less than 1 Ohm. The resistance between either filament pin and any of the other pins should be grater than 20 MOhm. The resistance between any of the other ion source pins, the two RF pins, or either of the two multiplier high voltage pins, and ground should also exceed 20 MOhm. The resistance between the two RF pins should also exceed 20 MOhm. If you have an ohmmeter that can accurately read in the 100 MOhm range (most hand-held units can't), you can use it to check for the resistance be tween the two multiplier high voltage pins. The reading should be in the range of 30 to 60 MOhms. If it is much greater than this, the high voltage connections to the bottom of the multiplier assembly are probably at fault. Disassemble the sensor and check to see if the multiplier assembly is misaligned by 180°.

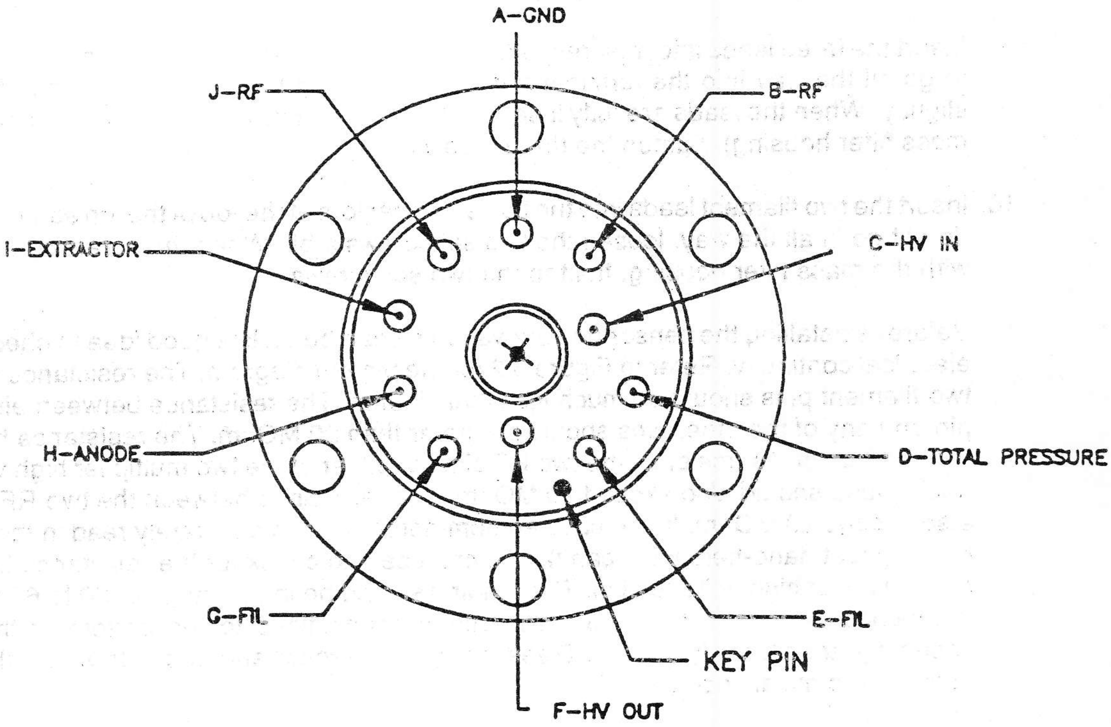


Figure 8.2 View of C100F/M Sensor Flange