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.

⚠ WARNING

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.

⚠ CAUTION

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.

NOTICE

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

⚡ SHOCK HAZARD

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

Table of Contents

1   Introduction / General Information

1.1   Description

The *FlexRax™4000* is a multi-gauge rack mount vacuum gauge controller designed specifically to operate either the glass-enclosed or nude Bayard-Alpert (B-A) ionization gauges (IG) including InstruTech's BA601, BA602 and BA603 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.

FlexRax can operate up to 10 vacuum gauges simultaneously as listed below:
● Up to a total of four ionization gauges (IG) configurable for:
    A) Up to two classic size BA600 series Bayard-Alpert (B-A) glass or nude ionization gauges or other equivalent brands of glass/nude B-A IG.
    B) Up to two InstruTech® IGM400 hot cathode or two CCM500 cold cathode IG modules

● Up to four CVG101 convection gauges (CG)

● Up to two analog input signals from other devices such as capacitance diaphragm gauges (CDG) or InstruTech *CDM900, CVM201, CVM211, IGM401, CCM50, CCM502* and *PCM301* gauge modules

Compatible Vacuum Gauges

| BA601 | BA602 | BA603 | IGM400 | CCM500 | CVG101 |

The *FlexRax* is offered as an industry standard 19-inch wide, 2U high, rack-mountable design. Easy to read LCD with backlighting provides sharp contrast with wide viewing angle. The instrument can be configured to display up to 6 gauges in a single screen or assign any number of gauges to various screens for auto-scrolling of display. The state of all setpoint relays and engineering units of measure will be displayed on the main screen. Filament operation including filament current, filament voltage, emission current and ion current can be displayed in real time to allow monitoring of filament condition. The system can be personalized by assigning specific names to individual gauges or use the factory default gauge symbols. Error messages will be displayed for all fault conditions.

High efficiency power supply design and effective thermal management techniques are used to enable operation of the *FlexRax* without the need for air movement devices such as troublesome fans often required in even single ionization gauge power supplies. Filament switching control from the *FlexRax* combined with capability to operate two conventional B-A ionization gauges *simultaneously,* offers the user low cost of ownership and unparalleled ease of use.

The number and types of sensors operated is dependent on the option cards that are installed in the locations available in the back side of 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.

Option card labeled IR4000 operates a resistive degas, sometimes referred to as I^{2}R Degas, hot filament nude or glass-enclosed B-A ion gauge (IG - InstruTech BA602/BA603 or similar).

 or

Option card labeled IE4000 operates an electron bombardment or 'EB' Degas hot filament nude UHV B-A (IG - InstruTech BA601 or similar).

Option card labeled IC4000 operates either one InstruTech IGM400 hot cathode IG or one CCM500 cold cathode IG module and two InstruTech CVG101 *Worker Bee* convection gauges (CG).

Option cards labeled AI4000-4 or AI4000-8 provide setpoint relays and analog outputs. Each option card (two maximum) can also 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.
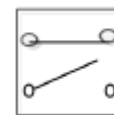
Option card labeled CM4000 provides RS485 or RS232 serial communications.

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

controller measurement range (vacuum gauge dependent)	BA601 Nude EB degas B-A UHV ion gauge: 2×10^{-11} to 1×10^{-3} Torr BA602/603 Nude/Glass I^2R Degas B-A ion gauge: 4×10^{-10} to 1×10^{-3} Torr InstruTech IGM400 hot cathode ionization gauge: 1×10^{-9} to 5×10^{-2} Torr InstruTech CCM500 cold cathode ionization gauge: 1×10^{-9} to 1×10^{-2} Torr convection gauges: 1×10^{-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	BA601: 40 W electron bombardment (EB), BA602/603: nominal 40 W resistive (I^2R), IGM400: 3 W EB programmable duration - permissible at measured pressure < 5×10^{-5} Torr
overpressure protection	turns off ion gauge filament/sensor at the following default settings: BA601, BA602, BA603: 1×10^{-3} Torr at 100 µA emission current, 5×10^{-4} Torr at 4 mA emission current, 1×10^{-4} Torr at 10 mA emission current IGM400 hot cathode: 5×10^{-2} Torr at 100 µA and 1×10^{-3} Torr at 4 mA emission current CCM500 cold cathode: 1×10^{-2} Torr
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 gauge modules CDM900, CVM201, CVM211, IGM401, CCM501, CCM502, PCM301. 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)[1]	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 ^{o}C storage; -40 to + 70 ^{o}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 (gauges) that you intend to use with the *FlexRax*.

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[1] The *FlexRax* 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*

Option Card selection   Complete Catalog Number: **FLX4000 -**   # -   # -   # -   # -   # - # - #

Card slot 1
IC = IC4000 card operates 2 convection and 1 IGM400 or CCM500 ion gauge   IC
AI4 = AI4000-4 card provides 4 setpoint relays, 4 analog outputs, 1 analog input   AI4
AI8 = AI4000-8 card provides 8 setpoint relays, 4 analog outputs, 1 analog input   AI8
X = None   X

Card slot 2
Same options as listed for slot 1 above. Select one of the following: IC, AI4, AI8 or X

Card slot 3
AI4 = AI4000-4 card provides 4 setpoint relays, 4 analog outputs, 1 analog input   AI4
AI8 = AI4000-8 card provides 8 setpoint relays, 4 analog outputs, 1 analog input   AI8
X = None   X

Card slot 4
Same options as listed for slot 3 above. Select one of the following: AI4, AI8 or X

Card slot 5
IR = IR4000 card operates one I^2R degas B-A ion gauge   IR
IE = IE4000 card operates one EB Degas B-A ion gauge   IE
X = None   X

Card slot 6
IR = IR4000 card operates one I^2R Degas B-A ion gauge   IR
IE = IE4000 card operates one EB Degas B-A ion gauge   IE
X= None   X

Card slot 7
CM = CM4000 card provides RS232/485 serial communication   CM
X = None   X

* Maximum of two IC (IC4000) and two AI4 (AI4000-4) or AI8 (AI4000-8) option cards per *FlexRax* controller is possible.

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

1.4   FlexRax Cable Assemblies for Gauges

BA601 and BA602 Nude IG Cable[2]

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[3]

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[4] 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	

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

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.**

$$\boxed{\text{⚠ WARNING}}$$

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 back 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 1.00×10^{-3} Torr at 4 mA emission current or 5.00×10^{-2} Torr at 100 µA emission current causing the IG to turn off.
- When using the BA600 series glass or nude B-A ion gauge or equivalent, the pressure exceeds 5.00×10^{-4} Torr at 4 mA emission current, 1.00×10^{-4} Torr at 10 mA emission current or 1.00×10^{-3} Torr (default; may be set to 1.00×10^{-2} Torr max.) at 100 µA emission current causing the IG to turn off.
- The pressure exceeds 1.00×10^{-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 3.00×10^{-4} Torr during Degas for the IGM400.
- The pressure exceeds 1.00×10^{-4} Torr during Degas for the BA600 series glass/nude IG 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 5.00×10^{-5} Torr before attempting to initiate Degas of the Series 600 glass/nude B-A IG and IGM400 ion gauge module.

Only use power from the *FlexRax* controller to power the IGM400 hot cathode ion gauge module, CCM500 cold cathode module and the CVG101 convection gauge. All power for the Series 600 B-A glass/nude IG (or similar) is provided by the 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 gauges 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 x 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 - Vacuum Gauges

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   Installation

3.1   *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 IR4000 or IE4000 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)
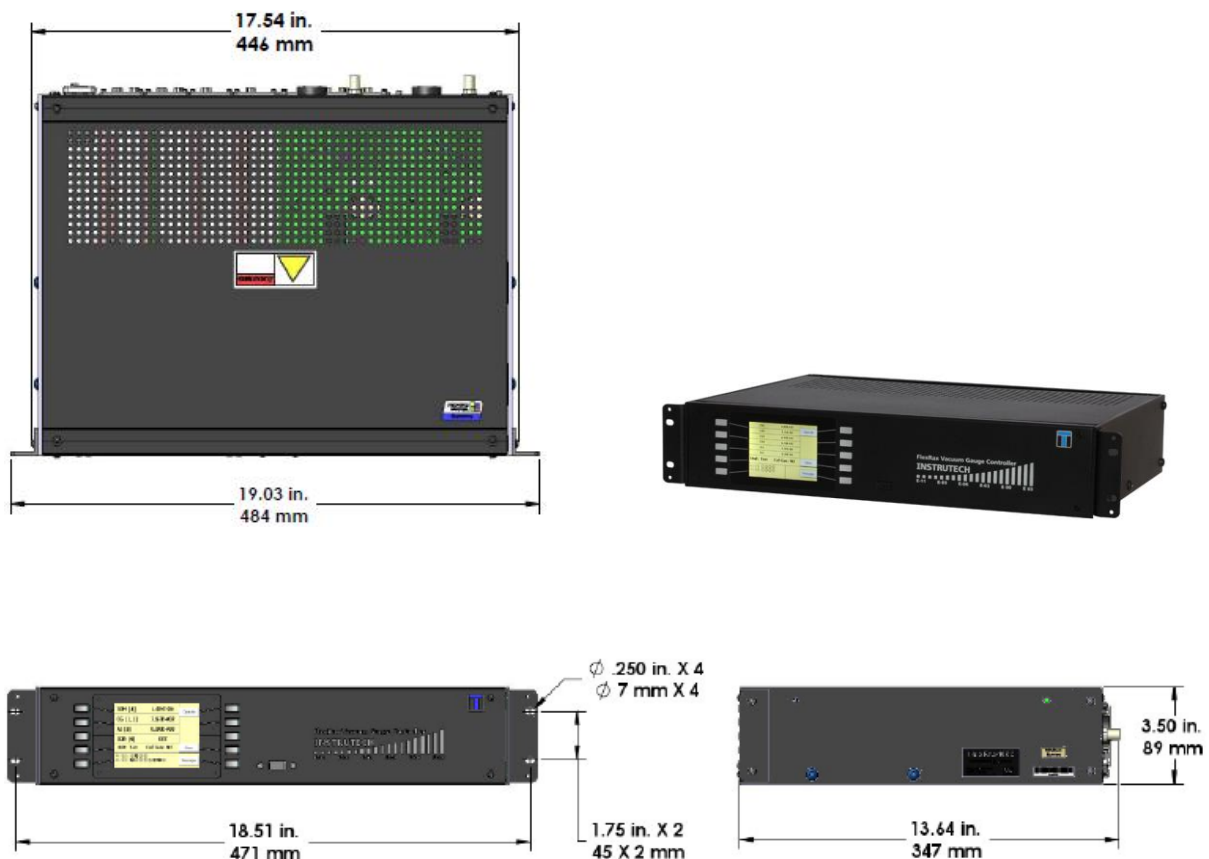
FlexRax **- Front Panel**

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 and setup, visual indications of pressure measurements, setpoint relay status and mode of operation.

FlexRax **- Back Panel**

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

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.

3.2   Mechanical Installation - Ionization Gauges

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

| IGM400 | CCM500 | BA601 | BA602 | BA603 |

Mount the ion 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 ion gauge too close to a gas source inlet may also cause measurement and control instability.

The ion 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 ion gauge where it will be subjected to excessive vibration. Vibrations may cause unstable readings, measurement errors and possible mechanical stress to components in the ion gauge.

Shield the ion 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).

3.3   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
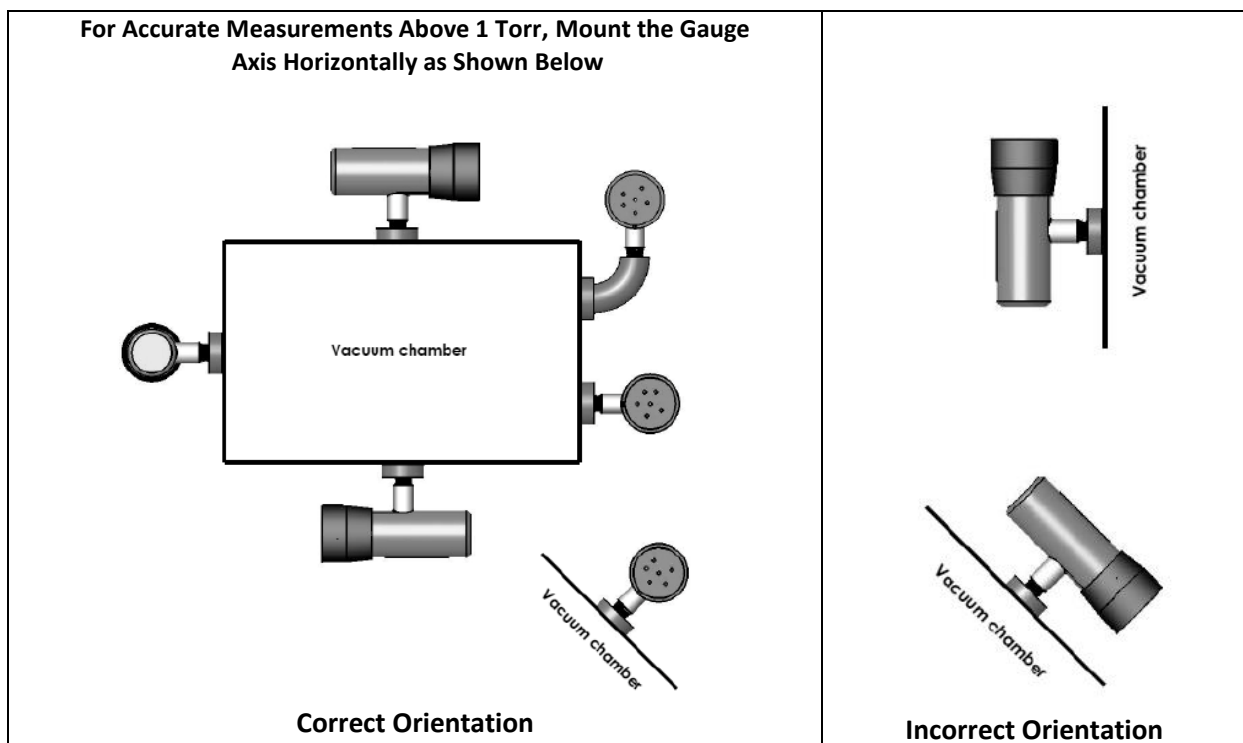
Mount the CVG101 with port down, if possible, to help minimize the effect of any particles or condensation from collecting in the gauge. Do not mount the CVG101 where it will be subjected to excessive vibration. Vibrations may cause unstable readings, measurement errors and possible mechanical stress 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.

3.4   Electrical Installation

3.4.1   Grounding

⚠ Be sure the vacuum gauges and the rest of your vacuum system are properly grounded to protect personnel from shock and injury. Be aware that some vacuum fittings, especially those with O-rings when not used with metal clamps, may not produce a good electrical connection between the gauge and the chamber it is connected to. Use a ground lug on the vacuum connection flange of the pressure measurement device if necessary.   The *FlexRax* control unit should be connected to earth ground via a good quality equipment earthing conductor. It is encouraged that you connect a separate 12-AWG earthing conductor between a known facility earth ground connection and the green colored screw provided on the back panel of the *FlexRax*.

3.4.2   Back Panel Connection Overview

⚠ **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 option cards and devices. Additionally, if you want to change an option card location within the *FlexRax* controller or install a new option card, 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 option cards to gauges or removing/installing option cards may result in equipment damage or possible injury to personnel. It is strongly recommended that the user reads the entire User Manual before connecting any of the cables.

The electrical connections for the *FlexRax* are located on the back panel of the device as shown in the typical example below (**Note-** Locations of specific option cards in your *FlexRax* may be different than shown below).
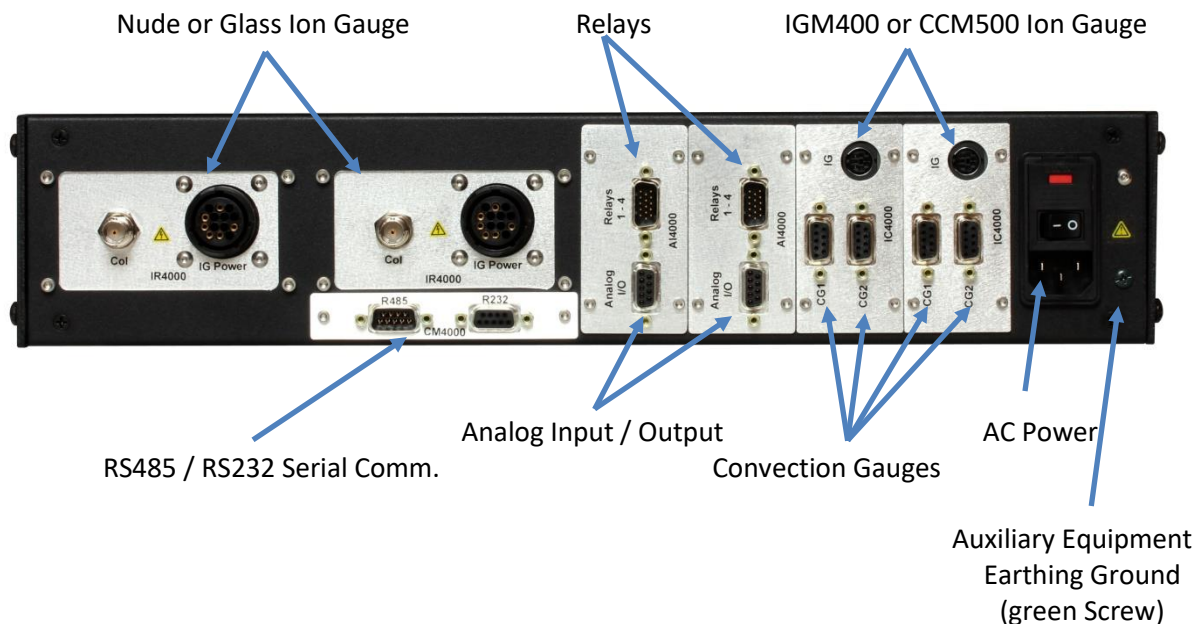
3.4.3   Nude or Glass Ion Gauge Connection

With either the EB Degas- nude type (BA601) or I^{2}R Degas- nude and glass type B-A (BA602/BA603) ion 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 card(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 IR4000 and IE4000 option cards 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 IG cable is connected at the BNC connector labeled 'Col' on the IR4000 or IE4000 option card.
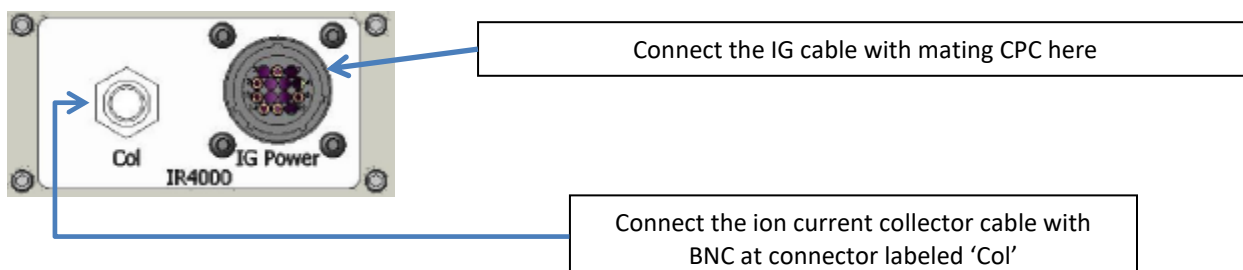
Connect the IG cable with mating CPC here

Connect the ion current collector cable with BNC at connector labeled 'Col'

⚠ **CAUTION!**   When changing or making cabling connections to any device controlled by the *FlexRax* option card(s), you must first turn AC power to the *FlexRax* **off**. See "Caution" Statement in section 3.4.2.

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

BA601/BA602 Nude IG Bakeable Cable 200 ^{o}C P/N IRNBD-441-1-…

Controller connection

Gauge connection

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

Controller connection

Gauge connection

BA603 Glass IG Cable P/N IRG-441-1-…

Gauge connection

Controller connection
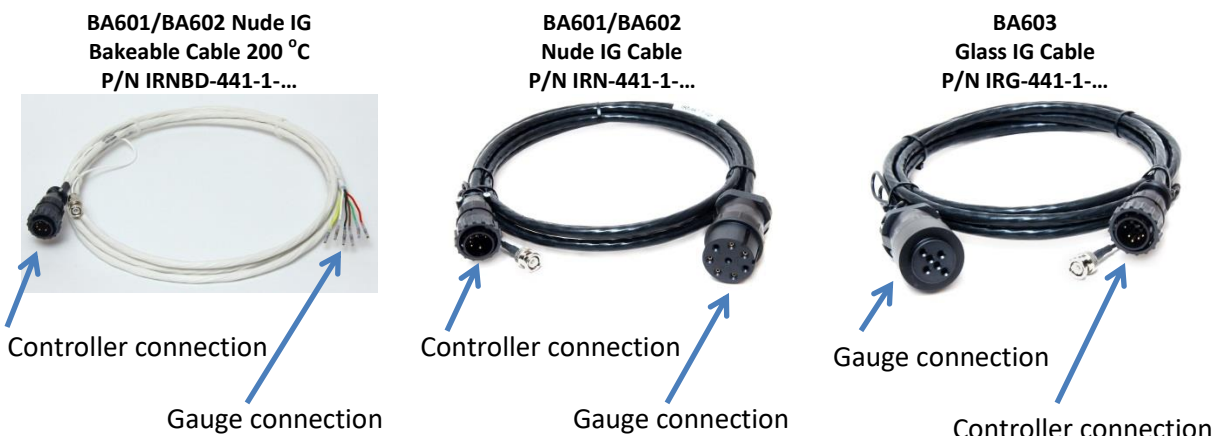
3.4.3.1   Standard Cable for Nude and Glass IG

For the glass IG, connect the IG cable (part numbers IRG-441-1…) at the *FlexRax* 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* 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

3.4.3.2   Bakeable Cable for Nude IG

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 ^{o}C **(See Bakeable Cable wiring information below).**   All other cables listed above are rated for 50 ^{o}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.

BA601/BA602 Nude IG Bakeable Cable 200 ^{o}C P/N IRNBD-441-1-…

Controller connection   Gauge connection

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

_____

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

Collector (White)
Grid (Red)
Grid (Green)
N/C
Filament 1 (Black)
Filament Com (Brown)
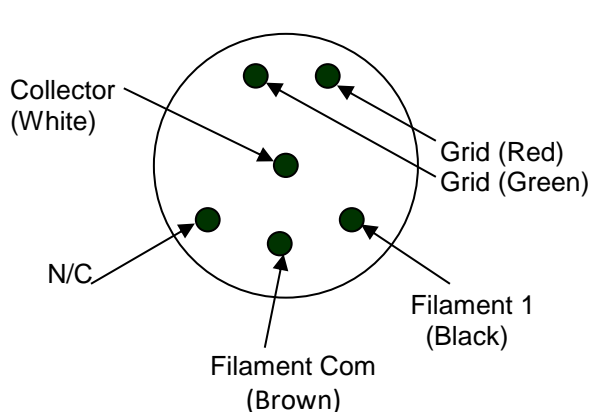
BA 602 Base View
I^{2}R Degas - single filament

Collector (White)
Grid (Red)
Grid (Green)
Filament 1 (Black)
Filament 2 (Yellow)
Filament Com (Brown)
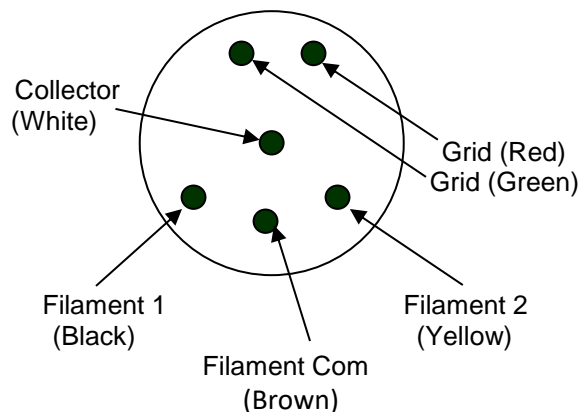
BA602 Base View
I^{2}R Degas - dual filament

_____

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

Collector (White)
Grid (**Red Only**)
Filament 1 (Black)
Filament 2 (Yellow)
Filament Com (Brown)
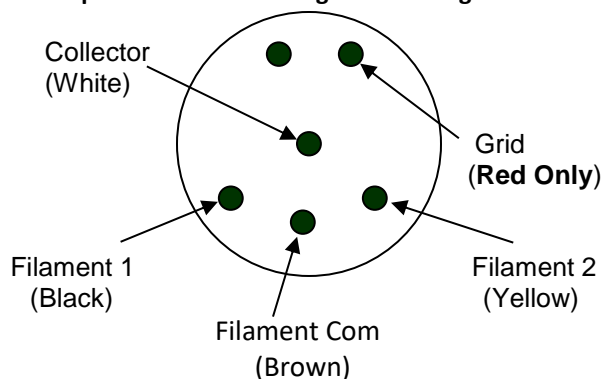
BA601 Base View
EB Degas - dual filament

_____

3.4.3.3   Standard Nude or Glass IG Cable Connector Pin Out

The information presented in this section is intended to address the installation/connection of a nude or glass 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*.

The pin-out of the CPC connector used on Granville-Phillips® 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*, 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 view shown below is the CPC connector end of the IG cable:
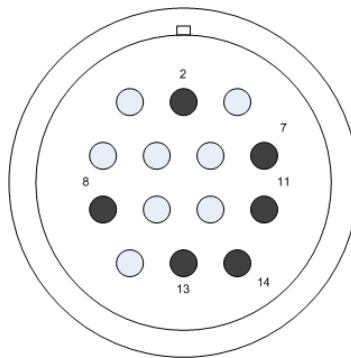
FlexRax Connector End of Cable View

Table - FlexRax IG Cable Connector[5]

Pin/Socket Contact Number	Description – I^{2}R Degas ion gauge cable for InstruTech® *FlexRax* (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)

---

[5] 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.

3.4.4   IGM400 or CCM500 Ion Gauge Connection

IC4000 option card allows connection to either the InstruTech IGM400 or CCM500 *Hornet* ion gauge module. Refer to the IGM400 and CCM500 User Manual for operational details.

⚠ **CAUTION!**   When changing or making cabling connections to any device controlled by the *FlexRax* option card(s), you must first turn AC power to the *FlexRax* **off**.

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 IC4000 card.

Connect the IGM400/CCM500 *Hornet* cable here. Connector is labeled IG.

BXC-400-1-XXX Cable for IGM400/CCM500 IG

3.4.5   CVG101 Convection Gauge Connection

The IC4000 option card also allows connections of up to two CVG101 *Worker Bee* convection gauge transducers or MKS/GP Convectron®. Refer to the CVG101 User Manual for operational details.

⚠ **CAUTION!**   When changing or making cabling connections to any device controlled by the *FlexRax* option card(s), you must first turn AC power to the *FlexRax* **off**.

CVG101 Worker Bee convection gauges are connected via an InstruTech provided cable (p/n CB421-1-XXX) to the CG1 and CG2 connectors on the IC4000 option card. Connect the 9-pin D-subminiature (DE-9P) connector end of the cable to the appropriate CG connector on the IC4000 option card. 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.
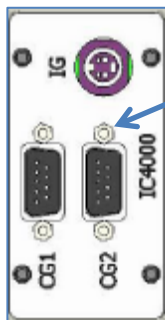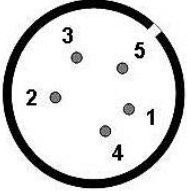
Connect the CVG101 *Worker Bee* cable(s) here. Connector(s) are labeled CG1 and CG2.

CB421-1-XXX Cable for CVG101 CG

3.4.6   CVG101 Convection Gauge Cable Connector Pin Out

Part number 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. As such, it is not necessary for you to fabricate your own cable. However for reference and in case you would like to fabricate your own cable for the convection gauge, 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) P/N CK431-01	
1		NC	
2		cable shield	
3		3	
4		3	
5		2	
6		5	
7		1	
8		1	

3.4.7   Analog Input and Output Connection

There are either two or three D-subminiature connectors located on the AI4000-4 or AI4000-8 option cards. The 9-pin connector (DE-9S) is used for the Analog Input / Output signals. The 15-pin connector (DE-15P) is used for relays.

DE-9S Connector for connections to Analog Inputs and Outputs
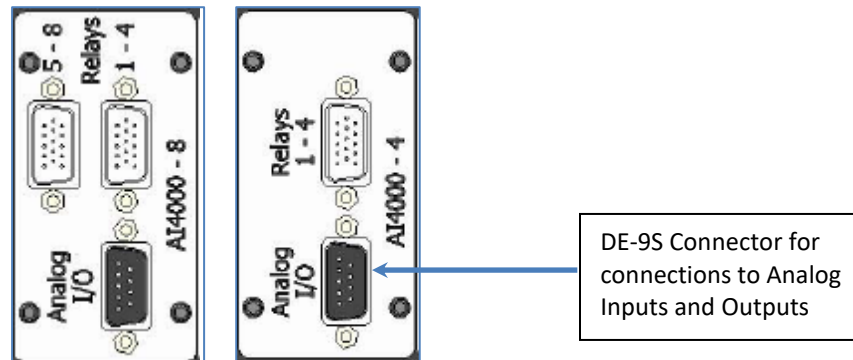
See the following table below for Analog Input and Analog Output pin-out descriptions of the D-subminiature connectors on these option cards.

9-pin (DE-9S) D-subminiature Analog Input / Output Connections		DE-9S D-subminiature Connector (on AI4000-4 or AI4000-8 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 below	
9	Analog Output Signal Return	

Pin 1

Pin 9
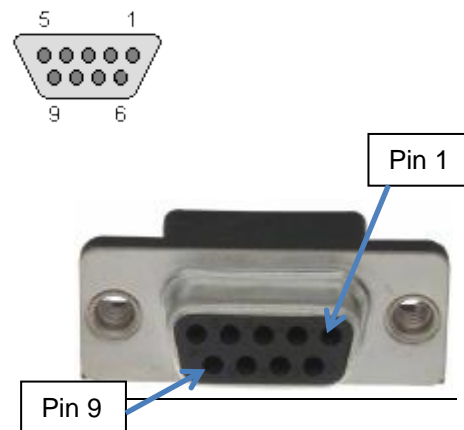
See the following page for Analog Input connections from other types of gauges such as a Capacitance Diaphragm Gauge.

Voltage signals from pressure measurement transducers (with analog outputs) may be connected to the Analog Input connection on the AI4000-4 or AI4000-8 option cards shown above. 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.

3.4.7.1   Capacitance Diaphragm Gauge Connection

If you are connecting a Capacitance Diaphragm Gauge (CDG) to the Analog Input, you will need to connect an external (user supplied) power supply to the CDG Device and make the wiring connection as shown below.
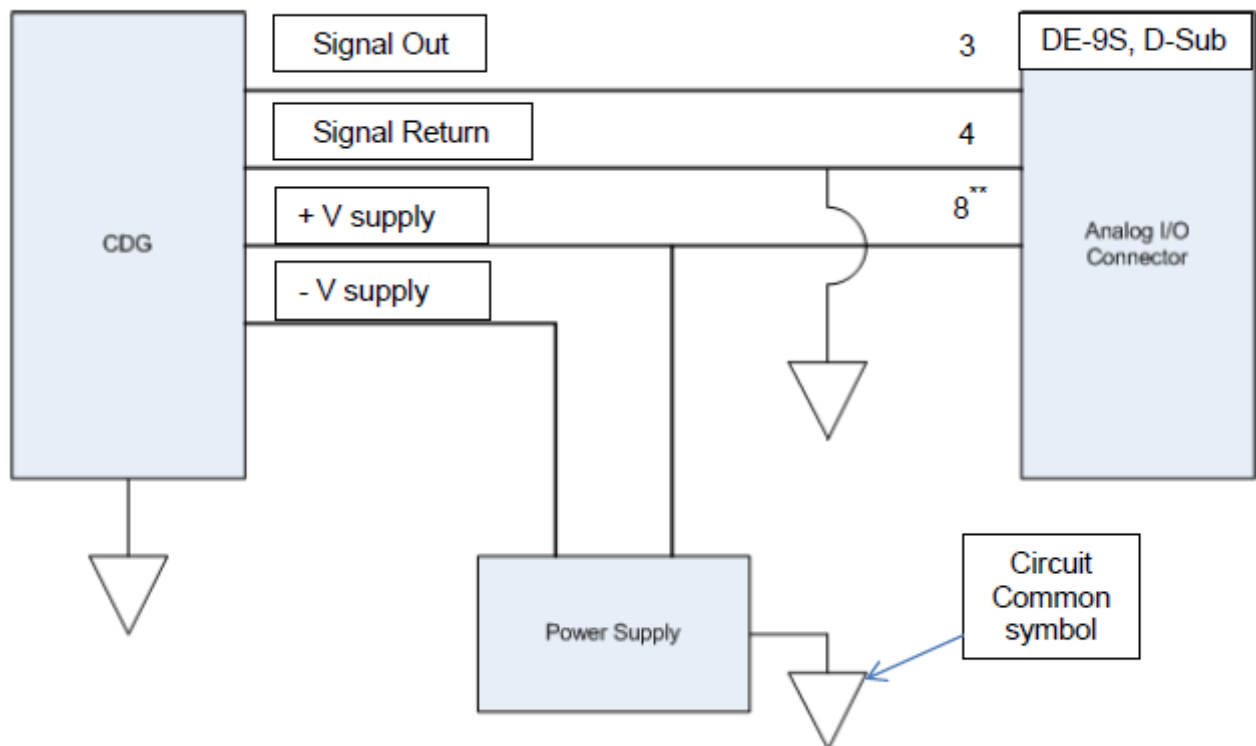
Detection Requirement: Connecting Any Type of Device to the Analog Input

Pin 8 of the DE-9S connector above 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 of the DE-9S D-sub connector must be continuously connected and may range in voltage from 10 Vdc, min. to 30 Vdc, max. If you intend to use a vacuum gauge other than a CDG to connect to the Analog Input of *FlexRax*, use the same wiring scheme shown above for the CDG.

3.4.8   Relay Connection - AI4000-4 Option Card

The 15-pin connector (DE-15P) on the AI4000-4 option card is used for relays. This option card provides 4 single-pole, double-throw (SPDT) setpoint relays rated at 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.
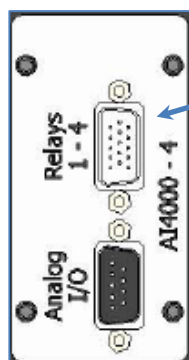
DE-15P Connector for connections to relays 1 thru 4

15-pin (DE-15P) D-subminiature Relay Contactor Connections

Connector Pin Number	Description
1	Relay 1 – Common (COM)
2	Relay 1 – Normally Open (N.O.)
3	Relay 3 – Normally Closed (N.C.)
4	Relay 3 – COM
5	Relay 3 – N.O.
6	Relay 1 – N.C.
7	– **No Connection**
8	– **No Connection**
9	– **No Connection**
10	Relay 2 – N.C.
11	Relay 4 – N.O.
12	Relay 4 – COM
13	Relay 4 – N.C.
14	Relay 2 – N.O.
15	Relay 2 – COM

DE-15P D-Subminiature Connector (on AI4000-4 Option Card)

Pin 1

Pin 6

Pin 15
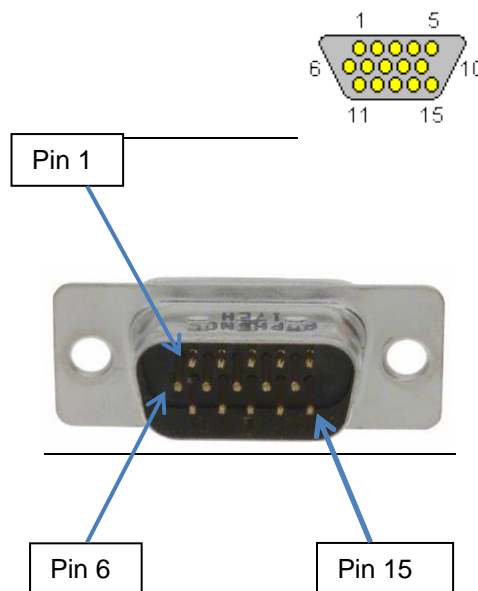
3.4.9   Relay Connection - AI4000-8 Option Card

There are two 15-pin connectors (DE-15P) on the AI4000-8 option card that is used for relays. This option card provides 8 single-pole, double-throw (SPDT) setpoint relays rated at 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.
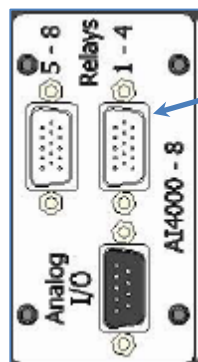
Contacts for Relays 1 thru 4 are located on DE15P connector on the right side (see next page for Relays 5 thru 8)

Pin out for connector labeled Relays 1 - 4

15-pin (DE-15P) D-subminiature Relay Contactor Connections

DE-15P D-Subminiature Connector (on AI4000-8 Option Card)

Connector Pin Number	Description
1	Relay 1 – Common (COM)
2	Relay 1 – Normally Open (N.O.)
3	Relay 3 – Normally Closed (N.C.)
4	Relay 3 – COM
5	Relay 3 – N.O.
6	Relay 1 – N.C.
7	– **No Connection**
8	– **No Connection**
9	– **No Connection**
10	Relay 2 – N.C.
11	Relay 4 – N.O.
12	Relay 4 – COM
13	Relay 4 – N.C.
14	Relay 2 – N.O.
15	Relay 2 – COM

Pin 1

Pin 6

Pin 15

See the following page for the Pin out of connector labeled Relays 5 - 8.

Contacts for Relays 5-8 are located on DE15P connector on the left side
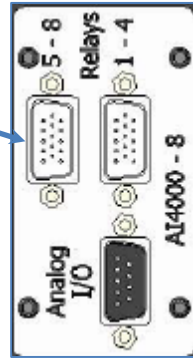
Pin out for connector labeled Relays 5 – 8

15-pin (DE-15P) D-subminiature Relay Contactor Connections

Connector Pin Number	Description
1	Relay 5 – Common (COM)
2	Relay 5 – Normally Open (N.O.)
3	Relay 7 – Normally Closed (N.C.)
4	Relay 7 – COM
5	Relay 7 – N.O.
6	Relay 5 – N.C.
7	– **No Connection**
8	– **No Connection**
9	– **No Connection**
10	Relay 6 – N.C.
11	Relay 8 – N.O.
12	Relay 8 – COM
13	Relay 8 – N.C.
14	Relay 6 – N.O.
15	Relay 6 – COM

DE-15P D-Subminiature Connector (on AI4000-8 Option Card)

Pin 1

Pin 6   Pin 15
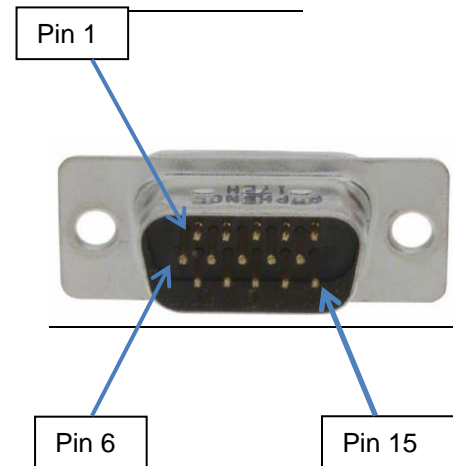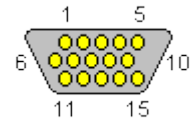
3.4.10 RS232 / RS485 Serial Communications Connection

CM4000 option card provides either RS232 or RS485 serial communications with the *FlexRax.* There are two DE9 (D-subminiature, shell size E, 9 pole) connectors that allow independent cable connections to the CM option.

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 Card

9-contact (DE-9S) D-subminiature RS232 Connections

DE-9S D-subminiature Connector (on CM4000 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
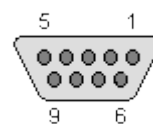
Contact 1

Contact 9

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

RS485 COM PORT - CM4000 Option Card

9-pin (DE-9P) D-subminiature RS485 Connections   **DE-9P D-subminiature Connector (on CM4000 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

Pin 1

Pin 9
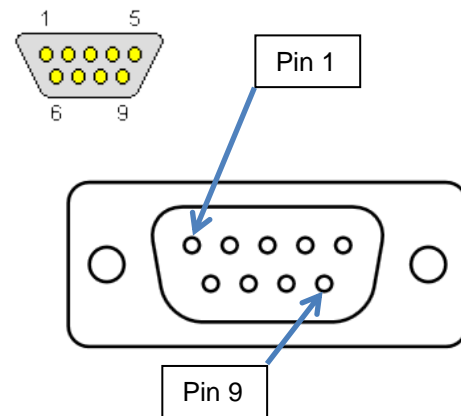
Connect either RS232 or RS485 cable to *FlexRax* – DO NOT CONNECT BOTH AT THE SAME TIME

4 IG and CG Overview

4.1 IG Emission Current

100 μA (0.1 mA), 4 mA, and 10 mA are available settings of emission current for the hot cathode nude or glass ion gauge while 100 μA (0.1 mA) and 4 mA are available for the IGM400 hot cathode ion gauge module.

1) In clean applications and when operating at higher pressure ranges (5.00×10^{-6} Torr to 1.00×10^{-3} Torr for nude and glass, 5.00×10^{-6} Torr to 5.00×10^{-2} Torr for IGM400) the 100 μA emission setting is preferred.

2) At lower operating pressures (1.00×10^{-9} Torr to 5.00×10^{-4} Torr) the 4 mA emission setting should be used.

3) Many vacuum measurement equipment users prefer to use the 10 mA emission current setting for the nude or glass ion gauges when making measurements in the UHV pressure regime (below 1.00×10^{-8} to 10^{-11} Torr).

4) When using a diffusion pump or other pumps that use fluids, there is a possibility of the pump oil vapors entering the IG transducer. These vapors may form an insulator on the internal components of the transducer which can lead to instability or failure in controlling the emission. In this case, 4 mA and 10 mA emission current may provide improved operating lifetime and measurement performance.

5) The emission current can also be set to automatically switch between various emission currents. This results in optimal and stable pressure readings over the entire measurement range from low to high vacuum. For example, if an application requires that pressure measurements be performed by the ion gauge from pressures lower than 1.00×10^{-6} Torr up to 1.00×10^{-3} Torr, then the user may want to consider selecting the auto switching feature of the emission current.

4.2 IG Degas

The degas function is used to rid a hot cathode ion gauge sensor of adsorbed gas. The intervals at which degas should be applied vary for each application. The low pressure measurement performance of the transducer will normally improve after each degassing cycle.

- Degas can only be applied while the filament is turned on and operating.

- Ensure that the vacuum pressure is at or less than 5.00×10^{-5} Torr before attempting to initiate degas.

- Degas will automatically turn off after 10 minutes when using factory default settings. Degas can be programmed for duration of 2 to 30 minutes.

- The *FlexRax* will continue to measure approximate pressure while degas is in progress.

- Degas will automatically turn off if the pressure exceeds 1.00×10^{-4} Torr during the degas cycle for the nude or glass ion gauge, off but the filament will remain turned on.

- Degas will automatically turn off if the pressure exceeds 3.00 x 10^{-4} Torr during the degas cycle for the IGM400 ion gauge, off but the filament will remain turned on.

- Degas can be interrupted by turning the IG filament off.

4.3   IG Filament Material Selection / Venting the Chamber

The choice of which filament to use is primarily dependent upon the process and process gases the ion gauge will be used with. For general vacuum applications, dual yttria coated filaments are offered for use with air and inert gases such as N_2, argon, etc. Optional dual tungsten filaments are available for use with gases that are not compatible with yttria coated iridium filaments.

1) Yttria coated iridium filament

In most general vacuum applications, the yttria coated iridium filament is the best choice.

Yttria coated iridium filaments typically operate at a lower temperature than tungsten filaments and thus have a lower outgassing rate at UHV and lower chemical reactivity with active gases. Yttria coated iridium filaments typically have a longer operating life than tungsten filaments in clean applications.

The yttria coated filament can survive occasional accidental start attempts at atmosphere in air, but the overall life of the filament may be shortened during each occurrence. Good vacuum practice is to use a separate pressure gauge such as InstruTech's *Worker Bee™* convection gauge to know when to turn on the ion gauge filament.

2) Tungsten filament

Typically, a bare tungsten filament is a better choice in those applications where an yttria coated filament is quickly damaged due to the gas type in use. For example, processes such as ion implantation may only use tungsten filaments. Be aware that corrosive applications are hard on any filament and filament life will be shortened while operating in such environments. Tungsten filaments are easily damaged by exposure to air/oxygen during accidental system vents or if considerable quantities of water vapor are outgassed during pump-down and bake-out. It is very important to make sure the tungsten filament is turned off before bringing the chamber up to atmosphere, especially if air is being used to vent the chamber. The use of pure N_2 gas is highly recommended to vent or purge your vacuum chamber. Testing has shown that tungsten filaments can withstand limited high pressure excursions when only N_2 is present.

Venting with air or other gases containing oxygen can damage the tungsten filaments. If you try to turn on an ion gauge with tungsten filaments while it is sitting on your desk exposed to room air, you will immediately damage or destroy the filament beyond repair.

> **NOTICE**   Do not use another gauge to automatically turn off the ion gauge when the ion gauge (IG) filament in use is constructed of <u>tungsten</u> (yttria coated filament is ok). The response time of other gauges may not allow for timely turn off of the tungsten filament leading to filament damage. Always turn off the IG filament manually before pressure is allowed to rise above 1.00 x 10^{-3} Torr for the nude or glass gauge and 5.00 x 10^{-2} Torr for the IGM400 gauge.

Note - Both types of filaments will suffer eventual damage if operated at high pressures. The type and amount of damage at high pressure is dependent upon the length of operating time, the pressure and the gas present.

4.4   IG Over Pressure Shut Down

The *FlexRax* is provided with factory set default values for over pressure shut down. The IG will shut off automatically should the pressure reach or rise above the pressure shut down values shown below:

Factory set nude or glass ion gauge overpressure shut down values

Emission Current	Overpressure Shut Down (Torr)	Overpressure Shut Down (mbar)	Overpressure Shut Down (Pa)
100 µA (0.1 mA)	1.00×10^{-3}	1.33×10^{-3}	1.33×10^{-1}
4 mA	5.00×10^{-4}	6.65×10^{-4}	6.65×10^{-2}
10 mA	1.00×10^{-4}	1.33×10^{-4}	1.33×10^{-2}

Factory set IGM400 overpressure shut down values

Emission Current	Overpressure Shut Down (Torr)	Overpressure Shut Down (mbar)	Overpressure Shut Down (Pa)
4 mA	1.00×10^{-3}	1.33×10^{-3}	1.33×10^{-1}
100 µA (0.1 mA)	5.00×10^{-2}	6.66×10^{-2}	6.66

Factory set CCM500 overpressure shut down values

Overpressure Shut Down (Torr)	Overpressure Shut Down (mbar)	Overpressure Shut Down (Pa)
1.00×10^{-2}	1.33×10^{-2}	1.33

4.5   Convection Gauge (CG) Initial Setup

Two of the most important steps for the initial setup of the convection gauges are to set vacuum (zero) and atmosphere. 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 vacuum 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 vacuum and atmosphere with the gauge installed in your actual system.

Setting Vacuum
See section 5.9.5.

Setting Atmosphere
See section 5.9.5.

The information presented in sections 4.1 through 4.6, above, is intended as an introduction to the programming capabilities of the *FlexRax* for use in controlling the selectable parameters and functions of the BA601, BA602, BA603, IGM400, CCM500 and CVG101 transducers.

5   Setup and programming

5.1   Applying Power

Before you turn on power to the *FlexRax* for the first time, ensure the cables from the *FlexRax* to the vacuum gauges are connected and secured. Use the power switch in the back of the controller to turn the *FlexRax* on.

5.2   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.

Programming push-button
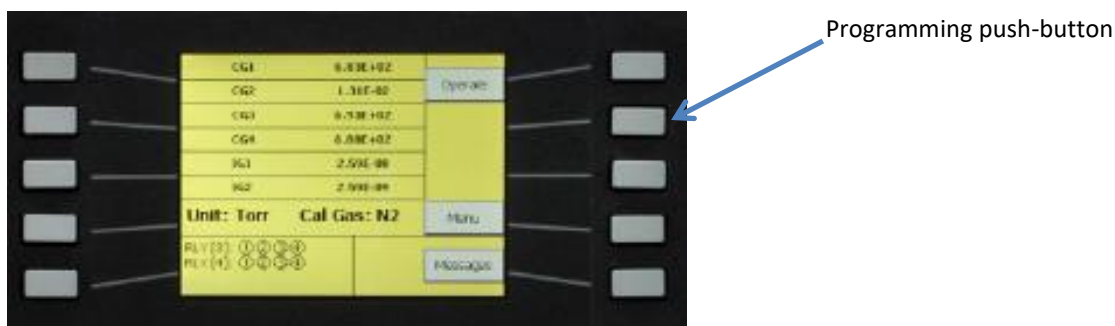
5.3   Pressure Measurement Screen

Depending on vacuum gauge devices connected and location and type of option cards installed, the displayed gauge and pressure measurements maybe the same or <u>similar</u> to what is shown below.

IGM400 or CCM500 Ion Gauge

Convection Gauges

IGM400 or CCM500 Ion Gauge

BA602 / BA603 or equivalent
Nude Glass I^{2}R Ion Gauge

BA601 or equivalent Nude
UHV Ion Gauge

Display Screen Scroll Pause

Relays Status Indicators

Pressure Mesurement

IGM [1]	OFF
CG [1,1]	1.00 E -04
CG [1,2]	1.00 E -04
IGM [2]	1.00 E -06
IGR [5]	OFF
IGE [6]	1.00 E -09

Operate

IGR [5] OFF

IGE [6] ON

Pause   Unit: Torr   Cal Gas: N2   Menu

RLY [3] ❶❷③❹
RLY [4] ①❷③④❺⑥❼⑧

Messages

Use key to change
from Operate to Stand-By

Use IGR key to turn
IG On/Off

Use IGE key to turn
IG On/Off

Use key to access
programming Menu

Use key to see
error messages

5.4   Operate / Stand-By Mode

During normal pressure measurement and gauge control, the **Pressure Measurement Screen** will display the operational mode in the upper right hand corner of the screen as either "Operate" or "Stand-By". The key associated with this function will allow the user to switch 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 switch to the **Stand-By** mode. Doing this will turn ion gauges (IGM, IGR, IGE) to the off condition. Also, the relays that have been setup to energize when the displayed pressure of an assigned ion gauge has reached a certain level will de-energize when the Operate/Stand-By mode is set to Stand-By. Pressing the key again will change the mode of operation from **Stand-By** to **Operate**.

⚠ **CAUTION!**   Damage to equipment and possible injury to operator may result if the 'Operate / Stand-by' key is left in the 'Operate' mode either while setting up the *FlexRax* 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.

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.

IGM [1]	OFF	Operate
CG [1,1]	1.00 E -04	
CG [1,2]	1.00 E -04	IGR [5] OFF
IGM [2]	1.00 E -06	
IGR [5]	OFF	IGE [6] ON
IGE [6]	1.00 E -09	
Pause	Unit: Torr Cal Gas: N2	Menu
RLY [3] ❶❷③❹		Messages
RLY [4] ①❷③❹❺❻❼❽		

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.

5.5   Ion Gauge Control

There are several methods of controlling operation of the ionization gauges connected to the *FlexRax*. For example the IG sensor can be turned on or off manually using the front panel push-buttons, automatically by using the pressure reading from a convection gauge or another type of device, or via serial communications. Degas can be initiated using the push-buttons or serial communications. Refer to the programming section for various IG sensors for more details on assigning these control methods.

5.6   *Gauge Name and I/O Identification on Display*

The *FlexRax* searches for the type and location of option cards installed by scanning the cards installed from right to left as viewed from the back panel of the controller.

Back of Controller and Physical location of option cards
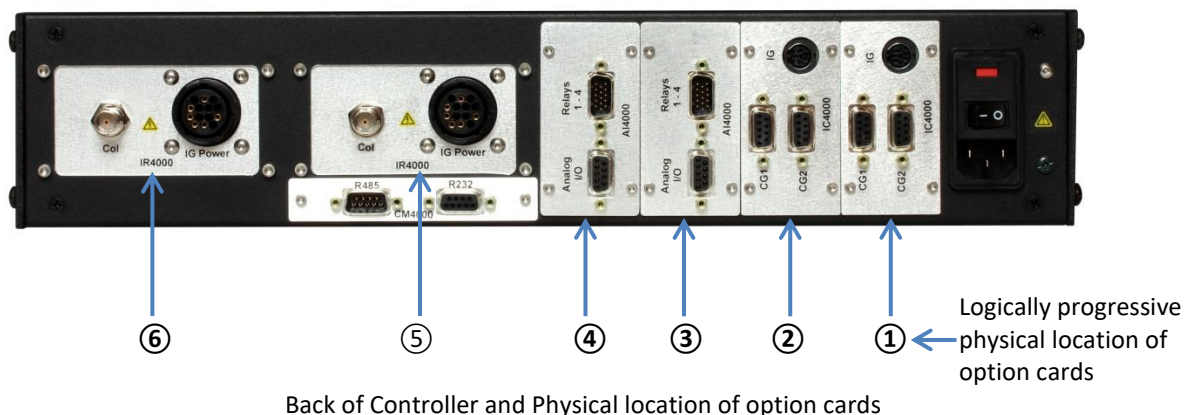
Example 1: In the example above, as the controls scans for the location of the option cards, the first physical location with an option card residing in it is assigned a logically progressive address (or name). There is an IC4000 option card in physical location 1 above, thus only one IG connection (IGM400 or CCM500) is available so the controller will display this gauge as IGM [1]. The controller will display convection gauges CG1 and CG2 connected to this same option card as CG [1,1] and CG [1,2] respectively. The first number represents the physical location of the option card and the second number is the number designation of the specific gauge or input/output on the option card as shown in the following examples.

CG [1,2]

Physical location of option card   Convection gauge number 2 (CG2)

Relay number 2

RLY [3,2]

The following table shows the displayed information for the option cards configuration example shown above.

Logically Progressive Physical locations of Option Cards	Option Card	Gauge type and Input/output	Default Display Identification
①	IC4000	One IGM400 or CCM500 IG	IGM [1]
		Two CVG101 convection gauges	CG [1,1] and CG [1,2]
②	IC4000	One IGM400 or CCM500 IG	IGM [2]
		Two CVG101 convection gauges	CG [2,1] and CG [2,2]
③	AI4000-4	Four Analog Outputs	AO [3,1], AO [3,2], AO [3,3], AO [3,4]
		One Analog Input	AI [3]
		Four Setpoint Relays	RLY [3,1], RLY [3,2], RLY [3,3], RLY [3,4]
④	AI4000-4	Four Analog Outputs	AO [4,1], AO [4,2], AO [4,3], AO [4,4]
		One Analog Input	AI [4]
		Four Setpoint Relays	RLY [4,1], RLY [4,2], RLY [4,3], RLY [4,4]
⑤	IR4000	One BA602/603 Nude/Glass IG	IGR [5]
⑥	IR4000	One BA602/603 Nude/Glass IG	IGR [6]

Note the physical locations are assigned in a logical progression so if there are less number of option cards than shown in the above example the physical location numbers will change accordingly. See next example below.

Example 2: In the example below not all option cards are installed in the controller. As such, the logical progressive physical location of option cards is different compared to the previous example.
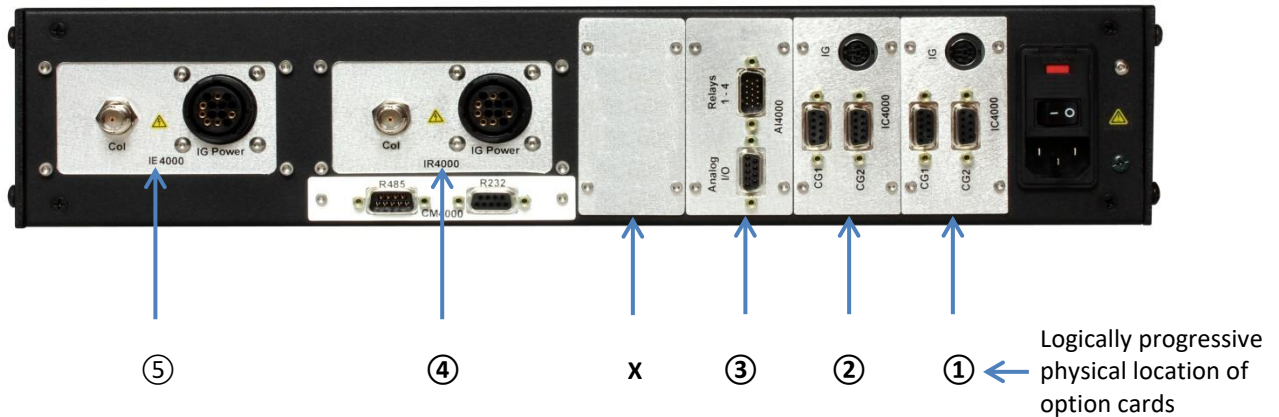
As discussed in the previous page, gauges and input/outputs are identified on the display with first number representing the physical location of the option card and the second number representing the number designation of the specific gauge or input/output on the option card as shown in the following example.

CG [2,2]
Physical location of option card   Convection gauge number 2 (CG2)
                                                Relay number 4
RLY [3,4]

The following table shows the displayed information for the option cards configuration example shown above.

Logically Progressive Physical locations of Option Cards	Option Card	Gauge type and Input/output	Default Display Identification
①	IC4000	One IGM400 or CCM500 IG	IGM [1]
		Two CVG101 convection gauges	CG [1,1] and CG [1,2]
②	IC4000	One IGM400 or CCM500 IG	IGM [2]
		Two CVG101 convection gauges	CG [2,1] and CG [2,2]
③	AI4000-4	Four Analog Outputs	AO [3,1], AO [3,2], AO [3,3], AO [3,4]
		One Analog Input	AI [3]
		Four Setpoint Relays	RLY [3,1], RLY [3,2], RLY [3,3], RLY [3,4]
④	IR4000	One BA602/603 Nude/Glass IG	IGR [4]
⑤	IE4000	One BA601 UHV Nude IG	IGE [5]

Note - In this User Manual you may see references to certain gauges or I/O with notations [n,m]. For example CG [n,m], IGR [n,m], RLY [n,m], etc.   These are used to describe the connected gauges or I/O in a generic sense regardless of the physical location of the option card they are connected to.

5.7   Relay Status Indicators on Display

If one or more AI4000-4 or AI4000-8 option cards are installed, relay status for each relay is shown in the lower left hand corner of the Pressure Measurement Screen similar to what is shown below.

IGM [1]	OFF	
CG [1,1]	1.00 E -04	Operate
CG [1,2]	1.00 E -04	
IGM [2]	1.00 E -06	IGR [5] OFF
IGR [5]	OFF	
IGE [6]	1.00 E -09	IGE [6] ON
Pause	Unit: Torr Cal Gas: N2	Menu

RLY [3] ❶❷③❹
RLY [4] ①❷③④❺⑥❼⑧   Messages

Relay Status Indicators

Refer to the previous section to review the physical locations of option cards and their identification on display.

The example **RLY [3]** ❶ ❷ ③ ❹ shown above indicates an AI4000-4 option card that has 4 relays is in physical location 3 and relay number ③ is de-energized while relay numbers ❶ ❷ and ❹ are energized.

The example RLY **[4]** ① ❷ ③ ④ ❺ ⑥ ❼ ⑧ shown above indicates an AI4000-8 option card that has 8 relays is in physical location 4 and relay numbers ①, ③, ④, ⑥ and ⑧ are de-energized while relay numbers ❷, ❺ and ❼ are energized.

5.8   User Assigned Gauge and I/O Names

The user may leave the factory default names of each gauge and I/O that were established by the controller during initialization or rename them. Refer to programming section for each gauge, analog I/O and relays to change the factory default names if desired. The example below shows the name CG [1,1] has been changed to read FORELINE.

IGM [1]	OFF	
FORELINE	1.00 E -04	Operate
CG [1,2]	1.00 E -04	
IGM [2]	OFF	IGR [5] OFF
CG [2,1]	0.00 E +00	IGR [6] OFF
CG [2,2]	1.00 E -04	
Pause	Unit: Torr Cal Gas: N2	Menu

RLY [3] ❶❷③❹
RLY [4] ①❷③④❺⑥❼⑧   Messages

⚠ **CAUTION!** If you prefer to change the factory default names, assign a unique name to each gauge and/or I/O. To prevent improper system operation **DO NOT ASSIGN THE SAME NAME TO ANY DEVICE.**

5.9   Programming

This section provides detailed information on programming and configuration of various menus and submenus of the controller. 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 option cards(s) installed and gauges connected. At various steps in the setup menus, there are messages or prompts displayed to direct the user to perform certain operations and input desired, valid values. When necessary press the keys associated with ⮕ ⬅ ⬆⬇ to input a value or select a parameter. In some menus you have to use either the up ⬆ or down ⬇ arrow key first before the SAVE key appears in the display. By pressing the CANCEL key the controller maintains the selection that was previously chosen.   If the user inputs a value outside the range in which settings may be allowed, another screen will appear directing the user to input a value for the setting that falls within a defined range of valid inputs. To start programming the controller press the Menu key while in the Pressure Measurement Screen.

Pressure Measurement Screen

The **Menu Screen below** is displayed when the **Menu** key is pressed in the **Pressure Measurement Screen** as shown here.

Main Menu Screen

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. 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 key. If displayed, pressing the hardware key associated with the MAIN key will return you directly to the **Pressure Measurement Screen.**

Press the Help key to see InstruTech contact 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, 001306-121).   You may need to convey the version number of your *FlexRax* to InstruTech technical support staff when verifying future device compatibility with your *FlexRax.*

5.9.1   Initial Setup of the Pressure Measurement Screen

For the initial setup of the Pressure Measurement Screen press the key aligned with Menu and you will see the Main Menu Screen appear as shown below.

Pressure Measurement Screen   ⇨   **Main Menu Screen**
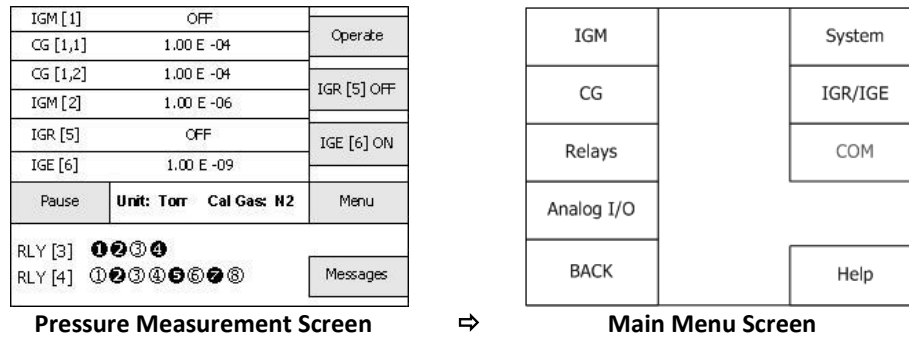
Press the System key in the Main Menu Screen above and the System Setup Screen appears as shown below.

System Setup Screen
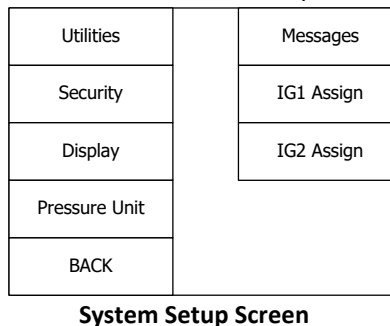
For the initial setup we will discuss the IG1/IG2 Assign, Pressure Unit and Display menus in this section. The Utilities and Security menus are discussed later in section 13. The Messages menu is discussed in section 10.2.

5.9.1.1   IG1 Assign and IG2 Assign Menu

IG1 Assign and IG2 Assign - This allows Assignment of the ion gauge(s) that you wish to control the on/off state from the main Pressure Measurement Screen.   These function keys are independent of each other. The intent of these two keys is to allow a single key press to turn the ion IG on or off.   In the Pressure Measurement Screen example shown below, 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 "IG2Assign" to other available ion gauges connected to the controller.

IG ON/OFF Key

IG ON/OFF Key
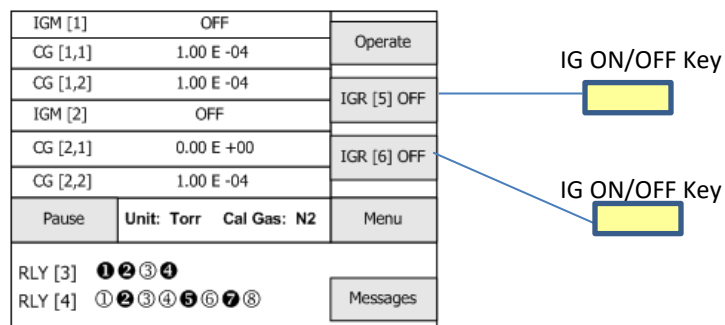
5.9.1.2   *Pressure Unit Menu*

Pressure Unit - Default is Torr. This selects the pressure measurement units in Torr, mbar or Pa (pascals).

5.9.1.3   *Display Menu*

Display - This allows setting up the display mode. When the key aligned with Display is pressed the Display Setup Screen appears as shown below. The first step would be to select the "Devices To Disp".

```
┌──────────────┐┌──────────────┐
│  Scroll Rate ││              │
├──────────────┤│              │
│ Devices to Disp│              │
├──────────────┤│              │
│ Prgrm Readout││              │
└──────────────┘└──────────────┘

┌──────────────┐ ┌──────────────┐
│     BACK     │ │     MAIN     │
└──────────────┘ └──────────────┘
```
Display Setup Screen

5.9.1.3.1 Devices To Disp Menu

Devices To Disp - This screen will show all available gauges that may be displayed. Press the key associated with a gauge listed on the screen to mark the selection box with a check-mark (✓) if you wish to display the pressure measurement for that gauge. If more than eight gauges are available for display, press the MORE key to see additional selections.

5.9.1.3.2 Prgm Readout Menu

Prgm Readout - Default is 4. This assigns the number of gauges (1 to 6) to be displayed on one Pressure Measurement Screen. The maximum number of gauges that can be assigned to one Pressure Measurement Screen is 6 so if more than 6 gauges are connected there will be a need for at least two scrolling screens.   When scrolling screens are necessary they are automatically generated based on how the Devices To Disp and the Prgm Readout menus are programmed. If six or less gauges are connected all six gauges can be displayed on one pressure measurement screen with no need for scrolling screens. However note that as you increase the number of gauges to display in one screen, the font size of the displayed pressures will decrease.

5.9.1.3.3 Scroll Rate

Scroll Rate - Default is 3 seconds.   When scrolling Pressure Measurement Screens are in use as described above, the Scroll Rate sets the time interval between the alternating Pressure Measurement Screens.   Note that if you select "MAN" instead of a time interval, you are disabling the automatic scrolling function. In this case, the Pause key on the Pressure Measurement Screen changes to the Page key. You can then use the Page key to manually scroll through multiple Pressure Measurement Screens.

⚠ Caution: As previously discussed in damage to equipment and possible injury to operator may result if the 'Operate / Stand-by' key is left in the 'Operate' mode either while setting up the *FlexRax* 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.

5.9.2   Programming the IGM Menu for IGM400 Hot Cathode IG

If you have connected an IGM400 *Hornet* hot cathode ion gauge to an IC4000 option card you need to program the IGM menu and its various submenus. To start programming the IGM menu press the key aligned with Menu and you will see the Main Menu Screen appear as shown below.

Pressure Measurement Screen   ⇨   **Main Menu Screen**
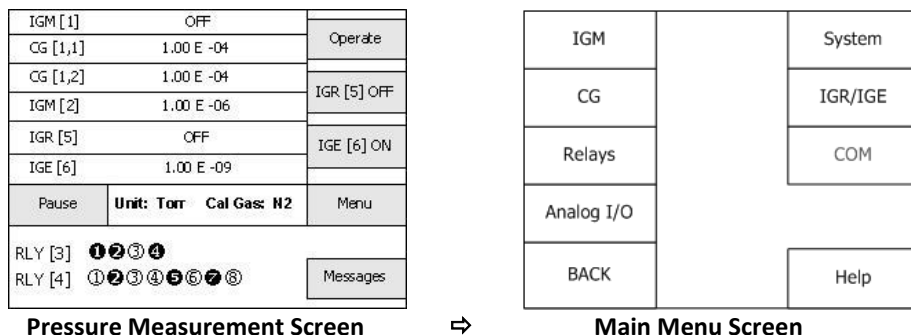
Note - If the IGM400 cable is not connected, the displayed key for that IGM maybe shown on display as "grayed-out". IGM400 cable must be connected to allow programming of the IGM menu.

Press the IGM key in the Main Menu Screen above and the IGM Select Screen (or similar depending on option cards installed) will appear as shown below.

IGM Select Screen

Assuming neither IGM [1] nor IGM [2] keys are grayed-out, select either IGM [1] ⇨ or IGM [2] ⇨ and the IGM Operations Screen will appear as shown below. Next, press the key aligned with Setup ⇨ to see to the IGM Setup Screen for IGM400.
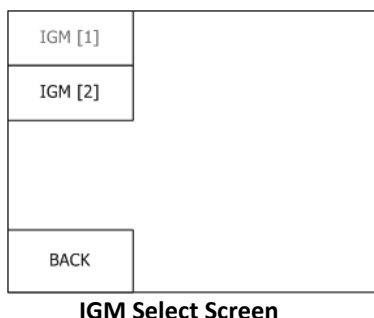
IGM Operations Screen for IGM400   ⇨   **IGM Setup Screen for IGM400**
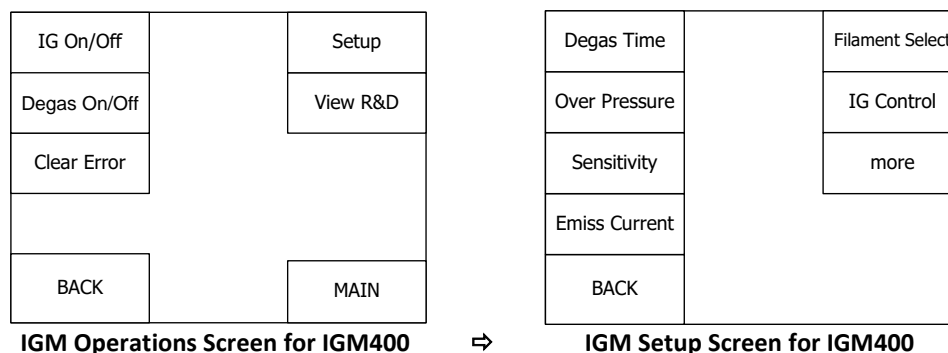
To program the IGM Setup Screen for IGM400 shown above, become familiar with the topics presented in the remaining pages of this section. In the preceding pages of this section, you have followed the key entry sequence of: | Menu | ⇨ | IGM | ⇨ | IGM [n] | ⇨ | Setup | ⇨

| Degas Time | - Default for IGM400 is 2 minutes.
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. 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.

| Over Pressure | - 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 filament 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 the ion gauge filament will be automatically turned on and off when IG is controlled by readings from one of the convection gauges or an analog input rather than using the push button (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:

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

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 value programmed in the *FlexRax* can be adjusted to compensate the reading for a gas other than nitrogen/air. Compensating the pressure reading using the sensitivity adjustment method may not be possible for certain gases if the new calculated Sensitivity results in a value outside the adjustment range.

⚠ **CAUTION!** The user assumes all risks if the IGM400 Sensitivity is programmed to a value not matching the actual transducer (sensor) sensitivity marked on the sensor mounting plate below the electronics enclosure. Failure to ensure that the *FlexRax* is programmed for the actual sensitivity of the transducer it is used with may result in pressure readings that are not true pressure. Equipment damage due to incorrect pressure readings and improper system control functions as a result of incorrect pressure measurement readings may result.

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. 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.
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 after exposure to certain chemical/physical effects.

IG Control   - Default is **Manual** filament on/off control using the front panel push-buttons. You may also select another device such as one of the convection gauges or an analog input to control the on/off state of the IGM400. If you choose a convection gauge (CG) or analog input (AI), the pressure set in the "Over Pressure" menu described above will be used to turn the IG filament on/off. When using an **analog input** to control the IG, pay particular attention to the **CAUTION** statement below.

⚠ **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 for IGM400 (more)

Set Defaults   - This function resets all user settable IGM (IGM400 hot cathode) parameters and values discussed in this section to factory default settings for the specific ion gauge selected.

Set Gauge Name   - This function allows you to change the name of the IGM from the default name, 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 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   - Default is Disable
This function allows the user to enable or disable the automatic emission current switching feature of the instrument. 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. To allow the *FlexRax* to automatically change the emission current between 100 µA and 4 mA , set the Auto Ie Enable to Enable.

Auto Ie Pressure   - Default is 1.00E-05 Torr.
If Auto Ie Enable above is set to Enable, then the Auto Ie Pressure value allows the user to select the pressure at which automatic switching of the emission current takes place. The user has the choice of programming the Auto Ie Pressure value anywhere between 1.00E-06 to 1.00E-04 Torr.   For example, if the Auto Ie Pressure value is set to 1.00E-05 Torr, then the ion gauge will operate at the emission current of 100 µA over a pressure range of 5.00E-02 to 1.00E-05 Torr. The emission current will then automatically switch to 4 mA for the lower pressure range of 1.00E-05 to 1.00E-09 Torr. The user has the choice of programming the Auto Ie Pressure value anywhere between 1.00E-06 to 1.00E-04 Torr. See Emiss Current above for more details on emission current selection for various pressure ranges.

Once you have setup the control parameters shown and discussed above, you may use the BACK key to return to the IGM Operations Screen (shown again below) to turn the IG or Degas 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 gauge using the research (R & D) screen.

IG On/Off		Setup
Degas On/Off		View R&D
Clear Error		
BACK		MAIN

IGM Operations Screen for IGM400

Pressing the MAIN key at any time will take you back to the main Pressure Measurement Screen.

5.9.3   Programming the IGM Menu for CCM500 Cold Cathode IG

If you have connected a CCM500 *Hornet* cold cathode ion gauge to an IC4000 option card you need to program the IGM menu and its various submenus.   To start programming the IGM menu press the key aligned with Menu and you will see the Main Menu Screen appear as shown below.


Pressure Measurement Screen   ⇨   **Main Menu Screen**
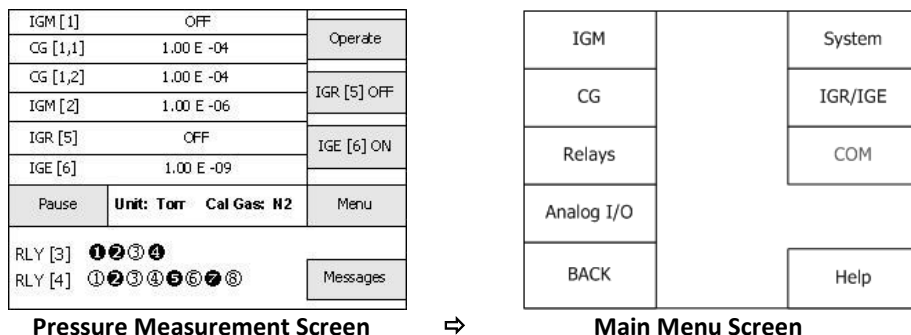
Note - If the CCM500 cable is not connected, the displayed key for that IGM maybe shown on display as "grayed-out". CCM500 cable must be connected to allow programming of the IGM menu.

Press the IGM key in the Main Menu Screen above and the IGM Select Screen (or similar depending on option cards installed) will appear as shown below.

IGM Select Screen

Assuming neither IGM [1] nor IGM [2] keys are grayed-out, select either IGM [1] ⇨ or IGM [2] ⇨ and the IGM Operations Screen will appear as shown below. Next press the key aligned with Setup ⇨ to see to the IGM Setup Screen for CCM500.

IGM Operations Screen for CCM500   ⇨   **IGM Setup Screen for CCM500**
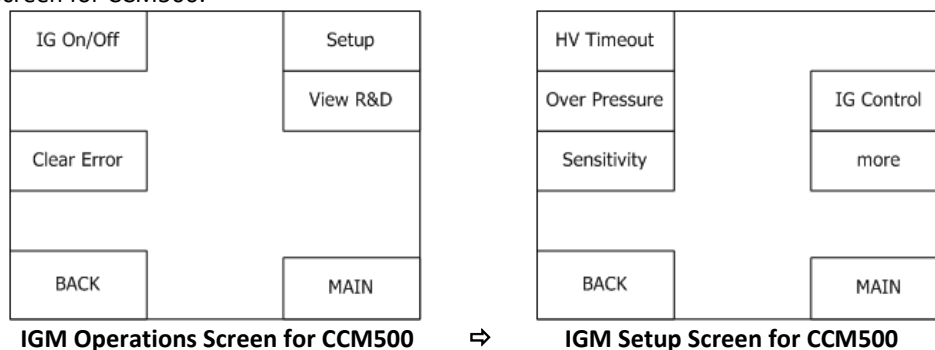
To program the IGM Setup Screen for CCM500 shown above, become familiar with the topics presented in the remaining pages of this section. In the preceding pages of this section, you have followed the key entry sequence of: Menu ⇨ IGM ⇨ IGM [n] ⇨ Setup ⇨

HV Timeout - Default is 10 minutes.
Enter this menu choice to program the maximum wait period after the cold cathode sensor on command is invoked and the CCM500 starts to read pressure. The HV TIMEOUT is the time allowed for the gauge to activate during which time the unit will attempt repeatedly to turn on the anode voltage. This time period can be set from 1 to 60 minutes. The recommended setting for 'HV Timeout' is 10 minutes. The cold cathode gauge will exhibit some level of activation time delay when the sensor is being activated at pressures below 1.00E-05 Torr. This is the time needed for the electrical discharge to establish itself at low pressures.   A rough estimate for this time delay can be determined by the following equation:

T, seconds = 1/pressure µTorr
Example: If the pressure at which the gauge is being activated is 1.00E-07 Torr (1.00E-07 X 1,000,000 = 0.1 µTorr), then T = 1 / 0.1 = 10 indicating that it may roughly take 10 seconds or more for the sensor to turn on.

Over Pressure - Default for CCM500 is 1.00E-02 Torr.
Over Pressure allows you to set the pressure at which the CCM500 sensor will turn off. This function is also used to define the pressure at which the cold cathode IG will be automatically turned on and off when IG is controlled by readings from one of the convection gauges or an analog input rather than using the push button (see the IG Control description below). The maximum pressure that the CCM500 should be allowed to operate is 1.00E-02 Torr. See the **CAUTION** statement following the 'IG Control' function description of this section.

Sensitivity - Default is 10 per Torr (10 Torr^{-1}).
Factory pre-set Sensitivity for the CCM500 is always set to 10.   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 value programmed in the *FlexRax* can be adjusted to compensate the reading for a gas other than nitrogen/air. Compensating the pressure reading using the Sensitivity adjustment method may not be possible for certain gases if the new calculated Sensitivity results in a value outside the adjustment range.

User assumes all risks if Sensitivity is set to a value different than the factory default setting of 10.

IG Control - Default is **Manual** sensor on/off control using the front panel push-buttons. 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 to control the on/off state of the CCM500. If you choose a convection gauge (CG) or analog input (AI) , the pressure set in the "Over Pressure" menu described above will be used to turn the IG sensor on/off. When using an **analog input** to control the IG, pay particular attention to the **CAUTION** statement below.

⚠ **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.

```
┌──────────────┬──────────────┐
│  Cal Factors │              │
├──────────────┤              │
│  Set Defaults│              │
├──────────────┤              │
│ Set Gauge Name│             │
├──────────────┘              │
│                             │
├──────────────┐  ┌──────────┤
│     BACK     │  │   MAIN   │
└──────────────┘  └──────────┘
```
IGM Setup Screen for CCM500 (more)

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 during factory calibration. These values are physically marked on the sensor mounting plate below the CCM500 electronics enclosure. See the CCM500 User Manual for additional details regarding the use, operation and maintenance of this product. 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 ion gauge mounting plate. The *FlexRax* factory default values are set to 10. The values can be set from 1 to 99.

Set Defaults - This function resets all user settable IGM (CCM500 cold cathode) parameters and values discussed in this section to factory default settings for the specific ion gauge selected.

Set Gauge Name - This function allows you to change the default name of the IGM, 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 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.

Once you have setup the control parameters shown and discussed above, you may use the BACK key to return to the IGM Operations Screen (shown again below) 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 gauge using the research (R & D) screen.
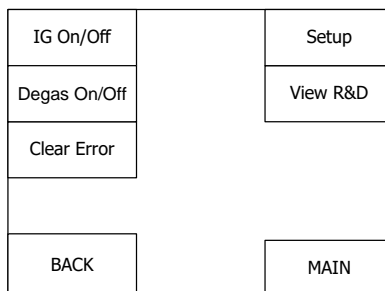
```
┌──────────────┬──────────────┐
│  IG On/Off   │    Setup     │
├──────────────┼──────────────┤
│ Degas On/Off │  View R&D    │
├──────────────┴──────────────┤
│  Clear Error │              │
├──────────────┐              │
│              │              │
├──────────────┤  ┌──────────┤
│     BACK     │  │   MAIN   │
└──────────────┘  └──────────┘
```
IGM Operations Screen for CCM500

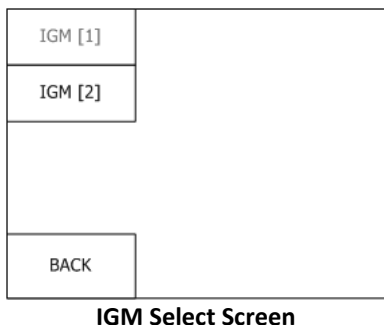Pressing the MAIN key at any time will take you back to the main Pressure Measurement Screen.

5.9.4 Programming the IGR/IGE Menu for Nude/Glass Hot Cathode IG

If you have connected an InstruTech BA602 I^2R nude / BA603 I^2R glass ion gauge (or equivalent) to an IR4000 option card, or a BA601 EB-degas UHV nude ion gauge (or equivalent) to an IE4000 option card, you need to program the IGR/IGE menu and its various submenus. To start programming the IGR/IGE menu press the key aligned with Menu and you will see the Main Menu Screen appear as shown below.

Pressure Measurement Screen ⇨ **Main Menu Screen**
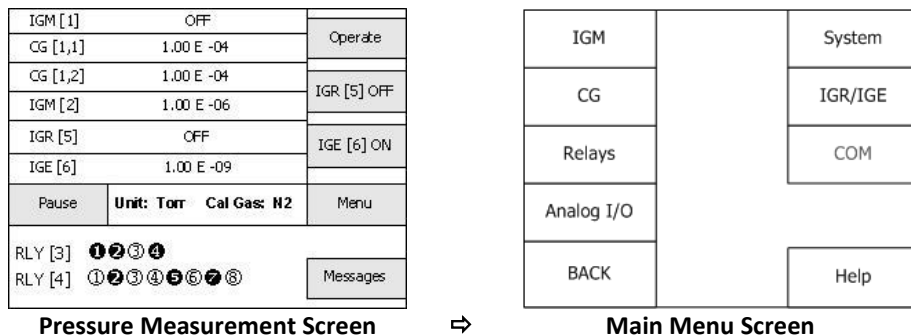
Press the IGR/IGE key in the Main Menu Screen above and the IGR/IGE Select Screen (or similar depending on option cards installed) will appear as shown below.

IGR/IGE Select Screen
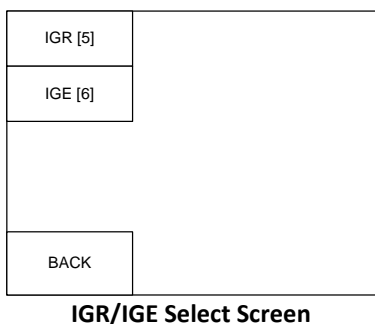
In the screen example shown above press IGR [5] ⇨ or IGE [6] ⇨ and the IGR/IGE Operations Screen will appear as shown below. Next, press the key aligned with Setup ⇨ to see to the IGR/IGE Setup Screen for the nude/glass ion gauge.

IGR/IGE Operations Screen for Nude/Glass Gauge ⇨ **IGR/IGE Setup Screen for Nude/Glass Gauge**
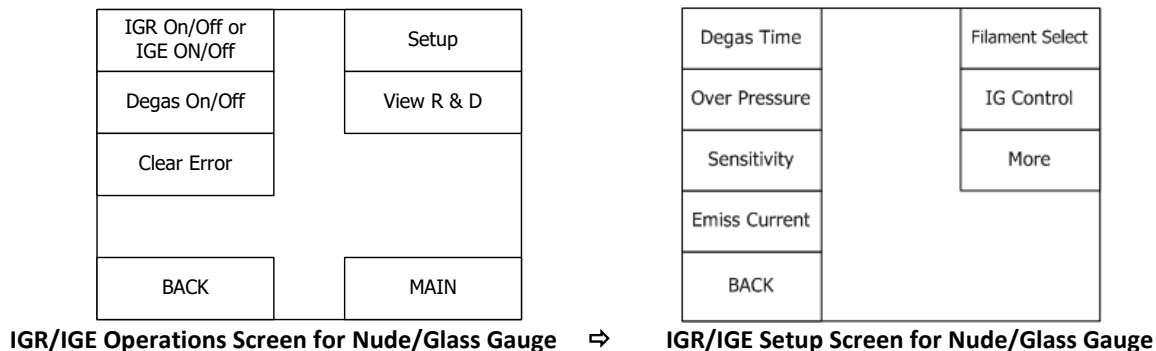
To program the IGR/IGE Setup Screen for glass/nude gauges shown above, become familiar with the topics presented in the remaining pages of this section.   In the preceding pages of this section, you have followed the key entry sequence of: Menu $\Rightarrow$ IGM $\Rightarrow$ (IGR[n]   or IGE[n]) $\Rightarrow$ Setup $\Rightarrow$

Degas Time   - Default degas time is 10 minutes.

Degas is used to rid the gauge sensor of adsorbed gas. Degas is achieved by applying Electron Bombardment (EB) to the grid when using the InstruTech BA601 UHV EB Degas nude IG (or equivalent) or electrically heating the grid (I^2R) when using the InstruTech BA602 nude BA603 nude/glass IG (or equivalent). 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. For the IGR/IGE option, 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.

Over Pressure   - Default for the BA600 series nude or glass enclosed ion gauge transducers or equivalent, is 1.00E-03 Torr 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 the ion gauge filament will be automatically turned on and off when IG is controlled by readings from one of the convection gauges or an analog input rather than using the push button (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 operating at. (BA600 series nude or glass 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.

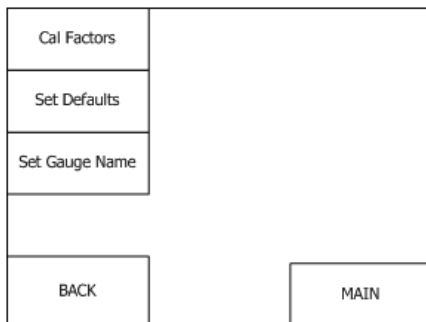Sensitivity   - Default is 10 per Torr (10 Torr^{-1}).

When using the resistive or I^2R degas nude IG (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 (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:

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

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 value programmed in the *FlexRax* can be adjusted to compensate the reading for a gas other than nitrogen/air. Compensating the pressure reading using the sensitivity adjustment method may not be possible for certain gases if the new calculated Sensitivity results in a value outside the adjustment range.

⚠ **CAUTION!** The user assumes all risks if the Sensitivity is programmed to a value not matching the actual nude or glass ion gauge transducer sensitivity described above. Failure to ensure that the *FlexRax* is programmed for the actual sensitivity of the transducer it is used with may result in pressure readings that are

not true pressure. Equipment damage due to incorrect pressure readings and improper system control functions as a result of incorrect pressure measurement readings may result.

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 convection gauge 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 after exposure to certain chemical/physical effects.

IG Control   - Default is **Manual** filament on/off control using the front panel push-buttons. 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 control the on/off state of the glass/nude gauge. If you choose a convection gauge (CG) or analog input (AI), the pressure set in the "Over Pressure" menu described above will be used to turn the IG filament on/off. When using an **analog input** to control the IG, pay particular attention to the **CAUTION** statement below.

⚠ **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.

IGR/IGE Setup Screen (more)

Set Defaults   - This function resets all user settable IGR/IGE (glass / nude IG) parameters and values discussed in this section to factory default settings for the specific ion gauge selected.

Set Gauge Name - This function allows you to change the default name of the IGR/IGE, 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 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 - Default is Disable.
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, 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. To allow the *FlexRax* to automatically change the emission current between 100 μA and 4 mA, set the Auto Ie Enable to Enable.

Auto Ie Pressure - Default is 1.00E-05 Torr.
If Auto Ie Enable above is set to Enable, then the Auto Ie Pressure value allows the user to select the pressure at which automatic switching of the emission current takes place. The user has the choice of programming the Auto Ie Pressure value anywhere between 1.00E-06 to 1.00E-04 Torr. For example, if the 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. See Emiss Current above for more details on emission current selection for various pressure ranges.

Once you have setup the control parameters shown and discussed above, you may use the BACK key to return to the IGR/IGE Operations Screen (shown again below) to turn the IG or Degas 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 gauge using the research (R & D) screen.

IGR On/Off or IGE ON/Off	Setup
Degas On/Off	View R & D
Clear Error	
BACK	MAIN

IGR/IGE Operations Screen for Nude/Glass Gauge

Pressing the MAIN key at any time will take you back to the main Pressure Measurement Screen.

5.9.5   Programming the CG Menu for CVG101 Convection Gauge

If you have connected a CVG101 *Worker Bee* or Granville-Phillips® Convectron® convection gauge to an IC4000 option card you need to program the CG menu and its various submenus.   To start programming the CG menu press the key aligned with Menu and you will see the Main Menu Screen appear as shown below.

IGM [1]	OFF	
CG [1,1]	1.00 E -04	Operate
CG [1,2]	1.00 E -04	
IGM [2]	1.00 E -06	IGR [5] OFF
IGR [5]	OFF	IGE [6] ON
IGE [6]	1.00 E -09	
Pause	Unit: Torr Cal Gas: N2	Menu

RLY [3] ❶❷③❹
RLY [4] ①❷③❹❺❻❼⑧   Messages

Pressure Measurement Screen   ⇨

IGM		System
CG		IGR/IGE
Relays		COM
Analog I/O		
BACK		Help
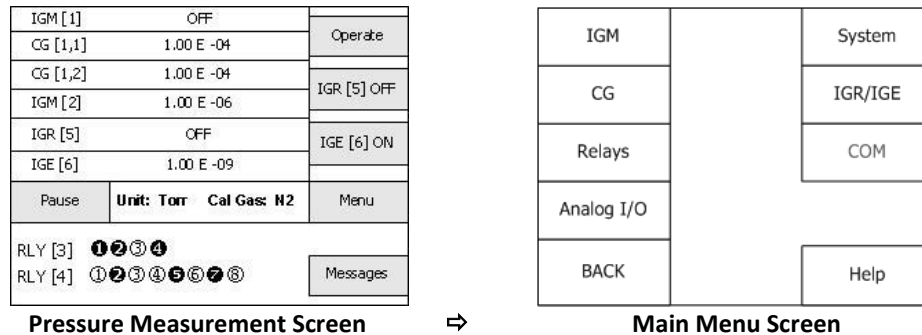
Main Menu Screen

Note - If the CVG101 cable is not connected, the displayed key for that CG maybe shown on display as "grayed-out". CVG101 cable must be connected to allow programming of the CG menu.

Press the CG key in the Main Menu Screen above and the CG Select Screen (or similar depending on option cards installed) will appear as shown below.   Next, assuming neither CG [1,1] or CG [1,2] keys are grayed-out, select either CG [1,1] ⇨ or CG [1,2] ⇨ to see to the CG Setup Screen for CVG101.

CG [1,1]		
CG [1,2]		
BACK		

CG Select Screen   ⇨

Set Atmosphere		Set Gauge Name
Set Vacuum		
Set Defaults		
BACK		Help

CG Setup Screen for CVG101
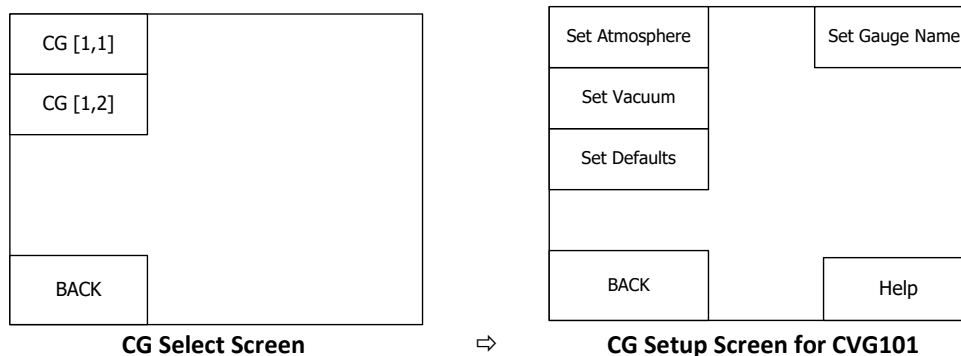
To program the CG Setup Screen shown above, become familiar with the topics presented in the remaining pages of this section. To reach this point you have followed the above key entry sequence of:
Menu ⇨ CG ⇨ CG[n,m] ⇨

Set Atmosphere   - This allows you to set the pressure reading for the CG device selected to your local uncorrected barometric pressure. At sea level, this pressure is usually near 760 Torr. At elevations above sea level, the pressure decreases. To set atmosphere backfill the vacuum vessel /chamber with nitrogen gas to a known pressure between 400 Torr and 1000 Torr. Alternatively, if your local uncorrected barometric pressure (air) is known, simply vent your vacuum system chamber to expose the gauge to the local atmospheric pressure. When desired system pressure is stable, adjust the pressure on the screen to the known atmospheric pressure. For example, if your known local uncorrected barometric pressure is 760 Torr, enter 760 in the Set Atmosphere Screen. The main Pressure Measurement Screen will now display 760 Torr while the gauge is at

atmosphere. 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.

Set Vacuum - This allows you to adjust the reading of pressure at vacuum (zero). Setting vacuum optimizes performance of the convection gauge when operating at a low pressure range of 1.00×10^{-4} Torr to 1.00×10^{-3} Torr. If your minimum operating pressure is higher than 1.00×10^{-3} Torr, it is not normally necessary to set vacuum and thus setting atmosphere should be adequate. If you are able to evacuate your system to below 1.00×10^{-4} Torr, it is always a good practice to check and set 0.00E+00 in this screen.   After setting vacuum, the main pressure measurement screen will now display 0.00E+00 while the gauge is at a vacuum level below 1.00×10^{-4} Torr. You may also set the vacuum pressure reading to a number higher than 0.00E+E00 if desired, although the most common practice is to set the CG vacuum pressure reading to 0.00E+00 when the vacuum level is below 1.00×10^{-4} Torr.

Note - Setting vacuum 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 vacuum and atmosphere.

Set Defaults - This function resets all user settable CG (CVG101) parameters and values discussed in this section to factory default settings for the specific convection gauge selected.

Set Gauge Name - This function allows you to change the default name of the CG, for example, CG [1,2] to another name of your choosing. This screen allows you to scroll through an eight (8) character field for the gauge 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.

5.9.6   Programming the Relays

If your *FlexRax* is equipped with AI4000-4 or AI4000-8 option card(s) you may program the relay parameters per instructions given in this section. To start programming the Relays menu press the key aligned with Menu and you will see the Main Menu Screen appear as shown below.

IGM [1]	OFF		Operate
CG [1,1]	1.00 E -04		
CG [1,2]	1.00 E -04		IGR [5] OFF
IGM [2]	1.00 E -06		
IGR [5]	OFF		IGE [6] ON
IGE [6]	1.00 E -09		
Pause	Unit: Torr Cal Gas: N2		Menu
RLY [3] ❶❷③❹			
RLY [4] ①❷③❹❺❻❼⑧			Messages

Pressure Measurement Screen   ⇨   **Main Menu Screen**

IGM		System
CG		IGR/IGE
Relays		COM
Analog I/O		
BACK		Help
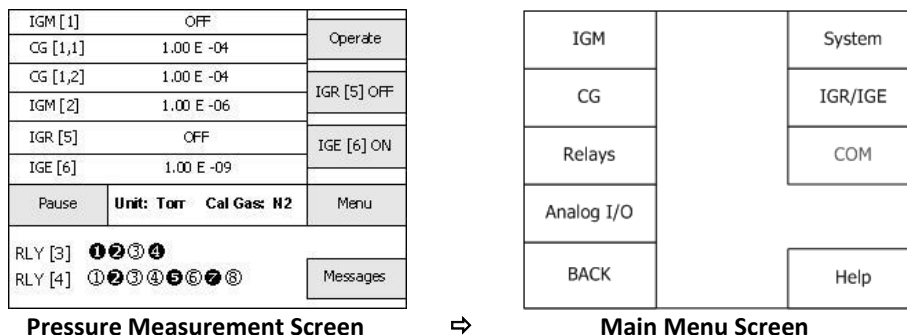
Press the Relays key in the Main Menu Screen above and the Relays Select Screen (or similar depending on option cards installed) will appear as shown below. Next, select any of the desired relays (for example RLY [2,1] ⇨ or RLY [2,2] , etc.) and the Relay Setup Screen for the selected relay will appear as shown below.

RLY[2,1]		RLY[2,5]
RLY[2,2]		RLY[2,6]
RLY[2,3]		RLY[2,7]
RLY[2,4]		RLY[2,8]
BACK		MORE

Relays Select Screen   ⇨   **Relay Setup Screen**

Assign Relay		Relay Name
Relay Turn ON		Relay Test
Relay Turn OFF		
Set Defaults		
BACK		MAIN
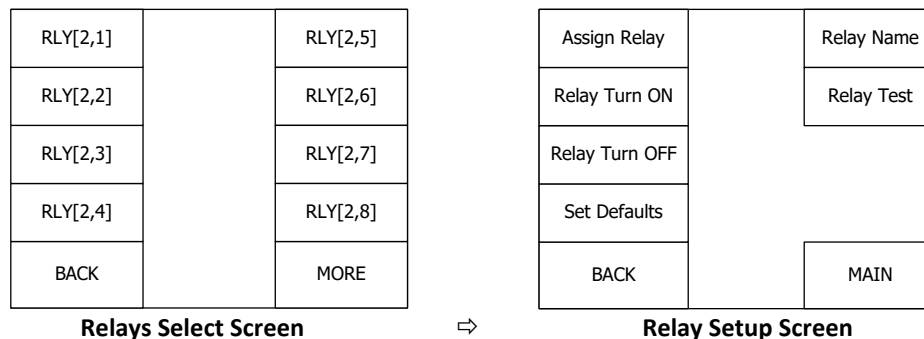
To program the Relay Setup Screen shown above, become familiar with the topics presented in the remaining pages of this section. To reach this point you have followed the above key entry sequence of:
Menu ⇨ Relays ⇨ RLY[n,m] ⇨

Assign Relay - This assigns the selected relay to a specific ion or convection gauge. The relay can also be assigned to another type of gauge such as a CDG that maybe providing a signal to the *FlexRax* and as an analog input.

Relay Turn ON - Default is 1.00E-10 Torr
This is a setpoint that corresponds to the turn on point for the selected relay. Relay will turn on when the pressure drops below this setting. If you are unable to increase the value of Relay Turn ON (*FlexRax* responding with a message indicating unable to change), you must first access the Relay Turn OFF menu below and increase that value to a number higher than the value of the Relay Turn ON you are trying to set.   Ensure the Relay Turn ON setpoint value you are programming is within the measurement range of the specific gauge the relay is assigned to.

Relay Turn OFF   - Default is 1.00E+03 Torr
This is a setpoint that corresponds to the turn off point for the selected relay.   Relay will turn off when the pressure rises above this setting. If you are unable to increase the value of Relay Turn OFF (*FlexRax* responding with a message indicating unable to change), you must first access the Relay Turn ON menu above and decrease that value to a number lower than the value of the Relay Turn OFF you are trying to set.   Ensure the Relay Turn OFF setpoint value you are programming is within the measurement range of the specific gauge the relay is assigned to.

Set Defaults   - This function resets all user settable relay parameters and values discussed in this section to factory default settings for the specific relay selected.

Relay Name   - This function allows you to change the default name of the relay selected, for example, RLY [2,2] to another name of your choosing. This screen allows you to scroll through an eight (8) character field for the relay 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.

Relay Test   This allows the user to manually toggle the specific selected relay to on and off to test for correct external circuit wiring and ensure polarity is as desired.

5.9.7   Programming the Analog I/O

If your *FlexRax* is equipped with AI4000-4 or AI4000-8 option card(s) you may program the analog input and/or analog outputs per instructions given in this section. To start programming the Analog I/O menu press the key aligned with Menu and you will see the Main Menu Screen appear as shown below.

Pressure Measurement Screen   ⇨   **Main Menu Screen**
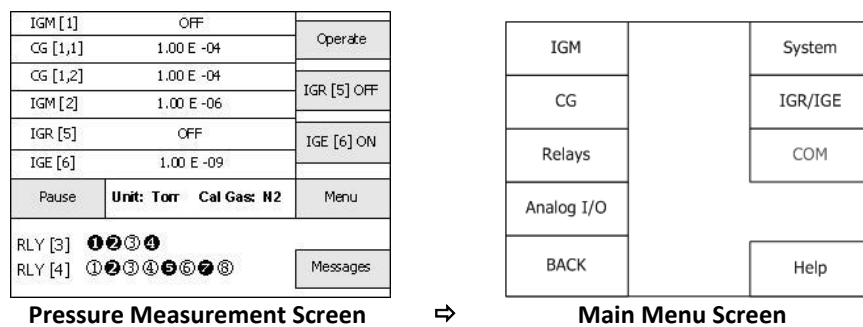
Press the Analog I/O key in the Main Menu Screen above and the Analog I/O Select Screen will display below:

Analog I/O Select Screen
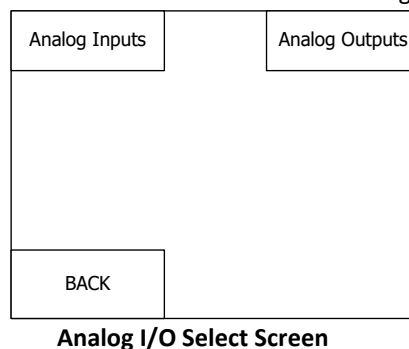
5.9.7.1   Programming the Analog Output

If you are using analog output(s) select Analog Outputs in the Analog I/O Select Screen shown above and the Analog Output Select Screen (or similar depending on option cards installed) will appear as shown below. Next, select any of the desired analog outputs (for example AO [2,1] ⇨ or AO [2,2] , etc.) and the Analog Output Setup Screen for the selected analog output will appear as shown below. (Note, if you are using more than four analog outputs select More in the Analog Output Select Screen to see additional output selections).

AO [2,1]			Assign Output	Min Pressure
AO [2,2]			Set Defaults	Min Voltage
AO [2,3]			Set Gauge Name	Max Pressure
AO [2,4]			Test	Max Voltage
BACK		MORE	BACK	MAIN

Analog Output Select Screen   ⇨   **Analog Output Setup Screen**
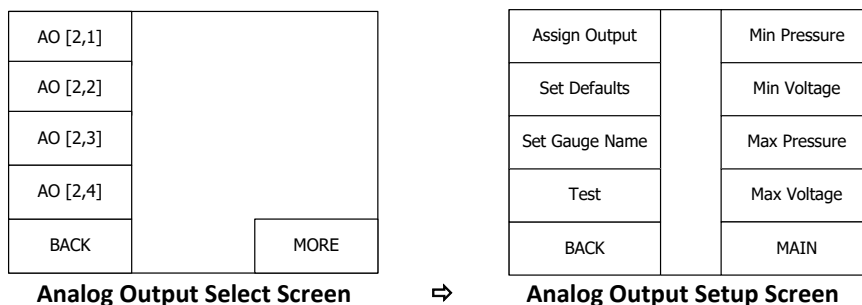
To program the Analog Output Setup Screen shown above, become familiar with the topics presented in the remaining pages of this section. To reach this point you have followed the above key entry sequence of:
Menu ⇨ Analog I/O ⇨ Analog Outputs ⇨ AO[n,m] ⇨

Assign Output - Default is None
This assigns the selected analog output to a specific ion or convection gauge. Press the Assign Output key in the Analog Output Setup Screen to assign the analog outputs(s). Use the up ⬆ and down ⬇ arrow keys on the left side to assign the selected analog output to a convection or an ion gauge. When you assign a gauge to the selected analog output and press the SAVE key a new screen will appear allowing selection of various analog output scaling choices listed below. 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.

Analog Output Scaling Choices:
- **Log-Linear IG 0-10V, n=10;** Log-linear analog output for IG only, output also compatible with GP 307, 350
- **Log-Linear IG 0-10V, n=11;** Log-linear analog output for IG only, output also compatible with GP 307, 350, 358
- **Log-Linear IG 0-10V, n=12;** Log-linear analog output for IG only, output also compatible with GP 307, 350
- **Linear IG;** Linear analog output for IG only, output also compatible with GP 307
- **Wide Range IG+CG 0.5-7V;** Log-linear analog output combining IG and CG as one signal. Note - When you select this option another screen appears prompting you to select which of the convection gauges you want to combine the IG analog output with. Make your selection accordingly.
- **1.8 to 8.7 V, .8/decade;** Log-Linear analog output for IG only, output also compatible with InstruTech CCM501
- **Long-Linear CG I-8V;** Log-linear analog output for CG
- **Long-Linear CG 0-7V;** Log-linear analog output for CG
- **Linear CG;** Linear analog output for CG
- **Non-Linear CG;** Non-linear analog output for CG1

Select **Log-Linear IG 0-10V, n=10** as the analog output type to set the analog output voltage proportional to the pressure measured by the ion gauge only. This selection provides an output voltage that is linear with respect to the common logarithm of pressure, i.e., log-linear analog output of 0 to 9 volts with a scaling factor of 1 V/decade of measured pressure. The log-linear output signal and pressure are related by the following formulas when **Pressure Unit** of measurement is in **Torr** and **mbar:** P= $10^{(volts-10)}$ where P is the pressure in Torr or mbar, and V is the output signal in volts.   Refer to section 7.1 for details regarding this type of output. This selection is also compatible with certain analog output from the Granville-Phillips 307 and 350 controllers.

Log-Linear IG 0-10V, n=11
Select **Log-Linear IG 0-10V, n=11** as the analog output type to set the analog output voltage proportional to the pressure measured by the ion gauge only. This selection provides an output voltage that is linear with respect to the common logarithm of pressure, i.e., log-linear analog output of 0 to 9 volts with a scaling factor of 1 V/decade of measured pressure. The log-linear output signal and pressure are related by the following formulas when **Pressure Unit** of measurement is in **Torr** and **mbar:** P= $10^{(volts-11)}$ where P is the pressure in Torr or mbar, and V is the output signal in volts. Refer to section 7.2 for details regarding this type of output.   This selection is also compatible with certain analog output from the Granville-Phillips 307, 350 & 358 controllers.

Log-Linear IG 0-10V, n=12
Select **Log-Linear IG 0-10V, n=12** as the analog output type to set the analog output voltage proportional to the pressure measured by the ion gauge only. This selection provides an output voltage that is linear with respect to the common logarithm of pressure, i.e., log-linear analog output of 0 to 9 volts with a scaling factor of 1 V/decade of measured pressure. The log-linear output signal and pressure are related by the following formulas when **Pressure Unit** of measurement is in **Torr** and **mbar:** P= $10^{(volts-12)}$ where P is the pressure in Torr or mbar, and V is the output signal in volts. Refer to section 7.3 for details regarding this type of output. This selection is also compatible with certain analog output from the Granville-Phillips 307 & 350 controllers.

Linear IG
Select **Linear IG** as the analog output type to provide a 0-10 Vdc output signal that has a direct linear relationship to the displayed pressure measured by the ion gauge only. This selection covers 3 decades of pressure change. If your application requires the ion gauge analog output voltage to cover a pressure range exceeding three decades, then consider using the log-linear analog outputs. When you select Linear IG the Analog Output Setup Screen will reappear to allow programming of values for Min Pressure , Min Voltage , Max Pressure and Max Voltage . Refer to section 7.4 for details regarding this type of output signal. This selection is also compatible with certain analog output from the Granville-Phillips 307 & 350 controllers.

Wide Range IG+CG 0.5-7V
Select **Wide Range IG+CG 0.5-7V** as the analog output type to set the analog output voltage proportional to the pressure measured by the combination of an ion gauge and a convection gauge. This selection combines the analog output from an ion gauge and a convection gauge as one signal to provide a log-linear analog output voltage of 0.5 volts to 7 volts with a scaling factor of 0.5 V/decade of measured pressure. The log-linear output signal and pressure are related by the following formulas when **Pressure Unit** of measurement is in **Torr** and **mbar:** P = $10^{(volts-5.5)/(0.5)}$ where P is the pressure in Torr or mbar, and V is the output signal in volts. When you select **Wide Range IG+CG 0.5-7V** a new screen will appear to allow selection of a specific convection whose signal will be combined with the selected ion gauge. Note - When you select this option another screen appears prompting you to select which of the convection gauges you want to combine the IG analog output with. Make your selection accordingly. Refer to section 7.5 for details regarding this type of output.

1.8 to 8.7 V, .8/decade
Select **1.8 to 8.7 V, .8/decade** as the analog output type to set the analog output voltage proportional to the pressure measured by the ion gauge only. This selection provides an output voltage that is linear with respect to the common logarithm of pressure, i.e., log-linear analog output of 1.8 to 8.7 volts with a scaling factor of 0.8 V/decade of measured pressure. The log-linear output signal and pressure are related by the following formulas when **Pressure Unit** of measurement is in **Torr** P= $10^{((1.25 \bullet volts) - 12.875))}$ where P is the pressure in Torr and V is the output signal in volts. Refer to section 7.6 for details regarding this type of output signal. This selection is also compatible with the InstruTech CCM501 cold cathode vacuum gauge module.

Long-Linear CG I-8V
Select **Long-Linear CG I-8V** the analog output type to set the analog output voltage proportional to the pressure measured by the selected convection gauge. This selection provides an output voltage that is linear with respect to the common logarithm of pressure, i.e., log-linear analog output of 1 to 8 volts with a scaling factor of 1 V/decade of measured pressure. The log-linear output signal and pressure are related by the following formulas when **Pressure Unit** of measurement is in **Torr** and **mbar:** P= $10^{(volts - 5)}$ where P is the pressure in Torr or mbar, and V is the output signal in volts. Refer to section 7.7 for details regarding this type of output.

Long-Linear CG 0-7V
Select **Long-Linear CG 0-7V** as the analog output type to set the analog output voltage proportional to the pressure measured by the convection gauge only. This selection provides an output voltage that is linear with respect to the common logarithm of pressure, i.e., log-linear analog output of 0 to 7 volts with a scaling factor of 1 V/decade of measured pressure. The log-linear output signal and pressure are related by the following formulas when **Pressure Unit** of measurement is in **Torr** and **mbar:** P= $10^{(volts - 4)}$ where P is the pressure in Torr or mbar, and V is the output signal in volts.   Refer to section 7.8 for details regarding this type of output signal. This selection is also compatible with certain analog output from the Granville-Phillips 307, 350 and 358 controllers.

Linear CG
Select **Linear CG** as the analog output type to provide a 0-10 Vdc output signal that has a direct linear relationship to the displayed pressure measured by the convection gauge only. This selection covers 3 decades of pressure change. If your application requires the ion gauge analog output voltage to cover a pressure range exceeding three decades, then consider using the log-linear analog outputs. When you select Linear CG the Analog Output Setup Screen will reappear to allow programming of values for Min Pressure , Min Voltage , Max Pressure and Max Voltage . Refer to section 7.9 for details regarding this type of output.

Non-Linear CG
Select **Non-Linear CG** as the analog output type to set the analog output (non-linear) voltage proportional to the pressure measured by the convection gauge only. This produces a non-linear analog output signal of **0.375 to 5.659 Vdc for 0 to 1000 Torr of N$_2$**, roughly in the shape of an "S" curve.   Refer to section 7.10 for details regarding this type of output signal.   **Note -** This non-linear analog output is also equivalent to the Granville-Phillips® Mini-Convectron® non-linear S-curve analog output.

Set Defaults   - This function resets all user settable analog output parameters and values discussed in this section to factory default settings for the specific analog output selected.

Set Gauge Name   - This function allows you to change the default name of the analog output selected, for example, AO [2,2] to another name of your choosing. This screen allows you to scroll through an eight (8) character field for the analog output 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.

Test - This allows the user to manually output a voltage for the specific analog output selected to test for correct external circuit wiring.   Press the key associated with the respective key-designators displayed (➔ ⬅ ⬆⬇) to change the voltage output anywhere from 0 to 10 Vdc.

Min Pressure , Min Voltage , Max Pressure , Max Voltage - As described previously in this section these parameters apply only when the analog output scaling selected is IG Linear or CG Linear (0-10 Vdc Linear output). Otherwise, these parameters are grayed-out not accessible.   If you have selected IG Linear or CG Linear analog output scaling refer to section 7.4 and section 7.9 to determine how to setup the values for Min Pressure, Min Voltage, Max Pressure and Max Voltage.

5.9.7.2   Programming the Analog Input

If you are using analog input(s) from devices such as a capacitance diaphragm gauge or other InstruTech active gauges review section 5.9.7 and access the Analog I/O Select Screen shown below.
(i.e. Menu ⇨ Analog I/O).
                                    ⇩

```
┌───────────────────────────────────┐
│ ┌───────────┐     ┌───────────┐    │
│ │Analog     │     │Analog     │    │
│ │Inputs     │     │Outputs    │    │
│ └───────────┘     └───────────┘    │
│                                    │
│                                    │
│                                    │
│ ┌───────────┐                      │
│ │   BACK    │                      │
│ └───────────┘                      │
└───────────────────────────────────┘
```
Analog I/O Select Screen

Select Analog Inputs in the Analog I/O Select Screen shown above and the Analog Input Select Screen (or similar depending on option cards installed) will appear as shown below.   Next, select any of the desired analog inputs (for example AI [2] ⇨ or AI [3] , etc.) and the Analog Input Setup Screen for the selected analog input will appear as shown below.

```
┌────────────────────────────┐        ┌────────────────────────────────┐
│ ┌─────────┐                 │        │ ┌──────────┐   ┌─────────────┐  │
│ │ AI [2]  │                 │        │ │Device    │   │Set Gauge    │  │
│ └─────────┘                 │        │ │Type      │   │Name         │  │
│ ┌─────────┐                 │        │ └──────────┘   └─────────────┘  │
│ │ AI [3]  │                 │        │ ┌──────────┐                    │
│ └─────────┘                 │        │ │Set       │                    │
│                             │        │ │Defaults  │                    │
│                             │        │ └──────────┘                    │
│ ┌─────────┐                 │        │ ┌──────────┐   ┌─────────────┐  │
│ │  BACK   │                 │        │ │  BACK    │   │   MAIN      │  │
│ └─────────┘                 │        │ └──────────┘   └─────────────┘  │
└────────────────────────────┘        └────────────────────────────────┘
```
Analog Input Select Screen   ⇨   **Analog Input Setup Screen**

To program the Analog Input Setup Screen shown above, become familiar with the topics presented in the remaining pages of this section. To reach this point you have followed the above key entry sequence of:
Menu ⇨ Analog I/O ⇨ Analog Inputs ⇨ AI[n,m] ⇨

Device Type - Default is ITI NON-LINEAR
This selects the type of device you wish to input the analog voltage signal from. Press the Device Type key in the Analog Input Setup Screen above to select the device type. Press the up ⬆ or down ⬇ arrow keys to scroll through the available device types. When you use either the up ⬆ or down ⬇ arrow key, you will see the SAVE key appear in the display. The Device Type choices are:

ITI NON-LINEAR
Select **ITI NON-LINEAR** if you are using InstruTech's convection vacuum gauge modules such as the CVM211 Stinger or CVM201 Super Bee with a non-linear analog output (S-Curve).

ITI LOG IG
Select **ITI LOG IG** if you are using InstruTech's ion gauge module such as the IGM401, CCM501 or CCM502 with a Log-linear analog output.

ITI LOG CG
Select **ITI LOG CG** if you are using InstruTech's convection vacuum gauge modules such as the CVM211 Stinger, CVM201 Super Bee or capacitance-pirani PCM301 Busy Bee with a Log-linear analog output.

1000 Torr CDG
Select **1000 Torr CDG** for a 1,000 Torr full scale capacitance diaphragm gauge (CDG)

100 Torr CDG
Select **100 Torr CDG** for a 100 Torr full scale CDG

10 Torr CDG
Select **10 Torr CDG** for a 10 Torr full scale CDG

1 Torr CDG
Select **1 Torr CDG** for a 1 Torr full scale CDG

100 mTorr CDG
Select **100 mTorr CDG** for a 100 mTorr full scale CDG

Set Defaults - This function resets all user settable analog input parameters and values discussed in this section to factory default settings for the specific analog input selected.

Set Gauge Name - This function allows you to change the default name of the analog input selected, for example, AI [2] to another name of your choosing. This screen allows you to scroll through an eight (8) character field for the analog output 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.

5.9.8   Programming the COM Menu (RS232/RS485)

Either RS232 or RS485 serial communications may be used to send/receive commands to/responses from the *FlexRax.* If your *FlexRax* is equipped with the CM4000 option card you may program the serial communications per instructions given in this section. To start programming the COM menu press the key aligned with Menu and you will see the Main Menu Screen appear as shown below.

IGM [1]	OFF		Operate
CG [1,1]	1.00 E -04		
CG [1,2]	1.00 E -04		IGR [5] OFF
IGM [2]	1.00 E -06		
IGR [5]	OFF		IGE [6] ON
IGE [6]	1.00 E -09		
Pause	Unit: Torr Cal Gas: N2		Menu

RLY [3] ❶❷③④
RLY [4] ①❷③④❺❻❼⑧   Messages

Pressure Measurement Screen   ⇨

IGM		System
CG		IGR/IGE
Relays		COM
Analog I/O		
BACK		Help
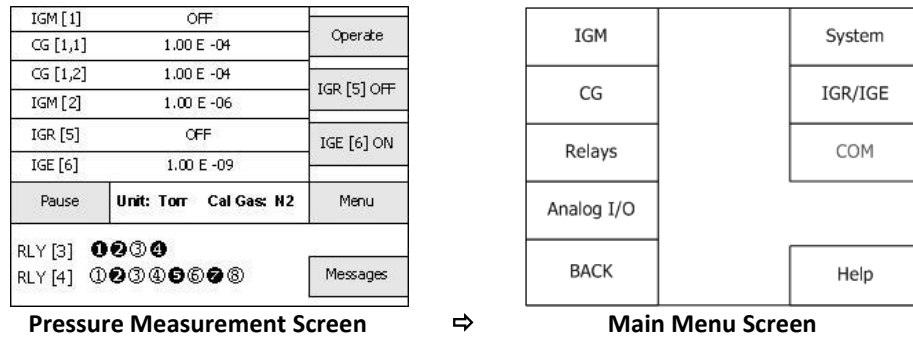
Main Menu Screen

Press the COM key in the Main Menu Screen above and the COM Setup Screen will appear as shown below.

COM Type		Parity
Baud Rate		Address
Data Bits		Pressure Unit
Stop Bits		Set Defaults
BACK		MAIN

COM Setup Screen

To program the COM Setup Screen shown above, become familiar with the topics presented in the remaining pages of this section. To reach this point you have followed the above key entry sequence of:
 Menu ⇨ COM   ⇨

 COM TYPE   - Default is RS232
This assigns the serial communications protocol. It supports three serial communications protocols as follow:

RS232
Select RS232 with start and stop characters, but no addressing is used. The syntax is the same as the RS485 protocol.

RS485
Select RS485 with address, start and stop characters and command/response syntax derived from the InstruTech IGM401 *Hornet* protocol.

GP232
Select RS232 protocol compatible with the Granville-Phillips (GP) Series 307 Vacuum Gauge controller.

Baud Rate - Default is 19200
Select Baud Rate from 300, 600, 1200, 2400, 4800, 9600, 14400, 19200, 28800, 38400 or 57600 baud.

Data Bits - Default is 8
Select number of Data Bits from 5, 6, 7, 8 or 9.

Stop Bits - Default is 1
Select parity from 1, 1.5 or 2.

Parity - Default is None
Select parity from None, Odd, Even, Mark or Space.

Address - Default is 01
Select *FlexRax* Address - not available when in RS232 modes. Address (for RS485 mode) can be set with the range of 01 to FF hexadecimal; default address is 01.   For example, an *ADDRESS* of 05 will make the address 0x05 in hexadecimal. An address of 15 will set the *ADDRESS* to 0x15 in hexadecimal.

Pressure Unit - Default is Torr
Select the pressure measurement unit from Torr, mbar or PA for serial communications.

Set Defaults - This function resets all user settable serial communications parameters and values discussed in this section to factory default settings.

Refer to Section 9 for more details including listing of various serial communications command protocols.

6   Activating and operating the Ionization Gauges

As previously discussed there are several methods of controlling operation of the ion gauges. For example the IG sensor can be turned on or off manually using the front panel push-buttons, automatically by using the pressure reading from a convection gauge or another type of device, or via serial communications. Degas can be initiated using the push-buttons or serial communications. It is assumed that you have read the previous sections of this User Manual as it applies to your application prior to operating any of the IG or CG transducers.

6.1   IG Turn On/Off Using the Push-Buttons

As shown in the display example below the user can turn on/off two of the IG sensors displayed as IGR [5] OFF and IGE [6] ON from the main Pressure Measurement Screen. These two IG sensors were either assigned as factory defaults or you have assigned them to the front panel per instructions for IG1 Assign and IG2 Assign section 5.9.1.1. In the example below press the Key aligned with IGR [5] OFF or IGR [6] ON to turn the respective IG on or off. If you have more than two IG sensors, the other two would have to be turned on or off in the specific IG programming menu. In the example below there are two additional ion gauges (IGM [1] and IGM [2]) that cannot be turned on from the Pressure Measurement Screen. To turn IGM [1] and IGM [2] on or off press the Main key to access the Main Menu Screen shown below .

Pressure Measurement Screen   ⇨   **Main Menu Screen**

Press the IGM key in the Main Menu Screen above and the IGM Select Screen (or similar depending on option cards installed) will appear as shown below. Select either IGM [1] or   IGM [2]   to access the IGM Operations Screen.   Press the Key aligned with IG On/Off and use the ⬆ or the down ⬇ keys to turn the IG on. Note that Operate/Stand-By must be in Operate mode.   Repeat the same steps to turn IG off.

IGM Select Screen   ⇨   **IGM Operations Screen**

Next, set up IGM [1]; perform the following programming sequence:

Menu ⇨ IGM ⇨ IGM1 ⇨ Setup ⇨ IG Control ⇨ You will see the following **Message box:**

Device Choice Shown Here

Either select 'Manual' to
direct IGM1 ON/OFF control
manually or choose an available
device to control IGM1 ON/OFF
setpoint using value programmed
for 'Over Pressure'

Use the up ⬆ or the down ⬇ keys to choose AI [1] in the highlighted box and press Save . After you press
Save , the IGM SETUP Screen will appear showing the Over Pressure as one of the menu choices.
Press the hardware key aligned with Over Pressure . You will see a Message:

{**Setup the pressure in Torr where the ion gauge IGM [1] will turn off**}.

Program the Over 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* 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 value, say, 20 mTorr will program an on/off switching point for
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* 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 sensor 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.

6.5   Degas Using the Push-Buttons

Degas for hot cathode ion gauges can be initiated using the push buttons. Use the same steps described in the previous section to access the IGM or IGR/IGE Operations Screen.

Menu ⇨(IGM or IGR/IGE) ⇨(IGM [n] or IGR [n] or IGE [n])

⇩

IG On/Off	Setup
Degas On/Off	View R&D
Clear Error	
BACK	MAIN

IGM/IGR/IGE Operations Screen
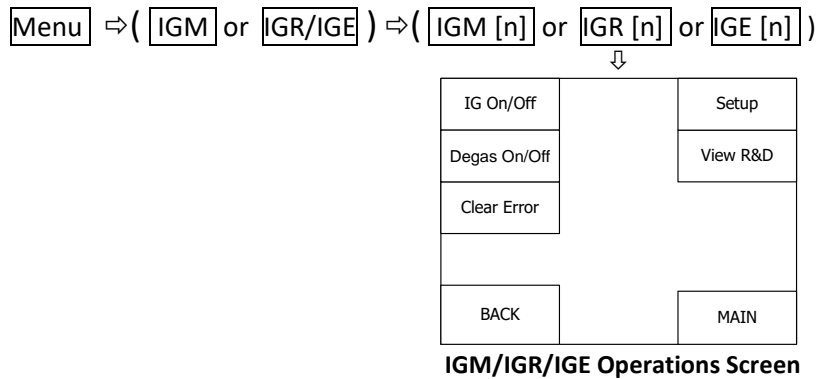
Press the Key aligned with Degas On/OFF and use the ⬆ or the down ⬇ keys to turn Degas on. If required, repeat the same steps to turn degas off. Note that degas turns off automatically when the value programmed for the Degas Time menu has elapsed.   Vacuum level must less than 5.00E-05 Torr before attempting to initiate Degas.   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.

6.6   Degas Using Serial Communications

Degas can also be initiated using serial communications. Refer to section 5.9.8 and section 9 for more details about using this control scheme.

6.7   Clearing IG Error

For any ion gauge device (IGM, 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 prior to being allowed to turn the IG to on. To clear an error condition which will otherwise prevent operation of the ion gauge, follow the menu sequence Menu ⇨ IGM ⇨ IGM [n] or   Menu ⇨ IGR/IGE ⇨(IGR [n] or IGE [n]) to access the IGM/IGR/IGE Operation Screen for the IG that is experiencing the error (showing IG as "OFF" in red). Press the Clear Error to perform the actions prompted to clear the error. Note - Sending an 'IG OFF' command when using RS232/RS485 serial communications or pressing IG OFF while in the R&D Display Screen will also clear any IG errors and allow the IG to be turned on again.

6.8   View R&D

The *FlexRax* provides an ion gauge transducer diagnostic display screen that allows you to monitor the measurements of the critical electrical IG filament parameters that is particularly helpful when troubleshooting IG issues. To view this type of screen access the IGM/IGR/IGE Operation Screen shown above and press the View R&D key. See section 10.1.5 or section 10.1.7 for more details.

7   Analog Output Charts & Equations (Nitrogen/Air Only)

This section provides various charts & equations for analog outputs available from the *FlexRax.*

7.1   *Analog Output for Log-Linear IG 0-10 V, n=10 (Nitrogen / Air only)*

When the analog output is setup, as described in section 5.9.7.1 for **Log-Linear IG 0-10 V, n=10**, the analog output voltage represents the pressured measured by the IG for nitrogen/air only. Refer to section 8.3.1 if you are using a gas other than nitrogen/air.

Analog output: IG Log-linear 0 to 9 Vdc, 1 V per decade

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

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

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 units of measurement is in **pascals:**

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

Where P is the pressure in pascals, and V is the output signal in V.

Notes: The output voltage will switch to above +11 Vdc under the following conditions:
1) The IG sensor is turned off or any IG fault condition.
2) When using the BA600 series glass/nude ion gauges the pressure exceeds 1.00×10^{-3} Torr at 100 µA emission current, 5.00×10^{-4} Torr at 4 mA emission current, 1.00×10^{-4} Torr at 10 mA emission current causing the IG to turn off.
3) 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.
4) When using the CCM500 the pressure exceeds 1.00E-02 Torr causing the IG to turn off.

Log-Linear Analog Output (N$_2$ /air only)

Pressure (Torr)	Voltage (V$_{DC}$)
1.00E-10	0.0
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
See Notes	≥ 11

The following chart shows the graphical results of table and formulas above for measurements in Torr.
Pressure is plotted on the X-axis with a log scale; the output signal is plotted on the Y-axis on a linear scale.

Log-Linear Analog Voltage to Pressure

7.2   Analog Output for Log-Linear IG 0-10 V, n=11 (Nitrogen / Air only)

When the analog output is setup, as described in section 5.9.7.1for *Log-Linear IG 0-10 V, n=11*, the analog output voltage represents the pressured measured by the IG for nitrogen/air only. Refer to section 8.3.1 if you are using a gas other than nitrogen/air.

Analog output: IG Log-linear 0 to 10 Vdc, 1 V per decade

A) The log-linear output signal and pressure are related by the following formulas when units 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 units of measurement is in **pascals:**

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

Where P is the pressure in pascals, and V is the output signal in volts.

Notes: The output voltage will switch to above +11 Vdc under the following conditions:

1) The IG sensor is turned off or any IG fault condition.
2) When using the BA600 series glass/nude ion gauges the pressure exceeds 1.00×10^{-3} Torr at 100 µA emission current, 5.00×10^{-4} Torr at 4 mA emission current, 1.00×10^{-4} Torr at 10 mA emission current causing the IG to turn off.
3) 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.
4) When using the CCM500 the pressure exceeds 1.00E-02 Torr causing the IG to turn off.

Log-Linear Analog Output (N$_2$ /air only)

Pressure (Torr)	Voltage (V$_{DC}$)
1.00E-11	0.0
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
See Notes	$\geq$11

The following chart shows the graphical results of table and formulas above for pressure measurements in Torr. Pressure is plotted on the X-axis with a log scale; the output signal is plotted on the Y-axis on a linear scale.
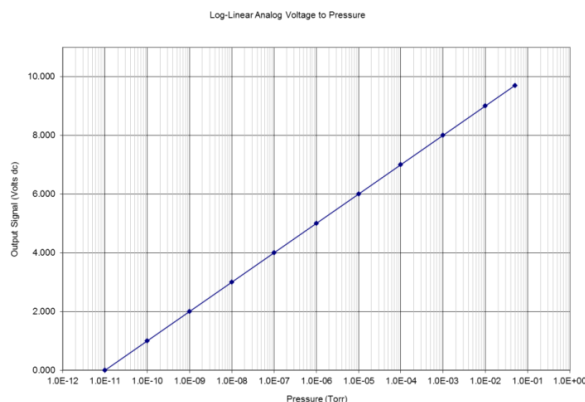
7.3   Analog Output for Log-Linear IG 0-10 V, n=12 (Nitrogen / Air only)

When the analog output is setup, as described in <u>section 5.9.7.1</u> for **Log-Linear IG 0-10 V, n=12**, the analog output voltage represents the pressured measured by the IG for nitrogen/air only. Refer to <u>section 8.3.1</u> if you are using a gas other than nitrogen/air.

Analog output: IG Log-linear 0 to 11 Vdc, 1 V per decade

A) The log-linear output signal and pressure are related by the following formulas when units 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 units of measurement is in **pascals:**

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

Where P is the pressure in pascals, and V is the output signal in volts.

Notes: The output voltage will switch to above +11 Vdc under the following conditions:

1) The IG sensor is turned off or any IG fault condition.
2) When using the BA600 series glass/nude ion gauges the pressure exceeds 1.00×10^{-3} Torr at 100 µA emission current, 5.00×10^{-4} Torr at 4 mA emission current, 1.00×10^{-4} Torr at 10 mA emission current causing the IG to turn off.
3) 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.
4) When using the CCM500 the pressure exceeds 1.00E-02 Torr causing the IG to turn off.

Log-Linear Analog Output (N$_2$ /air only)

Pressure (Torr)	Voltage (V_{DC})
1.00E-12	0.0
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
See Notes	>11

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

7.4   Analog Output for LINEAR IG (Nitrogen / Air only)

When the analog output is setup, as described in section 5.9.7.1 for **Linear IG** the analog output may be setup to provide a signal voltage that has a direct linear relationship to the displayed pressure by the ion gauge. 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 to the analog output voltage. For example, the following table is representative of a typical setup where;
Min P = 1.00E-06 Torr   Min Voltage = 0.01 Volts
Max P = 1.00E-03 Torr   Max Voltage = 10 V

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

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.

If your application requires the analog output voltage to cover a pressure range exceeding three decades, then consider using the log-linear analog output for 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 section 8.3.1.

Notes: The output voltage will switch to above +11 Vdc under the following conditions:
1) The IG sensor is turned off or any IG fault condition.

2) When using the BA600 series glass/nude ion gauges the pressure exceeds 1.00×10^{-3} Torr at 100 µA emission current, 5.00×10^{-4} Torr at 4 mA emission current, 1.00×10^{-4} Torr at 10 mA emission current causing the IG to turn off.

3) 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.

4) When using the CCM500 the pressure exceeds 1.00E-02 Torr causing the IG to turn off.

7.5 Analog Output for Wide Range IG+CG 0.5-7V (Nitrogen / Air only)

When the analog output is setup, as described in section 5.9.7.1 for **Wide Range IG+CG 0.5-7V**, the analog output voltage represents the combination of IG and CG for full range measurements. Refer to section 8.3.2 if you are using a gas other than nitrogen/air.

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

Log-Linear Analog Output (N_2 /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

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

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

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 units of measurement is in **pascals:**

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

Notes: The output voltage will switch to above +11 Vdc under the following conditions:
1) The CG is either damaged or disconnected.
2) The IG is off or faults and CG is damaged or disconnected.
3) The pressure exceeds 1.00E-03 Torr at 4 mA emission current, 5.00E-02 Torr at 100 µA emission current 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 emission current, 1.00E-04 Torr at 10 mA emission current, 1.00E-03 Torr at 100 µA emission current for BA600 series glass/nude IG and CG is damaged or disconnected.
5) Any IG or CG faults condition while operating in the IG or CG range respectively.

Note: When using this output, if the IG is turned off and pressure measured by CG is less than 1.00E-03 Torr, the output will be at 4 V.00 Volts. The minimum AO voltage for the CG is based on equivalent pressure of 1.00E-03.

The following chart shows the graphical results of table and formulas above for pressure measurements in Torr.

Log-Linear Analog Voltage to Pressure
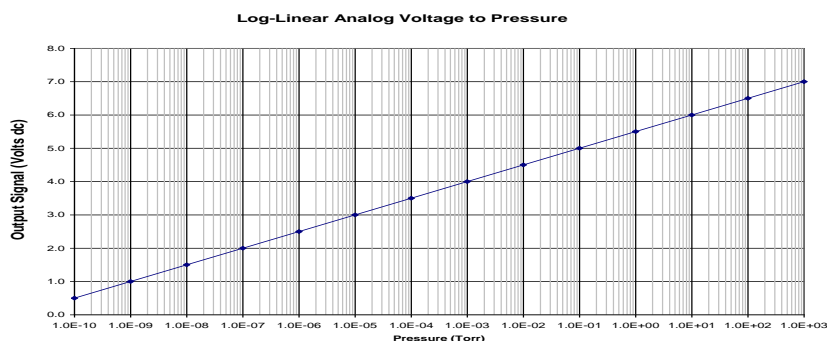
7.6   Analog Output for IG 1.8 - 8.7, .8V/decade (Nitrogen / Air only)

When the analog output is setup, as described in <u>section 5.9.7.1</u> for *1.8 - 8.7, .8V/decade,* the analog output voltage represents the pressured measured by the IG for nitrogen/air only. Refer to <u>section 8.3.1</u> if you are using a gas other than nitrogen/air.

Analog output: IG Log-linear 1.7 to 9.3 Vdc, 0.8 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:**

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

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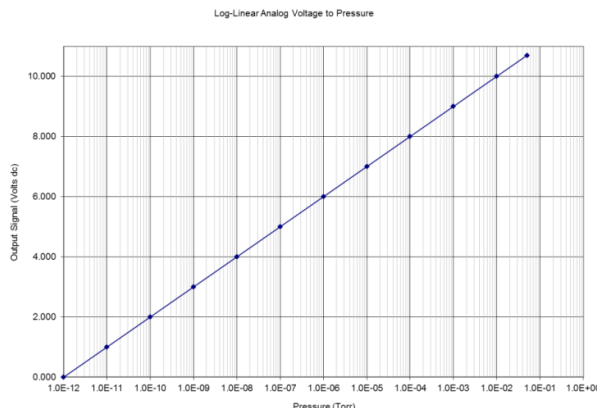
$$P = [10^{((1.25 \bullet volts) - 12.875)}] \times 133$$

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

Notes: The output voltage will switch to above +11 Vdc under the following conditions:

1) The IG is off or any IG fault condition.
2) When using the BA600 series glass/nude ion gauges the pressure exceeds 1.00×10^{-3} Torr at 100 μA emission current, 5.00×10^{-4} Torr at 4 mA emission current, 1.00×10^{-4} Torr at 10 mA emission current causing the IG to turn off.
3) 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.
4) When using the CCM500 the pressure exceeds 1.00E-02 Torr causing the IG to turn off.

Log-Linear Analog Output (N$_2$ /air only)

Pressure (Torr)	Voltage (V$_{DC}$)
2.00E-11	1.741
4.20E-11	2.0
7.50E-10	3.0
1.30E-08	4.0
2.40E-07	5.0
4.20E-06	6.0
7.50E-05	7.0
1.30E-03	8.0
5.00E-02	9.259
See Notes	$\geq$11

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

7.7   Analog Output for Log-Linear CG 1 - 8 V (Nitrogen / Air only)

When the analog output is setup, as described in section 5.9.7.1 for *Log-Linear CG 1 - 8 V*, the analog output voltage represents the pressure measured by a convection gauge for nitrogen/air only. Refer to section 8.3.3.1 if you are using a gas other than nitrogen/air.

Analog output: Convection Gauge Log-linear 1 to 8 Vdc, 1 V per decade

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

$$P = 10^{(volts - 5)} \qquad V = \log_{10}(P) + 5$$

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

The output voltage is 1 V when pressure is at 1.00E-04 Torr.

The output voltage is 8 V when pressure is at 1.00E+03 Torr.

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

$$P = 10^{(volts - 3)} \qquad V = \log_{10}(P) + 3$$

Where P is the pressure in pascals, and V is the output signal in volts.

Note - An analog output of above +11 volts indicates a faulty convection gauge or unplugged gauge cable.

The following chart shows the graphical results of table and formulas above for pressure measurements in Torr.
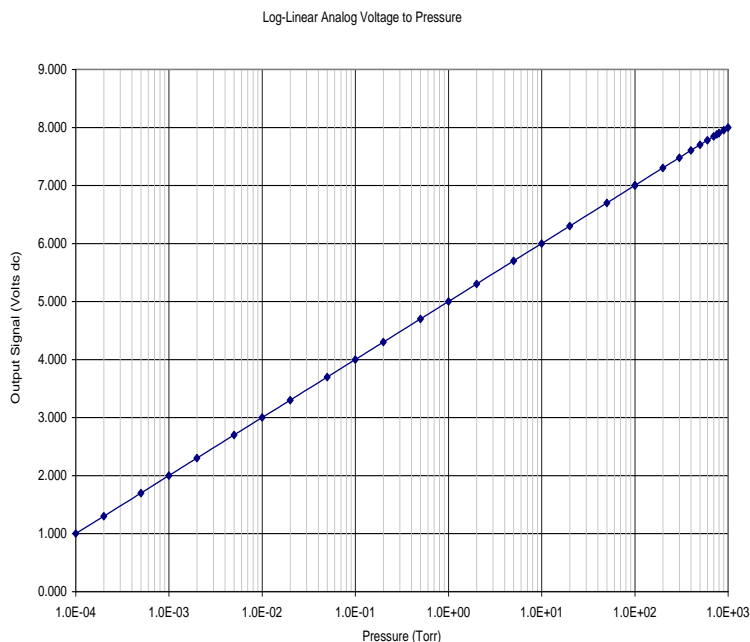
Log-Linear Analog Output (N$_2$/air only)	
Pressure (Torr)	**Voltage**
1.00E-04	1.000
2.00E-04	1.301
5.00E-04	1.699
1.00E-03	2.000
2.00E-03	2.301
5.00E-03	2.699
1.00E-02	3.000
2.00E-02	3.301
5.00E-02	3.699
1.00E-01	4.000
2.00E-01	4.301
5.00E-01	4.699
1.00E+00	5.000
2.00E+00	5.301
5.00E+00	5.699
1.00E+01	6.000
2.00E+01	6.301
5.00E+01	6.699
1.00E+02	7.000
2.00E+02	7.301
3.00E+02	7.477
4.00E+02	7.602
5.00E+02	7.699
6.00E+02	7.778
7.00E+02	7.845
7.60E+02	7.881
8.00E+02	7.903
9.00E+02	7.954
1.00E+03	8.000

Log-Linear Analog Voltage to Pressure

7.8   Analog Output for Log-Linear CG 0 - 7 V ((Nitrogen / Air only)

When the analog output is setup, as described in section 5.9.7.1 for *Log-Linear CG 0 - 7 V,* the analog output voltage represents the pressure measured by CG1 or CG2 for nitrogen/air only. Refer to section 8.3.3.2 if you are using a gas other than nitrogen/air.

Analog output: Convection Gauge Log-linear 0 to 7 Vdc, 1.0 V/decade.

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

$$P = 10^{(volts - 4)} \qquad V = \log_{10}(P) + 4$$

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

The output voltage is 0 V when pressure is at 1.00E-04 Torr.

The output voltage is 7 V when pressure is at 1.00E+03 Torr.

B) The log-linear output signal and pressure are related by the following formula when units of measurement is in **pascals**:

$$P = 10^{(volts - 2)} \qquad V = \log_{10}(P) + 2$$

where P is the pressure in pascals and V is the output signal in volts.

Note - An analog output above +11 volts indicates a faulty convection gauge or unplugged gauge cable.

The following chart shows the graphical results of table and formulas above for measurements in Torr.
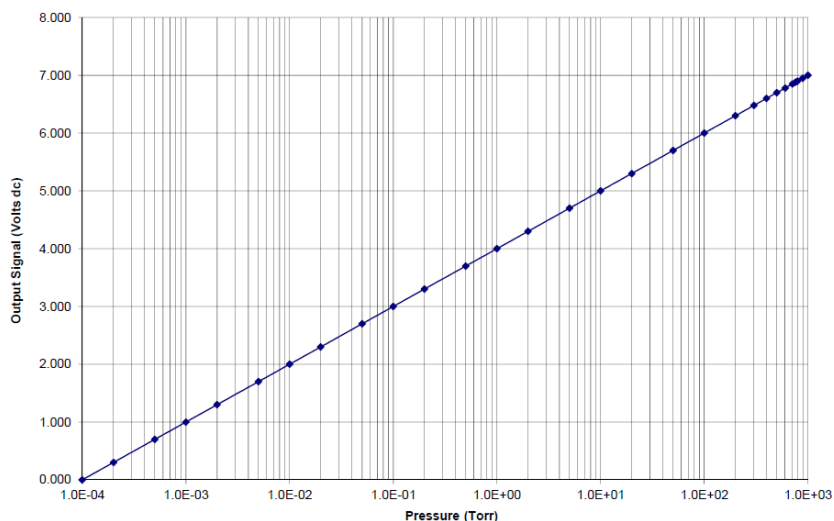
Log-Linear Analog (N$_2$ /air only)	
Pressure (Torr)	Voltage
1.00E-04	0.000
2.00E-04	0.301
5.00E-04	0.699
1.00E-03	1.000
2.00E-03	1.300
5.00E-03	1.700
1.00E-02	2.000
2.00E-02	2.300
5.00E-02	2.700
1.00E-01	3.000
2.00E-01	3.300
5.00E-01	3.700
1.00E+00	4.000
2.00E+00	4.300
5.00E+00	4.700
1.00E+01	5.000
2.00E+01	5.300
5.00E+01	5.700
1.00E+02	6.000
2.00E+02	6.300
3.00E+02	6.480
4.00E+02	6.600
5.00E+02	6.700
6.00E+02	6.780
7.00E+02	6.850
7.60E+02	6.880
8.00E+02	6.900
9.00E+02	6.950
1.00E+03	7.000

7.9   Analog Output for Linear CG (Nitrogen / Air only)

When the analog output is setup, as described in section 5.9.7.1 for **Linear CG** the analog output may be setup to provide a signal voltage that has a direct linear relationship to the displayed pressure by the convection gauge. 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 to the analog output voltage. For example, the following table is representative of a typical setup where;
Min P = 1.00E-03 Torr   Min Voltage = 0.01 Volts
Max P = 1.00 Torr   Max Voltage = 10 V

Linear Analog Output Voltage - volts	Measured (Displayed) Pressure - Torr
0.01	1.00E-03
0.10	1.00E-02
1.00	1.00E-01
10.00	1.00E+00

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 10.0 volts should not exceed 1.00 Torr.   Doing this is considered best practice when using this type of analog output signal.

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

Note - An analog output of above +11 volts indicates a faulty convection gauge or unplugged gauge cable.

7.10 Analog Output for Non- Linear CG (Nitrogen / Air only)

When the analog output is setup, as described in section 5.9.7.1 for **Non-Linear CG,** the analog output voltage represents the pressure measured by a convection gauge for nitrogen/air only. Refer to section 8.3.3.3 if you are using a gas other than nitrogen/air.

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 output of the *FlexRax* duplicates the original S-curve of 0.375 volts at pressure less than 1.00×10^{-4} Torr to 5.659 volts at 1000 Torr, nitrogen or air.
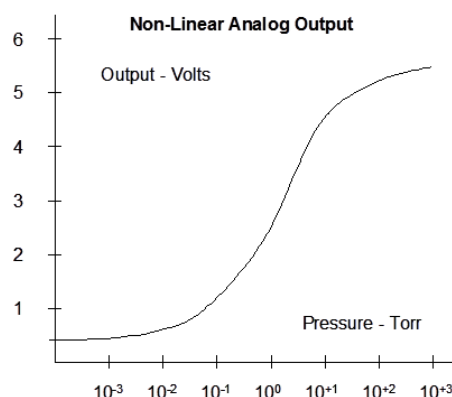
In general, one may use linear interpolation techniques to calculate the pressure using the non-linear analog output voltage measured at a specific pressure.   You may also calculate the N_2/air pressure represented by the non-linear analog output voltage for the original "S-curve" using a multi-segment, n^{th} order polynomial function calculation listed on the following page.

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		

Note - An analog output of above +11 volts indicates a faulty convection gauge or unplugged gauge cable.

The equations and coefficients for the nth order polynomial equation defined for various pressure measurement ranges for the Non-linear analog output (S-curve) for CG for N_2/air described above 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 $y(x) = \dfrac{a+cx+ex^2}{1+bx+dx^2+fx^3}$	
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 $y(x) = \dfrac{a+cx}{1+bx+dx^2}$	
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 = 1.00E-03 Torr

8   Using the gauge with different gases

The following tables and explanation contain important information regarding the use of ionization and convection gauges when used to measure pressure of gases other than nitrogen /air. The *FlexRax* pressure display assumes that the pressure measurement device is reading nitrogen pressure.   For both types of gauge transducers, corrections must be applied to both the display and analog outputs. This is particularly critical when using convection gauges at higher pressures than measured by the ion gauge when using gases other than N_2/air.

8.1   Ion Gauge Display Correction Factors for Selected Gases

There are two methods that can be used for monitoring the IG display when using gases other than nitrogen/air:

1)   If you are using a gas other than N_2 / air, <u>you must</u> manually apply a gas correction factor to the IG displayed measurement. Post a label on your ion gauge display showing the correction factor to be used for the pressure of the gas type you are measuring. The table below provides typical correction factors for ion gauges when used with gas types other than N_2 / air. To correct the display measurements, divide the displayed measured pressure by the correction factor for the gas type you are measuring.

Ion Gauge Gas Correction Factors for selected gases

Gas	Gas Correction Factor		Gas	Gas Correction Factor
He	0.18		H_2O	1.12
Ne	0.30		NO	1.16
D_2	0.35		Ar	1.29
H_2	0.46		CO_2	1.42
N_2	1.00		Kr	1.94
Air	1.00		SF_6	2.50
O_2	1.01		Xe	2.87
CO	1.05		Hg	3.64

For example, if the gas in use is argon (Ar) and the ion gauge measured pressure is displayed as 4.00×10^{-7} Torr, the actual, true pressure of argon is then determined by the following equation:

$$\frac{4.00 \ x \ 10^{-7}}{1.29} \text{ Torr} = 3.10 \times 10^{-7} \text{ Torr, Ar}$$

2)   Alternatively, you may correct the display for a direct reading of pressure for the type of gas you are using by adjusting the sensitivity factor for the IG. If you adjust the sensitivity factor for your ion gauge to compensate the readout of pressure for a gas type other than nitrogen / air, 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* could be set for 12.9 (10 X 1.29 = 12.9) so that the pressure readout would directly 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 "GAS: N_2" following the "Unit" notation in the Pressure Measurement Screen.

8.2   Effects of Different Gases on Convection Gauge Display

Convection gauge operation is based on the physical effect of thermal conductivity of the gas inside the gauge transducer. The convection gauge senses heat loss in a sensor wire. This heat loss depends on the thermal conductivity of the gas surrounding the sensor wire. 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, heat loss type gauges) are normally calibrated using nitrogen. When a gas other than N_2 is used, correction must be made for the difference in thermal conductivity between N_2 and the gas in use. The charts and tables below indicate how different gases affect the display from an InstruTech convection gauge.

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

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

Generally, air and N_2 are considered the same as far as thermal conductivity goes, but even these two gases 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 about 30 to 40 Torr after the chamber is opened and air gradually displaces the N_2 in the gauge. This is due to the partial pressure of oxygen (O_2) contained in atmospheric air.
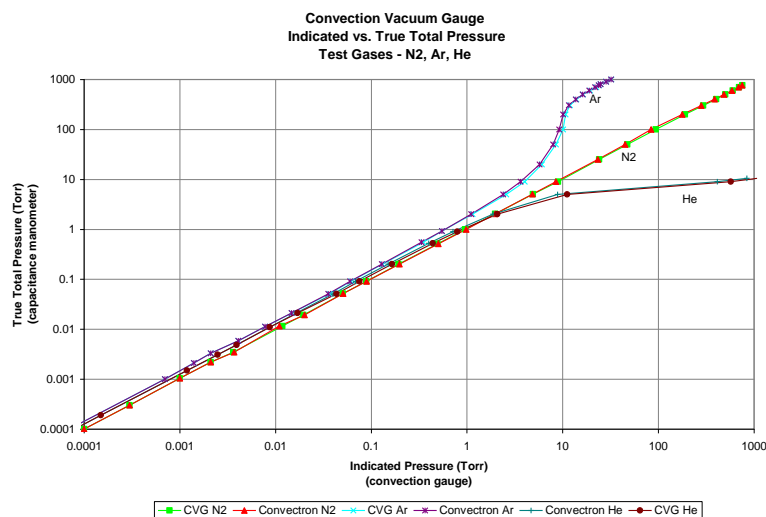
The Y- axis of the above chart is actual pressure as measured by a capacitance manometer, a diaphragm gauge that measures true total pressure independent of gas composition. The X-axis is the pressure reading indicated by the convection gauge under test. This chart shows readings for an InstruTech convection gauge (CVG) and Granville-Phillips® Convectron® gauge to illustrate that the difference in the response for both of these types of gauges is virtually indistinguishable.

⚠ **CAUTION!** Do not assume this data applies to other convection gauges which may or may not be the same. See Table below and note the following examples:

Displayed pressure readings for convection gauge type devices 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

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

Example C: If the gas is helium (He), the gauge will read 1.10E+03 (overpressure indication) Torr when pressure reaches about 10 Torr true pressure and opening the chamber to atmosphere prematurely may present other hazards for both people and product. You probably will not cause damage to your vacuum system, but opening the chamber to atmosphere with the internal chamber pressure at only 10 Torr true pressure, may present other hazards for both personnel in the proximity and product that may be inside the chamber/vessel.

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

Suggested precautions when using gases other than N_2:

- Install a pressure relief valve or burst disk on your chamber to provide protection from the dangers associated with over pressurizing the chamber.

- Post a warning label on your gauge readout such as "Do Not Exceed _____ Torr Indicated Pressure" (fill in the blank for the gas type you are using) so that an operator using the vacuum chamber system and connected gauge will not exceed a safe operating pressure.

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

⚠ **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.**

⚠ **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.

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.

8.3   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.

8.3.1   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)   Refer to section 7 and use the related equation to 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		Gas	Gas Correction Factor
He	0.18		H_2O	1.12
Ne	0.30		NO	1.16
D_2	0.35		Ar	1.29
H_2	0.46		CO_2	1.42
N_2	1.00		Kr	1.94
Air	1.00		SF_6	2.50
O_2	1.01		Xe	2.87
CO	1.05		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 = 1.00×10^{-6} Torr (based on nitrogen)

Applying the gas correction factor of 1.29 for argon listed in the table above,

P (argon) = $\dfrac{1.00 \times 10^{-6}}{1.29}$ = 7.75×10^{-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 = 1.00×10^{-7} Torr (based on nitrogen),

P (argon) = $\dfrac{1.00 \times 10^{-7}}{1.29}$ = 7.75×10^{-8} Torr true pressure of **argon** gas

8.3.2   Wide Range IG + CG 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)   **IG pressure range from the x-ray limit to 1.00E-03 Torr**
   Use the information described in <u>section 8.3.2.1</u> below to determine pressure from the voltage for selected gases.

B)   **CG pressure range from 1.00E-03 Torr to 1,000 Torr**
   Use the look-up table and information provided in <u>section 8.3.2.2</u> below to determine pressure from the voltage for selected gases.

8.3.2.1   *Wide Range 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 1.00E-03 Torr.

C)   Refer to <u>section 7.5</u> and use the related equation to convert the voltage in your receiving instrument to pressure. This pressure value is based on nitrogen gas.

A)   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	Gas	Gas Correction Factor
He	0.18	H_2O	1.12
Ne	0.30	NO	1.16
D_2	0.35	Ar	1.29
H_2	0.46	CO_2	1.42
N_2	1.00	Kr	1.94
Air	1.00	SF_6	2.50
O_2	1.01	Xe	2.87
CO	1.05	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) = $\frac{1.00 \times 10^{-5}}{1.29}$ = $\mathbf{7.75 \times 10^{-6}}$ Torr true pressure of **argon** gas

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

8.3.2.2 *Wide Range IG + CG Analog Output Correction Factors - 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 1.00E-03 Torr to 1,000 Torr. The look-up table below has been derived from table and related equation listed in section 7.5.

Analog output for IG + CG wide range selection when pressure is 1.00E-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 2.00E-01 Torr

8.3.3   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.

8.3.3.1   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 below has been derived from the equation provided in section 7.7.

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).

Example: The gas in use is O_2. Voltage output is 4.288 volts. True pressure of O_2 is 2.00E-01 Torr.

8.3.3.2 *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 below has been derived from the equation provided in section 7.8.

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).

Example:

The gas in use is O_2.
Voltage output is 3.288 volts.
True pressure of O_2 is 2.00E-01 Torr.

8.3.3.3 *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 below has been derived from the equation provided in section 7.10.

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).

Example:
The gas in use is O_2.
Voltage output is 1.141 volts.
True pressure of O_2 is 2.00E-01 Torr

9   Serial Communications

The following settings may be made from the *FlexRax* front panel controls as described in <u>section 5.9.8.</u>

- **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 01 to FF hexadecimal; default address is 01.
- **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*. 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.

9.1   *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 IC4000 option card	IG1
CG [1,1]	CG1
CG [1,2]	CG2
IGM [2] – second IC4000 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 AI4000-8 card installed in location [3]}	AI1
AI [4] {same assumption as above and a second AI4000-8 card is installed in location [4]}	AI2
RLY [3,1] {same assumptions as above – AI4000-8 card in slot [3]; card has 8 relays}	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 AI4000-8 card in slot [4]; card has 8 relays}	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] – IR4000 option card installed in location [5]	IG3
IGE [5] – IE4000 option card installed in location [5]	IG3
IGR [6] – IR4000 option card installed in location [6]	IG4
IGR [6] – IR4000 option card 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 AI4000-4 option located in card location ③ will be referred to as RL1, RL2, RL3 and RL4. The remaining 8 each relays installed on the AI4000-8 card are then referred to RL9 and RL10 thru RL16 in the serial communication command/response protocol.

9.2   RS485 /RS232 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>\n(e.g., #01RDIG1<CR>)\n\n**Note:** The '<CR>'used in all Command Syntax and Response examples represents a 'carriage return'	*xx_y.yyEzyy<CR>\n(e.g., *01_1.53E+06<CR>)\n\nWhen device does not exist:\n*01_9.90E+09\n\nWhen IG is off: *01_1.01E+03
READ CGn Pressure	Read the designated CG pressure in Torr units	#xxRDCGn<CR>\n(e.g., #01RDCG1<CR>)	*xx_ y.yyEzyy <CR>\n(e.g., *01_7.60E+02<CR>)\nWhen device does not exist:\n*01_9.90E+09\nWhen CG is over-ranged:\n*01_1.01E+03
READ AIn Pressure	Read the current pressure for AIn.	#xxRDAIn<CR>\n(e.g., #01RDAI1<CR>)	*xx_ y.yyEzyy <CR>\n(e.g., *01_7.60E+02<CR>)\nWhen device does not exist:\n*01_9.90E+09\nWhen 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>\n(e.g., #01RL<CR>)\n\n\n\n{Table continued below}	*xx_FFFFFFRL<CR>\n(e.g., right most 'F' represents the first 4 relays installed on the first installed AI4000 option card; hexadecimal 0003 = binary 0011 = RL1 and RL2 ON …)\nWhen device does not exist:\n?01_INVALID_<CR>

COMMAND	BRIEF DESCRIPTION	COMMAND SYNTAX	RESPONSE
READ one particular Relay state	Read the current state of *one* 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> **Note: 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 (01 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.

9.3   G-P Compatible (RS232) Interface - Device Name Conventions

Please reference section 9.1 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 IC4000 option card installed in card slot location ① of the *FlexRax* is named IGM [1] by the *FlexRax* (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 IC4000 option card	IG3
CG [1,1]	CG1
CG [1,2]	CG2
IGM [2] – second IC4000 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 AI4000-8 card installed in location [3]}	AI1
AI [4] {same assumption as above and a second AI4000-8 card is installed in location [4]}	AI2
RLY [3,1] {same assumptions as above – first AI4000-8 card in slot [3]; card has 8 relays}	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 AI4000-8 card in slot [4]; card has 8 relays}	PC9
RLY [4,2]	PC10
RLY [4,3]	PC11
RLY [4,4]	PC12
IGR [5] – IR4000 option card installed in location [5]	IG1
IGE [5] – IE4000 option card installed in location [5]	IG1
IGR [6] – IR4000 option card installed in location [6]	IG2
IGE [6] – IE4000 option card installed in location [6]	IG2

9.4   (G-P Series 307 Compatible[6]) 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[7] ; 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 PCₙ 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

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[6] 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 cards and gauges cannot be utilized when using the GP232 communications mode.

[7] 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 AI4000 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 AI4000-4 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 A4000-8 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.

10 Troubleshooting

10.1 Error Conditions

Certain events can occur that will generate an error condition for either one of the option cards installed or one of the gauges connected to the *FlexRax*. Some examples of these error conditions are presented below. If you are having trouble making one of the option cards or gauges 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.

10.1.1 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.
- The glass/nude 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.

10.1.2 IGM Indicates OFF

IGM 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: IGM cable is not connected to the IGM400/CCM500 *Hornet* and *FlexRax.*
- REMEDY: Be certain to fully engage and secure the IGM cable to the D-subminiature connector on the IGM400/CCM500 panel and ensure the mini-DIN connector end of the IGM cable is connected to the mating connector on the IC4000 option card.

10.1.3 Problems with Connected Gauges

Refer to the Troubleshooting Section of the User Manual for the gauge exhibiting problematic operating characteristics. In many situations, it is advised that you swap the suspect gauge/connecting cable with a known good gauge and/or cable to determine if the problem is with either the gauge or the cable.

When using a modular design type device such as the IGM400 or CCM500 *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:
- Atmosphere and zero has not been set
- 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

10.1.4 Unable to Access Setup Functions

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 gauges, be certain that the *FlexRAX* is in 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 gauges. You may not be allowed access to certain setup parameters when you are in the '**Stand-by**' mode.

IGM [1]	OFF
CG [1,2]	1.00 E -04
IGM [2]	OFF
CG [2,2]	1.00 E -04
AI [3]	0.00 E +00
IGR [5]	OFF

Operate

Unit: Torr Cal Gas: N2	Menu

RLY [3] ❶ ❷ ③ ❹
RLY [4] ① ❷ ❸ ④

Messages

Press the key aligned with the key-designator box shown in the display to alternate the *FlexRax* mode from '**Stand-by**' to '**Operate**'
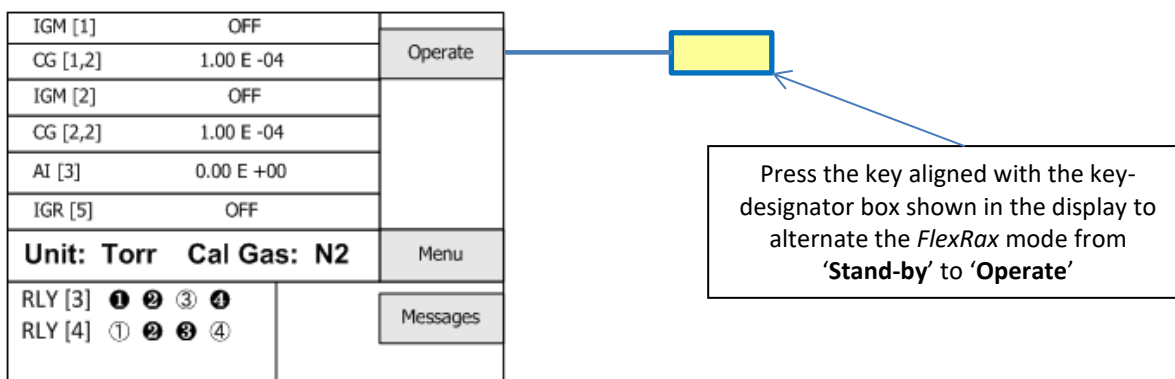
Refer to section **5.4** for more information related to '**Operate**' / '**Stand-by**'

10.1.5 View R&D - Hot Cathode Ion Gauge Diagnostic Display

Over time, the hot cathode (filament) of the ion 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 ion 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 ion gauge. To access this screen, perform the following key entry sequence for the glass/nude gauge | Menu | ⇨ | IGR/IGE | ⇨ | IGR [n] | ⇨ | View R&D | ⇨ or
| Menu | ⇨ | IGM | ⇨ | IGM [n] | ⇨ | View R&D | ⇨ for the IGM400 and the R&D Screen is displayed similar to what is shown below:

```
Unit:  Torr    IGR [n]
    Pressure              1.16 E-07          Degas On
    Collector Current     1.16 E-10
    Emission Current      1.00 E-04          Degas Off
    Filament Voltage      2.40 E00
    Filament Current      2.89 E00           IG On
         Gain Setting          High
                                             IG Off
    CLOSE
```

Example: R&D display of critical hot cathode ion gauge measurement parameters

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 ion gauge 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 ion gauges. 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 ion 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 ion gauge 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 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 few examples of these values are given below:

A new IGM400 *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).

A new BA602/BA603 glass/nude I^2R resistive degas ion gauge may operate at 100 µA emission current with only 3.5 A of filament current. By increasing the emission current to 10 mA, the filament current requirement may increase to 4.5 A. Maximum filament current is 6.5 A.

A new BA601 nude EB-degas ion gauge may operate at 100 µA emission current with only 3 A of filament current. By increasing the emission current to 10 mA, the filament current requirement may increase to 3.5 A. Maximum filament current is 4 A.

Again, the values mentioned above are representative; the actual values you may see for the IG you are using will be different and will vary over time and from gauge to gauge. 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 gauge 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.

In the example **R&D** Screen above for the IGM400, 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 emission current requirement will also change the filament heating power requirement.

For ion gauges 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 tables (***R & D (Research) Ion Gauge Diagnostic Display***) are 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 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.

10.1.6 Troubleshooting - Hot cathode IG

The parameters under the *"Indication"* column are seen in the View R & D Screen of *FlexRax.*

Indication	Possible Cause	Possible Solution
Displayed pressure appears very different from expected pressure	Sensor not in the proper location to measure system pressure	Ensure the sensor is located in appropriate location
	The process gas is different from the gas (nitrogen) used to calibrate the IG	Apply gas correction factor if applicable
	Sensor has been dropped causing mechanical damage	Replace the hot cathode gauge sensor
	The gauge sensor is contaminated	Clean or replace sensor
	Leak in the vacuum system	Re-check for leak in the system Re-check that all metal seals are used when operating below 1×10^{-7} Torr
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.	Determine source of contamination - Replace the ion gauge sensor tube.
	IGR or IGE Electrometer defective	Replace IGR or IGE option card
	IGM400 Electrometer defective	Replace IGM400 electronics
Pressure measurement is too high – Overpressure	The calculated pressure is greater than maximum setting for emission current.	Change hot cathode B-A IG to 100uA emission current which will allow operation at higher pressures
	System pressure too high	Reduce 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	Switch to 4 mA emission current and attempt repeated filament starts to clean electrodes
	Gauge contamination, possible coating on filament or grid surfaces	If using dual filaments switch to second filament or replace ion gauge sensor
	System pressure too high	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

Indication	Possible Cause	Possible Solution
IGM400 *Hornet* filament voltage[8] 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.
BA602/BA603 IG filament current is greater than 6.5 A	Filament nearing end-of-useful-operating-life	Switch to second filament or replace ion gauge sensor
BA601 IG filament current is greater than 4 A	Filament nearing end-of-useful-operating-life	Switch to second filament or replace ion gauge sensor
BA601/BA602/BA603 IG filament voltage is greater than 16 V	Excessive voltage drop in ion gauge cable	The ion gauge cable maybe too long, wire gauge is too small or a defect in the cable or connectors

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[8] 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.

10.1.7 View R&D - Cold Cathode Ion Gauge Diagnostic Display

When using a cold cathode CCM500 with the *FlexRax,* the R & D Screen can show electrometer current (discharge current) and the cold cathode IG anode voltage. To access this screen, perform the following key entry sequence: Menu ⇨ IGM ⇨ IGM [n] ⇨ View R&D ⇨ and the R&D Screen is displayed similar to what is shown below:

```
Unit:  Torr    IGM [n]
     Pressure              6.66E-05
     Current               3.60E-04


     Hi  Voltage           2.10E03        ┌──────────┐
                                          │  IG On   │
                                          ├──────────┤
                                          │  IG Off  │
                                          └──────────┘
     ┌──────────┐
     │  CLOSE   │
     └──────────┘
```

Example: R&D display of critical cold cathode ion gauge measurement parameters

The indication of "Current" in the R & D display is a real time measurement of the cold cathode discharge current. This current is proportional to the pressure of gas inside the transducer (sensor). The pressure measured is based on this discharge current level. As the gas pressure increases the discharge current also increases. The pressure reading for the cold cathode ionization gauge is determined by the output of an electrometer circuit in the CCM500, a nominal curve-fit algorithm and a look-up table that resides in the *FleRax* controller operating system.

The indication of "Hi Voltage" in the R & D display is a real time measurement of the cold cathode anode voltage. This voltage will change with increasing pressure. If the pressure reading that you see in the *FlexRax* is lower than expected, these two indications in the R & D Screen may be viewed to, perhaps, discern the relative conditions of the measurement being made. If the CCM500 has become contaminated, excess electrical current leakage may occur causing the anode voltage to be lower than it should be for the pressure measurement to be realistic. The best practice is to document the discharge current and anode voltage at initial installation of the device then, thereafter at periodic intervals over time at a known operating pressure for your system. In general, your system base pressure may be relatively stable (assuming no leaks have developed and that the vacuum pump is operating at normal pumping capacity). The base or ultimate pressure of your vacuum system may be a good pressure level to periodically check and record the readings displayed in the R & D Screen.
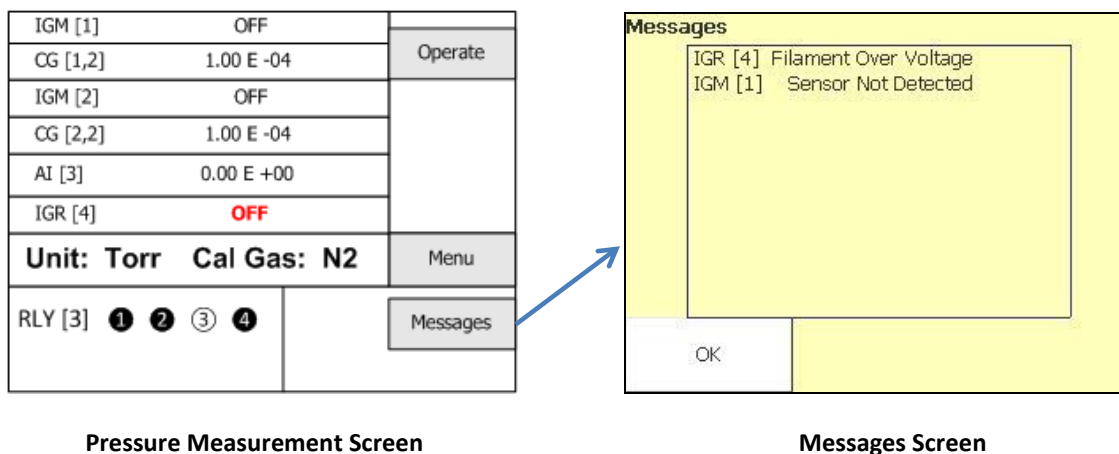
10.1.8 Troubleshooting - Cold cathode IG

Indication	*Possible Cause*	*Possible Solution*
Displayed pressure appears very different from expected pressure	Sensor not in the proper location to measure system pressure	Ensure the sensor is located in appropriate location
	The process gas is different from the gas (nitrogen) used to calibrate the CCM501	Apply gas correction factor if applicable
	Sensor has been dropped causing mechanical damage	Replace the Cold Cathode gauge sensor
	The gauge sensor is contaminated	Clean or replace sensor
	Leak in the vacuum system	Re-check for leak in the system Re-check that all metal seals are used when operating below 1×10^{-7} Torr
	Incorrect Sensitivity or CAL FACTORS C	Ensure correct values programmed
Displayed pressure is significantly lower than expected pressure	The gauge sensor is contaminated	Clean or replace sensor
	Incorrect Sensitivity and CAL FACTORS C	Ensure correct values programmed
Gauge cannot be activated (unable to turn anode voltage on)	Pressure exceeds value programmed for OVER PRESS	Decrease pressure below required value
	Chamber pressure higher than 1.00×10^{-2} Torr	Decrease chamber pressure below value programmed for OVER PRESS
Gauge will not start at low pressure	Pressure is too low to initiate discharge	Repeat step to activate sensor
		Increase HV TIMEOUT to allow more time for sensor activation
		Increase pressure
R & D Screen shows Hi Voltage is present but Current stays at 0	Defective electronics	Repair or replace CCM500 electronics

10.2 Error Indications and Messages

An *Error* message happens when the *FlexRax* issues a message to the Messages Screen or the pressure indication is either out-of-range or indicating something other than expected pressure.

Certain error conditions are indicated on the **Pressure Measurement Screen.** For example, you may see pressure measurement reading of **OFF** (OFF in red color letters). Refer to the **Pressure Measurement Screen Error Indication** table below in section section 10.2.1 to see the *Cause* and a *Solution* for the **OFF** condition of the IG.   The *Solution,* in this case, refers the user to the Messages Screen. Press the "Messages" key to access the Messages Screen.   Refer to the **Error Messages in the Messages Screen** table below (section 10.2.2**)** and find the 'Filament Over Voltage' entry in the Error Messages column.

IGM [1] OFF	
CG [1,2] 1.00 E -04	Operate
IGM [2] OFF	
CG [2,2] 1.00 E -04	
AI [3] 0.00 E +00	
IGR [4] **OFF**	
Unit: Torr Cal Gas: N2	Menu
RLY [3] ❶ ❷ ③ ❹	Messages

Pressure Measurement Screen

Messages
  IGR [4] Filament Over Voltage
  IGM [1]   Sensor Not Detected

  OK

Messages Screen

10.2.1 Pressure Measurement Screen Error Indication

The possible error indications you may see in the Pressure Measurement Screen are listed below.

Error Indication	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[9] 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 gauges that you may be operating with the *FlexRax*. If an error is preventing the operation of a gauge, 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 10.1.1 for an example of clearing an error condition.

---

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

10.2.2 Error Messages in the Messages Screen

The possible error messages that you may see in the Messages Screen are listed below.

| Error Messages	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 10.1.5 - 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

10.3 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 gauge names (if not using the default names provided) that are meaningful to your application yet do not appear misrepresented in the Pressure Measurement Screen.

10.4 Operating System Error
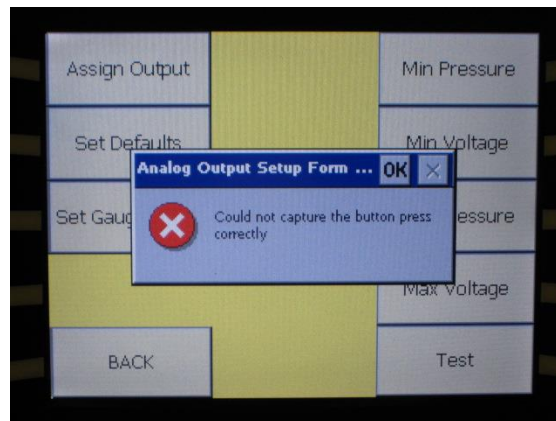
An operating system error is displayed similar to shown above. Although unlikely, there could be a set of conditions where the operating system utilized in the *FlexRax* issues an error condition causing a message box to overwrite on the display as shown above. These message boxes will be particular 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".   Contact for further action by InstruTech to remedy the conditions that cause these errors.

11 Replacing or Adding Option Cards

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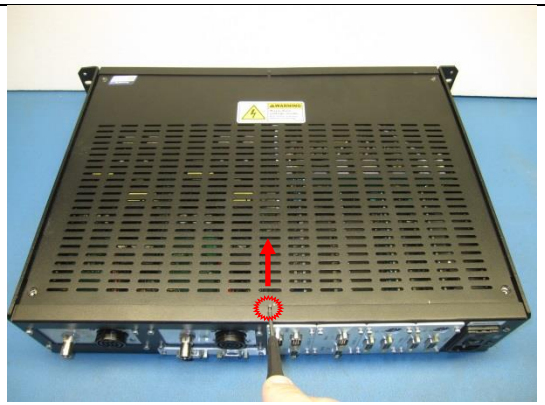
1. Remove top three screws of both sides of Instrument (6 total) marked with red circles.

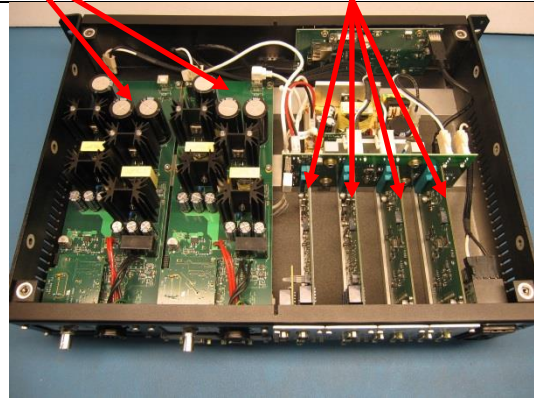| |
|---|
| 2. Remove all four screws of the top cover marked with red circles. |

| |
|---|
| 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.
IR4000 / IE4000 card Locations
        IC4000 & AI4000 option cards locations

6. Remove four socket head cap screws marked with red circles in order to add or replace a specific IC4000 and/or AI4000 card (Use a 3/32 in. Hex key to remove screws).
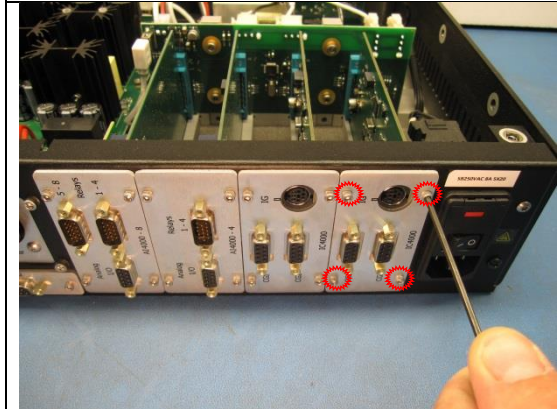
7. Slide the option card out of the enclosure. Add or replace card. When facing the back panel, always populate option cards from right to left. Do not leave empty slots between option cards.
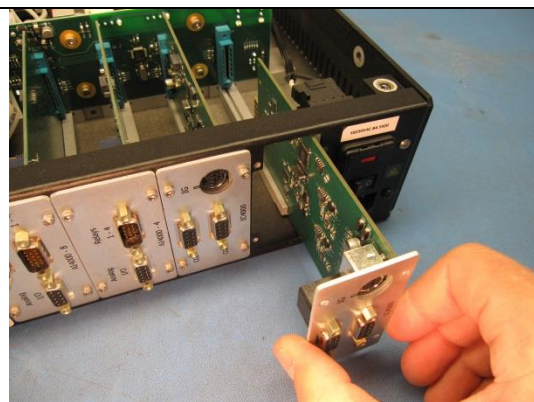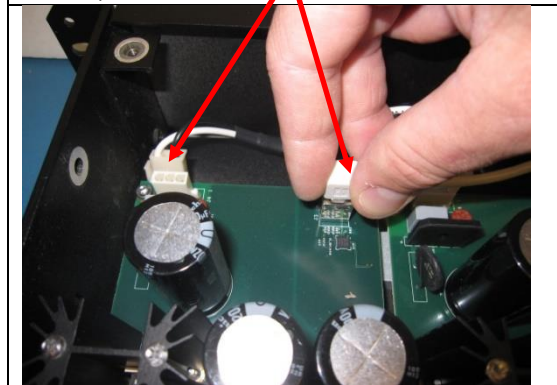

7. Remove four socket head cap screws marked with red circles in order to add or replace an Isection
8. 4000 or IE4000 card (Use 7/64 in. Hex key to remove screws).

9. Connectors attached to IR4000 / IE4000 card shown below.

10. Disconnect both connectors attached to the IR4000 / IE4000 card.

11. Remove four socket head cap screws marked with red circles for IR4000 card (two screws for IE4000 card).
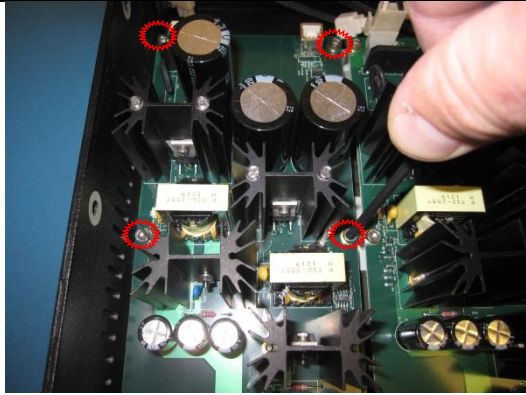
12. Lift and replace IR4000 or IE4000 card.
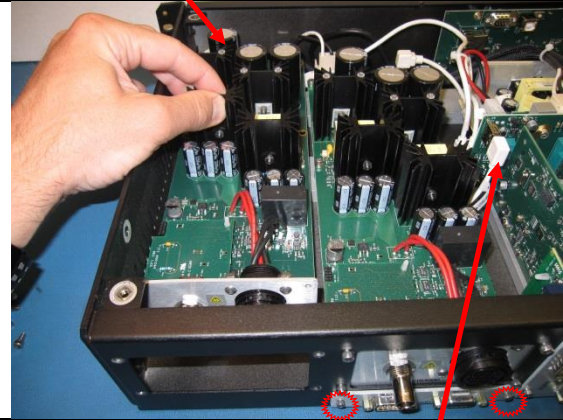
13. For the CM4000 option card, use a 3/32 in. Hex key to remove two socket head cap screws marked with red circles. Route the white cable connector attached to the CM4000 card under the IR4000 or IE4000 card as shown above.

12 AC Main 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.
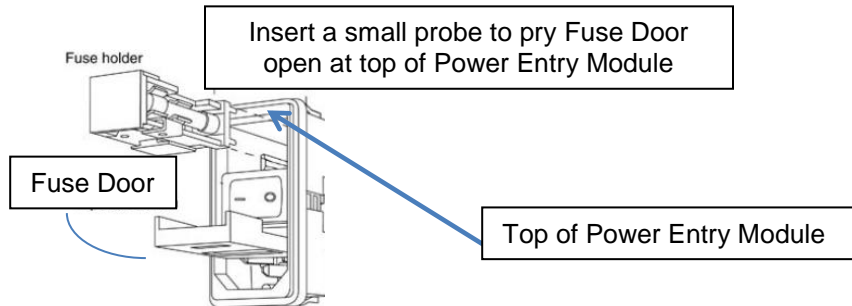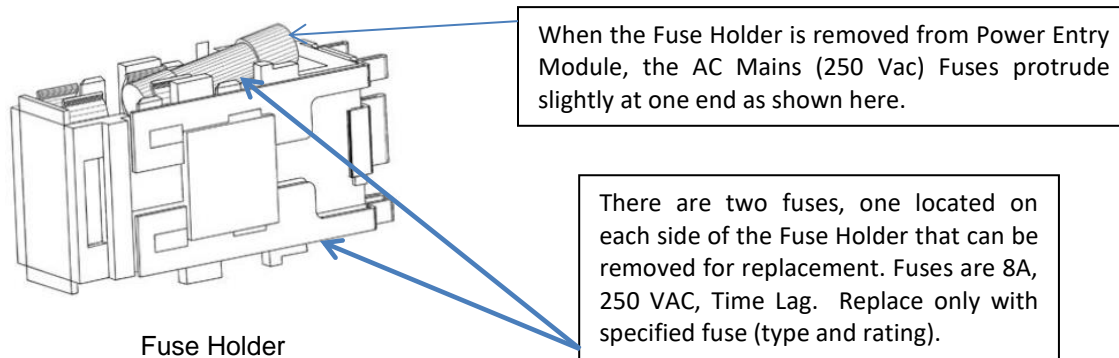

Fuse holder

Insert a small probe to pry Fuse Door open at top of Power Entry Module

Fuse Door

Top of Power Entry Module

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).

Fuse Holder

When the Fuse Holder is removed from Power Entry Module, the AC Mains (250 Vac) Fuses protrude slightly at one end as shown here.

There are two fuses, one located on each side of the Fuse Holder that can be removed for replacement. Fuses are 8A, 250 VAC, Time Lag. Replace only with specified fuse (type and rating).

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.

13 FlexRax Operating System

In section 5.9.1 we discussed several of the important System menus related to initial setup of the Pressure Measurement Screen.   These were the IG1/IG2 Assign, Pressure Unit and Display. In this section we will discuss the Security and Utilities submenus of the System Menu.   The Security menu allows the user to setup a password (if desired) for accessing the programming parameters of the controller.   The Utilities menu allows operating system software updates, database updates as well as controller configuration copying and uploads to a USB flash drive.

13.1 Security Menu (Password)

The password may be used to protect the *FlexRax* setup and configuration and control access to the instrument. For most applications, it is recommended that you do not use the password function.   The password function is only necessary if it is desired to strictly control access to and operation of the installed option cards and connected gauges.

> 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* 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.   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**.** Use the ⬆⬇ ➡⬅ keys 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 screen will be displayed offering you the choice to either **Enable** or **Disable** the password. If you choose to Enable ⇨ access to the main **Menu** functions of 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 option cards and connected gauges. During setup and initial configuration of the *FlexRax* option cards and gauges connected, 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 submenus without the need to enter the password each time. 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.

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.** .

If your *FlexRax* has been password enabled and your password is lost or forgotten you may contact InstruTech to obtain a master password.

13.2 Utilities Menu

The Utilities menu and its submenus allow operating system software and database updates as well as controller configuration uploads. To access the Utilities menu follow the key entry sequence: ⎿Menu⏌ ⇨ ⎿System⏌ ⇨ ⎿Utilities⏌   and the Utilities Screen will be displayed as shown below.
⇩

Backlight	Update Software
Show Options	Update Database
Upload Database	Sys Fact Defs
BACK	MAIN

⎿Backlight⏌ - Default is Always
This allows changing the period of time display backlighting stays on. Available selections are Always or a time period of 1 to 10 minutes. Changing the setting from Always to a time period will cause the display to go dark once the time period has elapsed and may help with longevity of the backlight. Pushing any of the push-button keys will result in the display becoming visible again. The recommended setting is Always.

⎿Show Options⏌ - This shows the physical location of option cards installed in the *FlexRax*. These are also physically visible when looking at the back panel of the *FlexRax*.

13.2.1 Upload Database

Upload Database

This function is provided to allow copying of the *FlexRax* configuration that the user has programmed and wishes to maintain either for future reference or to duplicate the setup exactly from one *FlexRax* to another where the controller configurations are exactly alike. Insert a USB flash drive into the USB port on the front panel of the *FlexRax* and follow the prompts to copy the database contents from the controller to the USB flash drive.

13.2.2 Update Database

Update Database   - This allows downloading the copied *FlexRax* configuration described in section 13.2.1 above to another *FlexRax*. Insert the USB flash drive that contains the copied configuration into the USB port of the other *FlexRax.* Press the Update Database   key and follow the prompts to copy the configuration into the other *FlexRax*.

After cycling the AC Mains power to the *FlexRax,* you will have completed downloading the copied *FlexRax* configuration into the other *FlexRax.*

Note that you may not be able to successfully copy the configuration from one *FlexRax* to another as described above if the controllers have different operating system software. Press Menu ⇨ Help ⇨ to see the Application (software) Version of the various *FlexRax* controllers you may have. If they have different software versions you would need to update your old *FlexRax* with the latest operating system software prior to performing the Update Database function. To do so follow the instructions given in the section below.

13.2.3 Update Software

Update Software   - Your *FlexRax* is delivered ready-to-use with all options cards ordered installed and configured in the Operating System[10] programmed to **Factory Default** settings. You **do not** need to perform the **Update Sofware** procedure when you receive your *FlexRax*. This information is included here for completeness, to convey the design concept of the operating system and to describe the Update Software procedure for those rare cases where this may become necessary.

To perform a software update you will need to obtain the update files from InstruTech. These files may be provided on a USB flash drive (or other electronics data exchange methods) and contain the operating system software (code) and database for operation of your *FlexRax.* Before proceeding we recommend recording all the various settings you have already programmed in the *FlexRax*. Simply insert the USB flash drive you have received from InstruTech into the USB port located on the front panel of the controller and follow the instructions below.

---

[10] 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* under normal operating conditions. It is at user discretion to perform an 'Update Software" procedure (installs new operating software for your *FlexRax* controller). You may opt to 'Update Software' 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.

1) Menu ⇨ System ⇨ Utilities ⇨ Update Database ⇨ Follow the prompt on the screen to complete the Update Database function (Note: You will also see another menu on the left side of the display screen called "Upload Database". Do not select Upload Database. Select Update Database).

2) Cycle power to *FlexRax.*

3) Menu ⇨System ⇨ Utilities ⇨ Update Software ⇨ Follow the prompt on the screen to complete the Update Software function.

4) Cycle power to *FlexRax.*

5) Menu ⇨ System ⇨ Utilities ⇨ Sys Fact Defs ⇨ Follow the prompt on the screen to complete setting system factory defaults.

6) Cycle power to *FlexRax.*

7) Reprogram *FlexRax* according to your previously recorded settings.

The process of updating the software, database and setting the operating system to factory defaults is now complete. Remove the USB flash drive provided to you from InstruTech from the USB port.   You may now conduct steps given in and if you wish to copy the configuration into a new *FlexRax*.

14 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.

15 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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