InstruTech, Inc.

Convection Vacuum Gauge
CVM-201 Module
The "Super Bee"

User's Manual

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Introduction / General Information

Description

The InstruTech CVM-201 "Super Bee" module provides the basic signal conditioning required to turn a convection vacuum gauge into a complete measuring instrument. The module provides non-linear, linear, and log-linear analog outputs, RS232/485 interface, and two setpoint relays. In addition, a built-in display provides a convenient user interface for setup and operation of the vacuum gauge. This manual applies to InstruTech CVM-201 series modules.

Specifications

measurement range (signal)	1×10^{-4} to 1000 Torr
	1×10^{-4} to 1333 mbar
	1×10^{-2} Pa to 133 kPa
resolution (signal)	1×10^{-4} Torr
display	LCD, 4 digits, user-selectable Torr, mbar, or Pa 1000Torr, (4 digits from 1100 Torr to 1000 Torr), (3 digits from 999 Torr to 10.0 mTorr), (2 digits from 9.9 mTorr to 1.0 mTorr), (1 digit from 0.9 mTorr to 0.1 mTorr)
materials exposed to gases	gold-plated tungsten, 304 & 316 stainless steel, glass, nickel, Teflon
internal volume	26 cm^3 (1.589 in^3)
internal surface area	59.7 cm^2 (9.25 in^2)
leak integrity	< 1×10^{-9} atm cc/sec He
weight	340 gm (12 oz)
housing	aluminum extrusion 105 x 66 x 35mm (4.12 x 2.58 x 1.35 inches)
fittings/flanges	1/8"NPT-1/2" tubulation, 4VCR, 8VCR, Mini-Conflat$^®$ (NW16CF), 2-3/4" Conflat$^®$(NW35CF), KF16, KF25, KF40
operating temperature	0 to +40 ^{o}C
storage temperature	-40 to +70 ^{o}C
bakeout temperature	150 ^{o}C (gauge only - electronics removed)
humidity	0 to 95% RH non-condensing
mounting position	horizontal
outputs/interface	1a) non-linear S-curve 0.375 to 5.659 Vdc or
	1b) log-linear 1 to 8 Vdc, 1V/decade
	2) linear 0 to 10 Vdc, user scalable (default is 10Vdc = 1 Torr),
	3) digital RS485/232
input power	11 to 30 Vdc,2.1W, protected against power reversal, transients, and over-voltages
trip point relays	two single-pole double-throw relays (SPDT)
contact rating	1A at 30 Vdc resistive, or ac non-inductive
trip point range	1×10^{-3} to 1000 Torr
adjustment	a) adjust value by panel pushbutton up/down keys and display
	b) adjust value, direction, and hysteresis by software/interface
connectors	1) 9-pin D male
	2) 15-pin high-density D male
RF/EMI protection	CE compliant

Options & Accessories

PS401-A Power Supply

Description: Wall-mount AC adapter to power one CVM module.

Power Input: 100-240 VAC

Power Plug: North America 115VAC Plug

Output: 24 VDC @ 500mA

Output Connector: 9-pin D sub, pre-wired to mate with CVM. Connector can be opened to enable user to make connections to signals and relays.
Cable Length: 2m (6ft)

Safety

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.   Failure to comply with these safety procedures may result in serious bodily harm, including death, and or property damage.** Failure to comply with these warnings violates the safety standards of the installation and intended use of the instrument. Instrutech, Inc. disclaims all liability for the customer's failure to comply with these requirements.

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 module. If you have any questions about the safe installation and use of this product, please contact Instrutech at the address shown on page 1 of this manual.

Service and operation

Do not modify this product or substitute any parts without authorization of a qualified Instrutech technician. 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.

After servicing this product, ensure that all safety checks are made by a qualified service person.
Replacement Parts: When replacement parts are required, ensure that the parts are specified by Instrutech Inc. Unauthorized substitutions or non-qualified parts may result in fire, electric shock, or other hazards.

To reduce the risk of fire or electric shock, do not expose this product to rain or moisture.   This product is not waterproof and careful attention must be paid to not spill any type of liquid onto this product.

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 the product be periodically inspected for sound electrical connections and grounding. Do not use if the grounding or electrical insulation has been compromised.

Electrical conditions:

Danger: When high voltage is present in any vacuum system, a life threatening electrical shock hazard may exist unless all exposed conductors are maintained at earth ground. This applies to all products that come in contact with the gas.

Danger: An electrical discharge through a gas may couple dangerous high voltage directly to any ungrounded conductor. A person may be seriously injured or killed by coming in contact with an exposed ungrounded conductor at a high voltage potential. This applies to all products that may come in contact with the gas.

Proper Grounding: Verify that the vacuum port on which the module is mounted is electrically grounded. This is essential for safety as well as proper operation. The gauge and/or case of the module must be connected to earth ground. Use a ground lug on the flange if necessary.

Overpressure:

Warning: Install suitable protective devices that will limit the level of the pressure to less than what the vacuum system can withstand. The gauge should not be used above 1000 Torr absolute pressure.

Gases other than Nitrogen:

InstruTech gauges and modules are calibrated for N_2. Do not attempt to use with other gases such as argon or CO_2 unless accurate conversion data for N_2 to the other gas is properly used. Refer to Appendix B for a more complete discussion of issues.

Do not use this device in an explosive atmosphere or in the presence of flammable gases or fumes.

Do not use this device to measure the pressure of explosive or combustible gases or mixtures. The sensor wire in the gauge normally operates at 125^oC, but under malfunction the wire temperature could exceed the ignition temperature of combustible mixtures.

Installation - Mechanical

Mount the CVM as close as possible to the pressure you want to measure. Long or restricted tubing will create a pressure difference (error) between your process and the gauge, and cause a delay in response to pressure changes. Mounting the CVM too close to a gas source will also cause errors in the readings.

Don't mount the CVM near a source of heating or cooling, such as heaters or air conditioning vents.

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

Mount CVM with this axis horizontal
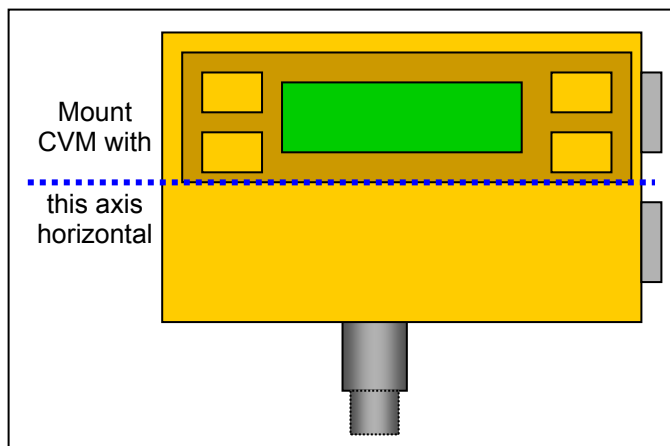
Mount the CVM with port down, if possible, to help minimize the effect of any particles or condensation in the gauge.

Don't mount the CVM where it will be subjected to excessive vibration, such as on mechanical pumps. Vibrations may cause 'noisy' readings, and reading errors due to induced cooling of the sensor.

Fittings - follow the fitting manufacturer's recommendations and note the following:
- NPT fittings: Wrap the threaded portion of the tubing with Teflon[®] tape and hand tighten the gauge into the gauge port. Do not use a wrench or other tool which may damage the gauge.

Installation - Electrical

Grounding: Be sure the vacuum gauge 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, do not produce a good electrical connection between the gauge and the chamber it is connected to.

A good recommended practice is to remove power from any cable prior to connecting or disconnecting it.

The InstruTech CVM-201 will directly replace most GP Mini-Convectron® modules using existing cables and electronics. If you are replacing a GP Mini-Convectron® module, simply plug your existing cable into the 9-pin or 15-pin D connector on the end of the InstruTech module.

For new installations, fabricate a cable to either the 9-pin or 15-pin D connector, depending on which signals you want to use. Signals and pin assignments are described below:

PIN NUMBER	PIN DESCRIPTION
1	Relay 1 Normally Open
2	Relay 1 Normally Closed
3	Power Input (11-30Vdc)
4	Power Ground
5	Analog Output 1 (Non-linear GP Compatible, or Log-Linear 1-8V)
6	Relay 1 Common
7	Relay Disable (Disables Relay 1 when pulled low)
8	Analog Ground
9	Analog Output 2 (Programmable Linear 0-10V)

PIN NUMBER	PIN DESCRIPTION
1	RS485 (A)
2	RS485 (B)
3	Power Input (11-30Vdc)
4	Power Ground
5	Analog Output 1 (Non-linear GP Compatible, or Log-Linear 1-8V)
6	Analog Ground
7	RS232 Out
8	RS232 In
9	Relay Disable (Disables Relay 1 when pulled low)
10	Relay 1 Normally Open
11	Relay 2 Normally Open
12	Relay 2 Common
13	Relay 2 Normally Closed
14	Relay 1 Normally Closed
15	Relay 1 Common

Setup and Operation

User Interface Basics:

The menus within the CVM-201 user interface have been designed for easy operation and a natural progression of setup parameters. The complete map of the user interface screens is shown in appendix A. The following sections give a brief explanation of the features for added clarity.

The four buttons to the left and right of the display are the programming buttons. During programming of the CVM-201, the display will identify what function each button represents.

To begin programming, press any of the four Programming Buttons. After setting the various parameters, press the SAVE/EXIT key to save the new setting and return to the main screen. To continue setting additional parameters, scroll forward with the MORE key until you reach the desired parameter.

Menu Item Explanations:

SET UNITS
This should be the first parameter that is set. This will be the units (Torr, mBar, or Pascal) that are used for all other settings. If the setpoints have already been set, changing units is not recommended because the setpoints will return to their default setting. [Factory default = Torr.]

SET VACUUM
Setting the Zero Point (Vacuum Adjust):
1. Evacuate the system to a pressure less than 0.1 mTorr.
2. Go to the "Set Vacuum" screen. When the pressure is below 0.1 mTorr, press the "Press to set vac" key. The zero point is now set.

SET ATM
Setting the Span Point (Atmosphere Adjust):
1. Backfill the system with Nitrogen to a known pressure above 400 Torr.
2. Go to the "Set ATM" screen. When desired system pressure is stable, adjust the pressure on the screen to the known value using the INCRease and DECRease keys on the left side of screen. Press the SAVE/EXIT key to save the new atmosphere value.

SET SP1 ON and SET SP2 ON:
These setpoints correspond to the turn on points for each relay. The relays will turn on when the pressure drops below this setting. [Factory default = 100 mTorr.]

SET SP1 OFF and SET SP2 OFF:
These setpoints correspond to the turn off points for each relay. The relays will turn off when the pressure rises above this setting. [Factory default = 200 mTorr.]

SET ADDR:
This is the lower nibble of the one byte RS485 device address. (e.g. Setting this to a 5 would make the address be 0x05 in hex; a 15 would be 0x0F in hex; if the address offset is equal to 0.)   Note that Address must be used even in RS232 commands. [Factory default = 1]

SET ADDR OFFSET
This is the upper nibble of the one byte RS485 address. (e.g. Setting this to a 5 (with ADDR = 0) would make the address 0x50, a 15 would be 0xF0.)   [Factory default = 0.]

SET BAUD
This sets the baud rate for the RS485 and the RS232. The baud rate can be set to many other values through the serial interface command set. The parity can also be changed. When this occurs, the current setting will be shown in the list of choices and can be re-selected if changed. [Factory default = 19.2K baud]

SET ANALOG
Selects Non-linear or log-linear for the analog output.

SET LINEAR
This will take the user to 4 screens to setup the linear analog output.
a) Set the minimum pressure,
b) Set the minimum voltage corresponding to the minimum pressure.
c) Set the maximum pressure.
d) Set the maximum voltage corresponding to the maximum pressure.
The linear output voltage can be any values between 10mV and 10V corresponding to pressure values between 1 mTorr and 1000 Torr. [Factory default is 10mV to 10 Vdc corresponding to 1 mTorr to 1 Torr.]

INFO
This screen shows the Instrutech phone number for questions and the unit software version.

Calibration:

Every InstruTech module is calibrated prior to shipment using Nitrogen. However, you can adjust the zero and span using the menu and the associated softkeys, as described above. Zero and span settings affect the displayed value and the output signals.   Care should be exercised when using gases other than nitrogen N_2 - See Appendix A for more information.

Interface

RS485/RS232 Command Protocol Summary

Note: This protocol was designed to be 100% compatible with the Helix / Granville-Phillips Mini-Convectron®.

COMMAND	BRIEF DESCRIPTION	COMMAND SYNTAX	RESPONSE
READ	Read the current pressure in Torr	#xxRD<CR> *(eg: #01RD<CR>)*	*xx_y.yyEzyy<CR> *(eg: *01_7.60E+02<CR>)*
SET ADDR OFFSET	Set the communications (RS485) address offset (upper nibble) *	#xxSAxx<CR> *(eg: #01SA20<CR>)*	*xx_PROGM_OK<CR>
SET SPAN	Set the span or atmosphere calibration point	#xxTSy.yyEzyy<CR> *(eg: #01TS7.60E+02)*	*xx_PROGM_OK<CR>
SET ZERO	Set the zero or vacuum calibration point	#xxTZy.yyEzyy<CR> *(eg: #01TZ0.00E-04<CR>)*	*xx_PROGM_OK<CR>
SET TRIP POINT #1	Set the 'turns on below' pressure point for relay #1 and set the 'turns off above' pressure point for relay #1.	#xxSLzy.yyEzyy<CR> *(eg: #01SL+4.00E+02<CR>)* *(eg: #01SL-5.00E+02<CR>)*	*xx_PROGM_OK<CR>
SET TRIP POINT #2	Set the 'turns on below' pressure point for relay #2 and set the 'turns off above' pressure point for relay #2.	#xxSHzy.yyEzyy<CR> *(eg: #01SH+4.00E+02<CR>)* *(eg: #01SH-5.00E+02<CR>)*	*xx_PROGM_OK<CR>
READ TRIP POINT #1	Read the 'turns on below' pressure point for relay #1 and read the 'turns off above' pressure point for relay #1.	#xxRLz<CR> *(eg: #01RL+<CR>)* *(eg: #01RL-<CR>)*	*xx_y.yyEzyy<CR> *(eg: *01_7.60E+02<CR>)*
READ TRIP POINT #2	Read the 'turns on below' pressure point for relay #2 and read the 'turns off above' pressure point for relay #2.	#xxRHz<CR> *(eg: #01RH+<CR>)* *(eg: #01RH-<CR>)*	*xx_y.yyEzyy<CR> *(eg: *01_7.60E+02<CR>)*
READ SW VERSION	Read the revision number of the firmware.	#xxVER<CR> *(eg: #01VER<CR>)*	*xx_mmnnv-vv *(eg: *0105041-00)*
SET FACTORY DEFAULTS	Force unit to return ALL settings back to the way the factory programmed them before shipment.*	#xxFAC<CR> *(eg: #01FAC<CR>)*	*xx_PROGM_OK<CR>
SET BAUD RATE	Set the communications baud rate for RS485 and RS232.*	#xxSByyyyy<CR> *(eg: #01SB19200<CR>)*	*xx_PROGM_OK<CR>
SET NO PARITY	Set the communications to NO parity, 8 bits for the RS485 and RS232.*	#xxSPN<CR> *(eg: #01SPN<CR>)*	*xx_PROGM_OK<CR>
SET ODD PARITY	Set the communications to ODD parity, 7 bits for the RS485 and RS232.*	#xxSPO<CR> *(eg: #01SPO<CR>)*	*xx_PROGM_OK<CR>
SET EVEN PARITY	Set the communications to EVEN parity, 7 bits for the RS485/ RS232.*	#xxSPE<CR> *(eg: #01SPE<CR>)*	*xx_PROGM_OK<CR>
RESET	Reset the device. (required to complete some of the commands.)	#xxRST<CR> *(eg: #01RST<CR>)*	No response

 * Commands marked with an asterisk will not take effect until after RESET command is sent or power is cycled.

NOTES:

1. All Responses are 13 characters long.
2. xx is the address of the device. (00 thru FF)
3. <CR> is a carriage return.
4. _ is a space.
5. The 'z' in the set or read trip point commands is a + or -. The plus is the 'turns on below' point and the minus is the 'turns off above' point.
6. All commands sent to the module start with a '#' character, and all responses from the module start with a '*' character.
7. This protocol was designed to be 100% compatible with the Helix Mini-Convectron®.
8. A valid address must be used even in RS232 commands. Factory default is 1.

Service

Maintenance

Under normal circumstances, there is no maintenance required for your InstruTech module. Good manufacturing practice suggests the unit should be periodically calibrated against known calibration standards.

Cleaning

The most common cause of all vacuum gauge failures is contamination of the sensor. Contamination can be generally characterized as either a reaction of process gases with sensor elements, or an accumulation of material on the sensor elements.   Sensors that fail due to chemical reaction are generally not salvageable. Sensors that fail due to coating may *possibly* be restored by cleaning. See Appendix C for a more complete discussion of contamination and cleaning procedures.

Troubleshooting

Indication	Possible Cause	Possible Solution
Display is off / blank	No power	Check cable connections and verify that power is being supplied.
Analog out goes to 10V (Log-linear and Non-linear only)	Damaged sensor wire.	Replace sensor
Readings appear very different from expected pressure	The process gas is different from the gas used to calibrate the CVM.	Correct readings for different gas thermal conductivity. See Appendix B.
	Module has not been calibrated or has been calibrated incorrectly	Check that zero and atm are adjusted correctly.
Readings are noisy or erratic	Loose cables or connections, Excessive vibration	Check and tighten connections.
	Contamination	Inspect gauge for signs of contamination such as particles, deposits, or discoloration on gauge inlet. Try cleaning if appropriate.
Gauge cannot be calibrated - zero and span (vacuum & atm)	Contamination.	See section below on cleaning.
	Sensor failure for other cause.	Replace sensor
Setpoint does not actuate	Incorrect setup	Check setpoint setup

Module and Gauge Replacement
The CVM module is factory calibrated for the specific gauge tube installed in it. Since each gauge tube and module calibration is different, the gauge cannot be replaced in the field. If the gauge fails for any reason, the CVM-201 module should be discarded and replaced, or returned to the factory for replacement of the gauge and recalibration of the complete CVM module. Given the low cost of a new CVM module, compared to the cost of gauge replacement and recalibration, the CVM module is generally considered an expendable item. If you prefer to have your gauge replaced and the module recalibrated, contact the factory for return authorization, as described below.

Factory Default Reset
When all else fails, the module can be returned to the original factory settings by pressing the upper left and upper right softkeys simultaneously. The user will then be prompted "Set Factory Defaults?". Choose Yes or No.

Factory Service and Support
If you need help setting up, operating, or troubleshooting your module, you are welcome to call us during normal business hours (8:00am to 5:00pm Mountain time) Monday through Friday, at 303-651-0551. Or e-mail us at info@instrutechinc.com .

If it becomes necessary to return the unit 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 down load 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 work on gauges that have been exposed to hazardous materials.

Trademarks & Acknowledgements
These trademarks, used throughout this manual, are the property of the following companies:
Convectron® and Mini-Convectron® are registered trademarks of Brook Automation/Helix Technology Corp and Granville Phillips Company .
Conflat® and Mini-Conflat® are registered trademarks of Varian Vacuum Technology.
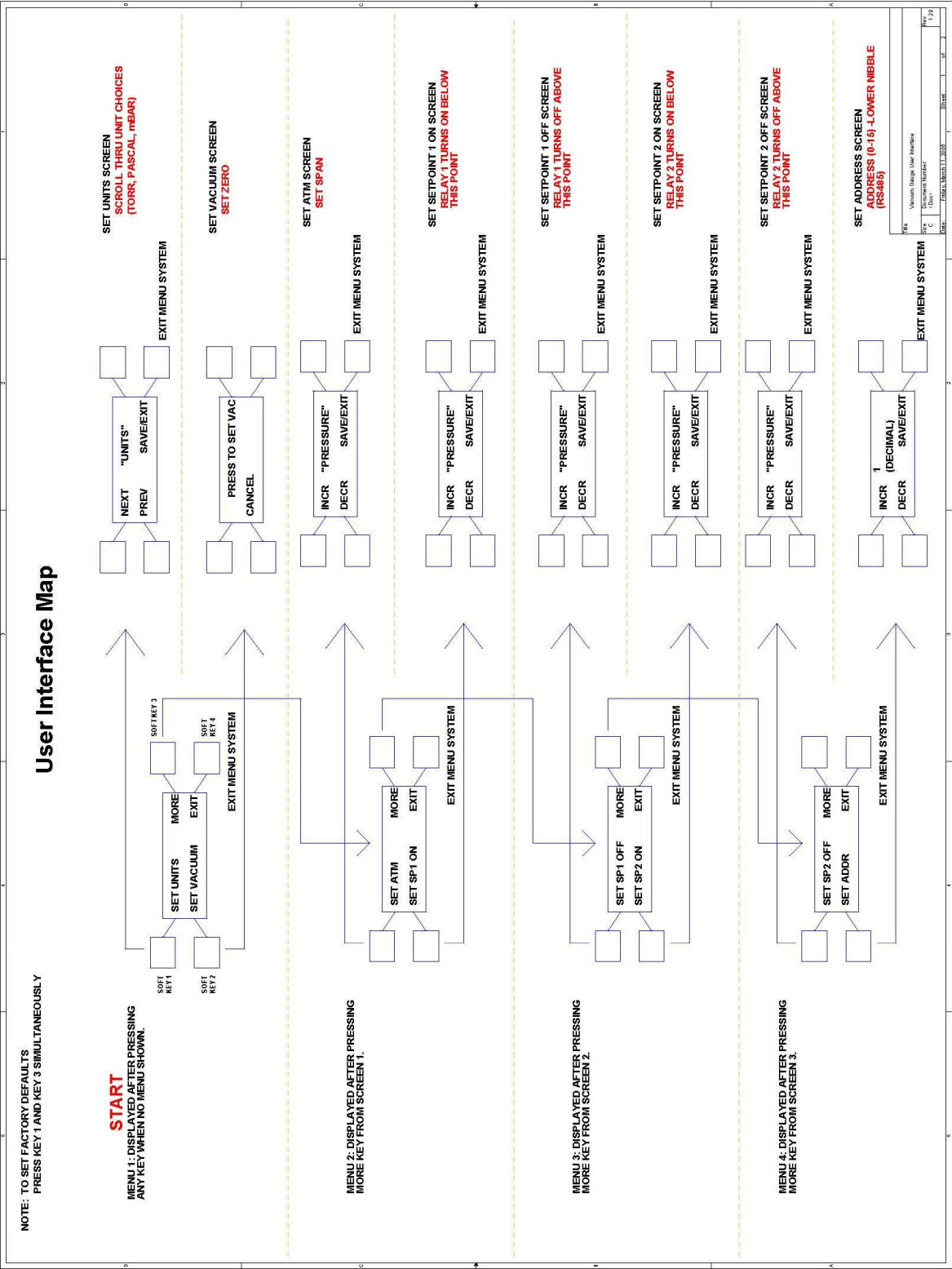Cajon® and VCR® are registered trademarks of the Swagelok.Company.
Teflon® is a registered trademark of DuPont.
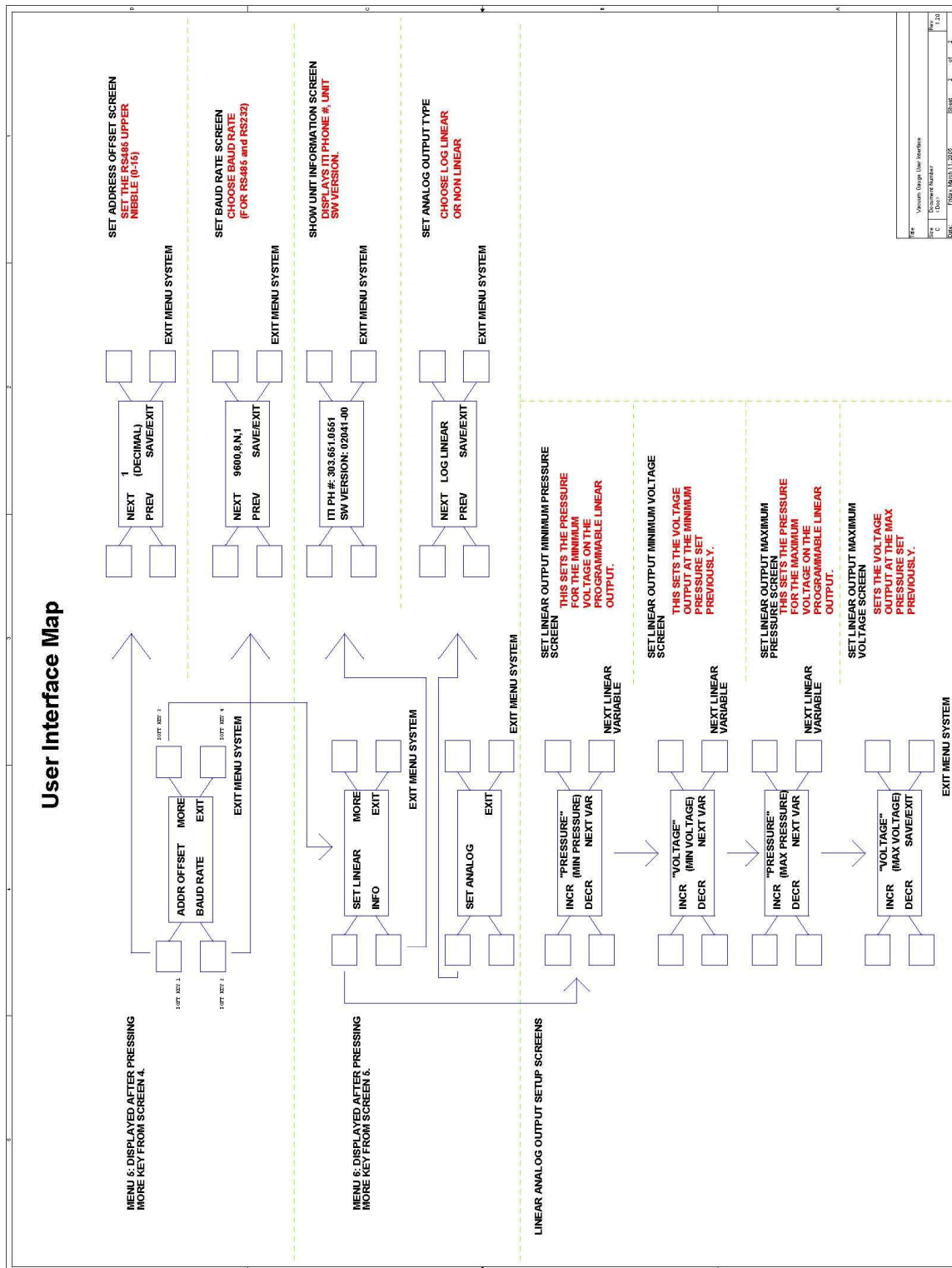

Appendices
A. User Interface Map
B. Using thermal vacuum gauges with different gases
C. Contamination and Cleaning

Appendix A: User Interface Map:

User Interface Map

Appendix A (continued):

User Interface Map

Appendix B: *Using thermal vacuum gauges with different gases*

Principal of Operation

Thermal conductivity gauges measure pressure indirectly, by sensing the loss of heat from a sensor to the surrounding gases.   The higher the pressure of the surrounding gas, the more heat is conducted away from the sensor. Pirani thermal conductivity gauges maintain a sensor (usually a wire) at some constant temperature, and measure the current or power required to maintain that temperature. A standard Pirani gauge has a useful measuring range of about 10^{-4} Torr to 10 Torr. By taking advantage of convection currents that are generated above 1 Torr, *convection-enhanced* Pirani gauges increase the measuring range to just above atmosphere.

Output Signals and Displays

A vacuum gauge sensor, by itself, does not generate any output signal or readout. Electronic signal conditioning is required to convert heat loss into a useable signal and/or readout of pressure. Note that the output signal voltage is not the same as the displayed pressure readings. Table 3 below shows the displayed readings at various pressures for selected gases.
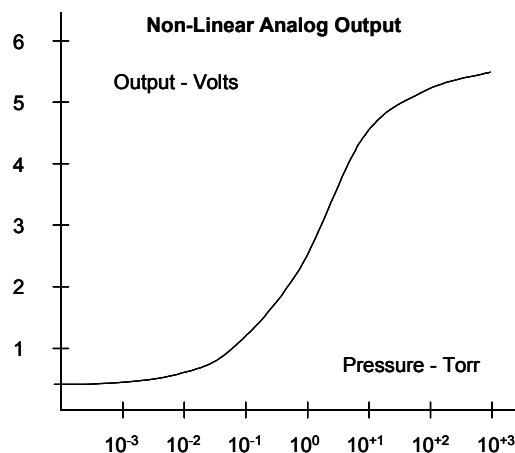
Non-Linear Output

Granville-Phillips' first Convectron® gauge controllers produced a non-linear 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, as shown at right. GP adopted the same output curve for most of their Mini-Convectron® modules and controllers with non-linear output (though in recent years, some GP controllers produced a different S-curve).

The non-linear output from InstruTech convection gauges, modules, and controllers duplicates exactly the original S-curve of 0.375 to 5.659 VDC for 0 to 1000 Torr.

Table 1 below contains the lookup data for converting the non-linear output voltage into pressure values.

Output goes to 10V under fault condition.

Non-Linear Analog Output

Log-Linear Output

Many InstruTech modules and controllers also provide a log-linear output signal, as an alternative to the non-linear signal described above. This output, shown at right, is a 1 Volt per decade signal that may be easier to use for data logging or control.

Table 2 below contains the lookup data and provides the formulas for converting the log-linear output voltage into pressure values.

Output goes to 10V under fault condition.

Log-Linear Analog Output
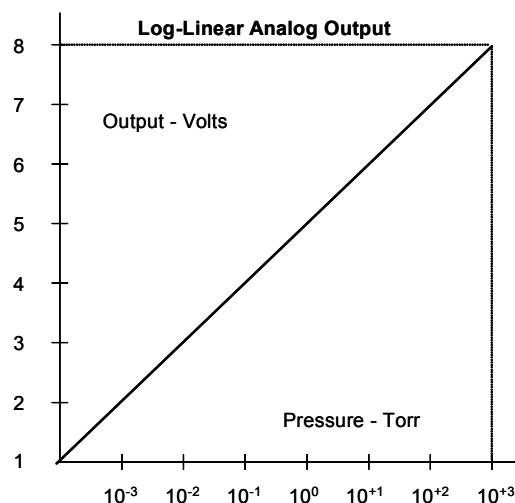
Linear Output

Some InstruTech controllers & modules offer a user-programmable linear analog output. In this case, the user chooses the two end points, and the signal is a linear output voltage between those two points.

A couple of examples are shown at right:

Example-A: A full scale of 10 Volts was chosen to equal 1 Torr, and 10 mVolts was chosen to equal "zero" pressure (considered here to be 10^{-4} Torr). [Note: These are the factory default settings, which also happen to be the same as the Granville-Phillips linear output.]
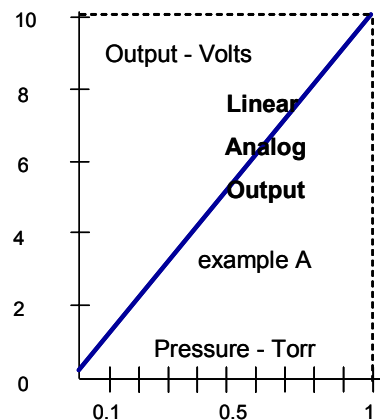
Example-B: In this case, a full scale of 5 Volts equals 100 mTorr and 1 Volt equals 10 mTorr.

Because you can choose virtually any zero and span settings, there are an infinite number of possible linear signal configurations. If needed, you must generate your own table of signal vs pressure values for your particular setup.
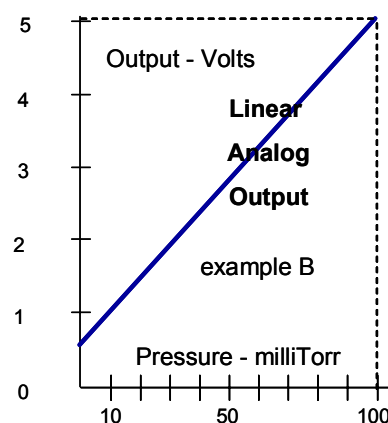
Some considerations in choosing the best analog signal to work with:

1. The non-linear S-curve is convenient if you are replacing a Convectron® which has that output, and you don't want to change anything in the control system. For new systems, however, the formulas needed to interpret the non-linear signal are complex and difficult to use. The linear or log-linear signal is generally easier to interface with today's data acquisition or control systems.

2. The linear signal is good when you want to monitor pressure over a limited range of 1 or 2 decades. If you try to use the linear signal over too wide a range, the signal at the low end of pressures will be too small to be useable by most electronic systems. For example: If you tried to setup the linear signal to cover the range from 1000 to 10^{-3} Torr, the signal at 10^{-3} Torr would be 1 microVolt. For most systems, that level of signal would be lost in the noise and you could never see it. For this reason, and to distinguish a valid low pressure reading from a power-loss/off/fail condition, the minimum linear signal cannot be set lower than 10 milliVolts.

3. If you need to monitor pressure over a wider range, you should use the log-linear signal. This output covers the entire measuring range with a high level 1 to 8 Volt signal. The signal changes by 1 Volt for each decade, and, even at the very low end, the smallest signal is still milliVolts, not microVolts. Also, the formulas defining the relationship between Voltage and pressure are simple and can be readily programmed into most computers / data acquisition systems.

The discussions above, about signals, assumed the gas being measured is Nitrogen. The following discussion illustrates how other gases affect both readings and outputs from thermal vacuum gauges.

Effect of Different Gases on Signals and Displayed Pressure

A thermal conductivity gauge senses heat loss, which depends on the thermal conductivity of the gas surrounding the sensor. Since different gases, and mixtures, have different thermal conductivities, the indicated pressure readings and outputs will also be different. InstruTech convection gauges (and most other thermal gauges) are normally calibrated using 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 and output from an InstruTech convection gauge.

For N_2 the calibration shows excellent agreement between indicated and true pressure throughout the range from 10^{-4} to 1000 Torr. (As it *should*, of course, since they're calibrated for N_2.) At pressures below 1 Torr, the calibration curves for the different gases are similar: the difference in readings at these low pressures is a constant, a function of the difference between thermal conductivities of the gases.

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

Generally, air and N_2 are considered the same 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 30 to 40 Torr after the chamber is opened and air gradually displaces the N_2 in the gauge.

For most other gases, the effect is much more significant, and may result in a hazardous condition, as described below.

Other considerations when using gases other than N_2

Flammable or explosive gases:

InstruTech CV gauges and modules are not intrinsically safe or explosion proof, and are not intended for the measurement, or use in the presence, of flammable or explosive gases or vapors.

Under normal conditions, the voltages and currents in InstruTech CV Gauges and Modules are too low to cause ignition of flammable gases. However, under certain failure conditions, sufficient energy could be generated to cause flammable vapors or gases to ignite or explode.

Thermal gauges like the InstruTech CV gauges and modules are not recommended for use with flammable or explosive gases.

Moisture / water vapor:

In some processes (lyophilization, for example). the gas composition may not change significantly, except for moisture content. Water vapor can significantly change the response of a thermal gauge and correction should be made, as you would for any other gas.

Other contaminants:

If your gases condense, coat, or corrode the sensor, the gauge calibration and response to different gases will change.   Generally, if the gauge can be "calibrated" ("zero" and "atmosphere" settings), these changes are small enough to be ignored. If you cannot set zero and atmosphere, the gauge should be replaced or cleaned. (See the Application Note on cleaning for more information.)

Convection Vacuum Gauge
Indicated vs. True Total Pressure
Test Gases - N2, Ar, He
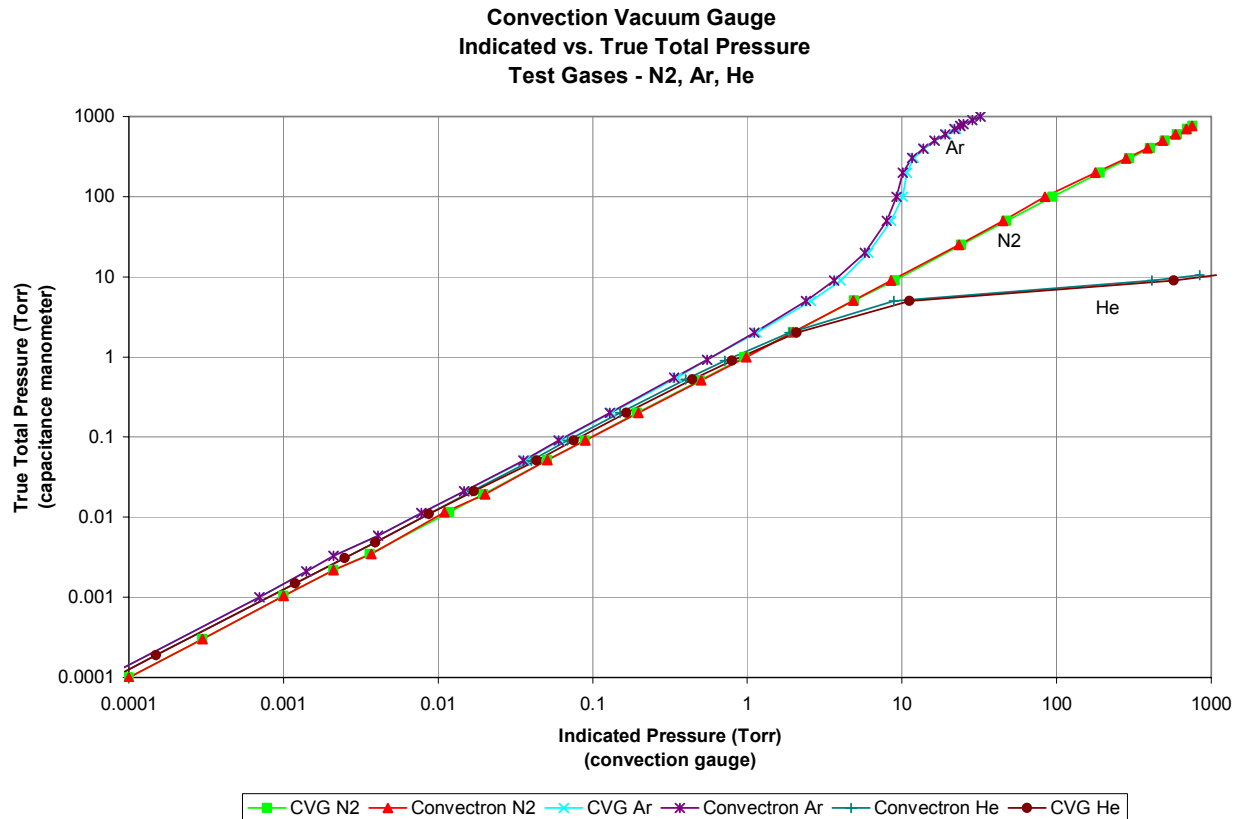
Gas Correction Chart

The Y- Axis is actual pressure, measured by a capacitance manometer, a diaphragm gauge that measures true total pressure, independent of gas composition.

The X-Axis is the pressure reading indicated by the convection gauge under test.

The chart shows readings for an InstruTech CVG as well as for a GP Convectron® gauge, to illustrate that the response of the gauges to these different gases is virtually indistinguishable. (Caution: Do not assume this data applies to other convection gauges, which may or may not be the same.)

If the gas is N_2, when the true total pressure is 100 Torr, the gauge will read 100 Torr

If the gas is Ar, when the true pressure is 100 Torr, the gauge will read only 10 Torr.
If you are backfilling your vacuum system with Ar, when your system reaches atmospheric pressure of 760 Torr true pressure, your gauge will be reading about 20 Torr. If you continue to backfill your system, attempting to increase the reading up to 760, you will overpressure your chamber and probably blow up your vacuum system !

If the gas is He, the gauge will read 1000 Torr when pressure reaches about 10 Torr actual pressure.
You probably won't blow up the vacuum system, but opening the chamber to atmosphere prematurely may present other hazards for both people and product.

What these examples illustrate is that, without proper precautions,

<u>*use of different gases can result in injury to personal and/or damage to equipment*</u>.

Suggested precautions when using gases other than N_2:

Install a pressure relief valve, or burst disk, on your chamber, to protect it from overpressure.

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

Table 1 - Non-Linear Analog Output Voltage vs Pressure, for Selected Gases

True Total Pressure		N2	Ar	He	O2	CO2	Kr	Freon12	Freon22	D2	Ne	CH4
0	mTorr	0.3751	0.3750	0.3750	0.3750	0.3750	0.3750	0.3750	0.3750	0.3750	0.3750	0.3750
0.1	**mTorr**	**0.3759**	**0.3757**	**0.3755**	**0.3760**	**0.3760**	**0.3755**	**0.3760**	**0.3760**	**0.3760**	**0.3757**	**0.3766**
0.2	mTorr	0.3768	0.3760	0.3765	0.3770	0.3770	0.3768	0.3780	0.3780	0.3770	0.3763	0.3780
0.5	mTorr	0.3795	0.3780	0.3790	0.3800	0.3810	0.3772	0.3820	0.3810	0.3810	0.3782	0.3825
1	**mTorr**	**0.3840**	**0.3810**	**0.3820**	**0.3840**	**0.3850**	**0.3790**	**0.3880**	**0.3880**	**0.3860**	**0.3810**	**0.3896**
2	mTorr	0.3927	0.3870	0.3890	0.3920	0.3950	0.3840	0.4010	0.4000	0.3960	0.3880	0.4030
5	mTorr	0.4174	0.4030	0.4090	0.4170	0.4120	0.3950	0.4370	0.4320	0.4250	0.4050	0.4380
10	**mTorr**	**0.4555**	**0.4290**	**0.4410**	**0.4530**	**0.4620**	**0.4150**	**0.4880**	**0.4800**	**0.4700**	**0.4330**	**0.4920**
20	mTorr	0.5226	0.4770	0.4970	0.5210	0.5360	0.4510	0.5810	0.5660	0.5490	0.4840	0.5840
50	mTorr	0.6819	0.5950	0.6370	0.6790	0.7050	0.5440	0.7780	0.7640	0.7270	0.6080	0.7960
100	**mTorr**	**0.8780**	**0.7450**	**0.8140**	**0.8680**	**0.9000**	**0.6680**	**1.0090**	**0.9900**	**0.9440**	**0.7680**	**1.0530**
200	mTorr	1.1552	0.9620	1.0680	1.1410	1.1790	0.8470	1.3150	1.2910	1.2650	1.0020	1.3920
500	mTorr	1.6833	1.3860	1.5890	1.6640	1.6680	1.1940	1.8260	1.8050	1.9140	1.4690	2.0140
1	**Torr**	**2.2168**	**1.8180**	**2.1640**	**2.1950**	**2.1720**	**1.5360**	**2.2570**	**2.2470**	**2.6030**	**1.9760**	**2.6320**
2	Torr	2.8418	2.3330	2.9390	2.8140	2.6950	1.9210	2.6470	2.6660	3.5080	2.6310	3.3130
5	Torr	3.6753	3.0280	4.3870	3.6720	3.3160	2.4290	3.0290	3.0900	5.0590	3.7150	
10	**Torr**	**4.2056**	**3.4800**	**5.7740**	**4.2250**	**3.6700**	**2.7340**	**3.2040**	**3.3300**	**6.3610**	**4.6050**	**4.6990**
20	Torr	4.5766	3.8010	7.3140	4.6200	3.9030	2.9660	3.3080	3.4140		5.4060	5.1720
50	Torr	4.8464	4.0370		4.9160	4.0710	3.0750	3.4300	3.5090		6.1590	5.5830
100	**Torr**	**4.9449**	**4.1220**		**5.0260**	**4.1540**	**3.1340**	**3.6180**	**3.6600**		**6.4830**	**5.7200**
200	Torr	5.0190	4.1920		5.1060	4.3360	3.2690	3.8270	3.8830		6.6610	5.8600
300	Torr	5.1111	4.2830		5.2000	4.5020	3.3840	3.9380	4.0050		6.7260	
400	Torr	5.2236	4.3860		5.3150	4.6210	3.4660	4.0160	4.0880		6.7670	6.1030
500	Torr	5.3294	4.4770		5.4220	4.7080	3.5260	4.0760	4.1510		6.8030	
600	Torr	5.4194	4.5500		5.5150	4.7750	3.5730	4.1240	4.2030		6.8430	6.3420
700	Torr	5.4949	4.6110		5.5920	4.8300	3.6130	4.1660	4.2470		6.8900	
760	Torr	5.5340	4.6430		5.6330	4.8600	3.6320	4.1900	4.2710		6.9200	
800	Torr	5.5581	4.6630		5.6580	4.8770	3.6450	4.2030	4.2860		6.9420	6.5190
900	Torr	5.6141	4.7060		5.7130	4.9190	3.6740	4.2370	4.3210		7.0000	
1000	**Torr**	**5.6593**	**4.7450**		**5.7620**	**4.9550**	**3.6900**	**4.2700**	**4.3540**		**7.0560**	**6.6420**

Note: By design, these values are identical to the outputs from Helix/Granville-Phillips Convectron® gauges, Mini-Convectron® modules, and Controllers, so that equivalent units can be interchanged without affecting your process system or software.

Table 2 - Log-Linear Analog Output Voltage vs Pressure, for Selected Gases

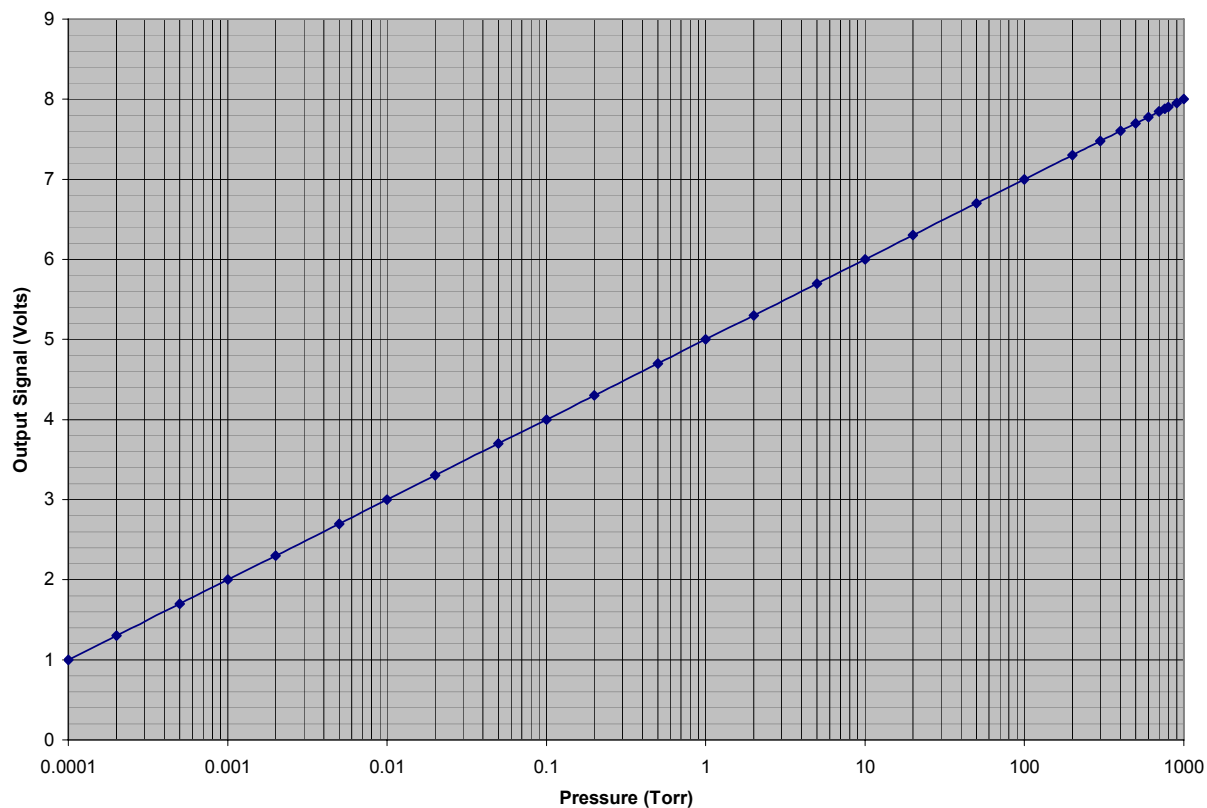| True Pressure (Torr)	N2	Ar	He	O2	CO2	Kr	Freon12	Freon22	D2	Ne	CH4
0.0001	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.0002	1.301	1.301	1.301	1.301	1.301	1.301	1.301	1.301	1.301	1.301	1.301
0.0005	1.699	1.699	1.699	1.699	1.699	1.477	1.699	1.699	1.699	1.699	1.699
0.0010	2.000	1.845	1.903	2.000	2.041	1.602	2.176	2.176	2.114	1.845	2.230
0.0020	2.301	2.146	2.204	2.301	2.362	2.000	2.491	2.491	2.380	2.176	2.519
0.0050	2.699	2.519	2.602	2.699	2.643	2.362	2.881	2.845	2.778	2.544	2.886
0.0100	3.000	2.820	2.908	2.987	3.041	2.681	3.167	3.130	3.083	2.851	3.185
0.0200	3.301	3.117	3.207	3.297	3.346	2.978	3.476	3.435	3.386	3.149	3.483
0.0500	3.699	3.511	3.607	3.692	3.740	3.371	3.860	3.839	3.778	3.542	3.888
0.1000	4.000	3.808	3.914	3.988	4.029	3.670	4.155	4.134	4.083	3.845	4.201
0.2000	4.301	4.100	4.217	4.288	4.322	3.960	4.439	4.418	4.398	4.149	4.498
0.5000	4.699	4.494	4.638	4.687	4.689	4.336	4.786	4.774	4.837	4.555	4.893
1.0000	5.000	4.778	4.973	4.987	4.978	4.602	5.021	5.017	5.190	4.872	5.204
2.0000	5.301	5.057	5.346	5.288	5.233	4.845	5.210	5.220	5.616	5.201	5.522
5.0000	5.699	5.389	6.130	5.697	5.524	5.107	5.389	5.418	7.391	5.719	5.877
10.0000	6.000	5.602	8.041	6.013	5.696	5.250	5.471	5.530	8.041	6.332	6.446
20.0000	6.301	5.763	8.041	6.348	5.819	5.360	5.521	5.571	8.041	7.766	7.550
50.0000	6.699	5.895	8.041	6.890	5.915	5.410	5.579	5.617	8.041	8.041	7.925
100.0000	7.000	5.946	8.041	7.320	5.966	5.438	5.670	5.691	8.041	8.041	8.041
200.0000	7.301	5.991	8.041	7.470	6.090	5.521	5.777	5.808	8.041	8.041	8.041
300.0000	7.477	6.053	8.041	7.580	6.228	5.555	5.838	5.876	8.041	8.041	8.041
400.0000	7.602	6.130	8.041	7.686	6.350	5.595	5.883	5.925	8.041	8.041	8.041
500.0000	7.699	6.207	8.041	7.781	6.458	5.624	5.918	5.964	8.041	8.041	8.041
600.0000	7.778	6.274	8.041	7.863	6.561	5.647	5.947	5.998	8.041	8.041	8.041
700.0000	7.845	6.338	8.041	7.934	6.664	5.667	5.974	6.029	8.041	8.041	8.041
760.0000	7.881	6.375	8.041	7.974	6.732	5.677	5.989	6.045	8.041	8.041	8.041
800.0000	7.903	6.400	8.041	7.999	6.774	5.685	5.998	6.057	8.041	8.041	8.041
900.0000	7.954	6.455	8.041	8.041	6.900	5.698	6.021	6.079	8.041	8.041	8.041
1000.0000	8.000	6.512	8.041	8.041	7.045	5.706	6.045	6.104	8.041	8.041	8.041

The log-linear output signal and pressure are related by the following formulas:

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

where P is the pressure in Torr, and V is the output signal in Volts.

The chart on the following page shows the graphical results of the table and formulas above. 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 Output Voltage vs Pressure

This is a plot of the formulas and data for the log-linear output signal, from the previous page.

Table 3 - Displayed Pressure Readings vs Pressure, for Selected Gases

True Total Pressure		N2	Ar	He	O2	CO2	Kr	Freon12	Freon22	D2	Ne	CH4
0	mTorr	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1	mTorr	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
0.2	mTorr	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
0.5	mTorr	0.5	0.5	0.5	0.5	0.5	0.3	0.5	0.5	0.5	0.5	0.5
1	mTorr	1.0	0.7	0.8	1.0	1.1	0.4	1.5	1.5	1.3	0.7	1.7
2	mTorr	2.0	1.4	1.6	2.0	2.3	1.0	3.1	3.1	2.4	1.5	3.3
5	mTorr	5.0	3.3	4.0	5.0	4.4	2.3	7.6	7.0	6.0	3.5	7.7
10	mTorr	10.0	6.6	8.1	9.7	11.0	4.8	14.7	13.5	12.1	7.1	15.3
20	mTorr	20.0	13.1	16.1	19.8	22.2	9.5	29.9	27.2	24.3	14.1	30.4
50	mTorr	50.0	32.4	40.5	49.2	54.9	23.5	72.5	69.0	60.0	34.8	77.2
100	mTorr	100	64.3	82.0	97.2	107	46.8	143	136	121	70.0	159
200	mTorr	200	126	165	194	210	91.1	275	262	250	141	315
500	mTorr	500	312	435	486	489	217	611	594	687	359	781
1	Torr	1.00	600	940	970	950	400	1.05	1.04	1.55	745	1.60
2	Torr	2.00	1.14	2.22	1.94	1.71	700	1.62	1.66	4.13	1.59	3.33
5	Torr	5.00	2.45	13.5	4.98	3.34	1.28	2.45	2.62	246	5.24	7.53
10	Torr	10.0	4.00	OP	10.3	4.97	1.78	2.96	3.39	OP	21.5	27.9
20	Torr	20.0	5.80	OP	22.3	6.59	2.29	3.32	3.72	OP	584	355
50	Torr	50.0	7.85	OP	77.6	8.22	2.57	3.79	4.14	OP	OP	842
100	Torr	100	8.83	OP	209	9.25	2.74	4.68	4.91	OP	OP	OP
200	Torr	200	9.79	OP	295	12.3	3.32	5.99	6.42	OP	OP	OP
300	Torr	300	11.3	OP	380	16.9	3.59	6.89	7.52	OP	OP	OP
400	Torr	400	13.5	OP	485	22.4	3.94	7.63	8.42	OP	OP	OP
500	Torr	500	16.1	OP	604	28.7	4.21	8.28	9.21	OP	OP	OP
600	Torr	600	18.8	OP	730	36.4	4.44	8.86	9.95	OP	OP	OP
700	Torr	700	21.8	OP	859	46.1	4.65	9.42	10.7	OP	OP	OP
760	Torr	760	23.7	OP	941	53.9	4.75	9.76	11.1	OP	OP	OP
800	Torr	800	25.1	OP	997	59.4	4.84	9.95	11.4	OP	OP	OP
900	Torr	900	28.5	OP	OP	79.5	4.99	10.5	12.0	OP	OP	OP
1000	Torr	1000	32.5	OP	OP	111	5.08	11.1	12.7	OP	OP	OP

Notes:
1) OP = overpressure
2) Display auto-ranges between Torr and mTorr at 1Torr
   Readings in normal font are in Torr. *Readings in blue italics are in mTorr* .

Appendix C: *Vacuum gauge contamination and cleaning*

The most common cause of all vacuum gauge failures is contamination of the sensor. Noisy or erratic readings, the inability to set zero or atmosphere, and total gauge failure, are all possible indications of gauge contamination.

Contamination can be generally characterized as either: A) a reaction of process gases with sensor elements, or B) an accumulation of material on the sensor elements.   Sensors that fail due to chemical reaction are generally not salvageable. Sensors that fail due to condensation, coatings, or particles may possibly be restored by following the cleaning procedure described below.

A) Reactive Gases

If process gases react with the materials of construction of the sensor, the result is corrosion and disintegration of the sensor over time. Plasma etching and other reactive semiconductor processes are examples where this failure mode is common. In this instance, cleaning can not solve the problem, because the sensor has been destroyed; the gauge or module must be replaced.

If you experience this failure mode quickly or frequently, you should consider a different vacuum gauge for your application.   Thermal vacuum gauges may be available with different sensor materials that are not as reactive with your particular process gases. Or you may consider a different type of gauge, such as a capacitance diaphragm gauge, which exposes only stainless steel or ceramic to the gases.

There is no material that is universally chemical resistant; your choice of vacuum gauge (as well as all other vacuum components) should take into consideration the potential reactions between your process gases and the materials of construction. Consider what effect water vapor will have when combined with your process gases because a finite amount of water will enter the chamber during venting to atmosphere.

B) Condensation, Coatings, and Particles

If the failure is due to an accumulation of material in the sensor, you may be able to restore your gauge or module by cleaning. Contamination may be as simple as condensed water, or as difficult as solid particles.

Condensation: Some gases (such as water vapor) can condense on sensor surfaces, forming a liquid coating that changes the rate at which heat is removed from the sensor (which changes the calibration). The sensor can often be restored simply by pumping on the gauge between process cycles. A dry N_2 purge will help speed up drying, or the gauge may be gently heated, provided temperature doesn't exceed the specified limit (150°C with cables or electronics removed).

Coatings: Some gases can condense on sensor surfaces, forming a solid coating, which again changes the rate at which heat is removed from the sensor. Some of these coatings may be removed using an appropriate solvent, following the procedure described below.

Particles: Particles generated by the process may enter the gauge during the process cycle or during the venting cycle. The result is interference with heat removal from the sensor. The cleaning procedure described below may be able to remove particles from the gauge. However, particulate contamination is the most difficult to remove as particles can become stubbornly trapped inside the gauge.

In some processes, solid particles are created during the process, throughout the chamber, including inside the gauge. Particles tend to form on cooler surfaces, such as in a gauge at room temperature. You may slow down the build-up of particles in the gauge, by keeping the gauge warm (within specified limits) during the process cycle.

More commonly, particles in the process chamber are swept into the gauge during the vent cycle. InstruTech gauges have a screen built into the gauge port, to help keep the largest particles out of the gauge. In very dirty applications, or where particles are small enough to get through the screen, an additional filter installed on the inlet may help prolong gauge life further.

C) Cleaning Procedures

Caution: Cleaning chemicals and their handling pose a variety of health, safety, and environmental issues.   Protect yourself, your co-workers, and your surroundings, by using protective clothing (gloves, eyewear, etc), performing the cleaning in a well-ventilated area, and disposing of waste materials in a responsible manner.

Cleaning solvents:

To be effective, the cleaning agent should be one that is likely to remove the suspected contaminant. It must also be compatible with the gauge materials of construction. Alcohol and water are recommended cleaning solvents, as they are compatible with most vacuum systems and components, and will remove many contaminants commonly found in vacuum processes, such as pump oil. However, depending on your particular contamination, you may need to use a more aggressive solvent.

Cleaning procedure:

1. With the gauge port up, pour your cleaning solution into the gauge port until it is full. Note: The fine mesh of the port screen may not allow the solution into the gauge tube because of surface tension effects. You may need to insert a small tool into the gauge vacuum port to push the port screen slightly away from the tube wall to allow solvent into the gauge. ("Slightly away" means less than about a millimeter.) Make sure the tool is not plated with high vapor pressure material such as zinc plating.

2. Let the solution sit for a while, 10-20 minutes should be sufficient. <u>Gentle</u> agitation will help disperse the solution throughout the gauge, but do not shake the gauge vigorously. (While the InstruTech gauge is constructed to be rugged, it was not designed to withstand forces exerted by *liquids* in motion.)

3. With the gauge port down, pour the solution out of the gauge and leave it to drain and dry for several hours or overnight. Warming the gauge, and/or pumping on it, will speed up the drying time.

4. When you are sure the gauge is completely dry, install it on a vacuum system, apply power, and run through the calibration setup. Pump the gauge below 10^{-4} Torr and confirm that the zero/vacuum can be set. If zero is ok, raise pressure and set the atmosphere adjustment.

5a. If both zero and atm can be set properly, you have successfully cleaned your gauge.

5b. If zero or atm cannot be set, the gauge has been contaminated beyond recovery and must be replaced. (You can try cleaning it again, but if the first pass doesn't recover the gauge, additional cleanings are not likely to succeed.)

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 twenty four (24) months (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.