Flange Systems Overview

When planning a new vacuum chamber, the designer should compare all the flange designs available and choose that which:

- Matches the vacuum conditions required
- Matches the temperature conditions required
- Is unaffected by the process’s starting materials or products
- Matches OEM fittings and components added to the system
- Is easiest to use in that particular system
- Has the lowest total costs

But note, the CF and ISO/KF types are so convenient, low cost, and widely available that they predominate in practical vacuum systems. Mixing flange types using adapters is possible but not recommended unless necessary to match existing components or fittings. However, using one flange type for chamber-mounted components and another for foreline components is common practice.

CF Flanges

The CF flange (originally called ConFlat) is a sexless design—both flanges are identical. Typical flange materials are austenitic stainless steel types 304L, 316L, 316LN, and surfaced-hardened aluminum (made from a weldable Al alloy). The seal mechanism is a knife-edge that is machined below the flange’s flat surface. As the bolts of a flange-pair are tightened, the knife-edges make annular grooves on each side of a soft metal gasket. The extruded metal fills all the machining marks and surface defects in the flange, yielding a leak-tight seal (Figure 1). The CF seal operates from 760 Torr (1013 mbar) to <1 x 10^-13 Torr (<1.3 x 10^-13 mbar), and within the temperature range -196º C to 450º C. Flange sizes in North America (NA) are determined by outside diameter (O.D.). In Europe and much of Asia (E/A), the internal diameter (I.D.)—actually the nominal I.D. of the largest tube that can be welded to a bored flange—is used. The NA sizes are: 1½" (‘mini’), 2½”, 4¼”, 6”, 8”, 10”, 12”, 13½”, 14” and 16½” O.D. The E/A sizes are digits (representing the nominal bore in mm) prefixed with either DN or NW (depending on manufacturer): DN16, DN40, DN63, DN100, DN160, DN200, and DN250. In addition, the NA system has intermediate O.D. sizes to enable the use of “standard” inch dimension tubes. They are 2/4” (1” diameter tube), 3/4” (2”), 4/4” (3”), 6/4” (5”). For other dimensions, see the ordering tables in this catalog.

CF flanges (with identical O.D.s up to 10” inclusive) from different (reputable) manufacturers will almost certainly seal. The vacuum equipment industry adheres to the de facto ConFlat standard.

CF flanges are offered in four distinct versions or combinations thereof:

- Fixed flange (Figure 2): once welded to a fitting, it has its bolt-hole orientation fixed with respect to that fitting.
- Rotatable flange (Figure 3): when welded to a fitting, it enables the bolt-hole ring to rotate.
- Through-hole flange: indicates a mating flange-pair accepts bolts that go through both flanges and is secured by nuts or plate nuts.
- Tapped flange: connected to a through-hole flange using only bolts. Vacuum components with a rough axis of symmetry—e.g., a gate valve—can have fixed CF flanges welded with the bolt holes either split by the axis or in-line with the axis. Regrettably, NA has adopted the former and E/A the latter as standards.

What are Flanges?

In vacuum technology, flanges are semi-permanent connections to join parts that:

(a) are frequently or occasionally disassembled;
(b) are light enough to be moved with available equipment; or
(c) cannot be welded due to heat sensitivity or replacement needs (e.g., valves, pumps, or gauges).

There are many flange designs:

- Formal standards (e.g., ISO, KF/QF/NW, ASA/ANSI flanges)
- De facto standards (e.g., CF/ConFlat® flanges)
- Some are best described as conforming to manufacturer’s standards (wire-seal flanges and ASA—as adapted for vacuum use), that is, two flanges from one manufacturer will mate, but may not if from different manufacturers.

Commonly used flange designs have a soft gasket squeezed between harder flange surfaces to form a leak-free seal. The various gasket materials are rubbers, elastomers (springy polymers), soft polymers covering a springy metal (e.g., PTFE covered stainless steel), and soft metal (copper or aluminum). Each flange design has merits.
Flange Systems Overview

Positive Pressures
When discussing system pressures, a common question is: What is the maximum internal pressure? Positive pressures are inherently dangerous and failure comes without warning. In a vacuum system, failure depends on various strength properties of bolts, clamps, chamber walls, welds, feedthroughs, valves, viewports, etc. The only safe answer is that the internal absolute pressure cannot exceed the external absolute pressure.

CF Flange Gaskets
The gasket material sealing two flanges determines the joint’s maximum temperature and, to an extent, the base pressure of the vacuum volume. Metal gaskets are impermeable to gases and withstand moderately high temperatures indefinitely. The normal gaskets for stainless steel CF flanges are punched from 1/4-hard, high-purity, oxygen-free (OFHC) copper stock, chemically cleaned and finished to be scratch- and burr-free.

Bolting the flanges together causes the CF’s knife-edges to deform the gasket. Under plastic flow, the copper fills in the knife-edges’ imperfections and, in doing so, work-hardens—inducing the “springy” characteristics that keep the seal, even as the knife-edges are cycled from -196° C to 450° C.

Given a correctly cleaned, baked, and pumped CF-flanged chamber, metal gaskets enable base pressures below 1 x 10^-13 Torr (1.3 x 10^-13 mbar). The work-hardening aspect means metal gaskets are one-time use only. There is strong anecdotal evidence that baking to 550° C for prolonged periods partially anneals the copper from its work-hardened state, since the joints will leak on cooling. When mounting fragile flanged components—e.g., viewports—fully annealed copper gaskets are recommended.

For systems requiring frequent high-temperature bakeouts, silver-plated copper gaskets are recommended. Without the plating, copper oxide forms on parts of the gasket exposed to air. It may flake into the chamber during flange disassembly. Aluminum CF flanges must use aluminum gaskets—never copper. However, aluminum gaskets can be used on stainless steel CF flanges if baking is restricted to 200° C.

CF Flange Hardware
Regular nuts and bolts are not suitable for CF flange applications. Various high-tensile strength nut/bolt combinations made from low magnetic permeability, 18-8 stainless steel are used.

It is strongly recommended that all bolt, nut, plate-nut combinations are lubricated, either by one component being silver-plated or the application of a suitable thread lubricant on page 1-56.

Hex Head
Hex-head bolts (socket hex head for the mini flange) are long enough to penetrate two (through-hole) flanges and leave sufficient length for washers, nuts, or plate-nuts. For tapped and blind-tapped flanges, a shorter bolt length is used that does not penetrate the tapped flange or bottom out in a blind-tapped flange.

12-Point
Where high temperature bakeouts and frequent reassemblies are needed, (dry lubricated) 12-point cap screws are the best choice. Note that cap screws do not require special wrenches—the appropriate sized 12-point socket or flat wrench suffices.

Metric
Tapped metric flanges must use metric bolts. While through-hole flanges (built to metric specifications) will accept inch or metric nuts/bolts, it is strongly recommended that, for vacuum systems containing some tapped metric fittings, all nuts and bolts have metric threads.

Studs and Threaded Rods
This hardware is used to:
- Connect double-sided flanges
- Make bolts “emerge” from blind-tapped flanges
- Mount protective plastic covers over glass viewports

Both inch and metric threads are available for these and most other components.

Plate Nuts
These are metal plates with two threaded holes, shaped to match the corresponding CF flange’s bolt hole patterns and replace the individual nuts (Figure 4). The plate nut’s major advantage is, once two bolts are manually started, the plate nut acts as its own backing wrench and washer—the bolts are tightened using one wrench.
Wire Seal Flanges

Wire seal flanges are sexed—with male/female flanges forming a mating pair that captures an OFHC copper "o-ring" gasket under extreme compression. The material of choice is 304L stainless although 316L stainless may be available as a custom material.

The flanges’ design constrains the gasket’s flow to form a seal between them. Wire seal flanges can be used over the same temperature/pressure ranges as CF flanges. They are used where tube dimensions exceed those of standard CF flanges.

There are three types:
- Bored ring flanges
- Flat blank flanges
- Domed blank flanges

The last uses a thin gauge spherical cap to blank off a ring flange—a considerable weight-saving device, compared to the flat blank flange. Manufacturers used the flange’s nominal O.D. to define the size.

While wire seal designs are similar among manufacturers, it is unlikely that a male flange from one manufacturer will match a female flange from another.

KF (QF) Flanges

KF flanges (Figure 6A) are a sexless design—made from 304L or 316L stainless, aluminum, or brass. The seal is a rubber/elastomeric o-ring mounted in a centering ring, which aligns the flanges and holds the o-ring in position.

Each flange has a chamfered back-surface and is mated by a circumferential clamp (Figure 6B) tightened by wing-nut, thumbscrew, bolt, or over-center lever.

KF flanges are limited (by the o-ring’s properties) to applications with temperatures between ~0° C and 120–180° C, and pressure from atmosphere to ~10⁻¹⁰ Torr or mbar.

The name KF (for Klein Flansche) was adopted by ISO, DIN, and Pneurop standards organizations. It is also called QF, NW, and occasionally, DN.
**ISO Flanges**

ISO flanges (also called Large ISO) have a sexless design and are made from 304L stainless or aluminum.

The design principles of ISO and KF seals are identical. Each flange face is counter-bored or grooved to receive a metal centering ring with an elastomeric o-ring around its O.D. As with KF, the ISO centering ring both aligns the flanges and holds the o-ring in place. However, because the larger diameter ISO o-ring is more likely to “roll off,” a spring-loaded retainer holds it externally. ISO flanges are limited (by the o-ring’s properties) to applications with temperatures between ~0° C and 120–180° C, and pressure from atmosphere to ~10^-8 Torr or mbar.

ISO flanges are universally sized by the nominal I.D. (in, mm) of the largest tube that can be welded to the flange. The standard sizes are: 63, 80, 100, 160, 200, 250, 320, 400, 500, and 630.

**ISO-K** flanges are convenient and have the smallest flange O.D. for any given tube I.D. The ISO-K offers greater strength when used as a structural element.

A variety of bolt/clamp options permit joints between mixed ISO-K and -F flanges. The illustrations (Figures 7A–7D) show various possible clamping arrangements.

**Two flange "styles":**

- ISO-K flanges (Figure 8): use separate clamps placed around the flange’s periphery
- ISO-F flanges (Figure 9): use conventional bolt holes and nuts/bolts

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**Figure 7A:** ISO Double Clamp Nipple Assembly

**Figure 7B:** ISO Bolt Nipple Assembly

**Figure 7C:** ISO Single Clamp/Bolt Nipple Assembly

**Figure 7D:** ISO Bolt Ring Nipple Assembly

**Figure 8:** ISO100 K-Style Flange & Hardware

**Figure 9:** ISO63 “F” & “K” Style Flanges
Flange Systems Overview

ASA Flanges
ASA flanges, adapted decades ago from 150# steam-pipe flanges, are simple, sexed vacuum seals—one flange is grooved to accept an o-ring (Figure 10) while the mating flange is smooth. They are made from 304L stainless or a weldable aluminum alloy.

ASA flanges are limited (by the o-ring’s properties) to applications with temperatures between ~0° C and 120-180° C and pressure from atmosphere to ~10^-2 Torr or mbar. The poorer vacuum level than other o-ring systems is suggested because ASA flanges are frequently larger in diameter and therefore have a larger gas load from permeation.

These flanges are sized by the connecting pipe’s nominal I.D. in inches. The normal range is: 1”, 1.5”, 2”, 3”, 4”, 6”, 8”, and 10”, although some manufacturers make sizes up to 36”. They have large diameter bolt holes through the rim—a legacy from positive pressure uses. Consequently, for any given tube diameter, ASA flanges have much larger O.D.s than other flange types. The adaptation and adjustment to suit vacuum conditions led to a deterioration of standards.

For example:
(a) “Large bore” flanges, introduced to increase gas conductance, may have a larger I.D. than the o-ring groove in normal bore flanges.
(b) Bolt holes are sometimes reduced in diameter, causing confusion when bolting flanges together.

As with any sexed flange type, additional issues arise when mating two flanges of the same sex. Here, if the mating pair both have o-ring grooves of identical I.D.s, a thin metal ring is placed between them. If both flanges are smooth, o-rings molded into carriers are installed.

When buying ASA flanged fittings and components, always compare dimensions carefully. When purchasing flanges to mate to an existing item, have that item’s flange O.D., I.D., number of bolt holes, bolt circle diameter, and the handy o-ring groove I.D. for quick reference.

Elastomeric Gaskets for KF, ISO, & ASA
Elastomeric gaskets, often o-rings of circular cross-section, are convenient, easy-to-use vacuum seals. With flange surface finishes of 32 rms or better, compressing the o-ring by 25% to 35% will form a vacuum seal that should be easily compatible with 10^-3 Torr or mbar and, with better design/preparation, perhaps 10^-4 Torr or mbar.

The drawbacks are the elastomer’s gas permeability, outgassing rate, and limited temperature compatibility. At elevated temperatures (but well below those causing pyrolysis), elastomeric gaskets have greatly increased permeation rates and have their sealing characteristics slowly compromised by compression set and lack of sealing force retention.

Compression set is the permanent deformation an o-ring exhibits when released from a flange seal. Sealing force retention is a measure of the elastomer’s resilience when held under a constant compressive force.

The debate about greasing o-rings is ongoing. Typically, the same vacuum level can be achieved with or without grease. However, when not using grease, the o-ring must be dust- and fiber-free, and the metal surfaces touching the o-ring must have at least a 32 rms finish. Grease permits sealing in less pristine conditions. Greasing o-rings that will reach high temperatures is not recommended. Most greases have a significant vapor pressure at ~200° C and almost certainly a grease film will form on every surface of a baked system.

The elastomeric materials most commonly used in vacuum seals are Buna-N (nitrite rubber-NBR), silicone, fluorocarbon (e.g., Viton-FKM), and perfluorocarbon (e.g., Kalrez and Chemraz—FFKM). The specific properties depend on the compounding, the inert materials mixed with the pure elastomer to give it acceptable mechanical properties, and the cross-linking agent used to “cure” it.

The general properties of o-rings made from these materials are:

Buna-N
- Least expensive o-ring
- Maximum operating temperature of ~100° C
- Permeation rate for water vapor ~20 times that of Viton
- Its chemical properties roughly match natural rubber and is just as readily attacked by ozone
- Must not be used in any O₂ plasma process
- Shelf-life is one year, but shorter if stored, or used, near an ozone source such as an electric motor with brushes

Silicone
- It is commonly thought that silicone has good high temperature characteristics; however, tests on one unspecified silicone rubber compound by DuPont Dow Elastomers indicate a compression set of 87% and a sealing force retention of ~80% after 70 hours at 204° C. In prolonged high temperature operation, much anecdotal evidence points to silicone losing its resilience, hardening, and sticking to the flange surfaces, making replacement difficult. Silicone’s permeation for water vapor is extremely high, ~200 times that of Viton®.

Viton
- Most commonly used elastomer in vacuum service
- Reasonably low gas permeability (except for helium, which is double that of Buna-N)
- Good performance at high temperatures. The upper temperature limit depends on the compounding with 180° C to 200° C being cited.

DuPont Dow Elastomers tests on Viton indicate a compression set of ~50%, and a sealing force retention of ~80% after 70 hours at 204° C.

Kalrez
Kalrez® and Chemraz® o-rings have the best high temperature performance. DuPont Dow Elastomers tests on o-rings made from a particular Kalrez compound showed a compression set of ~50%, and a sealing force retention of ~80% after 672 hours at 204° C. After 672 hours at 250° C, the compression set is still only ~63%.

Using Elastomeric Seals
When designing or specifying o-ring vacuum seals, some guidelines are:

- A double o-ring seal is no better than a single o-ring if the volume between the two o-rings is not differentially pumped.
- The surface finish of metal parts mating to the o-ring is critical. Scratches on the metal (or glass) that cross from the air-side to the vacuum-side of the o-ring’s footprint will cause leaks.
- Before installing o-rings, they should be vacuum baked (without compression). This greatly improves outgassing characteristics.
- Greasing o-rings: Purists tend to avoid it. Pragmatists tend to use it, claiming surface finishes on metal mating to the o-rings are frequently too scratched or rough to support the purist view.
- Do not apply grease with a bare fingertip. Use polyethylene gloves to handle the rings and apply the grease. Apply only the thinnest film possible.
- Choose the grease carefully. Consider its vapor pressure at the joint’s temperature, and whether it will liquefy and “surface creep” into the chamber.

After 672 hours at 250° C, the compression set is still only ~63%.
Flanged Components & Fittings

Fittings
Vacuum fittings are, essentially, conveniently shaped, flanged devices that can be assembled into complete vacuum envelopes.

While nominally identical fittings from different manufacturers will be similar, there may be small length differences. Where possible, vacuum systems should be designed so they are insensitive to small length changes.

The common construction materials for fittings are 304 stainless and aluminum; however, fittings may be available in 316 stainless.

The pressure and temperature range of any fitting is dictated by the construction material and the flange type. For example, a 304L stainless fitting with CF flanges and copper gaskets is compatible with \(<1 \times 10^{-13}\) Torr \((<1.3 \times 10^{-13}\) mbar) and 450°C. An aluminum fitting with fluorocarbon gaskets is compatible with \(~10^{-4}\) Torr or mbar and \~180°C.

Many types of fittings—full nipples, elbows, 4-way cross, etc.—have one or more identifiable “axis” (a line normal to the flange surface through the tube’s center line).

Flanges using bolts (CF and ASA) might have bolt-hole alignment problems with mating fittings or components. To avoid this, one flange on each axis is made rotatable—a full nipple (1 axis) has one rotatable flange, an elbow (2 axes) has two rotatable flanges, and a 4-way cross (2 axes) has two rotatable flanges, one on each axis.

Figure 11: CF Flanged Half Nipple

Figure 12: CF Flanged Full Nipple

Figure 13: 90º CF Flanged Radius Elbow

Figure 14: 90º CF Flanged Mitered Elbow

Figure 15: CF Flanged Tee

Figure 16: CF Flanged 6-Way Cross

Names of Fittings

Half-Nipple
- A length of tube with a flange on one end (Figure 11)

Full-Nipple
- A length of tube with flanges welded to both ends (Figure 12)

Elbows
- Essentially, nipples “bent” through 45° or 90° (when the bend is 180°, the fitting is called a return)
- They are either radius (Figure 13) or miter (Figure 14)

It is commonly believed that the gas conductance of a radius elbow is higher than a miter elbow of the same I.D. While true in continuum and transitional flow regimes, in molecular flow they have identical conductances.

Tees
- Shaped as the name suggests (Figure 15)
- In the standard tee fitting, all three flanges are identical sizes
- In the reducer tee fitting, the two flanges on the “run” are identical while the tube (and flange) on the “branch” has a smaller bore

Crosses and Cubes
- Available in standard forms as 4-, 5-, and 6-way (Figure 16). Other forms can be custom-made to include many more than 6 entry ports or different flanges sizes on different arms of the cross
- A cube starts as a solid metal block from which the cross is machined
- Cubes are particularly useful when a short distance between flange face and the cross’s center point is important
Adapters Flanges and Gas Fittings

Transitions between one flange size and another size within the same flange type are called reducers, not adapters. Adapters make transitions between:

- One flange type and another (e.g., ISO to ASA for mounting an ASA-flanged component, Figure 17)
- One flange type to a non-flanged vacuum seal (e.g.,KF to quick connect for mounting a tubulated ion gauge, Figure 18)
- One flange type to a small diameter gas tube fitting for gas inlet (e.g., CF to Cajon for connecting a gas supply line to the chamber for sputter process gas, Figure 19)
- One flange type to NPT thread (e.g.,KF to NPT for mounting a T/C gauge, Figure 20)

In all adapters, the transition length is made as short as possible to minimize the reduction in gas conductance.

Rubber Tube

Rubber tube is very susceptible to vacuum collapse and an internal spiral wire is recommended. However, this is not a complete solution because the spiral can slip and “flatten,” particularly where the tube length exceeds 12” (30 cm).

Plastic Tube

The commonly used plastic tube, polyvinyl chloride (PVC), is not naturally flexible. It is made so by adding a liquid organic plasticizer, usually dinonylphthalate. The presence of this plasticizer limits the ultimate pressure inside the PVC tube and, together with its permeability, confines its use to forelines.

As with rubber, PVC needs internal reinforcement to avoid collapse when evacuated. Fortunately, PVC tubes are available with spiral wire molded into the plastic. Standard length tubes can also be purchased with metal half-nipples already mounted. When mounting to metal tubes, use radiator or hose clamps to secure the PVC tube. Never bake PVC.

Stainless Steel Tube

For rigid tubes, the most commonly used material is 304L stainless steel. It accepts a high internal finish, has good welding properties, is impermeable, and can be outgassed by baking to 450°C—making it UHV compatible.

Its disadvantage is that compared to the flexible tubes noted at left, it requires special skills and welding equipment to install it.

Cautions and Recommendations when Using Rubber Tube

- Tubeing manufacturers often powder the tube’s internal surfaces. To avoid pump damage, remove the powder completely. The preferred method is to find an outdoor concrete pad, blow compressed air through one end of the tube while “whacking” the other against the pad, reverse the blow-in end and “whack” the other.
- Do not use water as lubricant when stretching rubber over an oversized metal tube. This exacerbates the tube’s already bad outgassing. Use a little hydrocarbon vacuum grease.
- Rubber in tension is very susceptible to cracking from ozone attack. Anecdotally, that is particularly true of rubber stretched over copper tube.
- Use radiator or hose clips to clamp rubber tube to metal.
- Do not attempt to bake a rubber tube! At best, the facility will stink of released sulphur compounds.
Bellows and Hoses

While not everyone agrees, short, wide I.D., flexible metal "tubes" are often called bellows, while long, smaller I.D., flexible metal tubes are often called hoses. Here, all such devices are called bellows. Flexibility is built into a metal "tube" by making its thin wall in the form of an accordion or concertina.

There are two methods:

Hydraulically Formed Bellows (HFBs)

These are made by pressurizing water inside a thin-wall tube mounted inside a die with a concertina surface. HFBs have restricted flexibility and are far from "floppy." They are used in applications requiring a semi-permanent change of direction or a rugged design. They are often used as foreline connections or to join manifolds to rough pumps.

Edge-Welded Bellows (EWBs)

A stack of thin punched diaphragms are sequentially welded around the inner and then the outer circumferences. EWIs are much more flexible than HFBs, enabling some motion in X- and Y-directions, in addition to a large motion in the (axial) Z-direction.

They are more easily damaged and must be rigidly supported at the ends to prevent complete collapse on evacuation. If used horizontally, they may need central support. They are used on manipulation devices requiring X, Y, and Z motion. If not significantly bent, the gas conductance of either type of bellows is about the same as a rigid tube of equal I.D. and length.

Wide bore bellows are often proposed as vibration isolation devices between a pump and chamber. However, under vacuum a bellows contracts, often to its minimum possible length. It then acts like a rigid tube with minimal vibration isolation. Any degree of vibration isolation requires some elastomeric component—for instance, rubber blocks—between the flanges to restrict the bellows' collapse. Shortening under vacuum applies to all bellows and, if not recognized, can lead to premature failure.

A KJLC® salesman was present at a customer's facility while a 0.75” I.D. bellows between the chamber and mechanical pump was being replaced by a 1.5” I.D. bellows. When the pump was restarted, the customer's technician shouted, in awe, "The pump's levitating!" Indeed, the pump (which weighed less than the ~26 pounds force being applied) was 3” above the floor.
**Glass-to-Metal Seals & Viewports**

**Cautions when Using GM Seals**

- Where glass is the transition between two fixed metal points in a vacuum system, anneal the glass after all parts are clamped in position. The smallest misalignment may cause the glass to shatter under the additional stress of evacuation.

- Do not use a metal bellows GM seal as a substitute for the annealing. Under vacuum, all bellows contract—which puts the glass and metal joint under considerable tension and frequently causes failure.

- For safety, cover the line-of-sight between GM seals and people with a suitably thick, transparent rigid plastic (Lexan®) to stop glass particles that may be released if an implosion or explosion occurs.

**Glass-to-Metal Seals**

Glass-to-metal (GM) seals are joints between metal and glass tubes. They are often used to observe a process or to provide electrical isolation.

Typically, the metal tube-end is terminated in a variety of standard vacuum flanges.

For a GM seal to work, the coefficients of thermal expansion (CTE) of the glass and metal must match, as in the Kovar-to-7052 glass combination. Where the required tube materials have non-matching CTEs, as in SS-to-7740 Pyrex® or SS-to-quartz, the seal is called mismatched. To form a mismatched seal, a graded glass seal is formed by fusing together many rings of glass, each with slightly different expansions. The graded seal’s one end almost matches the Pyrex (or quartz) expansion coefficient, while the other end almost matches stainless steel. Both matched and mismatched seals have proven reliable in vacuum service if correctly used.

The metal tube GM seals are constructed in the following forms:

- glass tube—metal tube
- glass dome end—metal tube
- glass tube—metal bellows tube
- glass tube—metal tube—glass tube
- metal tube—glass tube—metal tube
- metal bellows—glass tube—metal bellows

**Viewports**

Viewports are windows installed on vacuum chambers to transmit electromagnetic radiation from ultraviolet, through visible, to infrared—depending on the window material used.

Some of their applications are to:

- Let the operator view a process
- Initiate chemical or physical action using specific wavelengths
- Make measurements of emissions occurring in a process
- Monitor the effects of specific wavelengths, e.g., ellipsometry

Two basic designs:

**Zero Length Viewports**

- Have a greater field-of-view than top-hat models
- Less subject to accidental damage because the window does not protrude beyond the flange face

**Top-Hat Viewports**

- Do protrude, but undergo less stress during bolt tightening and chamber heating

All viewports are fragile and should be handled and mounted with extreme caution. Always make small adjustments. For example, when securing a bolted viewport, finger tighten all bolts and then, following the normal pattern for the flange, tighten each bolt no more than a 1/16 turn using a wrench.

For CF flanges, make sure the gasket is a fully annealed type.

Never scratch the viewing area—a weakened viewport may implode (or explode under wrong conditions). Where the viewport is for looking at the process, cover it externally with a thick Lexan disc. Replace three flange bolts with threaded rods and mount the Lexan on those.

Make sure special material viewports are protected from conditions that affect them. For example, protect alkyl halide viewports from water vapor; AgCl from visible light; or MgF2 from high temperature.

Do not subject viewports to rapid temperature changes or gradients. Opinions vary about maximum heating rate, but there is no penalty for being cautious and using the lowest quoted heating rate of ~2° C/minute. If a viewport is heated at the flange rim, cover it with layers of aluminum foil before bakeout to reduce temperature gradients.

It is critical to observe the caution noted in the sidebar on **positive pressures**. Any chamber equipped with a viewport must not be subject to a positive internal pressure.

Make sure the “glass” chosen has a reasonable transmission at the wavelengths of interest. And remember, what is not transmitted may be reflected or absorbed. That is, the viewport material may be heated by absorption.

In addition, where film deposition may obscure the viewport, use a shutter mechanism.

**Positive Pressures**

When discussing system pressures, a common question is: What is the maximum internal pressure?

Positive pressures are inherently dangerous and failure comes without warning. In a vacuum system, failure depends on various strength properties of bolts, clamps, chamber walls, welds, feedthroughs, valves, viewports, etc. The only safe answer is the internal absolute pressure cannot exceed the external absolute pressure.