SensaVac® Series 937 High Vacuum Combination Gauge System Instruction Manual

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HPS Series 937 Vacuum Gauge Controller

SensaVac® Series 937
High Vacuum Gauge System
INSTRUCTION MANUAL (Rev A)

Using This Instruction Manual

To efficiently gain an understanding of the 937:

To set-up the 937 for operation:

Overview Introduction to the 937

The 937 powers, reads, prepares and provides outputs for five types of vacuum gauge: the **cold cathode, Pirani, capacitance manometer, thermocouple**, and **convection gauge.** Two types of convection gauge, and six capacitance manometer heads are accommodated, for a total of eleven pressure sensors. The pressure range of the 937 is 1.0 x 10^{-11} Torr (cold cathode gauge) to 10,000 Torr (capacitance manometer).

Up to three cold cathode gauges can be operated simultaneously, or **up to four Pirani/capacitance manometer/thermocouple/convection gauges can be operated simultaneously,** either with or without a cold cathode operating at the same time.

Any combination of the five gauge controller modules for the five types of vacuum gauge can be plugged into slots "A" and "B" of the 937, while the "standard" slot is reserved for a cold cathode module. There are several special features provided by and for the "standard" cold cathode, such as capacitance manometer auto zeroing, and the 937 internal control function which enables/disables the high voltage of the "standard" cold cathode at a pressure set from the front panel.

The pressure from each of up to five gauges can be seen at the same time on the 937's liquid crystal display.

In addition to the liquid crystal display, the 937 controller provides the following outputs **for each of its five channels:**

* **Buffered analog output** ...Amplified sensor signal.
* 0 to 10 volt **logarithmic analog output** ...Torr=10^(Voltage/.6 - 12).
* **Communication output** ...RS-232, RS-485, IEEE-488.
* **Relays** with N.O. / N.C. contacts for process control ...Response as fast as 15 milliseconds.

There is a **combination logarithmic output** with a range from 1.0 x 10^{-11} Torr to 1,000 Torr which is a combination of the output from the standard cold cathode gauge and the output from its control gauge. The control gauge is selected from the gauges plugged into slots A and B of the 937. The control set point pressure (the pressure above which the standard cold cathode high voltage is switched off by the 937) can be set via the front panel with the **control set point function**, as can the process control relay set points with the **set point adjust function.**

A second cold cathode, installed in slot A or B, has a combination logarithmic output provided for it also.

All outputs of the 937 remain active and are updated no matter what operating function the 937 is in. Each of the eight operating functions has been carefully designed to be **easy to use.**

The 937 is also a leak detector capable, under ideal conditions, of detecting system leaks as small as 1.0 x 10^{-8} Torr-liters per second. The leak test function can be used with all sensors operated by the 937 except the capacitance manometer which is a gas independent type of sensor.

HPS Series 937 Vacuum Gauge Controller

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1. SPECIFICATIONS

CONTROLLER

Measurement Range	**$1x10^{-11}$ to $1.0x10^{+4}$ Torr**, $1x10^{-8}$ to $1.0x10^{+7}$ micron, $1x10^{-11}$ to $1.3x10^{+4}$ mbar, $1x10^{-9}$ to $1.3x10^{+6}$ Pascal.
Gas Calibration	Air/nitrogen.
Units of Measure	Torr, mbar, Pascal, micron.
Power needs	**100,120,220,240 Volts AC**, 50 or 60 Hz, **35 Watts max.**
Operating Temperature:	**0 to 50° Celsius.**
Humidity:	95% noncondensing maximum.
Process Set Points and Relays	5 nonvolatile pressure set points and SPDT relays. Up to 2 per gauge. Safety rated: 2 Amperes at 50 Volts AC. Contacts rated: 2 Amperes at 230 Volts AC.
Response Time:	**15 to 150 milliseconds**, depending on gauge type and extent of pressure change (see gauge specifications).
Analog Outputs	**Buffered analog output** for each gauge (see appropriate curve, Appendix E). **Logarithmic output** for each gauge (0.6 Volts/decade) **2 Combination outputs** (see section 6.3.3).
Leak Test	Logarithmic bar graph display and variable rate audio signal (selectable).
Display	**Liquid Crystal Display.** 5 pressure displays with 2 digit mantissas and 1-1/2 digit exponents; .36" digit height, ±60° viewing angle. Updated 20 times per second. 26 segment leak test bar graph. Indicators for unit of measure, relay status, user calibration, and high voltage on/off by the control function.
Communications	Parallel: **IEEE-488**: 24-pin ANSI MC1.1 connector. Serial: **RS-232** and **RS-485**: 9-pin D-sub, PC AT pinout; 2400, 4800, 9600, 19200, 57600 baud.
Weight	**8 pounds** typical (depends on gauge modules installed)
Safety Standard	Designed to comply with **IEC 950.**
Front Panel Controls	Power ON/OFF rocker switch; 8-position Function Select rotary switch; 5-position Gauge Select rotary switch; 2 push button adjustment switches.
Front Panel Functions	**PRESSURE, LEAK TEST, SET POINT ADJUST,** Cold Cathode **CONTROL SET POINT** Adjust, **Capacitance Manometer ZERO,** Pirani/Thermocouple/Convection **ZERO Calibration,** Pirani/Thermocouple/Convection **Atmosphere Calibration** **DISPLAY TEST** (with **Set-up Review**).

Configuration and Gauge Types	**3 gauge module slots**: 1 slot for cold cathode only, 2 slots for any combination of **cold cathode, Pirani, capacitance manometer, thermocouple,** and **convection** gauge modules. Cold cathode modules are single gauge modules; all others are both single and dual. Up to 3 cold cathode gauges or up to 5 gauges (with dual modules) can be operated (and displayed) at same time. 2 types of convection gauge (HPS & GPC). 6 capacitance manometer heads (.1,1,10,100,1K,10K). 5 channels, 1 set point relay per channel, 2 relays for single modules in slots A or B.
Update Rate:	50 milliseconds per gauge in PRESSURE and LEAK TEST functions, 250 milliseconds for full set of gauges. 100 milliseconds per gauge in all other functions.
Special Features:	See **Summary of Features**, pages 12 to 14.

937 Gauge Specifications:

COLD CATHODE

Gauge Type	HPS isolated collector inverted magnetron gauge.
Pressure Range Resolution Reproducibility	**$1x10^{-11}$ to $1x10^{-2}$ Torr**, $1x10^{-8}$ to $1x10^{+1}$ micron, $1x10^{-11}$ to $1x10^{-2}$ mbar, $1x10^{-9}$ to $1x10^{+0}$ Pascal. 1% of indicated decade between 10^{-10} and 10^{-3} Torr, 10% of indicated decade below 10^{-10} and above 10^{-3}. 5% of indicated pressure.
Set Point Range Response Time	**$2.0x10^{-10}$to $9.5x10^{-3}$ Torr**, $2.0x10^{-7}$to $9.5x10^{+0}$micron $2.7x10^{-10}$to $1.2x10^{-2}$ mbar, $2.7x10^{-8}$to $1.2x10^{+0}$Pascal **40 milliseconds.**
Cables and Connectors	High voltage: coax cable with SHV bayonet type connectors on each end. Ion current: low leakage, low noise coax cable with threaded SMA type connectors at each end. Bundled in common sheath. Maximum length 500 feet.
Gauge Head Materials (exposed to vac) Bakeout Dimensions Vacuum Connections	Stainless steel, silver-copper brazing alloy, alumina ceramics, aluminum AL 6061, Elgiloy®, OFHC®copper. 125°C bakeout with cables removed, 250°C with cables and backshell subassembly removed. **2.20"diam x (6.22" to 7.59")length** depending on type of vacuum connection. NW25 KF, NW40 KF, 2-3/4" CF, 1" tube, 8(1/2")VCR®-F.
937 Protection for the Cold Cathode	High voltage disables from **communications**, **rear panel**, and **front panel via control set point** (control set point for "standard" cold cathode only) Cold cathode NORMALLY ON if no disable in effect.
937 Features for the Cold Cathode	**Leak test**, output lock until **time delay** is up after high voltage is switched on, **combination outputs**, **control set point** for automatic pumpdown/vent cycles

PIRANI

Gauge Type	HPS Pirani gauge.
Pressure Range Resolution Reproducibility	**$5x10^{-4}$ Torr to atmosphere**, $5x10^{-1}$ micron to atmos., $7x10^{-4}$ mbar to atmosphere, $7x10^{-2}$ Pascal to atmos. 1% of indicated decade between 10^{-3} and 100 Torr, 10% of indicated decade below 10^{-3} and above 100Torr 5% of indicated pressure.
Set Point Range Response Time	**$2.0x10^{-3}$to $9.5x10^{+1}$ Torr**, $2.0x10^{+0}$to $9.5x10^{+4}$ micron $2.7x10^{-3}$to $1.2x10^{+2}$ mbar, $2.7x10^{-1}$to $1.2x10^{+4}$ Pascal **15 ms** to quick pressure rises to atmosphere, **150 ms** to smaller pressure changes.
Cables and Connectors	Multiconductor shielded cable. Max. length 500 ft. 9-pin D-sub to octal connector.
Gauge Head Materials Bakeout Dimensions Connections	304 stainless steel, platinum alloy, alumina ceramic silver brazing alloy, nickel 200. 50°C bakeout. **1.34"diam x (5.37" to 6.63")length** depending on type of vacuum connection. NW16 KF, 1-1/3" CF, 2-3/4" CF 8(1/2")VCR®-F, 1/8" NPT-M, 15mm tube, 18mm tube.
937 Features for the Pirani	**Leak test**, atmosphere and vacuum **user calibration** with UCAL disable switch, broken sensor wire or **improper connection detection** with relay disable.

CAPACITANCE MANOMETER

Gauge Type	Any +/-15 volt at 35 mA externally powered unheated 0 to 10 volt full scale transducer with 10 volts corresponding to one of **.1, 1, 10, 100, 1K, 10K Torr** such as MKS models 122/222/622/626 and 121/221.
Pressure Range Resolution Reproducibility	**Three decades of measurement below the full scale of the head.** For example, $1.0x10^{-3}$ to $1.0x10^{+0}$ Torr for the 1 Torr head (or $1.3x10^{-3}$ to $1.3x10^{+0}$ mbar). **1% of indicated decade.** 2% of indicated pressure.
Set Point Range Response Time	**2% to 95% of the full measurement range of the head.** **50 milliseconds.**
Cables and Connectors	Multiconductor shielded cable. Max. length 50 ft. 9-pin D-sub with polarized key to 15-pin D-sub or to "flying leads" for terminal connection.
Gauge Head Materials Dimensions Vacuum Connections	Inconel® (exposed to vacuum). **3.00"diam x (4.45" to 6.14")length** depending on type of vacuum connection. NW16 KF, 1-1/3" CF, 1/2" tube, 8(1/2")VCR®-F, 8(1/2")VCO®-F.
937 Features for the Cap. Manom.	**Auto zero**, and **front panel zero correction** with bar graph showing positive and negative zero voltage

THERMOCOUPLE

Gauge Type	Teledyne-Hastings DV-6M or equivalent.
Pressure Range Resolution Reproducibility	**$1.0x10^{-3}$to $1.0x10^{+0}$ Torr**, $1.0x10^{+0}$to $1.0x10^{+3}$ micron $1.3x10^{-3}$to $1.3x10^{+0}$ mbar, $1.3x10^{-1}$to $1.3x10^{+2}$ Pascal **1% of indicated decade.** 5% of indicated pressure.
Set Point Range Response Time	**$2.0x10^{-3}$to $9.5x10^{-1}$ Torr**, $2.7x10^{+0}$to $9.5x10^{+2}$ micron $2.7x10^{-3}$to $1.2x10^{+0}$ mbar, $2.7x10^{-1}$to $1.2x10^{+2}$ Pascal **150 milliseconds.**
Cables and Connectors	Multiconductor shielded cable. Max. length 25 ft. 9-pin D-sub with polarized key to octal connector.
Gauge Head Materials Dimensions Vacuum Connections	Nickel plated steel, noble metal alloy, glass (materials exposed to vacuum). **1.25"diam x 3.05"length.** 1/8" NPT-M.
937 Features for the Thermocouple	**Leak test**, atmosphere and vacuum **user calibration** with UCAL disable switch, broken sensor wire or **improper connection detection** with relay disable.

CONVECTION

Gauge Types	HPS platinum wire gauge and GPC tungsten wire gauge.
Pressure Range Resolution Reproducibility	**$1.0x10^{-3}$to $1.0x10^{+3}$ Torr**, $1.0x10^{+0}$to $1.0x10^{+6}$ micron $1.3x10^{-3}$to $1.3x10^{+3}$ mbar, $1.3x10^{-1}$to $1.3x10^{+5}$ Pascal **1% of indicated decade.** 5% of indicated pressure.
Set Point Range Response Time	**$2.0x10^{-3}$to $9.5x10^{+2}$ Torr**, $2.7x10^{+0}$to $9.5x10^{+5}$ micron $2.7x10^{-3}$to $1.2x10^{+3}$ mbar, $2.7x10^{-1}$to $1.2x10^{+5}$ Pascal **15 ms** to quick pressure rises to atmosphere, **150 ms** to smaller pressure changes.
Cables and Connectors	Multiconductor shielded cable. Max. length 500 ft. 9-pin D-sub to 9-pin D-sub (HPS gauge). 9-pin D-sub to 5-pin custom connector (GPC gauge).
Gauge Head Materials Bakeout Dimensions Vacuum Connections	Stainless steel, nickel, glass, platinum (HPS gauge) 200°C bakeout, not operating and without cable or electronics (HPS gauge). **1.63"diam x 4.40"length,** (2.76" to 2.93" port to far edge depending on type of vacuum connection). NW16 KF, 1-1/3"CF, 2-3/4"CF, 8(1/2")VCR®-F, 1/8" NPT-M, 15mm tube, 18mm tube.
937 Features for Convection Gauges	**Leak test**, atmosphere and vacuum **user calibration** with UCAL disable switch, broken sensor wire or **improper connection detection** with relay disable.

2. UNPACKING INSTRUCTIONS

The HPS SensaVac® Series 937 controller is provided with the following components:

1) HPS SensaVac® Series 937 Controller (with standard cold cathode plug-in module and other selected plug-in options installed).
2) 10 foot USA power cable.
3) Accessory connector kit.
4) Instruction manual.

Tubes and gauge cables must be ordered separately. Please ensure that your shipment is complete. If any shortages are noted, please notify the Customer Service Department, HPS Division of MKS Instruments, Inc. in Boulder, Colorado, USA, or your nearest MKS/HPS sales office. If your equipment was damaged in shipment, notify the carrier within 15 days of receipt. Hold all shipping materials and packing for claim verification.

3. SAFETY WARNINGS

********************************CAUTION********************************
THE HPS SENSAVAC® SERIES 937 CONTROLLER CONTAINS LETHAL VOLTAGES WITHIN THE ENCLOSURE. TO AVOID THE DANGER OF ELECTRIC SHOCK, DISCONNECT THE POWER LINE BEFORE OPENING THE ENCLOSURE, CONNECTING OR REMOVING GAUGE CABLES FROM EITHER THE TUBES OR CONTROLLER, OR BEFORE REMOVING OR REPLACING PLUG-IN MODULES. REFER ALL SERVICING TO QUALIFIED PERSONNEL.
****

********************************CAUTION********************************
THE CONTROLLER SHOULD NOT BE OPERATED WITH A LINE VOLTAGE OTHER THAN THAT FOR WHICH THE CONTROLLER IS SET. DOING SO MAY RESULT IN DAMAGE TO THE UNIT AND POSSIBLE DANGER TO PERSONNEL.
****

********************************CAUTION********************************
BOTH THE SERIES 937 CONTROLLER AND THE VACUUM SYSTEM MUST BE GROUNDED. OTHERWISE, DANGEROUS VOLTAGES MAY BE CREATED.
****

********************************CAUTION********************************
DO NOT USE THE PIRANI, THERMOCOUPLE, OR CONVECTION GAUGE WITH EXPLOSIVE GAS MIXTURES OR WITH FLAMMABLE GASES WHICH COULD FORM EXPLOSIVE GAS MIXTURES IN AIR.
****

********************************CAUTION********************************
PIRANI AND CONVECTION GAUGES USED WITH GASES OTHER THAN AIR OR NITROGEN MAY INDICATE PRESSURES ORDERS OF MAGNITUDE DIFFERENT THAN THE TRUE PRESSURE. THIS CAN CREATE THE HAZARD OF IMPLOSION OR EXPLOSION.
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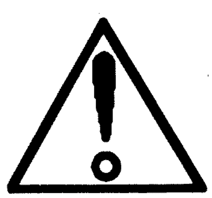
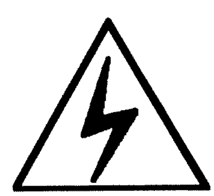
NOTE: THE SYMBOLS BELOW ARE LOCATED ON THE CONTROLLER. PLEASE NOTE THE DEFINITIONS.



ATTENTION - REFER TO MANUAL



DANGER - HIGH VOLTAGE!

4. SUMMARY OF FEATURES

The SensaVac® Series 937 High Vacuum Gauge System features include:

** 3 slots to plug in gauge controller modules -- a "standard" slot for a "standard cold cathode", and 2 "optional" slots for any combination of available gauge modules desired.

** Operation of:
up to **3 COLD CATHODES** (1 gauge per plug-in module);
up to **4 PIRANI GAUGES** (1 or 2 gauges per plug-in module);
up to **4 CONVECTION GAUGES** (1 or 2 gauges per plug-in module);
up to **4 THERMOCOUPLES** (1 or 2 gauges per plug-in module);
up to **4 CAPACITANCE MANOMETERS** (1 or 2 gauges per plug-in module);
(any one of: .1, 1, 10, 100, 1000, 10000 Torr heads).

** Pressure from up to 5 gauges is displayed simultaneously on a liquid crystal display with a wide viewing angle.

** Wide pressure range capability: **$1x10^{-11}$ to 10,000 Torr** (15 decades).

** User selectable units of measure: Torr, mbar, Pascal, or micron.

** User selectable 50 or 60 Hz line frequencies.

** **RS-232, RS-485, and IEEE-488 communications** (up to 57,600 baud).

** **5 nonvolatile set points provide fast system control** (as fast as 15 milliseconds).

** Up to 2 set points per gauge (for single gauge modules plugged into the optional slots).

** 2 ways to individually disable any of the 5 set point relays are provided:
1) by the front panel;
2) by communications.

** Broken sensor wire or improper connection detection is provided for Pirani, thermocouple, and convection gauges, with automatic relay disable in case of broken sensor wire or improper connection.

** Frequently used operating functions are accessible via the front panel, and **each function has been carefully designed to be easy to use:**

1) All set point values can be set via the front panel (there are 5 process control relay set points, and there is the standard cold cathode gauge control set point);
2) Pirani, thermocouple, and convection gauges can be calibrated at vacuum and atmosphere;
3) Capacitance manometer gauges can be zero corrected (negative voltage as well as positive voltage from capacitance manometers is indicated on the display with a +/- 5 millivolt per segment center zero bar graph).

** A **UCAL disable switch** is provided to lock in existing Pirani, thermocouple, and convection gauge calibrations.

** There is a capacitance manometer **auto zero feature**, controlled by the standard cold cathode.

** There is a **leak test function**, with bar graph and selectable audio signal, using cold cathode and thermal conductivity gauges.

** There is an **instrument set-up review feature.**

** All outputs of the 937 remain active and are updated no matter what operating function the 937 is in.

** There are unprocessed (fast response) and processed (logarithmic) **analog outputs** for each of the 5 gauge channels.

** There are 2 **combination logarithmic outputs** which have a pressure range from $1x10^{-11}$ to up to 1,000 Torr, depending on which gauges are installed for combination with the standard cold cathode and a second cold cathode in slot A or B (a smoothing formula is used where the sensor ranges overlap).

** 4 ways to disable the high voltage of cold cathode gauges:

1) By the circle-hex connector on the rear of the cold cathode plug-in module;
2) By communications;
3) By a **control set point** and **control gauge** (standard cold cathode only -- use disable #1 for cold cathodes in slots A and B);
4) By input to the Analog Module connector (standard cold cathode only).

** 3 or 30 second delay options provided for cold cathode gauges, to delay critical outputs until readings are stable after high voltage power-on.

** All set point pressures and user calibration values are saved, with triple redundancy, in nonvolatile memory when power is off to the 937 and special data loss detection and correction software is employed for extra protection of these critical values.

** Standard half rack mounting or free standing.

The 937 has been carefully designed to be as user-friendly as possible for its low cost and features. For example:

* Multicontrollers that have fewer display lines than channels are confusing, so the 937 has **five display lines**, one for each channel.

* Rotary switches provide instant visual feedback for function and gauge selection.

* **Color coding** relates the positions of the function select rotary switch to the functions of the push buttons, making most of the operations of the 937 self-evident.

* An instrument **set-up review** feature allows easy confirmation of set-up selections.

* **Alphabetics** indicating the channels and gauges that a function applies to are displayed if a channel or gauge is selected that the function does not apply to.

* When a cold cathode gauge is off, the displays shows **"O F F"**.

* When a Pirani, thermocouple, or convection gauge is not connected properly or its sensor wire is broken, the display shows **"- - -"**.

* When a sensor is above or below its pressure range, the display shows **"H I"** or **"L O"** (with the exponent giving a reminder of what the range limit is).

* A set point pressure value can be incremented or decremented with discrete button presses, or the UP or DOWN buttons can be held in to rapidly increment or decrement a set point (**it is not necessary to turn potentiometers** for set points, or for Pirani or thermocouple calibration).

* There is a **special calibration algorithm** in the 937 software which allows vacuum and atmosphere user calibrations for thermal conductivity gauges to be done independently of each other, and with greater accuracy.

* The 937 does not allow a calibration when the reading from the gauge is outside the appropriate range ("o u t" will momentarily appear on the display when a UCAL is attempted at too high or low of pressure).

* The 937 makes it easy to know whether a thermal conductivity gauge requires calibration (if some pressure is indicated, rather than "L O" or "0.0" when at vacuum, then a vacuum UCAL is needed; if some pressure is indicated rather than "H I" or "A A" when at atmosphere, then a atmosphere UCAL is needed).

* The processed analog pressure outputs from the 937 are designed for easy interpretation, allowing data acquisition and process control programming to be as easy as possible: special flag values are output when a gauge is below range, above range, is not connected properly, or is disabled; if the voltage is not one of these flag values, then **Pressure = 10^(Voltage/.6 - 12)** is all that is needed to translate the voltage to pressure in Torr for any gauge, on any channel.

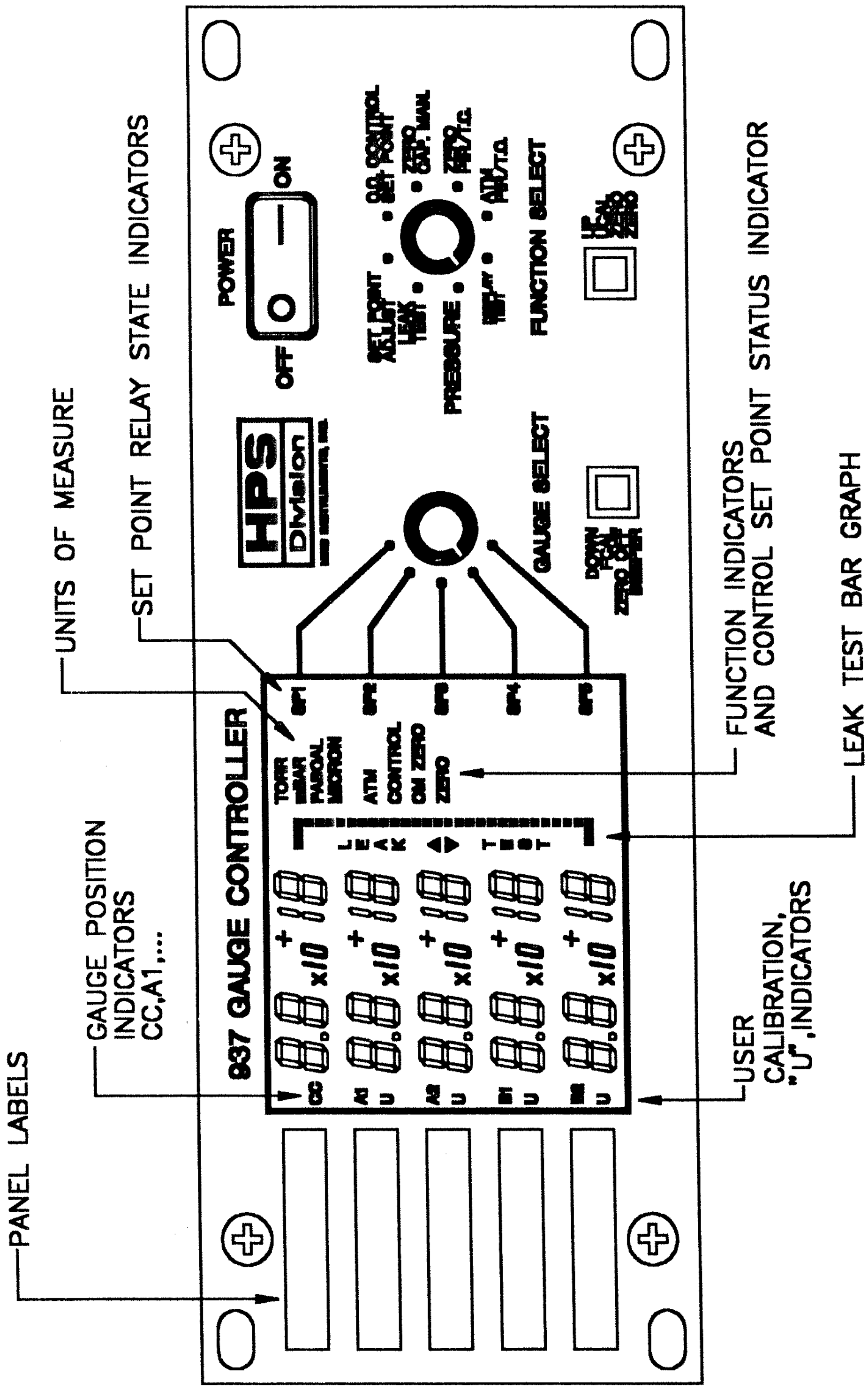


FIGURE 1 - FRONT PANEL

5. FRONT PANEL DESCRIPTION (See Figure 1)

5.1 Display

Depending on the function selected, the display shows:

- up to five pressure readings in exponential notation;
- the pressure unit (Torr, mbar, Pascal, or micron);
- a 26 segment center zero bar graph for leak detection and calibration functions;
- a channel indicator for each gauge installed;
- status of the five set points relays;
- standard cold cathode control status;
- user calibration status;
- diagnostic information (see section 8).

The display is updated twenty times per second. The liquid crystal display (LCD) makes possible the presentation of more information than a typical luminescent display. It is visible in a wide range of lighting situations and over a wide viewing angle.

5.2 Panel Labels

The five white labels located on the far left of the front panel are intended for customer use. These labels allow notation of the type and location of gauges, set point values, calibration status, or other pertinent information. Pencil may be used on the labels (and is easily removed with methanol or a pencil eraser), or adhesive labels may be applied.

5.3 Power

The POWER ON/OFF switch is located on the top right of the front panel. When in the OFF position, all functions of the controller are inoperative and there are no voltages going to any gauge or in any gauge cable. When the controller is not in use, this switch should be left in the OFF position.

5.4 Display Test

The DISPLAY TEST function will switch on every display segment used by the 937. An automatic display test is also performed on power up for the first few seconds. See section 8.1.

5.5 Pressure

Selecting the PRESSURE function displays the pressures measured by the gauges. The first display line with the "CC" is the reading from the **standard cold cathode** gauge (see section 7.1). To the left of the second through fifth lines may be "A1", "A2", "B1", and "B2" when a gauge module is plugged into the respective slots. These channel indicators are active in all functions, as are the indicators for set point relay status, standard cold cathode control status, user calibration status, and the pressure unit. See section 8.2 for detail.

5.6 Leak Test

The LEAK TEST function will work with all gauge types except the capacitance manometer which is not gas dependant. The push button switch labeled BEEPER will toggle the beeper on and off. When enabled, the beeper frequency will increase as the deviation from the base pressure increases. A 26 segment, center zero bar graph is displayed to provide a visual indication of any deviations. Use the ZERO push button to rezero the bar graph and beeper at a new base pressure. See section 8.3 for detail on the LEAK TEST function.

5.7 Set Point Adjust

There is a set point available for each of the five possible gauges. The desired gauge, or set point, is selected with the GAUGE SELECT switch. Use the UP and DOWN push buttons to adjust the selected set point. See section 8.4 for detail on the set points and the SET POINT ADJUST function.

5.8 Cold Cathode Control Set Point

With the FUNCTION SELECT switch set to C.C.CONTROL SET POINT, the control set point value is displayed. This value is the pressure from the **control gauge** (in slot A or B) above which the high voltage of the **standard cold cathode** will be switched off by the 937. As the pressure reading from the control gauge falls back below the control set point pressure, the 937 will resume gauge operation (if no disable source has come into effect, such as from communications). Use the UP and DOWN push buttons to adjust the control set point. See section 8.5 for detail on the control set point and the C.C.CONTROL SET POINT function.

5.9 Capacitance Manometer Zero Setting

When using this function, the GAUGE SELECT switch must select a channel with a capacitance manometer. If the switch is set to a channel without a capacitance manometer, the function cannot be performed. A push of the ZERO button corrects for the capacitance manometer gauge's zero voltage. If the voltage signal from the gauge exceeds 200 millivolts the new setting will not be accepted and "o u t" will momentarily appear on the display. The ZERO OFF button will clear any previously set capacitance manometer zero. See section 8.6 for detail on the ZERO CAP.MAN. function.

5.10 Pirani/Thermocouple/Convection Zero Calibration

When using this function, the GAUGE SELECT switch must select a Pirani, thermocouple, or convection gauge channel. If a channel without one of these gauges is selected, the zero calibration cannot be performed. Also, the UCAL ENABLE/DISABLE switch on the rear panel must be set to ENABLE. Pressing the UCAL (user calibration) button will save a new "zero" value for a Pirani, thermocouple, or convection gauge at "zero" pressure. If the gauge signal is not in range the new setting will not be accepted and "o u t" will momentarily appear on the display. The FCAL (factory calibration) button will reset the "zero" to the factory set value. See section 8.7 for detail on the ZERO PIR./T.C. function.

5.11 Pirani/Thermocouple/Convection Atmosphere Calibration

This function is much the same as the ZERO PIR./T.C. function. The UCAL button is used to reset the atmosphere calibration value of a Pirani, thermocouple, or convection gauge at atmospheric pressure. If the gauge signal is not in range the new setting will not be accepted and "o u t" will momentarily appear on the display. Pressing the FCAL button will return the Pirani, thermocouple, or convection gauge to the factory set atmosphere value. See section 8.8 for detail on the ATM PIR./T.C. function.

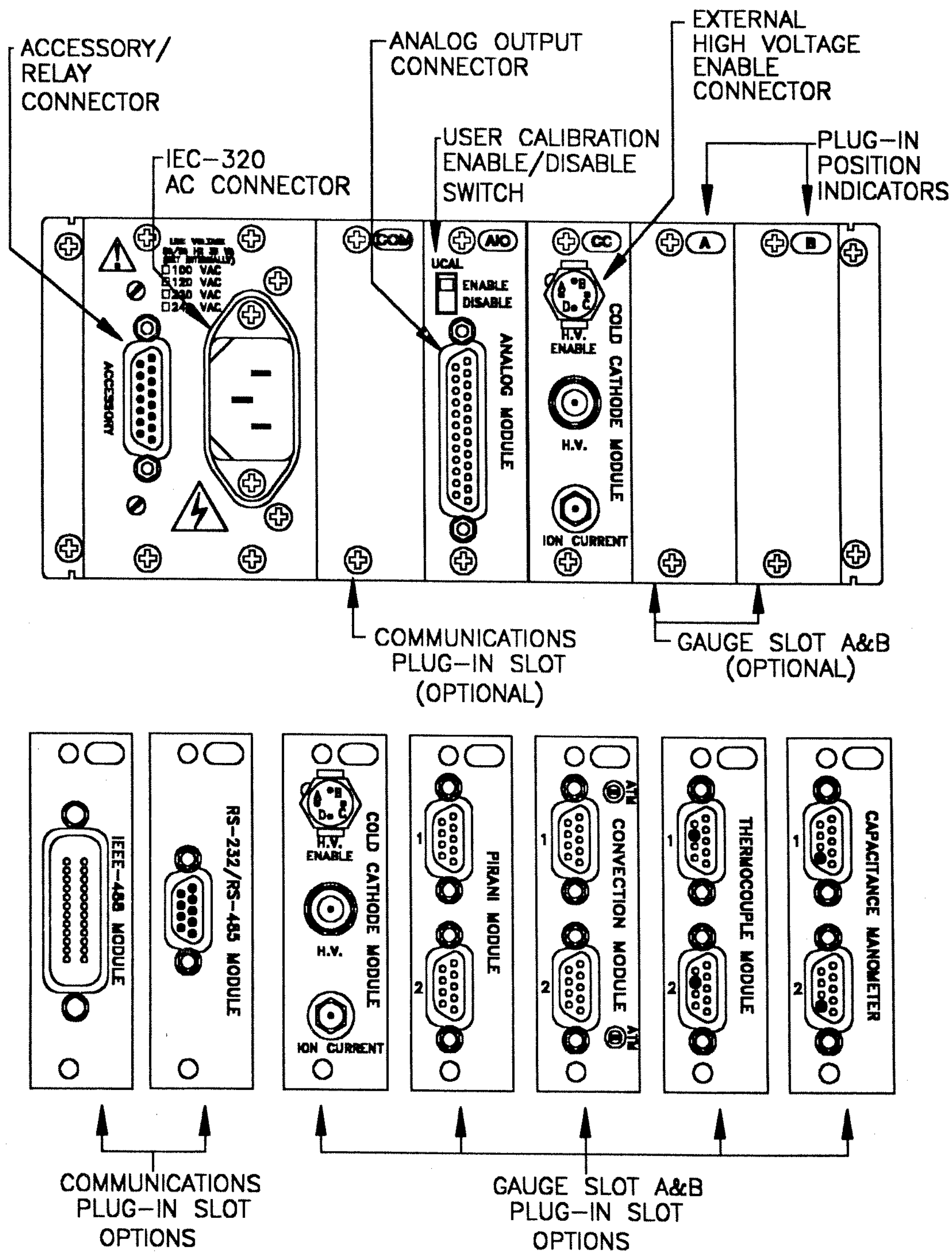


FIGURE 2 - REAR PANEL

NOTES: PLUG-INS FOR SLOTS A AND B ARE OPTIONAL.
ALL FIVE TYPES OF GAUGE PLUG-IN MODULES WILL FUNCTION IN SLOTS A AND B.
ALL DUAL MODULES ARE ALSO OFFERED AS SINGLE MODULES, ALLOWING TWO SET POINT RELAYS TO BE OPERATED BY ONE GAUGE.

6. REAR PANEL DESCRIPTION (See Figure 2)

6.1 Accessory (Relay) Connector (See Figure 29 in Appendix E)
The set point relay contacts are accessed through the male 15-pin D-sub connector on the rear panel of the controller. A connector kit to mate with this connector is provided with the Series 937 Gauge System.

6.2 Power Connector
Located immediately next to the Accessory connector is an IEC 320 AC connector where the power cord plugs into the 937.

6.3 Analog Module (See Figure 24 in Appendix E)
The Analog Module has a 25-pin D-sub, female connector. This connector offers a single input and several outputs to enhance the controller's usefulness in system and laboratory applications.

A **buffered analog output** and a **logarithmic output** are available from each installed gauge. The logarithmic output signal is scaled so that 0.6 Volts equals one decade of pressure. Also, there are two wide range **combination outputs** available (see section 6.3.3).

For twisted pair connections, individual analog ground pins have been provided for each of these signals. In addition, the Analog Module connector has a high voltage disable input for the **standard cold cathode** (see section 7.1), and a digital ground.

The small square opening above the connector allows access to the UCAL ENABLE/DISABLE switch. The switch will enable/disable the user calibration functions for Pirani, thermocouple, and convection gauges. When the controller is shipped, the UCAL switch is in the DISABLE position preventing access to the calibration functions from the front panel.

6.3.1 Buffered Analog Outputs
Curves for the buffered analog outputs as a function of pressure are presented in appendix E. These curves represent the gauge signal after the signal processing performed by each gauge plug-in board, but without any 937 software processing. The signals are not affected by calibrations performed with the ZERO or ATM PIR./T.C. functions.

Analog outputs are typically 0 to 10 volts. However, both the cold cathode and the capacitance manometer can have buffered analog outputs less than zero volts when the gauges are near or exceed the bottom of their ranges. The cold cathode buffered output will be greater than 10 volts when the high voltage is disabled. The thermocouple buffered output will exceed 10 volts when it is not connected properly.

6.3.2 Logarithmic Outputs
All logarithmic outputs, including the combination outputs, are within the 0 to 10 volt range. Only one curve (or one equation) is required to determine the pressure from the logarithmic output for all gauge types. For example, at 1.0×10^{-3} Torr a Pirani gauge will have the same logarithmic output value as a cold cathode, 5.4 volts. The pressure as a function of the voltage is given by:

$P_{(Torr)} = 10^{\left(\frac{V_{out}}{0.6V} - 12\right)}$ and inversely: $V_{out} = 0.6\left[\log_{10}(P_{[Torr]}) + 12\right] volts.$

Thus,	0.6 volts = 1.0 x 10^{-11} Torr	5.4 volts = 1.0 x 10^{-3} Torr
	1.2 volts = 1.0 x 10^{-10} Torr	6.0 volts = 1.0 x 10^{-2} Torr
	1.8 volts = 1.0 x 10^{-9} Torr	6.6 volts = 1.0 x 10^{-1} Torr
	2.4 volts = 1.0 x 10^{-8} Torr	7.2 volts = 1.0 Torr
	3.0 volts = 1.0 x 10^{-7} Torr	7.8 volts = 1.0 x 10^{+1} Torr
	3.6 volts = 1.0 x 10^{-6} Torr	8.4 volts = 1.0 x 10^{+2} Torr
	4.2 volts = 1.0 x 10^{-5} Torr	9.0 volts = 1.0 x 10^{+3} Torr
	4.8 volts = 1.0 x 10^{-4} Torr	9.6 volts = 1.0 x 10^{+4} Torr

Below 1.0 x 10^{-11} Torr, the output is 0.2 volts.
Above 10,000 Torr, the output is 9.8 volts.

For any gauge or channel, the logarithmic output is **0.2** volts when the gauge is exposed to a pressure below its measurement range and **9.8** volts when exposed to a pressure above its measurement range.

The logarithmic output is **10** volts if a Pirani, thermocouple, or convection gauge is not connected properly (or its sensor wire is burned out), or if a cold cathode high voltage is disabled. The 10 volt output is also present when there is no gauge on a channel and during the initial few seconds after the 937 is switched on. When the 937 is not powered, 0 volts will be sensed from the outputs, but a logarithmic output will never be 0 volts when power is on.

A data acquisition system with a 12-bit A/D converter and an input range of 0 to 10 volts will have enough resolution to resolve the equivalent of 1% per decade in the logarithmic outputs.

6.3.3 Combination Outputs

These wide range outputs combine the measurement range of a cold cathode gauge with the range of another gauge capable of measuring higher pressures. For example, if a convection gauge is selected as the high pressure gauge, the combination output shows pressures from 1.0x10^{-11} to 1,000 Torr. A smoothing formula is used where the sensor ranges overlap.

Combination outputs are present for the **standard cold cathode** and for a second cold cathode installed in either slot A or slot B. For the standard cold cathode, the high pressure combination gauge is the **control gauge** responsible for switching the high voltage of the standard cold cathode on and off (see section 8.5). The control gauge channel is selected with DIP switches on the Analog Module (see section 7.6).

Which gauge is in combination with the second cold cathode depends on which slot the cold cathode module is plugged into and on which channel is DIP switch selected to be the control channel for the standard cold cathode. Suppose the second cold cathode is in slot A. This leaves the two channels of slot B for the standard cold cathode control (and combination) gauge and the combination gauge for the second cold cathode:

* if there is a **dual gauge module** installed in slot B, whichever channel is **not** selected as the standard cold cathode control gauge will be the combination gauge for the second cold cathode (if one of the channels of slot A is selected as the control gauge channel by mistake, B1 will be the combination gauge channel for the cold cathode in slot A);

* if there is a **single gauge module** installed in slot B, this gauge will be the combination gauge for the second cold cathode **and** the control/combination gauge for the standard cold cathode (if channel B1 is selected as the control channel).

If the second cold cathode is in slot B rather than slot A, the above comments apply just the same, except the control and combination gauges reside in slot A, not B.

Pin 1 of the analog module rear panel connector is used for the combination output for the standard cold cathode. **Pin 9** of the same connector is used for the combination output for a second cold cathode installed in slot A (i.e., channel A2's digitized analog output pin). **Pin 11** is used for the combination output for a second cold cathode installed in slot B (i.e., channel B2's digitized analog output pin). See figure 24 in Appendix E.

Appropriate control/combination gauges are the Pirani, thermocouple, convection, and the 1 Torr and .1 Torr capacitance manometer heads.

If the gauge on the selected control or combination channel is **not** an appropriate control/combination gauge, the combination output will have the same value as the logarithmic output of the cold cathode gauge.

If the gauge on the selected control or combination channel **is** an appropriate control/combination gauge, and the cold cathode high voltage has been disabled, the combination output will have the same value as the logarithmic output of the control/combination gauge. This is also true for 3 or 30 seconds immediately after the high voltage is switched on (see section 7.6 for information on the 3 or 30 second time delay options).

If there is no gauge on the selected control or combination channel, or if the control/combination gauge is not connected properly ("- - -" on display), the combination output will be **10** volts.

If the cold cathode gauge power is on, the 3 or 30 second time delay has elapsed, and the gauge on the control/combination channel is an appropriate control/combination gauge and is properly connected:

* if the pressure reported by the combination gauge is greater than or equal to **3.0×10^{-3} Torr** (5.686 volts), the combination output will have the same value as the logarithmic output of the combination gauge;
* if the pressure reported by the cold cathode gauge is less than or equal to **7.0×10^{-5} Torr** (4.707 volts), the combination output will have the same value as the logarithmic output of the cold cathode gauge;
* if the pressure is **between 7.0×10^{-5} and 3.0×10^{-3} Torr,** the combination output will be a smoothed combination of the signals from the two sensors.

The two sensors should be on the same portion of the vacuum system, exposed to the same (or negligibly different) system pressure. Take care that the control/combination gauge is properly zeroed (see sections 8.6 and 8.7).

6.4 Cold Cathode Module (a **single** gauge plug-in module)
The high voltage, and the ion current are connected through the cold cathode cable to the cold cathode gauge. An SHV type connector is used for the high voltage (H.V.) connections, and an SMA type connector is used for the ion current connections. A 4-pin, circle-hex connector is used for external enable/disable of the high voltage power supply (see section 7.1).

6.5 Pirani Module (a **dual** gauge module, also offered as a **single**)
There are two female 9-pin D-sub connectors on the Pirani module. The top connector is the gauge that will display on either channel A1 or B1 depending on whether the module is plugged into slot A or B. The Pirani tubes are connected to the module through multi-conductor shielded cables, one cable per tube. The Pirani module is also offered as a single gauge plug-in module, allowing two set point relays to be operated by the one Pirani. In this configuration, the Pirani must be connected to the top connector, channel 1 (A1 or B1 depending on whether the module is plugged into slot A or B).

6.6 Capacitance Manometer Module (a **dual** or **single** gauge module)
There are two female 9-pin D-sub connectors on the capacitance manometer module. The top connector is the gauge that will display on either channel A1 or B1 depending on whether the module is plugged into slot A or B. Capacitance manometer heads are connected to the module through multi-conductor shielded cables, one per gauge head. The connection at the gauge head is either a female 15-pin D-sub connector or wire pigtails, depending on the style of the gauge head. The capacitance manometer module is also offered as a single gauge plug-in module (see last two sentences of section 6.5). To prevent connection of other gauge tubes to the capacitance manometer module, the capacitance manometer uses a polarized female 9-pin D-sub connector with a key in contact #6.

6.7 Thermocouple Module (a **dual** module, also offered as a **single**)
The thermocouple module's rear panel is configured identically to the Pirani module and the description in section 6.5 applies here. In addition, to prevent connection of other gauge tubes to the thermocouple module, the thermocouple uses a polarized female 9-pin D-sub connector with a key in contact #8.

6.8 Convection Module (a **dual** module, also offered as a **single**)
The convection module's rear panel is configured identically to the Pirani module and the description in section 6.5 applies here. The Pirani and convection modules have been designed to prevent damage in the event that tubes and modules are interchanged; however, the Pirani and convection modules are not the same and will not indicate an accurate pressure if the wrong tube is used.

6.9 RS-232 / RS-485 Module
A single 9-pin D-sub connector is used for both of the possible serial interfaces. Three pins are dedicated to the RS-232 interface using the standard PC-AT connections for a DTE (data terminal equipment) device. Two more pins are dedicated for use with the RS-485 interface.

6.10 IEEE-488 Module
An IEEE-488 Standard 24-pin ribbon connector is used to connect the IEEE-488 Module to the bus. All pinouts are according to the IEEE-488 Standard. The strain relief screwlocks have a female metric thread.

7. CONTROLLER AND GAUGE SET-UP / INSTALLATION

The first page of this instruction manual lists the sections that are recommended reading to set-up the 937 for operation. It is assumed at this point that section 2 (Unpacking Instructions), section 3 (**Safety Warnings**), section 5.2 (Panel Labels), and the relevant subsections of section 6 (Rear Panel Description) have been read. This section covers switch settings and jumpers on the various gauge controller boards or modules, the Analog Module, the power supply board, and the serial and parallel communication modules. Controller Mounting is also covered here (7.8). **For information on installing gauge heads on the vacuum system and cabling between the gauge heads and 937, see Appendix C.**

All DIP switches and jumpers are either set as requested before delivery or to factory settings as follows:

Controller switches and jumpers:

1. On the Analog Module:
   A. **Pressure unit** (Torr, mbar, Pascal, or micron) -- **set as requested** before delivery
   B. Control gauge channel -- set to **channel A1** (or to B1 if a cold cathode module is ordered plugged into slot A)
   C. **Line frequency** (50 Hertz or 60 Hertz) -- **set as requested** before delivery
   D. Cold cathode delay -- set to **3 seconds** (whenever a cold cathode high voltage is switched on, relays and other 937 outputs for the cold cathode will be locked for 3 seconds, rather than the longer 30 second delay period)
   E. UCAL ENABLE/DISABLE switch (accessible from the rear panel) -- set to **UCAL DISABLE** (this locks out use of the ATM PIR./.T.C. and ZERO PIR./T.C. user calibration functions)

2. On the power supply board:
   A. **Line voltage jumper** -- **set as requested** before delivery (as are the fuses)

Gauge module switches and jumpers:

1. Convection Gauge Module:
   A. Convection gauge type -- set for **HPS platinum wire gauge**

2. Capacitance Manometer Module (for both channels):
   A. Capacitance manometer head (full scale value) -- set to **1 Torr head**
   B. Auto zero enable / disable -- set to **auto zero disabled**

Communication module switches:

1. RS-232 / RS-485 Module:
   A. RS-232 or RS-485 selection -- set as requested before delivery
   B. Baud rate -- set to **9600 baud**
   C. RS-485 controller address -- set to **ASCII zero (30H)**

2. IEEE-488 Module:
   A. Controller address -- set to **ASCII zero (30H)**

In addition to the DIP switches and jumpers on the plug-in modules, there are additional parameters that may need to be set from the front panel after the 937 is powered. Set points for the process control relays may need to be set (see section 8.4), the control set point for the standard cold cathode high voltage may need to be set (see section 8.5), and if a thermocouple or convection gauge is to be operated, calibration is recommended (see sections 8.7 and 8.8).

Prior to delivery, the relay and control set points are set to their "0.0", or disabled, setting. This means **all relays are disabled**, and **the standard cold cathode high voltage control feature is disabled.**

If none of the above set-up items require changing, then it is not necessary to read further in this section, except for the following:
1. **Section 7.1**, if a cold cathode is to be operated (page 25)
2. **Section 7.8**, Controller Mounting (page 30)

Also note:
Following installation and set-up of the 937 or any time there is a question about how the 937 is configured, **use of the set-up review function is recommended.** This function allows review of what gauge modules are installed, their channels as well as present settings of most user selectable DIP switches and jumpers (see section 8.1). It may also be useful to note set-up information on the panel labels.

If it is necessary to change a set-up item, read the rest of this page, and see the relevant subsection(s) in this section (or in section 8 for set point setting and thermocouple or convection gauge calibration).

Removing and installing plug-in modules to modify controller set-up:

****CAUTION****
ALWAYS REMOVE THE POWER CABLE FROM THE CONTROLLER BEFORE PERFORMING ANY DISASSEMBLY. LETHAL VOLTAGES ARE PRESENT IN THE UNIT WITH POWER APPLIED

The 937 controller was designed for easy access to the plug-in modules. Use a #1 Phillips screwdriver to remove the two screws on the plug-in module to be removed. Use a small flat-blade screwdriver to gently pry the plug-in away from the rear frame until it slides freely. Carefully slide the board out; rapid action can cause damage to the components on the board or the internal connector on the end. As the plug-in is removed, place it in a static protected container.

To insert a plug-in module into the controller, place the end with the internal connector in first, and align the board to fit and slide freely in the card guides. Gently slide the board towards the front of the controller. When the internal connectors meet, carefully push on the rear panel to make the connection. Replace and tighten the two screws with a #1 Phillips screwdriver.

It is very important to place the correct plug-in module in the correct slot. See Figure 2, page 18, for the correct module positions.

NOTE: When removing one type of gauge plug-in and installing another type, if the set point values are within the acceptable range for the new plug-in, they will keep their values until changed via the front panel. If the set point values are not within the acceptable range, they will be reset to "0.0", the disabled value

NOTE: When the unit of measure (pressure unit) is changed, set point values are not converted to the new unit. Instead, if set point values are within the acceptable ranges for the gauges installed, they will keep their values until changed via the front panel. If the set point values are not within the acceptable ranges, they will be reset to "0.0", the disabled value.

7.1 Cold Cathode

A cold cathode plug-in module can be installed in the "CC" slot, in slot "A", or in slot "B". All three slots can have cold cathode modules installed, and the 937 can operate all three cold cathode gauges simultaneously.

The cold cathode plug-in module in slot "CC" is referred to as the **standard cold cathode** because it is standard equipment. If any gauge module other than a cold cathode module is installed in the standard slot, the 937 will ignore it. If no gauge module is installed in the standard slot, the 937 will operate the gauges installed in slots "A" and "B". However, it is the standard cold cathode which determines if the pressure is low enough for capacitance manometer auto zeroing. So if the auto zero feature is to be used (see section 8.6.1), there will need to be a cold cathode module plugged into the standard slot.

Also, the C.C.CONTROL SET POINT function applies to the standard cold cathode and not to cold cathodes installed in slots "A" and "B". So if the control feature is to be used (see section 8.5), the cold cathode that it will be used on will need to be installed in the standard slot.

Note that the standard slot is single channel rather than a dual channel, and there is one set point available for process control rather than two. Slots "A" and "B" are dual channel slots and have two set points available to them.

The high voltage for the standard cold cathode is forced off as soon as the 937 is powered and is then switched on only if software and hardware disables are not active. A software disable can originate from the control gauge indicating too high a pressure, from an input to the Analog Module connector, or from communications. A hardware disable is accomplished by shorting pins A and D on the circle-hex connector on the rear panel of the cold cathode plug-in module. See Figure 3 (top of next page).

Cold cathode gauges installed in slots "A" and "B" are not controlled by the control gauge or the Analog Module input. The two high voltage enable/disable sources available for each of these cold cathodes are: 1) the circle-hex connector on the rear panel of each cold cathode plug-in module; 2) communications.

There are three DIP switches to set on the Analog Module that are part of cold cathode set-up. See section 7.6.

There are additional cold cathode parameters that may need to be set from the front panel after the 937 is powered. These include set point pressures for cold cathode relays, as well as the standard cold cathode control set point. See section 8.

For information on installing cold cathode gauges on the vacuum system and cabling between the gauge and 937, see Appendix C.

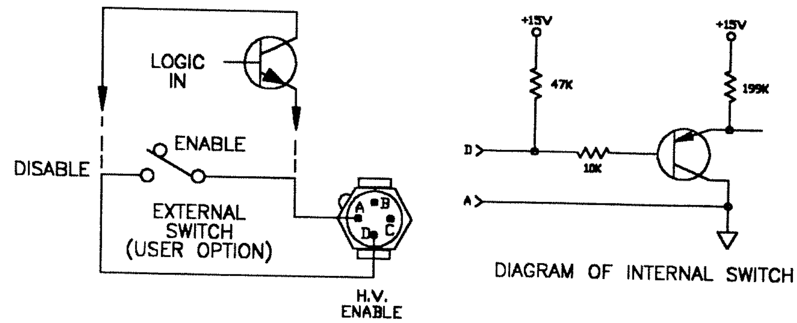


FIGURE 3 - COLD CATHODE CIRCLE-HEX CONNECTOR

7.2 Pirani

There are no switches or jumpers to be set on the Pirani plug-in module. Set point pressures may need to be set for Pirani relays from the front panel after the 937 is powered (see section 8). If the Pirani tube is new, it is very unlikely that the Pirani requires a vacuum or atmosphere calibration change from the factory values (see sections 8.7 and 8.8 on the ZERO PIR./T.C. and ATM PIR./T.C. functions). For information on installing Pirani gauges on the vacuum system and cabling between the gauge and 937, see Appendix C. Also see section 6.5.

7.3 Capacitance Manometer

Figure 4 (below) shows a diagram and table for the DIP switches located in the center of the capacitance manometer plug-in module. Switches 1, 2, and 3 are used for setting the plug-in to the capacitance manometer's full scale value. It is very important to set these switches for the head in use. The two combinations of switches 1, 2, and 3 that are not shown in Figure 4 will result in a "Setup Error" display at power-on. Switch 4 is the enable switch for the capacitance manometer auto zero feature. See section 8.6.1 for information on the auto zero feature. There are two sets of four switches, one set for each channel. Both channels are factory set to the 1 Torr head with auto zero disabled.

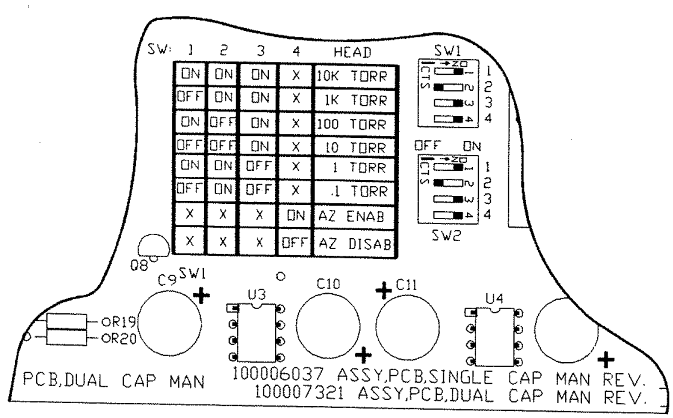


FIGURE 4 - CAPACITANCE MANOMETER DIP SWITCHES
SHOWN WITH 100 TORR HEAD AND AUTO ZERO ENABLED.

There are additional capacitance manometer parameters that may need to be set from the front panel after the 937 is powered. These include set point pressures for capacitance manometer relays, and the zero setting. See section 8.

For information on installing capacitance manometer gauges on the vacuum system and cabling between the gauge and 937, see Appendix C. Also see section 6.6.

Figure 5 (below) shows the capacitance manometer module rear panel connector (as viewed from the rear). A key in contact #6 is used to polarize the female 9-pin D-sub connector. This will prevent the use of a Pirani, thermocouple, or convection gauge cable with the capacitance manometer module. It is still possible to plug a capacitance manometer cable into a Pirani or convection gauge module, but this should not damage either the tube or the module. When using more than one gauge type, it is a good idea to verify the correct tube and cable are connected to the proper module.

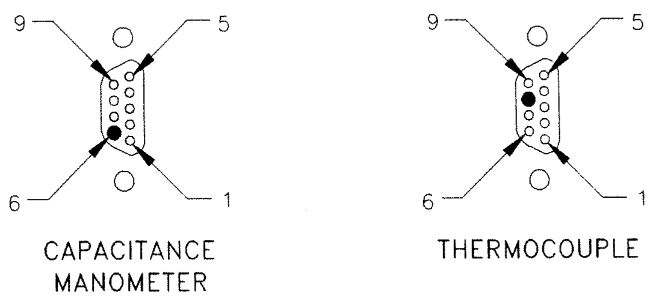


FIGURE 5 - POLARIZED D-SUB CONNECTOR FOR THE CAPACITANCE MANOMETER AND THERMOCOUPLE

7.4 Thermocouple

Figure 5 (above) shows the thermocouple module rear panel connector (as viewed from the rear). A key in contact #8 is used to polarize the female 9-pin D-sub connector. This will prevent the use of a Pirani, capacitance manometer, or convection gauge cable with the thermocouple module. It is still possible to plug a thermocouple cable into a Pirani or convection gauge module, but this should not damage either the tube or the module. When using more than one gauge type, it is a good idea to verify the correct tube and cable are connected to the proper module.

There are additional thermocouple parameters that may need to be set from the front panel after the 937 is powered. These include set point pressures for thermocouple relays, and the atmosphere and zero (vacuum) calibration values. Calibration of the thermocouple gauge is recommended before use. See section 8.

For information on installing thermocouple gauges on the vacuum system and cabling between the gauge and 937, see Appendix C. Also see section 6.7.

7.5 Convection

On the convection plug-in module, a three pin header with jumper is used to select either the HPS platinum wire convection gauge tube or the GPC tungsten wire tube. The header is located at the end of the board opposite the rear panel. With a jumper in the "Pt" position (see Figure 6, below) the 937 will convert the gauge signal to pressure according to the HPS platinum wire nominal curve. This is the factory setting. With a jumper in the other position or with no jumper used, the 937 will convert the gauge signal to pressure according to a curve which is accurate for the GPC tungsten wire convection gauge tube.

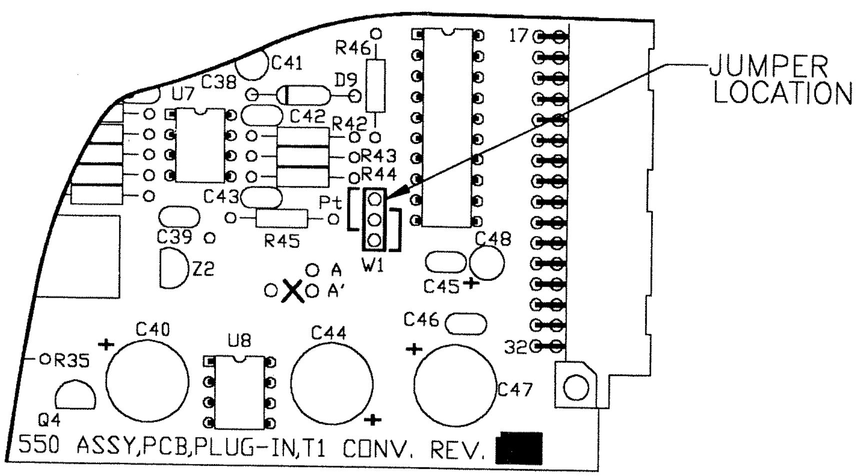


FIGURE 6 - CONVECTION JUMPER

There are additional convection gauge parameters that may need to be set from the front panel after the 937 is powered. These include set point pressures for convection gauge relays, and the atmosphere and zero (vacuum) calibration values. Calibration of the convection gauge is recommended before use. See section 8.

For information on installing convection gauges on the vacuum system and cabling between the gauge and 937, see Appendix C. Also see section 6.8.

7.6 Analog Module

Five controller features are selected using switches on the Analog Module. The UCAL ENABLE/DISABLE switch, accessible from the rear panel, can lock out front panel access to the ATM PIR./T.C. and ZERO PIR./T.C. user calibration functions (it does **not** apply to the ZERO CAP.MAN. function). A bank of seven DIP switches found in the middle of the board allow the selection of four set-up parameters:

(1) the pressure unit (Torr, mbar, Pascal, or micron);
(2) the **control gauge** channel for the **standard cold cathode;**
(3) the line frequency (50 or 60 Hz);
(4) the length of the time delay (3 or 30 seconds) which occurs after any cold cathode high voltage is switched on to allow the discharge to reach equilibrium before relays and other outputs are active for the cold cathode.

(1) PRESSURE UNIT SW1 SW2	(2) CONTROL CHANNEL SW3 SW4	(3) LINE FREQUENCY SW5	(4) COLD CATH DELAY SW6
Torr: OFF OFF	A1: OFF OFF	60 Hz: OFF	3 sec: OFF
mbar: ON OFF	A2: ON OFF	50 Hz: ON	30 sec: ON
Pascal: OFF ON	B1: OFF ON		
micron: ON ON	B2: ON ON		

Factory settings are 3 seconds for the cold cathode delay and channel A1 for the control gauge (or B1 if a 937 is ordered with a cold cathode module plugged into slot A). Prior to shipment, the pressure unit and line frequency switches are set to the unit and frequency requested.

Switches 1 and 2 select the pressure unit. Changing the pressure unit for the 937 is as easy as looking at the above table and setting these two DIP switches to the indicated positions. After power-on, all 937 outputs will be in the unit selected with these two switches. There are no unit switches on individual gauge modules, and no other switches or adjustments are needed, with the following possible exception: if set point pressures were set previous to a pressure unit change, they will require resetting via the front panel (see sections 8.4 and 8.5). See the NOTE at the top of page 25.

Switches 3 and 4 select the control gauge channel. The control gauge allows the standard cold cathode high voltage to be switched on and off at a specific pressure (see section 8.5). The control gauge is also used with the standard cold cathode for one of the two combination logarithmic outputs (see section 6.3.3).

Switch 5 selects the line frequency (either 50 or 60 Hertz). This selects the appropriate integration period for the A/D converter to optimize its rejection of any line frequency noise. Changing this switch has no influence on the power supply.

Switch 6 selects the 3 or 30 second cold cathode delay, during which time all 937 outputs for a cold cathode just switched on are locked (except for output to the display). For example, during the delay a setpoint relay cannot change state. This feature prevents (for up to 30 seconds) a slow starting cold cathode gauge from erroneously activating its setpoint relays.

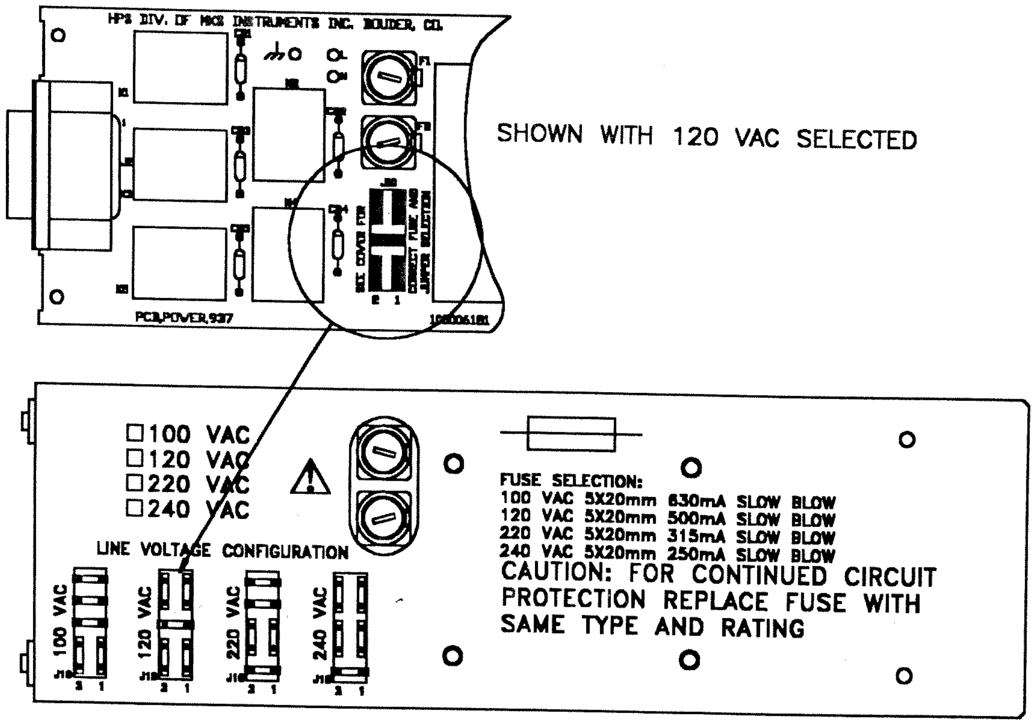


FIGURE 7 - POWER SUPPLY VOLTAGE SELECTION JUMPER

7.7 Power Supply

********************************CAUTION********************************
THE HPS SENSAVAC® SERIES 937 CONTROLLER CONTAINS LETHAL VOLTAGES WITHIN THE ENCLOSURE. TO AVOID THE DANGER OF ELECTRIC SHOCK, DISCONNECT THE POWER LINE BEFORE OPENING THE ENCLOSURE OR BEFORE REMOVING OR INSTALLING PLUG-IN BOARDS. REFER ALL SERVICING TO QUALIFIED PERSONNEL.

THE CONTROLLER SHOULD NOT BE OPERATED WITH A LINE VOLTAGE OTHER THAN THAT FOR WHICH THE CONTROLLER IS SET. DOING SO MAY RESULT IN DAMAGE TO THE UNIT AND POSSIBLE DANGER TO PERSONNEL.
****

Figure 7 shows the jumpers on the power supply plug-in which select the controller's line voltage. Prior to shipment, these jumpers are set to the line voltage requested. If it is necessary to change the line voltage, the jumpers must be set for the new voltage, AND the appropriate fuses for the voltage will need to be installed.
The fuse holders are located adjacent to the voltage selection jumpers. Any changes should be made by qualified service personnel.

7.8 Controller Mounting

The 937 controller is self contained, compact, and light weight; it is designed to be mounted either in a panel or to stand alone.

The 937's half rack enclosure is easily mounted in readily available 19 inch (full rack) and half rack frames. The controller requires a minimum of 17 inches of depth behind the panel face to accommodate the connectors and clearance for cables. Side clearance is not required.

The 937 requires no additional hardware to be mounted into a half rack. To mount the controller, insert it into the half rack frame opening from the front and fasten with four screws through the holes in the corners of the controller's front panel. For mounting into a full rack, use HPS panel mounting kit part number 1-00005651. Figure 32 in Appendix E illustrates mounting the 937 into a full rack.

For bench use, adhesive backed rubber feet are provided and can be attached to the bottom of the controller. To install the rubber feet, remove the protective paper from the mounting surface on each of the rubber feet. Place one of the rubber feet on each of the four corners of the bottom cover.

7.9 AC Power Cord

The 937 controller is supplied with a standard power cord terminated in a female IEC connector at the controller end and in a plug for 120 Volts AC, 60 Hertz at the supply end, unless otherwise specified at the time of order. If the power source is different than that specified at the time of order, see section 7.7 concerning line voltage and section 7.6 for line frequency selection. Power cords for standard power outlets are generally available at local electrical supply stores. A power cord with no male plug is available from HPS.

7.10 RS-232 / RS-485

The selection of the desired serial interface is made using the DIP switch bank labeled "SW1" shown in Figure 8 on the following page. Switch positions 5-7 select either the RS-232 or the RS-485 interface (see Figure 8). Switch positions 1-4 select the baud rate which can be 2400, 4800, 9600, 19200, or 57600 baud. Switch 1 selects 2400 baud, switch 2 selects 4800 baud, switch 3 selects 9600 baud, and switch 4 selects 19200 baud. When one of these rates is selected the remaining switches should be in their OFF position. To select 57600 baud, all switches must be in their ON position. Any other switch combination will select 9600 baud, the default. The 57600 rate may not be usable with all types of hardware as it exceeds the transmission rate specified by the RS-232 standard.

If the RS-485 interface is selected, an address character must also be selected using the DIP switch bank labeled SW3. RS-485 allows multiple controllers to be connected via two wires to a main computer. This distributed method requires a unique address for each device on the two wire bus. The switches should be set to the binary code representing an ASCII character and that character will be the controllers address. The "$" (0100100B or 24H) is the "attention" character, always preceding the address and may not be used for any other purpose. ASCII characters recommended for addresses include "0-9" (30H-39H), "A-Z" (41H-5AH) and "a-z" (61H-7AH).

RS-485 communications at high speed and over long wires may require both ends of the transmission line to be terminated in the characteristic impedance of the cable. The holes on the plug-in board marked "R1" are provided to allow the customer to add a termination resistor if required. NOTE: this resistor should only be used on plug-in if it is located at one end of the transmission line.

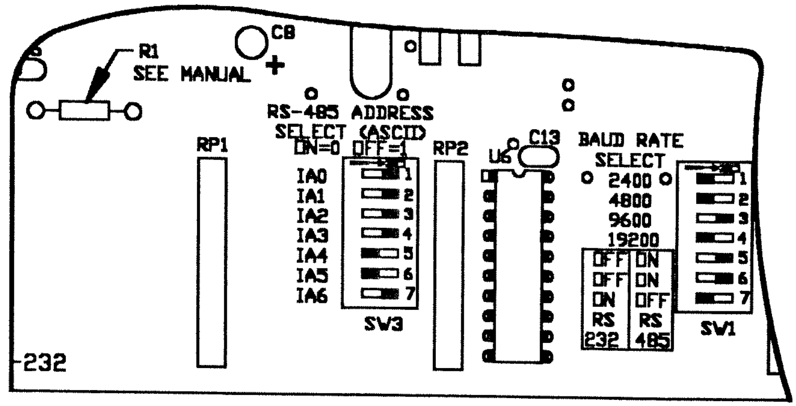


FIGURE 8 - RS-232 / RS-485 DIP SWITCHES
SHOWN WITH 9600 BAUD, RS-485 AND ADDRESS CHARACTER = ASCII ZERO

7.11 IEEE-488

An interface address must be selected using the DIP switch bank labeled "SW1". IEEE-488 allows multiple controllers to be connected to a main computer. This distributed method requires a unique address for each device. The switches should be set to the binary coded decimal equivalent of the device address. Allowable addresses are 0 through 30.

Example: for an address of 25, set DIP switches 1 through 5 to "11001" or OFF OFF ON ON OFF.

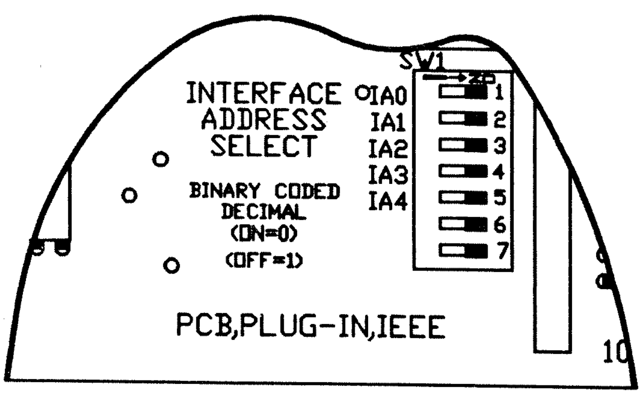


FIGURE 9 - IEEE-488 DEVICE ADDRESS DIP SWITCHES

8. OPERATION

****CAUTION****

BEFORE APPLYING POWER TO THE HPS SENSAVAC® SERIES 937 CONTROLLER, LINE VOLTAGE AND LINE FREQUENCY MUST BE SET TO MATCH THE POWER SOURCE

The HPS SensaVac® Series 937 features modes for pressure measurement, leak detection, set point adjustment, cold cathode gauge control set point adjustment, and a display test. Zero and atmosphere calibration capabilities are provided for the Pirani, thermocouple, and convection gauges. A zero correction function is provided for capacitance manometers.

The mode of the controller is selected by the FUNCTION SELECT rotary switch. Color coding relates the positions of the function switch to the function of the push buttons.

Five of the eight primary 937 modes or functions require selecting a certain gauge channel. For example, the ZERO CAP.MAN. function applies only to capacitance manometer gauges, and one of these gauges must be selected for the function to perform. Gauge channels are selected with the GAUGE SELECT rotary switch. If a channel is selected that has no gauge installed or has a gauge that the presently selected function does not apply to, "n o" is displayed on the channels display line. There is no point in selecting these channels, except to be reminded which channels are relevant for the function. At the same time "n o" appears on a selected but irrelevant channel, either "n o" or alphabetics indicating the gauges which the function applies to are displayed on each channels display line:

"**C C**"	indicates a cold cathode gauge;
"**P i r**"	indicates a Pirani gauge;
"**C o n**"	indicates a convection gauge;
"**t c**"	indicates a thermocouple gauge;
"**C A P**"	indicates a capacitance manometer head.

A brief description of each of the eight primary 937 functions is given in sections 5.4 to 5.11 under Front Panel Description. Full information on each of these functions is provided below.

If error messages appear on the display shortly after the 937 is switched on, see section 9.1.

8.1 Display Test (Review Function)

The DISPLAY TEST function will switch on every display segment used by the 937. An automatic display test is also performed on power up for the first few seconds.

A set-up review function is accessible when the FUNCTION SELECT switch is in the DISPLAY TEST position. Following installation and set-up of the 937 or any time there is a question about how the 937 is configured, use of the set-up review function is recommended. This function allows review of what gauge modules are installed, their channels as well as present settings of most user selectable DIP switches and jumpers.

With the FUNCTION SELECT switch in the DISPLAY TEST position, press the DOWN push button. Each time the DOWN push button is pressed additional set-up information is displayed until all information has been presented. The UP push button will step the display back through the previously reviewed information.

The information screens are:

---

1) **Display Test.** All display segments used by the 937 should be lit.

---

2) This screen shows **which gauges are installed and on which channels.** Indicators including "CC", "A1", "A2", "B1", and/or "B2" appear on the display line of any channel with a gauge installed. This test only indicates that a module is plugged in, not whether a gauge is connected to the module. The following alphabetics tell what type of gauge is installed on the channel:

"**C C**"	indicates a cold cathode gauge;
"**P i r**"	indicates a Pirani gauge;
"**C o n**"	indicates a convection gauge;
"**t c**"	indicates a thermocouple gauge;
"**C A P**"	indicates a capacitance manometer head.

In addition, the indicator for the **pressure unit** is lit. The pressure unit is selected with two DIP switches on the Analog Module (see section 7.6).

A "**U**" indicator will be lit next to any gauge operating with a zero (vacuum) or atmosphere **user calibration** value set with the ZERO CAP.MAN. or ZERO PIR./T.C. or ATM PIR./T.C. functions. The "U" will be lit if EITHER the zero or the atmosphere value -- or both -- is not the factory value.

---

3) This set-up review screen is displayed **if there is a capacitance manometer** installed and the head selection DIP switches on the capacitance manometer plug-in module have been set to valid head selection positions.

"**H d**" (for **head range**) appears on the top display line.

The full scale pressure reading of each head appears on its channels display line:

DISPLAY		HIGHEST READING		LOWEST READING	
"**1.0x10+4**"	for	10,000	Torr head	10	Torr;
"**1.0x10+3**"	for	1,000	Torr head	1	Torr;
"**1.0x10+2**"	for	100	Torr head	.1	Torr;
"**1.0x10+1**"	for	10	Torr head	.01	Torr;
"**1.0x10+0**"	for	1	Torr head	.001	Torr;
"**1.0x10-1**"	for	.1	Torr head	.0001	Torr.

---

4) This set-up review screen is displayed **if there is a capacitance manometer** installed and the head selection DIP switches on the capacitance manometer plug-in module have been set to valid head selection positions.

"**A u t**" (for **auto zero**) appears on the top display line.

The auto zero enabled/disabled status of each head appears on its channels display line:

"**o n**" if auto zero is enabled;
"**O F F**" if auto zero is disabled.

The auto zero feature is selected with a DIP switch (one for each channel) on the capacitance manometer plug-in module (see section 7.3).

---

5) This set-up review screen shows which gauge has been selected to be the **control gauge for the standard cold cathode:**

"**P i r**" indicates a Pirani gauge;
"**C o n**" indicates a convection gauge;
"**t c**" indicates a thermocouple gauge;
"**C A P**" indicates a 1 or .1 Torr capacitance manometer head.

The gauge alphabetics are displayed on the control channels display line.

If there is no gauge installed on the selected control channel, or if the gauge that is installed there is not an appropriate control gauge, or if there is no standard cold cathode installed, "**Error**" is displayed.

The control channel is selected with two DIP switches on the Analog Module (see section 7.6).

---

6) This set-up review screen shows the **time delay selected for cold cathode gauges.**

"**C C**" (for cold cathode) appears on the top display line.

One of the following appears on the next two display lines:

"**3 S E C**" if the 3 second delay is selected;
"**3 0 S E C**" if the 30 second delay is selected.

This is the delay that occurs after a cold cathode high voltage is switched on to allow the discharge to reach equilibrium before relays and other outputs are active for the cold cathode.
The 3 or 30 second delay option is selected with a DIP switch on the Analog Module. The same delay applies to all cold cathodes installed (see section 7.6).

---

7) This set-up review screen shows the **UCAL enable/disable switch state.** Either "UCAL Enab" or "UCAL disab" is shown. The UCAL enable/disable switch is on the rear of the Analog Module (see section 7.6).

---

8) The last set-up review screen shows:

"**5 0 H**" if **50 Hertz line frequency** is selected;
"**6 0 H**" if **60 Hertz line frequency** is selected.

The line frequency is selected with a DIP switch on the Analog Module (see section 7.6).

The letter code which appears in the lower left corner of the display is the revision of the 937 software.

8.2 Pressure

Once all gauge tubes and gauge plug-in modules are installed and 937 set-up is complete (see section 7 and section 8.1), the 937 is ready for operation. Be sure that line voltage and line frequency are set to match the power source, and all gauge tubes are connected to the 937, before switching on the 937.

To see the pressure from all gauges simultaneously, set the rotary switch to the PRESSURE position. All pressures are displayed in scientific notation (two digit mantissa with a signed exponent) with typical resolution equal to 1% of the decade. The controller displays up to five separate pressure readings. The pressure unit is shown in the upper right of the display (see section 7.6 for selecting one of the four pressure units: Torr, mbar, Pascal, or micron).

To the left of the pressure readings will be "**CC**", "**A1**", "**A2**", "**B1**", and/or "**B2**" from top to bottom. The top display line with the "CC" is the display line for the **standard cold cathode** (see section 7.1). The second and third display lines from the top are the "A1" and "A2" display lines or channels of slot A. The bottom two display lines are the "B1" and "B2" display lines or channels of slot B. Slots A and B are for any of the following gauge plug-in modules: single cold cathode, dual or single Pirani, dual or single capacitance manometer, dual or single thermocouple, or dual or single convection gauge. A single gauge plug-in module in slot A will display the pressure reading on the A1 display line. A single gauge module in slot B will display the pressure reading on the B1 display line. A dual gauge module will display pressure readings on both A1 and A2, or B1 and B2. If there is no gauge module in a slot, the channel indicators will not be lit for that slot, and both display lines will be blank.

A "**U**" indicator is located beneath each channel indicator for slots A and B. When a "U" is lit, this indicates that a zero (vacuum) setting or atmosphere **user calibration** has been saved in nonvolatile memory by use of the ZERO CAP.MAN. or ZERO PIR./T.C. or ATM PIR./T.C. functions (see sections 8.6, 8.7, 8.8). The "U" is lit if EITHER the zero or the atmosphere value -- or both -- is not the factory value.

If any of the five set point relays are energized (pressure below the set point), the corresponding indicator, "**SP1**" **to** "**SP5**", will be lit. These indicators are located on the right side of the display. See section 8.4, Set Point Adjust.

If the high voltage of the standard cold cathode is switched off because the **control gauge** is reporting a pressure above the control set point, the "**CONTROL**" indicator will be lit. Also, the standard cold cathode display line will show "**O F F**" in this case (or any case when the standard cold cathode high voltage is disabled). See section 8.5, Cold Cathode Control Set Point.

When a gauge is above or below its pressure range, "**H I**" or "**L O**" is displayed, with the exponent digit giving a reminder of what the range limit is (for example, "**L Ox10-3**" for a thermocouple below its pressure range limit of 1.0×10^{-3} Torr). The above range (or atmosphere) indication for a Pirani gauge is "**A Ax10+2**" Torr.

When a Pirani, thermocouple, or convection gauge is not connected properly or its sensor wire is broken, "- - -" is displayed.

8.2.1 Information Update Rate

The A/D has a conversion time of 50 milliseconds, so if signals from five gauges are being processed, the display and the logarithmic outputs for each gauge are updated every 250 milliseconds (in the PRESSURE or LEAK TEST functions). If there are fewer than five gauges installed, then the total pressure update cycle is the number of gauges multiplied by 50 milliseconds (in the PRESSURE or LEAK TEST functions).

All outputs remain active and are updated regardless of the function switch or gauge switch positions. This means, for example, that the 937 allows set points to be reviewed without interrupting data acquisition or any process using 937 outputs. However, when the 937 is switched to functions other than PRESSURE or LEAK TEST and is operating five gauges, the update time is 500 milliseconds rather than 250 milliseconds (100 milliseconds per gauge rather than 50). These update times do not apply to the buffered analog outputs or to the set point relays, which have a faster response. See section 1, Specifications, under Process Set Points and Relays Response Time.

There are some brief suspensions of the 50 (or 100) millisecond per gauge update time. These occur when the 937 performs self-calibration procedures, when the rotary switches are turned, when buttons are pressed, and when user calibration values are entered into nonvolatile memory. These suspensions are infrequent and are always less than a second. They will show themselves as short flat steps in plots of data acquired from the logarithmic outputs when polling is near the 250 (or 500) millisecond full cycle update rate.

8.3 Leak Test

Leaks in vacuum systems are often difficult to locate and typically require the use of mass spectrometer leak detectors and skilled operators. While the SensaVac® Series 937 is not intended to replace mass spectrometer leak detectors, it offers an ideal, inexpensive, and simple method for locating leaks in high vacuum systems. The leak test sensitivity depends on the pumping system and the location of the sensor with respect to the leak, as well as the difference in some physical property between the probe gas and the system background gas.

Since the indicated pressure of a cold cathode or a thermal conductivity type gauge is dependent on the type of gas being measured, introducing a probe gas through a leak into a steady state system will change the indicated pressure. The 937 controller uses a center zero bar graph to indicate gas leaks. The bar graph indicates pressure deviations with greater sensitivity than the displayed measurement.

To use the LEAK TEST function, pump the system to as low a pressure as possible. Then turn the FUNCTION SELECT switch to the LEAK TEST function and the GAUGE SELECT switch to the gauge that will be the leak test sensor. The pressure of the gauge continues to be displayed. The 26 segment center zero bar graph is activated. An audible indication of leak signal is selectable from the front panel.

A probe gas entering the gauge through a leak will cause segments to appear on one side of the center zero marker. The resolution of the bar graph is nonlinear with the first segment more sensitive and subsequent segments less sensitive. The bar graph can be rezeroed to compensate for system pressure drift or increased background due to residual search gas by pressing the ZERO push button.

See Appendix B for a detailed discussion of leak testing, including useful probe gases.

NOTE: The set points remain active in the LEAK TEST function, and entry of probe gas may cause enough indicated pressure change to switch relay states. It may be best to disable any process control while probe gas enters the vacuum system.

The LEAK TEST function will work with the cold cathode gauge, and with Pirani, thermocouple, and convection thermal conductivity gauges. The capacitance manometer will not work as a leak test gauge for the LEAK TEST function, because it is a gas independent type of sensor. If the GAUGE SELECT switch is set to a capacitance manometer or a channel with no gauge installed, the display will show "n o" on the display line of the selected channel and indicate which channels have leak test gauges installed on them: "C C" indicates a cold cathode gauge; "P i r" indicates a Pirani gauge; "t c" indicates a thermocouple gauge; "C o n" indicates a convection gauge. "n o" will appear on the display line of any channel with a capacitance manometer or any channel without a gauge.

The audio indicator emits beeps with a repetition rate proportional to the amplitude of the leak signal. The audio indicator can be silenced or reactivated by pressing the BEEPER push button.

8.4 Set Point Adjust

The SET POINT ADJUST function is used to review and set the switching pressures of the set point relays. The SPDT relay contacts are accessible through the rear panel ACCESSORY connector on the power supply plug-in. See Figure 29 in Appendix E for the pinout.

To read the set point trip value, turn the FUNCTION SELECT switch to the SET POINT ADJUST function, and the GAUGE SELECT switch to the desired gauge (or set point). The pressure displayed is the pressure at and below which the corresponding set point relay will be energized, i.e. the normally open (N.O.) terminal will be in contact with the common (C) terminal.

If the GAUGE SELECT switch is set to a channel that has no gauge installed, the display will show "n o" on the display line of the selected channel and indicate which channels have gauges installed: "C C" indicates a cold cathode gauge; "P i r" indicates a Pirani gauge; "C A P" indicates a capacitance manometer; "t c" indicates a thermocouple; "C o n" indicates a convection gauge. "n o" will appear on the display line of any channel without a gauge, and therefore without a set point.

The SP1 to SP5 indicators show the status of each set point relay. These indicators are lit when the corresponding relays are energized. The standard cold cathode controls one set point relay (i.e., SP1). A dual gauge module plugged into slot A or slot B controls one set point relay per gauge. A single gauge module plugged into slot A or slot B controls both set point relays associated with its slot (i.e. SP2 and SP3 for slot A, SP4 and SP5 for slot B).

The set points may be set within these values:

Cold Cathode:
2.0×10^{-10} to 9.5×10^{-3} Torr
2.7×10^{-10} to 1.2×10^{-2} mbar
2.7×10^{-8} to $1.2 \times 10^{+0}$ Pascal
2.0×10^{-7} to $9.5 \times 10^{+0}$ micron

Pirani:
2.0×10^{-3} to $9.5 \times 10^{+1}$ Torr
2.7×10^{-3} to $1.2 \times 10^{+2}$ mbar
2.7×10^{-1} to $1.2 \times 10^{+4}$ Pascal
$2.0 \times 10^{+0}$ to $9.5 \times 10^{+4}$ micron

Thermocouple:
2.0×10^{-3} to 9.5×10^{-1} Torr
2.7×10^{-3} to $1.2 \times 10^{+0}$ mbar
2.7×10^{-1} to $1.2 \times 10^{+2}$ Pascal
$2.0 \times 10^{+0}$ to $9.5 \times 10^{+2}$ micron

Convection gauge:
2.0×10^{-3} to $9.5 \times 10^{+2}$ Torr
2.7×10^{-3} to $1.2 \times 10^{+3}$ mbar
2.7×10^{-1} to $1.2 \times 10^{+5}$ Pascal
$2.0 \times 10^{+0}$ to $9.5 \times 10^{+5}$ micron

Capacitance Manometer:
(1 Torr head example)
2.0×10^{-2} to 9.5×10^{-1} Torr
2.7×10^{-2} to $1.2 \times 10^{+0}$ mbar
$2.7 \times 10^{+0}$ to $1.2 \times 10^{+2}$ Pascal
$2.0 \times 10^{+1}$ to $9.5 \times 10^{+2}$ micron

Set point range for each capacitance manometer head is from 2% to 95% of the full measurement range of the head.

There may be differences between the actual trip value and the trip value that is set, due to hysteresis. Fast set point relay response is provided by using analog comparators with hysteresis built-in. The hysteresis of the analog circuitry will be most noticeable at pressures where gauge curves are relatively flat (near the top or bottom of pressure range for most gauges).

The set point relays are not disabled while in the SET POINT ADJUST function. This allows a review of the set point values without interfering with data acquisition or process control.

Care should be taken when adjusting a set point value because the relay may change state when a new set point is stored (which occurs when either the FUNCTION SELECT or the GAUGE SELECT switch is turned to another position).

The set point pressures are easily changed by pressing the UP or DOWN push buttons, while the GAUGE SELECT switch is set to the desired gauge (or set point) position:

- to increment the set point pressure by one least significant digit, press and release the UP push button;
- to rapidly increment the set point pressure, press and hold the UP button;
- to decrement the set point pressure by one least significant digit, press and release the DOWN push button;
- to rapidly decrement the set point pressure, press and hold the DOWN button.

A set point value of "0.0" disables the set point. To set this value, first adjust the set point to the bottom of its range, then press the DOWN button one more time. The set point will decrement to "0.0". If the relay was energized, it will change state when the set point decrements to "0.0".

When new, the 937 is shipped with the set points disabled, i.e., set to "0.0". Use the UP push button to bring the set point into range.

A new set point will take effect and be saved in nonvolatile memory when either the FUNCTION SELECT switch or the GAUGE SELECT switch is turned to another position. The new value will not be saved if power to the 937 is switched off before the function or gauge switch is turned.

8.5 Cold Cathode Control Set Point

The C.C.CONTROL SET POINT function is used to review and set the control set point value for the **standard cold cathode**. The control set point value is the pressure from the **control gauge** above which the high voltage of the standard cold cathode will be switched off by the 937. As the pressure reading from the control gauge falls back below the control set point pressure, the 937 will resume gauge operation (if no disable source has come into effect, such as from communications).

The control gauge channel is selected with DIP switches on the Analog Module (see section 7.6). The control channel can be channel A1, A2, B1, or B2. Appropriate control gauges are the Pirani, thermocouple, convection, and the 1 Torr and .1 Torr capacitance manometer heads.

If there is no gauge installed on the selected control channel, or if the gauge that is installed there is not an appropriate control gauge, or if there is no standard cold cathode installed, "Error" is displayed. Otherwise, the control set point pressure is displayed on the control channels display line.

When a control set point pressure is on display, it may be adjusted with the UP or DOWN push buttons:

- to increment the set point pressure by one least significant digit, press and release the UP push button;
- to rapidly increment the set point pressure, press and hold the UP button;
- to decrement the set point pressure by one least significant digit, press and release the DOWN push button;
- to rapidly decrement the set point pressure, press and hold the DOWN button.

A set point value of "0.0" disables the set point. To set this value, first adjust the control set point to the bottom of its range, then press the DOWN button one more time. The control set point will decrement to "0.0".

When new, the 937 is shipped with the control set points disabled, i.e., set to "0.0". Use the UP push button to bring the set point into range. The control set point ranges for the various control gauges are the same as the set point ranges listed in section 8.4.

When in the C.C.CONTROL SET POINT function, "C C C" is displayed on the top display line to prevent confusion with the SET POINT ADJUST function.

If the high voltage of the standard cold cathode is disabled by the control gauge, "O F F" will appear on the standard cold cathode's display line and the "CONTROL" indicator will be lit. If the disable originates from a different source "O F F" will still appear on the display, but the "CONTROL" indicator will not be lit. Other methods of disabling cold cathode gauges are discussed in section 7.1.

A new control set point will take effect and be saved in nonvolatile memory when the FUNCTION SELECT switch is turned to another position. The new value will not be saved if power to the 937 is switched off before the FUNCTION SELECT switch is turned. The control set point can be reviewed without affecting any outputs by exiting the C.C.CONTROL SET POINT function with the original value displayed.

When using the control set point feature with a Pirani, convection, or thermocouple control gauge, and this control gauge becomes disconnected or fails while the 937 is in operation, the standard cold cathode high voltage will be switched off (the control set point must be SET, or not equal to "0.0", for this to occur).

CAUTION! For the control gauge to properly control the standard cold cathode gauge, both gauges should be sensing the same pressure.

CAUTION! All of the gauges controlled by the 937 except for capacitance manometers are gas dependent. When using the 937 with gases other than nitrogen, the standard cold cathode gauge and the control gauge may not agree near the control set point.

8.6 Capacitance Manometer Zero Correction

To determine if a capacitance manometer requires its zero to be corrected, pump the gauge to a pressure at least 1½ decades below the gauge's lower limit. If the pressure displayed in the PRESSURE function is "L O" (or "0.0" in the ZERO CAP.MAN. function), then there is no need to correct the gauge's zero.

If a zero correction is necessary, turn the FUNCTION SELECT switch to the ZERO CAP.MAN. function, and the GAUGE SELECT switch to the desired capacitance manometer. The pressure of the capacitance manometer selected by the GAUGE SELECT switch continues to be displayed and the "CM ZERO" function indicator is lit. If the switch is set to a channel without a capacitance manometer, "C A P" will be displayed on all channels with capacitance manometers and "n o" on channels without (capacitance manometer channels with invalid heads selected will also show "n o" -- see section 7.3).

Zero correction with the ZERO CAP.MAN. function requires the capacitance manometer's voltage be within ±200 millivolts of zero. If the reading is outside these limits, "o u t" will momentarily appear on the display and the zero value will not be accepted (in this case, an adjustment needs to be performed on the gauge head). The 26 segment center zero bar graph is activated to indicate positive and negative voltage signals with a resolution of 5 millivolts per segment. Negative voltage is indicated on the display with a minus sign preceding a single pressure digit and the exponent.

Pressing the ZERO button will set the new zero value (if within range), reset the pressure seen on the display to "0.0", and clear all bar graph segments. The user calibration indicator, "U", will be displayed to signify that a zero correction has occurred.

Pressing the ZERO OFF button will clear the zero correction, and switch the user calibration indicator off. The pressure display and bar graph will indicate values without zero correction (i.e., with a factory zero of 0, for a gauge head with a perfect zero).

Zero correction values are saved in nonvolatile memory after the push button is released.

CAUTION! A large change in the zero correction may cause set point relays controlled by the capacitance manometer to change state, and create a jump in the logarithmic and communication outputs.

8.6.1 Capacitance Manometer Auto Zero Operation

The capacitance manometer auto zero feature is enabled by setting DIP switch 4 on the capacitance manometer plug-in module to its ON position (see Section 7.3). The auto zero feature resets the capacitance manometer zero when the **standard cold cathode** gauge indicates vacuum system pressure is low enough. The capacitance manometer and the standard cold cathode should be on the same portion of the vacuum system, exposed to the same (or negligibly different) system pressure. Also, the standard cold cathode should not be allowed to operate above 0.1 Torr to avoid an erroneous measurement by the cold cathode from initiating an auto zero sequence.

The pressure below which auto zeroing happens is either 1½ decades below the low pressure limit for the capacitance manometer head or 1.0×10^{-2} Torr, whichever is less. The auto zeroing process cannot begin above 1.0×10^{-2} Torr since that is the top of the cold cathode's measurement range.

A delay of 3 or 30 seconds occurs after the high voltage for the standard cold cathode is enabled. No auto zeroing will occur until the delay has passed. See section 7.6 for information on the delay.

Zero setting for a capacitance manometer requires the gauge's voltage be within ±200 millivolts of zero. If the gauge's voltage exceeds these limits, auto zeroing will not be allowed (in this case, an adjustment needs to be performed on the gauge head).

If the standard cold cathode pressure is low enough, and the capacitance manometer signal is within range, a new zero setting is collected and "L O" is displayed for the capacitance manometer. When the pressure rises enough that either one of the above two conditions is no longer true, the last valid zero measurement will be used to correct the capacitance manometer.

NOTE: The "zero" value obtained during auto zeroing is not saved in nonvolatile memory and will be lost when the controller power is removed.

It is necessary for the conditions required for auto zeroing to be true for at least 30 seconds before bringing the pressure above the auto zero pressure. This allows time for the capacitance manometer to settle and for the set points to be corrected for the zero shift.

8.7 Pirani/Thermocouple/Convection Zero Calibration

The ZERO PIR./T.C. function is provided in case a Pirani, thermocouple, or convection gauge needs to be calibrated at vacuum. The 937 makes it easy to know whether one of these thermal conductivity gauges needs to be calibrated at vacuum. If some pressure is indicated, rather than "L O" or "0.0" when at vacuum, then a vacuum "UCAL" is needed.

Due to variations from gauge to gauge, **thermocouple gauges and convection gauges likely will require calibration even when new.** For convection gauges, if maximum accuracy is required, an atmosphere calibration may be required in addition to the vacuum (zero) setting (see section 8.8 and section 8.8.1). HPS Pirani gauges should not need any calibration beyond their factory calibration when new.

To zero calibrate a gauge, pump the system to a pressure 1½ decades below the gauge's lower limit. Pressures less than 1.0×10^{-5} Torr will work for all three gauge types.

The rear panel UCAL ENABLE/DISABLE switch on the Analog Module must be set to the ENABLED (up) position. If the switch is in the DISABLED (down) position, the display will show "UCAL disab" in this function.

NOTE: The UCAL ENABLE/DISABLE switch does not reset gauges to their factory calibration. The switch simply prevents (or enables) modifications to present gauge calibrations.

Turn the FUNCTION SELECT switch to the ZERO PIR./T.C. function, and the GAUGE SELECT switch to the desired thermal conductivity gauge. The pressure of the thermal conductivity gauge selected by the GAUGE SELECT switch continues to be displayed and the "ZERO" function indicator is lit. If the switch is set to a channel without a thermal conductivity gauge, the display will show "n o" on the display line of the selected channel and will indicate which channels have thermal conductivity gauges: "P i r" indicates a Pirani gauge; "t c" indicates a thermocouple; "C o n" indicates a convection gauge. "n o" will appear on the display line of any channel without a thermal conductivity gauge.

When in the ZERO PIR./T.C. function, and a thermal conductivity gauge is selected, the 26 segment center zero bar graph is activated to indicate differences between the gauge's signal and its factory calibration (or its last calibration value). The sensitivity of the bar graph varies with respect to the raw sensor signal, but each segment represents 5 millivolts with respect to the sensor signal times its gain. The gain for a Pirani is 3, for a thermocouple is 75, and for a convection gauge is 1.75.

The 937 does not allow a calibration when the reading from the gauge is outside the appropriate range. "o u t" will momentarily appear on the display after a zero calibration is attempted with pressure too high. In this case, the calibration will not be accepted. If the reading is within range, a press of the UCAL button will reset the pressure seen on the display to "0.0", and clear all bar graph segments. The user calibration indicator, "U", will be lit for the gauge. The new value is saved in nonvolatile memory after the push button is released.

Pressing the FCAL button will clear any zero calibration set with the ZERO PIR./T.C. function. The pressure display and bar graph will then indicate pressure based on the factory zero value. Unless there is a atmosphere calibration still in effect for the gauge that was set with the ATM PIR./T.C. function (see section 8.8), the user calibration indicator, "U", will clear.

CAUTION! A large change in the zero calibration may cause set point relays controlled by the gauge to change state, and create a jump in the logarithmic and communication outputs.

Summary of the zero calibration procedure:

1) put the UCAL ENABLE/DISABLE switch in its ENABLE (up) position (this switch is on the rear of the Analog Module);
2) pump the system to below $1x10^{-5}$ Torr;
3) turn the FUNCTION SELECT switch to the ZERO PIR./T.C. function.
4) turn the GAUGE SELECT switch to the gauge to be zeroed;
5) press the UCAL button (if "0.0" is seen on display after step 4, there is no need to rezero the gauge).

Pressing the FCAL button will restore the factory zero.

The 937 automatically adjusts for the new zero in such a way that the atmosphere calibration is not effected, so there is no need to do a atmosphere calibration simply because of the new zero.

8.8 Pirani/Thermocouple/Convection Atmosphere Calibration

The ATM PIR./T.C. function is provided in case a Pirani, thermocouple, or convection gauge needs to be calibrated at atmospheric pressure. The 937 makes it easy to know whether a Pirani or thermocouple gauge needs to be calibrated at atmosphere. If some pressure is indicated, rather than "A A" or "H I" when at atmospheric pressure, then a atmosphere "UCAL" is needed (this rule cannot be followed for the convection gauge, however). **There is more to know about convection gauge atmosphere calibration than is given in this section.** Read section 8.8.1 in addition to this section to atmosphere calibrate a convection gauge.

Due to variations from gauge to gauge, **thermocouple gauges and convection gauges likely will require calibration even when new.** HPS Pirani gauges should not need any calibration beyond their factory calibration when new.

To calibrate a thermal conductivity gauge at atmosphere, vent the system to atmospheric pressure or backfill with nitrogen using a reference gauge to avoid overpressure conditions.

The rear panel UCAL ENABLE/DISABLE switch on the Analog Module must be set to the ENABLED (up) position. If the switch is in the DISABLED (down) position, the display will show "UCAL disab" in this function.

NOTE: The UCAL ENABLE/DISABLE switch does not reset gauges to their factory calibration. The switch simply prevents (or enables) modifications to present gauge calibrations.

Turn the FUNCTION SELECT switch to the ATM PIR./T.C. function, and the GAUGE SELECT switch to the desired thermal conductivity gauge. The pressure of the thermal conductivity gauge selected by the GAUGE SELECT switch continues to be displayed and the "ATM" function indicator is lit. If the switch is set to a channel without a thermal conductivity gauge, the display will show "n o" on the display line of the selected channel and will indicate which channels have thermal conductivity gauges: "P i r" indicates a Pirani gauge; "t c" indicates a thermocouple; "C o n" indicates a convection gauge. "n o" will appear on the display line of any channel without a thermal conductivity gauge.

The 937 does not allow a calibration when the reading from the gauge is outside the appropriate range. "o u t" will momentarily appear on the display after a atmosphere calibration is attempted with pressure too low. In this case, the calibration will not be accepted. If the reading is within range, a press of the UCAL button will reset the pressure seen on the display to "A A" for a Pirani, or "H I" for a thermocouple, or 760 Torr for a convection gauge. The user calibration indicator, "U", will be lit for the gauge. The new value is saved in nonvolatile memory after the push button is released.

Pressing the FCAL button will clear any atmosphere calibration set with the ATM PIR./T.C. function. The display will then indicate pressure based upon the factory atmosphere value. Unless there is a vacuum calibration still in effect for the gauge that was set with the ZERO PIR./T.C. function (see section 8.7), the user calibration indicator, "U", will clear.

CAUTION! A large change in the atmosphere calibration may cause set point relays controlled by the gauge to change state, and create a jump in the logarithmic and communication outputs.

NOTE: The HPS Pirani gauge has a response that is gas dependent above 1.0×10^{-2} Torr. Slight convection characteristics are exhibited near atmosphere in the HPS gauge. For this reason, if a user calibration is required, and accuracy above 30 Torr is necessary, then the Pirani tube should be oriented in a **vertical** direction with the port opening down. The gas should be air or predominantly nitrogen and the gauge operated for 10 minutes prior to calibration.

Summary of the atmosphere calibration procedure:

1) put the UCAL ENABLE/DISABLE switch in its ENABLE (up) position (this switch is on the rear of the Analog Module);
2) vent the system to atmosphere or backfill with nitrogen;
3) turn the FUNCTION SELECT switch to the ATM PIR./T.C. function;
4) turn the GAUGE SELECT switch to the gauge to be recalibrated;
5) press the UCAL button (if "A A" is seen on the display for a Pirani, or "H I" for a thermocouple after step 4, there is no need to press the UCAL button).

Pressing the FCAL button will restore the factory atmosphere value.

The 937 automatically adjusts for the new atmosphere value in such a way that the vacuum calibration is not effected, so there is no need to do a vacuum calibration simply because of the new atmosphere value.

8.8.1 Atmosphere Calibration for the Convection Gauge

When performing a atmosphere calibration on a convection gauge a number of variables must be taken into account. One important one is defining or determining atmospheric pressure accurately.

Atmospheric pressure will vary depending on the altitude, and to a lesser degree due to weather systems and climate control (e.g. heating, air conditioning, and positive pressure for clean rooms.) While the convection gauge pressure curve has enough slope around atmosphere due to convection, the curve is much flatter between 30 and 200 Torr. As a result, if a calibration is performed on a convection gauge at a pressure other than 760 Torr of nitrogen and with the tube horizontal, a 90% error can be created.

For example, if a atmosphere calibration were performed in Boulder, Colorado at 5400 feet, where the typical atmospheric pressure is 630 Torr, using the ATM PIR./T.C. function the following effect would be produced:

True pressure (Torr)	Indicated pressure following ATM UCAL at 630 Torr	% error
10	11	+10%
50	82	+64%
100	190	+90%
200	280	+40%
300	370	+23%
500	600	+20%
630	760	+21%
760	920	+21%
800	960	+20%
840	1000	+19%
900	H I x10+3	
1000	H I x10+3	

The 937 controller allows three methods to calibrate a convection gauge at atmosphere. The easy method is to perform the procedure given in section 8.8. After the UCAL button is pressed, the pressure displayed by the convection gauge will be "7.6x10+2" Torr. If the local atmospheric pressure happens to be 760 Torr, this is an accurate calibration.

If the atmospheric pressure is not 760 Torr, a more accurate method is to measure the atmospheric pressure using a reference gauge, and adjust the rear panel trimpot until the display indicates the correct value. Figure 10 on the next page shows the location of the trimpots, one for each gauge channel. This method is standard on controllers for convection gauges. The procedure is:

1) vent the system to atmospheric pressure or backfill with nitrogen, taking care not to create an overpressure condition;
2) while monitoring the display, adjust the rear panel trimpot for the appropriate gauge until the displayed value agrees with the reference gauge;
3) calibrate the gauge at vacuum using the ZERO PIR./T.C. function (see section 8.7).

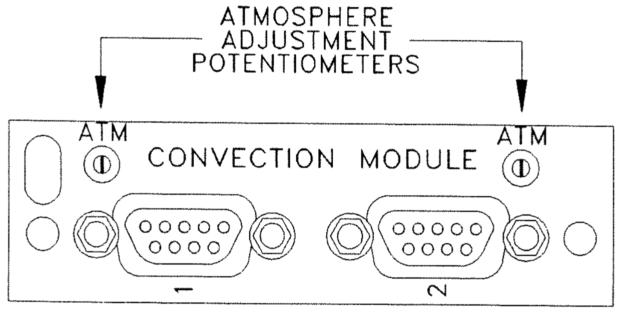


FIGURE 10 - LOCATION OF ATMOSPHERE ADJUSTMENT TRIMPOTS ON REAR OF CONVECTION GAUGE PLUG-IN MODULE

The third method is a combination of the first two. If the reference gauge happens to be a 1,000 or 10,000 Torr capacitance manometer and a method of maintaining a pressure of 760 Torr is available, then there is no need to adjust the rear panel trimpot. With the capacitance manometer and the convection gauge on the same portion of the vacuum system, and the pressure controlled to 760 Torr, the ATM PIR./T.C. function as described in section 8.8 will provide an accurate calibration. Vacuum calibration is not necessary when the ATM PIR./T.C. function (alone) is used.

CAUTION! A large change in the atmosphere calibration may cause set point relays controlled by the gauge to change state, and create a jump in the logarithmic and communication outputs.

8.9 Quick Reference Tables

Table I Effect of GAUGE SELECT and push button switches in the eight primary 937 functions.

FUNCTION SELECT SWITCH	FRONT PANEL PUSH BUTTONS		GAUGE SELECT SWITCH	DISPLAY
	LEFT	RIGHT		
PRESSURE	No effect	No effect	No effect	Shows pressure from ALL sensors
LEAK TEST	Toggles BEEPER on/off	Re ZEROes leak test bargraph and beeper	Selects sensor for leak testing	Shows pressure from leak test sensor
SET POINT ADJUST	Changes set point DOWN	Changes set point UP	Selects set point for adjustment	Shows set point pressure value "0.0" if disabled
CC CONTROL SET POINT	Changes set point DOWN (unless	Changes set point UP "Error")	No effect	Shows set point pressure value (or "Error") [top line="CCC"]
ZERO CAP MAN	Takes the ZERO OFF	Re-ZEROes the CM	Selects capacitance manometer	Shows pressure from the CM or "0.0"
ZERO PIR/TC	Returns to FCAL (unless	Saves new UCAL "UCAL disab")	Selects sensor for calibration	Shows pressure from the sensor or "0.0" (or "UCAL disab")
ATM PIR/TC	Returns to FCAL (unless	Saves new UCAL "UCAL disab")	Selects sensor for calibration	Shows pressure from the sensor or "AA" or "HI" (or "UCAL disab")
DISPLAY TEST	Steps DOWN thru. info displays	Steps UP thru info. displays	No effect	Shows information displays

Table II Display information in the eight primary 937 functions.

FUNCTION SELECT SWITCH	DISPLAY ANNUNCIATORS						
	SP(X) & CONTROL	FUNCTION	UNIT	CHANNEL	U (CAL)	BAR-GRAPH	BEEPER
PRESSURE	Lit for active relays	None	Lit	Lit for active channels	Lit for sensors w/UCAL	Not used	Off
LEAK TEST	Lit for active relays	LEAK TEST ¦ <> ¦	Lit	Lit for active channels	Lit for sensors w/UCAL	Shows leak info.	On or Off
SET POINT ADJUST	Lit for active relays	None	Lit	Lit for active channels	Lit for sensors w/UCAL	Not used	Off
CC CONTROL SET POINT	Lit for active relays	None "CCC" on top line	Lit	Lit for active channels	Lit for sensors w/UCAL	Not used	Off
ZERO CAP MAN	Lit for active relays	CM ZERO	Lit	Lit for active channels	Lit for sensors w/UCAL	Shows voltage from CM	Off
ZERO PIR/TC	Lit for active relays	ZERO	Lit	Lit for active channels	Lit for sensors w/UCAL	Shows sensor voltage	Off
ATM PIR/TC	Lit for active relays	ATM	Lit	Lit for active channels	Lit for sensors w/UCAL	Not used	Off
DISPLAY TEST (Review)	No indica-tion	None	(See Section 8.1 above)			Not used	Off

8.10 Serial Communications

Two types of serial interface are provided by the RS-232 Module: the 3-wire **RS-232** interface, and the 2-wire **RS-485** interface for multipoint applications. The pressure from any gauge, the pressure unit, the type of gauge in use, and the state of any set point relay may be read. A set of control commands allows enabling and disabling of any cold cathode gauge's high voltage, and enabling and disabling of any set point relay.

Baud rates are selected by setting DIP switches on the RS-232 / RS-485 plug-in module. **Baud rates of 2400, 4800, 9600, 19200, or 57600 are selectable.** The 57600 rate may not be usable with all types of hardware as it exceeds the transmission rate specified by the RS-232 standard. See section 7.10 for RS-232 / RS-485 installation.

The serial data format used with the RS-232 and RS-485 interfaces is 8 data bits, 1 stop bit, and even parity. Data is ASCII. Since all communication transfers are short strings (3 or 8 characters) neither hardware handshaking nor software handshaking (i.e. XON/XOFF) is implemented.

8.10.1 RS-232 Interface

The RS-232 interface is implemented using the minimal 3-wire method for transmitted data (TXD), received data (RXD), and signal ground (SG). The connections on the 9-pin D-sub are the same as the standard PC-AT connections for a DTE (data terminal equipment) device. See Figure 20 in Appendix E for connecting to DTE devices using either the standard 25-pin D-sub connectors or the PC-AT's 9-pin D-sub connector. See section 7 and subsection 7.10 for RS-232 installation (DIP switch setting).

8.10.2 RS-485 Interface

RS-485 is a balanced line interface, and is implemented using two wires. This implementation does not allow more than one device to be transmitting at any time. See Figure 21 in Appendix E for cabling information. See section 7 and subsection 7.10 for RS-485 installation (DIP switch setting).

RS-485 allows multiple 937 controllers to be connected via two wires to a main computer. This multi-point distribution method requires a unique address for each device on the two wire bus. A special "attention" character then precedes each address and alerts all devices on the bus that an address will follow. The "$" (0100100B or 24H) is the "attention" character, and may not be used for any other purpose. DIP switch bank SW3 selects a binary code representing an ASCII character and that character is the controller's address. ASCII characters recommended for addresses include "0-9" (30H-39H), "A-Z" (41H-5AH) and "a-z" (61H-7AH).

The most efficient way to modify a computer's (PC's) RS-232 serial port for use with RS-485 is to purchase an interface converter that controls the transmitter using the RTS (Request to Send) signal. The RTS signal needs to be activated before each transmission and deactivated following each transmission. An example of a BASIC program that controls the RTS line of a PC type computer is given in Appendix D.

Another method of transmitter control provided by some interface converters detects data coming from the computer to enable the transmitter. The length of time the transmitter is enabled is dependant on the design of the interface converter but the transmitter is disabled some time after the transmission is completed.

RS-485 communications at high speed and over long wires may require both ends of the transmission line to be terminated in the characteristic impedance of the cable. The holes on the plug-in board marked "R1" are provided to allow the customer to add a termination resistor if required. NOTE: this resistor should only be used on plug-in if it is located at the end of the transmisson line.

8.10.3 Commands and Responses

There are three types of commands available when using the 937's communications port. **Read commands** provide pressure measurement information. **Status commands** provide set-up and set point relay state information. **Enable / Disable commands** enable or switch off set point relays or the high voltage of cold cathode gauges.

An additional command type exists for **RS-485** applications to help minimize data collision problems, i.e. when two transmitters are on at the same time. These are **time delay commands** and they vary the time before the 937 responds to a command.

Each command consists of three ASCII characters including a carriage return <CR>.

For **RS-485** commands, the **attention character** and the **address character** are appended to the beginning of the command.

All pressure and status data responses from the 937 consist of eight ASCII characters. All responses indicating an error has occurred also consist of eight ASCII characters. If the command is an enable or disable and there is no error, the response is "**OK**<CR>" (a three character response including the carriage return).

(1) READ COMMANDS: (mnemonic: R means Read)

Command	Structure of response strings:
R1 Read standard channel(CH.1)	**m.lEexp**<CR>
R2 Read channel A1 (CH.2)	**m.lEexp**<CR>
R3 Read channel A2 (CH.3)	**m.lEexp**<CR>
R4 Read channel B1 (CH.4)	**m.lEexp**<CR>
R5 Read channel B2 (CH.5)	**m.lEexp**<CR>

where: **m** = most significant digit (msd)
"**.**" = ASCII character (2EH)
l = least significant digit (lsd)
"**E**" = ASCII character (45H)
exp = sign (+ or -), exponent msd, exponent lsd
<CR> = carriage return (0DH)
all numbers are ASCII format

Response strings for read pressure commands will typically indicate what is on the 937 display when PRESSURE is the selected function. Response strings that differ from the display are "HV OFF <CR>" instead of "O F F", "MISCONN<CR>" instead of "- - -", and "NOGAUGE<CR>" instead of a blank display line. All responses to read commands are eight characters long. Spaces (ASCII 20H) are used to fill out a reply that is shorter than eight characters. The carriage return (ASCII 0DH) is always the eighth character.

Examples of responses to read commands:

6.4E-04<CR> ...pressure in a region of 1% resolution;

6E-04<CR> ...pressure in a region of 10% resolution;

H IE+04<CR> ...gauge is above its pressure range (4 is the top exponent for a 10,000 Torr head capacitance manometer);

A AE+02<CR> ...Pirani is above its pressure range (or at atmosphere);

L OE-03<CR> ...gauge is below its pressure range (-3 is the bottom exponent for a thermocouple gauge);

L O <CR> ...cold cathode gauge is below its pressure range (or possibly system pressure is above .1 Torr and the cold cathode, still with its high voltage on, is in a "rollback" condition -- the -11 exponent is not given because of this possibility);

MISCONN<CR> ...Pirani, thermocouple, or convection gauge is not connected properly or its sensor wire is broken;

NOGAUGE<CR> ...there is no gauge on the channel, or a gauge plug-in module other than a cold cathode module is in the standard slot, or the capacitance manometer on the channel has its DIP switches in invalid positions;

HV OFF <CR> ...cold cathode gauge high voltage is disabled.

The "E" in the response string allows the use of BASIC's VAL command.

```
Examples:      response$="6.4E-04",  VAL(response$) = .00064;
               response$="   6E-04", VAL(response$) = .0006 ;
               response$="L OE-03",  VAL(response$) = 0     .
```

(2) STATUS COMMANDS: (mnemonic: S means Status)

SP	Set Point relay status
SG	Gauge modules installed
SU	pressure Unit selected

Examples of responses:

sp00110<CR>

CcPrCm <CR>

Torr <CR>

For the SP command, 1 = relay energized, 0 = relay off, disabled, or no gauge on the channel. The order is SP1>SP2>SP3>SP4>SP5, so that in the above example SP1 is off, SP2 is off, SP3 is ON, SP4 is ON, SP5 is off.

For the SG command, the order is standard slot > slot A > slot B, so that in the above example, there is a standard cold cathode installed, a Pirani in slot A, and a capacitance manometer in slot B. The complete list of gauge types is: **Cc** = cold cathode; **Pr** = Pirani; **Cm** = capacitance manometer; **Tc** = thermocouple; **Cv** = convection gauge; **Nc** = no gauge module in slot; **Wc** = wrong gauge module in standard slot.

For the SU command, the complete list of responses is: **Torr** <CR>; **mbar** <CR>; **Pascal** <CR>; **micron** <CR>.

(3) ENABLE / DISABLE COMMANDS: (E = Enable, X = Disable)

Command	Responses other than "OK<CR>"
E1 enables relay SP1	**NO SCC!** <CR> if no stand.cold cathode
E2 enables relay SP2	**NO CARD!**<CR> if no module in slot A
E3 enables relay SP3	**NO CARD!**<CR> if no module in slot A
E4 enables relay SP4	**NO CARD!**<CR> if no module in slot B
E5 enables relay SP5	**NO CARD!**<CR> if no module in slot B
X1 disables relay SP1	**NO SCC!** <CR> if no stand.cold cathode
X2 disables relay SP2	**NO CARD!**<CR> if no module in slot A
X3 disables relay SP3	**NO CARD!**<CR> if no module in slot A
X4 disables relay SP4	**NO CARD!**<CR> if no module in slot B
X5 disables relay SP5	**NO CARD!**<CR> if no module in slot B
ES enables stand.cold cath.HV	**NO SCC!** <CR> if no stand.cold cathode
EA enables slotA cold cath.HV	**NOT CC!** <CR> if not a cold cathode
EB enables slotB cold cath.HV	**NOT CC!** <CR> if not a cold cathode
XS disables stand.cold cath.HV	**NO SCC!** <CR> if no stand.cold cathode
XA disables slotA cold cath.HV	**NOT CC!** <CR> if not a cold cathode
XB disables slotB cold cath.HV	**NOT CC!** <CR> if not a cold cathode

("HV" = High Voltage)

NOTE: A **disable** will always force an item off regardless of enables from other sources. However, an **enable** is only an enable from communications and will not switch an item on if it is disabled from another source.

An "**OK**" response means the command has been received and did not generate an error.

For **RS-485** there are **TIME DELAY COMMANDS:** (mnemonic: T means Time)

Command	Responses other than "OK<CR>"
T1 sets 1 msec. Time delay	**NOT485!**<CR> if using RS-232
T4 sets 4 msec. Time delay	**NOT485!**<CR> if using RS-232
T8 sets 8 msec. Time delay	**NOT485!**<CR> if using RS-232

These time delays are effective immediately after reception. At power-on the default time delay is 8 msec. and any changes made are not saved when power is removed. The delay will only occur for RS-485. The time delay settings are useful for systems with a delay of more than 0.5 msec. between the end of data transmission and when the RS-485 transmitter is disabled.

8.10.4 Error Responses

There are two basic error responses: **SYNTAX!** and **NotCMD!**. Error messages always end with a "!" (just before the carriage return).

SYNTAX! is the response sent when the command string has too few or too many characters transmitted. There is no response until either a carriage return or a third character is received. All commands are expected to have three characters with the third character being a carriage return. If less than three characters is received before a carriage return, or three characters are received but the third is not a carriage return, then **SYNTAX!** is transmitted.

NotCMD! is transmitted for a two character plus carriage return command string that is not one of the commands serviced by the 937.

There are also four operational error responses or messages: **NOT485!**, **NO SCC!**, **NOCARD!**, and **NOT CC!**. Operational error messages are used to indicate that a set-up problem will not allow the command to be executed. These messages are sent only for enable, disable and time delay commands and only when the error condition exists. If no error condition exists then **OK** will be the response.

All response strings are 8 characters long including the carriage return except for OK<CR>, which is 3 characters long.

8.10.5 Parity

A parity bit is sent for each character transmitted. If the number of ones in the ASCII code for the character is odd, then the parity bit is 1, i.e. even parity. Otherwise, the parity bit is 0.

There is no parity checking performed by the 937 on received characters. The characters used for commands (i.e. R, S, E, X, and T) were selected in order to minimize the possibility that a transmission error could be incorrectly interpreted and result in an undesirable action.

8.10.6 Character Pacing and Timeout

The serial data bit stream consists of a start bit, 8 data bits, a parity bit and a stop bit resulting in 11 bits transmitted for each character. The time required to transmit one character as a function of the baud rate is:

2400 baud:	4.58 msec./character;
4800 baud:	2.29 msec./character;
9600 baud:	1.15 msec./character;
19200 baud:	0.57 msec/.character;
57600 baud:	0.19 msec./character.

Data is transferred from the 937's main processor to the communications plug-in module 20 times per second. This transfer requires about 0.3 msec. of the communication processor's time. Another 0.3 msec. is required each time a character is received through the serial port. But, the RS-232 / RS-485 plug-in module can only buffer one character, and without some delay between incoming characters, at 57600 baud the 937 will not acquire all of the transmitted characters. **A delay between characters of 0.15 msec.is required when operating at 57600 baud.** The delay is measured between the stop bit of one character and the start bit of the next character. This delay is typically not required when the 937 is transmitting a response to the host computer so data throughput is only reduced during transmissions of commands.

The 937 typically requires between 0.5 and 1.5 msec. for processing before a response is transmitted. Thus the time between the 937 receiving the full command and the host computer receiving the full response should be a maximum of 44, 24, 13, 8, and 5 msec. for the respective baud rates. These time estimates include a software processing time of 3 msec. (with a 1 msec. safety margin over the longest known processing time).

The response times listed above are for RS-232. When using RS-485 there is an additional 8, 4, or 1 msec. software delay. The two later delays may be selected using the time delay (T) commands (see section 8.10.3).

The information provided here may be used to calculate a reasonable value for a software timeout. A **timeout** is a period used for determining if a response will be received in the event the unit has been switched off. The maximum delay between transmission of the command string and receipt of the full response is 52 msec.

8.10.7 Miscellaneous

For RS-485, the attention character, "$", must be received and immediately followed by the DIP switch selected, ASCII character, address code. The next character received will be interpreted as the first command character. The attention and address characters must precede every command, every time. All commands must be preceded by the attention and address characters.

Both the RS-232 and the RS-485 interfaces are implemented as half duplex and reception by the 937 is disabled whenever a transmission by the 937 is required. Therefore transmission of multiple commands to the 937 without waiting for the responses is not allowed.

Within one second after the 937 is powered, the first transfer of pressure and status information occurs between the main processor and the communications processor. However, since no gauge measurements are made for 3-4 seconds after power-on, there is no pressure information available. If a "read pressure" command is issued during this period, the response will be "NOGAUGE". All other commands are unaffected by the pressure information and will therefore be processed as expected.

It is necessary that all ASCII characters received have 0's in bit 7; extended ASCII is not accommodated. Linefeeds are ignored by the 937, since they can follow a carriage return in BASIC. No other 7-bit ASCII characters are ignored.

8.11 IEEE-488 Parallel Communications

With the IEEE-488 communications board, the pressure from any gauge, the pressure unit, the type of gauge in use, and the state of any set point relay may be read. A set of control commands allows enabling and disabling of any cold cathode gauge's high voltage, and enabling and disabling of any set point relay. The data format is 7 bit ASCII. Since all communication transfers are short strings (3 or 8 characters) bus interaction occurs at a high rate.

The IEEE-488 bus interface implemented is actually a subset of the full IEEE-488 specification. The 937 can act only as an addressed talker or an addressed listener. Parallel Poll is not implemented as status of the 937 can be checked by issuing one of the status commands, **SU**, **SG**, or **SP**. If the correct response is received it can be assumed that the 937 is powered and operational.

When a command is received by the IEEE Communications board, it is processed by an on board microcontroller and when a reply is ready to be transmitted, a serial poll request is issued to the host computer. The command string sent by the host computer must be two ASCII characters and an ASCII "carriage return" (0DH). The interface should be set up so no "line feed" is transmitted to the 937. EOI handshaking is not implemented and should be disabled for both transmit and receive modes in the host. Secondary addressing is not implemented and the talk and listen address must be the same.

Possible card addresses are from 0-30 decimal. Keep in mind that each instrument on the bus must have its own unique address and this includes the "Controller In Charge" which is typically the host computer. See section 7 and subsection 7.11, IEEE-488 installation (address selection is via DIP switches on the IEEE-488 board).

IEEE-488 commands and responses are exactly the same as described in full detail in section 8.10.3. **See section 8.10.3** (ignore RS-485 information). For error responses, **see section 8.10.4.**

The 937 typically requires between 0.5 and 1.5 msec. for processing before a response is transmitted. Thus the time between the 937 receiving the full command and the host computer receiving a serial poll request should be a maximum of about 2 msec. This information may be used to calculate a reasonable value for a software timeout. A **timeout** is a period used for determining if a response will be received in the event the unit has been switched off.

Within one second after the 937 is powered, the first transfer of pressure and status information occurs between the main processor and the communications processor. However, since no gauge measurements are made for 3-4 seconds after power-on, there is no pressure information available. If a "read pressure" command is issued during this period, the response will be "NOGAUGE". All other commands are unaffected by the pressure information and will therefore be processed as expected.

It is necessary that all ASCII characters received have 0's in bit 7; extended ASCII is not accommodated. Linefeeds are ignored by the 937, since they can follow a carriage return in BASIC. No other 7-bit ASCII characters are ignored.

9. Error Messages

The HPS SensaVac® Series 937 controller is designed to be maintenance free under normal operation. There is one potential (but highly unlikely) fault in the 937 controller hardware that the software detects and displays an error message for should it occur. The message is "**corr Error**", which indicates a corruption was detected in certain critical elements of the nonvolatile memory. Other than "- - -" for improper gauge connection, the only error message apart from "corr Error" is "**Setup Error**". This message indicates that one or both of two detectable gauge plug-in module set-up errors have been made.

9.1 Power-On Error Messages

When power is switched on to the 937 all display segments used by the 937 are operated by the software for about three seconds to allow observation that all segments light. After this three seconds the display will blank, and one or both of the following two error messages could come on the display:

9.1.1 "corr Error" (nonvolatile memory corruption)

A serial EEPROM saves three different types of data in memory when the power to the 937 controller is off: (1) set point values; (2) user calibration values; (3) correction values. To prevent data corruption, an EEPROM with "inadvertent write" protection has been used and the 937 software has an error detection and correction scheme. Consequently, "corr Error" is extremely unlikely.

Correction values are written to the EEPROM when the microprocessor board is calibrated at the factory and they are never modified. The microprocessor uses these values to correct for up to 0.16% error due to the tolerance of the divider resistors at the input of the A/D converter. In the unlikely event the correction values can not be recovered, this message ("corr Error") will be displayed.

Press the UP button once to cancel the "corr Error" message. A "**CALL HPS**" message will come on screen next. Another press of the UP button will cancel this message, and the controller will then work normally -- except the lost correction factor (or factors) will no longer correct the effected channels A/D readings. This can cause errors of up to six most significant digits (60% of a decade) at pressures where gauge curves are relatively flat (near the top or bottom of pressure range for most gauges).

9.1.2 "Setup Error"

This message means one or both of the following:

(1) An invalid capacitance manometer head has been selected. When DIP switches 2 and 3 for either channel of the capacitance manometer plug-in module are switched to their OFF position, this does not code for any of the 6 capacitance manometer heads. See section 7.3.

(2) There are no gauge modules plugged into the 937, or the only ones plugged in are capacitance manometer modules which have the above set-up error, or the only gauge module plugged in is in the standard slot and it is not a cold cathode.

In case (1), the UP button will cancel the "Setup Error" message and subsequently the 937 will operate as though there was no gauge module plugged into the slot with the set-up error (i.e., display line blank, DAC output=10 volts). **In case (2)**, the UP button will not cancel the message, because in this case the 937 does not have any gauge to read and process (or it does not know which manometer head to process).

10. PARTS ORDERING

Replacement parts and subassemblies for the HPS SensaVac® Series 937 Controller may be obtained from HPS Division of MKS Instruments, Inc. in Boulder, CO. or any MKS Instruments, Inc. Sales Office. Orders for replacements should include the serial number.

Gauge Plug-in Modules

Description	Part Number
Cold Cathode Module	...100005964
Dual Pirani Module	...100005961
Single Pirani Module	100007033
Dual Capacitance Manometer	...100007321
Single Capacitance Manometer	100006037
Dual Thermocouple Module	...100006034
Single Thermocouple Module	100007034
Dual Convection Module	...100006550
Single Convection Module	100007035

Communication Plug-in Modules

Description	Part Number
RS-232 / RS-485 Module	100006040
IEEE-488 Module	100006799

System Plug-in Boards

Description	Part Number
Power Supply	100006181
Analog I/O Board	100006178

11. WARRANTY

11.1 Scope of Coverage

HPS Division of MKS Instruments, Inc. ("HPS") warrants the SensaVac® Series 937 Vacuum Gauge System and accessories to be free from defects in material and workmanship for a period of ONE YEAR from date of shipment by HPS or authorized representative to the original purchaser ("Purchaser"). Any product or parts of the product repaired or replaced by HPS under this warranty are warranted only for the remaining unexpired portion of the one year original warranty period applicable to the product which has been repaired or replaced. After expiration of the applicable warranty period, the Purchaser shall be charged HPS' current prices for parts and labor, plus any transportation for any repairs or replacements.

11.2 Repairs

The obligations of HPS under this warranty shall be at its option: (1) to repair, replace or adjust the product so that it meets applicable specifications published by HPS; or (2) to refund the purchase price.

11.3 Warranty Performance

To obtain warranty satisfaction, contact the following: HPS Division of MKS Instruments, Inc., 5330 Sterling Drive, Boulder Colorado, 80301, USA, Phone (303)449-9861.

11.4 What Is Not Covered The above warranties do not apply:

a. To damages or malfunctions due to failure to provide reasonable and necessary maintenance in accordance with HPS operating instructions.
b. To damages or malfunction due to chemical or electrolytic influences or use of the product in working environments outside the specification.
c. To fuses and all expendable items which by their nature or limited lifetime may not function for a year. If such items fail to give reasonable service for a reasonable period of time within the warranty period of the product they will, at the option of HPS, be repaired or replaced.
d. To defects or damages caused by modifications or repairs not authorized in this manual effected by the original purchaser or third parties.

11.5 Other Rights and Remedies

a. These remedies are exclusive. HPS SHALL NOT BE LIABLE FOR CONSEQUENTIAL DAMAGES, FOR ANTICIPATED OR LOST PROFITS, INCIDENTAL DAMAGES OR LOSS OF TIME OR OTHER LOSSES INCURRED BY THE PURCHASER OR BY ANY THIRD PARTY IN CONNECTION WITH THE PRODUCT COVERED BY THIS WARRANTY, OR OTHERWISE. SOME STATES DO NOT ALLOW THE EXCLUSION OR LIMITATION OF INCIDENTAL OR CONSEQUENTIAL DAMAGES, SO THE ABOVE LIMITATION OR EXCLUSION MAY NOT APPLY TO PURCHASER. ANY IMPLIED WARRANTY ON THESE PRODUCTS SHALL BE LIMITED TO ONE YEAR FROM DATE OF SHIPMENT TO PURCHASER. SOME STATES DO NOT ALLOW LIMITATIONS ON HOW LONG AN IMPLIED WARRANTY LASTS SO THE ABOVE LIMITATIONS MAY NOT APPLY TO PURCHASER.
b. Unless otherwise explicitly agreed in writing, it is understood that these are the only written warranties given by HPS. Any statements made by any persons including representatives of HPS which are inconsistent or in conflict with the terms of the warranty shall not be binding on HPS unless reduced to writing and approved by an authorized officer of HPS.
c. This warranty gives PURCHASER specific legal rights, and PURCHASER may also have other rights which vary from state to state.

APPENDIX A GAUGE THEORY

A.1 Theory of the Cold Cathode Ionization Gauge

Cold cathode ionization gauges have a number of inherent advantages. Among these are the fact that they have no filaments to burn out, which makes them immune to inrushes of air and relatively insensitive to damage by vibration. Also there is no x-ray limit for lower pressure measurements as is found with hot cathode ionization gauges. No adjustments such as emission current or filament voltage are necessary. Since there is no heating, and degassing is not required, there is little effect on the system. Properly designed sensor tubes can be cleaned and reused almost indefinitely. The control circuit is simple and quite reliable with only one current loop, as opposed to a hot cathode gauge which has three.

Penning developed the cold cathode ionization vacuum gauge in the 1930's to eliminate some of the limitations of the then prevalent hot cathode ionization gauge. His design used a wire anode loop at a potential of 2 to 10 KV with two grounded cathodes. A 1,000 to 2,000 Gauss magnet was placed around the tube.

The cold cathode magnetic discharge gauge sensor consists of a cathode and anode with a potential difference of several kilovolts. The electrodes are surrounded by a magnetic field, so arranged that the magnetic field is essentially perpendicular to the electric field. The crossed electric and magnetic fields cause the electrons to follow long spiral trajectories, which increases their likelihood of colliding with gas molecules, thereby providing a significant increase in ionization efficiency relative to a hot cathode gauge. In operation a near constant circulating electron current is trapped by the crossed fields. Collisions of electrons with residual gas molecules produce ions, which are collected by the cathode. The gauge current as a function of pressure obeys the relationship:

$$\mathbf{i}(\text{gauge}) = \mathbf{k}\ \mathbf{p}^{n}$$

where **k** is a constant
p is the pressure
n is a constant usually in the range of 1.00 to 1.15

This equation is valid for the pressure range from 10^{-8} Torr to an upper limit of about 10^{-3} Torr depending upon the series resistor used. Sensitivities of 1 to 10 Amps/Torr are not unusual.

Starting a cold cathode gauge depends upon some chance event such as field emission or a cosmic ray producing the first electron. This produces additional electron/ion pairs during its transit between the electrodes, and the discharge soon builds up to a stable value. Starting of the discharge normally requires a very short time at 10^{-6} Torr or above, a few minutes at 10^{-8} Torr, and longer times at lower pressures. An IgniTorr™ cold cathode starting device can significantly reduce starting times.

If the series resistor is small, e.g. one megohm, the current at high pressures becomes large and sputtering of the cathode can be a problem. Using a larger series resistor reduces the importance of sputtering, and causes the voltage across the tube to be pressure dependent for the range of 10^{-4} to 10^{-2} Torr. This permits extending the range of the cold cathode to 10^{-2} Torr. Because of the difficulty in maintaining the discharge at low pressures, gauges of the loop anode design do not work well below about 10^{-6} Torr. One way of reducing this problem is with a design which uses a cylindrical anode, cathode plates at each end, and a cylindrical magnet. During the 1950's, the inverted magnetron gauge was developed, which used auxiliary cathodes, and was able to measure pressures below 10^{-12} Torr.

Many electrode arrangements have been used in cold cathode gauges. Single feedthrough cold cathode gauges often suffer from spurious currents due to insulator leakage and field emission, which mask the small pressure dependent ionization currents. The HPS SensaVac® Series 937 gauge utilizes an inverted magnetron gauge tube designed to reduce these problems by using separate feedthroughs for the anode high voltage and the cathode current. This geometry uses a cylindrical cathode, a central wire anode, and external cylindrical magnet which provides an axial field. The cathode is insulated from the grounded metal housing.

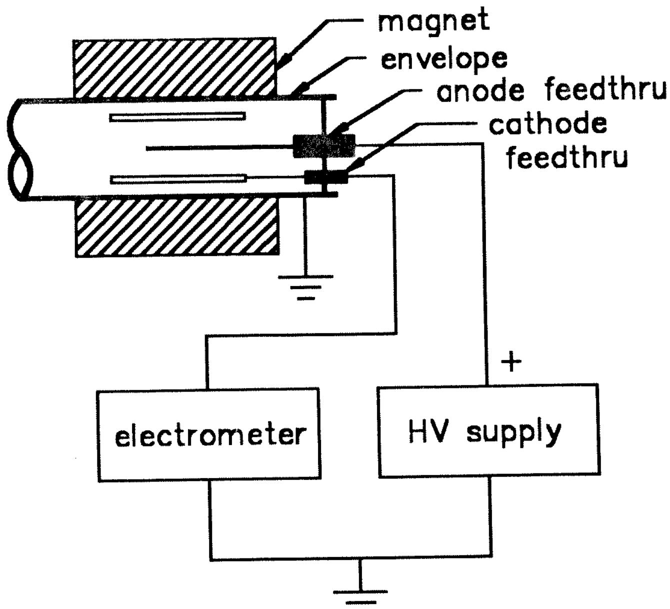
The inverted magnetron geometry has a current vs. pressure character which is more reproducible than the other arrangements, and also works well to low pressures without risk of the discharge going out. This, combined with the exclusive voltage/current ratio method (Patent No. 4,967,157), gives the gauge a measuring range from 10^{-2} to 10^{-11} Torr. Even long periods of operation at relatively high pressures does not cause a change in calibration. The gauge has the additional advantage of short starting time at low pressures.

Figure 11 (next page) shows (a) the HPS design with separate feedthroughs for anode and cathode and (b) the usual arrangement of the cold cathode gauge tube with a single anode feedthrough. In the latter, any cable or feedthrough insulator leakage to ground is indistinguishable from gauge current, while the HPS design suffers no such shortcoming.

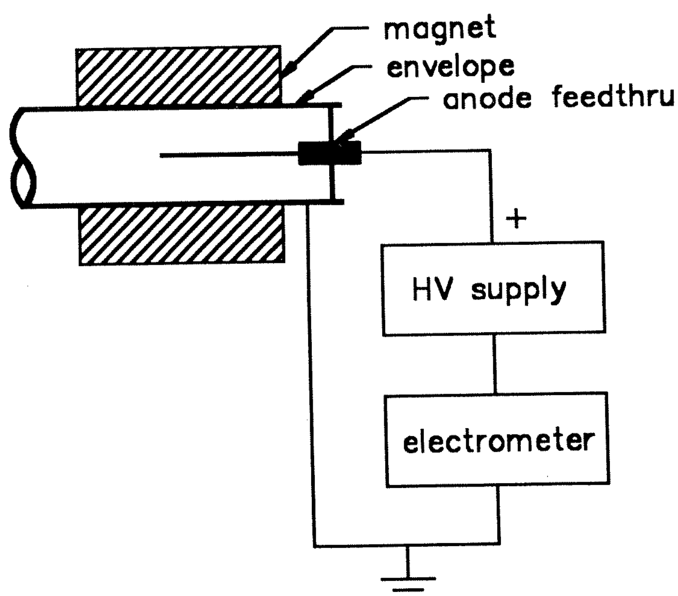
HPS gauge tubes are interchangeable without calibration. They contain only ultra high vacuum compatible materials and are rugged. The gauge tube is demountable for easy cleaning. Under appropriate conditions, they can be cleaned and reused indefinitely. To accommodate most applications, they are available with a variety of vacuum connections.

The HPS SensaVac® Series 937 uses the cold cathode gauge's inherent sensitivity to gas type to advantage in the leak detection mode. Allowing a gas different than the system gas to enter a system through a leak will change the amount of ionization. Maximum sensitivity is achieved by using a probe gas with an ionization probability which is much different than that of the system gas.

Sensitivity of the cold cathode gauge to gas leaks is also pressure dependent due to the complex nature of the ionization process and the electronic design of the gauge. Leak test sensitivity can be affected by gauge location, pumping speed, chamber volume, and other system parameters. The HPS SensaVac® Series 937 is useful in locating leaks in high vacuum chambers and lines. The minimum detectable leak is a function of pressure range and can be as low as 10^{-8} Torr-liters/second under ideal conditions.



a.



b.

FIGURE 11 - COLD CATHODE TUBE DESIGNS
a) DUAL FEEDTHROUGH AND b) SINGLE FEEDTHROUGH METHODS

A.2 Theory of the Thermal Conductivity Gauge

The HPS SensaVac® Series 937 Multi-Channel Gauge System is designed for use with Pirani, thermocouple, and convection gauges. These sensors are heat loss manometers, inferring the pressure of a gas by measuring thermal loss of a heated wire. A hot wire suspended from supports in a partial vacuum loses thermal energy in three ways: 1) end loss to the supports, 2) radiation to surrounding surfaces, and 3) gas transport. The latter mode, gas transport, is pressure dependent. It is the pressure dependence of thermal energy transport from a hot wire which is utilized in the Pirani, thermocouple, and convection gauges. The end loss and radiation terms are constant for a wire at constant temperature, and they provide a masking signal which largely determines the low pressure limit of gauges of this type. By optimizing parameters such as length of wire, wire diameter, thermal emissivity, thermal conductivity and wire temperature these terms can be controlled, although not eliminated.

The Pirani gauge uses the wire as one arm of a balanced Wheatstone bridge. A bridge amplifier maintains the wire at constant temperature and the amplifier output is related to the energy loss.

The measuring principle of the thermocouple gauge is the same as that of the Pirani gauge, in that it measures heat loss from a wire. The difference between them is that in the case of the thermocouple the temperature of the hot element in contact with the gas is allowed to vary and is directly measured by means of a thermocouple.

The mechanism of energy transfer between the wire and the gas is dependent upon the pressure range. For pressures below 10^{-1} Torr, it is possible to derive an equation showing a linear relationship between the thermal energy loss to the gas, E_{gas} ,and the pressure, P.

$$E_{gas}=const.\,\alpha\frac{1}{4}\frac{\delta+1}{\delta-1}\frac{T_w-T_g}{\sqrt{MT_g}}P$$

where for the particular gas:

- α is the accommodation coefficient;
- δ is the ratio of the specific heat at constant pressure to that at constant volume;
- M is the molecular weight of the gas;
- T_w is the temperature of the wire;
- T_g is the temperature of the gas;
- P is the pressure.

At pressures above about 100 Torr for nitrogen, and widely differing values for other gases, the gas acts like a insulating layer. At still higher pressures, and in a large enclosure, convection contributes to energy transport. The pressure range between 10^{-1} Torr and 100 Torr is a transition region, where the slope of the energy loss curve decreases continuously. Figure 12 (next page) shows an energy loss curve for a constant temperature Pirani transducer over the range from 10^{-4} Torr to atmosphere (E_{gas}), and a horizontal line indicating the total energy loss due to the end loss and radiation terms (E_{end} + E_{rad}). Note that the sum of end and radiation losses is about 10 times the gas transport at a pressure of 10^{-3} Torr. This determines the practical lower limit for thermal conductivity gauges. Measurement of lower pressures is possible, however long term stability becomes a serious problem.

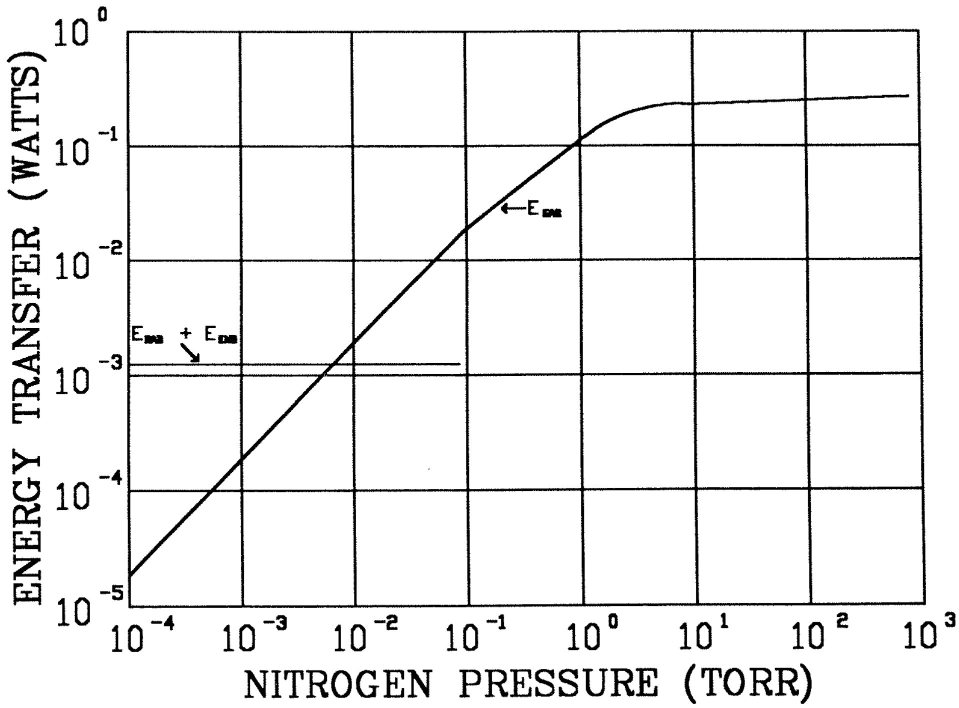


FIGURE 12 - ENERGY LOSS CURVE FOR CONSTANT TEMPERATURE PIRANI FILAMENT

From the energy loss equation above it is clear that the signal from a thermal conductivity gauge is not calculable from first principles and is dependent upon gas type. Because the energy transfer is dependent upon the rate of molecular collision with the wire surface and upon the energy transfer by each molecule, the gas transport is dependent upon the molecular weight, the internal degrees of vibrational freedom of the molecule, and the accommodation coefficient of the gas. For pressures greater than 10^{-1} Torr, it is not possible to write an equation for the energy transfer by the gas. However, since the indications of thermal conductivity gauges are reproducible for a given gas in this range, they may be calibrated against absolute standards for pressure measurements applications.

A Pirani gauge may be operated at constant current, constant voltage, or constant resistance (equivalent to constant temperature) at the sensor wire. At constant current or voltage, the wire temperature at high pressures is much less than the value at vacuum, reducing the high pressure sensitivity. The HPS SensaVac® Series 937 Pirani control circuit maintains the sensor wire at a constant temperature, extending the useful pressure range above 100 Torr.

In the thermocouple gauge a filament is heated electrically and its temperature is measured directly by means of a thermocouple. The heating current which is passed through the hot filament is kept constant at a standard value independent of the temperature of the filament. As the pressure increases, the heat conduction through the gas increases and the temperature of the filament decreases. The thermocouple (usually spot welded to the midpoint of the filament) responds to the temperature of the filament and provides a direct reading of the pressure.

A.3 Theory of the Capacitance Manometer Gauge

Capacitance manometer sensors are electromechanical pressure difference measuring devices. They include a single-sided dual electrode/AC bridge circuit. The device incorporates two capacitance electrodes plated in a concentric bull's-eye arrangement on a ceramic disc, which is positioned parallel to a thin, flat, tensioned Inconel® diaphragm. When the pressure on both sides of the diaphragm is equal, the diaphragm is flat and the bridge is balanced. If pressure on one side of the diaphragm increases relative to the other electrode side, the diaphragm deflects toward it. The center electrode capacitance changes more than the outer electrode capacitance, causing the bridge to be unbalanced. By amplifying and demodulating the output of the AC bridge, a usable high level DC output signal (commonly 0-10 VDC) is achieved. Electrical calibration of the sensor against a primary or transfer standard results in a highly linear output, reading directly in pressure units. Deflections as small as 10^{-8} inch can be sensed by this technique. Resolution of 1 part in 10^{+6} of full scale pressure change is achievable. Typical applications require much less resolution (1 part in 1000, or in 10000), so that wide variations in operating conditions can be tolerated without affecting the accuracy of the measurement. The technique is widely used for vacuum measurement in the range from 10^{-5} Torr to atmosphere, since measurements are made independent of gas composition (total pressure), in contrast to other techniques which are affected by gas composition.

Capacitance manometers are available in differential and absolute configurations. A differential sensor leaves open both the unknown (Px) side and the reference (Pr) electrode side of the diaphragm, allowing differential measurements to be made directly. Absolute measurements can be made with a differential sensor by vacuum pumping the Pr side. Absolute (only) sensors have the Pr side evacuated and sealed to $< 10^{-7}$ Torr. A chemical getter maintains this low pressure for a designed lifetime in excess of 10 years. Sensors are of all welded construction, with Inconel® or Inconel® and stainless steel exposed to the gas, allowing use in rough, dirty, and corrosive environments. Differential sensors are corrosion resistant on the Px side; ceramic materials are exposed on the Pr side of the diaphragm, limiting use to noncorrosive gases.

A variety of sensor accuracies are available, from 0.05% of reading to 1% of reading, so that accuracy/cost trade-offs can be made depending on application requirements. Sensor accuracy is normally stated as the uncertainty in the sensor measurement. Uncertainty is the sum of the errors due to non-linearity, hysteresis and non-repeatability.

Non-linearity is the deviation of the sensor's output from an ideal straight line from zero to full scale pressure. Hysteresis is the deviation at any given pressure of the sensor's output curve measured when increasing pressure from zero to full scale and then decreasing pressure from full scale to zero. Non-repeatability is the difference between successive measurement readings of the same pressure under identical conditions and methods.

The overall sensor accuracy also includes uncertainties resulting from temperature changes, but since temperature changes are determined by the environment (which is variable), these inaccuracies are given as temperature coefficient specifications. Uncertainties on most sensors are specified as a percent of Reading. The useful lower limits of a sensor's measuring range are dependent on resolution and temperature coefficients. Resolution is the smallest change in pressure that will cause a change in sensor output. When measuring pressures near the Full Scale (maximum diaphragm deflection), of a sensor, most of the errors are due to non-linearity. When measuring closer to the low end of the sensor's range (minimum diaphragm deflection), most errors are due to temperature effects and resolution.

Capacitance manometers are subject to errors resulting from ambient temperature changes which cause geometry changes induced in the sensor by differences in the thermal expansion coefficients of the sensor materials. A change in ambient temperature may therefore cause a mechanical change which is detectable as sensor output. Temperature effects are quantified by the temperature coefficient specification (change in output/change in ambient temperature) and are an important factor to consider in selecting any transducer. The greater the variability in ambient temperature, the greater the importance of low temperature coefficients in achieving reliable, repeatable measurements.

APPENDIX B LEAK TESTING WITH VACUUM GAUGES

The SensaVac® Series 937 LEAK TEST function is intended to supplement a mass spectrometer leak detector which is most efficient in locating smaller leaks. Leak testing with the Pirani is useful in locating system leaks greater than 10^{-4} Torr-liters/second and the cold cathode gauge can have a sensitivity as low as 10^{-8} Torr-liters/second.

Since indicated pressure of cold cathode and thermal conductivity gauges is dependent on the type of gas being measured, introducing a probe gas through a leak will change the indication (see Appendix A for theory of cold cathode and thermal conductivity gauges). The 937 uses a center zero bar graph to indicate gas leaks in fore and roughing vacuum systems (see section 8.3 on the LEAK TEST function).

To locate a leak in the vacuum system, probe the suspect areas with a search gas which has a molecular weight different than the system gas. Helium, argon or Freon® gas are suitable for probing a system pumping air or nitrogen. The probing should be done slowly and methodically with a small amount of search gas. Flooding the leak with gas or moving the gas source quickly past the leak can confuse the search since system time lags may be significant. While probing the suspect components, observe the bar graph display. The maximum deflection of the graph from the zero point indicates that the search gas is nearest the leak location. Once the leak location is determined, repeat the test to confirm.

As with any leak testing, many factors can influence the sensitivity of the test. These factors include system volume, system pressure, search gas, type of vacuum pump, location of the gauge, location of the pump, and size of tubulation in the system. Reducing the search area by minimizing the chamber volume will increase the efficiency of the test. Placement of the gauge and the pump in relation to the leak can also be a major factor in optimizing the sensitivity of leak detection. Placing the pump away from the suspected leak source and placing the gauge between the leak and the pump will reduce the gauge response time allowing most accurate pinpointing of the leak location. Tubulation between the suspected leak and the gauge tube should be as short and wide as possible to minimize the time required for the search gas to reach the gauge.

The 937's LEAK TEST function is effective with a probe gas of either lower or higher sensitivity than the gas in the vacuum system; however, for optimal effect the search gas should be selected to maximize the difference between its sensitivity and that of the system gas. Always use a search gas in small quantity to aid in pinpointing the leak. In general, the sensitivity of the leak test is greater for lower system pressures.

The type of vacuum pump used can also affect the accuracy of the leak test operation. For moderate size leaks, it is best to have the system pumped by a high vacuum pump such as a diffusion pump (ion pumps are not recommended). The LEAK TEST function will work with pumping by a mechanical pump; however, mechanical pumps may cause cyclical variations in pressure with rotation of the vanes. This is displayed as a large background noise signal possibly masking the leak signal. If the leak test method outlined above fails to indicate the location of a leak, consider that unexpected high pressures may be caused by a virtual leak, that is, outgassing of a system component.

APPENDIX C GAUGE INSTALLATION

C.1 Cold Cathode Gauge

Gauge Location and Orientation
In selecting the location and orientation of the gauge, consideration should be given to sources of contamination which might affect the tube interior. As an example, mounting the gauge directly in line with an evaporation source or where particulate material will fall into the tube could affect operation. Mounting the gauge with the vacuum port facing downward is most desirable since it reduces particulates and liquids falling or flowing into the gauge. If particulates in the system are common, it is necessary to restrict these from entering the gauge using a screen or porous filter at the port. In such applications, the HPS centering ring with screen may be useful.

The location of the gauge tube in the system should be chosen carefully so that the pressure measured is that of the chamber or manifold. In general, placing the gauge tube away from pumps and gas sources will result in the most representative pressure indication. The HPS cold cathode gauge tube was designed to allow operation in any position without compromising accuracy.

Vacuum Gauge Connection
The HPS cold cathode gauge tube is offered in five different vacuum connection configurations, NW25 KF, NW40 KF, 2-3/4" CF (metal sealed Varian type), 8(1/2") VCR®, and 1" tubulation for use with compression fittings.

The KF connections require no special mounting precautions, except where a screening function is desired as mentioned previously. Care must be taken to provide a solid electrical connection between the gauge tubulation and the grounded vacuum system. This is required to effect the shielding of the tube element from external radiation sources.

Gauge Electrical Connection

CAUTION

THE CONTROLLER MUST BE SWITCHED OFF BEFORE CONNECTING OR REMOVING THE GAUGE CABLES FROM THE GAUGE TUBE OR CONTROLLER.

The HPS cold cathode gauge tube is connected to the controller via coax cables with SHV and SMA connectors. These socket and connector combinations obviate the need for strain relief in most applications. In situations where stress could be applied to the cable, separate strain relief devices should be used to avoid damage to the gauge or the controller. Cables are available from the factory in standard lengths of 10, 25, 50 and 100 feet, and in custom lengths up to 500 ft.

The cables from the gauge tube are connected to the controller with SHV and SMA connectors labeled "H.V." and "ION CURRENT", respectively.

Some applications may require the use of special cables, such as where the connection must be routed through restrictive barriers or through conduit. Custom cables may be fabricated for these situations (contact HPS for information). The maximum length of the gauge cable is 500 feet. Please note that SHV and SMA connectors should be used for all applications.

Gauge Tube Testing

The HPS cold cathode gauge tube contains the anode and cathode (collector) electrodes. The gauge can easily be tested using an ohmmeter. There should be no shorts between the electrodes or to ground.

Gauge Tube Disassembly

The gauge is easily broken down into three subassemblies. These are shown in Figure 13 (next page) as the backshell subassembly, internal subassembly, and the body subassembly. Only the internal and body subassemblies are exposed to system vacuum.

To disassemble, first remove the backshell subassembly as follows:

1) Remove two 4-40 x 1/4 Phillips head SEMS screw and slide the backshell off the gauge.
2) Remove two 4-40 x 1/4 button head screws.
3) Pull the #22 contact off of the ion current feedthrough using standard needle nose pliers.
4) Using needle nose pliers, pull the #20 contact off of the 5kV feedthrough taking the entire bulkhead and connectors with it (there is no need to remove the SHV and SMA connectors from the bulkhead).

5) Remove eight 10-32 x .87 socket head cap screws and pull the back flange free. Note that these screws are silver plated for lubricity and should be used only once. However, they can be relubricated with a dry lubricant such as molybdenum disulfide. We recommend that new silver plated replacement screws be used. The copper gasket should be replaced and not reused.

The cathode and anode assemblies are attached to the flange. Here the disassembly generally proceeds from left to right with respect to Figure 13 (on next page).

6) Remove the cathode by releasing the two integral spring loaded ears hooked over the shoulder of the ceramic insulating support. This is done by gently pulling up on the ear until it just clears the outer diameter of the ceramic.

7) Slide the cathode and washer off the ceramic. Note the position of the small Elgiloy® leaf used to connect the ion current feedthrough to the cathode. Rotational position of the cathode with respect to the leaf is not critical, but some care should be taken not to bend the leaf.

8) The ceramic insulating support is captured by the guard bolt. Remove with a spanner wrench (available from HPS) and unscrew the guard bolt from the flange. Note the presence of the small curved spring washer located under the head of the guard bolt. The spring washer holds the insulating support tight, preloads the guard bolt to resist unscrewing due to possible system vibration, and provides compliance allowing for differential thermal expansion during bakeout.

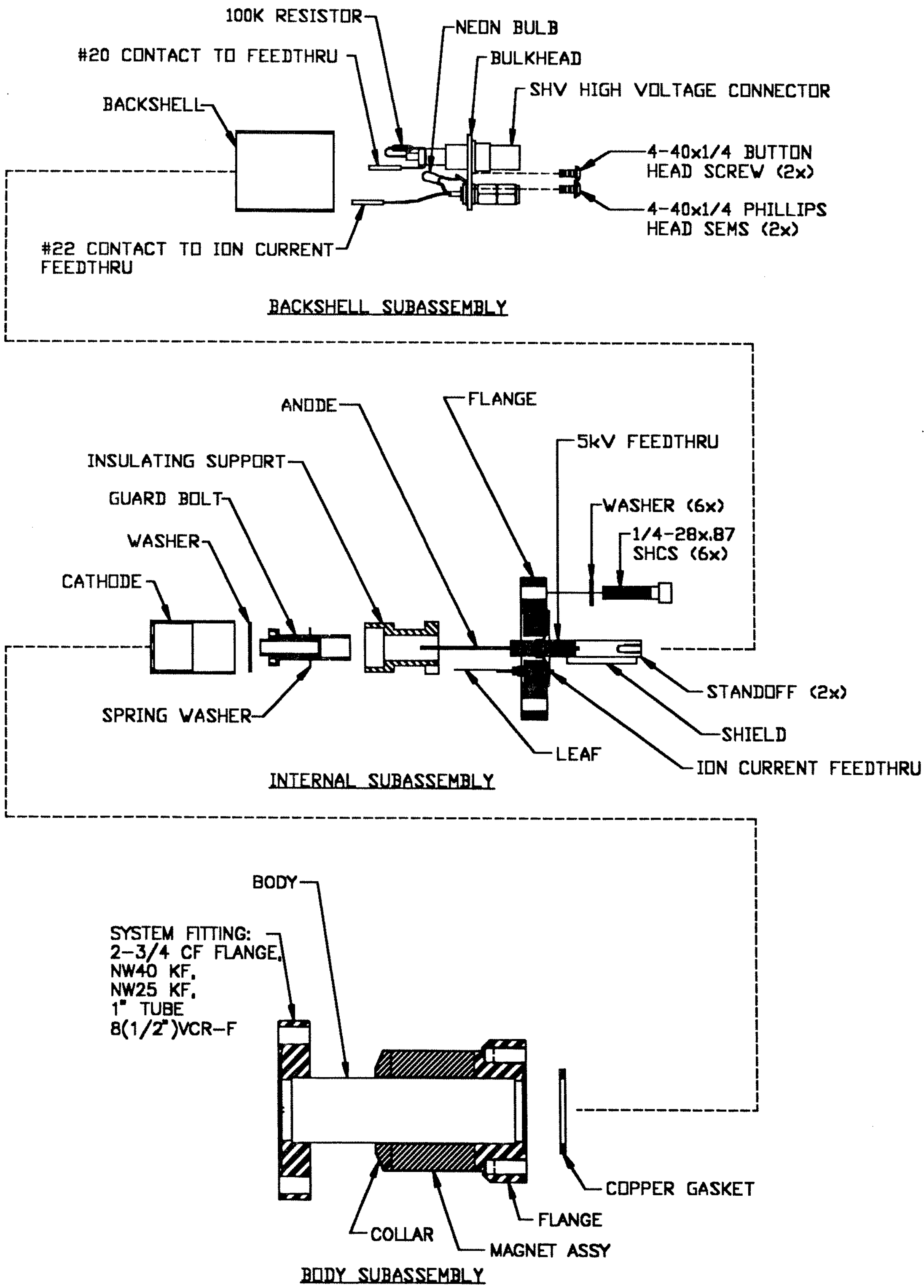


FIGURE 13 - COLD CATHODE GAUGE TUBE, EXPLODED VIEW

Gauge Tube Cleaning

The extent and type of cleaning will vary depending on particular system and process requirements. Note that the anode is not removable as it is integral with the welded 5kV high voltage feedthrough and requires care not to bend. Make sure that no cleaning solvents or acids remain in the weld crevices of the feedthroughs. Their presence may corrode the gauge over time, as well as be a source of outgassing later. The body subassembly is ready for cleaning as is and requires no further disassembly. The internal parts are now ready for cleaning.

A Freon® vapor degreasing is sufficient for many applications. However, if the gauge has been exposed to a "dirty" or corrosive atmosphere, the following cleaning procedure can be used. The aluminum parts, i.e. cathode, washer, and guard bolt can be cleaned using a 5% to 20% sodium hydroxide solution at room temperature for one minute, followed by a deionized water rinse. Then use a 50 - 70% nitric acid dip, also at room temperature, for approximately 5 minutes to remove smut, followed by several deionized water rinses. The anode can be cleaned using 50 - 70% nitric acid, preferably dipping only the anode and not the entire flange in the acid. Then rinse thoroughly in deionized water. Only the body internal diameter and the flange faces are exposed to vacuum. Again, the choice and extent of cleaning will depend on the particular application.

Gauge Tube Assembly

To reassemble, just reverse the order used during disassembly. Especially note the following tightening procedure of the guard bolt. The bolt has a 3/8-40 thread which is delicate. The bolt should be tightened to compress the spring washer about 80%. Do not over tighten as this will remove all compliance from the spring washer and possibly damage the aluminum 3/8-40 thread.

It is important to verify that the anode is well centered within the bore of the guard bolt. If it is off center, bend it back into position and continue with the assembly.

Gauge Tube Bakeout

The cold cathode gauge can be prepared for a 125°C bakeout simply by removing the high voltage and ion current cables.

A higher, 250°C temperature bakeout can also be done but first requires the removal of the backshell subassembly. See Figure 13.

To remove the backshell subassembly:

1) Remove two 4-40 x 1/4 Phillips head SEMS screw and slide the backshell off the gauge.
2) Remove two 4-40 x 1/4 button head screws.
3) Pull the #22 contact off of the ion current feedthrough using standard needle nose pliers.
4) Using needle nose pliers, pull the #20 contact off of the 5kV feedthrough taking the entire bulkhead and connectors with it (there is no need to remove the SHV and SMA connectors from the bulkhead).

The gauge is now ready for bakeout.

C.2 Pirani Gauge

Gauge Location
In selecting the location and orientation of the gauge, consideration should be given to sources of contamination which might affect the tube element. As an example, mounting the gauge directly above a roughing pump in the system could allow oil vapor to condense onto the filament wire of the gauge, causing a shift in emissivity and thereby in calibration. Mounting the gauge with the vacuum port facing downward is most desirable since it reduces particulates and liquids falling or flowing into the gauge. If particulates in the system are common, it is necessary to restrict these from entering the gauge using a screen or porous filter at the port. In such applications, the HPS P/N 100318601 centering ring with screen may be useful.

The location of the gauge tube in the system should be chosen carefully so that the pressure measured is that of the chamber or manifold. In general, placing the gauge tube away from the pumps and gas sources will result in the most representative pressure indication.

Gauge Orientation
The HPS Pirani gauge tube was designed to minimize convection so that operation is possible in any position without compromising accuracy. Convection is an effective heat transfer process only at pressures above approximately 400 Torr of nitrogen. The convection effect is sufficient to make a very small but detectable difference in pressure indication between a horizontal and a vertical gauge tube at atmospheric pressure. The gauge tube is factory calibrated with the tube vertical and the connector up. Recalibration with the gauge in any orientation will not affect accuracy at pressures below 30 Torr.

Gauge Vacuum Connection
The HPS Pirani gauge tube is offered in 5 different vacuum connection configurations, NW16 KF, 1-1/3" CF, 2-3/4" CF, 8(1/2") VCR®, and combination 1/8" NPT plus 1/2" compression seal. The NW16 KF connection requires no special mounting precautions except where a screening function is desired as mentioned earlier. When fitting the HPS Pirani gauge with the 1/8" NPT thread to the system, do not use the body of the gauge for tightening. The tubulation of the gauge has been fitted with 9/16" hex flats for tightening purposes. A single wrap of Teflon® tape should be used on the threads of the gauge to ensure a leak free seal. This gauge can also be connected to the system with a 1/2" O-Ring compression seal acting on the tubulation above the thread. Care must be taken to provide a solid electrical connection required to effect the shielding of the tube element from external radiation sources.

Gauge Venting to Atmosphere
The Pirani gauge senses pressure by measuring heat loss from a fine heated wire. Sudden venting of the gauge at its port can cause a great deal a physical stress to be applied to the sensor. To avoid risk of damage, vent the vacuum system to atmosphere before removing the gauge.

Gauge Electrical Connection

CAUTION

THE CONTROLLER MUST BE SWITCHED OFF BEFORE CONNECTING OR REMOVING THE GAUGE CABLE FROM THE GAUGE TUBE OR CONTROLLER.

The Pirani gauge tube is connected to the controller via a cable with a standard round octal socket. This socket contains an integrated polarizing tab and sufficient contact pressure to obviate the need for strain relief in most applications. In situations where stress could be applied to the cable, separate strain relief devices should be used to avoid damage to the gauge or the controller. Cables are available from the factory in standard lengths of 10, 25, 50 and 100 feet, and in custom lengths up to 500 feet.

The cable from the gauge tube is connected to the controller with the 9 pin D-Sub connector. This connector is equipped with integral strain relief hardware. The strain reliefs should be screwed into the mating standoffs on the rear of the controller to ensure proper electrical connection and to avoid excessive stress on the connectors.

Some applications may require the use of special cables, such as where the connection must be routed through restrictive barriers or through conduit. Custom cables may be fabricated for these situations using the information provided by Figure 14 in Appendix E. The maximum length of the gauge cable is 500 feet. Please note that a D-Sub connector with integral strain relief should be used for all applications.

Gauge Tube Testing

The HPS Pirani gauge tube contains the balanced bridge for sensing pressure and a temperature compensation circuitry to allow pressure measurements throughout a wide ambient temperature range. The most common cause of failure of the gauge is a broken sensor filament. This might be caused by physical abuse, or by sudden venting of the gauge to atmosphere at the inlet port. The gauge can be easily tested using an ohmmeter with less than 5 milliamperes of test current. Nearly all digital multimeters have test currents well within this specification. The table below lists the resistance readings of a normal gauge measured at atmospheric pressure and at room temperature (20°Celsius).

PIN NUMBERS	RESISTANCE
1 to 4	39 Ohms
1 to 5	114 Ohms
4 to 6	31 Ohms
5 to 6	114 Ohms
6 to 7	62 Ohms
7 to 8	345 Ohms

C.3 Capacitance Manometer (MKS Series 122)

For complete information on the Type 122 capacitance manometer, see the MKS Baratron® instruction manual.

Mechanical Installation

Although the 122A (or B) may be mounted in any position, it is recommended that it be placed in a system with the Px port facing down, as this allows contamination, if present, to fall away from the pressure sensing diaphragm. Any standard vacuum fitting may be used (Cajon VCR®, compression, KF flange, etc.). The sensor port will easily carry the weight of the transducer.

NOTE: DUE TO THE FAILURE OF MANY USERS TO FOLLOW THE PROPER TIGHTENING PROCEDURES FOR SINGLE OR DOUBLE METAL FERRULE COMPRESSION TYPE VACUUM FITTINGS AND THE RESULTING DAMAGE CAUSED TO THE PRESSURE SENSOR, MKS DOES NOT WARRANTY THIS PRODUCT WHEN SUCH FITTINGS ARE USED.

Gauge Electrical Connection
Shielded cable assemblies, in a nominal 10' (3m) length, with a "flying leads" (pigtail) termination for the 122A, or terminating in a 15 pin D-sub connector for the 122B are available at nominal cost. Cables may be fabricated using the information provided by Figures 16 and 17 in Appendix E. Shielded cable assemblies are recommended, especially if the transducer's environment contains high EMI/RFI noise.

Repairs
Should any difficulty be encountered in the use of the transducer, it is recommended that contact be made with any authorized MKS sales office, calibration and service facility, or home office for repair instructions.

User repair of the transducer signal conditioner is NOT recommended, since replacement or movement of many PC board components may require complete recalibration of the unit.

If it is necessary to return the instrument to MKS for repair or recalibration, it is desirable to have an ERA No. (Equipment Return Authorization Number) issued by MKS for identification purposes.

C.4 Thermocouple Gauge

Installation
The thermocouple gauge tubes may be installed anywhere in the system using a 1/8" NPT or .410 compression connection, or may be welded directly. Do not use compression fittings for positive pressure applications. If installed in an area where condensable vapors are present, mount with the open end pointing down to allow drainage.

Gauge Electrical Connection
Cables may be fabricated using the information provided by Figure 15 in Appendix E (maximum length 25 feet).

C.5 Convection Gauge (Granville-Phillips)

High Pressure Operation
Do not use a compression mount (quick connect) for attaching the gauge tube to the system in applications resulting in positive pressures in the gauge tube. Positive pressures might blow the tube out of a compression fitting and damage equipment and injure personnel. The Convection gauge is not intended for use above 1000 Torr (1333 mbar or $1.33 \times 10^{+5}$ Pascal).

Gauge Location
Refer to the gauge location section for the Pirani gauge.

Gauge Orientation
For measurement of pressures greater than 1 Torr the gauge tube must be

mounted with its axis horizontal. Measurements below 1 Torr are unaffected by tube position, but erroneous readings will result at higher pressures. An erroneous reading could result in an under- or over-pressure condition which could damage equipment and injure personnel. Mounting the gauge with the vacuum port facing downward is most desirable since it reduces particulates and liquids falling or flowing into the gauge.

Gauge Electrical Connection

CAUTION

THE CONTROLLER MUST BE SWITCHED OFF BEFORE CONNECTING OR REMOVING THE GAUGE CABLE FROM THE GAUGE TUBE OR CONTROLLER.

The Granville-Phillips convection gauge tube is connected to the controller via a cable with a custom round socket. This socket contains an integrated polarizing tab and sufficient contact pressure to obviate the need for strain relief in most applications. In situations where stress could be applied to the cable, separate strain relief devices should be used to avoid damage to the gauge or the controller. Cables are available from the factory in standard lengths of 10, 20, 30, 40, and 50 feet, and in custom lengths.

The cable from the gauge tube is connected to the controller with a 9-pin D-Sub connector. This connector is equipped with integral strain relief hardware. The strain reliefs should be screwed into the mating standoffs on the rear of the controller to ensure proper electrical connection and to avoid excessive stress on the connectors.

Some applications may require the use of special cables, such as where the connection must be routed through restrictive barriers or through conduit. Custom cables may be fabricated for these situations using the information provided by Figure 19 in Appendix E. Please note that a D-Sub connector with integral strain relief should be used for all applications.

Gauge Tube Testing

The most common cause of failure of the gauge is a broken sensor filament. This might be caused by physical abuse, or by sudden venting of the gauge to atmosphere at the inlet port. The gauge can easily be tested using an ohmmeter with less than 5 milliamperes of test current. Nearly all digital multimeters have test currents well within this specification. The table below lists the resistance readings of a normal gauge.

PIN NUMBERS	RESISTANCE
1 to 2	20 to 25 Ohms
2 to 3	50 to 60 Ohms
1 to 5	175 to 190 Ohms
Any pin to shell	open circuit

If the resistance between pins 1 and 2 is approximately 800 ohms then the filament is broken.

APPENDIX D COMMUNICATION PROGRAMS

D.1 RS-232 Program

This program tests the RS-232 / RS-485 plug-in module when it is configured for RS-232, and allows the selection of baud rate. The program uses a PC's COM 2. If COM 1 is required, change the instructions containing &H2F to &H3F. The program will not allow transmitting more than a 2-character command to the 937 and will strip off characters if more are entered. To exit from this program type the character "Q" for quit.

This program is written in Microsoft Quick Basic.

```
CLS
PROMPT:
PRINT "BAUD RATE SELECTION"
PRINT "1.   2400", "4.   19200"
PRINT "2.   4800", "5.   57600"
PRINT "3.   9600"
PRINT
INPUT "SELECT BAUD RATE (1,2,3,4,or 5)      "; BAUD

OPEN "COM2:300,E,7,1,RS,CS,CD,DS,PE" FOR RANDOM AS #1 LEN = 15
ON ERROR GOTO ERRORHANDLER

OUT &H2FB, 128       'set baud rate, 8 data bits, even parity
OUT &H2F9, &H0
IF BAUD = 1 THEN
   OUT &H2F8, &H30
ELSEIF BAUD = 2 THEN
   OUT &H2F8, &H18
ELSEIF BAUD = 3 THEN
   OUT &H2F8, &HC
ELSEIF BAUD = 4 THEN
   OUT &H2F8, &H6
ELSEIF BAUD = 5 THEN
   OUT &H2F8, &H2
ELSE CLS
   PRINT "NOT A VALID BAUD RATE, TRY AGAIN."
   PRINT
   GOTO PROMPT
END IF
OUT &H2FB, &H1B

Main:
   PRINT : INPUT "COMMAND  "; C$
   IF C$ = "Q" THEN GOTO DONE:
   GOSUB XMT:
   GOSUB Rcv:
   GOTO Main:

XMT:
'these statements take the first and second character only
'for transmission.
   A$ = MID$(C$, 1, 1)
   B$ = MID$(C$, 2, 1)
   PRINT #1, A$;
```

```
WAIT1:
'delays are included to allow the 937 to process incoming
'characters at 57,600 baud.
   IF (INP(&H2FD) AND &H60) <> &H60 THEN GOTO WAIT1
   FOR N = 1 TO 2: NEXT   'Increase loop length for computers
   PRINT #1, B$;          'faster than standard 486 PC's.
WAIT2:
   IF (INP(&H2FD) AND &H60) <> &H60 THEN GOTO WAIT2
   FOR N = 1 TO 2: NEXT   'Increase loop length for computers
   PRINT #1,              'faster than standard 486 PC's.
RETURN
Rcv:
   IF LOC(1) <> 0 THEN INPUT #1,Z$
   RX$ = "": Y$ = "": T = TIMER

Timeout:
   IF TIMER > T + .5 THEN PRINT "TIMEOUT ERROR": RETURN
   IF LOC(1) = 0 THEN GOTO Timeout:
   Y$ = INPUT$(1, #1)
   RX$ = RX$ + Y$
   IF Y$ <> CHR$(13) THEN GOTO Timeout:
'the response string from the 937 is input one byte at a time
'until a carriage return [CHR$(13)] is detected.
   PRINT "RESPONSE : "; RX$
   Z$ = INPUT$(LOC(1), #1)
 RETURN

 DONE:
 END

 ERRORHANDLER:
   IF ERR = 57 THEN PRINT "PARITY ERROR" ELSE PRINT "OTHER ERROR"
   RESUME
```

D.2 RS-485 Program

This program tests the RS-232 / RS-485 plug-in module when it is configured for RS-485, and allows the selection of baud rate. The address character and the time delay are also selectable. The program uses a PC's COM 1. If COM 2 is required, change the instructions containing &H3F to &H2F. The program will not allow transmitting more than a 2-character command to the 937 and will strip off characters if more are sent. To exit from this program type the character "Q" for quit.

This program is written in Microsoft Quick Basic.

```
CLS
PROMPT:
PRINT "BAUD RATE SELECTION"
PRINT "1.   2400", "4.  19200"
PRINT "2.   4800", "5.  57600"
PRINT "3.   9600"
PRINT
INPUT "SELECT BAUD RATE (1,2,3,4,or 5)      "; BAUD
INPUT "ENTER 937 TRANSMIT DELAY (1,4,or 8) "; TXDEL$
INPUT "ENTER ASCII ADDRESS CHARACTER        "; ADCHAR$

OPEN "COM1:300,E,7,1,RS,CS,CD,DS,PE" FOR RANDOM AS #1 LEN = 15
ON ERROR GOTO ERRORHANDLER

OUT &H3FB, 128       'set baud rate, 8 data bits, even parity
OUT &H3F9, &H0
IF BAUD = 1 THEN
    OUT &H3F8, &H30
ELSEIF BAUD = 2 THEN
    OUT &H3F8, &H18
ELSEIF BAUD = 3 THEN
    OUT &H3F8, &HC
ELSEIF BAUD = 4 THEN
    OUT &H3F8, &H6
ELSEIF BAUD = 5 THEN
    OUT &H3F8, &H2
ELSE CLS
    PRINT "NOT A VALID BAUD RATE, TRY AGAIN."
    PRINT
    GOTO PROMPT
END IF
OUT &H3FB, &H1B

SETDELAY:                         'the time delay is set here
    PRINT "T" + TXDEL$
    C$ = "T" + TXDEL$
    GOTO SKIPCOM

Main:
    PRINT : INPUT "COMMAND  "; C$
    IF C$ = "Q" THEN GOTO DONE:
SKIPCOM:
    GOSUB XMT:
    GOSUB Rcv:
    GOTO Main:
```

```
XMT:
'these statements take the first and second character only
'for transmission.
    A$ = MID$(C$, 1, 1)
    B$ = MID$(C$, 2, 1)
'RS-232's "RTS" signal is used to enable the RS-485 transmitter
'and is accessed by writing to bit 1 (of bits 0-7) in the register
'located at address &H3FC
'5 characters are transmitted
'1 = attention, 2 = address, 3/4 = command, 5 = <CR>
    OUT &H2FF, &H2  'This line must be tailored to your hardware.
    PRINT #1, "$";
WAIT1:
'delays are included to allow the 937 to process incoming
'characters at 57,600 baud.
    IF (INP(&H3FD) AND &H60) <> &H60 THEN GOTO WAIT1:
    FOR N = 1 TO 2: NEXT   'Increase loop length for computers
    PRINT #1, ADCHAR$;     'faster than standard 486 PC's.
WAIT2:
    IF (INP(&H3FD) AND &H60) <> &H60 THEN GOTO WAIT2:
    FOR N = 1 TO 2: NEXT   'Increase loop length for computers
    PRINT #1, A$;          'faster than standard 486 PC's.
WAIT3:
    IF (INP(&H3FD) AND &H60) <> &H60 THEN GOTO WAIT3:
    FOR N = 1 TO 2: NEXT   'Increase loop length for computers
    PRINT #1, B$;          'faster than standard 486 PC's.
WAIT4:
    IF (INP(&H3FD) AND &H60) <> &H60 THEN GOTO WAIT4:
    FOR N = 1 TO 2: NEXT   'Increase loop length for computers
    PRINT #1,              'faster than standard 486 PC's.
'when the UART's transmit register and transmit buffer are empty
'the RS-485 transmitter is disabled via "RTS"
Buffer:
    IF (INP(&H3FD) AND &H60) <> &H60 THEN GOTO Buffer:
    OUT &H2FF, &H1  'This line must be tailored to your hardware.
RETURN
Rcv:
'this next line is included in case the RS-485 receiver is always
'enabled and will clear the COM PORT's input buffer of the command
'that was just transmitted.
   IF LOC(1) <> 0 THEN INPUT #1, Z$
   RX$ = "": Y$ = "": T = TIMER
Timeout:
   IF TIMER > T + .1 THEN PRINT "TIMEOUT ERROR": RETURN
   IF LOC(1) = 0 THEN GOTO Timeout:
   Y$ = INPUT$(1, #1)
   RX$ = RX$ + Y$
   IF Y$ <> CHR$(13) THEN GOTO Timeout:
'the response string from the 937 is input one byte at a time
'until a carriage return [CHR$(13)] is detected.
   PRINT "RESPONSE : "; RX$
   Z$ = INPUT$(LOC(1), #1)
RETURN
DONE:
END
ERRORHANDLER:
   IF ERR = 57 THEN PRINT "PARITY ERROR" ELSE PRINT "OTHER ERROR"
   RESUME
```

D.3 IEEE-488 Program

This program was written for use with a Hewlett Packard Model 82990-65001 GPIB Interface board. Machine language drivers are included with this board as are programs that actually take care of calling these machine language functions. The program lines shown here are appended to the end of the program supplied by HP and start at line 1000. The program will not allow transmitting more than a 2-character command to the 937 and will strip off characters if more are entered. To exit from this program type the character "Q" for quit.

The program is written in GW BASIC.

IEEE-488 Program Comments

Lines 1000-1030	Provides initial setup. User enters the decimal card address that was programmed into the DIP switches on the 937 communications module.
Lines 1040-1100	Initial setup of the HP-IB card. Timeout value is set for 5 seconds. This value can be made longer or shorter, but should not be less than 10 msec.
Lines 1110-1230	Asks for command, appends it to two characters and transmits it to the 937. Line 1160 disables EOI handshaking.
Lines 1240-1290	Waits for Serial Poll request and interrogates the 937 when one is received.
Lines 1300-1420	Disables EOI handshaking during receive, inputs reply string from 937 and prints it on the screen then loops back to ask for another command.

(Program listing on next page)

IEEE-488 Program

```
1000 CODE$=SPACE$(5)
1010 CLS
1020 ISC=7
1030 INPUT "HPS CONTROLLER ADDRESS";ADDRESS:HPS=700+ADDRESS
1040 CALL IORESET (ISC)
1050 IF PCIB.ERR <> NOERR THEN ERROR PCIB.BASERR
1060 TIMEOUT = 5
1070 CALL IOTIMEOUT (ISC,TIMEOUT)
1080 IF PCIB.ERR <> NOERR THEN ERROR PCIB.BASERR
1090 CALL IOCLEAR (ISC)
1100 IF PCIB.ERR <> NOERR THEN ERROR PCIB.BASERR
1110 INPUT "COMMAND";COMMAND$
1120 IF COMMAND$="Q" THEN GOTO 1430
1130 CODE$=LEFT$(COMMAND$,2)
1140 ENDLINE$=CHR$(13)
1150 STATE=0
1160 CALL IOEOI (ISC,STATE)
1170 IF PCIB.ERR <> NOERR THEN ERROR PCIB.BASERR
1180 LENGTH=LEN(ENDLINE$)
1190 CALL IOEOL(ISC,ENDLINE$,LENGTH)
1200 IF PCIB.ERR <> NOERR THEN ERROR PCIB.BASERR
1210 LENGTH=LEN(CODE$)
1220 CALL IOOUTPUTS(HPS,CODE$,LENGTH)
1230 IF PCIB.ERR <> NOERR THEN ERROR PCIB.BASERR
1240 SRQ=1
1250 CALL IOSTATUS (ISC,SRQ,STATUS)
1260 IF PCIB.ERR <> NOERR THEN ERROR PCIB.BASERR
1270 IF STATUS=0 THEN GOTO 1250
1280 CALL IOSPOLL (HPS,RESPONSE)
1290 IF PCIB.ERR <> NOERR THEN ERROR PCIB.BASERR
1300 STATE=0
1310 CALL IOEOI (ISC,STATE)
1320 IF PCIB.ERR <> NOERR THEN ERROR PCIB.BASERR
1330 MATCH$=CHR$(13)
1340 FLAG=1
1350 CALL IOMATCH(ISC,MATCH$,FLAG)
1360 IF PCIB.ERR <> NOERR THEN ERROR PCIB.BASERR
1370 MAXLEN=10:ACTLEN=0
1380 REPLY$=SPACE$(MAXLEN)
1390 CALL IOENTERS (HPS,REPLY$,MAXLEN,ACTLEN)
1400 IF PCIB.ERR <> NOERR THEN ERROR PCIB.BASERR
1410 PRINT "REPLY : ";REPLY$
1420 GOTO 1090
1430 END
```

APPENDIX E ADDITIONAL FIGURES

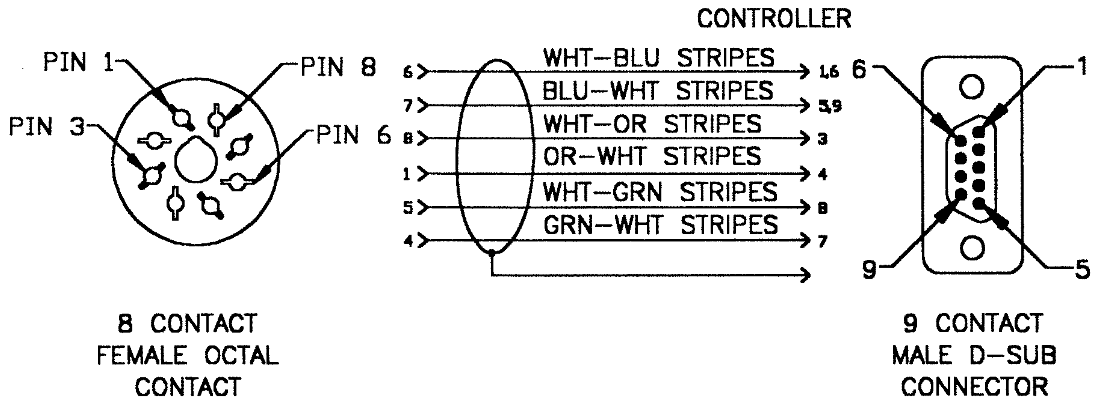


FIGURE 14 - PIRANI GAUGE CABLE

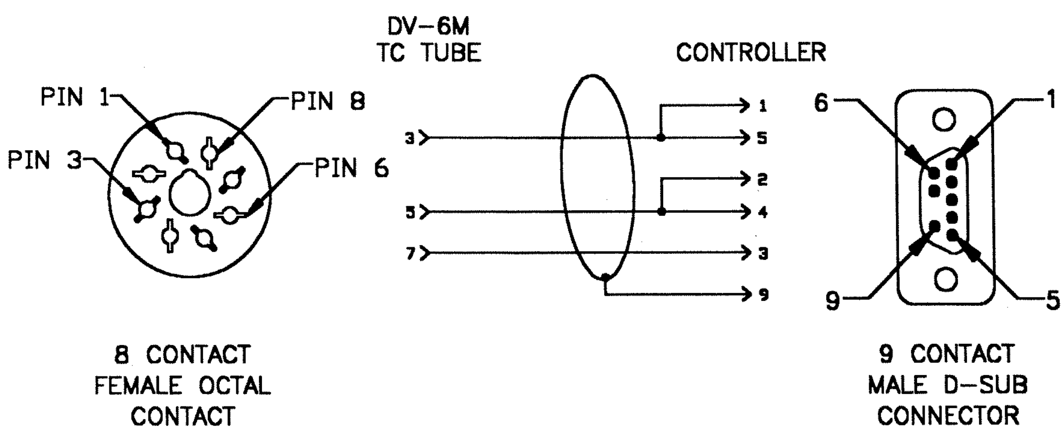


FIGURE 15 - THERMOCOUPLE GAUGE CABLE

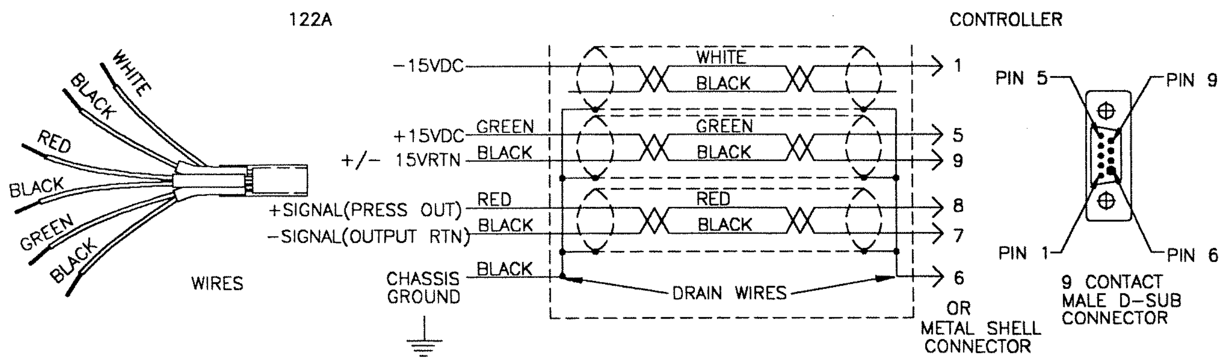


FIGURE 16 - CAPACITANCE MANOMETER CABLE FOR TYPE 122A GAUGE

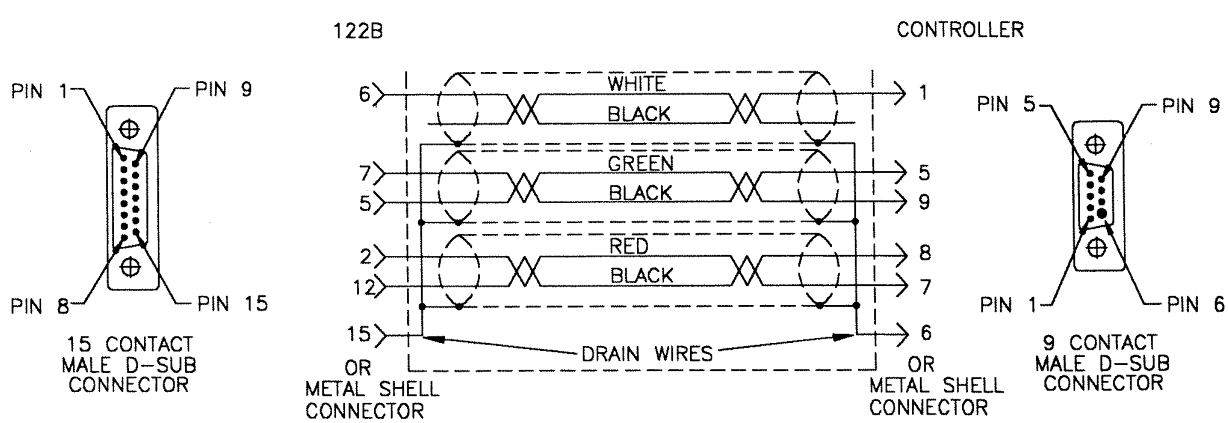


FIGURE 17 - CAPACITANCE MANOMETER CABLE FOR TYPE 122B GAUGE

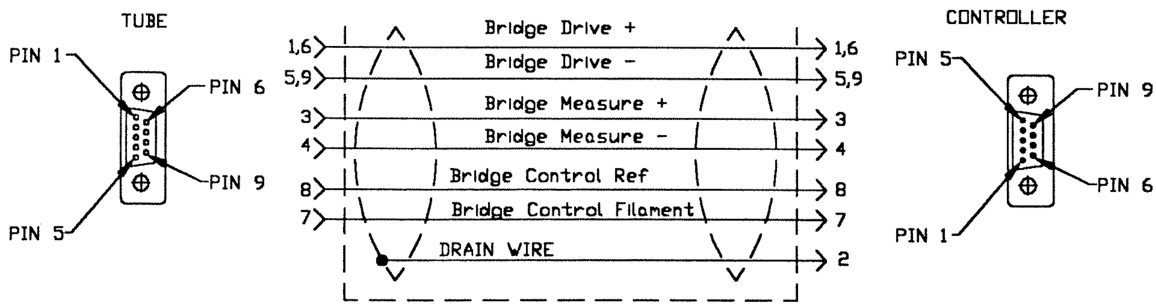


FIGURE 18 - HPS CONVECTION GAUGE CABLE

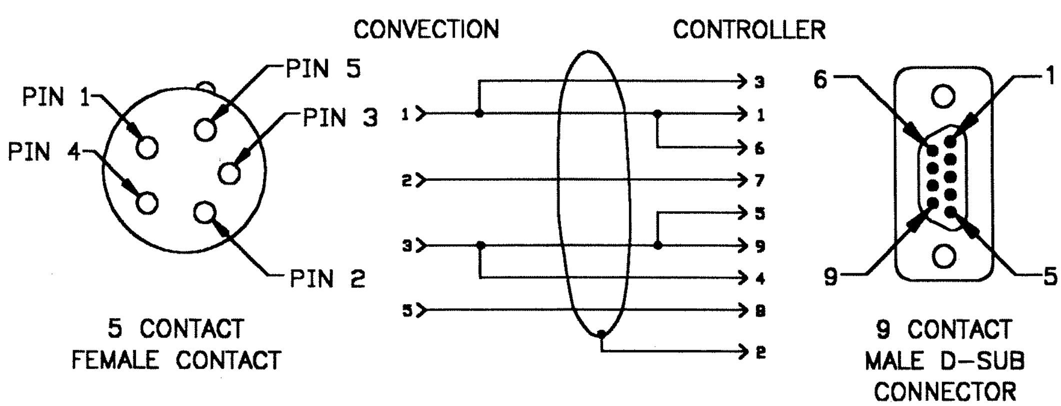


FIGURE 19 - GPC CONVECTION GAUGE CABLE

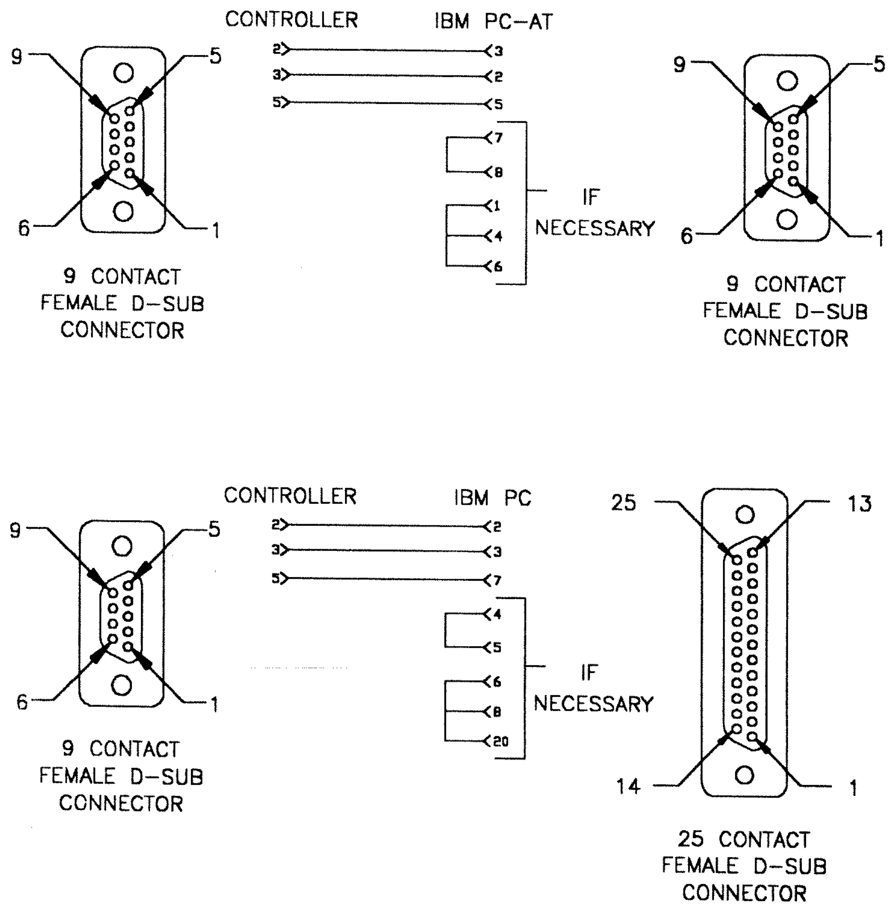


FIGURE 20 - RS-232 CABLES TO IBM PC's
UPPER: 9 PIN AT CONNECTION
LOWER: STANDARD 25 PIN CONNECTION
NOTE: CONNECTOR SEX ON PC's CAN VARY

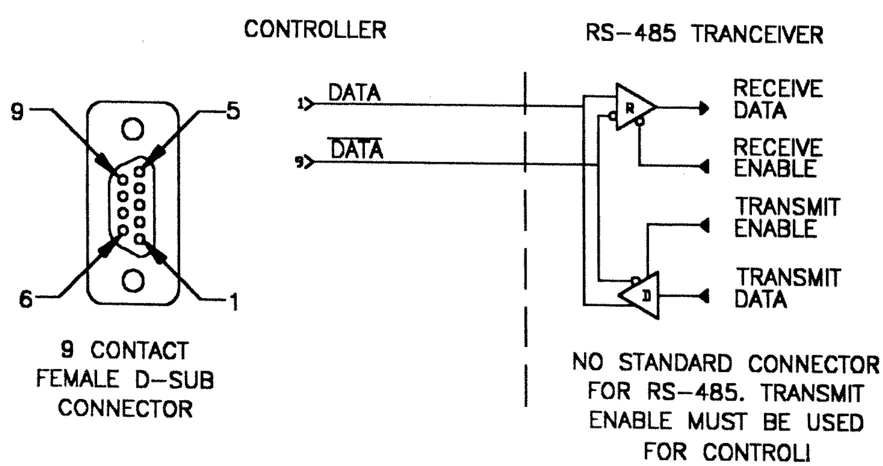
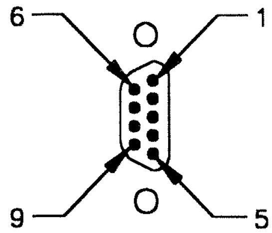
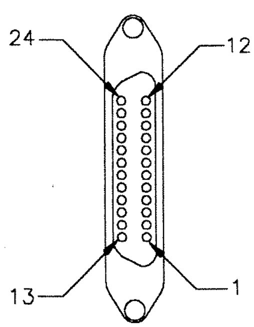


FIGURE 21 - RS-485 CABLE CONNECTORS



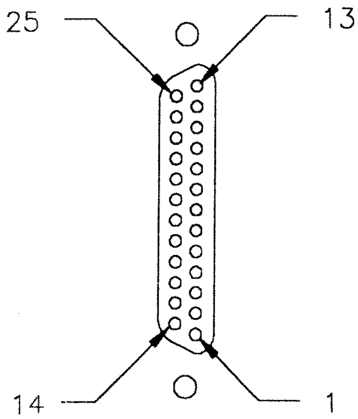
PIN	DESCRIPTION
1	RS-485 DATA
2	RS-232 RECEIVED DATA
3	RS-232 TRANSMIT DATA
4,7,8	NO CONNECTION
5	SIGNAL GROUND
6	RS-232 DATA SET READY UNUSED-INPUT
9	RS-485 $\overline{DATA}$

FIGURE 22 - RS-232 / RS-485 MODULE REAR PANEL CONNECTOR (MALE)



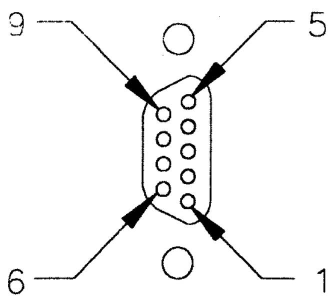
PIN	DESCRIPTION
1	DIO1
2	DIO2
3	DIO3
4	DIO4
5	EOI
6	DAV
7	NRFD
8	NDAC
9	IFC
10	SRQ
11	ATN
12	SHIELD
13	DIO5
14	DIO6
15	DIO7
16	DIO8
17	REN
18-24	GND

FIGURE 23 - IEEE-488 MODULE REAR PANEL CONNECTOR (MALE)



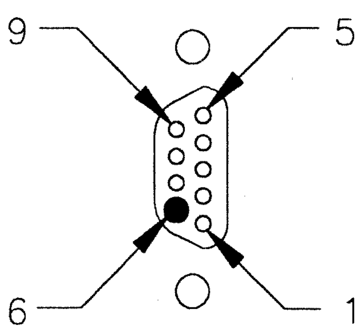
PIN	DESCRIPTION
1	COMBINATION ANALOG OUTPUT
2	ST BUFFERED ANALOG OUTPUT
3	A1 BUFFERED ANALOG OUTPUT
4	A2 BUFFFERED ANALOG OUTPUT
5	B1 BUFFERED ANALOG OUTPUT
6	B2 BUFFERED ANALOG OUTPUT
7	ST DIGITIZED ANALOG OUTPUT
8	A1 DIGITIZED ANALOG OUTPUT
9	A2 DIGITIZED ANALOG OUTPUT
10	B1 DIGITIZED ANALOG OUTPUT
11	B2 DIGITIZED ANALOG OUTPUT
12	NO CONNECTION
13	COLD CATHODE DISABLE
14-24	ANALOG GROUND
25	COLD CATHODE DISABLE GROUND

FIGURE 24 - ANALOG MODULE REAR PANEL CONNECTOR



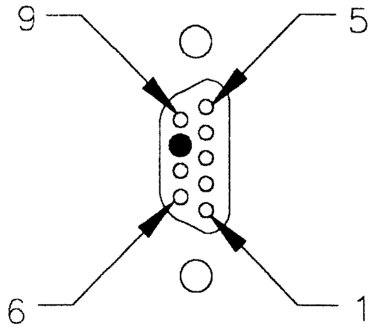
PIN	DESCRIPTION
1,6	+ BRIDGE DRIVE
5,9	- BRIDGE DRIVE
7	BRIDGE SENSOR LEG
8	BRIDGE REFERENCE LEG
3	+ SIGNAL
4	- SIGNAL
2	CHASSIS GROUND

FIGURE 25 - PIRANI MODULE REAR PANEL CONNECTOR



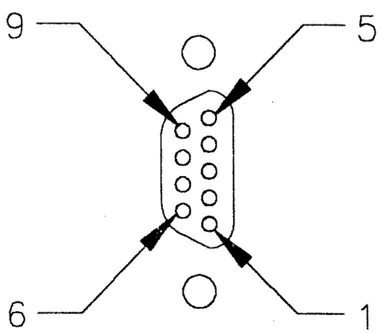
PIN	DESCRIPTION
5	+15 VOLTS
1	-15 VOLTS
8	+ SIGNAL
7	- SIGNAL
9	+/- 15 RETURN
6	CHASSIS GROUND

FIGURE 26 - CAPACITANCE MANOMETER MODULE REAR PANEL CONNECTOR



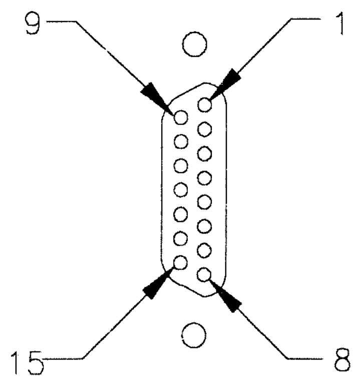
PIN	DESCRIPTION
1,5	THERMOCOUPLE AC DRIVE
2,4	THERMOCOUPLE AC DRIVE
3	+ SIGNAL
9	CHASSIS GROUND

FIGURE 27 - THERMOCOUPLE MODULE REAR PANEL CONNECTOR



PIN	DESCRIPTION
1,6	+BRIDGE DRIVE
5,9	−BRIDGE DRIVE
3	+ SIGNAL
4	− SIGNAL
7	BRIDGE SENSOR LEG
8	BRIDGE REFERENCE LEG
2	CHASSIS GROUND

FIGURE 28 - CONVECTION MODULE REAR PANEL CONNECTOR



RELAY	PIN NUMBER		
	NORMALLY OPEN	COMMON	NORMALLY CLOSED
SCC (SP1)	2	9	1
A1 (SP2)	10	11	3
A2 (SP3)	12	5	4
B1 (SP4)	13	14	6
B2 (SP5)	7	15	8

FIGURE 29 - ACCESSORY CONNECTOR PROCESS CONTROL RELAY PINOUTS

NOTE : If the process control relays are used with inductive loads (i.e. solenoids, relays, transformers, etc.) then arcing of the relay contacts may interfere with controller operation and/or reduce relay contact life. For this application, use of the arc suppression network is recommended. Values for the resistor and capacitor may be calculated by:

$$R = E/(I^{x}) \quad \text{and} \quad C = I^{2}/1x10^{7}$$

where:
- R is in Ohms, 0.5 Ohms minimum;
- C is in Farads, .001 microFarads minimum;
- I is the peak load current in volts;
- E is the peak source voltage in amps; and
- $x = 1+(50/E)$

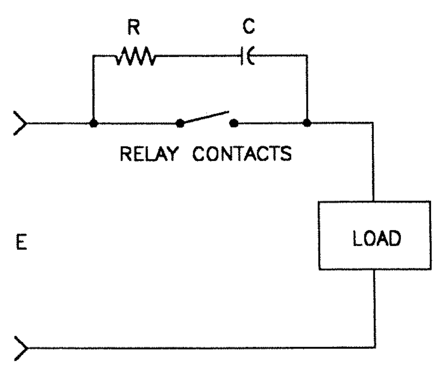


FIGURE 30 - ARC SUPPRESSION NETWORK FOR PROCESS CONTROL RELAYS

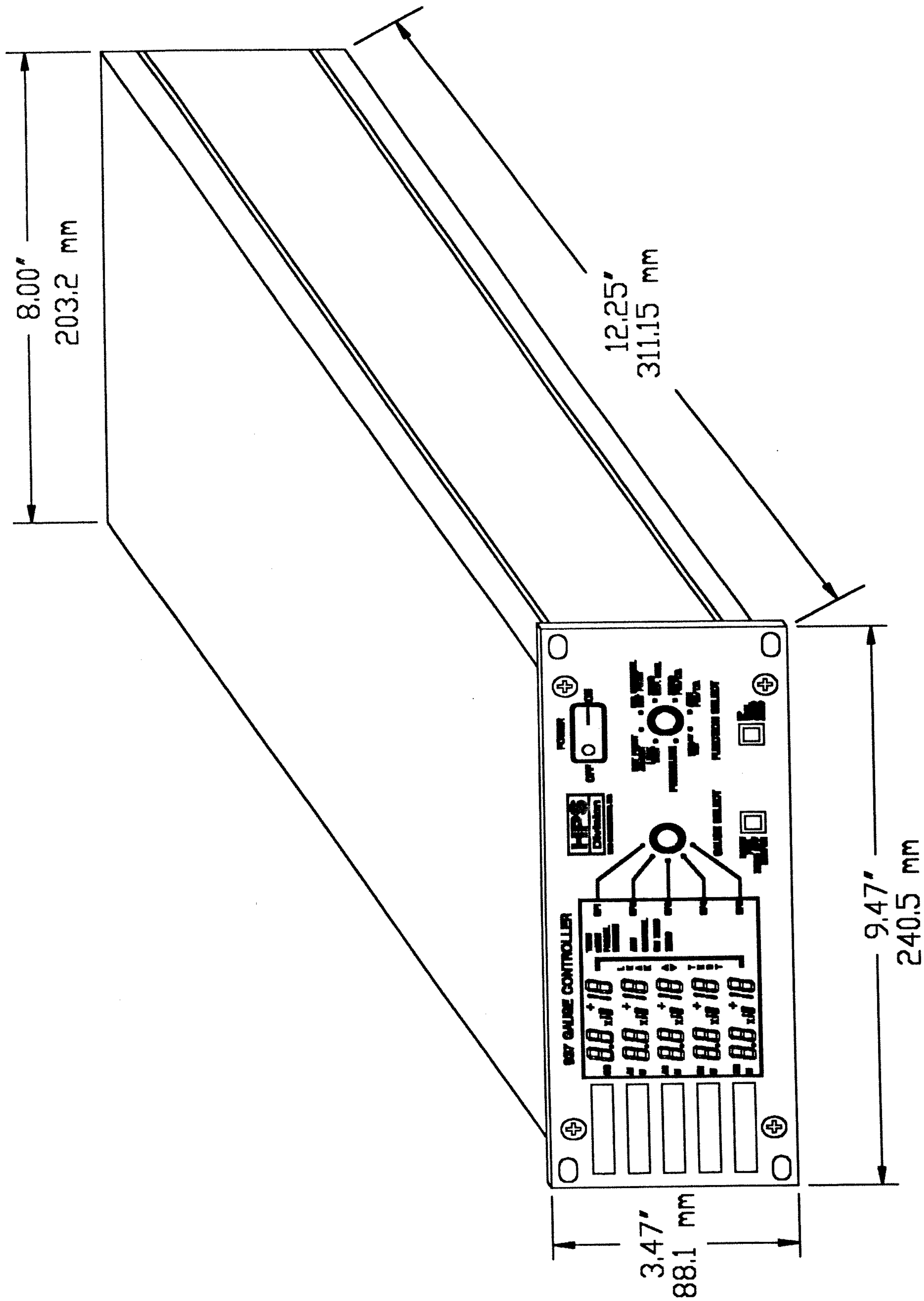


FIGURE 31 - 937 CONTROLLER DIMENSIONS

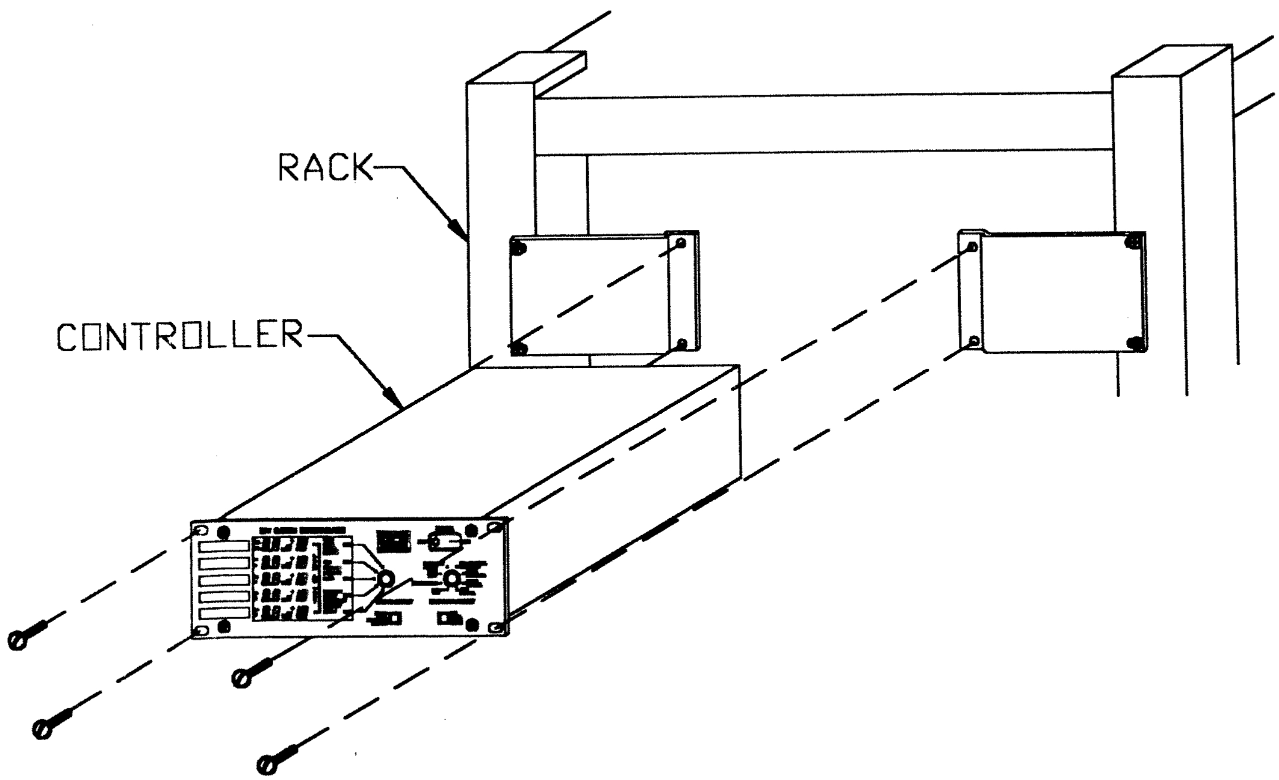


FIGURE 32 - PANEL MOUNTING METHOD FOR FULL RACK

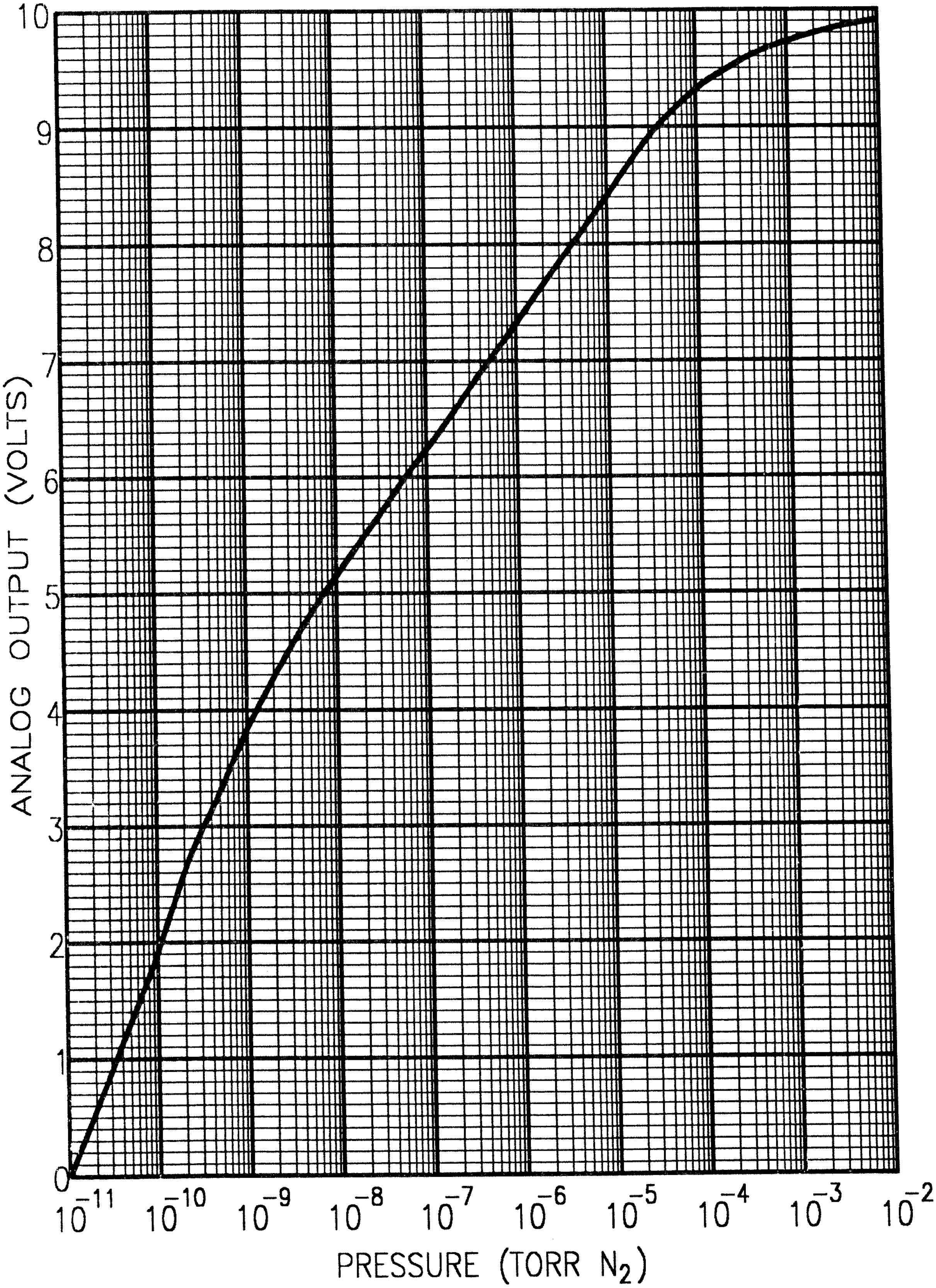


FIGURE 33 - COLD CATHODE CURVE ANALOG OUTPUT vs. PRESSURE
P(He)=P(display)*8; P(Ar)=P(display)*.8 (or .5 near 10^{-3}, .2 near 10^{-2})

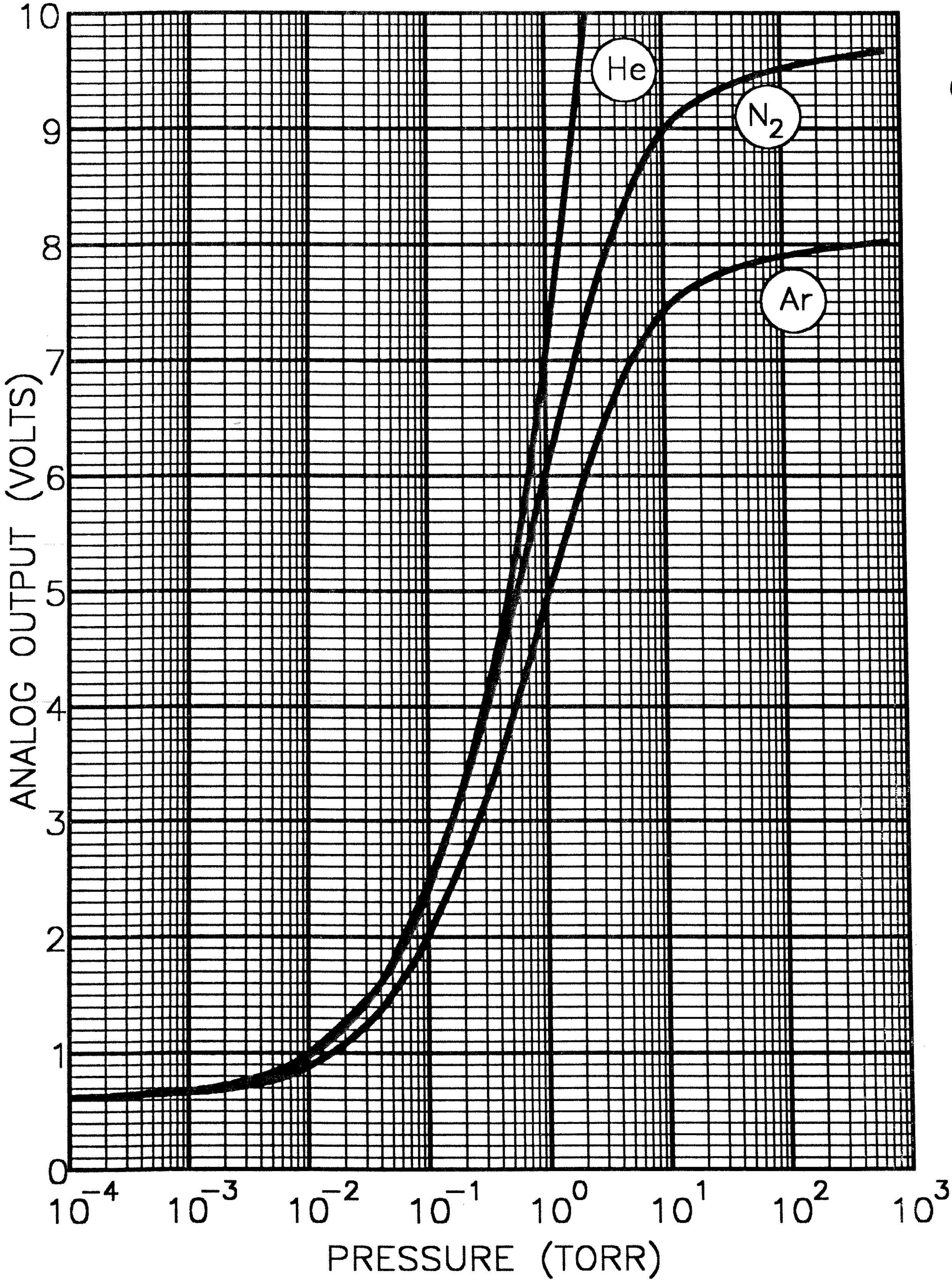


FIGURE 34 - PIRANI CURVE
ANALOG OUTPUT vs. PRESSURE

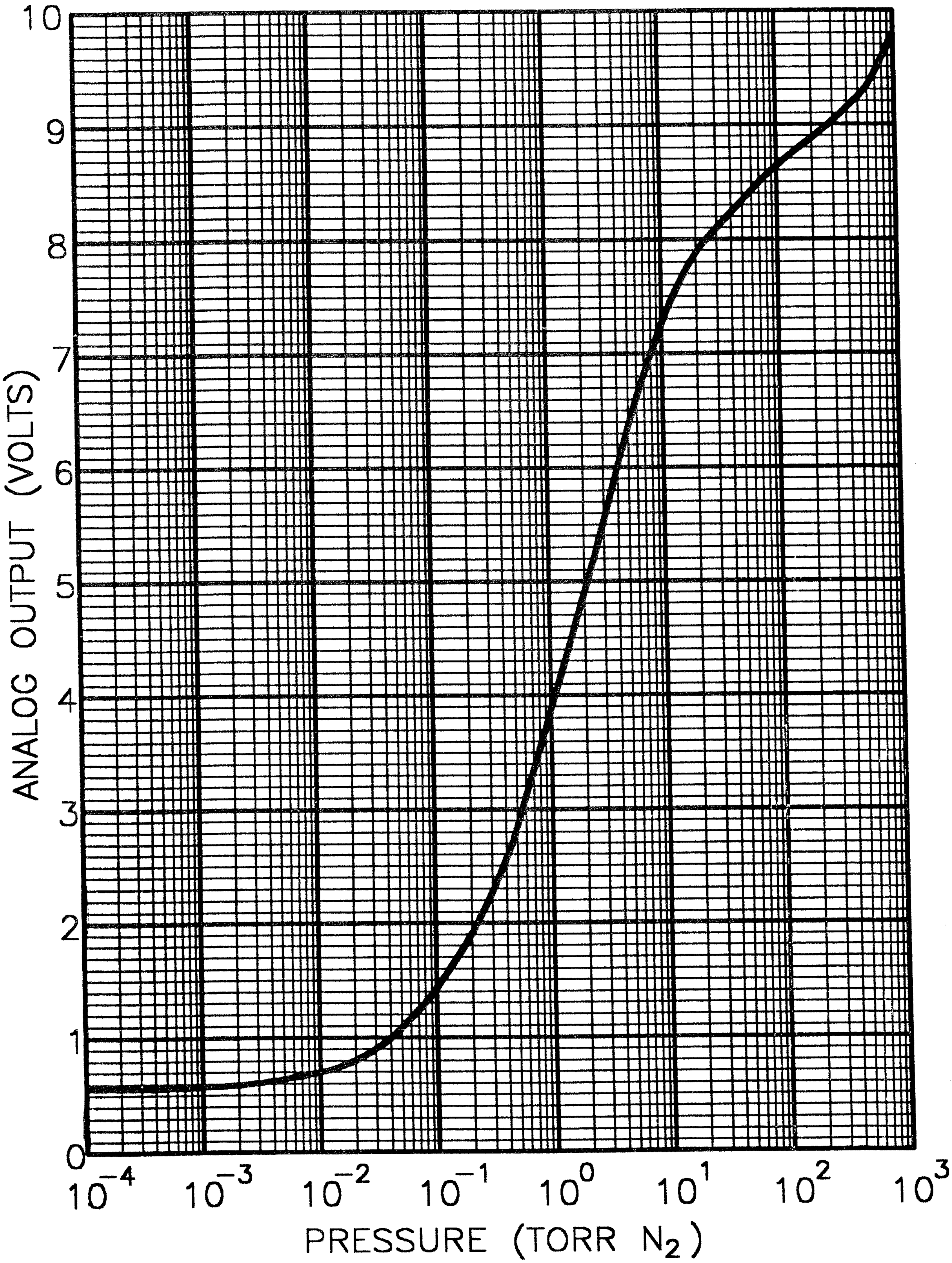


FIGURE 35 - GPC CONVECTION CURVE
ANALOG OUTPUT vs. PRESSURE

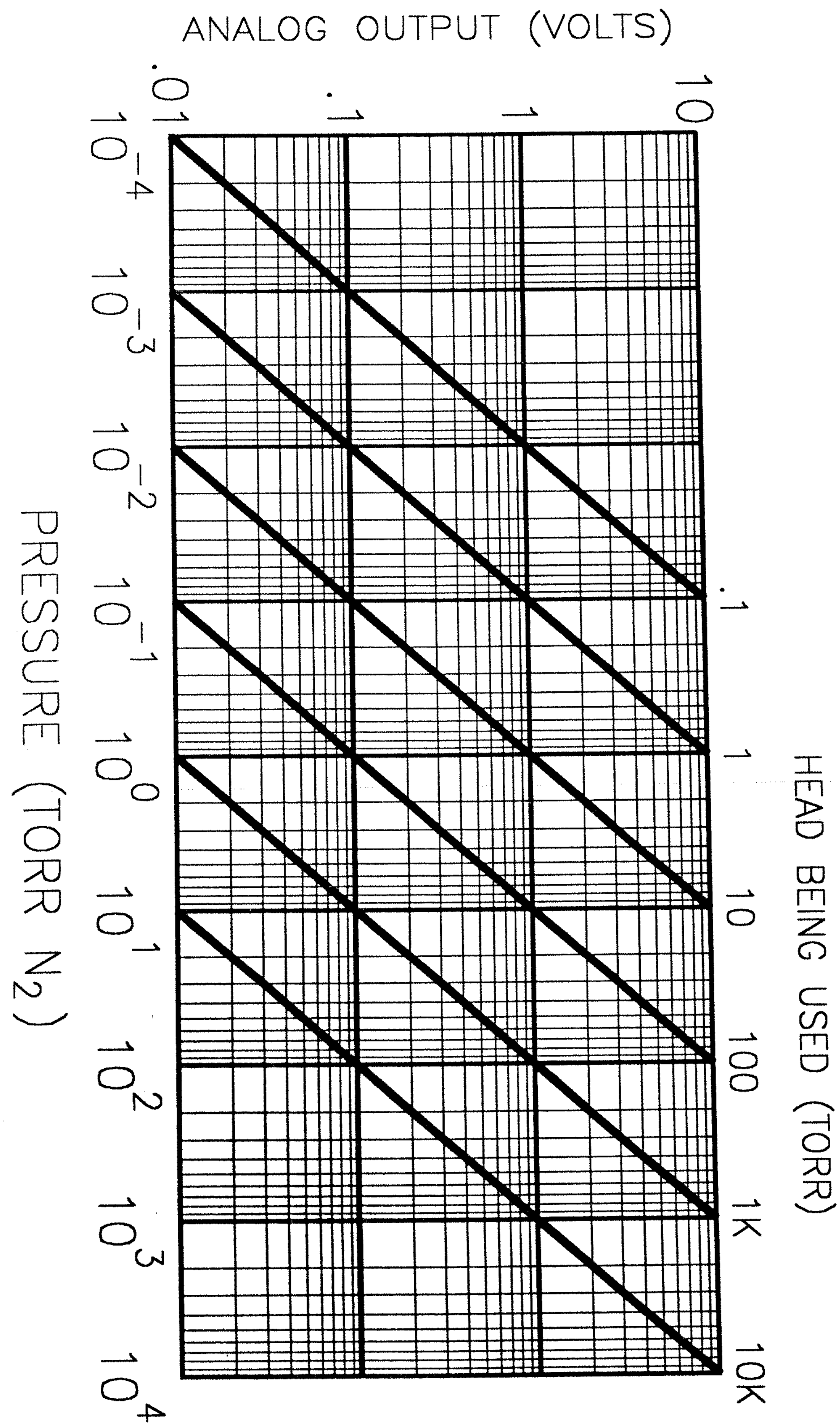


FIGURE 36 - CAPACITANCE MANOMETER CURVES
ANALOG OUTPUT vs. PRESSURE

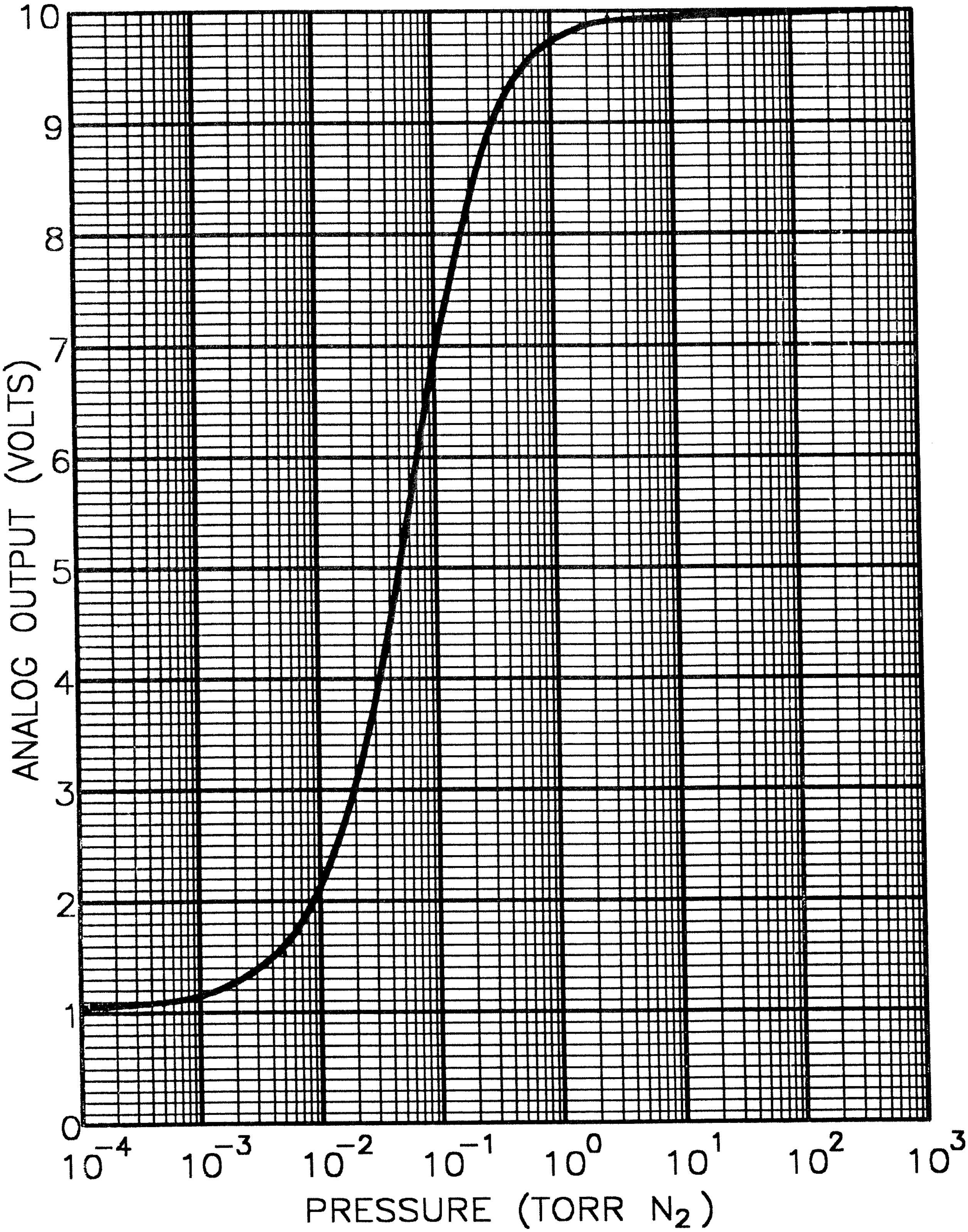


FIGURE 37 - THERMOCOUPLE CURVE
ANALOG OUTPUT vs. PRESSURE

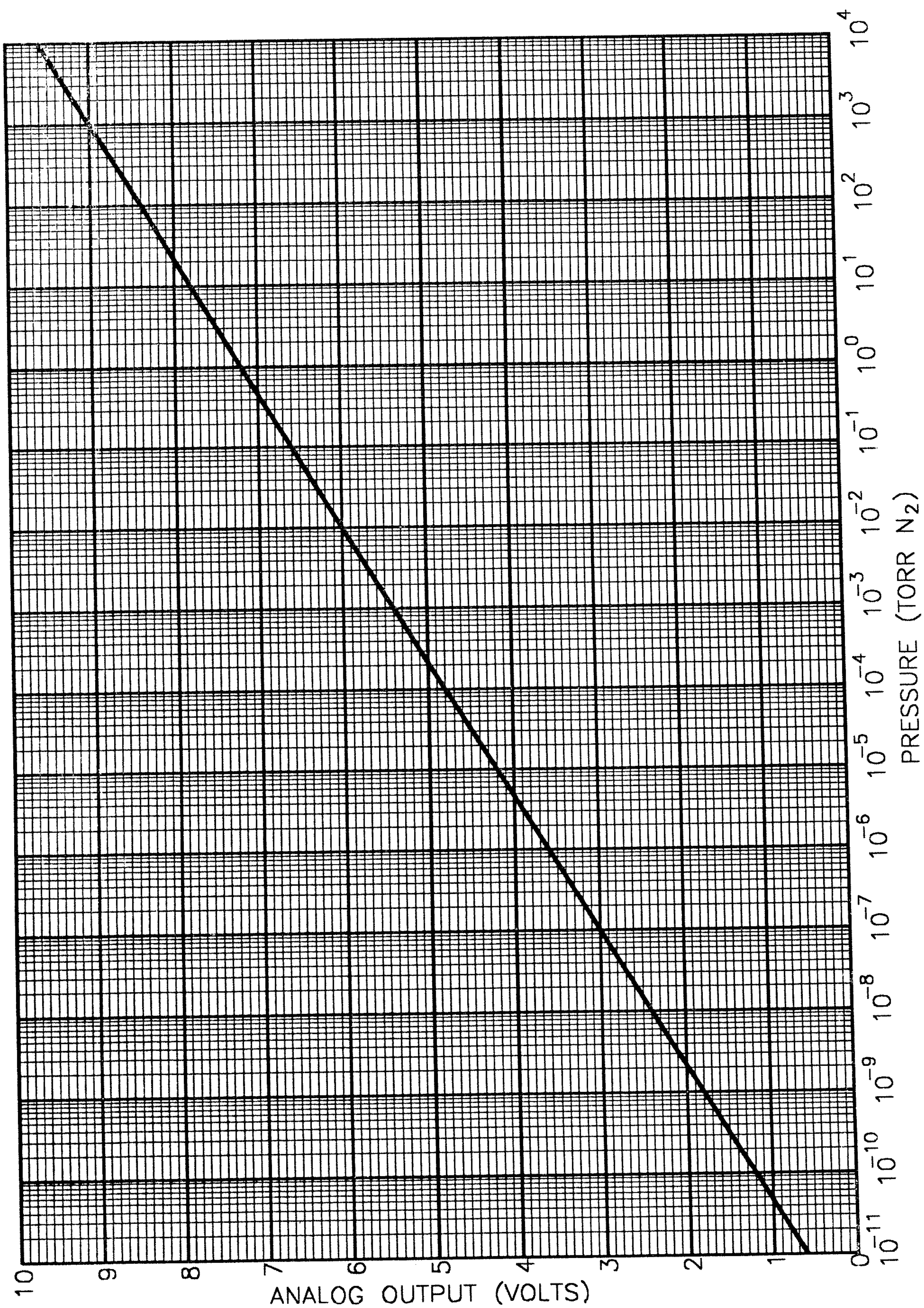


FIGURE 38 - LOGARITHMIC OUTPUT CURVE FOR ALL GAUGE TYPES
OUTPUT VOLTAGE vs. PRESSURE

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