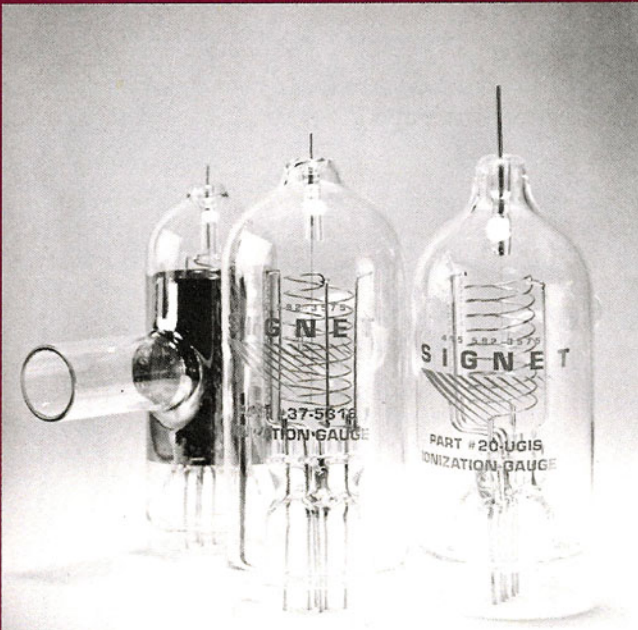
Signet Ionization Gauge Tubes



Installation & Operation

Installation & Operation

How Ionization Gauge Tubes Work

Ionization gauge tubes have been used to measure pressure in vacuum systems since 1916 when Buckley first described the device. Tubes were limited to measurement of pressure in the high vacuum range until Robert Bayard and Daniel Alpert introduced a revolutionary change in tube design in 1950 allowing the measurement of pressure in the ultrahigh vacuum range. This modern tube is called the Bayard-Alpert or BA tube.

All tube designs share a basic concept, shown in Figure 1. A hot filament boils out an emission current of electrons which are accelerated to a positively charged grid, usually in the form of a wire spiral. Some of the electrons pass through the spaces between the spiral and find themselves in a retarding field which reverses their direction before they strike the collector electrode. However, while in the space between the grid and the collector, a few of the electrons strike gas molecules, ionizing them by knocking off one or more of the molecules' peripheral electrons. The positive ions thus created are attracted to the collector; they form a current (ion current) which is proportional to the pressure of gas molecules and the emission current of electrons:

Ion Current = G x Emission Current x Pressure.

The constant G is called the gauge factor; when ion and emission current are expressed in amps and pressure in Torr, G has the dimension $Torr^{-1}$. The value of G depends on the type of gas, the dimensions of the tube, and the voltages applied to the electrodes.

The most sophisticated work on gauge factors has been carried out by Charles Tilford and his group at the National Institute for Standards and Technology (NIST). They define a tube's gauge factor with filament bias 30 V, grid bias 180 V, collector bias 0 V, and pure nitrogen as gas. They further recommend an emission current of 1 mA.

The gauge factors quoted in Table A for Signet tubes have all been measured using the NIST standard.

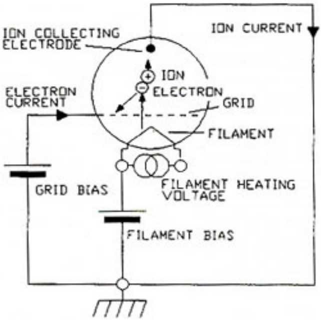


Figure 1. Ion gauge circuit

Tube Installation & Precautions

The glass envelopes used with Signet tubes are robust and rarely cause a problem. However, as with any device with a glass envelope, exercise reasonable care.

Signet tubes are designed for high vacuum service. They may be installed using an elastomer-sealed compression fitting. When installing a tube, be sure the compression fitting used to seal the tube to the vacuum system has the correct diameter for the tube used. Do not force the tube. Tubes should not be attached using a compression fitting. If the system is pressurized during the process cycle, the tube may pop out. Dress the electrical cable to the tube to prevent an inadvertent yank to the tube.

Note that the accelerating voltage applied to the grid by most controls is 180 V; take care not to touch the connection to this electrode while it is connected to the control. If the tubes are used with a control which uses electron bombardment outgassing, be especially careful since even higher voltages, up to 1,000 V, may be applied to the tube.

Note that under some circumstances an electrical breakdown of the gas in the vacuum system may occur; under these circumstances the gas in the vacuum system becomes an electrical conductor, allowing the voltage on any exposed electrode in the vacuum system to connect to the metal wall of the vacuum system. To prevent electrical shocks under this condition, be sure the gauge control and the vacuum system are separately grounded to a third-wire or waterpipe ground with a cable which can carry at least 10 amps.

Outgassing

All Signet tubes provide connection to both ends of the spiral grid structure; they therefore work with controls which pass a current through the spiral when operated in the "outgas" mode. This resistance heating of the grid creates an incandescent glow, removing layers of adsorbed gas. This procedure may shorten the time required for stable pressure readings.

If the control uses electron bombardment outgassing rather than the safer, more convenient resistance method (see *Tube Installation & Precautions*).

Range of Operation

BA tubes generate noise called the X-ray limit corresponding to a pressure of a few times 10^{-10} Torr; this noise establishes the lower limit to the pressure range over which they operate. Space charge and other phenomena limit the upper end of their range to a few times 10^{-4} Torr for most tubes; the broad-range tube (see Table A) will provide useful output to somewhat higher pressure. NIST research has established tube output as accurately linear with pressure between these limits.

Correction for Gas Other than Nitrogen

The true pressure for gases other than nitrogen may be estimated by multiplying the control reading by the factors measured by NIST for tubes equivalent to Signet's twin tungsten tubes:

Gas	Multiply Reading By
Xenon	0.35
Krypton	0.52
Argon	0.72
Water Vapor	1.4
Hydrogen	2.4
Neon	3.36
Helium	6.06

Accuracy of Pressure Measurement

The accuracy with which pressure measurements can be made depends on the gauge control and the ion gauge tube in use.

Control induced errors are associated with:

- The bias voltages used to operate the tube.
- Emission current setting.
- Gauge factor setting.
- The wave form used to heat the filament.
- Ion current measurement.
- It is not unusual for control errors to contribute an error of ±20% of the pressure reading.

An additional appreciable source of tube error is tube-to-tube variation in gauge factor. For tungsten filament tubes, this variation introduces an error of ±10% of pressure reading; for thoria coated iridium filament tubes, the error is ±20% of reading.

Combined tube and control error may thus be substantial. Process control may require longer pump-down time than necessary in order to deal with these errors.

Control/tube system calibration to a primary standard is available from NIST, A55 Metrology, Quince Orchard Blvd., Gaithersburg, MD 20899 (call Albert Filippelli at 301-975-4835). Uncertainty in NIST's primary standard is less than ±2% over the high vacuum range. Calibration to a secondary standard, traceable to NIST, is available with uncertainty of less than ±5% or ±10% over the high vacuum range from GFV Associates, Inc., 52 Louder's Lane, Boston, MA 02130 (call Fred Vanderschmidt at 617-524-0465).

Signet Tube Types

BA tubes are manufactured in a variety of configurations. Signet provides several tube types which are widely used as original equipment in ion implantation equipment, physical vapor deposition equipment and other equipment used in the manufacture of semiconductor devices and integrated circuits.

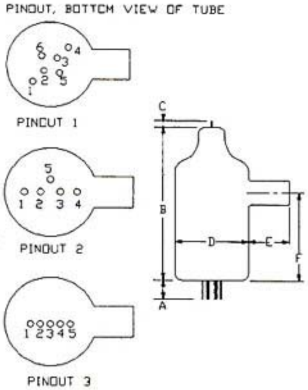


Figure 2.
Tube envelope dimensions and pinout.

Pinout 1	Filament 1: pins 2, 5 Filament 2: pins 3, 6 Grid: pins 1, 4
Pinout 2	Filament: pins 2, 3 Grid: pins 1, 4 Shield: pin 5

Figure 2 shows the outline and pinout for Signet tubes; dimensions are in Table A.

Glass tubulation is fire polished and supplied with a plastic cap. All glass tubulation tubes can be supplied evacuated and sealed off.

Signet Twin Tungsten Filament Tubes: 37-5319, 44-3302, 44-7631

These glass tubes use two independent tungsten filaments. This type of tube is often used with ion implantation equipment. Tungsten filaments operate at a relatively high temperature in order to produce the required electron emission because of tungsten's relatively high work function. NIST tests on this tube type show superior long term stability and low tube-to-tube variation in gauge factor. Should one filament burn out in operation, the other filament may be used without requiring a break in the vacuum to change the tube.

Signet Twin Tungsten Filament Anelva Tube Replacement: 20-UGIS

This twin tungsten filament tube is configured as a replacement for the Anelva tube, a tube of Japanese manufacture used on a variety of physical vapor deposition, ion implantation equipment and other equipment manufactured in Japan.

Signet Broad-Range Tube: 33-5641

This glass tube uses a single filament of thoria coated iridium. The tube is configured as a "broad range" type, using small spacings between electrodes and providing a conductive coating on the inside of the tube's glass envelope. The coating is usually connected externally to one end of the filament or to ground.

This filament type can produce the required emission current at relatively low temperature because of the low work function of thoria. Further, the low reactivity of iridium makes the tube's filament unlikely to burn out. The "broad-range" design improves the tube's performance at high pressure. NIST tests on tubes with thoria coated iridium filaments show a higher tube-to-tube variation in gauge factor than the tungsten filament tubes.

Table of Specifications

Detailed information on Signet tubes is contained in Table A.

The table of specifications uses inch and millimeter dimensions. Because of variations which are intrinsic to glass-blown products, the inch dimensions provided are accurate to ±0.1" except where noted; millimeter dimensions are accurate to ±2.5 mm except where noted.

The gauge factors shown in Table A were measured using the NIST recommended bias voltages and emission current. The values shown are the average of a number of measurements; the gauge factor of individual tubes may vary substantially from the average value as described in Table A.

Limited Warranty

This Signet product is warranted against defects in materials and workmanship for one year from the date of shipment provided the installation and operating instructions specified in this manual are followed.

Table A – Specifications for Signet Tubes

Signet No.	37-5319	44-3302	44-7631	33-5641**
Gauge Factor	11.5/Torr	11.5/Torr	11.5/Torr	6/Torr*
Tubulation: Material & Diameter	Glass 1.00±.01" (25.4mm)	Glass 0.75±.01" (19.1mm)	Kovar Sleeve 0.75±.003" (19.1mm)	Glass 1.00±.01" (25.4mm)
Pinout (See Figure 2)	Pinout 1	Pinout 1	Pinout 1	Pinout 2
Dimension A	0.5" (13mm)	0.5" (13mm)	0.5" (13mm)	0.32" (8mm)
Dimension B	5.05" (128mm)	5.05" (128mm)	5.05" (128mm)	4.8" (122mm)
Dimension C	0.3" (8mm)	0.3" (8mm)	0.3" (8mm)	0.32" (8mm)
Dimension D	2.25" (57mm)	2.25" (57mm)	2.25" (57mm)	1.68" (43mm)
Dimension E	2.15" (55mm)	2.15" (55mm)	2.15" (55mm)	2.15" (55mm)
Dimension F	3.15" (80mm)	3.15" (80mm)	3.15" (80mm)	2.35" (60mm)
Power Pins Diameter	0.060±.005" (1.52mm)	0.060±.005" (1.52mm)	0.060±.005" (1.52mm)	0.060±.005" (1.52mm)
Ion Collector Pin Diameter	0.040±.005" (1.02mm)	0.040±.005" (1.02mm)	0.040±.005" (1.02mm)	0.040±.005" (1.02mm)

*Shield attached to filament. **Broad-Range (other tube types available)

SIGNET

SIGNET Products, Inc.
2 Davis Drive
Belmont, CA 94002
650/592-3575
FAX 650/592-7223
email: sales@signet-inc.com