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# Vacuum Measurement

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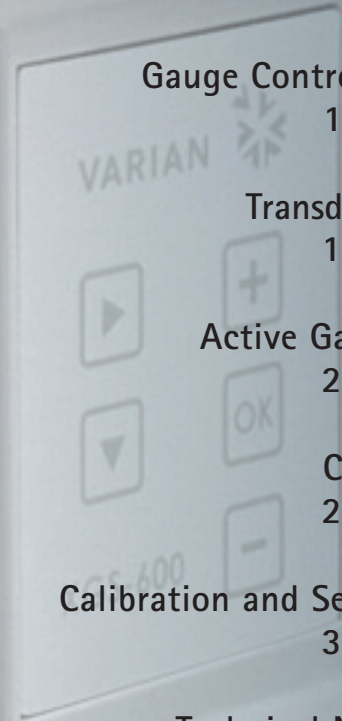
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The image shows a close-up of a white LCD display on a piece of equipment. The display shows a table of vacuum measurement data with columns for gauge ID, Torr, control status, and set points. At the bottom of the display, there are three buttons labeled "SETPTS", "SETUP", and "LARGER".

	<u>TORR</u>	<u>CONTROL</u>	<u>SET-PTS</u>
HFIG1	1.8E-5	FIL1 ON	
HFIG2	1.8E-6	FIL1 ON	3
IMG1	3.7E-11	ON	
IMG2	7.1E-7	ON	5
CNV1	5.7E+2	CAL	
CNV2	7.5E+2	CAL	7
CNV3	1.1E-4	CAL	
CNV4	4.7E+2	CAL	

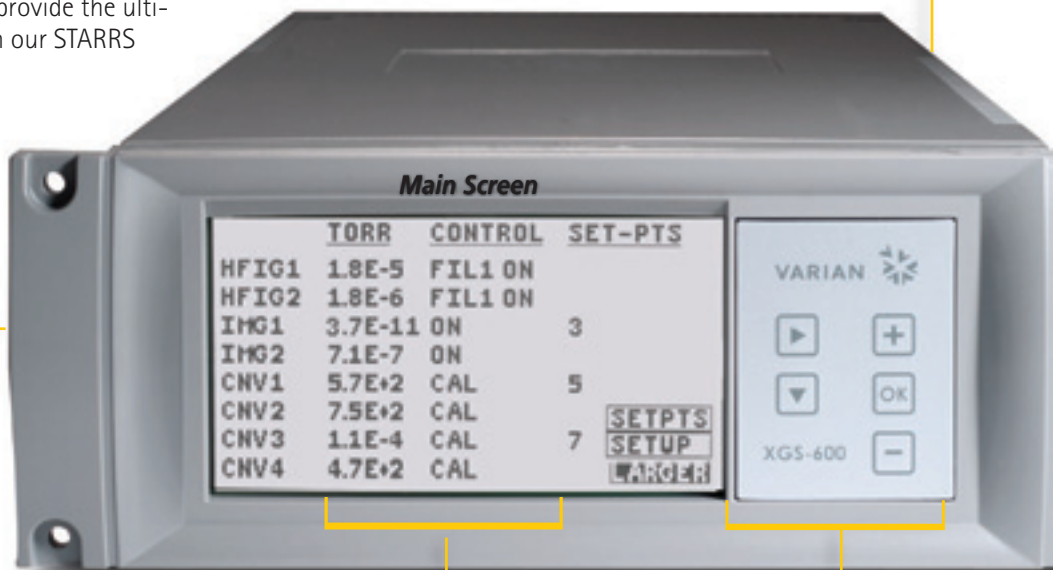


# Vacuum Measurement for Science and Industry

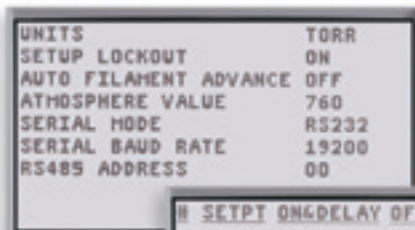
Varian vacuum gauges and controllers are reliable, accurate, and cost-effective tools for measuring and controlling vacuum pressure in a wide range of applications.

- Varian features pressure measurement technology designed for challenging industrial environments: simplicity, rugged design, plus ease of service to insure maximum productivity and uptime in your vacuum system or vacuum process.
- With over 50 years experience in science research, our superior accuracy and stability meets the most demanding scientific requirements, and Varian can provide the ultimate in measurement precision through our STARRS calibration and support program.

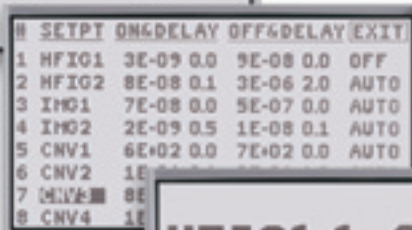
## XGS-600 Gauge Controller



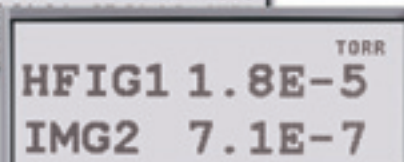
### User Friendly Interface



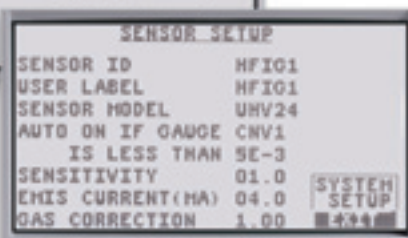
System Setup



Set Points



Large Font



Sensor Setup

### Intuitive screen functions

### Easy key pad navigation

- Displays up to 8 gauges on one screen
- Customizable gauge labels

## Intelligent Design & Functionality

- Simultaneous operation of all gauges – up to 12
  - <20 millisecond signal-to-set-point response time
  - Displays up to 8 gauges at one time
- Standard features include:
    - 8 gauge set points
    - fully programmable RS-232/485 serial communications
    - E-beam degas for hot filament gauges
    - pressure unit selection: Torr, Mbar, Pascal
    - universal voltage compatibility
    - analog output

## Capacity, Flexibility & Expandability

Only 3 gauge cards operate all Varian gauges:

- Add a gauge card when needed, simply and quickly
- Save the cost of additional controllers

Simultaneous operation of:

- Up to 4 hot filament gauges plus 4 convection gauges
- Up to 5 inverted magnetron gauges
- Up to 12 convection gauges



## Transducers

### Rough Vacuum Gauges

Reliable and cost-effective

#### ConvecTorr Gauge

Convection-enhanced thermal gauge combines rapid pressure response with excellent sensitivity and linearity over the entire rough vacuum range.



#### 531 & 536 TC Gauges

Robust, low-cost solution for simple tasks such as reading chamber or foreline pressure, or to trigger crossover for a high vacuum pump.



### High and Ultra-High Vacuum Gauges

#### Hot cathode gauges

Bayard-Alpert (B-A) ion gauges provide superior accuracy and repeatability over a wide range of vacuum pressures

#### All-metal ion gauges

Rugged and stable with excellent shielding from EMI



#### Glass B-A gauges

Low-cost option for measuring high and ultra-high vacuum.



#### Inverted Magnetron Gauges

Excellent low-pressure measurement capability; fast pressure response and superior robustness in challenging environments



## Active Gauges

Accurate, reliable vacuum transducers with integrated controllers

#### CT-100 Rough Vacuum Gauge

Pirani-like performance at thermocouple economy



#### FRG-700 Full Range Vacuum Gauge

Pirani-type sensor and Inverted Magnetron Gauge, plus controller in a compact, economical package.



# Applications

## High Energy Physics and Research Laboratories

- Synchrotron Light Sources and Beam Lines
- Particle Accelerator Rings

Vacuum gauges are widely used in High Energy Physics, Fusion Technology and general UHV research. Synchrotron Light Sources, Particle Accelerator Rings, UHV Laboratory research, and Fusion reactors need extremely accurate, reliable and cost effective HV and UHV vacuum gauges. Varian offers a full range of vacuum transducers that can be equipped with high function controllers to monitor and control HV and UVH environments. If desired, Varian can also offer "Active Gauges" equipped with on-board controllers that combine highly accurate and compact vacuum measurement and control that offers the smallest footprint. The following examples illustrate applications in R&D for Varian gauges:



## Industrial Processes

- Thin Film Deposition
  - glass coating equipment (architectural glass, automotive glass, flat panel display substrates)
  - thin film solar cells production (photo-voltaic)
  - optical data media (Compact Discs, Digital Versatile Discs, Magneto Optical Discs)
- Magnetic storage media (hard discs, read heads)
- Surface treatments (functional, decorative)
- Optical coating (ophthalmic, precision opto-electronics)
- Roll/web coating on films or foils

Our expertise with both OEMs and end users in the field of industrial vacuum equipment makes us the right partner for your Total Vacuum Solution. In single chamber batch systems, multiple chamber systems, with load locks, or large inline

continuous systems, Varian Vacuum Technologies has the right vacuum gauges for your process requirements. What really differentiates Varian is the expertise of its applications, support and custom system design staff to integrate these superior vacuum gauges into an optimized vacuum solution. Our experts will work with you to offer the right solutions to your particular vacuum equipment.

In thin film processing (PVD/sputtering) to major parameters that relate to total gas pressure which is a function of gas density and gas temperature and the partial pressure of the individual gaseous species. In order to have a reproducible deposition process, it is often necessary to measure these parameters precisely if not accurately. These vacuum parameters should be measured both during pump down to base pressure during processing since processing often releases gas and vapors into the deposition environment.



*Plasma vapour deposition (PVD). Worker adjusting the controls of a PVD machine which is being used to coat components (trays at lower centre and lower left) with a thin film metal alloy to provide a wear-resistant coating.*

Gauge placement in TF systems is very important, particularly at higher pressures and in "crowded" processing volumes. Generally gauges are connected to the processing volume through short, large diameter tubes, although some cases the gauge elements can be in the chamber (nude ionization gauges). Generally, gauges should be placed well away from the high vacuum pumping port and out of direct line-of-sight of vaporization source and gas inlet ports.

In crowded chambers at higher pressures (>1mTorr), in continually pumped systems, significant pressure differential can exist in the processing chamber. These pressure differential can affect film properties such as residual stress, composition, electrical resistivity, etc. When establishing a plasma, the pressure difference change the plasma density and thus the sputtering rate in sputter deposition – and the film composition in reactive sputter deposition. In such circumstances sev-

eral gauges may be used at different locations in the processing chamber to monitor the pressure differences.

- **Device Processing**
  - TV and monitor picture tube manufacture
  - Evacuation and coating of lamps (motorway lighting, beamers)
  - X-Ray tubes & electron devices (CPI, etc)
  - Medical accelerator tubes (medical devices)
  - Lasers
    - night vision systems
  - cryogenic processes and instrumentation, others
    - infrared detectors (DRS)
- **General Industrial Processes**
  - Vacuum furnaces – Metallurgy

#### Vacuum Furnaces for Metal Treatment

Brazing, sintering or annealing metals requires an atmosphere free of oxygen. Therefore, such processes are carried out under partial vacuum using inert gas. The vacuum level must be monitored and kept constantly low during the process in order to avoid oxidation of the products. As a result, it is necessary to measure the pressure in the high vacuum furnace near the gas inlet as well as at the vacuum port with high accuracy.

Varian convection active gauges with wide measuring range can detect the pressure at the furnace gas inlet and vacuum port with excellent precision. They are then linked to the system PLC by their serial port with either RS-232 or 485 communication. Based on this, all system pressure levels can be monitored at the main control system. This allows easy monitoring of the system gradient inside the furnace.

## Analytical Instrumentation

- **Electron Microscopy (SEM, TEM)**
- **Focused Ion-beam Systems (FIB) and Surface Analysis**

Modern focused-beam systems such as SEMs, TEMs and FIB's utilize columns that project electrons or ions onto microscopic samples for detailed analysis. End users analyze all types of substances from organic compounds to semiconductor wafers. In the Semiconductor industry, in particular, they require more sensitivity for better sample resolution. Another key requirement is high sample throughput in order to lower the cost of ownership of these instruments. Based on these requirements, the demand for high performance vacuum gauges is greater than ever. Varian offers a full range of high and ultra-high vacuum gauges designed especially for the demanding requirements of SEMs, TEMs and surface analysis systems. Vacuum gauges are also a key component in modern focused-beam systems because the process gas flow can cause significant fluctuations in chamber pressures demanding a wide range of control. From Varian's full range of vacuum gauges and controllers, the focused-beam system designer can choose a gauging package that offers the best controlled chamber evacuation time with the best cost of.

Varian offers a full range of application specific designed SEM vacuum gauges including active gauges for easy system integration and flexibility, or gauge controllers for systems that do not have integrated control systems or require dedicated remote read-out.

Mass Spectrometry has become an important analytical tool in many industries including pharmaceutical. Thanks to advances in electronics, instrument designers can implement cost-effective, high-performance analytical power in a cost-effective, easy-to-use system. These developments require advanced vacuum systems that are characterized by multi-chamber, high throughput designs on the high quality instruments. These requirements, in turn, demand cost-effective,



Scanning electron microscopes, like the one shown here, can "see" details as small as one nanometre – one millionth of a metre!

## Applications (*cont'd*)

high performance vacuum pumps. Varian offers a full line of pumps and controllers that meet the most challenging vacuum requirements and are optimized for the specific requirements of modern mass spectrometry systems. Varian can further customize its pumps by providing multi-inlet pumping systems that are compact and reliable. A few common application examples for mass spectrometry are listed below:

### Mass Spectrometry

Spectrometers must operate with high accuracy and reliability. Periodic offset adjustment under fine vacuum conditions guarantees that even slightest hints of contamination can be detected. The precise Pirani vacuum transducer controls whether the required vacuum level for zero adjustment is achieved. With its elastic helix filament and the rugged metal housing the transducer is especially durable.



*An NRC researcher uses a liquid chromatography-mass spectrometry system to quantify toxins in shellfish samples.*

### Semiconductor

The vacuum gauges are critical to controlling an appropriate environment in the world of semiconductor manufacturing. In fact, as semiconductor chip geometries continue to shrink, the reliance on vacuum to provide accurate control of the manufacturing process is more important than ever. For the majority of semiconductor manufacturing processes, the vacuum system operation usually can be enhanced through good vacuum control to improve reliability, throughput, uptime, contamination control, process control and process capability. For example, a vacuum pumpdown or purge cycle often can be shortened without degrading the product, and the time saved can significantly increase throughput. Varian's vacuum gauges provide unique and critical advantages in the measurement and control of vacuum in these stages of semiconductor processing. Varian has a complete line of on-board, direct measurement gauges that can be easily integrated into existing OEM system controllers through digital or analog control. These two additions provide the vacuum gauges with the ability to meet demanding rapid cycle applications, such as vacuum load locks, in which high gas-load cycling and high tolerable foreline pressures are critical to the success of the process. Varian's vacuum gauges capabilities are unique, and the most advanced in the industry, allowing the user to share a single roughing pump across multiple vacuum gauges, thus reducing costs and improving tool reliability by reducing the number of dynamic systems within the process tool.

The loadlock pressure usually is measured with a convection-enhanced Pirani gauge with a built-in crossover setpoint. If the setpoint is in a region where the gauge has low accuracy, the slow vent time can be longer than necessary. In one case,

the crossover pressure was specified at 80 Torr, and a test with a capacitance manometer showed the loadlock actually was slow venting to 120 Torr, adding two minutes to the process time. The Pirani gauge was replaced with an absolute pressure switch based on a capacitance manometer sensor with a 100 Torr full-scale range. The crossover pressure was accurately sensed, and the two minutes per cycle were reclaimed, significantly increasing throughput. A capacitance sensor also is insensitive to gas species, a plus if vent gases other than air or nitrogen are used. Two-stage soft-start isolation valves are available that simplify and automate two-stage pumping and venting.











The cold cathode gauge is an often overlooked, cost-effective gauge for ion implanters and other high-vacuum applications. A cold cathode gauge has no filament, is not subject to burnout and has a significantly longer life and lower annual replacement cost than a hot cathode Bayard-Alpert gauge. A cold-cathode gauge can be replaced at predictable intervals, whereas a hot cathode gauge must be replaced whenever a burnout occurs. In addition, the annual cost of replacement is less. A modern inverted magnetron cold cathode gauge is stable and can operate over a wide pressure range from 10 mTorr down to ultra-high vacuum. Repeatability is better than 9%.<sup>8</sup> Cold cathode gauges have a reputation as 'slow starters,' since they must rely on an ionization source such as a cosmic ray to initiate a discharge. The lower the pressure, the less likely an ionizing collision and the longer the start delay. At 1 mTorr or higher, there is no delay; but at 10<sup>-8</sup> Torr, starting can take up to 3 hours. The traditional solution is to start the gauge in the mTorr range, but often this is not practical. A relatively new technique uses ultraviolet induced photoemission to generate an ionizing electron to start the gauge.<sup>8</sup> At 10<sup>-6</sup> Torr the start time is 4-5 seconds.

# Gauge Selection Chart



XGS-600 Controller operates all Varian gauges with only three (3) gauge cards.



Learn about the XGS-600 on page 10.

Vacuum Regime	Controller Gauge Card			Gauge Type	Page #	Recommendation
	Convection C	Hot Filament H	Cold Cathode M			
ROUGH Atm to 10 <sup>-3</sup>	✓			Convectorr 	14	• Best overall convection gauge for accuracy, repeatability, secure connection
	✓			536 	15	• Same vacuum performance as the Convectorr but without bayonet connection
	✓			531 	15	• Most economical rough gauge
HIGH 10 <sup>-3</sup> to 10 <sup>-9</sup>		✓		572 (glass) 	17	• Most popular general purpose HV gauge (hot filament) • Dual filament
		✓		563 (glass) 	19	• Best general purpose HV gauge (hot filament) for overall performance and reliability
		✓		571 (glass) 	18	• Same as 563 without platinum coating
		✓		MBA-100 (one filament metal case) ----- MBA-200 (two filaments, metal case) 	20	• Break resistant HV gauge (hot filament)
			✓	IMG-100 Inverted Magnetron 	21	• Most durable and fastest responding HV gauge (cold cathode)
ULTRA HIGH 10 <sup>-9</sup> to 10 <sup>-12</sup>			✓	IMG-300 Inverted Magnetron 	22	• Most durable and fastest responding UHV gauge (cold cathode)
		✓		UHV-24 (nude) 	23	• Most popular UHV gauge (hot filament)
		✓		UHV-24p (nude)	23	• UHV gauge providing the highest vacuum reading

Gauge Characteristics	
	<ul style="list-style-type: none"> <li>• Stainless steel</li> <li>• 1/8 in. NPT, KF and CFF</li> <li>• Locking bayonet connector</li> </ul>
r	<ul style="list-style-type: none"> <li>• Stainless steel</li> <li>• 1/8 in. NPT, KF and CFF</li> </ul>
	<ul style="list-style-type: none"> <li>• Lowest cost</li> <li>• Mild steel</li> <li>• 1/8 in. NPT</li> </ul>
	<ul style="list-style-type: none"> <li>• Measures from 1 mTorr to <math>1 \times 10^{-9}</math> Torr</li> <li>• Tungsten filaments – more accurate and repeatable; better for hydrogen and halogen gases</li> <li>• Glass – can see that it is on</li> </ul>
	<ul style="list-style-type: none"> <li>• Measures from 10 mTorr to <math>1 \times 10^{-9}</math> Torr</li> <li>• Thoriated iridium filament tolerates accidental venting</li> <li>• Glass – can see that it is on</li> <li>• Platinum coating – provides higher performance in the <math>10^{-4}</math> range and a measure of EMI shielding</li> </ul>
	<ul style="list-style-type: none"> <li>• Less expensive than 563 without platinum coating</li> </ul>
	<ul style="list-style-type: none"> <li>• Measures from 5 mTorr to <math>1 \times 10^{-9}</math> Torr</li> <li>• General purpose hot filament with metal housing – not glass, will not break</li> <li>• Uses less power than glass gauges</li> <li>• Well shielded</li> <li>• Available in tungsten and thoriated iridium filament (see 572 and 563 above)</li> </ul>
	<ul style="list-style-type: none"> <li>• General purpose – measures from 5 mTorr to <math>2 \times 10^{-9}</math> Torr</li> <li>• Small, reliable, extremely rugged – will not burn out</li> <li>• Very fast response – &lt; 20 milliseconds</li> <li>• Less accurate and repeatable than hot filament</li> <li>• Longer starting in high vacuum than a hot filament</li> <li>• Can be cleaned</li> </ul>
	<ul style="list-style-type: none"> <li>• Measures from 1 mTorr to <math>1 \times 10^{-11}</math> Torr</li> <li>• Bakeable with magnet to 250°C – bakeable without magnet to 450°C</li> <li>• Reliable, rugged, will not burn out – can be cleaned</li> </ul>
	<ul style="list-style-type: none"> <li>• Measures from 1 mTorr to <math>1 \times 10^{-10}</math> Torr</li> <li>• Bakeable to 450°C</li> <li>• Thoriated iridium filaments run cooler-less outgassing</li> <li>• Dual tungsten filaments run hotter-more outgassing but measurements are more accurate and repeatable</li> </ul>
	<ul style="list-style-type: none"> <li>• Same as UHV-24 except it measures to <math>2 \times 10^{-11}</math> Torr</li> </ul>

## Active Gauges

Varian Active Gauges integrate the gauge and controller in a single compact package. These are ideal for embedded OEM and industrial systems where a control computer or PLC handles the display/control function for one or several gauges. The user provides input power (typically 24V) and reads pressure output via PC or PLC. A variety of set point interface features are available to automate your system.

Gauge Type	Page No.	Gauge Characteristics	Vacuum Regime
<b>CT-100</b> 	24	<ul style="list-style-type: none"> <li>• Low-cost solution for active rough vacuum pressure measurement</li> <li>• Designed for applications such as mass spectrometers, surface analysis systems, many industrial applications</li> <li>• Ideal for load locks, pressure sequencing of complex systems or to protect turbo pumps from damage due to sudden air in rush</li> <li>• Two user selectable pressure ranges between <math>1 \times 10^{-4}</math> and 760 Torr offer accurate, repeatable readings where most critical for the user</li> <li>• Fast pressure response &lt; 0.2 seconds</li> </ul>	<b>ROUGH</b>  <b>Atm to <math>10^{-3}</math></b>
<b>FRG-700 Full Range Gauge</b> 	26	<ul style="list-style-type: none"> <li>• Provides 2 measuring technologies in a single, compact, economical package</li> <li>• Measures process and base pressure from <math>5 \times 10^{-9}</math> mbar to atmosphere (<math>3.8 \times 10^{-9}</math> Torr to atmosphere)</li> <li>• A single, compact unit with one logarithmic analog out put signal significantly reduces the complexity of installation, setup and integration</li> <li>• Ideal for high vacuum pressure monitoring, base pressure for evaporation and sputtering systems, and general vacuum measurement and control in the medium and high vacuum range</li> <li>• Wide measurement range from <math>5 \times 10^{-9}</math> mbar to atmosphere</li> <li>• No filament to burn out</li> <li>• Excellent ignition properties</li> <li>• Easy to clean</li> </ul>	<b>HIGH</b>  <b><math>10^{-3}</math> to <math>10^{-9}</math></b>

# XGS-600 Vacuum Gauge Controller



The XGS-600 Vacuum Gauge Controller provides unprecedented capacity, performance and flexibility in a cost effective, standard half-rack package. A single controller can simultaneously operate up to four hot filament (or four cold cathode) gauges and four convection gauges, up to five cold cathode gauges, or up to twelve convection gauges. Expansion or re-configuration in the field is easy to do. Serial communications (RS-232 or RS-485), eight set points, and universal

voltage compatibility are standard in all units. A programmable dot matrix LCD provides display flexibility, and simple screen organization and navigation makes the unit extremely easy to use. Drop down gauge selection automatically sets the emission current, sensitivity and overpressure. The screen displays up to eight gauges and pressures simultaneously, and permits the user to label each gauge. A large-font feature provides visibility from up to 20 feet.

Features	Benefits
<ul style="list-style-type: none"> <li>Powerful</li> </ul>	<ul style="list-style-type: none"> <li>A single unit can simultaneously operate up to:                             <ul style="list-style-type: none"> <li>4 BA and 4 convection gauges (or 4 IMG and 4 convection gauges)</li> <li>5 ion gauges (5 IMG gauges or 4 hot filament and 1 IMG)</li> <li>12 Convection gauges</li> </ul> </li> <li>8 set points</li> <li>Standard Features in every unit:                             <ul style="list-style-type: none"> <li>Serial communication (RS-232 and RS-485), universal voltage, Degas</li> </ul> </li> </ul>
<ul style="list-style-type: none"> <li>Flexible</li> </ul>	<ul style="list-style-type: none"> <li>Operates hot filament, inverted magnetron (cold cathode) and convection gauges</li> <li>Can mix and match any gauges in a single unit</li> <li>Can expand or reconfigure easily in the field</li> </ul>
<ul style="list-style-type: none"> <li>Easy to Use</li> </ul>	<ul style="list-style-type: none"> <li>Simple screen organization and navigation</li> <li>Drop down gauge selection automatically sets the emission current, sensitivity and overpressure.</li> <li>Displays up to 8 gauges simultaneously on one screen</li> <li>Large font feature allows display of 2 gauges visible from 15-20 feet</li> <li>Capability of programming your own 5 character gauge label</li> <li>Set Point Screen: displays and adjusts set points for up to 8 gauges</li> </ul>
<ul style="list-style-type: none"> <li>Fast</li> </ul>	<ul style="list-style-type: none"> <li>&lt; 20 milliseconds from signal to set point response</li> </ul>
<ul style="list-style-type: none"> <li>Compact</li> </ul>	<ul style="list-style-type: none"> <li>All in the impressively small package of a standard 1/2 rack</li> </ul>

## XGS-600 Applications



**XGS-600 Controller operates all Varian gauges with only 3 gauge cards... convection, hot filament and cold cathode (inverted magnetron)**



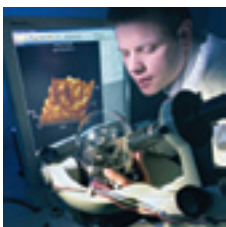
### Laboratory

- **Easy to use** – can be operated without a manual; screens and menus are easy to follow
- **Easy to order** – only 3 different controller gauge cards/modules to choose from, everything else is standard
- **Easy to adapt** – only one gauge card is needed to operate any Varian gauge of a given type
- **Practical** – the XGS-600 can be easily reconfigured – it just takes a few minutes to add or remove a gauge card – any Varian gauge can be operated in one unit
- **Convenient** – view up to 8 gauges at one time or change the font to view 2 from 15 feet away – all programming is stored in flash memory so no battery backups are needed



### Accelerators, Synchrotrons and Other Large Facilities

- **Signal response** – <20 milliseconds from signal to set point response – ideal for fast acting valves
- **Capacity** – operates up to 5 IMG\* gauges in one controller
- **Compact** – half-rack size saves up to 50-75% of rack space from other controller options
- **Operability** – fully programmable serial communications with individual gauge labeling; choice of RS-232/485
- **Flexibility** – combine UHV/HV metrology and IMG\* interlocking in one unit – ideal in beamline applications

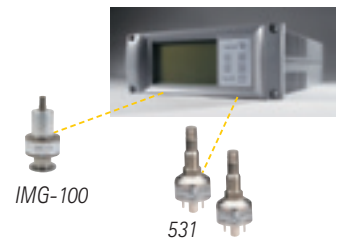


### OEM Equipment

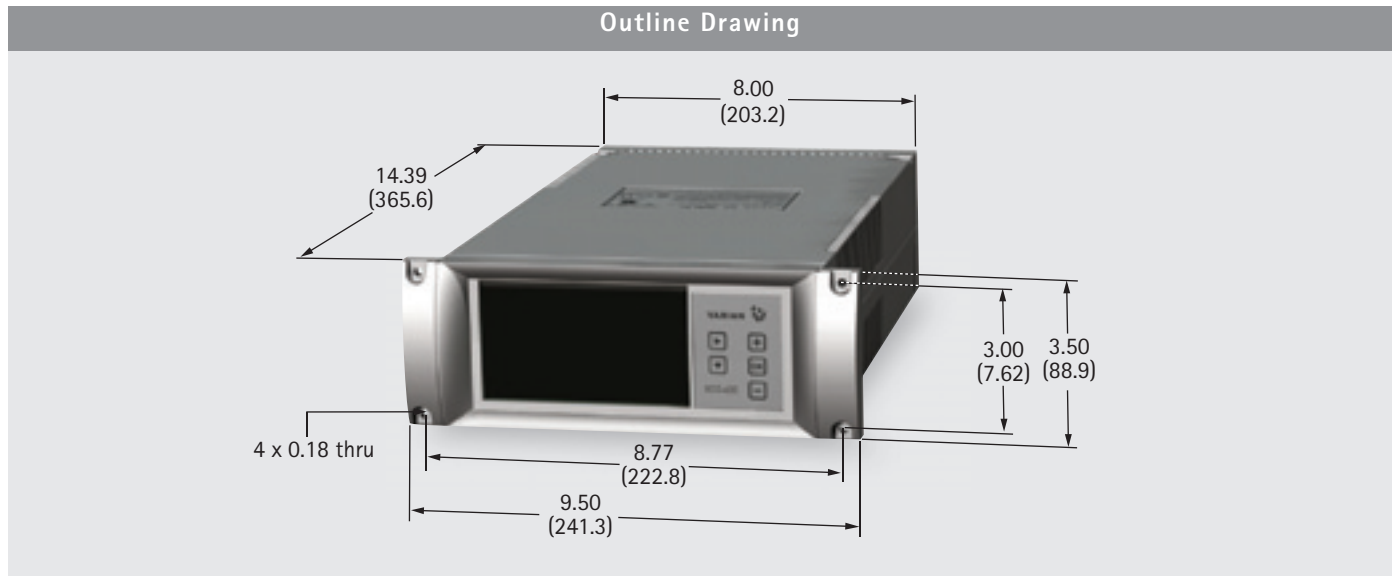
- **Reliable** – The XGS-600 controller has been qualified under demanding test standards; thermal management reduces component stress and provides consistency and durability in performance.
- **Compact** – half-rack size for up to 4 ion gauges and 4 convection gauges in one unit
- **Flexibility** – operates any Varian gauge in one controller
- **Performance** – fully programmable serial communication is standard. Serial response time <2 milliseconds. Displays up to 8 gauges in one screen, gauge labeling. All programming stored in flash memory – no batteries needed.

### Possible Configurations

Below are examples of ways to configure the XGS-600, but remember, you are not limited to these configurations. The flexibility of this unit allows you to setup the controller with the gauges that suit your needs.



# XGS-600 Technical Specifications



## Technical Specifications

User Interface	LCD monochrome dot matrix, 240 x 128, white LED backlight; 5 button keypad
Display Capability	Up to eight simultaneous channels of pressure measurement, up to a 5 character user label for each; up to two channels in a large font; readable from 15 feet; display updates every 200 msec
Gauge Capability	Up to 4 Hot Filament BA gauges including metal, glass, and nude UHV types using the HFIG** cards; up to 5 IMGs* using the IMG* cards; up to 12 rough gauges using the Dual Convection Gauge Cards
Measurement Range	1 x 10 <sup>-11</sup> Torr to Atm dependent upon card and gauge type selected
Setpoints	Eight normally open setpoints (open collector), with independently programmable ON and OFF delays, manual override (see detail specs for ratings)
Fast Setpoint Response	20 msec max (with delay set to 0.0 secs)
Serial Communications	RS232 and RS485 (fully programmable)
Analog Outputs	1v/dec LOG, 0 – 10V FS, on each card with 200 msec update rate
I/O Control	<b>HFIG** card:</b> Remote gauge ON/OFF, Fil select, DeGAS ON/OFF Inputs, Status Output <b>IMG* card:</b> Remote gauge ON/OFF Input, Status Output <b>Dual Convection Card:</b> Remote CAL inputs, Status Outputs
Other	Auto-ON capability for installed ion gauges when at least one convection card is installed Sensitivity, gas correction, emission current (BA gauges only) inputs for ion gauges E-BEAM degas, with auto turn off for BA gauges Selectable air or argon calibration for rough gauges Adjustable atmosphere value for rough gauges Text error messages All data stored in FLASH non-volatile memory requiring no batteries
Power Input/Temperature	Worldwide universal power input, 100-240VAC, 2A, 50/60HZ, IEC inlet; 5-40°C ambient
Regulatory Approvals	CE certified and RoHS compliant, CSA certified for USA and Canada

**Ordering Information**

Description	Part Number
XGS-600 Vacuum Controller, without cards	XGS600HOMOCO

Configure your XGS-600 Controller with cards – constructing your part number: XGS600HXMCC

- 1 Refer to the Gauge Selection Chart to help determine the gauge you need
- 2 Choose the number of HFIG\*\* cards you want; place after the "H"; will be 0 to 4
- 3 Choose the number of IMG\* (cold cathode) cards you want; place after the "M"; will be 0 to 5
- 4 Choose the number of Dual Convection Gauge Cards; place after the "C"; each card runs two convection type gauges, will be 0 to 6

**Note:**

- The XGS-600 has 6 gauge card slots permitting a total of 6 cards.
- Up to four slots can be used for HFIG\*\* cards. If four of these are chosen, one IMG\* card or up to two Dual Convection Gauge Cards may be selected also.
- Up to five slots can be used for IMG\* cards. If five of these are chosen, no additional gauge cards may be selected.
- All six slots may be used for Dual Convection Gauge Cards.

**Cables\*\*\***

Cable Description	Length	Part Number						
		10 ft	25 ft	50 ft	65 ft	75 ft	90 ft	100 ft
XGS-600 I/O, with flying leads		R32493010	R32493025	R32493050	Special Order (SO)			
Convectorr Gauge, non-bakeable		L91223010	L91223025	L91223050	Special Order (SO)			L91223100
Thermocouple Gauge (531, 536)		L91313010	L91313025	L91313050	SO	L91313075	SO	L91313100
MBA-100 Gauge		R32483010	R32483025	R32483050	Special Order (SO)			
Glass BA Gauge Standard, non-bakeable		R32443010	R32443025	R32443050	Not available over 50 feet – with 10 ft. standard cable, it is possible to order extension up to 250 ft.			
UHV-24/UHV-24p Standard, non-bakeable		R32453010	R32453025	R32453050				
UHV-24/UHV-24p Teflon UHV, bakeable to 250°C		R32463010	R32463025	R32463050				
Ion Gauge Extension – all hot filament		NA	NA	NA	R32473065	SO	R32473090	SO
IMG-100 Gauge, non-bakeable – may be used with IMG-300		R03113010	R03113025	R03113050	SO	R03113075	SO	R03113100
IMG-300 Gauge, bakeable		R03413010	R03413025	SO	R03413065	SO	SO	R03413100

\*\*\*Custom and longer lengths are available on request.

**Accessories**

Description	Part No.
Hot Filament Ion Gauge (HFIG) card, field Install	R3075301
Inverted Magnetron Ion Gauge (IMG) Card, field install	R3080301
Dual Convection Gauge Card, field install	R3084301
Tilt Stand Accessory	R3124301
Center Rack Mount Kit	L6423301
Off-Center Rack Mount Kit	L6422301
Dual Mount Rack Mount Kit	L6426301

\*IMG – Inverted Magnetron Gauge

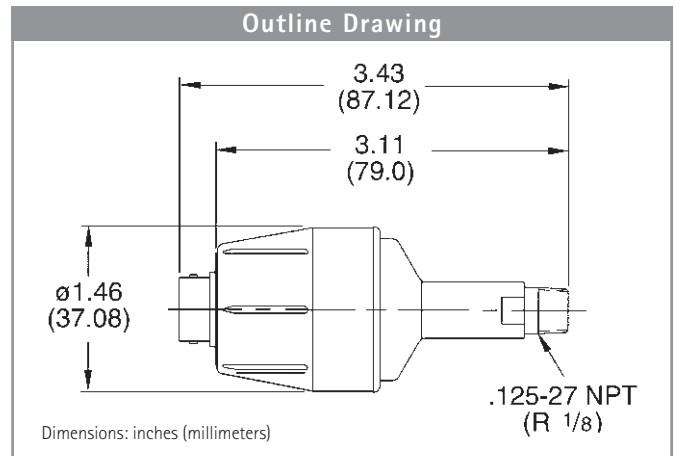
\*\*HFIG – Hot Filament Ion Gauge

**Power Cord Selection**

One power cord included with each unit

Description	Part No.
Europe, 10A /220-230 VAC, 2.5 meter	656494220
Denmark, 10A/220-230 VAC, 2.5 meter	656494225
Switzerland, 10A/230 VAC, 2.5 meter	656494235
UK/Ireland, 13A/230 VAC, 2.5 meter	656494250
India, 10A/220-250 VAC, 2.5 meter	656494245
Israel, 10A/230 VAC, 2.5 meter	656494230
Japan, 12A/100 VAC, 2.3 meter	656494240
North America, 13A/125 VAC, 2.0 meter	656458203

# ConvecTorr™ Gauge



Varian's unique ConvecTorr gauge is a stainless steel, convection-enhanced thermal gauge, which maintains the sensing element at a constant temperature for superior performance from 1 E-04 Torr to atmospheric pressure. The ConvecTorr features accurate pressure indication over the entire rough vacuum range with extremely fast response time (0.2 seconds) and superior readings at higher vacuum pressures due to enhanced thermal stability. ConvecTorr is ideally suited for a wide range of demanding vacuum applications where accurate pressure monitoring and rapid, repetitive pump downs from atmosphere are required, such as load lock applications or control of a two-stage pump down. And, with excellent sensitivity near atmospheric pressure, ConvecTorr can often save many hours of pumping time when monitoring initial pumping of large vacuum systems.

The ConvecTorr, unlike other convection-type gauges, is not affected by system vibration and features a locking bayonet connector. The ConvecTorr offers continuous and repeatable pressure indications between 0 °C and 50 °C. The ConvecTorr is offered with a variety of mounting options and is easily interfaced with Varian's XGS-600 gauge controller for integration in a complex vacuum system, or for use as a stand-alone pressure measurement tool.

## Technical Specifications

### Measurement Range

1 x 10<sup>-4</sup> Torr to Atmosphere, 1 x 10<sup>-1</sup> to 133 Pascal

### Measurement Precision

+ 30 % within a pressure decade

### Temperature Limits

Operating: 0 °C to 50 °C; Storage: -15 to 80 °C; Bake out: 80 °C with cable disconnected

### Pressure Response Time

Less than 0.2 seconds

### Materials

304 Stainless steel with Platinel filament and ABS housing

## Ordering Information

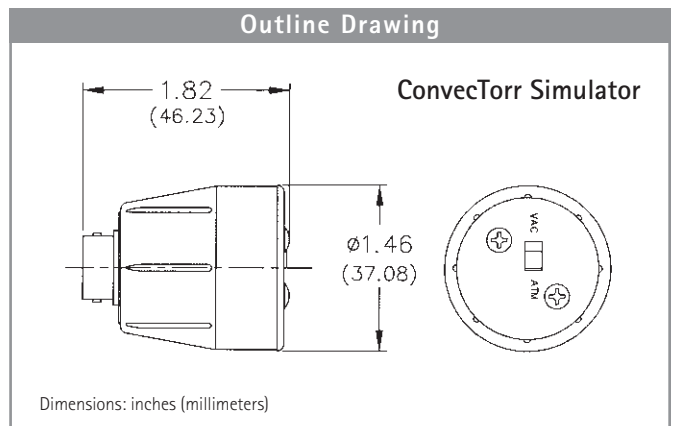
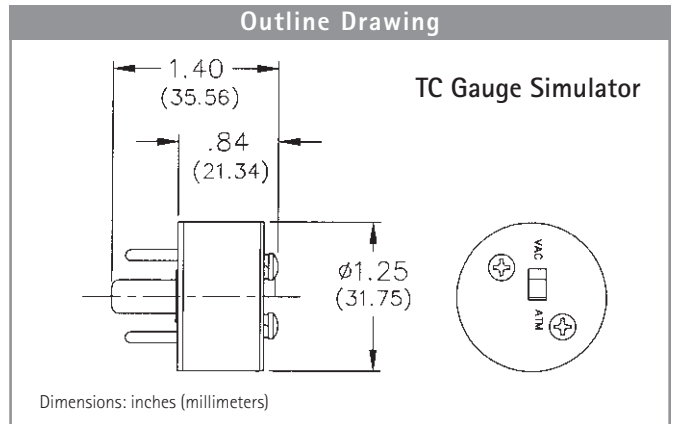
Description	Part Number	Fitting	Shipping Weight lbs. (kg)
ConvecTorr™ Gauge Tube, Platinel filament	L9090301	1/8 in. NPT	1.0 (0.5)
	L9090302	Mini-ConFlat®	1.0 (0.5)
	L9090303	Cajon 4 VCR (female)	1.0 (0.5)
	L9090305	NW16 KF	1.0 (0.5)
	L9090306	NW25 KF	1.0 (0.5)



# Thermocouple and ConvecTorr™ Gauge Simulators – Rough Vacuum



ConvecTorr and TC Gauge Simulators are designed to be convenient tools for verifying proper operation of the control unit. For those cases when the target gauge tube cannot be brought to proper pressure levels for true in-situ calibration, the simulator is used to ensure the control unit is calibrated to the average tube. The selectable "Vac" or "Atm" setting facilitates troubleshooting.



## Technical Specifications

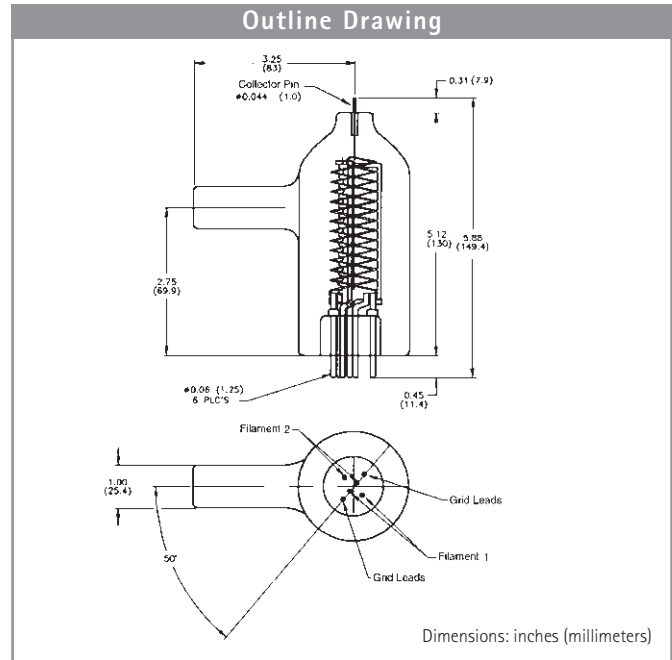
### Reference Pressure

Simulates high vacuum  $<10^{-4}$  torr and atmosphere 760 torr

## Ordering Information

Description	Part Number	Shipping Weight lbs. (kg)
ConvecTorr Simulator	L7382301	1.0 (0.5)
TC Simulator	L7383301	1.0 (0.5)

# 572 Dual Tungsten Filament Bayard-Alpert Type Standard Range Ionization Gauge Tube



The 572 is a high-performance gauge with a wide range of linear response: from  $2 \times 10^{-10}$  to  $10^{-3}$  torr. It is designed to withstand long periods of outgassing, and to facilitate simple external switching of filaments without disturbing the vacuum system. The 572 is compatible with virtually all modern hot filament ionization gauge controllers.

## Technical Specifications

### Sensitivity

$10 \text{ (torr)}^{-1} \text{ (mbar)}^{-1}$  (typical)

### Operating Ratings

- 0 VDC to ground (collector)
- + 180 VDC to ground (grid)
- + 30 VDC to ground (filament)

### X-Ray Limit

$2 \times 10^{-10}$  torr, ( $2.6 \times 10^{-10}$  mbar)

### Operating Pressure

$2 \times 10^{-10}$  torr to  $1 \times 10^{-3}$  torr  
 $(2.7 \times 10^{-10}$  mbar to  $1 \times 10^{-3}$  mbar)

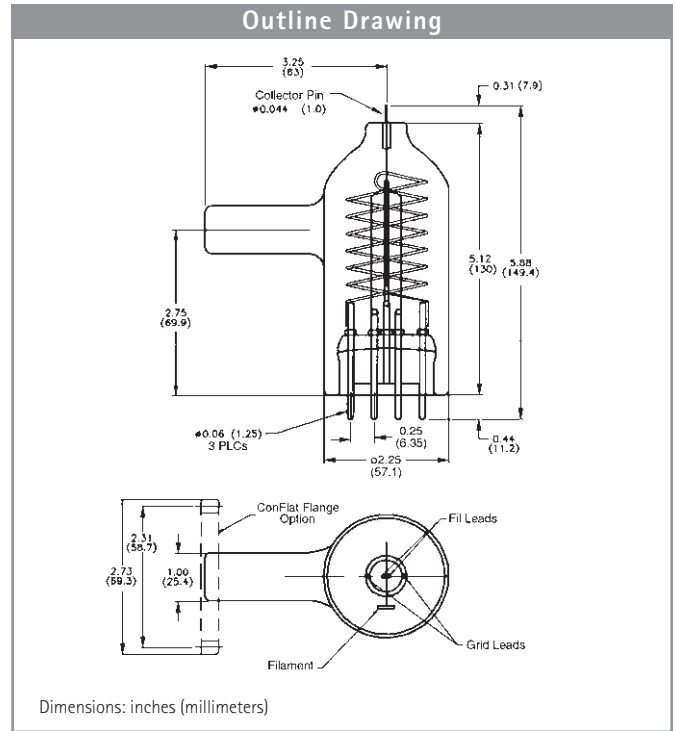
## Ordering Information

Description	Part Number	Fitting	Shipping Weight lbs. (kg)
572 Dual-tungsten-filament ionization gauge tube	K7360301	1 in. Glass tubulation	1.0 (0.5)
	K7360302	1 in. Kovar tubulation	1.0 (0.5)
	K7360303	$\frac{3}{4}$ in. Glass tubulation	1.0 (0.5)
	K7360304	$\frac{3}{4}$ in. Kovar tubulation	1.0 (0.5)
	K7360305	NW25 KF	1.0 (0.5)
	K7360306	NW40 KF	5.0 (0.5)
	K7360307	2.75 in. CFF	6.0 (0.5)

# 571 Series Bayard-Alpert Type Standard Range Ionization Gauge Tube



The 571 offers high performance and wide range ( $2 \times 10^{-10}$  to  $1 \times 10^{-3}$  torr). The gauge is rugged; it can withstand long periods of degassing or accidental exposure to atmosphere at operating temperature and still recover its original characteristics.



## Technical Specifications

### Sensitivity

$6 \text{ (torr)}^{-1} \text{ (mbar)}^{-1}$  (typical)

### Operating Ratings

- 0 VDC to ground (collector)
- 0 VDC (shield)
- + 180 VDC to ground (grid)
- + 30 VDC to ground
- 4.0 VAC nominal (filament)

### X-Ray Limit

$4 \times 10^{-10}$  torr, ( $5.2 \times 10^{-10}$  mbar)

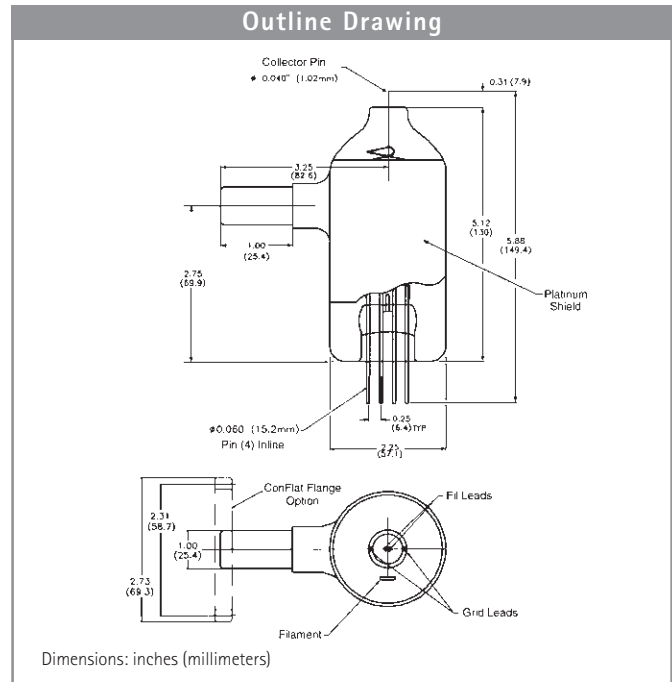
### Operating Pressure

- $4 \times 10^{-10}$  torr to  $5 \times 10^{-2}$  torr  
( $5 \times 10^{-10}$  mbar to  $6.7 \times 10^{-2}$  mbar) (Air)
- $4 \times 10^{-10}$  torr to  $1 \times 10^{-1}$  torr  
( $5 \times 10^{-10}$  mbar to  $1 \times 10^{-1}$  mbar) (Argon)

## Ordering Information

Description	Part Number	Fitting	Shipping Weight lbs. (kg)
571 Ionization tube with thoria-coated iridium filament	K2471301	1 in. Glass tubulation	1.0 (0.5)
	K2471302	1 in. Kovar tubulation	1.0 (0.5)
	K2471304	$\frac{3}{4}$ in. Glass tubulation	1.0 (0.5)
	K2471305	$\frac{3}{4}$ in. Kovar tubulation	1.0 (0.5)
	K2471306	NW25 KF	1.0 (0.5)
	K2471311	NW40 KF	1.0 (1.0)
	K2471303	2.75 in. CFF	2.0 (1.0)
	571 reference ionization tube with thoria-coated iridium filament (sealed off at $\leq 5 \times 10^{-6}$ torr)	K2471307	-

# 563 Series Bayard-Alpert Type Standard Range Ionization Gauge Tube



The 563 is a rugged gauge with wide range of linear response:  $2 \times 10^{-10}$  to  $1 \times 10^{-3}$  torr. The platinum coating inside the bulb shields the gauge elements from electrostatic charges at low pressures and drains off the static charges which can build up at high pressures. The 563 is available in a variety of tubulations.

## Technical Specifications

### Sensitivity

$10 \text{ (torr)}^{-1} \text{ (mbar)}^{-1}$  (Typical)  
Exact measurement available through Varian STARRS program.  
Contact Varian for details

### Operating Ratings

- 0 VDC (collector)
- + 180 VDC to ground (grid)
- + 30 VDC to ground
- 5 VAC nominal (filament)

### X-Ray Limit

$2 \times 10^{-10}$  torr, ( $2.6 \times 10^{-10}$  mbar)

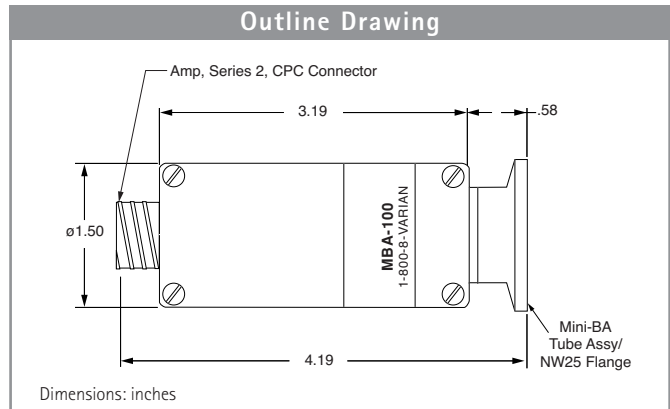
### Operating Pressure

$2 \times 10^{-10}$  torr to  $1 \times 10^{-3}$  torr  
( $2.7 \times 10^{-10}$  mbar to  $1 \times 10^{-3}$  mbar)

## Ordering Information

Description	Part Number	Fitting	Shipping Weight lbs. (kg)
563 Ionization tube with thoria-coated iridium filament	K2466301	1 in. Glass tubulation	1.0 (0.5)
	K2466302	1 in. Kovar tubulation	1.0 (0.5)
	K2466304	3/4 in. Glass tubulation	1.0 (0.5)
	K2466305	3/4 in. Kovar tubulation	1.0 (0.5)
	K2466306	NW25 KF	1.0 (0.5)
	K2466311	NW40 KF	2.0 (1.0)
	K2466303	2.75 CFF	2.0 (1.0)
563 reference ionization tube with thoria-coated iridium filament (sealed-off at $\leq 5.0 \times 10^{-6}$ torr)	K2466307	-	1.0 (0.5)

# MBA-100 Metal Bayard-Alpert Ion Gauge



The MBA-100 is a compact, all-metal high-vacuum gauge for use where measurement precision and repeatability are equally important, for example laboratory vacuum systems, mass spectrometers, electron microscopes and scientific instruments. A heated filament provides a constant source of electrons for gas ionization, creating superior accuracy and stability, and a wide measurement range from  $1 \times 10^{-2}$  to  $1 \times 10^{-9}$  Torr. Varian's unique etched-grid technology provides excellent gauge-to-gauge repeatability, and the small internal surface yields minimal outgassing to ensure accuracy and to protect your experimental process.

The MBA-100 is small and rugged to permit easy installation in a closely packed system. The locking electrical connector

ensures safe, positive contact, while the plastic housing protects people and nearby equipment from heat. A metal housing provides excellent shielding from electromagnetic interference (EMI) for superior gauge stability. The thoria-coated iridium filament resists burn out, even in the event of an accidental exposure to air. A dual filament model is available for the most critical applications; the spare filament will permit continued pressure measurement until the next scheduled maintenance period. The MBA-100 is easily interfaced with Varian's XGS-600 controller for use as a stand-alone pressure measurement tool, or for integration into an experimental or process system.

## Technical Specifications

### Pressure Range

$1 \times 10^{-2}$  to  $1 \times 10^{-9}$  Torr, 1.3 Pa to  $1.3 \times 10^{-7}$  Pa

### Sensitivity

15/Torr

### Measurement Precision

+ 25% within a pressure decade

### + 10 % with STARRS Calibration

### Emission Current

1 milliamp max

### Temperature Limits

Operation: 0 °C to 850 °C; Storage: -15 to 80 °C

### Bake Out Temperature

100 °C maximum with cable disconnected

### Filament Power

~3 watts, varies with pressure

### Degas

E-Beam, 600 VDC @ 10 ma maximum

### Materials

304 SST housing, flange & grid, thoria- iridium filament, tungsten collector

### Connector

Series 2 Circular Plastic Connector, size 11-9 (glass filled nylon)

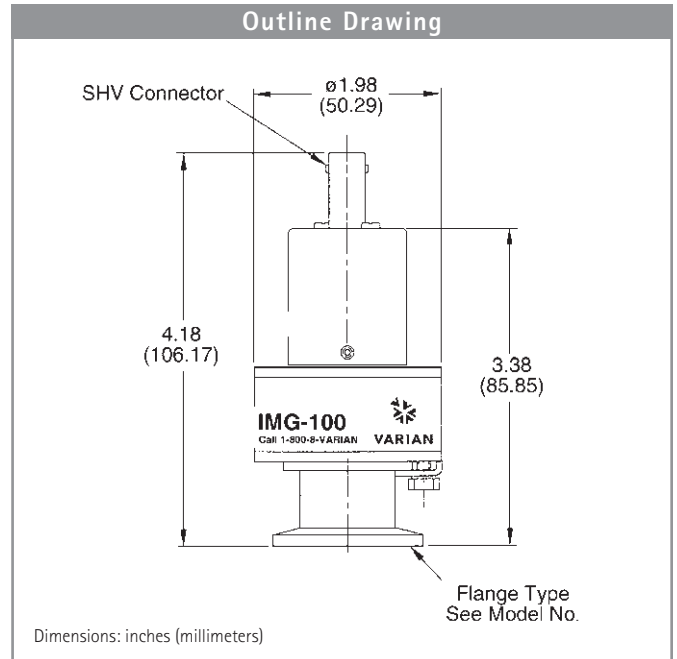
**NOTE** For vacuum pressure applications <  $10^{-8}$  Torr, a Conflat® flange (CFF) is recommended.

## Ordering Information

**NOTE** For information on a gauge controller and cables, please refer to the XGS-600 Controller section.

Description	Part Number	Fitting	Shipping Weight lbs. (kg)
MBA-100 Single Iridium Filament	R1170301	NW25 KF	2.0 (1.0)
MBA-100 Single Iridium Filament	R1170302	NW40 KF	2.0 (1.0)
MBA-100 Single Iridium Filament	R1170303	2.75 CFF	2.0 (1.0)
MBA-100 Dual Iridium Filament	R1170321	NW25 KF	2.0 (1.0)
MBA-100 Dual Iridium Filament	R1170322	NW40 KF	2.0 (1.0)
MBA-100 Dual Iridium Filament	R1170323	2.75 CFF	2.0 (1.0)

# IMG-100 Inverted Magnetron Gauge



The IMG-100 is a rugged and accurate high vacuum gauge featuring a wide measurement range, fast starting time, good accuracy and superior repeatability in challenging environments. The IMG-100 is ideal for use in industrial applications such as metal deposition, glass coaters, vacuum furnaces, degassing ovens, and electron-beam welders.

The simple design requires no heated filament, so the IMG-100 has an excellent lifetime, is easily serviced, and is tolerant of sudden or frequent exposure to atmosphere. Further, there is less risk of heat from the gauge interfering with a critical experiment or process. The compact size allows flexible installation in any orientation, while the locking SHV high-voltage connector ensures safety and positive electrical contact. A precisely designed magnetic field constrains ionized gas molecules for accurate pressure measurement, so emission of stray electrons and photons is minimized.

The IMG-100 is easily interfaced with Varian's XGS-600 gauge controller for integration into a variety of vacuum systems, or for use as a stand-alone pressure measurement tool.

## Technical Specifications

### Measurement Range

1 x 10<sup>-3</sup> Torr to 5 x 10<sup>-9</sup> Torr, 1 x 10<sup>-1</sup> Torr to 7 x 10<sup>-7</sup> Pascal

### Measurement Precision

+ xx % within a pressure decade standard, + xx % with STARRS Calibration

### Temperature Limits

Operating: 0 °C to 80 °C; Storage: -15 to 80 °C

### Bake Out Temperature with Conflat Flange

150 °C maximum with Cable Disconnected

### Ignition Response (Starting time)

T < 5 seconds at pressures < 1 x 10<sup>-6</sup> Torr

### Materials Exposed to Vacuum

300 series stainless steel, nickel, glass (feedthrough)

### Operating voltage

3 kilovolts

### Sensitivity

2.7 A / Torr + 20% at 5 E-06 Torr

## Ordering Information

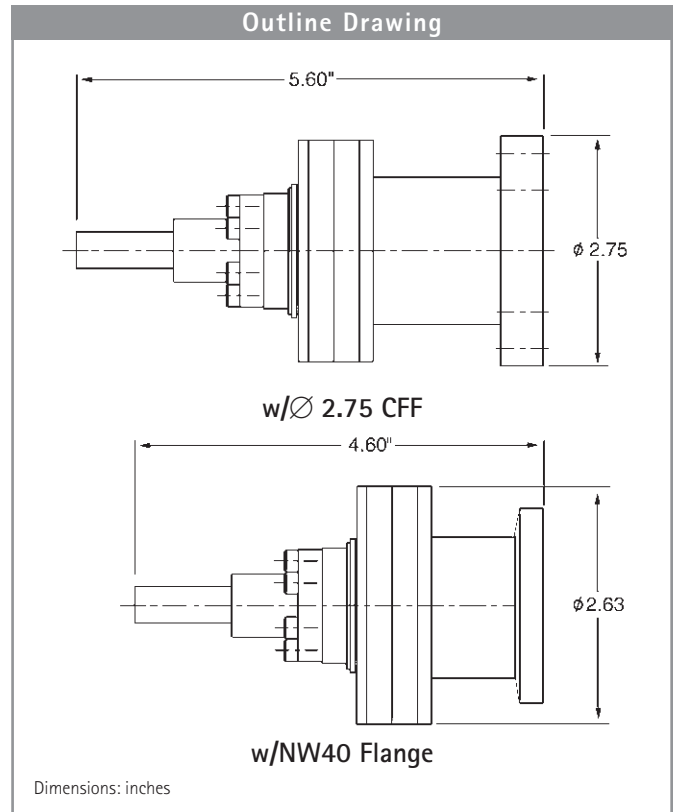
Description	Part Number	Shipping Weight lbs. (kg)
IMG-100 NW25 KF	R0310301	2.0 (1.0)
IMG-100 NW40 KF	R0310302	2.0 (1.0)
IMG-100 2.75 in. CFF	R0310303	2.0 (1.0)
IMG-100 Maintenance Kit	R0339301	1.0 (0.5)

# IMG-300 UHV Inverted Magnetron Gauge



The IMG-300 inverted magnetron gauge combines excellent ultra-high vacuum measurement capability with fast pressure response. This sensor is optimized for UHV applications such as particle accelerators, synchrotron light beam lines and energy research applications, where stable UHV pressure measurement and fast pressure response are equally critical. Inverted magnetron gauges have no x-ray limit, so the ability to read extremely low pressure is limited only by the number of gas molecules present.

The magnetic design provides superior sensitivity at UHV pressures and ensures starting within 30 seconds at  $1 \times 10^{-10}$  Torr (millibar). With no hot filament, there is minimal outgassing from within the gauge that would degrade absolute accuracy of pressure response, and there is no electron or photon emission to disrupt an experimental process. The all-metal gauge design is radiation-resistant and bakeable to 250 °C during operation, while the locking SHV



high-voltage connector ensures safety and positive electrical contact. Radiation-resistant, bakeable cables are also available.

The IMG-300 is easily interfaced with Varian's XGS-600 gauge controller for integration into a variety of vacuum systems, or for use as a stand-alone pressure measurement tool.

## Technical Specifications

### Measurement Range

$1 \times 10^{-3}$  Torr to  $1 \times 10^{-11}$  Torr,  $1 \times 10^{-1}$  Torr to  $1 \times 10^{-9}$  Pascal

### Measurement Precision

+ 50 % within a pressure decade standard, + 20 % with STARRS Calibration

### Temperature Limits

Operating: 0 °C to 250 °C; Storage: -15 to 80 °C

### Bake Out Temperature

250 °C maximum with cable and magnet attached

### Pressure Response Time

< 50 milliseconds @ UHV pressures

### Ignition Response (Starting time)

< 30 seconds @  $1 \times 10^{-10}$  Torr

### Operating voltage

3 kilovolts

### Materials Exposed to Vacuum

Stainless steel, nickel, glass, nickel alloy 52

### Sensitivity

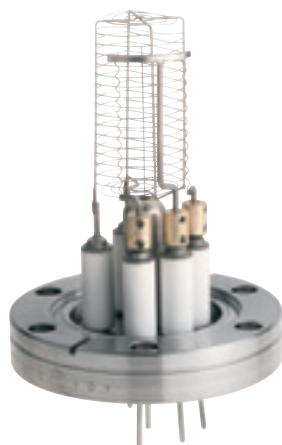
2 A / Torr + 20% at  $5 \times 10^{-6}$  Torr

## Ordering Information

**NOTE** For information on compatible gauge controllers and cabling, please refer to Multi-Gauge sections of catalog.

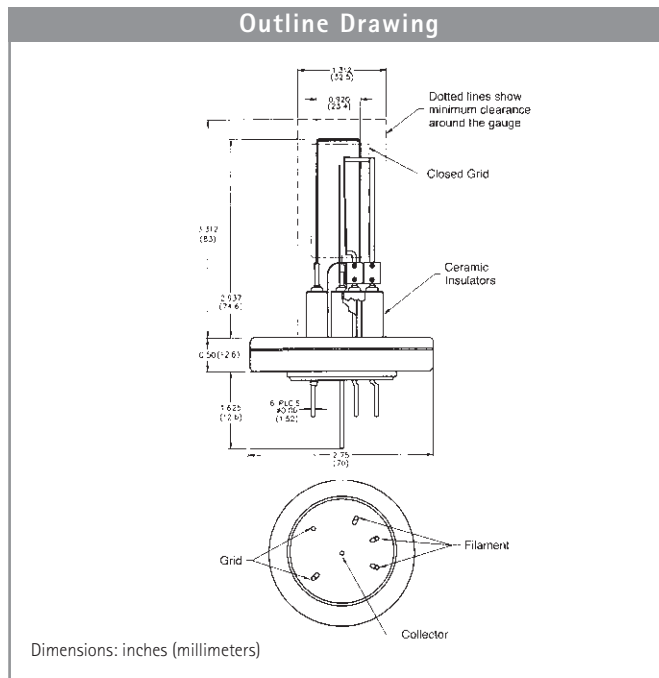
Description	Part Number	Fitting	Shipping Weight lbs. (kg)
IMG-300	R0343301	2.75 inch CFF	2.0 (1.0)
IMG-300 Maintenance Kit	R0040301		

# UHV-24 and UHV-24p Bayard-Alpert Ion Gauge



The UHV-24 is a Bayard-Alpert ion gauge using Varian's etched-grid structure to provide a broad operating pressure range with ionization effectiveness (sensitivity) at least 2 times that of other ionization gauges. The UHV-24 gauges excel in applications where superior measurement accuracy and repeatability of measurement are equally critical. The heated filament provides a constant source of electrons for ionization of gas molecules resulting in accurate and stable results. The precision collector limits X-ray current to a pressure equivalent of approximately  $5 \times 10^{-12}$  Torr ( $6.7 \times 10^{-12}$  mbar).

The UHV-24P, an extended range version of the UHV-24, measures pressure from  $5 \times 10^{-12}$  Torr to  $1 \times 10^{-3}$  Torr



( $6.7 \times 10^{-12}$  mbar to  $1 \times 10^{-3}$  mbar). The UHV-24 and 24P feature a 2-3/4-inch ConFlat flange with long-life thoria-coated iridium or tungsten filaments that are easily replaceable in the field.

The UHV-24 and 24P are easily interfaced with Varian's XGS-600 gauge controller for integration into a variety of vacuum systems, or for use as a stand-alone pressure measurement tool.

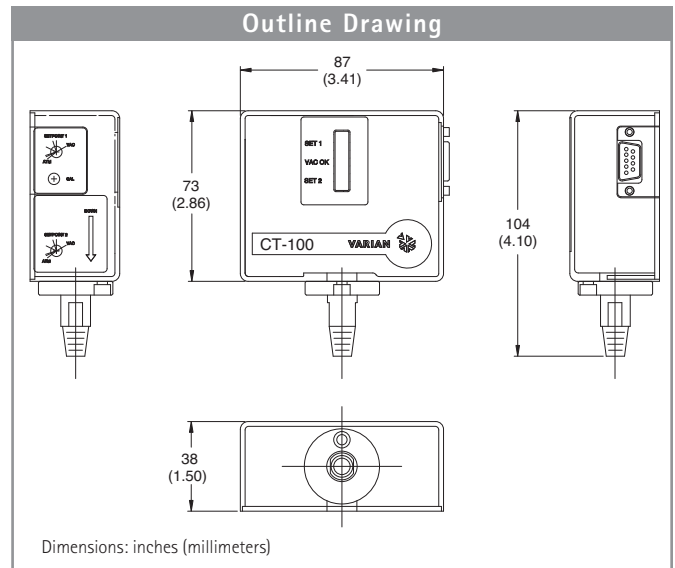
## Technical Specifications

	UHV-24	UHV-24p
Pressure range	$2 \times 10^{-11}$ to $1 \times 10^{-3}$ Torr $2 \times 10^{-11}$ to $1 \times 10^{-3}$ mbar	$5 \times 10^{-12}$ to $1 \times 10^{-3}$ Torr $6.7 \times 10^{-12}$ to $1 \times 10^{-3}$ mbar
Sensitivity	25 Torr-1	20 Torr-1
X-Ray Limit	$2 \times 10^{-11}$ Torr	$5 \times 10^{-12}$ Torr ( $6.7 \times 10^{-12}$ )
Measurement precision	+ 20% of full scale within a pressure decade	
Emission current	4 milliamps default (10 ?A to 9.99 mA)	
Bake temperature	450 °C with cable connected	
Temperature Limits	Operation 0 °C to 250 °C; Storage -15 to 80 °C	
Degas	Electron bombardment 400 volts @ 65 mA	
Materials	304 ST, ceramic, Kovar, iridium or tungsten	

## Ordering Information

Description	Part Number	Fitting	Shipping Weight lbs. (kg)
UHV-24, dual tungsten filaments	9715008	2.75 in. CFF	4.0 (2.0)
UHV-24, dual thoria-iridium filaments	9715007	2.75 in. CFF	4.0 (2.0)
UHV-24P Extended Range, dual tungsten filaments	9715014	2.75 in. CFF	4.0 (2.0)
UHV-24P Extended Range, dual thoria-iridium filaments	9715015	2.75 in. CFF	4.0 (2.0)
Filament replacement kit (thoria-iridium)	9710028		1.0 (0.5)
Filament replacement kit (tungsten filament)	9710018		1.0 (0.5)

# CT-100 Active Rough Vacuum Gauge



The Varian CT-100 active rough vacuum gauge delivers Pirani gauge performance, at lower cost, in a simple, durable design. Rapid Response Pirani-like response time of 0.2 seconds makes the CT-100 ideal for high productivity applications where process steps are critically time-dependent. Rapid response time enables fast-acting valves to protect turbo pumps from sudden inrush of gas.

Two user-defined set points per gauge allow the triggering of multiple process steps, alarms, or other pressure-related conditions. Selectable pressure range offers accurate and repeatable readings precisely where it is most critical to the user.

CT-100 operates over the full rough pressure spectrum ( $1 \times 10^{-4}$  Torr up to 100 Torr;  $1.33 \times 10^{-4}$  to 133 mbar;  $1.33 \times 10^{-2}$  Pa to  $1.33 \times 10^{-4}$  Pa), up to sensitivity to Atmosphere. The long-life sensing element is designed three times thicker than a typical gauge, which minimizes sensitivity to process vibration, shock, and all condensables found in vacuum. The robust sensing element results in longer life and higher repeatability making the CT-100 a more economical choice than traditional Pirani gauges. Single point calibration feature maintains gauge accuracy over time, unlike other gauges where more frequent replacement is required.

Features	Benefits
• Selectable pressure range	• Provides accurate and repeatable readings
• 0.2 second response time	• Improves productivity and performance
• Two setpoints per gauge	• Enables cost and space savings
• Thick sensing element	• Durable and reliable design
• Single point calibration offset	• Maintains gauge accuracy over time
• Status LEDs	• Quick visual indicator of vacuum status

### Technical Specifications

<b>Pressure range N<sub>2</sub>/Air</b>	Factory setting (1.000 V @ $\leq 1 \times 10^{-5}$ Torr): 1 x 10 <sup>-4</sup> to 100 Torr, sensitive to ATM (1.33 x 10 <sup>-4</sup> to 133 mbar, sensitive to ATM) (1.33 x 10 <sup>-2</sup> to 1.33 x 10 <sup>-4</sup> Pa, sensitive to ATM) Optional User Setting (8.255 V @ ATM): 20 mTorr to ATM (2.6 x 10 <sup>-2</sup> to 1000 mbar) (2.6 to 10 <sup>-5</sup> Pa)
<b>Response time</b>	0.2 second
<b>Relay response time</b>	<1 msec
<b>Setpoint adjustment range</b>	Greater than gauge pressure range
<b>Operating temperature</b>	15°C to 50°C, 90% relative humidity non-condensing
<b>Storage temperature</b>	-15°C to 85°C
<b>Mounting orientation</b>	Vacuum port pointing down for best results above 1 Torr (1.33 mbar, 133 Pa)
<b>Weight with NPT Fitting</b>	113 grams (1/4 lb)
<b>Interface</b>	
<b>Two setpoints</b>	Two user defined pressure setpoints for process steps, alarms, high vacuum gauge trigger, or other pressure-induced events
<b>Setpoint</b>	Dual, non-isolated, open collector output
<b>"Contact" Rating</b>	0.3 VDC @ 100mA (on), 30 VDC Max (off)
<b>Adjustment</b>	Trim pot, panel calibration, fixed hysteresis Analog voltage proportional to threshold available at connector (0 VDC - 12 VDC referred to analog output), output impedance 100 kohms

<b>Input voltage/power</b>	13 to 30 VDC @ 0.125 AMP, protected against reversals
<b>Output signal (analog)</b>	Non-linear, 1 to 9 VDC, nominal
<b>Fault</b>	<0.5 VDC or >9 VDC (for N <sub>2</sub> )
<b>Output impedance</b>	100 ohms
<b>Displays</b>	
<b>Setpoint indicators</b>	Red LEDs - Verify an operation is underway and the appropriate vacuum has been achieved
<b>Vacuum indicator</b>	Green LED - Indicates <100 mTorr vacuum is achieved
<b>Materials of construction</b>	
<b>Materials exposed to vacuum</b>	Nickel-plated mild steel, glass, nickel alloy (1/8" NPT) 304 SSt, glass, nickel alloy (NW16)
<b>Casing</b>	Flame retardant ABS (Acrylonitrile-butadiene-styrene)
<b>Sensor element</b>	Platinel
<b>Sensor internal volume</b>	5.4 mL
<b>Connections</b>	
<b>Electrical</b>	9-pin D-Sub
<b>Hardware</b>	1/8" NPT or NW16 KF
<b>Certification</b>	UL Recognized, cUL Recognized
<b>CE</b>	EMC: EU 89/336, EN55011, EN61326 Safety: 73/23/EEC, Low Voltage Directive EN61010

### Ordering Information

Description	Part Number	Shipping Weight lbs. (kg)
<b>CT-100 Active Rough Gauge*</b>		
CT-100, 1/8" NPT	L7426301	2.0 (0.9)
CT-100, NW16 KF	L7426302	2.0 (0.9)
Replacement Tube, CT-100, 1/8" NPT	L7426601	1.0 (0.5)
Replacement Tube, CT-100, NW16 KF	L7426602	1.0 (0.5)
<b>Accessories</b>		
<b>Vacuum Connections</b>		
CT-100 to KF	Stainless Steel	KF16
		KF25
	Aluminum	KF16
		KF25
<b>Interface Cable</b>	See page 29	
<b>Mating Connector</b>		
9-Pin D-sub connector kit with metal backshell	L7440301	
<b>Adapter Kit</b>		
RJ45 Adapter for Edwards ATC/APG	L7439301	
Power Supply/Breakout Box* (provides 24 VDC power and test points for signal access)	R2180302	
<b>Calibration Service</b>		
Factory calibration	CALEYECT-1	

\*Not UL, cUL, CE certified

# FRG-700/702 Full Range Gauge

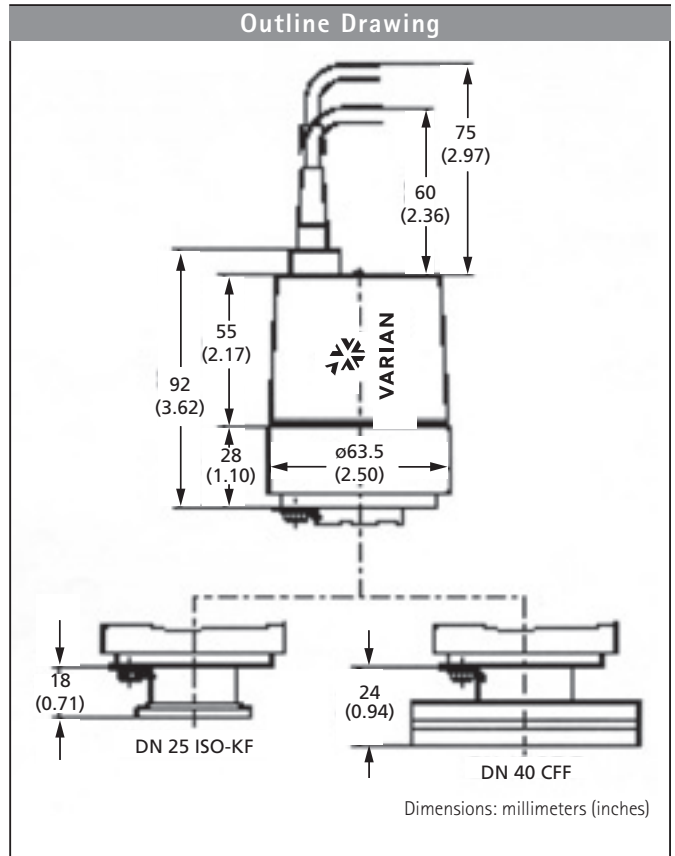


The Varian FRG-700 is a full range gauge that provides two measuring technologies in a single, compact and economical package to measure process and base pressure from  $5 \times 10^{-9}$  mbar to atmosphere ( $3.8 \times 10^{-9}$  Torr to atmosphere). The single, compact unit with one logarithmic analog output signal significantly reduces the complexity of installation, setup and integration. The benefit is reduced cost and reduction in valuable space requirements.

The FRG-702 is the all-metal version of the FRG-700, incorporating a metal sealed feedthrough. It can be operated at higher temperatures (max. 150°C at flange) than the FRG700 (max. 55°C at flange).



**FRG-700 Controller** – Compatible with FRG-700, the FRG-700 Single Channel Gauge Controller has an adjustable set-point and a menu-driven user interface that provides flexible vacuum control.



## Applications

- High vacuum pressure monitoring
- Base pressure for evaporation and sputtering systems
- General vacuum measurement and control in the medium and high vacuum range

## Features

- Combination gauge – inverted magnetron and Pirani, with wide measurement range from  $5 \times 10^{-9}$  mbar to atmosphere
- No filament to burn out; easy to clean
- Excellent ignition properties
- Can be operated by a Varian V-81 or V-301 rack controller and used with the TPS Compact and MiniTask
- LED indicator for high voltage on

## Benefits

- Measures 9 decades using 1 compact gauge, 1 connection, 1 sensor cable and 1 A/D converter; reduces complexity and cost
- Low maintenance and reduced cost
- Rapid start-up
- Greatly reduces cost and space requirements
- Provides quick visual indication of status

Technical Specifications

Measurement range	5 x 10 <sup>-9</sup> to 1000 mbar (3.8 x 10 <sup>-9</sup> to 760 Torr)			
Accuracy	± 30% of reading, typical			
Repeatability	± 5% of reading, typical			
Mounting orientation	Any			
Admissible temperature (ambient)	Operation	Storage	Bake-out * (Pirani)	Filament temperature
	5 to 55 °C	-40 to +65 °C	150 °C	120 °C
Supply voltage	At gauge	Ripple		Power consumption
	15 to 30 VDC	≤ 1 V <sub>pp</sub>		≤ 2 W
Output signal (measurement signal)	Voltage range		Measurement range	
	0 to 10.5 V		1.82 to 8.6 V	
Voltage vs. pressure	0.6 V/decade, logarithmic			
Error signal	<0.5 V (no supply), >9.5 V (Pirani sensor, filament rupture)			
Minimum loaded impedance	10 kΩ, short-circuit proof			
Response time	<10 ms (@ p > 10 <sup>-6</sup> mbar), ≈ 1000 ms (@ p = 10 <sup>-8</sup> mbar)			
Identification gauge	85 kΩ, referenced to supply common			
Status	Pirani-only mode	Combined Pirani/cold cathode mode		LED
	0 V (low)	15 V to 30 (high)		LED green high voltage on
Electrical connection	FCC 68 appliance connector, 8 poles, female			
Sensor cable	8 poles plus shielding			
Maximum cable length	≤ 50 m			
Operating voltage/current	≤ 3.3 kV/≤ 500 A			
Materials exposed to vacuum	SS, Al <sub>2</sub> O <sub>3</sub> , FPM75, Mo, Ni, Au, W			
Internal volume	≈ 20 cm <sup>3</sup>			
Weight	DN 25 ISO-KF ≈ 700g, DN 40 CF ≈ 980g			
Standards	EN 61000-6-2, EN 61000-6-3, EN 61010-1			

\*Without electronics and magnetic shielding.

Ordering Information

Description	Part Number	
		Metal Sealed
FRG Full Range Pirani/IMG Gauge, KF25	FRG700KF25	FRG702KF25
FRG Full Range Pirani/IMG Gauge, KF40		FRG702KF40
FRG Full Range Pirani/IMG Gauge, 2.75" CFF	FRG700CF35	FRG702CF35
FRG Full Range Gauge Maintenance Kit	FRG700MAINT	FRG702MAINT
FRG Full Range Gauge Repair Kit	FRG700REPR	FRG702REPR
FRG Full Range Gauge Controller, 1 Channel	FRG700CNTR1	
FRG Adapter For Controller	FRG700ADPT	
FRG Gauge Cable, 3m (for FRG-700 Controller)	FRG700CBL3	
FRG Gauge Cable, 5m (for FRG-700 Controller)	FRG700CBL5	
FRG Cable to AG Controller, 3m	9699960	
FRG Cable to AG Controller, 5m	9699961	

# Gauge Cables

**NOTE** • All cables are available in 5 foot increments.

Ordering Information			
Description	Length (in feet)	Part Number	Shipping Weight lbs. (kg)
<b>XGS-600</b> I/O, with flying leads	10	R32493010	2.0 (1.0)
	25	R32493025	2.0 (1.0)
	50	R32493050	3.0 (1.5)
Other lengths available – 65, 75, 90, 100 feet		<b>R32493XXX</b>	
Lengths in feet .....			
<b>Thermocouple Cables</b> ( <i>XGS-600 and senTorr only</i> ) For use with one 531 or 536 gauge tubes	10	L91313010	2.0 (1.0)
	25	L91313025	2.0 (1.0)
	50	L91313050	3.0 (1.5)
	75	L91313075	
	100	L91313100	
Other lengths		<b>R91313XXX</b>	
Lengths in feet (maximum 100 ft.) .....			
<b>Convectorr Cables</b> ( <i>XGS-600, Multi-Gauge, senTorr and PanelVac Convectorr</i> ) Standard non-bakeable	10	L91223010	2.0 (1.0)
	25	L91223025	2.0 (1.0)
	50	L91223050	3.0 (1.5)
	100	L91223100	
Other lengths		<b>R91223XXX</b>	
Length in feet (maximum 100 ft.) .....			
<b>Thermocouple Cables</b> ( <i>Multi-Gauge only</i> ) Dual (for use with two gauges) Dual (for use with two gauges) Quad (for use with four gauges) Quad (for use with four gauges)	10	L64752010	2.0 (1.0)
	25	L64752025	2.0 (1.0)
	10	L64754010	2.0 (1.0)
	25	L64754025	2.0 (1.0)
Other lengths		<b>R6475XXXX</b>	
Single (1 gauge) .....			
Dual (2 gauges) .....			
Triple (3 gauges) .....			
Quad (4 gauges) .....			
Length in feet (maximum 100 ft.) .....			
<b>Glass BA Gauge Cables</b> Standard non-bakeable	10	R32443010	2.0 (1.0)
	25	R32443025	2.0 (1.0)
	100	R32443050	2.0 (1.0)
Other lengths – not available over 50 feet – with 10 ft. standard cable, it is possible to order extension up to 250 feet			
<b>MBA-100 Gauge Cables</b>	10	R32483010	2.0 (1.0)
	25	R32483025	2.0 (1.0)
	50	R32483050	3.0 (1.5)
Other lengths – length in feet		<b>R3243XXX</b>	
Lengths in feet .....			

**Ordering Information**

Description	Length (in feet)	Part Number	Shipping Weight lbs. (kg)
<b>UHV-24/UHV-24p Standard</b> Standard non-bakeable	10	R32453010	2.0 (1.0)
	25	R32453025	2.0 (1.0)
	50	R32453050	3.0 (1.5)

Other lengths – not available over 50 feet – with 10 ft. standard cable, it is possible to order extension up to 250 ft.

<b>UHV-24/UHV-24p Teflon UHV</b> bakeable to 250°C	10	R32463010	2.0 (1.0)
	25	R32463025	2.0 (1.0)
	50	R32463050	3.0 (1.5)

Other lengths – not available over 50 feet – with 10 ft. standard cable, it is possible to order extension up to 250 ft.

<b>Ion Gauge Extension Cables (XGS-600)</b>	65	R3247065	
	90	R3247090	

Other lengths

**R3247XXX**

Other lengths – length in feet (maximum 350 feet) .....

<b>IMG-100 Cables (XGS-600)</b> Standard non-bakeable may be used with IMG-300	10	R03113010	2.0 (1.0)
	25	R03113025	2.0 (1.0)
	50	R03113080	3.0 (1.5)
	75	R03113075	
	100	R03113100	

<b>IMG-300 Cables</b> Inverted Magnetron Gauge (UHV) Bakeable to 250 °C	10	R03413010	2.0 (1.0)
	25	R03413025	2.0 (1.0)
	65	R03413065	
	100	R03413100	

Other lengths

**R03413XXX**

Other lengths – length in feet (maximum 350 feet) .....

<b>CT-100 Interface Cable</b>			2.0 (1.0)
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9-Pin D-sub to flying leads, shielded

**R0907XXX**

Length in feet up to 100 .....

<b>FRG-700 Cables</b>	Gauge to FRG Controller	3M	FRG700CBL3
	Gauge to FRG Controller	5M	FRG700CBL5
	Gauge to AG Turbo Controller	3M	9699960
		5M	9699961

## STARRS Calibration and Service Program

Varian introduces the STARRS Calibration and Service Program. STARRS is a total calibration, service and warranty program to ensure the optimum performance of your Varian vacuum measurement equipment. Vacuum gauges are often overlooked in many systems, however, their accurate and reliable operation is critical to any process. Proper calibration on Varian's state-of-the-art equipment will ensure that your gauges are accurate and repeatable. Our extended warranty and advanced exchange programs will eliminate downtime due to equipment problems. All of our calibration service is NIST-traceable and fully documented to meet exacting ISO standards.

The STARRS program encompasses a large number of options for calibration. We will calibrate new gauging on order from Varian or your existing Varian equipment. You may choose to have the gauges calibrated with the controllers or separately. In addition, you may choose a simple, inexpensive calibration or a more in-depth service.

In many cases, a multi-million dollar process depends on a vacuum gauge and controller. For this reason, Varian offers an advanced exchange program. This ensures that replacement equipment will be available to you right away should the need arise. Our extended warranty program offers peace of mind for all of your vacuum gauge instrumentation.

The XGS line of gauge controllers has an advanced exchange program available. Due to the multiple configurations available, we encourage you to call Varian to obtain the correct exchange part number for your product'



## Sensitivity

Sensitivity is the most important parameter for an ion gauge. Also referred to as gauge factor, sensitivity is a measure of the ionization efficiency of a gauge. In order to understand the accuracy of an ion gauge, the sensitivity must be known. For a Bayard-Alpert gauge, the sensitivity may be calculated as follows:

$$S = \left( \frac{I^+}{I^-} \right) \left( \frac{1}{P} \right)$$

Where:

- S = Sensitivity
- I+ = Ion Current in Amperes (from collector)
- I- = Emission Current in Amperes (from filament)
- P = Pressure in torr

Using the above equation, sensitivity is expressed in "per torr" units. Simply put, the higher the sensitivity, the better the resolution of the ion gauge. In order to accurately translate the ion current signal from a gauge into a pressure value, the sensitivity must be known. Typically, sensitivity values for gauges shown in manuals or marketing literature are average or "typical" values. In particular, older controllers used to operate these ion gauges are designed for this typical value. The actual sensitivity for a particular gauge tube may be significantly different from the published value, which will mean that your achieved accuracy will be much worse than expected. However, if the sensitivity of a gauge is known, then control electronics or the output signal may be adjusted accordingly.

## Traceability

The status quo for most manufacturing operations is ISO 9000 compliance, meaning all procedures and products must be completely and accurately documented. Therefore, vacuum gauge calibrations must be properly documented in order to satisfy this requirement. It is important to use equipment which has been checked and adjusted against a standard reference. Varian can supply ion gauges, Capacitance Diaphragm Gauges, and thermal rough vacuum gauges calibrated against NIST standards. In addition, Varian maintains calibration records both electronically and on paper.

## Accuracy

Accuracy is an issue often misunderstood in the vacuum environment. Accuracy is defined as measurement compared to a reference standard. Depending on the type of vacuum gauge, this value is quantified as a percentage of reading or full scale. For many vacuum applications such as high-energy physics research, accuracy must be known in order to ensure publishable results. By providing gauges calibrated against NIST-traceable standards, accuracy is quantified providing consistent data to the vacuum user.

## Repeatability

In the production environment, repeatability is often more important than accuracy. In this context, repeatability is the ability of a vacuum measurement system to obtain the same reading after several process cycles. Excellent repeatability means consistent, high-quality end product from your process. Poor repeatability means downtime and extra cost.

## Reliability

All applications demand a reliable vacuum measurement equipment. In many cases, a multi-million dollar process is dependent on a several hundred dollar vacuum gauge. Unnecessary downtime leads to unnecessary costs.

All Varian vacuum gauge controllers and electronics have at least a one-year guarantee – and we will exchange or replace the component at your request. In order to provide extra peace of mind, Varian will also arrange an advanced exchange program with your facility. Your local Varian Vacuum Technologies sales engineer can provide details on this program.

## Statistical Process Control

Varian Vacuum Technologies is constantly seeking to maintain our quality and improve performance. For our broad line of vacuum gauging products, we have implemented a rigorous statistical process control (SPC) program to ensure consistent, reliable gauges. We track key performance characteristics and manufacturing parameters to maintain a high quality product.

## Calibration Services Available

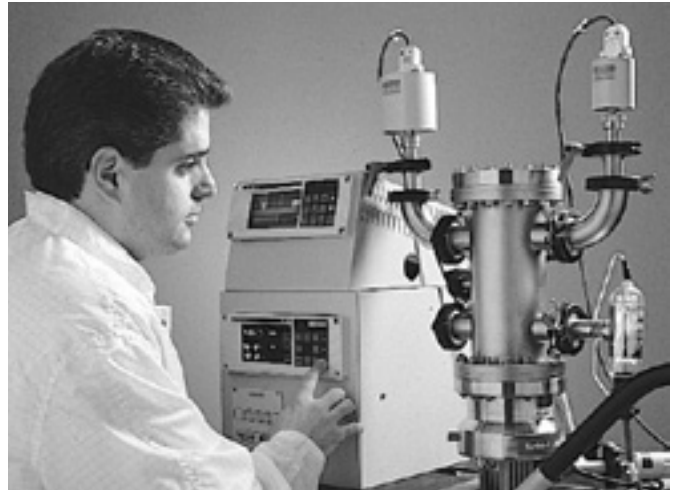
### NIST-Traceable Gauge Only Calibration Rough Gauges (1mTorr to Atmosphere)

The Unit-Under-Test (UUT) Gauge will be operated with a NIST-calibrated Varian controller and referenced against a suitable NIST-calibrated transfer-standard capacitance manometer. The customer will be given a four-point calibration sheet indicating the performance of the gauge relative to the standard, type number and serial number for transfer standard, and conditions at the time of test. Varian CeramiCel Capacitance Diaphragm Gauges will be internally adjusted for optimum calibration. A "four-point" calibration provides UUT readings referenced against an NIST-standard at 25%, 50%, 75%, and 100% of full scale.

A "ten-point" calibration means reference data at 10%, 20%,... 100% of full scale.

### NIST-Traceable System Calibration Includes Controller, Cables(s), Gauge(s)

All calibrations include documentation indicating equipment performance, environmental conditions, and NIST reference information.



### NIST-Traceable Gauge Only Calibration High Vacuum and Ultra-High Vacuum Gauges

Gauge will be operated with a NIST-calibrated Varian Controller. Two types of calibration will be available: standard, using a NIST-calibrated tube to determine a mid-range gauge factor ( $10^{-6}$ ), and premium, which includes an SRG calibration down to the  $10^{-6}$  torr range and a NIST-tube calibration below this pressure. Premium service will include three gauge factor measurements –  $10^{-4}$  torr,  $10^{-5}$  T and  $10^{-6}$  torr. Cost is per filament for hot-cathode gauges.

All calibrations include documentation indicating equipment performance, environmental conditions, and NIST reference information.

Ordering Information

Description	Part Number*
Unheated capacitance diaphragm gauge, 4 points	CALCDG-1
Unheated capacitance diaphragm gauge, 10 points	CALCDG-2
Heated capacitance diaphragm gauge, 4 points	CALCDG-3
Heated capacitance diaphragm gauge, 10 points	CALCDG-4
Standard cold cathode gauge	SCCG-1
Standard Inverted magnetron gauge	SIMG-1
Standard Bayard-Alpert gauge	SBAG-1
Standard UHV nude gauge	SUHV-1
Premium cold cathode gauge	PCCG-1
Premium inverted magnetron gauge	PIMG-1
Premium Bayard-Alpert gauge	PBAG-1
Premium UHV nude gauge	PUHV-1

Description	Part Number*	Service Performed
<b>Multi-Gauge Controller System Calibration</b>	CALMG-1	Calibration of electronics using NIST-traceable equipment
For each thermocouple or ConvecTorr	CALCNTC-1	Calibration of gauges using electronics and cables provided. Includes sensitivity adjustment on Multi-Gauge to match ion gauge performance

*Refer to ordering information above for Capacitance Diaphragm Gauge calibration part numbers.  
Refer to ordering information above for Ion Gauge calibration part numbers.*

<b>senTorr Controller System Calibration</b>	CALST-1	Calibration of electronics using NIST-traceable equipment
For each thermocouple or ConvecTorr	CALCNTC-1	Calibration of gauges using electronics and cables provided Includes sensitivity adjustment on senTorr to match ion gauge performance

*Refer to ordering information above for Ion Gauge calibration part numbers.*

<b>CT-100 and Eyesys ConvecTorr Electronics and Gauge Calibration</b>	CALEYECT-1	Calibration of transducer using NIST-traceable capacitance diaphragm gauge
<b>Eyesys Mini-BA Electronics and Gauge Calibration (Standard Calibration)</b>	CALYBAS-1	Calibration of transducer using NIST-traceable ion gauge. Includes sensitivity adjustment for optimum performance.
(Premium Calibration)	CALYBAP-1	Includes spinning rotor gauge reference
<b>860 Cold Cathode Controller and Gauge Calibration</b>	CAL860-1	Calibration of cold cathode gauge and controller using NIST-traceable ion gauge Documentation indicating results of testing and NIST reference data
<b>ConvecTorr Analog Controller and Gauge Calibration</b>	CALCVT-1	Calibration of ConvecTorr gauge and controller using NIST-traceable capacitance diaphragm gauge

- \* **Note regarding part numbers**
- Part numbers listed above have been created specifically for new gauges purchased for calibration through this program.
  - When returning gauges for calibration to Varian, add a "SER" prefix. Example: SER-CALCDG-1.

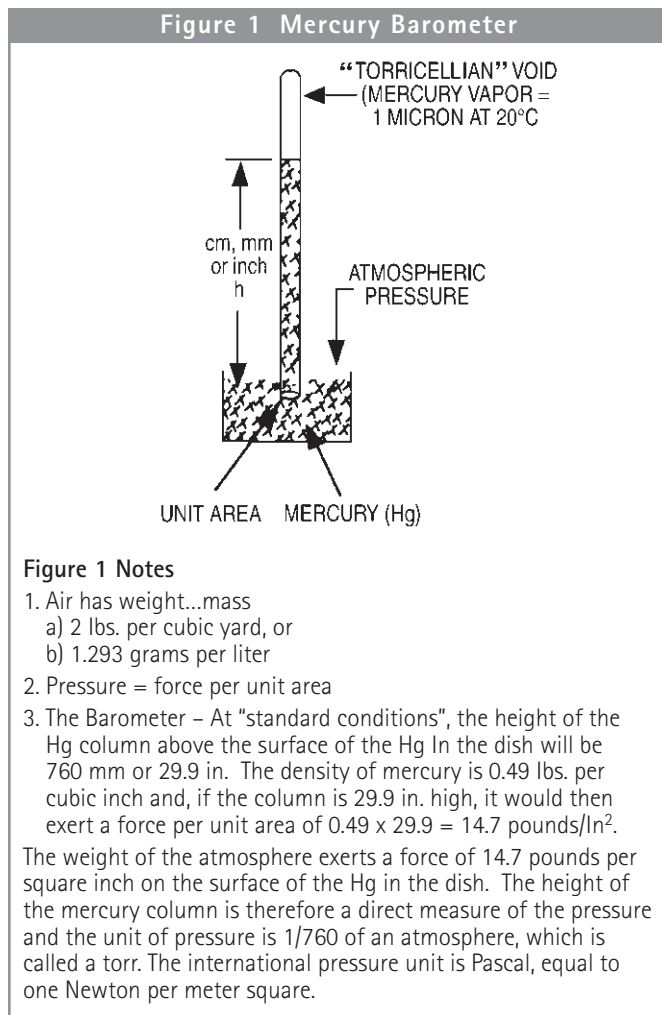
# Vacuum Gauge Technical Notes

## Historical Notes

Early interest in pressure measurement was stimulated in the 17th century by engineers who were concerned about the inability of suction pumps to remove water from mines. The pumps were limited to about 30 feet. For example, the Duke of Tuscany (Italy) commissioned Galileo to investigate the problem.

Galileo, among others, devised a number of experiments to investigate the properties of air. Among these experiments were pistons for measuring the "force of vacuum" and a water barometer that stood about 34 feet tall.

After Galileo's death in 1642, the work was carried on by his associate, Evangelista Torricelli. Torricelli invented the mercury barometer (Figure 1) and he concluded that atmospheric air forced water up to a height of 33.6 feet.

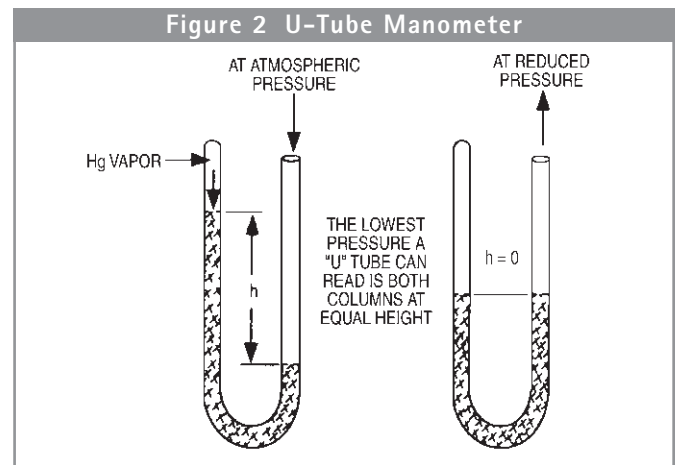


In 1644, the French mathematician, Blaise Pascal, sent a group of mountaineers up into the Alps with a barometer and proved that air pressure decreased with altitude. The average height of the mercury column at sea level is 760mm, and this is defined as a standard atmosphere.

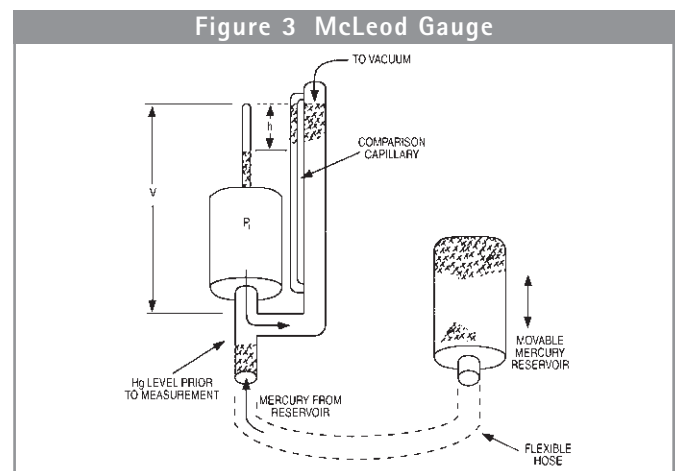
This also is  $1.01 \times 10^5$  Pascals or  $1.01 \times 10^5$  dynes cm<sup>2</sup>. The 1/760 of this value is called a Torr in honor of Torricelli.

An extension of the mercury barometer was the mercury U-tube manometer (Figure 2). Varying atmospheric pressures causes the mercury level to rise and fall in the "Torricellian Void." Likewise, if the pressure at the other end of the tube is artificially reduced by a vacuum pump, the mercury in the tube falls drastically.

With both the barometer and the manometer, it is the difference in heights of the mercury levels that indicates the pressure, that is, the force (weight of Hg) per unit area that the air pressure will support. As the pressure on the system side is reduced, the height of the columns on either side of the U-tube approaches the same, and any difference becomes very difficult to measure (Figure 2).



Many schemes were tried to magnify the very small differences that occurred at very low pressures, but the only one that really extended the range of the manometer was invented by H. McLeod in 1872. This gauge is an application of Boyle's Law and is still in use today as a standard for calibrating secondary gauges (Figure 3).



**Application of Boyle's Law**

$$\begin{aligned}
 P_2 & & V_2 \\
 (P_1 + h) bh &= & P_1 V_1 \\
 P_1 bh + bh^2 &= & P_1 V_1 \\
 bh^2 &= & P_1 V_1 - P_1 bh \\
 bh^2 &= & P_1 (V_1 - bh) \\
 P_1 &= & \frac{bh^2}{V_1 - bh} \\
 & & V_1 bh
 \end{aligned}$$

$V_1$  = Total volume, capillary plus bulb ( $\text{cm}^3$ )

$P_1$  = Pressure in system

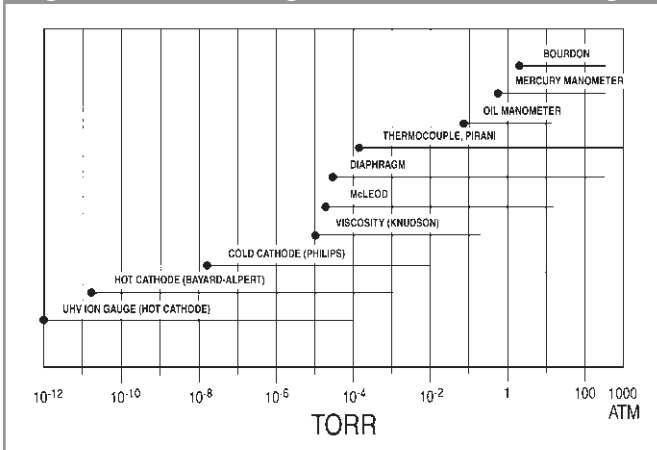
$b$  = Volume of capillary (in cubic cm)  
 $\text{mm}$  length

$h$  = Difference in height of mercury columns

$V_2 = bh$  ( $\text{cm}^3$ ) volume in capillary

$P_2$  = Pressure in capillary =  $P_1 + h$

**Figure 4 Pressure Ranges of Various Vacuum Gauges**



**Applications**

The vacuum gauges in use today mainly fall into three categories: mechanical, manometric, and electronic. Which gauge is used in a particular application generally depends on the pressure range it is intended to measure. Figure 4 shows useful pressure ranges of some typical gauges.

High pressures, such as those found in the rough pumping of a vacuum system, are generally measured with a thermocouple gauge. This instrument measures heat transfer rate from a heated wire. As gas is removed from the system, less heat is removed. The changes in temperature are measured by a thermocouple junction and its output is displayed as changes in pressure. The most useful pressure range for this gauge is from 5 torr to 5 microns.

At lower pressures – from  $1 \times 10^{-2}$  torr to  $1 \times 10^{-7}$  torr – found in many industrial applications, the cold cathode gauge is very useful. This instrument is basically a gaseous electric discharge cell which operates on the same principle as a diode-type ion pump. It is a rugged gauge that does not use a hot filament.

The most commonly used measurement device for high vacuum is the hot filament ionization gauge. This type of gauge can be designed to measure pressures as high as  $5 \times 10^{-1}$  torr, and as low as  $5 \times 10^{-12}$  torr. Since it is found in many industrial and scientific applications, it will be treated here in more detail.

**Basic Performance Factors of Ionization Gauges**

- 1. Reproducibility.** A gauge must be able to give reproducible readings for identical physical situations. Drift due to electric or geometric instabilities can have adverse effects on the measurement process.
- 2. Accuracy.** Gauges can be calibrated but, in general, their accuracy is limited to about  $\pm 20\%$ .
- 3. Sensitivity.** In the ion gauge, the positive ions that impact the collector (and pick up electrons from ground) account for the positive ion current ( $I^+$ ).

The electrons emitted from the filament ( $I^-$ ) produce the required ionization. The fundamental relationship is:

$$I^+ = (I^-)^{PK} \quad (1)$$

**Where:** (P) is the number of molecules present (Pressure)

**And:** (K) is the gauge constant which depends on the geometry of the device and the electrical parameters employed (K) is also referred to as the sensitivity (S), and:

$$S = \frac{I^+}{P \cdot I^-}$$

**Where:** Both ( $I^+$ ) and ( $I^-$ ) are measured in amperes and (P) is in torr.

Hence: 
$$S = \frac{(I^+) \text{ Amps}}{(I^-) \text{ Amps Torr}} = (\text{a number}) \text{ torr}$$

For instance, the sensitivity of the Varian UHV-24 nude gauge is 25 per torr.

# Technical Notes

## Operation of Ionization Gauges

**Table 1 Conversion Table**

	Pascal (N/m <sup>2</sup> ) (Pa)	Torr	Standard Atmosphere (atm)	Millibar (mbar)	Dyne per Square Centimeter (dyne/cm <sup>2</sup> )
1 Newton per square meter (N/m <sup>2</sup> ) = Pascal	= 1	7.5 x 10 <sup>-3</sup>	9.87 x 10 <sup>-6</sup>	10 <sup>-2</sup>	10
1 Torr = 1mm Hg	= 133	1	1.32 x 10 <sup>-3</sup>	1.33	1,330
1 standard atmosphere (atm)	= 101,000	760	1	1,010	1,010,000
1 millibar (mbar)	= 100	0.75	9.87 x 10 <sup>-6</sup>	1	1,000
1 dyne/square centimeter (dyne/cm <sup>2</sup> )	= 10 <sup>-1</sup>	7.5 x 10 <sup>-4</sup>	9.87 x 10 <sup>-7</sup>	x 10 <sup>-3</sup>	1

When an ionization gauge is used to measure pressure, two physically observable parameters are of interest; namely, emission current and ion current. These two currents must be observed simultaneously, and the pressure can be calculated by the following rule:

$$P = \frac{(I^+) 1}{(I^-) S}$$

I<sup>+</sup> = Observed ion current

I<sup>-</sup> = Observed emission current

S = Gauge sensitivity (constant for any particular gauge)

Although the McLeod gauge uses mercury in a way different from the manometer, it still expresses pressure in terms of the height of a mercury column. At the pressures attained by modern vacuum systems, gauges that depend on the mechanical effects of pressure are ineffective. So, other means had to be found that could take advantage of other properties of atoms and molecules, such as heat conductivity or the ability to be ionized.

There are many ways to express pressure and some of the more common units are listed in Table 1.

The gauge sensitivity, S, is a function of the design and construction of the gauge. For the Varian 563 Bayard-Alpert gauge, S has a nominal value of 10 torr. For the Varian 507 Triode gauge, S has a nominal value of 17 torr.

One could use an instrument that measured both the I<sup>+</sup> and I<sup>-</sup> currents with a high degree of accuracy. However, the absolute values of I<sup>+</sup> and I<sup>-</sup> are unimportant in determining P; only their ratio must be measured. Therefore, entirely equivalent results can be obtained with an instrument which measures I<sup>+</sup> as a fraction of I<sup>-</sup> (a ratiometric instrument).

**Table 2 Pressure and Flow Unit**

### Pressures

Standard atm	= 1.01325 x 10 <sup>6</sup> Dynes cm <sup>-2</sup> = 760 mm Hg (at 0 °C) = 29.9213 in. of Hg (at 32° F)
Bar	= 1 x 10 <sup>6</sup> Dynes cm <sup>-2</sup> 75.0062 cm Hg (at 0 °C) 0.986 atm
Torr	= 1333 Dynes cm <sup>-2</sup> = 1 mm Hg (at 0 °C) = (760) <sup>-1</sup> Standard atm
Micron	= (length) 1000 Angstroms (1A = 10 <sup>-10</sup> meter) = (pressure) 1.33 Dyne cm <sup>-2</sup> = (pressure) 1 x 10 <sup>-3</sup> torr
Barye	= 1 Dyne cm <sup>-2</sup> = 9.869 x 10 <sup>-7</sup> atm = 1 x 10 <sup>-6</sup> Bar
Dyne	= Force necessary to give a one-gram mass an acceleration of one cm/sec/sec

### Flows

Cubic Foot	= 28.3 liters = 2.83 x 10 <sup>4</sup> cm <sup>3</sup>
CFM	= 28.3 liters min <sup>-1</sup> = 0.47 liter sec <sup>-1</sup>
Liter sec <sup>-1</sup>	= 2.12 cfm = 3.53 x 10 <sup>-2</sup> cubic feet sec <sup>-1</sup>

It is convenient to maintain a constant emission current at a preselected value rather than to observe it for each measurement of pressure. Thus, in some gauge controls, the emission current is regulated at a nominal value of 9 ma (Bayard-Alpert) or 6 ma (triode). This value of emission leads to ion currents equal to 0.1 amp/torr. During the calibration procedure, emission current is sensed by the electrometer amplifier and displayed on the panel meter. When the ion current is measured, the same amplifier and meter are used. Hence, the meter deflection observed during ion current measurement is automatically interpreted as a fraction of emission current, providing a true ratiometric measurement, even though the absolute value of emission current may be 20% different from nominal.

In conventional gauge controls, emission current is measured by the panel meter with suitable precision resistor shunts. The ion current is then amplified by an electrometer and displayed on the meter. Overall accuracy of this kind of system depends on the individual accuracies of the shunt resistors, the meter movement, and the electrometer gain. Since these items all function independently, the errors can add up.

However, in the Varian ionization gauge controls, the electrometer and meter are always used together, whether measuring emission or ion currents. Thus, some of the errors are cancelled in the calibration process. As a result, the accuracy of the Varian controls is not critically dependent on the tolerances of a large number of components, and long-term accuracy and repeatability are assured.

Some additional conversion factors for pressure and flow units are shown in Table 2.