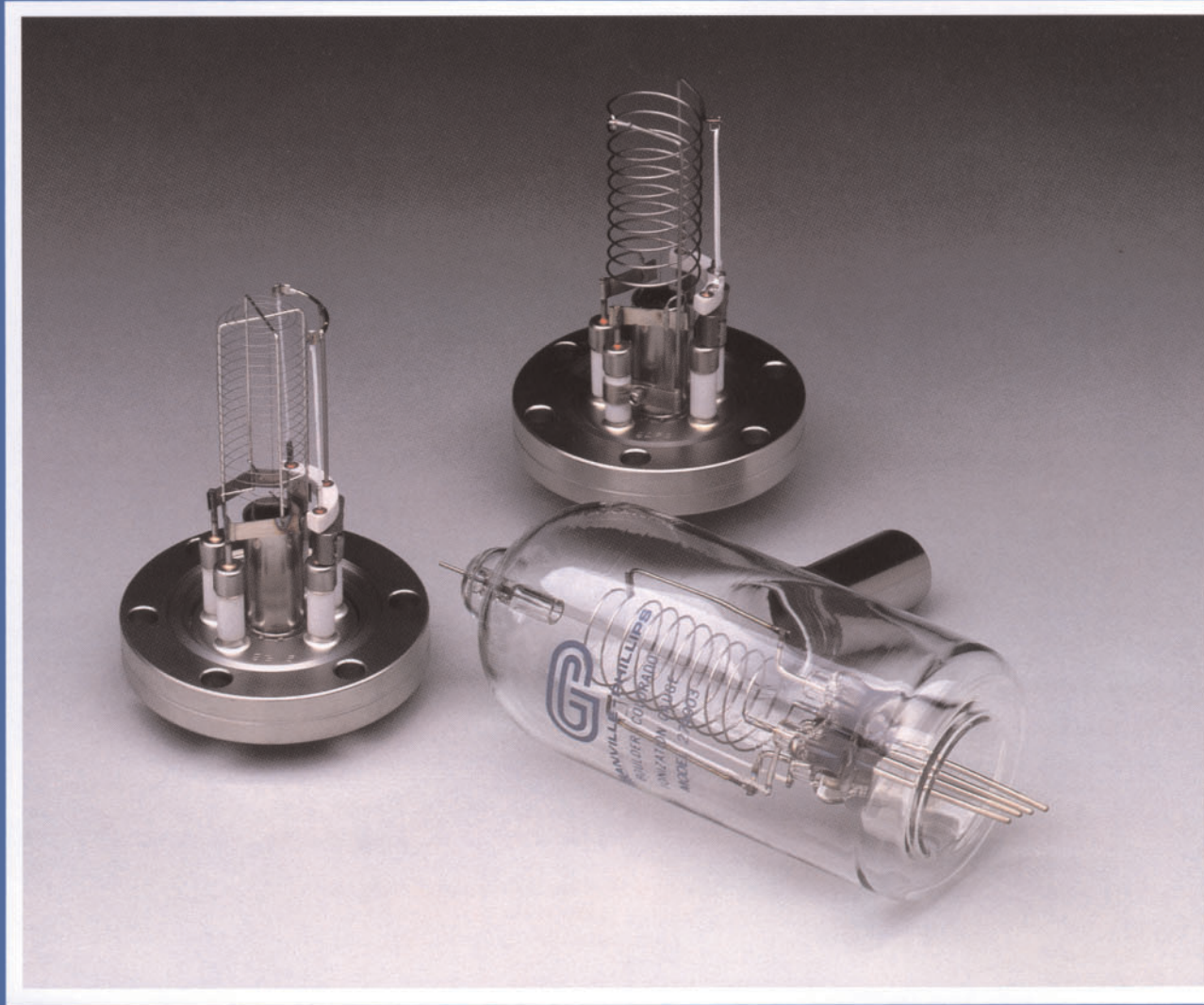


# 274 BAYARD-ALPERT TYPE IONIZATION GAUGE TUBES



**GRANVILLE-PHILLIPS**  
HELIX TECHNOLOGY CORPORATION

*Advanced Vacuum Measurement Solutions*

## Operating Principle

The pressure indication of a Bayard-Alpert (a hot cathode) gauge is based on the ionization of gas molecules by a constant flow of electrons. The negative electrons are emitted at a well-controlled, selectable rate from a heated cathode and are accelerated toward a positively charged wire grid (anode). Electrons pass into the space between the grid and a negatively charged collector wire. In this space the electrons collide with gas molecules, from the vacuum system, producing positive ions. The positive ions are then collected by the negative 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  $1 \times 10^{-3}$  Torr. The strength of the ion current is then indicated on a microammeter that is calibrated in units of pressure. Inasmuch as the pressure indication is linear, the hot cathode Bayard-Alpert gauge is generally considered the most accurate continuous indicator for pressures below  $1 \times 10^{-3}$  Torr.

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 cathode 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  $10^{-11}$  Torr range. Earlier gauges which had a cylindrical collector outside the grid experienced an X-ray limit of about  $10^{-8}$  Torr. The X-ray limit refers to the lowest pressure indication which 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.

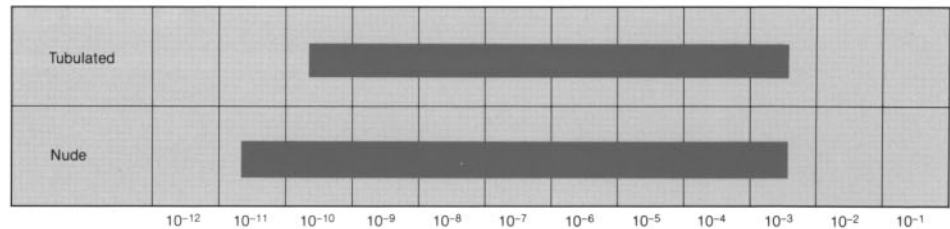


Figure 1. Operating Range for Bayard-Alpert Ionization Gauge Tube

Phenomenon	Tungsten Filament	Thoria-Iridium Filament
Accidental exposure to atmosphere	No tolerance	High tolerance
High Oxygen Partial pressure	Easily oxidized	Relatively immune to Oxidation
Chemical reaction with gas to be measured	Higher filament temperature, higher reaction rate	Lower filament temperature, lower reaction rate

Figure 2. Cathode Characteristics

## 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 cathode 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  $1 \times 10^{-3}$  Torr. Variations in design permit operation to various orders of vacuum. The nude type 274022, 274023, 274041 and 274042 are suitable to  $2 \times 10^{-11}$  Torr.

## Cathodes

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.

## Sensitivity

The sensitivity is defined as follows:

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

(Current measured in amperes. Pressure in torr.)

This definition makes the sensitivity 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 electron 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 (I<sup>2</sup>R) 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 helix gauges may be degassed by means of electron bombardment.

The 274022, 274023, 274041 and 274042 gauges utilize a squirrel cage grid and must use electron bombardment for degassing. To provide a nude gauge suitable for I<sup>2</sup>R degassing, the 274028 and 274043 gauges were developed.

## Electrical Leakage

The accuracy of pressure measurement, which depends on the measurement of currents in the order of 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-tubulated 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  $1 \times 10^{-9}$  Torr. Electronic, or ionic pumping saturates after pumping approximately three months at  $1 \times 10^{-9}$  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-in. tubulation, such as the 274002, has adequate conductance for use down to the  $10^{-8}$  scale. A gauge for use down to the  $10^{-10}$  scale is available with 1-in. tubulation (274015). To compensate for the high electronic pumping speed, all internally shielded gauges should be specified with 1-in. tubulations.

The nude gauges are the best solution to severe ionization gauge pumping problems. With the nude geometry, the gauge elements are positioned directly in 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.

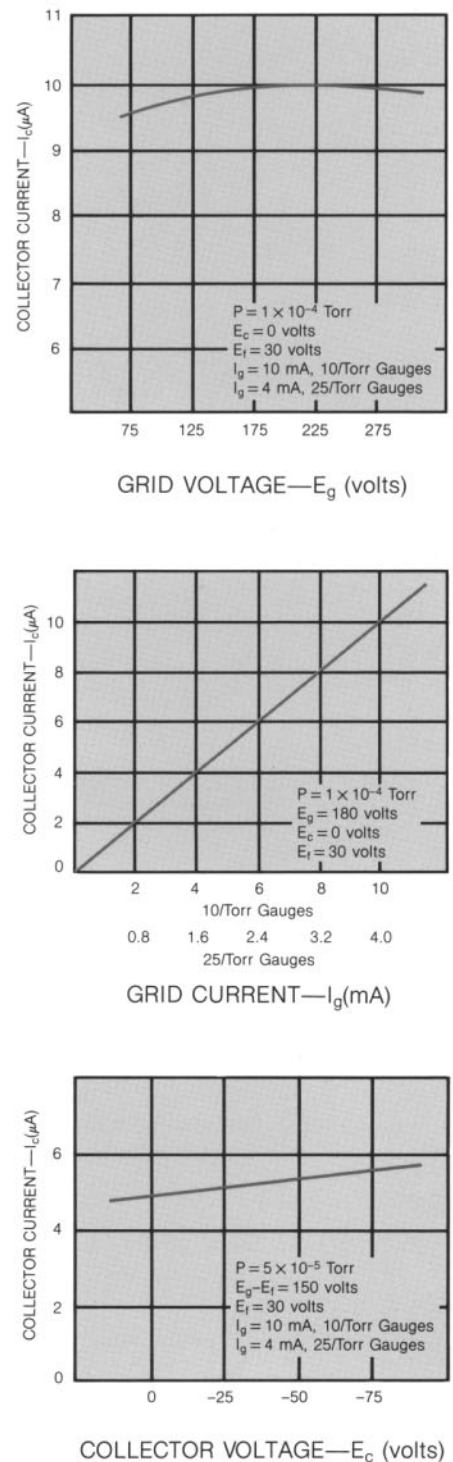
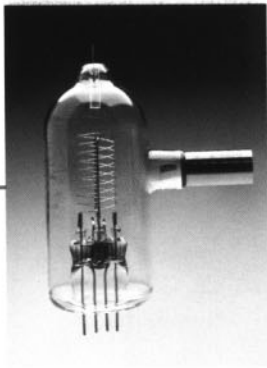


Figure 3. Operating Characteristics for Series 274 Ionization Gauge Tubes

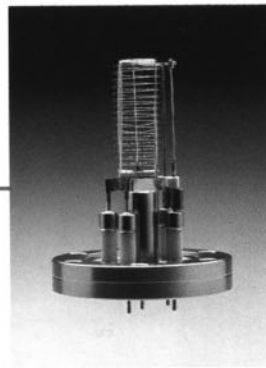




Tubulated Ionization gauge

**Features**

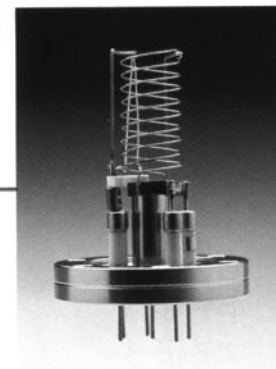
- Non-sag bifilar grid.
- Burn-out-resistant cathode or dual tungsten cathodes.
- Tubulation— 3/4-inch or 1-inch diameters in Kovar, Pyrex or flanged.
- I<sup>2</sup>R or electron bombardment degas.
- Mates with standard electric connector.



Electron Bombardment Degas Nude Ionization gauge

**Features**

- Cage grid.
- Burn-out-resistant cathode or dual tungsten cathodes.
- Electron bombardment degas.
- Mates with standard flanged connector.
- Uses replacement cathode assemblies.



I<sup>2</sup>R or EB Degas Nude Ionization gauge

**Features**

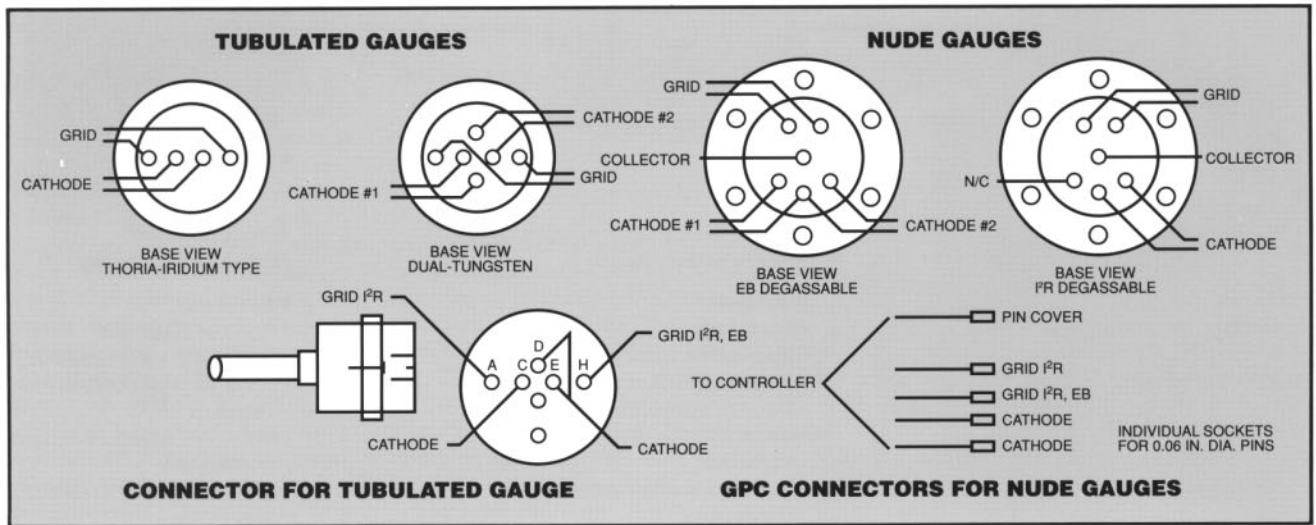
- Non-sag bifilar grid.
- Burn-out-resistant cathode.
- I<sup>2</sup>R or electron bombardment degas.
- Mates with standard flanged connector.
- Uses replacement cathode assemblies.

**SPECIFICATIONS**

PHYSICAL DATA	Tubulated Gauge	Electron Bombardment Degassable Nude Gauge	Resistance Heated (I <sup>2</sup> R) Degassable Nude Gauge
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 with 2 3/4 in. o.d. ConFlat® flange	Nude with 2 3/4 in. o.d. ConFlat® flange
Mounting Position	Any, Vertical preferred	Any	Any
Collector	Tungsten, .005 in. dia.	Tungsten, .005 in. dia.	Tungsten, .005 in. dia.
Cathode	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 <sub>2</sub>	10/Torr	25/Torr	10/Torr
Typical Accuracy	±20%	±20%	±20%
X-ray Limit	About 3 x 10 <sup>-10</sup> Torr	About 2 x 10 <sup>-11</sup> Torr	About 4 x 10 <sup>-10</sup> Torr
Electron Bombardment Degas	100 watts max.	40 watts max.	100 watts max. 70 watts nominal
Resistance Heated Degas (I <sup>2</sup> 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
Cathode Current	4 to 6 A	2.5 to 3.5 A with 4.0 mA emission current	4 to 6 A
Voltage Potential	3 to 5 V + 30 Vdc	3 to 5 V +30 Vdc	3 to 5 V + 30 Vdc
Collector potential	0 V	0 V	0 V
Grid potential	+180 Vdc	+180 Vdc	+180 Vdc



Gauge Tube and Cable Connector Data

<b>EQUIVALENT LIST</b>								
Bayard-Alpert Ion Gauge Tube Model Numbers								
CATHODE	TUBULATION DIAMETER	Description	Granville-Phillips	ETI Number	Huntington Mechanical Labs	CHA Ind.	Veeco	Varian (-K2471-) (-K7360-)
		IRIDIUM-Thoria Coated	3/4"	Pyrex	274002	4336-P	IP-100	IG-100-P
Kovar	274003			4336-K	IK-100	IG-100-K	RG-75-K	
1"	1 1/6" Flange		274020	4336-F	IK-100-F			
	2 3/4" Flange		274007					
TUNGSTEN	3/4"	Pyrex	274012	4336-TP	TP-100	IGT-100-P	TG-75-P	
		Kovar	274013	4336-TK	TK-100	IGT-100-K	TG-75-K	
	1"	1 1/6" Flange	274021	4336-TP/1	TP-150			
		2 3/4" Flange	274017					
NUDE*		Dual Tungsten EB Degas Only	274022 274041	8130T	IGT-T			971-5008
		Dual Iridium Thoria Coated EB Degas Only	274023 274042	8130	IGT-TI			971-5007
		Iridium Thoria Coated I <sup>2</sup> R or EB Degas	274028 274043	8140				

Figure 4. Bayard-Alpert Ion Gauge Tube Equivalent List

\*Electrically Equivalent, Pin Geometry May Vary

## Ordering Information

See GPC brochures No. 270, No. 271, No. 280, No. 303, No. 307, No. 330, No. 332, No. 338, No. 340, and No. 350 available free on request for Gauge Controllers.

## Tubulated Ionization Gauge Tubes

Connection	CATALOG NUMBERS					
	Thoria Coated Iridium Cathode			Dual Tungsten Cathodes		
	3/4 in.	1 in.	15mm	3/4 in.	1 in.	15 mm
Pyrex. ....	274002	274005	274036	274012	274015	274037
Kovar ....	274003	274006	—	274013	274016	—
1 5/16 in. non-rotatable ConFlat® flange ...	274020	—	—	274021	—	—
2 3/4 in. non-rotatable ConFlat flange ....	274007	274008	—	274017	274018	—
NW25KF flange.....	—	274032	—	—	—	—

## Nude-Ionization Gauge Tubes

	CATALOG NUMBERS		
	on 2 3/4 in. o.d. non-rotatable ConFlat flange	NW40KF flange	15MM
Dual tungsten cathodes, EB degas only. ....	274022	274050	274051
Dual thoria coated iridium cathodes, EB degas only. ....	274023	—	—
Single thoria coated iridium cathode, I <sup>2</sup> R or EB degas. ....	274028	274053	—

On 2 3/4 in. o.d. non-rotatable ConFlat-type flange with pin guard, order nude gauge cable with molded pin connector

Dual tungsten cathodes, EB degas only. ....	274041
Dual thoria coated iridium cathodes, EB degas. ....	274042
Single thoria coated iridium cathode, I <sup>2</sup> R or EB degas. ....	274043

## Broad Range Ionization Gauge Tubes

Kovar .....	1 in.	303039
2 3/4 in. non-rotatable ConFlat-type flange .....		303041

## Accessories

Replacement dual tungsten cathodes, for 274022, 274041 or 274051 only .....	274024
Replacement dual thoria coated iridium cathodes, for 274023 or 274042 only .....	274025
Replacement single thoria coated iridium cathode, for 274028, 274043 or 274053 only .....	274043
Vacuum simulator, tubulated ion gauge pumped down and pinched off at 1 x 10 <sup>-5</sup> Torr or lower .....	274031

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