Sealing in Difficult to Seal Fluid Handling Applications

By Jeff Spira

All too often, the limiting factor in the performance of a mechanical or fluid handling system is the seals. We can design equipment to handle extremes of pressure, temperature, corrosive chemicals, or other severe environments only to discover that we can't seal them at those extremes. Witness two of the biggest technological mishaps of the 20th century, the explosion of the space shuttle Colombia and the accident at the Three Mile Island nuclear power plant. Both of these accidents were caused by seal failures. Modern, proper seal design could have prevented both of these accidents from ever occurring.

Design engineers rarely think about that inexpensive little ring, when they design their fluid handling systems, but that lowly seal, often just indicated on the drawing by an X, can make or break their design.

Today's oil wells are deeper, the aircraft and missiles faster, and the allowable envelopes smaller, so as temperatures, pressures, speeds, and other operational parameters increase, no longer can the rubber o-ring keep up with the increasing demands of modern equipment.

Back in the 1940s, the early aircraft hydraulic systems featured a 1500 psi hydraulic assist on the controls, being input solely by the pilot, an o-ring could easily handle the fluid containment needs. In today's designs, the computer handles the controls with as many as four separate movements per second, and the pressures are 8000 psi. This much pressure runs the temperatures up in excess of 300 F as well. A rubber seal will simply not live in this environment.

The two primary advantages of using rubber are that they conform easily to the surface irregularities of the surface it is sealing against, so a fairly low contact pressure is needed to achieve a reliable seal. The second advantage of rubber is that the compression of seal itself serves as a spring to make up for seal wear and deformation. This means a one-piece, one material seal that can do the job quite nicely in applications that don't overtax the material.

In higher pressures, temperatures, or operating speeds, a non-elastomeric polymer must be used. The most common is PTFE (Teflon) though it is rarely used in its unfilled form. It is generally filled with different inert fillers, such as carbon, glass, or minerals to tailor it's pressure holding and wear characteristics. Sometimes other polymers are added to the PFTE to create polymeric alloys, to improve the performance even more.

Since they're not elastomeric, some sort of mechanical means must be used to keep the polymeric seal rings in contact with the sealed surface with enough pressure to prevent leakage. In moderate duty applications, such as Type II, Class 2 aircraft hydraulics (3500 psi, 275F max.) rubber o-rings or other shapes can be used to energize the polymer seal rings. If the application is more severe, such as in 5000 psi, 400F oilfield valves, the rubber is incapable of maintaining its characteristics, so a metallic spring is generally used. This can take many forms depending on the needs of the application, but is generally stainless steel, or, if highly corrosive environments are anticipated, one of the modern nickel super-alloys such as Hastelloy, Elgilloy, Inconel or similar.

Proper seal design using contact pressure, spring rate, seal wear, and pressure carrying capability calculations is a complex science, but can turn a failed design into a highly successful one. This vital piece of technology should be incorporated into every new piece of equipment utilizing fluid power or fluid control to help prevent future mishaps like the space shuttle Columbia and Three Mile Island.

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