

Fittings

Among the basic elements of virtually every hydraulic system is a series of fittings for connecting tube, pipe, and hose to pumps, valves, actuators, and other components.

If the components within hydraulic systems never had to be removed, connections could be brazed or welded to maximize reliability. However, it is inevitable that connections must be broken to allow servicing or replacing components, so removable fittings are a necessity for all but the most specialized hydraulic systems. To this end, fitting designs have advanced considerably over the years to improve performance and installation convenience, but the overall function of these components remains relatively unchanged.

Fittings seal fluid within the hydraulic system by one of two techniques: all-metal fittings rely on metal-to-metal contact, while O-ring type fittings contain pressurized fluid by compressing an elastomeric seal. In either case, tightening threads between mating halves of the fitting (or fitting and component port) forces two mating surfaces together to form a high-pressure seal.

All-metal fittings

Threads on pipe fittings are tapered and rely on the stress generated by forcing the tapered threads of the male half of the fitting into the female half or component port, Figure 1. Pipe threads are prone to leakage because they are torque-sensitive — over-tightening distorts the threads too much and creates a path for leakage around the threads. Moreover, pipe threads are prone to loosening when exposed to vibration and wide temperature variations — certainly no strangers to hydraulic systems.

Seepage around threads should be expected when pipe fittings are used in high-pressure hydraulic systems. Because pipe threads are tapered, repeated assembly and disassembly only aggravates the leakage problem by distorting threads, especially if a forged fitting is used in a cast-iron port. Thread sealant compound, a potential contaminant, is

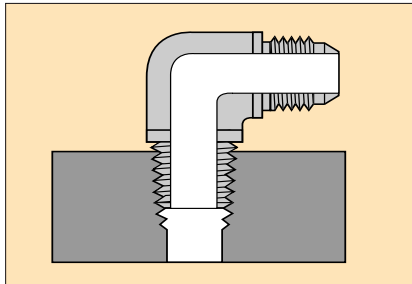


Fig. 1. Pipe fittings have given way to newer fitting designs that simplify assembly, maintenance, and reduce or eliminate leakage. Shown is a 90° adapter elbow with pipe threads at one end that mount permanently into the component port. Other end of fitting uses straight-thread flare fitting for tubing connection.

recommended for pipe fittings, which is still another reason why most designers consider them to be obsolete for use in hydraulic systems.

Flare-type fittings, Figure 2, were developed as an improvement over pipe fittings many years ago and probably remain the design used most often in hydraulic systems. Tightening the assembly's nut draws the fitting into the flared end of the tubing, resulting in a positive seal between the flared tube face and the fitting body. The 37° flare fittings are designed for use with thin-wall to medium-thickness tubing in systems with operating pressures to 3000 psi. Because thick-wall tubing is difficult to form to produce the flare, it is not recommended for use with flare fittings. The 37° flare fitting is suitable for hydraulic systems operating at temperatures from -65° to 400° F. It is more compact than most other fittings and can easily be adapted to metric tubing. It is readily available and one of the most economical.

The flareless fitting, Figure 3, gradually is gaining wider acceptance in the U.S. because it requires minimal tube

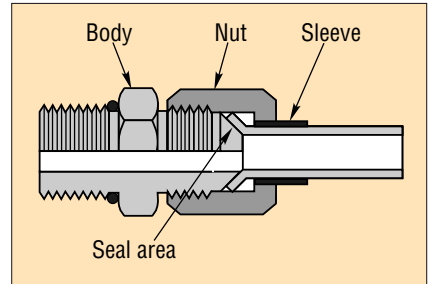


Fig. 2. Flare-type fittings offer several design and performance improvements over pipe fittings and are used with thin-walled and medium-thickness tubing.

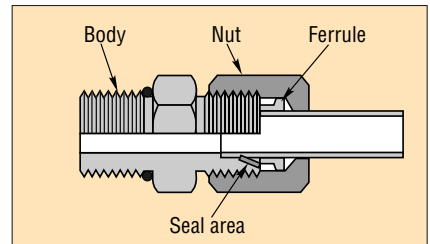


Fig. 3. Flareless fittings offer advantages similar to those of flare fittings and are used with medium- to thick-walled tubing.

preparation. It handles average fluid working pressures to 3000 psi and is more tolerant of vibration than other types of all-metal fittings. Tightening the fitting's nut onto the body draws a ferrule into the body. This compresses the ferrule around the tube, causing the ferrule to contact, then penetrate the outer circumference of the tube, creating a positive seal. Because of this, flareless fittings must be used with medium- or thick-walled tubing.

O-ring type fittings

Surprising as it may seem, leakage in hydraulic systems could have been eliminated more than a generation ago. Although leak-free hydraulic operation had always been desirable, the need became more acute with higher operat-

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ing pressures that became necessary during World War II, primarily in the hydraulic systems of military aircraft. Until then, common operating pressures had hovered around 800 to 1000 psi. The post-war era ushered in systems designed to operate at pressures to 1500 psi and higher on applications where rapid cycling and high shock pressures were present. It was not long until pressures climbed to 2500 and 3000 psi — which certainly are not uncommon today.

Faced with increased hydraulic fluid leakage brought on by higher pressures, a consortium of fittings manufacturers — working under the umbrella of SAE's Committee on Tubing, Piping, Hoses, Lubrication, and Fittings — undertook solving the problem. Their joint effort in the early 1950s culminated in the straight-thread design, which ultimately became known as the SAE straight-thread O-ring boss.

Fittings that use O-rings for leak-tight connections continue to gain acceptance by equipment designers around the world. Three basic types now are available: SAE straight-thread O-ring boss fittings, face seal or flat-face O-ring (FFOR) fittings, and O-ring flange fittings. The choice between O-ring boss and FFOR fittings usually depends on such factors as fitting location, wrench clearance, or individual preference. Flange connections generally are used with tubing that has an OD greater than $7/8$ -in. or for applications involving extremely high pressures.

O-ring boss fittings seat an O-ring between threads and wrench flats around the OD of the male half of the connector, Figure 4. A leak-tight seal is formed against a machined seat on the female port. O-ring boss fittings fall into two general groups: adjustable and non-adjustable. Non-adjustable (or non-orientable) fittings include plugs and connectors. These are simply screwed into a port, and no alignment is needed. Adjustable fittings, such as elbows and tees, need to be oriented in a specific direction.

The basic design difference between the two types is that plugs and connectors have no locknuts and require no back-up washer to effectively seal a

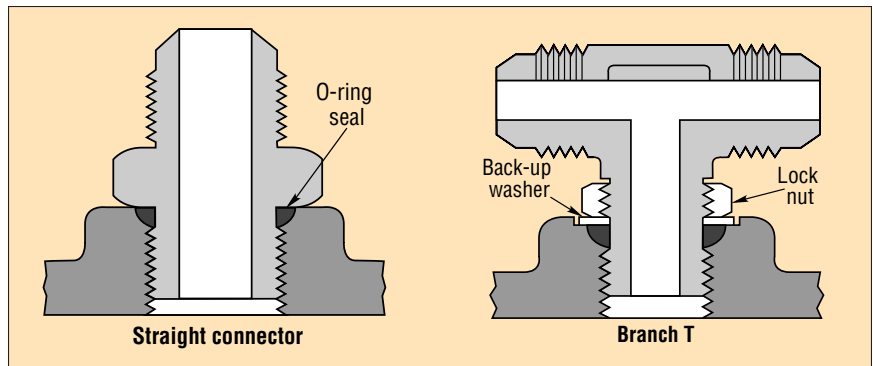


Fig. 4. Non-adjustable, left, and adjustable SAE straight-thread O-ring fittings offer ease of assembly and high potential for leak-tight connections.

joint. They depend on their flanged annular area to push the O-ring into the port's tapered seal cavity and squeeze the O-ring to seal the connection. Adjustable fittings are screwed into the mating member, oriented in the required direction, and locked in place when a locknut is tightened. Tightening the locknut also forces a captive backup washer onto the O-ring, which forms the leak-tight seal. Assembly is always predictable, because technicians need only make sure that the backup washer is firmly seated on the port's spot face surface when the assembly is completed and that it is tightened properly.

The FFOR fitting forms a seal between a flat, finished surface on the female half and an O-ring held in a recessed circular groove in the male half, Figure 5. Turning a captive threaded nut on the female half draws the two halves together and compresses the O-ring.

Fittings with O-ring seals offer a number of advantages over metal-to-metal fittings. While under- or over-tightening any fitting can allow leakage, all-metal fittings are more susceptible to leakage because they must be tightened to within a higher, yet narrower torque range. This makes it easier to strip threads or crack or distort fitting components, which prevents proper sealing. The rubber-to-metal seal in O-ring fittings does not distort any metal parts and provides a tangible “feel” when the connection is tight. All-metal fittings tighten more gradually, so technicians may have trouble detecting when a connection is tight enough but not too tight.

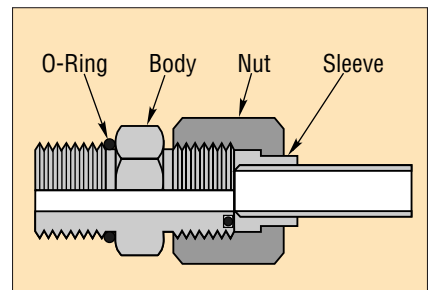


Fig. 5. Flat-face O-ring fitting uses O-ring in recessed groove in male half that mates with flat, smooth surface on female half.

On the other hand, O-ring fittings are more expensive than their all-metal counterparts, and care must be exercised during installation to ensure that the O-ring doesn't fall out or get damaged when the assemblies are connected. In addition, O-rings are not interchangeable among all couplings. Selecting the wrong O-ring or reusing one that has been deformed or damaged can invite leakage. Once an O-ring has been used in a fitting, it is not reusable, even though it may appear free of distortions.

Some manufacturers offer specially designed, high-pressure fittings that are equal in leak and weep resistance to FFOR fittings and interchangeable with a number of international fittings. Testing has shown these new designs to surpass all requirements with no evidence of leakage when exposed to vibrations up to 15 times more severe than those experienced on a typical hydrostatic drive. These designs may appear similar to standard fittings, but should not be mated with fittings from different manufacturers.

Hydraulic flanges

Fittings for tubing larger than 1-in. OD have to be tightened with large hexnuts which, in turn, require larger wrenches to enable workers to apply sufficient torque to tighten the fittings properly. To install such large fittings, system designers must provide the necessary space to give workers enough room to swing large wrenches. In addition, worker strength and fatigue could be factors affecting proper assembly. Extensions might be needed for some workers to exert an applicable amount of torque.

Fittings manufacturers have designed split-flange fittings so that they overcome both of these problems. Split-flange fittings, Figure 6, use an O-ring to seal a joint and contain pressurized fluid. An elastomeric O-ring rests in a groove on a flange and mates with a flat surface on a port — an arrangement similar to the FFOR fitting. The O-ring flange is attached to the port using four mounting bolts that tighten down onto flange clamps, thus eliminating the need for a large wrench when connecting large-diameter components. When installing flange connections, it is important to apply even torque on the four flange bolts to avoid creating a gap through which the O-ring can extrude under high pressure.

The basic split-flange fitting consists of four elements: a flanged head connected permanently (generally welded or brazed) to the tube, an O-ring that

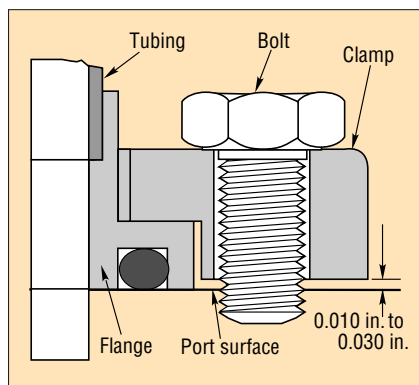


Fig 6. Properly designed and installed split-flange fitting has a uniform clearance of 0.010 to 0.030 in. between the port surface and clamp halves.

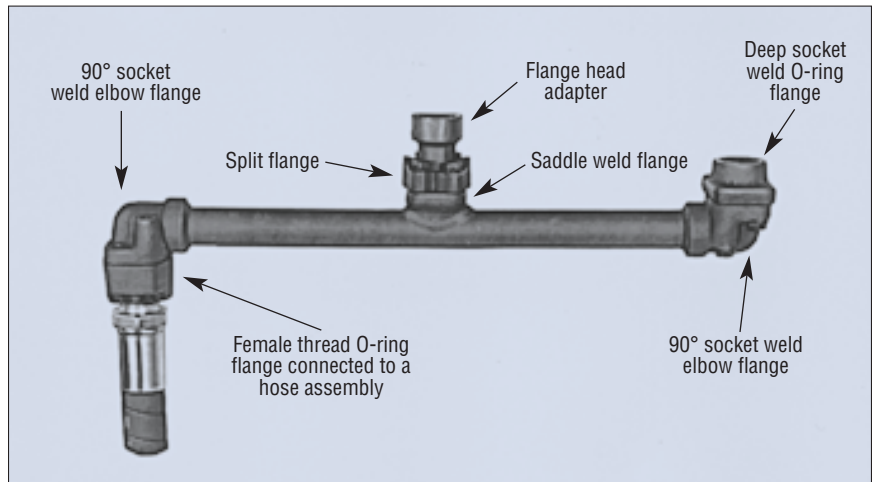


Fig. 7. Weld-type fittings used in conjunction with SAE 4-bolt flange clamp halves and O-ring flange head couplings offer convenience, economy for hydraulic connection assemblies.

fits into a groove machined into the end face of the flange, and two mating clamp halves with appropriate bolts to connect the split-flange assembly to a mating surface.

All mating surfaces must be clean and smooth. Joints are more likely to leak if either of the mating surfaces are scratched, scored, or gouged. Additionally, wear tends to accelerate on O-rings which are assembled against rough surfaces. Where perpendicular relationships are critical, all parts must meet appropriate tolerances. While 64- μ m. surface finishes are acceptable, most flange manufacturers prefer and recommend 32- μ m. finishes on mating surfaces to ensure leak-free connections.

In a properly designed split-flange assembly, the flange shoulder protrudes approximately 0.010 to 0.030 in. beyond the clamp face to ensure adequate contact and seal squeeze

with the mating face, Figure 6. However, the clamp halves *do not* actually contact the mating surface. The most critical operation during assembly of a split-flange fitting to its mating surface is to make certain that the four fastening bolts are tightened gradually and evenly in a cross pattern. Air wrenches should not be used because they are difficult to control and can easily over-tighten a bolt.

Fully tightening one of the bolts while the others are still loose will tend to cause the flange to tip upward, Figure 8. This action pinches the O-ring, and the joint can then be expected to leak. When the bolts are fully tightened, the flanges sometimes bend downward until they bottom on the port face, and the bolts bend outward, Figure 8. Should flanges and bolts bend, they tend to lift the flange off the shoulder; once again, the result will be a leaking joint.

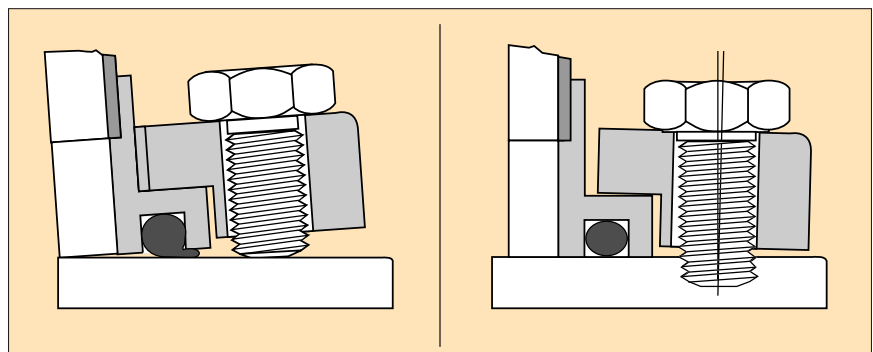


Fig. 8. Unevenly tightened split-flange bolts may cause flange to tip up and damage O-ring, as shown at left, while over-tightened bolts, right, can bend the flange and bolts.