# Understanding Sealing Solutions

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The right seal can help a plant save money, eliminate leaks, and avoid safety problems. Here's how to select and install gaskets for effective sealing.

Sealing devices* such as gaskets play a critical role in the chemical process industries (CPI), where they are commonly found in pumps, valves, pipe flanges, gearboxes, expansion joints, and other process equipment. They help to optimize plant performance by preventing equipment damage, minimizing production downtime, avoiding chemical releases and environmental violations — and ultimately saving money.

Sealing apparatuses disproportionally contribute to operational efficiency, as they represent a miniscule fraction of the cost of the systems in which they are installed. These low-cost, high-consequence devices often do not receive the attention they warrant — that is, until they leak.

Where and how a sealing device is used affect its ability to perform reliably over its service life. Seal selection and the prevention of leaks are paramount issues for the CPI. This article outlines the steps involved in selecting the right seal for a given application. Numerous criteria need to be considered, some of which are less obvious than others but just as important.

## Needs and expectations

The first step in choosing an equipment seal is establishing the expectation of performance, addressing both explicit and implied needs (Table 1). Explicit needs are typically immediate, urgent and factual in nature, whereas implied needs may not always be articulated. Examples of each are illustrated in Table 1.

* For convenience, this article uses the term "seal" to refer to gaskets, packings and expansion joints. The article does not deal with single and double mechanical seals, which were the subject of Ref. 1.

Fortunately, most fluid sealing applications involve only a few of these requirements. However, it is helpful to keep this list in mind when seeking sealing solutions for difficult problems, even though critical requirements will vary depending on the nature of the service and equipment.

A simple acronym, TAMPSS (Temperature, Application, Media, Pressure, Speed, Size) can serve as a general guide when selecting a sealing device for a particular application (Table 2).

## Gaskets and load conditions

One common type of mechanical seal is a gasket, which, under compression, fills the space between two objects to prevent leaks.

Many of the variables discussed in Table 2 seem to be self-explanatory, but it is important to understand the type of information required for each situation and why. One often-overlooked criterion for gaskets is service performance in low-load conditions. Frequently the result of structural deficiencies in the flange system, low-load conditions typically occur when flange materials are selected for reasons other than mechanical strength, such as chemical inertness or price. Nonmetallic flanges are typically used when operating temperatures, pressures, mechanical shock and vibration are less severe.

Material seletion is very important, as plastic can be very brittle, and even some metals, like cast iron, have poor ductility. Flanges made of these materials tend to be less robust — incapable of supporting high bending stresses caused by high bolt loads — and therefore require softer, more easily compressed gasket material that can be seated under lower compressive stresses.

Glass-lined flanges (which are commonly used in many chemical applications) pose an especially challenging low-load situation. Glass surfaces are inherently wavy, resulting in relatively large voids between mating flange surfaces. Filling these voids, which represent potential leak paths, requires thicker gaskets, ideally four to five times the thickness of the maximum gap.

Thicker gaskets call for higher compressive loads, but glass-lined flanges do not have the mechanical strength to sustain the corresponding increase in bolt loads. Glass-lined flanges require special sealing solutions that meet the seemingly incompatible requirements of filling relatively large gaps under low compressive loads.

The ability of a system to sustain high bolt loads can be limited by flange geometry, such as insufficient thickness to support a high compressive load. Flange geometry can also increase the demand for compressive load. Flange imperfections require gasket solutions that typically rely on higher compressive loads to compensate. Flange-related problems include misalignment, face-to-face

**Table 1. Performance needs and expectations may be explicit or implied.**

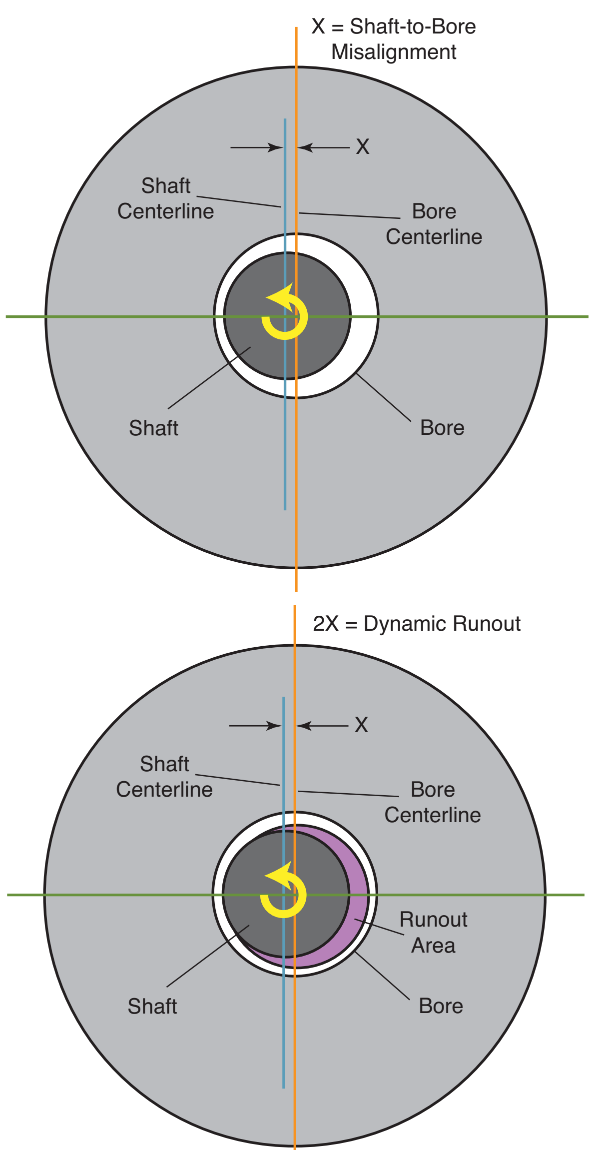
| Explicit Need | Implied Need |
|---|---|
| Able to withstand service conditions | Maintenance-free over service life |
| Cost-effective | Saves more money than it costs within budget constraints |
| Contains no color contamination | Must not impart color to the end product |
| Will not cause contamination or adulteration of process fluid | Must not leach into or extract from the process |
| Complies with U.S. Food and Drug Administration (FDA), U.S. Environmental Protection Agency (EPA), United States Pharmacopeia, 3-A Sanitary Standards, and other regulations and standards | Avoids regulatory issues (when a conformance certification is obtained from the seal manufacturer) |
| Seals effectively to parts per million (ppm) levels | Eliminates hazardous emissions and the risks they pose; regulatory compliance |
| Service life corresponds to maintenance cycles | Eliminates unscheduled outages |
| Protects machine components | Minimizes the need for replacement parts |
| Fire-safe/fire-resistant for use in flammable-fluid service | Maintains seal integrity under fire conditions; material will not further fuel a fire |
| Fewest number of seals through product consolidation | Minimizes stocking and inventory requirements |

**Table 2. Use TAMPSS as a guide to ensure proper sealing device selection.**

| | |
|---|---|
| Temperature | The temperature of the fluid contacting the seal should be considered first. In rotating equipment, this temperature will increase due to frictional heat. Knowing the temperature will quickly narrow the range of viable materials. |
| Application | Understanding the application often requires difficult-to-obtain, but necessary, information about the equipment in which the seal will be installed. This information also helps determine installation procedures that will optimize seal performance.<br>• *Gaskets* — flange type, material, and bolting information to determine the amount of compressive force available<br>• *Valve stem packing* — is stem motion reciprocating, helical or constantly moving?<br>• *Oil seals* — equipment in which the seal will be used (gearboxes, machine spindles, calender rolls, etc.)<br>• *Pumps* — centrifugal (rotating) pump or positive-displacement (reciprocating) pump?<br>• *Expansion joints* — function (vibration isolation, or linear/angular expansion/contraction); equipment connections |
| Media | Common or chemical names of the gas, solid or liquid that will come into contact with the seal are used to determine the seal material's compatibility with the medium. Any secondary media that may be present should also be considered, such as fluids that are used intermittently during chemical cleaning or steam/hot-water flushing processes. |
| Pressure | Most systems operate at fairly consistent pressure, but it is important to take into account any severe pressure spikes or surges that may occur. |
| Speed | Surface speed in ft/min at the seal-shaft interface is crucial in selecting pump packing, mechanical seals and oil seals. Two pumps with different shaft diameters operating at the same rotational speed (in rpm) will have different surface speeds (in ft/min). Surface speed indicates how much frictional heat will be generated. High speeds demand materials that can withstand and effectively dissipate heat. |
| Size | ASME B16.5, B16.20, B16.21 and B16.47 provide standard dimensions for flanges and gaskets. Required information includes nominal pipe size and flange class. Most pumps and valves conform to API/ANSI standards; if not, they must be measured in the field. Other equipment will require field measurements or manufacturers' drawings. |

spacing, and sealing surface damage. Any irregularities in flanged joints can result in areas of low compression, which, in turn, can lead to premature gasket failure.

The bolts in a flanged joint become elongated as they are tightened, developing tension that creates a force to compress and seal the gasket. This tensioning of the bolts is analagous to stretching a spring. As long as the bolt is stretched without exceeding the material's elongation limit, the bolt provides energy for maintaining the sealing force on the gasket. The more potential energy in the bolts, the greater the retentive force will be on the gasket to maintain a leakproof joint.




▲ **Figure 1.** Shaft-to-bore misalignment (top) and dynamic runout (bottom) are typical conditions found in older, worn equipment.

It is important to not tighten the flange bolts beyond their elastic limit or yield point. Doing so causes the bolts to lose their ability to return to their original shape and effectively transfer load to the flange assembly.

Bolts made of unhardened or wrought stainless steel are often employed because they are less susceptible to corrosion. However, the lower yield strength of these materials can compromise the performance of the sealing system. Many chemical plants use stainless steel flanges and low-strength stainless steel bolts. Specially designed gaskets can mitigate the problems arising from the use of these bolts, but a better solution is to use high-strength, strain-hardened stainless steel bolts.

Compressive load is also affected by operating conditions, such as hydrostatic end force, which is the force developed by the pressure inside a pipe or vessel. This force acts to separate flanges, thereby relieving some of the compressive load that is applied by the bolts. Operational torque loss, or stress relaxation, can also be caused by elongation of bolts, thermal cycling, flange distortion, and vibration.

## Gasket creep relaxation

Another common gasket problem is creep relaxation, which is a transient stress-strain condition for which the strain increases concurrently with the decay of stress. Creep relaxation results in loss of gasket thickness, which leads to the loss of compressive load and, ultimately, leakage. Progressive weakening of a gasket also results from changes to the material's properties due to aging and deterioration, or from crushing due to continuous or repetitive retorquing.

The performance of a gasket generally decreases as its thickness increases, requiring increasingly higher compressive loads. Using thinner gaskets wherever possible can reduce costs as well as enhance joint performance by lowering emissions, reducing product loss, and enhancing blowout resistance. It should be noted, however, that thinner gaskets require flatter flanges and cannot seal as many irregularities as thicker gaskets.

To decrease compressive load requirements, ring rather than full-face gaskets should be used wherever possible. Full-face gaskets cover the entire flange surface, including bolt holes. In contrast, ring gaskets are seated concentrically inside the bolt circle, and they have less surface area in contact with the flanges.

## Rotating equipment

In addition to TAMPSS, special consideration should be given to the state of the equipment that is being sealed. The dynamic runout or total indicator reading (TIR) of a pump shaft or valve stem and the static misalignment of the shaft to bore will determine sealing choices. As shown in Figure 1, the center point of the shaft shifts, causing the shaft to wobble. This is undesirable, but also unavoidable, because it occurs as bearings wear out and as shafts become bent over time. The amount of wobble experienced by the shaft is called "runout."

Certain compression packings, oil seals and bearing isolators are made for handling these conditions within limits. For example, square-braided compression packings are softer and more resilient. Therefore, they deliver better sealing for worn equipment than firmer, multi-track braided packings. In addition, oil seals with highly flexible, spring-reinforced sealing elements can handle upwards of 0.125 in. of combined misalignment and dynamic runout.

## Cost factors

For any particular application, there is usually more than one choice of sealing device. Unfortunately, cost too often trumps performance, with seals commonly targeted as a source of savings. Any savings that are realized by selecting the wrong sealing device are usually far outweighed by the cost of a single failure.

The selection process, therefore, should include an assessment of the differences among the high- and low-cost sealing solutions, including raw materials used in their production and their overall performance characteristics. Reliability, ease of installation and removal, and protection of equipment should also be taken into account. A complete value analysis of a proposed sealing solution should address the potential cost of seal failure in terms of lost production, repair or replacement, and safety, environmental and regulatory consequences.

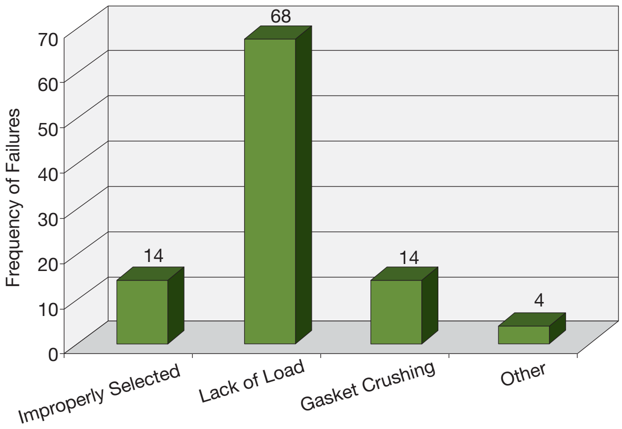
The optimal solution is a sealing product that will perform successfully through a standard maintenance cycle without causing unscheduled downtime. Therefore, before selecting a lower-cost but potentially less-reliable sealing solution, consider the financial impact of taking a process or plant offline to resolve an unnecessary leak or spill.

## Proper installation

Proper installation of an equipment seal is just as important as its selection. The process begins by adhering to the manufacturer's instructions for handling and installation. Field support from the manufacturer may be necessary in some cases, depending on the criticality of the application and the resources of the end user.

For example, consider the importance of proper gasket installation from the analysis of 100 randomly selected gaskets that failed prematurely (Figure 2). Of the 68 that failed due to insufficient load, 37 failed because of poor installation.

The use of torque wrenches or other controlled tightening methods can help to ensure that the proper gasket load is achieved and evenly distributed on the flange. However, torque wrenches are rarely used, or are reserved for applications that are considered to be critical. Noncritical services may still develop leaks if controlled tightening methods are not employed. For instance, an oil drip from a seemingly innocent application, such as a gear box, can cause safety problems by creating a slippery surface.




▲ **Figure 2.** Poor installation accounted for more than half of the gasket failures due to insufficient load.

In many cases, bolt-thread lubricants are applied to gaskets to facilitate removal. If the gaskets contain binders that are not oil-resistant, such as styrene-butadiene rubber (SBR) or ethylene propylene diene M-class rubber (EPDM), petroleum-based lubricants can attack them chemically, softening the binders and reducing their crush strength. Figure 3 shows a gasket that was both over-compressed and installed using a bolt-thread lubricant to facilitate removal.

Petroleum-based lubricants also reduce friction between the gasket and flange faces, allowing them to extrude and eventually blow out. Metal in the lubricants can bond to flanges and fill in surface serrations that bite into the gaskets and hold them in place. In addition, the lubricants

▲ **Figure 3.** The wrong lubricant reduced this gasket's retentive friction on the flange, allowing it to extrude, softening the EPDM binder, and reducing the gasket's crush strength.

## Preventing Leaks

The wisdom of the adage "if it's not dripping, it's not leaking" is insufficient for chemical and hydrocarbon processors, since they are subject to U.S. Environmental Protection Agency (EPA) regulations for fugitive emissions of volatile organic compounds (VOCs). Additional factors, such as water conservation and reduced downtime and their impacts on resource optimization and profitability, must also be considered.

Seals leak for a variety of reasons, both internal and external. Some common equipment-related causes include a worn pump shaft, a scarred valve stem, a rotating shaft with a high runout, and a warped flange. External causes of sealing failures include system temperature excursions, pressure upsets, and harsh environmental conditions, both inside and outside the plant. Often, failure is attributed to the selection of the wrong sealing device or improper handling and installation.

A certain amount of detective work is required to identify root cause(s) of seal failure. Fortunately (from a forensic standpoint), a used seal bears a "fingerprint" of the equipment in which it was installed.

A well-trained individual can determine how the sealing component was installed and the effects of exposure to thermal, chemical and equipment conditions. For example, inspecting the thickness of a used gasket reveals the condition of the flange in which it was installed, whether the gasket was properly compressed (see photos), and whether the previous gasket was properly removed.

Once the causes of a leak are understood, the required physical and functional requirements of a solution can be identified. For example, the application may require a seal that can accommodate temperature cycling, and also perform under imperfect equipment conditions.

Likewise, examination of a used compression-packing set will reveal how it was installed and give insight into its performance history. The inner diameter, outer diameter, and cross-sectional dimensions of the packing rings show the dynamic runout and alignment of the pump shaft or valve stem components. Ring thickness indicates how the packing was compressed, which in turn provides a good indication of the packing's in-service performance. The physical state of the rings (*e.g.*, hardness, softness, abrasion, etc.) demonstrates the effects of heat and chemical exposure.

▼ This under-compressed polytetrafluoroethylene (PTFE) gasket was extruded at the lowest point of compression as internal pressure forced it from the flange assembly, resulting in an oblong shape.

◀ Over-compression created concentric splitting throughout the compressed portion of this gasket, crushing it.

can degrade or vaporize at elevated temperatures, leaving a problematic void between the gasket and flange.

Another common practice is to use caulk to affix gaskets to flanges or to compensate for damaged or irregular flange surfaces. However, some caulks employ acidic curing systems that can attack gaskets containing rubber binders. Because of their lubricity, caulks may cause gaskets to shift or slide within the flange assembly, leading to loss of friction, crush strength and blowout resistance. Gaskets should be installed using only products specified by the gasket manufacturer.

Many gaskets (except those made of polytetrafluoroethylene (PTFE, or Teflon), because they do not require it) are coated with anti-stick agents. If it is necessary to apply more of these compounds to a gasket prior to installation, it is always advisable to use dry materials, such as talc, graphite or mica.

### Removal and replacement

The process of removing and replacing used gaskets is just as critical as initial gasket selection and installation.

Replacement of used gaskets begins with the removal of all flange fasteners, including bolts, studs, nuts and washers, and replacement of any that are worn, corroded or otherwise damaged. The flanged joint should be carefully opened using a special flange-spreading tool or soft wedges, so that the flanges' sealing surfaces are not damaged in the process. Once the joint is open, the old gasket can be removed.

If the gasket is stuck to the flange face, extraction is best accomplished by using an aerosol gasket remover or, if necessary, a brass scraper that will not nick, scratch or gouge the flanges, the surfaces of which are critical to achieving the necessary friction for an effective seal.

After removal of the old gasket, the flange faces should be inspected for imperfections that can adversely affect the new gasket's ability to seal. If surface damage exists, it may be necessary to re-machine or replace the flange. Acceptable surface finishes range between 125 and 250 micro-inches.

Flanges should be free of foreign material. Residual debris can be removed from the serrations by scouring the surface of the flange with a brass wire brush in a rotary (not linear) motion. After the old gasket has been removed and the flange faces cleaned and conditioned, the replacement gasket can be installed.

Selecting the new gasket depends on a number of variables. As previously noted, thinner gaskets are preferred unless the flanges are warped, bowed or severely pitted, or if space constraints exist. If the flanges cannot be pulled together more closely due to pipe anchoring, then a thicker gasket may be necessary.

Once the replacement gasket has been selected, it should be inspected for the correct inner diameter, outer diameter and thickness. If it has cracks, gouges, folds or other surface damage, it should not be used.

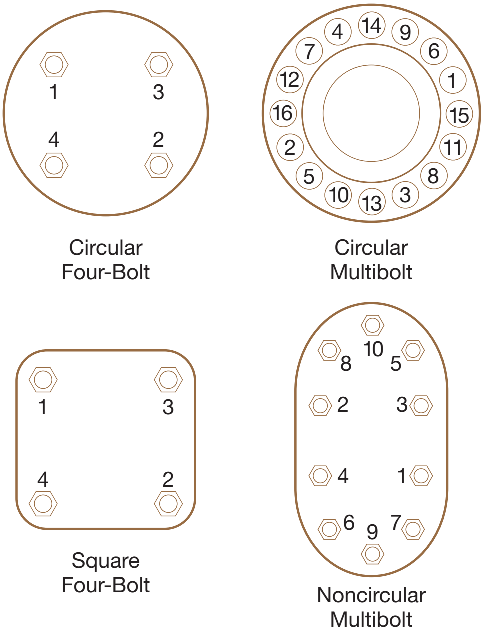
For ease of installation, all fasteners should be lubricated with an oil-and-graphite mixture or other suitable thread lubricant, which should not be allowed to come into contact with the gasket. Flanges with vertical seating surfaces should have at least two fasteners inserted into the bottom holes to support the gasket.

Then the gasket can be inserted between the flange seating surfaces. To avoid damaging the gasket, do not use an instrument to push it into place. The flange spreader can be carefully removed, allowing the flanges to come together, and the remaining fasteners inserted and finger-tightened, or "snugged."

The pattern in which the bolts are tightened is extremely important. If done improperly, the flange can move out of parallel. Refer to the gasket manufacturer's instructions to determine the appropriate bolting pattern for the application. Some typical patterns are illustrated in Figure 4.

Using a calibrated torque wrench, tighten each fastener to no more than one-third of the desired final torque value to uniformly compress the gasket. Repeat the same pattern using a torque wrench setting of two-thirds the desired final torque. Repeat the pattern again at the final torque value, and finish with a circular "check pass," moving from one fastener to the next in a counterclockwise direction to ensure that each fastener is applying the same load.

Fasteners should be retorqued 12–24 h after initial installation, except for pressurized systems — retorquing hot, pressurized flanges is dangerous and not recommended. In addition, all lock-out/tag-out procedures should be observed during the retorquing process.




▲ **Figure 4.** Flange bolts should be tightened uniformly, in a sequence that alternates from side to side in a star-like pattern.

## Final thoughts

Work closely with a seal provider to ensure optimal seal use and performance. Identification, troubleshooting and gathering information regarding problematic issues will lead to the specification of better sealing solutions. CEP


### Literature Cited

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