

Series 274

BAYARD-ALPERT TYPE IONIZATION GAUGE TUBE



Pressure & Vacuum Measurement Solutions

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Features & Benefits

- Good vacuum pressure measurement for economical cost
- Operates on industry standard electrode voltages and wide range of electron emission currents (10 μ A to 10 mA)
- Well-known performance characteristics in vacuum industry
- Ion collector electrode well-shielded from leakage currents
- Available with burn-out resistant filaments and standard vacuum connections
- All units can be degassed by electron bombardment; some can be resistance degassed

Description

Bayard-Alpert (hot cathode) gauges provide pressure measurement based on the ionization of gas molecules by a constant flow of electrons from a filament. The number of ions created is directly proportional to the density of molecules. The ions are collected and measured by a vacuum gauge controller and converted to pressure based on the sensitivity of the gauge. The Series 274 Bayard-Alpert gauges consist of 3 types: glass tubulated, nude gauge with electron bombardment degas (EB), and the nude gauge with I²R degas (resistive).

Operating Principle

Negative electrons are emitted at a well-controlled, selectable rate from a heated filament and are accelerated toward a positively charged wire grid (anode). Electrons pass into the space between the grid and a collector wire at ground. In this space the electrons collide with gas molecules from the vacuum system, producing positive ions. The positive ions are then collected by the grounded collector wire that is located along the axis of the cylindrical 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 space for pressures below 1×10^{-3} Torr. The strength of the ion current is then indicated on a microammeter that is calibrated in units of pressure.

The low end of the operating range of a Bayard-Alpert 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 filament impact the grid and support wires. Because of the geometry of the Bayard-Alpert gauge, only a small fraction of the emitted X-rays are intercepted by the ion collector. When the X-rays strike the collector wire they cause electrons to be photoelectrically ejected from the collector. This X-ray current limits the pressures that can be measured, and is equivalent to a pressure reading in the 10^{-10} or 10^{-11} Torr ranges, depending upon the gauge model. 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 will be increased as a result of hydrocarbon contamination of the electrodes, since contaminated surfaces release more secondary electrons under X-ray bombardment. Such contamination can generally be removed by thorough degassing of the electrodes.

Gas Species Effects

Bayard-Alpert ionization gauges have different relative sensitivities for different gas species. As a result, pressure readout provides a direct reading only for the gas for which the gauge is specified (Nitrogen). This is called a readout of Nitrogen equivalent pressure. A simple mathematical conversion of the direct pressure readout to the pressure of the non standard gas can be made. This conversion is made using the relative gauge sensitivity for the specific gas. These sensitivities are tabulated in reference material and are contained in the Granville-Phillips® instruction manual for Series 274.

Hot filament type ionization vacuum gauges work best in given pressure ranges for individual gauge designs. The following is a brief outline of the considerations relevant to selection of the proper gauge.

A glance at the chart (Figure 1) will quickly indicate the gauge or gauges suitable for a given application. The useful range of most of these gauges starts at 2×10^{-2} Torr. Variations in design permit operation to various orders of vacuum. The nude type 274022, 274023, 274041 and 274042 are suitable to 2×10^{-11} Torr.

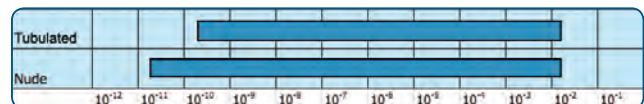


Figure 1 —
Operating Range for Bayard-Alpert Ionization Gauge Tube



Filaments

All gauges listed in this brochure have either tungsten or thoria coated iridium cathodes. The relative advantages and disadvantages of each are tabulated in Figure 2.

| Phenomenon | Tungsten Filament | Thoria-Iridium Filament |
|---|---|---|
| Accidental Exposure to Atmosphere | Do Not Use | High Tolerance |
| High Oxygen Partial Pressure | Easily Oxidized | Relatively Immune to Oxidation |
| Chemical Reaction with Gas to be Measured | Higher Filament Temperature, High Reaction Rate | Lower Filament Temperature, Lower Reaction Rate |
| Corrosive Gas Tolerance | Higher | Lower |

Figure 2 —

Filament Selection Guide

Sensitivity

The sensitivity is defined as follows:

$$S \text{ (Sensitivity)} = \frac{\text{(Ionization Current)}}{\text{(Electron Current) (Pressure)}}$$

Current measured in amperes. Pressure in Torr.

This definition makes the sensitivity relatively independent of the electron current and dependent only on gauge construction. In practice, it is often necessary to determine the lowest pressure that can be read with a given gauge tube and controller. To determine this, the lowest readable current sensitivity of the electrometer portion of the controller must be known.

Knowing the sensitivity of the gauge tube from the manufacturer's data, the relationship for ionization current vs. pressure can be determined.

Degassing

To reduce the outgassing in a gauge to a negligible level, the process of degassing is employed. For attainment of the lowest pressure levels the glass envelope gauges should be baked at 400°C for 1 hour.

The electrodes are degassed by heating to a temperature of 900°C nominally for approximately 15 minutes after baking.

The electrode heating is accomplished by either electron bombardment (EB) or by passing a heavy current (I²R) at low voltage through the grid. In general, gauges equipped with built up grids; i.e., squirrel cage or grids welded at multiple intersecting components, are degassed only by electron bombardment. The collector may be degassed only by the electron bombardment method. Grids consisting of a helix or double helix, in which both ends of the helix have external connections, are degassed by the heavy current method. All gauges with helical grids may also be degassed by means of electron bombardment.

The 274022, 274023, 274041, 274042, 274050, 274057, and 274058 gauges utilize a squirrel cage grid and must use electron bombardment for degassing. To provide a nude gauge suitable for I²R degassing, the 274028, 274043, and 274053 gauges were developed.

Electrical Leakage

The accuracy of pressure measurement, which depends on the measurement of currents as low as nanoamperes and below, is affected by leakage. These paths may be classified as either internal or external.

Internal and external leakage is held to the lowest possible value in designs such as the tubulated Bayard-Alpert. The collector terminal of the gauge is at the opposite end of the envelope from the grid and cathode terminals.

Designs which bring the collector out as one of a series of pins in a base or header are more susceptible to leakage problems than the tubulated design.

Internal leakage usually results from the evaporation of tungsten or thoria vapor from the cathode. This is controlled by means of a shield where the collector lead passes through the stem or header insulator. Great care must be exercised in insulating and shielding the lead to the collector terminal on the gauge from the controller.



Pumping

The ionization gauge exhibits a certain pumping capacity. This is due to both chemical and electrical effects. Chemical pumping is due, in general, to the affinity of gases for very clean surfaces. As the surface becomes saturated, the pumping action is diminished and reaches a steady state value. Readings for a typical glass tabulated gauge will be 20 to 50 percent lower during the period of chemical pumping. The duration of the pumping may be of the order of four hours at 1×10^{-9} Torr. Electronic or ionic pumping saturates after pumping approximately three months at 1×10^{-9} Torr. The most common remedy for pumping effects is to provide a passage of large conductance between the gauge and the vacuum system.

A third mechanism of pumping in gauges involves chemical reactions with the hot cathode. A number of gases such as oxygen, nitrogen, water vapor, and hydrogen have been shown to react with the carbon present in tungsten. The ratio of these reactions are dependent on the cathode temperature, and are low enough that serious errors in measurement can be avoided when high-conductance connections are used.

In small systems, however, the change in gas composition may be significant.

Several gauge configurations are available to cope with the pumping phenomenon.

The glass envelope gauge equipped with 3/4-inch tubulation, such as the 274002, has adequate conductance for use down to the 10^{-8} Torr range. A gauge for use down to the 10^{-10} Torr range is available with 1-inch tubulation (274015). To compensate for the high electronic pumping speed, all internally shielded gauges should be specified with 1-inch tubulations.

Nude gauges are the best solution to severe ionization gauge pumping problems. With the nude geometry, the gauge elements can be positioned directly into the vacuum chamber, thereby eliminating the pressure differential normally associated with a tubulated gauge. The time response of this gauge system is greatly reduced as compared to the tubulated gauge.

Comparing the requirements of a given application to the items above will permit the selection of the most appropriate gauge for the purpose.

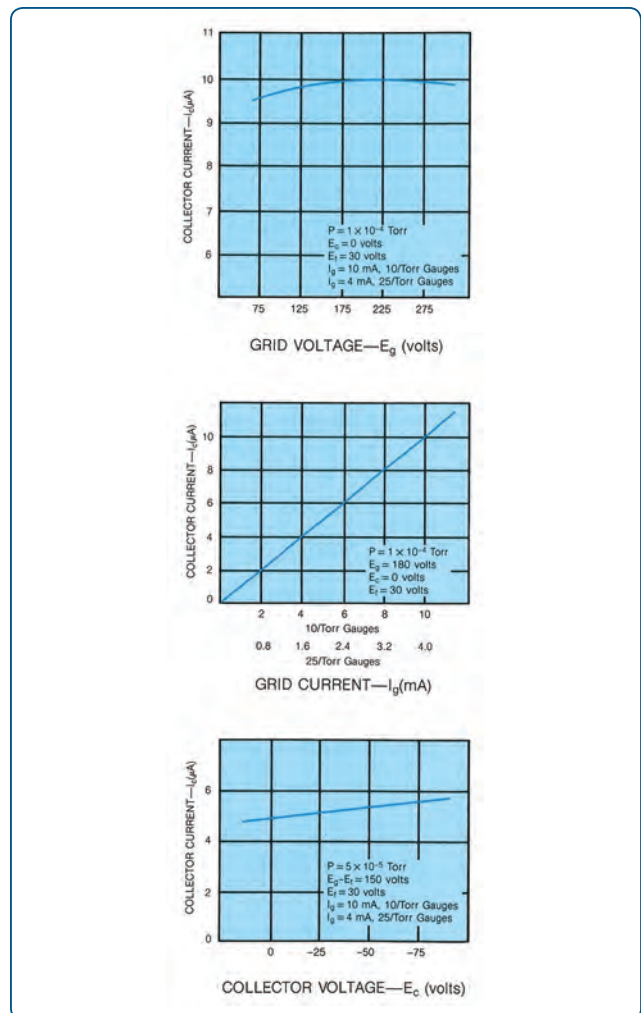





Figure 3 —
Operating Characteristics for Series 274 Ionization Gauge Tubes

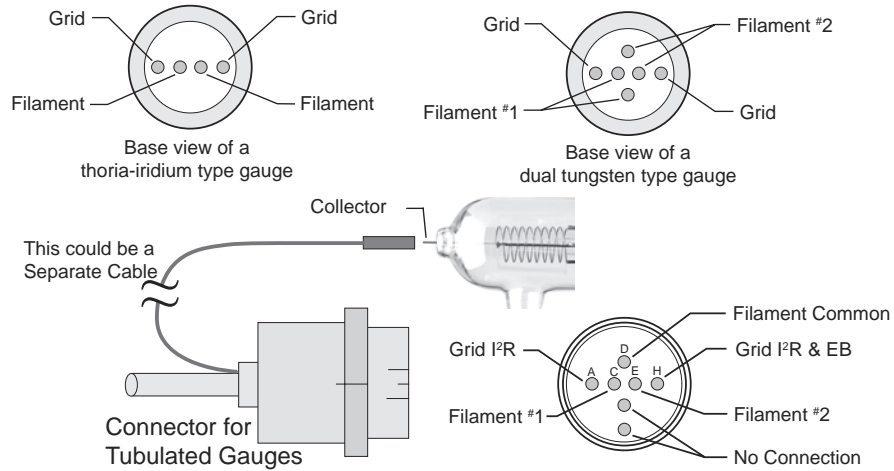


Specifications

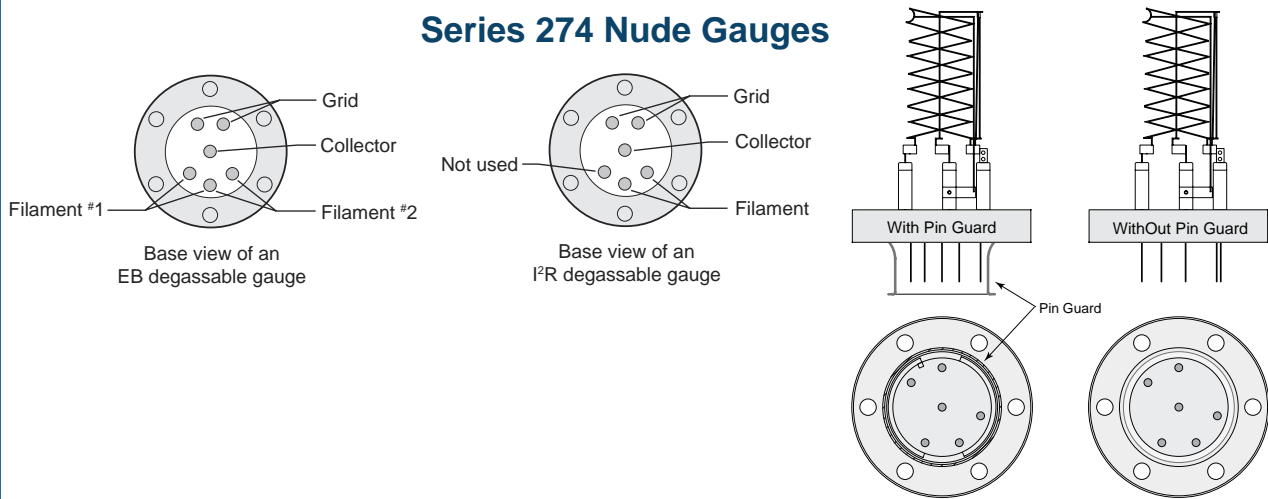
| | Tubulated Ionization Gauge | Electron Bombardment Degassable Nude Ionization Gauge | Resistance Heated (I ² R) Degassable Nude Ionization Gauge |
|--|--|--|---|
| Model |  |  |  |
| Benefits | <ul style="list-style-type: none"> • Non-sag bifilar grid • Burn-out resistant filament or dual tungsten filaments • Tubulation— 3/4-inch or 1-inch diameters in Kovar®, Pyrex or flanged • I²R or electron bombardment degas • Mates with standard electric connector | <ul style="list-style-type: none"> • Cage grid • Burn-out resistant filament or dual tungsten filaments • Electron bombardment degas • Mates with standard flanged connector • Replaceable filament | <ul style="list-style-type: none"> • Non-sag bifilar grid • Burn-out resistant filament • I²R or electron bombardment degas • Mates with standard electric connector • Replaceable filament |
| Physical Data | | | |
| Tubulation | 3/4 in. (19mm) or 1 in. (25 mm) dia. x 2 1/4 in. (57 mm) long, Kovar, Pyrex, or flanged | N/A | N/A |
| Envelope | Nonex 7720 glass, 2 1/4 in. (57 mm) dia. x 5 in. (127 mm) long | Nude | Nude |
| Mounting Position | Any, Vertical preferred | Any | Any |
| Collector | Tungsten, .010 in. dia. | Tungsten, .005 in. dia. | Tungsten, .010 in. dia. |
| Filament | Dual tungsten or one thoria coated iridium | Dual tungsten or dual thoria coated iridium on replaceable assembly | Thoria coated iridium on replaceable assembly |
| Grid | Refractory Metals | Refractory Metals | Refractory Metals |
| Overall Length | 6 in. (152 mm) | 4 1/8 in. (105 mm) | 4 1/8 in. (105 mm) |
| Insertion Length | N/A | 3 in. (76mm) | 3 in. (76mm) |
| Operating Data | | | |
| Sensitivity for N ₂ | 10/Torr | 25/Torr | 10/Torr |
| Typical Accuracy | ±20% | ±20% | ±20% |
| X-ray Limit | About 3 x 10 ⁻¹⁰ Torr | About 2 x 10 ⁻¹¹ Torr | About 4 x 10 ⁻¹⁰ Torr |
| Electron Bombardment Degas | 100 watts max. | 40 watts max. | 100 watts max. 70 watts nominal |
| Resistance Heated Degas (I ² R) | 6.3 to 7.5 VAC at 10 A | N/A | 6.3 to 7.5 VAC at 10 A |
| Bakeout | 450°C | 450°C | 450°C |
| Filament - Heating Current | 4 to 6 A | 2.5 to 3.5 A | 4 to 6 A |
| Filament - Heating Voltage | 3 to 5 V | 3 to 5 V | 3 to 5 V |
| Filament - Voltage Potential | +30 VDC | +30 VDC | +30 VDC |
| Collector Potential | 0 V | 0 V | 0 V |
| Grid Potential | +180 VDC | +180 VDC | +180 VDC |



Series 274 Tubulated (Glass) Gauges



Series 274 Nude Gauges



Cable Connections —

Series 274 tubulated glass and nude gauges shown



Ordering Information

Glass Tubulated Gauges

Single thoria-coated iridium filament

| | |
|---|--------|
| 3/4 inch Pyrex glass inlet port | 274002 |
| 3/4 inch Kovar metal inlet port | 274003 |
| 1 inch Pyrex glass inlet port | 274005 |
| 1 inch Kovar metal inlet port | 274006 |
| 15 mm Pyrex glass inlet port | 274036 |
| NW25KF flange with 1 inch port | 274032 |
| 1.33 inch (NW16CF) non-rotatable, 3/4 inch port | 274020 |
| 2.75 inch (NW35CF) non-rotatable, 3/4 inch port | 274007 |
| 2.75 inch (NW35CF) non-rotatable, 1 inch port | 274008 |

Dual tungsten filaments

| | |
|---|--------|
| 3/4 inch Pyrex glass inlet port | 274012 |
| 3/4 inch Kovar metal inlet port | 274013 |
| 1 inch Pyrex glass inlet port | 274015 |
| 1 inch Kovar metal inlet port | 274016 |
| 15 mm Pyrex glass inlet port | 274037 |
| 1.33 inch (NW16CF) non-rotatable, 3/4 inch port | 274021 |
| 2.75 inch (NW35CF) non-rotatable, 3/4 inch port | 274017 |
| 2.75 inch (NW35CF) non-rotatable, 1 inch port | 274018 |

Nude Gauges

Single thoria-coated iridium filament (resistive or electron bombardment degas)

| | |
|---|--------|
| NW40KF flange with pin guard/locking strain relief | 274053 |
| 2.75 inch (NW35CF) non-rotatable | 274028 |
| 2.75 inch (NW35CF) non-rotatable, pin guard/locking strain relief | 274043 |
| Replacement filament | 274029 |

UHV Nude Gauges

Dual thoria-coated iridium filament (electron bombardment degas only)

| | |
|---|--------|
| NW40KF flange with pin guard/locking strain relief | 274058 |
| 2.75 inch (NW35CF) non-rotatable | 274023 |
| 2.75 inch (NW35CF) non-rotatable, pin guard/locking strain relief | 274042 |
| Replacement filaments | 274025 |

Dual tungsten filaments (electron bombardment degas only)

| | |
|---|--------|
| NW40KF flange | 274050 |
| NW40KF flange, pin guard/locking strain relief | 274057 |
| 2.75 inch (NW35CF) non-rotatable | 274022 |
| 2.75 inch (NW35CF) non-rotatable, pin guard/locking strain relief | 274041 |
| Replacement filaments | 274024 |

Accessories

Glass tubulated test gauge with thoria-coated iridium filament, pumped down to approximately 10^{-5} Torr and sealed off. NOT to be used as a pressure reference.

274031





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