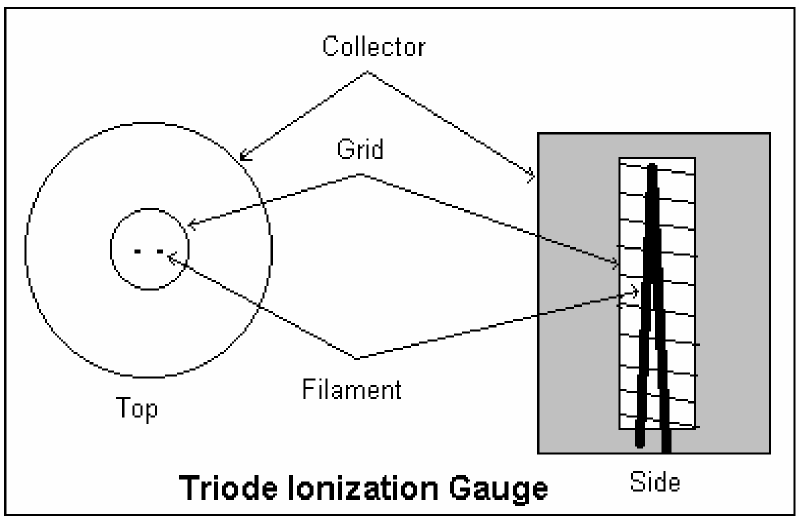
# Hot Filament Ionization Gauge Tubes

## HISTORY

Glass ion gauge tubes evolved from triode radio tubes. In early configurations, a filament was in the center with a grid surrounding the filament and a collector surrounding the grid. Electrons were emitted from the hot filament and attracted by a positive electrical potential toward the grid. Electrons collided with gas molecules, forming positive ions. The positive ions were attracted to the collector with an appropriate negative potential. The ion current was proportional to pressure over a large range of pressures.

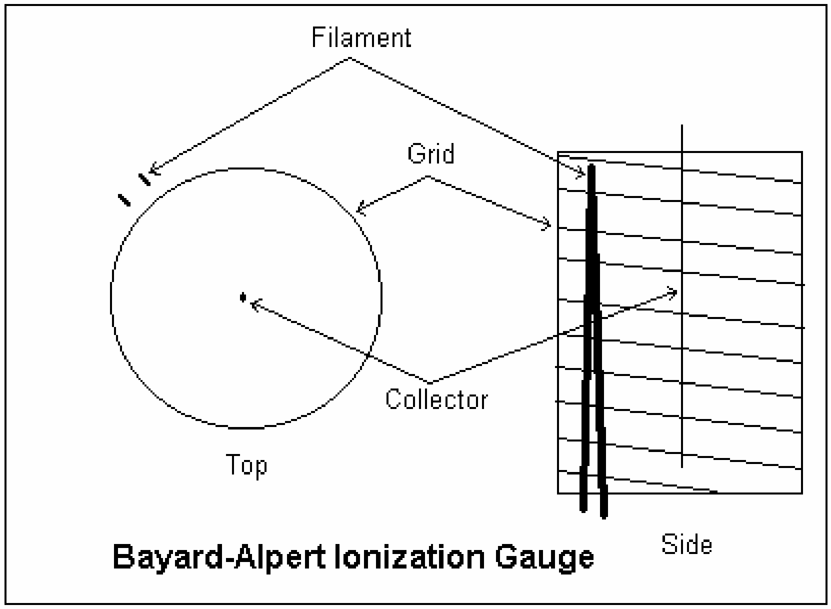



Although this tube was very dependable, it could not measure pressures below about $1 \times 10^{-7}$ torr, because of a background current, unrelated to pressure, called the “x-ray limit”. This was caused by electrons from the filament striking the grid, where they caused x-rays to be emitted. The x-rays then struck the collector, where they caused release of photo electrons. The resulting photoelectron current, independent of pressure is indistinguishable from the incoming ion current, and represented the lower limit of pressure measurement

## BAYARD ALPERT DESIGN

In 1950, the x-ray limit problem was solved by inverting the geometry of the triode tube: putting a small diameter wire collector in the center, surrounding the collector with a grid and finally putting the filament outside the grid. This geometry gave a much smaller cross section for collecting x-rays, reducing the x-ray limit by more than 3 decades. Now pressure could readily be measured to $1 \times 10^{-10}$ torr.

This geometry, the Bayard-Alpert gauge, represents the majority of ionization gauges sold today. Additional designs to further limit the x-ray currents by various shielding schemes have been implemented, but due to their complexity, are only used in applications where routine pressure measurement below $10^{-10}$ torr is required.




TUNGSTEN FILAMENT

The early tubes were all equipped with tungsten filaments. The filaments were low cost and performed very well. However, on many occasions, the operators forgot to turn the ion gauge tube OFF before letting the system up to atmospheric pressure. When the oxygen in the air reached the hot tungsten filament, it cause instant oxidation and burn-out of the filament. The tungsten oxide which forms on burn-out covers about half of the inside of the glass bulb with a creamy white coating which is easy to recognize. The solution was to find a filament material which did not easily oxidize, even when exposed to atmospheric pressure when hot.

IRIDIUM FILAMENTS

In order to extend the lifetime of the ion gauge tubes, scientists looked for a material which would provide a non-burnout filament. They discovered that iridium was a good alternative. Iridium could be operated at full temperature in air at atmospheric pressure with no bad effects. However, the iridium filaments had to be operated at very high temperatures in order to emit sufficient electrons for the ionization process. This took too much power and led to overheating of the gauge envelope.

The amount of work (thermal energy and voltage difference) required to generate sufficient electrons for an ion gauge varies from material to material. This characteristic of materials is called the “work function”. So, obviously, the work function for tungsten was lower than it was for iridium, and a method for reducing the work function for iridium filaments, while retaining the non burn out feature, was required.

This reduction in work function was accomplished by coating the iridium filament with a low work function material. The material chosen was thorium oxide. With this improvement, tube makers could deliver a tube which could read low pressures, operate with reasonable filament currents and endure exposure to atmospheric pressure while turned on. Although the thorium oxide coated iridium filaments were slightly more expensive than tungsten filaments, most users felt the extra cost was good insurance for longer life.

## MARKET EVOLUTION

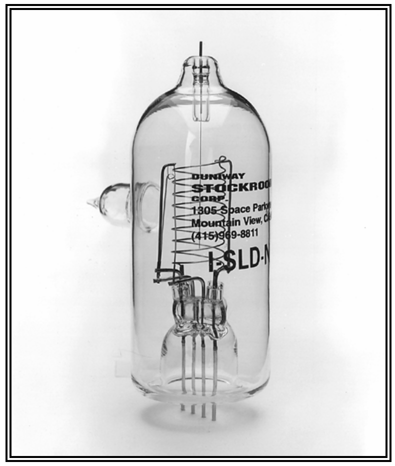
After the introduction of the thorium oxide coated iridium filament, it seemed as though the whole market would switch over to the new filament material. However, it was discovered that the new filaments could have problems under some conditions:

Reactive Gas Poisoning - In some processes, reactive gases, such as chlorine, fluorine, their compounds and some organic materials could combine with the thorium oxide and render it ineffective for electron emission. These materials may be encountered in metallurgical furnaces, semiconductor processing and at relatively high pressures in untrapped diffusion pumps.

Poor Adhesion - In the filament manufacturing process, lapses in process control can lead to poor adhesion for the thorium oxide coating. When the coating falls off, the filament loses its good emission characteristics and the tube does not work, even though the filament did not “burn out.”

## PORT DIAMETER, GAS ACCESS AND MATERIAL

Most ionization gauges are mounted in glass envelopes, with collector and electrical feed throughs sealed in the glass; and with the connection to the vacuum system through a glass tube in one side.



Glass Ionization Gauge - Sealed Reference |Tube
Duniway Stockroom Part Number: I-SLD-N

Most common material for the ionization gauge envelope is Nonex glass. The manufacturing process involves attaching the side arm for system connection, sealing in the collector on the top of the bulb and sealing in the rest of the gauge structure in the bottom of the bulb. Several considerations must be made as far as the side arm system connections are concerned:

Side Arm Diameter - In the early days, all tubes were equipped with ¾" diameter tubulation for attachment to the vacuum system After some time, there was a demand for 1" diameter tubulation, because the larger area gives better conductance between the system and the gauge. This better conductance (gas access) assures less difference between the system pressure and the pressure measured inside the tube. At different times, the ionization gauge could be a source of gas due to heating or represent a slight pumping speed due to the collection of ions. Better gas access helps reduce differences in pressure due to these effects.

Port Material: The glass envelope, historically, was made of Nonex glass, so naturally the least expensive material for the side arm was Nonex. However, other considerations as far as mounting to the vacuum system, such as material adhesion, coefficient of thermal expansion and mechanical accuracy must be taken into account. (Recently, due to discontinuance of Nonex glass, most tubes are made of a variety of Schott glass, but the same comments apply).

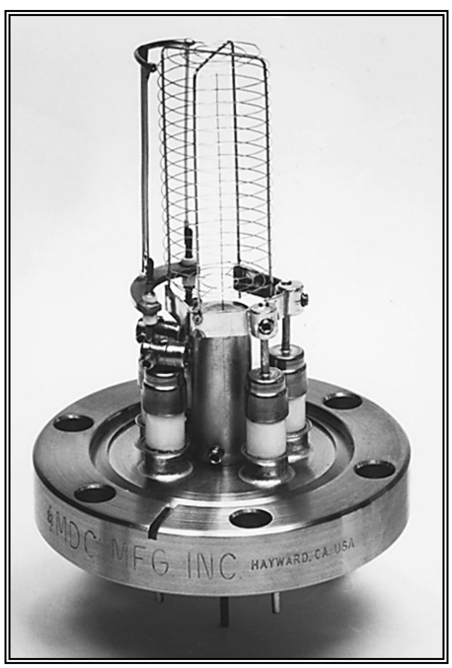
Pyrex Glass Vacuum Systems: For direct sealing to vacuum systems fabricated of Pyrex glass, a special transition material must be provided. Nonex and Pyrex will not bond to each other, so a transition material, such as uranium glass, which adheres to both Nonex and Pyrex, must be added to the side arm port. This material and process add cost to the tube, but provide benefit to users who must attach the tubes directly to Pyrex systems.

Compression Port/O-Ring Mounting:  In some cases, users prefer to mount the ionization gauge to a vacuum system using a compression port with o-ring seal.  The close tolerances required to make this type of seal can not be consistently met with glass tube side arms.  This application led to the use of a Kovar metal extension to the side arm.  Kovar, an alloy of cobalt, nickel and iron has a coefficient of thermal expansion which matches that of the glass.  Joining other metals to glass often leads to cracking during heating or cooling due to differences in coefficient of expansion.

Metal Vacuum Systems:  For systems made of stainless steel, the Kovar extension to the side arm of the ionization gauge, is also useful.  The Kovar can be welded into a stainless steel flange, typically ConFlat or KF flanges.

Conductive Coating of the Glass:  For all glass-systems where repeatability and uniform sensitivity in the ultrahigh vacuum range are required, a conductive coating on the inside of the ionization gauge tube is utilized.  The coating is platinum, is maintained at filament potential and prevents charge buildup usually associated with insulating glass surfaces.

Nude Gauges - The ultimate answer to reducing gas access problems is represented by the introduction of the “nude” gauge.  In this configuration, the whole gauge is mounted on a vacuum flange, usually a 2 ¾” ConFlat flange, with the electrodes mounted on feed through insulators.  This configuration allows the full immersion of the gauge structure into the vacuum system, assuring the most accurate representation of the system pressure.




Typical Nude Ionization Gauge
Duniway Stockroom Corp. Part Number:  I-NUDE-F

## OUTGASSING TECHNIQUES

Ionization gauges absorb gases on their surfaces, just like other parts of the vacuum system. As part of cleaning up a system for low pressure operation and as a means of assuring the most accurate representation of the system pressure, it is a standard practice to outgas the ionization gauge. Two methods are provided, depending on the gauge, supplier and application.

Grid Resistance Outgassing: In this method, electrical current is passed through the helical grid. The resistance of the grid wire causes it to heat up, driving gas molecules off the grid and other adjacent structures which are heated by radiation from the heated grid. With this technique, the gauge grid must have two insulated feed throughs, one for each end of the grid, in order to accomplish the heating

Electron Bombardment Outgassing: With this technique, the potentials of the filament and grid are changed, so that outgassing due to electron bombardment of the grid occurs. Some heating also occurs which assists in outgassing adjacent structures. This outgassing technique can be accomplished with only one insulated feed through for the grid, simplifying the gauge structure.

## PUMPING BY AN IONIZATION GAUGE

Since the ionization gauge involves formation and collection of ions, a clean gauge can represent a small source of pumping in a system. This pumping speed is far less than other pumps in a system, and normally does not require any consideration. However, in a sealed off ionization gauge tube, sometimes used as a reference, a gradual reduction of pressure may be observed as a result of this pumping.

Duniway Stockroom Corp.
48501 Milmont Drive
Fremont, CA 94538
800-446-8811 (Toll Free)
650-969-8811 (Phone)
650-965-0764 (FAX)
info@duniway.com (email)