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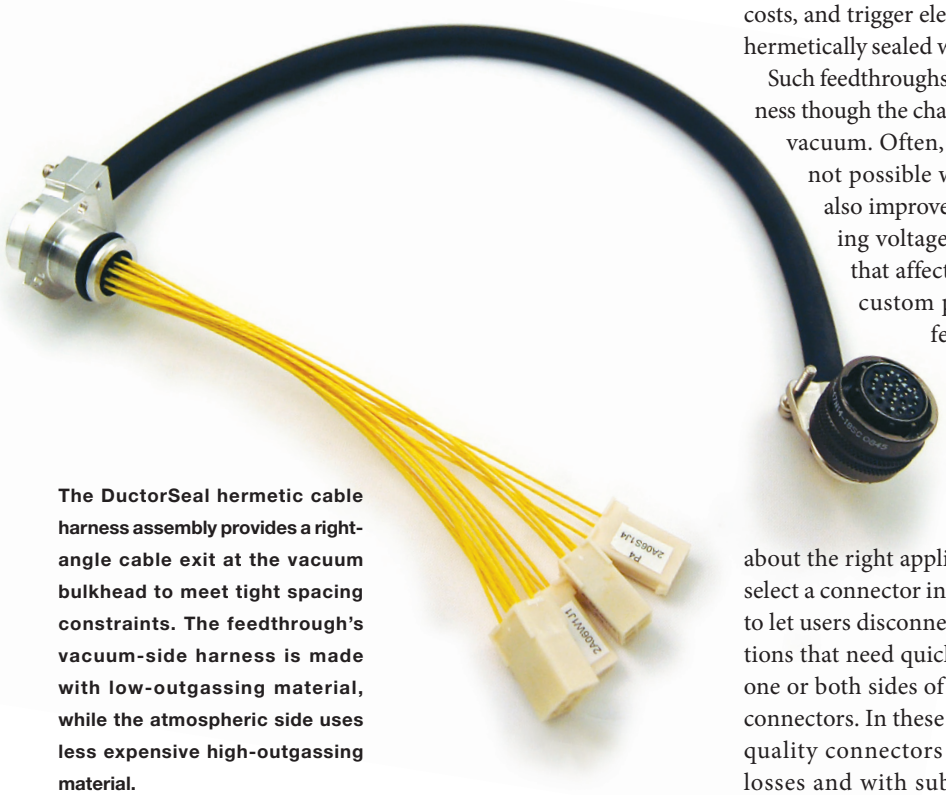
The difference between wire feedthroughs and bulkhead connectors

Bulkhead connectors are widely used to route power and data into isolated environments, but they're not always the best choice.



The DuctorSeal hermetic cable harness assembly provides a right-angle cable exit at the vacuum bulkhead to meet tight spacing constraints. The feedthrough's vacuum-side harness is made with low-outgassing material, while the atmospheric side uses less expensive high-outgassing material.

Engineers who need to pass power and signal wires through the walls of pressure and vacuum chambers usually reach for off-the-shelf sealed bulkhead connectors. Such connectors often seem like the best or only way to traverse chamber walls, but they can unnecessarily constrain designs, raise costs, and trigger electrical problems. Wire feedthroughs hermetically sealed with epoxy can be a better alternative.

Such feedthroughs pass all the conductors in a wire harness though the chamber wall with no loss of pressure or vacuum. Often, they permit design flexibility that's not possible with off-the-shelf connectors. They also improve electrical performance by eliminating voltage drop and contact-resistance issues that affect connectors. And although they are custom products, hermetically sealed wire feedthroughs have a lower installed cost than comparable bulkhead connectors when specced into the right application.

SUITABLE USES

It's important to stress that point about the right application. The most obvious reason to select a connector instead of a continuous feedthrough is to let users disconnect wires from the chamber. Applications that need quick connections or disconnections on one or both sides of the chamber wall require bulkhead connectors. In these cases, however, it pays to pick high-quality connectors to avoid problems with electrical losses and with substandard sealing *(see "Sealing off leaks," p. 48).*

Hermetic wire feedthroughs permit point-to-point wire harnessing, which minimizes connection points and associated voltage drops and signal degradation.

Most feedthrough applications, however, tend to be "sealed for life." Here, the main design considerations are robust sealing and resistance to mechanical stresses with minimal electrical losses. Lots of applications fall in this category. Typical examples include high-voltage electrical switches, semiconductor wafer-processing equipment, medical-imaging systems, military ordinance-control applications, and space-simulation vacuum chambers.

DESIGN FLEXIBILITY

Off-the-shelf bulkhead connectors address many application requirements, but they do impose fixed limits on the number and gauge of conductors. Many standard bulkhead connectors accommodate just four wire gauges with only 10 pin configurations per wire gauge. Mixed-wire-gauge connectors are often special-order items or simply unavailable.

What's more, off-the-shelf connectors are rarely perfect for a specific job. That forces engineers to compromise or over-engineer a design to accommodate the connectors, rather than the other way around. Continuous wire feedthroughs, though, can include thousands of conductors or just a handful, if that's all the application requires. Equally important, continuous wire feedthroughs let engineers mix and match conductors in ways that off-the-shelf connectors do not. For example, magnetic-bearing applications tend to combine twisted shielded pairs and thermocouple pairs that would be incompatible in most off-the-shelf connectors without signal degradation.

Wire feedthroughs also tend to be more compact. Compared to connectors, well-designed feedthroughs can easily double the number of conductors that can squeeze through a given opening. This density advantage often means a single wire feedthrough that combines all power and signal wires can replace several bulkhead connectors. And, feedthroughs don't protrude from the bulkhead the way connectors do. As a result, they provide more clearance for moving machine parts inside or outside the chamber.

Continuous wire feedthroughs offer design flexibility and space savings in new pressure and vacuum systems, but older systems can benefit too. Engineers often need to add new sensors or instrumentation to existing pressure or vacuum

chambers. These retrofit jobs can be arduous if the standard connector or opening in the chamber wall won't permit even a few more conductors to pass through. Wire feedthroughs usually can be engineered to squeeze in more conductors.

WIRE-FEEDTHROUGH PERFORMANCE

Even the best electrical connectors suffer more losses than continuous wire harnesses. For instance, typical voltage drop for connectors exceeds 1 mV per crimp, along with another 1 mV or more across the mated pin and socket. Contact resistance for the same connector is typically as high as 100 mΩ, which is enough to degrade the signal integrity in thermocouples and other sensors.

Wire feedthroughs also provide an edge in mechanical performance. Unlike bulkhead connectors, a wire feedthrough is not a wear item with life

(continued on p. 51)

SEALING OFF LEAKS

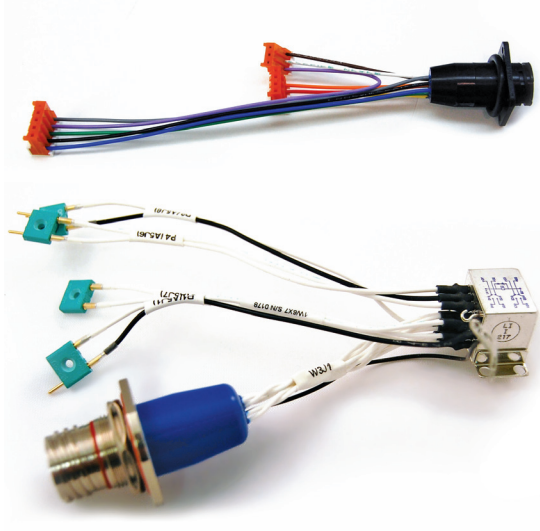
AN APPLICATION THAT requires a disconnect on one or both sides of a pressure or vacuum wall probably demands a hermetic bulkhead connector. However, not all hermetic connectors are the same.

Many mass-produced hermetic connectors have true leak rates that are far above their published specifications. In fact, leakage-rate specifications for some off-the-shelf hermetic connectors understate actual leakage by an order of magnitude. In addition, they can be fragile and susceptible to leaks after mechanical shock or thermal cycles.

How do we know this? Douglas Electric has developed an aftermarket process to seal hermetic box-mount connectors made by other manufacturers. Part of that process involves pressure testing every connector, so we have conducted thousands of leakage tests on off-the-shelf hermetic connectors and found many lacking.

The epoxy-potting treatment "fills the gaps" in connectors that leak more than they should. The treatment often costs less than upgrading to a true hermetic connector. It is also suitable for nonhermetic box-mount versions, even inexpensive plastic and plated-steel connectors, regardless of pin configuration.

As a side benefit, epoxy back potting a connector often allows crimped, rather than soldered, wire connections for additional assembly cost savings. Mated hermetic connectors also are fully submersible, which is an increasingly common requirement in power distribution and oil-and-gas applications.



Aftermarket epoxy backpotting hermetically seals off-the-shelf connectors, reducing cost and lead times over factory-built versions.

(continued from p. 48)
subject to a finite number of mating and unmating cycles. In nonflex applications, the life of a wire feedthrough equals that of the wire harness itself. There's no additional failure mode.

Some engineers believe epoxy-based feedthroughs suffer from poor sealing and outgassing. Perhaps this was once true, but modern epoxy formulations and manufacturing techniques prevent such problems. Today's epoxies have rugged mechanical properties and resist chemicals and temperature extremes. These properties make them well suited to challenging operating environments.

Take Douglas Electrical Components' epoxy hermetic seal for feedthroughs. It seals to 1×10^{-9} sccm He/sec in vacuums as powerful as 1×10^{-8} Torr and under pressures as high as 15,000 psi. Many off-the-shelf connectors listed as "hermetic" actually have leak rates of 1×10^{-7} sccm He/sec or greater. Because connectors are rarely inspected in use, actual leakage rates may be even worse. As for outgassing, Douglas often encapsulates wires in epoxy grades that meet NASA's ASTM E-595 low-outgassing specification with just 0.26% weight loss and less than 0.002% VCM.

CUTTING COST

Another myth about feedthroughs is that they're expensive. It's tempting to think that a catalog bulkhead connector will cost less than a custom-engineered wire feedthrough. But it's important to consider the total installed cost. Remember that a single continuous wire feedthrough with just one wire harness often can replace several bulkhead connectors, each with its own wire harness. Most of a feedthrough's savings comes from reducing the number of individual wire harnesses that must be designed, manufactured, and assembled.

But there's more. Eliminating bulkhead connectors can reduce bill-of-materials (BOM) items and simplify procurement. Feedthroughs also can avoid the costs associated with over-engineering connectors, which is common when off-the-shelf models cannot precisely match application requirements. Finally, engineers can spend more time on their core engineering competencies rather than designing wire harnesses.

These costs add up quickly. On a typical industrial feedthrough application, such as a magnetic bearing, a hermetically sealed wire feedthrough will cost about 50% less than a glass-to-metal connector, assuming a single off-the-shelf bulkhead connector can handle the application. If more than one connector is needed to meet all the power and signal requirements, then the cost advantage of continuous wire feedthroughs is even more dramatic.

One other factor to consider is lead times, which can affect time-to-market costs for new systems and maintenance costs for existing ones. If a standard connector truly meets the application requirements, speedy delivery may be a good justification for going off-the-shelf.

Keep in mind, however, that wire feedthroughs aren't necessarily long-lead items. Some manufacturers routinely turn around custom-engineered hermetic wire feedthroughs in as little as one week, while standard connectors can take longer. The wait is even longer for custom connectors, provided the production volume is sufficient to justify a custom design.

None of this should suggest that off-the-shelf or custom bulkhead connectors are not a good method for passing power and signal wires into pressure or vacuum systems. However, bulkhead connectors should not be the automatic choice when wires need to pass through a pressure or vacuum wall. Take the time to assess whether a hermetically sealed wire feedthrough is a better option. md

RESOURCES:

Douglas Electrical Components,
www.douglaselectrical.com