

[Return to Main Menu](#)

[Return to List of Standards](#)

[Return to History of Standards](#)



**American Water Works
Association**

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ANSI/AWWA C604-17
(Revision of ANSI/AWWA C604-11)

AWWA Standard

Installation of Buried Steel Water Pipe—4 In. (100 mm) and Larger

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Effective date: Aug. 1, 2017.

First edition approved by AWWA Board of Directors Feb. 12, 2006.

This edition approved Jan. 14, 2017.

Approved by American National Standards Institute Jan. 6, 2017.



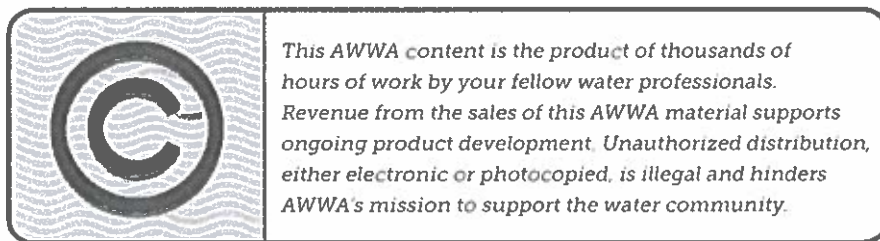
AWWA Standard

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ISBN-13, print: 978-1-62576-241-2

eISBN-13, electronic: 978-1-61300-432-6

DOI: <http://dx.doi.org/10.12999/AWWA.C604.17>

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Contents

All AWWA standards follow the general format indicated subsequently. Some variations from this format may be found in a particular standard.

SEC.	PAGE	SEC.	PAGE
<i>Foreword</i>		5	Trench Construction
I	ix	5.1	Alignment and Grade..... 7
I.A	ix	5.2	Trench Construction..... 8
I.B	ix	6	Pipe Installation
I.C	ix	6.1	General Pipe Installation..... 10
II	xi	6.2	Joint Assembly and Testing..... 11
II.A	xi	6.3	Thrust Restraint..... 28
II.B	xi	6.4	Backfilling..... 28
	xi	6.5	Flushing..... 31
III	xi	6.6	Disinfection..... 31
III.A	xi	6.7	Highway and Railroad Crossings 32
	xi	6.8	Subaqueous Crossings..... 32
III.B	xii	7	Verification
IV	xii	7.1	Inspection..... 32
V	xiii	7.2	Hydrostatic Field Testing..... 33
<i>Standard</i>		8	Delivery
1	General	8.1	Unloading, Handling, and Storage.. 34
1.1	1	8.2	Affidavit of Compliance..... 35
1.2	2		
1.3	2	Appendix	
2	References 2	A	Flange Joint Assembly
3	Definitions 3	A.1	General Flange Joint Assembly Procedures and Checklists..... 37
4	Preliminary Information	A.2	Flanges, Fasteners, and Gaskets (Additional Details)..... 41
4.1	6	A.3	Bolting Patterns and Sequences 44
4.2	6		
4.3	6		

SEC.	PAGE	SEC.	PAGE
Figures			
1	12	A.2	45
2	13		46
3	14	A.3	46
4	16	A.4	47
5	18		
6	20		
7	30		
A.1	45		
		Table	
		1	30

Foreword

This foreword is for information only and is not a part of ANSI/AWWA C604.

I. Introduction.

I.A. *History.* This standard pertains to the in-ground installation of steel pipelines for use in the distribution and transmission of water, air, and other products in water system facilities. It has been prepared by the AWWA Standards Committee on Steel Pipe, initially formed as Committee A7A in 1939. At that time, the Steel Water Pipe Manufacturers Technical Advisory Committee was organized as a subsidiary group to function as a source of technical information for the parent committee. Committee A7A and its successors, Committee 8310D and the AWWA Standards Committee on Steel Pipe, have assumed responsibility for all AWWA standards and manuals pertaining to steel pipe, fittings, linings and coatings, field installations, and related items.

In 1996 the AWWA Standards Council directed the Standards Committee on Steel Pipe to develop a standard for the installation of steel pipelines and their appurtenances used in water treatment or conveying facilities. The first edition of AWWA C604 was approved by the AWWA Board of Directors on Feb. 12, 2006. The second edition was approved on Jan. 23, 2011. The present edition of C604 was approved on Jan. 14, 2017.

I.B. *Discussion.* ANSI/AWWA C604 addresses the installation of steel pipe 4 in. (100 mm) in diameter and larger typically used in the water industry. ANSI/AWWA C604 anticipates the use of pipe produced in a fabricator's shop or pipe mill that meets the stringent design, quality control, and testing requirements of AWWA Manual M11, ANSI/AWWA C200, and the applicable AWWA steel pipe lining and coating standards.

I.C. *Acceptance.* In May 1985, the US Environmental Protection Agency (USEPA) entered into a cooperative agreement with a consortium led by NSF International (NSF)[†] to develop voluntary third-party consensus standards and a certification program for direct and indirect drinking water additives. Other members of the original consortium included the Water Research Foundation (formerly AwwaRF) and the Conference of State Health and Environmental Managers (COSHEM). The

* American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.

† NSF International, 789 North Dixboro Road, Ann Arbor, MI 48105.

American Water Works Association (AWWA) and the Association of State Drinking Water Administrators (ASDWA) joined later.

In the United States, authority to regulate products for use in, or in contact with, drinking water rests with individual states.* Local agencies may choose to impose requirements more stringent than those required by the state. To evaluate the health effects of products and drinking water additives from such products, state and local agencies may use various references, including

1. Specific policies of the state or local agency.
2. Two standards developed under the direction of NSF: NSF/ANSI 60, Drinking Water Treatment Chemicals—Health Effects, and NSF/ANSI 61, Drinking Water System Components—Health Effects.
3. Other references, including AWWA standards, *Food Chemicals Codex*, *Water Chemicals Codex*,[‡] and other standards considered appropriate by the state or local agency.

Various certification organizations may be involved in certifying products in accordance with NSF/ANSI 61. Individual states or local agencies have authority to accept or accredit certification organizations within their jurisdictions. Accreditation of certification organizations may vary from jurisdiction to jurisdiction.

Annex A, “Toxicology Review and Evaluation Procedures,” to NSF/ANSI 61 does not stipulate a maximum allowable level (MAL) of a contaminant for substances not regulated by a USEPA final maximum contaminant level (MCL). The MALs of an unspecified list of “unregulated contaminants” are based on toxicity testing guidelines (noncarcinogens) and risk characterization methodology (carcinogens). Use of Annex A procedures may not always be identical, depending on the certifier.

ANSI/AWWA C604 does not address additives requirements. Thus, users of this standard should consult the appropriate state or local agency having jurisdiction in order to

1. Determine additives requirements, including applicable standards.
2. Determine the status of certifications by parties offering to certify products for contact with, or treatment of, drinking water.
3. Determine current information on product certification.

* Persons outside the United States should contact the appropriate authority having jurisdiction.

‡ Both publications available from National Academy of Sciences, 500 Fifth Street, NW, Washington, DC 20001.

II. Special Issues.

II.A. *Application.* ANSI/AWWA C604, Installation of Buried Steel Water Pipe—4 In. (100 mm) and Larger, can be used as a reference when making extensions to existing distribution or transmission systems or when constructing new distribution or transmission systems using steel pipe. It is not the intent for this standard to be used as a contract document, but it may be used as a reference in contract documents. It is based on a consensus of the committee on the minimum practice consistent with sound, economical service under normal conditions, and its applicability under any circumstances must be reviewed by a responsible engineer. The standard is not intended to preclude the manufacture, marketing, purchase, or use of any product, process, or procedure.

II.B. *Chlorine and Chloramine Degradation of Elastomers.* The selection of materials is critical for water service and distribution piping in locations where there is a possibility that elastomers will be in contact with chlorine or chloramines. Documented research has shown that elastomers such as gaskets, seals, valve seats, and encapsulations may be degraded when exposed to chlorine or chloramines. The impact of degradation is a function of the type of elastomeric material, chemical concentration, contact surface area, elastomer cross section, and environmental conditions as well as temperature. Careful selection of and specifications for elastomeric materials and the specifics of their application for each water system component should be considered to provide long-term usefulness and minimum degradation (swelling, loss of elasticity, or softening) of the elastomer specified.

II.B.1 *Gasket Degradation Study.* A pipe gasket, having the hardness of a compressed elastomer with a large mass relative to the small exposed surface area, thus experiences minimal degradation. This was validated in a research paper reported in the *Journal AWWA*,* where the pipe gasket degradation in a 110 mg/L chloramine solution was found to degrade just the exposed surface.

III. **Use of This Standard.** It is the responsibility of the user of an AWWA standard to determine that the products described in that standard are suitable for use in the particular application being considered.

III.A. *Purchaser Options and Alternatives.* Considerable supplemental information is required in conjunction with the use of this standard, including, but not limited to, purchaser's documents consisting of detailed plans and specifications. The

* R.W. Bonds. 2004. Effect of Chloramines on Ductile-Iron Pipe Gaskets of Various Elastomer Compounds. *Jour. AWWA*, 96(4):153-160.

purchaser's documents should cover, as a minimum, detailed instructions pertaining to all references in this standard to "as specified" and "in accordance with the purchaser's documents." In addition, the purchaser shall provide specific supplementary information to the purchaser's documents regarding the following:

1. Standard used—that is, ANSI/AWWA C604, Installation of Buried Steel Water Pipe—4 In. (100 mm) and Larger, of latest revision.
2. Whether compliance with NSF/ANSI 61, Drinking Water System Components—Health Effects, is required.
3. Pipe design criteria and type of pipe ends.
4. Pipeline plan and profile drawings including appurtenances, vaults, valves, and existing utilities.
5. Pipe bedding specification and drawing details.
6. Inspection for pipe joints, protective coatings and linings, and pipe zone compaction.
7. Surface restoration.
8. Special handling requirements.
9. Details of other federal, state or provincial, and local requirements (Sec. 4.2).
10. Whether proof testing of the weld-after-backfill method is required for the project-specific conditions, including testing protocols (Sec. 6.2.2). **NOTE:** The exterior protective joint coating, backfill material, pipe wall thickness, and welding procedures should be considered when using this process.

III.B. Modification to Standard. Any modification of the provisions, definitions, or terminology in this standard must be provided by the purchaser.

IV. Major Revisions. Major revisions made to the standard in this edition include the following:

1. Sec. I.B in the foreword, which provides a discussion on ANSI/AWWA C604, was updated.
2. An advisory statement was added in the foreword (Sec. II.B) regarding chlorine and chloramine degradation of elastomers per the AWWA Standards Council directive.
3. Section 2, References, has been updated.
4. *Weld-after-backfill* was added to Section 3, Definitions.
5. The section numbering and subtitles were revised to streamline the document.
6. Additional information on pipe ends was added to Sec. 6.2.2, Pipe Placement for welded lap joints.

7. Sec. 6.2.4, Bolted Flange Joints, was significantly updated and expanded.
8. New Figure 5, Flat-Face Slip-on Ring Flange With Fillet Weld Detail, and Figure 6, Gasket Types, were added.
9. Old Figure 5, Bolt Torque Sequence, was deleted and is now covered in appendix A.
10. Sec. 6.2.10.4, Welded Joint Testing, was updated.
11. Sec. 6.2.12, Thermal Stress Control Joints, was revised.
12. Sec. 6.2.14.1, Tape Wrapping of Field Joints, was revised for clarity.
13. Sec. 6.2.14.3, Heat-Shrink Sleeves on Field Joints, was revised.
14. Additional information was added to Sec. 8.1.3, Internal Bracing.
15. A new appendix A was added to include flange assembly detail information.

V. Comments. If you have any comments or questions about this standard, please call AWWA Engineering and Technical Services at 303.794.7711, FAX at 303.795.7603; write to the department at 6666 West Quincy Avenue, Denver, CO 80235-3098; or email at standards@awwa.org.

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ANSI/AWWA C604-17
(Revision of ANSI/AWWA C604-11)

AWWA Standard

Installation of Buried Steel Water Pipe—4 In. (100 mm) and Larger

SECTION 1: GENERAL

Sec. 1.1 Scope

This standard provides the field installation guidelines for buried steel water pipe, 4 in. (100 mm)* and larger.

The information contained in this standard is intended to be used as a guide to assist in the installation of steel water pipe.

1.1.1 *Conditions that may require additional considerations.* Installations that require special attention, techniques, and materials are not covered by this standard. Some of these installations are

1. Piping through rigid walls or structures.
2. Connections to appurtenances.
3. Piping on supports or on piles aboveground or belowground.
4. Piping subject to significant thermal stresses.
5. Treatment plant or pump-station piping.
6. Industrial piping.
7. Piping in seismic areas.

* Metric conversions given in this standard are direct conversions of US customary units and are not those specified in the International Organization for Standardization (ISO) standards.

8. Piping in high-density, stray-current environments.
9. Piping through unstable soils or soils subject to sliding or soil drag.
10. Piping subject to excessive live loads.
11. Piping with cover less than 3 ft (900 mm).
12. Piping installed by horizontal directional drilling (HDD).

Sec. 1.2 Purpose

The purpose of this standard is to provide the minimum requirements for the installation of buried steel water pipelines, including inspection, unloading, handling, storage, and testing.

Sec. 1.3 Application

This standard is intended to cover typical pipeline construction practices that are deemed adequate for the satisfactory installation of steel water pipelines. Individual project requirements may vary substantially and should always be thoroughly reviewed before bidding or construction startup. For this reason, some practices discussed in this standard may not be suitable for all project conditions, and in some cases, specialized installation techniques may be required that are beyond the scope of this standard.

SECTION 2: REFERENCES

This standard references the following documents. In their latest editions, the referenced documents form a part of this standard to the extent specified herein. In case of conflict, the requirements of this standard shall prevail.

AASHTO^{*} M145—Standard Specification for Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes.

ANSI[†]/AWWA C200—Steel Water Pipe—6 In. (150 mm) and Larger.

ANSI/AWWA C203—Coal-Tar Protective Coatings and Linings for Steel Water Pipe.

ANSI/AWWA C205—Cement-Mortar Protective Lining and Coating for Steel Water Pipe—4 In. (100 mm) and Larger—Shop Applied.

ANSI/AWWA C206—Field Welding of Steel Water Pipe.

^{*} American Association of State Highway and Transportation Officials, 444 North Capitol Street, NW, Suite 249, Washington, DC 20001.

[†] American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.

ANSI/AWWA C207—Steel Pipe Flanges for Waterworks Service, Sizes 4 In. Through 144 In. (100 mm Through 3,600 mm).

ANSI/AWWA C209—Cold-Applied Tape Coatings for Steel Water Pipe, Special Sections, Connections, and Fittings.

ANSI/AWWA C210—Liquid-Epoxy Coatings and Linings for Steel Water Pipe and Fittings.

ANSI/AWWA C214—Tape Coatings for Steel Water Pipe.

ANSI/AWWA C216—Heat-Shrinkable Cross-Linked Polyolefin Coatings for Steel Water Pipe and Fittings.

ANSI/AWWA C217—Microcrystalline Wax and Petrolatum Tape Coating Systems for Steel Water Pipe and Fittings.

ANSI/AWWA C219—Bolted Sleeve-Type Couplings for Plain-End Pipe.

ANSI/AWWA C222—Polyurethane Coatings for the Interior and Exterior of Steel Water Pipe and Fittings.

ANSI/AWWA C223—Fabricated Steel and Stainless-Steel Tapping Sleeves.

ANSI/AWWA C227—Bolted, Split-Sleeve Restrained and Nonrestrained Couplings for Plain-End Pipe.

ANSI/AWWA C602—Cement-Mortar Linings of Water Pipelines in Place—4 In. (100 mm) and Larger.

ANSI/AWWA C606—Grooved and Shouldered Joints.

ANSI/AWWA C651—Disinfecting Water Mains.

ASTM D2487—Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System).

AWS* D1.1/D1.1M—Structural Welding Code—Steel.

AWWA M11—*Steel Pipe—A Guide for Design and Installation.*

SECTION 3: DEFINITIONS

The following definitions shall apply in this standard:

1. *Bell-and-spigot (or lap) joint:* A circumferential joint in which one of the members joined overlaps the other.
2. *Bevel:* The angle formed between the prepared edge of a pipe end and a plane perpendicular to the longitudinal axis of the pipe. Bevels are generally used for butt-joint welding of pipe ends.

* American Welding Society, 550 Northwest LeJeune Road, Miami, FL 33126.

3. *Butt joint:* A pipe joint in which the two pipe ends are aligned approximately in the same plane and do not overlap. This joint configuration is commonly beveled and may include a backup ring on the side opposite of which field joint welding is to be performed.

4. *Constructor:* The party that provides the work and materials for placement or installation.

5. *Dewatering:* The removal of water in and around construction operations. This usually pertains to underground water within construction zones, which can adversely affect the construction activities.

6. *Fillet weld:* A weld of approximately triangular cross section the throat of which lies in a plane disposed approximately 45 degrees with regard to the surface of the parts joined. The size of the fillet weld is expressed in terms of the width, in inches, of one of its adjacent fused legs (the shorter leg, if unequal).

7. *Final backfill:* Final backfill begins at top of initial backfill and continues to the top of trench or finished grade.

8. *Grade:* The elevation of a specific point of a structure or pipeline (i.e., invert, centerline [springline], or top of pipe). This elevation is usually measured relative to established survey points at the project.

9. *Haunch:* The area of the trench that begins at the bottom of the pipe and generally extends up to one-third of the pipe diameter.

10. *Initial backfill:* Initial backfill begins at the top of the bedding or haunch area and continues to the top of pipe.

11. *Manufacturer:* The party that manufactures, fabricates, or produces materials or products.

12. *Mechanical cutting:* The severing of materials using a power cut-off saw with a thin flat blade having a continuous line of teeth on its edge or high-speed abrasive disk.

13. *Miter:* The angle between the cut of a pipe end and a line drawn perpendicular to the longitudinal axis of the pipe. Miters are used on bells, butt joints, or to fabricate elbows and are used to facilitate pipe laying at changes in horizontal or vertical alignment.

14. *Nominal diameter or size:* The commercial designation or dimension by which pipe is designated for simplicity. Commonly, it is the finished inside diameter after lining.

15. *Nominal weight per foot (for pipe):* The theoretical weight, per foot, calculated from the wall thickness, as distinguished from the actual and measured

weight per foot of the finished pipe. A steel unit weight of 0.284 lb/in.³ (or 490 lb/ft³) shall be used when calculating weight per foot. Unit weights of 0.087 lb/in.³, or 150 lb/ft³, for cement mortar shall be used when calculating weight per foot.

16. *Pipe bedding:* The material immediately under the pipeline and by which the pipeline is supported. This material is usually of a specific description and may simply be the reuse of the originally excavated material.

17. *Pipe embedment:* The area comprising the pipe bedding plus the initial backfill.

18. *Plain-end pipe:* Pipe that is not threaded, beveled, belled, or otherwise given a special end configuration.

19. *Plans:* Drawings normally prepared by an engineer employed or retained by the purchaser or system-operator showing the location and details for the construction of the pipeline and appurtenances.

20. *Purchaser:* The person, company, or organization that purchases any materials or work to be performed.

21. *Purchaser's documents:* Requirements established by the purchaser, outlining minimum acceptable design, manufacture, quality of installation, or any other criteria the purchaser deems necessary for the procurement of the product required. Installation specifications may incorporate this standard by reference but should also include specification requirements for matters not covered by the standard.

22. *Random lengths:* Pipe lengths as produced in a pipe mill to which no special treatment is given to make the lengths uniform.

23. *Special section:* Any piece of pipe other than a normal full-length straight section. This includes but is not limited to elbows, pipe with outlets, short pieces, reducers, adapter sections with special ends, and other nonstandard sections.

24. *Specified lengths:* Sections of finished pipe the length dimensions of which do not vary from a fixed figure specified by the purchaser by more than the tolerance set forth.

25. *Supplier:* The party that supplies material or services. A supplier may or may not be the manufacturer.

26. *Underground utilities:* Previously installed utilities that are located within the right-of-way of a pipeline or structure. These utilities commonly include gas, power, water, cable TV, sewer, fiber-optic cable, steam lines, and telephone lines.

27. *Utility location service:* The cooperative organization of major utilities to provide services for the location and safe construction practices surrounding their respective utilities. These utilities often provide a site representative during construction when deemed necessary by the utility.

28. *Weld-after-backfill:* Weld-after-backfill is the sequence of assembling a welded lap joint, applying the exterior coating(s), backfilling the pipe, then welding the inside joint at a later time.

SECTION 4: PRELIMINARY INFORMATION

Sec. 4.1 Permeation

The selection of materials is critical for potable water, wastewater, and reclaimed water service, and for distribution piping in locations where there is likelihood the pipe will be exposed to significant concentrations of pollutants composed of low-molecular-weight petroleum products, organic solvents, or their vapors. Documented research has shown that pipe materials (such as polyethylene, and polyvinyl chloride) and elastomers, such as those used in jointing gaskets and packing glands, are subject to permeation by low-molecular-weight organic solvents or petroleum products. If a potable water, wastewater, or reclaimed water pipe must pass through such a contaminated area or an area subject to contamination, consult with the manufacturer regarding permeation of pipe walls, jointing materials, and so on *before* selecting materials for use in that area.

Sec. 4.2 Materials

Materials shall comply with the requirements of the Safe Drinking Water Act and other federal regulations for potable water, wastewater, and reclaimed water systems as applicable.

Sec. 4.3 Preconstruction Planning

The installation of steel pipelines usually involves multiple suppliers and subcontractors that have varying preparation requirements. For this reason, a preconstruction meeting is strongly recommended to confirm and coordinate the critical path aspects of all involved parties. In particular, pipe and valve materials are usually manufactured to fit specific locations of the project and often require an extended lead time for the purchase of raw material, drawing preparation, and drawing approvals that must precede construction activities. Any preconstruction planning meeting initiated by the purchaser should include all essential suppliers

and subcontractors. During the meeting, a schedule should be confirmed that is agreeable to all parties. The meeting also affords all parties the opportunity to elaborate on their respective preparations, such as procurement of materials, preparation of drawings, and submittals. The constructor shall provide the starting location and direction of construction. Care should be taken when preparing the construction schedule as later changes in construction plans may affect shop drawings, laying schedules, delivery dates, and other parties.

SECTION 5: TRENCH CONSTRUCTION

Sec. 5.1 Alignment and Grade

Pipelines shall be laid and alignment maintained to the required horizontal line and vertical grade established in the purchaser- and constructor-approved layout drawings for the project subject to allowable tolerances. Valves and special sections shall be installed at the required locations unless field conditions warrant otherwise and such changes are agreed to by the purchaser and constructor. Valve-operating stems shall be oriented in a manner to allow proper operation.

5.1.1 *Prior investigation.* Prior to excavation, investigation shall be made to the extent necessary to determine the precise location of existing underground utilities, structures, and conflicts. This will require the constructor to contact the utility location service for proper coordination and location of utilities and then perform excavations to verify the elevation at the point of intersection with the proposed pipe excavation. In addition, care shall be exercised during excavation to avoid damage to existing structures, which may not be identified by the utility location service. Special precautions shall be taken when the pipeline being installed crosses or is adjacent to a facility that is cathodically protected. When obstructions that are not shown on the purchaser's documents are encountered during the progress of work and interfere so that an alteration is required, such alterations or deviations in line and grade or the removal, relocation, or reconstruction of the obstructions shall be performed in accordance with the purchaser's documents.

5.1.2 *Clearance.* When crossing existing pipelines or other structures, alignment and grade shall be in accordance with the project requirements. Installed pipe and structures shall provide clearance as required by federal, state or provincial, and local regulations. Wherever possible, pipe and structures shall have a

minimum clearance of 12 in. (300 mm) from existing pipelines or structures to allow for proper compaction.

Sec. 5.2 Trench Construction

The trench shall be excavated to the required alignment, depth, and width specified or shown on the purchaser's documents and shall be in conformance with all federal, state or provincial, and local regulations for the protection of workers.

5.2.1 Trench preparation. Trench preparation shall proceed in advance of the pipe installation. The amount of open trench length allowed may be limited by the amount of nonbackfilled pipe, the purchaser's documents, safety, and public impact considerations (such as traffic, slope, etc.).

5.2.2 Dewatering discharges. Discharges from trench dewatering pumps shall be directed away from the trench in order not to affect trench stability, and shall be in accordance with federal, state, and local point-discharge requirements.

5.2.3 Excavated material. Excavated material shall be placed in a manner that will not obstruct the work, endanger workers or the public, or obstruct sidewalks, driveways, roadways, and other structures. If obstruction of such structures becomes necessary, the constructor shall plan for alternative means to accommodate the public. Placement of excavated material shall be done in compliance with federal, state or provincial, and local regulations.

5.2.4 Pavement removal. Removal of pavement and road surfaces shall be a part of the trench excavation. The amount removed shall depend on the width of trench required for installation of the pipe, including safety requirements and the dimensions of the area into which valves, specials, manways, or other structures will be installed. Methods such as sawing, drilling, or chipping shall be used to ensure the breakage of pavement along straight lines.

5.2.5 Trench width. The width of the trench at the top of the pipe shall be as dictated by the purchaser's documents or as necessitated by safety requirements. In any case, the trench width shall provide ample clearance to permit the pipe to be installed and joined properly, and to allow the backfill to be placed in accordance with the purchaser's documents and ensure elimination of voids in the haunch area and ensure proper placement and compaction of initial backfill materials. If mechanical compaction is required of the initial backfill materials, trench width shall provide clearance on each side of the pipe to allow room for compaction equipment. The trench width at the bottom of the pipe will be governed by the space required for compaction or consolidation equipment. In addition, trenches shall be of such extra width, when required, to permit the placement of sheeting,

bracing, and appurtenances as required by the safety requirements of the agency having jurisdiction.

5.2.6 *Trench bedding.* The trench shall be excavated and bedding installed. The bedding shall provide uniform support for the full length of the pipe barrel, except that a slight depression may be provided to facilitate the removal of pipe slings or other lifting devices without damaging the pipe coating. Pipe bedding and backfill material shall be installed so as to avoid abrasion or other damage to the coating on the pipe.

5.2.7 *Bell holes.* Holes for the pipe joints shall be provided at each pipe end. Holes shall be adequately sized for completing welding or coupled joints when required and any external coatings, but shall be no larger than necessary to allow joint assembly, inspection activities, or as required for safety considerations.

5.2.8 *Rock conditions.* If excavation of rock is necessary, all rock shall be removed to provide a clearance below and on each side of all pipe, valves, and fittings. The minimum clearance shall be 6 in. (150 mm) for pipe with an outside diameter (OD) up to 24 in. (600 mm) and 10 in. (250 mm) for pipe with an OD greater than 24 in. (600 mm). When the excavation is completed, a layer of appropriate subgrade material (see Sec. 6.4.1) shall be placed on the bottom of the trench, graded, and compacted to provide uniform support for the entire length of pipe. Loose bedding material shall be placed on the compacted subgrade material up to the bottom of the pipe. These clearances and bedding procedures shall also be observed for pieces of concrete or masonry and other debris or subterranean structures, such as masonry walls, piers, or foundations, that may be encountered during excavation.

5.2.9 *Previous excavations.* Should the trench pass over a sewer or other previous excavation, the trench shall be sufficiently compacted to provide support equal to that of the native soil or conform to other regulatory requirements in a manner that will prevent damage to the existing installation.

5.2.10 *Blasting.* Blasting for excavation shall be permitted only after securing approval(s) and establishing the hours of blasting as required by the purchaser's documents. The blasting procedure, including protection of existing utilities, persons, and property, shall be in strict accordance with federal, state or provincial, and local regulations.

5.2.11 *Protection of existing structures.* Temporary support, adequate protection, and maintenance of all underground and surface structures, drains, sewers,

and other obstructions encountered in the progress of the work shall be provided in accordance with the purchaser's documents and applicable regulations.

5.2.12 *Unsuitable subgrade material.* When the subgrade is found to include ashes, cinders, refuse, organic material, or other unsuitable material, such material shall be removed to at least 6 in. (150 mm) below the bottom of the pipe for pipe with an outside diameter (OD) up to 24 in. (600 mm) and 10 in. (250 mm) for pipe with an OD greater than 24 in. (600 mm). The removed material shall be replaced with clean, suitable subgrade material in accordance with the purchaser's documents or as directed by the purchaser. Once unsuitable material is removed or replaced, the bedding material shall be placed and graded so that it will provide uniform support for the entire length of the pipe.

5.2.13 *Unstable subgrade.* When the bottom of the trench or the subgrade consists of material that is unstable to such a degree that it cannot be removed, a foundation for the pipe and/or appurtenance shall be constructed in accordance with the purchaser's documents or as directed by the purchaser.

SECTION 6: PIPE INSTALLATION

Sec. 6.1 General Pipe Installation

Proper implements, tools, and facilities shall be provided and used for the safe and convenient performance of the work. All pipe, fittings, and valves shall be lowered carefully into the trench by means of a backhoe or crane, using nylon slings, guide ropes, or other suitable tools or equipment, in such a manner as to prevent damage to the pipe, protective coatings, and linings. Pipe shall not be dropped or dumped into the trench. The trench shall be dewatered prior to installation of the pipe and maintained until the pipeline is substantially covered as necessary to prevent pipe from floating.

At all times during construction of the pipeline, precautions shall be taken to prevent damage to the protective coating. Coating damaged during installation shall be repaired in accordance with this and other applicable AWWA standards and the coating manufacturer recommendations.

6.1.1 *Examination of material.* All pipe, fittings, coatings, and appurtenances shall be examined carefully for damage and other defects upon arrival at the installation site and immediately before assembly in the trench. Defective

materials shall be marked and held for final disposition as required by the purchaser's documents.

6.1.2 *Pipe ends.* All deleterious materials shall be removed from the ends of each pipe. For bell-and-spigot pipe, the outside of the spigot end and the inside of the bell shall be wiped clean and dry so that they are free from dirt, sand, grit, and other foreign matter before the pipe is installed.

6.1.3 *Pipe cleanliness.* As installation progresses, no debris, tools, clothing, or other materials shall be allowed to accumulate in the pipe during construction and shall be prevented from entering the pipe while it is being placed in the trench.

6.1.4 *Direction of bells.* It is common practice to lay lap-welded pipe joints with the spigot facing the direction in which work is progressing. For rubber-gasketed pipe, common practice is to lay the pipe joints with the bell facing the direction in which work is progressing to prevent debris from being scooped into the bell. The direction of the bells is not functionally related to the direction of flow within the system.

6.1.5 *Pipe end caps.* When pipe laying is not in progress, cover, cap, or secure the open ends of pipe where required. If end caps are used, they shall remain in place until the trench work proceeds. When pipe end caps are in place, care must be taken to prevent pipe flotation should the trench fill with water.

6.1.6 *Pipe on steep grades.* On grades exceeding 10 percent, depending on joint type and trenching and backfill practices, the pipe may need to be laid uphill or otherwise held in place by approved methods. Pipe may be laid downhill to prevent material from being dislodged during excavation potentially damaging the pipe or causing injury to personnel working on the pipe. Pipe with unrestrained joints laid downhill may need to be restrained to prevent pipe segments from sliding downhill during backfilling.

Sec. 6.2 Joint Assembly and Testing

Proper implements, tools, and facilities shall be provided and used for the safe and convenient performance of the work. The types of joints covered in this standard include gasketed, flanged, coupled, expansion, and welded, all of which have specific applications. The joint types required for a project will be dictated by the purchaser's documents.

6.2.1 *Rubber-gasketed joints.* The most common gasketed joint consists of a bell-and-spigot end configuration formed directly into the steel pipe cylinder or attached to the steel pipe cylinder. The spigot end includes a groove that retains a

gasket. The gasket groove and the bell end of the mating pipe shall be cleaned thoroughly. When the spigot is inserted into the bell, the gasket compresses between the steel surfaces to form a watertight seal. Rubber-gasketed joints shall be assembled as described in Sec. 6.2.1.1 and illustrated in Figures 1 and 2.

6.2.1.1 Pipe placement for O-ring rubber-gasketed joints. Mark the outside of the pipe at the quarter points for the minimum stab depth. This dimension is provided on the shop joint detail drawings. Lift the pipe using the appropriate method. On steep slopes, it may be advisable to use slings as chokers. Visually inspect the O-ring gasket for any visible defects, cuts, tears, or excessive stretching. Stretch the O-ring gasket over the pipe spigot end by hand or by using a dull pry bar (to avoid cuts or tears), and then carefully seat the gasket into the O-ring groove on the spigot (see Figure 1). After placement, relieve tension in the gasket by running a dull object, such as a wooden dowel, between the gasket and the spigot groove around the pipe circumference several times. Just prior to stabbing, apply a light coat of vegetable-based pipe lubricant to the spigot-end exterior and the bell-end interior, being sure to keep the joint clean. The spigot end shall be stabbed approximately 1 in. (25 mm) into the bell end, with the two mating pieces

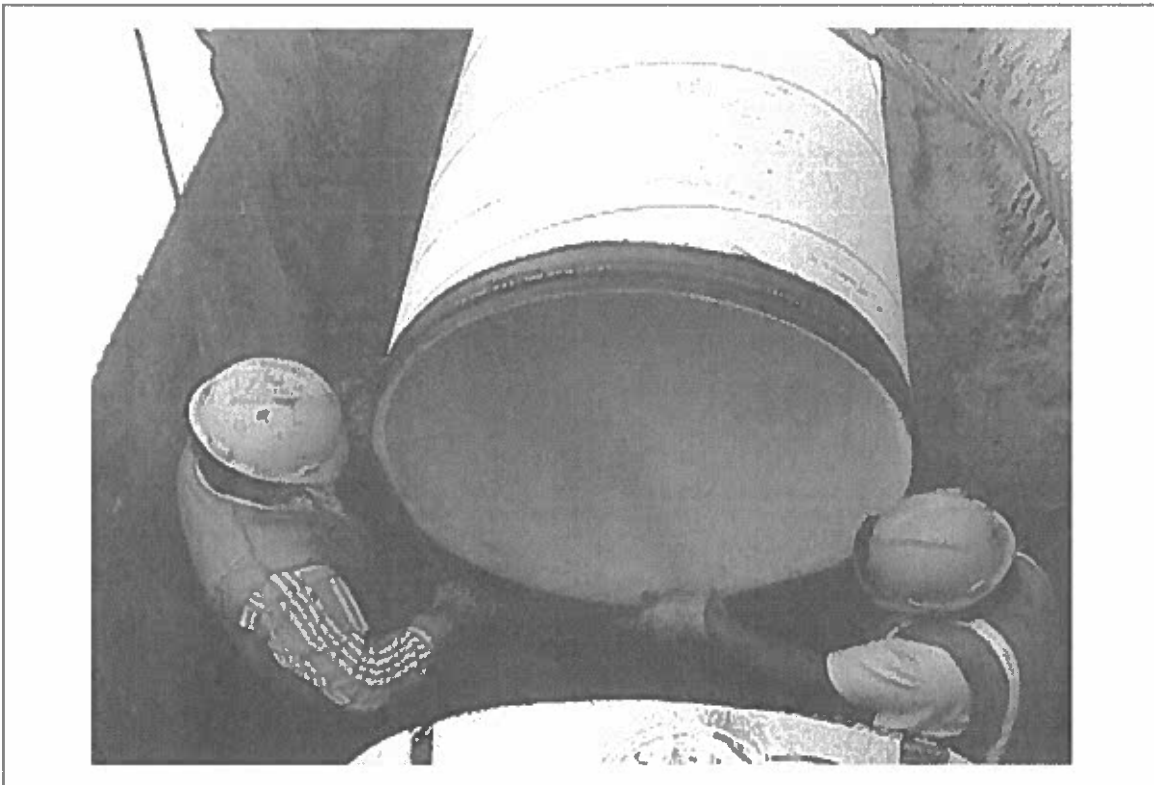


Figure 1 Typical O-ring gasket assembly

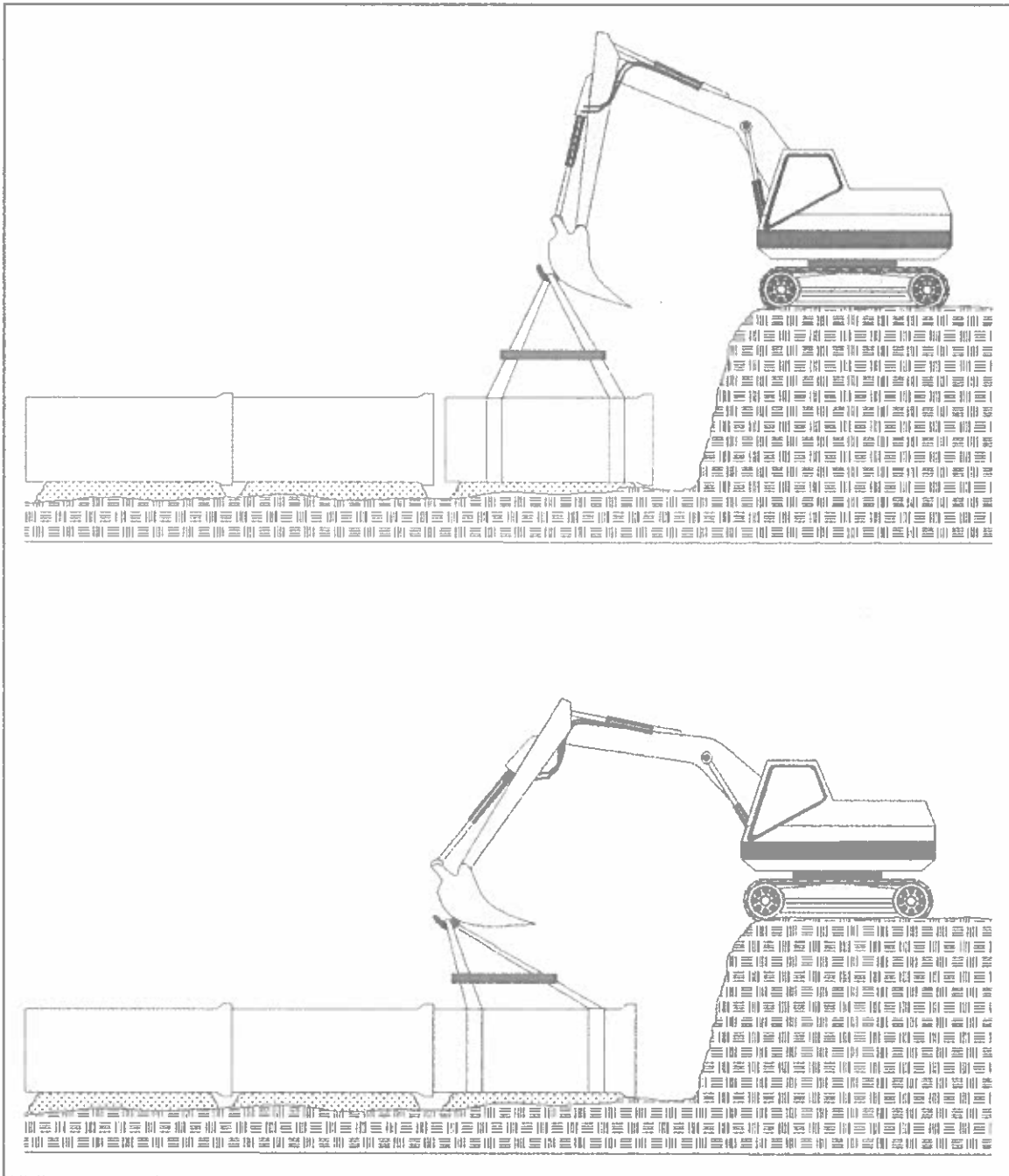


Figure 2 Typical installation of pipe with gasketed bell-and-spigot joints

in reasonably straight alignment (see Figure 2) ensuring that the gasket has been captured within the bell. The spigot shall then be engaged to the manufacturer's recommended distance. Rubber-gasketed pipe may be joined using a choker sling attached to the excavator bucket and drawing the pipe joint to full engagement. Small-diameter pipe spigots may be pushed into the bell with a long pry bar. Large-

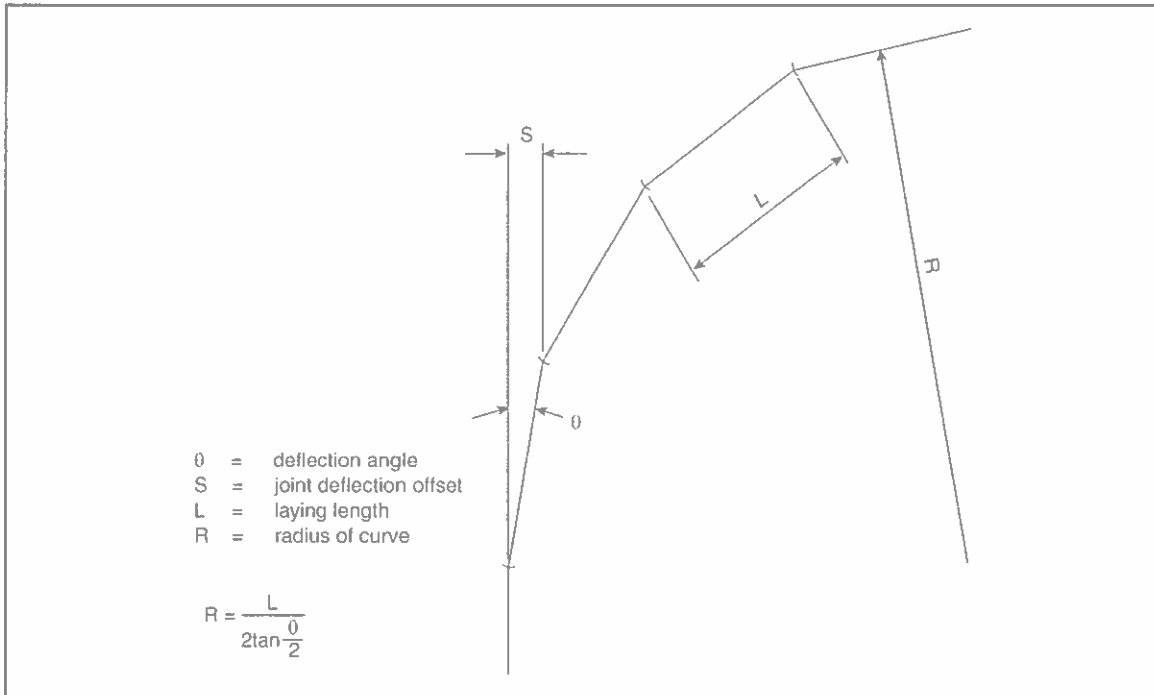


Figure 3 Joint deflection

diameter pipe may be pushed into the bell using the bucket of the excavator and appropriately sized timber, which is used to equalize the assembly loads and reduce the risk of damage to the bell, or pulled together using a winch or come-a-long. As each length of pipe is placed in the trench, the pipe shall be brought to the correct line and grade. After the joint is properly engaged, deflect the joint, if required, within the prescribed limits in Sec. 6.2.3 (see Figure 3) or the purchaser's documents. The pipe shall be secured in place with approved backfill material.

6.2.1.2 Rubber-gasketed joint testing. After the pipe has been laid to final grade, the rubber-gasketed joint shall be tested using a feeler gauge. This test ensures that the gasket has not rolled out of the groove, or "fish-mouthed." Perform this test by inserting a feeler gauge from the outside of the joint between the bell and spigot until reaching metal-to-metal contact between the spigot and bell, or the gasket. Continue completely around the pipe circumference to ensure the gasket is properly seated. Do not force the feeler gauge past the gasket. The only purpose of the feeler gauge test is to determine whether the gasket has rolled out of the groove during installation; it is not to determine the amount of clearance, if any, between the spigot and the bell.

If the gasket has disengaged at any point around the joint, the joint shall be pulled apart and the gasket shall be removed and discarded. Install a new gasket in accordance with procedures stated in Sec. 6.2.1.1. Alternatively, if a pipe segment cannot be removed, seal-weld the interior of the joint, or insert a rolled steel round bar into the flare of the bell and seal-weld the round bar to the bell and spigot.

6.2.2 Pipe placement for welded lap joints. Mark the outside of the pipe at the quarter points for the required stab depth range. This dimension is provided on the joint detail drawings. It should be noted that interior lap-welded pipe should never be engaged to the point where the weld would be within 1 in. (25 mm) of the tangency of the bell formation radius. See Sec. 6.2.10.1 for more detail. Standard lap-welded joints consist of a single fillet weld made on either the interior or exterior of the pipe. On steep slopes, it may be advisable to use slings as chokers. Pipe ends that have coatings or primers on the hold-back area that will be welded will require removal of these materials prior to engaging the two pipe ends because the engagement of the bell and spigot will not allow cleaning after engagement. Coatings or primers even when advertised as “weldable” are not allowed to remain on the pipe ends. Lower the pipe segment, bell end first, at an approximate 5-degree to 10-degree angle relative to the previously laid pipe segment. This will allow the bell edge to overlap the mating spigot (of the previously laid pipe) to the proper stab depth mark. On large-diameter pipe, a small tack weld may be placed onto the exterior of the bell and spigot at the “field top.” This tack will act as a hinge that will guide the remainder of the bell insertion as the pipe is lowered (see Figure 4). The tack welds may remain as part of the permanent weld if the welder is properly qualified and the weldment meets the requirements of ANSI/AWWA C206 and the purchaser’s documents. Under certain circumstances, some constructors may choose to insert the spigot straight into the bell by methods described in Sec. 6.2.1.1. As each length of pipe is placed in the trench, the joint shall be assembled and checked for stab depth, and the pipe shall be brought to correct line and grade. After the joint is properly engaged, deflect the joint, if required, within the prescribed limits in Sec. 6.2.3 or the purchaser’s documents. The clearance between faying surfaces shall be within the prescribed gap limits between the bell and spigot. As required by the purchaser’s documents, proceed with the welding of the joint in accordance with ANSI/AWWA C206. If required by the purchaser’s documents, perform nondestructive testing of the weld. Upon completion of the welding and/or weld testing, apply field joint coating per the appropriate standard. The pipe shall then be secured in place with

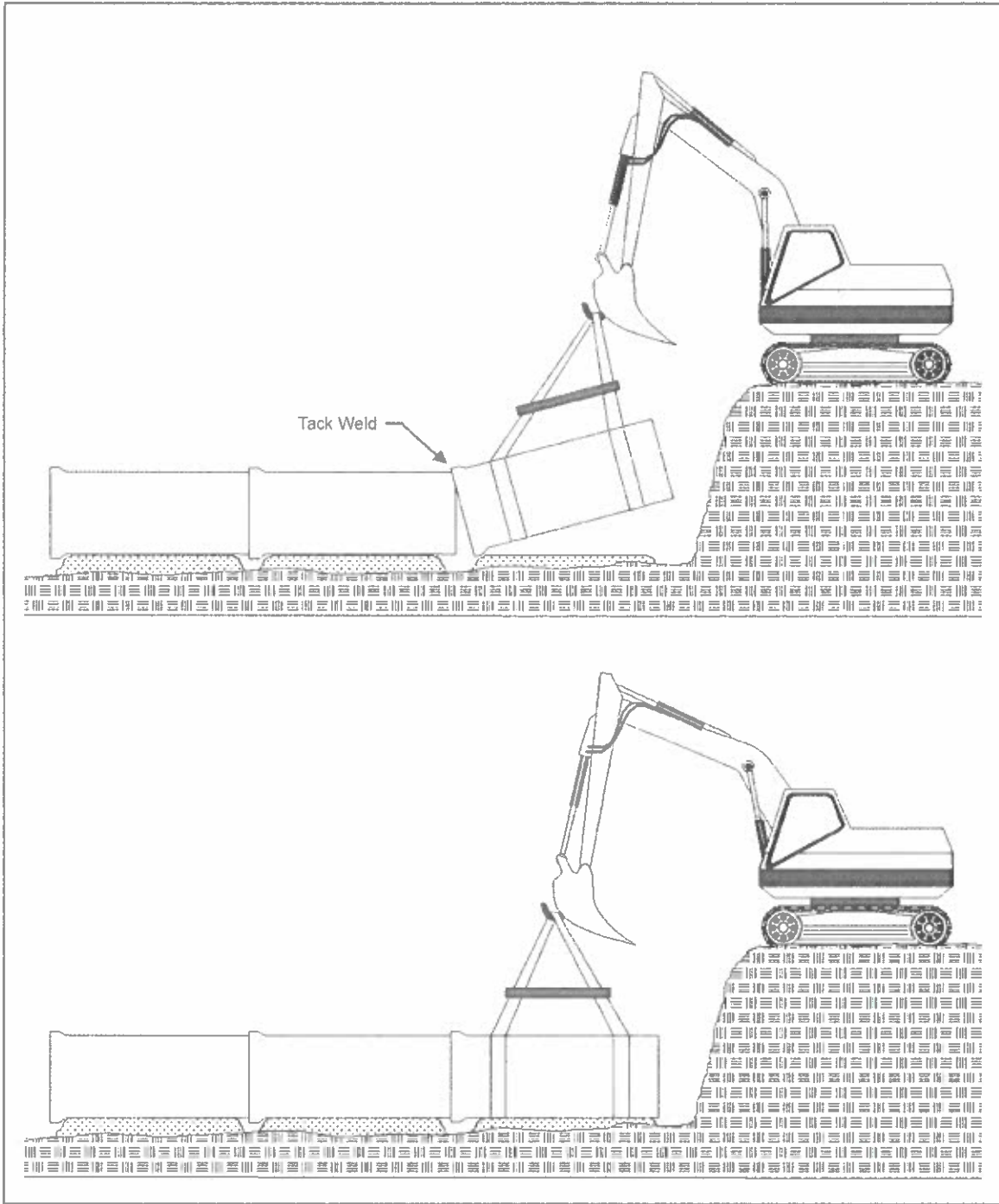


Figure 4 Typical installation of pipe with welded bell-and-spigot joints

approved initial backfill material. After backfilling the pipe, the interior lining at the joint shall be completed.

Weld-after-backfill is also an acceptable method for welding the pipe. This method involves assembling the pipe joint as described above, deflecting the joint if required, applying the appropriate exterior protective coating to the joint, and backfilling the pipe prior to welding the interior joint. The interior joint weld is completed after backfill is placed around the pipe and joint. With inside single-welded joints, this method can reduce or eliminate thermal stress issues associated with welding pipe exposed to the sun or atmosphere, which can eliminate the need for thermal stress control joints. Once interior welding and/or weld testing is complete, the interior lining at the joint may be completed. Project-specific conditions and materials can vary, such as the exterior protective joint coating, backfill materials, pipe wall thickness, the requirement for an exterior joint weld, and welding procedures. These variations may warrant testing to verify the method at the start of construction.

6.2.3 Joint deflection. When it is necessary to deflect rubber-gasketed or lap-welded pipe joints from a straight line, the amount of joint deflection shall not exceed the amount that would affect the watertight seal for rubber-gasketed joints or the amount that results in a field weld closer than 1 in. (25 mm) to the nearest point of tangency to a bell radius or less than the minimum insertion for lap-welded pipe as defined in ANSI/AWWA C206 (see Figure 3). The pull is further described as the dimension in which the pipe joint insertion varies when measured from opposite sides (180 degrees apart). This pull shall not diminish the minimum required insertion dimension or include gaps beyond the limits in ANSI/AWWA C206 between the bell and spigot. By using this joint pull, pipe can be aligned with long-radius curves as well as minor offsets during pipeline construction.

6.2.4 Bolted flange joints. Flange joints are made up of the flange, the fasteners, and the gasket. Obtaining a leak-free bolted flange joint requires following correct assembly procedures. These assembly guidelines reflect AWWA Manual M11 and ANSI/AWWA C207 combined with additional “best practices” recommendations. The guidelines provide general information for installers on the important points of joint components, bolting patterns, and bolt tightening. More detailed supplemental information is provided in appendix A.

6.2.4.1 Flanges. Flanged ends compliant with ANSI/AWWA C207 have a widened flat ring that slips over the end of the pipe and is attached with external and internal fillet welds (see Figure 5).

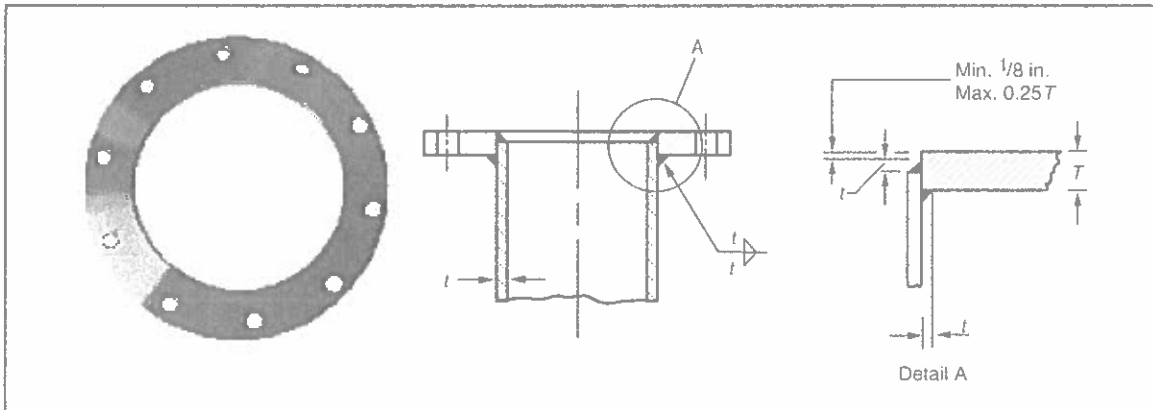


Figure 5 Flat-face slip-on ring flange with fillet weld detail

Bolts fit through the flange into a mating flange or sometimes directly into a pump, valve, or other component. Because the flanges form the foundational structure of the joint, some important considerations that the installer must verify are described in the following sections.

6.2.4.1.1 Class and size. Flanges are manufactured according to the standards in ANSI/AWWA C207. C207 flanges are “flat faced” (meaning their sealing surface is uniformly flat) and “slip on” (meaning that the flange slips over the end of the pipe as opposed to being butt welded to its end). The most common type is the “ring” flange (which is symmetrical and flat on both sides). Flanges are grouped into classes according to their pressure ratings at atmospheric temperatures. Nominal sizes are specified by their internal diameter, which corresponds to and is slightly larger than the outside diameter of the corresponding pipe. Flange information should be impression stamped on the outside edge of the flange as specified in ANSI/AWWA C207.

6.2.4.1.2 Sealing surface condition. Check for scratches or damage to the sealing surfaces that may cause leaks. Special attention should be given to scratches that cross the sealing surface and damage the serrations.

6.2.4.2 Alignment. Flange faces must be parallel and in line with each other before bolting begins and without the need to apply external force to bring them or hold them in proper position. To ensure a successful leak-tight flange connection, the following general guidelines should be followed:

1. *Pipe centerline alignment:* Should be within $\frac{1}{8}$ in. (3 mm) up or down, right or left as measured by a straight edge across the joint, or the bolts will not fit
2. *Parallelism:* The gap between the flanges must be uniform to within $\frac{1}{8}$ in. (3 mm) before tightening within any 30-degree arc around the flange.

3. *Flange gap clearance:* Minimum gap must allow the gasket to be inserted without interference. In general, the gap before tightening should not exceed three times the gasket thickness at any point around the circumference.

4. *Bolt hole alignment:* Bolt holes must not be out of rotational alignment by more than $\frac{1}{8}$ in. (3 mm), or the bolts will not fit.

NOTE: To meet these conditions it may be necessary to adjust the pipe position, pipe supports, or flange placement on the pipe. Given the relatively low lateral stiffness of ring flanges, especially in large diameters, and the inevitable bending moments caused by handling, pipe sag, and residual welding stresses, it is permissible to apply no more than 20 percent of the final bolt torque to selected bolts to adjust flange gap and uniformity spacing before patterned tightening begins. See appendix A for additional information on flanges.

6.2.4.3 Fasteners. The term *fasteners* refers to the bolts, nuts, and washers used to join the pipe sections or other components through the flanges. Their purpose is to create and maintain a clamping force sufficient to seal the joint as well as to provide the needed structural strength to the pipe system. These components are made of high-strength carbon steel and must comply with the specifications in ANSI/AWWA C207 with respect to grade and dimensions. Flange bolts may also be “studs” with nuts on both sides of the joint. It takes the proper tools to load these fasteners to seal pressure joints such as those in water service. See appendix A for additional information on fasteners.

6.2.4.4 Gaskets. Bolted flange joints depend on a gasket to seal the gap between the mating flanges. As bolts are tightened, the gasket is compressed to fill voids and minor imperfections in the flange faces resulting in a watertight seal. With too little compression, the gasket will not conform to fill the spaces and the gasket may be forced out of the joint when the system is pressurized. With too much compression, the gasket may be crushed, pinched, or cut, which could also result in leakage. Full-face gaskets contact the entire mating surface of the flanges; while ring gaskets fit inside the bolt circle (see Figure 6). Gaskets for water service are typically made of some type of compressed fiber sheet or one of several elastomeric (rubberlike) compounds. These soft yet resistant materials are ideal for the moderate temperatures and pressures encountered in water service. See appendix A for important considerations for the installation contractor concerning gaskets.

6.2.4.5 Assembly lubrication. Friction is substantially reduced by the application of a lubricant. Nut and bolt assemblies have two major points of friction: (1) within the mating threads, and (2) under the face of the nut or bolt head

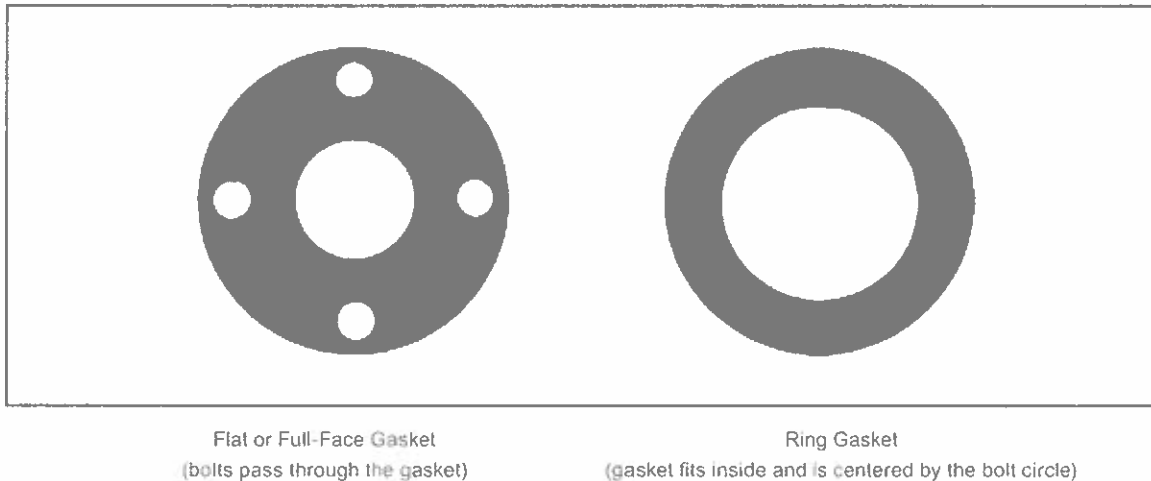


Figure 6 Gasket types

where it contacts the flange or washer. Therefore, lubricant must be applied to both the threads and under the nut to be effective. Different lubricants have different friction coefficients represented as a K value or “nut factor.” The K value must be known in order to accurately convert the turning force of torque into the clamping force of bolt load. (See AWWA Manual M11 for more details on torque.)

6.2.4.6 Fastener condition and washers. As noted above, damaged or corroded fasteners inhibit the efficient and accurate conversion of torque to bolt load. Ensure that all nuts are free-running by hand before torquing. It is recommended that hardened washers be used under all nuts not only because they protect the flange face from erosion but also because of their significant effect on required torque. (See AWWA Manual M11 for more details.)

6.2.4.7 Tools. Only calibrated tools can produce the measured torque appropriate for pressure flange bolting. These may include manual, electric, battery, and hydraulic-powered torque wrenches, impact tools or hammers, and slugging wrenches. Hydraulic wrenches can be used together in interconnected sets, which allow for simultaneous tightening around the flange. Powered tools, especially multiple hydraulic wrenches, should be favored for tightening all joints with bolts over 1 in. (25 mm) in diameter or where large quantities or large pipe diameters are involved. (See appendix A for suggestions.)

6.2.4.8 Training. Pressure joint bolting is highly technical work where the success of an entire installation project may depend on the skills of the bolting assemblers. Work by qualified and experienced bolters is paramount to the safety,

quality, and schedule of the job. Information on bolted-joint training programs is available online.

6.2.4.9 Bolting patterns. Bolt loading or tensioning compresses the gasket and seals flanged joints. Bolts must be tensioned evenly to ensure a proper seal, which is the purpose of a bolt tensioning pattern and bolting plan. A complication to achieving uniform tightness is that bolts act like interactive springs, where tightening one bolt will tend to loosen the effective load in its neighbors. This interdependence among bolts in a flange is called *bolt interaction* or *cross-talk*. Bolts should be tightened according to an approved pattern and in gradually increasing steps to final torque. The primary goals for this sequential and incremental tightening are to

- Apply sufficient bolt load to maintain a leak-free connection
- Achieve uniform bolt load and therefore uniform gasket stress around the flange
- Maintain parallel closure of the flanges during tightening
- Minimize excessive loading or unloading of the gasket during tightening
- Avoid localized over compression or crushing of the gasket
- Reduce tool movement to improve efficiency

See appendix A for more detailed information and examples.

6.2.4.10 Torque. Torque is the product of a force multiplied by the perpendicular distance over which the force is applied. In bolting terms, torque is usually expressed in units of foot-pounds. But torque is not the same as bolt load or tension. It is bolt load that compresses the gasket and creates a seal. How efficiently torque is converted to bolt load depends on a number of factors, the most important of which is lubrication. A “dry” bolt and nut may require up to three times the amount of torque to generate the same load on the gasket, due to the differences in friction. Fastener tightness requirements may vary according to joint design, the gasket material, and operating pressure inside the pipe. Reliable gasket sealing is generated by tightening the fasteners in a controlled and uniform manner. In addition to seating the gasket, tension in the fasteners allows the connection to resist movement and keep the pipe connection stable. Since the amount of tension in the fastener is difficult to measure directly, torque is used as a convenient way to approximate the desired load. Most pressure joints are tightened to approximately 50 percent of bolt yield, depending on the gasket material, and the corresponding lubrication instructions. Refer to AWWA Manual M11 or the gasket supplier for torque values and additional information on torque.

6.2.5 *Transition couplings.* Transition couplings may be required for joining different types or sizes of pipe. Such transition devices are typically available. When ordering, the outside diameter of the pipe ends shall be given.

6.2.6 *Tapping sleeves.* Tapping sleeves are a means of making branch connections to existing pipelines. The procedures for proper installation of tapping sleeves shall follow the manufacturer's recommendations and ANSI/AWWA C223.

6.2.7 *Sleeve couplings.* Follow the manufacturer's recommendations and ANSI/AWWA C219 for their installation.

6.2.8 *Split-sleeve couplings.* Follow the manufacturer's recommendations and ANSI/AWWA C227 for their installation.

6.2.9 *Grooved and shouldered joints.* Follow the manufacturer's recommendations and ANSI/AWWA C606 for their installation.

6.2.10 *Welded joints.* Welding shall meet the requirements of ANSI/AWWA C206 and the purchaser's documents for the project. The need for welded joints will vary by project and will be identified in the purchaser's documents. The single lap-weld joint is the most commonly used configuration.

WPSs (welding procedure specifications), welders, and welding operators shall be qualified under the requirements in ANSI/AWWA C206. Preheat and interpass temperature maintenance is often required prior to welding and during welding to prevent cracking. The specific preheat and interpass temperature maintenance requirements will vary depending on the welding process, steel specification, steel thickness, and metal temperature and should be determined by using AWS D1.1/D.1.1M.

A protective nonflammable cover shall be draped over the pipe near the vicinity of welding if protection of the lining or coating is required. Field welding in the interior of steel pipe is ordinarily limited to 30-in. (750-mm) or larger pipe to provide for safe access and egress. When personnel are working inside, ventilation shall be provided in strict accordance with federal, state or provincial, and local regulations.

Wire brushing is usually sufficient to remove any dirt or light rust to prepare the surface for welding. Small tack welds can be used to hold the pipe in position for welding, provided the tacks are sound and meet the requirements of ANSI/AWWA C206. The number of weld passes needed to complete the joint is a function of the steel wall thickness, type of joint, and type of welding. Interior welding using the weld-after-backfill method may require more than one weld pass to limit temperature at the joint and damage to the exterior coating.

6.2.10.1 **Welded lap joints.** There are several welding configurations for the lap joint. The single lap-weld joint is completed using a single weld that can be accomplished on either the inside or outside of the pipe joint. The nominal engagement of a lap-welded joint is 2- to 3-in. (50- to 75-mm) deep with a minimum required final overlap between the bell and the spigot after pullout of 1 in. (25 mm) or three times the thickness of the belled pipe, whichever is greater. The typical pullout is 1 in. (25 mm), but in all cases the minimum required overlap must be maintained. No part of any field weld shall be closer than 1 in. (25 mm) to the nearest point of tangency to a bell radius. The allowable angle of deflection is provided in Sec. 6.2.3.

6.2.10.2 **Butt joint.** Butt joints are sometimes specified for special design conditions. Butt joints are usually single-V-groove ends with a backup ring. If a backup ring is used, it will be located on the pipe interior for smaller-diameter pipe and on the exterior or interior for larger pipe (over 30 in. [750 mm] in diameter). Field joints shall be assembled so that longitudinal seams in adjacent pipes are offset from each other by at least five times the thickness of the thicker of the pipes being joined. Single-V-groove butt joints may be welded from the outside of the pipe or from the inside of the pipe if the diameter is large enough. The backing rings may be left in place after welding. Line-up clamps can assist in the pipe installation. The installation procedure of open butt joints is basically identical to butt joints with a backup ring except that when the two ends have touched, caution should be exercised to ensure that the proper root opening is achieved and the pipe is firmly secured in position prior to installing subsequent pipe segments.

6.2.10.3 **Welded butt-strap joints.** Where welded butt-strap joints are used, the butt straps shall have a minimum plate thickness equal to the thinnest member being joined, shall be fabricated from steel listed in ANSI/AWWA C200, and shall meet the purchaser's pipe design requirements. In accordance with ANSI/AWWA C206, the strap shall have a minimum width of 4 in. (100 mm) for pipe less than 24 in. (600 mm) in diameter and 6 in. (150 mm) for pipe 24 in. (600 mm) in nominal diameter and larger. The minimum lap between pipe ends and the edge of the butt strap shall be 1 in. (25 mm) for pipe less than 36 in. (900 mm) in nominal diameter and 2 in. (50 mm) for pipe 36 in. (900 mm) in nominal diameter and larger. Butt straps are generally provided in two 180-degree sections that require a complete joint penetration (CJP) weld at the splice after installation to create a full circumference band over the two adjoining pipe ends.

For butt-strap joints, the longitudinal seams of adjacent pipe sections may be in alignment provided that the butt-strap seams are offset from the pipe seams by at least five times the thickness of the thicker member involved in the joint. The butt strap may be welded on the pipe exterior, interior, or both.

6.2.10.4 *Welded joint testing.* Weld joint testing and repair methods shall be as defined in ANSI/AWWA C206. Vacuum look box testing has been used on a limited basis as an alternative method for fillet welds and butt welds. Radiographic testing and ultrasonic testing have been used on a limited basis as alternative methods for testing butt joints. Radiographic testing is not recommended for butt joints with backing nor for lap joints.

6.2.11 *Pipe cutting.* Prior to cutting, pipe shall be checked to ensure it is within the necessary tolerance for proper assembly with the adjoining pipe. If the adjoining pipes are not within the needed longitudinal tolerance, either replace the segment or use an alternative field joint such as a butt strap. Cutting pipe for insertion of valves, fittings, or closure pieces shall be done in conformance with all safety requirements. Cutting may be performed by a power abrasive saw, oxygen-acetylene torch, plasma arc, air-arc, or other suitable means. The resulting cut end will require corrective preparation before assembly with the adjoining pipe. Cut ends and rough edges shall be ground smooth.

6.2.12 *Thermal stress control joints.* Provisions shall be made for the expansion and contraction of welded pipelines exposed to extreme temperature differential during installation. Failure to provide for this expansion and contraction can result in undesirable levels of thermal stress in the steel. The most common control method for thermal expansion is by the use of a lengthened bell to increase the joint engagement range at specified locations. This method will avoid the accumulation of pipeline expansion or contraction during installation for trench-laid welded pipelines. This joint should be welded during the coolest part of the day and only after all adjacent pipe has been welded and buried. An alternate means for thermal stress control is the weld-after-backfill method as described in Sec. 6.2.2.

6.2.13 *Bonding of joints.* When required by the purchaser's documents, nonwelded joints shall be bonded to make the line electrically continuous. Electrical continuity allows for monitoring of the pipeline. Electrical bonding jumpers may be welded in the field to provide electrical continuity between adjoining pipes. The bond welds should be kept close to the ends of the pipe to allow joint end coatings to cover the bonding jumpers.

6.2.14 *Protective linings and coatings at field joints.* Generally, pipe lengths are lined and coated in the shop, excluding only the pipe ends that are completed in the field. The assembled joint assembly shall be lined and coated with a compatible material according to the field applied lining or coating manufacturer's recommendations and the applicable AWWA standard. Various pipe joint coatings and linings are available, which are further described in ANSI/AWWA C203, ANSI/AWWA C205, ANSI/AWWA C209, ANSI/AWWA C210, ANSI/AWWA C216, ANSI/AWWA C217, ANSI/AWWA C222, and ANSI/AWWA C602. For application and repair of these materials, follow the appropriate AWWA standard and the manufacturer's recommendations. Three commonly used materials for pipe-end field coatings are heat-shrink sleeves (ANSI/AWWA C216), hand-applied tape (ANSI/AWWA C209), and hand-applied cement mortar (ANSI/AWWA C205). Field joint and repair applications for these materials are briefly described by this standard.

6.2.14.1 *Tape wrapping field joints.* Taping can be completed at any temperature as long as the roll body temperature of the tape is maintained in accordance with the recommendations of ANSI/AWWA C209. The procedure for proper tape wrapping of field joints is fully described in ANSI/AWWA C209 and is summarized as follows:

1. Make sure the joint to be taped is complete, the gasket is checked, the weld is inspected, and the metal is cool to a temperature in accordance with the recommendations of ANSI/AWWA C209.
2. Clean the area to be taped to make sure all moisture has been removed.
3. When required by the tape manufacturer, prime all around the joint, including several inches on both sides beyond the area where the actual joint tape will be applied.
4. When required by the tape manufacturer or purchaser, place filler material at pipe joints, irregularities, and abrupt step downs to create a smooth surface.
5. Apply the tape in a spiral or straight circumferential method, starting approximately 10 to 15 degrees from the top centerline of the pipe, proceeding in a downhill direction and continuing circumferentially while maintaining tension. The tape should overlap itself by a minimum of 1 in. (25 mm) and the existing coating by a minimum of 3 in. (76 mm) making sure to encapsulate any bonding jumpers, if applicable.
6. Make sure the tape around the joint is wrinkle-free and stretched taut.

7. Make sure that tape is terminated in a downward orientation.

8. Inspect the completed wrap using a holiday detector in accordance with the recommendation of ANSI/AWWA C209.

6.2.14.2 Taped pipe repairs. Many taped pipelines include a three-layer system. The first layer that actually bonds to the pipe is typically a black tape. The second layer is a higher-density tape to give durable protection during handling and service. The third layer is a tape that provides mechanical protection to the inner layers of tape. In most cases, this outer layer is white. The three layers are generally supplied in three different colors so that in the event of damage, the colors will assist in determining the extent of damage to the total tape system. The procedure for properly taped pipe repairs is fully described in ANSI/AWWA C214 and is summarized as follows:

1. Minor wrinkles, scuffs, or any tears located on the edge of the tape that do not go past the overlap area are generally acceptable. These conditions listed still give the tape a full film thickness, and it is not practical to remove the high-density machine-applied tape and replace it with a softer patch-type material.

2. If a tear occurs in only the outer layer, repair the damaged area with one layer of tape with a minimum overlap of 4 in. (100 mm) onto the existing coating system.

3. If the damaged coating area shows evidence of going further into the coating system, use the repair method outlined below.

- a. Cut away the damaged tape at an angle tangent to the surface of the pipe so that the tape system is not cut or damaged any further.

- b. Wipe clean the area to be taped and make sure it is dry and free from dirt.

- c. Prime the area to be repaired and let the primer dry to a tackiness before applying the repair tape. The primed area shall be of sufficient size to extend beyond all applied patch tape.

- d. Cut the tape to such a size that it extends beyond the damaged area for a minimum of 4 in. (100 mm) in all directions around the area to be repaired. Apply the tape starting at the center and working toward the edge, making sure to smooth out all wrinkles. Make sure the primed area extends past the tape edges.

- e. When a second layer of tape is required to complete the patch, place the second layer of patch material over the first extending a minimum of 1 in.

(25 mm) in all directions past the first layer patch. It will always require two pieces of tape to accomplish this overlap process.

f. Perform a holiday test on the repair area in accordance with the requirements of ANSI/AWWA C214.

6.2.14.3 Heat-shrink sleeves on field joints. The procedure for proper application of heat-shrink sleeves is fully described in ANSI/AWWA C216 and is summarized as follows:

1. Clean the application area of the heat-shrink sleeve to remove all moisture, soil, and foreign materials.
2. Prepare the steel and abrade the existing coatings in accordance with the shrink-sleeve manufacturer's instructions.
3. Preheat the joint when required by the manufacturer.
4. When required by the heat-shrink sleeve manufacturer or purchaser, place filler material at pipe joints, irregularities, and abrupt step downs to create a smooth surface.
5. Fit the sleeve around the joint.
6. Secure the sleeve with a closure tab.
7. Heat the sleeve to shrink and seal the sleeve to the joint.
8. Using rollers as recommended by the sleeve manufacturer, remove all wrinkles to ensure that the sleeve has intimate contact with the pipe.

6.2.14.4 Cement mortar for field joints and repairs. Pipe ends and areas needing repairs shall be clean of deleterious materials and the surface prepared for the cement mortar in accordance with ANSI/AWWA C205. When feasible, interior cement mortar for field joints and repairs shall be applied after the trench has been backfilled. Typically for 24-in. (600-mm) and larger diameters, the inside recess is pointed with mortar. On smaller diameters, the shoulder of the bell is "battered" with a stiff mortar, and a swabbing device, such as an inflated rubber ball wrapped with wetted burlap, is placed in the previously laid section of the pipe. The ball has a wire attached to it, and the wire is threaded through the next pipe section to be laid. When the sections are joined, the spigot squeezes the mortar into position against the shoulder of the bell. Then the swabbing device is pulled past the joint by means of the wire, and the excess mortar is wiped away, leaving a smooth, flush inside joint. For exterior joints, cement mortar shall be poured in the joint space through a grout band that has been wrapped around the joint and firmly strapped onto both sides after field joint assembly. Repairs to the exterior mortar coating of the pipe shall be made during pipe installation and before backfilling. Pipe bedding shall not be installed in

the haunch zone or initial backfill until the mortar has cured sufficiently to prevent displacing the mortar.

Cracks in steel pipe lined with cement mortar are a common occurrence. These cracks are most commonly shrinkage cracks, which are caused when the mortar dries out. Contributing factors may be unprotected pipe ends, rough handling, or thermal stresses caused by weather. It is important to keep the pipe ends capped; small amounts of water can be added to the inside when the pipe is subjected to hot, dry climates. Cracks of $\frac{1}{16}$ in. (1.6 mm) or less are acceptable by ANSI/AWWA C205. If cracks exceed $\frac{1}{16}$ in. (1.6 mm), a cement slurry mixture can be brushed over the cracked area prior to filling the pipeline. The material requirements and application procedures of cement mortar for field joints and general repairs are described in ANSI/AWWA C205. Do not fill pipe for 72 hours after the last concrete repair.

Sec. 6.3 Thrust Restraint

The need for thrust restraint is a design consideration that is not covered by this standard. Such restraint typically is provided by welded joints.

Sec. 6.4 Backfilling

It is important to identify components of the trench and recognize how they relate to the overall backfilling process and material requirements. Pipe bedding, haunch zone, initial backfill, and final backfill materials are project specific and can be composed of different materials with varying compaction levels. Subgrade improvement is typically only required when unacceptable material causes an unstable trench bottom. The subgrade improvement depth (if required) is generally specified or directed by the purchaser. Pipe bedding is typically 2 in. to 6 in. (50 mm to 150 mm) in depth directly under the pipe and is loosely consolidated to provide uniform support for the pipe. The haunch zone typically extends from the bottom of the pipe up to as much as one-third the pipe diameter. Haunch area materials are typically the same material as the initial backfill. Proper installation of the haunch zone material provides uniform support of the pipe and has the greatest impact on limiting deflection of the pipe. Voids in the haunch zone of the pipe are unacceptable. Initial backfill typically begins at the top of the bedding or haunch zone and continues to the top of the pipe. Final backfill begins at the top of the initial backfill and proceeds to finished grade. The purchaser should specify if the initial backfill is to be placed above the top of the pipe. Placing initial backfill over the top of the pipe may provide a consistent environment encapsulating

the pipe, which may aid in the corrosion protection of the pipe. For this case, the initial backfill is typically placed 6 in. (150 mm) over the top of the pipe for pipe smaller in diameter than 24 in. (600 mm) and 12 in. (300 mm) over the top of the pipe for pipe 24 in. (600 mm) in diameter and larger. Typically, acceptable final backfill material and compaction requirements are detailed in purchaser's documents, but in all cases, stones or rocks larger than 3 in. (75 mm) in diameter for mortar-coated pipe and $\frac{3}{4}$ in. (19 mm) in diameter for dielectric-coated pipe may damage the coating and shall not be placed in direct contact with the pipe. From 6 in. to 12 in. (150 to 300 mm) above the top of the pipe to finish grade, material containing stones up to 8 in. (200 mm) in their greatest dimension may be used.

6.4.1 *Pipe embedment and subgrade material.* When the type of backfill material is not specified by the purchaser, the excavated material may be used provided that the material meets the requirements of this standard. All pipe embedment and subgrade material shall be free from cinders, ashes, refuse, vegetable or organic material, frozen soil, boulders, rocks or stones larger than 3 in. (75 mm) in diameter for mortar-coated pipe and $\frac{3}{4}$ in. (19 mm) in diameter for dielectric coated pipe, or other unsuitable materials.

6.4.1.1 Initial backfill may be class SC1, SC2, and SC3 (see Table 1), and shall be densified around the pipe in accordance with Figure 7. Minimum density levels of the backfill are important in preventing over deflection of the pipe. The density shall be specified by the purchaser or shall be as determined in AWWA Manual M11 by the soil class used and the recommended pipe deflection limits. Regardless of the method of densification used, materials shall be brought up at substantially the same rate on both sides of the pipe. When installing pipe 20 in. (500 mm) and larger, confirm that the backfill properly supports the pipe haunch area. Always ensure that the pipe is not floated or displaced before backfilling is complete.

Pipe deflection should be monitored to verify that the proper installation techniques are being used.

6.4.1.2 Cohesive soils shall be compacted with mechanical equipment or hand tamping. Care shall be taken not to damage coatings during compaction. Proper equipment and care in placement will ensure the required compaction under the haunch of the pipe. Initial backfill for pipe up to 48 in. (1,200 mm) in diameter shall be placed in layers of not more than 12 in. (300 mm) in thickness. Initial backfill for pipe larger than 48 in. (1,200 mm) in diameter shall be placed

Table 1 Soil stiffness categories

Soil Stiffness Category	Soil Type*	AASHTO Soil Groups†
SC1	Clean, coarse-grained soils: SW, SP, GW, GP, or any soil beginning with one of these symbols with 12% or less passing a No. 200 sieve.	A-1, A-3
SC2	Coarse-grained soils with fines: GM, GC, SM, SC, or any soil beginning with one of these symbols more than 12% fines. Sandy or gravelly fine-grained soils: CL, ML (or CL-ML, CL/ML, ML/CL) with more than 25% retained on a No. 200 sieve.	A-2-4, A-2-5, A-2-6, or A-4 or A-6 soils with more than 25% retained on a No. 200 sieve
SC3	Fine-grained soils: CL, ML (or CL-ML, CL/ML, ML/CL) with 25% or less retained on a No. 200 sieve.	A-2-7, or A-4 or A-6 soils with 25% or less retained on a No. 200 sieve

* ASTM D2487, Standard Classification of Soils for Engineering Purposes (Unified Soil Classification System).

† AASHTO M145, Standard Specification for Classification of Soils and Soil Aggregate Mixtures for Highway Construction Purposes.

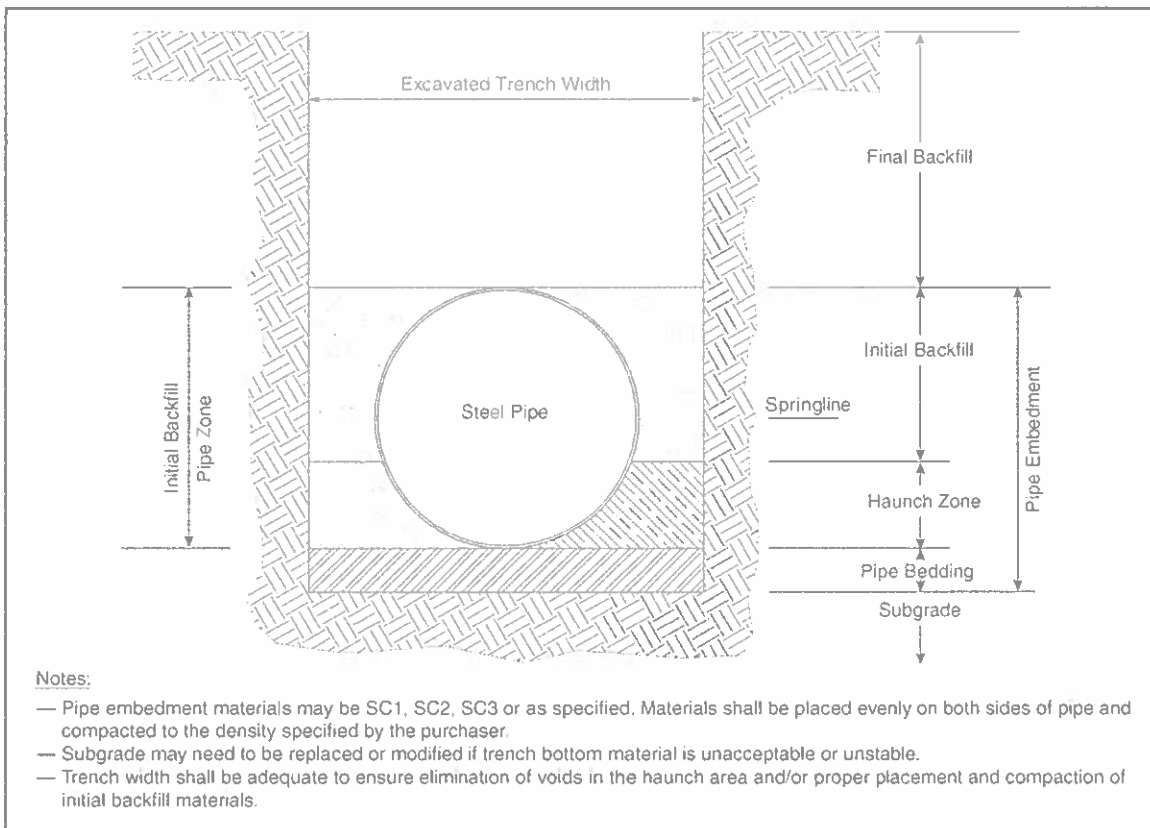


Figure 7 Trench cross section

in layers not exceeding 24 in. (600 mm) in thickness and subject to meeting the compaction requirements.

6.4.1.3 Free-draining soils may be densified by mechanical equipment, hand tamping or tamping with water-using devices, or through methods such as water jets, immersion-type vibrators, or flooding. These soils are usually placed in a minimum of two layers, with the first layer placed loose to no higher than the spring line of the pipe. The thickness of the layers shall not exceed the penetrating depth of the vibrators if consolidation is performed by jetting and internal vibration.

6.4.1.4 Final backfill above the pipe embedment shall not be placed until the compaction of the pipe embedment backfill is satisfactorily complete. To prevent damage to the pipe, sufficient compacted backfill shall be placed over the pipe before allowing any type of vehicle over it.

NOTE: Loosely placed final backfill above the pipe may promote unwanted surface settlement, which could be detrimental to improvements subsequently placed over the trench.

6.4.2 *Compaction.* Care shall be taken to ensure compaction equipment does not damage the pipe coating. Ensure proper compaction of backfill to avoid ovaling of the pipe beyond the allowable limits.

6.4.3 *Partial backfilling during testing.* Newly installed pipelines are normally tested after backfilling. When unusual conditions require that pressure and leakage testing be accomplished before completion of backfilling or with pipe joints accessible for examination, sufficient backfill material shall be placed over the pipe barrel between the joints to prevent movement, and due consideration shall be given to restraining thrust forces during testing.

Sec. 6.5 Flushing

Foreign material left in pipelines during installation can result in valve or hydrant seat leakage during pressure tests. Every effort shall be made to keep lines clean during installation. Thorough flushing is recommended prior to a pressure test; flushing shall be accomplished by partially opening and closing valves several times under expected line pressure, with flow velocities adequate to flush foreign material out of the valves.

Sec. 6.6 Disinfection

Newly installed mains carrying potable water shall be disinfected in accordance with ANSI/AWWA C651. Provisions shall be made to avoid contamination of existing mains by cross connection during testing/disinfection/flushing of newly installed mains.

NOTE: Discharge from flushing or disinfection shall be directed away from the pipe alignment so that trench stability is not affected and shall be in accordance with federal, state, and local point-discharge requirements.

Sec. 6.7 Highway and Railroad Crossings

6.7.1 *Casing pipe.* When casing pipe is specified for highways or railroad crossings, the project shall be completed in accordance with applicable federal, state or provincial, and local regulations. In the case of railroad crossings, the project shall also comply with regulations established by the railroad.

6.7.2 *Carrier pipe.* The casing pipe and other pipe appurtenances shall be a minimum of 8 in. (200 mm) larger than the outside diameter of the steel pipe bells to prevent damage during installation and to prevent pipe-to-casing contact. Carrier pipe may be pushed or pulled through the completed casing pipe. Spacers and/or insulator skids shall be placed around the carrier pipe to ensure approximate centering within the casing pipe and to prevent damage during installation or flotation. Care shall be exercised to avoid metal-to-metal contact. If the casing annulus is grouted, grout pressures and lifts must be maintained to avoid deflecting or collapsing the steel carrier pipe. Carefully monitor the carrier pipe during the grouting operation to verify the proper grouting techniques are being used.

Sec. 6.8 Subaqueous Crossings

6.8.1 *Subaqueous installations.* When it is necessary to cross a body of water, the preferable practice is to dewater the area and proceed according to the conventional pipeline construction practices described in this standard. In the event the purchaser's documents allow subaqueous construction, the constructor is strongly advised to use an engineered system specifically developed for the pipe, crossing depth, intended cover, and means planned for such a crossing. The use of a restrained-type joint (welded, mechanical, or grooved) is recommended. However, the additional details necessary for subaqueous construction are not covered in this standard.

SECTION 7: VERIFICATION

Sec. 7.1 Inspection

7.1.1 *Inspection on delivery.* All pipe and appurtenances are subject to inspection at the point of delivery. Material found to be defective because of manufacture or damage in shipment shall be recorded on the bill of lading and may be

rejected. There shall be agreement between the purchaser and constructor regarding any necessary repairs. The purchaser shall be allowed to monitor the repairs prior to installation.

Sec. 7.2 Hydrostatic Field Testing

Warning: The testing methods described in this section are specific for water-pressure testing. These procedures shall not be applied for air-pressure testing because of the serious safety hazards involved.

The main objective of a field hydrostatic pressure test (hydro test) is to check the water tightness of joints, because each length of pipe is shop tested per the purchaser's documents. The hydro test can be performed after backfilling is complete and at a purchaser-specified pressure above the design working pressure of the line. Where possible, bolted flexible joints should be left uncovered until the hydro test is complete.

7.2.1 Test restrictions. Test pressure shall not exceed 125 percent of working pressure unless taken into consideration in the design, and shall never exceed pipe or thrust-restraint design pressures. The line shall be vented and care shall be taken to ensure that all air in the line escapes during the filling operation. The line shall be filled slowly to prevent water hammer.

Upon completion of filling with water, the hydrostatic test shall last at least 2 hours. Pipe with cement-mortar linings should be filled for a minimum of 24 hours prior to testing to allow for water absorption into the lining. Water absorption into linings and other factors may extend the duration required for a successful hydro test.

7.2.2 Air removal. Before applying the specified test pressure, air shall be expelled from all air vents along the section of piping being tested.

7.2.3 Examination. Any exposed pipe, fittings, valves, and joints shall be examined carefully during the test. In addition, the entire length of the pipeline shall be examined for movement, defects, and leaks that may appear at the surface. Any revealed damage or defective pipe, fittings, valves, or joints shall be repaired or replaced with sound material, and the test shall be repeated until satisfactory results are obtained.

7.2.4 Allowable makeup water. Makeup water shall be defined as the quantity of water that must be supplied into the newly laid pipe or any valved section thereof to maintain pressure within 5 psi (34.5 kPa) of the specified test pressure after the pipe has been filled with water and the air has been expelled.

Makeup water shall not be measured by a drop in pressure in a test section over a period of time.

The allowable makeup water shall not exceed 10 gal per in. diameter per mile of pipe per 24 hr (0.93 L per mm diameter per km of pipe per 24 hr) as measured by the water required to maintain the specified test pressure.

NOTE: The air removal and test procedure above will expel most but not all air from the pipeline. This section assumes some air will remain in the pipeline during testing and provides for this condition.

7.2.5 Valve seat leakage. When testing against closed valves, makeup water per closed valve of 0.0078 gal/hr/in. (1.2 mL/hr/mm) of nominal valve size shall be allowed. This is in addition to the makeup water in Sec. 7.2.4. When testing against existing valves is necessary, some leakage can be expected and should not be the sole basis for rejection.

7.2.6 Acceptance of installation. Acceptance shall be determined on the basis of the hydro test. If any test of laid pipe requires makeup water greater than that specified, repairs or replacements shall be accomplished and the pipe retested.

7.2.6.1 All visible leaks shall be repaired regardless of the amount of leakage.

SECTION 8: DELIVERY

Sec. 8.1 Unloading, Handling, and Storage

Care shall be exercised when unloading, handling, and storing pipe. Nylon or protected slings at least 4-in. (100-mm) wide or padded forks shall be used to handle coated pipe. Cables, chains, ropes, or other equipment that is likely to damage pipe coatings shall not be used.

Coated pipe shall be handled, stored, and shipped in a manner that will prevent damage to the coating. If the coating is damaged during handling, storage, or shipping, it shall be repaired with the original or a compatible repair coating as recommended by the coating manufacturer and in accordance with the applicable AWWA standard.

All pipe, fittings, and accessories shall be loaded and unloaded carefully to avoid impact or damage. Under no circumstances shall such material be dropped.

8.1.1 Secure pipe. Before release of tie-downs around the pipe, the loads shall be checked to ensure the pipe is secure and stable.

8.1.2 *Padding.* Slings, hooks, and pipe tongs shall be padded and used in such a manner to prevent damage to the exterior surface or internal lining of the pipe, fittings, or related product.

8.1.3 *Internal bracing.* Pipe manufacturers provide internal bracing for handling and shipping purposes if required. The constructor should maintain the bracing and ensure its adequacy during unloading and joining of the pipe. Bracing can help support the pipe shape until sufficient side soil support is in place to hold the shape of the pipe. Manufacturer-supplied bracing is not designed or intended to support construction activity above the pipe. Flexible pipe relies on adequate side soil support and adequate soil cover to distribute the load from construction equipment and other loading above the pipe. Damage to the pipe lining, coating, and cylinder can occur from attempting to support excessive construction loads with the bracing in the pipe. The purchaser should specify the requirements for bracing if its use is desired to limit pipe deflection during backfilling.

8.1.4 *Jobsite storage.* Stored materials shall be kept safe from damage. The interior of all pipe, fittings, and other appurtenances shall be kept reasonably free from dirt or foreign matter at all times.

Coated pipe shall be protected from ultraviolet and weathering damage as recommended by the coating manufacturer. Coated pipe should never be placed, dragged, or rolled directly on the ground. Padded skids, earthen berms, burlap sacks filled with sand, and old car tires are some of the means to adequately bunk the pipe at the jobsite. Pipe shall not be bunched on the pipe ends to prevent damage to the ends. Pipe shall not be stacked without proper padding. Plastic caps on the pipe ends for pipe that is cement–mortar lined shall be left in place until just prior to installation.

Sec. 8.2 Affidavit of Compliance

The purchaser may require an affidavit of compliance or test reports from the constructor stating that the material installed and work or tests performed comply with all applicable requirements of this standard.

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APPENDIX A

Flange Joint Assembly

This appendix is for information only and is not a part of ANSI/AWWA C604.

SECTION A.1: GENERAL FLANGE JOINT ASSEMBLY PROCEDURES AND CHECKLISTS

Sec. A.1.1 Prejob Preparation and Inspection of Joint Components

Factors to consider during the prejob preparation and inspection of joint components are as follows:

1. Verify the delivered materials are as specified and complete in advance of the intended assembly
2. Identify any special safety issues associated with the assembly including complying with any lock-out/tag-out or other work procedures
3. Select all necessary tools and parts including pipe or valve joints, bolts, nuts, washers, gaskets, lubricants, wrenches, pumps, sockets, backup tools, micrometers, alignment tools, lifting equipment, and so on.
4. Verify the flange details regarding pressure rating, size, face configuration, and compatibility with mating flanges (see Sec. A.2.1, Flanges).
5. Inspect the flange surfaces to ensure that they are free from cracks, warping, gouges, paint, coatings, damage, or conditions that could jeopardize achieving a proper seal.
6. Confirm that the gaskets meet the requirements of the purchaser's documents and specifications including type, material, thickness, OD, and ID, and inspect the gasket condition (see Sec. A.2.6, Gaskets).
7. Always use a new gasket and verify it is undamaged. Gaskets should not be reused irrespective of their apparent condition.
8. Verify that the bolts, nuts, and washers meet the specifications for size, grade, thread pitch, and so on. If flange joints are being reassembled, the bolts and nuts may be reused as long as the nut can be easily run down the bolt threads by hand without interference (see Sec. A.2.2, Fasteners).

9. Examine, clean, dress, and lubricate all bolt and nut turning surfaces including in the threads and under the nut where it contacts the top of the washer. It is not necessary to lubricate under the washer and is generally only necessary to lubricate the nuts on the side of the flange that will be tightened.

10. Align the pipe and ensure that flanges are in line and will mate properly with one another and with the gasket. Make sure that both sides of the joint are parallel by measuring the gap or the distance between the outside faces of both flanges on 90-degree centers before beginning the tightening procedure. The gap should allow insertion of a ring gasket without interference. Bolts are not flange alignment tools and should not be used in this manner except that minor adjustments to large-diameter flanges may be made by selective tightening of bolts as long as no more than 20 percent of the final torque is used before patterned tightening begins.

Sec. A.1.2 Bolting Plan

A bolting plan should include the following items:

1. Determine the required final target torque and other criteria to be measured (see AWWA Manual M11 for additional information).
2. Determine whether a single wrench will be used or multiple wrenches will be used simultaneously.
3. Provide a written bolting sequence and progressive tightening steps that will be followed.
4. Provide a recording sheet to document each step of the bolting plan as it is performed.
5. Provide instructions for numbering the bolts and flanges according to your bolting plan (see Sec. A.3 for examples).

Sec. A.1.3 Selection of Tools

Guidance on selection of tools is provided below:

1. Select and assemble the hydraulic, pneumatic, or manual tools to be used in the bolting plan ensuring that the selected tools have the desired torque capacity and accuracy.
2. Verify that all torque wrenches have a current calibration certificate and sticker.
3. Verify that all assembly personnel are trained and qualified to use the tools.

4. Ensure that appropriate torque charts, pressure-to-torque conversion charts, or other guidance documents specific to the tools to be used are on hand and available to operators and inspectors.

Sec. A.1.4 Tightening

Guidance on tightening of bolts is provided below:

1. Assemble the joint, gasket, and fasteners to a snug-tight condition prior to applying measured torque (see Sec. 6.2.4.10, Torque).
2. Adjust stud nut locations to allow space on one stud end for use of a torquing tool or socket. Recheck alignment and ensure that the mating flanges are parallel.
3. Torque according to the first pass of your bolting plan.
4. Recheck alignment and inspect for any problems.
5. Torque according to your plan.
6. Recheck for alignment and problems after each step.
7. Perform a final check pass to ensure that all tightened bolts are equally torqued.
8. Retorque after 4 to 6 hours to compensate for gasket creep or relaxation (see Sec. A.2.6, Gaskets).
9. Stud threads should protrude beyond the nut a minimum of 2 threads after tightening to ensure that full nut engagement has been achieved.
10. Record all steps including the plan and actual activities, as well as any problems or concerns.

Sec. A.1.5 Testing

Guidance on testing is provided below:

1. Perform torque, bolt elongation, or other measurements as necessary to verify assembly specifications have been met.
2. Tests should only be performed after all retorque has been completed and gasket creep or relaxation has occurred (see Sec. A.2.6, Gaskets).
3. Pressure test the joint according to the job specifications.
4. If leaks are encountered, retighten in progressive steps as necessary to address any leaks.
 - a. First, reverify that the torque is uniform by making a circular pass at the specified torque until no nuts turn. If the leak is extreme or from multiple locations, this pass should be performed with the pressure off. However,

small leaks can generally be addressed while the system is pressurized as long as the gasket is not displaced.

b. Repressurize (if required) and if the leak has stopped, then the process is complete.

c. If leakage continues, begin at the leak location and tighten the bolt by rotating 1–2 flats of the nut. Perform this added tensioning to the bolts adjacent to the starting bolt alternating from side to side until involving an approximate 45-degree region of tensioning.

d. If the leak has stopped, then the process is complete.

e. If the leak does not stop, repeat the above procedure by tightening 1 more flat of the nut.

f. If the leak does not stop following these procedures, it may be necessary to disassemble, assess the conditions, and repeat the process. The use of a thicker gasket is often the remedy of choice when this is allowed by the specifications. Consult with the gasket manufacturer or joint designer for alternative solutions.

Sec. A.1.6 Disassembly (When Necessary)

The following steps should be followed if disassembly of the flange joint assembly is necessary:

1. Ensure the system is out of service, empty, and properly secured.
2. Check records for any concerns or problems noted from the assembly.
3. Examine for corrosion or damage.
4. Apply penetrating oil to the nuts and bolts if corroded and allow time to penetrate.
5. Utilize tools with sufficient capacity to break loose corroded fasteners. Breakout torque may exceed twice the torque required at the time of original assembly to overcome friction due to corrosion.
6. Set the hydraulic tool power at or near the maximum setting.
7. Bolts on larger systems should be disassembled using a star pattern to avoid causing misalignment of the flanges or excessive load on the remaining bolts.
8. Break all nuts loose rotating only 1–2 flats on the first pass, then continue loosening on successive passes.
9. Leave the loose nuts loosely connected until confirming the flanges are properly supported and secure.

SECTION A.2: FLANGES, FASTENERS, AND GASKETS (ADDITIONAL DETAILS)

Sec. A.2.1 Flanges

ANSI/AWWA C207 specifies four classes of flanges based on the internal working pressure at atmospheric temperature to which they will be subjected in service. For purposes of bolting information, Class B (86 psi [593 kPa]) and Class D (150–175 psi [1,034 kPa –1,207 kPa]) are usually grouped together and treated the same, as are Classes E (275 psi [1,896 kPa]) and F (300 psi [2,068 kPa]). All of these flanges are generally available in nominal sizes from 4 in. to 144 in. (100 mm to 3,600 mm).

Sec. A.2.2 Fasteners

Fasteners are typically “stud bolts” (*fully or partially threaded*) used in conjunction with nuts and washers on both ends, or in some applications studs are inserted directly into a threaded opening on one connecting end such as a valve body.

Sec. A.2.3 Bolts

Some of the important factors that must be considered are listed in the following sections:

A.2.3.1 Strength grade. Bolts including stud bolts must be marked with their grades, which indicate such properties as tensile strength and yield point.

A.2.3.2 Grade marking. ASTM studs must have the grade mark stamped into one end along with a second mark identifying the manufacturer. Care should be taken to ensure that the marked end of the stud is visible from the tensioning side of the joint for inspection purposes.

A.2.3.3 Dimensions. Bolt diameter should be $\frac{1}{8}$ in. (3 mm) less than the flange bolt hole diameter and bolt length should be sufficient to allow 1–3 threads to extend beyond the nut for inspection purposes on both sides of the joint after tightening. A greater length is acceptable as long as the longer bolts do not cause interference problems. It should also be noted that if the lengthened bolt is subjected to corrosive elements, this may make future removal difficult.

A.2.3.4 Condition. All fasteners should be free of dirt, rust, paint, and corrosion especially in the threads and on bearing surfaces. Bolts and nuts should be inspected for thread condition.

A.2.3.5 *Length.* Studs or bolts should be of sufficient length to protrude beyond the nut at least 2 threads after tensioning.

A.2.3.6 *Diameter and thread pitch.* Nominal bolt diameter is the distance across the bolt measured to the outside of the thread crest. All B7 studs of 1-in. (25-mm) diameter or greater have 8 threads per inch of length, which is referred to as *thread pitch*. Smaller-diameter studs (less than 1 in. [25 mm]) may have more threads per inch.

Sec. A.2.4 Nuts

Nuts used for these applications are designed to have greater load-carrying capacity than the bolts they engage. As a result, the bolt should yield before the internal threads of the nut yield.

A.2.4.1 *Grade marking.* ASTM nuts must have the grade marking stamped onto one face of the nut while the opposite face has a smooth flat surface. The marks should always be visible after tightening while the smooth side should face the flange.

A.2.4.2 *Size across flats.* Nuts and sockets used to engage the nuts are measured across the flats. For all bolts 1 in. (3 mm) or greater in nominal diameter, the across flats (A/F) distance = $([\text{bolt diameter} \times 1.5] + \frac{1}{8} \text{ in.})$ and is referred to as a “heavy hex.” For bolts smaller than 1-in. (3-mm) nominal diameter, the A/F distance equals the bolt diameter $\times 1.5$ and in both cases the height of the nut is approximately equal to the bolt diameter.

Sec. A.2.5 Washers

Washers are important for effective bolting and should be “through-hardened” in accordance with ASTM F436. Hardened washers may or may not be clearly marked, but their properties must nevertheless meet hardness specifications as indicated by their manufacturer.

A.2.5.1 *Flange protection.* The hardened washer keeps the turning nut from embedding or damaging the flange.

A.2.5.2 *Equal friction.* The washers provide a smooth turning surface for all nuts in the joint so the nut torque will transfer an equal load under all the nuts on the flange irrespective of flange damage or condition.

A.2.5.3 *Distributed load.* Because the washer diameter is larger than the nut, this will distribute the bolt load more equally over the flange body.

Sec. A.2.6 Gaskets

Important gasket considerations for the assembly are outlined in the following sections:

A.2.6.1 *New gaskets.* Gaskets must always be new and never reused. Once a gasket has been compressed, it is no longer pliable enough to seal flange gaps and imperfections. The gasket should fit the flange and be centered by the bolts as they pass through the flange or gasket. Gaskets should be stored in accordance with the manufacturer's recommendations.

A.2.6.2 *Gasket dimensions.* Full-face gaskets should conform to the nominal flange size and match the bolt pattern. Ring gaskets should match the nominal flange size and just fit inside the bolt circle. Standard gaskets used in water line flanges are typically $\frac{1}{16}$ -in. (1.5-mm) or $\frac{1}{8}$ -in. (3-mm) thicknesses. Thinner gaskets are generally preferred; however, flanges that are warped, bowed, or pitted may require thicker gaskets to seal such imperfections. Installers should bring any flange condition concerns to the attention of the project engineer. Never use more than a single gasket on the same joint.

A.2.6.3 *Uniformity of compression.* Achieving equal gasket compression around the flange is very important to the success of the seal. Applying equal torque to all the bolts is generally the best method for ensuring consistent gasket compression, but considerations such as lubrication can drastically affect the achieved bolt load even when torque is equal. (See Sec. 6.2.4.10, Torque, for more information.) Fiber gaskets will typically compress from 10 to 25 percent, and rubber-type gaskets may compress from 20 to 50 percent during assembly. Consult the gasket manufacturer for details if there is a concern or if leakage occurs.

A.2.6.4 *Gasket creep or relaxation.* A phenomenon that occurs to gasketed connections is referred to as *gasket creep*, relaxation, or cold flow, which warrants special attention by the installer. Gasket creep can result in bolt load loss and leaks. When soft gasket materials are first put under load, they initially resist compression; however, within a few minutes to a few hours they tend to flow away from the locations of higher pressure by permanently thinning and causing a corresponding drop in the bolt load. Most creep occurs within the first 4 to 6 hours after assembly and is not repeated as the gasket material reaches a stable density, although a small percentage of creep may continue for 12 to 24 hours after assembly. To compensate for gasket creep, after 4 to 6 hours (12 to 24 hours if time allows), retighten the joint to the prescribed torque value with a circular "check pass" as outlined in Sec. A.3, Bolting Patterns and Sequence.

A.2.6.5 *Gasket installation.*

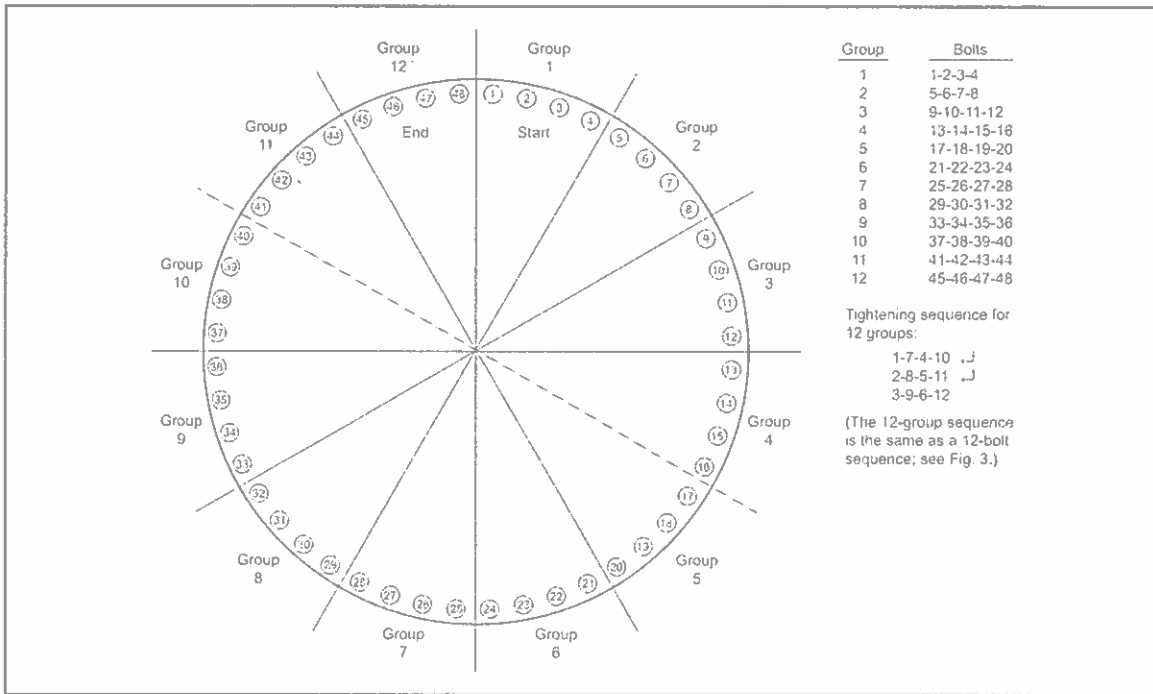
a. With full-face gaskets, place at least two bolts or studs in the top half of one flange, then hang the gasket on these bolts through the bolt holes before mating the flanges. Insert the remaining bolts or studs, nuts, and washers and snug them to a hand-tight condition through the flange and gasket. (See Sec. A.1.4 and Sec. A.3 for additional tightening instructions.)

b. With ring gaskets, place at least two bolts or studs through the bottom half of one or both flanges then rest the outer edge of the gasket on these bolts for support while the joint is assembled. Insert the remaining bolts and snug them while taking care to keep the gasket centered in the joint. Install the remaining bolts or studs and nuts to a hand-tight condition through the flange while centering the gasket. (See Sec. A.1.4 and Sec. A.3 for additional tightening instructions.)

Consult the gasket manufacturer with questions on your specific gaskets.

SECTION A.3: BOLTING PATTERNS AND SEQUENCES

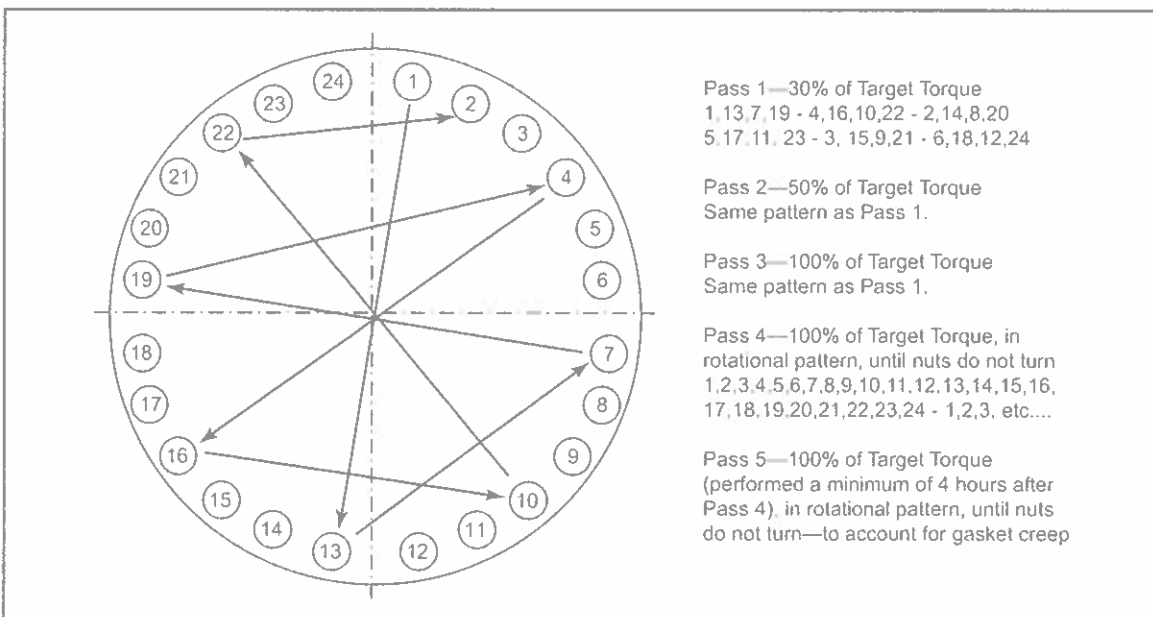
Figures A.1, A.2, A.3, and A.4 illustrate typical bolting pattern methods. Recommended bolting patterns are provided below and can be found in ASME PCC-1, Guidelines for Pressure Boundary Bolted Flange Joint Assembly, appendix F. Water pipe systems often involve large-diameter flanges with a considerable quantity of fasteners, in which case bolts may be grouped together and those groups tightened as if they were single bolts in a pattern. This reduces the movement required of the tightening tools and generally reduces confusion and assembly time. Bolts within a 30-degree arc segment of the flange can be included for this purpose. Figure A.1 shows an example of the numbering and tensioning on a 48-bolt flange. In this case a 12-group sequence is treated the same as a 12-bolt sequence by using the same pattern. This grouping rule for flanges of 48 or more bolts may be used in any of the following example tightening patterns.



GENERAL NOTE: This figure is an illustration of how bolts may be grouped for tightening. Bolts maybe grouped and tightened treating these groups as one bolt in the tightening sequence. A suggested number of bolts for a group is the number contained within a 30 deg. arc. However, potential gasket damage or flange misalignment should be considered when bolts are grouped.

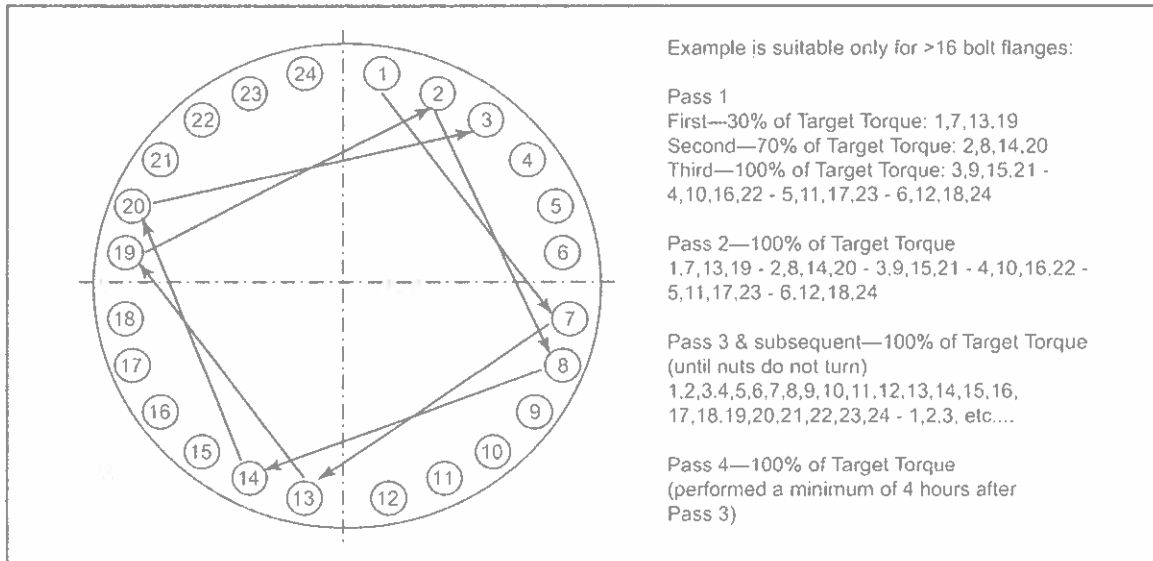
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Figure A.1 Legacy Pattern—48-bolt flange bolt grouping example



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Figure A.2 Quadrant/Circular Pattern Example—reduces tool movement and time vs Legacy Pattern



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Figure A.3 Simultaneous Pattern Example—maintains parallel flanges and reduces passes and bolt interaction

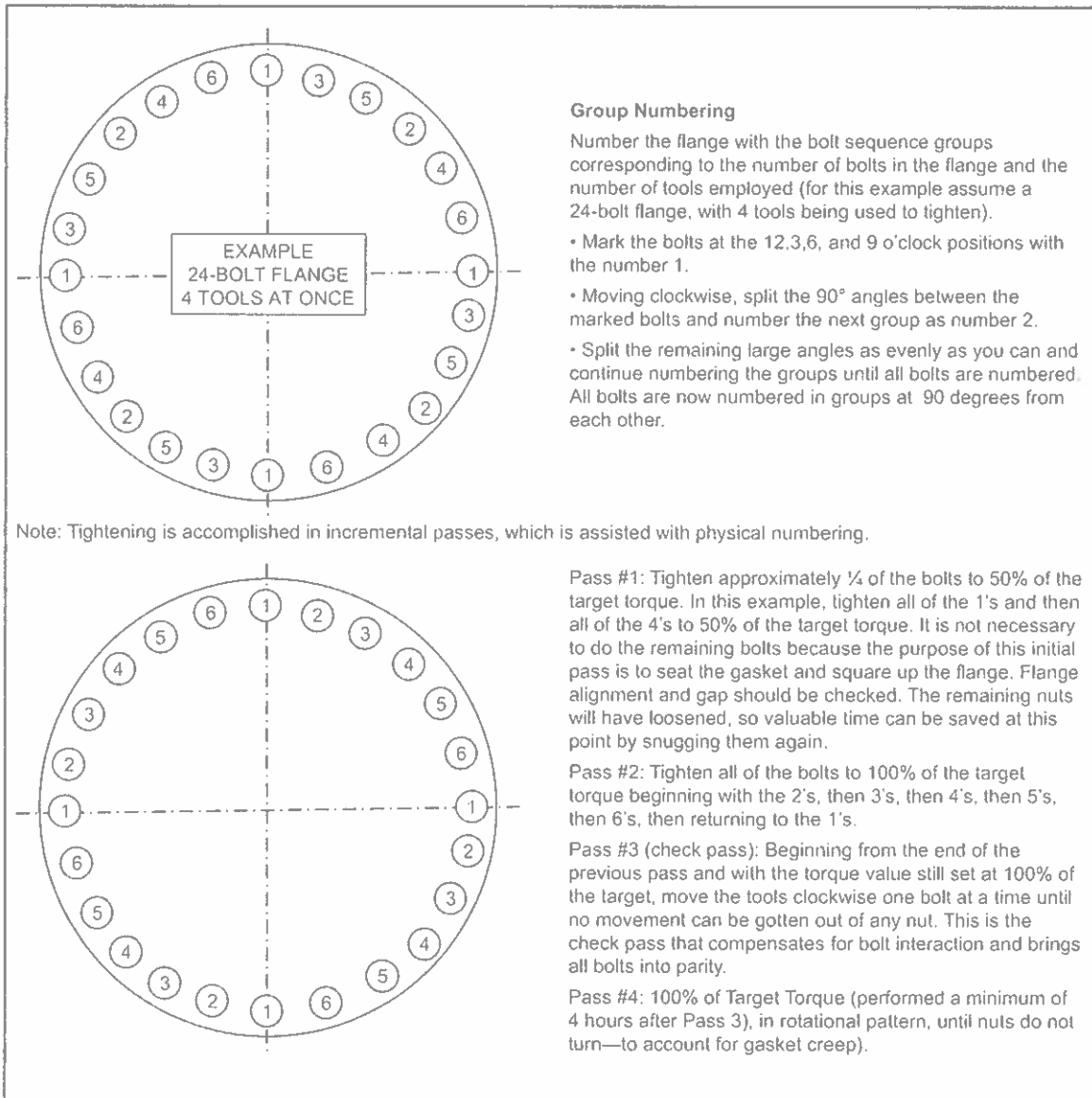


Figure A.4 Simultaneous pattern with multiple tools example

The simultaneous use of multiple tools spaced evenly around a flange has been shown to give equal and predictable tightening parity with parallel closure in less time than using a single tool in a cross-pattern (see Figure A.4). This method has been successfully applied across the full range of gasket and joint configurations. As a practical matter, multitool tightening works best on larger flanges (bolt diameters ¾ in. (19 mm) or larger, with hydraulic tools connected to a common pressure source. One tool per every 4 to 8 bolts in the flange should be used in even numbered groups of tools equally distributed around the flange.

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1P-2M 43604-2017 (8/17) IW

Printed on Recycled Paper

ISBN 978-1-62576-241-2



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