



Dry Technology®

The Guide to Leak-Free Connections

4300-DT December 2004

Parker

ENGINEERING YOUR SUCCESS.

Forward

The Dry Technology Guide® is presented as a generic source of information to assist designers, assemblers and maintenance personnel who create and maintain dry (leak-free) systems. The intent is to clearly and completely present the subject matter in a manner usable by individuals with varying levels of expertise.

The information is provided in a logical and sequential order, which allows the user to build a base of knowledge. Whenever possible, trade names associated with Parker components are removed in favor of industry accepted terms.

The Dry Technology Guide incorporates a great deal of graphical information to help illustrate and reinforce the concepts. While these graphics are representative in nature, they are not intended to serve as engineering drawings.

Dry Tech tips have also been incorporated in the right-hand margin and deal with commonly asked questions. In many instances, the Dry Tech tips are discussed in greater detail in the body text.

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Defining Dry Technology®

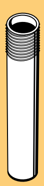
Dry Technology is today's most comprehensive and effective process for determining the best hydraulic connections for the application. It provides a foundation of knowledge for evaluating hydraulic applications and making informed decisions.

When specifying components, several key issues should be addressed: zero leakage, oil loss, availability, assembly and maintenance, and cost control. Through Dry Technology, these key issues can be systematically evaluated to determine an appropriate solution.

History of the Hydraulic Fitting

Today many different types of connectors are being used around the world. The main reasons are historical use and local preference for certain designs. Some connections of North American origin such as 4-bolt flange, SAE straight thread and 37° flare have found some degree of acceptance and use in Europe and Japan. Their acceptance was due in large part to the large volume of machinery exports to these regions following World War II. Still, a majority of usage is made up of indigenous port and tube connections.

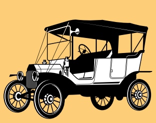
A review of typically used designs around the world reveals that there are nine primary port connections and ten primary tube/hose connections.



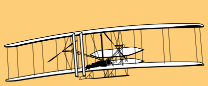
First threading of pipe, allowing for hydraulic fluid conveyance systems to be developed

Late 1800s

Henry Ford builds his first automobile



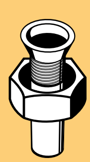
1896



Wright brothers fly their first mechanically propelled plane

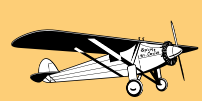
1903

Flare fitting developed for joining tube, the first being an inverted style used in the aircraft industry



1926

Charles Lindbergh makes first intercontinental flight

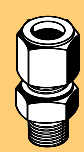


1927

Development of 3-piece 37° flare fitting, which has become the world's most widely used fitting

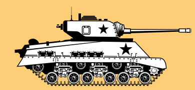
1930

Metric flareless or bite-style fitting developed and introduced in Germany



1937

U.S. officially enters World War II



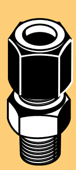
1941

Port Connections	Tube/Hose Connections
NPT/NPTF	37° Flare
BSPT (JIS-PT)	30° Flare (Metric)
Metric Taper	45° Flare
SAE Straight Thread	24° Flareless (SAE)
ISO 6149	24° Flareless (DIN)
JIS-B2351	30° Flare (BSPP)
DIN Metric	O-Ring Face Seal (ORFS)
BSPP (JIS-PF)	60° NPSM Swivel
4-Bolt Flange	60° Cone (BSPP)
	60° Cone (Metric)

To fully understand the function and features of today's fittings, it is worthwhile to take a look at their history. This timeline highlights major advancements in fitting and sealing technology.

Numerous modifications to those basic designs continue to occur today. Most of the advancements in fitting technology have been in response to growing demands for solutions to:

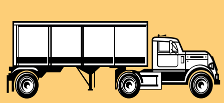
- Increasing system pressures
- Faster/easier tube preparation
- Environmental concerns
- Safety



Imperial version (for inch tube) of flareless fitting introduced in the U.S.

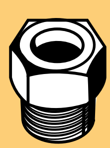
1945

America's first interstate highway system is inaugurated



1956

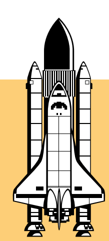
SAE straight thread port developed



1960

Neil Armstrong becomes first man to walk on the moon

1969



First space shuttle, Columbia, successfully completes its mission

1981

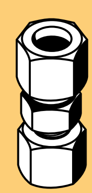
O-ring face seal fitting developed

1984

Public use of the Internet and the information superhighway

1990

Elastomer incorporated into metric bite-style fitting



1993

Causes of Leakage

Commonly considered the biggest nemesis of a hydraulic system, fluid leakage is a problem that virtually everyone has seen at one time or another. But just what causes leakage may be somewhat surprising. The chart below reveals the four leading contributors to leakage along with the percentage of the time they were a factor.

Improper Installation.............. **60%**

Poor System **Design**................ **20%**

Quality of Components............ **15%**

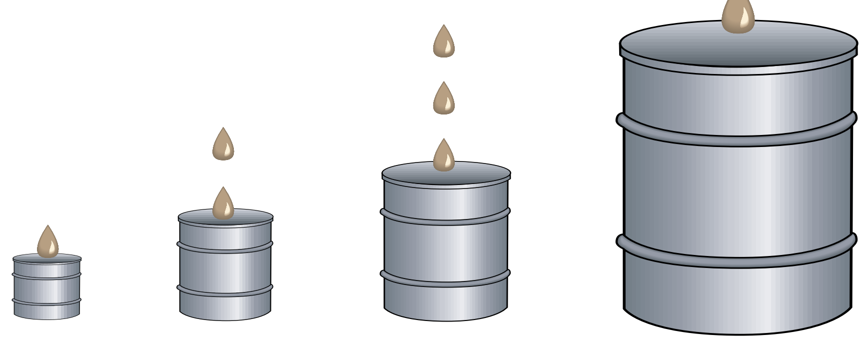
System **Abuse**.............................**5%**

As shown, the leading cause of leaks is improper installation, which is primarily why Dry Technology was developed. This guide will outline the appropriate techniques and steps for properly specifying and installing fittings for a reliable system.

Results of Leakage

While the causes of leakage are now identifiable, the results can vary widely. One sure consequence is that leakage will cost money. The obvious cost associated with leakage is the loss of system fluid. The graphic below illustrates how leaks can add up to sizeable expenditures if not corrected.

1 drop every 1 minute = 6.7 gallons per year	=	**$33.50**
1 drop every 10 seconds = 40 gallons per year	=	**$200.00**
1 drop every 5 seconds = 80 gallons per year	=	**$400.00**
1 drop every second = 402 gallons per year	=	**$2,010.00**



Based on 24 hours a day runtime at $5 per gallon

In addition to system fluid loss, there are many costs associated with leakage that are often overlooked. Some of the less visible ones are revealed here.

Preventing Leakage

Dry Technology is a methodology for preventing leakage by addressing the four major causes previously identified: poor system design, improper installation, quality of components, and system abuse. A large portion of Dry Technology covers system design and installation since these contribute to 80 percent of the leakage problems.

System design is the first critical phase in leakage prevention. It involves selecting the right components to fit the application. The system designer must thoroughly examine all the major considerations and how they will affect the choice of components. Once a designer looks at the application and determines which components can meet the requirements, other more subjective factors can be considered.

DRY TECH TIP:

✎ *Fittings with elastomer seals provide the most reliable performance.*

✎ *Elastomers have the ability to compensate for imperfections in surface finishes. When applying fittings with seals, verify they are compatible with the application.*

- *Temperature range*
- *Fluid type (compatibility)*

Application Considerations for System Design

Pressure — What is the minimum and maximum pressure, and the number of times the pressure will cycle between those two points?

Shock — Will the component be subjected to mechanical or hydraulic shocks that could be detrimental to its expected life?

Vibration — How severe, and will it cause the components to loosen or prematurely fail?

Temperature (Ambient and Fluid) — What extremes will the system be subjected to and how will they affect the material in the components?

Environment — Where will the system be operating and how will that affect its performance? Will there be excessive corrosive or mechanical abuse?

Contamination — Are contaminants being introduced to the system due to the style or quality of fitting being selected?

Fluid Velocities — Does the tube and fitting size allow for acceptable velocity?

Proper installation is detailed for each fitting type in the **"Tube and Fitting Assembly"** section of this guide. Dry Technology will provide the proper techniques and guidelines for the various port and tube end styles. Proper installation always requires training of assembly personnel.

Quality of components can be controlled by working with a manufacturer that consistently provides high-quality parts. Dry Technology details the characteristics of high-quality fittings and how they affect performance.

System abuse, the final and often-overlooked factor, can also be controlled. This is typically assumed to be the responsibility of the end-user. However, through proper system development, the potential for abuse can be reduced. This can be accomplished by proper routing, clamping and training, to list just a few.

Specific Considerations in System Design and Manufacture Include:

- Providing enough space (wrench clearances) to maintain equipment properly
- Providing specialty tools to which the user, normally, would not have access (e.g., captive O-ring insertion tools)
- Maintenance manuals outlining not only OEM and manufacturers part numbers, but proper assembly techniques for servicing
- Utilizing protective caps and plugs for threaded connections, and not removing until final connection with the mating tube or hose assembly
- Routing designed to reduce the possibility of user standing or climbing on plumbing

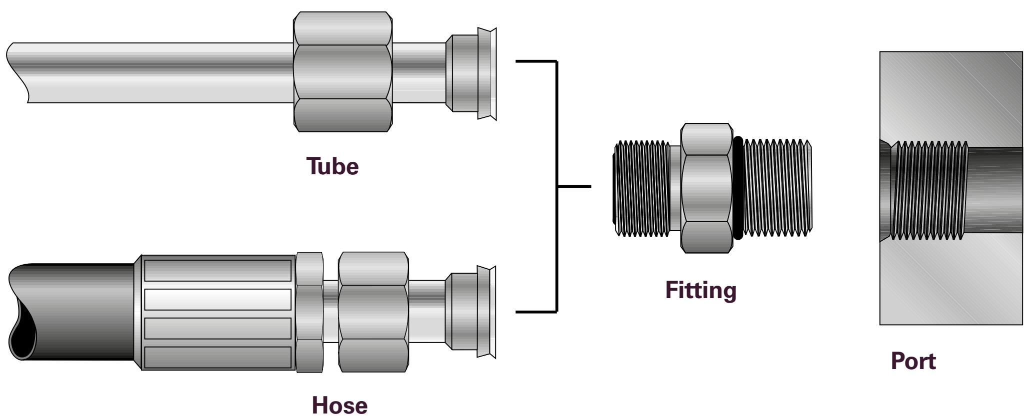
When proceeding through this Dry Technology guide, it will become apparent how all of the factors that cause leakage are related. The elimination of leakage and creation of a dry system can only be accomplished by addressing all four major factors.

DRY TECH TIP:

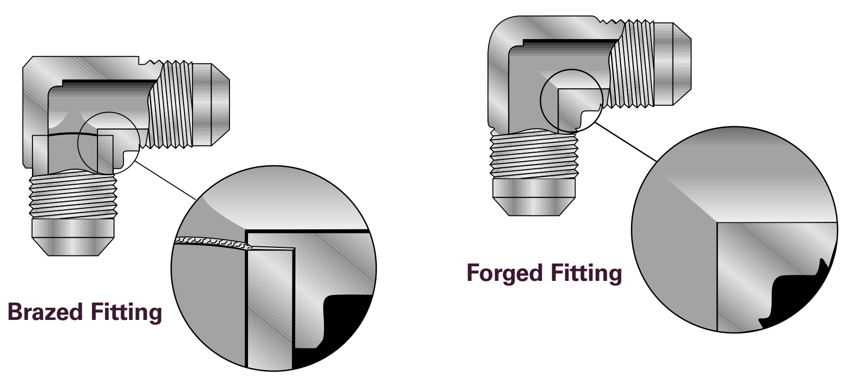
✎ *A well-designed system is one that takes ease of maintenance into consideration along with proper function and ease of installation.*

Selecting Tube Fittings

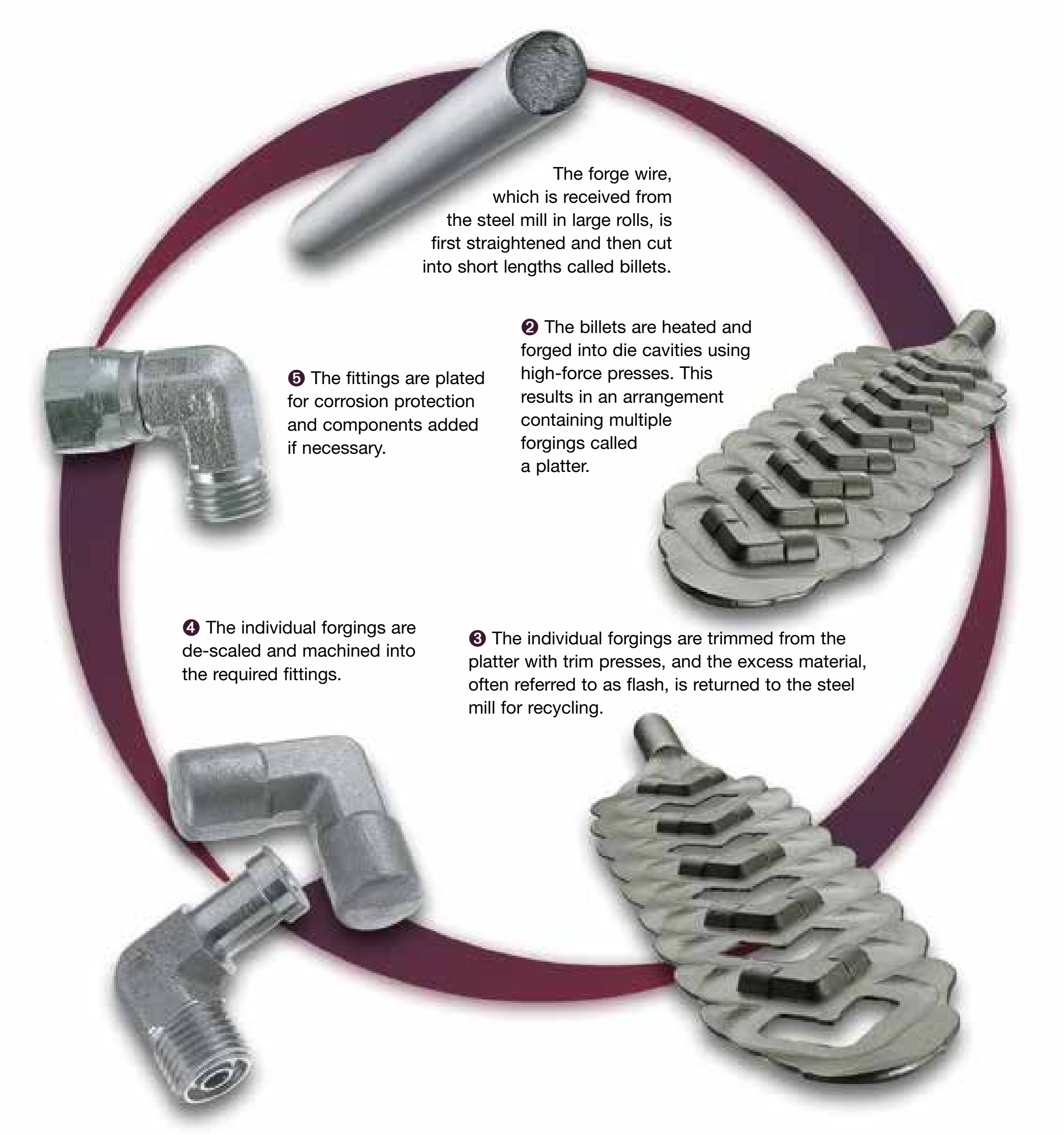
In evaluating tube fittings, it is important to first understand their purpose and design. A tube fitting typically serves as a connector between a component and a tube or hose. The ends of fittings themselves are commonly called the port end and the tube end. The port end of a fitting connects to the component (e.g., pump, valve, motor, etc.), while the tube end connects to a tube or hose.



Fittings are divided into two main categories, straights and shapes. Straights are typically machined from hexagonal (hex) bar stock, while shapes are typically forged or brazed. As the illustrations show, there are characteristics that make it easy to identify forged and brazed styles.



In addition to the obvious visual differences, there are several key performance differences. Because forgings are a single-piece construction, there are no potential leak paths created as with a two-piece brazed fitting. Forged fittings are also stronger because of the optimum grain structure achieved in the forging process. The added strength of a forged fitting typically produces longer life, higher-pressure ratings, and greater assembly torque capabilities.



Brazed fittings are popular with some manufacturers due to the large number of configurations that can be made with little investment required in capital equipment. As a result, brazed fittings are usually offered at a lower price to the user.

DRY TECH TIP:

✎ *Not all forgings are created equal. When forging material is too hard, brittle failures can occur. A higher hardness forging is not necessarily better.*

Fitting Selection Criteria

To ensure a leak-free connection, several factors must be considered when selecting the proper fitting. These include size, temperature, application, media and pressure.

Selecting the proper fitting for a given application is an important part of system design. This selection process is driven by the following fluid system parameters. The acronym STAMP is an easy tool for determining the proper fitting selection.

Size
Temperature
Application
Media
Pressure

Size: The tube outside diameter (O.D.) and wall thickness should be considered for all tube fittings. With most tube end types, there exist limitations with respect to the tube wall thickness. The flare-type fitting typically has a maximum tube wall limitation, while the flareless bite-type fitting has a minimum wall limitation. The proper selection of the tube O.D. and wall thickness depends on other factors such as system pressure, flow, temperature, and service environment. This is covered in the section titled **"Selecting Hydraulic Tube."**

Temperature: The operation temperature range for tube fittings depends on the material type, plating and type of seal, if applicable. The following table contains temperature ranges for the most common fitting materials and seals.

Material Temperature Table

Fitting Material	Temperature Range
Steel (electroplated)	-65° to 500°F (-54° to 260°C)
Stainless Steel	-425° to 1200°F (-254° to 649°C)
Brass	-40° to 400°F (-40° to 204°C)
Aluminum	-40° to 400°F (-40° to 204°C)
Seal Material	**Temperature Range**
Nitrile (SAE J515, Type I)	-30° to 250°F (-34° to 121°C)
Fluorocarbon (SAE J515, Type III)	-15° to 400°F (-26° to 204°C)
EPDM (SAE J515, Type II)	-40° to 400°F (-40° to 204°C)

Application: The system environment influences the design and selection of all types of fittings as well. Protective coatings are usually applied to steel fittings to extend their useful life in corrosive environments. The most common finish for steel fittings is electroplated zinc with a yellow chromate. Zinc will corrode sacrificially, protecting the steel base metal from normal rusting due to the presence of oxygen, moisture and acidic gases. For highly corrosive environments, stainless steel or brass material is a viable option.

Media: The type of fluid being conveyed is another important factor that should be considered when selecting the fitting material and seal. The "Fluid Compatibility Chart" (Table 1 in the Appendix) can be used as a guide.

Pressure: Rated dynamic pressure of the fitting should be equal to or higher than the system pressure. Tube fittings are customarily rated at a 4:1 design factor. The design factor is generally applied as a ratio of the ultimate strength of the material with respect to the dynamic pressure rating of the connection. This provides a measure of safety against the unknowns in material and operating conditions. The 4:1 design factor applies to "normal" operating conditions, with moderate mechanical and hydraulic shocks.

DRY TECH TIP:

✎ *Hydraulic systems should be classified as either dynamic or static. Static systems are free of pressure surges, shocks and vibration and do not exceed 30,000 operating cycles. Dynamic systems are far more common and are rated for 1 million operating cycleswithout failure.*

For more severe operating conditions, a "Derating Factor" should be applied directly to the dynamic pressure of the fitting. The following table displays the "Derating Factor" for three operating conditions.

Severity of Service	Description	Design Factor	Derating Factor
A (Normal)	Moderate mechanical and hydraulic shocks.	4:1	1.00
B (Severe)	Severe hydraulic shocks and mechanical strain.	6:1	0.67
C (Hazardous)	Hazardous application with severe service conditions.	8:1	0.50

Example of derating the dynamic pressure of a fitting:

Dynamic pressure rating of the fitting = 5000 psi
Severity of Service: B (Severe hydraulic shock and mechanical strain)

Design factor for "B" severity of service = 6:1

Derating factor for design factor of 6 = 0.67

Derated Pressure = 5000 X 0.67
= 3350 psi

Caution: Applications in which failures could result in bodily injury should have a higher design factor.

Tube/Hose End Selection

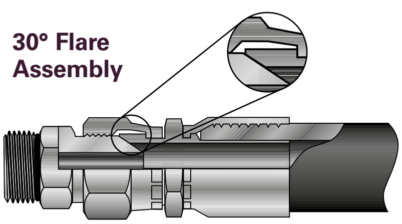
There are several types of fittings for industrial hydraulic applications. Fittings are used to connect either a tube or hose to a component or can be used to connect a tube/hose to another tube/hose. For the purpose of Dry Technology, the tube/hose end of the fitting will be referred to as the tube end. The tube ends of some fittings conform to industrial standards, while others are considered proprietary. The most popular styles, each conforming to an SAE, ISO, DIN and/or other standards, will be covered in this section.

- Flare Type
- Flareless (Bite-type)
- O-Ring Face Seal
- 60° Cone

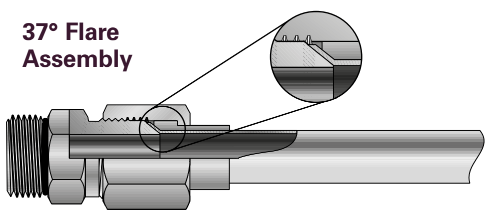
Flare Type

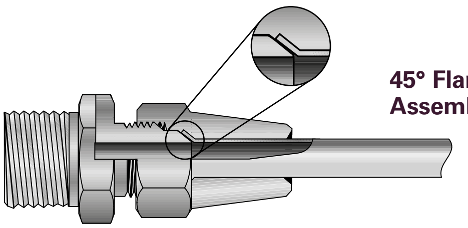
The flare type fitting has been in existence since the early 1900s when it was being used in the automotive industry. Today, there exist three common types: 45°, 30° and 37°.

30° Flare Assembly



37° Flare Assembly





45° Flare Assembly

The 45° flare fitting is typically used in low-pressure applications such as those found in automotive and HVAC industries. The 30° flare fitting is typically used as hose adapters on equipment designed and/or manufactured in Japan and Korea. The most widely used hydraulic flare fitting in the world is the 37° flare fitting. For this reason, this section will focus on the 37° flare fitting.

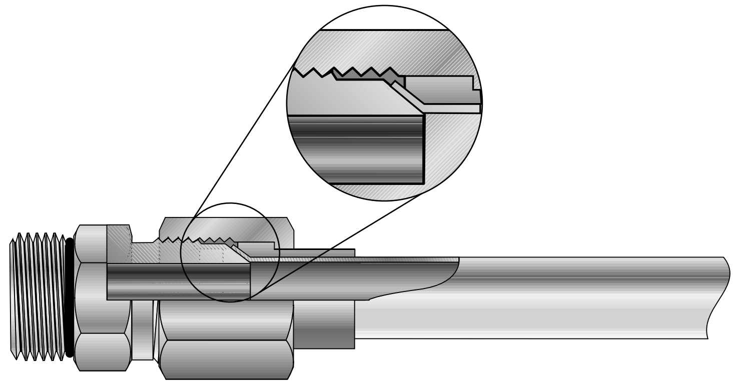
DRY TECH TIP:

✎ *Protective plastic caps and plugs for connections should be left in place as long as possible during installation to prevent thread damage and contamination.*

✎ *Derating of Rated Pressure: Two factors that can affect the rated pressure of the fitting are severity of service and operating temperature. See Table 2 in the Appendix for temperature derating factors.*

37° Flare Design

The 37° flare fitting design is quite simple. It consists of three components: the fitting body, sleeve and nut. The tube end is flared at a 37° angle and held captive between the fitting nose and the sleeve with the nut as shown. A single metal-to-metal seal point is formed between the fitting nose and the flared tube end.



Some fitting manufacturers offer a two-piece 37° flare design that eliminates the use of the sleeve. It is not as reliable as the three-piece design as the sleeve provides support against vibration, tube twist, misalignment and potential cross threading.

Features

Sealing Capability: The seal for the 37° flare fitting is created by metal-to-metal contact between the fitting nose and the flared tube end. This sealing method allows the fitting to be used with a greater range of media and temperature. On the other hand, the metal-to-metal seal is not as reliable as an elastomeric seal, such as an O-ring face seal fitting, that may be used by other fitting types.

Conical seals, usually made from soft metal materials such as copper and aluminum, are sometimes utilized to improve sealing capability. They are positioned over the fitting nose and can be easily formed to fill out surface imperfections on the nose and/or flared tube. However, conical seals are considered a ”Band-Aid” because they do not cure the root problem: the poor machining of the fitting nose and/or damage due to abuse. Additionally, because of their soft material, conical seals tend to creep while in service and can cause the joint to loosen and leak.

Operating Pressure: The 37° flare fitting is generally considered to be a 3000 psi fitting. However, its working pressure capability can range from 1500 to over 7000 psi, depending on size, configuration and material.

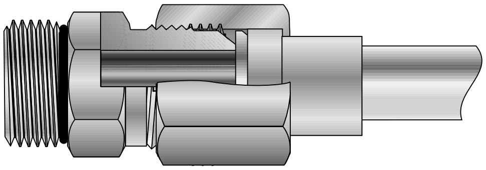
Temperature Range: The absence of an elastomeric seal allows for a wider operating temperature range and use in more applications. If a seal exists on the port end, then the temperature range will be that of the seal.

Tube Wall Range: The 37° flare fitting is suitable for very thin to medium wall tubing. The use of low-cost, thin wall tube can help reduce the overall system cost. Refer to Table 7 in the Appendix for tube wall range.

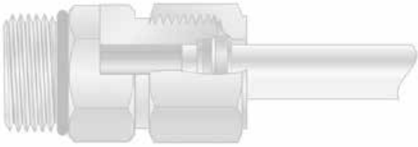
Heavy Wall Limitation: Heavy wall is difficult to flare and may not provide enough contact area to properly seal with the fitting nose. If it were possible to flare the heavy wall for adequate contact area, the outside O.D. of the flared end will be too large to allow the nut to slide over it. The heavy wall limitation does not allow the 37° flare fitting to be used with tube in higher-pressure applications.

Wall thickness limitations must be considered in order to provide adequate sealing without over-flaring

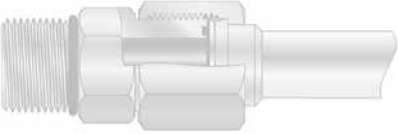
Tube Entry: The 37° flare fitting requires a small amount of tube entry when installing or removing a tube assembly. The greater the tube entry, the more difficult it is to install or remove a tube line. The entry for 37° flare fittings is usually less than that for flareless bite-type fittings and more than that for O-ring face seal fittings.



37° Flare Fitting



Bite-type Fitting



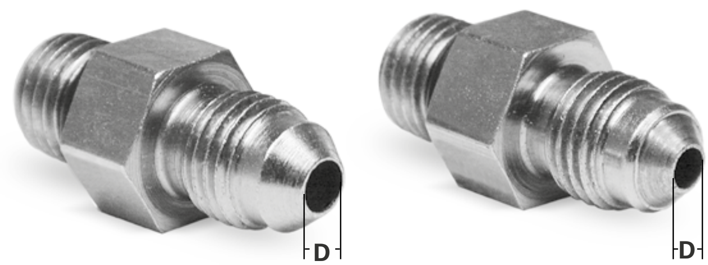
O-Ring Face Seal Fitting

DRY TECH TIP:

✎ *If the required tubing has a wall thickness that is too thick to flare, consider a hose connection as an alternative.*

Adaptability to Metric Tubing: One of the primary reasons for its worldwide acceptance is its versatility. The 37° flare fitting can be easily adapted to metric tube by merely changing the sleeve. The same fitting and nut are used for both inch or metric tube by changing the inside diameter profile of the sleeve.

Assembly Torque: Because of the small seal area, high pressure capability can be reached at relatively low assembly torque levels. This allows for use of small wrenches for easy installation and maintenance. The low torque requirement can be a reason for caution as over-tightening during assembly can lead to nose collapse. This distortion can result in reduced flow and leakage.



Before:
D = 0.172"
Area = 0.0233 sq. inch

After:
D = 0.1335"
Area = 0.0014 sq. inch

22.4% Diameter Reduction
39.8% Reduction in Flow Area

Reusability/Remakeability: Because this fitting relies on a metal-to-metal seal, it has limited remakeability. This is due to damage caused during assembly and its tendency to be over-tightened.

Availability: As the most commonly used fitting in the world, 37° flare fittings are available in the broadest range of sizes, configurations and materials.

Conformance Standards: The 37° flare fittings conform to SAE J514 and ISO 8434-2. They may also conform to the military specification MIL-F 18866.

Flareless (Bite-Type)

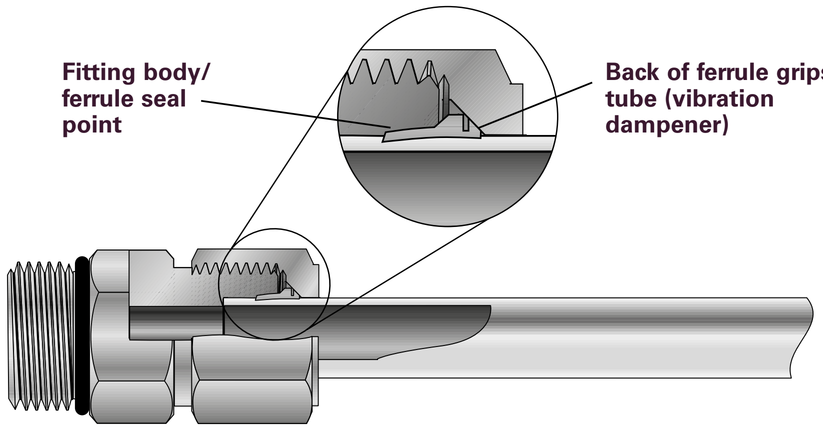
The flareless bite-type connection originated in Europe in the 1930s and was initially suited for metric tube only. A similar flareless bite-type design was later introduced in the U.S. in the mid-1940s and is suitable for inch tube only. Recently, other European designs have been developed incorporating an elastomeric seal with a bite ring. These fitting designs have worldwide acceptance and are especially popular in Europe.

Flareless Design

The North American and the European bite-type connections are constructed in a similar fashion. Each of the original designs consists of three pieces: the flareless fitting body, nut, and ferrule or bite ring. The newer version, with the elastomeric seal ring in front of the bite ring, adds a fourth piece to the assembly.

Although their number of pieces may differ, all of these connections function similarly. As the bite ring or ferrule is wedged between the fitting body and the nut, it is forced to cut/bite into the O.D. of the tube. The bite provides the holding power needed to withstand the system pressures. In the European versions, a second bite takes place but is not visible during inspection.

The ferrule or bite ring is designed to grip the tube at the rear of the ferrule to distribute vibration/flexural stresses at several points in the joint, therefore the bite is isolated and stress in the bite is minimized. This isolation allows for a reliable connection even in vibration applications.



DRY TECH TIP:

✎ *Flareless fittings can be used as a hose adapter as well as a tube fitting.*

Flareless (Bite-type) Features

Sealing Capability: Bite-type fittings have demonstrated an ability to remain leak-free under various service conditions ranging from sealing high-vacuum and small-molecule gase to high-pressure hydraulic fluids. Utilizing an elastomeric seal, as in some European designs, can provide even greater sealing reliability.

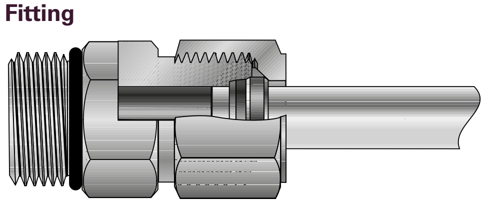
Operating Pressure: Due to the different operating principle, bite-type fittings have a wider range of suitable pressures compared with 37° flare fittings. The European style offers three different series of the bite-type fitting for different pressure ranges. Pressures typically range from 100 to 630 bars (approximately 1450 to 9100 psi).

Temperature Range: Flareless fittings that do not incorporate an elastomeric seal have a wide operating temperature range and can be used in more applications. For the flareless design that includes an elastomer seal, and for fittings that include an elastomer seal on the port connection, the temperature range will be limited by the seal material.

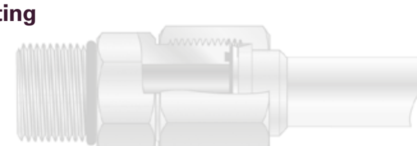
Tube Wall Range: Flareless bite-type connections are suitable for medium to heavy wall thickness tubes. Due to the nature of the connection, the bite in the tube may cause thin wall tube to collapse during assembly and make-up. Refer to Table 7 in the Appendix for tube wall range. Some bite-type fittings allow the use of a tube support for thinner wall tubes.

Tube Entry: Flareless bite-type fittings generally require more tube entry into the fitting than other fitting styles. This makes it more difficult to assemble and disassemble.

37° Flare Fitting



Bite-Type Fitting



O-Ring Face Seal Fitting

Adaptability to Inch/Metric Tube: Inch size flareless fittings are designed only for inch tube, and metric sizes only for metric tube. A custom adapter would be required to interchange from one type to the other.

Assembly: The ferrule must be preset in all bite-type fittings. For sizes below 3/4" or 20 mm, no special equipment is required to preset the ferrule. The steel ferrules may be preset manually with wrenches.

Availability: Bite-type fittings are available as standard in many sizes and configurations, and in many different countries around the world. Global inventory ensures parts availability.

Conformance Standards: Most flareless bite-type fittings conform to SAE J514, MIL-F-18866, and ISO 8434-1 and/or DIN 2353 (European versions).

Visible Bite: The critical ferrule-to-tube bite is clearly visible to tube fitters and inspectors. The presence of the recommended bite virtually eliminates the risk of catastrophic blow-off, a very important safety feature.

Reusability/Remakeability: Joints can be disassembled and reassembled many times to facilitate system maintenance. This reduces the labor and material costs of tube and fitting replacement.

Pre-lubricated Nut: Stainless-steel tube nuts are pre-lubricated. The SAE version is manufactured with a bonded dry film lubricant, making additional thread lubricant unnecessary. The ISO/DIN versions are typically manufactured with silver-plated threads (size 15L-42L, 12S-38S). Thread galling is eliminated and assembly torque is reduced as much as 50 percent.

DRY TECH TIP:

✎ *When using stainless-steel tubing, a carbon steel flareless fitting body can be used as long as the ferrule is also made of stainless steel. This practice is utilized to reduce cost and where corrosion is not a factor.*

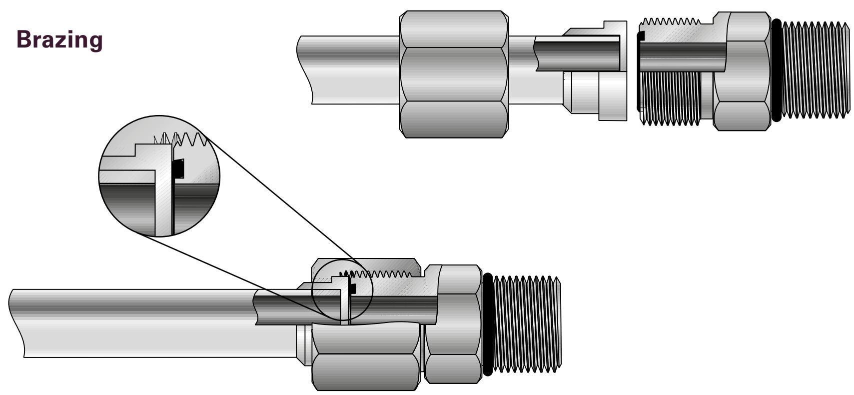
O-Ring Face Seal

The O-ring face seal fitting for industrial hydraulic applications was introduced in the early 1980s in an effort to eliminate leakage in hydraulic systems experiencing higher operating pressures and more severe mechanical shocks. It utilizes an O-ring that provides a more reliable seal than traditional metal-to-metal tube fitting types. Today, it is one of the fastest growing fittings in North America.

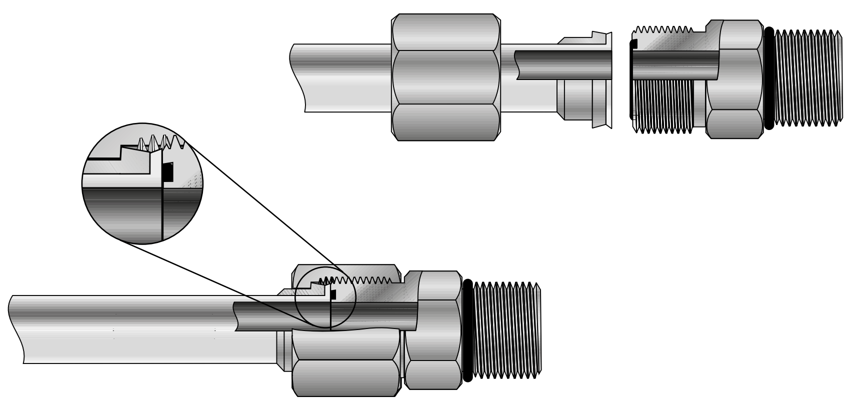
Design

The O-ring face seal fitting consists of a fitting body, nut, sleeve and O-ring. The fitting is designed with a groove on its face for an O-ring. The sleeve is permanently attached to the tube by one of two methods: mechanically or brazing. As the nut is tightened onto the fitting body, the O-ring is compressed between the body and the flat face of the tube flange (or braze sleeve) to form a tight, positive seal.

Brazing



Mechanical Attachment (Flanging)



In its original design, the O-ring face seal fitting was manufactured with a square groove for the O-ring. This groove did not always retain the O-ring, resulting in leaky connections as well as extra handling to replace the lost O-ring. Today, several fitting manufacturers incorporate their fittings with a half dove-tail groove, as shown, to provide positive retention of the O-ring.

Features

Sealing Capability: The O-ring faceseal fitting utilizes a 90 durometer O-ring that provides a more reliable seal than the metal-to-metal seal of other fitting types. Under pressure, the O-ring is compressed into the fitting groove ensuring a leak-tight connection. It is also more forgiving to surface imperfections. On the other hand, this sealing method limits the media and temperature range when compared with the metal-to-metal sealing method.

Operating Pressure: The maximum operating pressure range for O-ring face seal fittings is generally 6000 psi for sizes up to 1" and 4000 psi for sizes 1-1/4" and 1-1/2". However, some manufacturers have qualified their fittings up to 9000 psi depending on size. Because of its superior sealing capability, the O-ring face seal fitting is also ideal for lower pressure applications.

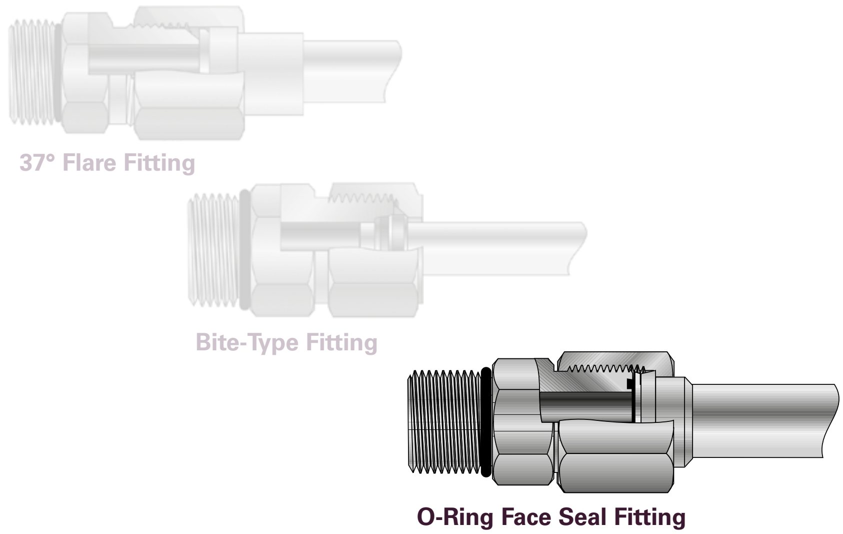
Temperature Range: The temperature range of the fitting is dependent on the temperature range of the O-ring. Nitrile O-rings are the most popular with a temperature range of -30°F to 250°F. For temperatures up to 400°F, a fluorocarbon O-ring is commonly used.

Tube Wall Range: The tube wall range for the O-ring face seal fitting is greater than that of all other fitting types. It is recommended for thin to heavy wall tubing when the braze method is utilized. For the flange method, the tube wall range is dependent on other factors, such as the capability of the flange equipment, and is usually available from the fitting manufacturer. Refer to Table 7 in the Appendix for tube wall range.

DRY TECH TIP:

✎ *Face seal O-rings should always be installed with an insertion tool to prevent them from twisting or popping out.*

No Tube Entry: The O-ring face seal fitting requires no tube entry during installation as illustrated below. This facilitates installation, repair and maintenance. Other fitting types require some tube entry and are more difficult to maintain.



Adaptability to Metric Tubing: Similar to the 37° flare fitting, the O-ring face seal fitting is adaptable to metric tubing by simply changing the sleeve. The same fitting and nut are used for both inch and metric tubing.

Assembly Torque: The flat face design of the O-ring face seal fitting provides a greater resistance to over-torque during assembly. A sharp rise in torque after the flat face components have come into contact gives a "solid feel," minimizing the possibility of over-tightening and damage.

Remakeability: Because the sealing surfaces are flat and perpendicular to the assembly pull, they remain virtually free of distortion during assembly, giving the O-ring face seal fitting virtually unlimited remakeability as long as the O-ring is in good condition. It is recommended that the inexpensive O-ring be replaced before reassembling the fitting.

Availability: Although not as common as the 37° flare fitting, it is gaining worldwide acceptance at a fast pace. It is readily available in a broad range of sizes, configurations and materials.

Conformance Standards: The O-ring face seal fitting conforms to SAE J1453 and ISO 8434-3. These are the first two standards to include performance requirements.

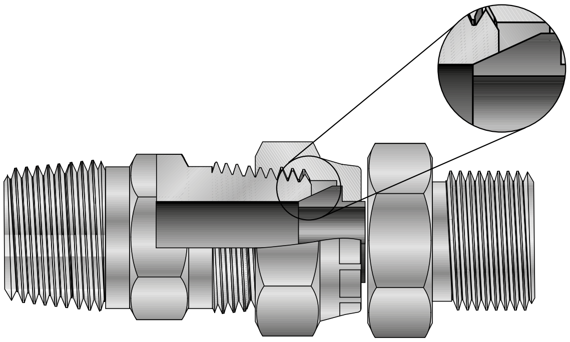
60° Cone

60° cone fittings are typically used for connecting to a hose or another mating fitting. They are seldom used with tube. Sealing is achieved by a line contact between the conical surface of the 60° cone seat and a corresponding surface of the mating component. This style of fitting can have either NPT/NPTF, BSPP, PF or metric threads. There are four types of 60° cone fittings that are commonly used in hydraulic applications.

- SAE J516/J514
- JIS B8363 Code C and R
- BS B5200
- DIN 7631

SAE J516/J514

This version of the 60° cone is very common in North America, especially in mobile applications that have lower pressures. The fitting is designed with NPT/NPTF threads that mate with NPSM (National Standard Straight Pipe Thread for Mechanical Joints) threads that are usually found on swivel hose ends. Sealing is accomplished by a metal-to-metal seal between its 60° cone and the mating seat of the hose fitting. The threads are intended for clamping load and not for sealing.



60° Cone Fitting – Sealing between NPSM swivel adapter and mating chamfer in male pipe thread

DRY TECH TIP:

✎ *Because sealing occurs on the cone seat and not with threads, thread sealants are not needed with 60° cone fittings.*

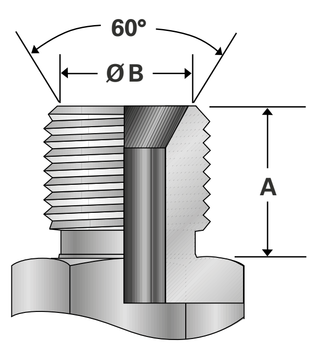
The most important preparation prior to assembly is to make certain that the NPT/NPTF thread has a 30° seat as shown in the photo below. This is critical because most NPT/NPTF male ends are standard without the required 30° seat.

Two male pipe thread ends, the one on the left has a special chamfer for sealing

JIS B8363 (Code C and R) and BS B5200

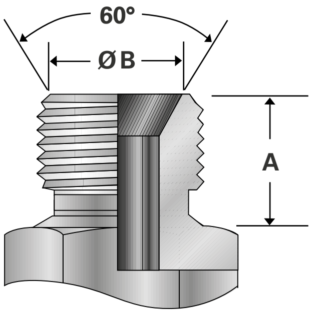
The JIS B8363 and BS B5200 are typically used as hose adapters on equipment designed and/or manufactured in Japan and Korea. Even though these fittings have the same thread (BSPP) and seat angle, they are not identical in other dimensions. Therefore, there are instances when these fittings will not function properly if the components are interchanged. The graphic below will help distinguish between the two.

JIS B8363 60° Cone



Size	BSPP Thread	A	B
2	1/8 – 28	0.418	0.276
4	1/4 – 19	0.570	0.394
6	3/8 – 19	0.609	0.531
8	1/2 – 14	0.726	0.650
12	3/4 – 14	0.805	0.866
16	1 – 11	0.883	1.102
20	1-1/4 – 11	0.945	1.417
24	1-1/2 – 11	0.962	1.654
32	2 – 11	1.102	2.126

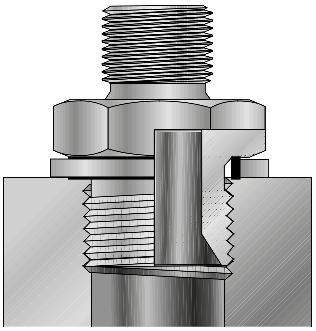
BS B5200 60° Cone



Size	BSPP Thread	A	B
2	1/8 – 28	0.315	0.295
4	1/4 – 19	0.433	0.409
6	3/8 – 19	0.472	0.551
8	1/2 – 14	0.551	0.689
10	5/8 – 14	0.630	0.760
12	3/4 – 14	0.630	0.902
16	1 – 11	0.748	1.130
20	1-1/4 – 11	0.787	1.449
24	1-1/2 – 11	0.866	1.681
32	2 – 11	0.984	2.150

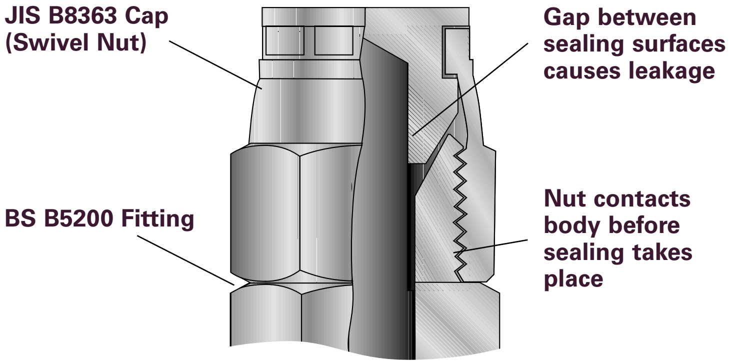
The more pronounced differences are: thread length, chamfer diameter and undercut area.

The BS B5200 is designed as a dual-function end connection (hose connection and port end connection). When used as a port end connection, a bonded seal is utilized as shown below.



BS B5200 Design being used as a port end connection

Interchanging components between JIS and BS can, in some cases, lead to leakage problems. The differences in thread length and chamfer diameter may cause the swivel nut to contact the fitting body before sealing takes place.



DRY TECH TIP:

✎ *The internal seat on a 60° cone fitting should always be inspected to make sure there are no nicks or scratches prior to assembly.*

DIN 7631

The DIN 7631 fitting is the least widely used of all the 60° cone fittings. Its distinguishing characteristic is its metric parallel threads.

Common Features of 60° Cone Fittings

Sealing Capability: The 60° cone fitting utilizes a single metal-to-metal seal point formed between the conical surface of the fitting's cone seat and the corresponding surface of the mating component.

Operating Pressure: The 60° cone fitting is generally used for medium-pressure applications. However, its working pressure capability can range from 1100 to 5000 psi, depending on size, configuration and material.

Temperature Range: The absence of an elastomeric seal allows for a wider operating temperature range and use in more applications. If a seal exists on the port end, then the temperature range will be that of the seal.

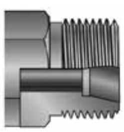
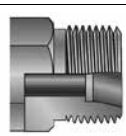
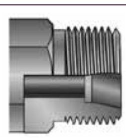
Adaptability: 60° cone fittings are designed specifically for use as hose ends. As discussed previously, some of these fittings are dual functional and can be used as a port connection.

Remakeability: Because this fitting relies on a metal-to-metal seal, it has limited remakeability. This is due to its low assembly torque and possible damage to sealing surfaces.

Summary

This section has covered the popular tube end connections. The following chart rates the key features of these tube ends.

Tube/Hose End Summary

Tube/Hose End Type	Illustration	Pressure–Dynamic	Pressure–Static	Seal Reliability	Vibration Resistance (in Rigid Systems)	Ease of Installation	Ease of Maintenance	Reusability	Temperature
Seal-Lok O-Ring Face Seal		Excellent	Excellent	Excellent	Very Good	Excellent	Excellent	Excellent	Limited by Seal
Triple-Lok 37°Flare		Very Good	Very Good	Good	Good	Good	Very Good	Good	Excellent
Ferulok Inch Bite Type		Very Good	Very Good	Very Good	Very Good	Good	Good	Very Good	Excellent
EO Metric Bite Type		Excellent	Excellent	Very Good	Very Good	Good	Good	Very Good	Excellent
EO-2 Soft Seal Metric Bite Type		Excellent	Excellent	Excellent	Very Good	Very Good	Good	Excellent	Limited by Seal
Intru-Lok Brass Flareless		Fair (Low)	Fair (Low)	Very Good	Good	Good	Good	Good	Excellent
JIS 30°Flare		Good	Good	Very Good	Not Applicable	Very Good	Very Good	Very Good	Limited by Seal
JIS 60° Cone B8363		Good	Good	Very Good	Not Applicable	Very Good	Very Good	Very Good	Limited by Seal
Komatsu 30°Flare		Good	Good	Very Good	Not Applicable	Very Good	Very Good	Very Good	Limited by Seal
K4 BSP Adapters		Good	Good	Very Good	Not Applicable	Very Good	Very Good	Very Good	Limited by Seal
NPSM (Swivel)		Good	Good	Very Good	Not Applicable	Good	Good	Very Good	Limited by Seal

Dimensions and pressures for reference only, subject to change.

DRY TECH TIP:

✎ *When selecting a tube/hose connection, use an elastomeric seal, if possible, to ensure the highest level leak-free performance.*

Port Selection

The port end connection is a vital aspect of leak-free hydraulics. This portion of Dry Technology focuses on proper selection of hydraulic ports and the mating port ends of hydraulic fittings.

There are many different versions of hydraulic ports and port end connections. Each has advantages and applications for which it is best suited, and some have several disadvantages as well.

A particular port connection is usually selected based on one or more of these criteria:

- Pressure-holding capacity
- Seal reliability
- Availability of mating components
- Previous experience/familiarity
- Available space
- Government, industry or corporate standards
- Standard port offering on selected components

Types and Design

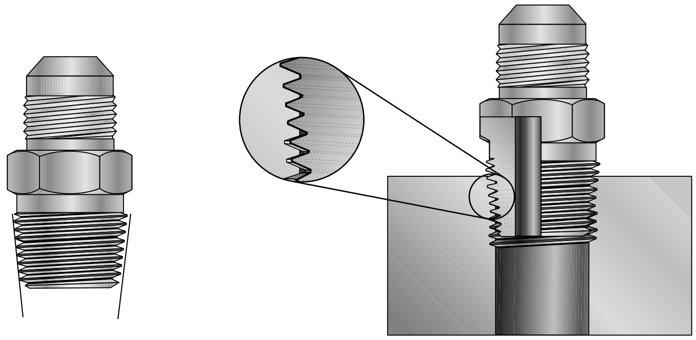
There are three general types of hydraulic port connections used in industrial and mobile applications:

1. Tapered Thread
2. Straight (Parallel) Thread
3. Flange Type

An important selection consideration is how the port connection seals. In general, most hydraulic systems are moving toward elastomeric sealing, similar to the trend in tube/hose ends. However, due to varying reasons, metal-to-metal port sealing is still quite prevalent.

Tapered Thread

Tapered thread ports are the oldest style ports used in hydraulic applications and, until recently, were the most widely used. Tapered threads serve two functions: holding the fitting in place and serving as the primary seal. That seal is created by the metal-to-metal contact between the mating roots, crests and flanks of the male thread and female port thread. The taper allows for further sealing and holding by wedging as the fitting is tightened.



There are three thread forms used for tapered ports: NPT/NPTF (National Pipe Thread, or American pipe), BSPT (British Standard Pipe Taper) and metric taper. Each is commonly used in hydraulic systems; however, their popularity is diminishing.

While the primary seal of tapered threads is the metal-to-metal contact (literally crushing) between the male thread and the port, a thread sealant is required to reduce the potential for leakage. These sealants fill in imperfections in the surfaces, creating the seal and providing lubrication to ease assembly.

Features

Tapered thread port ends are available in almost all tube fitting styles and, thus, are widely used and accepted. Tapered port connections withstand relatively high static pressures; however, today's hydraulic systems are rarely static. Tapered thread ports require a relatively small amount of space (for machining), thus allowing for more compact multiple port connections.

While tapered thread ports are still widely accepted, they are becoming less desirable due to inherent limitations which tend to reduce their reliability. In general, tapered thread ports and connectors are not preferred in hydraulic applications. In fact, many leakage problems associated with the tapered thread design can be avoided by specifying straight thread and flange type connections.

DRY TECH TIP:

✎ *If tapered threads are used in a system, one of the most common causes of contamination is applying sealant to the first one to two threads. Those first threads should remain sealant-free.*

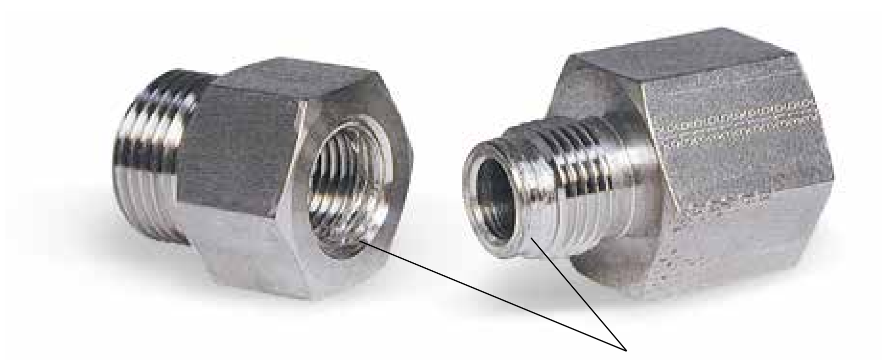
✎ *It is quite typical for hydraulic connectors and their mating port to be manufactured of slightly different materials. Due to the varying thermal expansion properties of each, temperature fluctuations may cause intermittent leakage in tapered thread connections.*

The taper's wedging action tends to damage or crack the port and male threads, leading to leakage and limited reusability. Simply over-tightening the male adapter as well can cause permanent thread damage.

Added thread sealants such as pipe dope, tape or thread lockers can contaminate hydraulic systems. Today's systems are less tolerant of contamination. Certain sealants are available that serve as a lubricant, sealant and thread locker, some of which are reusable and will not cause contamination, as they are soluble in most hydraulic fluids.

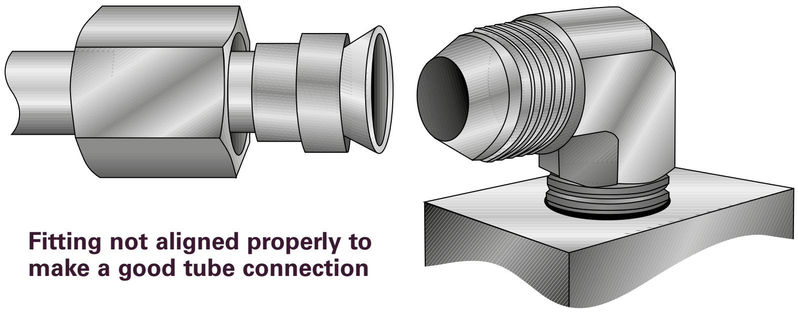
Hydraulic systems are typically not static; they tend to be dynamic with pressure spikes, shock, vibration, and temperature cycling (variations). Thus, tapered threads do not perform well in dynamic systems.

Tapered threads, in certain materials such as stainless steel and aluminum, are quite prone to a phenomenon known as galling (shown below). This is the tendency for mating threads to literally weld together due to the high contact stresses and friction as they are tightened. This localized welding does not inhibit leakage, but rather, compounds it and renders the components virtually non-reusable. Thread sealants and anti-galling compounds can minimize this problem but increase the risk of system contamination.



Galling renders the components virtually non-reusable

Positioning or orienting a shaped connector with a tapered thread connection can be quite challenging. The shape connector must be aligned properly to attain a good tube/hose connection. It must also be tightened enough to allow for proper sealing and holding but not so much as to cause port and connection damage.



Fitting not aligned properly to make a good tube connection

Manufacturing defects, handling damage and shipping abuse are not issues common only to tapered thread connections. However, if tapered thread connections are to be used, specify that the manufacturer use thread protectors, and do not remove them until assembly.

Leakage on shaped tapered threads is further magnified by such instances as hose pull or tube assembly pull. This pulling can be caused by hydraulic shock, accidental bumping or similar occurrences and tends to loosen the tapered end thread connection.

DRY TECH TIP:

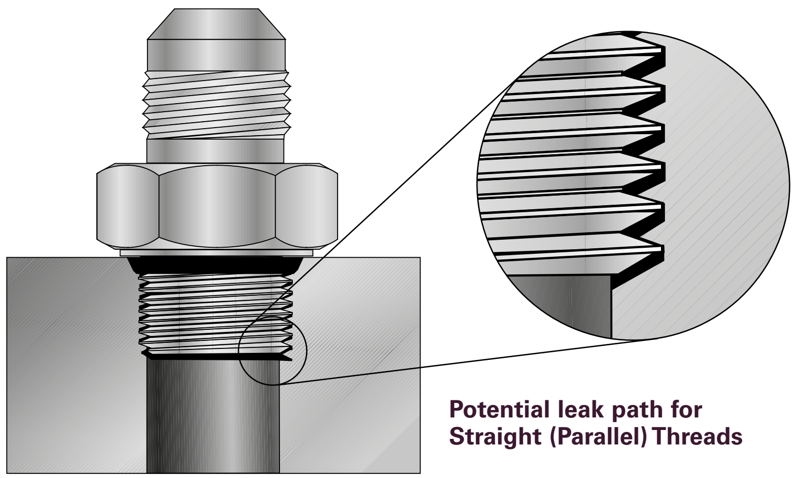
✎ *Once fully assembled, a pipe thread connector should not be "backed-off" to attain alignments with a tube or hose.*

Straight (Parallel) Thread

Straight, or parallel, thread ports in various forms are becoming more popular in hydraulic systems because they are more reliable and easier to service.

Three types of threads are used for parallel thread ports: UN/UNF (SAE straight thread), BSPP (British Standard Pipe, Parallel) and metric parallel.

Because parallel threads only serve one function (i.e., holding the fitting in place), some other means of sealing is always present, such as an elastomeric O-ring or a metal seal. There are many variations of sealing methods, and in some cases, they are interchanged among the different thread forms and may appear to be similar.



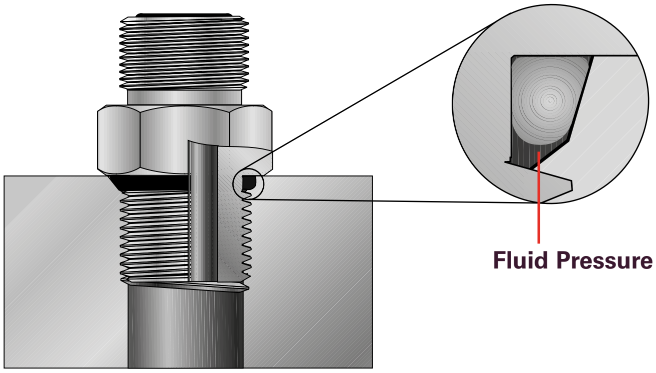
Potential leak path for Straight (Parallel) Threads

Unlike tapered thread ports, parallel thread ports offer the advantage of orientation or positioning for shaped fittings. A locknut and backup washer are added to the parallel port end, allowing for infinite positioning. The locknut, and not the fitting body, is tightened to the recommended torque during final installation.

O-Ring in Chamfer Sealing

This method of sealing is considered to be the most reliable. A conical cavity (chamfer) is provided at the top of the port to accept the O-ring. When the fitting is tightened into the port, the O-ring is compressed within the cavity and thereby prevents fluid from escaping.

ISO/SAE/JIS B2351 Straight Thread Port O-Ring Deformation



Three different ports use this principle of sealing. Other than some subtle identification differences, they may appear to be the same. Even though these ports operate on the same principle, their O-ring sizes differ and must be in accordance with the appropriate specifications for optimum performance.

- **ISO 6149** uses metric parallel threads and the male port end has a special groove for identification purposes. This port style is recommended for all new designs and is considered the world standard.
- **SAE J1926** uses UN/UNF threads and is often referred to as SAE Straight Threads. The female port is often referred to as ORB or O-ring boss. This port style is widely used in North America.
- **JIS B2351** uses JIS PF pipe threads (similar to and inter-changeable with BSPP threads). This style is usually found only on equipment manufactured and/or designed in Japan or Korea.

DRY TECH TIP:

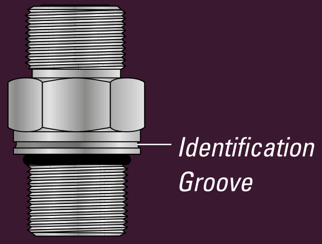
✎ ISO 6149 (world standard part) has specific identification requirements. There are three acceptable methods for identifying a female ISO 6149 port:

1. Identification ridge located on the spot face of the port

2. Stamp "metric" next to the port

3. Component label can indicate the port is metric

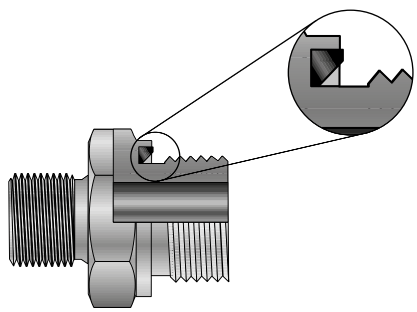
✎ ISO 6149 stud end incorporates an identification groove beneath the hex to i ndicate the end type.

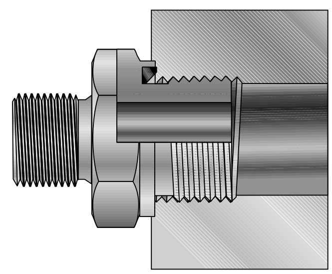


Spot Face Sealing

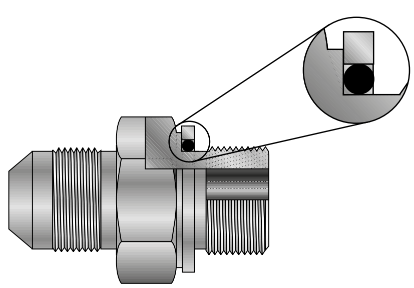
In this common parallel port sealing method, the sealing actually takes place on the top surface of the port (which is specially machined) called the spot face. There are many variations of this sealing style, but they are usually available only with metric or BSPP threads. Various sealing styles are interchangeable with this type of port. The six common sealing styles are as follows:

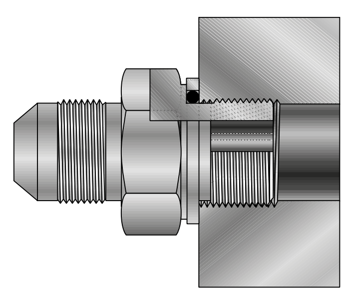
Eolastic Seal: This type has a groove which is cut into the body of the fitting. An elastomeric seal ring with a trapezoidal cross-section fits into this groove. When the fitting is tightened, the seal ring is compressed into the groove by the spot face of the female port where it creates a seal. This sealing method may have either BSPP or metric threads and is considered a Type E seal.



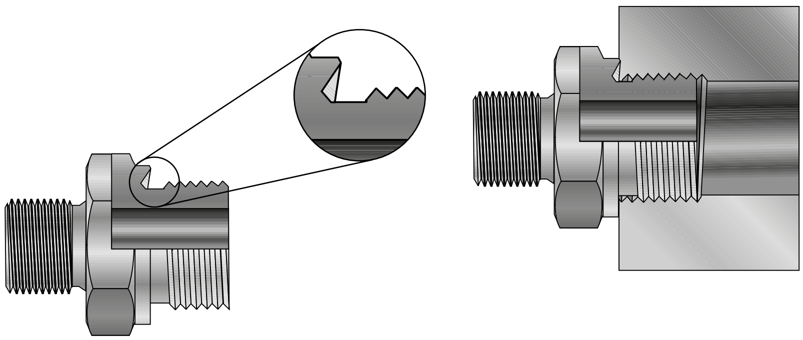


O-Ring with Retaining Ring: This type of port sealing method uses an O-ring that is supported on the outside by a removable metal retaining ring. When the fitting is tightened into the port, a seal is created by compressing the O-ring into the cavity created between the fitting body, the inside of the metal ring and the spot face of the port. This sealing method is available with metric and BSPP threads and is considered Type G or H seal.

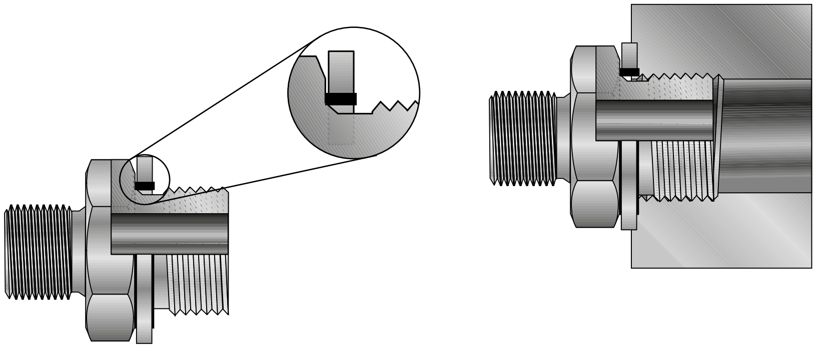




Cutting Face Seal: In this style, the body of the fitting is machined with a relatively sharp ridge of material that seals by coining the spot face of the female port when the fitting is tightened. This sealing method is neither reliable nor reusable. It is often used in situations where the temperature is too extreme for an elastomeric seal capability. However, it may be preferred with certain hydraulic fluids or when external environments may inhibit the use of elastomer seals. This sealing method is available with metric and BSPP threads and is considered a Type B seal.



Bonded Seal: This style consists of a metal ring with some form of elastomer bonded to the inside surface (often referred to as Dowty® seal). That combination is trapped between the fitting body and the spot face of the port to create a seal. The fitting body intended for this method has a taper in the undercut section between the threads and the body of the fitting. This serves to center the seal underneath the fitting body when the fitting is being tightened. This sealing method is available with metric and BSPP threads.



DRY TECH TIP:

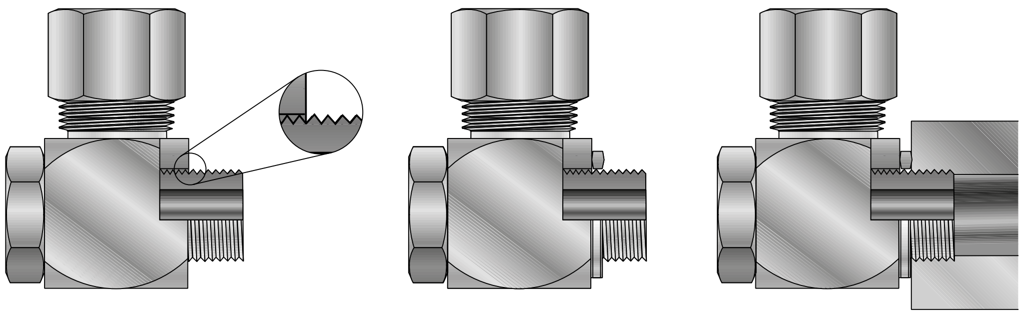
✎ *While elastomer port sealing methods are typically preferred, they may have temperature limitations. For this reason, metallic port sealing may be preferred.*

Nitrile (NO552)
-30° to 250° F

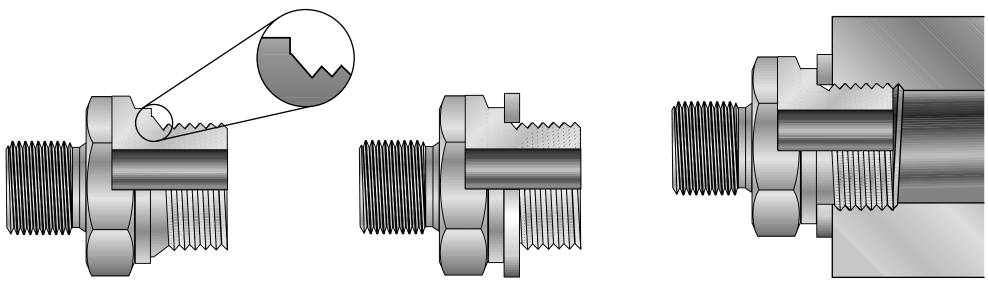
Fluorocarbon (VO894)
-15° to 400° F

Ethylene-Propylene (EO540)
-65° to 275° F

Hard Metal Seal: This seal is achieved with a metal ring that is machined to provide a relatively sharp edge on both sides. These edges provide for sealing between the body of the fitting and the spot face of the female port and are not reusable due to potential port damage. This method is usually found on banjo-style fittings and may have either metric or BSPP threads.



Soft Metal Seal: This method incorporates a washer made from a soft metallic material, such as copper or aluminum. The relatively soft washer is trapped between the body of the fitting and the spot face of the port. The fitting body intended for this method has a taper in the undercut section between the threads and the body of the fitting. That serves to center the seal under the fitting body when the fitting is being tightened. This sealing method is available with metric and BSPP threads.



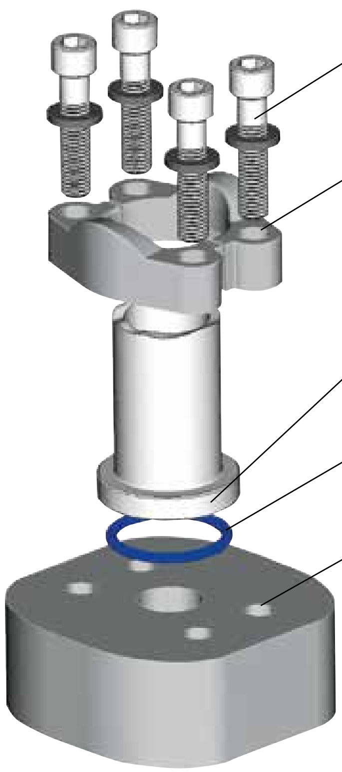
For additional details on the sealing methods described above, see Appendix Table 3.

Flange Type

Flange connections are a hydraulic port option offering many of the same advantages of straight thread port connections with elastomeric seal. However, the flange connection offers the unique ability to connect tube or hose directly to the port without the use of traditional threaded connectors or adapters. This advantage is among several afforded by flange connections.

Design

The 4-bolt flange port connection consists of four primary components: flange head, O-ring, flange clamp (captive or split) and four bolts. The port is simply a flow passage surrounded by four tapped holes that accept the clamping bolts. Typically, the flat-machined surface of the port compresses the O-ring contained in the groove of the flange head when the bolts are tightened. The bolts, placed through the flange clamp, clamp down on the flange head, thus compressing the O-ring in the groove and leaving no leak path or possibility of O-ring extrusion.



DRY TECH TIP:

✎ *Flange connections are used in the most demanding applications of mobile equipment, particularly because they:*

1. Are well suited for high pressures, shock and vibration, especially in larger sizes

2. Allow for easy connection between hose and tube/pipe where flexibility is needed, without adding adapters

3. Allow for easy connection between rigid lines (tube-to-tube or pipe-to-pipe) and aid in installation and repair

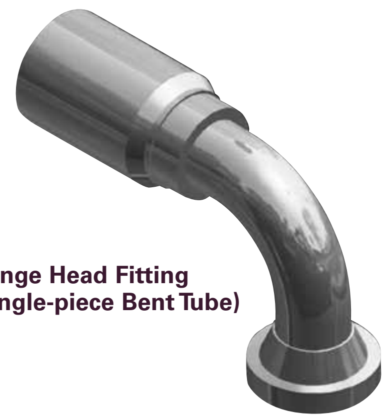
4. Maintain a high resistance to loosening in severe hydraulic service

5. Can be assembled with reasonable assembly torques, even in larger sizes

6. Can be assembled in close quarters where wrench swing clearances are limited

For pipe or tube connections, a flange head with a machined O-ring groove is typically welded or brazed on. An alternate method for connecting either tube or pipe is to create a flat face flange onto the end of the tube or pipe and use a bonded elastomeric seal plate as the seal between the two flat surfaces. This eliminates the need for welding or brazing. Hose connections can be achieved with a single-piece flange that is crimped onto the end of the hose, such as with the special flange head fitting shown below. Flange adapters, such as that shown below, are used to adapt either tube or hose to a four-bolt flange connection. When using flange adapters, the pressure rating of the threaded end should be taken into consideration. For all of these various connections, O-rings, flange halves and bolts are available from several manufacturers.

Forged Flange Adapter



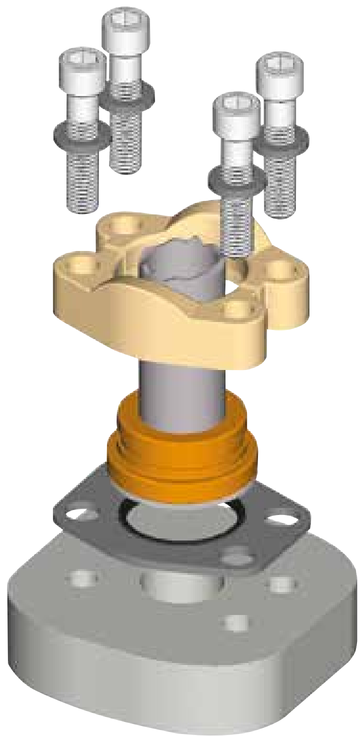
Flange Head Fitting
(Single-piece Bent Tube)

Types

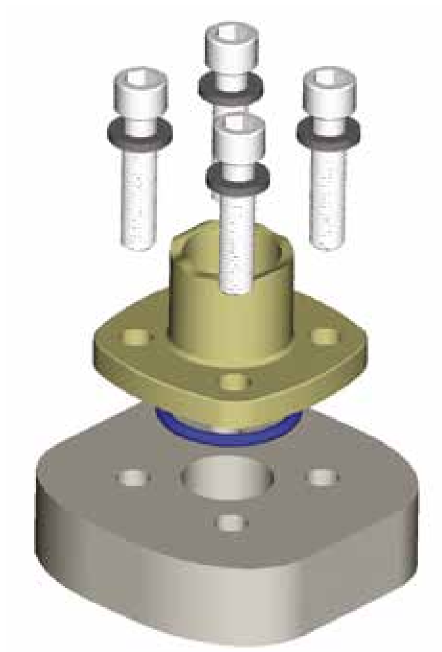
There are two common industrial standard hydraulic flange connections and several specialized and proprietary types available. The most common is the ISO 6162 connection. This rectangular bolt-patterned design is available in two pressure classes: a series for up to 5000 psi/34.5 MPa and a series for up to 6000 psi/41.4 MPa.

For obvious reasons, the two pressure classification flanges are not interchangeable, which is reinforced by their differing bolt patterns. The ISO 6162 is considered the worldwide hydraulic flange standard, as it includes the North American Standard (i.e., SAE Code 61 and 62 or SAE J518) with UNC bolts/holes and the International Standard with metric bolts/holes.

The second style, most common in Germany, is a square bolt pattern flange connection in accordance with ISO 6164. While the technology is identical, the flange connection is not generally accepted in North America.



ISO 6162
4-Bolt Flange Connection



ISO 6164
4-Bolt Flange Connection

DRY TECH TIP:

✎ *Consider how difficult it would be to tighten a coupling on a 10" or even 20" pipe. For that reason, flange connectors have been used for years in process piping, shipbuilding and in-plant applications where large piping is used.*

✎ *Flanges have limited use below 3/4" (-12) due to the larger mounting interface compared with threaded fittings. This would add cost, weight and size to the component.*

Features

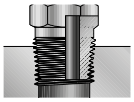
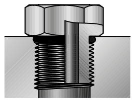
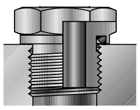
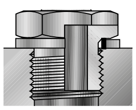
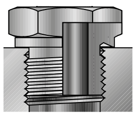
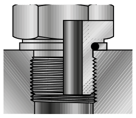
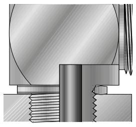
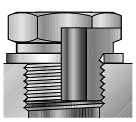
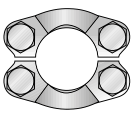
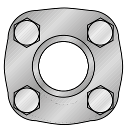
The hydraulic flange connection was developed as a large-sized high-pressure connection. While large-sized threaded connections require a very high assembly torque to resist high pressures in hydraulic systems, flange port connections divide the assembly torque among multiple bolts, each of which requires much less torque. Large threaded connections also present assembly difficulties especially where wrench clearance is limited, while flange types require much smaller clearances.

In fact, flange connections provide for zero-clearance assembly, enabling easy connecting, disconnecting and maintenance of tube-to-tube, tube-to-hose and manifold connections. Infinite positioning is a "built-in" feature, in that the flange can be positioned at any angle. In addition, flange connections have the highest resistance to loosening, due to the clamping load distribution over the flange head. This makes flange connections an ideal choice for bent hose end connections that are subjected to very high lateral forces that can cause loosening.

Summary

As shown in this section, the selection of a port end can be very involved due to the number of choices available to component and system designers. The table on the following page summarizes the key features associated with a port and rates the different end types.

Port End Summary

Port End Type and Seal Style	Illustration	Pressure-Dynamic	Pressure-Static	Temperature	Positioning	Contamination	Seal Reliability	Reusability	Fluid Compatibility
Tapered (NPT, NPTF, BSPT & Metric Taper)		Poor	Good	Excellent	Poor	Poor	Poor	Poor	Excellent
O-ring in Chamfer (SAE J1926, ISO 6149 JIS B2351)		Excellent	Excellent	Limited by Seal	Excellent	Very Good	Excellent	Excellent	Limited by Seal
Spot Face with ED Seal (ISO 1179 & ISO 9974)		Excellent	Excellent	Limited by Seal	Not Applicable	Very Good	Excellent	Excellent	Limited by Seal
Spot Face with Bonded Seal (ISO 1179 & ISO 9974)		Good	Good	Good	Not Applicable	Very Good	Good	Excellent	Limited by Seal
Spot Face with Cutting Face (ISO 1179 & ISO 9974)		Poor	Fair	Excellent	Not Applicable	Fair	Poor	Poor	Excellent
Spot Face with O-ring and Retaining Ring (ISO 1179)		Good	Good	Good	Excellent	Very Good	Good	Excellent	Limited by Seal
Spot Face with Hard Metal Seal (ISO 1179 & ISO 9974)		Poor	Fair	Excellent	Not Applicable	Fair	Poor	Poor	Excellent
Spot Face with Soft Metal Seal (ISO 1179 & ISO 9974 with copper gasket)		Poor	Fair	Good	Not Applicable	Very Good	Poor	Fair	Excellent
4-Bolt Flange (SAE J518 & ISO 6162)		Excellent	Excellent	Good	Very Good	Very Good	Excellent	Excellent	Limited by Seal
4-Bolt Flange (ISO 6164)		Excellent	Excellent	Good	Very Good	Good	Excellent	Excellent	Limited by Seal

DRY TECH TIP:

✎ *Flange connections are the most popular method for connecting pipe in hydraulic systems. The other connection types mentioned in Dry Technology are not typically used with pipe.*

✎ *For high-pressure high-flow connections, such as in hydrostatic drives, flange connections are more reliable than threaded adapters.*

Selecting Hydraulic Tube

Proper tube selection for a given application and type of fitting is critical for efficient, trouble-free fluid system operation. Making the proper selection involves choosing the right tube material, type and size (O.D. and wall thickness).

Tube Material

Material selection is important primarily for fluid and ambient compatibility. Carbon steel is the most common tube material used in industrial applications, due to its low cost compared with other types. Carbon steel tubes are compatible with most hydraulic fluids; however, ambient conditions must also be considered. For example, a typical hydraulic power unit being operated near seawater may require stainless-steel or Monel® tube to ensure that oxidation (rust) does not destroy the tube. Of course, painted or plated tube can also protect the tube from certain ambient conditions.

Likewise, a light-duty application may only require a copper or thermoplastic tube material. Tube weight may also be a factor in critical applications. Occasionally, temperature may play a role in tube selection as well. Certain high- or low-temperature applications may exclude the use of carbon steel, thermoplastic or copper tube. For a more complete guide to tube and fitting material compatibility, consult Table 4 in the Appendix.

Tube Type

Hydraulic tube is available in several forms: seamless, welded and redrawn, and welded and flash controlled.

Seamless Tube (e.g., SAE J524), as the name implies, is manufactured by extruding raw material over/through a series of dies or mandrels. This is typically the most expensive type of hydraulic tube and, due to the manufacturing process, is also more prone to eccentricity.

Seamless tube can be used with all tube fittings as long as the concentricity is good. Seamless tube is commonly available in carbon steel and stainless steel.

Welded and Redrawn Tube (e.g., SAE J525) starts as flat-stock and is formed through a series of dies or mandrels into a tubular shape and then welded. This tube is typically more economical than seamless, and concentricity problems are rarely an issue. Welded and redrawn tube is commonly available in carbon steel and stainless steel, and it can be used with all tube fittings.

Welded and Flash Controlled Tube (e.g., SAE J356) is made by forming flat-stock into a tubular shape and then welding. This is not preferred for most industrial hydraulic tube fittings. The weld seam on the inside diameter (without subsequent redrawing) can be a source of leakage. A double flare is a potential solution to this problem because it relies on the external surface of the tube for sealing.

Certain structural tubes are not meant for hydraulic tube fitting applications. Some of this tube, primarily made for welding structures, may not be annealed. The annealing process allows for proper tube fabricating, including bending, flaring, flanging, ferrule presetting, etc.

DRY TECH TIP:

✎ *Titanium tube is often required in aerospace/ aircraft applications due to weight considerations.*

Tube Size

Proper line sizing (tube O.D. and I.D. selection) in a hydraulic system results in an optimum combination of efficient and cost-effective performance.

A tube that is too small produces high flow velocities and pressure drops that can adversely affect system performance.

Oversized tube increases system cost, weight and relative size. Thus the optimum line/tube sizing is important. The following two steps should serve as a guideline:

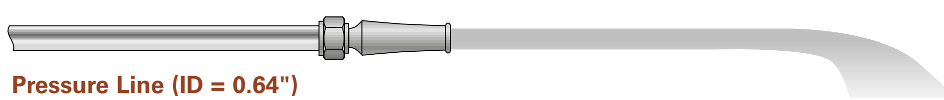
1. Determine required flow diameter.
2. Determine tube O.D. and wall thickness based upon flow diameter and system pressure.

Determine Required Flow Diameter (Tube I.D.)

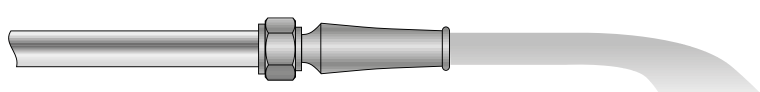
The required flow diameter may be different for each line in the hydraulic system, depending primarily on desired flow rate and fluid velocity. First, it is important to understand the relationship between flow, flow diameter and fluid velocity.

In general, system flow = fluid velocity x flow area (flow is a function of area). Typically, the flow rate is known (e.g., 25 GPM). Also, the desired or recommended fluid velocity may be known. These industry-recognized standard maximum fluid velocities are shown below.

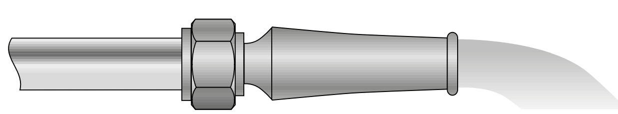
Typical Fluid Velocity
(Line Sizes Based on 25 GPM)



Pressure Line (ID = 0.64")
25 ft/sec (7.6 meter/sec)



Return Line (ID = 1.01")
10 ft/sec (3.0 meter/sec)



Suction Line (ID = 1.6")
4 ft/sec (1.2 meter/sec)

Thus, to maintain the desired flow, while not exceeding the maximum fluid velocities, the flow area and diameter can easily be determined by mathematical calculations or flow/velocity charts. For examples of such charts and calculations, see Table 5 in the Appendix.

Determine Required Tube O.D. and Wall Thickness

Once a suitable flow diameter (or tube I.D.) is determined, a tube O.D. can be determined based on the system pressure requirements and severity of service. Standard industry practice is to use a design factor of 4:1 for normal hydraulic application.

Due to certain service conditions, alternate design factors and derating factors may be applicable. These conditions include severe hydraulic shock and vibration, and high temperatures See Table 2 in the Appendix for temperature derating factors.

Severity of Service	Description	Design Factor	Derating Factor
A (Normal)	Moderate mechanical and hydraulic shocks	4:1	1.00
B (Severe)	Severe hydraulic shocks and mechanical strain	6:1	0.67
C (Hazardous)	Hazardous application with severe service conditions	8:1	0.50

If the normal design service factors apply, the next step is to use the pressure charts (see Table 6 in the Appendix) to determine O.D. Based on the predetermined flow requirements and desired tube material, a suitable tube O.D., I.D. and material can be selected.

Finally, there may be several tube O.D. and wall thickness options available. The tube should then be selected based upon the following characteristics:

- Smallest size possible (weight, fitting, cost, space constraints)
- Commonly available/cost-effective tube
- Fittings compatibility (wall thickness too thin, too thick, etc.) Consult Table 7 in the Appendix.

DRY TECH TIP:

✎ *Sometimes thicker than required tube is used to create a more rugged system.*

Tube and Fitting Assembly

A key ingredient in achieving Dry Technology is the proper assembly of the tube and port ends of the fitting. As previously noted, 60 percent of the all leaks are due to improper installation. Understanding how fittings seal (covered in the ***"Selecting Tube Fittings"*** *section) and following the procedures outlined in this section will contribute greatly to a leak-free hydraulic system.*

Port Assembly

Often the first step in assembling the system, proper port assembly is critical in achieving leak-free performance. For proper port end assembly, the type of port must be accurately determined. Refer to the "Port Selection" section for style and configuration details.

The assembly of the following ports will be covered in this section:

Tapered Thread

Straight (Parallel) Thread

(adjustable and non-adjustable)

4-Bolt Flange

Tapered Thread

In this type of connection, the threads serve two roles. First, they must hold the fitting in place, maintaining the "clamping load." Second, they must create a wedging action that produces a metal-to-metal seal to prevent the fluid from escaping.

Because a metal-to-metal seal cannot ensure leak-free performance in demanding hydraulic applications, sealants are used to resolve a number of challenges inherent in tapered thread port connections.

Sealant Types and Advantages

Sealant/Lubricants assist in sealing and provide lubrication during assembly, reducing the potential for galling.

Pipe Thread Sealants are available in various forms such as dry pre-applied, tape, paste and anaerobic liquid. Pre-applied sealant, such as Vibraseal®, and powdered PTFE are usually applied to connectors by the manufacturer. Connectors with some pre-applied sealants may be remade a few times without additional sealant. Vibraseal may also be used as a method to help reduce loosening due to vibration.

Tape Sealant, such as commonly used PTFE tape, may actually contribute to system contamination if not properly applied. This occurs during assembly and disassembly when the tape is applied too closely to the end. PTFE tape also has high lubricity characteristics, which allows the fittings to wedge into the port with less torque, making it very easy to over-tighten. This same high lubricity does not provide much resistance to loosening in vibration applications.

Paste Lubricants tend to be messy to work with and may require curing before system start-up. Similar to other manually applied sealants, they can cause system contamination if misapplied.

Anaerobic Liquids are available from several manufacturers and perform both sealing as well as thread locking functions. They are applied to the connector by the user and require a cure period prior to system start-up. Some of these are soluble in common hydraulic fluid and will not contaminate the system. For proper performance they must be applied to clean, dry components and according to the manufacturer's recommendations.

DRY TECH TIP:

✎ *Over-tightening fittings can be as detrimental as under-tightening.*

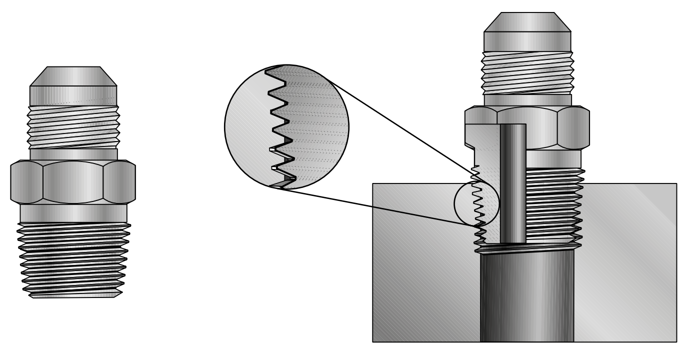
Tapered Thread Assembly

Due to the nature of the design and various applied sealants, tapered thread connectors utilize a specific number of "turns from finger tight" in lieu of a specific torque rating. Referred to as TFFT, this method is used to minimize the risk of leaks or damage to the components. The following steps should be followed when installing tapered thread connectors:

1. Inspect port and connectors to ensure that threads on both are free of dirt, burrs and excessive nicks.

2. Apply sealant/lubricant to male pipe threads (pre-applied dry sealants are preferred). Do not apply sealant of any type to the first one to two threads to avoid system contamination. If PTFE tape is used, it should be wrapped 1-1/2 to 2 turns in the clockwise direction when viewed from the tapered thread end. More than 2 turns is not recommended and may cause distortion or cracking of the port.

3. Turn the connector into the port to the finger tight position.



4. Wrench-tighten the connector to the appropriate TFFT (turns from finger tight) values shown in Appendix Table 8. Make sure the tube end of the shaped connector is aligned to receive the incoming tube or hose assembly. Never back off (loosen) tapered threaded connectors to achieve alignment.

5. If leakage persists after following the above steps, check for damaged threads and total number of threads engaged. If threads on the fitting are badly nicked or galled, replace the fitting. If port threads are damaged, re-tap if possible, or replace the component. Typically, a proper thread engagement would be between 3-1/2 and 6 threads. In cases where thread engagement is less than 3-1/2, tighten the connector further, but no more than one full turn. If the thread engagement is greater than 6 threads, check both parts and replace any part with out-of-tolerance threads.

Straight (Parallel) Thread

Unlike tapered threads, parallel threads are only required to function as a holding mechanism. The seal is obtained by another means, typically an elastomeric seal. When assembled properly, parallel-type ports provide the best leak-free port connection available.

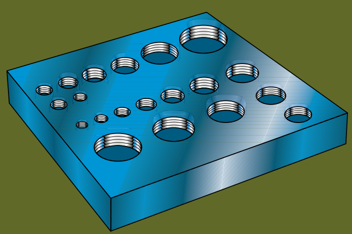
There are numerous types of sealing arrangements for parallel ports, as outlined in the **"Port Selection"** section of this guide. For assembly purposes, there are two main categories of parallel ports: adjustable and non-adjustable. The procedure for proper assembly is distinct for both types as outlined on the following pages.

DRY TECH TIP:

✎ *Not all tapered threads are pipe, and not all pipe threads are tapered.*

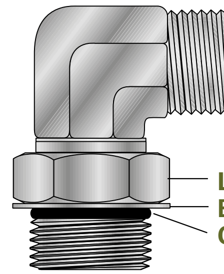
PIPE BSPP BSPT NPT/NPTF	***NON PIPE*** UN/UNF METRIC METRIC TAPER
TAPER METRIC TAPER BSPT NPT/NPTF	***PARALLEL*** UN/UNF BSPP METRIC PARALLEL

✎ *Port boards are an easy way to identify fitting threads for male end.*



Adjustable End Assembly

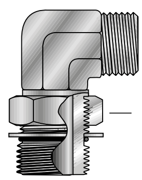
When a specific orientation of the fitting is required, the use of adjustable style port ends is required (shown below).



1. Inspect to ensure that both mating parts are free of burrs, nicks, scratches or any foreign particles.

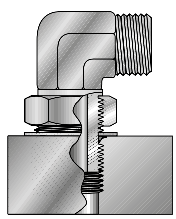
2. Install O-ring on port end of fitting, if it is not pre-installed. Take care not to nick the O-ring.

3. Lubricate O-ring with light coat of system fluid or compatible oil.

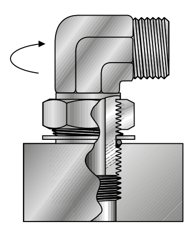


Step 4

4. Back off locknut as far as possible. Make sure backup washer is not loose and is pushed up as far as possible. (Step not needed with Parker's new Robust Port Stud.™)

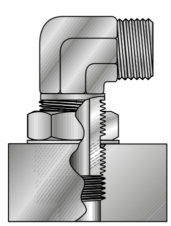

Step 5

5. Screw fitting into the port until backup washer contacts the face of the port. Light wrenching may be necessary to make contact.


Step 6

6. To align the tube end of the fitting to accept incoming tube or hose assembly, unscrew the required amount, but no more than one full revolution.

7. Using two wrenches, hold the fitting in the desired position and tighten lock nut to the appropriate torque value shown in Tables 9 through 12 in the Appendix.


Step 7 and 8

8. Inspect to ensure that the O-ring is not pinched and the backup washer seats flat on face of port.

Non-Adjustable Assembly

When there is no specific connector orientation requirement, the use of non-adjustable ends is permissible.

1. Inspect to ensure that both mating parts are free of burrs, nicks, scratches or any foreign particles.

2. Install O-ring on port end of fitting, if it is not pre-installed. Take care not to nick the O-ring.

3. Lubricate O-ring with light coat of system fluid or compatible oil.

4. Screw fitting into port until hex flat (retaining ring) contacts the port face.

5. Tighten to given torque for the size as shown in Tables 9 through 12 in the Appendix.

Be aware that torque values change for different materials, and values in charts may have to be adjusted to achieve the proper torque values.

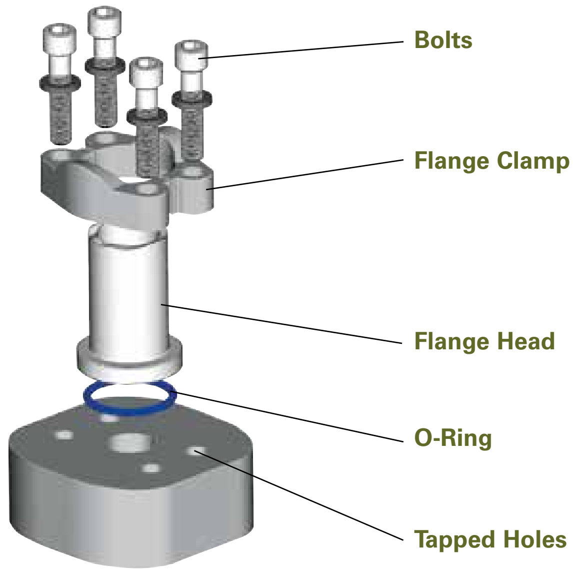
DRY TECH TIP:

✎ *When using an adjustable end with a Robust Port Stud locknut, backing off the locknut is not a necessary step. Positioning steps remain the same.*

✎ *Adjustable straight threads are much more reliable than pipe threads on shaped fittings.*

4-Bolt Flange Connections

As discussed previously in **"Port Selection,"** 4-bolt flange connections provide an alternative to threaded connections to simplify assembly in large-sized connections. The ability to spread the clamping force over four threaded bolts greatly reduces the amount of individual torque required per bolt.



4-Bolt Flange Assembly

1. Make sure sealing surfaces are free of nicks, burrs, scratches or any foreign particles.

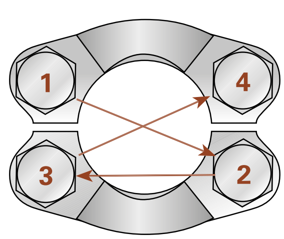
2. Lubricate O-ring/bonded seal with system or compatible fluid.

3. Position flange and clamp halves.

4. Place lock washers on bolts and install through clamp halves.

5. Hand tighten bolts.

6. Torque bolts in a diagonal sequence in small increments to the appropriate torque value shown in Table 13 in the Appendix.



Recommended Bolt Torque Sequence

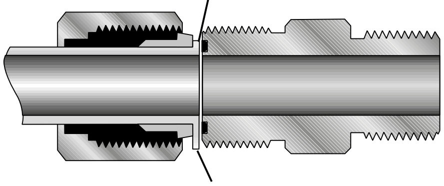
Tube End Preparation

Tube end preparation is one of the most critical processes in obtaining an optimum seal of any flanged, brazed, flared or preset tube end connection. Regardless of the tube material, similar guidelines for tube cut-off, deburring and cleanliness can help assure that the tube-to-fitting connection remains leak-free.

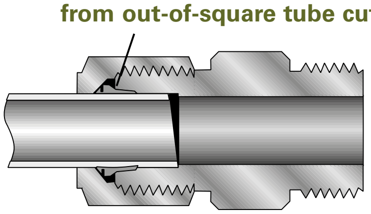
Tube Cutting

It is critical that the tube be cut squarely within ±1° in order to assure the proper connection. If it is not cut squarely, it will not rest properly in the braze sleeve (ORFS connection) or fitting body (flareless connection). A tube end that is not cut squarely may also result in a flange or flare that is not circular.

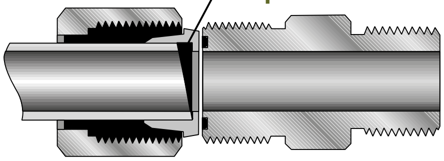
O-Ring Face Seal – Flange



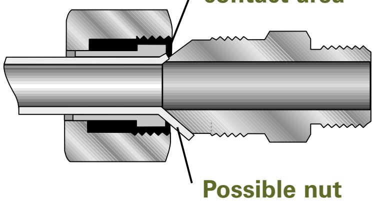
Flareless Fitting



O-Ring Face Seal – Braze



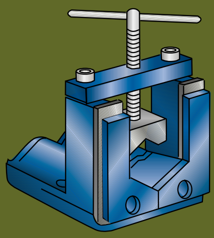
37° Flare

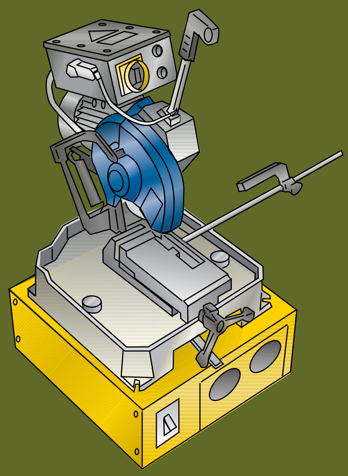


DRY TECH TIP:

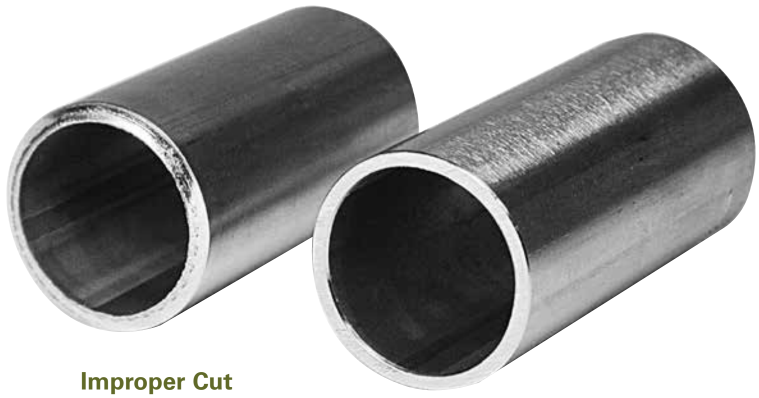
✎ Cutting of steel and stainless-steel tube should be performed with tools designed to maintain ±1° squareness.

- *Sawing Vise*
- *Cut-off Saw*





When cutting tube in preparation for flanging, brazing, flaring or presetting, a saw with a toothed blade is recommended. This type of tool will assure that the tube end is cut clean, with minimal burrs or contamination, and is not exposed to excessive heat or working of material, typical of abrasive saws and tube cutters.



Improper Cut

Proper Cut

Rotary tube cutters cold form the tube, hardening the material and creating excessive I.D. collapse or burr. The hardened material causes problems during end forming.

Rotary Tube Cutter

Tube Deburring

Deburring the inside and outside diameter of the tube end is necessary to assure the tube fits properly inside the braze/ flange/flare sleeve or ferrule and fitting body. Proper deburring of the tube end is also necessary to form a tube flange or flare which is free of imperfections that may create a leak path between the tube and the fitting sealing surface.

Tube/Hose Cleanliness

Debris may remain in the tube end from both the cutting and deburring processes. Debris present in the tube end can result in system contamination or can be lodged (or can embed itself) into the flange or flare, which may result in imperfections that are potential leak paths. It is recommended that the tube end be cleaned properly prior to any further processing such as flanging, flaring, brazing or presetting.

Abrasive saws tend to throw debris inside tube or hose

DRY TECH TIP:

✎ *Removing too much material when deburring tube ends can be detrimental. Lightly breaking off the edge is sufficient.*

37° Flare Assembly

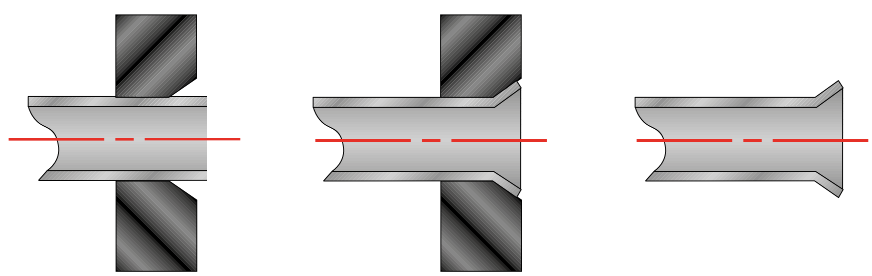
The 37° flare fitting requires the following fabrication and assembly steps to ensure long-term leak-free performance:

1. Cutting, deburring and cleaning the tube
2. Selecting flaring tools
3. Flaring the tube
4. Flare inspection
5. Assembly and installation

Step 1, above, is covered in the previous section, **"Tube End Preparation."** Those principles apply to all tube end types. (Refer, if needed, to the section, **"Tube End Selection."** This section details the subsequent processes).

Flaring Methods

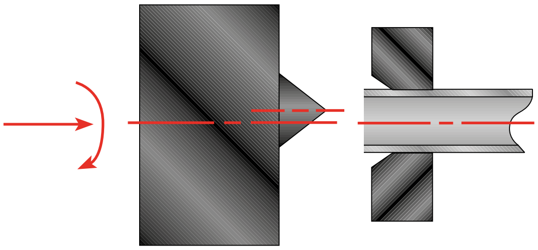
There are a wide variety of tools and several different methods for forming a flare on the end of a rigid tube. Some of the more common methods are rotary eccentric, rotary orbital, straight axial push and rotary axial push. In all cases, a cone or pin of the appropriate shape is forced into the end of the tube and causes it to take the form of the die that is holding it captive. Required flaring force is usually generated manually, electrically, with hydraulics, pneumatics or any combination of these methods.



Tube positioned in the die for flaring | **After flaring the tube, takes the form of die and cone** | **Finished Flare**

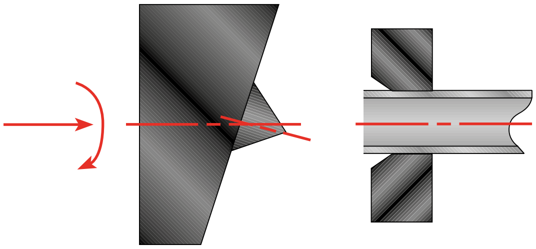
Rotary Eccentric

Rotating cone, that is set slightly off center, incrementally forms the tube end and burnishes the flare surface.



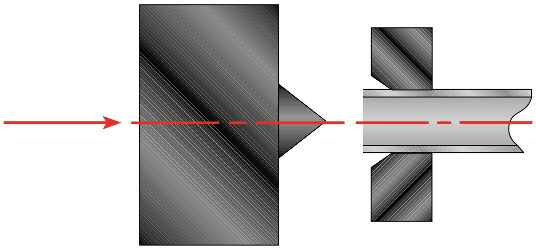
Rotary Orbital

Rotating cone, that is set at an angle, incrementally forms tube and burnishes flaring surface.



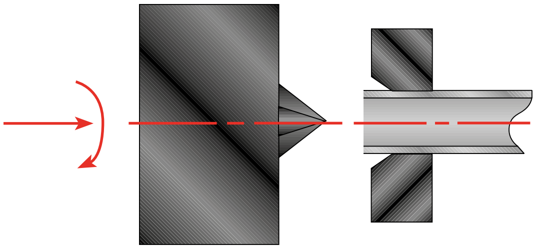
Straight Axial

Appropriately shaped cone is forced axially into end of tube. Typically accomplished with hydraulic or pneumatic force or simply by hammering a cone into the end of the tube.



Rotary Axial

Rotating cone is forced axially into end of tube. Cone sometimes has lobes to make flaring easier.



Before flaring the tube, ensure that the tube nuts and sleeves are on the tube in the proper sequence and orientation.

DRY TECH TIP:

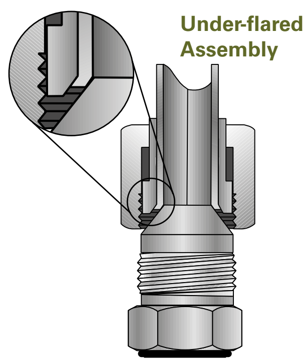
✎ *When flaring tube, the final diameter of the flare can be controlled by the amount of tube extending from the face of the flaring die.*

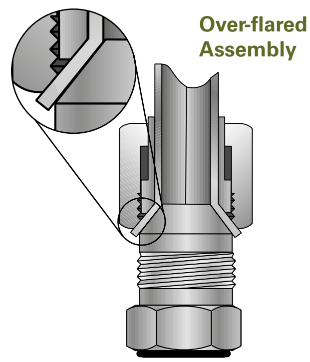
✎ *Two simple visual checks of the flare tooling, prior to flaring, can help achieve optimal flare quality:*

- *Check the flare cone surface for cleanliness (free of debris) and assure that it is well lubricated (STP), for smoother flare sealing surface*
- *Check the die grip surface for wear and assure that it is free of lubrication to prevent tube slippage during flaring*

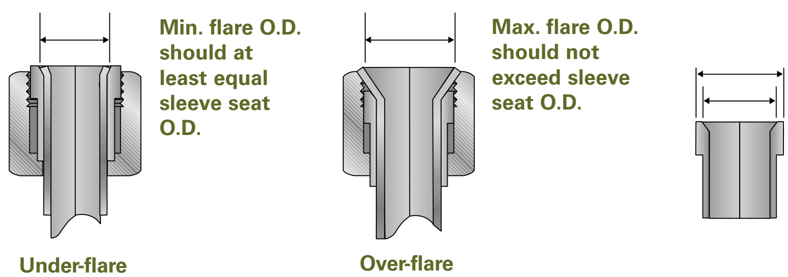
37° Flare Inspection

Once the tubing is flared, the flare should be inspected for proper diameter, angle and sealing surface quality. Under-flaring reduces contact area, which causes excessive nose collapse and leakage. In extreme cases, the tube may pull out while under pressure. Over-flaring causes tube nut interference.

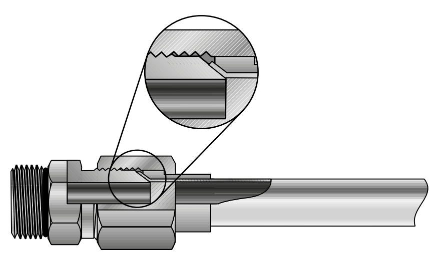




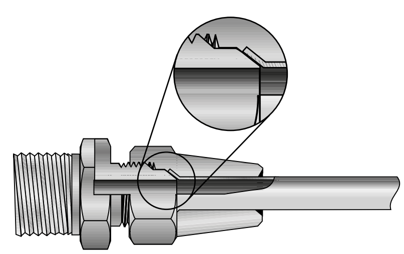
Fortunately, the 37° flare tube sleeve can be used as a quick gauge of the flare diameter (see illustrations below).



The flare angle must be 37°. Most flaring tools have preset flaring angles and this should not be a problem. However, a 45° flare fitting exists in the marketplace, and the flaring tools tend to look very similar.



37° Flare Fitting



45° Flare Fitting

Finally, the flare surface needs to be inspected for surface quality. Embedded burrs, grit, etc., may cause leakage and contribute to system contamination. Scratches, nicks, pits, or tube cracks may also lead to failure.

Final Installation

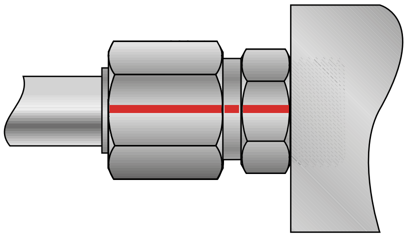
Align the tube flare against the nose of the fitting body and lightly tighten (pre-tighten) the nut. This will clamp the tube flare between the nose and sleeve. A light wrench pull (no more than 30 in.-lb) may be necessary to accomplish this.

Two methods are acceptable for final assembly or installation of the 37° flare fitting: the FFWR ("flats from wrench resistance") method and the torque method.

The FFWR Method: This is the preferred method for tightening 37° connections. In this method, the joint is tightened a given number of hex flats from the light wrench pull position.

Because the FFWR method relies strictly upon nut rotation, which translates into a prescribed axial movement, it produces consistent clamping load.

More forgiving than the torque method, FFWR circumvents such effects as plating differences, lubrication and surface finishes. Those parameters can dramatically affect the torque required to achieve the proper joint tightness and clamping load. Variations in plating, lubrication and surface finish are considered friction modifiers. Because friction is directly related to the creation of clamping load by assembly torque, minor differences in these parameters will affect the clamping load or joint tightness.



It is recommended that a reference mark be made on the tube nut and adjacent fitting hex at the properly tightened position. These marks serve as a quick quality assurance check that the joint has been tightened.

The torque method: This is the simpler of the two assembly methods. A torque wrench and counter wrench are used to tighten the joint to the appropriate manufacturer's specification.

However, as noted, the torque method should not be used with dissimilar plating (or if the platings are unknown). Severe over-tightening or false sense of tightening may occur. In applications where most variables are controlled (consistent plating, lubrication, etc.), the torque method can be used quite effectively. For FFWR and torque requirements, see Table 14 in the Appendix.

DRY TECH TIP:

✎ *It's important not to force or "draw in" a tube assembly that is too short, too long or misaligned. The misalignment places undesirable strain on the joint leading to premature loosening/ leakage. A false sense of tightening may also occur due to the fact that part of the assembly torque is overcoming the misalignment.*

O-Ring Face Seal Assembly

Proper assembly of the O-ring face seal fitting requires several steps, each important in guaranteeing a leak-free connection:

1. Cutting, deburring and cleaning the tube
2. Sleeve attachment
   – Flanging or brazing
   – Inspection
3. Final Installation

Step 1, above, is covered in the previous section, **"Tube End Preparation."**

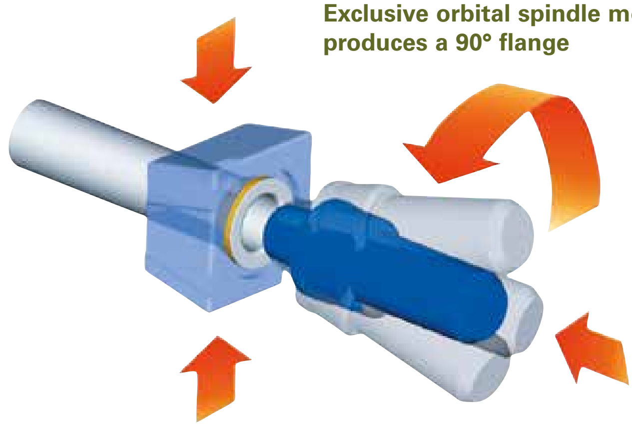
Sleeve Attachment

Tube end attachment for O-ring face seal fittings involves the attachment of a sleeve to the tube. This process can be accomplished by two methods: flanging or brazing. The flanging method requires an end forming machine that creates a 90° flat face on the tube end. The brazing method is accomplished by brazing a flat face sleeve to the tube end using a pre-formed braze ring or a wire-fed filler material.

Flanging

The flanging method requires an end forming or flanging machine to create the flange on the tube. Because the flat face of the flanged tube seals against the O-ring within the groove of the fitting, it is important that this surface be relatively smooth. Proper tube end preparation (cutting, deburring and cleaning) will help obtain this objective.

Exclusive orbital spindle motion produces a 90° flange



The flanging machine utilizes an orbital cold-forming process to produce the flange in front of the support sleeve. The sleeve provides the contact shoulder for the nut, a backup for the 90° tube flange, and support for the tube.

The steps for the proper sleeve attachment for the flanging process are:

1. Allow for extra tube cut-off length that will be lost during the flanging, following manufacturer's recommendation as a guide.

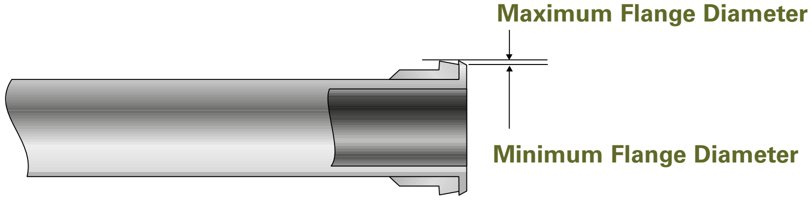
2. Select the proper flange tooling for the tube size.

3. Before flanging, ensure that the tube nut and flange sleeve are positioned in the proper sequence and orientation.

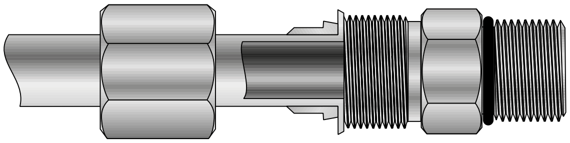
4. Flange the tube end using the appropriate flanging machine.

Flange Inspection

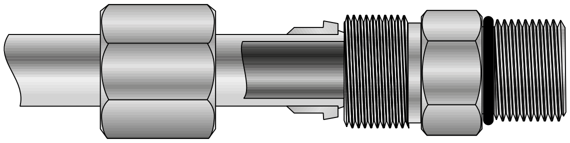
After flanging, the flanged tube end should be inspected for proper diameter and sealing surface quality. The flange sleeve can be used as a quick gauge of the flange diameter.



Over-flanging will result in tube nut interference. Under-flanging reduces contact area for sealing against the O-ring in the fitting. The under-flanged tube end may also result in a tube pullout.



Over-flanged Assembly



Under-flanged Assembly

DRY TECH TIP:

✎ *Flanging has several advantages over brazing. It is at least five times faster than brazing. Additionally, it is environmentally clean and safe.*

Brazing

Silver brazing is the other method of attaching the sleeve to a tube. This method requires a braze sleeve rather than a flange sleeve. The braze process may be accomplished by using a multi-flame torch or induction brazing equipment. The pre-formed braze ring or the wire-fed filler material melts during the heating process, flows into the clearance between the tube O.D. and sleeve I.D., and creates a strong bond between the two.

Multi-flame Torch

The proper steps for tube attachment when brazing are:

1. Clean the tube end prior to brazing. All oil and oxide build-up must be removed from the end of the tube for at least the length of the braze joint. Oil may be removed using an oil-free solvent. Oxide build-up may be removed by pickling or by lightly sanding with aluminum-free emery paper.

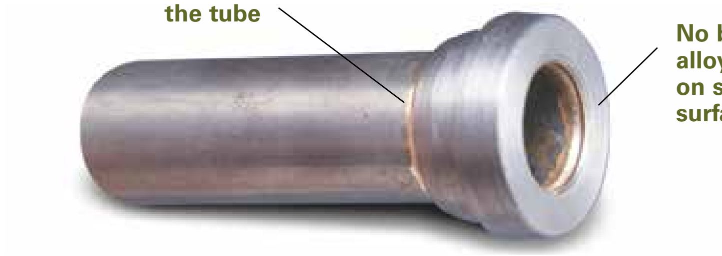
2. Apply braze flux to the area to be heated. This helps to prevent oxidation of the metal surfaces, dissolves the residual oxides and cleans the surface to help the alloy to flow.

3. Apply heat uniformly to the joint. At melting temperature, the braze alloy will always flow toward the area of higher temperature. When this occurs, the sleeve will usually settle (if the tube is held vertically), and the braze is then complete. If the sleeve does not settle, a slight pressure will cause it to do so, completing the braze. The tube assembly should be brazed in the vertical position, if possible, for optimum braze flow.

4. After brazing is complete, immerse the brazed end in a post-braze cleaning solution. This will ease the removal of flux residue. Any remaining residue can be removed by careful wire brushing, making sure not to scratch the sealing surface of the sleeve. The inside of the tube end should also be carefully cleaned to remove excess flux residue.

Braze Inspection

Inspect the braze for a fillet all the way around the tube at the far end (smaller diameter) of the sleeve, as shown below. Inspect the sealing surface of the flanged end of the tube. There should be no braze alloy overrun or build-up on this surface.



Because the residual flux after brazing and the post-braze cleaner are acidic and generally corrosive, it is important to neutralize the joint with a neutralizing solution. If the assembly will not be used shortly after brazing, a coating of rust inhibitor should be applied to the braze joint.

Final Installation

Assembling the braze or flange tube assembly to the O-ring face seal fitting requires several important steps in order to achieve a leak-tight connection.

O-Ring Installation: Ensure that the proper O-ring is installed in the groove of the O-ring face seal fitting. For grooves machined with the half-dovetail design (for optimum O-ring retention), it is recommended that a special tool be used to prevent twisting of the O-ring during installation.

Tube Alignment: Align the tube assembly against the fitting body so that the flat face of the flanged tube (or braze sleeve) comes in full contact with the O-ring. The tube nut should be able to turn freely until it bottoms out. Improper tube alignment may lead to O-ring extrusion, cross-threading and/or a false sense of assembly, and eventual leaks. It may also cause excessive tube strain that can lead to premature tube failure.

DRY TECH TIP:

✎ *Even though the multi-flame torch is more convenient than a single point torch, induction brazing is still much better than both for brazing steel.*

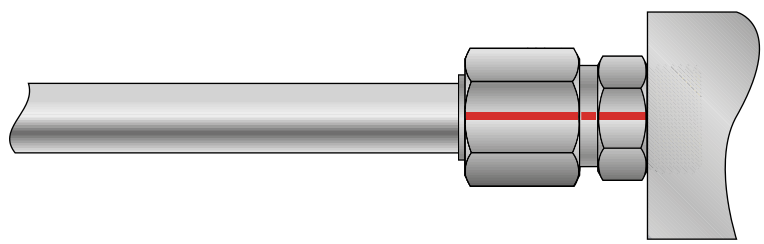
✎ *It is strongly recommended that the torque assembly method is utilized during tube nut assembly of O-ring face seal fittings. Tube nuts assembled using the FFWR (flats from wrench resistance) method are often under-torqued, resulting in premature loosening while in service. The torque method assures that all assemblies are tightened to the same values.*

✎ *Tube nuts should turn freely by hand when the tube assembly is properly aligned.*

Tube Nut Assembly: There are two methods of assembling the tube nut to the fitting body: the torque method and the FFWR ("Flats From Wrench Resistance") method. The torque method is preferred and more accurate. Errors are more prevalent in the FFWR method due to human variation in wrench resistance and the small amount of nut turn required. FFWR should only be used when torque wrenches are not available. It may be necessary to use a second wrench to prevent either fitting movement or over-tightening of the smaller end of a straight jump size fitting.

- **Torque Method**
  Thread the nut on the fitting body by hand and further tighten with a torque wrench to the manufacturer's recommended torque.

- **FFWR Method**
  Wrench-tighten the tube nut on the fitting body until a noticeable wrench resistance is reached. Tighten further to the manufacturer's FFWR value.



It is recommended that a reference mark be made on the tube nut and adjacent fitting hex at the properly tightened position. These marks serve as a quick quality assurance check that the joint has been tightened.

For torque and FFWR requirements, see Table 15 in the Appendix.

Flareless Fitting Assembly

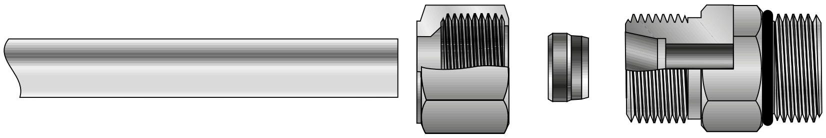
The flareless fitting requires the following fabrication and assembly steps to ensure long-term leak-free performance:

1. Cutting, deburring and cleaning the tube
2. Presetting
3. Inspection of Preset
4. Final Assembly

Step 1, above, is covered in the previous section, **"Tube End Preparation."**

Presetting Methods

Flareless fittings, regardless of whether they are metric or inch size, are assembled the same way. Prior to final assembly, presetting of the ferrule is required. Presetting can be accomplished by three different methods: in the fitting body, with a hardened presetting tool, and by means of a hydraulic or mechanical axial load.

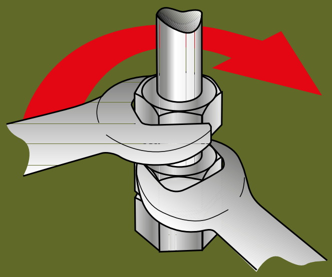


Presetting in the fitting body is usually only acceptable for smaller-sized fittings such as 3/4" or 20 mm and below. The threads of the fitting body and other contact surfaces are lubricated prior to hand assembling the components in the proper orientation. Based on the manufacturer's recommendation, the nut is then tightened to a prescribed amount of turns from the finger-tight position. It is a good practice to mark the initial and final positions of the tube nut. After initial tightening, the nut is removed and the ferrule and tube are inspected for proper bite, tube insertion and grip area.

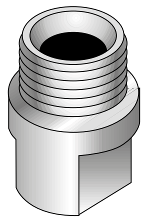
DRY TECH TIP:

✎ *A fitting body should not be used for multiple presets, and the final assembly should be made in the same body as that used for presetting.*

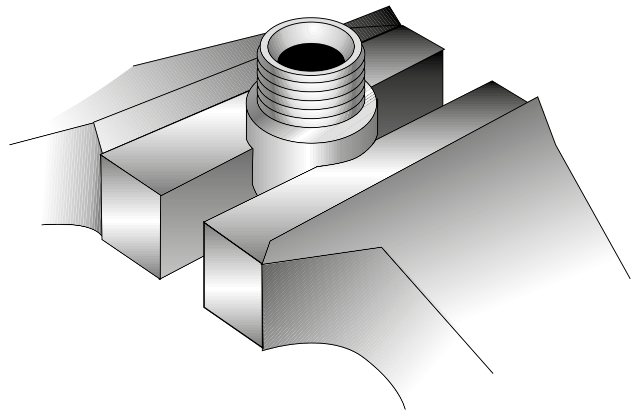
✎ *Counter wrenches should be used to prevent tube twist during final assembly.*



Presetting in hardened body is accomplished the same way as presetting in the fitting body. The advantage of the hardened tool is that it can be reused many times without excessive wear and expansion.



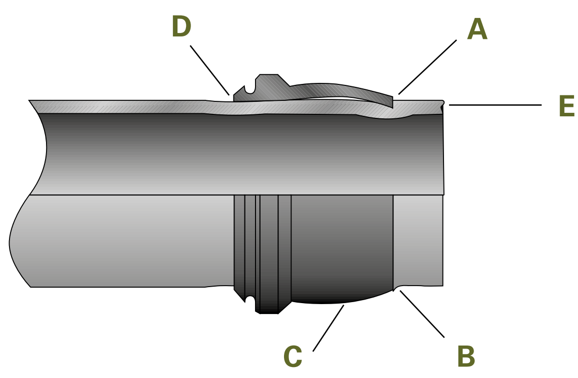
Hardened Preset Body



Presetting with hydraulic or mechanical equipment is preferred for large-sized fittings or large (production) quantities. The nut, ferrule and presetting die are assembled on the tube in proper sequence and orientation. A hydraulic or mechanical axial load is then applied according to the manufacturer's recommendations.

Inspection of Preset

The tube and ferrule are then inspected for proper preset. The following areas should be checked.



1. A ridge of metal (A) has been raised above the tube surface to a height of at least 50% of the thickness of the ferrule's leading edge, completely around the tube.

2. While the leading edge of the ferrule may be coined flat (B), there is a slight bow to the balance of the pilot section (C).

3. The tail or back end of the ferrule is snug against the tube (D).

4. There is a slight indentation around the end of the tube (E) that indicates the tube was bottomed in the tool or fitting during pre-setting (if evidence of this complete contact is not visible the ferrule may not be properly preset).

5. Avoid rotating the ferrule. Steel ferrules should not be capable of moving back and forth along the tube beyond the bite area (a stainless-steel ferrule will move more than steel because of its spring-back characteristics).

Caution: Wrench torque should never be used as the gauge for reliable Ferulok preset and/or assembly. The reliability of the preset and assembly of bite-type fittings is dependent on the ferrule traveling a prescribed distance into the tapered fitting throat in order to bite into the tube and create a strong grip and seal.

Final Assembly

Final assembly should only be attempted after verifying that the preset meets all of the desired criteria. The fitting or tube is then positioned as required, and the nut taken to the finger tight position. From this position, the nut is then wrench-tightened to a prescribed number of turns, as specified by the manufacturer.

Summary

The tube and fitting assembly procedure outlined in this section will help in achieving a leak-free system or "Dry Technology." The values for the torque or turns method of assembly may vary by fitting manufacturer; therefore, it is important to properly apply them accordingly. Troubleshooting fittings is covered later in this book.

DRY TECH TIP:

✎ *Most hydraulic leaks at initial start up are caused by joints that were not tightened properly and are now too buried for easy access.*

Bending

Routing and Clamping

Most hydraulic, pneumatic and lubrication systems require some form of tube line fabrication and fitting installation for completion. Proper fabrication and installation are essential for the overall efficiency, leak-free performance and general appearance of any system.

The following factors should be considered early in the design process, after sizing the tube lines and selecting the appropriate style of fitting:

- Proper routing of lines
- Adequate tube line supports

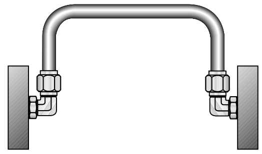
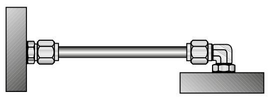
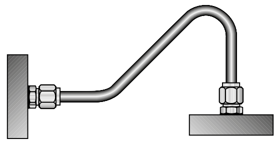
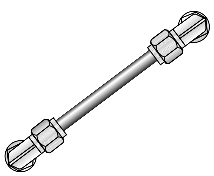
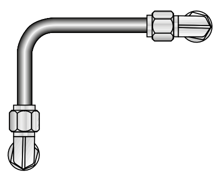
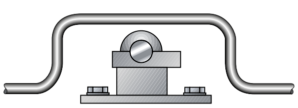
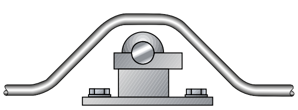
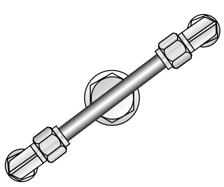
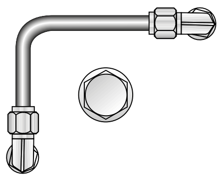
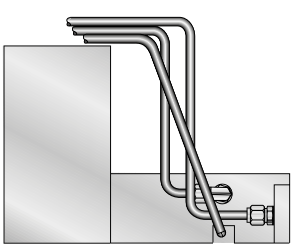
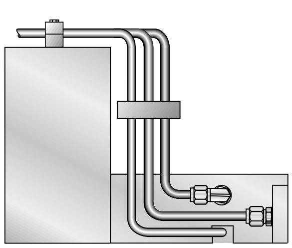
Fewer Joints = Fewer Leaks

While it is occasionally necessary to use extra fittings or adapters, using the fewest fittings possible is preferred for:

1. Less Chance of Leakage
2. Less Time on Assembly
3. Easier Maintenance
4. Reduced Pressure Drop/Turbulence

Proper Routing of Lines

Routing is probably the most difficult and significant of these system design considerations. Proper routing involves getting a connecting line from one point to another through the most efficient means. On the following page are several examples of typical routing situations.The graphics show both the incorrect and preferred path along with an explanation.

Current Routing	Preferred Routing	Explanation
		Allow for expansion and contraction of lines by utilizing "U" bend.
		Allow for motion under load, even some apparently rigid systems move under load.
		Avoid straight tube lines due to excessive joint strains. There is no margin of error on a straight line.
		Due to tube entry in some fitting styles, it might not be possible to assemble the current routing.
		Avoid excessive pressure loss by getting around obstructions without 90° bends. One 90° bend has more pressure loss than two 45° bends.
		Avoid creating an obstruction by routing lines over areas that require access.
		Route lines to allow for proper clamping. When done properly, several lines can typically be clamped together. Route lines to allow for troubleshooting; lines that cross and are not in logical order tend to be difficult to service during maintenance.

DRY TECH TIP:

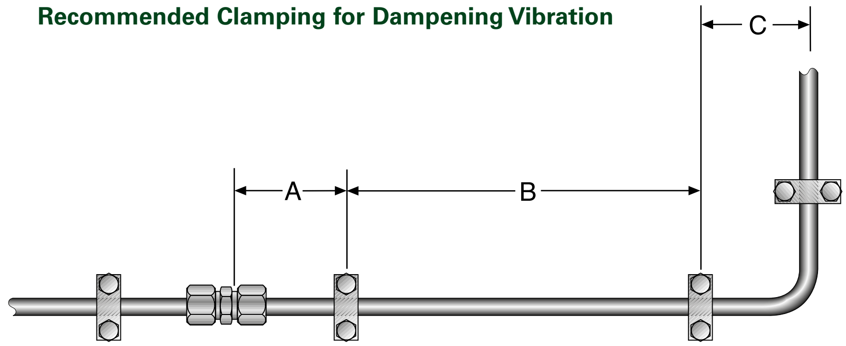
✎ *Always try to leave fitting joints as accessible as possible. Hard to reach joints are difficult to assemble and tighten properly. Inaccessible joints are also more difficult and time-consuming to service.*

✎ *Computer software can greatly expedite otherwise labor-intensive calculations such as pressure drop.*

Adequate Tube Line Supports

With proper routing accomplished, clamping must be considered to avoid premature tube line failure. Tube line supports are mainly for tube support and dampening vibration. Fatigue failure due to mechanical vibration accounts for the majority of tube line failures. Proper clamping of the tube also reduces system noise and minimizes transmitted vibration. For an optimal clamping system, space the clamps according to the diagram and table shown below.

Recommended Clamping for Dampening Vibration



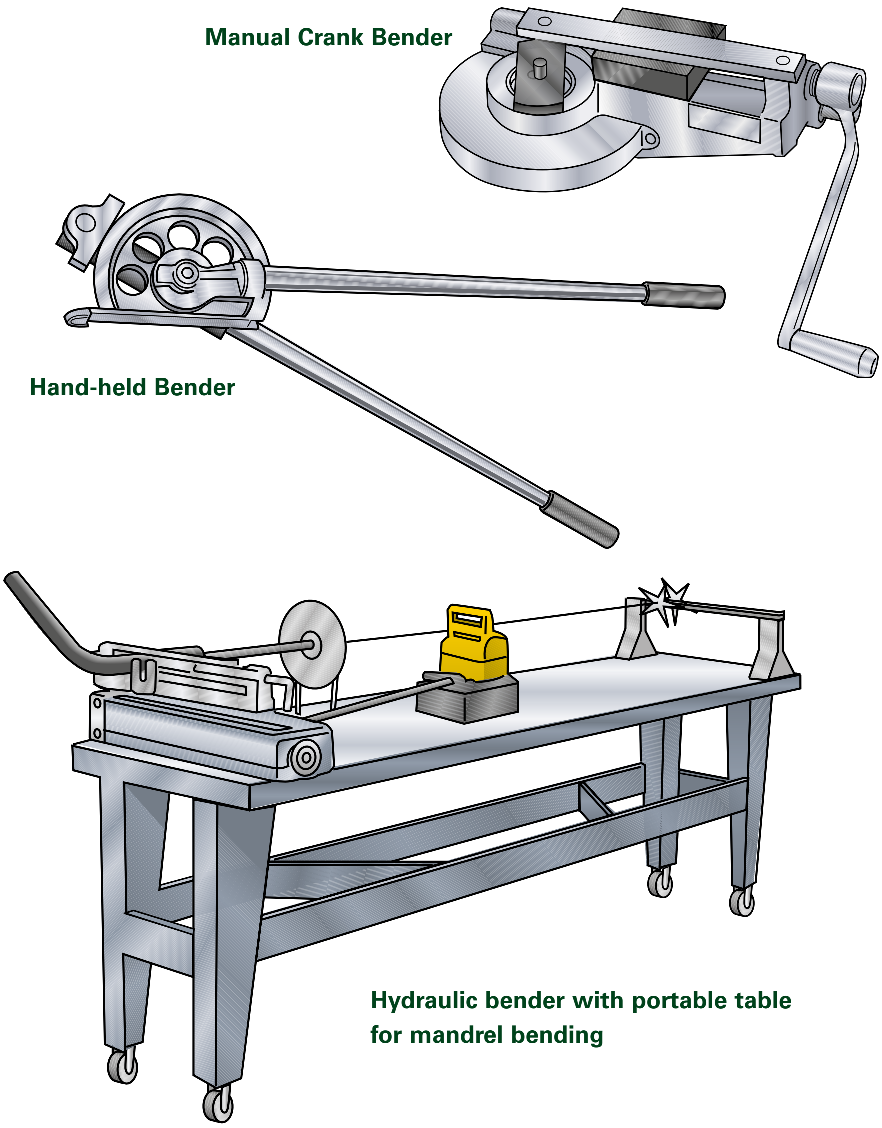
Recommended Tube Clamp Spacing

Tube O.D. (in)	Tube O.D. (mm)	A (in)	B (in)	C (in)
1/4 5/16 3/8	6 8 10	2	36	4
1/2 5/8 3/4 7/8 1	12 14 18 22 25	4	60	8
1-1/4 1-1/2 2	30 38 50	6	84	12

Tools for Tube Line Fabrication (Bending)

Using the proper tool for the job is the best way of achieving good results. For smooth, wrinkle-free bending without excessive tube flattening, there are a number of bender types to choose from:

- Hand-held lever-type benders, individually sized for tube sizes 1/8" through 1" and 5 mm through 14 mm
- Manual crank, table mount or vise mount benders
- Hydraulically powered benders
- CNC



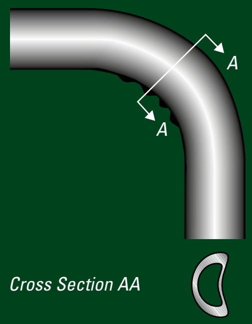
Manual Crank Bender

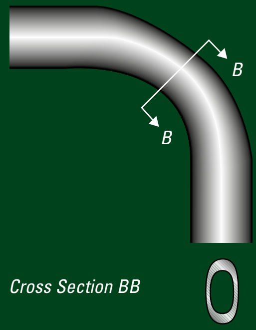
Hand-held Bender

Hydraulic bender with portable table for mandrel bending

DRY TECH TIP:

✎ *Mandrel bending can be used to minimize both tube flattening and tube wrinkling. A mandrel is used to support inside of the tube as it is bent, thus minimizing the tube deformation. Other considerations may be to use a larger center-line-bend radius or heavier tube wall thickness.*

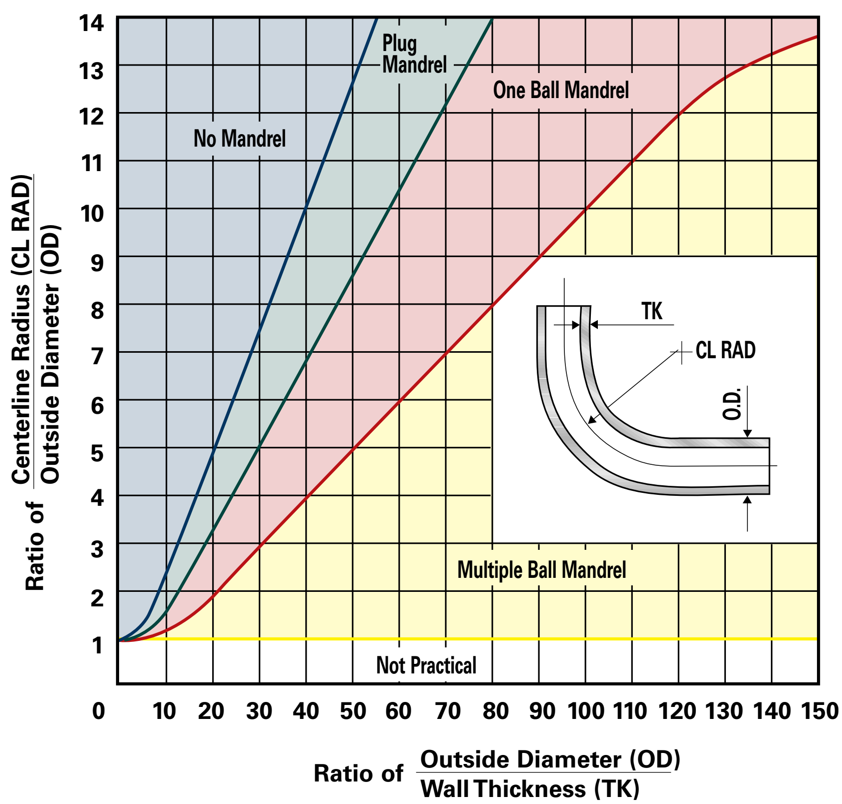




Mandrel Bending Components

When bending thin wall tubing it may be necessary to insert a mandrel into the tube to prevent excessive distortion or flattening. To accomplish such bending, a mandrel, mandrel rod, and a mandrel rod stop assembly are required. The rod stop assembly holds the end of the mandrel rod in proper alignment with the tube while the mandrel, which is threaded onto the other end of the mandrel rod, supports the tube on its I.D., thus preventing tube kinking or flattening during bending. The following chart provides a method to determine when a mandrel is required.

Mandrel Bending Requirements Chart



When to Use Mandrel

Example: Determine if it's necessary to use mandrel for bending 3/4 x 0.049 steel tube through a 3" bend radius without excessive flattening.

Solution:
$$\frac{\text{Centerline Radius}}{\text{Outside Diameter}} = \frac{3}{0.75} = 4$$

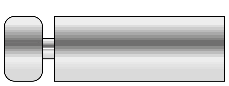
$$\frac{\text{Outside Diameter (OD)}}{\text{Wall Thickness (TK)}} = \frac{.75}{0.049} = 15.3$$

Intersection of these two ratios on the graph falls within the area indicating that no mandrel is required. Note, however, for the same tube at a smaller bend radius, a mandrel would be required for preventing excessive flattening.

If the tube wall is very thin, then a plug mandrel alone may not be adequate to prevent wrinkling. In such cases, special ball-type mandrels and wiper shoes may be necessary

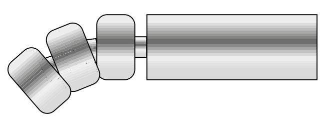
Common Mandrel Designs

One Ball Mandrel



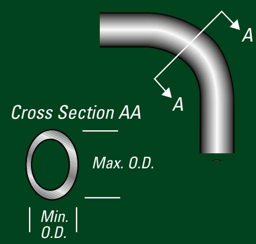
Plug Mandrel

Multiple Ball Mandrel



DRY TECH TIP:

✎ *As a rule of thumb, if the tube wall thickness is less than 7 percent of the tube O.D., then mandrel bending is recommended. The Mandrel Chart at the left may help in determining the mandrel, which may be needed.*



✎ *Flatness in the area of a tube bend is usually defined in terms of percentage flatness and may be calculated from the following:*

$$\%\ \text{Flatness} = \frac{\text{Max OD} - \text{Min OD}}{\text{Nominal OD}} \times \frac{100}{1}$$

✎ *Acceptable values are usually in the range of 0-5 percent and 0-10 percent depending on the tube material and pressure application.*

TROUBLESHOOTING

This section covers typical connection leakage problems, their causes, and recommendations for resolving them. It consists of quick-reference charts and helpful illustrations for troubleshooting tube end connections, port end connections and tube.

Conditions listed are those typically found or suspected when investigating the connection. Be sure to determine the true location of a leak. Just because a connection may appear to be leaking, it may have become wet from a leak at another location.

Causes, or likely reasons, provide future preventive insight.

Recommendations provide the approaches that normally resolve the problem in the most efficient, effective way. In addition, review the related detailed sections of this guide and consult the manufacturer's specifications.

Above All, Safety First: Always exercise appropriate precautions and safe practices when investigating a connection leak.

Troubleshooting Tube End Connections

37° Flare

CONDITION	PROBABLE CAUSE(S)	RECOMMENDATION
Tube nut binds to tube flare Tube nut cannot engage the fitting body	• Flare too large or tube wall too heavy	• Flare new tube end using proper flare diameters
Flare is out-of-round (lopsided)	• Tube cut at an angle	• Re-cut tube, reasonably square, to 90° ± 1° and flare new tube end
Nicks, scratches, pock marks on tube flare of fitting	• Contaminants on tube ID or flaring cone/pin prior to flaring • Worn/damaged flaring cone/pin • Poor-quality tube	• Flare new tube end using proper tube preparation techniques • Assure that flare cone is clean • Replace poor-quality tube
Tube crack on flare	• Poor-quality welded tube; work-hardened tube; tube not annealed (too hard)	• Flare new tube end using appropriate tube (e.g.,fully annealed) and tube cutting methods
Tube nut bottoms out before seats are mated properly	• Unintentional use of 45° flare tube nut, or tube sleeve was omitted	• Use appropriate 37° flare components (body, nut and sleeve)
Immediate leakage from tube nut	• Connection may not be tightened properly (if at all)	• Check joint for appropriate FFWR or torque; retighten as appropriate
Tube nut continues to back off or loosen	• Excessive vibration • Improper assembly torque	• Re-route or clamp properly • Assemble to appropriate torque
Damaged fitting and/or nose collapse, flow reduction	• Frequent assembly and disassembly or over-tightening	• Fitting should be replaced and tightened properly; avoid frequent assembly/disassembly

Troubleshooting Tube End Connections

24° Flareless Bite

CONDITION	PROBABLE CAUSE(S)	RECOMMENDATION
Immediate leakage when system is pressurized	• Improper ferrule/bite ring orientation	• Reset ferrule to ensure that the leading edge of ferrule/bite ring is pointing towards end of tube and seat of the mating fitting
Additional/excessive stress apparent on bite	• Non-square tube cut; tube not being properly supported in seat of adapter	• Re-cut tube to 90° ± 1°
Flexural stresses allow tube to"rock" back and forth	• Tube not fully supported in fitting's body seat	• Reset tube end. This time ensure that the tube is bottomed in the presetting tool or fitting body
Poor ferrule/bite ring pre-set and/or tube collapse	• Tube may be too hard; or preset pressure or torque might be too high • Tube is too thin	• Use fully annealed tube max hardness HRB 72 for steel, HRB 90 for stainless steel • Consult manufacturer's minimum tube wall thickness requirements; tube supports must be used with certain thin-walled steel or stainless-steel tube. Review preset requirements
Tube not bottoming out in fitting body	• Improper preset or wrong tool used for presetting	• In the presetting process, it is important to exert axial force on the tube to keep it fully bottomed in the tool. Check for indentation on end of the tube
Shallow bite of ferrule or cut ring into tube	• Worn preset tool • Too low preset pressure or torque • Tube too hard • Tube not bottomed against stop initially in preset	• Replace preset tool • Observe manufacturer's recommendation for proper preset • Ensure that tube is of correct hardness or material • Hold tube against stop in preset
Tube pulls out of fitting in application and ferrule skives end of tube	• Improper preset • Tube too hard • Excessive internal pressure • Excessive axial load on tube • Inadequate make up	• Preset must be inspected for evidence of proper preset, such as raised ridge of metal in front of leading edge • Ensure that tube is of proper hardness and material • Ensure that internal pressure is within rating of fitting (tube might be of a higher rating) • Avoid additional axial load than that caused by internal pressure • Follow proper presetting and assembly procedures
Fitting nut is tight but leakage still occurs	• Overset ferrule • Cracked tube • Damaged components	• Excessive force used in presetting of ferrule can cause it not to spring back and effect a seal. Follow manufacturer's recommendation for preset • Check tube for circumferential crack due to fatigue • Check components for damage such as nicks, scratches and cracks

24° Flareless Bite (Continued)

CONDITION	PROBABLE CAUSE(S)	RECOMMENDATION
Circumferential crack in tube,coinciding with bite of ferrule after fitting has been in service	• Excessive vibration or flexural loading on tube • Inadequate preset and make-up	• Use tube clamps and proper routing to reduce flexural loads • Follow proper preset and assembly procedures. This causes rear of ferrule to grip tube and prevent vibration failures
Ferrule or bite ring able to turn excessively on tube after preset	• Inadequate preset • Springback of ferrule bite ring	• Verify proper presetting pressure/ manual presetting turns are adequate • Material springback is normal and ferrule or bite ring might be able to turn but should not be able to move too much axially
Fitting leaks and there is evidence of small axial scratches on front of ferrule or bite ring	• Worn or damaged preset tool • Lack of lubrication in preset and assembly process	• Replace preset tool • Use proper lubrication for preset and assembly
Ferrule or bite ring cocked on tube	• Misalignment of tube in preset and/or assembly • Inadequate lubrication preset • Poor tube bending	• Align tube properly and follow proper presetting procedures • Lubricate throat of preset body as well as sloping angle in back of tube nut • Measure accurately and bend exactly

Troubleshooting Tube End Connections

O-Ring Face Seal

CONDITION	PROBABLE CAUSE(S)	RECOMMENDATION
Immediate leakage when system is pressurized	• Improper tightening of joint	• Check for O-ring damage and re-tighten connection to the recommended torque value
Under-flanged assembly	• Undersized tube diameter resulting in tube slippage during flanging • Die gripping surface is worn or dirty	• Inspect die gripping surface; if undersized, replace flange
Over-flanged assembly	• Sleeve is positioned incorrectly in die	• Check for proper positioning of sleeve in die; if over-flanged, replace tubing
Flange out-of-round	• Tubing was not cut properly • Tube was not properly supported during flanging • Tubing is eccentric	• Cut tubing within 90° ±1° • Support tubing so that tube end is perpendicular to tube stop during flanging • Replace with quality tubing • Replace out-of-round flanges
Cracked flange	• Tubing too hard	• Replace tubing using recommened quality tube
Scored, pitted flange	• Improper deburring and cleaning of tube prior to flanging • Flange pin not cleaned and lubricated properly	• Replace flange using proper deburring and cleaning recommendations
Leakage at braze joint	• Poor braze joint/improper joint clearance • Mixing of sleeve and tube material • Improper/inadequate flux, braze alloy overrun, or buildup on face	• Flux and reheat the joint, remove and replace with new sleeve • Always use steel sleeves with steel tubing and stainless sleeves with stainless tubing • Apply flux liberally to sleeve and tube end prior to brazing, using recommended flux
Leakage at face-seal end	• Misalignment or improper fit • Damaged, pinched, or missing O-ring • Extruded O-ring	• Align tube end and connecting fitting properly before tightening tube nut, holding the flat face of the mating fitting against O-ring while tightening • Replace O-ring, properly installing it in the face seal groove • Replace O-ring and check for proper alignment and pressure surges exceeding 133% of rated pressure of fitting; tighten the nut to recommended torque

60° Cone (Metric, BSPP and NPSM)

CONDITION	PROBABLE CAUSE(S)	RECOMMENDATION
End of swivel nut contacts hex shoulder of adapter before cone and ball nose tightens	• Wrong combination of swivel nut and adapter	• Ensure that components are to the same specification (even with the same type, there are different designs for 60° cone fittings)
Thread engagement seems adequate and swivel nut is tight but leakage still occurs	• Scratches or nicks on sealing surface • Chatter marks on sealing surface	• Replace components. These fittings depend on metal-to-metal seal and require smooth mating surfaces to seal
There is leakage from the joint and the swivel nut is loose	• Inadequate make-up torque	• Use proper torque to create a seal as well as prevent vibration loosening
Swivel nut tightens, cone is tight but connection still leaks	• Inadequate or no chamfer in adapter	• Use components with proper chamfer (very common occurrence with NPTF/ NPSM 60° cone fittings). Male pipe end must have chamfer for proper sealing. Not all male pipe ends have chamfer as standard

Troubleshooting Port End Connections

Tapered Thread (Including BSPT, NPT and Metric Taper)

CONDITION	PROBABLE CAUSE(S)	RECOMMENDATION
Thread galling	• Most common in stainless steel, caused by friction and lack of lubricant	• Replace fitting and apply proper thread sealant/lubricant to replacement fitting and tighten to appropriate TFFT
Fitting leaks, even after proper tightening	• Sealant omitted or inadequately applied • Damaged or cracked threads • Cracked port • Thread mixing of BSPT and NPT threads	• Re-apply sealant to appropriate TFFT and re-tighten • Replace fitting • Replace component • Determine port thread type and replace fitting with matching thread type
Insufficient thread engagement (3 to 6 threads of engagement required)	• Quality problem with port or adapter • Too much thread sealant (tape)	• Have port and adapter thread inspected; replace faulty parts • Remove all thread sealant and re-apply 1 to 2 layers of tape
Too much thread engagement (more than recommended 3 to 6 threads)	• Typically port or adapter machining or wear problem, or port could be cracked due to excessive torque	• Inspect port and adapter for proper tolerance or wear, replace faulty parts, retighten to appropriate TFFT
Poor-quality threads or damaged/nicked threads	• Larger sizes are more prone to having nicked threads due to handling damage	• Replace fitting with threads that are free of scratches and nicks

Parallel (SAE, BSPP and Metric)

CONDITION	PROBABLE CAUSE(S)	RECOMMENDATION
Washer is too loose (moves by its own weight or rocks too much on the undercut)	• Washer damaged	• Replace fitting
Fitting threads are distorted	• Over-torqued • Mixed threads	• Replace fitting and tighten to proper torque • Determine correct thread type
Several scratches or nicks on the port face	• Port face contaminated (dirty)	• Reface the port
Spot face of port is smaller than washer diameter	• Improper port tool was used • Wrong fitting selected for port	• Reface the port • Select a proper fitting
Port threads are distorted (yielded)	• Fitting over-torqued	• Replace component
Leakage persists after locknut has been torqued	• Damaged O-ring • Damaged washer • Improper assembly	• Replace O-ring with new quality O-ring (90 durometer) and reconnect fitting to proper torque • Replace fitting • Follow proper assembly procedure
Washer distorted, allowing opportunity for O-ring to extrude	• Exposed upper thread forced washer into port during assembly (over-torquing makes this more prevalent)	• Replace fitting, using proper installation techniques for adjustable port ends

Troubleshooting Port End Connections

Flange (i.e., ISO 6162 4-Bolt)

CONDITION	PROBABLE CAUSE(S)	RECOMMENDATION
Missing or improper O-ring	• Assembly/re-assembly oversight	• Replace with proper O-ring and re-tighten connection using incremental alternating tightening procedure
O-ring pinched or extruded	• Improper tightening procedure	• Replace O-ring and re-tighten connection using incremental alternating tightening procedure
Evidence of yielded or cracked flange head, tube or hose end	• Misaligned tube or hose connection	• Re-bend or re-route hose/tube lines to eliminate misalignment
Components do not mate or gap is too large	• Proprietary flange or pressure series matching problem	• Properly identify all components – most proprietary flanges use standard Code 61/62 bolt patterns and threads but are not usually interchangeable
Port has severe scratches or nicks in seal area	• Mishandling or abuse	• Resurface the port to remove cratches and nicks
Clamp halves are bent	• Over-pressurization or over-torque	• Replace clamp halves and tighten to proper torque
Bolts are bent	• Bolts are too weak or over-torqued	• Replace bolts with grade 5 or better; retighten to proper torque

Troubleshooting Tube

CONDITION	PROBABLE CAUSE(S)	RECOMMENDATION
Circumferential cracking	• Excessive vibration • Inadequate/improper clamping • Tube misalignment • Improper routing	• Improve tube line support via clamping • Clamp tube lines properly (see "Bending, Routing and Clamping" section) • Measure and bend tubes properly to improve alignment • See "Proper Routing of Lines" in Bending, Routing and Clamping section
Longitudinal cracking	• Crack along weld of tube • Thin spots on low-quality seamless tube • Excessive cyclic pressure • Dynamic or static pressure too much for current wall thickness	• Use only SAE J525 or ISO equivalent tube • Use only SAE J524 tube • Design factor should be increased due to the high number of cycles; therefore, tube wall thickness should be increased • Use tube with increased wall thickness to handle the higher pressures

GLOSSARY OF TERMS

Alloy: Substance having metallic properties and composed of two or more chemical elements of which at least one is a metal.

Annealing: Heat-treating process used primarily to soften metals or to stabilize their structures.

Brass: Alloy consisting mainly of copper (more than 50 percent) and zinc, to which smaller amounts of other elements may be added.

Brazing: Joining of metals through the use of heat and capillary flow of a filler metal. Filler metal has a melting temperature above 840 degrees Fahrenheit, but below the melting point of the metals being joined.

Brittleness: Quality of a material that leads to crack propagation without appreciable plastic deformation.

Burnishing: Smoothing surfaces of a work piece through frictional contact between it and some hardened tooling.

Cavitation: Localized gaseous condition within a liquid stream which occurs when the pressure is reduced to the vapor pressure. Generally occurs in pumps and suction lines where fluid velocity is too high due to poorly sized (too small) line size.

Chromate Treatment: Treatment of metal in a solution of a chromium compound to produce a conversion coating of chromium compounds on the surface of the metal, thus improving the resistance to corrosion.

Cold Heading: Working metal at room temperature in such a manner that the cross-sectional area of a portion or all of the stock is increased.

Cold Working (Cold Forming): Permanently deforming metal, usually at room temperature, by the application of an external force in order to produce a near net shape component.

Corrosion: Deterioration of a metal by chemical or electrochemical reaction with its environment.

Deburring: Removing burrs, sharp edges or fins from metal parts usually by filing, grinding or tumbling the work in a barrel containing a suitable liquid medium and abrasives.

Dynamic Pressure Rating: See Pressure, Rated Dynamic.

Elastic Deformation: Change of dimensions accompanying stress in the elastic range, original dimensions being restored upon release of stress.

Elastomer: Often referred to as rubber, is a high polymer that can be, or has been, modified to a state exhibiting little plastic flow and quick recovery from an extending force.

Extrusion: Conversion of an ingot slug or billet into lengths of a uniform cross section by plastically forcing the metal through a die orifice having the desired cross-sectional profile.

Fatigue/Endurance Limit: Maximum stress below which a material can presumably endure an infinite number of stress cycles.

Fatigue Fracture: Initiation of minute cracks, propagating into ultimate fracture under the application of repeated or fluctuating stresses having a maximum value less than the tensile strength of the material.

Flaring: Forming an outward acute-angle flange on a tubular part, usually less than 90° from centerline.

Flow: Movement of fluid generated by pressure differences.

Flow Lines: Fiber pattern, frequently observed in wrought metal, which indicates the manner in which the metal flowed during forming.

Flow Rate: Volume, mass or weight of a fluid passing through any conductor per unit of time.

Flow, Turbulent: Flow situation in which the fluid particles move in a random fluctuation manner. Generally caused by too high fluid velocity.

Fluid Power System: System that transmits and controls power through the use of a pressurized fluid within an enclosed circuit.

Fluorocarbon Rubber: Elastomeric material which is extensively used for O-ring. Fluorocarbon is recommended for higher temperatures than nitrile (Buna N) material.

Flux: In brazing, cutting, soldering or welding, material used to dissolve or facilitate the removal of oxides and other undesirable substances.

Forging: Plastically deforming metal, usually hot, into desired shapes with compressive force, with or without dies.

Galling: Localized welding on mating surfaces of metal parts caused from excessive friction developed during the rubbing action that occurs during assembly.

Galvanic Corrosion: Corrosion resulting from the placing of two dissimilar metals in direct contact with each other, then exposing them to an incompatible fluid or atmosphere.

Hammer, Liquid: Pressure and depression waves created by relatively rapid flow changes and transmitted through the system.

Hardening: Increasing the hardness of a material by suitable treatment, usually involving heating and rapid cooling.

Hardness: Resistance of a material to scratching, abrasion, cutting or deformation.

Hot Finishing/Hot Forming: Deformation operation performed at an elevated temperature, usually above the recrystallization temperature of the metal.

Hydraulic Power: Power derived from flow rate and pressure differential of the fluid.

Hydraulics: Engineering science pertaining to liquid pressure and flow.

Lubricant: Any substance used to reduce friction between two surfaces which are in contact.

Machinability: Relative ease of machining a metal.

Machining: Removing material, in the form of chips, from work, usually through the use of a machine.

Mandrel: (1) Metal bar around which other metal may be cast bent, formed or shaped. (2) Rod used to retain the cavity in hollow metal products during working.

Mechanical Properties: Properties of a material that reveal its elastic and inelastic behavior under the application of force, thus indicating the material's suitability for mechanical applications. Examples of such properties are tensile strength, elongation, modulus of elasticity, yield strength, reduction in area and fatigue limit.

Mild Steel: Carbon steel with a maximum of 0.25 percent carbon.

Nitrile (Buna N): Copolymer of butadienne and acrylonitrile. Elastomer most widely used to manufacture O-rings.

O-ring: Torus, or doughnut-shaped object, generally made from elastomer and used primarily for sealing.

Passivation: Process used to improve corrosive behavior of a metal by changing its chemically active surface to a much less reactive state.

Pipe: (1) Defect in wrought or cast products resulting from the central cavity formed by contraction in metal, especially ingots, during solidification. (2) Tubular metal product that includes iron pipe size (I.P.S.) and schedule number in its classification.

Pipe Thread, Dry Seal: Tapered pipe threads in which sealing is a function of root and crest interference.

Pitting: Forming small sharp cavities in a metal surface by corrosion, mechanical action or non-uniform electrodeposition.

Plastic Deformation: Deformation that does or will remain permanent in an element after removal of the stress that caused it.

Port: Terminus of a passage in a component to which conductors can be connected.

Port, Pipe: Port which conforms to pipe thread standards.

Port, Straight Thread: Port which conforms to straight thread standards. Typically employs an O-ring compressed in a wedge-shaped cavity.

Pressure: Force per unit area, usually expressed in pounds per square inch (psi).

Pressure, Burst: Pressure which causes failure of, and consequential loss of a fluid through the product envelope.

Pressure, Cyclic Test: Pressure range applied in cyclic endurance tests that are performed to help determine recommended working pressure.

Pressure, Differential (Pressure Drop): Difference in pressure between any two points of a system or a component.

Pressure, Operating: See Pressure, Rated Dynamic/Static.

Pressure, Rated Dynamic: Maximum fluctuating pressure load that a pressure containing envelope is capable of sustaining for a minimum of 1 million operating cycles without failure.

Pressure, Rated Static: Maximum pressure that a pressure containing envelope is capable of sustaining in an application not exceeding 30,000 operating cycles in a system free of pressure surges, shocks, vibration, temperature excursions, etc.

Pressure, Surge: Pressure increases resulting from pressure fluctuations in a hydraulic system.

Quenching: Rapid cooling method used in heat-treating process.

Specific Gravity, Liquid: Ratio of the weight of a given volume of liquid to an equal volume of water.

Springback: (1) Elastic recovery of metal after stressing. (2) Degree to which metal tends to return to its original shape or contour after undergoing a forming operation.

Stainless Steel: Basically, low-carbon alloy steels containing at least 11.5 percent chromium. Characterized by their high resistance to corrosion.

Static Pressure Rating: See Pressure, Rated Static.

Steel: Iron-based alloy containing manganese, usually carbon, and often other alloying elements.

Strain: Measure of the relative change in size or shape of a body. Example: linear strain is computed as the ratio of change in length to the original length.

Stress: Result of a force acting on a given surface area. Computed as the ratio of the applied force to the affected area.

Temperature, Ambient: Temperature of the environment in which the apparatus is working.

Tensile Strength: In tensile testing, the ratio of maximum load to original cross-sectional area.

Tensile Strength, Ultimate: Maximum stress that a material can withstand.

Torque: Turning effort (moment) applied to a component for fastening, tightening or assembling.

Tube: Hollow, cylindrical products having outside diameters that are not standardized for threading. Tubes are dimensionally classified in terms of their outside diameters and wall thicknesses.

Viscosity: Measure of the internal friction or the resistance of a fluid to flow.

Welding: Joining two or more pieces of metal by applying heat, pressure or both with or without filler metal, to produce a localized union through fusion or recrystallization across the interface.

Working Pressure, Dynamic: See Pressure, Rated Dynamic.

Working Pressure, Static: See Pressure, Rated Static.

APPENDIX

TABLE 1 – Fluid Compatibility

	Fitting Material			Seal Material			
Media	**Brass**	**Steel**	**316 SS**	**BUNA-N**	**Propylene**	**Ethylene Fluorocarbon**	**Neoprene**
Acetylene	NR	F	S	S	S	S	F
Air (oil free) @ 190° F	S	F	S	S	S	S	S
Air (oil free) @ 300° F	S	F	S	F	F	S	F
Air (oil free) @ 400° F	S	F	S	NR	NR	S	NR
Alcohol, Ethyl	S	NR	NR	NR	S	NR	S
Animal Oils (Lard Oil)	F	F	F	S	F	S	F
Aromatic Fuel - 50%	ID	ID	ID	F	NR	S	NR
Aromatic Solvents	ID	ID	F	F	ID	S	NR
Asphalt	NR	NR	S	F	NR	S	F
ASTM Oil #1	S	S	S	S	NR	S	S
ASTM Oil #2	S	S	S	S	NR	S	F
ASTM Oil #3	S	S	S	S	NR	S	NR
ASTM Oil #4	S	S	S	F	NR	S	NR
ATF Oil	S	S	S	S	NR	S	F
Automotive Brake Fluid	ID	ID	ID	NR	S	NR	F
Benzene	NR	F	NR	NR	NR	S	NR
Brine (Sodium Chloride)	NR	NR	S	S	S	S	S
Butane	NR	S	S	S	NR	S	S
Carbon Dioxide	S	F	S	S	S	S	S
Carbon Monoxide	S	S	S	S	S	S	F
Chlorine (Dry)	F	F	NR	NR	ID	F	F
Compressed Air	S	F	S	S	S	S	S
Crude Oil	NR	F	S	F	NR	S	NR
Cutting Oil	ID	S	S	S	NR	S	F
Diesel Fuel	S	S	S	S	NR	S	NR
Ethanol	S	NR	NR	NR	S	NR	S
Ethers	S	S	S	NR	F	F	NR
Freon 11	S	ID	ID	F	NR	F	NR
Freon 12	S	S	NR	F	NR	S	S
Freon 22	S	NR	S	NR	NR	NR	S
Fuel Oil	NR	S	S	S	NR	S	F
Gasoline	S	F	S	S	NR	S	NR
Gas, Liquid Propane (LPG)	S	S	S	S	NR	S	F
Gas, Natural	F	S	S	S	NR	S	S
Helium	S	S	S	S	S	S	S
Hydraulic Oil, Petroleum Base	S	S	S	S	NR	S	S
Hydraulic Oil, Water Base	ID	S	S	F	S	NR	F
Hydrogen Gas	S	S	S	S	S	S	S
Jet Fuel	S	S	S	S	NR	S	NR
Kerosene	S	S	S	S	NR	S	F
Lubricating Oil SAE 10, 20, 30, 40, 50	S	S	S	S	NR	S	F
Methanol	S	S	S	S	S	NR	S
MIL-F-8192 (JP-9)	S	S	S	NR	NR	S	NR
MIL-H-5606	S	S	S	S	NR	S	F

Codes: S = Satisfactory NR = Not Recommended F = Fair ID = Insufficient Data

TABLE 1 – Fluid Compatibility (Continued)

	Fitting Material			Seal Material			
Media	**Brass**	**Steel**	**316 SS**	**BUNA-N**	**Propylene**	**Ethylene Fluorocarbon**	**Neoprene**
MIL-H-6083	S	S	S	S	NR	S	S
MIL-H-7083	S	S	S	S	S	F	F
MIL-H-8446 (MLO-8515)	F	S	S	F	NR	S	S
Mil-L-2104 & 2104B	S	S	S	S	NR	S	F
MIL-L-7808	NR	F	S	F	NR	S	NR
Mineral Oil	S	S	S	S	NR	S	F
Nitrogen	S	S	S	S	S	S	S
Petrolatum	S	S	S	S	NR	S	F
Petroleum Oil (<250° F)	S	S	S	S	NR	S	F
Propane	S	S	S	S	NR	S	F
R134A	S	S	S	NR	S	NR	NR
Sea Water	F	NR	S	S	S	S	F
Skydrol 500, Type 2	NR	S	S	NR	S	NR	NR
Skydrol 7000, Type 2	NR	S	S	NR	S	F	NR
Soap Solutions	NR	NR	S	S	S	S	F
Steam (<400° F)	F	S	S	NR	S	NR	NR
Stoddard Solvent	F	S	S	S	NR	S	F
Transmission Fluid (Type A)	S	S	S	S	NR	S	F
Trichloroethane	ID	F	S	NR	NR	S	NR
Water	S	F	S	S	S	F	F

Codes: S = Satisfactory NR = Not Recommended F = Fair ID = Insufficient Data

TABLE 2 – Temperature Derating Factors* for Tubes

Maximum Operating Temperature (degrees F)	Steel C-1010 and C-4130	Stainless Steel		Copper	Aluminum 6061-T6	Monel Type 400
		304	316			
100	1.00	1.00	1.00	1.00	1.00	1.00
150	1.00	0.91	1.00	0.85	1.00	0.97
200	1.00	0.84	1.00	0.80	1.00	0.94
250	1.00	0.79	1.00	0.80	0.94	0.91
300	1.00	0.75	1.00	0.78	0.80	0.88
350	0.99	0.72	0.99	0.67	0.60	0.86
400	0.98	0.69	0.97	0.50	0.43	0.85
500	0.96	0.65	0.90	—	—	0.84
600	—	0.61	0.85	—	—	0.84
700	—	0.59	0.82	—	—	0.84
800	—	0.57	0.80	—	—	0.83
900	—	0.54	0.78	—	—	—
1000	—	0.52	0.77	—	—	—
1100	—	0.47	0.62	—	—	—
1200	—	0.32	0.37	—	—	—

* The derating factors are based on allowable design stress values at various temperatures per ASME B31.1 code for pressure piping (1986).

TABLE 3 – Threaded Port End Sealing Method

This table summarizes the various sealing methods for threaded ports on industrial hydraulic fittings. The individual blocks show some pertinent specifications for the male stud end for the combined sealing style and the thread type.

	Sealing Method					
Sealing Method	**UN/UNF**	**Metric Parallel**	**BSPP**	**NPT/NPTF**	**BSPT**	**Metric Taper**
O-Ring in Chamfer	SAE J1926 (ISO 11926)	ISO 6149 (SAE J2244) DIN 3852-3	JIS B2351*	—	—	—
O-Ring in in Groove	—	DIN 3852-1 Type E (ISO 9974-1)	DIN 3852-2 Type E (ISO 1179-1)	—	—	—
O-Ring with Retaining Ring	—	DIN 3852-1 Type G and H	DIN 3852-2 Type G and H (ISO 1179-1)	—	—	—
Bonded Seal	—	DIN 3852-1 Type D (ISO 9974-1)	DIN 3852-2 Type D (ISO 1179-1)	—	—	—
Hard Metal Seal	—	DIN 3852-1 (ISO 9974-1)	DIN 3852-2 (ISO 1179-1)	—	—	—
Soft Metal Seal	—	DIN 3852-1 Type A (ISO 9974-1)	DIN 3852-2 Type A (ISO 1179-1)	—	—	—
Cutting Face Seal	—	DIN 3852-1 Type B (ISO 9974-1)	DIN 3852-2 Type B (ISO 1179-1)	—	—	—
Tapered Thread	—	—	—	SAE J476	DIN 3852-2 TYPE C (JIS B8363)	DIN 3852-1 TYPE C

*JIS B2351 specifies threads as JIS Parallel Pipe Threads (PF) per JIS B202, but for identification purposes these threads can be treated as BSPP.

TABLE 4 – Tube and Fitting Material Compatibility

Tube Material	Specification	Construction	Condition	Max. Hardness	Temperature Range (7)	Application	Tube Material to Fitting & Material Compatibility: Seal-Lok™ ORFS (SAE J1453) S	SS	B	Triple-Lok® 37° Flare (SAE J514) S	SS	B	M	Ferulok® Flareless (SAE J514) S	SS	M	Intru-Lok® Flareless B	EO/EO-2 Flareless (ISO 8434-1) S, SS, B, M
Carbon Steel C-1010	SAE J524 (ASTM A179) (8)	Seamless	Fully Annealed	HRB 72	-65° to 500°F -55° to 260°C	High-pressure hydraulic, air & some specialty chemicals	E	NR	(6)	G	NR	(6)	NR	E	NR	NR	NR	NR
	SAE J525 (ASTM A178) (8)	Welded & Drawn					E	NR	(6)	E	NR	(6)	NR	E	NR	NR	NR	NR
	SAE J356	Welded & Flash Controlled					G	NR	(6)	NR	NR	(6)	NR	G	NR	NR	NR	NR
Carbon Steel C-1021	SAE J2467	Welded & Drawn	Fully Annealed	HRB 75	-65° to 500°F -55° to 260°C	High-pressure hydraulic	E	NR	(6)	NR	NR	(6)	NR	E	NR	NR	NR	NR
	SAE J2435	Welded & Flash Controlled					E	NR	(6)	E	NR	(6)	NR	E	NR	NR	NR	NR
Carbon Steel High Strength Low Alloy (HSLA)	SAE J2613	Welded & Flash Controlled	Sub-critically Annealed	HRB 90	-65° to 500°F -55° to 260°C	High-pressure hydraulic	E (10)	NR	(6)	NR	NR	NR	NR	NR	NR	NR	NR	NR
	SAE J2614	Welded & Drawn					E	NR	(6)	NR	NR	NR	NR	NR	NR	NR	NR	NR
Alloy Steel 4130	ASTM A519	Seamless	—	—	-65° to 500°F -55° to 260°C	High-pressure hydraulics	E (4)	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
St 37.4 (Carbon Steel)	DIN 2391 Part 2 (Metric)	Seamless	Fully Annealed	HRB 72	-65° to 500°F -55° to 260°C	High-pressure hydraulic, air & some specialty chemicals	E	NR	NR	G	NR	NR	NR	NR	NR	NR	NR	E
Stainless Steel 304 & 316	ASTM A213 ASTM A269	Seamless	Fully Annealed	HRB 90	-425° to 1200°F -255° to 650°C (3)	High pressure, high temperature or generally corrosive media (1)	(6)	E	(6)	(6)	G	(6)	NR	(6)	E	NR	NR	NR
	ASTM A249 ASTM A269	Welded & Drawn					(6)	E	(6)	(6)	E	(6)	NR	(6)	E	NR	NR	NR
1.4571 1.4541 Stainless Steel	DIN 17458 Tab 8 (Metric)	Seamless	Fully Annealed	HRB 90	-425° to 1200°F -255° to 650°C (3)	High pressure, high temperature or generally corrosive media (1)	(6)	E	NR	(6)	G	NR	NR	NR	E	NR	NR	E
Copper	SAE J528 (ASTM B-75) (8)	Seamless	Soft Annealed Temper 0	60 Max. Rockwell 15T	-325° to 400°F -200° to 205°C	Low pressure, low temperature, water, oil & air	E	(6)	E	G	(6)	E	NR	G (2)	NR	NR	E	E
Aluminum 6061	ASTM-B210	Seamless	T6 Temper	HRB 56	-325° to 400°F -200° to 205°C	Low pressure, low temperature water, oil, air & some specialty chemicals	NR	NR	NR	G	NR	NR	NR	E (2)	NR	NR	(6)	NR
			0 & T4 Temper	HRB 30			E (5)	NR	NR	G	NR	NR	NR	E (2)	NR	NR	(6)	NR
Monel 400	ASTM-B165	Seamless	Fully Annealed	HRB 70	-400° to 800°F -240° to 425°C	Sour gas, marine & general chemical processing media	NR	(6)	NR	NR	(6)	NR	E	NR	(6)	E	NR	NR
Nylon	—	Extruded	Flexible & Semi-Rigid	—	-60° to 200°F -50° to 95°C	Lube lines, chemical process controls & air	NR	NR	NR	NR	NR	NR	NR	G (2)	G (2)	G (2)	E	G (2), (9)
Polyethylene	ASTM D-1248	Extruded	Instrument Grade	—	-80° to 150°F -60° to 65°C	Instrumentation lines	NR	NR	NR	NR	NR	NR	NR	G (2)	G (2)	G (2)	E	G (2), (9)
PVC	—	Extruded	Instrument & Laboratory Grade	—	0° to 140°F -20° to 60°C	General purpose laboratory use	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	G	NR
PTFE	—	Extruded & Sintered	—	—	-65° to 400°F -55° to 205°C	Very low pressure, high temperature, fuel, lube, chemical & air applications	NR	NR	NR	NR	NR	NR	NR	G (2)	G (2)	G (2)	G	G (2), (9)

Ratings:
NR = Not Recommended
F = Fair
G = Good
E = Excellent

Fitting Materials:
S = Steel
SS = Stainless Steel
B = Brass
M = Monel

Notes:
(1) For highly corrosive media or service environment, contact the Tube Fittings Division.
(2) Requires different assembly procedure. Contact the Tube Fittings Division.
(3) Low-temperature limit for stainless steel Ferulok fittings is -20°F (-30°C).
(4) For brazing only Grade 4130 not recommended with Parflange process.
(5) For use with Parflange process only. Not recommended with brazing.
(6) Use depends on specific application. Contact the Tube Fittings Division.
(7) Applies to tube material.
(8) Comparable specifications to SAE.
(9) With metric version of tubing.
(10) Not tested with Parflange. Contact the Tube Fittings Division.

APPENDIX

TABLE 5 – Recommended Flow Diameters

Maximum Flow Rate GPM	Recommended Flow Diameter in Inches			Maximum Flow Rate LPM*	Recommended Flow Diameter in Millimeters		
	Pressure Lines	Return Lines	Suction Lines		Pressure Lines	Return Lines	Suction Lines
0.25	0.064	0.101	0.160	1	1.670	2.640	4.180
0.50	0.091	0.143	0.226	2	2.362	3.734	5.911
0.75	0.111	0.175	0.277	3	2.893	4.573	7.240
1.00	0.128	0.202	0.320	4	3.340	5.280	8.360
1.25	0.143	0.226	0.358	5	3.734	5.903	9.347
1.50	0.157	0.247	0.392	6	4.091	6.467	10.239
1.75	0.169	0.267	0.423	7	4.418	6.985	11.059
2.00	0.181	0.286	0.453	8	4.723	7.467	11.823
2.50	0.202	0.319	0.506	9	5.010	7.920	12.540
3.00	0.222	0.350	0.554	10	5.281	8.348	13.218
3.50	0.239	0.378	0.599	12	5.785	9.145	14.480
4.00	0.256	0.404	0.640	14	6.249	9.878	15.640
4.50	0.272	0.429	0.679	16	6.680	10.560	16.720
5.00	0.286	0.452	0.716	18	7.085	11.201	17.734
5.50	0.300	0.474	0.750	20	7.468	11.806	18.694
6.00	0.314	0.495	0.784	22	7.833	12.383	19.606
6.50	0.326	0.515	0.816	24	8.181	12.933	20.478
7.00	0.339	0.534	0.847	26	8.515	13.461	21.314
7.50	0.351	0.553	0.876	28	8.837	13.970	22.118
8.00	0.362	0.571	0.905	30	9.147	14.460	22.895
8.50	0.373	0.589	0.933	32	9.447	14.934	23.646
9.00	0.384	0.606	0.969	34	9.738	15.394	24.373
9.50	0.395	0.623	0.986	36	10.020	15.840	25.080
10.00	0.405	0.639	1.012	38	10.295	16.274	25.767
11.00	0.425	0.670	1.061	40	10.562	16.697	26.437
12.00	0.443	0.700	1.109	45	11.203	17.710	28.040
13.00	0.462	0.728	1.154	50	11.809	18.668	29.557
14.00	0.479	0.756	1.197	55	12.385	19.579	31.000
15.00	0.496	0.782	1.239	60	12.936	20.449	32.378
16.00	0.512	0.808	1.280	65	13.464	21.284	33.700
17.00	0.528	0.833	1.319	70	13.972	22.088	34.972
18.00	0.543	0.857	1.358	75	14.463	22.863	36.200
19.00	0.558	0.880	1.395	80	14.937	23.613	37.387
20.00	0.572	0.903	1.431	85	15.397	24.340	38.538
22.00	0.600	0.947	1.501	90	15.843	25.045	39.655
24.00	0.627	0.990	1.568	95	16.277	25.732	40.742
26.00	0.653	1.030	1.632	100	16.700	26.400	41.800
28.00	0.677	1.069	1.693	110	17.515	27.689	43.840
30.00	0.701	1.106	1.753	120	18.294	28.920	45.790
32.00	0.724	1.143	1.810	130	19.041	30.101	47.659
34.00	0.746	1.178	1.866	140	19.760	31.237	49.458
36.00	0.768	1.212	1.920	150	20.453	32.333	51.194
38.00	0.789	1.245	1.973	160	21.124	33.394	52.873
40.00	0.810	1.278	2.024	170	21.774	34.421	54.501
42.00	0.830	1.309	2.074	180	22.405	35.419	56.081
44.00	0.849	1.340	2.123	190	23.019	36.39	57.617
46.00	0.868	1.370	2.170	200	23.617	37.335	59.114
48.00	0.887	1.399	2.217	220	24.770	39.158	61.999
50.00	0.905	1.428	2.263	240	25.872	40.899	64.756
55.00	0.949	1.498	2.373	260	26.928	42.569	67.400
60.00	0.991	1.565	2.479	280	27.944	44.176	69.945
65.00	1.032	1.629	2.580	300	28.925	45.726	72.400
70.00	1.071	1.690	2.677	320	29.874	47.226	74.774
75.00	1.109	1.749	2.771	340	30.793	48.679	77.075
80.00	1.145	1.807	2.862	360	31.686	50.090	79.310
85.00	1.180	1.862	2.950	380	32.554	51.463	81.483
90.00	1.214	1.916	3.036	400	33.400	52.800	83.600
95.00	1.248	1.969	3.119	450	35.426	56.003	88.671
100.00	1.280	2.020	3.200	500	37.342	59.032	93.468
110.00	1.342	2.119	3.356	550	39.165	61.913	98.030
120.00	1.402	2.213	3.505	600	40.906	64.667	102.389
130.00	1.459	2.303	3.649	650	42.577	67.307	106.570
140.00	1.515	2.390	3.786	700	44.184	69.848	110.592
150.00	1.568	2.474	3.919	750	45.735	72.299	114.474
160.00	1.619	2.555	4.048	800	47.235	74.670	118.228
170.00	1.669	2.634	4.172	—	—	—	—
180.00	1.717	2.710	4.293	—	—	—	—
190.00	1.764	2.784	4.411	—	—	—	—
200.00	1.810	2.857	4.525	—	—	—	—

* LPM = Liters Per Minute

TABLE 6 – Recommended Design Pressure for Tubes

Inch Tubes							Metric Tubes				
			Design Pressure (4:1 Design Factor) – PSI							Design Pressure (Bar)	
Tube O.D. (in.)	Wall Thick (in.)	Tube I.D. (in.)	Steel 1010	Steel 1021	Stainless Steel 304 & 316, 4130, HSLA	Copper	Tube O.D. (mm)	Wall Thick (mm)	Tube I.D. (mm)	Steel Low-Carbon St. 37-4	Stainless Steel 1.4571
0.125	0.010	0.105	2150	2600	3250	1050	4	0.5	3.0	313	256
0.125	0.020	0.085	4600	5500	6900	2200	4	0.75	2.5	409	366
0.125	0.028	0.069	6650	8000	10000	3200	4	1.0	2.0	522	465
0.125	0.035	0.055	8450	10150	12700	4050	5	0.8	3.5	376	301
0.188	0.010	0.168	1400	1700	2100	650	5	1.0	3.0	432	386
0.188	0.020	0.148	2950	3550	4450	1400	6	0.75	4.5	333	256
0.188	0.028	0.132	4250	5100	6400	2050	6	1.0	4.0	389	330
0.188	0.035	0.118	5450	6550	8200	2600	6	1.5	3.0	549	465
0.188	0.049	0.090	7850	9400	11800	3750	6	2.0	2.0	692	585
0.250	0.020	0.210	2150	2600	3250	1050	6	2.25	1.5	757	639
0.250	0.028	0.194	3100	3700	4650	1500	8	1.0	6.0	333	256
0.250	0.035	0.180	3950	4750	5950	1900	8	1.5	5.0	431	366
0.250	0.049	0.152	5750	6900	8650	2750	8	2.0	4.0	549	465
0.250	0.058	0.134	6900	8300	10400	3300	8	2.5	3.0	658	556
0.250	0.065	0.120	7800	9350	11750	3750	10	1.0	8.0	282	209
0.250	0.083	0.084	9950	11950	15000	4800	10	1.5	7.0	373	301
0.313	0.020	0.273	1700	2050	2550	800	10	2.0	6.0	478	386
0.313	0.028	0.257	2450	2950	3650	1150	10	2.5	5.0	576	465
0.313	0.035	0.243	3100	3700	4650	1500	10	3.0	4.0	666	539
0.313	0.049	0.215	4500	5400	6750	2150	12	1.0	10.0	235	177
0.313	0.058	0.197	5400	6500	8150	2600	12	1.5	9.0	353	256
0.313	0.065	0.183	6150	7400	9250	2950	12	2.0	8.0	409	330
0.313	0.072	0.169	6850	8200	10350	3300	12	2.5	7.0	495	400
0.313	0.083	0.147	8000	9600	12050	3850	12	3.0	6.0	576	465
0.313	0.095	0.123	9150	11000	13800	4400	12	3.5	5.0	651	527
0.375	0.020	0.335	1400	1700	2100	650	14	1.0	12.0	201	153
0.375	0.028	0.319	2000	2400	3000	950	14	1.5	11.0	302	223
0.375	0.035	0.305	2550	3050	3850	1200	14	2.0	10.0	403	289
0.375	0.049	0.277	3650	4400	5550	1750	14	2.5	9.0	434	351
0.375	0.058	0.259	4450	5350	6650	2100	14	3.0	8.0	507	410
0.375	0.065	0.245	5000	6000	7550	2400	14	3.5	7.0	676	465
0.375	0.072	0.231	5600	6700	8450	2700	14	4.0	6.0	641	518
0.375	0.083	0.209	6550	7900	9900	3150	15	1.0	13.0	188	143
0.375	0.095	0.185	7600	9100	11450	3650	15	1.5	12.0	282	209
0.375	0.109	0.157	8750	10500	13200	4200	15	2.0	11.0	376	271
0.500	0.028	0.444	1500	1800	2200	700	15	2.5	10.0	409	330
0.500	0.035	0.430	1850	2200	2800	900	15	3.0	9.0	478	386
0.500	0.049	0.402	2700	3250	4050	1300	16	1.0	14.0	176	135
0.500	0.058	0.384	3250	3900	4850	1550	16	1.5	13.0	264	197
0.500	0.065	0.370	3650	4400	5500	1750	16	2.0	12.0	353	256
0.500	0.072	0.356	4100	4900	6150	1950	16	2.5	11.0	386	312
0.500	0.083	0.334	4800	5750	7200	2300	16	3.0	10.0	452	366
0.500	0.095	0.310	5550	6650	8350	2650	18	1.0	16.0	157	121
0.500	0.109	0.282	6450	7750	9750	3100	18	1.5	15.0	235	177
0.500	0.120	0.260	7200	8650	10800	3450	18	2.0	14.0	313	230
0.500	0.134	0.232	8050	9650	12150	3850	18	2.5	13.0	392	281
0.500	0.148	0.204	8950	10750	13450	4300	18	3.0	12.0	409	330
0.500	0.188	0.124	11050	13250	16600	5300	20	1.5	17.0	212	160
0.625	0.028	0.569	1150	1400	1750	550	20	2.0	16.0	282	209
0.625	0.035	0.555	1500	1800	2200	700	20	2.5	15.0	353	256
0.625	0.049	0.527	2100	2500	3200	1000	20	3.0	14.0	373	301
0.625	0.058	0.509	2550	3050	3800	1200	20	3.5	13.0	426	345
0.625	0.065	0.495	2850	3400	4300	1350	20	4.0	12.0	478	386
0.625	0.072	0.481	3200	3850	4800	1550	22	1.0	20.0	128	100
0.625	0.083	0.459	3750	4500	5650	1800	22	1.5	19.0	192	146
0.625	0.095	0.435	4350	5200	6550	2100	22	2.0	18.0	266	192
0.625	0.109	0.407	5050	6050	7600	2450	22	2.5	17.0	320	235
0.625	0.120	0.385	5600	6700	8450	2700	22	3.0	16.0	385	277
0.625	0.134	0.357	6350	7600	9550	3050	25	2.0	21.0	226	170
0.750	0.035	0.680	1200	1450	1850	600	25	2.5	20.0	282	209
0.750	0.049	0.652	1750	2100	2600	850	25	3.0	19.0	338	247
0.750	0.058	0.634	2100	2500	3150	1000	25	4.0	17.0	394	319
0.750	0.065	0.620	2350	2800	3550	1150	25	4.5	16.0	437	353
0.750	0.072	0.606	2650	3200	3950	1250	25	5.0	15.0	478	386
0.750	0.083	0.584	3050	3650	4600	1450	28	1.5	25.0	151	117
0.750	0.095	0.560	3550	4250	5350	1700	28	2.0	24.0	201	153
0.750	0.109	0.532	4150	5000	6200	2000	28	2.5	23.0	252	188
0.750	0.120	0.510	4600	5500	6900	2200	28	3.0	22.0	302	223
0.750	0.134	0.482	5200	6250	7800	2500	28	4.0	20.0	403	289
0.750	0.148	0.454	5800	7000	8700	2800	28	5.0	18.0	434	351
0.750	0.188	0.374	7500	9000	11300	3600	30	2.0	26.0	188	143

TABLE 6 – Recommended Design Pressure for Tubes (Continued)

Inch Tubes							Metric Tubes				
			Design Pressure (4:1 Design Factor) – PSI							Design Pressure (Bar)	
Tube O.D. (in.)	Wall Thick (in.)	Tube I.D. (in.)	Steel 1010	Steel 1021	Stainless Steel 304 & 316, 4130, HSLA	Copper	Tube O.D. (mm)	Wall Thick (mm)	Tube I.D. (mm)	Steel Low-Carbon St. 37-4	Stainless Steel 1.4571
0.875	0.035	0.805	1050	1250	1550	500	30	2.5	25.0	235	177
0.875	0.049	0.777	1500	1800	2200	700	30	3.0	24.0	282	209
0.875	0.058	0.759	1750	2100	2650	850	30	4.0	22.0	376	271
0.875	0.065	0.745	2000	2400	3000	950	30	5.0	20.0	409	330
0.875	0.072	0.731	2200	2650	3350	1050	35	2.0	31.0	161	124
0.875	0.083	0.709	2600	3100	3900	1250	35	2.5	30.0	201	153
0.875	0.095	0.685	3000	3600	4500	1450	35	3.0	29.0	242	181
0.875	0.109	0.657	3500	4200	5250	1650	35	4.0	27.0	322	236
0.875	0.120	0.635	3900	4700	5850	1850	35	5.0	25.0	403	289
0.875	0.134	0.607	4400	5300	6600	2100	35	6.0	23.0	419	339
0.875	0.148	0.579	4900	5900	7350	2350	38	2.5	33.0	186	142
1.000	0.035	0.930	900	1100	1350	450	38	3.0	32.0	223	168
1.000	0.049	0.902	1300	1550	1950	600	38	4.0	30.0	297	219
1.000	0.058	0.884	1550	1850	2300	750	38	5.0	28.0	371	268
1.000	0.065	0.870	1750	2100	2600	850	38	6.0	26.0	390	315
1.000	0.072	0.856	1950	2350	2900	950	38	7.0	24.0	446	360
1.000	0.083	0.834	2250	2700	3400	1100	42	2.0	38.0	134	104
1.000	0.095	0.810	2600	3100	3900	1250	42	3.0	36.0	201	153
1.000	0.109	0.782	3000	3600	4550	1450	42	4.0	34.0	269	200
1.000	0.120	0.760	3350	4000	5050	1600	50	6.0	38.0	338	247
1.000	0.134	0.732	3800	4550	5700	1800	50	9.0	32.0	437	353
1.000	0.148	0.704	4200	5050	6350	2000	65	8.0	49.0	347	253
1.000	0.156	0.688	4450	5350	6700	2150	80	10.0	60.0	353	256
1.000	0.188	0.624	5500	6600	8250	2650	—	—	—	—	—
1.000	0.220	0.560	6550	7850	9800	3150	—	—	—	—	—
1.250	0.049	1.152	1000	1200	1550	500	—	—	—	—	—
1.250	0.058	1.134	1200	1450	1850	600	—	—	—	—	—
1.250	0.065	1.120	1350	1600	2050	650	—	—	—	—	—
1.250	0.072	1.106	1500	1800	2300	750	—	—	—	—	—
1.250	0.083	1.084	1750	2100	2650	850	—	—	—	—	—
1.250	0.095	1.060	2050	2450	3050	1000	—	—	—	—	—
1.250	0.109	1.032	2350	2800	3550	1150	—	—	—	—	—
1.250	0.120	1.010	2650	3200	3950	1250	—	—	—	—	—
1.250	0.134	0.982	2950	3550	4450	1400	—	—	—	—	—
1.250	0.148	0.954	3300	3950	4950	1600	—	—	—	—	—
1.250	0.156	0.938	3500	4200	5250	1700	—	—	—	—	—
1.250	0.188	0.874	4300	5150	6450	2050	—	—	—	—	—
1.250	0.22	0.810	5100	6100	7700	2450	—	—	—	—	—
1.500	0.065	1.370	1150	1400	1700	550	—	—	—	—	—
1.500	0.072	1.356	1250	1500	1900	600	—	—	—	—	—
1.500	0.083	1.334	1450	1750	2200	700	—	—	—	—	—
1.500	0.095	1.310	1700	2050	2550	800	—	—	—	—	—
1.500	0.109	1.282	1950	2350	2950	950	—	—	—	—	—
1.500	0.120	1.260	2150	2600	3250	1050	—	—	—	—	—
1.500	0.134	1.232	2450	2950	3650	1150	—	—	—	—	—
1.500	0.148	1.204	2700	3250	4050	1300	—	—	—	—	—
1.500	0.156	1.188	2850	3400	4300	1350	—	—	—	—	—
1.500	0.188	1.124	3500	4200	5300	1700	—	—	—	—	—
1.500	0.220	1.060	4150	5000	6300	2000	—	—	—	—	—
1.500	0.250	1.000	4800	5750	7250	2300	—	—	—	—	—
2.000	0.065	1.870	850	1000	1250	400	—	—	—	—	—
2.000	0.072	1.856	950	1150	1400	450	—	—	—	—	—
2.000	0.083	1.834	1100	1300	1600	500	—	—	—	—	—
2.000	0.095	1.810	1250	1500	1850	600	—	—	—	—	—
2.000	0.109	1.782	1450	1750	2150	700	—	—	—	—	—
2.000	0.120	1.760	1600	1900	2400	750	—	—	—	—	—
2.000	0.134	1.732	1800	2150	2700	850	—	—	—	—	—
2.000	0.148	1.704	2000	2400	3000	950	—	—	—	—	—
2.000	0.156	1.688	2100	2500	3150	1000	—	—	—	—	—
2.000	0.188	1.624	2550	3050	3850	1250	—	—	—	—	—
2.000	0.220	1.560	3050	3650	4600	1450	—	—	—	—	—
2.000	0.250	1.500	3500	4200	5250	1700	—	—	—	—	—
2.000	0.281	1.438	4000	4800	6000	1900	—	—	—	—	—

TABLE 7 – Recommended "Min./Max." Tube Wall Thickness for Common Fittings

Tube Material			Steel Stainless Steel Copper Aluminum	Steel Stainless Steel Monel	Steel Alloy Steel Stainless Steel Copper Monel	Copper Aluminum Plastics	Steel Stainless Steel
Size							
O.D. (in.)	O.D. (mm)	Dash Number	SAE 37° Flare Triple-Lok®	SAE Flareless Ferulok®	SAE O-ring Face Seal Seal-Lok™ 1)	Intru-Lok®	Metric Flareless
1/8	4	-2	.010 – .035	.010 – .035	—	.012 – .028	0.5 – 1
3/16	6	-3	.010 – .035	.020 – .049	—	.012 – .035	1 – 2
1/4	8	-4	.020 – .065	.028 – .065	.020 – .083	.020 – .0491	1 – 2.5
5/16	10	-5	.020 – .065	.028 – .065	.020 – .095	.020 – .065	1 – 3
3/8	12	-6	.020 – .065	.035 – .095	.020 – .109	.028 – .065	1.5 – 3.5
1/2	14	-8	.028 – .083	.049 – .120	.028 – .148	.035 – .083	1.5 – 4
5/8	15	-10	.035 – .095	.058 – .120	.035 – .134	.035 – .083	1.5 – 4
3/4	16	-12	.035 – .109	.065 – .120	.035 – .148	.035 – .095	2 – 4
7/8	18	-14	.035 – .109	.072 – .120	—	.049 – .095	2 – 4
1	20	-16	.035 – .120	.083 – .148	.035 – .188	.049 – .120	2.5 – 4
1-1/4	22	-20	.049 – .120	.095 – .188	.049 – .220	—	2.5 – 4
1-1/2	25	-24	.049 – .120	.095 – .220	.049 – .250	—	2.5 – 4.5
2	28	-32	.058 – .134	.095 – .220	.065 – .220	—	2.5 – 4.5
—	30	—	—	—	—	—	2.5 – 5
—	35	—	—	—	—	—	3 – 5
—	38	—	—	—	—	—	3 – 6
—	42	—	—	—	—	—	3.5 – 7

(1) Brazing to attach sleeve can be used for all wall thicknesses. See manufacturer's recommendation for mechanical attachments.

TABLE 8 – Assembly Turns From Finger Tight (TFFT) for Tapered Threads

Tapered Pipe Thread Size		
BSPT	NPTF	TFFT
1/8-28	1/8-27	2-3
1/4-19	1/4-18	2-3
3/8-19	3/8-18	2-3
1/2-14	1/2-14	2-3
3/4-14	3/4-14	2-3
1-11	1-11 1/2	1.5 - 2.5
1 1/4-11	1 1/4-11 1/2	1.5 - 2.5
1 1/2-11	1 1/2-11 1/2	1.5 - 2.5
2-11	2-11 1/2	1.5 - 2.5

TABLE 9 – SAE J1926 Straight Thread Port Assembly Torques

		Assembly Torque (+10% -0)											
		Non-Adjustable				Adjustable				Plugs			
		Seal-Lok™		Triple-Lok® Ferulok® Pipe Fittings		Seal-Lok™		Triple-Lok® Ferulok®		Hollow Hex HP5ON-S		Hex Head P5ON-S	
Dash Size	SAE Size (UN/UNF)	ft. lbs. (in. lbs)	N-m	ft. lbs. (in. lbs)	N-m	ft. lbs. (in. lbs)	N-m	ft. lbs. (in. lbs)	N-m	ft. lbs. (in. lbs)	N-m	ft. lbs. (in. lbs)	N-m
2	5/16-24	–	–	(85)	10	–	–	(60)	7	(30)	3.5	(85)	10
3	3/8-24	–	–	(155)	18	–	–	(100)	11	(55)	6	(155)	18
4	7/16-20	(310)	35	(260)	29	(180)	20	(180)	20	(120)	13.5	(260)	29
5	1/2-20	(360)	40	(280)	32	(360)	40	(250)	28	(170)	19	(280)	32
6	9/16-18	(420)	46	(350)	40	(420)	46	(350)	40	(410)	46	(350)	40
8	3/4-16	60	80	(620)	70	60	80	(620)	70	60	80	(620)	70
10	7/8-14	100	135	85	115	100	135	85	115	100	135	85	115
12	1 1/16-12	135	185	135	185	135	185	135	185	135	185	135	185
14	1 3/16-12	175	235	175	235	175	235	175	235	175	235	175	235
16	1 5/16-12	200	270	200	270	200	270	200	270	200	270	200	270
20	1 5/8-12	250	340	250	340	250	340	250	340	250	340	250	340
24	1 7/8-12	305	415	305	415	305	415	305	415	305	415	305	415
32	2 1/2-12	375	510	375	510	375	510	375	510	375	510	375	510

TABLE 10 – Metric (ISO Thread M) Port Assembly Torques (ISO 9974-1/DIN 3852-T1)

Series	Tube O.D.	Metric Thread M Size	Assembly Torque N-m (+10% -0)							
			Straight Male Stud Fittings			Non-Return Valves RHV/RHZ	Banjo Fittings		Plugs VSTI-ED	Straight and Ajustable Fittings
			Form A for Sealing Washer	Form B for Cutting Face	Form E with ED-Sealing	Form E with ED-Sealing	WH/TH	SWVE	Form E with ED-Sealing	O-Ring with Retaining Ring
L	6	M 10 x 1	9	18	18	18	18	18	12	18
L	8	M 12 x 1.5	20	30	25	25	45	35	25	25
L	10	M 14 x 1.5	35	45	45	35	55	50	35	40
L	12	M 16 x 1.5	45	65	55	50	80	60	55	55
L	15	M 18 x 1.5	55	80	70	70	100	80	65	70
L	18	M 22 x 1.5	65	140	125	125	140	120	90	90
L	22	M 27 x 2	90	190	180	145	320	130	135	180
L	28	M 33 x 2	150	340	310	210	360	—	225	310
L	35	M 42 x 2	240	500	450	360	540	—	360	450
L	42	M 48 x 2	290	630	540	540	700	—	360	540
S	6	M 12 x 1.5	20	35	35	35	45	35	—	35
S	8	M 14 x 1.5	35	55	45	45	55	50	—	55
S	10	M 16 x 1.5	45	70	70	55	80	60	—	70
S	12	M 18 x 1.5	55	110	90	70	100	80	—	90
S	14	M 20 x 1.5	55	150	125	100	125	110	80	125
S	16	M 22 x 1.5	65	170	135	125	135	120	—	135
S	20	M 27 x 2	90	270	180	135	320	135	—	180
S	25	M 33 x 2	150	410	310	210	360	—	—	310
S	30	M 42 x 2	240	540	450	360	540	—	—	450
S	38	M 48 x 2	290	700	540	540	700	—	—	540

Note: Lubricate threads before assembly. Tightening torques are for steel fittings assembled in steel components.

TABLE 11 – BSPP (Thread G) Port Assembly Torques (ISO 1179/DIN3852-T2)

Series	Tube O.D.	BSPP Thread G Size	Assembly Torque N-m (+10% -0)							
			Straight Male Stud Fittings			Non-Return Valves RHV/RHZ	Banjo Fittings		Plugs VSTI-ED	Straight and Ajustable Fittings
			Form A for Sealing Washer	Form B for Cutting Face	Form E with ED-Sealing	Form E with ED-Sealing	WH/TH	SWVE	Form E with ED-Sealing	O-Ring with Retaining Ring and Bonded Washer
L	6	1/8 - 28	9	18	18	18	18	18	13	18
	8	1/4 - 19	35	35	35	35	45	40	30	35
	10	1/4 - 19	35	35	35	35	45	40	30	35
	12	3/8 - 19	45	70	70	50	70	65	60	70
	15	1/2 - 14	65	140	90	85	120	90	80	90
	18	1/2 - 14	65	140	90	85	120	90	80	90
	22	3/4 - 14	90	180	180	140	230	125	140	180
	28	1 - 11	150	330	310	190	320	—	200	310
	35	1 1/4 - 11	240	540	450	360	540	—	400	450
	42	1 1/2 - 11	290	630	540	540	700	—	450	540
S	6	1/4 - 19	35	55	40	45	45	40	—	40
	8	1/4 - 19	35	55	40	45	45	40	—	40
	10	3/8 - 19	45	90	80	60	70	65	—	60
	12	3/8 - 19	45	90	80	60	70	65	—	60
	14	1/2 - 14	65	150	115	145	120	90	—	90
	16	1/2 - 14	65	130	115	100	120	90	—	90
	20	3/4 - 14	90	270	180	145	230	125	—	180
	25	1 - 11	150	340	310	260	320	—	—	310
	30	1 1/4 - 11	240	540	450	360	540	—	—	450
	38	1 1/2 - 11	290	700	540	540	700	—	—	540

Note: Lubricate threads before assembly. Tightening torques are for steel fittings assembled in steel components.

TABLE 12 – ISO 6149/DIN 3852-T3 Port Assembly Torques

Metric Thread M Size	Assembly Torque (+10% -0)[3)]			
	ISO 6149-2 Stud Ends (S-Series) (Seal-Lok, EO & VSTI-OR Plugs)		ISO 6149-3 Stud Ends (L-Series) (Triple-Lok, EO, Ferulok & Pipe Adapters)	
	N-m	ft. lbs.	N-m	ft. lbs.
M8x1	10	7.5	8	6
M10x1	20	15	15	11
M12x1.5	35	26	25	18
M14x1.5	45	33	35	26
M16x1.5	55	41	40	30
M18x1.5	70	52	45	33
M20x1.5[4)]	80	59	—	—
M22x1.5	100	74	60	44
M27x2	170	125	100	74
M30x2[1)]	235	175	130	95
M33x2	310	230	160	120
M38x2[2)]	320	235	185	135
M42x2	330	245	210	155
M48x2	420	310	260	190
M60x2	500	370	315	230

(1) M30X2 will be added to ISO 6149 standards at next revision.
(2) M38X2 is not covered in ISO 6149 standards.
(3) These torques are for steel fittings, assembled lubricated.
(4) For cartridge valves only.

TABLE 13 – Code 61 and 62 Flange Recommended Bolt Torques

Code 61						Code 62					
Dash Size	Flange Size	Inch Bolt (SAE J518)	Torque ft. lbs.	Metric Bolt (ISO 6162)	Torque N-m	Dash Size	Flange Size	Inch Bolt (SAE J518)	Torque ft. lbs.	Metric Bolt (ISO 6162)	Torque N-m
8	1/2	5/16-18	17	M8	24	8	1/2	5/16-18	17	M8	24
12	3/4	3/8-16	31	M10	50	12	3/4	3/8-16	31	M10	50
16	1	3/8-16	31	M10	50	16	1	7/16-14	52	M12	92
20	1-1/4	7/16-14	52	M12*	50	20	1-1/4	1/2-13	77	M14*	130
24	1-1/2	1/2-13	77	M12	92	24	1-1/2	5/8-11	155	M16	210
32	2	1/2-13	77	M12*	92	32	2	3/4-10	265	M20	400
40	2-1/2	1/2-13	77	M12	92						
48	3	5/8-11	155	M16	210						
56	3-1/2	5/8-11	155	M16	210						
64	4	5/8-11	155	M16	210						
80	5	5/8-11	155	M16	210						

*Does not meet ISO 6162 specification.

TABLE 14 – 37° Flare Assembly Torques and FFWR

SAE Dash Size	Thread Size	Assembly Torque (+10% -0)		Tube Connection FFWR	Swivel Nut or Hose Connection FFWR
		in. lb.	ft. lb.		
-2	5/16-24	35	3	—	—
-3	3/8-24	65	5	—	—
-4	7/16-20	155	13	2 1/2	2
-5	1/2-20	165	14	2	2
-6	9/16-18	265	22	2	1 1/2
-8	3/4-16	505	42	2	1 1/2
-10	7/8-14	720	60	1 1/2	1 1/2
-12	1 1/16-12	1000	84	1 1/2	1 1/4
-14	1 3/16-12	1200	100	1 1/2	1 1/4
-16	1 5/16-12	1415	118	1 1/2	1
-20	1 5/8-12	2015	168	1	1
-24	1 7/8-12	2340	195	1	1
-32	2 1/2-12	3180	265	1	1
-40	3-12	—	—	1	1

TABLE 15 – O-Ring Face Seal Assembly Torques and FFWR

O.D.		SAE Dash Size	Tube Side Thread Size	Assembly Torque (+10% -0)			Flats from Wrench Resistance (FFWR)	
(in.)	(mm)			in.-lb.	ft.-lb	N-m	Tube Nuts	Swivel and Hose
1/4	6	-4	9/16-18	220	18	25	1/4 to 1/2	1/2 to 3/4
3/8	8, 10	-6	11/16-16	360	30	40	1/4 to 1/2	1/2 to 3/4
1/2	12	-8	13/16-16	480	40	55	1/4 to 1/2	1/2 to 3/4
5/8	14, 15, 16	-10	1-14	—	60	80	1/4 to 1/2	1/2 to 3/4
3/4	18, 20	-12	1 3/16-12	—	85	115	1/4 to 1/2	1/3 to 1/2
1	22, 25	-16	1 7/16-12	—	110	150	1/4 to 1/2	1/3 to 1/2
1 1/4	28, 30, 32	-20	1 11/16-12	—	150	205	1/4 to 1/2	1/3 to 1/2
1 1/2	35, 38	-24	2-12	—	230	315	1/4 to 1/2	1/3 to 1/2
2	50	-32	2 1/2-12	—	375	510	1/4 to 1/2	1/3 to 1/2

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