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Vacuum-Systems I: Flanges and Seals

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Overview:

Many modern physics experiments require a very low pressure environment, commonly referred to as a vacuum. At its most basic level, a vacuum requires four things: a vessel to hold it in (the vacuum and the experiment); a pump to remove the air from the vessel; an appropriately-sealed tube between the two; and gauges for measuring the quality of the vacuum. This video covers the chambers and seals, with particular emphasis on forming a vacuum-tight seal with two commercial standards, KF/QF and ConFlat.

Principles:

Vacuum chambers must be connected to pumps via airtight tubes,. Various gand gauges, windows, and auxiliary chambers are often part of the experimental design, as well. All of these connections must be made airtight, and a considerable industry has risen to meet these needs. Two types of flange connections widely used follow the KF/QF and ConFlat standards. Both of these are compression fittings, and both require certain techniques to make an airtight seal. This video demonstrates the proper technique to accomplish this task.

Commented [AM1]: What are the structural/material requirements for the components used in low pressure environments?

KF/QF stands for "Klein Flansche/Quick Flange," which is a designation set, along with the dimensional standards, by the International Standards Organization (ISO). It is a compression fitting with an elastomeric gasket (o-ring), ~~usually made from either Buna or Viton,~~ a separate centering ring to hold the shape of the gasket, and a clamp to provide the compression (**Figure 1**). Sizes are designated by the inner diameter of the flange in millimeters. For example, KF16 means ISO KF/QF standard with a 16-mm nominal inner diameter, and this size specifies the dimensions of the flange, gasket, centering ring, and clamp. The five common sizes are KF10, KF16, KF25, KF40, and KF50. Hardware from different sizes usually can't be mixed. A KF16 flange requires a KF16 gasket, a KF16 clamp, etc.

Commented [AM2]: Are these the two most common materials? Do they have generic names? What is the material?

How do you select which o-ring is appropriate for your system? What are the limitations of these?

ConFlat is a registered trademark of Varian, Inc., and other manufacturers who make hardware compatible with that standard often use the term CF in reference to it. The design is similar to that of KF/QF, but in ConFlat, the gasket is made from copper. The seal is made by two sharp rims that bite into the gasket (**Figure 2**). This makes for a seal that can withstand higher temperatures than KF/QF, allowing the chamber to be baked out after assembly, but it also means the gaskets can only be used once. If the seal is opened, a new gasket must be used when the system is put back together.

ConFlat sizes are designated in North America by the flange outer diameter in inches, with common sizes being 1.33", 2.75", 4.50", 6.00", 8.00" and 10.00". In

Europe and Asia, the designation is by tube inner diameter in millimeters. Conveniently, the parts are interchangeable between the metric and English standards, so American 1.33” hardware can be mixed with Asian or European 16-mm hardware with impunity.

Flanges cannot be thrown together and expected to work properly. To get an airtight seal, the operator must follow certain practices for both assembly and cleanliness, or contamination control, which we will describe in this video. A contaminated or improperly-assembled seal leaks and is a common cause of inability to attain design pressures in vacuum systems.

Commented [AM3]: What are some examples of these common practices?

Procedure:

1. Clamp assembly using KF/QF o-rings:

   1.1. Lay the o-ring and its clamp on a clean surface, and inspect the threads on the clamp, verifying that the condition is good enough to allow the nut to be tightened.

   Commented [AM4]: Do you inspect the o-ring before using? What should the viewer look for when inspecting a new or used o-ring?

   ~~1.1.~~1.2. Inspect the o-ring itself. It should be clean ~~and~~, dry, and free from cracks, scratches, or other deformities.

   ~~1.2.~~1.3. Using a Kimwipe soaked in isopropanol, clean the inner surfaces of the flange and the elastomer o-ring, along with its centering ring.

   ~~1.3.~~1.4. Using gloved hands, place the dry o-ring between the two halves of the flange. If the flange and gasket are both in good condition, there should be no need to apply any sort of grease or sealant.

   ~~1.4.~~1.5. Wrap the clamp around the flange, engage the pivoting bolt in its slot, and tighten the nut to finger-tight. The flange is now sealed.

   ~~1.5.~~1.6. Another type of clamp uses a lever to close, rather than a bolt and nut. If using this method, adjust the tension before closing the clamp, instead of after.

2. Clamp assembly using ConFlat o-rings:

   2.1. Lay out all the required bolts on a clean surface, and place a small dab of anti-seize lubricant on the start of the threads of each bolt. This lubricant both eases assembly and disassembly by preventing “seizing,” i.e. the nut fusing to the bolt either by rusting or cold welding.

   Commented [AM5]: What is the purpose of the lubricant?

   2.2. Using a Kimwipe soaked in isopropanol, clean the ConFlat copper gasket and both inner sides (knife edges) of the flange. Inspect all surfaces for dust, hairs, wire, etc., and remove any that escape cleaning.

2.3. Place the gasket on the knife edge on the inner side of one flange.

2.4. Place the second side of the flange over the gasket, and adjust its position until it settles in, engaging with the gasket on both sides.

2.5. Rotate the flange until the small slots in the edges line up.

2.6. Insert two bolts approximately 180° from each other, and tighten the nuts. This keeps the gasket in place while freeing up both hands to insert the remaining bolts.

2.7. Insert the remaining bolts, and tighten all the respective nuts to finger-tight.

2.8. Use a wrench to tighten the bolt at 12:00 by approximately ¼ of a turn.

2.9. Tighten the 6:00 bolt by ¼ of a turn.

2.10. Tighten the 3:00 bolt by ¼ of a turn.

2.11. Tighten the 9:00 bolt by ¼ of a turn.

2.12. Tighten the 12:30 bolt by ¼ of a turn.

2.13. Tighten the 6:30 bolt by ¼ of a turn, then the 3:30, followed by the 6:30 bolts.

2.14. Follow this pattern around the flange until the gap between the two halves of the flange closes completely.

3. Inspect the finished seal. There should be no daylight visible in the gap, and it should not be possible to insert a piece of paper between the two halves of the flange. If tightening the bolts begins to get difficult before the gap closes, tighten by only $^1/_8$ of a turn, rather than ¼. The flange is now sealed.

~~2.14.~~3.1. The final test of all seals is the base pressure of the system when under vacuum. The most common source of leaks in a newly-assembled system is an improperly-assembled flange, and if the system fails to achieve a base pressure at least in the 1e-6 torr range, that is the first thing that should be suspected.

Results:

Properly-assembled seals do not leak, at least not at a level detectable in typical applications. Of course, there are limits. KF/QF seals are typically rated to approximately 1e-8 torr and are often used in forelines, the tube connecting the roughing or backing pump to the high-vacuum pump. A ConFlat seal should be good down to 1e-13 torr, if it is properly cleaned and baked. The copper gaskets in a conflat seal are rated to most temperatures commonly used in bakeouts, 100° to 200° C. KF/QF seals, however, should not be baked, as high temperatures will distort or destroy the elastomeric o-rings.

Seals are not something that should command the attention of a good experimentalist, once they are installed. However, if they're badly done, they can be a source of seemingly infinite headaches to the experimenter (e.g., tracking down leaks). If it's done right the first time, it saves a lot of grief later on.

Applications:

As mentioned above, KF/QF seals are used most often in relatively-undemanding vacuum applications where the pressure does not need to go below 1e-8 torr. This includes forelines, as well as a large number of run-of-the-mill, condensed-matter and optics experiments that are performed at room temperature.

At pressures lower than 1e-8 torr, and at temperatures very different from room temperature (in heated or cryogenic experiments, for example) the elastomer o-ring in a KF/QF fitting is inadequate, and a ConFlat fitting is more appropriate.

Legend:

Figure 1 Exploded view of the components of a KF/QF seal.
(Image courtesy of HyVac Products, Inc.)

Figure ~~3~~2: ~~Cutaway view of an assembled~~A ConFlat flange~~. Pressure is provided by bolts in this case, which drive knife edges into the copper gasket, forming the seal~~ with its copper gasket.
(Image courtesy of sev-vacuum.com.)

Commented [AM6]: What are the temperature ranges for these types of o-rings?

How do you test for proper installation?

Commented [AM7]: We typically aim to provide footage for three applications to the topic using some footage from past JoVE articles or from newly filmed applications. Do you have any applications that we could briefly film in the lab to demonstrate the concept? Perhaps equipment or systems you already have set up?

Commented [DM8R7]: Author has confirmed that he does have filmable applications in his lab.

Commented [DM9]: We're fine to use these (with citations provided) but they might be better conveyed if we redraw them.

Photo or Graphic File
Click here to download Photo or Graphic File: Eric Black_Vacuum-Systems I, Flanges and Seals_Figure 1.jpg

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