

Inspection Practices for Piping System Components

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Contents

1	Scope.....	1
2	Normative References	1
3	Terms, Definitions, Acronyms, and Abbreviations	1
3.1	Terms and Definitions	1
3.2	Acronyms and Abbreviations	11
4	Introduction to Piping.....	12
4.1	Piping Components	12
4.2	Tubing	14
4.3	Valves	14
4.4	Fittings	22
4.5	Flanges.....	25
4.6	Expansion Joints	25
4.7	Piping Supports	26
4.8	Flexible Hoses	27
5	Piping Design and Construction	27
5.1	Design and Construction Standards.....	27
5.2	Methods of Construction.....	28
5.3	Materials of Construction.....	34
6	Reasons for Inspection	37
6.1	General	37
6.2	Process and Personnel Safety	37
6.3	Regulatory Requirements	37
6.4	Reliable Operation	37
7	Inspection and Monitoring Planning.....	38
7.1	Background	38
7.2	Developing an Inspection Plan	38
7.3	Monitoring Process Piping	44
7.4	Inspection Guidance for Location-specific Damage	49
7.5	Inspection Guidance for Specific Damage Mechanisms	67
7.6	Reviewing and Updating Inspection Plans (Future Content)	73
7.7	IOWs	73
7.8	Inspection of New Fabrication.....	73
7.9	Newly Commissioned Piping Inspection (Future Content)	74
8	Strategies for Establishing Frequency of Inspection.....	74
8.1	Fixed Interval	74
8.2	RBI	74
8.3	Opportunities for Inspection (Future Content)	75
8.4	On-stream Inspection	75
8.5	Offline Inspection	76
8.6	Inspection Scope	76
9	Safety Precautions and Preparatory Work.....	76
9.1	Safety Precautions.....	76
9.2	Communication	77
9.3	Preparatory Work	77
9.4	Cleaning and Surface Preparation for Inspection (Future Content).....	79
9.5	Investigation of Active Leaks	79
10	Inspection Types, Methods, and Limitations	79
10.1	External Visual Inspection	79
10.2	Internal Visual Inspection	86

10.3	Specific Areas or Components for Inspection.....	88
10.4	Thickness Measurements	93
10.5	Determination of Minimum Required Thickness	101
10.6	Other Inspection Methods/Techniques.....	105
10.7	Nonmetallic Piping.....	106
11	Inspection Results	107
11.1	Evaluation of Inspection Results	107
11.2	Determination of Follow-up Actions	109
11.3	Using Fitness-For-Service	109
12	Rerating and Repair	110
12.1	Rerating of Piping System	110
12.2	Repairing Pipe Damage	111
13	Pressure Tests	113
13.1	Purpose of Testing.....	113
13.2	Types of Pressure Tests (Future Content)	113
13.3	Performing Pressure Tests	113
13.4	Pressure Testing Considerations (Future Content)	115
13.5	Pressure Test Safety Considerations	115
14	Records and Reports.....	115
14.1	General	115
14.2	Records	116
14.3	Reports (Future Content)	118
Annex A	(informative) External Inspection Checklist for Process Piping	119
Annex B	(informative) Tables of Pipe Schedules	120
Annex C	(informative) Statistical Analysis of Circuit Thickness Data	127
Bibliography		130
Figures		
1	Cross Section of a Typical Wedge Gate Valve.....	16
2	Cross Section of a Typical Globe Valve	17
3	Cross Sections of Typical Lubricated and Nonlubricated Plug Valves	18
4	Cross Section of a Typical Ball Valve	19
5	Cross Section of a Typical Diaphragm Valve.....	19
6	Typical Butterfly Valve.....	20
7	Cross Sections of Typical Check Valves.....	21
8	Cross Section of a Typical Slide Valve	23
9	Flanged-end Fittings and Wrought Steel Butt-welded Fittings	24
10	Forged Steel Threaded and Socket-welded Fittings	25
11	Cross Section of a Socket-welded Tee Connection	29
12	Flange Facings Commonly Used in Refinery and Chemical Plant Piping	30
13	Types of Flanges.....	31
14	Cross Section of a Typical Bell-and-Spigot Joint.....	31
15	Cross Sections of Typical Packed and Sleeve Joints.....	32
16	Cross Sections of Typical Tubing Joints	33
17	Erosion of Piping	40
18	Corrosion of Piping.....	41
19	Internal Corrosion of Piping	41
20	Severe Atmospheric Corrosion of Piping.....	42
21	Piping Circuit Example	48
22	SAI Corrosion	54
23	Underground Piping Corrosion beneath Poorly Applied Tape Wrap	58

24	Pipe-to-Soil Internal Potential Survey Use to Identify Active Corrosion.....	59
25	Example of Pipe-to-Soil Potential Survey Chart	60
26	Wenner Four-pin Soil Resistivity Test	62
27	Soil Bar Used for Soil Resistivity Measurements	63
28	Two Types of Soil Boxes Used for Soil Resistivity Measurements	64
29	Case of Doubling due to Mode Converted Shear Wave Echo Occurring between the Backwall Echoes	97
30	Example of Screen Display of UT Thickness Gauge with Automatic Temperature Compensation	98
31	Radiograph of a Catalytic Reformer Line	100
32	Radiograph of Corroded Pipe Whose Internal Surface Is Coated with Iron Sulfide Scale	100
33	Sketch and Radiograph of Dead-end (Deadleg) Corrosion	101
34	Typical Isometric Sketch	117
35	Typical Tabulation of Thickness Data.....	118

Tables

1	API and ASME Valve Design Standards and Codes.....	15
2	Mix Point Thermal Fatigue Screening Criteria	52
3	Damage Mechanisms Associated with Nonmetallic Piping	72
4	Table 2 of API 570	86
5	Minimum Structural Thickness and Minimum Alert Thicknesses for Carbon and Low-alloy Steel Pipe	103
6	Comparison of Common Nonmetallic Piping NDE Techniques.....	108
B.1	Nominal Pipe Sizes, Schedules, Weight Classes, and Dimensions of Ferritic Steel Pipe.....	120
B.2	Nominal Pipe Sizes, Schedules, and Dimensions of Stainless Steel Pipe	124
B.3	Permissible Tolerances in Diameter and Thickness for Ferritic Pipe	126

Inspection Practices for Piping System Components

1 Scope

This recommended practice supplements API 570 by providing piping inspectors with information that can improve their skills and increase their basic knowledge of inspection practices. This recommended practice describes inspection practices for piping, tubing, valves (other than control valves), and fittings used in petroleum refineries and chemical plants. Common piping components, valve types, pipe joining methods, inspection planning processes, inspection intervals and techniques, and types of records are described to aid the inspectors in fulfilling their role in implementing API 570. This publication does not cover the inspection of specialty items, including instrumentation, furnace tubulars, and control valves.

2 Normative References

The following documents are referred to in the text in such a way that some or all their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document, including any addenda, applies.

API 570, *Piping Inspection Code: In-service Inspection, Rating, Repair, and Alteration of Piping Systems*

API Recommended Practice 571, *Damage Mechanisms Affecting Fixed Equipment in the Refining Industry*

API Recommended Practice 578, *Material Verification Program for New and Existing Assets*

API 579-1/ASME FFS-1 ¹, *Fitness-For-Service*

API Recommended Practice 580, *Elements of a Risk-based Inspection Program*

ASME B16.20, *Metallic Gaskets for Pipe Flanges*

ASME B16.25, *Buttwelding Ends*

ASME B16.34, *Valves—Flanged, Threaded, and Welding End*

ASME B31.3, *Process Piping*

ASME Boiler and Pressure Vessel Code (BPVC), *Section V: Nondestructive Examination*

ASTM G57 ², *Standard Test Method for Measurement of Soil Resistivity Using the Wenner Four-Electrode Method*

3 Terms, Definitions, Acronyms, and Abbreviations

For the purposes of this document, the following terms and definitions apply.

NOTE Definitions for terms delineated with asterisks are maintained by API 574. If another document plans to reference, see API Bulletin 590 for reference.

3.1 Terms and Definitions

3.1.1

alloy material

Any metallic material (including welding filler materials) that contains alloying elements, such as chromium, nickel, or molybdenum, which are intentionally added to enhance mechanical or physical properties and/or corrosion resistance.

¹ American Society of Mechanical Engineers, Two Park Avenue, New York, New York 10016, www.asme.org.

² ASTM International, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.

NOTE 1 Alloys may be ferrous or nonferrous based.

NOTE 2 For purposes of this recommended practice, carbon steels are not considered alloys.

3.1.2 alteration

A physical change in any component that has design implications affecting the pressure-containing capability of a piping system beyond the scope described in existing data reports.

NOTE The following are not considered alterations: comparable or duplicate replacement and replacements in-kind and the addition of small-bore attachments that do not require reinforcement or additional support.

3.1.3 auxiliary piping

Instrument and machinery piping, typically small-bore secondary process piping that can be isolated from primary piping systems but is normally not isolated.

NOTE Examples include flush lines, seal oil lines, analyzer lines, balance lines, buffer gas lines, drains, and vents.

3.1.4 cladding

A metal integrally bonded onto another metal under high pressure and temperature whose properties are better suited to resist damage from the process than the substrate metal.

3.1.5 condition monitoring location CML

A designated area on piping systems where periodic examinations are conducted to directly assess and monitor the condition of the piping system using a variety of examination methods and techniques based on damage mechanism susceptibility.

NOTE 1 CMLs may contain one or more examination points and can be a single small area on a piping system [e.g. a 2 in. (50 mm) diameter spot] or a plane through a section of pipe where examination points exist in all four quadrants of the plane.

NOTE 2 CMLs include, but are not limited to, what were previously called "thickness monitoring locations."

3.1.6 contact points

The locations at which a pipe or component rests on or against a support or other object, which may increase its susceptibility to external corrosion, fretting, wear, or deformation, especially because of moisture and/or solids collecting at the interface of the pipe and supporting member.

3.1.7 corrosion allowance

Additional material thickness available to allow for metal loss during the service life of the piping component.

NOTE Corrosion allowance is not used in design strength calculations.

3.1.8 corrosion rate

The rate of metal loss due to erosion, erosion-corrosion, and/or the chemical reaction(s) with the environment, either internal and/or external.

3.1.9 corrosion specialist

A person acceptable to the owner-operator who is knowledgeable and experienced in the specific process chemistries, damage mechanisms, materials selection, corrosion mitigation methods, corrosion-monitoring techniques, and their impact on piping systems.

3.1.10**corrosion under insulation****CUI**

External corrosion of piping, pressure vessel, and structural components resulting from water trapped under insulation.

NOTE External chloride stress corrosion cracking (ECSCC) of austenitic and duplex stainless steel under insulation is also classified as CUI damage.

3.1.11**critical check valves**

Check valves that need to operate reliably to avoid the potential for hazardous events or substantial consequences should reverse flow occur.

3.1.12**cyclic service**

Refers to service conditions that may result in cyclic loading and produce fatigue damage or failure (e.g. cyclic loading from pressure, thermal, and/or mechanical loads).

NOTE 1 Other cyclic loads associated with vibration may arise from such sources as impact, turbulent flow vortices, resonance in compressors, and wind, or any combination thereof.

NOTE 2 API 579-1/ASME FFS-1—Section I.A.15 has a definition of cyclic service. A screening procedure to determine if a component is in cyclic service is provided in Part 14. A definition of “severe cyclic conditions” is in ASME B31.3—Section 300.2, Definitions.

3.1.13**damage mechanism**

Any type of deterioration encountered in the refining and chemical process industry that can result in flaws/defects that can affect the integrity of equipment.

EXAMPLE Corrosion, cracking, erosion, dents, and other mechanical, physical, or chemical impacts. See API 571 for a comprehensive list and description of damage mechanisms.

3.1.14**deadlegs**

Components of a piping system that normally have little or no significant flow.

3.1.15**defect**

A discontinuity or discontinuities that by nature or accumulated effect render a part or product unable to meet minimum applicable acceptance standards or specifications (e.g. total crack length).

NOTE The term designates rejectability.

3.1.16**design pressure**

The pressure at the most severe condition of coincident internal or external pressure and temperature (minimum or maximum) expected during service.

NOTE It is the same as the design pressure defined in ASME B31.3 and other code sections and is subject to the same rules relating to allowances for variations of pressure or temperature or both.

3.1.17**design temperature**

The temperature used for the design of the piping system per the applicable construction code.

NOTE It is the same as the design temperature defined in ASME B31.3 and other code sections and is subject to the same rules relating to allowances for variations of pressure or temperature or both. Different components in the same piping system or circuit can have different design temperatures. In establishing this temperature, consideration should be given to process fluid temperatures, ambient temperatures, heating/cooling media temperatures, and insulation.

3.1.18*

doubling

The error that can occur when an ultrasonic thickness measurement instrument displays the measured thickness value based on the second back-wall echo (i.e. double the thickness) versus the first back-wall echo.

NOTE 1 This can occur when measuring thicknesses below the minimum specified range of a transducer (probe) or when the transducer element is either worn or low in sensitivity.

NOTE 2 Doubling (or even tripling) can also occur in some cases when measuring thicknesses around 0.200" (5 mm) while using echo-to-echo mode if the signals from the second or third back-wall echo are smaller in amplitude than subsequent echoes.

3.1.19

examination point

recording point

measurement point

test point

A more specific location within a CML. CMLs may contain multiple examination points, for example, a piping component may be a CML and have multiple examination points (e.g. an examination point in all four quadrants of the CML on the piping component).

NOTE The term "test point" is no longer in use because "test" refers to mechanical or physical tests (e.g. tensile tests or pressure tests).

3.1.20

examinations

A process by which an examiner or inspector investigates a component of the piping system using nondestructive examination (NDE) in accordance with approved NDE procedures (e.g. inspection of a CML and quality control of repair areas).

NOTE Examinations would be typically those actions conducted by NDE personnel, welding inspectors, or coating inspectors but may also be conducted by authorized piping inspectors.

3.1.21

examiner

A person who assists the inspector by performing specific NDE on piping system components and evaluates to the applicable acceptance criteria but does not evaluate the results of those examinations in accordance with API 570 requirements, unless specifically trained and authorized to do so by the owner-operator.

3.1.22

external inspection

A visual inspection performed from the outside of a piping system to find conditions that could impact the piping systems' ability to maintain pressure integrity or conditions that compromise the integrity (e.g. stanchions, pipe supports, shoes, and hangers). The external inspection may be done either while the piping is operating or while the piping is out of service and can be conducted at the same time as an on-stream inspection.

NOTE External inspections are also intended to find conditions that compromise the integrity of the coating and insulation coverings, and attachments (e.g. instrument and small branch connections).

3.1.23

Fitness-For-Service evaluation

A methodology whereby flaws and other deterioration/damage contained within piping systems are assessed in order to determine the integrity of the piping for continued service.

3.1.24**fitting**

A piping component usually associated with a branch connection, a change in direction, or a change in piping diameter.

NOTE Flanges are not considered fittings.

3.1.25**flammable materials**

As used in this recommended practice, includes all fluids that will support combustion.

NOTE 1 Refer to NFPA 704 for guidance on classifying fluids.

NOTE 2 Some regulatory documents include separate definitions of flammables and combustibles based on their flash point. In this document, flammable is used to describe both, and the flash point, boiling point, autoignition temperature, or other properties are used in addition to better describe the hazard.

3.1.26**flash point**

The lowest temperature at which a flammable product emits enough vapor to form an ignitable mixture in air.

NOTE 1 For example, gasoline's flash point is about -45 °F, and diesel's flash point varies from about 125 °F to 200 °F.

NOTE 2 An ignition source is required to cause ignition above the flash point but below the autoignition temperature.

3.1.27**flaw**

An imperfection in a piping system detected by NDE, which may or may not be a defect, depending upon the applied acceptance criteria.

3.1.28**general corrosion**

Corrosion distributed approximately uniform over the surface of the metal.

3.1.29**hold point**

A point in the repair or alteration process beyond which work may not proceed until the required inspection or NDE has been performed.

3.1.30**imperfection**

Flaws or other discontinuities noted during inspection or examination that may or may not exceed the applicable acceptance criteria.

3.1.31**indication**

A response or evidence resulting from the application of NDE that may be nonrelevant, flawed, or defective upon further analysis.

3.1.32**injection points**

Injection points are locations where water, steam, chemicals, or process additives are introduced into a process stream at relatively low flow/volume rates as compared to the flow/volume rate of the parent stream.

NOTE 1 Corrosion inhibitors, neutralizers, process antifoulants, desalter demulsifiers, oxygen scavengers, caustic, and water washes are most often recognized as requiring special attention in designing the point of injection. Process additives, chemicals, and water are injected into process streams to achieve specific process objectives.

NOTE 2 Injection points do not include locations where two process streams join (see 3.1.48, "mixing points").

EXAMPLE Chlorinating agents in reformers, water injection in overhead systems, polysulfide injection in catalytic cracking wet gas, antifoam injections, inhibitors, and neutralizers.

3.1.33

in-service

The life-cycle stage of a piping system that begins after initial installation (where typically initial commissioning or placing into active service follows) and ends at decommissioning.

NOTE 1 Piping systems that are idle in an operating site and piping systems not currently in operation because of a process outage are still considered in-service piping systems.

NOTE 2 Does not include piping systems that are still under construction or in transport to the site prior to being placed in service or piping systems that have been retired.

NOTE 3 Installed spare piping is also considered in-service, whereas spare piping that is not installed is not considered in-service.

3.1.34

in-service inspection

All inspection activities associated with in-service piping (after installation, but before it is decommissioned).

3.1.35

inspection

The external, internal, or on-stream evaluation (or any combination of the three) of the condition of a piping system conducted by the authorized inspector or the designee.

3.1.36

inspection code

Shortened title for API 570.

3.1.37

inspection plan

A strategy defining how and when a piece of pressure equipment and associated components will be inspected, examined, repaired, and/or maintained.

3.1.38

inspector

A shortened title for an authorized piping inspector qualified and certified in accordance with API 570.

3.1.39

integrity operating window

Established limits for process variables (parameters) that can affect the integrity of the equipment if the process operation deviates from the established limits for a predetermined length of time [includes critical, standard, and informational integrity operating windows (IOWs)].

3.1.40

intermittent service

The condition of a piping system whereby it is not in continuous operating service (i.e. it operates at regular or irregular intervals rather than continuously).

NOTE Occasional turnarounds or other infrequent maintenance outages in an otherwise continuous process service does not constitute intermittent service.

3.1.41**internal inspection**

An inspection performed on the inside surface of a piping system using visual and/or NDE techniques.

NOTE NDE on the outside of the pipe to determine the remaining thickness does not constitute an internal inspection.

3.1.42**jurisdiction**

A legally constituted governmental administration that may adopt rules relating to process piping systems.

3.1.43**level bridle**

The piping assembly associated with a level gauge attached to a vessel.

3.1.44**lining**

A nonmetallic or metallic material, installed on the interior of a pipe, whose properties are better suited to resist damage from the process than the substrate material.

3.1.45**localized corrosion**

Corrosion that is typically confined to a limited or isolated area(s) of the metal surface of a piping system.

3.1.46**minimum alert thickness**

flag thickness

A thickness greater than the required thickness that provides for early warning from which the future service life of the piping is managed through further inspection and remaining life assessment.

3.1.47**minimum required thickness**

required thickness

The minimum thickness without corrosion allowance for each component of a piping system based on the appropriate design code calculations and code allowable stress that consider internal and external pressure, temperature, mechanical, and structural loadings, including the effects of static head.

NOTE Minimum required thicknesses may be reassessed using Fitness-For-Service analysis in accordance with API 579-1/ASME FFS-1.

3.1.48**mixing point**

Mixing points are locations in a process piping system where two or more streams meet.

NOTE The difference in streams may be composition, temperature, or any other parameter that may cause deterioration and may require additional design considerations, operating limits, inspection, and/or process monitoring.

3.1.49**owner-operator**

An owner or operator of piping systems who exercises control over the operation, engineering, inspection, repair, alteration, maintenance, pressure testing, and rerating of those piping systems.

3.1.50**pipe**

A pressure-tight cylinder used to convey, distribute, mix, separate, discharge, meter, control, or snub fluid flows or to transmit a fluid pressure and that is ordinarily designated "pipe" in applicable material specifications.

NOTE 1 Materials designated as “tube” or “tubing” in the specifications are treated as a pipe when intended for pressure service external to fired heaters.

NOTE 2 See API 530 for piping internal to fired heaters.

3.1.51

pipe spool

A section of piping with a flange or other connecting fitting, such as a union, on both ends, that allows the removal of the section from the system.

3.1.52

piperack piping

Process piping that is supported by consecutive stanchions or sleepers (including straddle racks and extensions).

3.1.53

piping circuit

A subsection of piping systems that includes piping and components that are exposed to a process environment of similar corrosivity and expected damage mechanisms and is of similar design conditions and construction material, whereby the expected type and rate of damage can reasonably be expected to be the same.

NOTE 1 Complex process units or piping systems are divided into piping circuits to manage the necessary inspections, data analysis, and recordkeeping.

NOTE 2 When establishing the boundary of a particular piping circuit, it may be sized to provide a practical package for recordkeeping and performing field inspection.

3.1.54

piping engineer

One or more persons or organizations acceptable to the owner-operator who are knowledgeable and experienced in the engineering disciplines associated with evaluating mechanical and material characteristics affecting the integrity and reliability of piping components and systems.

NOTE The piping engineer, by consulting with appropriate specialists, should be regarded as a composite of all entities necessary to properly address piping design requirements.

3.1.55

piping system

An assembly of interconnected pipes that typically are subject to the same (or nearly the same) process fluid composition or operating conditions, or both.

NOTE 1 Some may refer to these as “loops,” but this designation is being supplanted by the “system” or “circuit” designation.

NOTE 2 Piping systems also include pipe-supporting elements (e.g. springs, hangers, guides, etc.) but do not include support structures, such as structural frames, vertical and horizontal beams, and foundations.

3.1.56

pressure design thickness

Minimum allowed pipe wall thickness needed to hold the design pressure at the design temperature.

NOTE 1 Pressure design thickness is determined using the rating code formula, including needed reinforcement thickness.

NOTE 2 Pressure design thickness does not include thickness for structural loads, corrosion allowance, or mill tolerances and therefore should not be used as the sole determinant of structural integrity for typical process piping.

3.1.57**primary process piping**

Process piping in normal, active service that cannot be valved off or, if it were valved off, would significantly affect unit operability.

NOTE Primary process piping typically does not include small-bore or auxiliary process piping (see also 3.1.65 “secondary process piping”).

3.1.58**process piping**

Hydrocarbon or chemical piping located at, or associated with, a refinery or manufacturing facility.

NOTE Process piping includes piperack, tank farm, and process unit piping, but excludes utility piping (e.g. steam, water, air, nitrogen, etc.).

3.1.59**quality assurance**

All planned, systematic, and preventative actions specified to determine if materials, equipment, or services will meet specified requirements so that the piping will perform satisfactorily in-service.

NOTE 1 Quality assurance plans will specify the necessary quality control activities and examinations.

NOTE 2 The contents of a quality assurance inspection management system for piping systems are outlined in API 570—Section 4.3.1.

3.1.60**quality control**

Those physical activities conducted to check conformance with specifications in accordance with the quality assurance plan.

EXAMPLE NDE techniques, hold point inspections, material verifications, checking certification documents, etc.

3.1.61**rating**

The work process of making calculations to establish pressures and temperatures appropriate for a piping system, including design pressure/temperature, maximum allowable working pressure (MAWP), structural minimums, required thicknesses, etc.

3.1.62**repair**

The work necessary to restore a piping system to a condition suitable for safe operation at the design conditions.

NOTE 1 Any welding, cutting, or grinding operation on a pressure-containing piping component not specifically considered an alteration is considered a repair.

NOTE 2 Repairs can be temporary or permanent.

3.1.63**rerating**

A change in either the design temperature rating, design pressure rating, or the MAWP of a piping system.

NOTE A rerating may consist of an increase, decrease, or a combination. Derating below original design conditions is a permissible way to provide additional corrosion allowance.

3.1.64**risk-based inspection****RBI**

A risk assessment and management process that considers both the probability of failure and the consequence of failure due to material deterioration.

3.1.65**secondary process piping**

Process piping located downstream of a block valve that can be valved off without significantly affecting the process unit.

NOTE Often, secondary process piping is small-bore piping (SBP).

3.1.66**small-bore piping****SBP**

Pipe or pipe components that are less than or equal to NPS 2.

3.1.67**soil-to-air interface****SAI**

An area in which external corrosion may occur or be accelerated on partially buried pipe or buried pipe where it egresses from the soil.

NOTE 1 The zone of the corrosion will vary depending on factors such as the moisture and oxygen content of the soil and operating temperature. The zone generally is from 12 in. (30 cm) below to 6 in. (15 cm) above the soil surface.

NOTE 2 Pipe running parallel with the soil surface that contacts the soil is included.

3.1.68**structural minimum thickness**

Minimum required thickness without corrosion allowance based on the mechanical loads other than pressure that result in longitudinal stress.

NOTE The thickness is either determined from a standard chart or engineering calculations. It does not include thickness for corrosion allowance or mill tolerances.

3.1.69**tell-tale holes*****sentinel holes**

Small pilot holes drilled in the pipe or component wall using specified and controlled patterns and depths to act as an early detection and safeguard against ruptures resulting from internal corrosion, erosion, and erosion-corrosion.

3.1.70**temporary repairs**

Repairs made to piping systems in order to restore sufficient integrity to continue safe operation until permanent repairs are conducted.

3.1.71**testing**

Within this document, testing generally refers to either pressure testing, whether performed hydrostatically, pneumatically or a combination hydrostatic/pneumatic, or mechanical testing to determine data such as material hardness, strength, and notch toughness.

NOTE Testing does not refer to NDE using techniques such as liquid penetrant (PT), magnetic particle (MT), etc.

3.1.72**utility piping**

Non-process piping associated with a process unit (e.g. steam, air, water, and nitrogen).

3.1.73**weld overlay**

The use of weld metal of a composition different than the base metal to provide corrosion and/or erosion resistance to the base metal.

NOTE The filler metal typically has better corrosion and/or erosion resistance to the environment than the underlying metal.

3.2 Acronyms and Abbreviations

For the purposes of this document, the following acronyms and abbreviations apply.

ACFM	alternating current field measurement
AE	acoustic emission examination technique
CML	condition monitoring location
CSCC	chloride stress corrosion cracking
CUI	corrosion under insulation
DN	diameter nominal (used in SI system to describe pipe size)
ECSCC	external chloride stress corrosion cracking
EMAT	electromagnetic acoustic transducer
ET	eddy current technique
FCC	fluid catalytic cracking
FRP	fiber-reinforced plastic
GRP	glass-reinforced plastic
HF	hydrofluoric
	NOTE Generally referred to as HF acid.
ID	inside diameter
IDMS	Inspection Data Management System
ILI	in-line inspection
IOW	integrity operating window
IP	initial pulse
MAWP	maximum allowable working pressure

MOC	management of change
MT	magnetic particle examination technique
MW	microwave examination technique
NDE	nondestructive examination
NPS	nominal pipe size

NOTE The term is typically followed, when appropriate, by the specific size designation number without an inch symbol.

EXAMPLE NPS 24 refers to a nominal pipe size of 24 in.

OD	outside diameter
P&ID	piping and instrument diagram
PFD	process flow diagram
PMI	positive material identification
PPE	personal protective equipment
PT	liquid penetrant examination technique
PWHT	postweld heat treatment
RBI	risk-based inspection
RT	radiographic examination (method) or radiography
SAI	soil-to-air interface
SBP	small-bore piping
SCC	stress corrosion cracking
UT	ultrasonic examination technique
UV	ultraviolet

4 Introduction to Piping

4.1 Piping Components

4.1.1 Pipe

Steel and alloy pipe diameter is expressed as nominal pipe sizes (NPSs) and are manufactured to standard dimensions in NPSs up to 48 in. (1219 mm). The size refers to the approximate inside diameter (ID) of standard weight pipe for NPSs equal to or less than 12 in. (305 mm). For NPS equal to or greater than 14 in. (356 mm), the size denotes the actual outside diameter (OD).

Pipe wall thicknesses are designated as pipe schedules in NPSs up to 36 in. (914 mm); refer to Annex B. The traditional thickness designations—standard weight, extra strong, and double extra strong—differ from schedules and are used for NPSs up to 48 in. (1219 mm). In all standard sizes, the OD remains nearly constant regardless of the thickness. Table B.1 and Table B.2 list the dimensions of ferritic and stainless steel pipe from NPS $\frac{1}{8}$ [DN (diameter nominal) 6] up through NPS 24 (DN 600). See ASME B36.10M for the dimensions of welded and seamless wrought steel piping and ASME B36.19 for the dimensions of stainless steel piping.

Allowable tolerances in pipe diameter differ from one piping material to another. Table B.3 lists the acceptable tolerances for diameter and thickness of most ASTM ferritic pipe standards. The actual thickness of seamless piping can vary from its nominal thickness by a manufacturing tolerance of as much as 12.5 %. The under tolerance for welded piping is 0.01 in. (0.25 mm). Cast piping has a thickness tolerance of $+1/16$ in. (1.6 mm) and -0 in. (0 mm), as specified in ASTM A53/A53M. Consult the ASTM or the equivalent ASME material specification to determine what tolerances are permitted for a specific material.

Piping that has ends that are beveled or threaded with standard pipe threads can be obtained in various lengths. Piping can be obtained in different strength levels depending on the grades of material, including alloying material and the heat treatments specified.

Cast iron piping is generally used for nonhazardous services, such as water; it is generally not recommended for pressurized hydrocarbon service because of its brittle nature. The standards and sizes for cast iron piping differ from those for welded and seamless piping.

4.1.2 SBP, Secondary Piping, and Auxiliary Piping

SBP can be used as primary process piping, secondary piping, auxiliary piping, and for vents/drains. SBP vent/drain valves are normally connected to nipples 6 in. (152 mm) or less in length and are most often used to vent piping high points, drain piping low points, and provide a connection point for secondary/auxiliary piping. Secondary piping is normally isolated from the main process lines by closed valves and can be used for such functions as sample taps. Auxiliary piping is normally open to service but can be isolated from the primary process. Examples include flush lines, instrument piping, analyzer piping, lubrication, and seal oil piping for rotating equipment.

Inspectors and piping engineers should be aware of design, maintenance, and operating issues that cause SBP failures and may require mitigation. Those issues include, but are not limited to, the following:

- mismatched union connections from differing manufacturers;
- the potential for thermal growth or contraction that could cause SBP stresses that may lead to failure;
- cyclic loading from thermal or mechanical loads that could cause fatigue cracking (e.g. overhung SBP piping systems, the potential for PRV chattering in certain relief scenarios, flow-induced vibration, vaporization, and cavitation);
- inadequate management of change (MOC) consideration that may cause unanticipated thermal, mechanical, or corrosive scenarios on SBP;
- inadequate design (e.g. support and pipe schedule) for the various unanticipated transient loads imposed on SBP;
- inadequate protection from external impacts (e.g. vehicular traffic and maintenance activities);
- inadequate protection or support for SBP that could be subject to being used as personnel or tool/equipment support (e.g. step, tie-off, handrail, pulley, and lever);

- improperly selected components for the class of service;
- inadequate consideration for the use of socket weld versus threaded fittings, both of which can lead to premature failure if not specified and/or installed properly;
- inadequate thickness for threaded SBP after accounting for the loss of thickness from thread cutting or lack of bottom gap when welding socket welded fittings;
- not including alloy SBP in positive material identification (PMI) procedures;
- not including SBP in piping damage mechanism reviews;
- replacement of SBP components with different alloys without adequate consideration for potential new damage mechanisms (e.g. “upgrading” to stainless steel in a wet chloride environment).

Additional guidance on SBP may be found in API 570—Section 6.6.

4.2 Tubing

Tubing is similar to piping in that it is used to convey fluid and is manufactured in many ODs and wall thicknesses. Tubing is generally seamless but can be welded. Its stated size is typically the actual OD rather than NPS. [ASTM B88 tubing, which is often used for steam tracing, is an exception in that its size designation is $\frac{1}{8}$ in. (3.2 mm) less than the actual OD.] Methods used to join tubing sections include flared, flareless, and compression-type tube fittings instead of typical piping joints, such as threads, flanges, or welding. Tubing is usually made in small diameters and is often used for instrument connections, lubricating oil services, steam tracing, and similar services. Generally, tubing is more flexible than piping that allows it to be bent to desired shapes and configurations, as opposed to piping that relies much more frequently on elbows and other fittings for directional changes and is less often bent. When used for heat exchange applications, such as heaters, boilers, or other heat exchangers, the tubular component is commonly referred to as a tube rather than as tubing.

Inspectors and piping engineers should be aware of design, maintenance, and operating issues that cause tubing failures and may require mitigation. Those issues include, but are not limited to, the following:

- a) inadequate protection from external impacts (e.g. vehicular traffic and maintenance activities);
- b) improperly selected components for the class of service;
- c) improper assembly of tubing joints;
- d) cyclic loading, vibration, shock, and thermal expansion and contraction;
- e) longitudinal defects from forming;
- f) chloride stress corrosion cracking (CSCC) of stainless steel tubing, particularly at tubing supports in elevated temperatures or offshore environments;
- g) inadequate support structure for tubing.

4.3 Valves

4.3.1 General

The basic types of valves are gate, globe, plug, ball, diaphragm, butterfly, check, and slide valves. Valves are made in standard pipe sizes, materials, body thickness, and pressure ratings. Body thicknesses,

pressure ratings and other design data are provided in the applicable standards as shown in Table 1. Valve bodies can be cast, forged, machined from bar stock, or fabricated by welding a combination of two or more materials. The seating surfaces in the body can be integral with the body, or they can be made as inserts. The insert material can be the same as or different from the body material. When special nonmetallic material that could fail in a fire is used to prevent seat leakage, metal-to-metal backup seating surfaces can be provided (see API 607). Other parts of the valve trim can be made of any suitable material and can be cast, formed, forged, or machined from commercially rolled shapes. Valve ends can be flanged, threaded for threaded connections, recessed for socket welding, or beveled for butt welding. Although many valves are manually operated, they can be equipped with electric motors and gear operators or other power operators to accommodate a large size or inaccessible location or to permit actuation by instruments. Refer to API 615 for a complete overview of valve designs and reference standards.

Table 1—API and ASME Valve Design Standards and Codes

Valve Design Standard	Applicable Valve Type
API 594	Check valves
API 599	Metal plug valves
API 600	Steel gate valves
API 602	Gate, globe, and check valves
API 603	Corrosion-resistant, bolted bonnet gate valves
API 607	Fire test for quarter-turn valves and valves equipped with nonmetallic seats
API 608	Metal ball valves
API 609	Butterfly valves
ASME B16.34	Valves: flanged, threaded, and welding end

4.3.2 Gate Valves

A gate valve consists of a body that contains a gate that interrupts the process flow. This type of valve is normally used in a fully open or fully closed position and as such is often called a “block valve,” since it is not generally designed for regulating fluid flow. Gate valves larger than 2 in. (51 mm) usually have port openings that are approximately the same size as the valve end openings—this type of valve is called a “full-ported valve.” Figure 1 shows a cross section of a full-ported wedge gate valve.

Reduced port gate valves are also very common and have port openings that are smaller than the end openings. Reduced port valves should not be used as block valves associated with pressure-relief devices or in erosive applications, such as slurries, or lines that are to be “pigged.”

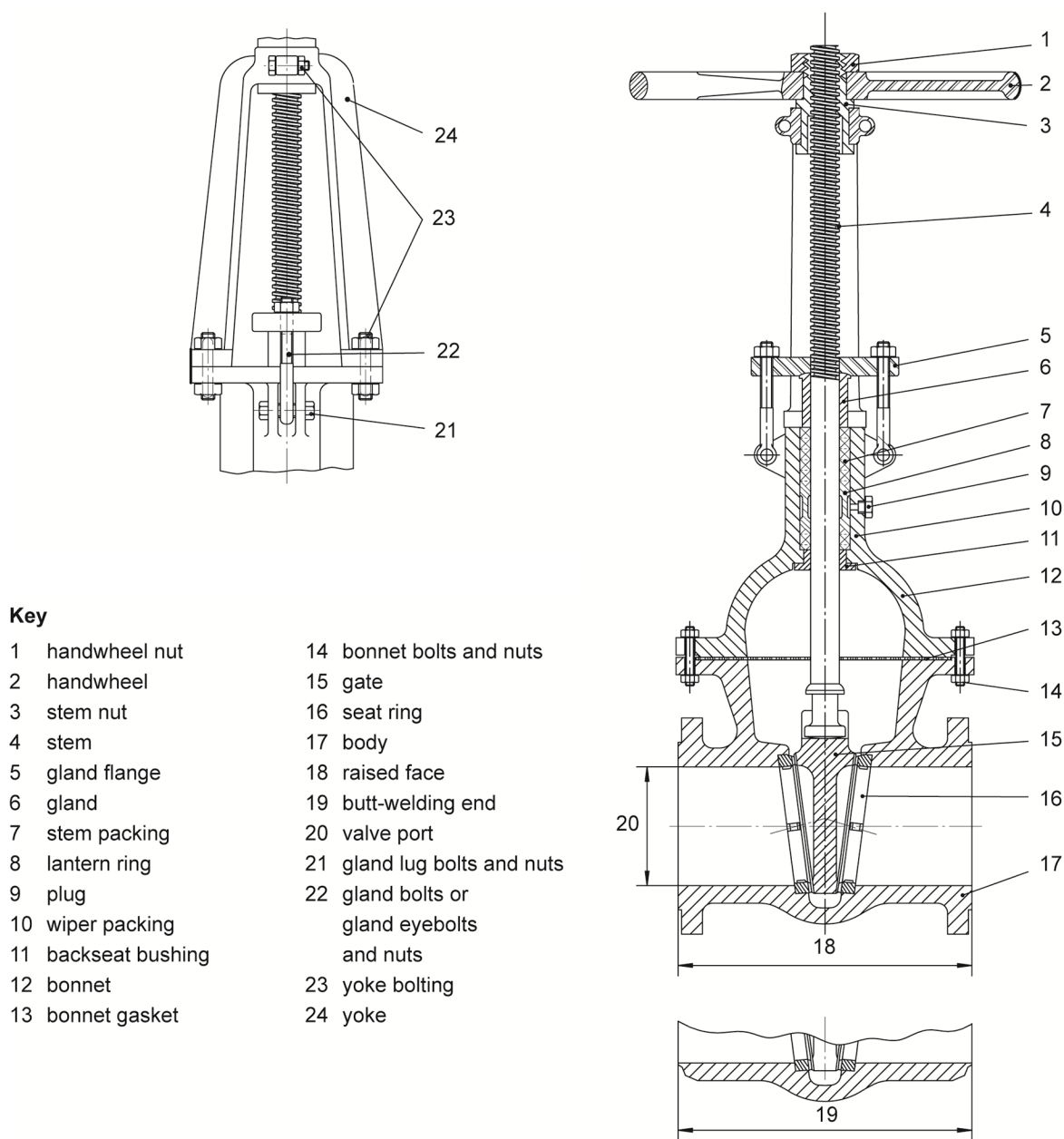


Figure 1—Cross Section of a Typical Wedge Gate Valve

4.3.3 Globe Valves

A globe valve, which is commonly used to regulate fluid flow, consists of a valve body that contains a circular disc that moves parallel to the disc axis and contacts the seat. The stream flows upward generally, except for vacuum service or when required by system design (e.g. fail closed), through the seat area against the disc, and then changes direction to flow through the body to the outlet disc. The seating surface can be flat or tapered. For fine-throttling service, a very steep tapered seat can be used; this particular type of globe valve is referred to as a needle valve. A globe valve is commonly constructed with its inlet and outlet in line and with its port opening at right angles to the inlet and outlet. Figure 2 illustrates a cross section of a globe valve.

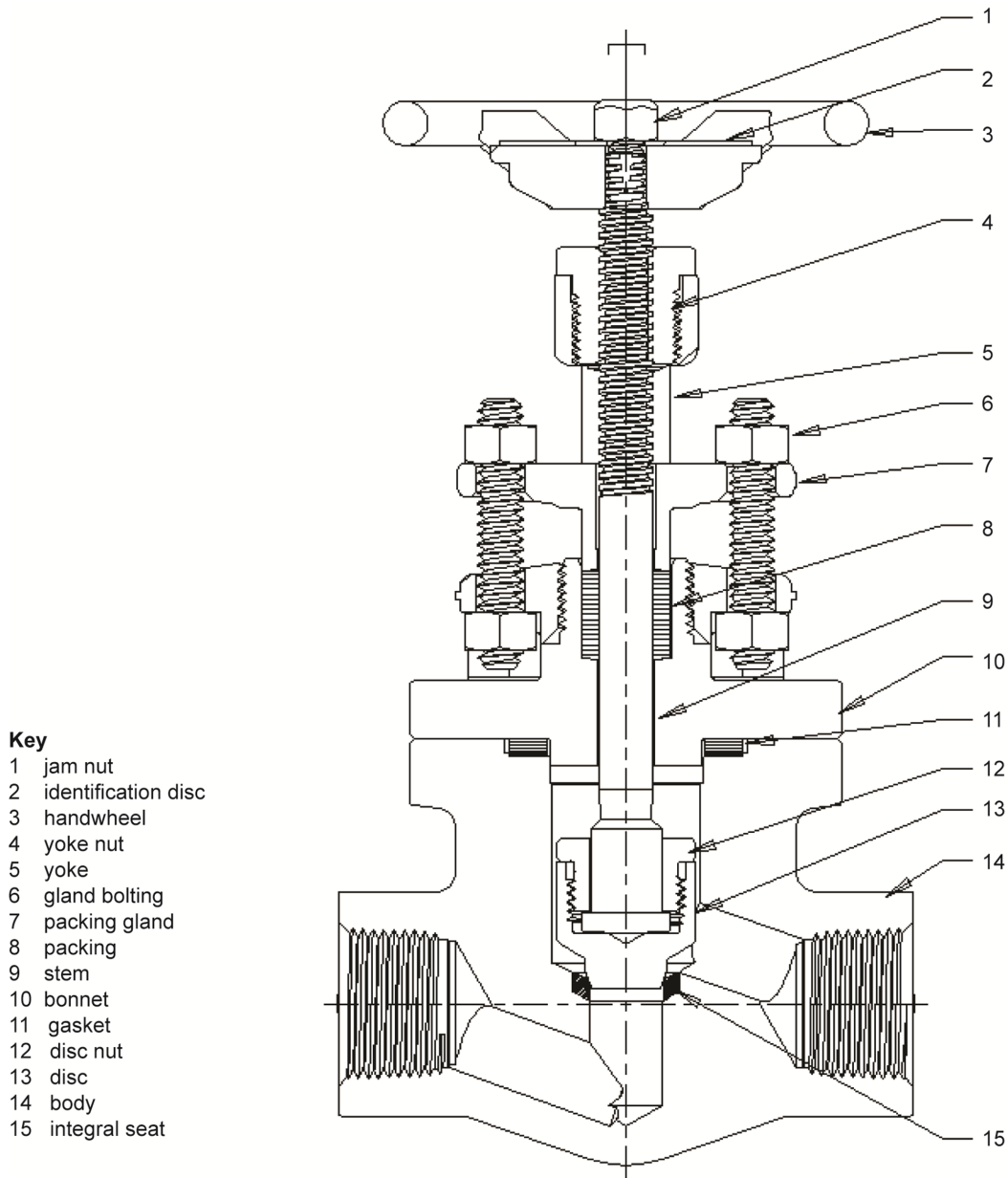


Figure 2—Cross Section of a Typical Globe Valve

4.3.4 Plug Valves

A plug valve consists of a tapered or cylindrical plug fitted snugly into a correspondingly shaped seat in the valve body. Plug valves usually function as block valves to close off flow. When the valve is open, an opening in the plug is in line with the flow openings in the valve body. The valve is closed by turning the plug one-quarter turn so that its opening is at right angles to the openings in the valve body. Plug valves can be operated by a gear-operated device or by turning a wrench on the stem. Plug valves are either lubricated or nonlubricated; Figure 3 illustrates both types. Lubricated plug valves use a grease-like lubricant that is pumped into the valve through grooves in the body and plug surfaces to provide sealing for the valve and promote ease of operation. On the other hand, nonlubricated plug valves may use metal seats or nonmetallic sleeves, seats, or complete or partial linings or coatings.

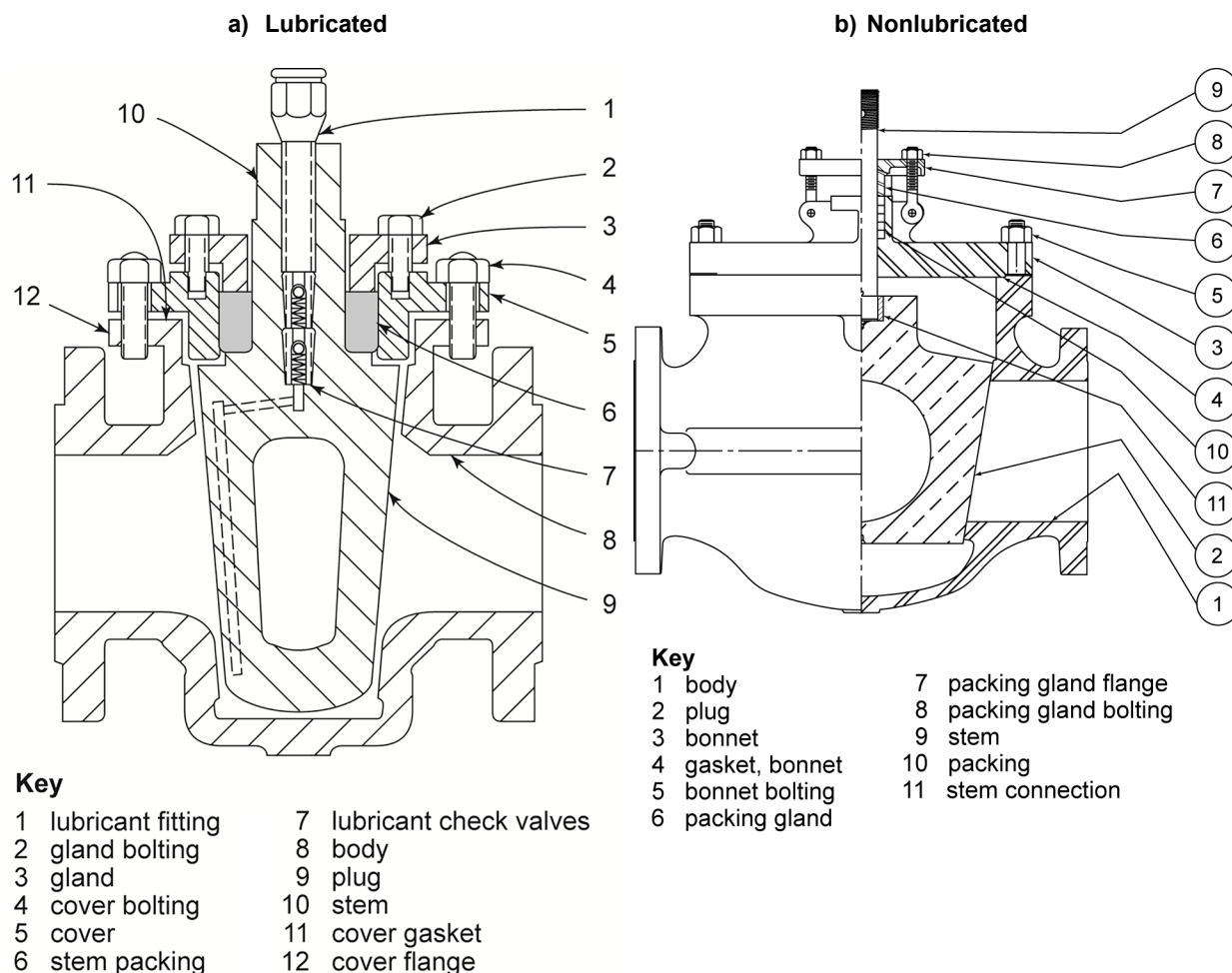


Figure 3—Cross Sections of Typical Lubricated and Nonlubricated Plug Valves

4.3.5 Ball Valves

A ball valve is another one-quarter turn valve like a plug valve except that the plug in a ball valve is spherical instead of tapered or cylindrical. Ball valves usually function as block valves to close off flow. They are well suited for conditions that require quick on/off or bubble-tight service. A ball valve is typically equipped with an elastomeric seating material that provides good shutoff characteristics; however, all-metal, high-pressure ball valves are available. Figure 4 illustrates a ball valve.

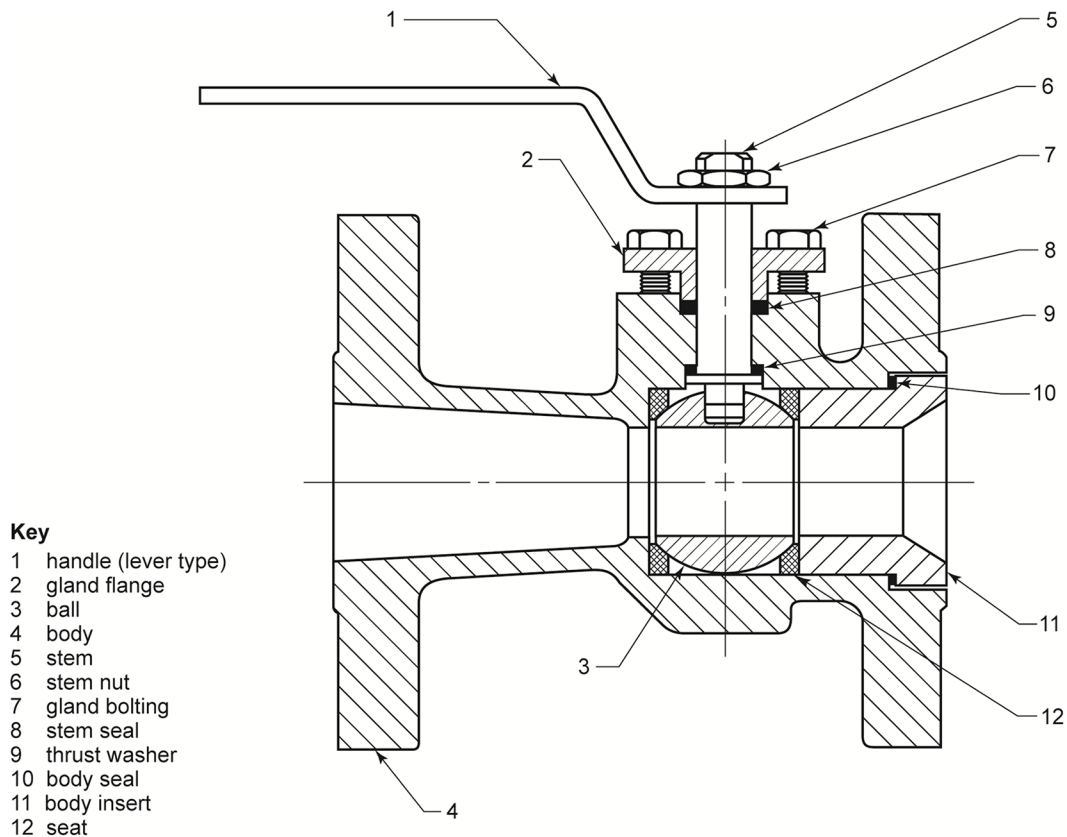


Figure 4—Cross Section of a Typical Ball Valve

4.3.6 Diaphragm Valves

A diaphragm valve is a packless valve that contains a diaphragm made of a flexible material that functions as both a closure and a seal. When the valve spindle is screwed down, it forces the flexible diaphragm against a seat, or dam, in the valve body and blocks the flow of fluid. These valves are not used extensively in the petrochemical industry, but they do have application in corrosive services below approximately 250 °F (121 °C), where a leak-tight valve is needed. Figure 5 illustrates a diaphragm valve.

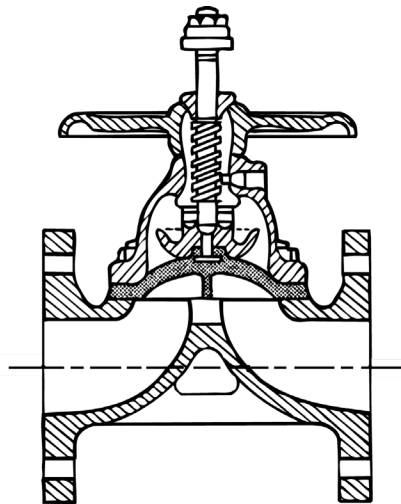


Figure 5—Cross Section of a Typical Diaphragm Valve

4.3.7 Butterfly Valves

A butterfly valve consists of a disc mounted on a stem in the flow path within the valve body. The body is usually flanged and of the lug or wafer type. A one-quarter turn of the stem changes the valve from fully closed to completely open. Butterfly valves are most often used in low-pressure service for coarse flow control. They are available in a variety of seating materials and configurations for tight shutoff in low- and high-pressure services. Large butterfly valves are generally mechanically operated. The mechanical feature is intended to prevent them from slamming shut in service. Figure 6 illustrates the type of butterfly valve usually specified for water service.

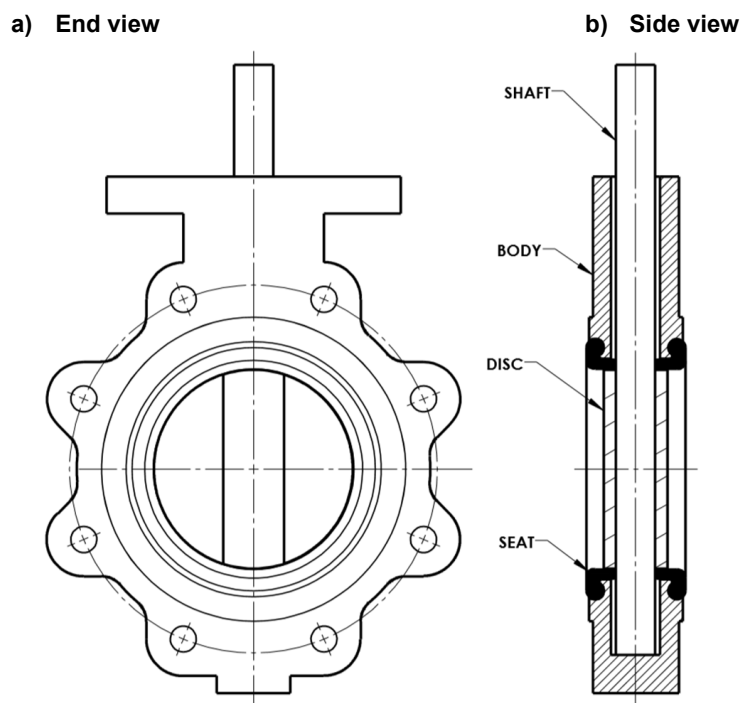


Figure 6—Typical Butterfly Valve

4.3.8 Check Valves

A check valve is used to automatically prevent backflow. The most common types of check valves are swing, lift-piston, ball, axial flow, and spring-loaded wafer check valves. Figure 7 illustrates cross sections of each type of valve; these views portray typical methods of preventing backflow.

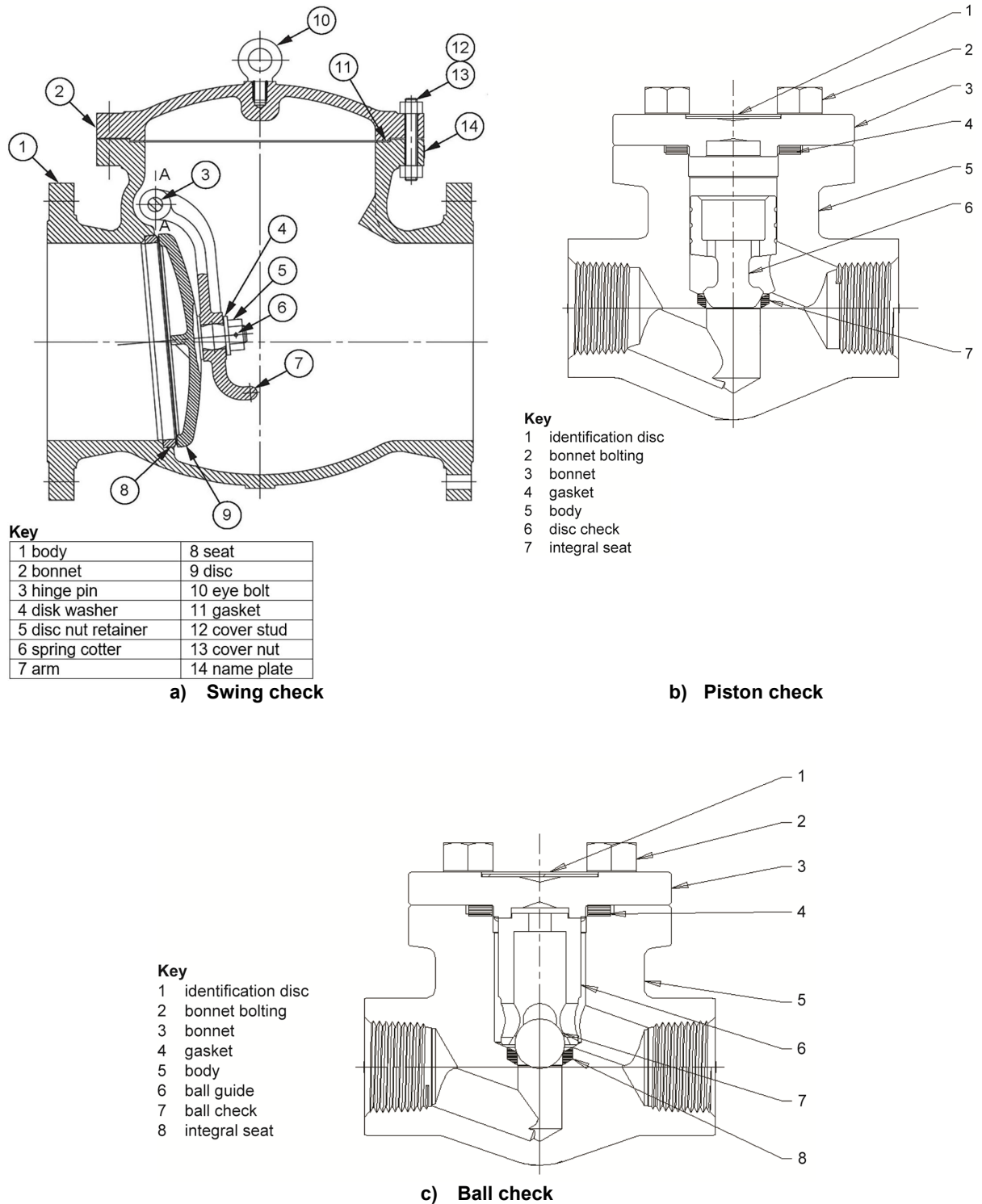


Figure 7—Cross Sections of Typical Check Valves

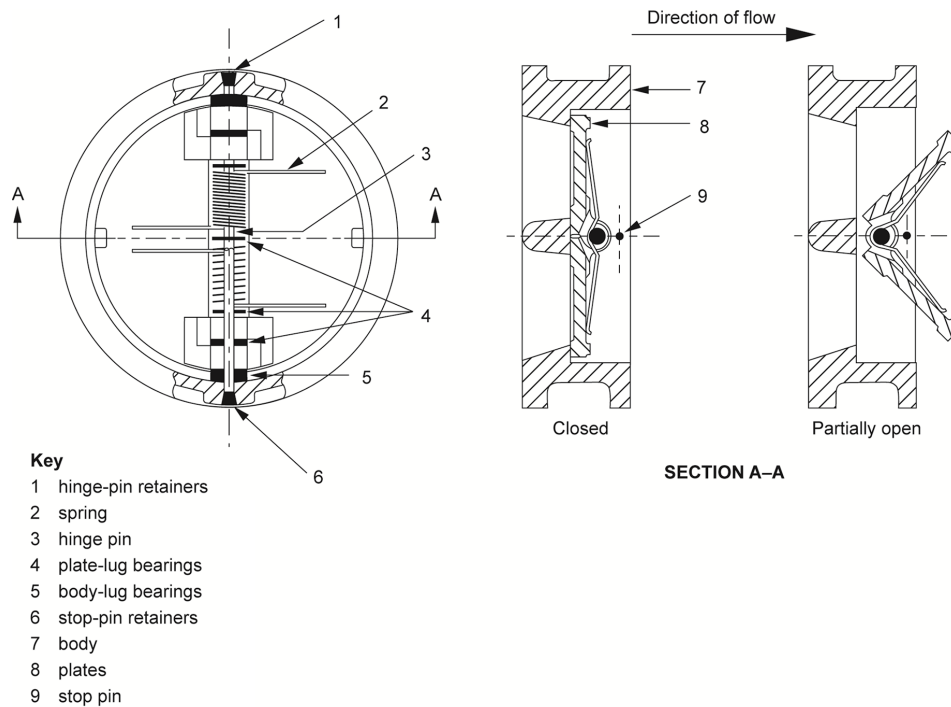


Figure 7—Cross Sections of Typical Check Valves (*continued*)

4.3.9 Slide Valves

The slide valve is a specialized gate valve generally used in erosive or high-temperature service. It consists of a flat plate that slides against a seat. The slide valve uses a fixed orifice and one or two solid slides that move in guides, creating a variable orifice that make the valve suitable for throttling or blocking. Slide valves do not make a gas-tight shutoff. One popular application of this type of valve is controlling fluidized catalyst flow in fluid catalytic cracking (FCC) units. Internal surfaces of these valves that are exposed to high wear from the catalyst are normally covered with erosion-resistant refractory. Figure 8 illustrates a slide valve.

4.4 Fittings

4.4.1 Metallic Fittings

Fittings are used to connect pipe sections and change the direction of flow or allow the flow to be diverted or added to. Fittings can be cast, forged, drawn from seamless or welded pipe, or formed and welded. Fittings can be obtained with their ends flanged, recessed for socket welding, beveled for butt welding, or threaded for threaded connections. Fittings are made in many shapes, such as wyes, tees, elbows, crosses, laterals, and reducers. Figure 9 illustrates types of flanged and butt-welded fittings. Figure 10 illustrates types of threaded and socket-welded fittings.

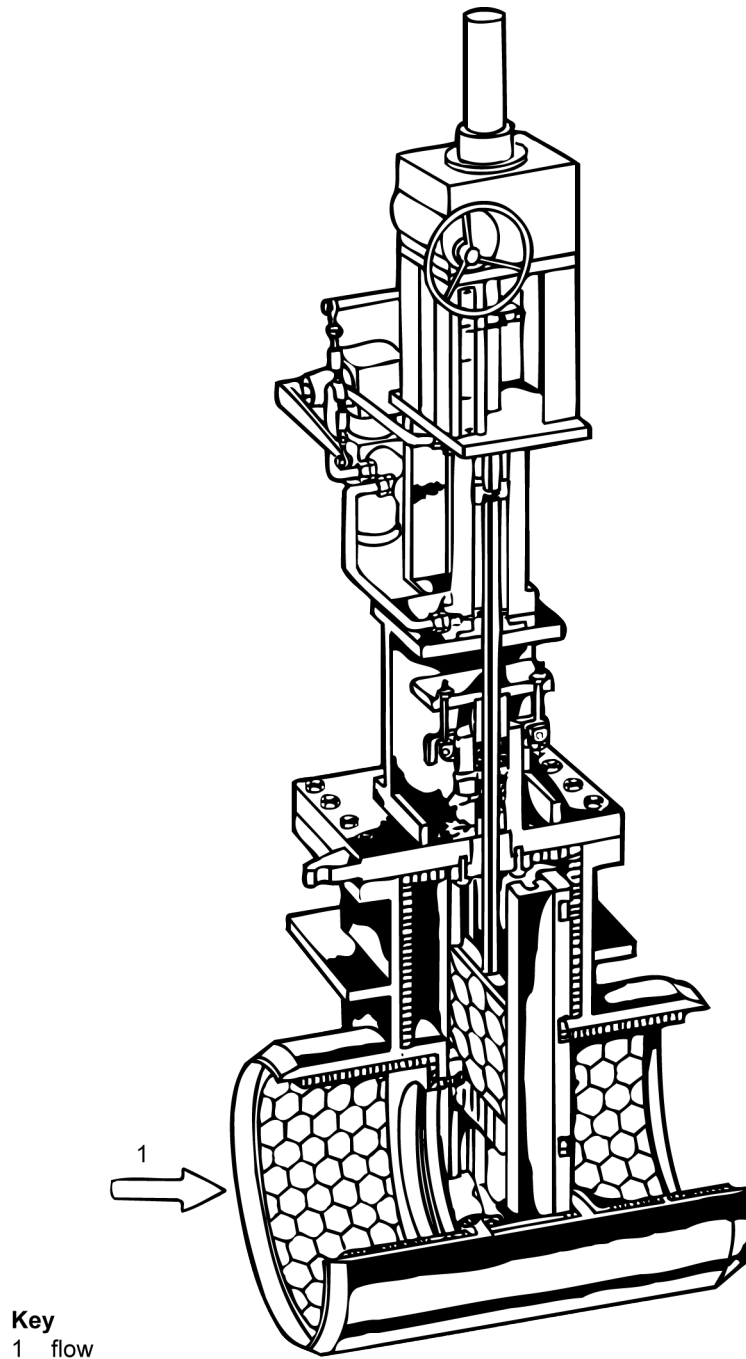
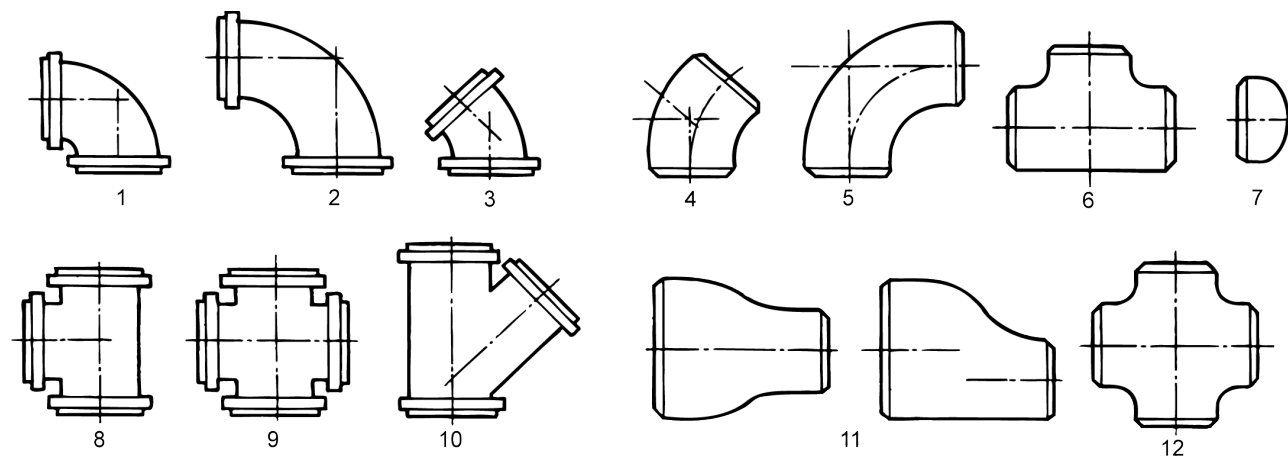


Figure 8—Cross Section of a Typical Slide Valve

4.4.2 Fiber-reinforced Plastic Fittings

Fiber-reinforced plastic (FRP) fittings are manufactured by different processes. Injection molding, filament winding, and contact molding are the most common techniques. The same criteria used to accept the pipe should be applied to fittings. Contact molded fittings should be inspected to ensure that they are manufactured to the same specification as the pipe. Contact molded fittings fabrication is critical because the layers of reinforcement must be overlapped to make sure that the strength of the layers is not compromised. One-piece contact molded fittings are the preferred method, but many items, such as tees

and branch connections, are often manufactured using two pieces of pipe. The inspector must check to make sure that the reinforcement on those pieces and the gap between them is within the tolerance specified. The exposed cut edges must be protected accordingly.



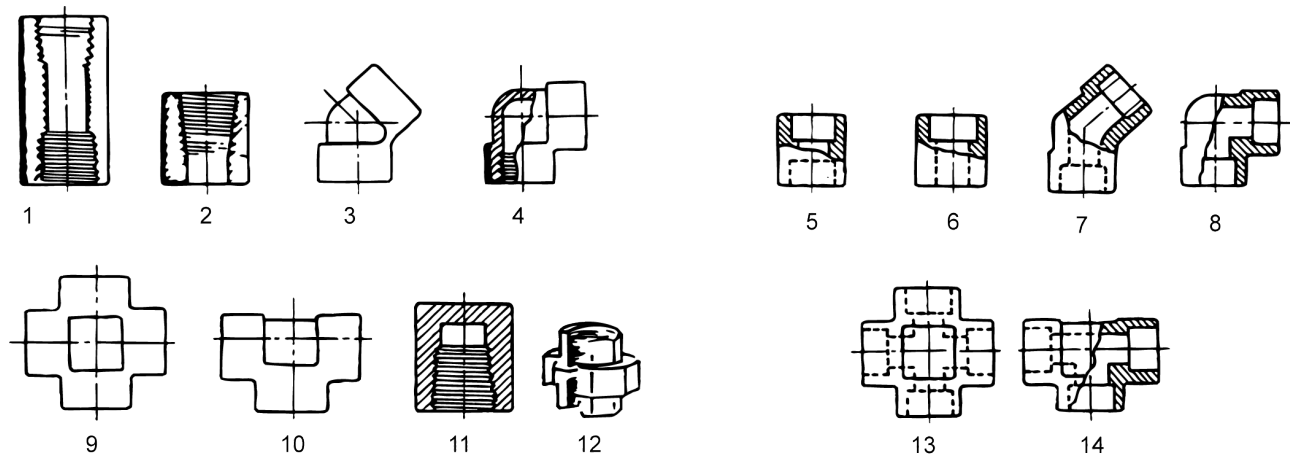
a) Flanged-end Fittings

b) Wrought Steel Butt-welded Fittings

Key

1 elbow	7 cap
2 long-radius elbow	8 tee
3 45° elbow	9 cross
4 45° elbow	10 45° lateral (wye)
5 long-radius elbow	11 reducers
6 tee	12 cross

Figure 9—Flanged-end Fittings and Wrought Steel Butt-welded Fittings



a) Threaded Fittings

b) Socket-welded Fittings

Key

1 coupling	8 90° elbow
2 half-coupling	9 cross
3 45° elbow	10 tee
4 90° elbow	11 cap
5 coupling	12 union
6 half-coupling	13 cross
7 45° elbow	14 tee

Figure 10—Forged Steel Threaded and Socket-welded Fittings**4.5 Flanges****4.5.1 Metallic Flanges**

ASME B16.5 covers flanges of various materials through an NPS of 24 in. (610 mm). ASME B16.47 covers steel flanges that range from NPS 26 through NPS 60. The flanges of cast fittings or valves are usually integral with the fitting or the valve body.

4.5.2 FRP Flanges

FRP flanges are manufactured using the same methods as the fittings. Contact molded flanges should be inspected for dimensions, drawback, and face flatness. The layers of reinforcement should extend onto the pipe to create the proper bond and hub reinforcement. More information on FRP flanges can be found in MTI Project 160-04. FRP flanges should have the proper torques and gaskets.

4.6 Expansion Joints

Expansion joints are devices used to absorb dimensional changes in piping systems, such as those caused by thermal expansion, to prevent excessive stresses/strains from being transmitted to other piping components, and connections to pressure vessels and rotating equipment. While there are several designs, those commonly found in a plant are metallic bellows and fabric joint designs. Metallic bellows can be single-wall or multilayered, containing convolutions to provide flexibility. Often, these joints will have other design features, such as guides, to limit the motion of the joint or the type of loading applied to the joint. Metallic bellows expansion joints can be used in higher-temperature services than nonmetallic joints.

All expansion joints have specific design limits for allowable movement (axial, angular, and offset), as well as pressure and temperature design limits. These limits should be understood and not exceeded. An expansion joint may limit the pressure/temperature rating of a piping system well below the pressure/temperature rating of the piping itself. Fabric joints are often used in flue gas services at low pressure and where temperatures do not exceed the rating of the fabric material.

4.7 Piping Supports

4.7.1 General

There are many different pipe support designs, types, and styles. They include hanger type, support shoes, saddles, bearing surfaces (e.g. structural members, concrete plinth blocks, etc.), spring type, dummy legs (trunnions), slide plates, sway braces/snubbers/struts, stands, sleeves, rollers, straps, clamps, and restrictive guides or anchors.

An understanding of the function and design of pipe supports is required to manage both their integrity and the integrity of piping systems. Pipe supports can be subject to various damage mechanisms (see 7.4.6) and significant stresses from static loading and thermal movements that can affect the pipe support itself, as well as the supported piping and piping components.

4.7.2 Piping Support Design—General Considerations

Piping supports usually are designed to carry the weight of piping including valves, insulation, and the weight of the fluid contained in the pipe, including hydrostatic test conditions. Properly designed piping supports will ensure that:

- a) pipes and piping components are not subjected to unacceptable stresses from sustained loads, external loads, or vibration;
- b) the piping does not impose an unacceptable load on the connections to the equipment it services (e.g. pressure vessels, pumps, turbines, and tanks);
- c) thermal movement is controlled within allowable displacements so as not to interfere with adjacent piping or equipment and be maintained within allowable stress levels;
- d) the potential for corrosion, cracking, and other in-service damage is minimized.

4.7.3 Piping Support Design—Specific Considerations

Pipe support design considerations can differ depending on the support type or style. While some pipe support manufacturers offer innovative and proprietary designs to eliminate or minimize some of the credible damage mechanisms, the following is a list of some special piping support design parameters to take into consideration.

- a) **Pipe Shoes**—It is important that the shoe is long enough and/or guides or stops are provided on the structural steel to prevent the shoe from coming off the support, which could cause tearing or other damage to the pipe. Also, some pipe shoes may trap water between the pipe and shoe (e.g. clamp-on, bolt-on, saddles that have been stitch welded, etc.) and make inspection difficult to determine the condition of the pipe.
- b) **Pipe Sleeves**—Pipe sleeves are often used where pipe passes through a wall, under a roadway, or through an earthen berm. When used, design precautions should be taken to prevent corrosion on both the pipe and the pipe sleeve. Centering devices should also be considered to keep the inner pipe centered and prevent coating damage and corrosion. Fully welded and/or sealed sleeves may be considered if loss of containment detection and control are necessary. It should be noted that sleeves can make future pipe inspections and examinations more difficult.

- c) **Doubler Plates, Half Soles, and Wear Pads**—Additional plates may be attached to a pipe system at points where the pipe rests on bearing surfaces. Plates should be fully welded to avoid crevice corrosion except in hydrogen-charging environments, where a weep hole should be included that will not lead to moisture ingress. The use of adhesive-bonded stainless steel or composite half soles may be considered, but it is very important to make sure that the adhesive is fully bonded and maintained to effectively eliminate water entrapment. Galvanic corrosion should also be considered when using dissimilar materials for this purpose.
- d) **Dummy Legs (Trunnions)**—Historically, dummy leg (trunnion) supports were simple open-ended lengths of pipe welded to a piping system from which the piping system was supported. An open-ended design can allow moisture and debris to become trapped inside the support and cause corrosion of the support and the pipe. Dummy leg design should include, as a minimum, drain holes no smaller than $\frac{1}{4}$ in. (6 mm) located at a low point, with the unattached end of the support being fitted with a fully welded cap or end plate to prevent debris or animals from entering. Trunnion design can be improved by using solid sections, such as “C” channels or “I/H” beams, to reduce the risk of this problem. However, even solid member sections can trap water and debris depending upon their design and orientation. Incorporating a fully welded doubler pad to the pipe at the trunnion attachment location can provide additional corrosion protection and may help distribute loads more evenly. The end of a dummy leg support that is not attached to the pipe may or may not be anchored or restrained.
- e) **Supports on Insulated Lines**—Special attention is necessary for the design of supports on insulated lines to minimize the possibility of water ingress and wicking of water into the insulation.
- f) **Accessibility**—The accessibility, and therefore inspectability/maintainability, of pipe supports should be considered during design.
- g) **Welding**—Paths for water ingress into hollow supports can be minimized with the use of fully welded seams. Avoid welding undercut or excessive penetration. Welding defects associated with supports can contribute to loss of containment events and, in some cases, be of sufficiently small size to make leak detection and source identification difficult. In hydrogen-charging environments, a weep hole should be provided to avoid the buildup of pressure between the plate and pipe.
- h) **Anchors and Restraints**—A connection of a pipe to a stationary structure or foundation to restrict the movement of the pipe in one or more directions (X, Y and/or Z plane). The attachment of an anchor or restraint to a pipe should preferably encircle the pipe to distribute the stresses evenly about the circumference of the piping component(s).

4.8 Flexible Hoses

Flexible hoses are often temporarily used to transfer hydrocarbons and other process fluids to facilitate turnaround activities (clearing equipment, deinventorying, purging, etc.) and for transfer of process fluids/products to rail cars and/or tanker trucks for shipment. Flexible hoses may also be installed within process piping systems to mitigate the effects of thermal expansion, vibration, or movement during normal operations. Some sites will maintain several flexible hoses to be used as needed in multiple services. Flexible hoses come in a variety of different construction materials and designs. Owner-operators should ensure the design of the flexible hose is compatible with the process service in which it is used. In addition, have appropriate quality assurance and test and inspection systems in place to ensure the mechanical integrity of the hose is maintained while in service.

5 Piping Design and Construction

5.1 Design and Construction Standards

Piping should be fabricated in accordance with the appropriate construction standards for the application. Some commonly used construction standards are ASME B31.3 and ASME B31.1.

5.2 Methods of Construction

5.2.1 Pipe Joining Methods

5.2.1.1 General

The common joining methods used to assemble piping components are welding, threading, and flanging. Welded joints are most used to connect piping spools and components. Some owner-operators still rely on threaded joints in SBP and where piping is connected to equipment that requires periodic maintenance. Flanged joints are most used where piping is connected to equipment or other flanged valves and fittings. Cast iron piping and thin-wall tubing require special connections/joining methods due to inherent design characteristics.

5.2.1.2 Threaded Joints

Threaded joints are generally limited to auxiliary piping in noncritical service (minor consequence should a leak occur) that has a nominal size of 2 in. (51 mm) or smaller. Threaded joints for NPSs of 24 in. (610 mm) and smaller are standardized (see ASME B1.20.1).

Lengths of pipe can be joined by any of several types of threaded fittings (see 4.4). Couplings, which are sleeves tapped at both ends for receiving a pipe, are normally used to connect lengths of threaded pipe. When it is necessary to remove or disconnect the piping, threaded unions or mating flanges are required (see 5.2.1.4). Threaded joints that are located adjacent to rotating equipment or other specific sources of high vibration can be especially susceptible to failure due to fatigue. Special consideration should be given to these situations.

5.2.1.3 Welded Joints

5.2.1.3.1 General

Where welded joints are used, the joints are either butt-welded (in various sizes of pipe) or socket-welded (typically NPS 2 and smaller).

5.2.1.3.2 Butt-welded Joints

Butt-welded connections are the type most widely utilized in industry. The ends of the pipe, fitting, or valve are prepared (beveled) and aligned with adequate root opening in accordance with ASME B16.25 or any other end preparation that meets the welding procedure specification, permitting the ends to be joined by fusion welding.

5.2.1.3.3 Socket-welded Joints

Socket-welded joints are made by inserting the end of the pipe into a recess in a fitting or valve and then fillet welding the joint. Two lengths of pipe or tubing can be connected by this method using a socket-weld coupling. Figure 11 illustrates a cross section of a socket-welded joint.

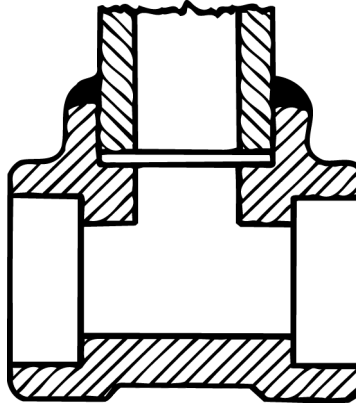


Figure 11—Cross Section of a Socket-welded Tee Connection

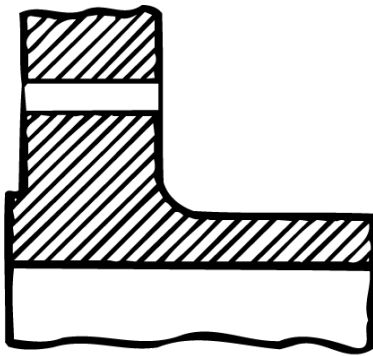
5.2.1.3.4 Welded Branch Connections

Many piping failures occur at pipe-to-pipe welded branch connections. Branch connections often fail because they are subject to higher-than-normal stresses. These may be caused by excessive structural loadings from unsupported valves or piping, vibration, or thermal expansion, or other configurations that promote high stress. The result is concentrated tri-axial stresses (e.g. bending and torsional) that can cause fatigue cracking or other types of failures. Where joints are susceptible to such failures, a forged piping tee typically offers better reliability because it removes the weld from the point of highest stress concentration. Self-reinforced branch connections also can offer better reliability if they are properly welded to the main pipe using appropriate weld procedures and meet the manufacturer's recommendations for full penetration welds.

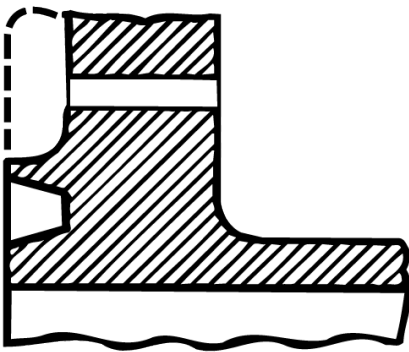
5.2.1.4 Flanged Joints

Flanged joints are made by bolting two flanges together with some form of gasket between the seating surfaces. The gasket surfaces can be flat and range from serrated (concentric or spiral) to smooth (depending on the type of gasket, gasket material, and service conditions), or grooves can be cut for seating metal-ring gaskets. Flanged joints should be assembled by trained and qualified personnel (see Appendix A of ASME PCC-1). Consideration should be given to establishing a finished joint examination process. See 6.2 on flanged joint leakage.

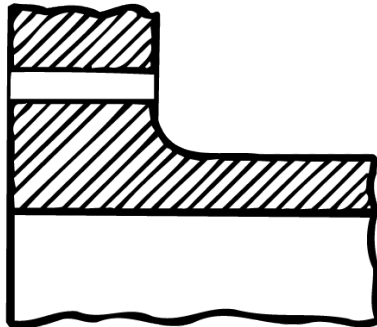
Figure 12 illustrates common flange facings for various gaskets. The common types of flanges are weld neck, slip-on welding, threaded, blind, lap joint, and socket-welded. Each type is illustrated in Figure 13.



a) Raised face



b) Ring-joint face



c) Flat face

Figure 12—Flange Facings Commonly Used in Refinery and Chemical Plant Piping

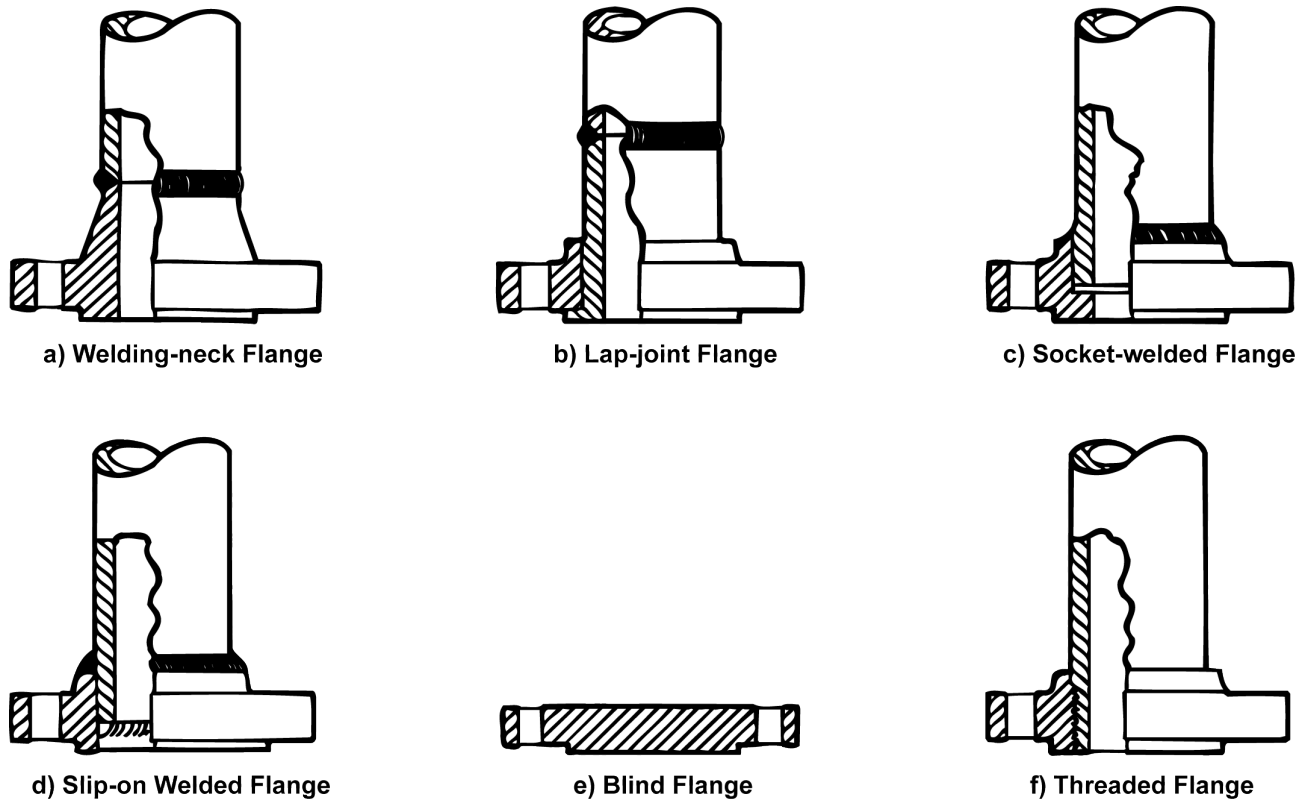


Figure 13—Types of Flanges

5.2.1.5 Cast Iron Pipe Joints

Cast iron pipe joints can be of the flanged, packed, sleeve, hub-and-spigot-end or hub-and-plain-end, or bell-and-spigot-end or bell-and-plain-end type. Push-on joints with rubber or synthetic ring gaskets are available. Clamped joints are also used. The hub-and-plain-end joint is shown in Figure 14. Figure 15 illustrates cross sections of a bell-type mechanical joint, a sleeve connection, and a typical proprietary connection (see 5.2.1.7). These types of joints are rarely used in process piping service because of their low toughness and tendency toward brittle fracture.

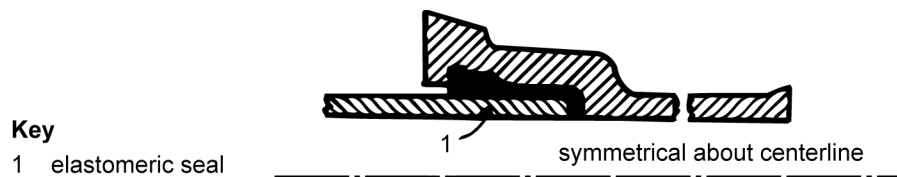


Figure 14—Cross Section of a Typical Bell-and-Spigot Joint

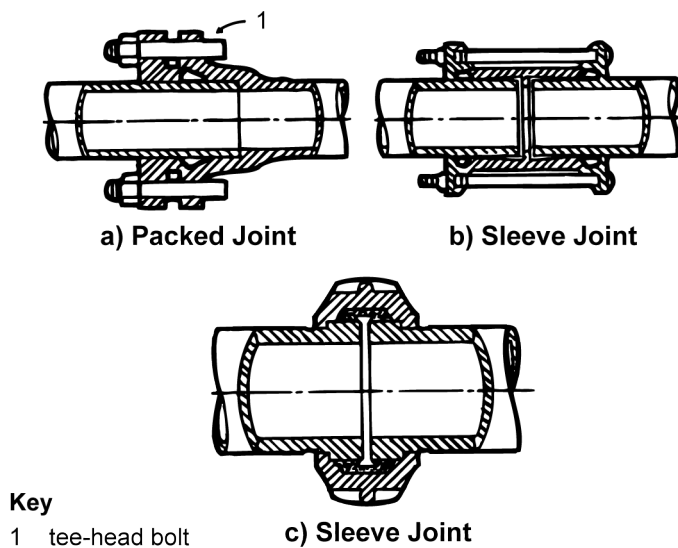


Figure 15—Cross Sections of Typical Packed and Sleeve Joints

5.2.1.6 Tubing Joints

Tubing can be joined by welding, soldering, or brazing or by using flared or compression fittings. Figure 16 illustrates flared and compression joints. Tubing joints should be assembled by trained and qualified personnel. Consideration should be given to establishing a finished joint examination process in accordance with tubing joint manufacturer's recommendations.

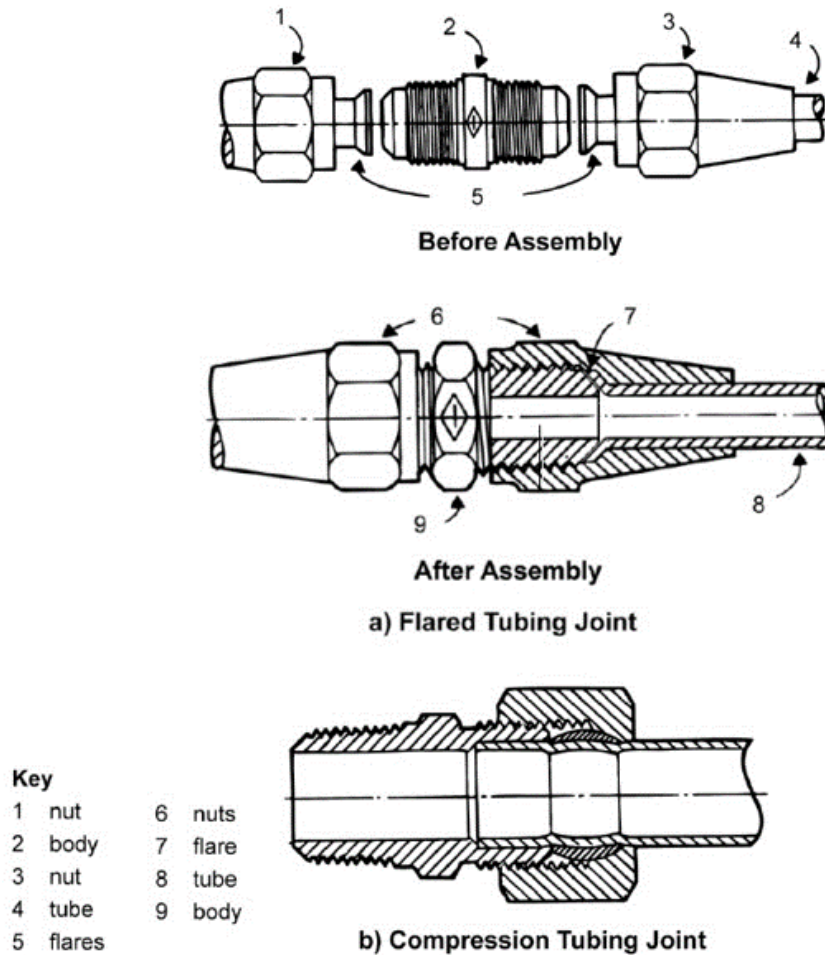


Figure 16—Cross Sections of Typical Tubing Joints

5.2.1.7 Special Joints

Proprietary joints are available that incorporate unique gaskets, clamps, and bolting arrangements. These designs offer some advantages in some services over conventional joints in certain services, including the following:

- a) higher pressure and temperature ratings;
- b) smaller dimensions;
- c) easier installation—axial and angular alignment requirements are less stringent;
- d) greater force and moment toleration.

5.2.1.8 Nonmetallic Piping Joints

5.2.1.8.1 General

There are several methods of joining FRP pipe and fittings. Joints in nonmetallic piping are often of several different designs depending upon the manufacturer of the pipe. Some common joint designs in FRP pipe systems include a bell and spigot, butt and wrap, taper-taper, and flange-flange.

5.2.1.8.2 Bell and Spigot/Taper-taper

Bell-and-spigot and taper-taper joints are created by inserting the spigot end into the bell end. Proper surface preparation, insertion, and adequate adhesive are the key to making these types of joints.

5.2.1.8.3 Butt and Wrap

Butt-and-wrap joints involve butting plain end pipe together and applying layers of resin and fiber reinforcement layers around the joint. These types of joints should be done by qualified personnel.

NOTE Fitting thickness is often greater than the matching pipe thickness. The proper taper of the fitting thickness is required to make the proper butt-and-wrap joint.

5.2.1.8.4 Flange-flange

Proper flange joint makeup involves the use of appropriate gaskets, bolt torques, and alignment. Using a calibrated torque wrench helps ensure proper torquing and avoids damage by overstressing the FRP flanges. Proper flange alignment, flatness, and waviness according to the specification can prevent damage when torquing to specified values. Full-face gaskets are typically used for bolting full-face flanges. Flanges bolted to raised-face connections should be evaluated individually for required torque values and proper gasket requirements.

5.2.2 Pipe Fabrication

5.2.2.1 General

Pipe fabrication is the process of cutting, beveling, and welding piping components, such as pipes, tees, elbows flanges, etc. to provide a means to safely transport or process liquids, gases, and solids.

5.2.2.2 Seamless Pipe

Seamless pipe is made as a continuous tube with no longitudinal weld. This type of pipe is generally known to withstand higher pressure and is widely used in industry. A common carbon steel seamless pipe is ASME SA106.

5.2.2.3 Seam Welded Pipe

Seam welded pipe is formed by using a rolling machine to roll the longer sides of plate together to form a cylinder and then welding the seam together. The most common method of joining the seam is electric resistance welding. This produces a weld seam that cannot be seen or felt. This pipe is generally used in lower-pressure applications and services that would not be selectively corrosive to welds/heat-affected zone.

5.3 Materials of Construction

5.3.1 Base Material

Piping can be made from any material that can be rolled and welded, cast, or drawn through dies to form a tubular section. The two most common carbon steel piping materials used in the petrochemical industry are ASTM A53 and ASTM A106. The industry uses both seamless and electric resistance welded piping for process services, depending upon current economics and the potential for accelerated corrosion of the weld seam in service. Piping of a nominal size larger than 16 in. (406 mm) is usually made by rolling plates to size and welding the seams. Pipe can be centrifugally cast and then machined to any desired thickness.

5.3.2 Pipe Linings

Internal linings can be incorporated into the piping design to reduce corrosion, erosion, product contamination, and pipe metal temperatures. The linings can generally be characterized as metallic and nonmetallic.

Metallic liners are installed in various ways, such as cladding and weld overlay.

- a) Clad pipe has a metallic liner that is an integral part of the plate material rolled or explosion bonded before fabrication of the pipe.
- b) Corrosion-resistant metal can also be applied to the pipe surfaces by various weld overlay processes.
- c) Metallic liners can be made of any metal resistant to the corrosive or erosive environment, depending upon its purpose. These include stainless steels, high alloys, cobalt-based alloys, etc.

Nonmetallic liners can be used to resist corrosion and erosion or to insulate and reduce the temperature on the pipe wall. Some common nonmetallic lining materials for piping are concrete, castable refractory, plastic, and thin-film coatings.

5.3.3 Nonmetallic Piping

5.3.3.1 General

Nonmetallic materials are not covered by API 570. The term “nonmetallic” has a broad definition, but this section refers to the fiber-reinforced plastics group encompassed by the generic acronyms FRP (fiber-reinforced plastic) and GRP (glass-reinforced plastic). Another group of materials, for example high- and low-density polyethylene and polyvinyl, have a homogeneous structure produced by extrusion and are outside the scope of this document.

Nonmetallic materials have limited application to specific piping systems in the process industry, such as in utilities. For example, typical service applications of FRP piping include service water, process water, cooling medium, potable water, sewage/gray water, nonhazardous waste, nonhazardous drains, nonhazardous vents, chemicals, firewater ring mains, firewater deluge systems, and produced and ballast water. Nonmetallic materials have significant advantages over more familiar metallic materials, but they also have unique construction and deterioration mechanisms that can lead to premature failures if not addressed adequately.

The design of these piping systems is largely dependent on the application. Many companies have developed their own specifications that outline the materials, quality, fabrication requirements, and design factors. It is noted that other codes and standards have requirements and guidance. In particular:

- a) ASME B31.3, Chapter VII, covers design requirements for nonmetallic piping;
- b) the American Water Works Association is an organization that also provides guidance on FRP pipe design and testing.

These codes and standards, however, do not offer guidance as to the right choice of corrosion barriers, resins, fabricating methods, and joint systems for a particular application. The user should consider other sources, such as resin and pipe manufacturers, for guidance on their application.

5.3.3.2 FRP Pipe Manufacturing

Historically, while many of the failures in FRP piping are related to poor construction practices, a poor understanding of the application to a service or the manufacturing of the materials can also lead to failure.

For example, a lack of familiarity with the materials can lead to a failure to recognize the detail of care that must be applied in construction.

FRP materials require understanding of their manufacturing process and their service limitations. For example:

- a) each manufacturing technique will generate a different set of physical properties;
- b) each resin system has a temperature limitation, and each joint system has its advantages and disadvantages.

FRP piping is manufactured in many ways. Every service application should be reviewed for proper resin, catalyst, corrosion barrier (liner) composition, and structural integrity. Although FRP is corrosion resistant, using the wrong resin or corrosion barrier can cause premature failure.

FRP pipe can experience ultraviolet (UV) degradation over time if not adequately protected. Adding a UV inhibitor in the resin will help prevent premature fiber blooming caused by UV. The user should consider this option for all FRP piping applications and be aware that this would be a supplemental specification.

Standardized FRP piping systems commonly called “commodity piping” are manufactured for a variety of services and are sold as products with a predetermined design, resin, corrosion barrier, and structure. Piping manufacturers typically have a quality control specification that identifies the level of quality and allowable tolerance that is built into their product.

Custom fabricated pipe is typically designed and manufactured for a specific application. The resin, catalyst system, corrosion barrier, and structure are specified, and the pipe is manufactured to a specification and to a specified level of quality and tolerances.

5.3.3.3 Qualification of Assemblers

The qualification of bonders and jointers is as important for FRP fabrication as the qualification of welders is for metal fabrication. Due to limitations in NDE methods, the emphasis must be placed on procedure and bonder qualifications and testing.

Similarly, because the material stiffness is much less than metal and because FRP has different types of shear, small-bore connections will not withstand the same shear stress, weight loadings, or vibrations that are common with metallic piping. Supporting attachments, such as valves, etc., on small-bore connections should be analyzed in detail to prevent premature failure of the system.

5.3.3.4 Inspection

All FRP piping should be inspected by a person who is knowledgeable in the curing, fabrication, and quality of FRP materials. The level of inspection should be determined by the user. ASME RTP-1—Table 6-1 can be used as a guide to identify liner and structure imperfections that are common in FRP laminates.

The FRP inspector should verify by documentation and inspection that the piping system has been built with the proper materials, quality, hardness, and thickness as requested in the pipe specification. A final inspection should be performed at the job site to ensure that the pipe has not experienced any mechanical damage during shipment or assembly.

6 Reasons for Inspection

6.1 General

The primary purposes of inspection are to observe, report, and quantify damage (see API 571) and then to specify needed repairs or replacements. Planning for inspection entails identifying credible damage mechanisms for the purposes of directing the inspection activity. The inspection activity requires obtaining information about the physical condition of the piping, which will lead to determining the causes of any deterioration and the rate of deterioration. By developing a database of inspection history, the user can predict and recommend future repairs and replacements, act to prevent or retard further deterioration, and most importantly, prevent loss of containment. These actions should result in increased operating safety, reduced maintenance costs, and more reliable and efficient operations. API 570 provides the basic requirements for a piping inspection program which addresses these issues and concerns.

6.2 Process and Personnel Safety

A leak or failure in a piping system can be a minor inconvenience for low-consequence fluids or it can become a potential source of a process safety incident for higher-consequence fluids depending on the temperature, pressure, contents, and location of the piping. Piping in a petrochemical plant typically contains flammable fluids, acids, alkalis, toxic fluids, and other harmful fluids that would make leaks potentially hazardous to exposed personnel. Leaks in these kinds of piping systems can also have environmental consequences associated with their failure. Adequate inspection is a prerequisite for maintaining piping systems in a safe, reliable condition.

Leakage can occur at flanged joints in piping systems for a variety of reasons, including corrosion, cracking, bolt tightness issues, and gasket issues. In addition, thermal expansion issues can cause leaks particularly for joints in high-temperature services during start-ups and shutdowns, and sometimes during normal operation. For these reasons, process plant practices should include quality assurance/control procedures to help ensure flanged joint integrity after maintenance activities where the joints have been disassembled. Procedures typically include, for example, proper gasket and fastener selection, assembler qualifications, proper assembly instruction, inspection, and testing requirements. Refer to ASME PCC-1 for flange joint assembly practices.

6.3 Regulatory Requirements

Regulatory requirements may cover those piping systems that could affect personnel or process safety and environmental concerns. Process safety regulations, such as OSHA 29 *CFR* 1910.119 in the United States, have mandated that equipment, including piping, that handles significant quantities of hazardous chemicals be inspected according to accepted codes and standards, which includes API 570. Local and state regulations may also cover process piping inspection and maintenance.

6.4 Reliable Operation

In addition to the need for inspection to provide for process and personnel safety, thorough inspection, data analysis, and maintenance of detailed inspection/repair/replacement records of piping systems are essential to the attainment of acceptable process reliability to meet the business plan. Piping maintenance and replacement schedules are developed to coincide with scheduled maintenance turnarounds to avoid unplanned outages and the consequences of lost production opportunities.