



STABIL-ION® Gauge



Glass B-A Gauge



Nude B-A Gauge



UHV Nude B-A Gauge

*Introduction to Bayard-Alpert Style Ionization Gauges: This bulletin discusses the different types of B-A gauges, basics of operation, components of a B-A gauge, and degassing techniques.*

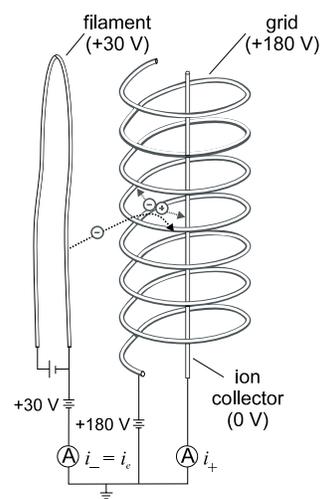
### Introduction to Bayard-Alpert Style Ionization Gauges

A Bayard-Alpert vacuum gauge ionizes the gas molecules within the gauge volume, collects those ions on a thin ion collector wire, and measures the resulting current to the ion collector to determine the number of molecules present and indicates a pressure based on that measurement.

The Bayard-Alpert gauge was invented by R.T. Bayard & D. Alpert in 1950 to overcome a limitation in vacuum pressure measurement by the triode gauge. The triode gauge cannot indicate pressure lower than  $10^{-8}$  Torr because electrons striking the grid create low-energy x rays, which emit photoelectrons when they strike the ion collector. The current that results from the photoelectrons leaving the collector is what causes the lower pressure limit of the triode gauge. The solution proposed by Bayard and Alpert was to reconfigure the collector and grid of the triode gauge to lower the current from the x ray effect.

### Operating Principles of Bayard-Alpert Ionization Gauges

A Bayard-Alpert (B-A) gauge is a hot-filament style ionization gauge. It is called such because a heated filament (cathode) is used to emit electrons toward a grid (anode).



Electrons are created by a hot filament and accelerated to the grid. The current is actively controlled by the electronics.

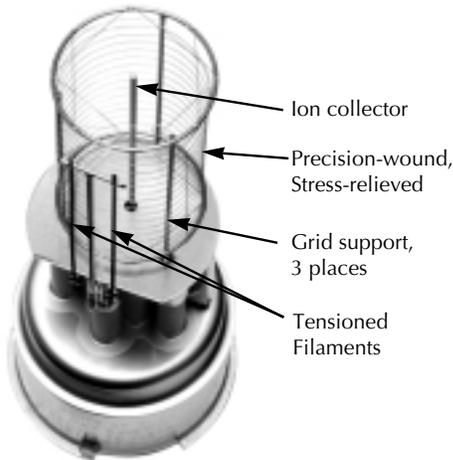
The pressure indication of a B-A vacuum gauge is based on the ionization of the gas molecules by a constant flow of electrons. The negative electrons are emitted at a well-controlled, selectable rate from a heated filament (cathode) and are accelerated toward a positively-charged wire grid (anode). Electrons pass into the space enclosed

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## Introduction to Bayard-Alpert Ionization Gauges

by the grid. In this space the electrons collide with the gas molecules that are in the vacuum system, and produce positive ions. The positive ions are then collected by the ion collector that is located along the axis of the cylindrical grid. The ion collector is at nearly ground potential, which is negative with respect to the grid. At a constant filament-to-grid voltage and electron emission current, the rate that positive ions are formed is directly proportional to the density of molecules (pressure) in the gauge for pressures below approximately  $1 \times 10^{-3}$  Torr. The strength of the ion current is then indicated on an electrometer that is calibrated in units of pressure.

Because the pressure indication is linear, the hot cathode B-A gauge is generally considered to be the most accurate continuous indicator for pressures below  $1 \times 10^{-3}$  Torr.



**STABIL-ION®** Gauge from Granville-Phillips  
(Shown with the stainless steel enclosure removed for clarity.)

With the recent development of the *STABIL-ION* Gauge, Granville-Phillips brought the accuracy of B-A technology to the 3% to 6% range. Although prior B-A style vacuum gauges were usually inaccurate as much as 20% to 50%, they were still the best, commonly available vacuum gauge in the  $1 \times 10^{-3}$  to  $2 \times 10^{-11}$  Torr range.

### *X Ray Limit of Bayard-Alpert Gauges*

The low end of the operating range of a B-A gauge is determined by the x ray limit of this type of gauge. The x ray limit varies with different gauge designs. x rays are produced when the electrons emitted by the cathode impact the grid (anode). Because of the geometry of the B-A gauge, only a small fraction of the x rays emitted from the grid are intercepted by the ion collector. When the x rays strike the collector they cause electrons to be photoelectrically ejected from the collector. This photoelectron current *from* the ion collector is detected the same as positive ions *arriving* at the ion collector and consequently adds to the ion current. This x ray current limits the pressures that can be measured, and is equivalent to a pressure reading in the  $10^{-10}$  to  $10^{-11}$  Torr ranges. Earlier design triode gauges which have a cylindrical collector outside the grid experience an x ray limit of about  $10^{-8}$  Torr. The x ray limit refers to the lowest pressure indication that may be obtained in a gauge when all the output current is due to x ray induced photoemission and there is an absence of gas.

The x ray limit of standard glass or nude B-A gauges is approximately  $3 \times 10^{-10}$  Torr. To measure below this limit, an ultrahigh vacuum (UHV) nude B-A gauge can be used. The UHV nude gauge has an x ray limit of approximately  $2 \times 10^{-11}$  Torr. This lower x ray limit is achieved by modifying two elements of the standard B-A gauge design. First, the diameter of the collector is reduced. The smaller cross-sectional area reduces the probability that the x rays created at the grid will strike the collector. Second, the helical grid structure is replaced with a fine-wire mesh grid structure, and there is also a fine-wire structure across both ends of the grid. The fine grid wires provide a more transparent grid for longer electron path lengths, and the grid ends confine the positive ions for better ion collection. Together, these two modifications cause a higher gauge sensitivity for ions from the gas phase which causes the x ray current to

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be converted into a smaller pressure indication (i.e., a lower x ray limit).

The x ray limit may be increased as the result of hydrocarbon contamination of the electrodes, since contaminated surfaces can release more electrons under x ray bombardment. Such contamination can generally be removed by degassing the electrodes.

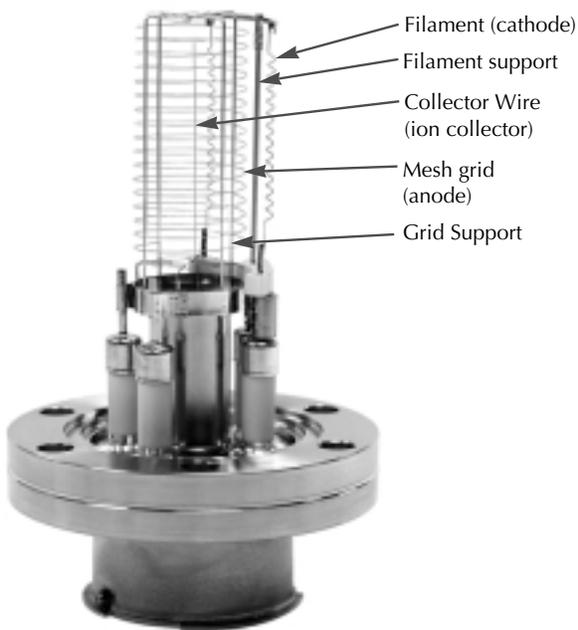
### *Filaments (Cathodes) used in Bayard-Alpert Gauges*

There are two types of materials commonly used for filaments: tungsten and iridium. And, there are two types of coatings used on the filaments: thorium and yttria.

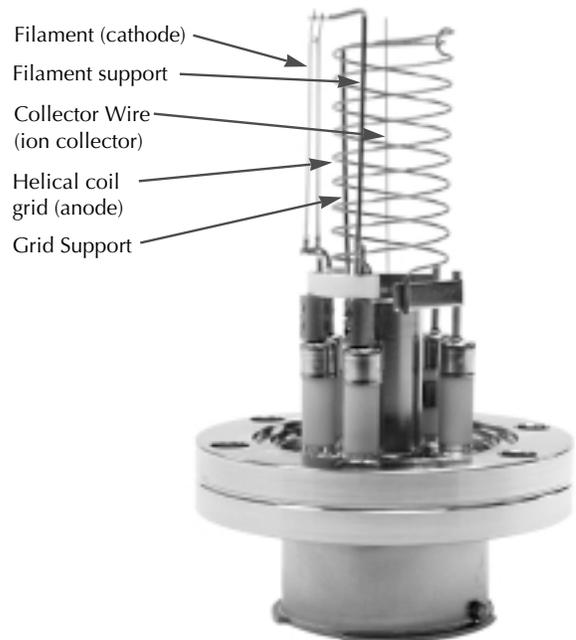
Generally, filaments are yttria-coated iridium, thorium-coated iridium, or uncoated tungsten. The most common style is coated iridium because they operate at a lower temperature than

tungsten, therefore less reactive. Coated iridium filaments are also more burnout resistant when exposed to atmospheric pressure while power is on. Tungsten filaments will burn out immediately if exposed to pressures of  $1 \times 10^{-2}$  Torr or higher while they're on. However, tungsten filaments are the best type to use when the chemistry (such as halogen compounds) of the vacuum process causes premature failure of coated iridium filaments.

The amount of emission current that a B-A gauge requires for proper operation depends on many factors such as: the type of filament, the size or style of the gauge, the process in which the gauge is used, the pressure range of operation, and the desired sensitivity of the indicated pressure. Emission currents are typically in the range of 25  $\mu$ A to 10 mA.



UHV Nude Bayard-Alpert Gauge  
with dual tungsten filaments



Nude Bayard-Alpert Gauge  
with thorium-coated iridium filament

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## Degassing Bayard-Alpert Gauges

Because of the heated filaments, B-A gauges operate at higher temperatures than other styles of vacuum gauges. Thus, volatile contaminants (molecules of gases or elements) are less likely to accumulate on the surfaces than is the case with other types of vacuum gauges. However, collected contaminants can be removed by “degassing” the gauge, which drives the molecules that have collected on the inner walls and surfaces of the gauge back into the vacuum chamber where they can be pumped out of the system. Degassing can be done as required or as part of a regular pumpdown sequence. Regular degassing helps prevent contaminants from collecting and allows the gauge to provide lower and more repeatable pressure indications by bringing the pressure in the gauge closer to equilibrium with the chamber.

Water vapor is a type of contaminant that can collect inside the gauge while the vacuum chamber is exposed to atmosphere – especially in humid climates. Vapors from sputtering or coating operations can also contaminate the surfaces of a gauge.

Cleaning a gauge with solvents is not recommended. However, if a gauge is contaminated with silicone-based pump oil, solvent may be needed to remove the oil. Be sure the gauge is thoroughly dried before installing it back on the system and operating or degassing it.

There are two types of degassing techniques: Electron Bombardment (EB), and Resistive. EB degas must be used for UHV nude gauges with fine-wire mesh grids and can also be used for glass or nude gauges with helical coil grids. Resistive degas can only be used for gauges with helical grids.

The two degas techniques have similar effects but are quite different in the mechanisms of causing the contaminants to be removed. EB degassing is accomplished by increasing anode voltage and the emission current enough to provide electrons of sufficient quantity and energy to displace the contaminating molecules. Resistive degassing is accomplished by passing current through the grid (anode) sufficient to raise the grid temperature to displace the molecules. 

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