LOW **LEAKAGE**

Achieving ANSI Class VI shutoff with graphite laminated seals in butterfly valves

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Butterfly valves are common in even the most demanding industries, including oil and gas, cryogenic, nuclear and other applications that require American National Standards Institute (ANSI) Class VI performance with regard to leakage.

Delivering this level of performance, however, has as much to do with the sealing solution as the valve itself. That is why promotional material for valves gives attention to the graphite laminated seal. This engineered sealing component is essential to achieving a low-leakage rate in shutoff, particularly in bidirectional flow environments.

Why are graphite laminated seals common? This article explores the characteristics and design features that allow graphite laminated seals to deliver the low-leakage characteristics required of the most demanding applications.

Why graphite?

As a material, graphite can be made to exhibit varying degrees of hardness and resistance to compression. However, seals consisting of a lamination of graphite and metal offer a combination of compressible and resilient materials that form a strong seal against the rigid valve seat. A modern laminated graphite seal will consist of layers of engineered graphite material and metal, usually stainless steel or duplex stainless steel.

These laminated gaskets can be installed on the disc itself or on the body of the valve. Through thoughtful design and precise manufacturing, these laminated seals can achieve bidirectional ANSI Class VI shutoff, the most stringent leakage performance standard as tested with liquid nitrogen.

Laminated seals deliver the best results — in terms of leakage rates, cycle frequency and fire safety — when paired with a secondary seal on the opposing valve face. This can be a comparatively simple die-formed graphite seal often bound by an inner and/or outer metallic ring to mitigate seating stress as concentrations, temperatures and other variables within the valve are in flux and have not stabilized.

By carefully engineering the qualities and performance of these two seals, a valve manufacturer and sealing solution manufacturer can collaboratively deliver a package with a guaranteed level of reliability. This performance can encompass leakage rates, cycle frequency and fire safety.

This article will provide insight into how laminated seal solutions can either make or break ANSI VI performance in butterfly valves in oil and gas, liquid natural gas and nuclear power. Some of these applications will require exotic or very exacting grades of materials, but a primary challenge will be fabricating the laminated seal itself at tight enough tolerances to perform adequately. This laminated seal should also be combined with an appropriate secondary seal on the facing surface to reliably achieve performance objectives.

This laminated sealing system is a central component for valves used in critical applications and needs to be taken into consideration early in the valve design process of the entire valve product line. Most valve designs are fairly standard and will cut across standard industrial applications and more demanding markets such as semiconductor, nuclear power, cryogenic or oil and gas. The same seal used for general industrial applications must often accept a more advanced sealing solution to meet performance criteria of different industries and ensure that leakage rates meet with regulatory, safety and business requirements.

Material composition is critical

While dual-gasket systems, including laminated seals, are used widely in butterfly valves, a lack of thoughtful design or manufacturing can lead to failure or unacceptable leakage rates. This may in turn result in negative outcomes including fugitive emissions or threats to environmental health and safety.

Seals can range from 1 to 96 inches in diameter, but regardless of the size, the physical contour and dimensionality of the laminated seal is crucial to withstanding pressures up to 150 bar and temperatures from -196°C cryogenic applications to 500°C steam applications.

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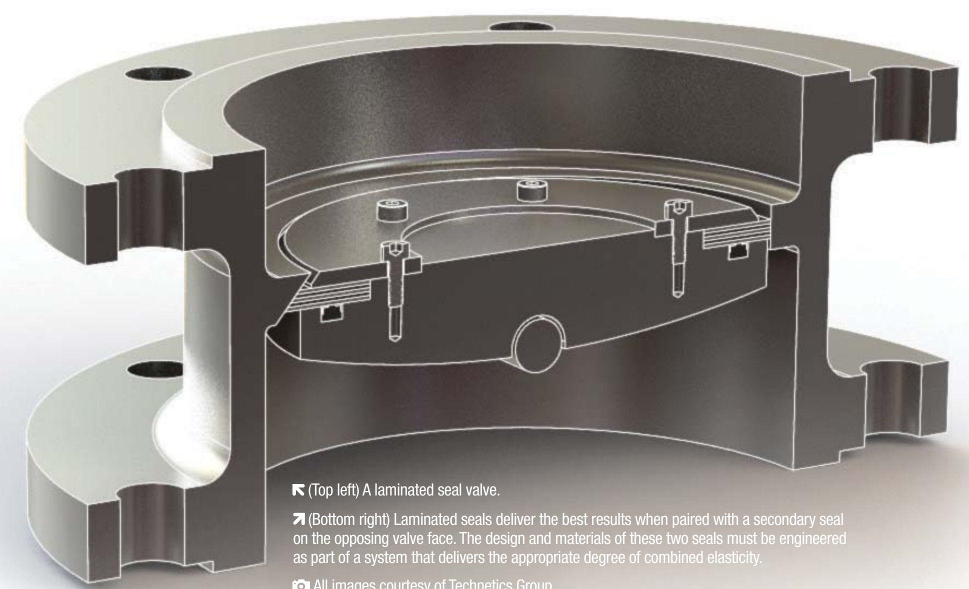

(Top left) A laminated seal valve.

(Bottom right) Laminated seals deliver the best results when paired with a secondary seal on the opposing valve face. The design and materials of these two seals must be engineered as part of a system that delivers the appropriate degree of combined elasticity.

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precisely managed through aggressive batch control. Failing this, a manufacturer can make a seal that is geometrically the same as the next, but if the density of the material is lower on one than another, the sealing qualities will not be the same once the seal is fitted on the valve.

If the density of the graphite is too low, it will not seal adequately, mainly because the external shape of the seal will be deformed during fitting and compression of the seal on the valve. If the density of the graphite is too high, the seal will not be resilient enough to absorb the geometric imperfections of the contact area.

Different densities of graphite may be required to engineer performance of the laminated seal or the secondary seal. This means the supply chain of the seal manufacturer becomes very important. Developing a strong relationship with a graphite supplier, or one that has expanded into its supply chain to acquire that source of graphite technology, will help ensure that consistent, high-quality raw materials are available to meet specific needs.

While the graphite is probably the most highly engineered material in most laminated seals, the metal layer can also be designed around specific challenges. In the majority of laminated seals, the metal layers consist of duplex stainless steel, a combination of ferritic and austenitic stainless steels that is almost twice as strong as either one alone. Duplex stainless steel is tough, ductile and fairly resistant to corrosion and corrosion cracking. However, in some specific settings, a seal manufacturer and valve manufacturer will need to consider an exotic material.

For one recent application involving seawater, Technetics opted for a copper alloy. This change had largely to do with the need to mitigate against corrosion. Duplex is fairly resistant to corrosion, but immersion in warm seawater could make the material more susceptible to external stress corrosion cracking and hydrogen embrittlement.

Temperature can also be a factor in metal alloy selection. A super-duplex steel might be specified for a cryogenic application because it will remain ductile at low temperatures. A seal manufacturer must be prepared to engineer both the graphite and metal layers of a laminated seal to meet specific performance criteria and the demands of the application environment.

Maintaining dimensional consistency

The laminated seal must meet very tight tolerances with regard to its physical dimensions. The seal will be designed with a series of offsets around the outside edge to ensure even contact with the valve face. Imagine a common door, like one found in a home where there is the typical small gap between the door and the frame. Imagine placing a seal around this door and needing to design the edges of the seal so that, as the door closes, the seal will contact the frame simultaneously all the way around the door. Bevels around a laminated seal and well-defined offsets will perform a similar function and must, therefore, be engineered to extremely tight tolerances.

Ensuring that two laminated seals are geometrically identical can be a challenge for some manufacturers, primarily due to the adhesive used in the lamination process. Many companies glue the graphite and metal layers together by troweling adhesive onto one of the surfaces before compressing two layers together. The resulting bond may or may not be good.

The greater challenge is determining a method to apply glue evenly across the graphite at a uniform thickness. Inconsistent thickness of the adhesive layer

ACHIEVING OPTIMAL LEAKAGE RATES

What can valve manufacturers and valve end users look for to ensure butterfly valves will reliably deliver ANSI VI leakage rates at shutoff — even in bidirectional applications? Here is a quick checklist.

- ✔ The most effective sealing solutions feature a laminated seal and a die-formed graphite seal as the back seal.
- ✔ Pay close attention to the sealing solution company's graphite and the degree to which the density and performance of the graphite can be engineered.
- ✔ The metal layer of the laminate seal must be chosen carefully. If it is too soft, the laminate seal can deform under load. Keep in mind the effect of temperature and corrosion on various metals.
- ✔ Ask questions about the gluing process between the laminations. How consistently and evenly is the glue distributed? Do the laminated seals require machining before installation?

can make it difficult to manufacture a geometrically compliant seal. To overcome this challenge, Technetics developed proprietary technologies that deliver a uniform dispersion of adhesive evenly across the material at a precise and reproducible thickness.

Uneven layers of glue or layers of glue that are thicker than specified alter the performance of the seal. This can result in a seal with faces that are not parallel to each other. When the valve is closed, the seal will not be equally flush to the valve face all the way around the periphery, allowing for leakage. These failures to meet the required specification will have a measurable effect on leakage rates and consistency from one seal to the next.

Part of a two-part system

As noted earlier, augmenting the laminated seal with a secondary seal will yield the highest levels of performance. This secondary seal can be something as simple as a spiral-wound graphite gasket. These gaskets have evolved over time to deliver beneficial performance properties and may be encased in an engineered metal. When the graphite material is compressed to the point of deformation on the sealing faces, the optimized profile of the metal strip provides elastic recovery. This prevents extreme pressure and/or temperature from damaging or permanently deforming the seal during transients.

These graphite gaskets used as the secondary seal may be standard products, but in many cases they are engineered for a given application to avoid any extrusion of the graphite. The goal is to engineer an accumulated degree of elasticity of the combined solution of laminated seal and die-formed ring. This is the most direct path to achieving the guaranteed leakage rate requirement for even the most demanding and bidirectional sealing requirements.

Relying on just a spiral wound gasket or a flexible graphite gasket alone would make the leakage rate substantial. However, when the laminated seal and a secondary gasket are combined, they behave like two springs pressing against each other.

In critical applications that require very low leakage rates, it may be tempting to specify a secondary seal with a high sealing load. However, that very hard seal and high sealing load can cause deformation of the laminated gasket (when fitting it) and compromise the sealing on the external area of the laminated seal. Each application needs to compromise between the laminated seal and the secondary gasket to deliver the required leakage rate regardless of which direction the fluid is flowing without risking damage to either sealing component.

A collaborative relationship

For applications that require leakage rates in compliance with ANSI VI standards, precision of the seal is of the utmost concern. While the design of a typical laminated seal is well known, the ability to consistently achieve high-performance levels requires a thorough understanding of and commitment to sealing technology.

One valve manufacturer, for instance, was experiencing deformation of its laminated seal. Its secondary seal was quite hard. Because laminated seals are more complex to engineer than a graphite gasket, engineers often consider making an adjustment to the secondary seal, but in this case, alteration to the density of the graphite was made in the laminated seal to make it more resistant to deformation. While in this case the problem was solved on an existing valve, it is best to be involved early enough in the valve design process to eliminate false starts and retooling.

Conclusion

Butterfly valves deployed in mission-critical applications will generally have a laminated seal, but the design of this seal from a materials and machining standpoint will determine whether or not that laminated seal will successfully meet ANSI VI criteria. This laminated seal should be paired with a facing seal so the sealing system provider and valve manufacturer can engineer an optimal degree of elasticity between the two. A thoughtfully engineered combination of laminated and secondary seal will be able to deliver guaranteed levels of leakage at shutoff and perform reliably even in bidirectional applications. PR

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