InstruTech®

FlexRax® 4000
Multi-Gauge Controller

Powered by Windows® Embedded

User Manual

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Important User Information

There are operational characteristic differences between solid state equipment and electromechanical equipment. Because of these differences, and because there are a variety of uses for solid state equipment, all persons that apply this equipment must take every precaution and satisfy themselves that the intended application of this equipment is safe and used in an acceptable manner.

In no event will Instrutech be responsible or liable for indirect or consequential damages that result from the use or application of this equipment.

Any examples or diagrams included in this manual are provided solely for illustrative purposes. Because of the many variables and requirements imposed on any particular installation, Instrutech cannot assume responsibility or liability for any actual use based on the examples and diagrams.

No patent liability is assumed by Instrutech with respect to use of information circuits, equipment, or software described in this manual.

Throughout this manual we use notes, notices and apply internationally recognized symbols and safety messages to make you aware of safety considerations.

Identifies information about practices or circumstances that can cause electrical or physical hazards which, if precautions are not taken, could result in death or serious injury, property damage, or economic loss.

Identifies information about practices or circumstances that can cause electrical or physical hazards which, if precautions are not taken, could result in minor or moderate injury, property damage, or economic loss.

Identifies information that is critical for successful application and understanding of the product.

Labels may be located on or inside the device to alert people that dangerous voltages may be present.

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1 Introduction - General Information

1.1 Description

The *FlexRax™4000* is a multi-gauge rack mount vacuum gauge controller designed specifically to operate either glass-enclosed or nude Bayard-Alpert (B-A) ionization gauges (IG) including InstruTech's Series 600 B-A gauges. Additionally, it can operate either InstruTech's *Hornet™* IGM400 miniature hot cathode Ionization Gauge Module or CCM500 double inverted magnetron Cold Cathode Ion Gauge (CCIG) module, the *Worker Bee™* CVG101 Series and Granville-Phillips® Convectron® convection vacuum gauges. These gauges are designed to measure gas density (pressure) from slightly above atmospheric pressure to less than one-billionth of an atmosphere[1]. The *FlexRax* is offered as an industry standard 19-inch wide, 2U high, rack-mountable design. The number and types of sensors operated is dependent on the options that are installed in the locations available in the *FlexRax* controller. There are several unique option cards that will allow operation of different types of vacuum gauges, serial network communications and provide process input-output control.

1) IGR option card (Ion[2] Gauge, I^2R, resistive degas) – operates a resistive degas, sometimes referred to as I^2R degas, hot filament nude or glass-enclosed B-A Ion Gauge (IG – InstruTech Series BA602/BA603 or similar).
2) IGE option card (Ion Gauge, electron bombardment) – operates an electron bombardment or 'EB' degas hot filament nude UHV B-A (IG – InstruTech Series BA601 or similar).
3) IGM/CG option card (Ion Gauge Module and Convection Gauge) – operates either one InstruTech IGM400 *Hornet* IGM or one CCM500 Cold Cathode Module and two InstruTech CVG101 *Worker Bee* Convection Gauges (CG).
4) AI/O-R option card (Analog Input/Output – Relay) – provides up to 16 setpoint relays and eight analog outputs. Each option (two maximum) will accept one analog input signal from another type of pressure gauge transducer such as a Capacitance Diaphragm Gauge (CDG) or other pressure measurement device with compatible signal proportional to pressure.
5) COM option card (communication) – provides RS485 or RS232 serial communications.

 ***FlexRax* 4000 Multi-Gauge Controller**	CCM500 / IGM400 *Hornet* Ionization Gauge Modules, BA600 Series classic size resistive and e-beam degas type glass enclosed or nude B-A ion gauge transducers and CVG101 *Worker Bee* Convection Gauges may be operated by the *FlexRax* Multi-Gauge controller. With combined operation of these devices, wide range pressure measurement is possible.	

[1] At sea-level, 1 atmosphere (air) is ~760 Torr, 1013 mbar or 101 kPa. The measurement of vacuum or very low pressures may extend to less than 1.00E-09 Torr when using InstruTech's vacuum measurement and control instrumentation.

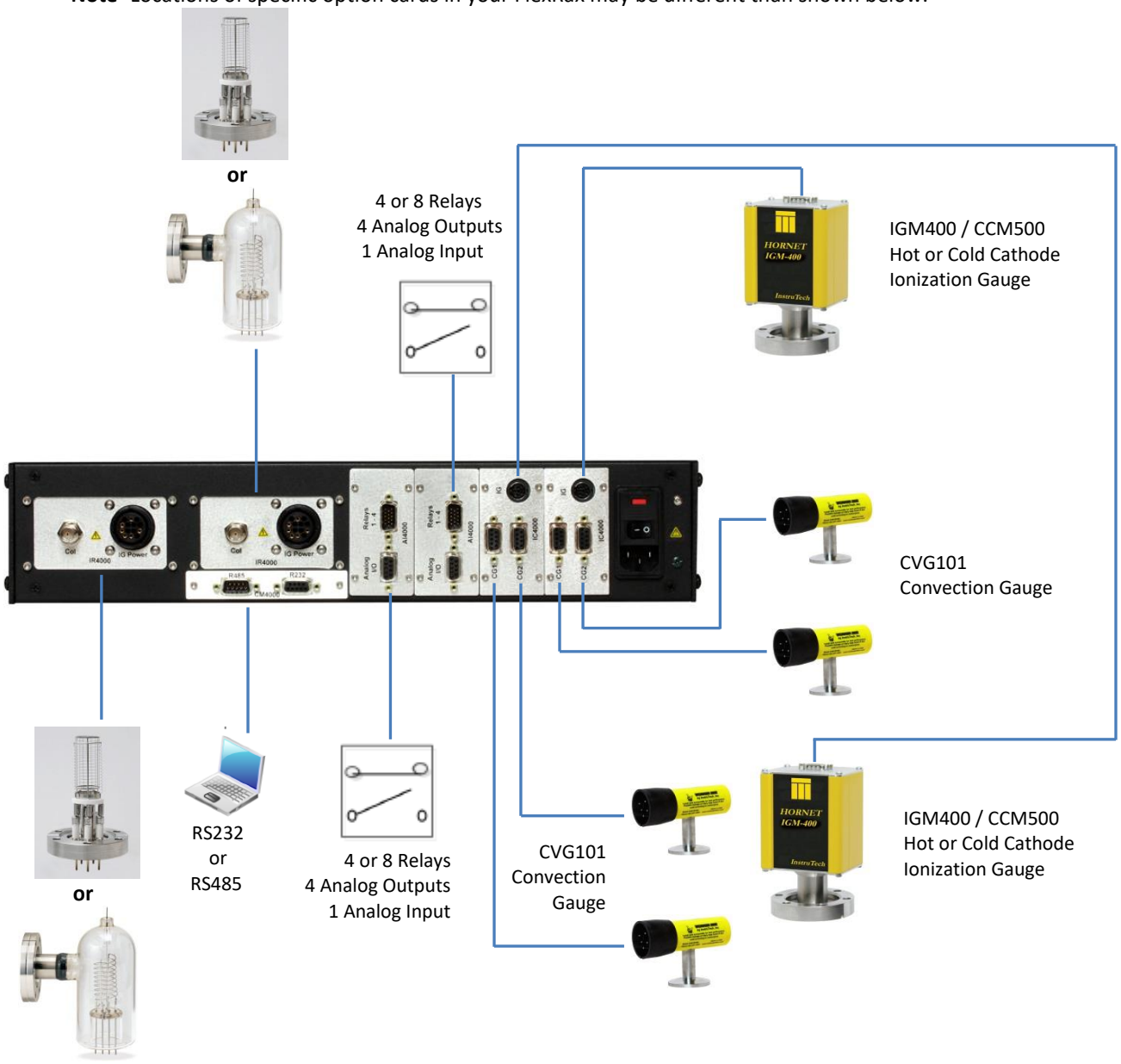
[2] Ion and Ionization Gauge (IG) may be used interchangeably throughout this User Manual. The Bayard-Alpert hot cathode (filament) Ionization (Ion) Gauge is used to both ionize the gas within the gauge internal volume and collect the ions created by the ionization process. The quantity of ions collected by the IG is directly proportional to the gas density (pressure) inside the gauge tube. Similarly, a cold cathode IG operates on the principle of ionizing the gas creating a discharge of electrons and ions that is proportional to the gas density inside the gauge transducer.

The *FlexRax* 4000 will provide simultaneous operation and pressure measurement of either up to two InstruTech IGM400 *Hornet* miniature ionization gauge modules or CCM500 double inverted magnetron cold cathode ion gauge modules, up to two glass-enclosed or nude B-A ionization gauge transducers and four convection gauges dependent on the gauge control option cards installed. The maximum number of glass-enclosed or nude B-A gauges in any gauge card configuration is two.

Setup and programming of the *FlexRax* is provided via a front panel display screen and keys for selection of the parameters displayed on the front panel screen.

1.1.1 Typical FlexRax to Gauge Connection Diagram

Note- Locations of specific option cards in your FlexRax may be different than shown below.



1.2 Specifications - FlexRax 4000 Multi-Gauge Controller

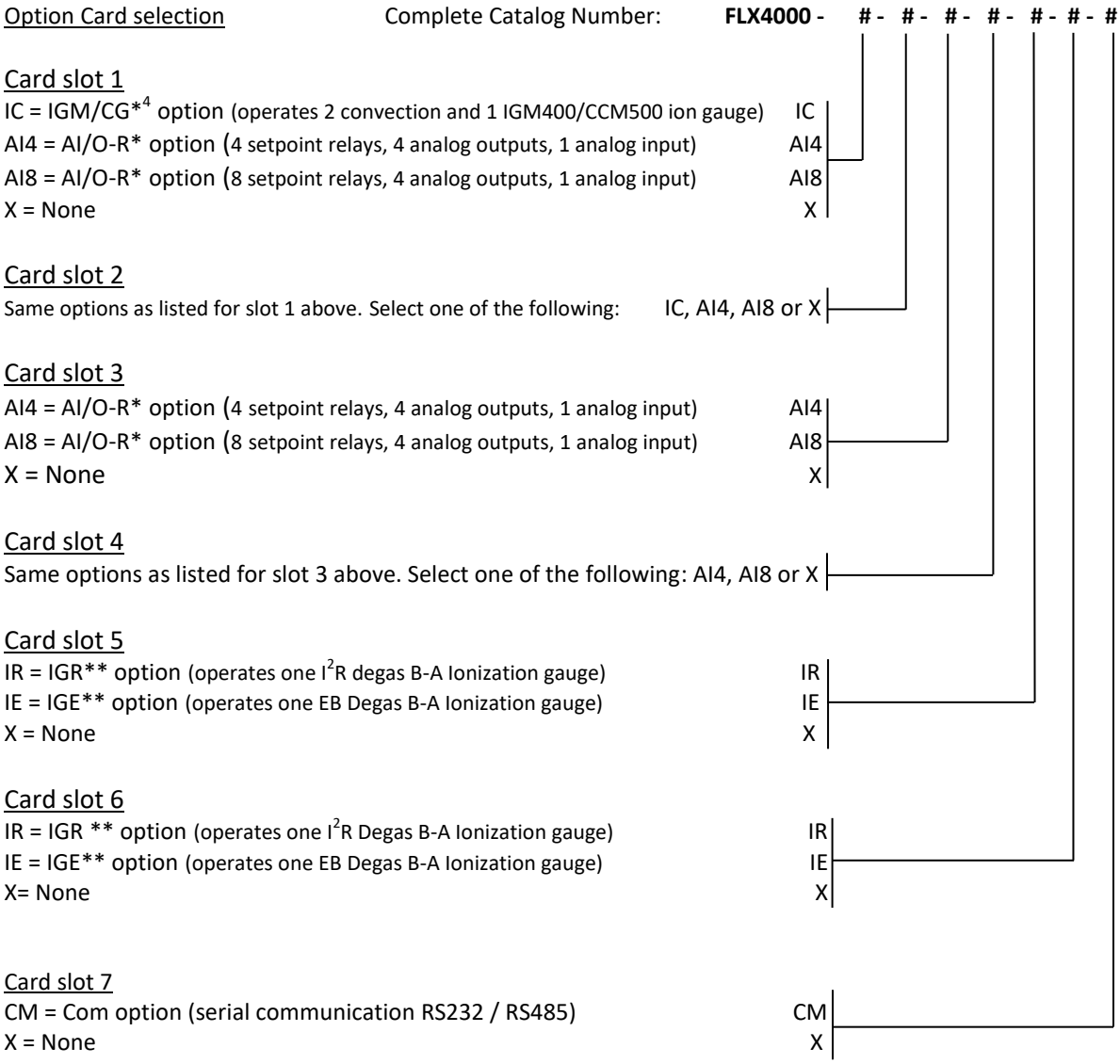
controller measurement range (vacuum gauge dependent)	BA601 EB degas B-A UHV nude ionization gauge: 2 x 10^{-11} to 1 x 10^{-3} Torr BA602/603 I^2R degas B-A nude or glass ionization gauge: 4 x 10^{-10} to 1 x 10^{-3} Torr InstruTech IGM400 hot cathode ionization gauge: 1 x 10^{-9} to 5 x 10^{-2} Torr InstruTech CCM500 cold cathode ionization gauge: 1 x 10^{-9} to 1 x 10^{-2} Torr convection gauges: 1 x 10^{-4} to 1,000 Torr
display -	3.7 inch LCD with LED backlight; 240 x 320 pixel format (resolution)
pressure measurements and output control	user selectable LCD screen to display pressure measurement and status of output controls for all options installed
setup and programming	front panel LCD setup screen with function/parameter selection keys
units of measure	Torr, mbar, Pa (user selectable)
function: ionization gauge (4 max)	powers and operates up to two glass-enclosed or nude B-A ion gauges and up to two InstruTech IGM400 or CCM500 *Hornet* miniature ion gauge modules
convection gauge (4 max)	powers and operates up to four *Worker Bee™* CVG101 or Granville-Phillips® Convectron® convection gauge transducers
capacitance diaphragm gauge (2 max)	accepts analog input signals from CDGs or other InstruTech vacuum gauge modules (external power source for these type auxiliary devices will be required)
IG filament/sensor control - on /off	front panel push buttons, automatic using convection gauges, digital input or serial communications
filament control	user selectable between filament 1 or filament 2 using front panel display menu and select keys
emission current	100 µA, 4 mA, 10 mA or automatic switching between 100 µA and 4 mA at user programmed pressure
degas (IGR/IGE)	40 W resistive (I^2R); 40 W electron bombardment (EB), nominal; programmable duration – permissible at measured pressure < 5 x 10^{-5} Torr
overpressure protection	For IGR/IGE option (glass/nude IG), turns ion gauge off at a factory default setting of 5 x 10^{-4} Torr at 4 mA emission current, 1 x 10^{-4} Torr at 10 mA emission current or 1 x 10^{-3} Torr (default; may be set to 1 x 10^{-2} Torr max.) at 100 µA emission current. For IGM option (IGM400 hot cathode IG module), turns ion gauge off at a factory default setting of 1 x 10^{-3} Torr at 4 mA emission current or 5 x 10^{-2} Torr at 100 µA emission current. The CCM500 cold cathode is set for IG turn off at 1 x 10^{-2} Torr. *FlexRax* may also be set up for IG auto turn ON/OFF using a CG or CDG auxiliary device.
status	emission current, Relay, Filament and Degas ON/OFF status are available for viewing at the front panel display screen

setpoint relays	up to 16 user programmable single-pole, double-throw (SPDT), 2A at 30 Vdc, 2A at 250 Vac, resistive load, assignable to any of the gauges ⚠**Caution!** The relay contact rating above applies to units shipped on/after February 28, 2017. Serial numbers 17B761C and higher have this new contact rating. Older units shipped before this date with serial numbers 17B760C and lower had a contact rating of 1A at 30 Vdc, 0.5A at 125 Vac, resistive or ac non-inductive. Applying a load to older units which draws more than 0.5 A could cause damage to relays.
analog output	Up to 8 analog outputs may be configured. Analog outputs can be assigned to the ion gauges (IG) and convection gauges (CG) or combination of IG + CG for full range measurements IG only: Log linear 0 to 10 Vdc, 1 V/decade with various scaling selections compatible with Granville-Phillips® Series 307, 350 and 358 IG only: Log linear 1.7 V to 9.3 Vdc (nominal 1.8 to 8.7 Vdc) 0.8 V/decade IG Linear 0 to 10 Vdc (useable over 3 full decades). Compatible with various Granville-Phillips® VGC controller options for Series 307, 350 and 358 Wide Range (combination) IG + CG : Log linear 0.5 V to 7 V, 0.5 V/decade CG : Log linear 0 to 7 V or 1 to 8 V, 1 V/decade; Linear & Non-Linear
analog input (or use, alternatively, for remote IG filament turn on)	accepts up to two 0-10 Vdc analog inputs from 100 mTorr, 1, 10, 100, 1000 Torr F.S. capacitance diaphragm gauges or analog inputs from other InstruTech vacuum gauge modules series CVM201, CVM211, IGM401, CCM501. alternatively, the analog input can be used as a digital input for remote IG sensor turn on by applying a continuous ground (zero volt potential)
serial communications	RS485 / RS232 - ASCII protocol (RS232 protocol compatible with GP 307)
input power (AC Mains)[3]	100-240 Vac, 50/60 Hz nominal; universal power, 600 VA
AC Mains (source power) Fuses	8.0 A, Time Lag, 250 Vac, IEC/UL/CSA certified component
temperature	operating; 0 to + 40 °C storage; -40 to + 70 °C
humidity	0 to 95% relative humidity, non-condensing
weight	14 lb. (6.4 kg)
altitude	operating; 8,200 ft. (2,500 m) max storage; 41,000 ft. (12,500 m) max
CE compliance	EMC Directive 2004/108/EC, EN61326-1, EN55011 Low Voltage Directive 2006/95/EC, EN61010-1
environmental	RoHS compliant
Ingress Protection	IP30

Use the chart shown on the next page to create Catalog (Part) Numbers for the complete *FlexRax* Multi-Gauge controller. Some of the above specifications are applicable only when the configuration of your *FlexRax* includes the Option Card(s) listed and you connect the compatible vacuum pressure measurement transducer (sensor). See user manuals for specifications and additional information not included here for the devices that you intend to use with the *FlexRax* 4000.

[3] The *FlexRax 4000* controller is provided with a NRTL approved AC power cordset suitable for use with nominal AC Mains power of 115 Vac. The controller may be powered by AC Mains from 100 to 240 Vac, nominal, provided that the user provides and uses an agency approved AC Mains power cordset suitable for use with local installation requirements at the geographic location of use.

1.3 FlexRax 4000 Part Number Configuration



* Maximum of two IGM/CG and two AI/O-R option cards per *FlexRax* controller is possible

****** The FlexRax will operate two glass-enclosed or nude, classic size I^2R or EB degas B-A IG's simultaneously.

[4] The IGM/CG option card will operate either the IGM400 hot cathode miniature ionization gauge module or the CCM500 double inverted magnetron cold cathode ionization gauge module.

1.4 FlexRax Cable Assemblies for Gauges

BA601 and BA602 Nude IG Cable[5]

Cable lengths	BA602 Nude IG Cable P/N	BA601 / BA602 Nude IG Cable
10 Ft (3m)	IRN441-1-10F	
25 Ft (8m)	IRN441-1-25F	
50 Ft (15m)	IRN441-1-50F	
> 50 Ft	Consult factory	

BA601 / BA602 Nude IG Cable: Bakeable to 200 °C, provided with push-on sockets for connection to transducer pins.

Cable lengths	BA601 and BA602 Nude IG Bakeable Cable (200 °C) P/N	BA601 / BA602 Nude IG Bakeable Cable with push-on sockets
10 Ft (3m)	IRNBD441-1-10F	
25 Ft (8m)	IRNBD441-1-25F	
50 Ft (15m)	IRNBD441-1-50F	
> 50 Ft	Consult factory	

BA603 Glass IG Cable[6]

Cable lengths	BA603 Glass IG Cable P/N	BA603 Glass IG Cable
10 Ft (3m)	IRG441-1-10F	
25 Ft (8m)	IRG441-1-25F	
50 Ft (15m)	IRG441-1-50F	
> 50 Ft	Consult factory	

IGM400 / CCM500[7] Ionization Gauge Cable

Cable lengths	IGM400 Cable P/N	IGM400 / CCM500 Cable
10 Ft (3m)	BXC400-1-10F	
25 Ft (8m)	BXC400-1-25F	
50 Ft (15m)	BXC400-1-50F	
> 50 Ft	Consult Factory	

CVG101 Convection Gauge Cable

Cable lengths	CVG101 Cable P/N	CVG101 Cable
10 Ft (3m)	CB421-1-10F	
25 Ft (8m)	CB421-1-25F	
50 Ft (15m)	CB421-1-50F	
> 50 Ft	Consult factory	

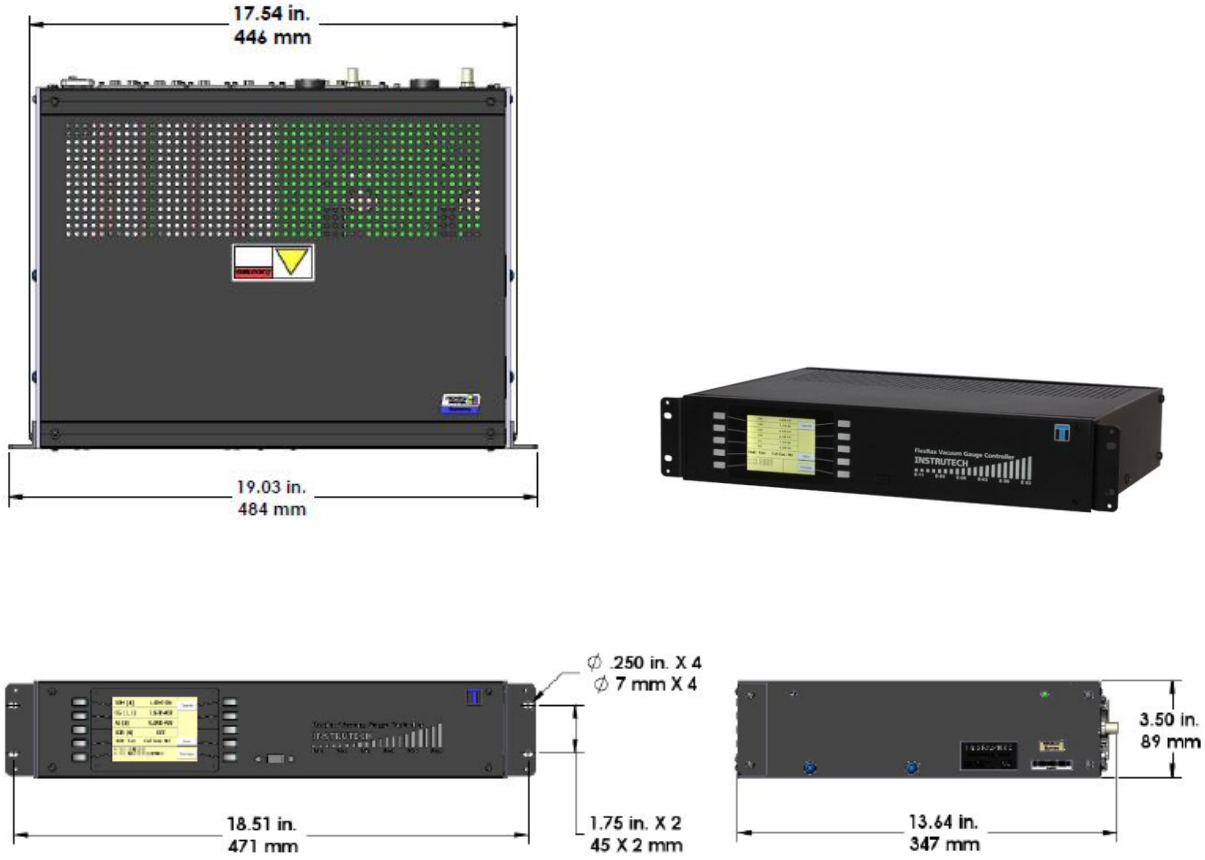
[5] Maximum ambient operating temperature for BA602 Nude IG cables should be 50 °C.
[6] Maximum ambient operating temperature for BA603 Glass IG cables should be 50 °C.
[7] BXC400-1-xxF cables are compatible with both IGM400 and CCM500 modules.

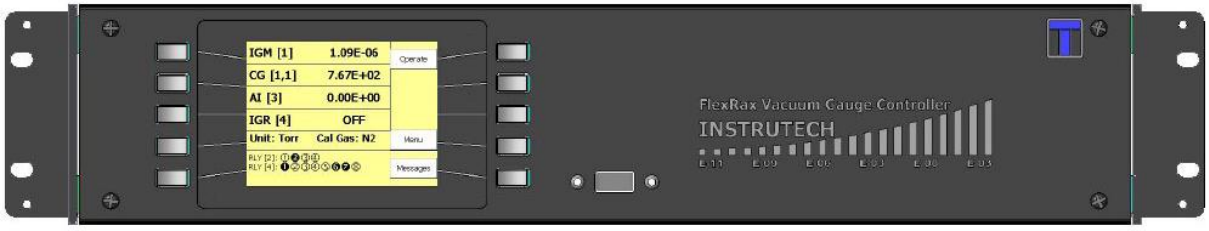
1.5 Mechanical Installation - FlexRax Controller

When mounting multiple units in your rack mount enclosure or mounting the FlexRax below other electronic equipment in your rack, **allow at least 1U of space** (1.75 in., 45 mm) between the units to ensure adequate ventilation especially if operating one or more IGR/IGE option cards in your *FlexRax.*

The revelevant EIA standard 19-inch wide, 2U high rackmount instrument dimensions are listed in each view of the *FlexRax* shown below. If you are mounting the *FlexRax* in a rackmount instrumentation enclosure, use screws (user supplied) appropriate for the enclosure screw clips or threaded holes available on your enclosure.

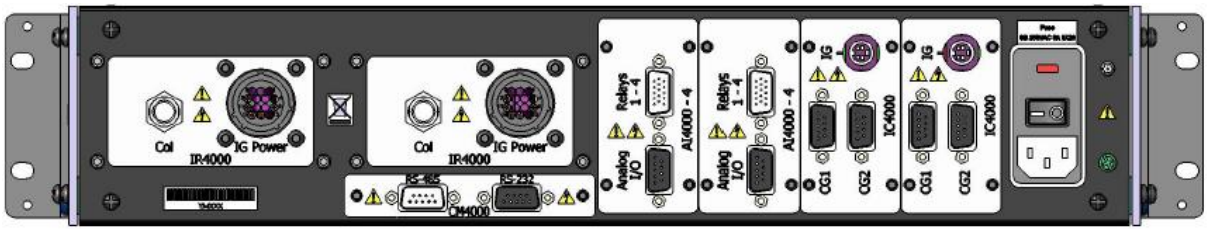
Inches (mm)





***FlexRax 4000* - Front Panel**

The functions and operation of the *FlexRax* Multi-Gauge Controller are provided by the 10 front panel keys (push-button switches) linked to the displayed functions on the front panel LCD Display. DO NOT press the soft-keys displayed on the LCD screen. Press only the hardware key linked to the displayed soft-key on front panel LCD Display. The instrument should be installed to allow access to the front panel for programming/setup, visual indications of pressure measurements, setpoint relay status and mode of operation.



***FlexRax 4000* - Back Panel**

All connections to external devices and AC Mains power are provided by connectors located on the back panel of the *FlexRax 4000.*

The controller may be installed in an EIA standard rack mount enclosure using appropriate hardware for your rack mount system.

Provide adequate protection to prevent liquid from splashing on or otherwise flowing into the *FlexRax.* Ventilation holes are provided to allow convection cooling within the controller. Provide adequate prevention of objects and foreign matter which may cause an electrical circuit malfunction or failure, from falling through the ventilation holes in the *FlexRax* top cover.

1.6 Mechanical Installation - Ionization Gauges

NOTICE - For more detailed information about the IGM400 *Hornet™* hot cathode ionization gauge and CCM500 cold cathode ionization gauge, please refer to the User Manual for each of these products.

IGM400

CCM500

BA601

BA602

BA603

Mount the ionization gauge as close as possible to the pressure you want to measure. Long or restricted, small diameter tubing will create a pressure difference between your process chamber and the gauge. This may cause a delay in response to pressure changes. Mounting the ionization gauge too close to a gas source inlet may also cause measurement and control instability.

The ionization gauge can be mounted in any orientation, however, if possible, mount the gauge with port down to help minimize the effect of any particles or condensation collecting in the gauge.

Do not mount the ionization gauge where it will be subjected to excessive vibration. Vibrations may cause unstable readings, measurement errors and possible mechanical stress to components in the ionization gauge.

Shield the ionization gauge near ion or electron sources such as an electron beam or in a sputtering system.

For electrical safety purposes the housing of the gauge must be grounded to the vacuum chamber. When using KF flanges, metal clamps must be used to ensure proper grounding. Do not attempt to modify your flange in order to use non-metallic-type flange clamps.

Fittings/Flanges - follow the fitting/flange manufacturer's recommendations for installation and use.

Use all metal vacuum fittings with metal seals when operating pressures are expected to be below 1.00×10^{-7} Torr (1.33×10^{-7} mbar, 1.33×10^{-5} Pa).

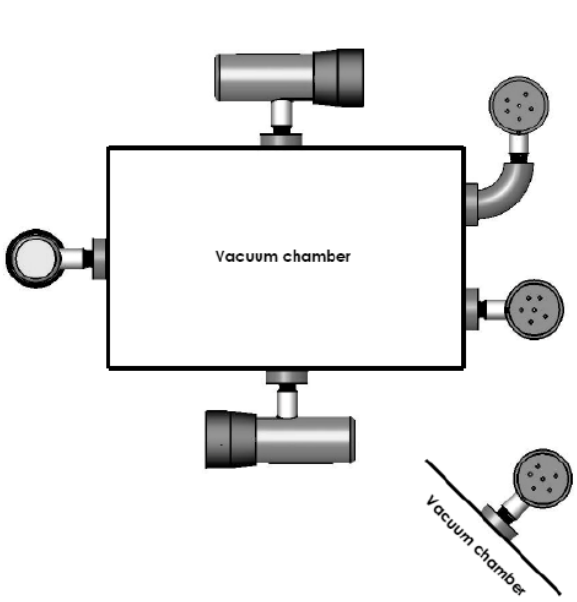
1.7 Mechanical Installation - Convection Gauges

NOTICE - For more detailed information about the CVG101 Worker Bee™ convection gauge, please refer to the User Manual for the CVG101.

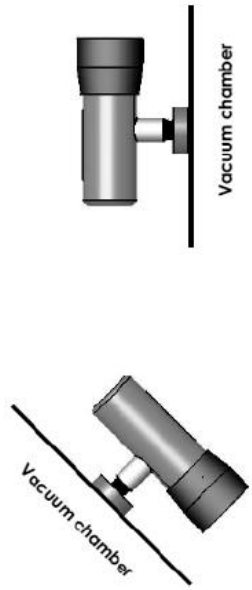
Mount the CVG101 as close as possible to the pressure you want to measure. Long or restricted, small diameter tubing will create a pressure difference between your process chamber and the gauge. This may cause a delay in response to pressure changes. Mounting the CVG101 too close to a gas source inlet may also cause measurement and control instability. Do not mount the CVG101 near a source of heating or cooling, such as heaters or air conditioning vents.

Mount the CVG101 with its main axis horizontal (see diagram below). Pressure reading errors may occur above 1 Torr if the unit is not mounted horizontally. Below 1 Torr, mounting position has little to no effect.

For Accurate Measurements Above 1 Torr, Mount the Gauge Axis Horizontally as Shown Below



Correct Orientation



Incorrect Orientation

Mount the CVG101 with port down, if possible, to help minimize the effect of any particles or condensation from collecting in the gauge. Do not mount the CVG101 where it will be subjected to excessive vibration. Vibrations may cause unstable readings, measurement errors and possible mechanical stress to components in the CVG101.

Flanges/ Fittings - follow the manufacturer's recommendations and note the following:
- NPT fittings: When connecting the device using a NPT fitting, apply a thread sealant compound or wrap the threaded portion of the tubing with one-and-a-half to two wraps of pipe thread seal tape such as PTFE (Teflon®) tape and hand tighten the gauge into the gauge port. Do not use a wrench or other tool which may damage the gauge.

2 Important Safety Information

InstruTech has designed and tested this product to provide safe and reliable service, provided it is installed and operated within the *strict safety guidelines provided in this manual*. **Please read and follow all warnings and instructions.**

⚠ WARNING

To avoid serious injury or death, follow the safety information in this document. Failure to comply with these safety procedures could result in serious bodily harm, including death, and or property damage.

Failure to comply with these warnings violates the safety standards of installation and intended use of this instrument. InstruTech disclaims all liability for the customer's failure to comply with these instructions.

Although every attempt has been made to consider most possible installations, InstruTech cannot anticipate every contingency that arises from various installations, operation, or maintenance of the control instruments, connections and devices. If you have any questions about the safe installation and use of this product, please contact InstruTech.

This device meets FCC part 15 requirements for an unintentional radiator, class A.

2.1 General

This product is designed for use in accordance with IEC 61010 safety requirements for electrical equipment for measurement, control and laboratory use; Installation Category 2, Pollution Degree 2. This product is a Protection Class 1 device which utilizes protective earthing to ensure operator safety. Hazardous voltages are present with this product during normal operation. The product should never be operated with the covers removed unless equivalent protection of the operator from accidental contact with hazardous internal voltages is provided.

⚠ **WARNING!** There are no operator serviceable parts or adjustments inside the product enclosure; refer servicing to service trained personnel.

Do not modify this product or substitute any parts without authorization of qualified InstruTech service trained personnel. Return the product to an InstruTech qualified service and repair center to ensure that all safety features are maintained. Do not use this product if unauthorized modifications have been made.

⚠ **WARNING!** For continued fire protection, use specified AC mains (~ line) fuse.

⚠ **WARNING!** This product is designed for use with nominal AC mains voltages indicated on the rating nameplate.

InstruTech provides an agency/NRTL approved NEMA 5-15P/IEC60321-1 C14 power cordset only for intended installations using 115 Vac, nominal AC Mains power. If the intended installation at the location of use requires AC Mains power other than 115 Vac to power the *FlexRax* controller, use only an agency approved AC power cordset suitable for the intended installation at the geographical location of use.

WARNING! Source power must be removed from the product prior to performing any servicing.

After servicing this product, ensure that all safety checks are made by a qualified service person. When replacement parts are required, ensure that the parts are specified by InstruTech Substitutions of non-qualified parts may result in fire, electric shock or other hazards. Use of unauthorized parts or modifications made to this product will void the warranty.

To reduce the risk of fire or electric shock, do not expose this product to rain or moisture. These products are not waterproof and careful attention must be paid to not spill any type of liquid onto these products. Do not use these products if they have been damaged. Immediately contact InstruTech to arrange return of the product if it is damaged.

Due to the possibility of corrosion when used in certain environmental conditions, it is possible that the product's safety could be compromised over time. It is important that the product be periodically inspected for sound electrical connections and equipment grounding. Do not use if the equipment grounding or electrical insulation has been compromised.

2.1.1 Service and Operation - FlexRax 4000 Multi-Gauge Controller

The *FlexRax* Controller should be connected to a high quality equipment grounding conductor (earth ground). A terminal is provided on the rear panel of the *FlexRax* for making this connection.

Use an appropriate power source of 100-240 Vac, 50/60 Hz nominal universal power, for the *FlexRax***.** The *FlexRax* will provide appropriate power to the Ion Gauges and Convection gauges. Turn off power to the *FlexRax* if a cable or plug is damaged or the product is not operating normally according to this instruction manual. Contact InstruTech for any service or troubleshooting condition that may not be covered by this instruction manual.

When servicing the *FlexRax* control unit, disconnect AC Mains power to the power entry connector and wait a minimum of 5 minutes before removing the instrument enclosure covers or any option card from the device.

After waiting 5 minutes from the time you have disconnected the AC Mains power to the *FlexRax* power entry module, option cards can be safely added or removed from the controller. The top cover of the *FlexRax* enclosure may be removed in order to gain access to some mechanical feature retention devices for some of the installed option cards. If an option card or option location cover plate is removed and not replaced, ensure that you have obtained the appropriate InstruTech part to adequately cover the cutout on the back panel of the *FlexRax* for that option.

DO NOT apply AC Mains power to the *FlexRax* power entry connector until all option card locations and enclosure covers are securely in place. Refer servicing to InstruTech qualified service personnel.

Gases other than Nitrogen

WARNING! Do not attempt to use with gases other than nitrogen (N_2) or air without referring to Correction Factor Data Tables or Correction Curves for the type of pressure measurement device you intend to use.

InstruTech gauges and modules are calibrated for direct readout of nitrogen or air. Do not attempt to use with other gases such as argon (Ar) or carbon dioxide (CO_2) unless accurate conversion data for N_2 to other gas is properly used. Refer to sections titled "Using the gauge with different gases", "Display" and "Analog Output" for a more complete discussion.

WARNING! The electrodes within the CVG101 convection gauge normally operate at 125 ^{o}C, but if malfunction should occur, the wire temperature could exceed the ignition temperature of certain combustible gases and gas mixtures. Do not use this device in an explosive atmosphere or in the presence of flammable gases, vapors or fumes. Do not use this device to measure the pressure of explosive or combustible gases or gas mixtures.

2.1.2 Service and Operation - Vacuum Gauge Transducers

WARNING! The electrodes within ionization gauges and, under certain conditions, convection gauges could be at temperatures sufficient to ignite explosive or combustible gases or vapors present within the gauge. Do not use ion gauges or convection gauges in an explosive atmosphere or in the presence of flammable gases or fumes. Do not use any Ionization Gauge (IG) or Convection Gauge (CG) to measure the pressure of explosive or combustible gases or gas mixtures. The filaments within the hot cathode ionization gauge operate at incandescent temperatures and could become an ignition source.

If measured pressure exceeds the thresholds that are defined under the following conditions, the ion gauge will turn off:

- When using the IGM400, the pressure exceeds 1.00 x 10^{-3} Torr at 4 mA emission current or 5.00 x 10^{-2} Torr at 100 µA emission current causing the IG to turn OFF.
- When using the IGR/IGE (BA600 series glass or nude B-A ion gauge or equivalent), the pressure exceeds 5.00 x 10^{-4} Torr at 4 mA emission current, 1.00 x 10^{-4} Torr at 10 mA emission current or 1.00 x 10^{-3} Torr (default; may be set to 1.00 x 10^{-2} Torr max.) at 100 µA emission current causing the IG to turn OFF.
- The pressure exceeds 1.00 x 10^{-2} Torr as measured by the CCM500 causing the IG to turn OFF.

During the Degas cycle, if the measured pressure exceeds the thresholds that are defined under the following conditions, Degas will turn off but the filament will remain turned on:

- The pressure exceeds 3.00 x 10^{-4} Torr during DEGAS for the IGM400.
- The pressure exceeds 1.00 x 10^{-4} Torr during DEGAS for the IGR/IGE (BA600 series transducers).

Do not attempt to turn the IG on if the pressure is near the threshold limits defined here.

Ensure vacuum level is less than 5.00 x 10^{-5} Torr before attempting to initiate Degas of the Series 600 B-A IG and IGM400 Ion Gauge Module.

Only use power from the *FlexRax* controller to power the IGM400 Ion Gauge Module, CCM500 Cold Cathode Module and the CVG101 convection gauge. All power for the Series 600 B-A IG (or similar) is provided by the IGR/IGE option card – do not connect external power sources other than those provided by the *FlexRax* to any electrode of a gauge transducer that is connected to the *FlexRax*.

Before attempting to service the devices such as the IGM400, CCM500 and CVG101 connected to the *FlexRax*, turn off AC Mains power to the *FlexRax* controller first. Then disconnect the cables between the gauges and the *FlexRax* controller before proceeding with the service. Do not touch any of the gauge tube pins when the device is at vacuum pressure.

NOTICE **-** Never use an auxiliary or convection gauge to automatically turn off the Ion Gauge when the Ion Gauge filament in use is constructed of **tungsten**. The response time of other gauges may not allow for timely turn off of the **tungsten** filament possibly leading to filament damage. Always turn off the IG filament (tungsten) manually before pressure is allowed to rise above 1.00E-03 (1.00×10^{-3}) Torr.

Turn off power to the IGM400/CCM500 ion gauge module and disconnect the cable from the *FlexRax* controller before detaching the IGM400/CCM500 electronics enclosure from the IG sensor for sensor replacement or bake-out purposes. Refer to the user manual for the IGM400/CCM500 for further information on use, procedures and precautions associated with these products.

It is highly recommended to periodically alternate operating the IGM400 or BA600 series ion gauge filaments 1 and 2. An inactive filament not operating for an extended period of time may result in failure of that filament to establish and maintain emission current in applications where the filament coating may become contaminated by residual application or process related chemistries.

Due to the possibility of corrosion under certain environmental conditions, it is possible that the product's safety could be compromised over time. It is important that all products be periodically inspected for sound electrical connections and grounding. Do not use if the equipment grounding or electrical insulation has been compromised.

The most common cause of all vacuum gauge failures is contamination of the sensor or transducer electrodes. Noisy or erratic readings and total gauge transducer failures are all possible indications of gauge contamination. Contamination can generally be characterized as either: A) a chemical reaction of process gases with transducer/sensor electrodes, or B) an accumulation of material on the transducer (sensor) electrodes. Sensors that fail due to contamination are not covered under warranty.

After servicing these products, ensure that all safety checks are made by a qualified service person.

2.2 Electrical Conditions

⚠ **WARNING!** When high voltage is present in any vacuum system, a life threatening electrical shock hazard may exist unless all exposed electrical conductors are maintained at earth ground potential. This applies to all products that come in contact with the gas contained in vacuum chambers. An electrical discharge within a gaseous environment may couple dangerous high voltage directly to any ungrounded conductor of electricity. A person could be seriously injured or killed by coming in contact with an exposed, ungrounded electrical conductor at high voltage potential. This condition applies to all products that may come in contact with the gas inside the vacuum chamber (vacuum/pressure containment vessel).

Proper Equipment Grounding

⚠ **WARNING!** Hazardous voltages that could seriously injure or cause death are present in many vacuum processes. Verify that the vacuum connection ports on which any ion gauge, ion gauge module, convection gauge and other vacuum gauge transducers are mounted are electrically grounded. Consult a qualified Electrician if you are in doubt about your equipment grounding. Proper grounding of your equipment is essential for safety as well as intended operation of the equipment. The vacuum gauge transducer and enclosure of any control module must be connected directly to a good quality equipment earthing conductor. Use a ground lug on the vacuum connection flange of the pressure measurement device if necessary.

⚠ **WARNING!** In order to protect personnel from electric shock and bodily harm, shield all conductors which are subject to potential high voltage electrical discharges in or around the vacuum system.

⚠ **WARNING!** The power supplies used inside the IGM400/CCM500 Ion Gauge Module are subject to high voltages which could cause severe injury or death. In order to prevent electric shock and bodily harm, the user should wait at least 1 minute after power is removed before touching the IGM's power supply components.

⚠ **DANGER!** When the IGM400 Ion Gauge Module is turned ON from the *FlexRax* controller, 180 volts (Vdc) is present at the power supply and other components inside the IGM400 electronics enclosure (Yellow enclosure connected to the Ion Gauge sensor). Voltages as high as 350 Vdc are present inside the IGM400 electronics enclosure during Degas operation. Do not operate the *FlexRax* controller or the IGM400 *Hornet* without the protective enclosure / covers in place.

⚠ **DANGER!** When the CCM500 anode voltage is turned on and the sensor activated, approximately 3,900 Vdc is present at the power supply and other components. **DO NOT** operate the CCM500 with the CCM500 enclosure removed. Contact with exposed electrical circuits in the CCM500 could result in death or serious injury. Do not operate the *FlexRax* Controller or the CCM500 *Hornet* without the protective enclosure / covers in place.

It is the user's responsibility to ensure that the electrical signals from these products and any connections made to external devices, for example, relays and solenoids, are used in a safe manner. Always double check the system set-up before using any signals to automate your process. Perform a hazardous operation analysis of your system design and ensure safeguards and personnel safety measures are taken to prevent injury and property damage.

2.3 Overpressure and use with hazardous gases

⚠ **WARNING!** Install suitable protective devices that will limit the level of pressure inside your vacuum chamber to less than what the vacuum chamber system components are capable of withstanding. InstruTech gauges should not be used at pressures exceeding 1000 Torr absolute pressure.

In cases where an equipment failure could cause a hazardous condition, always implement fail-safe system operation. For example, use a pressure relief device in an automatic backfill operation where a malfunction could result in high internal pressures if the pressure relief device was not installed on the chamber.

The IGM400/CCM500 Ion Gauge Module, convection gauges and other vacuum pressure measurement transducers should not be exposed to pressures above 1000 Torr absolute. The terms, "sensor", "transducer", "gauge tube", "ion gauge tube", "convection gauge tube", "module", "gauge tube enclosure" "hot cathode IG", "cold cathode IG" and "pressure measurement device" are synonymous with and used interchangeably throughout this User Manual, instructions for use and related collateral materials. In all cases, these terms refer to the component of a vacuum gauging, pressure measurement system that is connected and exposed to the gases contained in the chamber, vessel or gas containment apparatus.

Overpressure - All types of Vacuum Measurement Devices

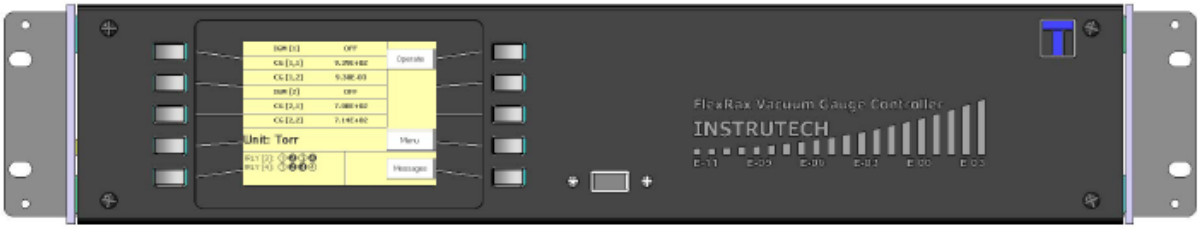
InstruTech convection gauges and similar devices from other manufacturers are not intended for use at pressures above 20 psia (1000 torr); DO NOT exceed 35 psig (< 2 ½ bars) pressure inside the gauge tube. If your chamber goes to higher pressures, you should install an isolation valve or pressure relief device to protect the gauge tube from overpressure conditions. With some fittings, actual safe overpressure conditions may be lower; for example, a quick-connect, O-ring compression fitting may forcibly release the gauge tube from the vacuum chamber fitting with only a few psi over local uncorrected barometric (atmospheric) pressure.

⚠ **CAUTION! If the internal pressure of a vacuum gauge device is allowed to increase above local uncorrected barometric pressure (atmospheric pressure side), vacuum fittings may release and possible overpressure conditions may cause leaks that would allow the gas inside the gauge tube to release into the atmosphere of the surrounding environment. Toxic, pyrophoric and flammable gases are examples of hazardous gases that if allowed to leak out of the vacuum/pressure containment vessel into the atmospheric environment, could cause bodily injury and possible damage to equipment. Never expose the gauge tube internal volume to pressure above local atmospheric pressure when using hazardous gases.**

3 User Interface - Installation and Operation

3.1 User Interface Basics

The setup and programming of the *FlexRax* is done via the ten push-button switches (keys), five each located on the left and right side of the display screen. During programming of the *FlexRax*, the display will identify what function each key represents.



3.1.1 Update Memory –

Your *FlexRax* is delivered ready-to-use with all options ordered installed and configured in the Operating System[8] programmed to **Factory Default** settings. You **do not** need to perform the **Update Memory** procedure when you receive your *FlexRax 4000* Multi-Gauge System. The procedure is included here for completeness and to convey the design concept of the *FlexRax* operating system.

The *FlexRax* is capable of being upgraded in the field by installing new option cards required for your application and performing operating system software updates to match the latest standard of performance available.

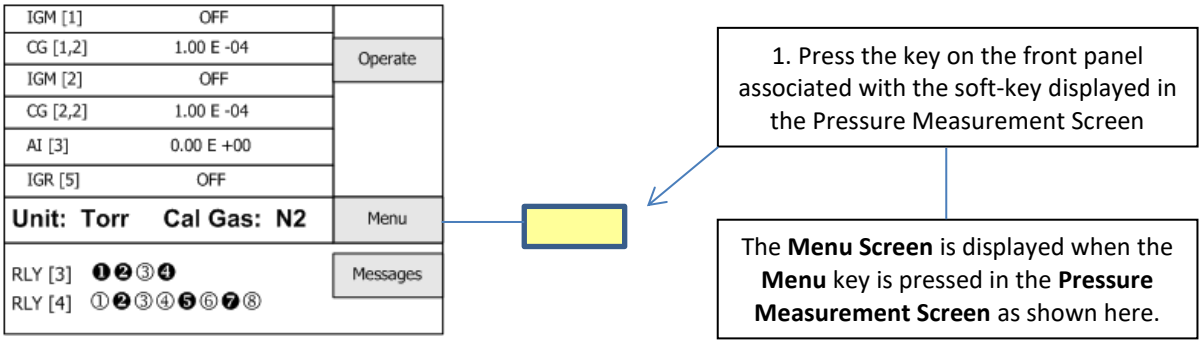
To perform a memory update you will need to obtain the update files from InstruTech. These files may be provided on a USB flash drive which contains the operating system software (code) and database for operation of your *FlexRax.* Simply insert the USB flash drive into the type-A USB connector located on the front panel of the controller. InstruTech may provide access to these files via other electronic data exchange methods. Contact support@instrutechinc.com for further information.

The operations the user may perform during the memory update procedure are:

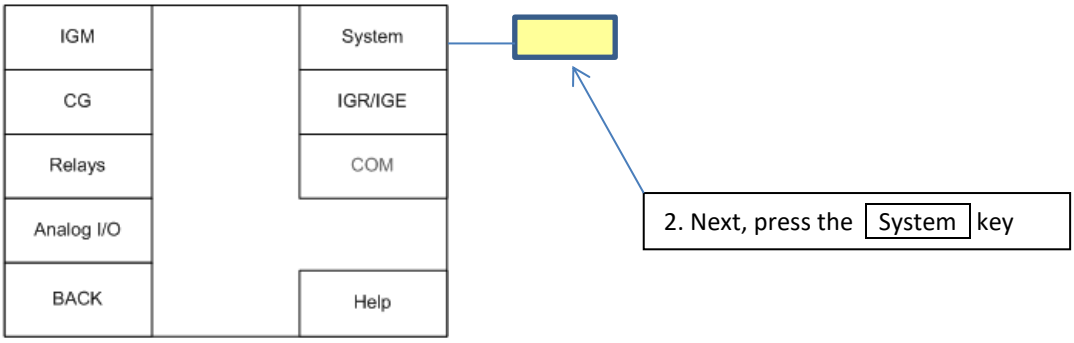
- **Update Memory** (**Software)** – install new software in the *FlexRax* **Memory** for operation of the Multi-Gauge controller.
- **Update Database** – install a new **Database** that the operating system refers to during program execution.
- **Set System Factory Defaults** – establish operation of the operating system at known **Factory Default** settings.

[8] The Operating System in your FlexRax controller is running in the Windows® Embedded Compact environment. You will never be required to perform a Windows® Embedded Compact operating system update when using the *FlexRax 4000* under normal operating conditions. It is at user discretion to perform an 'Update Memory" procedure (installs new operating software for your *FlexRax 4000* controller). You may opt to 'Update Memory' at a future date in order that your *FlexRax* be updated to a software version that allows you to operate a new type of device or to obtain added capability.

After turning AC Mains power to your *FlexRax 4000* to ON, the operating system in the controller will initialize and the **Pressure Measurement Screen** similar to the following[9] will appear. Press the Menu key.



Pressure Measurement Screen



Menu Screen

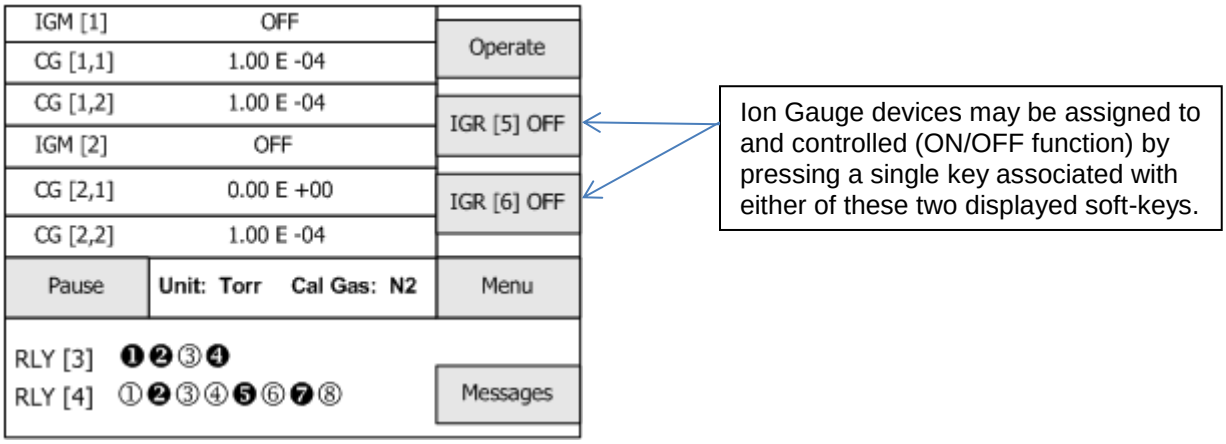
The main **Menu Screen** displays the various keys associated with the menu selections available. The convention used from here forward in this manual will be described in the following notation to indicate the sequence of key selections necessary to get to the screen where the user will enter required values or settings. The display screen soft-keys are linked to hardware keys (push-button switches) located on the front panel. The annotation used in this manual for the sequence of selecting the displayed soft-key is a key-designator box such as Menu followed by a stylized arrow ⇨ which indicates the action of pressing a hardware key associated with a displayed soft-key. The front panel display is not a touch screen display. Do not attempt to activate a function by pressing the soft-key shown on the LCD.

So far, you have pressed two keys that represent the sequence of Menu ⇨ System ⇨ Now, the remaining key entries required to perform the **Update Memory (Software)** procedure will follow this same notation. Press the keys in the sequence shown from left to right.

Menu ⇨ System ⇨ {you are already here in the sequence} Utilities ⇨ Update Software ⇨ the following message will be displayed: {**Messages:** Make sure that the USB Flash Drive is installed into the USB port} OK ⇨ {**Messages:** Software update complete. Turn the AC Mains Power to the *FlexRax* OFF then back to ON}.

[9] The actual Pressure Measurement Screen you will see depends on the particular version and hardware configuration of your FlexRax system. You will note a difference in the example *Pressure Measurement Screen* shown on the next page.

After cycling the AC Mains power to the *FlexRax* (set the AC power switch to OFF, wait a few seconds then set the power switch to ON) you will have loaded the new software into the operating system program memory. It will take about one minute each time you cycle AC power for the *FlexRax* to initialize. You will see a ***FlexRax 4000*** startup screen followed by an **InstruTech** information screen before the **Pressure Measurement Screen** is displayed.



Pressure Measurement Screen

Your version of *FlexRax* may display a pressure measurement screen similar to the example immediately above. In this example screen display, the version of *FlexRax* depicted here provides additional ion gauge ON/OFF function control as well as the capability to pause a scrolling pressure readout sequence at a particular device displayed pressure. Up to two IG devices may be assigned to the two key-designators labeled 'IGR [5] OFF' and 'IGR [6] OFF' shown in the above example.

Assignment of the IG device that you wish to control the ON/OFF state of is accomplished by pressing the sequence of Menu ⇨ System ⇨ and selecting the device to be controlled by either of these two keys at IG1 Assign or IG2 Assign. These function keys are independent of each other. The intent of these two keys is to allow a single key press to switch the IG from one state of operation to the alternate state, i.e., either ON ⇨ OFF or OFF ⇨ ON. In the Pressure Measurement Screen shown immediately above, by default, the IG1 assignment is set to IGR [5] and the IG2 assignment is set to IGR [6]. The user can program 'IG1 Assign' and 'IG2 Assign' to other available IG option cards at designated locations within the *FlexRax.* Again, the default assignments for these two function keys are for IGR option cards installed in physical locations ⑤ and ⑥ (see section 3.1.5 for discussion related to physical locations within the *FlexRax* controller).

Depending on the version and configuration of your *FlexRax,* a key-designator labeled Pause may be displayed. Pressing the hardware key associated with this displayed soft-key will halt a scrolling pressure measurement screen at the device display being shown when the key is pressed. The key-designator label will change to past tense as Paused when the key associated with it is pressed. The display will freeze at the line that was being displayed when the key was pressed. Pressing the key when labeled as Paused will allow scrolling of the displayed lines (as setup by the user) to commence.

If the 'Scroll Rate' function (when setting up devices to display) is set to MAN (manual), the 'Pause' / 'Paused' soft-key label will change to read as 'Page'. This function allows the user to page through the devices or combination of devices selected for display one at a time.

NOTICE - The following steps for **Update Database** and **Set System Factory Defaults** are not always required after performing the **Update Memory (Software)** procedure. If you either **Update Database** or set the operating system to **Factory Defaults**, the control of the Devices on your vacuum system will not be the same as before you perform either of these two procedures.

In most cases, the user will want to keep the previously modified Database and ***not*** want to return the operating system to Factory Defaults. These steps are included here to illustrate the sequence required to initialize the Operating System Database and set user definable parameters for the options installed in your *FlexRax.*

3.1.2 Update Database –

The next step is to update the **Database** used in the operating system:

NOTICE – There are two functions involving the **Database** shown on the System menu screen. The first is to perform an **Update** of the *FlexRax* Database. The second function available allows the user to copy an existing system configuration database on to the USB flash drive. This feature is useful for duplicating the database in multiple *FlexRax* installations where it is desired to copy a master, approved system operating database configuration so that all *FlexRax* systems are setup with exactly the same user defined parameters. The second **Database** function is **Upload** Database. Contact support@instrutechinc.com for more information on the use of the Upload Database function before you attempt to perform this Setup function.

Menu ⇨ System ⇨ Utilities ⇨ Update Database ⇨ various messages will instruct the user to perform certain activities such as described in the previous sequence for updating the software (memory).

After cycling the AC Mains power to the *FlexRax,* you will have loaded the new database into the operating system program memory. The next step will be to set the operating system to use **Factory Defaults.**

3.1.3 Set System Factory Defaults –

Menu ⇨ System ⇨ Utilities ⇨ Sys Fact Defs ⇨ {Messages: This will reset the *FlexRax* operating system parameters including the installed Options to factory defaults. Continue?} OK ⇨

After cycling AC Mains power to the *FlexRax,* you will have finished updating the memory in the controller with the new operating system software, the latest required database and, if you have performed the **Sys Fact Defs** key input sequence described above, restored the operating system to **Factory Defaults**. The process of updating the software, database and setting the operating system to factory defaults is now complete. Remove the USB Flash Drive from the USB port.

3.1.4 Changing a Default Name[10] –

The factory default names and locations for the installed options and designated devices may require that you change them from the factory default settings to suit your requirements for naming conventions and documentation purposes. For example, as instructed in various sections of this manual, you may change the default name of, say, CG [1,2] to a descriptor such as 'FORELINE' or 'ROUGHVAC'.

To change a descriptor for an Option or Device, perform a key entry sequence similar to the following example of changing CG [1,2] to '**FORELINE**':

⚠ **CAUTION!** Assign a unique name to each Option / Device. Failure to assign a unique name to each Option / Device may result in improper system operation. **DO NOT ASSIGN THE SAME NAME TO ANY DEVICE.**

As you navigate through the various menus, you will find that some menu sequences will differ depending on the choice of device that you make. Two examples of achieving the result of finding 'Set Gauge Name' are given here to illustrate.

If you choose to change the default name of one of the 'CG' devices, the key press sequence is:

Menu ⇨ CG ⇨ CG [1,2] ⇨ Set Gauge Name ⇨

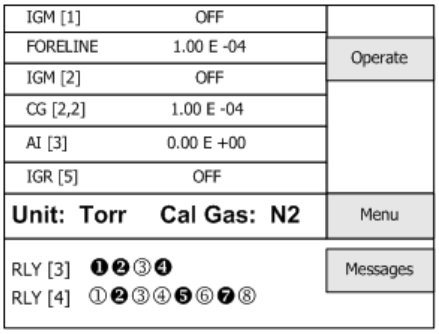
If you choose to change the default name of one of the 'IGR/IGE' options, the key press sequence will be, for example:

Menu ⇨ IGR/IGE ⇨ IGR [5] ⇨ Setup ⇨ More ⇨ Set Gauge Name ⇨

A screen will appear which allows you to scroll through an eight (8) character field for the gauge or device name you wish to create. Press the key associated with the respective key designators displayed (→ ← ↑ ↓) to move to the character place within the name field and select the available characters for each place.

After pressing the SAVE key and returning to the **Pressure Measurement Screen,** the display will look similar to the following unique example.

Each Option / Device Name may be changed by the User to a name other than the factory default names. Here, the name CG [1,2] has been changed to read FORELINE.



Unique Pressure Measurement Screen example with a Device name changed to read 'FORELINE'

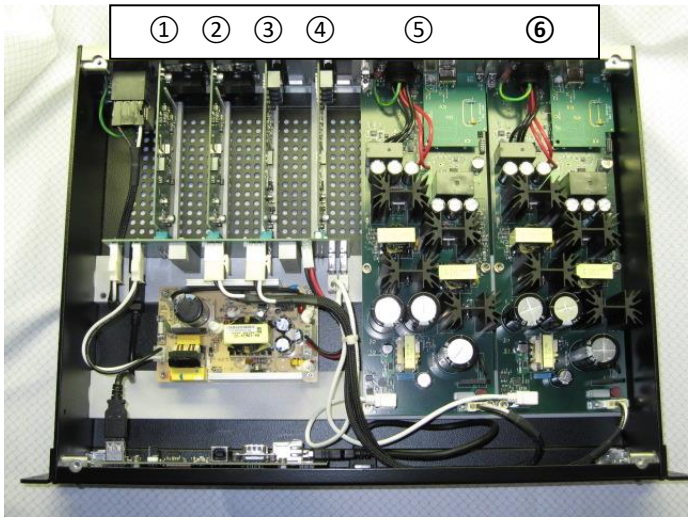
[10] Depending on the setup of the Pressure Measurement Screen, certain alpha-numeric character sets that you may use for a device name may be truncated. For example, you may see all of the letters in the name 'FORELINE' displayed, but the name 'ROUGHVAC' may only be displayed as 'ROUGHVA' – choose device names that will be unambiguous to the operator if the name should be either abbreviated or truncated by limitations of display resolution selected.

3.1.5 Logical Progression / Physical Location –

As the software executes, the program searches for physical, installed options in the *FlexRax* by scanning the physical locations within the *FlexRax* from left to right as viewed from the front panel of the controller.

FlexRax 4000 **Top View** (top cover removed)

BACK of controller



FRONT of controller

→→→ Operating System software scans available Options from Left to Right →→→

BACK of controller[11]

①	②	③	④	⑦ see footnote 11 - - - - - - - - - - - - ⑤	⑥

FRONT of *FlexRax* controller

Physical locations inside the controller as viewed from the TOP

[11] Option location ⑦ may contain the CM4000 Serial Communication option. This option resides below an IGR/IGE option which may be installed in location ⑤. See Section 3.6.1 (back panel view) of FlexRax for exact location of the CM4000 Serial Communication (labeled COM) option.

Not all physical locations need to have an option card present. As the software scans the locations, the first location with an option residing in it is assigned a logically progressive address (a numeral) combined with the notation for the installed option. For example, assume that the following options are installed in the following physical locations:

PHYSICAL LOCATION	OPTION INSTALLED
①	IGM/CG
②	IGM/CG
③	AI/O-R
④	AI/O-R
⑤	IGR
⑥	<empty – none>

→→→ Operating System software scans available Options from Left to Right →→→

BACK of controller

IGM/CG ①	**IGM/CG ②**	**AI/O-R ③**	**AI/O-R ④**	**IGR ⑤**	**Location ⑥ <empty>**

FRONT of *FlexRax* controller

Example Option locations inside the controller as viewed from the TOP

The operating system software assigns an address name to each option contained at each occupied physical location. In the above example there are five option cards installed in sequential locations ① → ⑤ with physical location ⑥ unoccupied. The software, following its logical progression protocol, assigns the following names to each of the options:

Logically Progressive PHYSICAL LOCATION	OPTION INSTALLED	Name Assigned
①	IGM/CG	IGM [1], CG [1,n]
②	IGM/CG	IGM [2], CG [2,n]
③	AI/O-R	AI [3], AO [3,m], RLY [3, m]
④	AI/O-R	AI [4], AO [4,m], RLY [4, m]
⑤	IGR	IGR [5]
⑥	<empty – none>	----------

Where n = 1 or 2
and m = 1 thru 4

To further illustrate the concept of how the software uses logical progression to locate and name an installed option card, consider the following example:

Only three of the available option locations are used to install one each **IGM/CG** option card, one each **AI/O-R** card and one each **IGR** card. The three options are installed in the following locations of the *FlexRax:*

Logically Progressive PHYSICAL LOCATION	OPTION INSTALLED	Name and Address Assigned
①	**IGM/CG**	IGM [1], CG [1,1], CG [1,2]
②	<none – empty>	
③	**AI/O-R**	AI [2], AO [2,m], RLY [2, n]
④	<none – empty>	
⑤	**IGR**	IGR [3]
⑥	<none – empty>	

Note that even though the three chosen options were installed, in this example, in physical locations ①, ③ and ⑤, the addresses assigned by the *FlexRax* software during the logical progression routine are the Option names with addresses '1', '2' and '3', respectively. The user can choose to either display each of the named available options or to not display selected options on the main **Pressure Measurement Screen** (see section 3.2, below).

In addition, the user may rename the default names and addresses of each option that were established by the software during initialization of the *FlexRax.* For example, the default named options / devices from the above example could either be left as is defined by the default naming convention or renamed by the user as IGM [1]; CG [1,1]; CG [1,2]; AI [3]; IGR [5] where the address numeral assigned to the option name is the actual physical location that the option resides in within the *FlexRax*. Note that in resetting the name AI [2] for the AI/O-R option installed in physical location ③ to AI [3], this will automatically assign the Relays (four each) that are installed on the AI/O-R option card to physical location [3]. By doing this the Relay Status indicators will read as RLY [3] ① ② ③ ④ in the lower left hand corner section of the **Pressure Measurement Screen.**

A good reason for renaming the options to align with the actual physical locations in the *FlexRax* is that it will aid the user in identifying the location of connectors on the back panel of the *FlexRax* to which various device cables may be attached. Also, when you decide to install additional option cards in your *FlexRax,* the previously assigned/renamed options/devices and their respective connectors/cables for the connected devices will be readily apparent.

The displayed screens are intuitive, following a natural, logically progressive pattern or sequence as the user programs or sets (SAVEs) the various parameters that are required for desired operation of the options installed and devices connected to each option. At various steps in the setup menus, there are messages or prompts displayed to direct the User to perform necessary operations and input desired, valid values. If the user inputs a value outside the range in which settings may be allowed, another message screen will appear directing the user to input a value for the setting that falls within a defined range of valid inputs.

3.1.6 Upload Database –

This function is provided to allow the user to copy a *FlexRax* configuration that is specifically setup for the configuration and control that the user wishes to maintain either for future reference or to duplicate the setup exactly from one *FlexRax* system to another where the controller configurations are exactly alike. Follow the

prompts to insert a USB flash drive into the USB port on the front panel of the *FlexRax* and copy the database contents from the controller memory to the USB flash drive.

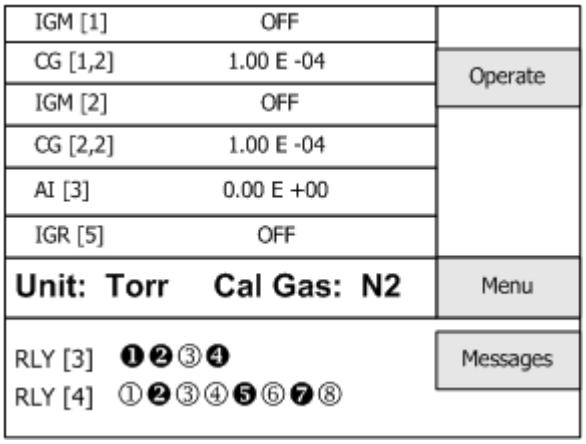
3.1.7 Getting Help – Info Screen

From the Pressure Measurement Screen press [Menu] ⇨ and then [Help] ⇨ to see InstruTech contact information including mailing address, phone numbers and other useful information. You will notice that immediately below the InstruTech logo ribbon at the top of the displayed screen, you will see 'Version:' followed by a six digit number and a three digit suffix (for example, 001306-118). You may need to convey the version number of your *FlexRax* to InstruTech technical support staff when verifying future device compatibility with your *FlexRax.*

3.2 Pressure Measurement Screen

When you first turn power ON, the *FlexRax* controller will take about one minute to initialize. You will see the InstruTech logo screen followed by an information screen before the pressure measurement screen as shown below appears. Depending on the options installed and the type of vacuum/pressure measurement devices connected, the pressure measurement screen will display the gauge device notations, corresponding pressure measurements, unit of measure, the [Messages] and [Menu] navigation start keys and a dual function key named 'Operate' ([Operate]) which will change to display 'Stand-By' ([Stand-By]) alternating between these two modes each time the key is pressed. If one or more Analog I/O-Relay options are installed, relay status for each relay is also shown in the lower left hand corner of the screen. A typical pressure measurement screen is shown below.

⚠ **CAUTION!** Damage to equipment and possible injury to operator may result if the 'Operate / Stand-by' soft-key is left in the 'Operate' mode either while setting up the *FlexRax* 4000 or during system start up. It is recommended that the operating mode is set to 'Stand-by' immediately after AC Mains power cycling until operator is certain that all operating parameters of the vacuum pressure system are at a known safe / normal state.



Pressure Measurement Screen [12]

[12] This screen example is shown in the mode of scrolling the readout of pressure data in small font as opposed to the mode of displaying in large font where data for only one pressure readout device is displayed at a dwell time selected during setup of the FlexRax (explained later in these instructions). Also, devices CG [1,1], CG [1,2] and AI [4], referred to previously in this section, have not been selected for display in the example screen shown here.

- Display line (top line in the **Pressure Measurement Screen** example) indicating **IGM [1] -**

IGM is the notation for either the InstruTech IGM400 *Hornet* Ionization Gauge Module or the CCM Cold Cathode Module that you will connect to the *FlexRax*. The notation **[1]** is the location of this option card in the *FlexRax* controller.

- Display line indicating **CG [1,2]** -

CG is the notation for a convection gauge. The notation **[1,2]** is the convection gauge option location and channel number of the convection gauge device. The first number (shown in bold here) in the brackets [**1**,2] indicates the physical and logical location of the IGM/CG option card in the *FlexRax* that the convection gauge transducer (also referred to in this manual as a 'device') is to be connected to. The IGM/CG card is the first option card detected by the operating system as it scans from left to right as viewed from the front of the *FlexRax.*

The software has detected the first module going from left to right as viewed from the front of the *FlexRax* is an IGM/CG option card. The address or location of the option card controlling all transducers (devices) connected to this option is identified by the first numeral, in this case **1.** The convection gauge transducers connected to this option at the back panel will be identified with location notation **1**.

The second numeral (shown in bold here) in the brackets [1,**2**] indicates which convection gauge device connected to the IGM/CG option card is being displayed. Since the IGM/CG can operate two convection gauge transducers, the second number in the bracket, in this case, indicates this convection gauge device is connected to CG channel **2** of the IGM/CG option card.

NOTE – In the **Pressure Measurement Screen** shown above, the designations for the devices installed in the *FlexRax* are variable. In this example, the notations listed from top to bottom of the display have been chosen specifically to illustrate the flexibility of the *FlexRax* to show chosen devices and data as desired by the User.

In this case, two IGM/CG option cards are installed in the *FlexRax.* With this option, you have the capability to operate either IGM400 or CCM500 *Hornet* (IGM [1]) and two Convection Gauges (CG [1,1] and CG [1,2]). You will note that for the first IGM/CG option, only **IGM [1]** and **CG [1,2]** are shown on the display. This is made possible by selecting the Devices to Display function which will be explained later in this manual. Likewise, the second of the two IGM/CG option cards installed in the *FlexRax* is listed in the display screen as **IGM [2]** and **CG [2,2]**; (The CG [2,1] device has not been selected in the Devices to Display function therefore it is not displayed).

- Display line indicating **AI [3]** –

The next displayed device is **AI [3]**. This is the analog input channel for an installed **Analog Input/Output–Relay** (AI/O-R) option card. In this example, you will see the relay status indicators for the four (4 each) relays installed on the AI/O-R option listed in the lower left hand corner of the screen. The relays associated with the AI/O-R option installed in location [3] of the *FlexRax* are listed on a single line as **RLY [3]** ❶ ❷ ③ ❹, in this case. If a relay status indicator is shown as a black color filled circle (with numeral inside), the relay is energized. If the indicator is an open (not filled with black color) circle, the indicator is showing that the relay is not energized. The pressure display for the **AI [3]** option corresponds to an input voltage from an external device that provides an output signal proportional to pressure.

- Display line indicating **IGR [5]** –

The **IGR [5]** display line is for a resistive degas-type Bayard-Alpert ionization gauge option that is installed in location [5] of the *FlexRax.*

- Display line indicating **Unit:** Pressure is indicated in **Torr** units of measure or engineering units –

To select the unit of measure for pressures displayed in Torr, Pa or mbar follow the key sequence of:

Menu ⇨ System ⇨ Pressure Unit ⇨ and then select the unit of pressure you want to use for all displayed pressure readings in the **Pressure Measurement Screen.** In the choices screen shown after executing the key sequence above, you will see that keys associated with the up ↑ or down ↓ arrow keys in the display allow you to enter the pressure unit of measure desired. If you select either the up or the down arrow key, you will notice that a SAVE key will be displayed in the screen. This implies that you have readied a change to the pressure unit and the operating system is confirming that you want to perform this change. You have the option in this screen to press the key associated with CANCEL and the pressure unit will remain as previously set.

Following the setup **Unit** indication, this area of the screen is reserved for an indication of the type of gas the pressure measurement devices such as the Ion Gauge(s) and Convection Gauge(s) are calibrated for. This area of the screen may include the displayed characters of: **CAL GAS: N2** which indicates to the user that the gas used for calibration of the IG and CG devices is nitrogen (N_2). See related sections of this User Manual for making corrections to the indicated pressures as measured by the CG and IG devices for gases other than nitrogen and air.

- Example hardware configuration and pressure measurement display –

For this particular example of *FlexRax* configuration and the related Pressure Measurement Screen (shown on previous page), there is a second AI/O-R Option card installed in the *FlexRax.* It is located in the *FlexRax* controller in physical location [4]. The display screen does not show, in this example, a pressure signal for the AI/O-R Option at physical location [4]. However, since this second AI/O-R Option is installed, the eight (8) relays on that option are shown on the display immediately below the relays for AI/O-R [3]. This line is shown, in this case, as RLY **[4]** ① ❷ ③ ④ ❺ ⑥ ❼ ⑧. The interpretation of this display line is that RLY **[4]** ①, ③, ④, ⑥ and ⑧ are de-energized, **RLY [4]** ❷, ❺ and ❼ are energized.

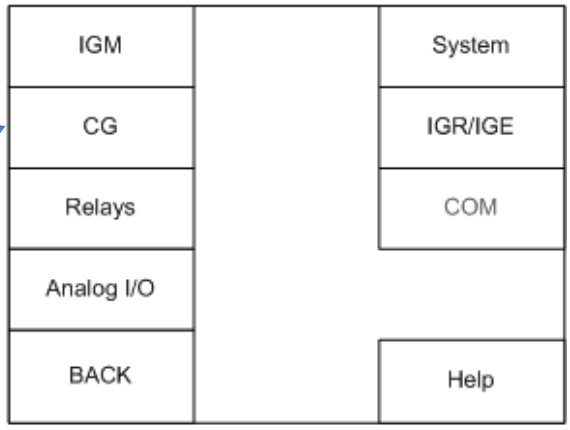
This example of having two AI/0-R options installed in the *FlexRax*, but having only one of the options used for displaying pressure as measured by an external device, illustrates the versatility possible in your configuration of the *FlexRax*. In this example, with these two AI/O-R Options installed, there are twelve each relay contactors available for use. Each option will allow you to connect one additional analog voltage from an external pressure measurement device to the Analog Input and display the pressure measured by that device. Each AI/O-R option will also allow you to output voltage signals proportional to the pressure measured by the multiple pressure measurement devices controlled by the *FlexRax.*

Again, this is only an example representation of a possible *FlexRax* configuration and related Pressure Measurement Screen. Your *FlexRax* configuration and corresponding Pressure Measurement Screen will most likely be and look different than the examples used in this User Manual. The examples used here are for illustrative purposes only that are intended to convey the flexibility of configuration and use of the multiple options and devices that are available for use in and with the *FlexRax.*

The Messages and MENU navigation start keys allow you to move either to the start MENU for programming and setting up the devices you wish to connect to the *FlexRax* option cards, or to the Messages screen to view important status information regarding the options installed.

By pressing the MENU key on the front panel of the *FlexRax* you will see the following screen on the display:

Key-Designator boxes are shown on the Display. Each box shown is associated with a hardware key (push-button) to the left or right of the key designator on the front panel of the *FlexRax.*

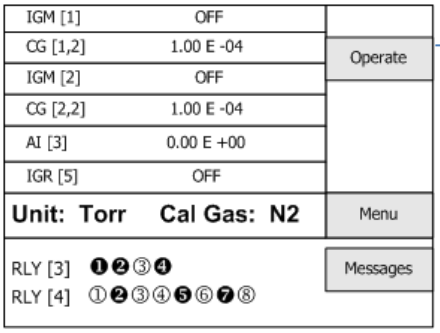


Menu Screen(s)

In the **Menu Screen** depicted above, the RS485/RS232 option is displayed as 'COM' on the screen. Any option that shows with the lettering within the key-designator box 'grayed-out' indicates that the option card is not installed in the *FlexRax.* The other key-designator boxes allow you to move forward to other screens which direct you to take action for control or to program or set the available parameters of the chosen option(s).

Press the BACK key to return to the **Pressure Measurement Screen.**

3.3 Operate / Stand-By



To gain full access to certain device parameters and actions such as turning an ion gauge **ON**, this key designator must be displayed in the Operate mode.

NOTICE The *FlexRax* will resume either the **Operate** or **Stand-by** state of operation if AC Mains power is cycled. If the controller was in the **Operate** mode prior to an AC power ON-OFF-ON event, it will return to the **Operate** mode and IG [n] will turn ON if controlled by another device such as a convection gauge.

During normal pressure measurement and device control, the **Pressure Measurement Screen** will display a key indicator function in the upper right hand corner of the screen. The key associated with this function will allow the user to alternate the *FlexRax* operating system between two modes: **Operate** and **Stand-By**. When the function indicated by this key is in the **Operate** mode, all functions of the *FlexRax* are available. During normal

operation, the user may elect, at any time, to press this hardware key forcing the system to invoke the **Stand-By** mode. Doing this will turn the hot cathode ion gauges (IGM, IGR, IGE) and, if used, the CCM cold cathode ion gauge to the OFF condition. Also, the relays that have been setup to energize when the displayed pressure of an assigned ion gauge is equal to or less than the relay turn ON pressure will de-energize when the Operate/Stand-By mode is set to Stand-By. Pressing the key indicated as shown in the diagram above will change the key indicator function from **Operate** to **Stand-By**. Pressing the key again will change the mode of operation from **Stand-By** to **Operate**.

3.4 Setting up the Pressure Measurement Screen

In the example above, several option cards are installed in the *FlexRax.* There are two IGM/CG option cards, two AI/O-R cards and an IGR option installed in this example configuration of the *FlexRax.* With this example configuration, a total of nine display lines are necessary to show the status of each available pressure measurement device. The user may select which devices to display. If the display is set up to display multiple devices simultaneously, the screen may appear as shown above with the number of displayed pressure measurements equal to the number of devices selected to display.

The first step in setting up the display mode is to select the devices to display:

3.4.1 Devices to Display –

Follow the key entry sequence: Menu ⇨ System ⇨ Display ⇨ Devices to Display ⇨ the screen will change at the press of the last key in the sequence to the 'Select Devices' screen. This screen will show all available devices that may be displayed. Press the key associated with a device listed on the screen to mark the selection box with a check-mark (✓) if you wish to display the pressure measurement for that device. If more than eight devices are available for display, press the MORE key to see additional selections. Now press SAVE and the BACK keys on each of the screens shown as you return to the main **Menu Screen**. Alternatively, if a menu screen shows both a BACK and MAIN soft-key, you may return directly to the **Pressure Measurement Screen** by pressing the MAIN hardware key.

3.4.2 Scroll Reading - Fixing Displayed Pressure Reading Font Size

Follow the key entry sequence: (Menu ⇨ not required if you are in the main **Menu Screen**) System ⇨ Display ⇨ Prgm Readout ⇨

A screen will display with Up ↑ and Down ↓ arrow soft-keys and a message dialog box that instructs you to {**Select Up or Down to set number of pressures to display on each scrolling screen**.} A numeral from 1 to 6 will be displayed above this message box as you press either the up or down arrow key.

The **Pressure Measurement Screen** format will change as you change the number of pressures to be displayed. For example, if you choose one (1) pressure to display, only one (1) pressure will display at a time during the time programmed for 'Scroll Rate' (see **3.4.3 Scroll Rate**, below). If you choose more than one pressure to display, the **Pressure Measurement Screen** will change to show the number of pressures programmed to be displayed – alternating through the devices selected for display on each screen that is scrolled. As you increase the number of pressures to display in the Prgm Readout screen, the number of pressure displays selected

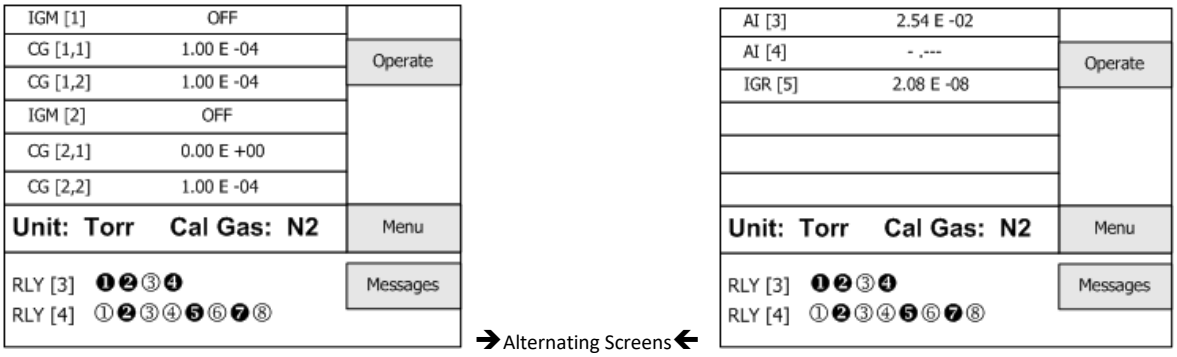
will appear simultaneously on the **Pressure Measurement Screen** and the font size of the displayed pressures will decrease as you increase the number of pressures to be displayed on each scrolling screen.

Press the SAVE key to select the desired number of pressures to be displayed. See section 5.4 for additional information regarding formatting of the displayed information on the Pressure Measurement Screen.

3.4.3 Scroll Rate –

After entering SAVE as directed in the previous step, you will see a menu screen with a choice of 'Scroll Rate'. Press the key on the left side of the display corresponding to Scroll Rate ⇨ You may now press the keys associated with the up ↑ or down ↓ arrow keys to set the dwell time (the time between changing from one to the next displayed reading) of the displayed pressure readings you have chosen to display. The default time between display readings is 3 seconds.

After making your selections as described above, you will return to the main **Pressure Measurement Screen** by keying in the MAIN, BACK or SAVE keys available at various display screens to return to the main pressure measurement screen. An example of displaying several pressure measurements simultaneously is given below (Note: this display assumes the above example configuration is present in the *FlexRax* and all available, installed options/devices are selected for display):



The **Pressure Measurement Screen** will alternate (default = every 3 seconds, or at the dwell time you set) similar to this example when more than six (6 each) options / devices are selected to be displayed and the readout is set to display six (6) pressure measurements at one time.

The programming and setup of the installed options and devices follows an easy, intuitive, natural progression from one screen to the next as you navigate through the various menus. The above tutorial will give you a sense of the basic operations of the *FlexRax* and the installed options and associated devices connected to the option cards. Simply follow the progression of the menus and choices associated with each selection to setup, operate and measure pressure from the multiple pressure/vacuum gauge sensors, transducers, transmitters; output analog voltages proportional to the displayed values and control relay contactor states with your *FlexRax* Multi-Gauge controller.

At any menu level, you may return to the **Pressure Measurement Screen** by repeatedly pressing the BACK key. In some menus you may alternatively press either the SAVE key or the CANCEL key to get to a menu with the BACK key displayed. Again, repeated entry of the BACK key will ultimately return the display to the **Pressure Measurement Screen.** There are several key-entry sequences that you may make while navigating the various menus available when using the *FlexRax.* If you find that you are in a menu that you are either not sure of or you do not want to be at, simply return to previous menus by pressing either the BACK key or the CANCEL key. Some menu screens may display a MAIN soft-key. If displayed, pressing the hardware key associated with the MAIN soft-key will return you directly to the **Pressure Measurement Screen.**

3.5 Password

The password may be used to protect the FlexRax 4000 setup and configuration and control access to the instrument. Most User applications will not require the use of the Password function available in the *FlexRax* operating system (software). Deliberate consideration must be given to programming and enabling the Password function.

NOTICE **If you choose to Enable the Password and return to the Pressure Measurement Screen, you will NOT be allowed to perform any Device control functions from the front panel including turning Ion Gauge(s) ON/OFF using the Operate / Stand-By mode key. Once the Password security mode is enabled, you will be required to enter the password you have previously enabled every time you enter the main Menu from the Pressure Measurement Screen *before* the *FlexRax* operating system will allow *any* changes to the operational parameters and function of the controller.**

You have the option to enable a password of your choice to limit access to the controller setup, configuration and operating menus. If your *FlexRax* has been password enabled and your password is lost or forgotten you may contact InstruTech to obtain a master password that will allow you to access the main menu and subsequent setup menus including the enable password screen.

3.5.1 Enable Password –

You may elect to enable password when system operation is ready for supervisory control.

To select and enable a password follow the key entry sequence: Menu ⇨ System ⇨ Security ⇨

A screen will be displayed which will allow you to enter a password of up to eight (8) characters**.** In the screen shown, after executing the preceding key sequence, you will see up 🡅 and down 🡇 arrow indicators in the display that are associated with the front panel keys that allow you to enter, in each of the eight character spaces available, the password.

Each available character that comprises the password is selected as you press the respective up or down arrow keys in each of the eight character spaces available. Move the cursor right [➔] or left [🡐] to select which character you wish to edit.

When you have finished entering the password you have the option to either [SAVE] the entry or [CANCEL] the entry if you are undecided. If you choose [Save] ⇨ , a message screen will be displayed offering you the choice to either **Enable** or **Disable** the password. If you choose to [Enable] ⇨ the password you have saved and then return to the **Pressure Measurement Screen**, access to the main **Menu** functions of the *FlexRax* will be limited to only those who enter the correct password when prompted.

In most cases, it may be undesirable to **Enable** the password function until you have completed all necessary setup, configuration and control requirements for the installed options and connected devices. During setup and initial configuration of the *FlexRax* options and devices, it is recommended that you select [Disable] if you have performed the steps described above to enter and save a password. Doing this will allow you to move back and forth from the **Pressure Measurement Screen** to other main menu functions and their respective sub-menus without the need to enter the password each time you return to the **Pressure Measurement Screen** and want to go back to a main menu function.

Enabling the password function is only necessary if it is desired to strictly control access to and operation of the *FlexRax* installed options and connected devices while the controller is powered ON. For most applications, it is recommended that you do not access the password setup menu. The password menu function is provided in the operating system of the *FlexRax* solely for the intended use of the *FlexRax* when supervisory control of the measurement devices and setpoint control relays is necessary. Only when you are certain that all settings and parameters are as you want them, set the password function to **Enable.** Once you have enabled the password function you will be required to either enter the saved password to perform any changes to the operating parameters or disable the saved password to regain full, unlimited access to device control and setup choices.

With the password function enabled, to regain access to setup and control of the *FlexRax* (including the Operate/Stand-By function key) press the key associated with [Menu] ⇨ and re-enter your password.

3.5.2 Disable Password –

If a password has been entered and saved, it is recommended that you disable the password enabled mode of operation until you are certain of the operating conditions of your vacuum system and the setup, configuration and control of the *FlexRax* is complete. If you do not save a password in the password selection screen, you may skip this section.
To disable the password security function, follow the key entry sequence: [Menu] ⇨ [System] ⇨ [Security] ⇨ At the password setup screen, press [SAVE] then you will see a screen with {**Messages:** Enable or Disable the Password Security?**}** [Enable] ……. [Disable]

Select the key on the front panel associated with [Disable]

Enter: [Back] ⇨ [Back] ⇨ to return to the **Pressure Measurement Screen. A**lternatively, you may stop at either displayed sub-menu and select the key associated with the various displayed functions at these menus.

3.6 Operation - Connecting Options and Devices

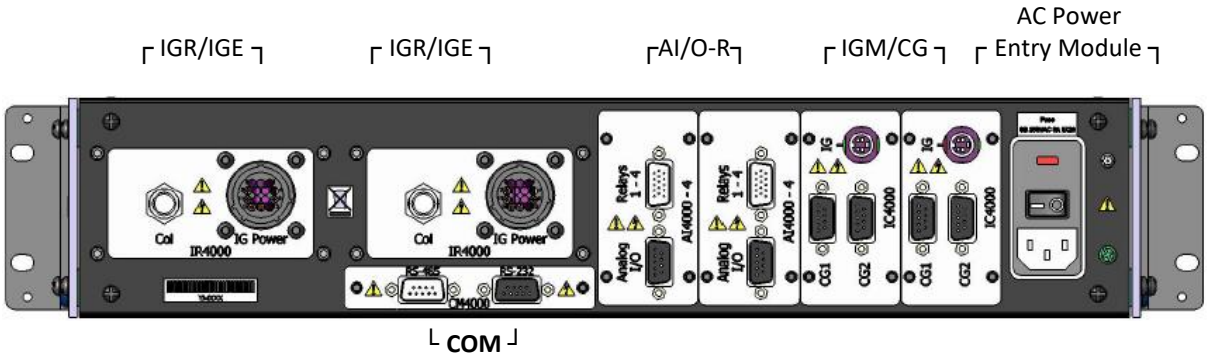
⚠ **CAUTION!** In order that you prevent equipment damage, it is recommended that you switch AC Mains power to the *FlexRax* to **OFF** when either connecting or disconnecting cables to options and devices.

3.6.1 Back Panel Connections and Operation –

Referring to the above section (**3.1.5 Logical Progression / Physical Location**) regarding the example *FlexRax* configuration used to describe the overall operational characteristics of the *FlexRax*, two each IGM/CG, two each AI/O-R and one IGR option cards were used as the example configuration of installed options. Each option requires physical connection to the device(s) that the option will control or receive/send input from/to. The physical connection to each device is made via an appropriate cable with connectors on each end that interface the option to the device.

The *FlexRax* may be configured in many, different ways. In keeping with the concept of demonstrating the versatility and capability of the *FlexRax* operating system, we depart from the previous configuration example and show another example configuration to demonstrate the required cable connections from some of the possible devices to several of the options you may use.

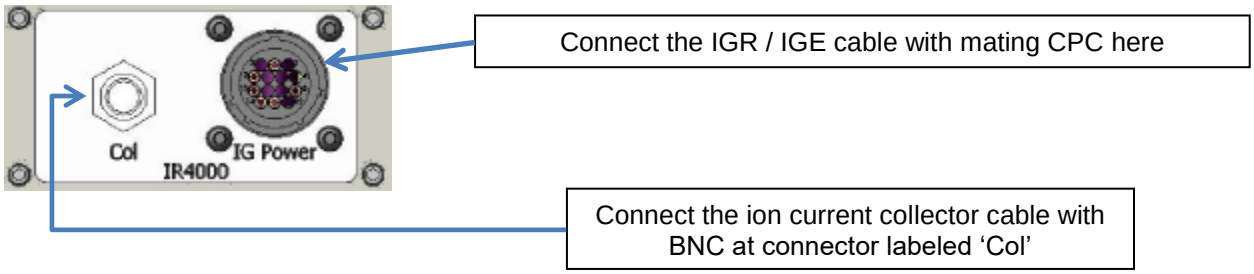
As shown in the example *FlexRax* configuration back panel below, the *FlexRax* contains one each IGR/IGE (Resistive, I^2R Degas or Electron Bombardment, EB) B-A Ion Gauge option at the leftmost location (as viewed from the back panel). The next option card shown here is the IGR (Resistive, I^2R Degas) option. To the right of the IGR/IGE options are four additional option cards (from left to right): two each AI/O-R and two each IGM/CG Options. The RS232/RS485 serial communications option resides under option location⑤.



Typical *FlexRax 4000* Multi-Gauge Controller - Back Panel

3.6.1.1 Connecting the IGR or IGE [13] Options –

With either the EB Degas-type or the I^{2}R Degas-type B-A ionization gauge transducer connected to your vacuum chamber, connect an appropriate length of ion gauge cable (see various IG cable configurations shown below) from the ion gauge transducer on the vacuum chamber to the back panel connectors for the desired option(s) installed in the *FlexRax.* The circular plastic connector (CPC) on the option card is keyed to allow easy orientation of the mating connectors. Insert the plug end on the cable into the socket end on the option card. The IGR and IGE options have a BNC connector for connecting the low-level ion current signal from the ion collector electrode of the transducer. The coaxial cable with the BNC connector at the controller end of your IGR or IGE cable is connected at the BNC connector labeled 'Col' on the IGR and IGE Options.



⚠ **CAUTION!** When changing or making cabling connections to any device controlled by the *FlexRax* options, you must first turn AC power to the *FlexRax* **OFF**. If you want to either change an option location within the *FlexRax* controller or install a new option, you must first switch the AC power to the *FlexRax* **OFF**. Failure to disconnect AC Mains power to the *FlexRax* before either changing cable connections from options to devices or removing/installing option cards in the *FlexRax* may result in equipment damage or possible injury to personnel.

Various InstruTech nude or glass IG cable configurations are shown below.

BA601/BA602 Nude IG Bakeable Cable 200 °C
P/N IRNBD-441-1-…

BA601/BA602 Nude IG Cable
P/N IRN-441-1-…

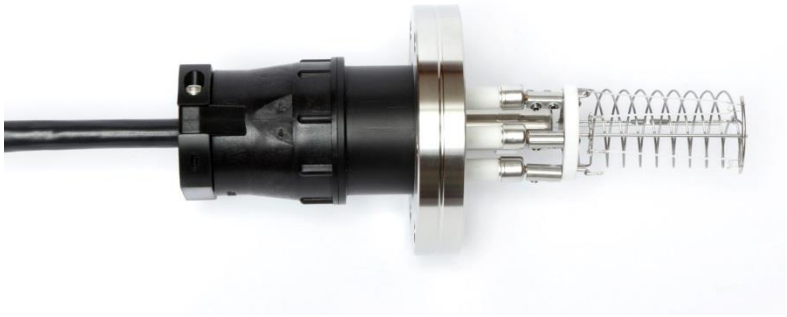
BA603 Glass IG Cable
P/N IRG-441-1-…

[13] Cables for connections to the IGR and IGE options may differ in design. Cables from certain manufacturers may be specifically constructed for the type of DEGAS used in various versions of the B-A ionization gauge transducer. Contact support@instrutechinc.com if you have any questions regarding the connections to be made to ionization gauge transducers that you wish to operate with the *FlexRax 4000* IGE/IGR options.

For the glass IG, connect the IG cable (part numbers IRG-441-1…) at the FlexRax 4000 controller as described in the previous page. After installing the glass IG transducer on your vacuum system, connect the transducer end of the IG cable as shown below.

Glass IG Transducer Cable Connection

For the nude IG, connect the IG cable (part numbers IRN-441-1…) at the FlexRax 4000 controller as described in the previous page. After installing the nude IG transducer on your vacuum system, connect the transducer end of the IG cable as shown below.

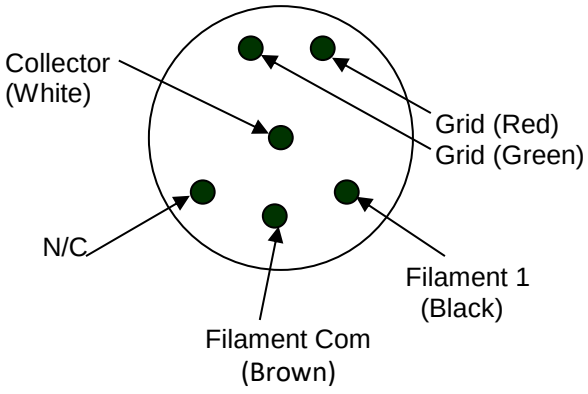


Nude IG Transducer Cable Connection

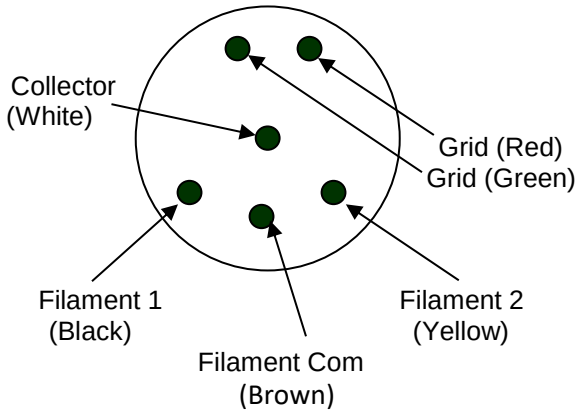
The **bakeable** Nude IG cable (part numbers IRNBD-441-1-…) is provided with push-on sockets for connection to the nude gauge pins (BA601/BA602 pins) and is bakeable to 200 °C **(See Bakeable Cable wiring information below).** All other cables listed above are rated for 50 °C ambient temperature. All IG cables provided by InstruTech can be used with either single or dual filament ion gauges and filament switching is controlled from the FlexRax controller.

When using the Bakeable IG Cable P/N IRNBD-441-1-… connect to BA602 or equivalent Nude I^2R B-A Gauge according to wire colors listed below.

BA602 or Equivalent Nude I^2R (Resistive Degas) B-A Gauge Pin Pattern



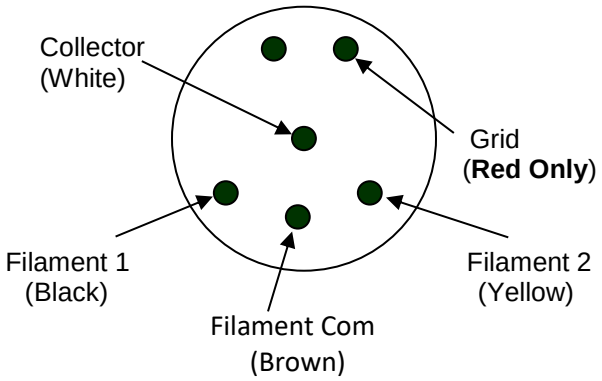
Base View
BA602
I^2R Degas - single filament



Base View
BA602
I^2R Degas - dual filament

When using the Bakeable IG Cable P/N IRNBD-441-1-… connect to BA601 or equivalent Nude EB-Degas UHV B-A Gauge according to wire colors listed below**.**

BA601 or Equivalent Nude EB-Degas UHV Gauge Pin Pattern

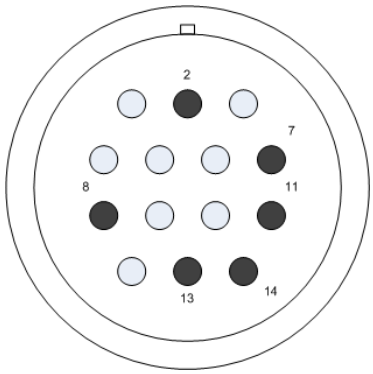


Base View
BA601
EB Degas - dual filament

3.6.1.1.1 IGR / IGE Option Cable Connector Pin Out –

The pin-out of the CPC connector used on G-P and InstruTech Ion Gauge cables is shown below. When using InstruTech two-filament switch capable cables such as those for use with controllers capable of switching the filament from the control unit, e.g., the *FlexRax 4000*, there is an additional pin/socket connection at contact N$^{O.}$ 7 for FIL2. This type of cable and control unit will allow the user to switch filaments from the control unit – there is no need to go to the transducer end of the cable and physically remove, rotate and reconnect the cable connector when it is desired to switch filaments. The information presented in this section is intended to address the installation/connection of a B-A type ionization gauge transducer or an IG cable that you may already have installed on your vacuum vessel which may not be directly compatible with InstruTech® product designs, and you wish to continue using either that transducer/cable with the *FlexRax 4000.*

The view shown below is the CPC connector end of the IG cable:



FlexRax Connector End of Cable View

Table – FlexRax IG Cable Connector[14]

Pin/Socket Contact Number	Description – I^{2}R Degas Ion Gauge Cable for InstruTech® FlexRax 4000 (compatible with Granville-Phillips® ion gauge cables)
2	Shield, chassis ground
7	FIL 2 (this contact is only present on dual filament IG cables available from Instrutech)
8	FIL COM
11	FIL 1
13	Grid Source (supply)
14	Grid Return (used only during I^{2}R degas operations)

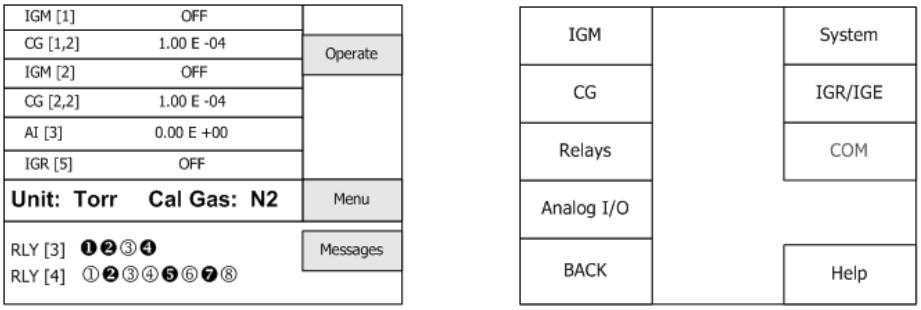
[14] Electron Bombardment (EB Degas type) IG cables may not have a Grid Return connection (pin N$^{O.}$14 of the CPC connector). It is permissible to use an IG cable that has both contact N$^{O.}$13 and N$^{O.}$14 wired when using electron bombardment degas control. During EB Degas operation, the grid potential is raised to voltages as high as 535 Vdc. Only cables with wiring to both contact N$^{O.}$13 and N$^{O.}$14 mAy be used when using I^{2}R degas.

3.6.1.1.2 Operation of the IGR and IGE Options –

BA600 series glass enclosed or nude B-A Ion gauges are powered and controlled by the *FlexRax* when the IGR or IGE option cards are installed. In the example configuration depicted in section 3.1.5 above, there is one IGR option card installed in the *FlexRax,* allowing operation of one BA602 or one BA603 IG or an equivalent Ion Gauge. In this example, when AC power to the *FlexRax* is switched to ON, the operating system software detects this module as the fifth option card available when it scans the physical locations and assigns each option an address or location. The device connected to that option card is also assigned an address that will be referred to in the various menus and messages displayed on the *FlexRax* display. In the example configurations used in this manual (see above sections), the fifth physical location option detected is an IGR option with an assigned name of IGR [5].

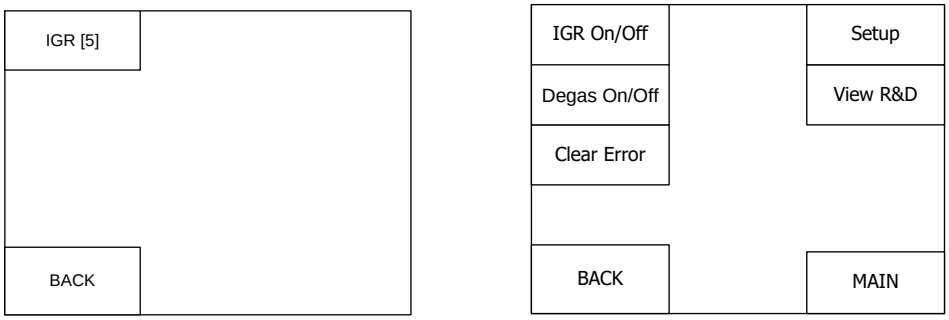
To setup and operate the IGR, follow the sequence of key entries shown here:
Menu ⇨ IGR/IGE ⇨ IGR [n] ⇨ Setup ⇨

Press the key aligned with Menu ⇨ then, on the next screen, press the key aligned with IGR/IGE ⇨



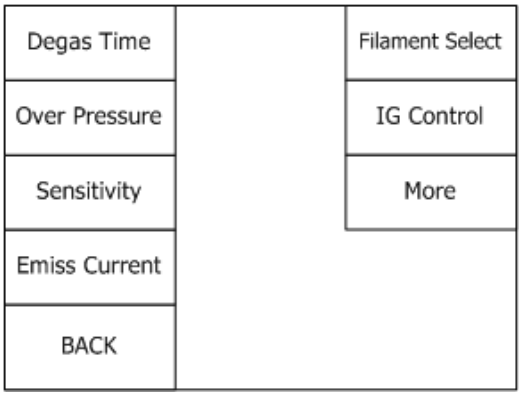
Pressure Measurement Screen ⇨ **Main Menu Screen**

Press the key aligned with IGR [n] (IGR [5] in this example) ⇨ then, on the next screen, press the key aligned with Setup ⇨



IGR Select Screen ⇨ **IGR Operations Screen**

When you have pressed the key aligned with Setup, you will see the following screen showing various choices as in the following displayed sub-menu screen for the BA600 series or equivalent hot cathode IG setup:



IGR/IGE Setup Screen

To setup and operate the IGR and IGE shown in the screen above, become familiar with the topics presented in the remaining pages of this chapter then follow the sequence of key entries shown next; at the end of each sequence, a brief description of the function is given.

Degas Time ⇨ - Default degas time is 10 minutes[15]. Degas is used to rid the gauge sensor of adsorbed gas. Degas is achieved by applying Electron Bombardment (EB) to the grid or electrically heating the grid (I^2R). Ensure vacuum level is less than 5.00E-05 Torr before attempting to initiate Degas. The intervals at which degas should be applied vary for each application. The low pressure measurement performance of the transducer will normally improve after initial degassing cycle.

Over Pressure ⇨ - For the BA600 series nude or glass enclosed ion gauge transducers or equivalent, Over Pressure shut OFF default is 1.00E-03 Torr (1 mTorr) with emission current (I_e) set at 100 µA; 5.00E-04 Torr at 4 mA I_e; 1.00E-04 at 10 mA I_e. Over Pressure allows you to set the pressure at which the ion gauge will turn OFF. It is **not** recommended to attempt operation of the B-A hot cathode ionization gauge transducer above certain, defined pressures. This function is also used to define the pressure at which an Ion Gauge will be turned ON and OFF when 'IG Control' is set for other than the 'Manual' control mode (see the IG Control description below). When using the emission current setting of 4 mA and 10 mA, the overpressure values are fixed at 5.00E-04 Torr and 1.00E-04 Torr respectively. When using the emission current setting of 100 µA, the overpressure value can be set to any value between 1.00E-04 Torr to 1.00E-02 Torr. However, when setting the overpressure value to 1.00E-02 Torr, review your ion gauge transducer specifications to determine the maximum pressure your ion gauge transducer is capable of measuring. (BA600 series transducers are capable of measuring a maximum pressure of 1.00E-03 Torr). See the **CAUTION** statement following the 'IG Control' function description of this section.

[15] For the IGR/IGE option (BA600 series transducers), the Degas function will turn off if the measured pressure rises above 1.00E-04 Torr. The filament however will remain turned on. You may be required to make several Degas turn ON attempts in order to allow sustained Degas operation. When DEGAS is asserted, the measure of pressure inside the IG transducer will continue to be displayed. While in the DEGAS mode, the displayed pressure measurement value will be shown on the front panel LCD display in BLUE color. For example: 6.54 E-06 (the pressure value shown on the display line for the IG device being degassed).

Sensitivity ⇨ - Default is 10 per Torr (10 $Torr^{-1}$).
When using the resistive or I^2R degas nude IG (Series BA602, or equivalent) or glass enclosed IG (BA603, or equivalent) set sensitivity to 10 per Torr. Set sensitivity to 25 per Torr for the UHV EB Degas nude IG (Series BA601, or equivalent). If you are using an IG with a known sensitivity other that 10 per Torr or 25 per Torr, you may set the actual sensitivity for the IG transducer you are using. The Sensitivity constant used by the operating system for the pressure calculation is based on the following mathematical formula for the B-A ion gauge pressure measurement:

$I_c = P \bullet S \bullet I_e$ where P is Pressure, S is Sensitivity[16] ; I_c is the collector current and I_e is the emission current.

Emiss Current ⇨ - Default is 100 µA emission current. See 'Over Pressure', above, for pressure measurement range restrictions when operating the IGR/IGE with various emission current settings. If you plan to operate in the 'IG Control' mode where a CG [n,m] or other Analog Input device is used to control the IG ON/OFF function, you will only have 100 µA and 4 mA emission current selections available (not available with 10 mA emission current). In clean applications and when operating at higher pressure ranges (5.00E-06 Torr to 1.00E-03 Torr) the 100 µA emission setting is preferred. At lower operating pressures (1.00E-09 Torr to 5.00E-04 Torr) the 4 mA emission setting should be used. Many vacuum measurement equipment users prefer to use the 10 mA emission current setting when making measurements in the UHV pressure regime (below 1.00E-08 to 1.00E-11 Torr).

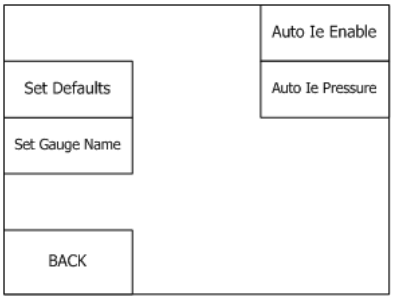
Filament Select ⇨ - Default is Filament 1. When using dual filament ion gauges, this menu allows the user to select which filament to operate: *Filament 1* or *Filament 2*
It is recommended that you alternate operation of both filaments from time-to-time. A filament that is not used periodically may exhibit difficulty in establishing emission current after exposure to certain chemical/physical effects.

IG Control ⇨ - Default is **Manual** filament ON/OFF control using the front panel keys (push-button switches). You may also select another device such as one of the convection gauges **CG [n,m]** or an analog input **AI [n]** to control the ON/OFF state of the IGR/IGE. See 'Emiss Current', above, for related information regarding this function capability. When you choose CG [n,m] or AI [n], the pressure at which the Ion Gauge will be controlled, i.e., turned to ON or turned to OFF will be determined by the pressure set in the 'Over Pressure' setup screen (see Over Pressure – setting described above). When using the **AI [n]** to control the IG, pay particular attention to the **CAUTION** statement immediately below this paragraph.

⚠ **CAUTION!** In order that you prevent equipment damage and possible injury to personnel, you must have control safeguards to prevent the IG from accidentally turning on above the trip-point in the event the device assigned to control the IG fails or is turned off. **DO NOT** rely on an external device to turn the IG ON/OFF without performing a thorough hazardous operation study of your control system design.

more ⇨ - This will display another menu screen shown below with the following additional setup functions.

[16] Sensitivity for the B-A type ionization gauge is a constant. A number defined as the quantity of ions created and collected (collector current) per unit measure of pressure per the controlled quantity of emission current from which the ion current is generated. This setting can be useful for compensating the readout of pressure when measured by the ion gauge for gases other than nitrogen/air. Consult support@instrutechinc.com for further discussion on the use of this setting for compensated readings. Typical sensitivity for the resistive or I^2R degas ionization gauges used is 10 per Torr (10 $Torr^{-1}$). Typical sensitivity for the UHV EB degas nude B-A ionization gauge used is 25 per Torr (25 $Torr^{-1}$).



IGR/IGE Setup Screen (more)

Set Defaults ⇨ - Default factory setup parameters for the IGR/IGE selected are set when the front panel key associated with this key-indicator box is pressed.

Set Gauge Name ⇨ - This function allows you to change the name of the IGR/IGE from the default notation, for example, IGR [5] to another name of your choosing. This screen allows you to scroll through an eight (8) character field for the gauge or device name you wish to create. Press the key associated with the respective key designators displayed (→ ← ↑ ↓) to move to the character place within the name field and select the available characters for each place.

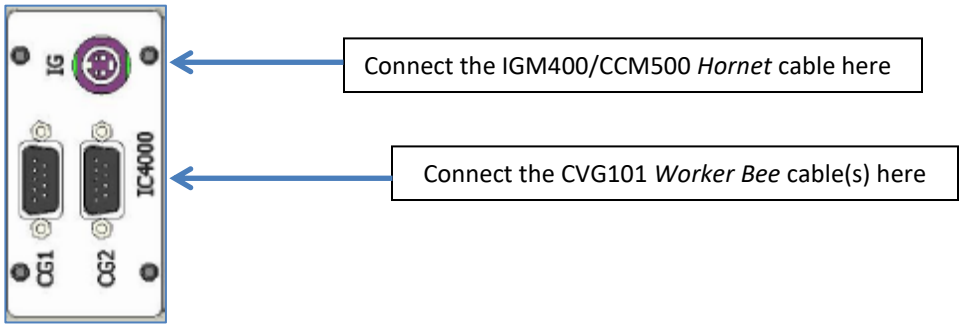
Auto Ie Enable ⇨ - This function allows the user to enable or disable the automatic emission current switching feature of the instrument. Note that with the IGR/IGE Emission Current set for 10 mA, this function key-indicator will be grayed-out (not available). The automatic emission current switching is only available between 100 µA and 4 mA. In many applications the User will opt to set the Ion Gauge emission current to either 100 µA, 4 mA or 10 mA depending on the ultimate pressure of the vacuum system and the pressure region that the vacuum process is intended to operate at. As the measurement extends to higher vacuum (lower pressures), it is common practice to increase the ion gauge emission current from 100 µA to 4 mA or 10 mA. In some process applications the pressure may range from 1.00E-05 Torr to above 1.00E-02 Torr. At pressures above 1.00E-05 Torr, the ion gauge emission current is usually set for 100 µA. The BA 600 series ion gauges are capable of operating at pressures up to 1.00E-03 Torr with emission current (I_e) set at 100 µA. To allow the IGR/IGE to automatically change the emission current between 100 µA and 4 mA , set the Auto Ie Enable to Enable.

Auto Ie Pressure ⇨ If Auto Ie Enable above is set to Enable, then Auto Ie Pressure allows the user to setup the IGR/IGE to automatically change emission current at a user defined pressure. To allow the IGR/IGE to automatically change the emission current in the ionization gauge at a certain pressure, program the Auto Ie Pressure at which you wish to have the emission current change from 100 µA to 4 mA and vice versa.
Example: If Auto Ie Pressure point is set to 1.00E-05 Torr, then the ion gauge can operate at an emission current of 100 µA over a pressure range of 1.00E-03 Torr to 1.00E-05. The emission current will then automatically switch to 4 mA for pressure ranges below 1.00E-05 Torr.

Pressing the key aligned with any of the key-designator boxes shown in the menu screens of the *FlexRax* will take you to a setup or control screen which you are now familiar with from preceding examples of operation. In using the *FlexRax* you will find that the available setup and control selections are intuitive and, if you should enter a value that is not permissible for the control and operation of the Option/Device, a message dialog box will appear with direction appropriate for the action you are taking. In certain cases, a displayed key-indicator will be grayed-out. This indicates that a condition exists that does not allow you to change or even enter the setup menu for that Option/Device.

3.6.1.2 Connections to and Operation of the IGM/CG Option –

The IGM/CG Option allows connections to either the InstruTech IGM400 or CCM500 *Hornet* and two *Worker Bee* convection gauge transducers. Refer to the User Manuals for the IGM400 and CCM500 *Hornet* modules for addition instructions and information related to the operation, setup and control of the IGM400 and CCM500.



⚠ **CAUTION!** When changing or making cabling connections to any device controlled by the *FlexRax* options, you must first turn AC power to the *FlexRax* **OFF**. If you want to either change an option location within the *FlexRax* controller or install a new option, you must first switch the AC power to the *FlexRax* **OFF**. Failure to disconnect AC Mains power to the *FlexRax* before either changing cable connections from options to devices or removing/installing option cards in the *FlexRax* may result in equipment damage or possible injury to personnel.

3.6.1.2.1 Connecting the IGM –

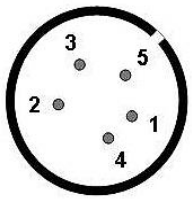
The IGM400/CCM500 *Hornet* module is connected to the *FlexRax* via an InstruTech provided control cable (P/N BXC-400-1-XXX). With either the IGM400 or CCM500 connected to your vacuum chamber, connect the 9-pin D-subminiature (DE-9S) connector end of the cable to the mating connector on the IGM400/CCM500. Connect the other end of the cable with the 7-pin, mini-DIN connector to the connector labeled 'IG' on the IGM/CG Option (IC4000) panel. Operating power for the IGM400/CCM500 *Hornet* is provided by the *FlexRax.* The IGM400 module electronics circuitry operates the miniature hot cathode B-A ionization gauge transducer contained within the module providing pressure measurement information to the *FlexRax*. The CCM500 module electronics circuitry operates the double inverted magnetron cold cathode ionization gauge sensor contained within module. All measurement data, operating power and control signals are provided via the single interconnect cable between the *FlexRax* and either the IGM400 or CCM500 *Hornet* module.

3.6.1.2.2 Connecting the CG –

Worker Bee Convection Gauges are connected via an InstruTech provided cable (p/n CB421-1-XXX) to the CG1 and CG2 connectors on the IGM/CG option panel. Connect the 9-pin D-subminiature (DE-9P) connector end of the cable to the appropriate CG connector on the IGM/CG option panel. Connect the other end of the cable with the *Worker Bee* connector to the CG corresponding to the CG number designator you have chosen for the location of the CG on your vacuum chamber. The *Worker Bee* is a convection enhanced pirani-type pressure measurement transducer. The *FlexRax* IGM/CG option card provides the voltages required to power and control the *Worker Bee* CG. You may connect the CG portion of the IGM/CG module to similar transducers from other manufacturers. The IGM/CG option is capable of detecting and operating either InstruTech *Worker Bee* or Granville-Phillips® Convectron® convection enhanced pirani transducers. The InstruTech *FlexRax* IGM/CG option and CG cables are directly compatible with Convectron® CG transducers.

P/N CB421-1-XXXF is a custom cable assembly provided in different lengths from InstruTech for connecting the FlexRax to InstruTech CVG101 *Worker Bee* or MKS Instruments / Granville-Phillips® 275 Convectron® vacuum gauge sensor.

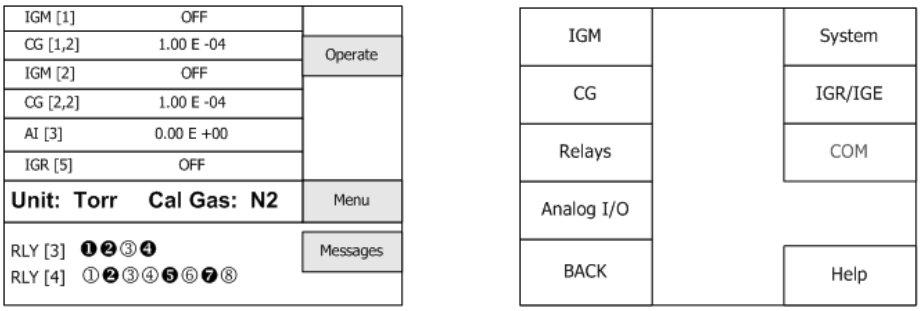
For your reference, the wiring chart for the CVG101 cable provided by InstruTech is shown below. In addition to InstruTech provided standard cable assembly lengths, InstruTech will provide custom length cable assemblies upon request.

FlexRax CG1/CG2 pin number (9-Pin D Sub.)	**connects to ⇨**	**CVG101 gauge pin number (InstruTech molded, custom connector)**	
1		NC	
2		cable shield	
3		3	
4		3	
5		2	
6		5	
7		1	
8		1	

3.6.1.2.3 Operation of the IGM –

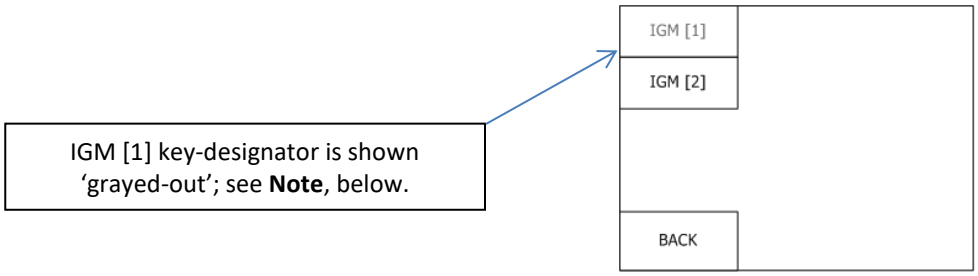
Either the IGM400 or CCM500 *Hornet* is powered and controlled by the *FlexRax* when the IGM/CG option card is installed. In the example configuration depicted in section 3.1.5 above, there are two IGM/CG option cards installed in the *FlexRax.* The first option installed at the rightmost side of the *FlexRax* (as viewed from the back of the instrument) is in physical location number ①. When AC power to the *FlexRax* is switched to ON, the operating system software detects this module as the first option available when it scans the physical locations and assigns each option an address or location. Devices connected to that option are also assigned addresses that will be referred to in the various menus and messages displayed on the *FlexRax* display. In the example configurations used in this manual (see above sections), the first option detected is an IGM/CG option with an assigned name for the IGM/CCM *Hornet* of IGM [1]. The two convection gauge (CG) channels available for use with this option are assigned names of CG [1,1] and CG [1,2].

The next option location, in this example, is filled with a second IGM/CG option card. Following the logical progression of scanning the available options and assigning address notations for each, the operating system software assigns the notations IGM [2], CG [2,1] and CG [2,2] to the second IGM/CG card, at the example location ②, in the *FlexRax.* To setup and operate the IGM/CCM, follow the sequence of key entries shown here. Press the key aligned with Menu ⇨ then, on the next screen, press the key aligned with IGM ⇨



Pressure Measurement Screen ⇨ **Main Menu Screen**

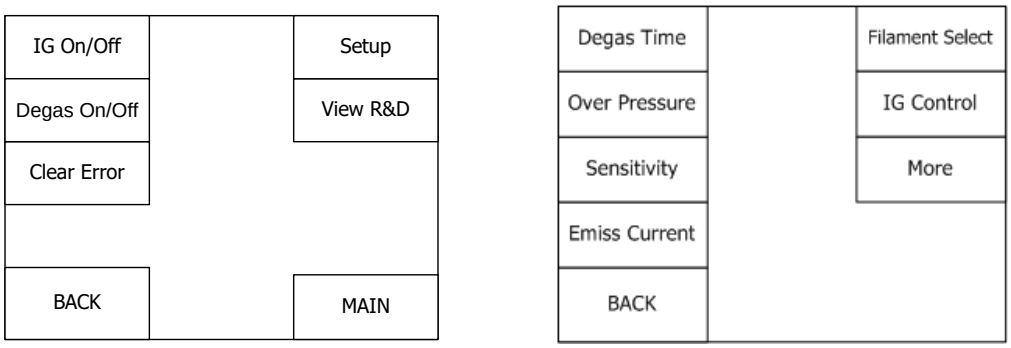
In the example **Pressure Measurement Screen** shown here, you will note that the Operate / Stand-By mode key-designator box is displayed as Operate. This mode will allow access to control for the IGM/CCM options and other installed ionization gauge options - the IGE/IGR, for example. If the *FlexRax* mode of operation is in either the '**Stand-By**' mode or the **'Operate'** mode and the device cables are not connected, both IGM [1] and IGM [2] shown in the next example menu screen will be grayed-out.
Here, assuming neither IGM [1] nor IGM [2] keys are grayed-out, select either IGM [1] ⇨ or IGM [2] ⇨



IGM Select Screen

Note – if the control cable for the IGM400/CCM500 *Hornet* is not connected, the displayed key for that IGM [n] will be shown in the display as 'grayed-out'. The *FlexRax* operating system will ignore the key press associated with any key that is grayed-out. As shown, in the example display above, the IGM [1] option *is* installed in the *FlexRax,* however, since the key-designator is grayed-out, the control cable *must be* disconnected and therefore no access is granted to the setup and control of this option.

Press the key aligned with Setup ⇨ to see to the IGM Setup Screen.



IGM Operations Screen ⇨ **IGM Setup Screen**

3.6.1.2.3.1 Operation of the IGM - Using the IGM400 hot cathode IG module

If you have an IGR/IGE option card and operating a Nude or Glass enclosed B-A ionization gauge, the information in this section may seem redundant as many of the menu selections are the same for the IGR/IGE and IGM operations. There are however some important differences between the IGR/IGE and IGM operations. As such, all menu selection choices for the IGM Setup has been listed and discussed in this section.

In the preceding pages of this section, you have followed the key entry sequence of: Menu ⇨ IGM ⇨ IGM [n] ⇨ Setup ⇨

To setup and operate the IGM shown in the screen above, become familiar with the topics presented in the remaining pages of this chapter then follow the sequence of key entries shown next; at the end of each sequence, a brief description of the function is given.

Degas Time ⇨ - Default degas time for IGM400 is 2 minutes[17]. Degas is used to rid the gauge sensor of adsorbed gas. Degas is achieved by applying Electron Bombardment (EB) to the grid. Ensure vacuum level is less than 5.00E-05 Torr before attempting to initiate Degas. The intervals at which degas should be applied vary for each application. The low pressure measurement performance of the transducer will normally improve after initial degassing cycle.

[17] For the IGM400, the Degas function will turn off if the measured pressure rises above 3.00E-04 Torr. The filament however will remain turned on. You may be required to make several Degas turn ON attempts in order to allow sustained Degas operation. When DEGAS is asserted, the measure of pressure inside the IG transducer will continue to be displayed. While in the DEGAS mode, the displayed pressure measurement value will be shown on the front panel LCD display in BLUE color. For example: 6.54 E-06 (the pressure value shown on the display line for the IG device being degassed).

Over Pressure ⇨ - Over Pressure shut OFF default for IGM400 is 5.00E-02 Torr with emission current (I_e) set at 100 µA and 1.00E-03 Torr at 4 mA I_e. Over Pressure allows you to set the pressure at which the IGM400 will turn OFF. It is **not** recommended to attempt operation of the IGM400 B-A hot cathode ionization gauge above certain, defined pressures. This function is also used to define the pressure at which an Ion Gauge will be turned ON and OFF when 'IG Control' is set for other than the 'Manual' control mode (see the IG Control description below). When using the emission current setting of 4 mA, the overpressure value is fixed at 1.00E-03 Torr. When using the emission current setting of 100 µA, the overpressure value can be set to any value between 1.00E-04 Torr to 5.00E-02 Torr. See the **CAUTION** statement following the 'IG Control' function description of this section.

Sensitivity ⇨ - Default is 10 per Torr (10 $Torr^{-1}$).
Program the IGM400 sensitivity that is marked on the IGM400 mounting plate. The sensitivity value is designated with the letter "S" and it is a number that normally ranges between 8 and 15.

The Sensitivity constant used by the operating system for the pressure calculation is based on the following mathematical formula for the B-A ion gauge pressure measurement:

$I_c = P \cdot S \cdot I_e$ where P is Pressure, S is Sensitivity[18] ; I_c is the collector current and I_e is the emission current.

Emiss Current ⇨ - Default is 100 µA emission current. See 'Over Pressure', above, for pressure measurement range restrictions when operating the IGM with various emission current settings. You can use both 100 µA and 4 mA emission currents when operating the 'IG Control' mode where a CG [n,m] or other Analog Input device is used to control the IG ON/OFF function. In clean applications and when operating at higher pressure ranges (5.00E-06 Torr to 5.00E-02 Torr) the 100 µA emission setting is preferred. At lower operating pressures (1.00E-09 Torr to 5.00E-04 Torr) the 4 mA emission setting should be used.

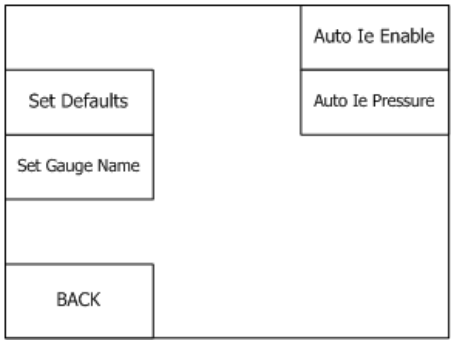
Filament Select ⇨ - Default is Filament 1. When using dual filament ion gauges, this menu allows the user to select which IGM400 filament to operate: *Filament 1* or *Filament 2*
It is recommended that you alternate operation of both filaments from time-to-time. A filament that is not used periodically may exhibit difficulty in establishing emission current after exposure to certain chemical/physical effects.

IG Control ⇨ - Default is **Manual** filament ON/OFF control using the front panel keys (push-button switches). You may also select another device such as one of the convection gauges **CG [n,m]** or an analog input **AI [n]** to control the ON/OFF state of the IGM. See 'Emiss Current', above, for related information regarding this function capability. When you choose CG [n,m] or AI [n], the pressure at which the Ion Gauge will be controlled, i.e., turned to ON or turned to OFF will be determined by the pressure set in the 'Over Pressure' setup screen (see Over Pressure – setting described above). When using the **AI [n]** to control the IG, pay particular attention to the **CAUTION** statement immediately below this paragraph.

[18] Sensitivity for the B-A type ionization gauge is a constant. A number defined as the quantity of ions created and collected (collector current) per unit measure of pressure per the controlled quantity of emission current from which the ion current is generated. This setting can be useful for compensating the readout of pressure when measured by the ion gauge for gases other than nitrogen/air. Consult support@instrutechinc.com for further discussion on the use of this setting for compensated readings. Typical sensitivity for the miniature B-A ionization gauge used in the IGM400 is 10 per Torr (10 $Torr^{-1}$). Your IGM400 IG transducer sensitivity is marked on the ion gauge mounting plate.

⚠ **CAUTION!** In order that you prevent equipment damage and possible injury to personnel, you must have control safeguards to prevent the IG from accidentally turning on above the trip-point in the event the device assigned to control the IG fails or is turned off. **DO NOT** rely on an external device to turn the IGM ON/OFF without performing a thorough hazardous operation study of your control system design.

more ⇨ - This will display another menu screen shown below with the following additional setup functions.



IGM Setup Screen (more)

Set Defaults ⇨ - Default factory setup parameters for the IGM selected are set when the front panel key associated with this key-indicator box is pressed.

Set Gauge Name ⇨ - This function allows you to change the name of the IGM from the default notation, for example, IGM [2] to another name of your choosing. This screen allows you to scroll through an eight (8) character field for the gauge or device name you wish to create. Press the key associated with the respective key designators displayed (→ ← ↑ ↓) to move to the character place within the name field and select the available characters for each place.

Auto Ie Enable ⇨ - This function allows the user to enable or disable the automatic emission current switching feature of the instrument. The automatic emission current switching is only available between 100 µA and 4 mA. In many applications the User will opt to set the Ion Gauge emission current to either 100 µA or 4 mA depending on the ultimate pressure of the vacuum system and the pressure region that the vacuum process is intended to operate at. As the measurement extends to higher vacuum (lower pressures), it is common practice to increase the ion gauge emission current from 100 µA to 4 mA. In some process applications the pressure may range from 1.00E-05 Torr to above 1.00E-02 Torr. At pressures above 1.00E-05 Torr, the ion gauge emission current is usually set for 100 µA. The IGM400 ion gauge is capable of operating at pressures up to 5.00E-02 Torr with emission current (I_e) set at 100 µA. To allow the IGM to automatically change the emission current between 100 µA and 4 mA , set the Auto Ie Enable to Enable.

Auto Ie Pressure ⇨ If Auto Ie Enable above is set to Enable, then Auto Ie Pressure allows the user to setup the IGM to automatically change emission current at a user defined pressure. To allow the IGM to automatically change the emission current in the ionization gauge at a certain pressure, program the Auto Ie Pressure at which you wish to have the emission current change from 100 µA to 4 mA and vice versa.

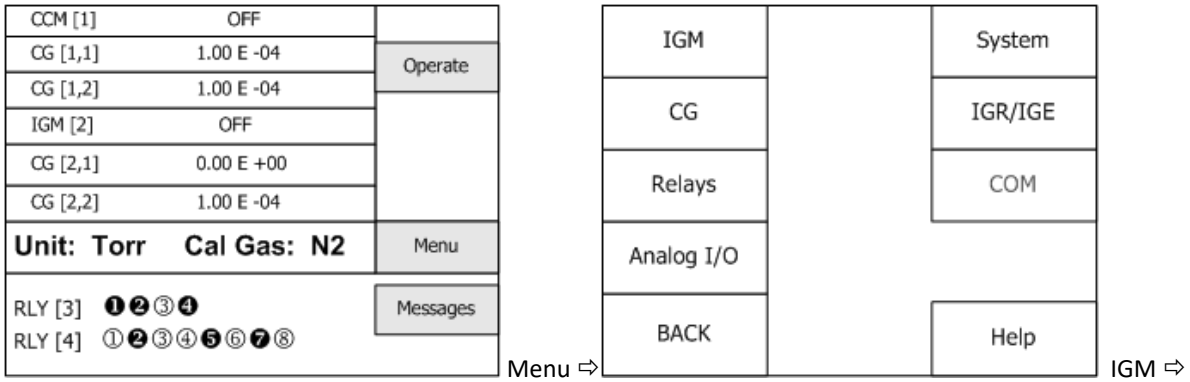
Example: If Auto Ie Pressure point is set to 1.00E-05 Torr, then the IGM400 can operate at an emission current of 100 µA over a pressure range of 5.00E-02 Torr to 1.00E-05. The emission current will then automatically switch to 4 mA for pressure ranges below 1.00E-05 Torr.

Pressing the key aligned with any of the key-designator boxes shown in the menu screens of the *FlexRax* will take you to a setup or control screen which you are now familiar with from preceding examples of operation. In using the *FlexRax* you will find that the available setup and control selections are intuitive and, if you should enter a value that is not permissible for the control and operation of the Option/Device, a message dialog box will appear with direction appropriate for the action you are taking. In certain cases, a displayed key-indicator will be grayed-out. This indicates that a condition exists that does not allow you to change or even enter the setup menu for that Option/Device.

3.6.1.2.3.2 Operation of the IGM - Using the CCM500 cold cathode IG module

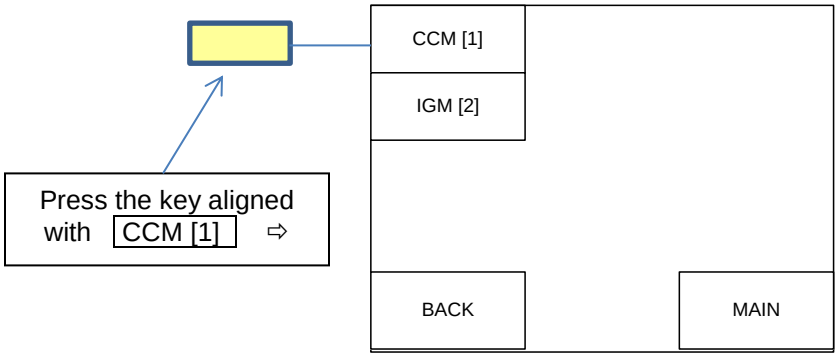
You will note from the discussion in above section 3.6.1.2.3, ***Operation of the IGM***, that the **Main Menu Screen** example shows the option card in location ① as IGM [1]. Now, this IGM/CG option card may operate either the IGM400 or the CCM500 *Hornet* module. If you have connected the CCM500 cold cathode module to either one of the two available IGM/CG option (IC4000) cards, the **Main Menu Screen** will annotate the option as 'IGM' regardless of whether the connected module is an IGM400 or a CCM500. You are urged to consider renaming the option card from the default name of IGM [n] to, say, CCM [n] when operating the CCM500 from the IGM/CG (IC4000) option card location (see Set Gauge Name discussion in this section). You may find it helpful to read this entire section prior to initiating any changes to the settings and parameters for operation of the CCM500.

If you have renamed an IGM [n] to a CCM [n] as suggested, as you move from screen to screen while navigating the FlexRax displays as shown in the following display screen examples, you will arrive at a CCM/IGM Select Screen similar to that as indicated below:



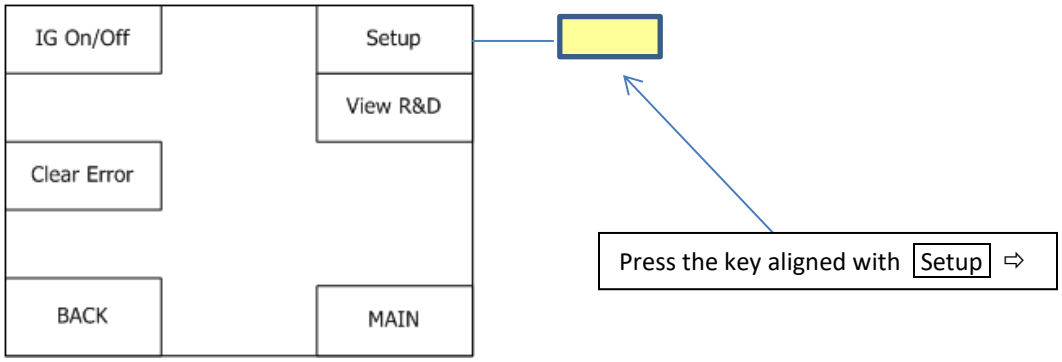
Pressure Measurement Screen –
(Option Location [1] set for CCM500 Device Readout)

Main Menu Screen



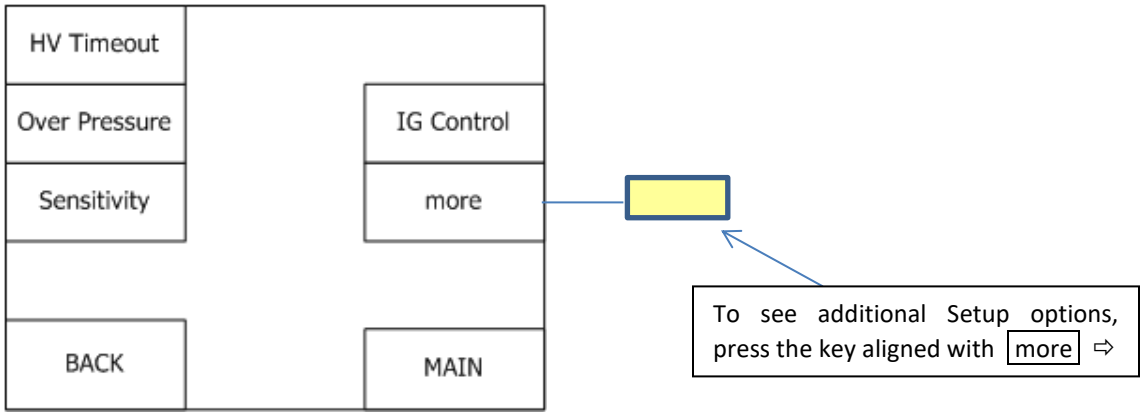
CCM/IGM Select Screen

The following examples and user instructions in this section are for use of the CCM500 cold cathode ionization gauge module and assume that the option location ① card has been renamed to CCM [1] for operation of the CCM500 module. It is also assumed that a CCM500 module and interface cable is connected to this IGM/CG option card.

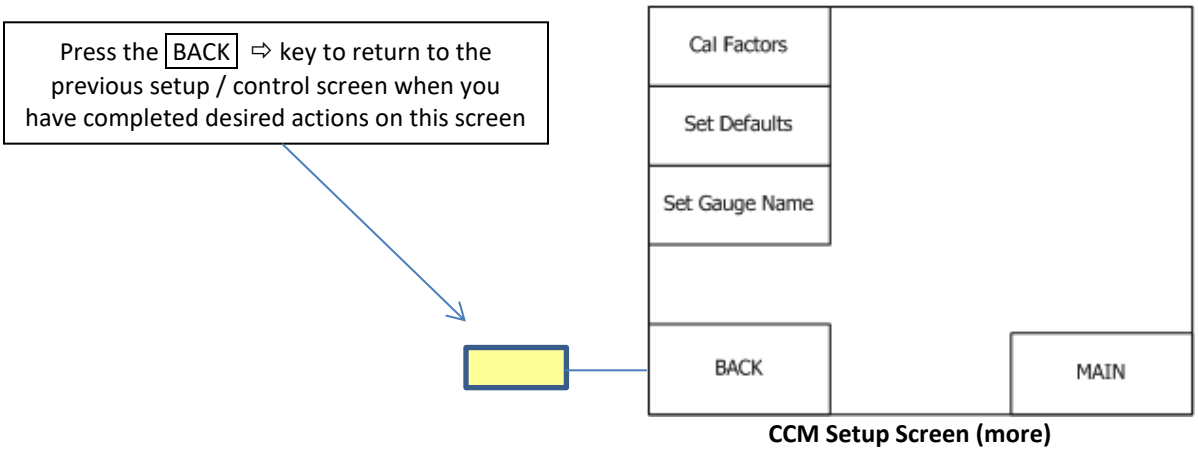


CCM Operations Screen

After progressing from the **Pressure Measurement Screen** to the **Main Menu Screen** and the **CCM/IGM Select Screen,** press the key aligned with key-indicator Setup. You will see a screen showing various choices as in the following displayed sub-menu screen for the CCM500 cold cathode IG:



CCM Setup Screen



CCM Setup Screen (more)

Once you have arrived at one of the CCM Setup Screens shown above, you may opt to select any of the available function/parameter keys to adjust or set the operation of the CCM500 module as desired.

HV Timeout Default is 10 minutes.
This function allows you to set a period of time in which the CCM500 will continue to apply high voltage to the anode of the CCIG sensor in order that an ionizing discharge is established – also known as the maximum allowable startup period. The default setting for this function is 10 minutes. You may change the maximum startup period at any time prior to initiating an IG On condition. This function is provided to allow the user some control at ensuring the CCM500 does start the sensor and valid pressure readings are established within a reasonable period of time. The time period can be set from 1 to 60 minutes – enter this menu choice to program the maximum wait period after the IG On command is invoked and the CCM500 starts to read pressure. The recommended setting for 'HV Timeout' is 10 minutes.

Over Pressure - Over Pressure shut OFF default for CCM500 is 1.00E-02 Torr.
Over Pressure allows you to set the pressure at which the CCM500 will turn OFF. The maximum pressure that the CCM500 should be allowed to operate is 10 mTorr [1.00E-02 Torr]. It may operate at higher pressures without damage, but the calibrated pressure reading range is from 1.00E-08 to 1.00E-02 Torr and readings of vacuum pressures above the 10 mTorr 'Over Pressure' set point may not be as accurate as desired for your application. It is advised that you check the programmed value of 'Over Pressure' prior to operating your CCM500 with the *FlexRax.* In some cases, the 'Over Pressure' value may be set at a higher value, such as that of the IGM400 hot cathode IG module if the *FlexRax* was previously configured and setup for operation of an IGM400 at the IGM/CG card location now used to operate a CCM500. If, for example, the 'Over Pressure' setpoint is set to 5.00E-02 Torr (50 mTorr) when you check it, adjust the setpoint to read 1.00E-02 Torr prior to operating the CCM500 to measure vacuum pressure (IG On). Operating any ion gauge at too high a pressure in the presence of certain gases and gas mixtures may result in sputtering of the internal electrodes of the transducer (sensor) leading to changes in performance of the device. 'Over Pressure' may be used as the turn on point for the CCM500 sensor when operating in the CG controls IG mode.

Sensitivity - Default is 10 per Torr (10 $Torr^{-1}$).
The Sensitivity value for the CCM500 is always set to 10 per Torr. The Sensitivity is designated with the letter "S" and marked on the CCM500 mounting plate. This function also allows you to offset the reading of vacuum pressure to compensate for gas type, known sensitivity adjustments/changes and for use in certain other experimental techniques. Read the section regarding setting of 'Sensitivity' for hot cathode ionization gauges in this user manual for further information.

IG Control - Default is **Manual** filament ON/OFF control using the front panel keys (push-button switches).
This function allows the user to choose the source of control for the IG. The IG can be controlled from either the front panel (Manual Mode) or one of the convection gauges or analog inputs may be assigned to initiate the CCM500 IG turn On/Off function.

Cal Factors This function allows you to program the six sensor calibration factor constants referred to as 'Cal Factors' that are established for your particular CCM500 CCIG sensor during factory calibration. These values are physically marked on the sensor mounting plate below the CCM500 control electronics enclosure. See the CCM500 User Manual for additional details regarding the use, operation and maintenance of the CCIG. The six calibration factors are designated C0, C1, C2, C3, C4 and C5 and are used to characterize the sensor response over the pressure measurement range of the device. This results in enhanced and optimum performance over the entire vacuum pressure measurement range. The user should ensure that the values marked on the instrument match the 'Cal Factors' programmed in the *FlexRax.* Use care in setting these values to other than

the actual values provided on your CCM500 CCIG sensor mounting plate. The *FlexRax* operating system factory default values are set to 10. The values can be set from 1 to 99.

Set Defaults This function programs all user settable values as discussed in this section to the factory default settings.

Set Gauge Name This function allows you to customize the displayed device name. For example, in this section, it was previously advised when operating a CCM500, that you set the gauge name for the IGM [n] (operating option card in the *FlexRax*) to read CCM [1]. This will distinguish it from the IGM400 *Hornet* module and corresponding IGM/CG option card located, for example, at physical location [2] in the *FlexRax* controller (IGM [2], shown in examples above). This screen allows you to scroll through an eight (8) character field for the gauge or device name you wish to create. Press the key associated with the respective key designators displayed (→ ← ↑ ↓) to move to the character place within the name field and select the available characters for each place.

You may go back one menu level or return to the main pressure measurement screen by pressing the hardware key associated with either the BACK or the MAIN key-indicators at either setup screen.

Once you have setup the control parameters shown and discussed above, you may return to the **CCM Operations Screen** to turn the IG On. You may also return to that screen later to turn the IG Off, to either clear an error condition or to view the operation of the device using the research (R & D) screen.

3.6.1.2.4 Operation of the CG –

Two of the most important steps for the initial setup for the convection gauges are to *set vacuum* and set atmosphere as described below. This will ensure proper operation of the gauge and accurate pressure measurements. The gauge is calibrated at the factory using nitrogen. Furthermore, the gauge is also installed in a certain orientation when calibrated at the factory. Without setting zero and atmosphere after the gauge is installed in your system, the gauge may not display the expected and correct pressures. This could be caused by the fact that you may be using a different gas than Nitrogen such as air to setup and calibrate the gauge (most commonly the case) and the gauge orientation is different than the orientation used at the factory. As such, it is very important to perform your own initial setup and calibration by setting zero and atmosphere with the gauge installed in your actual system. Please note the following:

***Set Vacuum*:** Setting zero optimizes performance of the gauge when operating at a low pressure range of 1.00 x 10^{-4} Torr to 1.00 x 10^{-3} Torr. If your minimum operating pressure is higher than 1.00 x 10^{-3} Torr, it is not normally necessary to set zero and thus setting atmosphere should be adequate. If you are able to evacuate your system to below 1.00 x 10^{-4} Torr, it is always a good practice to check and set zero if necessary. See "*Set Vacuum" below.*

***Set Atmosphere*:** Setting atmosphere is the most important step for a newly installed gauge. If you prefer to use air to set atmosphere, vent your vacuum system chamber to expose the gauge to the local atmospheric pressure (air) and set atmosphere to match your known local uncorrected barometric pressure (air). This is the reading of ambient air pressure you will expect if you were to vent and open your vacuum chamber to the atmosphere surrounding the outside of your chamber. At sea level, this pressure is usually near 760 Torr. At elevations above sea level, the pressure decreases. Check your local aviation authority or airport web sites or your current local weather conditions online to help find your local uncorrected barometric pressure if you do not have this information. See "*Set Atmosphere" below.*

Note - Setting zero and atmosphere is normally required only once during the initial setup and maybe checked by the user periodically. After power has been applied to the gauge during the initial setup, allow five minutes for the gauge to stabilize (warm-up) before setting zero and atmosphere.

With your *Worker Bee* convection gauge transducers connected to the CG cables and the IGM/CG Option, you may perform several setup functions for the CGs with the *FlexRax* operating system. From the **Pressure Measurement Screen** perform the following key-entry sequence:

Menu ⇨ CG ⇨ then select the CG Device you wish to setup (if not grayed out; otherwise, connect the CG cable to the IGM/CG Option and the CG Device to the cable).

After pressing the key aligned with the CG [n,m] device you wish to setup, you will see the following choices:

Set Atmosphere – allows you to adjust the pressure reading for the CG device selected to the local uncorrected barometric pressure at your locale. This is the reading of ambient air pressure you will expect if you were to vent and open your vacuum chamber to the atmosphere surrounding the outside of your chamber.

This adjustment (Set Atmosphere) is also referred to as "ATM", an acronym for "atmosphere" – it may be thought of as a 'span' adjustment in commonly used vernacular for devices where a 'zero' and 'span' adjustment are made to correct for offsets that are unique to each measurement / output device. As stated above, at sea level, this pressure is usually near 760 Torr. At elevations above sea level, the pressure decreases. Check with your local aviation authority, other agencies, online search (current barometric pressure - your city), etc., for the local uncorrected barometric pressure if you do not have this information for your locale.

Set Vacuum – allows you to adjust the reading of pressure at "vacuum". The acronym "VAC" is often used to describe the 'vacuum' setting adjustment. This adjustment is recommended if you know that the pressure in your vacuum chamber is less than 1.00E-04 Torr and you want to use the CG for measurement of pressure near 1.00E-03 Torr. All *Worker Bee* convection gauges are factory calibrated to provide a vacuum pressure reading of +/- 1 mTorr for a CG control circuit setup for nominal 'zero' (VAC) reading. The range of adjustment allowed is controlled by the *FlexRax* operating system. It is permissible to adjust the 'zero' or VAC reading for a reading at the lower end of the CG measurement range that is not within the nominal +/- 1 mTorr, true pressure at "vacuum".

Set Defaults – when this function is invoked, the CG settings will be restored at factory default settings.

Set Gauge Name – as previously described, above, you may change the default name of the chosen CG Device to an 8-character name of your choice using the available character set in the *FlexRax* operating system.
When the *Worker Bee* convection gauge is connected via the CG cable to the IGM/CG Option in the *FlexRax,* pressure measurement is continuous and immediate. There is no ON/OFF control function required to display the pressure measured by the CG transducer.

3.6.1.2.5 Connection to Other Devices –

Refer to Instructions and related, additional information for connections to other devices in the User Manuals for those devices and connections not mentioned in this User Manual.

3.6.1.3 Connecting the COM Option –

Either RS232 or RS485 serial communications may be used to send/receive commands to/responses from the *FlexRax.* There are two DE9 (D-subminiature, shell size E, 9 pole) connectors that allow independent cable connections to the COM option. The COM option supports three serial communication protocols.

1. RS485 with address, start and stop characters and command/response syntax derived from the InstruTech IGM401 *Hornet* protocol.
2. RS232 with start and stop characters, but no addressing is used. The syntax is the same as the RS485 protocol.
3. RS232 protocol compatible with the Granville-Phillips (G-P) Series 307 Vacuum Gauge controller.

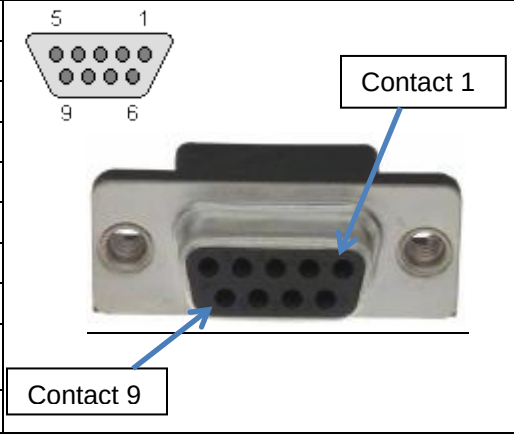
The RS232 COM port on the CM4000 option is configured to allow, for example, a 9-pin extension cable, male to female, wired "pin-to-pin" to be connected from the *FlexRax* to your COM port. **DO NOT** connect both of the RS232 and RS485 cables to the *FlexRax* as the instrument cannot provide both serial communication types at the same time. Use only one or the other as programmed by the user.

An extension cable wired pin-to-pin may be used to connect the RS232 COM port on the *FlexRax* directly to your PC COM port (a converter may be necessary).

DE-9 Connectors for connections to user supplied cables for serial communication port – DE9P (RS485), DE9S (RS232)

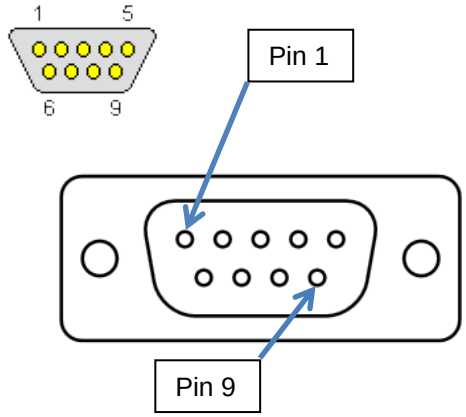
RS232 COM PORT - CM4000 Option

9-contact (DE-9S) D-subminiature RS232 Connections		DE-9S D-subminiature Connector (on CM4000 COM Option Card)
Connector Socket Number	**Description**	
1	No connection	
2	Transmitted Data (OUT)	
3	Received Data (IN)	
4	No connection	
5	Signal Ground	
6	No connection	
7	No connection	
8	No connection	
9	No connection	



Connect either RS232 or RS485 cable to *FlexRax* – DO NOT CONNECT BOTH AT THE SAME TIME

RS485 COM PORT - CM4000 Option

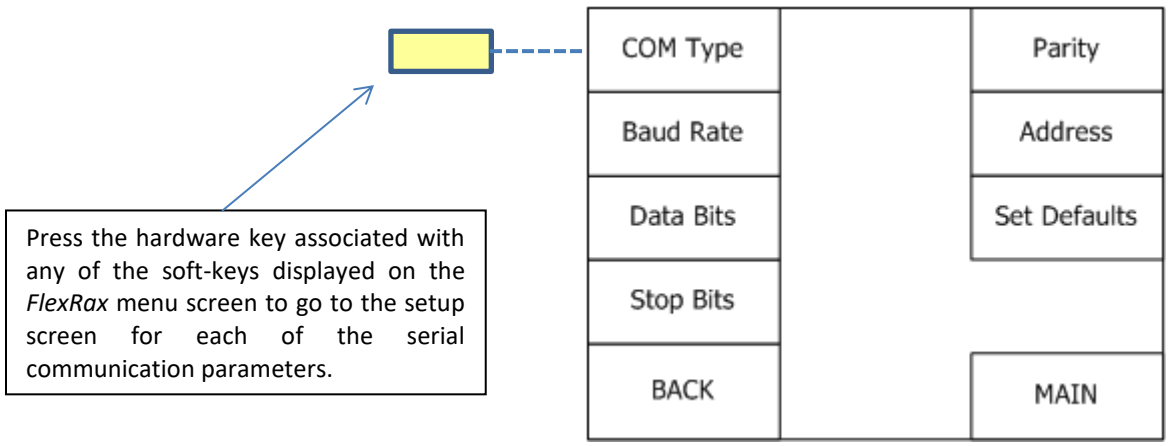
9-pin (DE-9P) D-subminiature RS485 Connections		DE-9P D-subminiature Connector (on CM4000 COM Option Card)
Connector Pin Number	**Description**	
1	DATA A (-)	
2	DATA B (+)	
3	No connection	
4	No connection	
5	No connection	
6	Signal Ground	
7	No connection	
8	No connection	
9	Ground	

Connect either RS232 or RS485 cable to *FlexRax* – DO NOT CONNECT BOTH AT THE SAME TIME

3.6.1.3.1 Setup of the FlexRax COM Option –

From the Pressure Measurement Screen press the MENU key to proceed to the menu screen where you will see the COM soft-key (not grayed-out if this option is installed in slot 7). Follow the progression of menu choices to setup the CM4000 option for your application. The following settings may be made from the *FlexRax* front panel controls:

- **COM Type** – selections available are RS485, RS232 and G-P 307 compatible RS232 (GP232).
- **Baud Rate** – select from 300 to 57600 baud; default is 19200 baud.
- Number of **Data Bits** – select from 5 to 9 data bits; default is 8 data bits.
- **Parity** – can be set to None, Odd, Even, Mark or Space; default is None parity
- Number of **Stop Bits** – can be set to 1, 1.5 or 2; default is 1 stop bit.
- Device (*FlexRax)* **Address** – not available when in RS232 modes. Address (for RS485 mode) can be set with the range of 00 to FF hexadecimal; default address is 01h.
- **Defaults** – sets all programmable parameters to default settings.



There is a finite period of time between the time a command is sent from a terminal (PC COM Port, for example) and the point in time in which the *FlexRax* CM4000 option sends a response to that command. This delay is dependent upon the command sent and the configuration of the *FlexRax* 4000. The minimum interval may be as short as 20 milliseconds with a mean delay time of 300 milliseconds. The maximum interval may be up to 1 second in duration.

3.6.1.3.2 RS485 (RS232) Interface - Device Name Conventions

The relationship of the *FlexRax* device name and the serial COM name for each device in the *FlexRax* is given in the following example table. The names of each device are the same for both RS485 and RS232 syntax. In RS232 mode, the node address is ignored and may be either eliminated from the command string or replaced with 'space' characters (ASCII punctuation - 0020h). RS232 response strings will not contain an address; the address is replaced with space characters. Because device names identified by the *FlexRax* control may be defined either by the user or assigned by the *FlexRax* operating system based on the physical location and logical progression assignment discussed previously, to keep the serial communication protocol consistent, all *FlexRax* devices are defined with specific names to be used for the serial communication syntax.

You will note that certain *FlexRax* default names listed in the table below will have a different serial communication device name and number assigned. For example, the *FlexRax* device name 'CG [2,1]' is known as 'CG3' when communicating via either the RS485 or RS232 serial COM option.

NOTICE The following table is for demonstrative purposes. The default and assigned names shown in this table are based on the assumption that the *FlexRax* is configured in a specific manner. The point of the table is to illustrate the relationship between the name of the device as shown in the FlexRax column of the table and the naming convention used by the CM4000 option for communication with that device. It is recommended that the user construct a similar table based on the specific configuration and naming convention of each device in the user's *FlexRax* configuration. The rule to follow when defining the **Serial Communication Name** is, while following the logical progression used by the *FlexRax* operating system; assign the next progressive number to the type of device that the operating system detects. Use the following table as an example of determining the correct device name for the serial command syntax.

FlexRax Device Name (default)	CM4000 (Serial Communication Name)
IGM [1] – first IGM/CG option card	IG1
CG [1,1]	CG1
CG [1,2]	CG2
IGM [2] – second IGM/CG option card	IG2
CG [2,1]	CG3
CG [2,2]	CG4
AI [3] {assumes slot 1 and 2 are filled as shown above and there is an AI/O-R card installed in location [3]}	AI1
AI [4] {same assumption as above and a second AI/O-R card is installed in location [4]}	AI2
RLY [3,1] {same assumptions as above – first AI/O-R card in slot [3]; card has 8 relays installed}	RL1
RLY [3,2]	RL2
RLY [3,3]	RL3
RLY [3,4]	RL4
RLY [3,5]	RL5
RLY [3,6]	RL6
RLY [3,7]	RL7
RLY [3,8]	RL8
RLY [4,1] {second AI/O-R card in slot [4]; card has 8 relays installed}	RL9
RLY [4,2]	RL10
RLY [4,3]	RL11
RLY [4,4]	RL12
RLY [4,5]	RL13
RLY [4,6]	RL14
RLY [4,7]	RL15
RLY [4,8]	RL16
IGR [5] – IGR option installed in location [5]	IG3
IGE [5] – IGE option installed in location [5]	IG3
IGR [6] – IGR option installed in location [6]	IG4
IGR [6] – IGR option installed in location [6]	IG4

Example Table for Naming Convention used to cross reference *FlexRax* device name and serial COM name

To further illustrate the complexity of the naming convention requirement and the care one must use to ensure that the serial communications protocol is followed correctly, consider the case where a *FlexRax* is configured with one AI4000-4 in location ③ and one AI4000-8 is installed in location ④, i.e., 12 total relays exist. The default *FlexRax* device names for the 4 each relays installed on the first AI/O-R option located in card location ③ will be referred to as RL1, RL2, RL3 and RL4. The remaining 8 each relays installed on the second AI/O-R card are then referred to RL9 and RL10 thru RL16 in the serial communication command/response protocol.

3.6.1.3.3 RS485/232 Serial Communication Command Protocol –

See notes after table, below, for legend/interpretation of syntax used and examples given in this table.

COMMAND	BRIEF DESCRIPTION	COMMAND SYNTAX	RESPONSE
READ IGn Pressure	Read the designated IG pressure in Torr units	#xxRDIGn<CR> *(e.g., #01RDIG1<CR>)* **Note:** The '*<CR>'used in all Command Syntax and Response examples represents a 'carriage return'*	*xx_y.yyEzyy<CR> *(e.g., *01_1.53E+06<CR>)* When device does not exist: *01_9.90E+09 When IG is off: *01_1.01E+03
READ CGn Pressure	Read the designated CG pressure in Torr units	#xxRDCGn<CR> *(e.g., #01RDCG1<CR>)*	*xx_ y.yyEzyy <CR> *(e.g., *01_7.60E+02<CR>)* When device does not exist: *01_9.90E+09 When CG is over-ranged: *01_1.01E+03
READ AIn Pressure	Read the current pressure for AIn.	#xxRDAIn<CR> *(e.g., #01RDAI1<CR>)*	*xx_ y.yyEzyy <CR> *(e.g., *01_7.60E+02<CR>)* When device does not exist: *01_9.90E+09 When AI is over-ranged or not powered: *01_1.01E+03
READ all Relay states	Read the current state of all process control relays	#xxRL<CR> *(e.g., #01RL<CR>)* *{Table continued below}*	*xx_FFFFFFRL<CR> *(e.g., right most 'F' represents the first 4 relays installed on the first installed AI/O-R option card; hexadecimal 0003 = binary 0011 = RL1 and RL2 ON …)* When device does not exist: ?01_INVALID_<CR>

COMMAND	BRIEF DESCRIPTION	COMMAND SYNTAX	RESPONSE
READ one particular Relay state	Read the current state of <u>one</u> of the available process control relays	#xxRLn<CR> *(e.g., #01RL1<CR>)*	*xx_0_RL_OFF<CR> *xx_1_RL_ON_<CR> Response does not give name (RLn) of device (Relay) queried. When device does not exist: ?01_INVALID_<CR>
READ IGn ON/OFF STATUS	Find out if IG is ON and gauge is reading	#xxIGnS<CR> *(e.g., #01IG1S<CR>)*	*xx_0_IG_OFF<CR> *xx_1_IG_ON_<CR> Response does not give name (IGn) of device (IG) queried. When device does not exist: ?01_INVALID_<CR>
TURN ON IGn	Turn ON the designated Ion Gauge (IGn).	#xxIGn_1<CR> *(e.g., #01IG1 1<CR>)* *Note: The '_' underscore character in the command string represents a 'space' character for purposes of description; do not use a 'underscore' in the string*	*xx_PROGM_OK<CR> When in Standby mode: ?01_INVALID_<CR> When CG controlled: ?01_INVALID_<CR> When IG error exists: ?01_INVALID_<CR> When device does not exist: ?01_INVALID_<CR>
TURN OFF IGn	Turn OFF the designated Ion Gauge (IGn).	#xxIGn_0<CR> *(e.g., #01IG1_0<CR>)*	*xx_PROGM_OK<CR> **<u>Note:</u> This command is also used to clear errors associated with the operation of the designated IG.** When device does not exist: ?01_INVALID_<CR>
TURN ON DEGAS for IGn	Turn DEGAS ON for the designated Ion Gauge Use only the number 'n' associated with the designated IG.	#xxDGn_1<CR> *(e.g., #01DG1 1<CR>)*	*xx_PROGM_OK<CR> When IG off: ?01_INVALID_<CR> When device does not exist: ?01_INVALID_<CR> When in Standby mode: ?01_INVALID_<CR> When Pressure is greater than 5e-5 Torr: ?01_INVALID_<CR>
TURN OFF DEGAS for IGn	Turn DEGAS OFF for the designated Ion Gauge Use only the number 'n' associated with the designated IG	#xxDGn_0<CR> *(e.g., #01DG1_0<CR>)* *{Table continued below}*	*xx_PROGM_OK<CR> When device does not exist: ?01_INVALID_<CR>

COMMAND	BRIEF DESCRIPTION	COMMAND SYNTAX	RESPONSE
READ DEGAS STATUS (ON or OFF) for designated IGn	Find out if DEGAS is ON or OFF for the designated IG Use only the number 'n' associated with the designated IG	#xxDGnS<CR> *(e.g., #01DG1S<CR>)*	*xx_0_DG_OFF<CR> or, *xx_1_DG_ON_<CR> When device does not exist: ?01_INVALID_<CR>
SET EMISSION Current for IGn	Choose either 10 mA, 4 mA or 100 µA emission current (I_e) for designated Ion Gauge	#xxSEn_y<CR> (*e.g., #01SE1 1<CR>* will set the emission current for IG1 to 4 mA) For y = 2, I_e = 10 mA; For y = 1, I_e = 4 mA; For y = 0, I_e = 100 µA	xx_PROGM_OK<CR> When device does not exist: ?01_INVALID_<CR> When in Auto I_e mode: ?01_INVALID_<CR> When 10 mA is selected and in 'CG Controls IG' mode: ?01_INVALID_<CR> When 10 mA selected with IGM: ?01_INVALID_<CR>
Read EMISSION Current for IGn	Read emission current setting for designated ion gauge device number.	#xxSEnS<CR> (e.g., #01SE1S<CR>)	*xx_0.1MA_EM<CR> *xx_4.0MA_EM<CR> *xx_10_MA_EM<CR> When in Auto I_e mode: ?01_INVALID_<CR> When device does not exist: ?01_INVALID_<CR>
READ device STATUS	Finds out the cause of the specified device (IGn, AIn, CGn) inactive reading. Most responses will apply to the IG, but two of these responses also apply to the CG and AI.	#xxRSIGn<CR> *(e.g., #01RSIG1<CR>)* #xxRSCGn<CR> (*e.g., #01RSCG2<CR>)* #xxRSAIn<CR> (e.g., #01RSAI3<CR>)	*xx_00_ST_OK {*status okay}* *xx_01_OVPRS {IG over pressure; AI *pressure over 1100 Torr}* *xx_02_EMISS {I_e *failure}* *xx_04_ FLVLO {*filament V low)* *xx_08_ FLOPN {IG filament open; CG *sensor wire is open circuit-or CG cable unplugged}* *xx_10_ DEGAS {*upper pressure limit exceeded during DEGAS operation}* *xx_20_ ICLOW {I_c *too low}* *xx_40_ FLVHI {*filament V high)* When device does not exist: ?01_INVALID_<CR>
		{Table continued below}	

COMMAND	BRIEF DESCRIPTION	COMMAND SYNTAX	RESPONSE
SET CGn ZERO	Set the zero or vacuum calibration point for CGn	#xxTZCGn_x.xxe-yy<CR> *(e.g., #01TZCG1 0<CR>)* *(e.g., #01TZCG1 1.00e-02<CR>)*	*xx_PROGM_OK<CR> When measured pressure > 100mT: ?01_INVALID_<CR> When requested (SET) pressure > 100mT: ?01_INVALID_<CR> When device does not exist: ?01_INVALID_<CR> When requested gauge number <1 or >4: ?01_SYNTX_ER <CR>
SET CGn SPAN	Set the span or atmosphere calibration point for CGn	#xxTSCGn_y.yyEzyy<CR> *(e.g., #01TSCG1 7.60E+02)*	*xx_PROGM_OK<CR> When P < 400 Torr: ?01_INVALID_<CR> When requested P < 400 Torr ?01_INVALID_<CR> When requested P > 1000 Torr ?01_INVALID_<CR> When device does not exist: ?01_INVALID_<CR> When requested gauge number <1 or >4: ?01_SYNTX_ER <CR>
READ SW VERSION	Read the revision number of the firmware	#xxVER<CR> *(e.g., #01VER<CR>)*	*xx_mmmmm-vv *e.g., *01_01306-11* <CR> (*version for FlexRax operating system code is 'vv' of part number 'mmmmm'*)
Syntax Error	Response to an unknown command	#xxXXX<CR>	?01_SYNTX_ER<CR>

NOTES RELATED TO THE RS485/232 Protocol SUMMARY TABLE ABOVE:

1. All responses are 13 characters long.
2. The lower case 'n' as in IGn represents the serial communication device name, e.g., IG3 where n = 3.
3. xx is the RS485 address of the device (00 thru FF).
4. xx is two 'space characters' for RS232.
5. <CR> denotes a 'carriage return' character (Unicode Standard C0 controls CR 000Dh).
6. _ denotes a 'space character'.
7. All commands sent to the CM4000 start with a '#' character, and all responses from the module start with either a '*' or a '?' character.
8. RS422 mode does not exist.

3.6.1.3.4 G-P 307 Compatible (RS232) Interface - Device Name Conventions

Please reference section 3.6.1.3.2 for information on Device Name Conventions. The information contained in that section is, also, pertinent to the naming convention used for defining the *FlexRax* device names and corresponding name for the Granville-Phillips Series 307 compatible RS232 serial communications interface. Due to the prior definition of the ASCII character serial communication protocol used, there are seemingly confusing serial communication device names assigned to specific *FlexRax* devices. For instance, you will note that the Ion Gauge for the IGM/CG option installed in card slot location ① of the *FlexRax* is named IGM [1] by the *FlexRax* operating system (default name). The name assigned to this device by the G-P 307 RS232 serial communications protocol is IG3. Due to the naming convention / serial communication protocol definition used in the G-P Series 307, the *FlexRax* IGR [5] installed in the *FlexRax* is called IG1 by the G-P 307 RS232 protocol. This illustrates the importance of constructing a 'naming cross-reference table' similar to that shown previously, but unique to the naming conventions used for the G-P 307 RS232 protocol.

***FlexRax* Device Name (default)**	**CM4000 (G-P RS232 Serial Communication Name)**
IGM [1] – first IGM/CG option card	IG3
CG [1,1]	CG1
CG [1,2]	CG2
IGM [2] – second IGM/CG option card	IG4
CG [2,1]	CG3
CG [2,2]	CG4
AI [3] {assumes slot 1 and 2 are filled as shown above and there is an AI/O-R card installed in location [3]}	AI1
AI [4] {same assumption as above and a second AI/O-R card is installed in location [4]}	AI2
RLY [3,1] {same assumptions as above – first AI/O-R card in slot [3]; card has 8 relays installed}	PC1
RLY [3,2]	PC2
RLY [3,3]	PC3
RLY [3,4]	PC4
RLY [3,5]	PC5
RLY [3,6]	PC6
RLY [3,7]	PC7
RLY [3,8]	PC8
RLY [4,1] {second AI/O-R card in slot [4]; card has 8 relays installed}	PC9
RLY [4,2]	PC10
RLY [4,3]	PC11
RLY [4,4]	PC12
IGR [5] – IGR option installed in location [5]	IG1
IGE [5] – IGE option installed in location [5]	IG1
IGR [6] – IGR option installed in location [6]	IG2
IGR [6] – IGR option installed in location [6]	IG2

3.6.1.3.5 RS232 (G-P Series 307 Compatible[19]) Protocol

See notes after table below for legend/interpretation of syntax used and examples given.

RS232 Command Protocol Summary: G-P 307 Compatibility Mode

COMMAND	BRIEF DESCRIPTION	COMMAND SYNTAX	RESPONSE
READ IGn Pressure	Read the designated IG pressure in Torr units	DS_IGn<CR> <LF> *(e.g., DS IG1<CR><LF>)*	y.yyEzyy<CR><LF> *(e.g. 1.53E-06<CR><LF>)* When device does not exist: 9.90E+09 When IG is off: 9.90E+09
READ CGn	Read the designated CG pressure in Torr units	DS_CGx<CR> <LF> *(e.g., DS CG1<CR><LF>)*	y.yyEzyy<CR><LF> *(e.g., 1.53E+02<CR><LF>)* When device does not exist: 9.90E+09 When CG pressure is over-range: 9.90E+09
READ PCs (long form) – first 6 relays only	Read the setpoint status of all Process Control relays	PCS<CR> <LF> *(e.g., PCS<CR><LF>)*	x,x,x,x,x,x<CR><LF> *(e.g., 1,1,0,0,0,0<CR><LF>) (Process Control Relays 1 and 2 are energized)* When device does not exist: INVALID
READ PCs (binary form) – first 6 relays only	Read the setpoint status of all Process Control relays	PCS_B<CR> <LF> *(e.g., PCS B<CR><LF>)*	x<CR><LF> *(e.g., C<CR><LF>) (01000011 or 43hex[20] ; note reversal of status bit locations from above example only; this response puts relays 1 and 2 at the right side (end) of the response string: relays 1 and 2 are energized - see Note 5* below When device does not exist: INVALID
READ status of an individual PC relay	Read the current individual PC setpoint status	PCS_n<CR> <LF> *(e.g., PCS 1<CR><LF>)*	x<CR><LF> *(e.g., 1<CR><LF>) (Designated PC_n is energized if response is a '1'; if response is a '0', PCn relay is not energized). See Note 6* below When device does not exist: INVALID
IGR ON	Turn specified IGR ON	IGn_ON<CR> <LF> *(e.g., IG1 ON<CR><LF>)* *(n=1=IGR1, 2=IGR2)*	OK<CR><LF> *(e.g., OK<CR><LF>)* When IG already ON response is: 'INVALID' When Device does not exist, response is: 'INVALID'
IGR OFF	Turn specified IGR OFF	IGn_OFF<CR> <LF> *(e.g., IG1 OFF<CR><LF>)* *(n=1=IGR1, n=2=IGR2)*	OK<CR><LF> *(e.g., OK<CR><LF>)* When IG is already OFF: INVALID When Device does not exist: INVALID

[19] The *InstruTech FlexRax* CM4000 RS485/232 Option is capable of operating RS232 serial communications protocol developed by Granville-Phillips (G-P) for the G-P Series 307 Vacuum Gauge Controller. The G-P RS232 communication protocol mode is not recommended by Instrutech The interpretation of some of the Responses to Commands given in this mode is ambiguous and may lead to operational confusion. Full capability of the *FlexRax* installed options and devices cannot be utilized when using the GP232 communications mode.

[20] Response is the uppercase Latin alphabet character 'C'. This is defined by the Unicode Standard as 43 hexadecimal (0100 0011b). If the first 4 relays of the first AI/O-R option card were energized, the returned response would be an O (Latin capital letter) equivalent to 4Fh (0100 1111b).

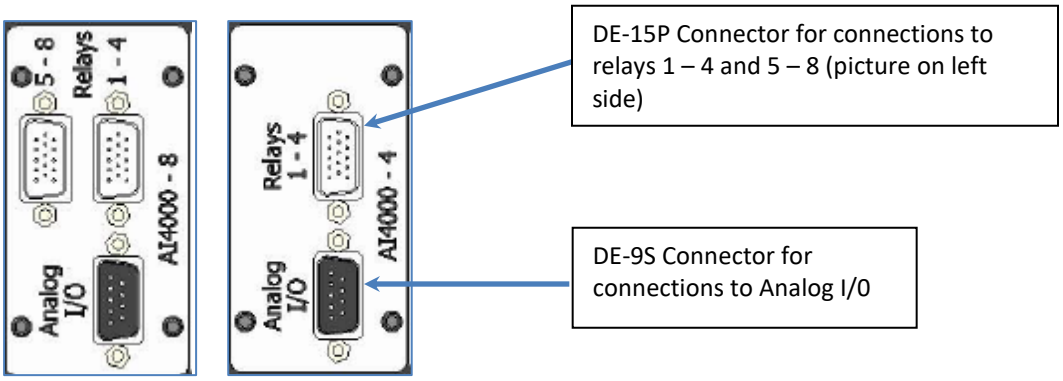
COMMAND	BRIEF DESCRIPTION	COMMAND SYNTAX	RESPONSE
IGR DEGAS ON	Turn IGR Degas ON (first IG that is ON)	DG_ON<CR> <LF> *(e.g., DG ON<CR><LF>)*	OK<CR><LF> *(e.g., OK<CR><LF>)* When Degas is already ON: INVALID When Device does not exist: INVALID When IG is OFF: INVALID
IGR DEGAS OFF	Turn IGR Degas OFF	DG_OFF<CR> <LF> *(e.g., DG OFF<CR><LF>)*	OK<CR><LF> *(e.g.,: OK<CR><LF>)* When Degas is already OFF: INVALID When Device does not exist: INVALID
IGR Degas Status	Detect Degas on/off status	DGS<CR> <LF> *(e.g., DGS<CR><LF>)*	1<CR><LF> *(e.g., 1<CR><LF>) (or 0<CR><LF> when OFF* When device does not exist: INVALID

NOTES related to G-P 307 RS232 (GP232) Compatibility Mode:

1. <CR> is a carriage return.
2. <LF> is a line feed (this is the terminator character); keyboard key stroke: Ctrl J
3. _ in Command Syntax represents a space character.
4. PC refers to a Process Control Relay, a.k.a, Setpoint Relay.
5. An understanding of the Granville-Phillips Series 307 configuration rules is necessary for a complete understanding of the various Process Control (PC) relay status (READ PCs) command responses. The G-P 307 could only be configured with up to 6 process control relays. Thus, the GP232 serial response string contains an encrypted yield of the status for those six relays. The example given in the above table for reading the installed PC relay status in binary form illustrates the limitation of the G-P 307 RS232 protocol. A response of an uppercase Latin alphabet character 'C' (43h or binary 0100 0011) represents, or in other words is interpreted as simply, PC relays numbers 1 and 2 are energized. The '4' resident in the upper nibble of the hexadecimal character set is a placeholder – this bit is always set to a '1' and it represents the point in the binary string to follow where one should start looking for either 1's or 0's to represent an ON (energized) or OFF (de-energized) state for the maximum 6 relays that can be configured in a G-P 307. So, interpreting an uppercase Latin character 'C' (43h) as 0100 0011 base 2, you might place the spacing of these binary digits as follows: 01 000011 (where the six least significant zeros and ones each represent the state of a single relay, numbers 1-6). If, for example, relays 1 thru 4 and 6 are energized, the response to a 'PCS_B<CR><LF> command will be 'o' (Latin small letter O; a 6Fh) followed by the <CR><LF>. On the other hand, if all of the first 6 relays on an AI8 option card are energized, the response to the 'PCS_B' command will be a 7Fh (a Unicode DELETE character; 01 111111b).
6. If an AI4 option is installed in the first available card slot location, only 4 PCs (relays) will be accessible via the GP232 communication mode. It is recommended that an AI8 option be installed in the first available card slot location if 6 PCs are intended to be used and status accessed via the GP232 serial communication mode. Using the PCS_n<CR><LF> command (Read status of an individual PC relay) is the recommended method to ensure that all relay statuses can be recorded. The 'PCS_n' will allow the user to determine up to 12 installed relay states – this allows you to extend beyond the limit imposed by the GP232 protocol.

3.6.1.4 Connections to and Operation of the AI/O-R Option –

There are either two or three D-subminiature connectors located on the panel of the AI/O-R Option. The 9-pin connector (DE-9S) is used for the Analog Input / Output signals. The 15-pin connector (DE-15P) is used for the normally open (N.O.), normally closed (N.C.) and common (COM) connections for either the four (4 each) relays (contactors) on the AI/O-R option (AI4) card or if an AI8 option card is installed, a second DE-15P connector is provided to connect to the four additional relays. See the **AI/O-R Connector Pin Description** tables below for pin-out descriptions of the D-subminiature connectors on these option cards.



3.6.1.4.1 Connecting the Analog Input –

Voltage signals from pressure measurement transducers (external devices) may be connected to the Analog Input connection on the AI/O-R Option card. There are choices available in the operating system of the *FlexRax* for various transducer types that you may connect to this option and display the pressure measured by the external device.

To select the type of device you wish to input the analog voltage signal from, perform the following key-entry sequence:

Menu ⇨ Analog I/O ⇨ Analog Inputs ⇨ AI [n] ⇨ Device Type ⇨ You will see a M**essage:**

{Scroll Up or Down to assign an external device type to Analog Input AI [n]}

Press the up ↑ or down ↓ arrow keys to scroll through the available device types. Until you select either the up ↑ or down ↓ arrow key, you will not see the SAVE key in the display. This is a feature of the operating system software that ensures that you want to either change or, if you do not change the choice, keep the existing selection displayed at the top of the message box in the display. By pressing the CANCEL key the operating system maintains the selection that was previously chosen. If you were to inadvertently select a choice by pressing the up or down arrow key and you do not remember the selection that was originally selected, you may simply press the CANCEL key and the operating system will return to the selection that was used prior to entering the analog input setup screen.

The available choices, each choice shown at the top of the message dialog box, are:

- **ITI NON-LINEAR**
- **ITI LOG IG**
- **ITI LOG CG**
- **1000 Torr CDG** (Capacitance Diaphragm Gauge)
- **100 Torr CDG**
- **10 Torr CDG**
- **1 Torr CDG**
- **100 mTorr CDG**

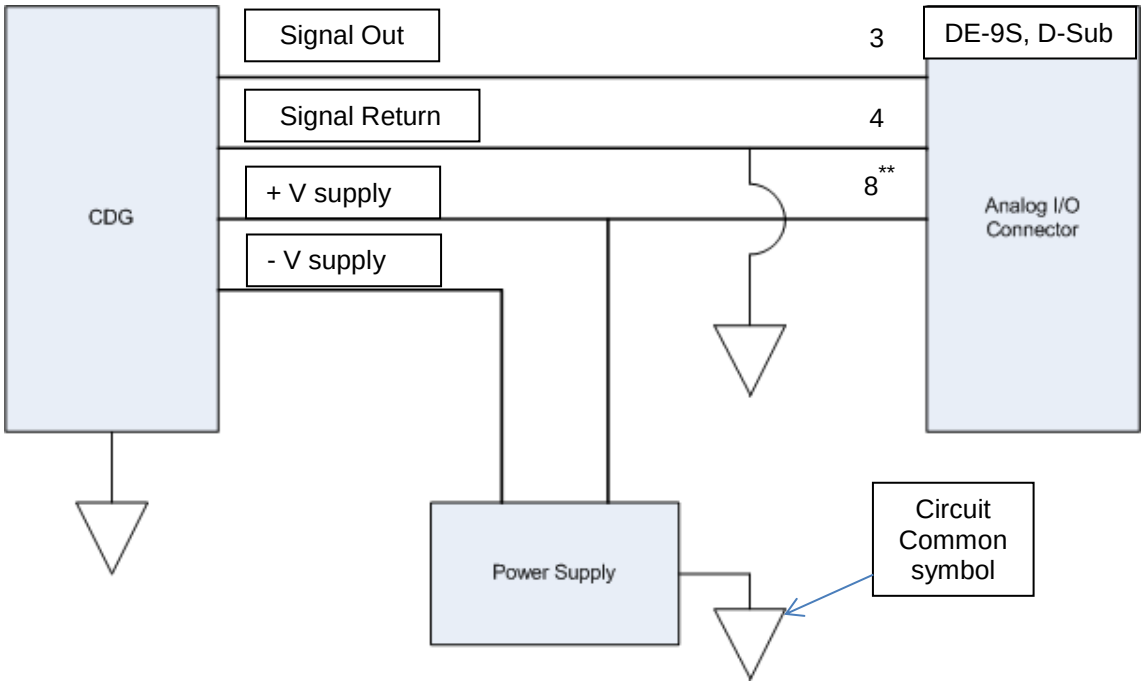
The acronym **ITI** is used to designate an InstruTech pressure measurement device. The analog output signal from one of the many available InstruTech pressure measurement instruments such as the IGM401/ IGM402/CCM501 Hornet™, Super Bee™, Stinger™ and VGC301 Worker Bee™ Vacuum Gauge Controller devices may be connected to the *FlexRax* AI/O-R Option. Displaying the readout of the pressure measured at the ITI device on the *FlexRax* display is convenient, especially if the device is installed at a location on your vacuum chamber where it may be inconvenient for the user to easily read the displayed pressure on the display of the device (that is located at point-of-use).

InstruTech devices provide a choice of **NON-LINEAR** and **LOG**-Linear (linear with respect to the logarithm of pressure) analog output signals for convection and ionization gauges. Refer to the section of the User Manual pertaining to the types of analog outputs for the various pressure measurement devices available from InstruTech. Scroll to the choice of analog input device type you wish to use and press the SAVE key.

By pressing either the SAVE key or the CANCEL key the screen will return to a previous display giving you, for example, choices of 'Device Type', 'Set Defaults', 'Set Gauge Name' and 'BACK'. Press the 'Back' key repeatedly to return to the **Pressure Measurement Screen.** The **AI [n]** pressure display line is now assigned to the 'Device Type' you selected. If you invoke 'Set Defaults' while in the **AI [n]** setup screen, the **AI [n]** assignment will default to **"ITI NON-LINEAR".**

Connecting Capacitance Diaphragm Gauges –

If you are connecting the Analog Input section of the AI/O-R Option to a Capacitance Diaphragm Gauge (CDG), you will need to connect an external (user supplied) power supply to the CDG Device. The following schematic shows the necessary connections for the CDG, Power Supply and AI/O DE-9S, D-Subminiature connector wiring:



Wiring Connections for a Capacitance Diaphragm Gauge (CDG)

**** Detection Requirement: Connecting Any Type of Device to the Analog Input of the AI/O-R Option –**

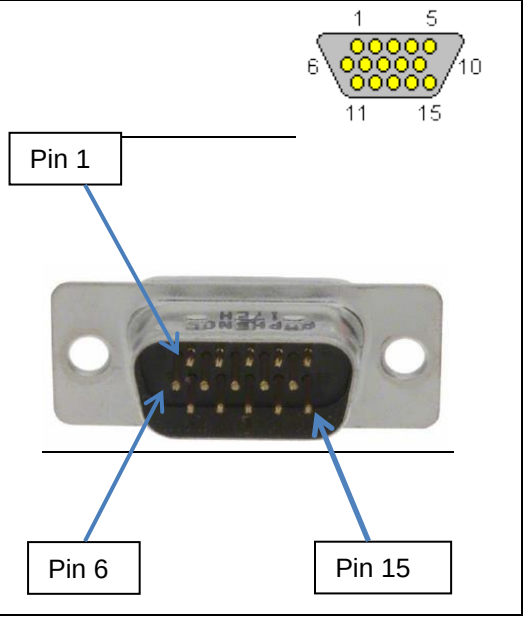
Pin 8 of the Analog Input/Output DE-9S connector is defined as 'Analog Input Device Detect'. This pin must be connected to an external voltage of +10 Vdc minimum in order that the *FlexRax* will recognize that you intend to setup the controller to display a pressure from an external device type as described above. This voltage, as shown in the wiring diagram for a CDG above, may be the supply voltage for the device. The external regulated supply voltage that you connect to pin 8 (see AI/O-R Connector Pin Description below) of the DE-9S D-sub connector must be continuously connected and may range in voltage from 10 Vdc, min. to 30 Vdc, max.

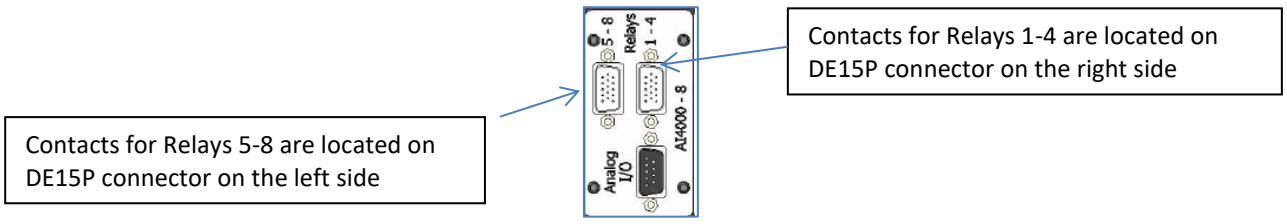
AI/O-R Option - Connector Pin Description

Relays are single-pole, double-throw (SPDT), 2A at 30 Vdc, 2A at 250 Vac, resistive load, assignable to any of the gauges.

⚠**Caution!** The relay contact rating above applies to units shipped on and after February 28, 2017. Serial numbers 17B761C and higher have this new contact rating. Older units shipped before this date with serial numbers 17B760C and lower had a contact rating of 1A at 30 Vdc, 0.5A at 125 Vac, resistive or ac non-inductive. Applying a load to older units which draws more than 0.5 A could cause damage to relays.

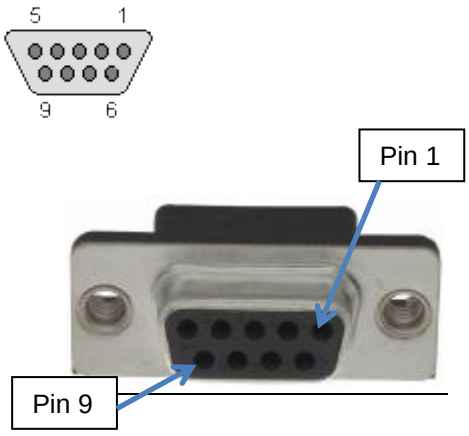
15-pin (DE-15P) D-subminiature Relay Contactor Connections		DE-15P D-Subminiature Connector (on AI/O-R Option Card)
Connector Pin Number	**Description**	
1	Relay 1/5[21] – Common (COM)	
2	Relay 1/5 – Normally Open (N.O.)	
3	Relay 3/7 – Normally Closed (N.C.)	
4	Relay 3/7 – COM	
5	Relay 3/7 – N.O.	
6	Relay 1/5 – N.C.	
7	– **No Connection**	
8	– **No Connection**	
9	– **No Connection**	
10	Relay 2/6 – N.C.	
11	Relay 4/8 – N.O.	
12	Relay 4/8 – COM	
13	Relay 4/8 – N.C.	
14	Relay 2/6 – N.O.	
15	Relay 2/6 – COM	





Back panel view of AI/O-R Option

[21] "Relay 1/5" indicates that on the right most connector of this option card as viewed facing the back panel, this pin is a connection to Relay number 1 and, for the connector located to the left of the first, this pin is a connection to Relay number 5. This convention follows from pin-to-pin for all relays available on AI8 option cards.

9-pin (DE-9S) D-subminiature Analog Input / Output Connections		DE-9S D-subminiature Connector (on AI/O-R Option Card)
Connector Socket Number	**Description**	
1	Analog Output 1 Signal	
2	Analog Output Signal Return	
3	Analog Input Signal	
4	Analog Input Signal Return	
5	Analog Output 2 Signal	
6	Analog Output 4 Signal	
7	Analog Output 3 Signal	
8	Analog Input Device Detect (+10 Vdc, minimum) See Detection Requirement above	
9	Analog Output Signal Return	

3.6.1.4.2 Digital Input Control of Ion Gauge ON/OFF State –

The *FlexRax* may be setup to use a digital input control signal to turn an assigned ion gauge transducer on or off. This method of ion gauge on/off control relies on programming the *FlexRax* to turn the assigned IG transducer on and off at a pressure defined by the user as measured by another device. For example, if a control system is configured with a programmable logic or automation controller (PLC), the PLC may control a TTL or CMOS logic level output that can be connected to an analog input port of the *FlexRax* AI/O-R option. When the voltage on the analog input contact (pin 3 of the DE9S connector, shown above) is a high voltage, say +5 to +10 Vdc, with respect to the analog input signal return contact (pin 4 of the DE9S connector), the IG that is using the assigned analog input (AI[n]) for on/off control will be in the OFF state. If the control line is asserted low (near zero volts, DC) the IG will be turned to the ON state by the *FlexRax* operating system.

To use the analog input (AI[n]) of an available AI/O-R option to digitally control the on/off state of an IG, connect the PLC digital control line to the Analog Input Signal line (pin 3 of the AI/O-R DE9S connector) and the PLC control signal return line (common) to the Analog Input Signal Return (pin 4 of the AI/O-R DE9S). Program the selected FlexRax IG to be controlled by the PLC digital output to turn on/off using the AI[n] device.

For this example, assume you will control IGM [2] using the digital control signal (asserted low = IG ON) connected to AI [4]. There are two *FlexRax* programming sequences to perform in order that the digital input control signal can be used for this purpose.

First, set up AI [4]; perform the following *FlexRax* programming sequence:

Menu ⇨ Analog I/O ⇨ Analog Inputs ⇨ AI [4] ⇨ Device Type ⇨ You will see a M**essage:**

{**Scroll Up or Down to assign an external device type to an Analog Input AI [4]**}

For digital input control, choose one of the AI [n] CDG device choices. For this example, we choose [100 mTorr CDG] – as you press either the up 🡅 or the down 🡇 arrow keys, the highlighted box above the message

screen will change to display the selected device. You want to ensure that the PLC digital control line will assert the ON state of the IG. By choosing the 100 mTorr CDG device as your proxy for receiving the output from your PLC you will ensure that when the PLC asserts the control line (turn the IG ON by changing the PLC control line from a high voltage to a low voltage-near zero volts), the *FlexRax* operating system will control the on/off state of the IG. The assertion state (IG ON) is effectively a continuous "ground" (a voltage near zero volts from your PLC digital output port).

Next, set up IGM [2]; perform the following *FlexRax* programming sequence:

Menu ⇨ IGM ⇨ IGM2 ⇨ Setup ⇨ IG Control ⇨ You will see a M**essage box:**

Device Choice Shown Here

Either select 'Manual' to direct IGM2 ON/OFF control manually or choose an available device to control IGM2 ON/OFF setpoint using value programmed for 'Over Pressure'

Choose AI [4] in the highlighted box – as you press either the up ↑ or down ↓ arrow keys, the highlighted box above the message screen will change to display the selected device. Then, press Save when AI [4] is displayed.

After you press Save, a submenu screen will be displayed showing a programming choice of Over Pressure in the setup menu.

Press the hardware key aligned with Over Pressure. You will see a Message:

{**Setup the pressure in Torr where the Ion Gauge IGM2 will turn off**}.

Program the IG ON/OFF setpoint pressure to a value that you know will be proportional to a voltage on the PLC digital output control line that will provide a reliable ON/OFF switching point.

For example, by choosing the 100 mTorr full-scale CDG which is assumed by the *FlexRax* operating system to have an output voltage of 0 to 10 Vdc that CDG will have an output that is mapped for a voltage of 10 Vdc at 100 mTorr and 1 Vdc at 10 mTorr. Choosing an *Over Pressure* setpoint of, say, 20 mTorr will program an ON/OFF setpoint for the IG when the PLC digital control line drops below 2 Vdc (IG will turn ON) and rises above 2 Vdc (IG will turn OFF).

After setting the *Over Pressure* setpoint pressure, press the Save key.

The above example illustrates the method used to setup the *FlexRax* operating system to create a digital input control line such that an external control device that switches a digital output from a high voltage (e.g., +5 to +10 volts DC) to near zero volts may turn and Ion Gauge transducer ON and OFF. If the digital control line is high (unasserted), the IG will be off. If the line is asserted low, the IG will turn on.

3.6.1.4.3 Connecting the Analog Output –

Several voltage signal types are available to be output from the *FlexRax.* The available choices, each choice shown at the top of the message dialog box, are dependent upon the type of device chosen to provide the analog output voltage. The choices that are available to the user are defined by the configuration (options installed) of the *FlexRax.* For example, using the *FlexRax* configuration shown in the previous section **3.1.5 Logical Progression / Physical Location** above**,** follow the key-entry sequence:

Menu ⇨ Analog I/O ⇨ Analog Outputs ⇨ AO [n,m] ⇨ Assign Output ⇨

You will see a screen with the up 🡅 and down 🡇 arrow keys on the left side of the display and a message dialog box that reads:

{Scroll **Up or Down to assign a device to Analog Output AO [3,m]}**

AO [3,m] is shown here as in the example configuration used in section 3.1.5, above. With two AI/O-R option cards installed, a total of 8 analog output signal channels are available. These outputs may be assigned to represent the pressure measured by any of the devices controlled by the *FlexRax*.

Above the message dialog box, the available choices for the options to use or assign an analog output to are shown. Using the previous configuration example in section **3.1.5,** the following choices would be displayed:

- **None**
- **CG [1,1]**
- **CG [1,2]**
- **CG [2,1]**
- **CG [2,2]**
- **IGM [1]**
- **IGM [2]**
- **IGR [5] Note that either IGE [n] or IGR [m] may be listed as a choice, depending on your *FlexRax* configuration.**

If you were to choose **IGR [5]**, for example, then press the key linked to SAVE, a new screen will be displayed with the up 🡅 and down 🡇 arrow keys on the left side of the display and a message dialog box that reads:

{Scroll **Up or Down to select Analog Output AO [3,m] type.}**

The choices of analog output types available for the device type chosen are shown at the top of the message dialog box in this screen. Analog output types available for use may be dependent upon the setup parameters chosen for the type of device you have selected to use for the analog output. For example, if the emission current selection for an ionization gauge transducer is set to 10 mA, the analog output type choices may change to reflect the measurement range capability of the ion gauge transducer when using an emission current of 10 mA.

Choose the type of analog output signal you want to use by pressing the key linked to SAVE shown in the display. For example, with **IGR [5]** selected, a choice of '**Log-Linear IGR/IGE 0-9V'** is available (only if you are operating the IGR/IGE at either 100 µA or 4 mA emission current). This type of analog output signal is described in the following section:

3.6.1.4.4 Analog Output - Log-Linear IG 0-10V, n = 10

The analog output voltage types described below represent the pressure displayed for the selected IG option for **nitrogen / air only. Refer to Section 4 if you are using a gas other than nitrogen/air.**

The **Log-Linear IG 0-10V, n = 10** is one of the available analog output scaling selections for the various Ion Gauge options. This selection assigns the analog output scaling for any of the selected IG options to allow the user to calculate the measured pressure from the selected IG. The mathematical relationship of pressure and analog output voltage as well as a table and chart to describe this function over the allowed pressure measurement range are given below.

⚠ **CAUTION!** In order that you prevent equipment damage and possible injury to personnel, you must ensure that measured pressure readings of the device are corrected for the type of gas composition that is in your vacuum chamber. When using gas dependent-type pressure measurement devices such as a convection or ionization gauge transducer, refer to the correction charts and tables within this User Manual and the User Manual for the connected device you are using when measuring pressure of gases other than nitrogen/air.

Analog Output: $P = 10^{(volts - n)}$, Log-Linear 0-10 V, n = 10 with 1 volt per decade output signal characteristic.

A) The log-linear output signal and pressure are related by the following formulas when **Pressure Unit** of measurement is in **Torr** and **mbar:**

$P = 10^{(volts - 10)}$ $V = \log_{10}(P) + 10$

, where P is the pressure in Torr or mbar, and V is the output signal in volts.

B) The log-linear output signal and pressure are related by the following formulas when **Pressure Unit** of measurement is in pascals (**Pa**)**:**

$P = 10^{(volts - 8)}$ $V = \log_{10}(P) + 8$

, where P is the approximate pressure in pascals (Pa), and V is the output signal in volts.

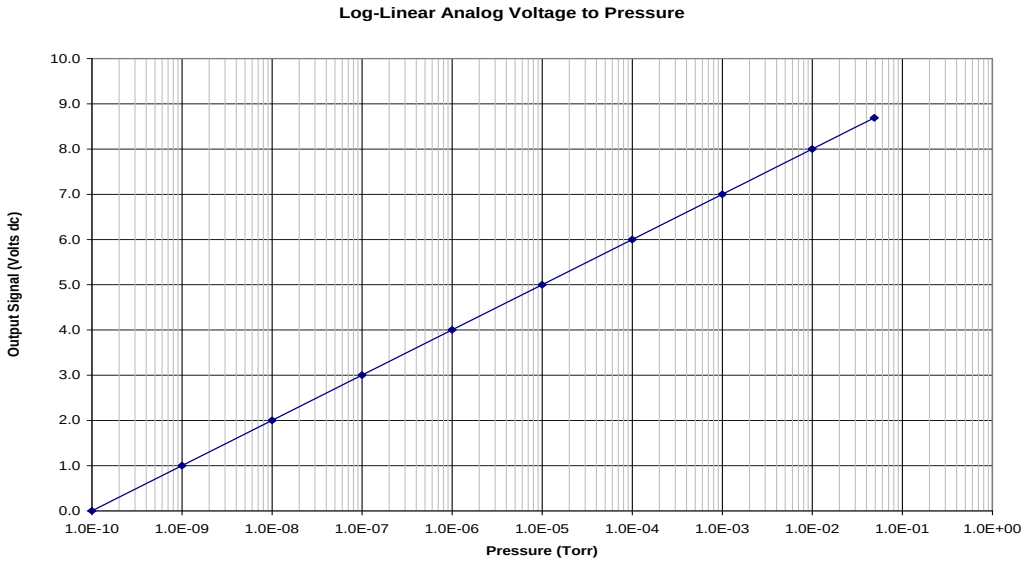
Table 1 - Log-Linear Analog Output

(Applies to all IGs when programmed for the Log-Linear 0-10V, n = 10 analog output with N_2/air only)

Pressure (Torr)	*Voltage (V_{DC})*
1.00E-10	*0.0* [22]
1.00E-09	*1.0*
1.00E-08	*2.0*
1.00E-07	*3.0*
1.00E-06	*4.0*
1.00E-05	*5.0*
1.00E-04	*6.0*
1.00E-03	*7.0*
1.00E-02	*8.0*
5.00E-02	*8.698*
Filament is OFF	*≥11*

[22] The lowest voltage signal output by the *FlexRax* is the voltage proportional to the x-ray limit of the B-A ionization gauge transducer in use. For example, even if your vacuum system can be pumped to a pressure less than 1.00E-10 Torr, it will not be possible to measure that pressure if the x-ray limit of your B-A IG is, say, 3.00 or 4.00 E-10 Torr.

The following chart shows the graphical results of the table and formulas given above. Indicated pressure is plotted on the X-axis with a log scale; the output signal is plotted on the Y-axis on a linear scale.



Plot of the log-linear analog output signal for Log-Linear IG 0-10V, n = 10 (for N_2/Air, only)

If the analog output has been assigned to be derived from the pressure measured by either the IGM/CCM, IGR or IGE option, when the IG is turned to **OFF**, the analog output voltage will increase to a voltage of 11 volts DC or greater (not shown in the chart above). With Over Pressure shut-OFF set at **Default** settings, the analog output voltage will switch to +11 Vdc under the following conditions:

- The IG is either turned **OFF** or any IG fault condition exists.
- When using the IGM400, the pressure exceeds 1.00E-03 Torr at 4 mA emission current or 5.00E-02 Torr at 100 µA emission current causing the IG to turn OFF.
- When using the IGR/IGE (BA600 series glass or nude B-A ion gauge or equivalent), the pressure exceeds 5.00E-04 Torr at 4 mA emission current, 1.00E-04 Torr at 10 mA emission current or 1.00E-03 Torr (default; may be set to 1.00E-02 Torr max.) at 100 µA emission current causing the IG to turn OFF.
- The pressure exceeds 1.00E-02 Torr as measured by the CCM500 causing the IG to turn OFF.

Clear Error (for IG operation) –

For any Ion Gauge device (IGM, CCM, IGR or IGE) that is turned OFF due to a faults condition such as an 'Over Pressure' condition, the display line in the **Pressure Measurement Screen** will show the IG as "OFF" (in red color). The error condition must be remedied and the error cleared in the *FlexRax* operating system prior to being allowed to turn the IG to ON (Operating). To clear an error condition which will otherwise prevent operation of the ionization gauge, follow the menu sequence to get to a select screen for the IGM, CCM or IGR/IGE that you wish to turn ON. When you select the device that is displaying an error condition (OFF in red color), you will see a Clear Error key-designator box in the display where the 'Clear Error' box is not grayed-out. Press the key associated with the Clear Error key-designator box to perform the actions prompted to clear the error. Sending an 'IG OFF' command when using RS232/RS485 serial communications or pressing IG OFF while in the R&D Display Screen will clear any IG errors and allow the IG to be turned ON again.

3.6.1.4.5 Analog Output - Log-Linear IG 0-10V, n = 11

The analog output voltage types described below represent the pressure displayed for the selected IG option for **nitrogen / air only. Refer to Section 4 if you are using a gas other than nitrogen/air.**

The **Log-Linear IG 0-10V, n = 11** is one of the available analog output scaling selections for the various Ion Gauge options. This selection assigns the analog output scaling for any of the selected IG options to allow the user to calculate the measured pressure from the selected IG. The mathematical relationship of pressure and analog output voltage as well as a table and chart to describe this function over the allowed pressure measurement range are given below.

⚠ **CAUTION!** In order that you prevent equipment damage and possible injury to personnel, you must ensure that measured pressure readings of the device are corrected for the type of gas composition that is in your vacuum chamber. When using gas dependent-type pressure measurement devices such as a convection or ionization gauge transducer, refer to the correction charts and tables within this User Manual and the User Manual for the connected device you are using when measuring pressure of gases other than nitrogen/air.

Analog Output: $P = 10^{(volts - n)}$ Log-Linear 0-10 V, n=11 with 1 volt per decade output signal characteristic.

A) The log-linear output signal and pressure are related by the following formulas when **Pressure Unit** of measurement is in **Torr** and **mbar:**

$P = 10^{(volts - 11)}$ $V = \log_{10}(P) + 11$

, where P is the pressure in Torr or mbar, and V is the output signal in volts.

B) The log-linear output signal and pressure are related by the following formulas when **Pressure Unit** of measurement is in pascals (**Pa**)**:**

$P = 10^{(volts - 9)}$ $V = \log_{10}(P) + 9$

, where P is the approximate pressure in pascals (Pa), and V is the output signal in volts.

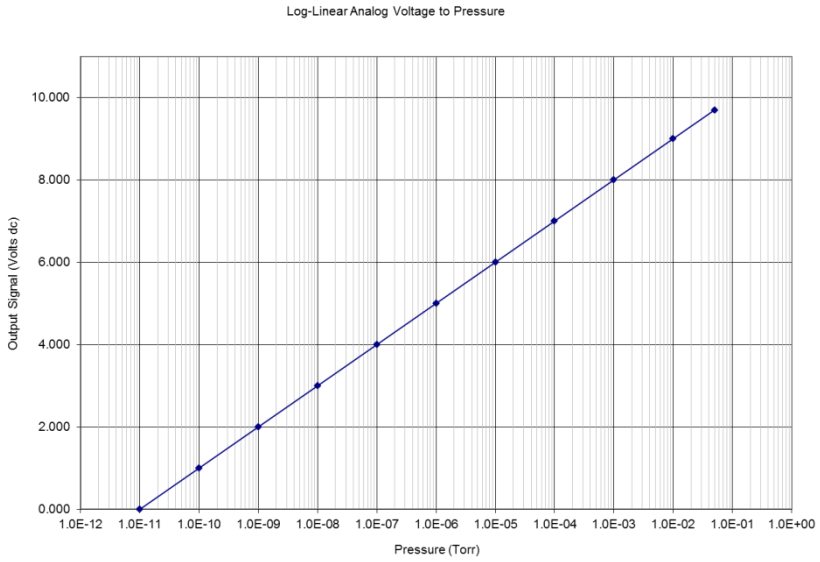
Table 2 - Log-Linear Analog Output

(Applies to all IGs when programmed for the Log-Linear 0-10V, n = 11 analog output with N_2/air only)

Pressure (Torr)	*Voltage (V_{DC})*
1.00E-11	*0.0* [23]
1.00E-10	*1.0*
1.00E-09	*2.0*
1.00E-08	*3.0*
1.00E-07	*4.0*
1.00E-06	*5.0*
1.00E-05	*6.0*
1.00E-04	*7.0*
1.00E-03	*8.0*
1.00E-02	*9.0*
5.00E-02	*9.698*
Filament is OFF	*≥11*

[23] The lowest voltage signal output by the *FlexRax* is the voltage proportional to the x-ray limit of the B-A ionization gauge transducer in use. For example, even if your vacuum system can be pumped to a pressure less than 1.00E-10 Torr, it will not be possible to measure that pressure if the x-ray limit of your B-A IG is, say, 3.00 or 4.00 E-10 Torr.

The following chart shows the graphical results of the table and formulas given above. Indicated pressure is plotted on the X-axis with a log scale; the output signal is plotted on the Y-axis on a linear scale.



Plot of the log-linear analog output signal for Log-Linear IG 0-10V, n = 11 (for *N_2/Air, only)*

If the analog output has been assigned to be derived from the pressure measured by either the IGM/CCM, IGR or IGE option, when the IG is turned to **OFF**, the analog output voltage will increase to a voltage of 11 volts DC or greater (not shown in the chart above). With Over Pressure shut-OFF set at **Default** settings, the analog output voltage will switch to +11 Vdc under the following conditions:

- The IG is either turned **OFF** or any IG fault condition exists.
- When using the IGM400, the pressure exceeds 1.00E-03 Torr at 4 mA emission current or 5.00E-02 Torr at 100 µA emission current causing the IG to turn OFF.
- When using the IGR/IGE (BA600 series glass or nude B-A ion gauge or equivalent), the pressure exceeds 5.00E-04 Torr at 4 mA emission current, 1.00E-04 Torr at 10 mA emission current or 1.00E-03 Torr (default; may be set to 1.00E-02 Torr max.) at 100 µA emission current causing the IG to turn OFF.
- The pressure exceeds 1.00E-02 Torr as measured by the CCM500 causing the IG to turn OFF.

Clear Error (for IG operation) –

For any Ion Gauge device (IGM, CCM, IGR or IGE) that is turned OFF due to a faults condition such as an 'Over Pressure' condition, the display line in the **Pressure Measurement Screen** will show the IG as "OFF" (in red color). The error condition must be remedied and the error cleared in the *FlexRax* operating system prior to being allowed to turn the IG to ON (Operating). To clear an error condition which will otherwise prevent operation of the ionization gauge, follow the menu sequence to get to a select screen for the IGM, CCM or IGR/IGE that you wish to turn ON. When you select the device that is displaying an error condition (OFF in red color), you will see a [Clear Error] key-designator box in the display where the 'Clear Error' box is not grayed-out. Press the key associated with the [Clear Error] key-designator box to perform the actions prompted to clear the error. Sending an 'IG OFF' command when using RS232/RS485 serial communications or pressing [IG OFF] while in the R&D Display Screen will clear any IG errors and allow the IG to be turned ON again.

3.6.1.4.6 Analog Output - Log-Linear IG 0-10V, n = 12

The analog output voltage types described below represent the pressure displayed for the selected IG option for **nitrogen / air only. Refer to Section 4 if you are using a gas other than nitrogen/air.**

The **Log-Linear IG 0-10V, n = 12** is one of the available analog output scaling selections for the various Ion Gauge options. This selection assigns the analog output scaling for any of the selected IG options to allow the user to calculate the measured pressure from the selected IG. The mathematical relationship of pressure and analog output voltage as well as a table and chart to describe this function over the allowed pressure measurement range are given below.

⚠ **CAUTION!** In order that you prevent equipment damage and possible injury to personnel, you must ensure that measured pressure readings of the device are corrected for the type of gas composition that is in your vacuum chamber. When using gas dependent-type pressure measurement devices such as a convection or ionization gauge transducer, refer to the correction charts and tables within this User Manual and the User Manual for the connected device you are using when measuring pressure of gases other than nitrogen/air.

Analog Output: $P= 10^{(volts - n)}$ Log-Linear 0-10 V, n=12 with 1 volt per decade output signal characteristic.

A) The log-linear output signal and pressure are related by the following formulas when **Pressure Unit** of measurement is in **Torr** and **mbar:**

$P= 10^{(volts - 12)}$ $V= \log_{10}(P) + 12$

, where P is the pressure in Torr or mbar, and V is the output signal in volts.

B) The log-linear output signal and pressure are related by the following formulas when **Pressure Unit** of measurement is in pascals (**Pa**)**:**

$P= 10^{(volts - 10)}$ $V= \log_{10}(P) + 10$

, where P is the approximate pressure in pascals (Pa), and V is the output signal in volts.

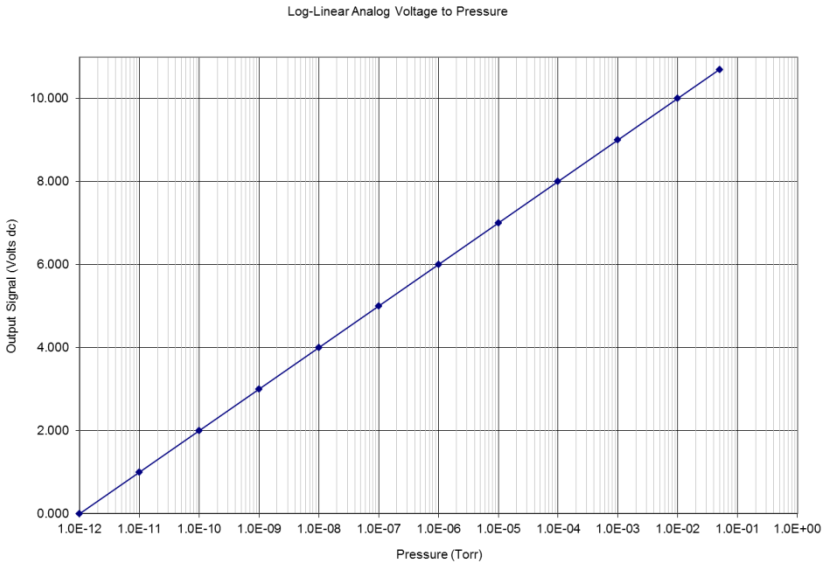
Table 3 - Log-Linear Analog Output

(Applies to all IGs when programmed for the Log-Linear 0-10V, n = 12 analog output with N_2/air only)

Pressure (Torr)	*Voltage (V_{DC})*
1.00E-12	*0.0* [24]
1.00E-11	*1.0*
1.00E-10	*2.0*
1.00E-09	*3.0*
1.00E-08	*4.0*
1.00E-07	*5.0*
1.00E-06	*6.0*
1.00E-05	*7.0*
1.00E-04	*8.0*
1.00E-03	*9.0*
1.00E-02	*10.0*
5.00E-02	*10.698*
Filament is OFF	*≥11*

[24] The lowest voltage signal output by the *FlexRax* is the voltage proportional to the x-ray limit of the B-A ionization gauge transducer in use. For example, even if your vacuum system can be pumped to a pressure less than 1.00E-10 Torr, it will not be possible to measure that pressure if the x-ray limit of your B-A IG is, say, 3.00 or 4.00 E-10 Torr.

The following chart shows the graphical results of the table and formulas given above. Indicated pressure is plotted on the X-axis with a log scale; the output signal is plotted on the Y-axis on a linear scale.



Plot of the log-linear analog output signal for Log-Linear IG 0-10V, n = 12 (for N_2/Air, only)

If the analog output has been assigned to be derived from the pressure measured by either the IGM/CCM, IGR or IGE option, when the IG is turned to **OFF**, the analog output voltage will increase to a voltage of 11 volts DC or greater (not shown in the chart above). With Over Pressure shut-OFF set at **Default** settings, the analog output voltage will switch to +11 Vdc under the following conditions:

- The IG is either turned **OFF** or any IG fault condition exists.
- When using the IGM400, the pressure exceeds 1.00E-03 Torr at 4 mA emission current or 5.00E-02 Torr at 100 µA emission current causing the IG to turn OFF.
- When using the IGR/IGE (BA600 series glass or nude B-A ion gauge or equivalent), the pressure exceeds 5.00E-04 Torr at 4 mA emission current, 1.00E-04 Torr at 10 mA emission current or 1.00E-03 Torr (default; may be set to 1.00E-02 Torr max.) at 100 µA emission current causing the IG to turn OFF.
- The pressure exceeds 1.00E-02 Torr as measured by the CCM500 causing the IG to turn OFF.

Clear Error (for IG operation) –

For any Ion Gauge device (IGM, CCM, IGR or IGE) that is turned OFF due to a faults condition such as an 'Over Pressure' condition, the display line in the **Pressure Measurement Screen** will show the IG as "OFF" (in red color). The error condition must be remedied and the error cleared in the *FlexRax* operating system prior to being allowed to turn the IG to ON (Operating). To clear an error condition which will otherwise prevent operation of the ionization gauge, follow the menu sequence to get to a select screen for the IGM, CCM or IGR/IGE that you wish to turn ON. When you select the device that is displaying an error condition (OFF in red color), you will see a Clear Error key-designator box in the display where the 'Clear Error' box is not grayed-out. Press the key associated with the Clear Error key-designator box to perform the actions prompted to clear the error. Sending an 'IG OFF' command when using RS232/RS485 serial communications or pressing IG OFF while in the R&D Display Screen will clear any IG errors and allow the IG to be turned ON again.

3.6.1.4.7 Analog Output – Log-Linear 1.8 to 8.7V, 0.8V/decade

The analog output voltage types described below represent the pressure displayed for the selected IG option for **nitrogen / air only. Refer to Section 4 if you are using a gas other than nitrogen/air.**

The **1.8 to 8.7V, 0.8V/decade** analog output is one of the available analog output scaling selections for the various Ion Gauge options. This selection assigns the analog output scaling for any of the selected IG options to allow the user to calculate the measured pressure from the selected IG. The mathematical relationship of pressure and analog output voltage as well as a table and chart to describe this function over the allowed pressure measurement range are given below.

⚠ **CAUTION!** In order that you prevent equipment damage and possible injury to personnel, you must ensure that measured pressure readings of the device are corrected for the type of gas composition that is in your vacuum chamber. When using gas dependent-type pressure measurement devices such as a convection or ionization gauge transducer, refer to the correction charts and tables within this User Manual and the User Manual for the connected device you are using when measuring pressure of gases other than nitrogen/air.

Analog Output: $P= 10^{((1.25 \bullet volts) - 12.875)}$ Log-Linear 1.7 to 9.3V, with 0.8 volt per decade output signal characteristic.

A) The log-linear output signal and pressure are related by the following formulas when **Pressure Unit** of measurement is in **Torr** and **mbar:**

$$P= 10^{((1.25 \bullet volts) - 12.875)} \qquad V = (\log_{10}(P) + 12.875)/1.25$$

, where P is the pressure in Torr or mbar, and V is the output signal in volts.

B) The log-linear output signal and pressure are related by the following formulas when **Pressure Unit** of measurement is in pascals (**Pa):**

$$P= [10^{((1.25 \bullet volts) - 12.875)}] \times 133$$

, where P is the pressure in pascals (Pa), and V is the output signal in volts.

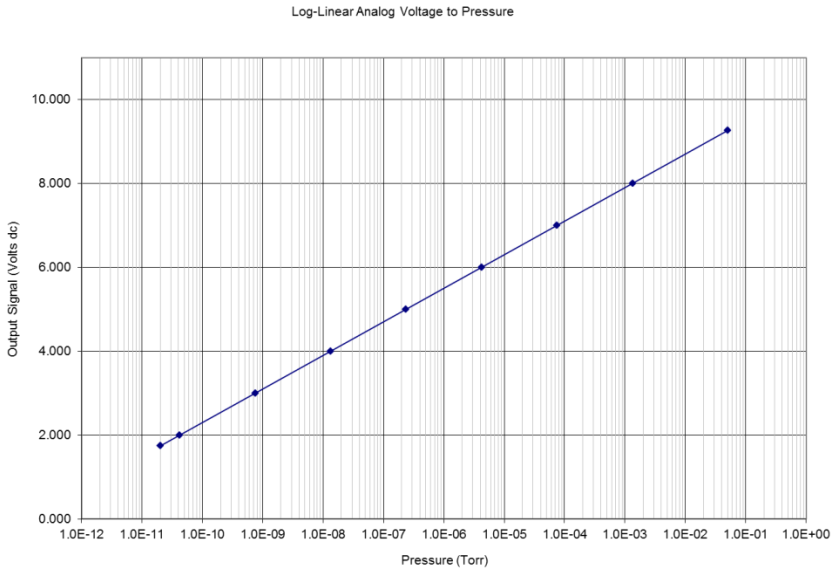
Table 4 - Log-Linear Analog Output

(Applies to all IGs when programmed for the 1.8 to 8.7V, 0.8V/decade analog output with N_2/air only)

Pressure (Torr)	*Voltage (V_{DC})*
2.00E-11	*1.741* [25]
4.20E-11	*2.00*
7.50E-10	*3.00*
1.30E-08	*4.00*
2.40E-07	*5.00*
4.20E-06	*6.00*
7.50E-05	*7.00*
1.30E-03	*8.00*
5.00E-02	*9.259*
Filament is OFF	*≥11*

[25] The lowest voltage signal output by the *FlexRax* is the voltage proportional to the x-ray limit of the B-A ionization gauge transducer in use. For example, even if your vacuum system can be pumped to a pressure less than 1.00E-10 Torr, it will not be possible to measure that pressure if the x-ray limit of your B-A IG is, say, 3.00 or 4.00 E-10 Torr.

The following chart shows the graphical results of the table and formulas given above. Indicated pressure is plotted on the X-axis with a log scale; the output signal is plotted on the Y-axis on a linear scale.



Plot of the log-linear analog output signal for 1.8 to 8.7V, 0.8V/decade (for *N_2/Air, only)*

If the analog output has been assigned to be derived from the pressure measured by either the IGM/CCM, IGR or IGE option, when the IG is turned to **OFF**, the analog output voltage will increase to a voltage of 11 volts DC or greater (not shown in the chart above). With Over Pressure shut-OFF set at **Default** settings, the analog output voltage will switch to +11 Vdc under the following conditions:

- The IG is either turned **OFF** or any IG fault condition exists.
- When using the IGM400, the pressure exceeds 1.00E-03 Torr at 4 mA emission current or 5.00E-02 Torr at 100 µA emission current causing the IG to turn OFF.
- When using the IGR/IGE (BA600 series glass or nude B-A ion gauge or equivalent), the pressure exceeds 5.00E-04 Torr at 4 mA emission current, 1.00E-04 Torr at 10 mA emission current or 1.00E-03 Torr (default; may be set to 1.00E-02 Torr max.) at 100 µA emission current causing the IG to turn OFF.
- The pressure exceeds 1.00E-02 Torr as measured by the CCM500 causing the IG to turn OFF.

Clear Error (for IG operation) –

For any Ion Gauge device (IGM, CCM, IGR or IGE) that is turned OFF due to a faults condition such as an 'Over Pressure' condition, the display line in the **Pressure Measurement Screen** will show the IG as "OFF" (in red color). The error condition must be remedied and the error cleared in the *FlexRax* operating system prior to being allowed to turn the IG to ON (Operating). To clear an error condition which will otherwise prevent operation of the ionization gauge, follow the menu sequence to get to a select screen for the IGM, CCM or IGR/IGE that you wish to turn ON. When you select the device that is displaying an error condition (OFF in red color), you will see a Clear Error key-designator box in the display where the 'Clear Error' box is not grayed-out. Press the key associated with the Clear Error key-designator box to perform the actions prompted to clear the error. Sending an 'IG OFF' command when using RS232/RS485 serial communications or pressing IG OFF while in the R&D Display Screen will clear any IG errors and allow the IG to be turned ON again.

3.6.1.4.8 Analog Output – Linear IG

The *FlexRax 4000* analog output may be setup to provide a signal voltage that has a direct linear relationship to the displayed pressure. When preparing to setup the analog output signal for ***Linear IG*** type output, first define the following parameters that you will program into the *FlexRax:*

- Minimum measured pressure (for the defined analog output range)
- Minimum output voltage desired (proportional to the minimum pressure)
- Maximum measured pressure (for the analog output signal range)
- Maximum output voltage desired (proportional to maximum pressure)

Constructing a table of these parameters may be useful in documenting the relationship of displayed pressure (measured by the IG) to the analog output voltage. For example, the following table is representative of a typical setup where the IG may be used in a limited range of pressure measurement where a direct linear relationship exists between the displayed pressure (mantissa) and the analog output signal. The linear analog output voltage characteristic depicted in the following table represents the ***Default*** settings for this function covering 3-decades of pressure measurement:

Linear Analog Output Voltage - volts	Measured (Displayed) Pressure - Torr
0.01	1.00E-06
0.10	1.00E-05
1.00	1.00E-04
10.00	1.00E-03

The uncertainty of the measurement increases at the lower end of the measurement range of the device when using a linear analog output type signal. It is recommended that the *Linear IG* output signal be setup such that the range covers, at most, 3 decades of pressure change. For example, if the minimum pressure selected is 1.00E-06 Torr, with a corresponding minimum voltage output of 0.01 volts, then the maximum pressure selected to correspond to a maximum voltage of 10.00 volts should not exceed 1.00E-03 Torr. Doing this is considered best practice when using this type of analog output signal with the *FlexRax.*

If your application requires the analog output voltage to cover a pressure range exceeding three decades, then consider using a log-linear analog output type for the IG.

NOTE – The information discussed above regarding the Linear IG analog output applies only to N_2 / air. If you are using a gas other than N_2 / air, refer to table titled "**Ion Gauge Gas Correction Factors for selected gases"** in section 4.1.1. Apply the gas correction factor by dividing the pressure derived (from using the **Linear IG** output discussed above) by the specific Gas Correction Factor to obtain the true pressure of the specific gas in your vacuum chamber.

3.6.1.4.9 Analog Output - Wide Range IG + CG 0.5 - 7 V

The analog output voltage type described below represents the pressure displayed for the selected IG+CG option for N_2 / air only**. Refer to Section 4 if you are using a gas other than N_2 / air.**

By using the **Wide Range IG + CG 0.5 – 7V** analog output voltage type, it is possible to monitor the pressure in your vacuum chamber using a single measurement signal spanning the range from the x-ray limit of the ionization gauge transducer to 1000 Torr, N_2/air.

The wide range analog output is generated from the Ion Gauge at pressures from the x-ray limit of the hot cathode IG transducer and then the output is derived from the CG measured pressure at 1.00E-03 Torr to 1000 Torr. For example, if you are using an IGM400 Ion Gauge module, the wide range analog output is generated from the Ion Gauge at pressures from 1.00E-09 to 1.00E-03 and then the output is derived from the CG measured pressure from 1.00E-03 Torr to 1000 Torr. Even if the IG assigned to this analog output type is ON, if the pressure measured by the assigned CG is ≥ 1.00E-03 Torr, the output is derived from the CG reading. It is recommended that the CG reading at high vacuum be carefully adjusted such that the CG reading is near 1.00E-04 Torr (see Section 3.6.1.2.4 Set Vacuum regarding setting the CG 'zero' reading). This will ensure that the IG reading is used to derive the wide range analog output at pressures less than 1.00E-03 Torr.

NOTICE

The Wide Range IG + CG 0.5 – 7V Analog Output type is only available if you set Emission Current for the IGR/IGE to either 4 mA or 100 µA. To see this Analog Output type in the menu choices, set IGR/IGE emission current to 100 µA or 4 mA.

Perform the following key-entry sequence:

Menu ⇨ Analog I/O ⇨ Analog Outputs ⇨ AO [n] ⇨ Assign Output ⇨

You will see a screen with the up 🡅 and down 🡇 arrow keys on the left side of the display and a message dialog box that reads: { **Scroll Up or Down to assign a device to Analog Output AO [3]** }

As in the previous example of selecting device **IGR [5]** using the up or down arrow keys, select **IGR [5]** then press the SAVE key. In the next screen shown, press the up 🡅 or down 🡇 arrow key to display the AO [n] type **Wide Range IG + CG 0.5 – 7V** at the top of the message dialog box then press the SAVE key.

Now, a screen showing the up 🡅 and down 🡇 arrow keys with a message dialog box that reads **{Select the CG Device}** is displayed. Press the up 🡅 or down 🡇 arrow key to select the CG you want to use in combination with the IG device selected for the analog output type: **Wide Range IG + CG 0.5 – 7V** (Log-Linear 0.5 to 7 Vdc with 0.5 V per decade).

Enter SAVE ⇨ BACK ⇨ BACK ⇨ to return to the **Pressure Measurement Screen.** In certain menu screens, you may see the soft-key MAIN displayed. If the MAIN soft-key is present, press the hardware key associated with it to return to the main **Pressure Measurement Screen.**

⚠ **CAUTION!** In order that you prevent equipment damage and possible injury to personnel, you must ensure that measured pressure readings of the device are corrected for the type of gas composition that is in your vacuum chamber. When using gas dependent-type pressure measurement devices such as a convection or ionization gauge transducer, refer to correction charts and tables within this User Manual and the User Manual for the connected device you are using or related information in later sections of this User Manual when measuring pressure of gases other than nitrogen/air.

Analog output: Wide Range Log-linear 0.5 to 7 Vdc, 0.5 V per decade

A) The log-linear output signal and pressure are related by the following formulas when **Pressure Unit** of measurement is in **Torr** and **mbar:**

$P = 10^{(volts - 5.5) / (0.5)}$ $V = ((0.5 \bullet \log_{10}(P)) + 5.5$

, where P is the pressure in Torr or mbar, and V is the output signal in volts.

B) The log-linear output signal and pressure are related by the following formulas when **Pressure Unit** of measurement is in pascals (**Pa**)**:**

$P = 10^{(volts - 4.5) / (0.5)}$ $V = ((0.5 \bullet \log_{10}(P)) + 4.5$

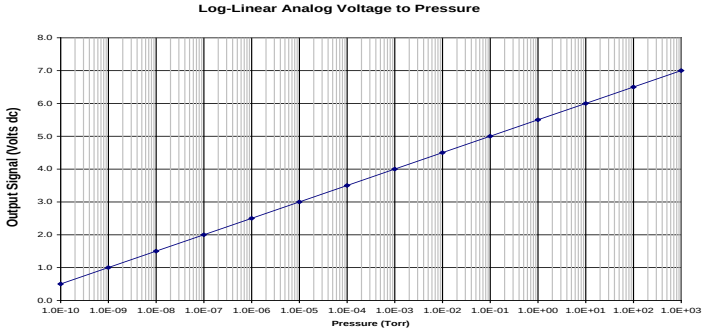
When the IG Control mode is in either 'CG Controls IG' or the IG is OFF, **the output voltage will switch to +11 Vdc**, or greater, under the following conditions:

1) The CG is either damaged or disconnected.
2) The IG is off or faults and the CG is damaged or disconnected.
3) The pressure exceeds 1.00E-03 Torr at 4 mA I_e, 5.00E-02 Torr at 100 µA I_e for IGM400 or 1.00E-02 Torr for CCM500 and the CG is damaged or disconnected.
4) The pressure exceeds 5.00E-04 Torr at 4 mA I_e, 1.00E-04 Torr at 10 mA I_e, 1.00E-03 Torr at 100 µA I_e for IGR/IGE and the CG is damaged or disconnected.
5) Any IG or CG faults condition while operating in the IG or CG range, respectively.

Note: When using the **Wide-Range IG+CG 0.5 – 7V** analog output-type, if the IG is turned OFF and the pressure measured by the CG is less than 1.00E-03 Torr for example, the Analog Output (AO) voltage will be 4.00 volts. The minimum AO voltage available for the CG device is equivalent to the pressure in Torr pressure units, of 1.00E-03 Torr. The *FlexRax* operating system assumes that when in this AO-type mode, the IG will be turned ON and is capable of measuring pressure up to 1.00E-03 Torr or higher.

Table 5 - Log-Linear Analog Output
Applies to Nitrogen/Air only

Pressure (Torr)	Voltage (Vdc)
1.00E-10	0.50
1.00E-09	1.00
1.00E-08	1.50
1.00E-07	2.00
1.00E-06	2.50
1.00E-05	3.00
1.00E-04	3.50
1.00E-03 (see note)	4.00 (see note)
1.00E-02	4.50
1.00E-01	5.00
1.00E+00	5.50
1.00E+01	6.00
1.00E+02	6.50
1.00E+03	7.00



Plot of the formulas and data for the log-linear output signal *(IG + CG for Nitrogen/Air)*

3.6.1.4.10 Analog Output - Convection Gauge (CG) –

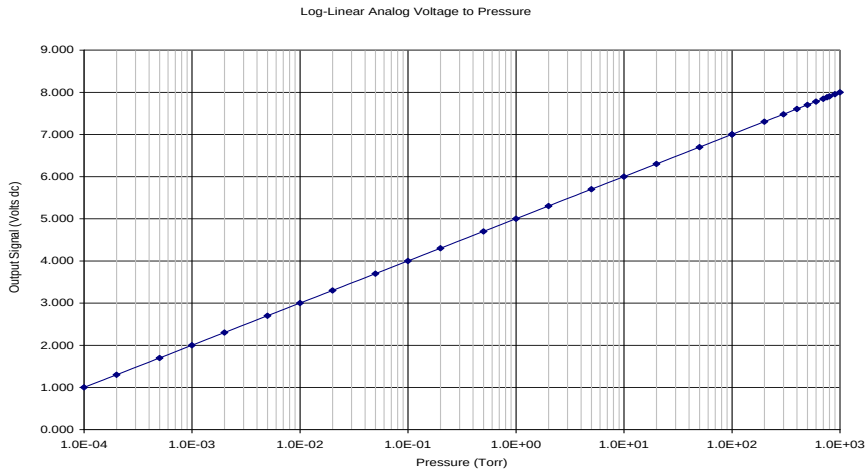
The analog output voltage type described below represent the pressure displayed for the selected CG option for N_2 / Air only**. Refer to Section 4 if you are using a gas other than N_2 / Air.**

When you choose one of the Convection Gauge (CG) devices to use for an analog output signal proportional to the CG [n,m] displayed pressure, the following analog output types are available to choose from:

(A) Log-Linear CG 1-8 V (B) Log-Linear CG 0-7 V (C) Linear CG (D) Non-Linear CG

3.6.1.4.10.1 Log-Linear CG 1-8 V –

The Log-Linear CG 1-8V analog output voltage signal is defined as a voltage proportional to the displayed pressure that is linear with respect to the common logarithm of pressure. The relationship of pressure to voltage is given by $P = 10^{(V-5)}$, where pressure is in Torr units. Solving this equation for voltage (V), the relationship is represented by $V = \log_{10}(P) + 5$. Graphically, this relationship is represented as shown in the following chart:

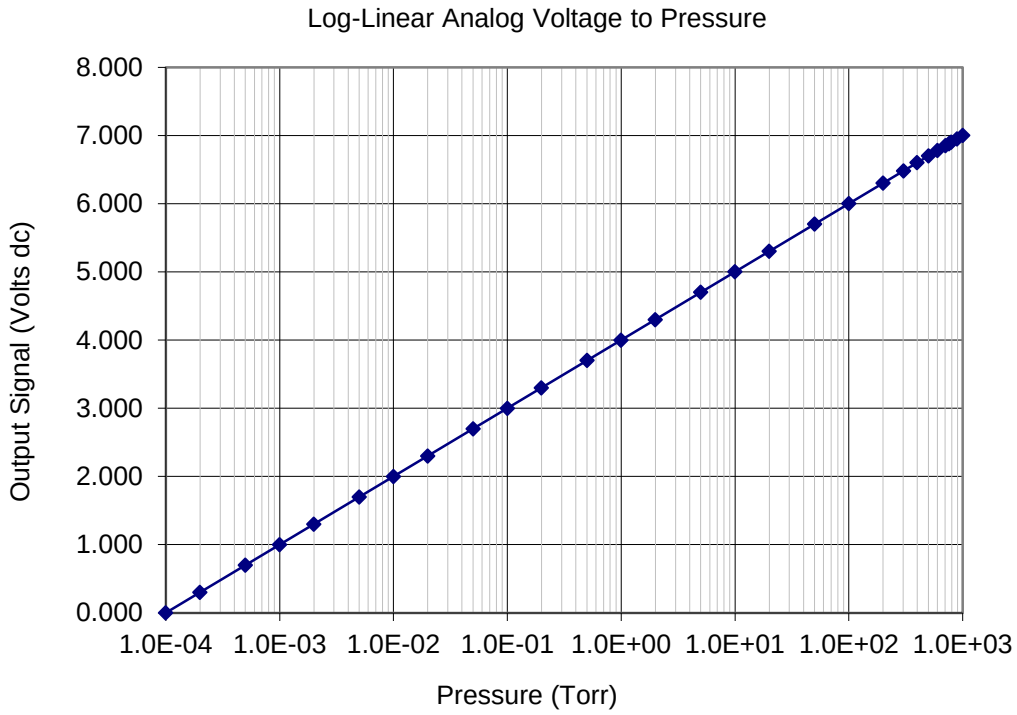


The following table is representative of the analog output voltage at various diplayed (measured) pressures when using the ***Log-Linear CG 1-8 V*** analog output type. (applies to N_2 / Air only)

Pressure (Torr)	Voltage (Vdc)	Pressure (Torr)	Voltage (Vdc)	Pressure (Torr)	Voltage (Vdc)
1.00E-04	1.000	5.00E-01	4.699	5.00E+02	7.699
2.00E-04	1.301	1.00E+00	5.000	6.00E+02	7.778
5.00E-04	1.699	2.00E+00	5.301	7.00E+02	7.845
1.00E-03	2.000	5.00E+00	5.699	7.60E+02	7.881
2.00E-03	2.301	1.00E+01	6.000	8.00E+02	7.903
5.00E-03	2.699	2.00E+01	6.301	9.00E+02	7.954
1.00E-02	3.000	5.00E+01	6.699	1.00E+03	8.000
2.00E-02	3.301	1.00E+02	7.000		
5.00E-02	3.699	2.00E+02	7.301		
1.00E-01	4.000	3.00E+02	7.477		
2.00E-01	4.301	4.00E+02	7.602		

3.6.1.4.10.2 Log-Linear CG 0-7 V –

The **Log-Linear CG 0-7V** analog output voltage signal is defined as a voltage proportional to the displayed pressure that is linear with respect to the common logarithm of pressure. The relationship of pressure to voltage is given by $P = 10^{(V-4)}$, where pressure is in Torr units. Solving this equation for voltage (V), the relationship is represented by $V = \log_{10}(P) + 4$. Graphically, this relationship is represented as shown in the following chart:



The following table is representative of the analog output voltage at various diplayed (measured) pressures, in Torr units, when using the ***Log-Linear CG 0-7 V*** analog output type. (applies to N_2 / Air only)

Pressure (Torr)	Voltage (Vdc)	Pressure (Torr)	Voltage (Vdc)	Pressure (Torr)	Voltage(Vdc)
1.00E-04	0.000	5.00E-01	3.699	5.00E+02	6.699
2.00E-04	0.301	1.00E+00	4.000	6.00E+02	6.778
5.00E-04	0.699	2.00E+00	4.301	7.00E+02	6.845
1.00E-03	1.000	5.00E+00	4.699	7.60E+02	6.881
2.00E-03	1.301	1.00E+01	5.000	8.00E+02	6.903
5.00E-03	1.699	2.00E+01	5.301	9.00E+02	6.954
1.00E-02	2.000	5.00E+01	5.699	1.00E+03	7.000
2.00E-02	2.301	1.00E+02	6.000		
5.00E-02	2.699	2.00E+02	6.301		
1.00E-01	3.000	3.00E+02	6.477		
2.00E-01	3.301	4.00E+02	6.602		

3.6.1.4.10.3 Linear CG –

The *FlexRax 4000* analog output may be setup to provide a signal voltage that has a direct linear relationship to the displayed pressure. When preparing to setup the analog output signal for *Linear CG* type output, first define the following parameters that you will program into the *FlexRax:*

- Minimum measured pressure (for the defined analog output range)
- Minimum output voltage desired (proportional to the minimum pressure)
- Maximum measured pressure (for the analog output signal range)
- Maximum output voltage desired (proportional to maximum pressure)

Constructing a table of these parameters may be useful in documenting the relationship of displayed pressure (measured by the CG) to the analog output voltage. For example, the following table is representative of a typical setup where the CG may be used to check or corroborate the readings of a 10 Torr full-scale CDG that has a known linear analog output voltage characteristic:

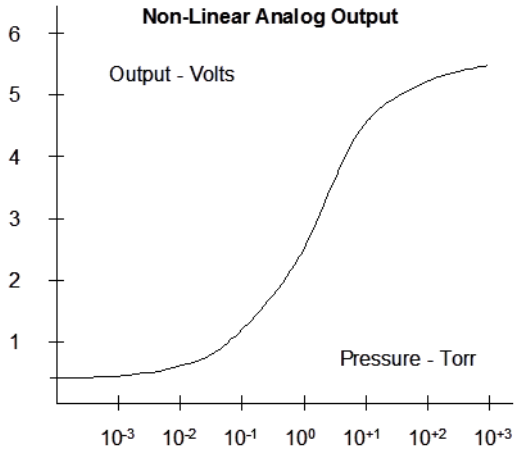
Linear Analog Output Voltage - volts	Measured (Displayed) Pressure - Torr
0.001	1.00E-03
0.010	1.00E-02
0.100	1.00E-01
1.000	1.00E+00
10.00	1.00E+01

As with the CDG, the uncertainty of the measurement increases at the lower end of the measurement range of the device when using a linear analog output type signal. It is recommended that the *Linear CG* output signal be setup such that the range covers, at most, 3 decades of pressure change. For example, if the minimum pressure selected is 1 mTorr (1.00E -03 Torr) with a corresponding minimum voltage output of 0.01 volts, then the maximum pressure selected to correspond to a maximum voltage of 10.00 volts should not exceed 1.00 Torr. Doing this is considered best practice when using this type of analog output signal with the *FlexRax.* As indicated in the example table above, it is possible to achieve setup for the linear output to cover 4 decades. However, you must realize that the uncertainty of the measurement increases when the range exceeds 3 decades of pressure measurement just as it does for a linear analog output CDG.

If your application requires the analog output voltage to cover a pressure range exceeding three decades, then consider using the non-linear or log-linear analog output for the CG. Refer to User Manuals for InstruTech products such as the CVM201 *Super Bee*™ and VGC301 vacuum gauge controller for *Worker Bee*™ convection gauges for additional details on the use of the linear analog output type.

3.6.1.4.10.4 Non-Linear CG –

The first convection enhanced pirani transducer introduced was the Convectron®. The controller for the Convectron® provided an analog output signal referred to as the "S-curve" which represented the actual voltage applied across the transducer circuit, proportional to the pressure inside the pressure transducer enclosure. The Granville-Phillips® Convectron® controllers were designed to output this transducer voltage and in later years, the non-linear voltage applied to the transducer was scaled to provide various signal spans of the original "S-curve". The non-linear analog outputs of the *FlexRax 4000* and other InstruTech products duplicate the original S-curve of 0.375 volts at pressure less than 1.00E-04 Torr to 5.659 volts at 1000 Torr, nitrogen or air.



Refer to the User Manuals for the InstruTech *Super Bee* and VGC301 *Worker Bee* controller for tables, charts and additional details on the use of the non-linear analog output signal. In general, one may use linear interpolation techniques to calculate the pressure using the non-linear analog output voltage measured at a specific pressure. The voltage outputs proportional to the displayed pressure on the controller are published in the User Manuals for various convection enhanced pirani sensor products.

Non-Linear Output Voltage vs. Pressure in Torr units for N_2 /Air only

Pressure (Torr)	Voltage (Vdc)	Pressure (Torr)	Voltage (Vdc)	Pressure (Torr)	Voltage (Vdc)
0.0000	0.3751	2.00E-01	1.1552	4.00E+02	5.2236
1.00E-04	0.3759	5.00E-01	1.6833	5.00E+02	5.3294
2.00E-04	0.3768	1.00E+00	2.2168	6.00E+02	5.4194
5.00E-04	0.3795	2.00E+00	2.8418	7.00E+02	5.4949
1.00E-03	0.3840	5.00E+00	3.6753	7.60E+02	5.5340
2.00E-03	0.3927	1.00E+01	4.2056	8.00E+02	5.5581
5.00E-03	0.4174	2.00E+01	4.5766	9.00E+02	5.6141
1.00E-02	0.4555	5.00E+01	4.8464	1.00E+03	5.6593
2.00E-02	0.5226	1.00E+02	4.9449		
5.00E-02	0.6819	2.00E+02	5.0190		
1.00E-01	0.8780	3.00E+02	5.1111		

You may also calculate the N_2/air pressure represented by the non-linear analog output voltage for the original "S-curve" using a multi-segment, n^{th} order polynomial function calculation. Contact support@instrutechinc.com for information related to the use of the n^{th} order polynomial equations for calculating nitrogen or air pressure using the non-linear analog output voltage signal.

The coefficients for the n^{th} order polynomial equation defined for various pressure measurement ranges are given in the following table:

For **0 mTorr to about 2 Torr**,the Non-Linear Analog Output voltage range of **0.375 to 2.842 volts**, use this table.

Coefficients for $y(x) = a + bx + cx^2 + dx^3 + ex^4 + fx^5$	
a	-0.02585
b	0.03767
c	0.04563
d	0.1151
e	-0.04158
f	0.008738

For **2 Torr to about 100 Torr,** the Non-Linear Analog Output voltage range of **2.842 to 4.945 volts**, use this table.

Coefficients for $y(x) = \frac{a+cx+ex^2}{1+bx+dx^2+fx^3}$	
a	0.1031
b	-0.3986
c	-0.02322
d	0.07438
e	0.07229
f	-0.006866

For **100 Torr to 1000 Torr,** the Non-Linear Analog Output voltage range of **4.94 to 5.659 volts**, use this table.

Coefficients for $y(x) = \frac{a+cx}{1+bx+dx^2}$	
a	100.624
b	-0.37679
c	-20.5623
d	0.0348656

Where y(x) = pressure in Torr, x= measured analog output in volts

Example: Measured analog output voltage is 0.3840 V.
From first table shown above use equation:
$y(x) = a + bx + cx^2 + dx^3 + ex^4 + fx^5$

X = 0.3840 volts
A = -0.02585, b=0.03767, c=0.04563, d=0.1151, e=-0.04158, f=0.008738
y(x) = Pressure = 1.0E-03 Torr

4 Effect of Different Gas Types on Displayed Pressure

The *FlexRax 4000* pressure display assumes that the pressure measurement device is reading nitrogen pressure. For both convection and ionization type vacuum gauges, corrections must be applied to both the display and analog outputs.

NOTICE

The following tables and text contain important information regarding the use of Ionization and Convection gauges when measuring total pressure of gas and gas mixtures other than Nitrogen / Air. For both types of gauge transducers, corrections must be applied to both the displayed pressure and the analog output to determine the true measured pressure. This is particularly critical when using Convection gauges to measure density of gases other than N_2/Air.

⚠ **CAUTION! Risk of over pressurizing a gas containment vessel and attached apparatus exists when using pressure measurement devices that are calibrated for a specific gas type. Use a pressure relief device to safely limit the internal pressure of a containment vessel to less than the maximum allowable working pressure rating for the vacuum/pressure system and all devices attached to the system.**

4.1 Effects of different gas types on Ionization Gauge display –

Ion Gauge pressure readings are calibrated for nitrogen. If you use a different species of gas or mixture of gases, you will be required to either make manual corrections to the pressure readout or compensate the reading. The Sensitivity adjustment function of the *FlexRax* for the IG you are using to measure the pressure of gas other than nitrogen/air may be set to compensate the reading. Compensating the pressure reading using the Sensitivity adjustment method may not be possible for certain gases if the gas correction factor results in a calculated sensitivity outside the adjustment range possible.

4.1.1 Ion Gauge display Correction Factors –

If you intend to use gases other than N_2 / Air, you must manually apply a gas correction factor to the IG displayed pressure measurement. The following table provides correction factors for some typical gas species. To correct the display measurement, divide the displayed measured pressure by the correction factor for the gas type being measured by your Ionization Gauge device:

Gas	Gas Correction Factor
He	0.18
Ne	0.30
D_2	0.35
H_2	0.46
N_2	1.00
Air	1.00
O_2	1.01
CO	1.05

Gas	Gas Correction Factor
H_2O	1.12
NO	1.16
Ar	1.29
CO_2	1.42
Kr	1.94
SF_6	2.50
Xe	2.87
Hg	3.64

Ion Gauge Gas Correction Factors for selected gases

For example, if the gas in use is argon (Ar) and the display indicates a measured pressure of 4.00E-07 Torr, from the table above for Ion Gauge Gas Correction Factors, the correction factor for argon is 1.29. Divide the displayed pressure, 4.00E-07 Torr, by the correction factor, 1.29, to obtain the true pressure of argon gas in your vacuum chamber: 4.00E-07 Torr / 1.29 = 3.10E-07 Torr.

If you adjust the Sensitivity factor for your Ion Gauge to compensate the readout of pressure for a gas type other than nitrogen, the displayed pressure readout for that device must be annotated to indicate that the displayed pressure is for the gas type the readout is compensated for. In the above example, if the N_2 Sensitivity of the Ion Gauge being used is 10 $Torr^{-1}$ ("10 per Torr"), the Sensitivity factor programmed during setup of the *FlexRax* for that IG could be set for 12.9 (~13) so that the pressure readout would indicate the true pressure of argon. Again, the display line for that particular device pressure readout would require annotation so as to not conflict with the notation "CAL GAS: N_2" following the "Unit" notation in the Pressure Measurement Screen.

4.2 Effects of different gas types on Convection Gauge display –

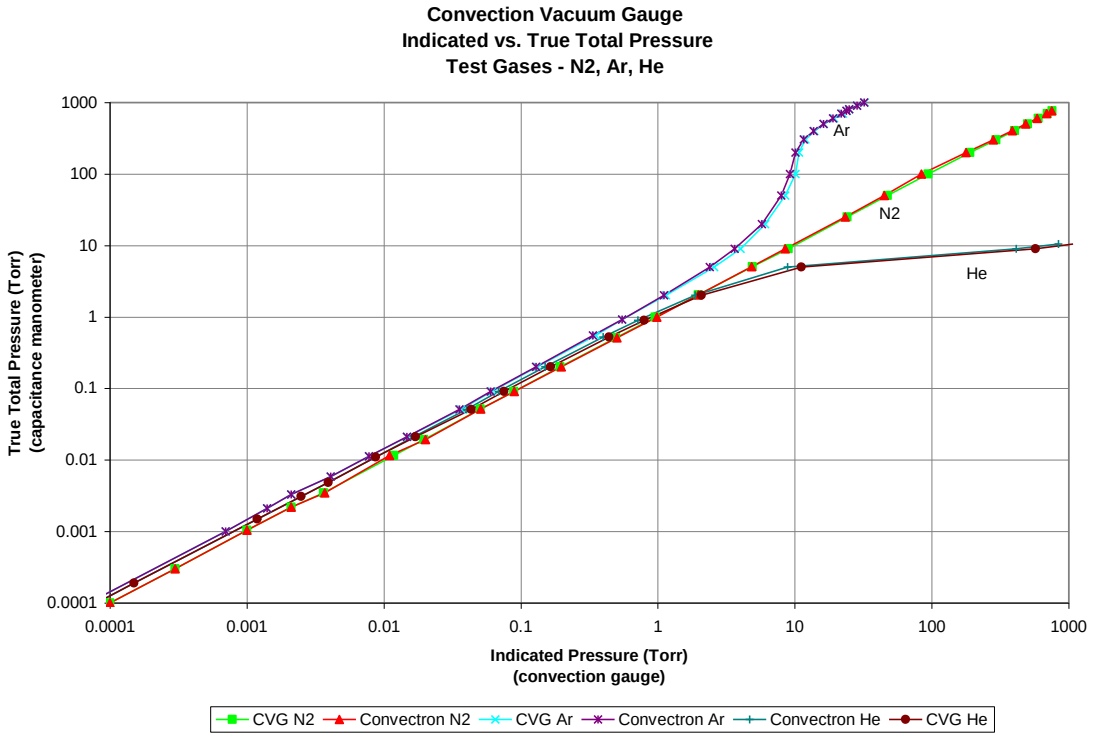
A thermal conductivity gauge senses heat loss, which depends on the thermal conductivity of the gas surrounding the sensor. Since different gases, and mixtures, have different thermal conductivities, the indicated pressure readings and outputs will also be different. InstruTech convection gauges (and most other thermal gauges) are normally calibrated using dry nitrogen (N_2). When a gas other than N_2 is used, correction must be made for the difference in thermal conductivity, between nitrogen (N_2) and the gas in use. The charts and tables on the following pages indicate how different gases affect the display and output from an InstruTech convection gauge.

WARNING! Using a thermal conductivity gauge with gases other than that for which it is calibrated could result in death or serious injury. Be sure to use gas correction data in this manual when measuring pressures of gases other than N_2 / air.

For N_2 the calibration shows excellent agreement between indicated and true pressure throughout the range from 10^{-4} to 1000 Torr. At pressures below 1 Torr, the calibration curves for the different gases are similar. The difference in readings at these low pressures is a constant, a function of the difference between thermal conductivities of the gases.

At pressures above 1 Torr, indicated pressure readings may diverge significantly. At these higher pressures, convection currents in the gauge become the predominant cause of heat loss from the sensor, and calibration depends on gauge tube geometry and mounting position, as well as gas properties.

Generally, air and N_2 are considered the same with respect to thermal conductivity, but even N_2 and air will exhibit slight differences in readings at higher pressures. For example, when venting a system to atmosphere using N_2, you may see readings change by 30 to 40 Torr after the chamber is opened and air gradually displaces the N_2 in the gauge. For most other gases, the effect is much more significant, and may result in a hazardous condition, as described below.



The Y-axis is actual pressure, measured by a capacitance manometer, a diaphragm gauge that measures true total pressure, independent of gas composition. The X-axis is the pressure reading indicated by the convection gauge under test. The chart above shows readings for an InstruTech Convection Gauge (CVG) as well as for a Granville-Phillips® Convectron® gauge, to illustrate that the response of both these type of gauges is virtually the same.

4.2.1 Convection Gauge display conversion for select gases –

When using gas species or mixtures of gas other than nitrogen or air, you must use a look-up table to determine the true pressure of the selected gas as measured by the convection gauge. This holds true for any manufacturer's convection enhanced pirani type transducer where the principle of measurement is based on heat-loss from a heated wire contained in the vacuum gauge transducer volume exposed to the inlet gas or gas mixture.

Refer to the look-up table on the next page and note the following examples:

Example A: If the gas is nitrogen (N_2), when the true total pressure is 500 Torr, the gauge will read 500 Torr.

Example B: If the gas is argon (Ar), when the true pressure is 100 Torr, the gauge will read about 9 Torr.

If you are backfilling your vacuum system with Ar, when your system reaches a true pressure of 760 Torr, Your gauge will be reading about 23 Torr. Continuing to backfill your chamber in an attempt to increase the displayed pressure reading to 760 Torr will over pressurize your chamber which may present a hazard.

Example C: If the gas is helium (He), the gauge will read OP (Overpressure) when pressure reaches about 10 Torr true pressure and opening the chamber to atmosphere prematurely may present other hazards for both people and product.

CAUTION! What these examples illustrate is that when using gases other than nitrogen (N_2), without using accurate gas conversion data and other proper precautions, could result in injury to personal and/or damage to equipment.

Suggested precautions when using gases other than N_2:

Exercise caution when admitting positive pressures (above local ambient, atmospheric pressure) of gas into any enclosed volume. Install pressure relief devices on your vacuum / pressure vessel or chamber to limit the maximum allowable working pressure inside the devices and vessel internal volume to less than the lowest rated device – in some cases, the maximum allowable working pressure may be dictated by the type of connections or fittings used to attach devices to your chamber. An O-ring compression fitting type device may be forcibly released (ejected) from the fitting if internal pressure exceeds the local barometric, ambient pressure.

Post a warning label on your gauge readout "Do Not Exceed ____ Torr Indicated Pressure" (fill in the blank for maximum indicated pressure for the gas you use) so that an operator using the gauge will not exceed a safe pressure.

CAUTION! Do not assume this data applies to other convection gauges, which may or may not be the same.

The following table was carefully constructed by comparison of the Convection Gauge (CG) transducer Displayed Pressure to the displayed pressure of a gas-independent gauge such as the Capacitance Diaphragm Gauge (CDG) for several commonly used gas types:

Table 6 - Displayed Pressure Readings for Convection Gauge type devices versus True Pressure for Selected Gases

True Pressure (Torr)	N_2	Ar	He	O_2	CO_2	Kr	Freon12	Freon22	D_2	Ne	CH4
1.00E-4	1.00E-4	1.00E-4	1.00E-4	1.00E-4	1.00E-4	1.00E-4	1.00E-4	1.00E-4	1.00E-4	1.00E-4	1.00E-4
2.00E-4	2.00E-4	2.00E-4	2.00E-4	2.00E-4	2.00E-4	2.00E-4	2.00E-4	2.00E-4	2.00E-4	2.00E-4	2.00E-4
5.00E-4	5.00E-4	5.00E-4	5.00E-4	5.00E-4	5.00E-4	3.00E-4	5.00E-4	5.00E-4	5.00E-4	5.00E-4	5.00E-4
1.00E-3	1.00E-3	7.00E-4	8.00E-4	1.00E-3	1.10E-3	4.00E-4	1.50E-3	1.50E-3	1.30E-3	7.00E-4	1.70E-3
2.00E-3	2.00E-3	1.40E-3	1.60E-3	2.00E-3	2.30E-3	1.00E-3	3.10E-3	3.10E-3	2.40E-3	1.50E-3	3.30E-3
5.00E-3	5.00E-3	3.30E-3	4.00E-3	5.00E-3	4.40E-3	2.30E-3	7.60E-3	7.00E-3	6.00E-3	3.50E-3	7.70E-3
1.00E-2	1.00E-2	6.60E-3	8.10E-3	9.70E-3	1.10E-2	4.80E-3	1.47E-2	1.35E-2	1.21E-2	7.10E-3	1.53E-2
2.00E-2	2.00E-2	1.31E-2	1.61E-2	1.98E-2	2.22E-2	9.50E-3	2.99E-2	2.72E-2	2.43E-2	1.41E-2	3.04E-2
5.00E-2	5.00E-2	3.24E-2	4.05E-2	4.92E-2	5.49E-2	2.35E-2	7.25E-2	6.90E-2	6.00E-2	3.48E-2	7.72E-2
1.00E-1	1.00E-1	6.43E-2	8.20E-2	9.72E-2	1.07E-1	4.68E-2	1.43E-1	1.36E-1	1.21E-1	7.00E-2	1.59E-1
2.00E-1	2.00E-1	1.26E-1	1.65E-1	1.94E-1	2.10E-1	9.11E-2	2.75E-1	2.62E-1	2.50E-1	1.41E-1	3.15E-1
5.00E-1	5.00E-1	3.12E-1	4.35E-1	4.86E-1	4.89E-1	2.17E-1	6.11E-1	5.94E-1	6.87E-1	3.59E-1	7.81E-1
1.00E+0	1.00E+0	6.00E-1	9.40E-1	9.70E-1	9.50E-1	4.00E-1	1.05E+0	1.04E+0	1.55E+0	7.45E-1	1.60E+0
2.00E+0	2.00E+0	1.14E+0	2.22E+0	1.94E+0	1.71E+0	7.00E-1	1.62E+0	1.66E+0	4.13E+0	1.59E+0	3.33E+0
5.00E+0	5.00E+0	2.45E+0	1.35E+1	4.98E+0	3.34E+0	1.28E+0	2.45E+0	2.62E+0	2.46E+2	5.24E+0	7.53E+0
1.00E+1	1.00E+1	4.00E+0	OP	1.03E+1	4.97E+0	1.78E+0	2.96E+0	3.39E+0	OP	2.15E+1	2.79E+1
2.00E+1	2.00E+1	5.80E+0	OP	2.23E+1	6.59E+0	2.29E+0	3.32E+0	3.72E+0	OP	5.84E+2	3.55E+2
5.00E+1	5.00E+1	7.85E+0	OP	7.76E+1	8.22E+0	2.57E+0	3.79E+0	4.14E+0	OP	OP	8.42E+2
1.00E+2	1.00E+2	8.83E+0	OP	2.09E+2	9.25E+0	2.74E+0	4.68E+0	4.91E+0	OP	OP	OP
2.00E+2	2.00E+2	9.79E+0	OP	2.95E+2	1.23E+1	3.32E+0	5.99E+0	6.42E+0	OP	OP	OP
3.00E+2	3.00E+2	1.13E+1	OP	3.80E+2	1.69E+1	3.59E+0	6.89E+0	7.52E+0	OP	OP	OP
4.00E+2	4.00E+2	1.35E+1	OP	4.85E+2	2.24E+1	3.94E+0	7.63E+0	8.42E+0	OP	OP	OP
5.00E+2	5.00E+2	1.61E+1	OP	6.04E+2	2.87E+1	4.21E+0	8.28E+0	9.21E+0	OP	OP	OP
6.00E+2	6.00E+2	1.88E+1	OP	7.30E+2	3.64E+1	4.44E+0	8.86E+0	9.95E+0	OP	OP	OP
7.00E+2	7.00E+2	2.18E+1	OP	8.59E+2	4.61E+1	4.65E+0	9.42E+0	1.07E+1	OP	OP	OP
7.60E+2	7.60E+2	2.37E+1	OP	9.41E+2	5.39E+1	4.75E+0	9.76E+0	1.11E+1	OP	OP	OP
8.00E+2	8.00E+2	2.51E+1	OP	9.97E+2	5.94E+1	4.84E+0	9.95E+0	1.14E+1	OP	OP	OP
9.00E+2	9.00E+2	2.85E+1	OP	OP	7.95E+1	4.99E+0	1.05E+1	1.20E+1	OP	OP	OP
1.00E+3	1.00E+3	3.25E+1	OP	OP	1.11E+2	5.08E+0	1.11E+1	1.27E+1	OP	OP	OP

Values listed under each gas type are in Torr units.

OP = Overpressure

4.3 Effect of different gases on Analog Output

The following tables and explanation contains important information regarding the use of Ionization and Convection gauges on gases other than N_2 / Air. For both types of gauges, corrections must be applied to the analog outputs.

4.3.1 Ion Gauge Analog Output Correction Factors

When using the Log-Linear analog outputs for ion gauges, use the following steps to convert the analog output to pressure:

A) Referring to sections following section 3.6.1.4.3, using Tables and the related equations, convert the voltage in your receiving instrument to pressure. This pressure value is based on nitrogen gas.

B) Apply the gas Correction Factor for the particular gas you are using to the pressure value obtained in step A. Use correction factors and example listed below:

Ion Gauge Gas Correction Factors for selected gases

Gas	Gas Correction Factor
He	0.18
Ne	0.30
D_2	0.35
H_2	0.46
N_2	1.00
Air	1.00
O_2	1.01
CO	1.05

Gas	Gas Correction Factor
H_2O	1.12
NO	1.16
Ar	1.29
CO_2	1.42
Kr	1.94
SF_6	2.50
Xe	2.87
Hg	3.64

Example:
The gas in use is argon. IG analog output scaling selected is **Log-Linear IG 0-10V, n = 10**
Voltage output is 4 volts. Pressure unit is Torr.

P (nitrogen) = $10^{(volts - 10)}$
P = $10^{(4 - 10)}$
P = 1.00 x10^{-6} Torr (based on nitrogen)

Applying the gas Correction Factor of 1.29 for argon listed in the table above,

P (argon) = $\frac{\mathbf{1.00 \times 10^{-6}}}{\mathbf{1.29}}$ = $\mathbf{7.75 \times 10^{-7}}$ Torr true pressure of **argon** gas

When measuring pressure of argon gas, the same correction factor (in the above example, **1.29** for argon) must be applied over the entire pressure range as measured by the ion gauge. Furthermore, apply the Gas Correction Factor in the same way shown in example above to all other analog output scaling selections. For example, if you are using **Log-Linear IG 0-10V, n = 11** analog output scaling, then the above example translates to:
P (nitrogen) = $10^{(volts - 11)}$ P = $10^{(4 - 11)}$ P = 1.00 x10^{-7} Torr (based on nitrogen),
P (argon) = $\frac{\mathbf{1.00 \times 10^{-7}}}{\mathbf{1.29}}$ = $\mathbf{7.75 \times 10^{-8}}$ Torr true pressure of **argon** gas

4.3.2 IG + CG Wide Range Analog Output Correction Factors –

When using the Wide Range IG + CG 0.5 – 7V Log-Linear output for gases other than N_2 / Air, the analog output is interpreted differently over two different pressure ranges as discussed below:

A) Pressure range from the x-ray limit of the Ion gauge to 1.0E-03 Torr - IG Range
Use the same information described in section 4.3.2.1 below to determine pressure from the voltage for selected gases.

B) Pressure range of 1.0E-03 to 1,000 Torr - CG Range
Use the look-up table and information provided in section 4.3.2.2 below to determine pressure from the voltage for selected gases.

4.3.2.1 IG + CG Analog Output Correction Factors - IG range

When using the wide range **IG + CG 0.5-7 V** Log-Linear analog output for gases other than N_2 / Air use the following steps to convert the analog output to pressure when operating in the pressure range of the x-ray limit of the Ion gauge to 1.0E-03 Torr.

A) Refer to section 3.6.1.4.9 Using Table 5 and related equations; convert the voltage in your receiving instrument to pressure. This pressure value is based on nitrogen.

B) Apply the sensitivity correction factor for the particular gas you are using to the pressure value obtained in step A (Use correction factors and example listed below).

Ion Gauge Gas Correction Factors for selected gases

Gas	Gas Correction Factor
He	0.18
Ne	0.30
D_2	0.35
H_2	0.46
N_2	1.00
Air	1.00
O_2	1.01
CO	1.05

Gas	Gas Correction Factor
H_2O	1.12
NO	1.16
Ar	1.29
CO_2	1.42
Kr	1.94
SF_6	2.50
Xe	2.87
Hg	3.64

Example:
The gas in use is argon. Output voltage is 3 volts. Pressure unit is Torr.
P (nitrogen) = $10^{\frac{volts-5.5}{0.5}}$ = $10^{(3.0-5.5)/(0.5)}$, P = 1.00×10^{-5} Torr (based on nitrogen)

P (argon) = $\frac{\mathbf{1.00 \times 10^{-5}}}{\mathbf{1.29}}$ = $\mathbf{7.75 \times 10^{-6}}$ Torr true pressure of **argon** gas

The same correction factor must be applied over the entire pressure range as measured by the ion gauge.

4.3.2.2 IG + CG Analog Output Conversion - CG range

When using the wide range **IG + CG 0.5-7 V** Log-Linear analog output for gases other than N_2 / Air, use the following look-up table and information to convert the analog output to pressure when operating in the pressure range of 1.0E-03 Torr to 1,000 Torr. The look-up table has been derived from Table 5 and related equation listed in section 3.6.1.4.9.

Table 7 – Analog output for IG + CG wide range selection when pressure is 1.0E-03 to 1,000 Torr

True Pressure (Torr)	N_2	Ar	He	O_2	CO_2	KR	Freon12	Freon22	D_2	Ne	CH_4
1.00E-3	4.000	3.923	3.952	4.000	4.021	3.801	4.088	4.088	4.057	3.923	4.115
2.00E-3	4.151	4.073	4.102	4.151	4.181	4.000	4.246	4.246	4.190	4.088	4.259
5.00E-3	4.349	4.259	4.301	4.349	4.322	4.181	4.440	4.423	4.389	4.272	4.443
1.00E-2	4.500	4.410	4.454	4.493	4.521	4.341	4.584	4.565	4.541	4.426	4.592
2.00E-2	4.651	4.559	4.603	4.648	4.673	4.489	4.738	4.717	4.693	4.575	4.741
5.00E-2	4.849	4.755	4.804	4.846	4.870	4.686	4.930	4.919	4.889	4.771	4.944
1.00E-1	5.000	4.904	4.957	4.994	5.015	4.835	5.078	5.067	5.041	4.923	5.101
2.00E-1	5.151	5.050	5.109	5.144	5.161	4.980	5.220	5.209	5.199	5.075	5.249
5.00E-1	5.349	5.247	5.319	5.343	5.345	5.168	5.393	5.387	5.418	5.278	5.446
1.00E+0	5.500	5.389	5.487	5.493	5.489	5.301	5.511	5.509	5.595	5.436	5.602
2.00E+0	5.651	5.528	5.673	5.644	5.616	5.423	5.605	5.610	5.808	5.601	5.761
5.00E+0	5.849	5.695	6.065	5.849	5.762	5.554	5.695	5.709	6.695	5.860	5.938
1.00E+1	6.000	5.801		6.006	5.848	5.625	5.736	5.765		6.166	6.223
2.00E+1	6.151	5.882		6.174	5.909	5.680	5.761	5.785		6.883	6.775
5.00E+1	6.349	5.947		6.445	5.957	5.705	5.789	5.809			6.963
1.00E+2	6.500	5.973		6.660	5.983	5.719	5.835	5.846			
2.00E+2	6.651	5.995		6.735	6.045	5.761	5.889	5.904			
3.00E+2	6.739	6.027		6.790	6.114	5.778	5.919	5.938			
4.00E+2	6.801	6.065		6.843	6.175	5.798	5.941	5.963			
5.00E+2	6.849	6.103		6.891	6.229	5.812	5.959	5.982			
6.00E+2	6.889	6.137		6.932	6.281	5.824	5.974	5.999			
7.00E+2	6.923	6.169		6.967	6.332	5.834	5.987	6.015			
7.60E+2	6.940	6.187		6.987	6.366	5.838	5.995	6.023			
8.00E+2	6.952	6.200		6.999	6.387	5.842	5.999	6.028			
9.00E+2	6.977	6.227			6.450	5.849	6.011	6.040			
1.00E+3	7.000	6.256			6.523	5.853	6.023	6.052			

Values listed under each gas type are in volts (V).

Example:

The gas in use is **O_2**. Voltage output is 5.144 volts.
True pressure of **O_2** is 2.0E-01 Torr

4.3.3 Convection Gauge Analog Output for selected gases –

If you have assigned any of the analog outputs to one or more Convection Gauges (CG), you must also apply corrections to the analog output. Use the following tables to determine pressure from voltage for gases other than nitrogen or air.

4.3.3.1 Log-Linear CG 1-8 V - selected gases conversion

When using the Log-Linear CG 1-8 V analog output for gases other than N_2 / Air, use the following look-up table and information to convert the analog output to pressure. The look-up table has been derived from the equation provided in section 3.6.1.4.10.1

Table 8 – Analog Output for Log-Linear CG 1-8 V

True Pressure (Torr)	N_2	Ar	He	O_2	CO_2	KR	Freon12	Freon22	D_2	Ne	CH_4
1.00E-4	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
2.00E-4	1.301	1.301	1.301	1.301	1.301	1.301	1.301	1.301	1.301	1.301	1.301
5.00E-4	1.699	1.699	1.699	1.699	1.699	1.477	1.699	1.699	1.699	1.699	1.699
1.00E-3	2.000	1.845	1.903	2.000	2.041	1.602	2.176	2.176	2.114	1.845	2.230
2.00E-3	2.301	2.146	2.204	2.301	2.362	2.000	2.491	2.491	2.380	2.176	2.519
5.00E-3	2.699	2.519	2.602	2.699	2.643	2.362	2.881	2.845	2.778	2.544	2.886
1.00E-2	3.000	2.820	2.908	2.987	3.041	2.681	3.167	3.130	3.083	2.851	3.185
2.00E-2	3.301	3.117	3.207	3.297	3.346	2.978	3.476	3.435	3.386	3.149	3.483
5.00E-2	3.699	3.511	3.607	3.692	3.740	3.371	3.860	3.839	3.778	3.542	3.888
1.00E-1	4.000	3.808	3.914	3.988	4.029	3.670	4.155	4.134	4.083	3.845	4.201
2.00E-1	4.301	4.100	4.217	4.288	4.322	3.960	4.439	4.418	4.398	4.149	4.498
5.00E-1	4.699	4.494	4.638	4.687	4.689	4.336	4.786	4.774	4.837	4.555	4.893
1.00E+0	5.000	4.778	4.973	4.987	4.978	4.602	5.021	5.017	5.190	4.872	5.204
2.00E+0	5.301	5.057	5.346	5.288	5.233	4.845	5.210	5.220	5.616	5.201	5.522
5.00E+0	5.699	5.389	6.130	5.697	5.524	5.107	5.389	5.418	7.391	5.719	5.877
1.00E+1	6.000	5.602		6.013	5.696	5.250	5.471	5.530		6.332	6.446
2.00E+1	6.301	5.763		6.348	5.819	5.360	5.521	5.571		7.766	7.550
5.00E+1	6.699	5.895		6.890	5.915	5.410	5.579	5.617			7.925
1.00E+2	7.000	5.946		7.320	5.966	5.438	5.670	5.691			
2.00E+2	7.301	5.991		7.470	6.090	5.521	5.777	5.808			
3.00E+2	7.477	6.053		7.580	6.228	5.555	5.838	5.876			
4.00E+2	7.602	6.130		7.686	6.350	5.595	5.883	5.925			
5.00E+2	7.699	6.207		7.781	6.458	5.624	5.918	5.964			
6.00E+2	7.778	6.274		7.863	6.561	5.647	5.947	5.998			
7.00E+2	7.845	6.338		7.934	6.664	5.667	5.974	6.029			
7.60E+2	7.881	6.375		7.974	6.732	5.677	5.989	6.045			
8.00E+2	7.903	6.400		7.999	6.774	5.685	5.998	6.057			
9.00E+2	7.954	6.455			6.900	5.698	6.021	6.079			
1.00E+3	8.000	6.512			7.045	5.706	6.045	6.104			

Values listed under each gas type are in volts (Vdc).

4.3.3.2 *Log-Linear CG 0-7 V - selected gases conversion*

When using the Log-Linear CG 0-7 V analog output, use the following look-up table and information to convert the analog output to pressure. The look-up table has been derived from the equation provided in section 3.6.1.4.10.2.

Table 9 – Analog Output for Log-Linear CG 0-7 V

True Pressure	N2	Ar	He	O2	CO2	KR	Freon12	Freon22	D2	Ne	CH4
1.00E-4 Torr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2.00E-4 Torr	0.301	0.301	0.301	0.301	0.301	0.301	0.301	0.301	0.301	0.301	0.301
5.00E-4 Torr	0.699	0.699	0.699	0.699	0.699	0.477	0.699	0.699	0.699	0.699	0.699
1.00E-3 Torr	1.000	0.845	0.903	1.000	1.041	0.602	1.176	1.176	1.114	0.845	1.230
2.00E-3 Torr	1.301	1.146	1.204	1.301	1.362	1.000	1.491	1.491	1.380	1.176	1.519
5.00E-3 Torr	1.699	1.519	1.602	1.699	1.643	1.362	1.881	1.845	1.778	1.544	1.886
1.00E-2 Torr	2.000	1.820	1.908	1.987	2.041	1.681	2.167	2.130	2.083	1.851	2.185
2.00E-2 Torr	2.301	2.117	2.207	2.297	2.346	1.978	2.476	2.435	2.386	2.149	2.483
5.00E-2 Torr	2.699	2.511	2.607	2.692	2.740	2.371	2.860	2.839	2.778	2.542	2.888
1.00E-1 Torr	3.000	2.808	2.914	2.988	3.029	2.670	3.155	3.134	3.083	2.845	3.201
2.00E-1 Torr	3.301	3.100	3.217	3.288	3.322	2.960	3.439	3.418	3.398	3.149	3.498
5.00E-1 Torr	3.699	3.494	3.638	3.687	3.689	3.336	3.786	3.774	3.837	3.555	3.893
1.00E+0 Torr	4.000	3.778	3.973	3.987	3.978	3.602	4.021	4.017	4.190	3.872	4.204
2.00E+0 Torr	4.301	4.057	4.346	4.288	4.233	3.845	4.210	4.220	4.616	4.201	4.522
5.00E+0 Torr	4.699	4.389	6.130	4.697	4.524	4.107	4.389	4.418	6.391	4.719	4.877
1.00E+1 Torr	5.000	4.602		5.013	4.696	4.250	4.471	4.530		5.332	5.446
2.00E+1 Torr	5.301	4.763		5.348	4.819	4.360	4.521	4.571		6.766	6.550
5.00E+1 Torr	5.699	4.895		5.890	4.915	4.410	4.579	4.617			6.925
1.00E+2 Torr	6.000	4.946		6.320	4.966	4.438	4.670	4.691			
2.00E+2 Torr	6.301	4.991		6.470	5.090	4.521	4.777	4.808			
3.00E+2 Torr	6.477	5.053		6.580	5.228	4.555	4.838	4.876			
4.00E+2 Torr	6.602	5.130		6.686	5.350	4.595	4.883	4.925			
5.00E+2 Torr	6.699	5.207		6.781	5.458	4.624	4.918	4.964			
6.00E+2 Torr	6.778	5.274		6.863	5.561	4.647	4.947	4.998			
7.00E+2 Torr	6.845	5.338		6.934	5.664	4.667	4.974	5.029			
7.60E+2 Torr	6.881	5.375		6.974	5.732	4.677	4.989	5.045			
8.00E+2 Torr	6.903	5.400		6.999	5.774	4.685	4.998	5.057			
9.00E+2 Torr	6.954	5.455			5.900	4.698	5.021	5.079			
1.00E+3 Torr	7.000	5.512			6.045	4.706	5.045	5.104			

Values listed under each gas type are in volts (Vdc).

4.3.3.3 *Non-Linear CG - selected gases conversion*

When using the Non-Log-Linear CG analog output, use the following look-up table and information to convert the analog output to pressure. The look-up table has been derived from the equation provided in section 3.6.1.4.10.4.

Table 10 – Analog Output for Non-Linear CG

True Pressure (Torr)	N_2	Ar	He	O_2	CO_2	KR	Freon12	Freon22	D_2	Ne	CH_4
0	0.3751	0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.375	0.375
1.00E-4	0.3759	0.3757	0.3755	0.376	0.376	0.3755	0.376	0.376	0.376	0.3757	0.3766
2.00E-4	0.3768	0.376	0.3765	0.377	0.377	0.3768	0.378	0.378	0.377	0.3763	0.378
5.00E-4	0.3795	0.378	0.379	0.38	0.381	0.3772	0.382	0.381	0.381	0.3782	0.3825
1.00E-3	0.384	0.381	0.382	0.384	0.385	0.379	0.388	0.388	0.386	0.381	0.3896
2.00E-3	0.3927	0.387	0.389	0.392	0.395	0.384	0.401	0.4	0.396	0.388	0.403
5.00E-3	0.4174	0.403	0.409	0.417	0.412	0.395	0.437	0.432	0.425	0.405	0.438
1.00E-2	0.4555	0.429	0.441	0.453	0.462	0.415	0.488	0.48	0.47	0.433	0.492
2.00E-2	0.5226	0.477	0.497	0.521	0.536	0.451	0.581	0.566	0.549	0.484	0.584
5.00E-2	0.6819	0.595	0.637	0.679	0.705	0.544	0.778	0.764	0.727	0.608	0.796
1.00E-1	0.878	0.745	0.814	0.868	0.9	0.668	1.009	0.99	0.944	0.768	1.053
2.00E-1	1.1552	0.962	1.068	1.141	1.179	0.847	1.315	1.291	1.265	1.002	1.392
5.00E-1	1.6833	1.386	1.589	1.664	1.668	1.194	1.826	1.805	1.914	1.469	2.014
1.00E+0	2.2168	1.818	2.164	2.195	2.172	1.536	2.257	2.247	2.603	1.976	2.632
2.00E+0	2.8418	2.333	2.939	2.814	2.695	1.921	2.647	2.666	3.508	2.631	3.313
5.00E+0	3.6753	3.028	4.387	3.672	3.316	2.429	3.029	3.09	5.059	3.715	
1.00E+1	4.2056	3.48	5.774	4.225	3.67	2.734	3.204	3.33	6.361	4.605	4.699
2.00E+1	4.5766	3.801	7.314	4.62	3.903	2.966	3.308	3.414		5.406	5.172
5.00E+1	4.8464	4.037		4.916	4.071	3.075	3.43	3.509		6.159	5.583
1.00E+2	4.9449	4.122		5.026	4.154	3.134	3.618	3.66		6.483	5.72
2.00E+2	5.019	4.192		5.106	4.336	3.269	3.827	3.883		6.661	5.86
3.00E+2	5.1111	4.283		5.2	4.502	3.384	3.938	4.005		6.726	
4.00E+2	5.2236	4.386		5.315	4.621	3.466	4.016	4.088		6.767	6.103
5.00E+2	5.3294	4.477		5.422	4.708	3.526	4.076	4.151		6.803	
6.00E+2	5.4194	4.55		5.515	4.775	3.573	4.124	4.203		6.843	6.342
7.00E+2	5.4949	4.611		5.592	4.83	3.613	4.166	4.247		6.89	
7.60E+2	5.534	4.643		5.633	4.86	3.632	4.19	4.271		6.92	
8.00E+2	5.5581	4.663		5.658	4.877	3.645	4.203	4.286		6.942	6.519
9.00E+2	5.6141	4.706		5.713	4.919	3.674	4.237	4.321		7	
1.00E+3	5.6593	4.745		5.762	4.955	3.69	4.27	4.354		7.056	6.642

Values listed under each gas type are in volts (Vdc).

5 Troubleshooting –

5.1 Error Conditions

Certain events can occur that will generate an error condition for either one of the option cards installed or one of the devices connected to the *FlexRax.* Some examples of these error conditions are presented below. If you are having trouble making one of the options or devices operate, the first step in troubleshooting the problem is to press the [Messages] key displayed in the **Pressure Measurement Screen.** The 'Messages' screen will list descriptive narratives informing you of the problem, as detected by the *FlexRax.* Usually, resolving the issue is accomplished by taking action as prompted by the message in the 'Messages' screen.

5.1.1 IGR/IGE indicates OFF –

If after attempting to manually turn the IGR/IGE to ON the IGR/IGE indicates OFF (OFF in red color), the error message screen may display:

- ERROR: Message screen displays "Filament Over Voltage" error.
- CAUSE: You may see this error message if the IG cable is not connected to the IG and connected to the *FlexRax.*
- REMEDY: Ensure the IG cable is correctly connected at the IG transducer pins *and* the cable connector is securely attached to the IGR/IGE CPC connector at the back panel of the *FlexRax.* With cable securely attached to IG transducer and controller, perform the following key entry sequence to clear the error: [Menu] ⇨ [IGR/IGE] ⇨ [IGR [n]] ⇨ [Clear Error] ⇨

After pressing the 'OK' key, you will be returned to the menu that will allow you to manually turn ON the IGR/IGE.

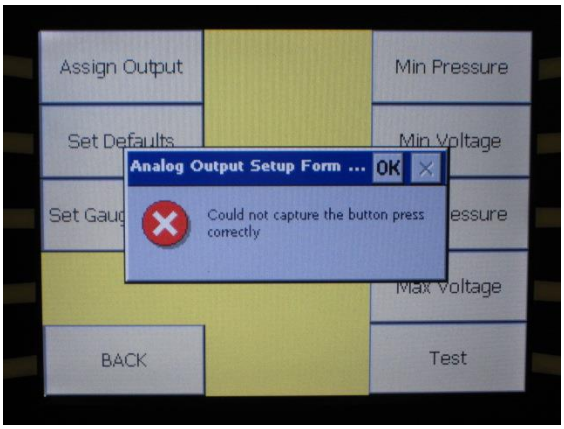
The above example illustrates the key entry sequence you will follow to clear an error condition that is preventing a device from operating as you desire. Various error conditions may exist for the multiple devices that you may be operating with the *FlexRax*. In the case where an error is preventing the operation of the pressure measurement device, you will note that certain function key-designator boxes will be grayed-out indicating that the function is not available. If there is an existing error condition, you must first remedy the condition causing the error then you must clear the error in the *FlexRax* before you will be allowed to resume operation of the device.

5.1.2 IGM [n] is OFF –

IGM [n] indication is OFF in the pressure measurement screen. You have followed the menu sequence to manually turn the IGM ON. At the screen to select the IGM you wish to turn ON, the IGM key-indicator is grayed-out. Returning to the pressure measurement screen, you press the 'Messages' key and see "IGM [n] Sensor Not Detected" displayed.

- ERROR: Message screen displays "**IGM [n] Sensor Not Detected**" error.
- CAUSE: Cable is not connected to the IGM400 *Hornet* and *FlexRax.*
- REMEDY: Be certain to fully engage and secure the IGM cable to the D-subminiature connector on the IGM400 panel *and* ensure the mini-DIN connector end of the IGM cable is connected to the mating connector on the IGM/CG option card you intend to use for control of the IGM.

5.1.3 Operating System ERROR –



An operating system error is displayed similar to shown above. Although unlikely, there could be a set of conditions where the operating system utilized in the *FlexRax* issues an error condition causing a message box to overwrite on the display as shown above. These message boxes will be particular to the type of error detected by the operating system. When errors of this type occur, it is recommended that you note the text displayed in the heading of the error box and the actual wording of the displayed message. In the above example, you would note that the heading information is: "Analog Output Setup Form…" and the specific wording of the error message is "Could not capture the button press correctly". Send this information to Support@instrutechinc.com for further action by InstruTech to remedy the conditions that cause these errors.

- REMEDY: When you see an error box of the form depicted above, you will be required to cycle the AC Mains power to reset the *FlexRax* and resume operation.

5.1.4 Problems with connected Devices –

Refer to the Troubleshooting Section of the User Manual for an external device exhibiting peculiar operating characteristics. In many situations, it is advised that you swap the suspect device/connecting cable(s) with a known good device to determine if the problem is with either the device or the cable.

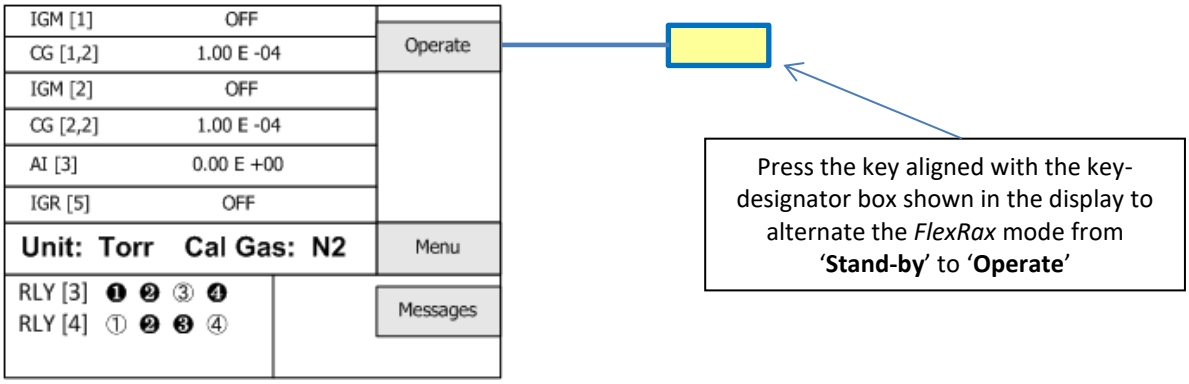
When using a modular design type device such as the IGM400 *Hornet*, it is important to remember that there are two parts of the module: the electronics portion and the transducer portion. If a problem exists with operating a connected module, it is possible to isolate the module problem to either half by replacing the transducer with a new or known good transducer. Before doing this, remember that the hot-cathode IG transducer in the IGM is designed with two filaments. Be sure to switch to the back-up filament and re-try starting the emission current before assuming that the IG transducer needs to be replaced.

When using a convection gauge transducer and the pressure readings for that device are abnormal, the most likely causes of incorrect readings with the convection gauge are:

- Contamination/foreign substance(s) on the sensor wire
- Chemical attack/reaction of process related chemistries with the transducer sensor wire
- Gas composition includes a gas species that influences the "calibration" of the device

5.1.5 Unable to Access Setup Functions / Operate Ion Gauge Devices –

In the event that you find you are either unable to gain access to certain setup functions or you cannot perform operation of the ion gauge devices, be certain that you have invoked the '**Operate**' mode. In the main **Pressure Measurement Screen** you will see a key-designator box in the upper rightmost corner of the display. This key-designator box indicates that the *FlexRax* is in either the '**Stand-by**' or the '**Operate**' mode. If you have the control set for '**Stand-by'**, you will not be allowed to activate or turn ON the ion gauge devices. You may not be allowed access to certain setup parameters when you are in the '**Stand-by**' mode.



Refer to section ***3.6.1.2.3*** ***Operation of the IGM –*** for more information related to '**Stand-by**' / '**Operate**'

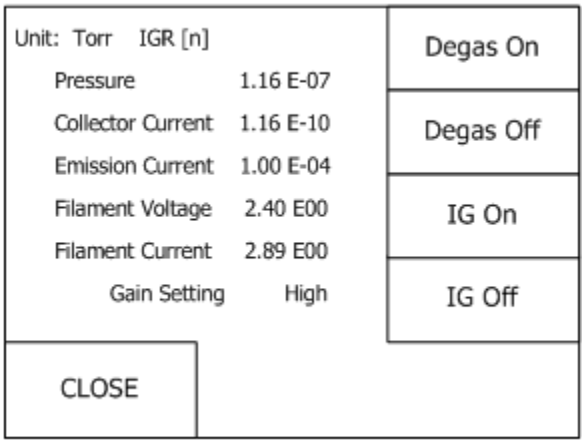
5.1.6 View R&D - Ion Gauge Diagnostic Display

Over time, the hot cathode (filament) of the ionization gauge may degrade. Coated iridium filaments are made using thorium or yttrium oxide to lower the work function of the heated wire material and enable substantial emission of electrons from the hot cathode. These electrons are accelerated in an electric field toward the grid structure of the B-A ionization gauge device. The electron emission is commonly referred to as the 'emission current'. As the emission current electrons orbit within the electric field formed by the bias voltages applied to the grid, collector and filament electrodes, the molecules that the gas is comprised of will be ionized by these energetic electrons.

The positive ions that are created within the grid structure are captured in another electric potential field created by the grid structure (at +180 Vdc with respect to ground potential) and the collector wire (at zero volts, i.e., ground potential). In simple terms, the ions collected by the collector electrode (a small diameter wire within the grid electrode structure) are measured with an electrometer circuit connected to the collector. The amount of ion current measured is directly proportional to the density of the gas within the ion gauge transducer. This ion current is commonly referred to as the 'collector current'.

The collector current measured, being directly proportional to the gas density inside the ion gauge transducer enclosure, is therefore a measure of the pressure inside the ion gauge transducer and, if the ion gauge transducer is exposed to the vacuum chamber, vessel or line, an approximate measure of the pressure inside the vacuum chamber.

The *FlexRax* provides a hot-cathode ion gauge transducer diagnostic display screen that allows you to monitor the measurements of the critical electrical parameters used for measurement of very low pressures, i.e., high vacuum, made by the ionization gauge. The R&D display screen is shown below:



EXAMPLE
R&D Display of Critical Hot-Cathode Ion Gauge Measurement Parameters

To access this screen, perform the following key entry sequence: Menu ⇨ IGR/IGE ⇨ IGR [n] ⇨ View R&D ⇨

You will notice that the Unit of Measure (sometimes referred to as the 'engineering units') will be displayed along with the name of the particular IG device you chose when performing the above example key entry sequence. You may choose to display the R&D parameters for the IGR, IGE or IGM ionization gauge devices. In addition to the parameters measured, you will have immediate access to turning DEGAS on or off as well as control of the IG ON/OFF function.

The Pressure, Collector Current and Emission Current are indications that the ionization gauge transducer is operating and pressure (vacuum) is being measured. In the above example, most of the critical, measured quantities required for the calculation of measured pressure are displayed. For a typical I^2R Degas-type B-A IG, the sensitivity of this type of transducer is 10 $Torr^{-1}$. From previous discussion, we know that the relationship of these parameters leads to the calculation of pressure given by $P = I_c \bullet (I_e \bullet S)^{-1}$ where I_c is the Collector Current, I_e is the Emission Current and S is the sensitivity of the specific IG transducer.

The pressure indication may be checked by using the displayed values and calculating the pressure as indicated by the specific B-A IG you are using to measure that pressure.

Other important information such as Filament Voltage and Filament Current are given in the R&D display screen. These values vary widely dependent upon filament design type, material used for constructing the filament, filament condition, length of IG connection cable and operating emission current. The product of the filament voltage and current is the power dissipation (V•A) required to maintain the set emission current. The interpretation of these displayed values is a qualitative measure. The values will change over time dependent upon the pressure, filament coating condition and possibly even surface properties of the grid electrode. It is a

good practice to make note of these values at initial installation and from time-to-time during the operating lifetime of the B-A IG.

A new IGM *Hornet* may operate at 100 µA emission current with only 3 to 4 watts of power required (e.g., 1.5V @ 2.0A). By increasing the emission current to 4 mA, the power requirement may increase to 4 or 5 watts (e.g., 2.0V @ 2 to 2.5 A). Again, the values mentioned here are representative; the actual values you may see for the IG you are using will be different and will vary over time and from device to device. In general, keeping a record of the filament heating power (given by the Filament Voltage and Filament Current readings) will aid you in monitoring the condition of your B-A IG filaments over time and, perhaps, give you an indication of when to schedule replacement of either the device or the filament assembly (if filament assembly replacement is possible).

In cases where the IG does not turn ON or does not stay in the ON condition after you have made sure that the pressure is below the maximum permissible pressure for the emission current setting you have chosen, you will be able to monitor the values displayed in the **R&D** screen and determine if the turn ON / stay ON trouble is related to filament condition. There are maximum operating levels for filament voltage and current; if either of these is exceeded the *FlexRax* control circuitry will sense the condition and force an OFF condition.

The filament heating power (V•A) for the IGR and IGE type devices may be higher than the values used in the above discussion for the miniature ionization gauge (transducer) used in the IGM400 *Hornet.* In the example **R&D** screen display above, with the emission current operating at 100 µA, you will note that the filament voltage and current are 2.4V and 2.89A, respectively. This equates to about 7 watts (V•A) of filament heating power to generate and maintain the 100 µA electron emission current. Turning DEGAS ON will change the filament heating power; changing the electron emission current requirement will also change the filament heating power requirement.

For IG devices connected to the *FlexRax* via cables that deliver the operating voltage and current to the transducer, the Filament voltage displayed in the **R&D** screen is the filament voltage at the IGR/IGE Option Card. There is always some voltage drop (an I•R drop) in the cable due to the resistance of the wires connected from the power supply to the filament (hot cathode) of the B-A IG device.

The following table (***R & D (Research) Ion Gauge Diagnostic Display***) is intended to assist you in using the information provided in this display as a means to ascertain if the ion gauge transducer is performing as expected under your vacuum chamber operating conditions. There are various causes of trouble that at times may make it difficult to use a single measurement parameter as an indicator of what the problem is. In general, if you have monitored and recorded the values displayed in the R & D (Research) screen over time, you may be able to detect a pattern or trend that, if correlated to a particular failure mode, may prove to be a valuable indication of probable cause.

R & D (Research) Ion Gauge Diagnostic Display

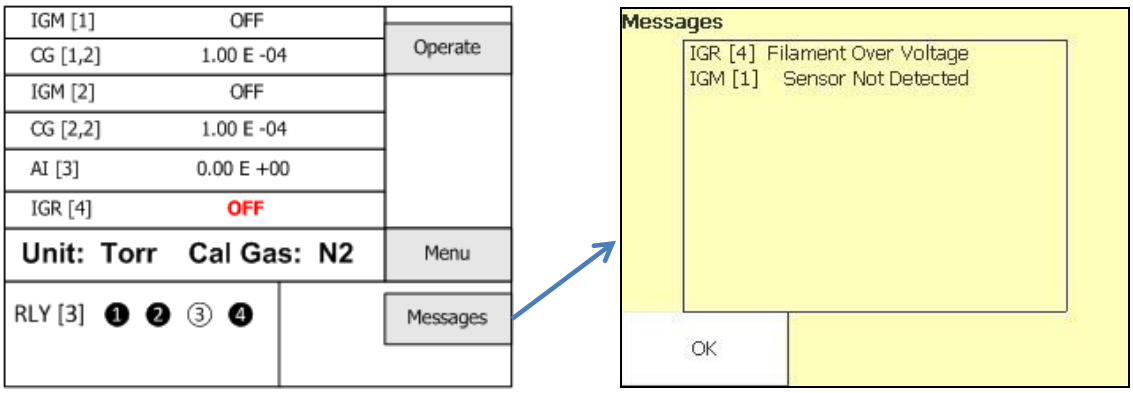
Indication	*Possible Cause*	*Possible Solution*
Pressure measurement is too low (compared to known pressure for vacuum system chamber)	Sensor Contamination - Collector current is below the calculated parameter for the actual, true pressure in chamber. IGR or IGE Electrometer defective IGM /CCM Electrometer defective	Determine source of contamination - Replace the Ion gauge sensor tube. Replace IGR or IGE option card Replace IGM400 electronics
Pressure measurement is too high – Overpressure	The calculated pressure is greater than maximum setting for emission current. System pressure too high	Change hot cathode B-A IG to 100uA emission current which will allow operation at higher pressures Reduce chamber pressure
Emission Current for hot cathode B-A IG measurement is not at programmed setting	The desired emission current (I_e) could not be established Gauge contamination, possible coating on filament or grid surfaces System pressure too high	Switch to 4 mA emission current and attempt repeated filament starts to clean electrodes If using dual filaments switch to second filament or replace ion gauge sensor Reduce pressure
Hot Cathode IG Filament voltage values are present for several seconds immediately after turning IG ON, but then the values are zero	Filament is contaminated or filament has reached end-of-useful operating life for required emission current setting	Switch emission current setting from initial setting and re-start the IG; make several attempts to establish emission current at both 100 µA and 4 mA. If using dual filaments switch to second filament or replace ion gauge sensor
All parameters in the R&D screen are zero after IG turn ON is attempted	Failed electronics	Replace IGR or IGE option card Replace IGM400 electronics
IGM400 *Hornet* filament voltage[26] is greater than 1.7 V and filament current is greater than 2.5 A with emission current = 100 µA	Filament nearing end-of-useful-operating-life	If using dual filaments switch to second filament or replace ion gauge sensor
IGM400 *Hornet* filament voltage is greater than 2.3 V and filament current is greater than 2.7 A with emission current = 4 mA	Filament nearing end-of-useful-operating-life	*Hornet* may be operated at either 100 µA or 4 mA emission current setting. If trouble with maintaining 4 mA emission current (Ie) persists, switch to 100 µA emission current.

[26] The values of filament voltage and current presented here are approximate voltages that one may see in the Research screen for the IGM400 *Hornet*. The representative, average values used in this table may vary depending on the condition of the filament and the vacuum chamber environment. For example, you may see a reading of 2.0 V at 100 µA emission current with a corresponding filament drive current of 2.1 A. This doesn't mean that because the voltage is higher than the value listed (1.7 V) above that there is a problem with the IG. The readings taken should be viewed with the notion that there may be an indication of reaching end-of-useful filament lifetime if the power required to sustain emission current continues to increase over time. These representative filament voltages and currents will be significantly higher for the glass-enclosed and nude B-A Ion Gauges.

5.2 FlexRax Exception Indications

An *Exception* happens when the *FlexRax* operating system issues a message to the "Messages" screen or the pressure indication is either out-of-range or indicating something other than expected pressure.

Refer to the **Pressure Measurement Screen *Exceptions*** table below for possible indications you may see on the *FlexRax* Pressure Measurement Screen (listed under the Exception column). If the *Solution* refers you to the 'Messages' screen, refer to the table titled **Messages Screen *Exceptions*** following the pressure measurement screen exceptions table.



Pressure Measurement Screen **Messages Screen**

Your *FlexRax* **Pressure Measurement Screen** (an example screen display is shown above) may indicate a pressure measurement reading of **OFF** (OFF in red color letters). The example M**essages** screen (press the key aligned with the key-designator box labeled 'Messages' to see) indicates that a 'Filament Over Voltage' error occurred (in this case for IGR [4]). You will find the **Pressure Measurement Screen** *Exception* for the **OFF** condition on an IG provides a *Cause* and a *Solution* (see table below). The *Solution,* in this case, refers the user to the 'Messages' screen. Go to the Messages Screen Exceptions table following the Pressure Measurement Screen *Exceptions* table below and find the 'Filament Over Voltage' entry in the Exception column.

Pressure Measurement Screen *Exceptions*

The *Exceptions* are the possible indications you may see in the displayed Pressure Measure Screen.

Exception	*Cause*	*Solution*
IGM, IGR or IGE indicates "**OFF**" (in red color)	An abnormal condition caused the ion gauge to turn off	Review 'Messages' screen to determine specific cause
CG indication is '-.---'	An abnormal condition prevents pressure reading	Review 'Messages' screen to determine specific cause
AI indication is '-.---'	An abnormal condition prevents pressure reading.	Review 'Messages' screen to determine specific cause
CG indicates '1.10E+03'	Pressure is above measurement range of the CG.	Reduce vessel pressure
AI indicates '1.30E+02' with, for example, a 100 Torr full-scale CDG connected	Pressure is above measurement range of the CDG[27] Other CDGs will indicate a maximum of 30% over-range except the 1000 Torr head which can indicate 10% over-range	Reduce vessel pressure
IGM, IGR or IGE indicates 'STARTING'	IG is turned ON but not yet indicating pressure	Wait for stabilization of transducer - Pressure reading will appear after required start period

NOTICE Various error conditions may exist for the multiple devices that you may be operating with the *FlexRax*. If an error is preventing the operation of the pressure measurement device, you will note that certain function key-designator boxes will be grayed-out indicating that the function is not available. If there is an existing error condition listed for the device in the 'Messages' screen, you must first remedy the condition causing the error then you must clear the error in the *FlexRax* before you will be allowed to resume operation of the Device. See section 5.1.1 for an example of clearing an error condition.

[27] See manufacturer's specification for full scale (F.S.) measurement capability of your Capacitance Diaphragm Gauge (CDG). The CDG may allow measurement above the F.S. range of the device.

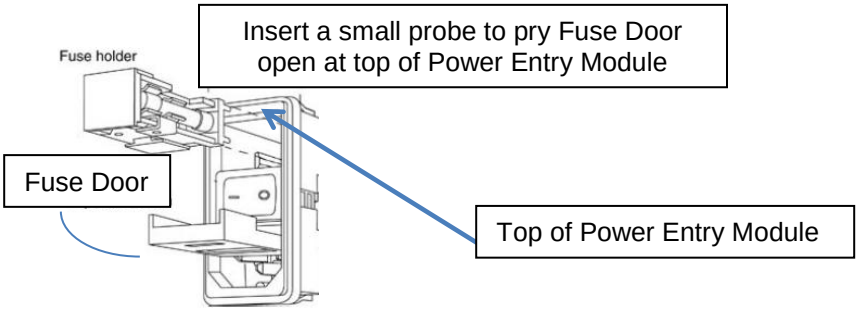
Messages Screen *Exceptions*

The *Exceptions* listed here are possible conditions that will generate a message in the Messages Screen.

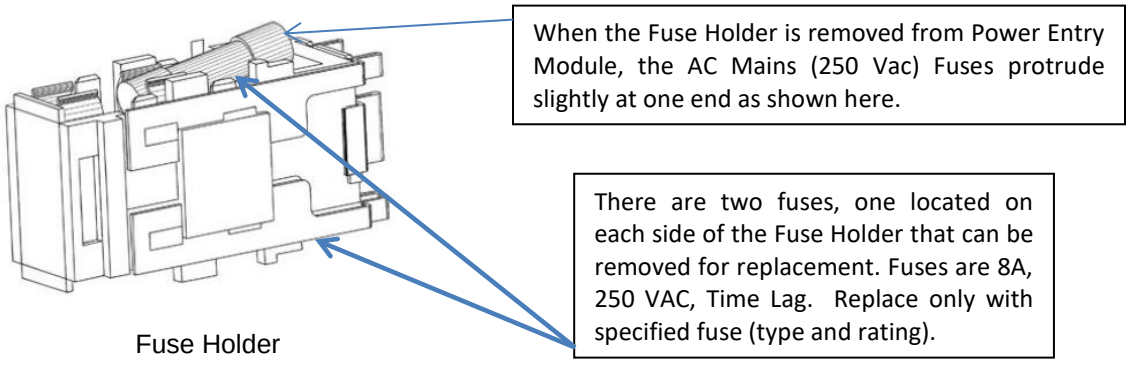
Exception	*Cause*	*Solution*
CG [n,m] 'Sensor Not Detected'	CG is not plugged into cable, cable not plugged into *FlexRax or* CG sensor wire is broken	Connect CG or cable – replace CG transducer is sensor wire is broken
Slot [n] 'Option Card Not Detected'	Option card not correctly seated Option card failure	Reseat Option card Replace Option Card
IGM [n] or IGR [n] or IGE [n] Emission Current Failure	Ion gauge unable to establish electron current	Check operation with backup filament Replace Ion Gauge Transducer
IGM [n] or IGR [n] or IGE [n] 'Filament 1(or 2) is Open'	Defective ion gauge filament	Switch to backup filament or replace ion gauge if both filaments are open
IGM [n] or IGR [n] or IGE [n] 'Degas failed'	Pressure burst – system pressure increases during DEGAS operation due to gas evolution from surrounding surfaces	Allow chamber pressure to drop to lowest attainable pressure and restart DEGAS operation
IGM [n] or IGR [n] or IGE [n] 'Over-pressure'	Pressure higher than Over Pressure setpoint	Reduce pressure before restarting ion gauge
IGM [n] or IGR [n] or IGE [n] 'Ion Current Failure'	No collector current	Connect collector coax cable to BNC connector (on back panel of FlexRax) and collector electrode on IG or replace ion gauge
IGR [n] or IGE [n] 'Filament Volt Failure'	Filament voltage failed to reach normal level	Replace cable or ion gauge
IGR [n] or IGE [n] 'Filament Over Voltage'	Filament voltage is too high	Verify that filament is connected (check cable connections); If using a single filament IG, be sure that Filament 1 is selected for operation; Replace ion gauge option card
AI [n] 'Device Over-pressure'	Voltage from external device higher than expected for pressure range of device	Reduce external device voltage Connect Device cable
IGM [n] 'Sensor Not Detected'	No communication to ion gauge module (IGM)	Connect IGM cable
IGM [n] 'Filament Over Power'	Filament voltage failed to reach normal level	See section 5.1.6 – If filaments in IG transducer indicate end-of-life condition, replace IG4 transducer; Replace IGM
CG [n,m] 'Over Pressure Failure'	CG pressure is higher than 1000 Torr	Reduce vessel pressure
No Option cards were found 'Comm Failure'	No communication with option card	Install option cards If option cards exist, ensure they are seated Replace *FlexRax* controller

5.3 AC Mains Fuse Replacement

In the unlikely event that your *FlexRax* AC Mains fuse(s) open due to an overload condition, you may replace one or both of the fuses located inside the power entry module on the back panel of the controller. Use care and gently open the fuse holder cover (a door that swings down as shown in the picture below) to gain access to the fuse holder.



Using the small probe that you used to open the Fuse Door, gently pry the Fuse Holder away from the Power Entry Module (the Fuse Holder location is shown in the picture above).

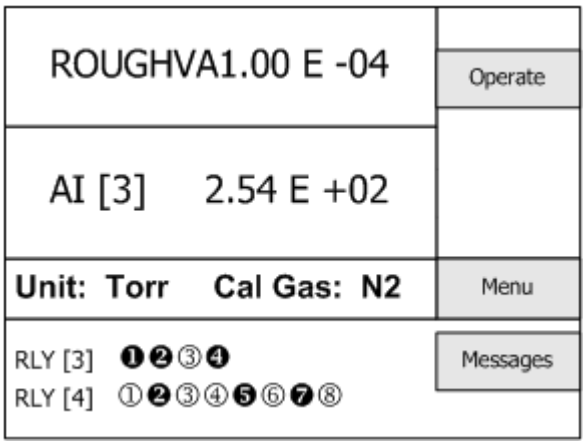


You will notice that the NEMA 5-15P/IEC 60321-1 C14 Power Cord must be disconnected from the *FlexRax* before you will be allowed to open the door that covers the access to remove the fuse holder. The two fuses protrude slightly from the fuse holder when the fuse is removed from the Power Entry module. This is by design to ensure that the end of the fuse makes contact with the terminals inside the module when the fuse holder is inserted.

⚠ **WARNING!** To prevent risk of fire and possible electric shock hazard, replace the two AC Mains fuses with type and rating specified on product nameplate. Do not substitute with other rated types or bypass the intended fusing method. Use only fuses that are recognized by a nationally recognized testing laboratory to meet IEC, CSA, UL or similar agency related standards for fire protection and safety.

5.4 Displayed Device Name characters are missing

As the number of displayed pressure readings is decreased, the size of the font used to display the device pressure measurement is increased. This will result in the possibility of some names/information being truncated in the display. An example Pressure Measurement Screen where truncation of the programmed device name occurred is shown here to illustrate:



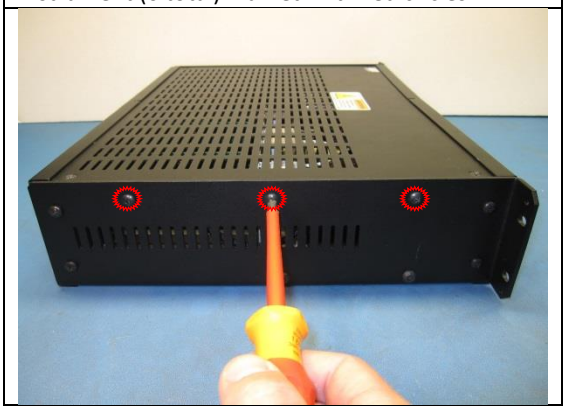
Note that the 'C' character in 'ROUGHVAC' is missing in the displayed device pressure reading. Choose device names (if not using the default names provided) that are meaningful to your application yet do not appear misrepresented in the Pressure Measurement Screen of your *FlexRax.*

6 Replacing or adding option cards in the field

The type and number of gauges operated by the controller depends on user specified option cards installed at the factory. The user however can replace or add additional option cards in the field to expand the capabilities of the instrument. See the following information for steps necessary to perform such tasks.

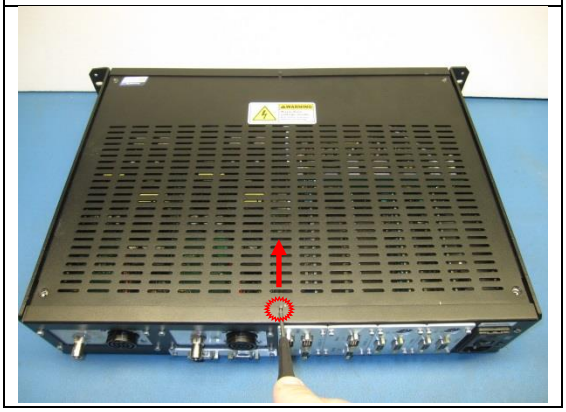
⚠ **DANGER!** When servicing the unit, **disconnect** AC Mains power to the unit and wait a minimum of 5 minutes before removing the instrument enclosure covers or any option card from the device. **DO NOT** apply AC Mains power to the unit until all option card locations and enclosure covers are securely in place. Failure to do so could result in equipment damage, death or serious injury. For best viewing of this section see User Manual online at www.instrutechinc.com.

1. Remove top three screws of both sides of Instrument (6 total) marked with red circles.



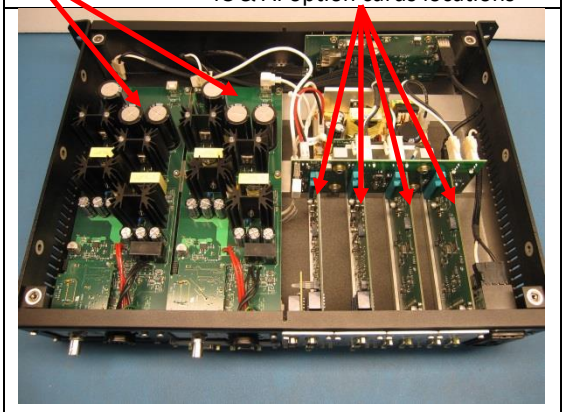
2. Remove all four screws of the top cover marked with red circles.

3. Slide forward top cover with a flat head screw driver inserted in slot shown below.

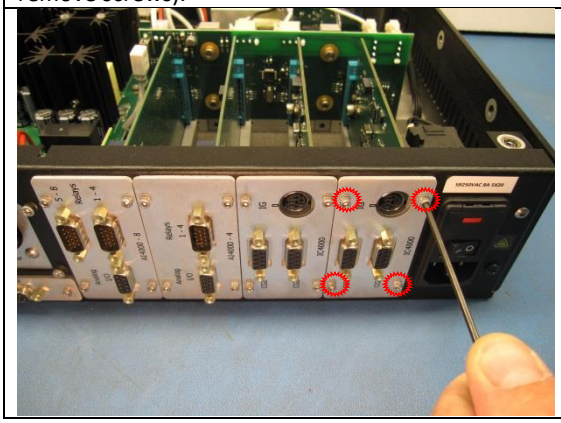


4. Lift top cover and remove.

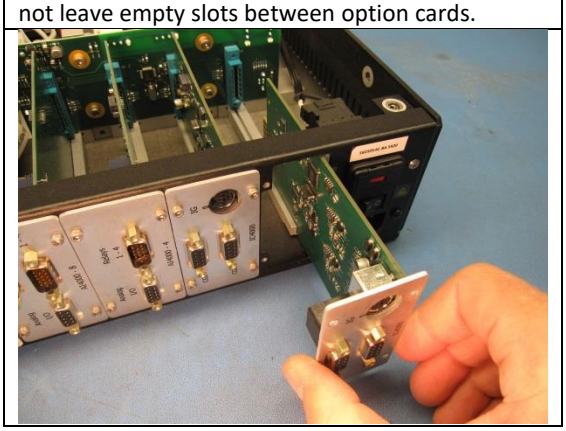
5. A typical configuration is shown below. Your Instrument may not have all cards installed.
IR / IE card Locations
IC & AI option cards locations



6. Remove four socket head cap screws marked with red circles in order to add or replace a specific IC and/or AI option card (Use a 3/32 in. Hex key to remove screws).



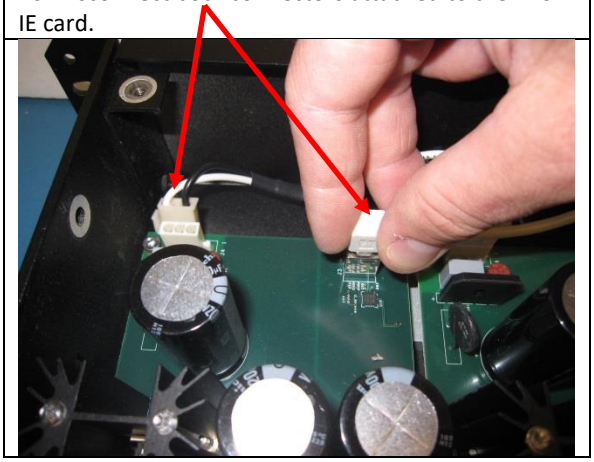
7. Slide the option card out of the enclosure. Add or replace card. When facing the rear panel, always populate option cards from right to left. Do not leave empty slots between option cards.



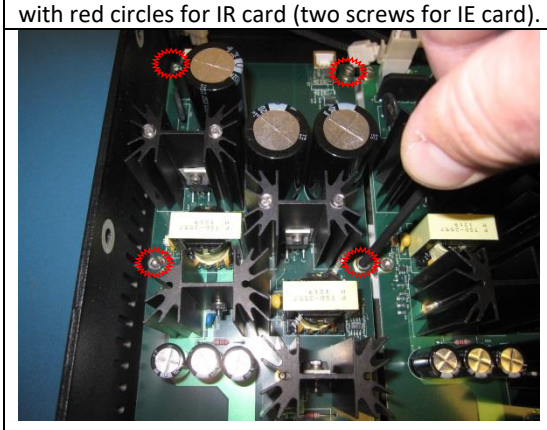
8. Remove four socket head cap screws marked with red circles in order to add or replace an IR or IE card (Use 7/64 in. Hex key to remove screws).

9. Connectors attached to IR or IE card shown below.

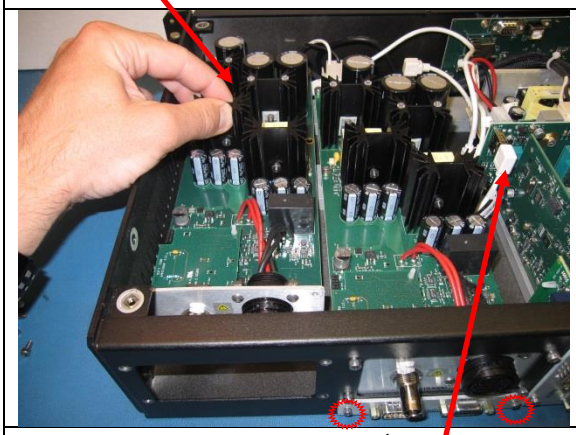
10. Disconnect both connectors attached to the IR or IE card.



11. Remove four socket head cap screws marked with red circles for IR card (two screws for IE card).



12. Lift and replace IR or IE card.



13. For the CM option card, use a 3/32 in. Hex key to remove two socket head cap screws marked with red circles. Route the white cable connector attached to the CM card under the IR or IE card as shown above.

7 Factory Service and Support

If you need help setting up, operating, or troubleshooting your *FlexRax* Multi-Gauge Controller, you are welcome to call us during normal business hours (8:00am to 5:00pm Mountain time) Monday through Friday, at +1-303-651-0551 or E-mail us at support@instrutechinc.com

If it becomes necessary to return the controller to InstruTech for service or calibration, please call or E-mail us for a return authorization number. For the safety of our employees, you must download a material disclosure form from our website at www.instrutechinc.com Please use this form to provide a history of the gauge detailing what gases have been used. We cannot accept returns of vacuum measurement products that have been exposed to hazardous materials.

8 Warranty

SELLER warrants that its products are free of defects in workmanship and material and fit for the uses set forth in SELLER's catalog or product specifications, under the normal use and service for which they are intended.

The entire warranty obligation of SELLER is for the repair or replacement, at SELLER's option, of products or parts (examination of which shall disclose to SELLER's satisfaction that it is defective) returned, to SELLER's plant, properly identified within 3 years (unless otherwise noted) after the date of shipment from InstruTech Plant. BUYER must obtain the approval of SELLER and a return authorization number prior to shipment.

Alteration or removal of serial numbers or other identification marks renders this warranty void. The warranty does not apply to products or components which have been abused, altered, operated outside of the environmental specifications of the product, improperly handled or installed, or units which have not been operated in accordance with SELLER's instructions. Furthermore the warranty does not apply to products that have been contaminated, or when the product or part is damaged during the warranty period due to causes other than ordinary wear and tear to the product including, but not limited to, accidents, transportation, neglect, misuse, use of the product for any purpose other than that for which it was designed.

THIS WARRANTY IS EXCLUSIVE AND IN LIEU OF ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. THIS WARRANTY EXTENDS ONLY IN FAVOR OF THE ORIGINAL BUYER. THE BUYER'S SOLE REMEDY SHALL BE THE REPAIR OR REPLACEMENT, AS IS EXPRESSLY PROVIDED HEREIN, OF ANY WARRANTED DEFECTIVE PRODUCT OR PART, AND UNDER NO CIRCUMSTANCE SHALL SELLER BE LIABLE TO BUYER OR ANYONE ELSE FOR ANY CONSEQUENTIAL DAMAGES TO PERSONS OR PROPERTY, FOR INCIDENTAL DAMAGES OR LOSS OF TIME, FOR ANTICPATED OR LOST PROFITS, OR ANY OTHER LOSS INCURRED BY THE BUYER RELATED TO THE PRODUCT COVERED BY THIS WARRANTY. THIS EXCLUSIVE REMEDY SHALL NOT BE DEEMED TO HAVE FAILED OF ITS ESSENTIAL PURPOSE SO LONG AS SELLER IS WILLING AND ABLE TO REPAIR OR REPLACE DEFECTIVE PARTS IN THE PRESCRIBED MANNER. THIS LIMITED WARRANTY MAY NOT BE MODIFIED BY SELLER UNLESS SUCH MODIFICATION OR WAIVER IS IN WRITING, EXECUTED BY AN AUTHORIZED OFFICER OF SELLER.

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