Measuring Pressure

Units of Measure

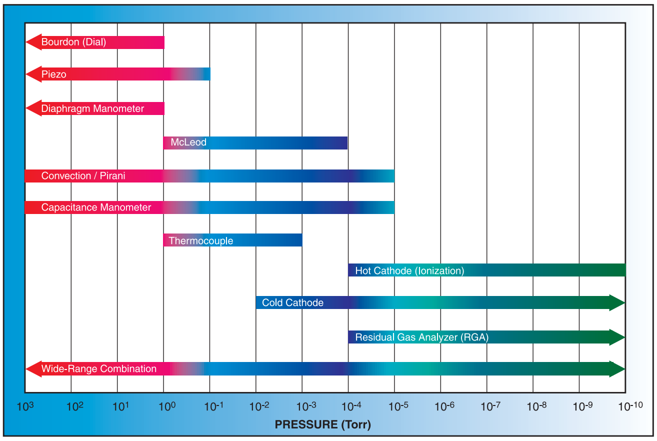
Sub-atmospheric pressures are measured in several units, including: Torr (also called millimeters of mercury, mmHg), milliTorr (mTorr but also called micron, μ), inches of mercury (" Hg), millibar (mbar), and pascal (Pa). In the U.S., three units are in common use: micron as the unit for pressures reached by backing pumps, Torr for high vacuum and UHV pumps, and inches of mercury for coarse vacuum pumps. In Europe, millibar is the common unit for all pressure measurements. Japan uses the pascal unit, but often has Torr as a secondary unit. Most authors of scientific/technical papers are urged to use the SI unit pascal, and some do.

The units are derived from:

- **Pascal—**the force of 1 newton (1 kg accelerating at 1m/sec./sec.) acting on 1 m^2
- **Millibar—**1,000 times the force of 1 dyne (1g accelerating at 1cm/sec./sec.) acting on 1 cm^2
- **Torr—**1/760 times the height of a mercury barometer under “standard” atmospheric pressure
- **MilliTorr or micron—**1,000th of 1 Torr
- **Inches of Hg (vacuum)—**1/29.92 times the height of a mercury barometer under “standard” atmospheric pressure (taking atmospheric pressure as 0" Hg)
- **Inches of Hg (weather forecasts)—**1/29.92 times the height of a mercury barometer under “standard” atmospheric pressure (taking no pressure as 0" Hg)

Pressure Ranges

There is no “universal” gauge that can measure from atmosphere to UHV pressures (a dynamic range of 10^{15}). There are, essentially, three mechanisms used in pressure measurement and the one chosen depends on the pressure range and the residual gases in the vacuum.



Mechanical Gauges have liquid or solid diaphragms that change position under the force of all the gas molecules bouncing off them. These gauges measure absolute pressures unaffected by gas/vapor properties. Unfortunately, this type of gauge is ineffective below 10^{-5} Torr.

Gas Property Gauges measure a bulk property, such as thermal conductivity or viscosity. They are dependent on gas composition and are effective over limited pressure ranges below approximately 100 Torr and above 10^{-4} Torr.

Ionization Gauges For high vacuum and UHV measurements, charge collection is used. The residual gas molecules are ionized by electrons and the resulting ion current measured. Although such gauges will ionize vapors as well as permanent gases, their response depends on parameters other than ionization potential, making accurate total pressure measurement difficult in gas mixtures. Ionization gauges cover the pressure range from 10^{-4} Torr to 10^{-10} Torr.

The typical arrangement of two gauges covering the range of interest between 10 and 1 x 10^{-9} Torr leaves a poorly covered band at pressures widely used in sputtering, etching, CVD, etc. Fortunately, the precise measurements needed between 10^{-1} and 10^{-3} Torr for reproducible processing can be made by adding a third gauge—the capacitance manometer.

When choosing a gauge, in addition to pressure range, other features should be considered: the gauge’s pumping speed; how it is affected by radiation, magnetism, temperature, vibration, and corrosive gases; and the damage caused by switching it on at atmospheric pressure. These subjects are discussed in comprehensive vacuum texts such as John F. O’Hanlon’s *A User’s Guide to Vacuum Technology* (see page 17-20 to order).

Vacuum Gauges

Mechanical Gauges

A gas’s pressure is the sum of all the individual forces caused by each atom or molecule colliding with a surface at any instant. Mechanical gauges register this total force by monitoring the surface’s movement against the (restoring) force trying to keep the surface in its original place. Because mechanical gauges respond to molecular momentum only, they measure pressures of any gas or vapor. They can be very accurate or inaccurate depending on how the movement is registered.

McLeod

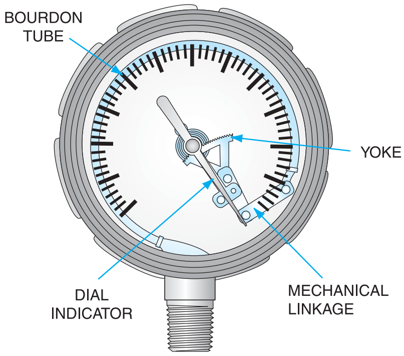
This gauge, though seldom used, is employed mostly as a primary calibration standard for other gauges. In effect, a large known volume of gas at unknown pressure is captured in a glass bulb and compressed by raising the mercury level until the gas is confined in a small, closed capillary of known volume. Because the ratio between the original and final volumes is known and the final pressure can be measured, the original pressure is calculated by Boyle’s law (P1 x V1 = P2 x V2). McLeod gauges are particularly useful in the 1 Torr to 10^{-4} Torr range but, because of the compression, cannot be used to measure vapors.

Bourdon

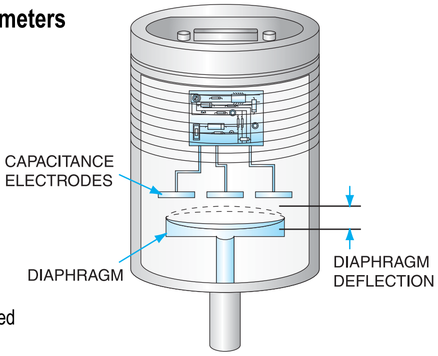
When a closed-end, curved, oval cross-section, copper alloy tube is connected to the vacuum, atmospheric pressure bends it to a greater or lesser degree, depending on the internal pressure. The mechanical force moves an indicator needle through a geared linkage. Bourdon gauges are used primarily in high-pressure measurement (most commonly attached to regulators on gas cylinders), but variations are built to indicate pressures from 0" Hg to 30" Hg and are used for freeze drying, “house” vacuum systems, vacuum impregnation, etc., where the major concern is whether vacuum exists rather than its accurate measurement.

Piezo

Piezo-resistive pressure sensors are typically comprised of a silicon wafer that is machined on a surface that makes the crystal into a suitable deflecting diaphragm when subjected to a normal stress (pressure). The thickness of the silicon crystal at its minimum section is the primary factor that determines the pressure range of the gauge from 1,500 to 0.1 Torr. As the diaphragm deflects under pressure, the resistances of the piezo-resistive elements change in value, causing the Wheatstone bridge network to move out of balance. Applying a voltage to this bridge produces an output voltage that is proportional to the applied pressure. If the elements are of equal resistance, there will be a zero output voltage with no pressure differential across the diaphragm.



Capacitance Manometers



The deflection of a thin metal diaphragm separating a known pressure from an unknown pressure is a measure of the pressure difference between the two volumes. In the capacitance manometer, as the name suggests the deflection is measured using the electrical capacitance between the diaphragm and some fixed electrodes. Capacitance manometers are the most accurate devices for measuring the differential or absolute pressure of all gases (including vapors that do not condense at the gauge's operating temperature).

Gauge heads are specified by their maximum measured pressure (25,000 Torr down to 1 x 10^{-1} Torr), with each head having a dynamic range of approximately 10^4 below that. Accuracies of 0.25% gauge reading are common, with 0.08% available from high-accuracy products.

All types of pressure gauges are affected by ambient temperature changes, but other error sources are so much larger that temperature is ignored. The capacitance manometer, by contrast, is so accurate that gauge-head temperature variation is a critical source of error. We strongly suggest that capacitance manometers be purchased only from reputable manufacturers who understand sources of error and demonstrate effective ways of counteracting them.

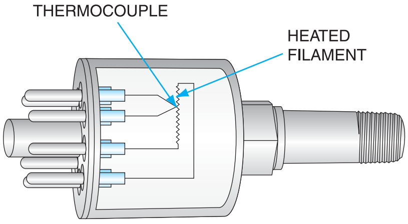
Diaphragm Manometers

Like the capacitance manometer, these gauges use the deflection of a thin metal (or silicon) diaphragm separating a known pressure from an unknown pressure. However, in this type of gauge, the deflection is sensed by a strain gauge attached to the diaphragm. While this limits the minimum measurable pressure to 1 Torr, it does provide a stable, repeatable, device reading pressures up to 1,200 Torr.

Gas Property Gauges

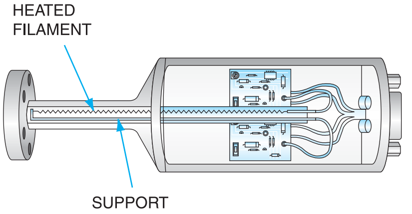
The thermal conductivity or viscosity value for each specific gas is different and varies non-linearly with pressure. Gas property gauges, presented with the typical vacuum chamber gases, are inaccurate. This, and numerous other inherent error sources, suggest the gauge readings are acceptable for noting repeating pressure events but of little use in measuring absolute pressures.

Thermocouple (T/C)



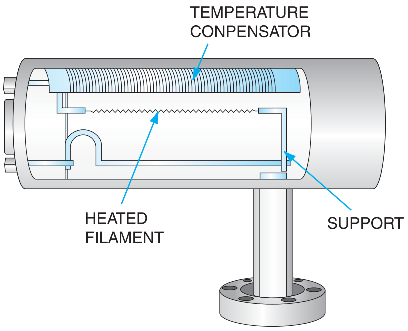
The pressure range between 10 Torr and 10^{-3} Torr is indicated by measuring the voltage of a thermocouple spot-welded to a heated filament exposed to system gas. The filament, fed from a constant current supply, reaches a temperature determined by the amount of energy extracted by the gas. At higher pressures, more molecules hit the filament and extract more energy than at low temperatures. The filament temperatures induce thermocouple voltage changes. These gauges are used extensively in foreline monitoring and to provide the signal to automatically switch the main chamber from backing and high-vacuum pumps at the crossover pressure.

Pirani



In a Pirani gauge, two filaments, often platinum, are used as two arms of a Wheatstone bridge. The reference filament is immersed in a fixed-gas pressure, while the measurement filament is exposed to the system gas. Both filaments are heated by the current through the bridge but, unlike most T/Cs, the Pirani gauge does not use constant voltage or power, but constant filament temperature. Gas molecules hitting the immersed element conduct energy away that is detected and replaced by the feedback circuit to the power supply. This variation of mechanism gives the Pirani gauge perhaps 100 times longer total pressure range (although the same dynamic range for each sensor head) and a faster response. The Pirani gauge is used in the same applications as the T/C gauge. Although the dynamic range for any single gauge matches the T/C, Pirani's cover a pressure range from about 10 Torr to 1 x 10^{-5} Torr.

Convection



This gauge's mechanism differs from that used in the T/C and Pirani gauges only by using a structure that enables the natural convection in (viscous flow) gases to aid in removing heat from the hot filament. Convection gauges measure pressures over the range from about 10 Torr to atmosphere.

Ionization Gauges

With relatively minor differences, all ionization gauges use the same principle. Energetic electrons ionize the residual gases—the positive ions are collected at an electrode and the current is converted to a pressure indication. Hot filament gauges (Bayard-Alpert, Schulz-Phelps) use thermionic emission of electrons from a hot wire, while cold cathode gauges (Penning, Inverted Magnetron) use electrons from a glow discharge or plasma.

All ion-gauge measurements are seriously affected by gas composition. For example, a report in J. Vac. Sci. Tech. indicates an ion gauge's relative sensitivity (relative to N_2 = 1) is 5 for acetone vapor and 0.18 for He. That is, the same absolute pressure of these pure (gaseous) materials will give a gauge indication differing by a factor of almost 28. Ionization gauges do not give accurate absolute pressure measurements unless recently calibrated with the exact gas mixture that is to be measured.

Sensitivity

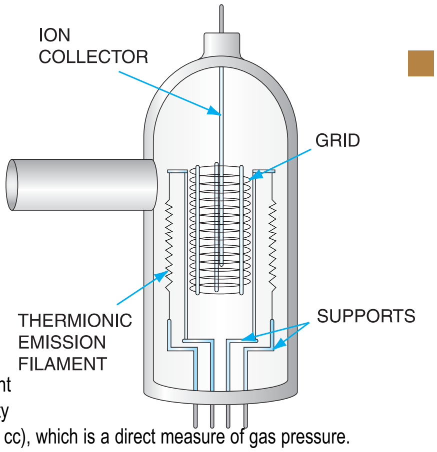
The term *relative sensitivity* used **above** should not be confused with the parameter called the "gauge sensitivity." The latter comes from the equation relating the gauge's positive ion current (i_p) for a given electron emission (i_e) at given gas pressure (P):

$i_p = S \times i_e \times P$ or $P = 1/S \times i_p/i_e$

The constant of proportionality (S in units of reciprocal pressure) is the "gauge sensitivity." Practical (hot filament) ion gauges have gauge sensitivities ranging from 0.6 $Torr^{-1}$ to 20 $Torr^{-1}$. This is important when selecting an ion gauge controller because the gauge's sensitivity must be within the controller's available range.

Hot Filament Gauges

The two common hot filament ion gauges, Bayard/Alpert (B-A) and Schulz-Phelps (S-P), differ only in the physical size and spacing of their electrodes. Both have heated filaments biased to give thermionic electrons of 70eV, energetic enough to ionize any residual gas molecules with which they collide. The positive ions formed move to an ion collector held at -150V. The current varies with the gas number density (the number of molecules in each cc), which is a direct measure of gas pressure.



Bayard-Alpert ion gauges have a reasonably linear response from 1 x 10^{-4} Torr to 1 x 10^{-9} Torr, with gauge sensitivities from 5 to 20 Torr^{-1}. B-A gauges are available with one or two filaments (the second acting as a spare) and with two filament materials thoria-coated iridium, used in oxygen-rich applications and for "burn-out" protection if accidentally vented and tungsten, used for lower cost and in residual gases containing halogens.

The standard B-A gauge measures down to 1 x 10^{-9} Torr. It does not go lower because primary electrons generate soft X-rays when they hit the grid. An X-ray hitting the ion collector electrode releases a photoelectron, which is indistinguishable from positive ions arriving there. Below 1 x 10^{-9} Torr, photoelectron emission is a large enough fraction of the ion current to distort the pressure reading. Special B-A structures with ultra-thin ion collectors will reach 10^{-10} Torr and perhaps even into the 10^{-11} Torr range.

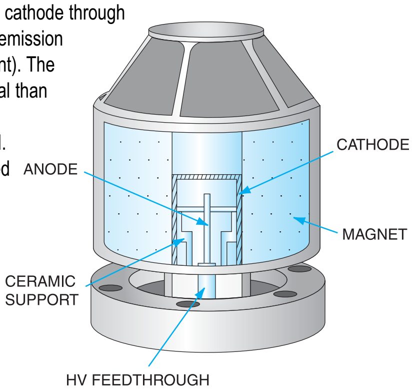
Cold Cathode Gauges

In the CCGs the ionizing electrons are part of a self-sustaining discharge. However, since the CCG has no (thermionic emission) filament, the discharge is initiated by stray field emission or external events (cosmic rays or radioactive decay). At low pressures, this can take minutes and CCGs are usually switched on at high pressure. Once started, the gauge's magnetic field constrain the electrons in helical paths, giving them long path lengths and a high probability of ionizing the residual gas. The ions are collected and measured to determine the gas pressure.

Many electrode geometries have been used—cylinders, plates, rings, rods, in various combinations with the magnetic field direction and strength chosen to maximize the measured current. If the gauge's central or "end" electrodes are negative, the convention is to call this a magnetron. If the same electrodes are positive, the gauge is called an inverted magnetron.

Magnetron: The initial Penning design (cylindrical anode and end plate cathodes) was neither precise nor accurate and it was replaced by other geometries. However, the name Penning is still used even for magnetrons with central wire or ring cathodes. The operating voltage is limited (typically to ~2kV) to avoid field emission effects that cause increases in the ion current unrelated to pressure. While the newer magnetron designs are satisfactory, they are limited to the top of the high vacuum range and attract little commercial attention.

Inverted Magnetron: Largely due to the development efforts of Redhead and his colleagues, this design works into the UHV pressure range. Its axial central anode enters the cylinder/end plates cathode through voltage guard rings (to prevent field emission affecting the ion current measurement). The anode carries a much higher potential than the normal magnetron (~6kV) and is parallel to the gauge's magnetic field. Some commercially available inverted magnetron designs have good linearity and operating characteristics down to 1 x 10^{-11} Torr. However, attempting to start one at such low pressures may take hours or days.



Residual Gas Analyzers

Special mass spectrometers designed to analyze gases remaining in a vacuum chamber are called residual gas analyzers or RGAs. The wealth of information about experimental or process conditions offered by an RGA makes a permanently attached unit a convenient, often necessary, diagnostic device.

Quadrupole RGAs, named for the four rods used in the mass filter section, are powered by mixed RF/DC voltages. Full operating details are beyond this text but are dealt with adequately in many books, such as Dawson's *Quadrupole Mass Spectrometry And Its Applications* and the AVS's monograph by Drinkwine, et al, *Partial Pressure Analyzers and Analysis*. The quadrupole analyzer (or sensor head) bolts to the vacuum system. It consists of an ionizer (ion source) connected to the mass filter, which in turn is attached to an ion detector, all mounted on a UHV flange (often a $2^{3}/_{4}$" O.D. CF) carrying the feedthroughs for power and signals. The combined RF/DC voltage is generated close to the sensor head. From here, only main power voltage and returning signal information connect to the control chassis and display or desktop PC. In the ionizer, neutral gas atoms and molecules are bombarded with 70eV electrons from a hot filament. The ionized species are extracted into the quadrupole, where only those ions with the appropriate mass-to-charge (m/e) ratio for the applied RF/DC voltages are transmitted. By varying the RF/DC voltage with time, the m/e ratios are scanned and the ion current at each mass is recorded as a spectrum.

Diagnosing vacuum problems with an RGA requires only a collection of fragmentation patterns from which the following may be quickly determined: the presence of air and water leaks; unacceptable levels of active gases such as O_2, H_2, and H_2O, pump oil backstreaming, the presence of Fl or Cl compounds; the regeneration requirements of a cryopump, and the purity of backfill gases. Because an RGA operates at or below 10^{-4} Torr, high-pressure processes are analyzed with the RGA installed in an auxiliary vacuum system, often a mobile cart moved to various vacuum stations.

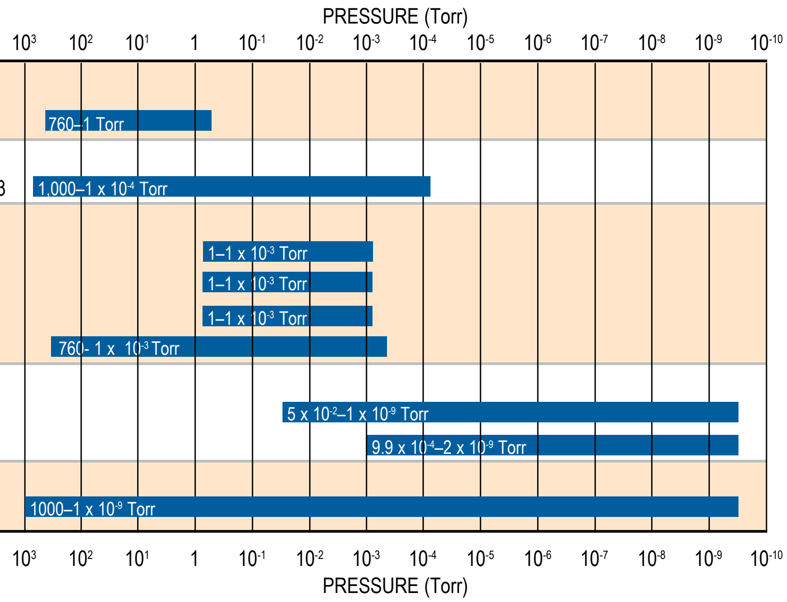
Leak Detectors

Leak detectors are mass spectrometers that detect only helium ions at m/e = 4. Because they are specific, they detect extremely small concentrations of helium in the presence of large quantities of other gases. As the name implies, these devices determine the presence of leaks and help locate them. Excellent leak detection instructions are available in Harris' book, Modern Vacuum Practice or available as part of our Lesker University curriculum (see page 16-12 for available training courses).

The chamber under test and the leak detector are connected via a vacuum-tight tube and the chamber is evacuated using the leak detector's own vacuum system. Helium is sprayed from a fine nozzle at the chamber's surface where it displaces the air diffusing through the leak only while the probe is directed at the leak's position. It is a common misconception that the pressure in the chamber must be low before leak testing can start. In fact, chamber pressures lower than 10^{-2} Torr are rarely needed. Once the leak detector inlet valve is fully open, further efforts to reduce pressure in the chamber only waste time. During one operator's 11-year leak-checking experience, for example, most leaks were detected while the leak detector's inlet valve was only partially cracked. Leaks larger than 1 x 10^{-5} atm cc/sec. are the most common—"some" leaks were in the 1 x 10^{-6} atm cc/sec. range, six leaks were in the 1 x 10^{-7} atm cc/sec. range, two in the 1 x 10^{-8} atm cc/sec. range, and only one in the 1 x 10^{-9} atm cc/sec range. Because most leak detectors have a minimum detectable leak rate of 1 x 10^{-10} atm cc/sec., detection sensitivity is rarely a problem for locating real leaks.

Gauge Selection Guide

	PAGES	PRESSURE (Torr)
■ BOURDON (DIAL)		
KJLC BDG	7-6	760–1 Torr
■ CONVECTION		
KJLC Convectron® Equivalent Series	7-12 to 7-13	1,000–1 x 10^{-4} Torr
■ THERMOCOUPLE		
KJLC 205 with KJLC 6000 Tube	7-19	1–1 x 10^{-3} Torr
KJLC 610T with KJLC 6000 Tube	7-19	1–1 x 10^{-3} Torr
KJLC 500TC with KJLC 6000 Tube	7-20	1–1 x 10^{-3} Torr
KJLC510TC with Varian 531 Tube	7-20	760- 1 x 10^{-3} Torr
■ HOT CATHODE/IONIZATION		
KJLC 354	7-23	5 x 10^{-2}–1 x 10^{-9} Torr
KJLC 2200	7-25	9.9 x 10^{-4}–2 x 10^{-9} Torr
■ WIDE-RANGE COMBINATION		
KJLC 392 with KJLC CONVECTION Tube	7-36	1000–1 x 10^{-9} Torr



➤ 760–1 Torr

KJLC® BDG Series

Our liquid-filled bourdon vacuum gauges are industrial-grade dial gauges suitable for pressures down to 1 Torr (mbar).

Features:

- Bourdon tube constructed of phosphor bronze
- Corrosion- and impact-resistant, industrial-grade Zytel nylon case
- Removable Zytel nylon bezel design for easy calibration
- Large $2^1/_2$" dial and non-yellowing clear glycerin fill for readability
- Internal "breathing diaphragm" and diaphragm seal:
  - —Virtually eliminates the air bubble in the mid-range of the gauge for improved readability
  - —Prevents freezing, clogging, and corrosion of gauge
  - —Compensates for temperature
- Brass $^1/_4$" NPT male stem-style connection
- 3 major pressure measurement systems available:
  - —Torr, mbar, and in. Hg

Gauges

Description	Termination	Dial Size	Pressure Units	Part No.	Price
Liquid-Filled Bourdon Gauge	$^1/_4$" NPT Male	$2^1/_2$"	Torr	KJLDGTORR	**Call**
Liquid-Filled Bourdon Gauge	$^1/_4$" NPT Male	$2^1/_2$"	mbar	KJLDGMBAR	**Call**
Liquid-Filled Bourdon Gauge	$^1/_4$" NPT Male	$2^1/_2$"	in Hg	KJLDGINHG	**Call**

Gauge Accessories

Description	Part No.	Price
KF16 to $^1/_4$" Female NPT Adapter	QF16XFNPT4	**Call**
KF25 to $^1/_4$" Female NPT Adapter	QF25XFNPT4	**Call**
KF40 to $^1/_4$" Female NPT Adapter	QF40XFNPT4	**Call**
KF50 to $^1/_4$" Female NPT Adapter	QF50XFNPT4	**Call**
Viton® Centering Ring for KF16 Flange	QF16-075-SRV	**Call**
Clamp for KF16 Flange	QF16-075-C	**Call**
Viton Centering Ring for KF25 Flange	QF25-100-SRV	**Call**
Clamp for KF25 Flange	QF25-100-C	**Call**
Viton Centering Ring for KF40 Flange	QF40-150-SRV	**Call**
Clamp for KF40 Flange	QF40-150-C	**Call**
Viton Centering Ring for KF50 Flange	QF50-200-SRV	**Call**
Clamp for KF50 Flange	QF50-200-C	**Call**

➤ 1,000–1 x 10^{-4} Torr

➤ 1–1 x 10^{-3} Torr

KJLC™ 205 Series

These economical controllers are noted for their fast response and high stability.

KJL-205

- Economical analog display
- Offer an easy, accurate calibration procedure with dry air
- Can be operated on any voltage between 90 and 240 VAC without rewiring or switching
- Available in panel-mount and benchtop-mount versions (both are compatible with the KJL-6000 or DV-6 series tubes)
- Models with 3-position switch feature monitors 3 tubes sequentially
- Includes a 10’ sensor cable, a 6’ line cord, and one KJL-6000 tube ($^{1}/_{8}$” NPT male)

KJL-205BM

SPECIFICATIONS

Pressure Range — 1 to 1,000 mTorr
Accuracy — ± 1 m Torr (1–20 mTorr), 5% of Reading (20–1000 mTorr)
Response Time — < 1.0 sec
Power — 90–240 VAC, 50/60 Hz
Display — Analog
Analog Output — 0–5 VDC
Compatible T/C Gauge Tubes — KJL-6000, DV-6R, DV-6M
Mounting — Panel or Benchtop
Set Points — None
Temperature: Operating — 4–60° C
Temperature: Bakeout — 100° C

Description	Part No.	Price
KJLC 205 Panel-Mount Gauge Controller with (1) KJL-6000 Gauge Tube	KJL-205	Call
KJLC 205 Bench-Mount Gauge Controller with (1) KJL-6000 Gauge Tube	KJL-205BM	Call
KJLC 205 Bench-Mount Gauge Controller with 3-Tube Switch & (1) KJL-6000 Gauge Tube	KJL-205BM3X	Call
KJLC 205 Panel-Mount Gauge Controller (only)	KJL-205NT	Call
Replacement KJLC Thermocouple Gauge Tube		
$^{1}/_{8}$” NPT	KJL-6000	Call
$^{1}/_{8}$” NPT (rugged enclosure)	KJL-6000R	Call
1$^{3}/_{4}$” CF	KJL-6000MC	Call
KF16	KJL-6000QF16	Call
VCR® 4 Female	KJL-6000VCR4	Call
Replacement Thermocouple Interconnect Cable Extension (15 ft.)	KJL-200EC15	Call

➤ 20–1 x 10^{-3} Torr

KJLC® 510TC Series

Battery Operated,Wide Range Digital Vacuum Instrumentation measuring in mTorr, mBar and kPa

Each vacuum gauge includes:

- A vacuum gauge controller
- A thermocouple vacuum gauge tube (vacuum sensor)
- A cable to connect the vacuum gauge controller to the thermocouple vacuum gauge tube
- Pre-tested under actual vacuum against a NIST standard

SPECIFICATIONS

Pressure Range —
.001-760 Torr with Varian 531
1-1999 mtorr with KJL-6000 or DV-6

Units — Torr, mBar or kPa

Vac Interface — 1/8 inch MNPT

Sensor — Varian 531, Hastings DV-6M, or KJL6000

Sensor Cable Length — 10 feet

Display — .70 inch high 3.5 Digit LCD display

Dimensions — 2.37" high, 5.12" wide, 5.25" deep

Power — "D" Battery

NOTE: Sensor type must be chosen at time of ordering.

Description	Part No.	Price
KJLC510TC Package Configured for Varian 531 Tubes	KJL510TC-V	**Call**
KJLC510TC Package Configured for KJLC6000 Tubes	KJL510TC-K	**Call**
KJLC510TC Package Configured for Hastings DV-6M Tubes	KJL510TC-H	**Call**

KJLC® Thermocouple Tubes

Our KJL-6000 thermocouple gauge tube is a direct, plug-in replacement (pin-outs, electrical specifications, and operating characteristics) for the commonly used DV-6 gauge.

KJL-6000 Thermocouple Advantages:

- All-metal construction with no fragile plastic headers and breakable plastic keys
- Rugged drop-resistant design withstands an 8’ drop to a hard floor
- Integral stainless steel screen prevents particles from damaging gauge elements
- Lifetime guarantee against leaks (leaking tubes are replaced free of charge)

OEM Cross-Reference & Ordering Chart

We identify 7 types of thermocouple tubes that are not interchangeable because of:

- Pin-out differences
- Electrical specifications
- Operating characteristics

Each sensor tube type must be connected to the correct gauge controller or indicator to give sensible pressure readings. Some resellers of gauge tubes have a number of tubes with identical specifications but, to the confusion of the customer, identify them with different part numbers. The cross-reference/replacement chart (at right) matches our tubes with those from other manufacturers and resellers.

To ensure successful measurement, always match the controller to the specific gauge tubes that were built for it.

Manufacturer	OEM Part No.	KJLC Part No.	Price
Cooke Vacuum	HTT-O	KJL-1518	**Call**
CTI	8080015K003	KJL-6000VCR4	**Call**
CVC Products	GTC-004	KJL-1504	**Call**
	GTC-036	KJL-0036	**Call**
D & W Industries	DW880-003	KJL-1504	**Call**
Frederick’s Televac	(No KJLC equivalent — use OEM tubes)		
Teledyne Hastings Raydist	DV-3M	KJL-1000	**Call**
	DV-6M	KJL-6000	**Call**
	DV-6R	KJL-6000R	**Call**
JC Controls	DV-6M	KJL-6000	**Call**
Stokes	MB-3M	KJL-1000	**Call**
Temescal	DV-6M	KJL-6000	**Call**
Thermionics	6343	KJL-1518	**Call**
	6343/004	KJL-1504	**Call**
Varian	0531-F0472-301	KJL-5311	**Call**
	0531-F0472-303	KJL-531S	**Call**

Teledyne Hastings Raydist Thermocouple Tubes

Frederick’s Televac Thermocouple Tubes

These tubes are well known in the vacuum industry by their part numbers (we stock and sell these company’s tubes under their part numbering schemes).

Description	Part No.	Price
Thermocouple Gauge Tube		
$^{1}/_{8}$” NPT	DV-3M	**Call**
$^{1}/_{8}$” NPT	DV-4D	**Call**
$^{1}/_{8}$” NPT	DV-4R	**Call**
$^{1}/_{8}$” NPT	DV-5M	**Call**
$^{1}/_{8}$” NPT	DV-6M	**Call**
$^{1}/_{8}$” NPT	DV-23	**Call**
$^{1}/_{8}$” NPT	DV-24	**Call**
$^{1}/_{8}$” NPT	DV-6R	**Call**

Description	Part No.	Price
Thermocouple Gauge Tube		
$^{1}/_{8}$” NPT	TE2100-10	**Call**
$^{1}/_{8}$” NPT	TE2100-11	**Call**
$^{1}/_{8}$” NPT	TE2100-14	**Call**
$^{1}/_{8}$” NPT	TE2100-37	**Call**

➤ Convection & Thermocouple

■ Thermocouple

KJL610TC

KJL6000QF16

Gauge Tube Type	Description	Manufacturer	Part No.	Price
Thermocouple				
	Gauge Tube, 1/8" NPT	Hastings Raydist®	DV-23	Call
	Gauge Tube, 1/8" NPT	Hastings Raydist	DV-24	Call
	Gauge Tube, 1/8" NPT	Hastings Raydist	DV-3M	Call
	Gauge Tube, 1/8" NPT	Hastings Raydist	DV-4D	Call
	Gauge Tube, 1/8" NPT	Hastings Raydist	DV-5M	Call
	Gauge Tube, 1/8" NPT	Hastings Raydist	DV-6M	Call
	Gauge Tube, 1/8" NPT	KJLC	KJL-0036	Call
	Gauge Tube, 1/8" NPT	KJLC	KJL-1000	Call
	Gauge Tube, 1/8" NPT	KJLC	KJL-1504	Call
	Gauge Tube, 1/8" NPT	KJLC	KJL-1518	Call
	Gauge Tube, 1/8" NPT	KJLC	KJL-5311	Call
	Gauge Tube, 1/8" NPT	KJLC	KJL-531S	Call
	Gauge Tube, 1/8" NPT	KJLC	KJL-6000	Call
	Gauge Tube, 1.33" CF Flange	KJLC	KJL-6000MC	Call
	Gauge Tube, QF 16	KJLC	KJL-6000QF16	Call
	Gauge Tube, VCR 4 (Female)	KJLC	KJL-6000VCR4	Call
	Gauge Tube, 1/8" NPT	Frederick's Televac®	TE2100-10	Call
	Gauge Tube, 1/8" NPT	Frederick's Televac	TE2100-11	Call
	Gauge Tube, 1/8" NPT	Frederick's Televac	TE2100-14	Call
	Gauge Tube, 1/8" NPT	Frederick's Televac	TE2100-37	Call

➤ 5 x 10^{-2}–1 x 10^{-9} Torr

KJLC 354

A miniature dual filament ionization gauge with built in controller and display.

Features:

- Wide measurement range 5 x 10^{-2}–1 x 10^{-9} Torr
- Built-in controller and display eliminates the need for expensive external controllers and cabling
- Pre-programmed, selectable calibration to 16 widely used gases
- Dual hot filament design, rugged and compact metal construction
- A direct drop-in plug-and-play replacement for the Granville Phillips Micro-Ion module
- Field serviceable—the sensor assembly can be easily replaced

SPECIFICATIONS

Pressure Range —
1 x 10^{-9} to 5 x 10^{-2} Torr
(1.33 x 10^{-9} to 6.66 x 10^{-2} mbar)

Display — 3 digits plus 2 digit exponent

Materials Exposed to Gases —
Dual Filaments: Yttria Coated Iridium,
Ion Collector: Tungsten, Grid: Tantalum,
Others: 316/304 SS, Glass, Nickel

X Ray Limit — <5 x 10^{-10} Torr

Accuracy (Typical) — ±20% of Reading
1 x 10^{-8} to 5 x 10^{-2} Torr

Emission Current — 100 uA, 4 mA,
or automatic switching between
100 uA and 4 mA

Degas — 3 Watts e-beam

Overpressure Protection — Gauge turns off
at factory default setting of
5 x 10^{-2} Torr

Bakeout Temperature — 200° C
(sensor only - electronics removed)

Mounting Orientation — Any

Digital Interface — RS-485

Output signal (analog output) —
Log-linear 0 to 9 VDC, 1V/decade

Input Power — 20 to 28 VDC, 13 W

RF/EMI Protection — CE marked

Set-Point Relays — 1 SPDT Relay

Relay Contact Rating — 1A at 30 Vdc
resistive, 0.3 A at 125 Vac non-inductive

Set-Point Range — User configurable from
1 x 10^{-9} to 5 x 10^{-2}

Description	Part No.	Price
NW16KF	KJLC354401YB	**Call**
NW25KF	KJLC354401YC	**Call**
NW40KF	KJLC354401YD	**Call**
1 ⅓” / NW16CF Mini- Conflat®	KJLC354401YE	**Call**
2 ¾” CF / NW35CF Conflat®	KJLC354401YF	**Call**

Replacement Sensors and Accessories

Description	Flange Type	Part No.	Price
Replacement Sensor	NW16KF	IG4YB	**Call**
Replacement Sensor	NW25KF	IG4YC	**Call**
Replacement Sensor	NW40KF	IG4YD	**Call**
Replacement Sensor	1⅓” CF	IG4YE	**Call**
Replacement Sensor	2¾” CF	IG4YF	**Call**
Power supply - 24 VDC, US plug	Any	PS501A	**Call**
International Power Supply 100-240V, 50/60Hz,US, EU, UK, and AU plug ends included	Any	PS-DB9F-ION	**Call**

➤ 9.9 x 10^{-4}–2 x 10^{-9} Torr

KJLC® 2200 Series

A convenient, low-cost gauge controller for single Bayard-Alpert ion gauges, suitable for either tubulated or nude gauge tubes.

- Front panel access to all operating functions, including four set points for system control
- RS-232 interface
- Adjustments for sensitivity and emission
- Ability to measure pressure during the degas cycle
- Includes 6' power cord, accessory connector kit, rackmounting ears, and instruction manual

NOTE: Ion gauge tube and cable must be ordered separately.

WARRANTY: We're so confident in the quality and performance of our 2200 Series controller that it comes with a standard 3-year warranty!

SPECIFICATIONS

Pressure Range — 2.0 x 10^{-9} to 9.9 x 10^{-4} Torr
Ion Gauge Type — Bayard-Alpert
Sensitivity — 1 to 80/Torr (adjustable)
Emission Current — 1 to 20 mA (adjustable)
Set Points
  Number — 4 SPST
  Range — Full range
  Rating — 3A @ 100VAC
Ion Gauge Tubes
  Type — Hot filament
  Degas — Resistive
  Degas Timer — 1–60 min. (adjustable)
Operating Temperature — 0–50° C
Communications — RS-232 9-pin data port
Dimensions — 3.5" x 8" x 10.5"
Input Voltage — 110 or 220 VAC 50/60 Hz, factory set

Gauge Controllers & Accessories

Description	Part No.	Price
KJLC 2200 Series Ion Gauge Controller		
115 VAC	KJL2200	**Call**
220 VAC	KJL2200-220	**Call**
Glass Gauge Tube Interconnect Cable (10 ft.)	KJLIGC10G	**Call**
Nude Gauge Tube Interconnect Cable (10 ft.)	KJLIGC10N	**Call**
Nude Ion Gauge Tube (2.75" CF/ThO-Ir filament)	G8120	**Call**
Tubulated Ion Gauge Tube		
1" O.D. Nonex tube/ThO-Ir filament	G100N	**Call**
1" O.D. Kovar tube/ThO-Ir filament	G100K	**Call**
2.75" CF flange/ThO-Ir filament	G100F	**Call**

ORDERING NOTE: The KJLC 2200 is designed for gauge tubes requiring resistive degas (such as tube part number G8120). Do not use with nude ion gauge tubes requiring e-beam degas.

Hot Filament (Ionization)

Hot Filament (Ionization)

Legend:
G = Grid
F_1, F_2 = Filament
F_C = Filament Common
C = Ion Collector

Figure 1

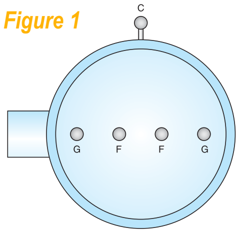


Figure 2

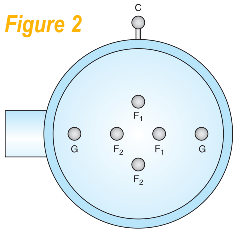


Figure 3

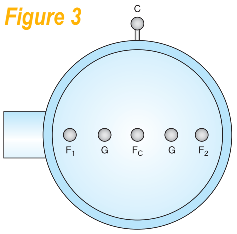


Figure 4

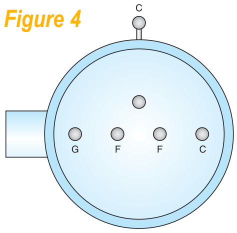


Figure 5

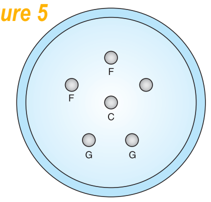
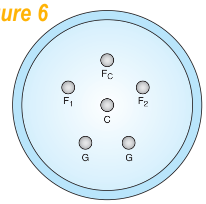


Figure 6



G100F

G075N

G8120

G8130

G100K

Gauge Tube Type	Figure	Description	Manufacturer	Part No.	Price
B-A Ion, Flanged					
	1	Gauge Tube, 2.75" CF, 1 x ThO-Ir filament, $^3/_4$" O.D., 10 Torr-1 sensitivity	KJLC	G075F	**Call**
	1	Gauge Tube, 2.75" CF, 1 x ThO-Ir filament, 1.0" O.D., 10 Torr-1 sensitivity	KJLC	G100F	**Call**
	1	Gauge Tube, 2.75" CF, 1 x ThO-Ir filament, 1.0" O.D., 10 Torr-1 sensitivity	KJLC	G100F-PT	**Call**
	1	Gauge Tube, QF-25, 1 x ThO-Ir filament, 1.0" O.D., 10 Torr-1 sensitivity	KJLC	G100KQF25	**Call**
	1	Gauge Tube, QF-40, 1 x ThO-Ir filament, 1.0" O.D., 10 Torr-1 sensitivity	KJLC	G100KQF40	**Call**
	2	Gauge Tube, 2.75" CF, 2 x W filament, 1.0" O.D., 12.5 Torr-1 sensitivity	KJLC	G100TF	**Call**
	4	Gauge Tube, 2.75" CF, 1 x ThO-Ir filament, 1.0" O.D., 8 Torr-1 sensitivity	KJLC	GX100-564F	**Call**
B-A Ion, Nude					
	5	Gauge Tube, 1 x ThO-Ir filament, 10 Torr-1 sensitivity	KJLC	G8120	**Call**
	6	Gauge Tube, 2 x ThO-Irq filament, 25 Torr-1 sensitivity	KJLC	G8130	**Call**
	6	Gauge Tube, 2 x W filament, 25 Torr-1 sensitivity	KJLC	G8130T	**Call**
	5	Gauge Tube, 1 x ThO-Ir filament, 10 Torr-1 sensitivity	KJLC	G8140	**Call**
	6	Gauge Tube, 2 x ThO-Ir filament, 10 Torr-1 sensitivity	KJLC	G8140-DI	**Call**
	N/A	Gauge Tube, 2 x W filament, 14 Torr-1 sensitivity	VG	VZVIG17	**Call**
	N/A	Gauge Tube, 2 x ThO-Ir filament, 14 Torr-1 sensitivity	VG	VZVIG18	**Call**
	N/A	Gauge Tube, 2 x W filament, 12.7 Torr-1 sensitivity	VG	VZVIG22	**Call**
	N/A	Gauge Tube, 2 x ThO-Ir filament, 12.7 Torr-1 sensitivity	VG	VZVIG24	**Call**
B-A Ion, Tubulated					
	1	Gauge Tube, Kovar®, 1 x ThO-Ir filament, $^3/_4$" O.D., 10 Torr-1 sensitivity	KJLC	G075K	**Call**
	1	Gauge Tube, Kovar, 1 x ThO-Ir filament, $^3/_4$" O.D., 10 Torr-1 sensitivity	KJLC	G075K-PT	**Call**
	1	Gauge Tube, Nonex®, 1 x ThO-Ir filament, $^3/_4$" O.D., 10 Torr-1 sensitivity	KJLC	G075N	**Call**
	2	Gauge Tube, Kovar, 2 x W filament, $^3/_4$" O.D., 12.5 Torr-1 sensitivity	KJLC	G075TK	**Call**
	1	Gauge Tube, Kovar, 1 x ThO-Ir filament, 1.0” O.D., 10 Torr-1 sensitivity	KJLC	G100K	**Call**
	1	Gauge Tube, Kovar, 1 x ThO-Ir filament, 1.0” O.D., 10 Torr-1 sensitivity	KJLC	G100K-PT	**Call**
	1	Gauge Tube, Nonex, 1 x ThO-Ir filament, 1.0” O.D., 10 Torr-1 sensitivity	KJLC	G100N	**Call**
	1	Gauge Tube, Nonex, 1 x ThO-Ir filament, 1.0” O.D., 10 Torr-1 sensitivity	KJLC	G100N-PT	**Call**
	2	Gauge Tube, Kovar, 2 x W filament, 1.0” O.D., 12.5 Torr-1 sensitivity	KJLC	G100TK	**Call**
	3	Gauge Tube, 7052, 2 x W filament, $^1/_2$" O.D., 12.5 Torr-1 sensitivity	KJLC	GX050-015-2	**Call**
	3	Gauge Tube, 7052, 2 x W filament, $^3/_4$" O.D., 12.5 Torr-1 sensitivity	KJLC	GX075-016-2	**Call**
	3	Gauge Tube, Pyrex, 2 x W filament, $^3/_4$" O.D., 12.5 Torr-1 sensitivity	KJLC	GX075-016-P	**Call**
	3	Gauge Tube, 7052, 2 x W filament, 1.0” O.D., 12.5 Torr-1 sensitivity	KJLC	GX100-017-2	**Call**
	4	Gauge Tube, Kovar, 1 x ThO-Ir filament, 1.0” O.D., 7.5 Torr-1 sensitivity	KJLC	GX100-564K	**Call**
	4	Gauge Tube, Nonex, 1 x ThO-Ir filament, 1.0” O.D., 7.5 Torr-1 sensitivity	KJLC	GX100-564N	**Call**

➤ OEM Cross-Reference

G8120

G8130

G100F

G100K

G075N

Replacement Ion Gauge Tubes

OEM	OEM Part No.	Style	Part No.	Price
CHA	IG-100-K	B-A, Tubulated	G075K	Call
CHA	IG-100-N	B-A, Tubulated	G075N	Call
CHA	IG-100-P	B-A, Tubulated	G075N	Call
CHA	IG-101-K	B-A, Tubulated	G100K	Call
CHA	IG-101-N	B-A, Tubulated	G100N	Call
CHA	IG-101-P	B-A, Tubulated	G075N	Call
CHA	IGT-100K	B-A, Tubulated	G075TK	Call
CHA	IGT-100N	B-A, Tubulated	G075TN	Call
CHA	IGT-100P	B-A, Tubulated	G075TN	Call
Cooke Vac	BA60K	B-A, Tubulated	G075K	Call
Cooke Vac	BA60KF	B-A, Flanged	G100F	Call
Cooke Vac	BA60N	B-A, Tubulated	G075N	Call
Cooke Vac	BA60P	B-A, Tubulated	G075N	Call
Cooke Vac	BA61KF	B-A, Flanged	G100F	Call
Cooke Vac	BA61KT	B-A, Tubulated	G100TK	Call
Cooke Vac	BA61N	B-A, Tubulated	G100N	Call
Cooke Vac	BA61P	B-A, Tubulated	G075N	Call
Cooke Vac	GA61PT	B-A, Tubulated	G100TN	Call
CVC	GIC-015-2	B-A, Tubulated	GX050-015-2	Call
CVC	GIC-016-2	B-A, Tubulated	GX075-016-2	Call
CVC	GIC-017-2	B-A, Tubulated	GX100-017-2	Call
G-Phillips	274002	B-A, Tubulated	G075N	Call
G-Phillips	274003	B-A, Tubulated	G075K	Call
G-Phillips	274005	B-A, Tubulated	G075N	Call
G-Phillips	274006	B-A, Tubulated	G100K	Call
G-Phillips	274007	B-A, Flanged	G075F	Call
G-Phillips	274008	B-A, Flanged	G100F	Call
G-Phillips	274012	B-A, Tubulated	G075TN	Call
G-Phillips	274013	B-A, Tubulated	G075TK	Call
G-Phillips	274015	B-A, Tubulated	G100TN	Call
G-Phillips	274016	B-A, Tubulated	G100TK	Call
G-Phillips	274022	B-A, Nude	G8130T	Call
G-Phillips	274023	B-A, Nude	G8130	Call
G-Phillips	274028	B-A, Nude	G8140	Call
Huntington	IK-100	B-A, Tubulated	G075K	Call
Huntington	IK-100-F	B-A, Flanged	G075F	Call
Huntington	IK-150	B-A, Tubulated	G100K	Call
Huntington	IK-150-F	B-A, Flanged	G100F	Call
Huntington	IN-100	B-A, Tubulated	G075N	Call
Huntington	IN-150	B-A, Tubulated	G100N	Call
Huntington	IP-100	B-A, Tubulated	G075N	Call
Huntington	IP-150	B-A, Tubulated	G075N	Call
Huntington	TK-100	B-A, Tubulated	G075TK	Call
Huntington	TK-150	B-A, Tubulated	G100TK	Call
Huntington	TP-150	B-A, Tubulated	G100TN	Call
Leybold	850-675-G1	B-A, Tubulated	G075K	Call
Leybold	850-675-G3	B-A, Tubulated	G075TK	Call
Leybold	850-675-G4	B-A, Tubulated	G100TK	Call
Leybold	850-675-G5	B-A, Flanged	G100F	Call
MKS	IG-1	B-A, Tubulated	G075K	Call
MKS	IG-2	B-A, Tubulated	G100K	Call
MKS	IG-4	B-A, Flanged	G100F	Call
MKS	IG-5	B-A, Nude	G8140	Call
MKS	IG-6	B-A, Tubulated	G100K-PT	Call
MKS	IG-7	B-A, Tubulated	G100F-PT	Call
Perkin-Elmer	605-7000	B-A, Tubulated	G075N	Call
Perkin-Elmer	605-7152	B-A, Flanged	G100F	Call
Perkin-Elmer	605-76726	B-A, Nude	G8130	Call
Perkin-Elmer	605-7673	B-A, Nude	G8130T	Call
Sloan	67035	B-A, Tubulated	G075K	Call
Temescal	924A	B-A, Tubulated	G075K-PT	Call
Temescal	924B	B-A, Tubulated	G100K-PT	Call
Torr	IG4336KI	B-A, Tubulated	G075K	Call
Torr	IG4336NI	B-A, Tubulated	G075N	Call
Torr	IG4336NI	B-A, Tubulated	G075N	Call
Varian	0563-K2466-301	B-A, Tubulated	G100N-PT	Call
Varian	0563-K2466-302	B-A, Tubulated	G100K-PT	Call
Varian	0563-K2466-303	B-A, Tubulated	G100F-PT	Call
Varian	0563-K2466-304	B-A, Tubulated	G100N-PT	Call
Varian	0563-K2466-305	B-A, Tubulated	G075K-PT	Call
Varian	0564-K2500-301	B-A, Tubulated	GX100-564N	Call
Varian	0564-K2500-302	B-A, Tubulated	GX100-564K	Call
Varian	0564-K2500-303	B-A, Tubulated	GX100-564F	Call
Varian	0571-K2471-301	B-A, Tubulated	G100N	Call
Varian	0571-K2471-302	B-A, Tubulated	G100K	Call
Varian	0571-K2471-303	B-A, Flanged	G100F	Call
Varian	0571-K2471-304	B-A, Tubulated	G075N	Call
Varian	0571-K2471-305	B-A, Tubulated	G075K	Call
Varian	0572-K7360-301	B-A, Tubulated	G100TN	Call
Veeco	RG-100K	B-A, Tubulated	G100K	Call
Veeco	RG-100N	B-A, Tubulated	G100N	Call
Veeco	RG-100P	B-A, Tubulated	G075N	Call
Veeco	RG-75K	B-A, Tubulated	G075K	Call
Veeco	RG-75N	B-A, Tubulated	G075N	Call
Veeco	RG-75P	B-A, Tubulated	G075N	Call
Veeco	TG-100K	B-A, Tubulated	G100TK	Call
Veeco	TG-100N	B-A, Tubulated	G100TN	Call
Veeco	TG-100P	B-A, Tubulated	G100TN	Call
Veeco	TG-75K	B-A, Tubulated	G075TK	Call
Veeco	TG-75N	B-A, Tubulated	G075TN	Call
Veeco	TG-75P	B-A, Tubulated	G075TN	Call
VG	VIG17	B-A, Nude	VZVIG17	Call
VG	VIG18	B-A, Nude	VZVIG18	Call
VG	VIG22	B-A, Nude	VZVIG22	Call
VG	VIG24	B-A, Nude	VZVIG24	Call

1,000–1 x 10^{-9} Torr

KJLC 392

The KJLC 392 is our KJLC 392 Ionization gauge with the ability to control and display two convection gauges.

Features:

- Full measurement range from atmosphere down to 1 x 10^{-9} Torr plus monitoring of your foreline
- Built in controller and display eliminates the need for expensive external controllers and cabling
- Dual Hot Filament design, rugged and compact metal construction
- Field serviceable - the sensor assembly can be easily replaced

SPECIFICATIONS

Pressure Range —
Ionization: 1 x 10^{-9} to 5 x 10^{-2} Torr
(1.33 x 10^{-9} to 6.66 x 10^{-2} mbar)
Convection: 1 x 10^{-4} to 1000 Torr
(1.33 x 10^{-4} to 1333 mbar)
Used as a full range measurement gauge: 1 x 10^{-9} to 1000 Torr
(1.33 x 10^{-9} to 1333 mbar)

Display — OLED graphical display, 3 digits plus 2-digit exponent, bright yellow

Functionality — Ionization gauge can operate up to 2 Convection gauges

Materials Exposed to Gases — Dual Filaments: Yttria Coated Iridium, Ion Collector: Tungsten, Grid: Tantalum, Others: 316/304 SS, Glass, Nickel

Accuracy (Typical) —
Ionization: ±20% of Reading from 1 x 10^{-8} to 5 x 10^{-2} Torr
Convection: ±10% of Reading from 1 x 10^{-3} to 400 Torr; ±2.5% of Reading from 400 Torr to atm

Sensitivity — Factory pre-set. Also user adjustable between 2 to 99.

X Ray Limit — <5 x 10^{-10} Torr

Emission Current — 0.1, 4 mA

Degas — 4 Watts e-beam

Overpressure Protection — Gauge turns off at factory default setting of 5 x 10^{-2} Torr

Bakeout Temperature — 200º C (sensor only - electronics removed)

Mounting Orientation — Any

Digital Interface — RS485

Convection Gauge Compatibility — KJLC275 Tube or Granville Phillips 275 Convectron®

Convection Gauge Cables — One 10 foot cable is included. See order info below for additional gauge cables.

Analog Output —
Ionization Only: One log-linear 0 to 9 Vdc, 1 V/decade, semi-log
Used as a full range gauge: One 0.5 to 7 Vdc, ,0.5 V/decade, semi-log
Convection Gauge 1 & 2: Two 1-8 Vdc, 1 V/decade, semi-log

Set-Point Relays — 3 SPDT Relays

Relay Contact Rating — 1A at 30 Vdc resistive, 0.3 A at 125 Vac non-inductive

Set-Point Range — User configuration from 1 x 10^{-9} Torr to atmosphere when used with a Convection gauge

Description	Part No.	Price
NW16KF	KJLC392402YB	**Call**
NW25KF	KJLC392402YC	**Call**
NW40KF	KJLC392402YD	**Call**
1 ⅓” CF / NW16CF Mini- Conflat®	KJLC392402YE	**Call**
2 ¾” CF / NW35CF Conflat®	KJLC392402YF	**Call**

Replacement Sensors and Accessories

Description	Part No.	Price
Replacement Sensor, QF16 flange	IG4TB	**Call**
Replacement Sensor, QF25 flange	IG4TC	**Call**
Replacement Sensor, QF40	IG4YD	**Call**
Replacement Sensor, 1 ⅓” CF	IG4YE	**Call**
Replacement Sensor, 2 ¾” CF	IG4YF	**Call**
Convectron Gauge Cable, 10 ft.	HB431-1-10F	**Call**
Convectron Gauge Cable, 25 ft.	HB431-1-25F	**Call**
Convectron Gauge Cable, 50 ft.	HB431-1-50F	**Call**
Power Supply - 24 VDC, US plug	PS501A	**Call**
International Power Supply 100-240V, 50/60Hz,US, EU, UK, and AU plug ends included	PS-DB9F-ION	**Call**