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19 Fittings

A piping system is much more than a collection of straight pieces of pipe. At some point the line must turn a corner, connect to equipment, split into branches, change size, or be closed off. These functions are performed by fittings.

Fittings are the components that join sections of pipe together and direct the flow of steam, water, air, or other fluids through the system. Common fittings include elbows, tees, reducers, couplings, unions, caps, and plugs.

Understanding the purpose and limitations of each fitting is an essential skill for anyone involved in piping installation, maintenance, or inspection.

19.1 What Fittings Do

Most fittings perform one of five functions:

- Change direction
- Create a branch
- Change pipe size
- Connect or disconnect equipment
- Close the end of a pipe

The fitting selected for a particular application depends on the operating pressure, temperature, material, connection type, and service conditions.

19.2 Changing Direction

The most common fittings in any piping system are elbows.

19.2.1 90° Elbow

A 90° elbow changes the direction of flow by ninety degrees and is commonly used where space is limited.

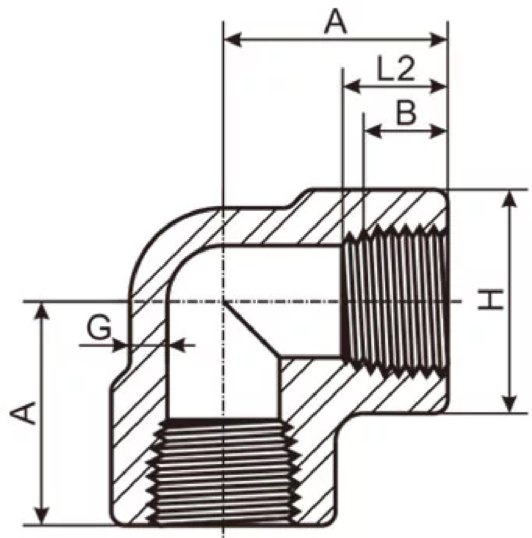

Fig. 1 90-Degree Elbow

19.2.2 45° Elbow

A 45° elbow changes direction more gradually and generally produces less pressure loss than a 90° elbow.

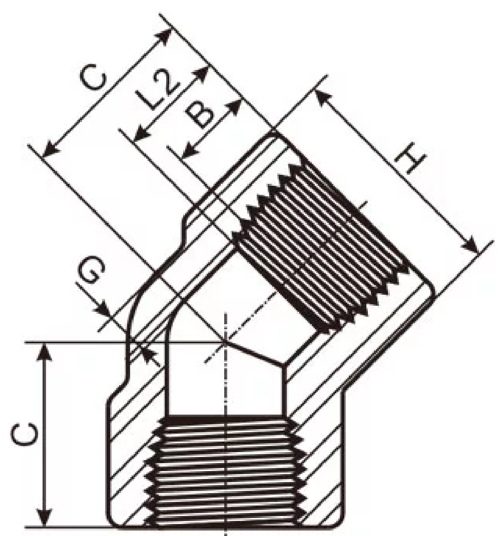

Fig. 2 45-Degree Elbow

19.2.3 Long-Radius and Short-Radius Elbows

Elbows are manufactured with different bend radii.

- Long-radius (LR) elbows have a centerline radius equal to 1.5 times the pipe diameter.
- Short-radius (SR) elbows have a centerline radius equal to the pipe diameter.

Long-radius elbows produce less turbulence and lower pressure loss. For this reason they are commonly used in steam and process piping systems.

19.2.4 Street Elbows

A street elbow has a male connection on one end and a female connection on the other. This allows it to connect directly to another fitting without requiring a short piece of pipe between them.

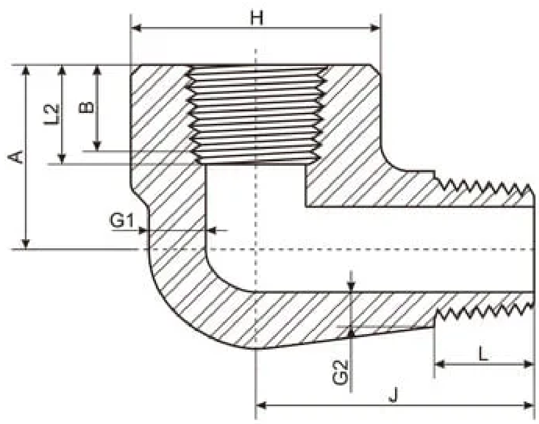

Fig. 3 Street Elbow

19.2.5 Why Direction Changes Matter

Every change in direction creates resistance to flow.

As fluid passes through an elbow:

- Velocity distribution changes.
- Turbulence increases.
- Pressure is lost.

For this reason, piping systems should avoid unnecessary direction changes whenever practical.

19.3 Creating Branches

At some point a piping system must divide flow into two or more paths.

19.3.1 Tee

A tee has three openings and is the most common branch fitting.

A standard tee provides a branch connection that is the same size as the run.

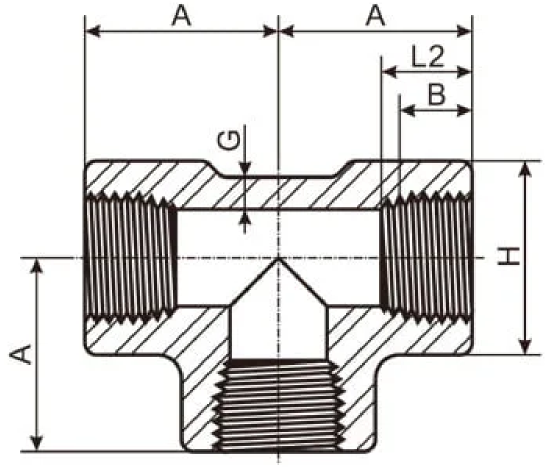

Fig. 4 Tee

19.3.2 Cross

A cross has four openings.

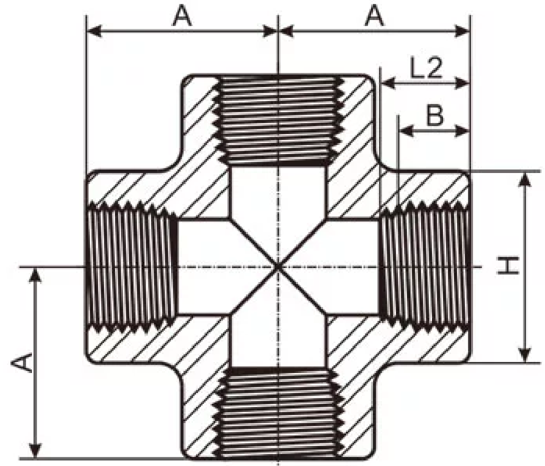

Fig. 5 Cross

19.3.3 Reducing Tee

A reducing tee provides a branch connection that is smaller than the main run.

For example:

- Run: 2"
- Branch: 1"

19.3.4 Lateral

A lateral fitting creates a branch at an angle, typically 45°.

Because the flow path is smoother than a standard tee, pressure losses may be reduced.

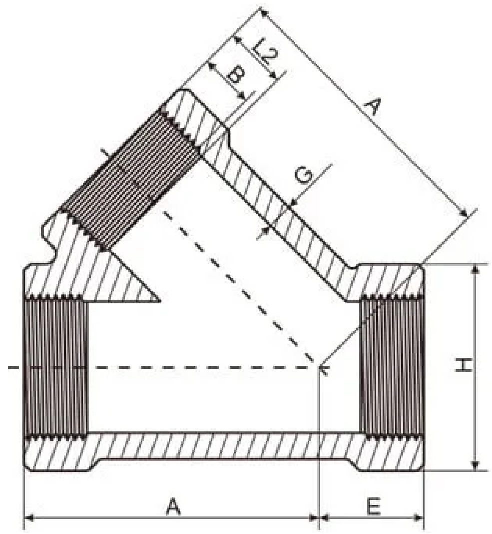

Fig. 6 Lateral Tee

19.3.5 Branch Connection Considerations

Branch connections can experience significant stresses from:

- Internal pressure
- Thermal expansion
- Vibration
- External loads

As pipe size and pressure increase, branch reinforcement requirements become increasingly important.

19.4 Changing Size

Pipe size often changes within a system as flow rates increase or decrease.

Size reductions can be accomplished using either reducing fittings or reducers. The choice depends on the amount of space available, the desired flow characteristics, and the service conditions.

A bushing reduces a fitting; a reducer reduces a pipe.

19.4.1 Bushings

A bushing is a fitting that threads into a larger fitting and provides a smaller threaded opening.

For example, a 1" × 3/4" bushing allows a 3/4" pipe to be connected to a 1" fitting.

Because the reduction occurs within the fitting itself, a bushing requires very little space.

Advantages:

- Compact installation
- Lower cost
- Fewer fittings required

Disadvantages:

- Creates an abrupt change in flow area
- Concentrates stress in a small area
- Can be more difficult to remove after years of service

Bushings are commonly used on instrument connections, drain lines, vent connections, and small auxiliary piping.

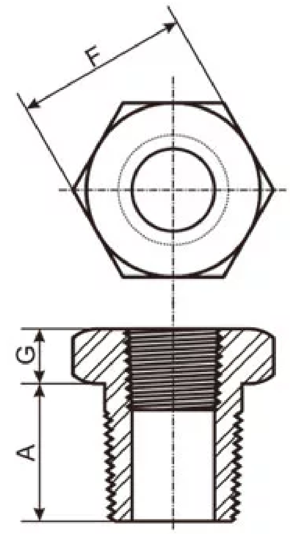

Fig. 7 Bushing

19.4.2 Reducing Couplings

A reducing coupling joins two different pipe sizes in a straight run.

For example:

- 1" × 3/4"
- 1-1/4" × 1"
- 2" × 1-1/2"

Unlike a bushing, a reducing coupling occupies additional length in the piping system but generally provides a stronger and more conventional connection.

Advantages:

- Better mechanical support
- Easier maintenance
- Commonly accepted piping practice

Disadvantages:

- Requires more space
- Adds another fitting to the system

19.4.3 Reducers

In welded piping systems, pipe size changes are usually accomplished using reducers.

Common examples include:

- 2" × 1-1/2"
- 4" × 3"
- 6" × 4"

Reducers are available in two styles:

- Concentric
- Eccentric

A reducer connects two different pipe sizes.

Common examples include:

- 2" × 1-1/2"
- 4" × 3"
- 6" × 4"

19.4.4 Concentric Reducers

Fig. 8 Concentric Reducer

A concentric reducer maintains a common centerline.

Concentric reducers are commonly used in vertical piping systems.

19.4.5 Eccentric Reducers

Fig. 9 Eccentric Reducer

An eccentric reducer maintains one side of the pipe in a straight line.

In steam systems, eccentric reducers are often installed with the flat side down in horizontal lines to prevent condensate from collecting in the pipe.

19.4.6 Why Reducer Selection Matters

Poor reducer selection can create:

- Condensate pockets
- Air traps
- Increased turbulence
- Water hammer conditions

Proper orientation is especially important in steam service.

19.5 Joining Pipe Sections

Some fittings primarily exist to connect sections of pipe together.

19.5.1 Couplings

A coupling joins two pieces of pipe in a straight line.

Threaded couplings are common in smaller piping systems.

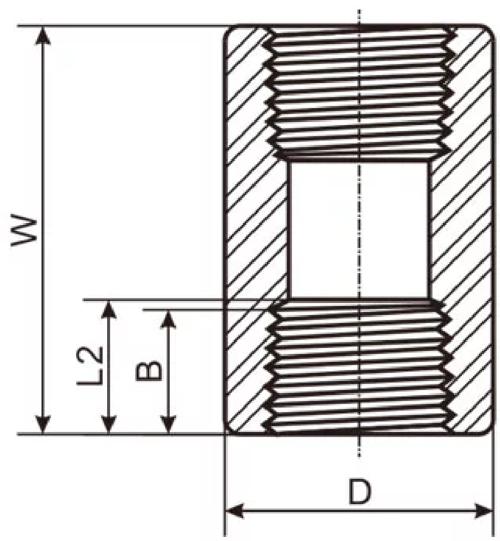

Fig. 10 coupling

19.5.2 Half Couplings

A half coupling is essentially half of a coupling and is commonly welded to a vessel or larger pipe to create a branch connection.

19.5.3 Unions

A union provides a means of disconnecting piping without rotating the pipe.

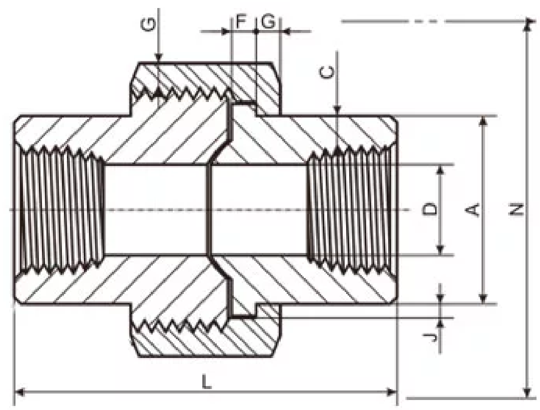

Fig. 11 Union

Unions are commonly installed near:

- Valves
- Steam traps
- Pumps
- Instruments

They simplify maintenance and replacement.

19.5.4 Why Use a Union?

Without a union, disassembly may require removing a large section of piping.

A union allows components to be removed quickly for servicing.

19.6 Closing Pipe Ends

Sometimes a piping system requires a temporary or permanent closure.

19.6.1 Caps

A cap fits over the end of a pipe and closes it.

A useful way to think of a cap is that it fits over the outside of the pipe.

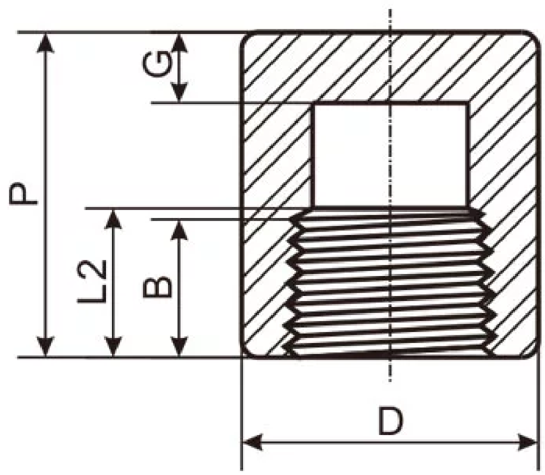

Fig. 12 Cap

19.6.2 Plugs

A plug screws into a threaded fitting and closes an opening.

A plug fits into a fitting rather than over a pipe.

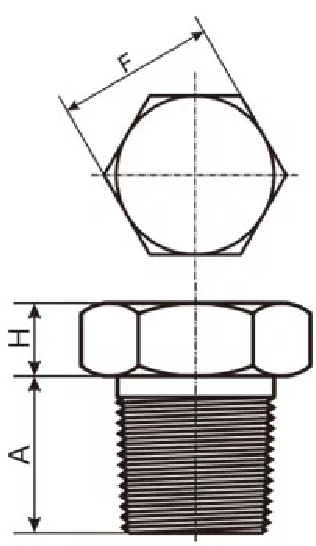

Fig. 13 Hex-head Plug

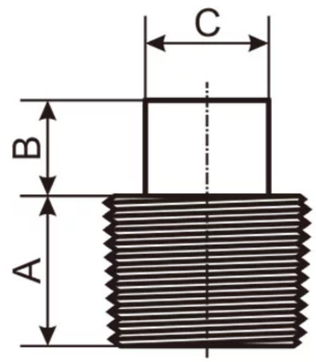

Fig. 14 Square-head Plug

19.6.3 Remembering the Difference

A useful memory aid is:

- A cap goes over a pipe.
- A plug goes into a fitting.

19.7 End Connections

Fittings are available with several different end connections.

19.7.1 Threaded

Used primarily on smaller pipe sizes.

Advantages:

- Easy to assemble
- No welding required

Disadvantages:

- Potential leak paths
- Limited pressure and temperature capability

19.7.2 Socket-Weld

The pipe is inserted into a socket and welded around the outside.

Advantages:

- Strong connection
- Suitable for higher-pressure service

Disadvantages:

- Requires welding
- More difficult to inspect internally

19.7.3 Butt-Weld

The pipe and fitting are welded directly end-to-end.

Advantages:

- Highest strength
- Smooth internal bore
- Preferred for larger steam systems

Disadvantages:

- Requires qualified welding procedures

19.8 Key Takeaway

Fittings make a piping system practical. They allow pipe to change direction, create branches, change size, connect equipment, and terminate lines. Proper fitting selection affects not only how easily a system can be assembled, but also its pressure capability, maintainability, and long-term reliability.

19.9 Nipples

A nipple is a short length of pipe with external threads on both ends. Nipples are used to connect two threaded fittings or components.

Unlike most fittings, which are cast or forged into a particular shape, a nipple is essentially a short piece of pipe prepared for threaded service

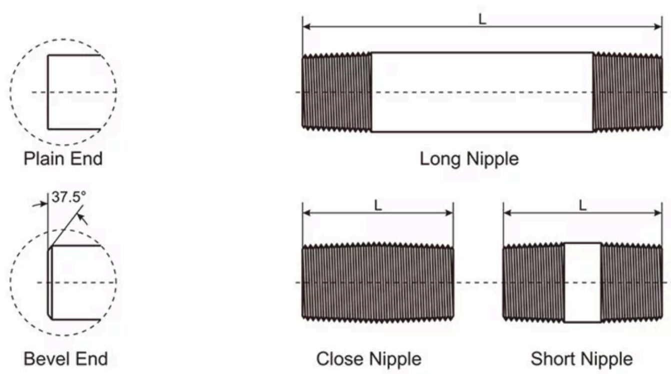

Fig. 15 Nipples: Close, Short and Long

Common uses include:

- Connecting valves to fittings
- Extending a branch line
- Installing pressure gauges
- Connecting steam traps
- Creating spacing between components

19.9.1 Common Nipple Lengths

Nipples are available in a variety of standard lengths, including:

- Close
- Shoulder
- Short
- Long
- Custom-cut

The exact dimensions vary by manufacturer and pipe size.

19.9.2 Close Nipples

A close nipple has threads over its entire length.

When assembled, very little of the nipple remains visible between the fittings.

Close nipples are useful where space is limited, but they can be difficult to remove because there is no unthreaded section available for a pipe wrench.

19.9.3 Shoulder Nipples

A shoulder nipple, also called a short, contains a short unthreaded section between the threaded ends.

The unthreaded "shoulder" is visible after assembly and may provide limited wrench grip.

19.9.4 Long Nipples

Long nipples are simply longer sections of threaded pipe.

They are commonly used to:

- Create space between components
- Bridge short distances
- Position instruments or valves for easier access

19.9.5 Barrel Nipples

A barrel nipple has threads only near the ends, with an unthreaded section in the middle.

This style is commonly used when greater length is required while minimizing the amount of threading.

19.9.6 Running Nipples

A running nipple is a nipple that is threaded continuously from end to end, similar to a long close nipple.

Running nipples are useful when one fitting must be rotated onto the nipple during assembly.

19.9.7 Why Pipefitters Care

Nipples may appear simple, but they are often the components that determine whether a system can be assembled and maintained efficiently.

The correct nipple length can:

- Provide wrench clearance
- Allow valve handles to move freely
- Improve accessibility

- Simplify future maintenance

Poor nipple selection can leave components difficult or impossible to service.

19.9.8 Common Steam-Service Examples

Nipples are frequently found:

- Between a steam trap and isolation valve
- Between a pressure gauge and gauge valve
- Between a tee and a drain valve
- Between a boiler nozzle and a valve assembly
- In instrument and control piping

19.9.9 Key Takeaway

A nipple is a short piece of threaded pipe used to connect fittings and components. Although simple in appearance, proper nipple selection is important for accessibility, assembly, maintenance, and overall piping layout.

19.10 Flanges

A flange is a mechanical method of connecting pipe, valves, vessels, and other equipment. Unlike threaded or welded joints, flanges can be disassembled relatively easily, making them ideal for equipment that requires periodic inspection, maintenance, or replacement.

A flanged joint consists of:

- Two mating flanges
- A gasket
- Bolts and nuts

As the bolts are tightened, the flanges compress the gasket and create a pressure-tight seal.

19.10.1 Why Use Flanges?

Flanges are commonly used where equipment must be removable.

Typical examples include:

- Valves
- Steam traps
- Pumps
- Heat exchangers
- Pressure vessels
- Boilers

Without flanges, removing large equipment would often require cutting and rewelding the piping.

19.10.2 Common Flange Types

Several flange designs are commonly encountered in piping systems.

19.10.2.1 Weld Neck Flange

The weld neck flange is considered the preferred flange for many pressure piping applications.

The tapered hub provides a smooth transition between the pipe and flange, reducing stress concentrations.

Advantages:

- Excellent strength
- Good fatigue resistance
- Suitable for high pressure and temperature service

Common applications:

- Steam systems
- Process piping
- High-pressure service

19.10.2.2 Slip-On Flange

A slip-on flange slides over the outside of the pipe and is welded in place.

Advantages:

- Easy alignment
- Lower cost
- Simplified fit-up

Disadvantages:

- Lower strength than weld neck flanges
- More susceptible to fatigue

19.10.2.3 Threaded Flange

A threaded flange contains internal pipe threads and does not require welding.

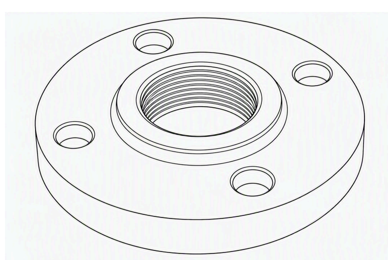

Fig. 16 Threaded flange

Advantages:

- No welding required
- Convenient for small piping systems

Disadvantages:

- Limited pressure and temperature capability
- Potential leak paths through the threads

19.10.2.4 Socket Weld Flange

A socket weld flange contains a recessed socket into which the pipe is inserted before welding.

Socket weld flanges are commonly used on smaller high-pressure piping systems.

19.10.2.5 Blind Flange

A blind flange is a solid plate used to close the end of a flanged connection.

Common uses include:

- Future expansion points
- Equipment isolation
- Pressure testing

19.10.3 Gaskets

A flange alone does not normally provide the seal.

The seal is created by a gasket compressed between the flange faces.

Common gasket materials include:

- Compressed fiber
- Graphite
- PTFE
- Spiral wound metal gaskets

The gasket material must be suitable for the system temperature, pressure, and fluid.

19.10.3.1 Why Gaskets Matter

An improperly selected gasket can result in:

- Steam leaks
- Blowouts
- Loss of pressure
- Equipment damage

In steam service, gasket selection is often just as important as flange selection.

19.10.4 Flange Faces

The flange face is the surface that contacts the gasket.

19.10.4.1 Flat Face (FF)

A flat-face flange has a completely flat sealing surface.

Flat-face flanges are commonly used with cast-iron equipment.

####Raised Face (RF)

A raised-face flange contains a small raised sealing surface around the bore.

Raised-face flanges are the most common type found in industrial piping systems.

The raised face concentrates gasket loading and improves sealing performance.

19.10.4.2 Ring-Type Joint (RTJ)

RTJ flanges use a machined metal ring seated in precision grooves.

They are typically reserved for:

- Very high-pressure service
- High-temperature service
- Specialized industrial applications

19.10.5 Bolting and Tightening

The bolts in a flanged joint do not directly seal the pipe. Their purpose is to compress the gasket with sufficient force to maintain a seal.

Proper tightening is important because:

- Uneven tightening can damage the gasket.
- Excessive tightening can crush the gasket.
- Insufficient tightening can cause leaks.

Bolts are normally tightened in a crisscross or star pattern to ensure even gasket compression.

This pattern distributes the load evenly around the flange.

19.10.6 Flange Ratings

Flanges are manufactured with pressure-temperature ratings known as classes.

Common ratings include:

- Class 150
- Class 300
- Class 600
- Class 900
- Class 1500
- Class 2500

A higher class generally indicates a flange capable of higher pressure service.

A common misconception is that a Class 150 flange is limited to 150 psi. In reality, flange ratings vary with both material and temperature. The actual allowable pressure must be determined from the applicable standard.

19.10.7 Why Pipefitters Should Care

Flanges are among the most common connection methods in industrial piping systems. Proper alignment, gasket selection, bolting techniques, and pressure-class selection all affect the safety and reliability of the system.

Many steam leaks occur not because the flange was defective, but because the joint was assembled incorrectly.

19.10.8 Key Takeaway

Flanges provide a removable method of connecting piping and equipment. A flanged joint consists of two flanges, a gasket, and bolting. Understanding flange types, gasket selection, flange ratings, and proper assembly practices is essential for anyone working with steam systems.

19.11 Fitting Ratings and Markings

Like pipe, fittings are marked with information that identifies their size, material, pressure class, and manufacturer. Understanding these markings helps ensure that the correct fitting is selected for the intended service.

19.11.1 Why Markings Matter

A fitting may look identical to another fitting while having a completely different pressure rating, material specification, or intended service.

Before installation, the markings should be checked to verify:

- Size
- Material
- Pressure class
- Manufacturing standard
- Traceability requirements

Installing the wrong fitting can compromise the safety and reliability of the entire piping system.

19.11.2 Pressure Classes

Most forged steel threaded and socket-weld fittings are marked with a pressure class.

Common examples include:

```
3000
6000
9000
```

A fitting marked: 3000 is often referred to as a "three-thousand pound fitting."

19.11.2.1 A Common Misunderstanding

The pressure class is not the maximum allowable working pressure in psi.

For example, a Class 3000 fitting is not necessarily limited to 3000 psi, nor is it automatically suitable for 3000 psi service.

The actual pressure rating depends on:

- Material
- Temperature
- Applicable standards
- Service conditions

The pressure class simply identifies the fitting's rating category.

19.11.3 Material Markings

Fittings are commonly marked with a material specification.

Examples include:

```
A105
A182 F304
A182 F316
```

These markings identify the material from which the fitting was manufactured.

19.11.3.1 Common Materials

A105
: Forged carbon steel. Commonly used in steam and process piping.

A182 F304
: Forged 304 stainless steel.

A182 F316
: Forged 316 stainless steel.

Material markings help ensure compatibility with the piping system and service environment.

19.11.4 Manufacturing Standards

Many fittings are marked with the standard to which they were manufactured.

Examples include:

```
B16.11
B16.9
```

19.11.4.1 ASME B16.11

Applies to:

- Forged threaded fittings
- Socket-weld fittings

Examples include:

- Couplings
- Unions
- Tees
- Elbows
- Bushings

19.11.4.2 ASME B16.9

Applies to:

- Factory-made wrought butt-weld fittings

Examples include:

- Welded elbows
- Reducers
- Tees
- Caps

Knowing the standard helps verify that the fitting is suitable for the intended piping system.

19.11.5 Size Markings

Most fittings are marked with their nominal size.

Examples:

```
1
1-1/2
2
```

Reducing fittings may show both sizes.

Examples:

```
2 × 1
1-1/2 × 3/4
```

These markings indicate the pipe sizes for which the fitting is intended.

19.11.6 Manufacturer Identification

Most fittings contain the manufacturer's trademark, logo, or identification code.

This marking provides:

- Product identification
- Traceability
- Quality-control verification

If questions arise regarding material or certification, the manufacturer marking helps identify the source of the fitting.

19.11.7 Heat Numbers and Traceability

Higher-grade piping systems may require fittings to be traceable to their material test reports.

In such cases, fittings may carry a heat number that links the fitting to:

- Chemical analysis records
- Mechanical test records
- Material certifications

Like pipe markings, these numbers are used to establish material traceability.

19.11.8 Canadian Registration Numbers (CRNs)

Many pressure-retaining components used in Canada carry a Canadian Registration Number (CRN).

A CRN indicates that the design has been accepted by the appropriate regulatory authority for use in Canadian pressure systems.

A fitting may therefore contain markings such as: `CRN 0C12345.5C`.

The details of CRNs and their interpretation are discussed in a later chapter.

19.11.9 Reading a Typical Fitting

A fitting marked:

```
ABC
3000
A105
1
B16.11
```

can be interpreted as:

- Manufacturer: ABC
- Pressure class: 3000
- Material: ASTM A105 forged carbon steel
- Size: 1"
- Standard: ASME B16.11

From a few simple markings, a pipefitter can determine a great deal about the fitting.

19.11.10 Key Takeaway

Fitting markings are the component's identification card. They provide information about size, material, pressure class, manufacturing standard, and traceability. Learning to read these markings is an important skill for pipefitters, inspectors, and maintenance personnel because many fittings appear similar even though their pressure ratings and intended applications may be very different.

19.12 Cast vs. Forged Fittings

Although many fittings may appear similar from the outside, they are not all manufactured in the same way. One of the most important distinctions is whether a fitting is cast or forged.

The manufacturing method affects:

- Strength
- Pressure capability
- Toughness
- Reliability
- Suitable service applications

19.12.1 Cast Fittings

Cast fittings are manufactured by pouring molten metal into a mold and allowing it to solidify.

Common cast fitting materials include:

- Cast iron
- Malleable iron
- Cast steel
- Bronze

A cast fitting can be produced in complex shapes with relatively little machining.

19.12.2 Advantages of Cast Fittings

- Lower manufacturing cost
- Complex shapes are easy to produce

- Suitable for many low-pressure applications

19.12.3 Disadvantages of Cast Fittings

- Generally lower toughness
- More susceptible to casting defects
- Less resistant to shock loading
- Lower pressure ratings than forged equivalents

19.12.4 Forged Fittings

Forged fittings are manufactured by mechanically forming heated metal under high pressure.

Rather than being poured into a mold, the metal is compressed into shape.

The forging process improves the grain structure of the steel and produces a stronger component.

19.12.5 Advantages of Forged Fittings

- Higher strength
- Better toughness
- Improved fatigue resistance
- Higher pressure capability
- Greater reliability in severe service

19.12.6 Disadvantages of Forged Fittings

- Higher cost
- More machining may be required

19.12.7 Visual Differences

A forged fitting often has:

- Smooth machined surfaces
- Clearly stamped markings
- Class ratings such as 3000, 6000, or 9000

A cast fitting often has:

- A rougher surface finish
- Cast-in markings
- Pressure ratings such as 125 lb or 150 lb

While appearance can provide clues, markings should always be used for positive identification.

19.12.8 Which Type Is Used in Steam Service?

For most industrial steam systems, forged steel fittings are preferred.

Common examples include:

- ASTM A105 forged carbon steel fittings
- ASME B16.11 threaded fittings
- ASME B16.11 socket-weld fittings
- ASME B16.9 butt-weld fittings

These fittings are designed to withstand the temperatures and pressures commonly encountered in steam service.

19.12.9 Malleable Iron Fittings

Malleable iron threaded fittings are common in:

- Compressed-air systems
- Water systems
- Low-pressure utility piping

Historically, malleable iron fittings have been used in some low-pressure steam systems. However, many industrial facilities now prefer forged steel fittings because of their superior strength and durability.

When working on an existing installation, it is common to encounter both types.

19.12.10 Cast Iron Fittings

Cast iron fittings should generally be viewed with caution in steam service.

Cast iron is:

- Strong in compression
- Relatively brittle
- Less tolerant of thermal stress and mechanical shock

A cast iron fitting that performs satisfactorily in water service may not be suitable for higher-temperature steam applications.

19.12.11 A Typical Comparison

110 lb Malleable Iron Elbow	**vs.**	**3000 lb A105 Forged Elbow**
Cast construction		Forged construction
Lower pressure rating		Higher pressure capability
Utility service		Industrial steam service

Although both fittings may be the same nominal size, they are intended for very different operating conditions.

19.12.12 Why Pipefitters Should Care

Two fittings may have identical dimensions and threads yet possess vastly different pressure and temperature capabilities. Before installing a fitting, verify:

- Material
- Pressure class
- Manufacturing standard
- Service suitability Never assume a fitting is acceptable simply because it fits.

19.12.13 Key Takeaway

Cast and forged fittings may look similar, but their performance can be very different. Forged steel fittings are the preferred choice for most industrial steam systems because they provide greater strength, toughness, and pressure capability. Cast and malleable iron fittings are commonly used in lower-pressure utility services but may not be suitable for demanding steam applications.