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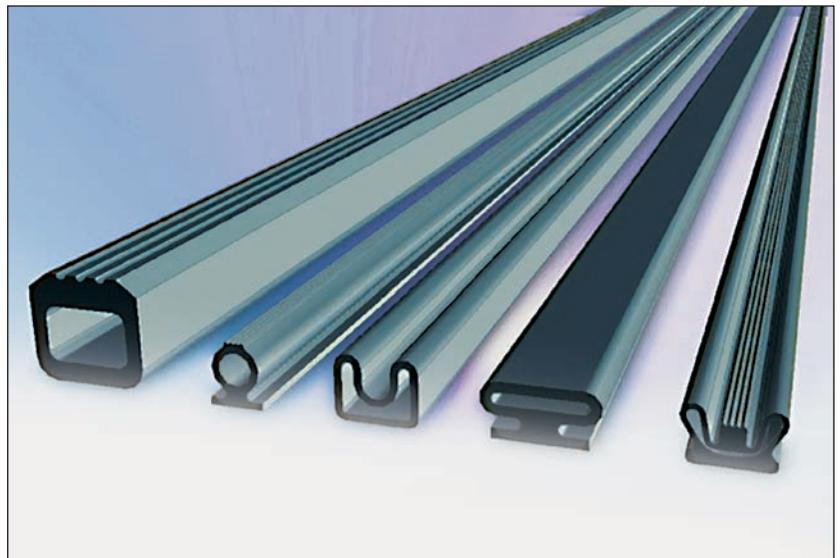
Designing with inflatable seals

Inflatable seals are easier to use and more forgiving with misaligned parts than more-common compression seals.

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For enclosures and equipment that rely on flexible seals, inflatable bladder-type seals might be a better choice than compression seals. They are more forgiving of irregular or misaligned mating surfaces, which cuts manufacturing costs and boosts sealing integrity. They're also easier to use by requiring less force, so technicians don't have to force two components together for a good seal. Instead, they just move the mating parts freely into place and inflate the seal. The only downside is that the inflatable part of the seal, the bladder, needs compressed air to operate. But in many settings, especially the factory floor, compressed air is readily available.

Based on these advantages, inflatable seals have long been used for dry-bulk-handling equipment and drug and food-processing machines. But now they can also be found in growing numbers on processing equipment, industrial isolation



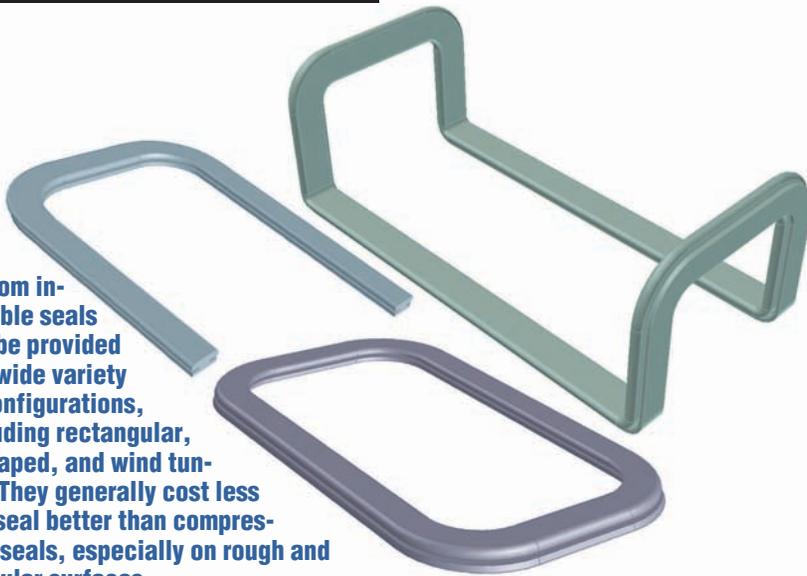
Inflatable seals come in a variety of shapes and sizes and are being used in a growing number of industries, including drug and food processing and IC manufacturing.

chambers, flood barriers, as well as in ultraclean rooms and chip fabs. They also found favor among engineers designing high-end vehicles such as aircraft, spacecraft, and yachts. On yachts for example, inflatable seals isolate holds that contain jets skis, scuba equipment, and other gear from harsh marine environments. Besides keeping out harsh environments, inflatable seals can also help keep cold things cold and hot things hot.

The first issue the engineer needs to decide is in what direction will the seal expand. Should it expand inward, outward, or axially? Next, the engineer needs to consider cross section, air connection, retention, materials, and reinforcing fabrics. And there are some general issues with corners, end treatment, and joining of extra-long extruded seals. Let's look at these issues one at a time.

FASTENING & JOINING

Custom inflatable seals can be provided in a wide variety of configurations, including rectangular, U-shaped, and wind tunnel. They generally cost less and seal better than compression seals, especially on rough and irregular surfaces.



CROSS SECTIONS

Inflatable seals come in a wide variety of shapes or cross sections. But engineers can meet most design needs with one of six basic designs. All seals can expand in whatever direction is needed. The main issues regarding cross-section selection are required pressures and amount of travel. In some applications, cleanliness is also a consideration. For instance, some cross sections have fewer crevices to trap contaminants and are easier to clean. In fact, they were developed mainly for food and pharmaceutical industries.

The **footed seal** is the most widely used. It can be fastened in place using the foot, while its wall provides a good combi-

nation of durability, pressure capacity, and range of travel. There are usually used around doors and hatches.

The **footless seal** delivers the same performance as the footed seal, but is held in place by friction. It is often used in tight spaces where there's no room for a footed seal, or geometry of mating parts can be used to keep it in place. A footless seal should not be glued in place because the base doesn't remain flat after inflating the seal.

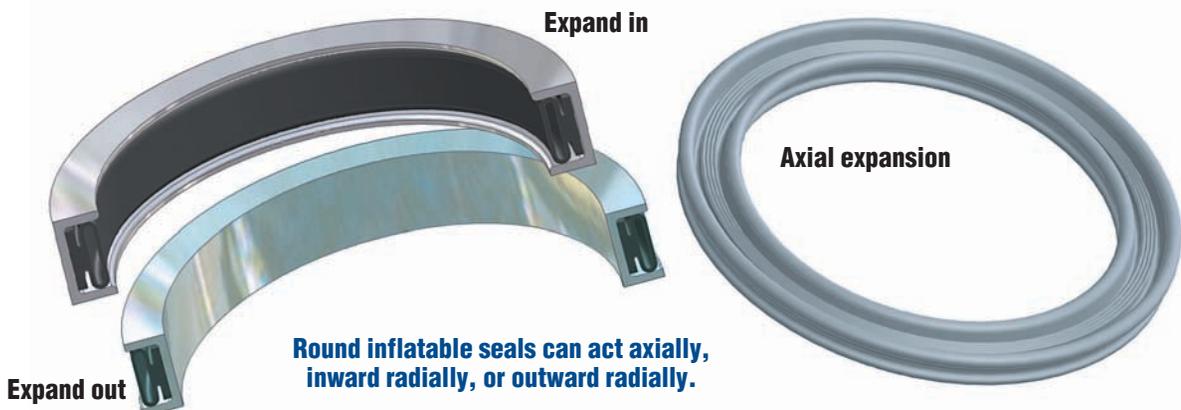
The **footed snap seal** delivers relatively large travel for its width, so it can close big gaps, but this comes at the expense of durability and pressure capacity. When deflated, the seal collapses into itself.

And if it is inflated beyond a certain point, it snaps into a round cross section. The contact surface is made extra thick to withstand wear.

The **heavy-duty snap seal** handles higher pressures and is more durable than standard footed snap seals. But it delivers less travel and has no foot to act as a mounting point. Instead, it is held in place with adhesives. This seal is widely found on food and pharmaceutical-processing equipment because its straight sides make it easy to clean and it has no crevices to trap debris.

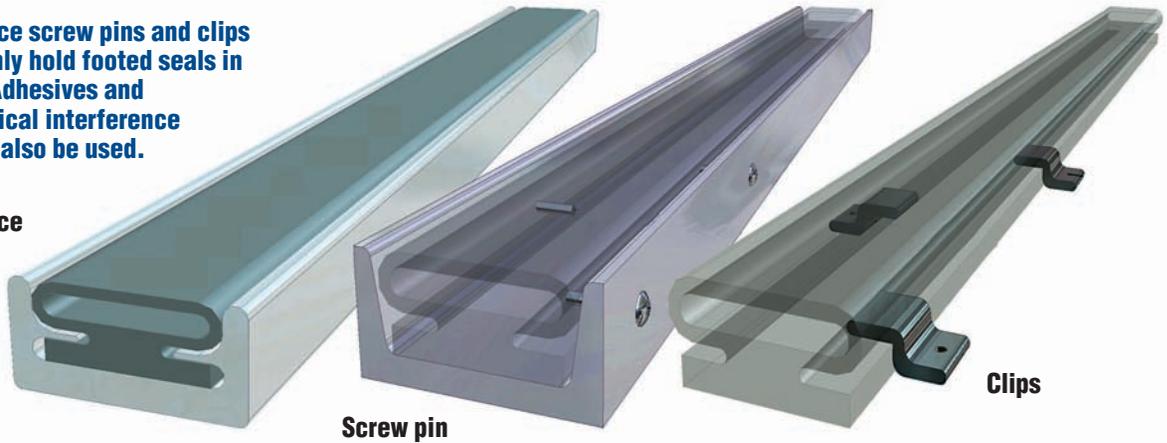
The **channel seal** handles heavy-duty applications and mounts in a groove or metal channel that supports its sides and helps keep it in place. It may be held in place by adhesives or simply by friction with the sidewalls. These seals are widely used as grippers on robots and in part fixtures and handling.

The **heavy-duty channel seal** handles higher pressures but doesn't have much travel. It features a top surface and base that are reinforced to hold their shapes. But its sidewalls are not reinforced, letting them stretch when the



One-piece screw pins and clips commonly hold footed seals in place. Adhesives and mechanical interference fits can also be used.

One-piece retainer



seal is inflated to deliver the necessary travel.

For extra heavy or uneven loads and rough mating surfaces, sealing pads are often placed atop any of the seals mounted in grooves or channels.

AIR CONNECTIONS

Most seals need only one air connection and it can be built into the base or the end, depending on requirements. More connections may be needed for faster cycling, to hold large seals in place, or when inflating seals with a fluid.

RETENTION

There are several ways to hold footed inflatable seals in place. The simplest is to snake the seal through a series of

passivated aluminum or stainless-steel clips. This works on both curved and irregular surfaces. Adhesives can also be used rather than clips. For straight seals, a variety of extrusions provide strong mounting points. And straight snap seals are best held in place by form-fitted extrusions. Passivated aluminum or stainless steel should be used for components that touch the seals.

To retain seals in grooves, size the grooves to the width of the seal itself plus the tolerance. Following this sizing rule for circular seals that expand outward or inward radially, especially smaller diameters, creates enough compression forces to hold the seal in place. Other configurations generally use adhesives.

used elastomer, based on its performance and price. All the elastomers can be molded or extruded.

Seal materials can be combined to meet special requirements. Adding a layer of Viton over EPDM, for example, enhances chemical resistance. And a copper mesh over EPDM creates a conductive seal suitable for EMI isolation on a machine cabinet or to shield an entire room. A heating element used with a silicone seal can keep the seal flexible down to -60°F .

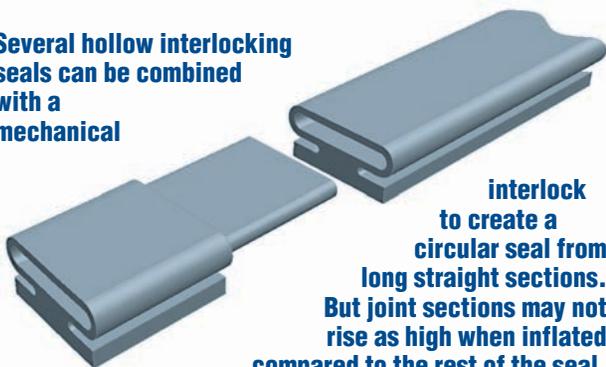
SPECIAL ISSUES

There are also several other issues that commonly arise with inflatable seals. Be aware of these as you proceed with your design.

Cutting corners: A lot of inflatable seals run around corners and they usually won't rise to their full travel height unless the bend radius is generous. And some seals must be made to work on preexisting openings with sharp corners.

As a general rule for outward radial seals, corner radii should be at least four to eight times the relaxed height of the seal. For inward radial seals, corner radii should be

Several hollow interlocking seals can be combined with a mechanical

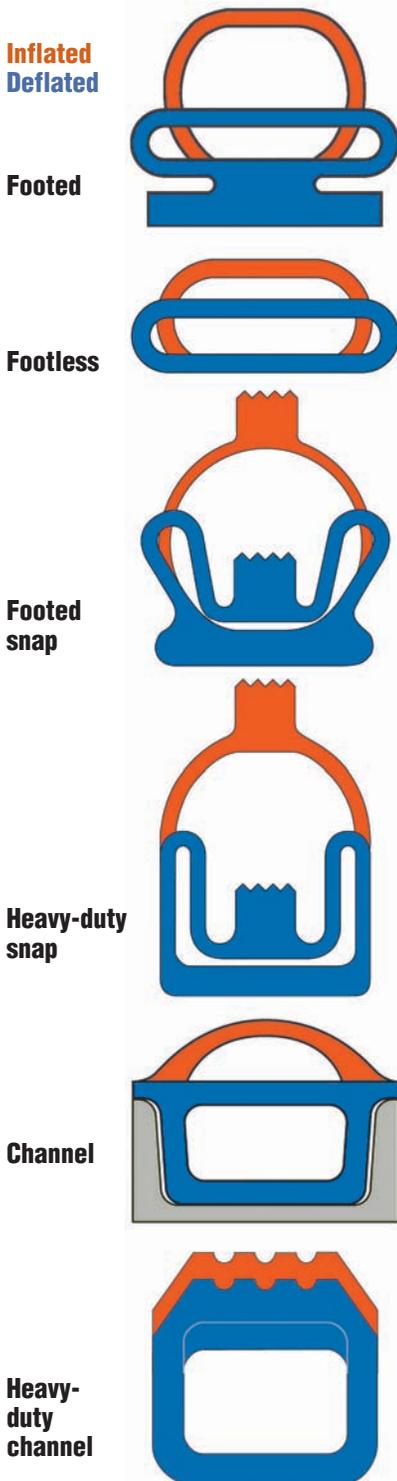


interlock to create a circular seal from long straight sections. But joint sections may not rise as high when inflated compared to the rest of the seal.

MATERIALS

Inflatable seals are made out of all the principle elastomers and reinforcing materials. EPDM (ethylene propylene di-monomer) is by far the most widely

Most common cross sections for inflatable seals. The footed seal is most widely used.



eight times as higher. Even then, the expansion height at the corner will be a slightly lower than on straight sections. Often, it's better to put the seal around the door than around the opening.

For sharp corners, use a fillet pad to create a sealing curve. The pad can be

mounted to the seal or the opening.

Large-circumference seals: Seals must sometimes be joined end to end to form a large hoop. These cases can be handled by combining one or more seals into a larger one. The most common method of doing this is to in-

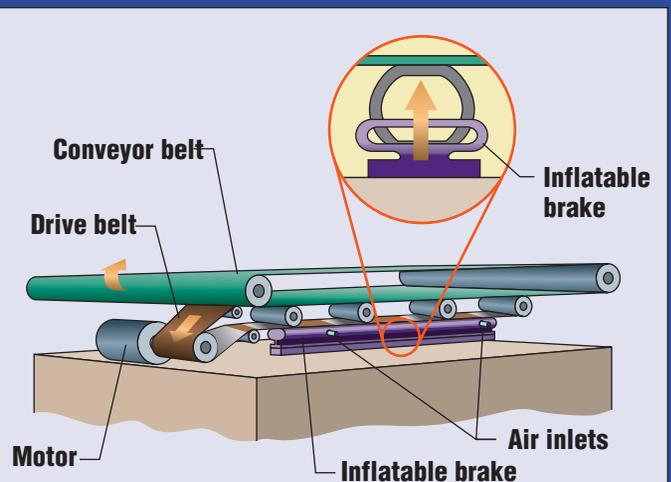
Inflatable actuators and clamps

Inflatable bladders have solved a variety of actuating problems, especially when some "softness" is required. For example, small annular bladders have been used for decades to hold round bar stock and tubing in place during production. Because inflated bladders are gentle and easy to keep clean, they are often relied upon to handle fragile, glass containers in food and pharmaceutical equipment. Heavier-duty bladders assist in short-stroke lifting, holding, and temporary positioning in fabrication shops and construction sites.

One machine builder reworked the conveyor brake on a plate-glass cutting machine for soft stops and reliability. The previous setup jerked the belt to a stop and was a leading source of service calls. Jerky stops also caused glass sheets to shift on the conveyor, creating scrap and wasting material.

The new brake consisted of a footed seal running beneath the conveyor. When inflated, it presses against the drive belt under the main conveyor belt and stops it by friction. The seal is quickly inflated and deflated on command through two pressurizing connections, meeting the cycling requirements. When inflated, the tube expands and gently, but quickly, stops and holds the conveyor in position. When deflated, the tube's top surface falls $\frac{3}{8}$ in., letting the drive belt move the conveyor belt forward. Other than expansion and contraction of the bladder, the brake has no moving parts.

Though the functions differ, designing bladders for clamping or actuating follows the same approach as designing seals, as outlined in the main article. The main difference is that engineers must define the forces, required displacements (strokes) and duty cycles in greater detail.



An inflatable seal is used as a fast-acting soft brake in a web-processing conveyor. It uses dual air connections for rapid fill and evacuation.

sert a length of the seals' parent material inside the ends of the seals being joined and fasten it with an adhesive.

End treatments: At the end of all straight seals, there is a solid section lower than the active length. It completes the seal and provides an anchoring surface. They should be clamped in place.

Small-diameter seals: The OD or ID of the opening being sealed is often too small for standard cross sections. The cut-off is at about 2-in. diameters. In such cases, small, molded, inflatable bladders solve the problem.

The dip: Certain spots on inflatable seals may not rise to the full height of the active section. This is especially true at ends, corners, and joints. To compensate, add a 10 to 15% margin of safety to the specified inflated height.

Air supply: Engineers often dismiss inflatable seals because of the air-supply issue. This needn't be a problem. In most industrial or bulk transport settings, compressed air is usually available. And there are often simple solutions for nonindustrial applications requiring infrequent seal cycling. On yachts, for example, the same foot pump or compressor that inflates rafts can easily activate the seals. For flood doors, which may be deployed only once or twice a season, built-in compressed air tanks fill the bill. **MD**

Design checklist for inflatable seals

Specification checklist

Engineers specifying seals will get better results if they define requirements and take them to a reputable, custom-seal fabricator early in the design process. Most fabricators are happy to provide technical assistance. And some have wide experience across several industries, so they can offer a wider palette.

Here are the key application elements that should be defined at the outset.

- What are you sealing against? Air? Water? Gas? Something else?
- Pressure differential across seal
- Service-temperature range
- Other environmental factors (UV, particulates, ozone)
- Duty cycle: Frequency of inflation, Duration of inflation
- Applicable codes and standards
- Direction of expansion: radial inward, radial outward or face and axial.
- Inflated height
- Overall dimensions for active length
- Corner radii (if applicable)
- Maximum allowable deflated profile

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