DUCTILE IRON PIPE RESEARCH ASSOCIATION

HANDBOOK

OF

Ductile Iron Pipe

Sixth Edition

DUCTILE IRON PIPE RESEARCH ASSOCIATION
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PREFACE

The Ductile Iron Pipe Research Association (DIPRA) (formerly the Cast Iron Pipe Research Association-CIPRA) is a non-profit corporation whose members are manufacturers of ductile cast iron pressure pipe. Throughout its 69 years of operation, the Association has served its members, the engineering profession, private and public utilities, industry and the public by providing sound engineering and research information at the highest level of integrity, thus setting an example of good business conduct. Results have included steady improvements in cast and ductile iron pipe, significant contributions to public health and safety through research and education.

DIPRA's staff of professional engineers and researchers provide services to consulting engineers, utilities and industry through the following activities:

1. Participation in national standards development by American National Standards Institute (ANSI), American Water Works Association (AWWA), and American Society for Testing and Materials (ASTM).
2. Presentation of engineering seminars on design, specifications and pipeline construction, corrosion control, and special applications and problems.
3. Provision of field services, such as soil and environmental investigations, flow tests, consultation with engineers on piping problems, including pipe and system design.
4. Publication of research and engineering information in technical papers, brochures and manuals.

Engineering services are available by request through member companies or by direct request to the President of DIPRA.

This Handbook is furnished to design engineers and purchasers of cast and ductile iron pipe as a complete reference for use in development of piping design and specifications. ANSI and AWWA Standards are included, together with other helpful reference material.

Membership Directory

DUCTILE IRON PIPE RESEARCH ASSOCIATION

AMERICAN CAST IRON PIPE COMPANY
General Office, Birmingham, Alabama

ATLANTIC STATES CAST IRON PIPE COMPANY
General Office, Phillipsburg, New Jersey

CLOW WATER SYSTEMS CORPORATION
General Office: Carol Stream, Illinois

McWANE CAST IRON PIPE COMPANY
General Offices, Birmingham, Alabama

PACIFIC STATES CAST IRON PIPE COMPANY
General Office, Provo, Utah

UNITED STATES PIPE AND FOUNDRY COMPANY
General Office, Birmingham, Alabama

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Cast Iron Pipe Installed 1664 Versailles

SECTION I

EVOLUTION AND HISTORY OF GRAY AND DUCTILE CAST IRON PIPE

Early Uses of Cast Iron as Pipe

Man's ability to cast pipe probably developed from or coincidentally with the manufacture of cannons, which is reported as early as the year 1313. There is an official record of cast iron pipe manufactured at Siegerland, Germany, in 1455 for installation at the Dillenburg Castle.

A Revolutionary Experiment

In the year 1664, King Louis XIV of France ordered the construction of a cast iron pipe main extending fifteen miles from a pumping station at Marly-on-Seine to Versailles to supply water for the fountains and town. This cast iron pipe is still functioning after more than 300 years of continuous service. When the line was begun (1664), the production of iron required the use of expensive charcoal for the reduction of the iron ore; however, by 1738 success had been achieved in the production of lower cost iron through the use of coke instead of charcoal. Immediately thereafter, the more progressive cities began to install cast iron mains.

Extensive Use of Cast Iron Pipe

Waterworks engineers had long searched for an affordable piping material with reliable strength and durability. Thus, it is not surprising that cast iron pipe rapidly became the standard material for water distribution mains. In the United States alone, there are over 225 utilities that have had cast iron distribution mains with continuous service records of more than 100 years.

The use of cast iron pipe was introduced into this country shortly after 1816. Since that time, various other piping materials have been offered as suitable for water distribution piping. However, none of these proved able to supplant cast iron in the confidence and preference of waterworks engineers until ductile iron, a stronger and equally durable piping material, became available.

Development of Joints

Flanged. Originally, cast iron pipe was made with flanged joints, using lead gaskets. Much improved joints of this type are still used for many above ground plant installations using rubber, fiber, metal or other types of gaskets.

Bell and Spigot. The bell and spigot joint was developed in 1785 and was extensively used for new installations until the 1950's. This joint is assembled by caulking yarn or braided hemp into the base of the annular bell cavity, then pouring molten lead into the remaining space inside the bell. Upon solidification, the lead is compacted by caulking, thus effecting a water-tight seal.

Mechanical Joint. The mechanical joint was developed for gas industry use in the late 1920's, but has since been used extensively in the water industry. This joint utilizes the basic principle of the stuffing box.

Roll-on Joint. The roll-on joint was developed in 1937 and was in use approximately 20 years. Assembly of the joint involved a compresssed rubber gasket rolled under a restriction ring, followed by caulked square braided jute, with the remainder of the joint packed with a bituminous compound.

Push-on Joint. The push on joint was developed in 1956 and represented an extremely important advance in the water distribution field. This joint consists of a single rubber gasket placed in a groove inside the bell end of the pipe. By pushing the plain end of the pipe through the lubricated rubber gasket, the gasket is compressed and the joint becomes pressure tight. Assembly of the push-on joint is simple and fast. Large bell holes are not required for this joint, and it may be assembled under wet-trench conditions or even under water.

Special Joints. Several special joints are available. These joints include ball and socket for submarine or stream crossings, plain end coupled, threaded and coupled, and various restrained type joints (see Section IX).

Ductile Iron Pipe

The advent of ductile iron pipe in 1948 was the most significant development in the pressure pipe industry. Quickly recognized as a pipe material with all of the good qualities of gray cast iron pipe plus additional strength coupled with ductility, it was first used for special and severe conditions of high pressure, water hammer and excessive external loads. More than 25 years of experience have proved it to be completely trouble-free as an underground pressure pipe material, and today it is used in the transportation of raw and potable water, sewage, gas, slurries and process chemicals.

Ductile iron pipe is designed as a flexible conduit and separate and distinct American National Standards were developed and have been available since 1965. Casting processes are similar to those for gray cast iron pipe; however, ductile iron pipe requires significant refinement in casting, higher quality raw materials, treatment with special additives, and a higher level of quality control. It has an ultimate tensile strength of 60,000 psi, a yield strength of 42,000 psi with 10 percent elongation, and is available with standard joints and many types of special joints.

The high level of operational dependability of ductile iron pipe stems from its major advantages of machineability, impact and corrosion resistance and high strength, making it a pipe material that is rugged and durable with high resistance to impact requiring virtually no maintenance. For these reasons, it has completely replaced cast iron as the choice piping material of waterworks professionals.

Manufacture of Ductile Iron Pipe

The centrifugal casting methods used in the manufacture of ductile iron pipe have been in the process of commercial development and refinement since 1925. The steady improvements that have led to the present state of the art have been covered by literally hundreds of patents and technical papers, and represent the ingenuity of many dedicated engineers, metallurgists, and foundrymen.

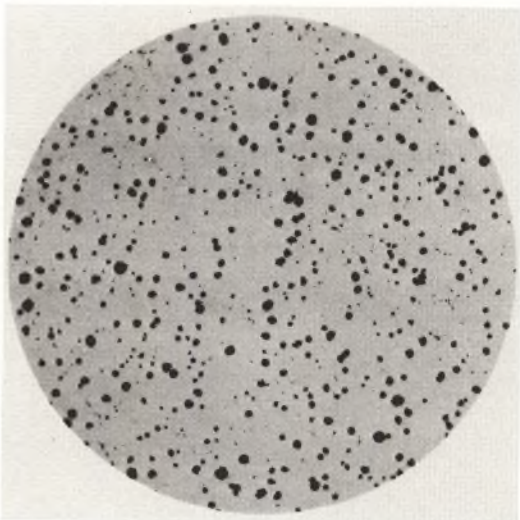
In the centrifugal casting process, a controlled amount of molten metal having the proper charactericstics is introduced into a rotating metal or sand-lined mold, fitted with a socket core, in such way as to distribute the metal over the interior of the mold surface by centrifugal force. This force holds the metal in place until solidification occurs. Pipe removed from the mold is furnace-annealed to produce the prescribed physical and mechanical properties and eliminate any casting stresses that may have been present.

After cleaning, hydrostatic testing, dimensional gaging, weighing, coating, lining and marking, the pipe is ready for shipment.

Microstructures

Gray Iron (100X)

Ductile Iron (100X)



SECTION II

DUCTILE IRON PIPE

Introduction

Ductile iron was originally invented by a member company of DIPRA, and the first ductile iron pipe was cast experimentally in 1948. Years of metallurgical, casting, and quality control refinement followed, and in 1955 ductile iron pipe was introduced into the marketplace.

Its phenomenal strength and impact resistance, along with many other advantages, created a rapid increase in demand for this product as engineers and utility officials realized that it could be transported, handled and installed with virtually no damage to the pipe. In service, ductile iron pipe showed that expense of repair was practically eliminated. Its corrosion resistance exceeds that of gray cast iron, a pipe product with a reputation of centuries of service in the transmission and distribution of water and gas. Evidence of wide acceptance of ductile iron pipe is demonstrated by its adoption throughout the world as an accepted underground pressure pipe for the transportation of water, wastes, and many industrial materials.

Ductile iron pipe with dimensions that make it compatible with gray iron pipe and fittings is available with a wide variety of joints which equip it for specific types of service (see Section V). As with gray cast iron pipe, protection from severe environmental factors is available (see Section VII).

Ductile iron pipe provides versatility in design and while it may be designed in accordance with details of ANSI/AWWA C150/A21.50, it is not confined to this specific system. Engineers may choose other use conditions such as those recommended by the American Society of Civil Engineers (ASCE) and, observing the available strength and ductility of ductile iron pipe.

Ductile iron pipe is manufactured in accordance with ANSI/AWWA C151/A21.51 Standard. The outstanding characteristics of ductile iron pipe result from its unique metallurgical properties effected during the manufacturing process.

Metallurgy of Ductile Iron Pipe

Structure

Ductile iron is usually defined as cast iron with primary graphite in the nodular or spheroidal form. This change in the graphite form is accomplished by adding an inoculant, usually magnesium, to molten iron of appropriate composition.

The matrix is predominantly ferritic for maximum impact resistance and ductility.

The chemical composition of ductile iron is similar to gray cast iron except for the inoculant addition. The chemistry is adjusted to meet the physical test requirements of the Standards.

Properties

Ferritic ductile iron, as compared to gray cast iron, will have about twice the strength as determined by tensile test, beam test, ring bending test, and bursting test. The tensile elongation and impact strength of ductile iron are many times that of gray cast iron.

Acceptance Test Requirements

The acceptance test requirements of the ANSI/AWWA C151/A21.51 Ductile Iron Pipe Standard are:

1. Strength and ductility properties of specimens machined from the pipe wall: ultimate strength, 60,000 psi minimum; yield strength, 42,000 psi minimum; elongation, 10 percent minimum.
2. Charpy V-Notch impact strengths on specimens cut from the pipe wall: 7 ft.-lb. minimum at 70°F; 3 ft.-lb. minimum at -40°F.

Quality Control

In addition to the acceptance tests, the manufacturers conduct other quality control tests to assure quality castings having the desired combination of properties.

A great deal of corrosion testing of ductile iron has been made since its commercial introduction. It has been found that the soil corrosion resistance of ductile iron pipe equals or exceeds that of gray cast iron pipe.

Ductile Iron Pipe Design

The method of thickness design of ductile iron pipe presented in ANSI/AWWA C150/A21.50 is based on flexible-pipe principles. The principal characteristics that distinguish flexible pipe from more rigid types of pipe are as follows:

1. In a flexible pipe the bending stress from trench load is reduced by the lateral soil reaction that is developed as the pipe deflects under the trench load and pushes outward against the sidefill soil.
2. A flexible pipe, initially deflected by trench load, is partially rerounded by internal pressure, and the bending stress of trench load is thus reduced.
3. A flexible pipe is usually required to carry less earth load than a more rigid pipe because the flexible pipe, in deflecting under the earth load, transfers a significant part of the load to the sidefill soil columns.

These characteristics are expressed mathematically in equations from which may be calculated the earth loads on flexible pipe and bending stresses and deflections of flexible pipe when subjected to: (1) external trench load and no internal pressure and (2) external trench load in combination with internal pressure. These equations are applicable to pipe made of various elastic metals, of which ductile iron is one.

During the development of the design procedures in this standard, a thorough investigation was carried out to establish conservative design criteria, metal stresses, and soil mechanics factors for use in applying the equations to the design of ductile iron pipe. This investigation included the following studies: ring-bending tests on a large number of ductile iron pipe; a review of the literature on the structural behavior of ductile iron pipe and other flexible pipe; and numerous calculations of pipe thicknesses, stresses, and deflections for various design criteria and loading conditions. From this investigation the design criteria and factors used in this standard were established as described below.

1. **Design Criterion for external trench load.** The appropriate criterion for design of ductile iron pipe against external load is either the bending stress developed at the pipe invert or the percentage of pipe deflection. The design standards provide formulas for calculating both. The largest thickness would then prevail for the external trench load.

2. **Deflection.** Numerous tests have been conducted regarding deflection. Results indicate that a deflection of 3% is appropriate and conservative for cement mortar lined ductile iron pipe, and larger percentages can be used for unlined or special lined ductile iron pipe.

3. **Design bending stress.** Results of a large number of ring-bending tests of ductile iron pipe of various sizes and thicknesses showed that a design bending stress of 48,000 psi is appropriate and conservative.

4. **Trench factors.** The design equations for bending stress and deflection contains the modulus of soil reaction and coefficients determined by the bedding angle, all of which are governed by the laying condition. The bedding angle is the angle subtended by the pipe surface that carries the load reaction at the bottom of the trench. Appropriate criteria for the five standard laying conditions are shown in Table 50.2 of the standard (American Society of Civil Engineers' trench classes B and C as well as other commonly used trench conditions are also used for ductile iron pipe. These trench conditions may be used in any design for underground ductile iron pipe).

   The design equations for bending stress and deflection which incorporated the effect of lateral soil support, applies to the full range of sizes and thicknesses available in ductile iron pipe. For pipe with small diameter-thickness ratios, the effect of sidefill soil support is relatively small. For pipe with larger ratios of diameter to thickness, the effect of lateral support in the equation is correspondingly larger.

5. **Separate stress design.** Because of partial rerounding by the internal pressure, the total stress in the pipe wall at the design pressure is less than the stress at zero pressure with external load only. Calculations showed that the larger of the two thicknesses obtained by designing separately for (1) external load with no internal pressure and (2) internal pressure with no external load is greater than the thickness calculated by the appropriate equation for combined external load and internal pressure. Therefore, the separate stress design detailed in the standard was selected.

6. **Design for internal pressure.** Results of a large number of wall tensile tests conducted in conjunction with full-length bursting tests of ductile iron pipe of various sizes and thicknesses showed that a design safety factor of 2 for

internal pressure is appropriate and conservative. Internal pressures used for calculation of the thicknesses in ANSI/AWWA C150/A21.50 include an allowance of 100 psi for surges.

7. **Earth loads.** As stated previously, the deflection of a flexible pipe reduces the earth load to less than that imposed on a more rigid pipe in the same condition, because the sidefills carry a part of the trench load transferred to them by the deflection of the pipe. In the standard, the prism load is used for pipe laid in trenches of any width. This is conservative practice because it does not take into account friction forces on the trench walls.

   In the calculations for earth loads, the unit weight of 120 lbs. per cubic foot for backfill soil is used. Soil weights generally vary from 110 to 130 lbs. per cubic foot. Experience has shown that 120 lbs. per cubic foot is commonly considered to be a conservative value for most installations.

8. **Allowance for truck superload.** In computing ductile iron pipe thicknesses, truck loads are added to earth loads. The truck superload allowance is a single AASHTO H-20 truck with 16,000 lbs. on each rear wheel with an impact factor of 1.5. These truck superloads are based on having the design depth of cover over the pipe and are applied at all depths of cover. Consideration should be given to the loads that may be transmitted to the pipe if either truck superloads or heavy construction equipment is permitted to pass over the pipe at less than the design depth of cover.

9. **Beam load.** Beam stress may be calculated using standard engineering beam formulas, and the deflection may be calculated using a modulus of elasticity of 24,000,000 psi.

10. **Service allowance.** Comparative corrosion tests of cast iron and ductile iron pipe have proved that the corrosion resistance of ductile iron pipe is equal to or greater than that of gray cast iron pipe. ANSI design thickness is increased by 0.08 in. to provide an arbitrary service allowance. DIPRA studies have shown that most soils are not corrosive to ductile iron pipe. In those soils, the service allowance serves as an added safety factor. Some of the remaining soils are moderately aggressive, and the service allowance serves as a protection against corrosion of the designed pipe wall thickness. In severely corrosive soils, special corrosion protection procedures must be employed (see Section VII).

11. **Thickness tolerance.** The standard thickness includes a casting tolerance, and the standard weight is calculated from this thickness. The average thickness of a pipe is controlled by the minimum-weight limitation. The minimum thickness is limited by the casting tolerance.

12. **Thickness for tapping.** The number of threads for taps of various sizes in different pipe thicknesses are provided in ductile iron pipe Standard ANSI/AWWA C151/A21.51. Tests have demonstrated that standard ¾ and 1 inch corporation stops m ay be threaded directly into all classes of ductile iron pipe for pressures through 350 psi. Installation torque may be reduced significantly by using teflon tape as a thread lubricant.

13. Safety Factors. As stated, the safety factor for internal pressure is 2.0 based on minimum yield strength of ductile iron in tension. For external loads, two safety factors are specified: 1.5 based on minimum ring yield strength and at least 2.0 based on ultimate strength. Also the design ring deflection provides a safety factor of at least 2.0 based on test data regarding deflections required to cause failure in cement-mortar lining.

The above safety factors are used to establish a design criterion and should not be confused with the total available safety factor of ductile iron pipe which is much greater than the specified safety factors used in design calculations for the following reasons:

a. The design criteria for ductile iron pipe are not based on performance limits associated with failure of the pipe wall.

b. Specified safety factors are used to calculate net wall thickness requirements, after which both service allowance and casting tolerance are added.

c. The yield strength of ductile iron pipe will consistently exceed the minimum values specified for design.

d. Ductile iron pipe can sustain stresses considerably higher than yield strength determined by standard test methods without damage to the pipe wall.

e. Design considerations dependent on laying conditions were established on a conservative basis.

Extensive tests have been conducted on ductile iron pipe to determine average values for tensile strength, ring strength, hardness and elongation. Test pipes ranged in size from 2-inch to 24-inch and represented by five different producers. These test results showed the average bursting tensile strength to be 53,320 psi and the average ring yield strength to be 84,880 psi for all pipes tested. These values remain consistent when compared to test data derived from burst tests and ring crush tests which are conducted on a continuing basis. Using these values, an example of total safety factor with regard to internal pressure design can be made:

To determine the total safety factor of 6-inch, Class 50 ductile iron pipe with respect to internal pressure for 350 psi working pressure and a standard surge pressure allowance of 100 psi:

1. Compute the hoop stress developed:

$$S = \frac{P_i D}{2t}$$

Let $P_i = 350 + 100 = 450$ psi since total safety factor is desired.

$$D = 6.90 \text{ in.}$$

Nominal thickness of Class 50 = 0.25 in.

Subtract casting tolerance to obtain minimum thickness manufactured (t_1)

$t_1 = 0.025 - 0.05 = 0.20$ in.

$$S = \frac{(450)(6.90)}{(2)(0.20)} = 7{,}762.5 \text{ psi}$$

2. Compare computed hoop stress to average bursting tensile strength to determine a representative total safety factor:

$$\frac{52{,}320 \text{ psi average}}{7{,}762.5 \text{ psi computed}} = 6.74$$

The total safety factor for internal pressure design will vary with pipe size, thickness class and design working pressure, but the above example serves to prove that the total available safety factor of ductile iron pipe is much greater than the design safety factor of 2.0.

With regard to external load design, actual external loading tests were conducted on large-diameter ductile iron pipe at Utah State University for the purpose of evaluating the C150/A21.50 procedure. From this test data, safety factors were calculated by dividing the loads at cement-mortar lining failure by allowable loads as well as by dividing the loads at pipe failure by allowable loads. Allowable loads were calculated using the C150/A21.50 design procedure for external loads. This comparison showed that when cement-mortar lining failure was used, the calculated safety factor of the test pipe averaged 2.98; when pipe failure was used, the calculated safety factor averaged 5.46. Using this data as a basis, it is apparent that the total available safety factor of ductile iron pipe with respect to external loads is far greater than the design safety factors of 1.5 and 2.0. Further, the above total available safety factors were determined on the basis of a separate stress design; for a combined stress situation (i.e., external load + internal pressure), the total available safety factor would be even greater because internal pressure would tend to reround the pipe, thereby reducing deflection and ring bending stresses created by external load. It is therefore evident that the total safety factor for ductile iron pipe is much more than adequate and that a thorough analysis of both the pipe material and the design procedure is necessary to properly determine safety factors.

Special Design Considerations

Ductile Iron Pipe is also well suited for many piping applications that are not specifically covered by the standard design procedure. For example: pipe on supports, shallow depths of cover, geological hazardous areas, high pressure applications, etc. Information relative to applications that involve special design considerations can be obtained from DIPRA or the pipe manufacturers.

ANSI/AWWA C150/A21.50-81

Revision of
A21.50-1976
(AWWA C150-76)

AMERICAN NATIONAL STANDARD

for the

THICKNESS DESIGN OF DUCTILE-IRON PIPE

SECRETARIATS

AMERICAN GAS ASSOCIATION
AMERICAN WATER WORKS ASSOCIATION
NEW ENGLAND WATER WORKS ASSOCIATION

NOTICE

This Standard has been especially printed by the American Water Works Association for incorporation into this volume. It is current as of October 1, 1984. It should be noted, however, that all AWWA Standards are updated at least once in every five years. Therefore, before applying this Standard it is suggested that you confirm its currency with the American Water Works Association.

Revised edition approved by American National Standards Institute, Inc., Nov. 3, 1981.

Published by

AMERICAN WATER WORKS ASSOCIATION
6666 West Quincy Avenue, Denver, Colorado 80235

American National Standard

An American National Standard implies a consensus of those substantially concerned with its scope and provisions. An American National Standard is intended as a guide to aid the manufacturer, the consumer, and the general public. The existence of an American National Standard does not in any respect preclude anyone, whether he has approved the standard or not, from manufacturing, marketing, purchasing, or using products, processes, or procedures not conforming to the standard. American National Standards are subject to periodic review, and users are cautioned to obtain the latest editions. Producers of goods made in conformity with an American National Standard are encouraged to state on their own responsibility in advertising and promotion material or on tags or labels that the goods are produced in conformity with particular American National Standards.

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Printed in USA

Committee Personnel

Subcommittee 1, Pipe, which reviewed this standard, had the following personnel at that time:

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WALTER AMORY, *Vice-Chairman*

User Members	*Producer Members*
W. AMORY	W.D. GOODE
R. BRYANT	T.D. HOLMES
F.E. DOLSON	H. KENNEDY, JR.
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G.F. KEENAN	L.L. NEEPER
W.H. SMITH	E.C. SEARS
	T.F. STROUD
	T. UPCHURCH
	T.B. WRIGHT

Standards Committee A21, Cast Iron Pipe and Fittings, which reviewed and approved this standard, had the following personnel at the time of approval:

ARNOLD M. TINKEY, *Chairman*
THOMAS D. HOLMES, *Vice-Chairman*
JOHN I. CAPITO, *Secretary*

Organization Represented	*Name of Representative*
American Gas Association	HARRY J. FORR
American Society of Mechanical Engineers	JAMES S. VANICK
American Society for Testing and Material	JOSEPH J. PALMER*
American Water Works Association	GERALD S. ALLEN
	ROBERT A. ARTHUR
	DONALD R. BOYD
	KENNETH W. HENDERSON
	JOHN PORTER HENNINGS

*Liaison representative without vote

Organization Represented	*Name of Representative*
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Ductile Iron Pipe Research Association	THOMAS D. HOLMES HAROLD KENNEDY, JR. PHILIP I. MCGRATH, JR. LELAND L. NEEPER TROY F. STROUD
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*Liaison representative without vote
†Alternate

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NOTE: Metric Tables Not Included In This Handbook.

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Foreword

This foreword is for information only and is not a part of ANSI/AWWA C150/A21.50-81.

I. History of Standard

American National Standards Committee A21, Cast-Iron Pipe and Fittings, was organized in 1926 under the sponsorship of the American Gas Association, the American Society for Testing and Materials, the American Water Works Association, and the New England Water Works Association. Since 1972, the cosecretariats have been AGA, AWWA, and NEWWA, with AWWA serving as the administrative secretariat. The present scope of Committee A21 activity is:

> Standardization of specifications for cast-iron and ductile-iron pressure pipe for gas, water and other liquids, and fittings for use with such pipe. These specifications to include design, dimensions, materials, coatings, linings, joints, accessories and methods of inspection and test.

The work of Committee A21 is conducted by subcommittees. The directive to Subcommittee 1—Pipe is as follows:

> The scope of the subcommittee activity shall include the periodic review of all current A21 standards for pipe, the preparation of revisions and new standards when needed, as well as other matters pertaining to pipe standards.

The first edition of A21.50, Standard for Thickness Design of Ductile-Iron Pipe, was issued in 1965, and revisions were issued in 1971 and 1976. Subcommittee 1 reviewed the 1976 edition and submitted a proposed revision to American National Standards Committee A21 in 1980.

II. Major Revisions

1. *Metric Conversions.* Metric conversions of all dimensions and physical requirements are included in this standard. Metric conversions of Tables 50.1–50.14 are shown in the appendix. Metric dimensions are direct conversions of customary US inch-pound units and are not those shown in International Standards Organization (ISO) standards.

2. *Metric Design Example.* Also shown in the appendix is a design example in metric units equivalent to the design example shown in Sec. 50-3 of the standard.

3. *Metric Dimensions for Formulas.* The formulas for earth load, truck load, and surface load factor have been modified to make them dimensionally consistent and compatible with metric as well as inch-pound units.

Revision of
A21.50-1976
(AWWA C150-76)

American National Standard
for the
Thickness Design of Ductile-Iron Pipe

Sec. 50-1—Scope

This standard covers the thickness design of ductile-iron pipe complying with the requirements of ANSI/AWWA C151/A21.51, Ductile-Iron Pipe, Centrifugally Cast in Metal Molds or Sand-Lined Molds for Water or Other Liquids.

Section 50-2 outlines the design procedure and Sec. 50-3 gives a design example.

Section 50-4 explains the bases of design.

As opposed to using procedures in Sec. 50-2 or 50-4, the designer may reference Tables 50.12–50.14 directly.

Table 50.12 lists thicknesses for standard laying conditions and depths of cover up to 32 ft (9.8 m).

Table 50.13 lists thicknesses for 150–350 psi (1.03–2.41 MPa) water working pressure.

The greater thickness from Table 50.12 or 50.13 for given trench load or internal pressure should be used.

Table 50.14 lists working pressures and maximum depths of cover for standard laying conditions and thickness classes.

Sec. 50-2—Procedure for Calculating Thickness

The thickness of ductile-iron pipe is determined by considering trench load and internal pressure separately.

50-2.1 *Step 1—Design for trench load.*

a. Determine trench load P_v. Table 50.1 gives trench load, including earth load P_e, plus truck load P_t, for 2.5–32 ft (0.8–9.8 m) cover.

b. Determine the standard laying condition from the descriptions in Table 50.2 and select the appropriate table for diameter-thickness ratios from Tables 50.7–50.11. Each table lists diameter-thickness ratios calculated for both bending stress and deflection over a range of trench loads.

c. For bending stress design, enter the column headed "Bending Stress Design" in the appropriate table of Tables 50.7–50.11 and locate the tabulated trench load P_v nearest to the calculated P_v from paragraph 50-2.1.a. (If the calculated P_v is halfway between two tabulated values, use the larger P_v value.)

Select the corresponding D/t value for this P_v.

Divide the pipe's outside diameter D (Table 50.5) by the D/t value to obtain net thickness t.

d. For deflection design, enter the column headed "Deflection Design" in the appropriate table of Tables 50.7–50.11 and locate the tabulated trench load P_v, nearest to the calculated P_v from paragraph 50-2.1.a. (If the calculated P_v is less than the minimum P_v listed in the table, design for trench load is not controlled by deflection and this determination need not be completed.) If the calculated P_v is halfway between two tabulated values, use the larger P_v value.

Select the corresponding D/t_1 value for this P_v.

Divide the pipe's outside diameter D (Table 50.5) by the D/t value to obtain minimum manufacturing thickness t_1. Deduct 0.08 in. (2.0 mm) service allowance to obtain net thickness t.

e. Compare the net thicknesses from steps *c* and *d* and select the larger of the two. This will be the net thickness required for trench load.

50-2.2 *Step 2—Design for internal pressure.* Calculate the net thickness required for internal pressure using the equation for hoop stress:

$$t = \frac{P_i D}{2S}$$

in which:

t = net thickness, in. (mm)

P_i = design internal pressure, psi (MPa)

= $2(P_w + P_s)$

P_w = working pressure, psi (MPa)

P_s = surge allowance, 100 psi (0.69 MPa)

D = outside diameter of pipe, in. (mm)

S = minimum yield strength in tension

= 42 000 psi (289.6 MPa)

If anticipated surge pressures are greater than 100 psi (0.69 MPa), the maximum anticipated pressure must be used.

50-2.3 *Step 3—Selection of net thickness and addition of allowances.*

a. Select the net thickness t from step 1 or 2, whichever thickness is larger.

b. Add the service allowance of 0.08 in. (2.0 mm) to the net thickness t. The resulting thickness is the minimum manufacturing thickness t_1.

c. Add the casting tolerance from Table 50.3 to the minimum manufacturing thickness t_1. The resulting thickness is the total calculated thickness.

50-2.4 *Step 4—Selection of standard thickness and class.* Use the total calculated thickness from Sec. 50-2.3.c to select a standard class thickness from Table 50.5. Select the standard thickness nearest to the calculated thickness. When the calculated thickness is halfway between two standard thicknesses, select the larger of the two.

In specifying and ordering pipe, use the class number listed in Table 50.5 for this standard thickness.

Sec. 50-3—Design Example for Calculating Thickness

Problem: Calculate the thickness for 30-in. ductile-iron pipe laid on a flat-bottom trench with backfill lightly consolidated to centerline of pipe, laying condition Type 2, under 10 ft of cover for a working pressure of 200 psi.

50-3.1 *Step 1—Design for trench load.*

a. Earth load (Table 50.1) P_e = 8.3 psi
Truck load (Table 50.1) P_t = 0.7 psi

Trench load, $P_v = P_e + P_t = 9.0$ psi

b. Select Table 50.8 for diameter thickness ratios for laying condition Type 2.

c. Entering P_v of 9.0 psi in Table 50.8, the bending stress design requires D/t of 128. From Table 50.5, diameter D of 30-in. pipe is 32.00 in.

Net thickness t for bending stress = $D/(D/t) = 32.00/128 = 0.25$ in.

d. Also, from Table 50.8, the deflection design requires D/t_1 of 108.

Minimum Thickness t_1 for deflection design

$$= \frac{D}{t_1} = \frac{32.00}{108} = 0.30 \text{ in.}$$

Deduct service allowance −0.08 in.

Net thickness t
for deflection control 0.22 in.

e. The larger net thickness is 0.25 in., obtained by the design for bending stress.

50-3.2 *Step 2–Design for internal pressure.*

$P_i = 2.0$ (Working pressure + 100 psi surge allowance)

(If anticipated surge pressures are greater than 100 psi, then the actual anticipated pressures must be used.)

$$P_i = 2.0\,(200 + 100)$$

$$= 600 \text{ psi}$$

$$t = \frac{P_i D}{2s} = \frac{600 \times 32.00}{2 \times 42\,000} = 0.23 \text{ in.}$$

Net thickness t for internal pressure is 0.23 in.

50-3.3 *Step 3–Selection of net thickness and addition of allowances.* The larger of the thicknesses is given by the design for trench load, Step 1, and 0.25 in. is selected.

Net thickness	= 0.25 in.
Service allowance	= 0.08 in.
Minimum thickness	= 0.33 in.
Casting tolerance	= 0.07 in.
Total calculated thickness	= 0.40 in.

50-3.4 *Step 4–Selection of standard thickness and class.* The total calculated thickness of 0.40 in. is nearest to 0.39, Class 50, in Table 50.5. Therefore, Class 50 is selected for specifying and ordering.

Note: This example is calculated in customary US inch-pound units. The same example in metric units is shown in the appendix.

Sec. 50-4—Design Method

50-4.1 *Ductile-iron pipe thickness.* The thickness of ductile-iron pipe is determined by considering trench load and internal pressure separately.

Calculations are made for the thicknesses required to resist the bending stress and the deflection caused by trench load. The larger of the two is selected as the thickness required to resist trench load. Calculations are then made for the thickness required to resist the hoop stress of internal pressure.

The larger of these is selected as the net design thickness. To this net thickness is added a service allowance to obtain the minimum manufacturing thickness and a casting tolerance to obtain the total calculated thickness.

The standard thickness and the thickness class for specifying and ordering are selected from a table of standard class thicknesses.

The reverse of the preceding procedure is used to determine the rated working pressure and maximum depth of cover for pipe of a given thickness class.

50-4.2 *Trench load, P_v.* Trench load is expressed as vertical pressure in pounds per square inch (kPa) and is equal to the sum of earth load P_e and truck load P_t.

50-4.3 *Earth load, P_e.* Earth load is computed by Eq 4 for the weight of the unit prism of soil with a height equal to the distance from the top of the pipe to the ground surface. The unit weight of backfill soil is taken to be 120 lb/cu ft (1922 kg/m^3). If the designer anticipates additional loads, the design load should be increased accordingly.

50-4.4 *Truck load, P_t.* The truck loads shown in Table 50.1 were computed by Eq 5 using the surface load factors in Table 50.6 and the reduction factors R from Table 50.4 for a single AASHTO H-20 truck on unpaved road or flexible pavement, 16 000-lb (7257-kg) wheel load, and 1.5 impact factor. The surface load factors in Table 50.6 were calculated by Eq 6 for a single concentrated wheel load centered over an effective pipe length of 3 ft (0.9 m).

50-4.5 *Design for trench load.* Tables 50.7–50.11, the tables of diameter–thickness ratios used to design for trench load, were computed by Eq 2 and 3. Equation 2 is based on the bending stress at the bottom of the pipe. The design bending stress f is 48 000 psi (331×10^3 kPa), which provides at least a 1.5 safety factor based on minimum ring yield strength and a 2.0 safety factor based on ultimate strength. Equation 3 is based on the deflection of the pipe ring section. The design deflection Δx is 3 percent of the outside diameter of the pipe, which is well below the deflection that might damage cement linings. Design values of the trench parameters E', K_b, and K_x are given in Table 50.2.

Tables similar to Tables 50.7–50.11 may be compiled for laying conditions other than those shown in this standard by calculating the trench loads P_v for a series of diameter–thickness ratios, D/t and D/t_1, using Eq 2 and 3 with values of E', K_b, and K_x appropriate to the bedding and backfill conditions.

Design Equations

$$t = \frac{P_i D}{2S} \qquad (1)$$

$$P_v = \frac{f}{3\left(\frac{D}{t}\right)\left(\frac{D}{t} - 1\right)\left[K_b - \dfrac{K_x}{\dfrac{8E}{E'\left(\frac{D}{t} - 1\right)^3} + 0.732}\right]} \qquad (2)$$

$$P_v = \frac{\frac{\Delta x}{D}}{12K_x}\left[\frac{8E}{\left(\frac{D}{t_1} - 1\right)^3} + 0.732E'\right] \qquad (3)$$

$$P_e = \frac{wH}{a} \qquad (4)$$

$$P_t = \frac{C \cdot R \cdot P \cdot F}{bD} \qquad (5)$$

$$C = \frac{1}{3} - \frac{2}{3\pi}\arcsin\left(H\sqrt{\frac{A^2 + B^2 + H^2}{(A^2 + H^2)(B^2 + H^2)}}\right) + \frac{2}{3\pi}\left(\frac{A \cdot H \cdot B}{\sqrt{A^2 + H^2 + B^2}}\right)\left(\frac{1}{A^2 + H^2} + \frac{1}{B^2 + H^2}\right) \quad (6)$$

Explanation of Symbols Used in Design Equations

A = Outside radius of pipe. For A in feet, D in inches: $A = D/24$ (For A in metres, D in millimetres: $A = D/2000$)

a = Conversion factor. For pounds-per-square-foot to pounds-per-inch: $a = 144$ (For kilograms-per-square-metre to kilopascals: $a = 120$)

B = 1.5 ft (0.457 m)

b = Conversion factor. For pounds-per-linear-foot to pounds-per-square-inch: $b = 12$ (For kilograms-per-linear-metre to kilopascals: $b = 0.031$)

C = Surface load factor: See Table 50.6 (Table 50.6M)

D = Outside diameter, in inches (millimetres): See Table 50.5 (Table 50.5M)

E = Modulus of elasticity: 24×10^6 psi (165.5×10^6 kPa)

E' = Modulus of soil reaction, in pounds per square inch (kilopascals): See Table 50.2 (Table 50.2M)

F = Impact factor: 1.5

f = Design bending stress: 48 000 psi (331×10^3 kPa)

H = Depth of cover, in feet (metres)

K_b = Bending moment coefficient: See Table 50.2 (Table 50.2M)

K_x = Deflection coefficient: See Table 50.2 (Table 50.2M)

P = Wheel load: 16 000 lb (7257 kg)

P_e = Earth load, in pounds per square inch (kilopascals)

P_i = Design internal pressure, in pounds per square inch (megapascals): $P_i = 2$ (working pressure + 100 psi [0.69 MPa] surge allowance)

P_t = Truck load, in pounds per square inch (kilopascals)

P_v = Trench load, in pounds per square inch (kilopascals): $P_v = P_e + P_t$

R = Reduction factor, which takes account of the fact that the part of the pipe directly below the wheels is aided in carrying the truck load by adjacent parts of the pipe that recieve little or no load from the wheels: See Table 50.4 (Table 50.4M)

S = Minimum yield strength in tension: 42 000 psi (289.6 MPa)

t = Net thickness in inches (millimetres)

t_1 = Minimum manufacturing thickness. In inches: $t_1 = t + 0.08$ (In millimetres: $t_1 = t + 2.0$)

w = Soil weight: 120 lb/cu ft (1922 kg/m^3)

Δx = Design deflection, in inches (millimetres): $\Delta x = 0.03D$

NOTE: In Eq 6, angles are in radians.

TABLE 50.1

Earth Loads P_e, *Truck Loads* P_t, *and Trench Loads* P_v—psi

Depth of Cover ft	P_e	3-in. Pipe		4-in. Pipe		6-in. Pipe		8-in. Pipe	
		P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v
2.5	2.1	9.9	12.0	9.9	12.0	9.9	12.0	9.8	11.9
3	2.5	7.4	9.9	7.4	9.9	7.3	9.8	7.3	9.8
4	3.3	4.4	7.7	4.5	7.8	4.4	7.7	4.4	7.7
5	4.2	3.0	7.2	3.0	7.2	3.0	7.2	3.0	7.2
6	5.0	2.1	7.1	2.1	7.1	2.1	7.1	2.1	7.1
7	5.8	1.6	7.4	1.6	7.4	1.6	7.4	1.6	7.4
8	6.7	1.2	7.9	1.2	7.9	1.2	7.9	1.2	7.9
9	7.5	1.0	8.5	1.0	8.5	1.0	8.5	1.0	8.5
10	8.3	0.8	9.1	0.8	9.1	0.8	9.1	0.8	9.1
12	10.0	0.6	10.6	0.6	10.6	0.6	10.6	0.6	10.6
14	11.7	0.4	12.1	0.4	12.1	0.4	12.1	0.4	12.1
16	13.3	0.3	13.6	0.3	13.6	0.3	13.6	0.3	13.6
20	16.7	0.2	16.9	0.2	16.9	0.2	16.9	0.2	16.9
24	20.0	0.2	20.2	0.1	20.1	0.1	20.1	0.1	20.1
28	23.3	0.1	23.4	0.1	23.4	0.1	23.4	0.1	23.4
32	26.7	0.1	26.8	0.1	26.8	0.1	26.8	0.1	26.8

Depth of Cover ft	P_e	10-in. Pipe		12-in. Pipe		14-in. Pipe		16-in. Pipe	
		P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v
2.5	2.1	9.7	11.8	9.6	11.7	8.7	10.8	8.2	10.3
3	2.5	7.2	9.7	7.2	9.7	6.6	9.1	6.2	8.7
4	3.3	4.4	7.7	4.4	7.7	4.4	7.7	4.1	7.4
5	4.2	2.9	7.1	2.9	7.1	2.9	7.1	2.8	7.0
6	5.0	2.1	7.1	2.1	7.1	2.1	7.1	2.0	7.0
7	5.8	1.6	7.4	1.6	7.4	1.6	7.4	1.5	7.3
8	6.7	1.2	7.9	1.2	7.9	1.2	7.9	1.2	7.9
9	7.5	1.0	8.5	1.0	8.5	1.0	8.5	1.0	8.5
10	8.3	0.8	9.1	0.8	9.1	0.8	9.1	0.8	9.1
12	10.0	0.5	10.5	0.5	10.5	0.5	10.5	0.5	10.5
14	11.7	0.4	12.1	0.4	12.1	0.4	12.1	0.4	12.1
16	13.3	0.3	13.6	0.3	13.6	0.3	13.6	0.3	13.6
20	16.7	0.2	16.9	0.2	16.9	0.2	16.9	0.2	16.9
24	20.0	0.1	20.1	0.1	20.1	0.1	20.1	0.1	20.1
28	23.3	0.1	23.4	0.1	23.4	0.1	23.4	0.1	23.4
32	26.7	0.1	26.8	0.1	26.8	0.1	26.8	0.1	26.8

TABLE 50.1—(*cont.*)

Depth of Cover *ft*	P_e	18-in. Pipe		20-in. Pipe		24-in. Pipe		30-in. Pipe	
		P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v
2.5	2.1	7.8	9.9	7.5	9.6	7.1	9.2	6.7	8.8
3	2.5	5.9	8.4	5.7	8.2	5.4	7.9	5.2	7.7
4	3.3	3.9	7.2	3.9	7.2	3.6	6.9	3.5	6.8
5	4.2	2.6	6.8	2.6	6.8	2.4	6.6	2.4	6.6
6	5.0	1.9	6.9	1.9	6.9	1.7	6.7	1.7	6.7
7	5.8	1.4	7.2	1.4	7.2	1.3	7.1	1.3	7.1
8	6.7	1.2	7.9	1.1	7.8	1.1	7.8	1.1	7.8
9	7.5	1.0	8.5	0.9	8.4	0.9	8.4	0.9	8.4
10	8.3	0.8	9.1	0.7	9.0	0.7	9.0	0.7	9.0
12	10.0	0.5	10.5	0.5	10.5	0.5	10.5	0.5	10.5
14	11.7	0.4	12.1	0.4	12.1	0.4	12.1	0.4	12.1
16	13.3	0.3	13.6	0.3	13.6	0.3	13.6	0.3	13.6
20	16.7	0.2	16.9	0.2	16.9	0.2	16.9	0.2	16.9
24	20.0	0.1	20.1	0.1	20.1	0.1	20.1	0.1	20.1
28	23.3	0.1	23.4	0.1	23.4	0.1	23.4	0.1	23.4
32	26.7	0.1	26.8	0.1	26.8	0.1	26.8	0.1	26.8

Depth of Cover *ft*	P_e	36-in. Pipe		42-in. Pipe		48-in. Pipe		54-in. Pipe	
		P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v
2.5	2.1	6.2	8.3	5.8	7.9	5.4	7.5	5.0	7.1
3	2.5	4.9	7.4	4.6	7.1	4.4	6.9	4.1	6.6
4	3.3	3.4	6.7	3.3	6.6	3.1	6.4	3.0	6.3
5	4.2	2.3	6.5	2.3	6.5	2.2	6.4	2.1	6.3
6	5.0	1.7	6.7	1.7	6.7	1.6	6.6	1.6	6.6
7	5.8	1.3	7.1	1.3	7.1	1.2	7.0	1.2	7.0
8	6.7	1.1	7.8	1.0	7.7	1.0	7.7	1.0	7.7
9	7.5	0.8	8.3	0.8	8.3	0.8	8.3	0.8	8.3
10	8.3	0.7	9.0	0.7	9.0	0.7	9.0	0.7	9.0
12	10.0	0.5	10.5	0.5	10.5	0.5	10.5	0.5	10.5
14	11.7	0.4	12.1	0.4	12.1	0.4	12.1	0.4	12.1
16	13.3	0.3	13.6	0.3	13.6	0.3	13.6	0.3	13.6
20	16.7	0.2	16.9	0.2	16.9	0.2	16.9	0.2	16.9
24	20.0	0.1	20.1	0.1	20.1	0.1	20.1	0.1	20.1
28	23.3	0.1	23.4	0.1	23.4	0.1	23.4	0.1	23.4
32	26.7	0.1	26.8	0.1	26.8	0.1	26.8	0.1	26.8

TABLE 50.2

Design Values for Standard Laying Conditions

Laying Condition*	Description	E'	Bedding Angle *deg*	K_b	K_x
Type 1†	Flat-bottom trench.‡ Loose backfill.	150	30	0.235	0.108
Type 2	Flat-bottom trench. Backfill lightly consolidated to centerline of pipe.	300	45	0.210	0.105
Type 3	Pipe bedded in 4-in.-minimum loose soil.§ Backfill lightly consolidated to top of pipe.	400	60	0.189	0.103
Type 4	Pipe bedded in sand, gravel, or crushed stone to depth of ⅛ pipe diameter, 4-in. minimum. Backfill compacted to top of pipe. (Approx. 80 per cent Standard Proctor, AASHTO T-99)**	500	90	0.157	0.096
Type 5	Pipe bedded to its centerline in compacted granular material, 4-in. minimum under pipe. Compacted granular or select§ material to top of pipe. (Approx. 90 per cent Standard Proctor, AASHTO T-99)**	700	150	0.128	0.085

* See Fig. 1.
† For pipe 30 in. and larger, consideration should be given to the use of laying conditions other than Type 1.
‡ Flat-bottom is defined as "undisturbed earth."
§ Loose soil or select material is defined as "native soil excavated from the trench, free of rocks, foreign material, and frozen earth."
** AASHTO T-99, "Moisture Density Relations of Soils Using a 5.5 lb (2.5 kg) Rammer 12-in. (305-mm) Drop."

TABLE 50.3

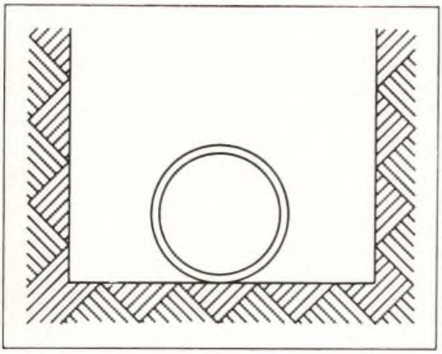
Allowances for Casting Tolerance

Size *in.*	Casting Tolerance *in.*
3–8	0.05
10–12	0.06
14–42	0.07
48	0.08
54	0.09

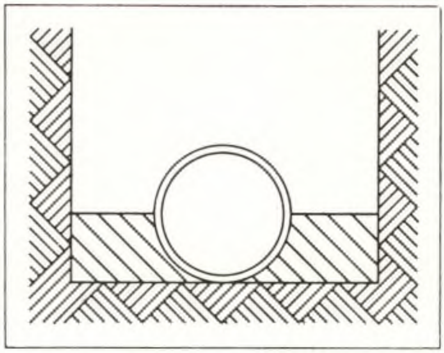
TABLE 50.4

Reduction Factors R *for Truck Load Calculations*

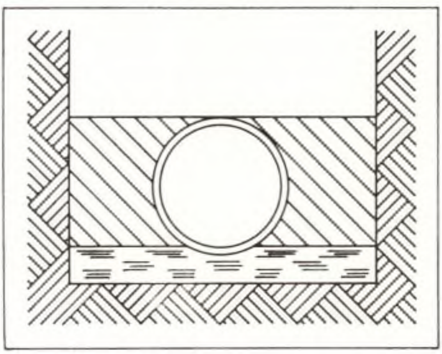
Size *in.*	Depth of Cover—*ft*			
	<4	4–7	8–10	>10
	Reduction Factor			
3–12	1.00	1.00	1.00	1.00
14	0.92	1.00	1.00	1.00
16	0.88	0.95	1.00	1.00
18	0.85	0.90	1.00	1.00
20	0.83	0.90	0.95	1.00
24–30	0.81	0.85	0.95	1.00
36–54	0.80	0.85	0.90	1.00



Type 1



Type 2



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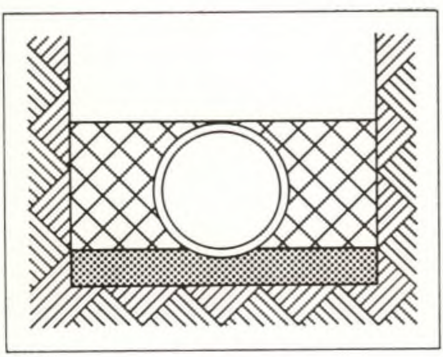

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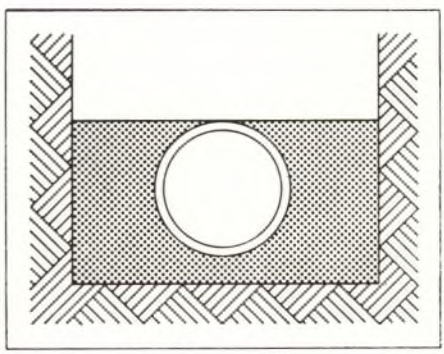

Type 5

Figure 1. Standard Pipe Laying Conditions

See Table 2

TABLE 50.5

Standard Thickness Classes of Ductile-Iron Pipe

Size *in.*	Outside Diameter—*in.*	Thickness Class						
		50	51	52	53	54	55	56
		Thickness—*in.*						
3	3.96	—	0.25	0.28	0.31	0.34	0.37	0.40
4	4.80	—	0.26	0.29	0.32	0.35	0.38	0.41
6	6.90	0.25	0.28	0.31	0.34	0.37	0.40	0.43
8	9.05	0.27	0.30	0.33	0.36	0.39	0.42	0.45
10	11.10	0.29	0.32	0.35	0.38	0.41	0.44	0.47
12	13.20	0.31	0.34	0.37	0.40	0.43	0.46	0.49
14	15.30	0.33	0.36	0.39	0.42	0.45	0.48	0.51
16	17.40	0.34	0.37	0.40	0.43	0.46	0.49	0.52
18	19.50	0.35	0.38	0.41	0.44	0.47	0.50	0.53
20	21.60	0.36	0.39	0.42	0.45	0.48	0.51	0.54
24	25.80	0.38	0.41	0.44	0.47	0.50	0.53	0.56
30	32.00	0.39	0.43	0.47	0.51	0.55	0.59	0.63
36	38.30	0.43	0.48	0.53	0.58	0.63	0.68	0.73
42	44.50	0.47	0.53	0.59	0.65	0.71	0.77	0.83
48	50.80	0.51	0.58	0.65	0.72	0.79	0.86	0.93
54	57.10	0.57	0.65	0.73	0.81	0.89	0.97	1.05

TABLE 50.6

Surface Load Factors for Single Truck on Unpaved Road

Depth of Cover *ft*	Pipe Size—*in.* 3	4	6	8	10	12	14	16
	Surface Load Factor—*C*							
2.5	0.0196	0.0238	0.0340	0.0443	0.0538	0.0634	0.0726	0.0814
3	0.0146	0.0177	0.0253	0.0330	0.0402	0.0475	0.0546	0.0614
4	0.0088	0.0107	0.0153	0.0201	0.0245	0.0290	0.0335	0.0379
5	0.0059	0.0071	0.0102	0.0134	0.0163	0.0194	0.0224	0.0254
6	0.0042	0.0050	0.0072	0.0095	0.0116	0.0138	0.0159	0.0181
7	0.0031	0.0038	0.0054	0.0071	0.0087	0.0103	0.0119	0.0135
8	0.0024	0.0029	0.0042	0.0055	0.0067	0.0079	0.0092	0.0104
9	0.0019	0.0023	0.0033	0.0043	0.0053	0.0063	0.0073	0.0083
10	0.0015	0.0019	0.0027	0.0035	0.0043	0.0051	0.0060	0.0068
12	0.0011	0.0013	0.0019	0.0025	0.0030	0.0036	0.0042	0.0047
14	0.0008	0.0010	0.0014	0.0018	0.0022	0.0027	0.0031	0.0035
16	0.0006	0.0007	0.0011	0.0014	0.0017	0.0020	0.0024	0.0027
20	0.0004	0.0005	0.0007	0.0009	0.0011	0.0013	0.0015	0.0017
24	0.0003	0.0003	0.0005	0.0006	0.0008	0.0009	0.0011	0.0012
28	0.0002	0.0002	0.0003	0.0005	0.0006	0.0007	0.0008	0.0009
32	0.0002	0.0002	0.0003	0.0003	0.0004	0.0005	0.0006	0.0007

Depth of Cover *ft*	Pipe Size—*in.* 18	20	24	30	36	42	48	54
	Surface Load Factor—*C*							
2.5	0.0899	0.0980	0.1130	0.1321	0.1479	0.1604	0.1705	0.1784
3	0.0681	0.0746	0.0867	0.1028	0.1169	0.1286	0.1384	0.1466
4	0.0422	0.0464	0.0545	0.0657	0.0761	0.0853	0.0936	0.1008
5	0.0283	0.0312	0.0369	0.0449	0.0525	0.0595	0.0661	0.0720
6	0.0202	0.0223	0.0264	0.0323	0.0381	0.0435	0.0486	0.0534
7	0.0151	0.0167	0.0198	0.0243	0.0288	0.0329	0.0370	0.0409
8	0.0117	0.0129	0.0154	0.0189	0.0224	0.0258	0.0290	0.0322
9	0.0093	0.0103	0.0122	0.0151	0.0179	0.0206	0.0233	0.0259
10	0.0076	0.0084	0.0100	0.0123	0.0147	0.0169	0.0191	0.0213
12	0.0053	0.0059	0.0070	0.0086	0.0103	0.0119	0.0135	0.0151
14	0.0039	0.0043	0.0052	0.0064	0.0076	0.0088	0.0100	0.0112
16	0.0030	0.0033	0.0040	0.0049	0.0059	0.0068	0.0077	0.0087
20	0.0019	0.0021	0.0025	0.0032	0.0038	0.0044	0.0050	0.0056
24	0.0013	0.0015	0.0018	0.0022	0.0026	0.0030	0.0035	0.0039
28	0.0010	0.0011	0.0013	0.0016	0.0019	0.0022	0.0026	0.0029
32	0.0008	0.0008	0.0010	0.0012	0.0015	0.0017	0.0020	0.0022

TABLE 50.7

*Diameter–Thickness Ratios for Laying Condition Type 1**

Trench Load (P_v)—*psi*			Trench Load (P_v)—*psi*		
Bending Stress Design	Deflection Design	$\frac{D\dagger}{t}$ or $\frac{D}{t_1}$	Bending Stress Design	Deflection Design	$\frac{D\dagger}{t}$ or $\frac{D}{t_1}$
4.40	3.46	170	6.33	4.71	128
4.43	3.48	169	6.40	4.76	127
4.46	3.50	168	6.46	4.82	126
4.50	3.51	167			
4.54	3.53	166	6.53	4 87	125
			6.60	4.93	124
4.57	3.55	165	6.67	4.99	123
4.61	3.57	164	6.74	5.05	122
4.64	3.59	163	6.82	5.11	121
4.68	3.61	162			
4.72	3.63	161	6.89	5.18	120
			6.97	5.25	119
4.76	3.65	160	7.05	5.32	118
4.80	3.67	159	7.13	5.39	117
4.84	3.69	158	7.21	5.46	116
4.88	3.71	157			
4.92	3.74	156	7.29	5.54	115
			7.38	5.62	114
4.96	3.76	155	7.47	5.71	113
5.00	3.78	154	7.56	5.79	112
5.04	3.81	153	7.65	5.88	111
5.08	3.83	152			
5.13	3.86	151	7.75	5.97	110
			7.85	6.07	109
5.17	3.89	150	7.95	6.17	108
5.21	3.91	149	8.05	6.27	107
5.26	3.94	148	8.16	6.38	106
5.30	3.97	147			
5.35	4.00	146	8.27	6.49	105
			8.38	6.61	104
5.40	4.03	145	8.49	6.73	103
5.45	4.06	144	8.61	6.86	102
5.49	4.09	143	8.74	6.99	101
5.54	4.13	142			
5.59	4.16	141	8.86	7.12	100
			8.99	7.26	99
5.65	4.20	140	9.13	7.41	98
5.70	4.23	139	9.27	7.57	97
5.75	4.27	138	9.41	7.73	96
5.80	4.31	137			
5.86	4.35	136	9.56	7.89	95
			9.71	8.07	94
5.91	4.39	135	9.87	8.25	93
5.97	4.43	134	10.03	8.44	92
6.03	4.47	133	10.20	8.64	91
6.09	4.52	132	10.37	8.85	90
6.15	4.56	131	10.55	9.06	89
			10.74	9.29	88
6.21	4.61	130	10.93	9.53	87
6.27	4.66	129	11.13	9.78	86

TABLE 50.7—(*cont.*)

Trench Load (P_v)—*psi*		
Bending Stress Design	Deflection Design	$\frac{D}{t}$† or $\frac{D}{t_1}$
11.34	10.04	85
11.55	10.31	84
11.78	10.60	83
12.01	10.90	82
12.25	11.22	81
12.50	11.56	80
12.76	11.91	79
13.03	12.28	78
13.31	12.67	77
13.60	13.08	76
13.91	13.51	75
14.23	13.97	74
14.56	14.45	73
14.91	14.96	72
15.27	15.50	71
15.65	16.07	70
16.05	16.68	69
16.46	17.32	68
16.89	18.00	67
17.35	18.73	66
17.83	19.50	65
18.33	20.32	64
18.85	21.19	63
19.40	22.12	62
19.98	23.12	61
20.59	24.18	60
21.23	25.32	59

Trench Load (P_v)—*psi*		
Bending Stress Design	Deflection Design	$\frac{D}{t}$† or $\frac{D}{t_1}$
21.91	26.54	58
22.63	27.85	57
23.38	29.26	56
24.18	30.77	55
25.02	32.39	54
25.92	34.15	53
26.86	36.05	52
27.87	38.10	51
28.94	40.32	50
30.07	42.73	49
31.28	45.35	48
32.57	48.20	47
33.95	51.31	46
35.42	54.72	45
37.00	58.44	44
38.69	62.53	43
40.50	67.03	42
42.46	71.99	41
44.56	77.47	40
46.84	83.54	39
49.30	90.28	38
51.96	97.80	37
54.86	106.20	36
58.02	115.62	35
61.46	126.21	34
65.23	138.18	33
69.36	151.73	32
73.92	167.15	31

* $E' = 150$; $K_b = 0.235$; $K_x = 0.108$.

† The $\frac{D}{t}$ for the tabulated P_v nearest to the calculated P_v is selected; when the calculated P_v is halfway between two tabulated values, the smaller $\frac{D}{t}$ should be used.

TABLE 50.8

*Diameter–Thickness Ratios for Laying Condition Type 2**

Trench Load (P_v)—psi: Bending Stress Design	Trench Load (P_v)—psi: Deflection Design	$\frac{D\dagger}{t}$ or $\frac{D}{t_1}$
6.29	6.18	170
6.34	6.19	169
6.39	6.21	168
6.44	6.23	167
6.50	6.25	166
6.55	6.26	165
6.60	6.28	164
6.66	6.30	163
6.71	6.32	162
6.77	6.34	161
6.82	6.37	160
6.88	6.39	159
6.94	6.41	158
6.99	6.43	157
7.05	6.46	156
7.11	6.48	155
7.17	6.50	154
7.23	6.53	153
7.29	6.56	152
7.35	6.58	151
7.42	6.61	150
7.48	6.64	149
7.54	6.67	148
7.61	6.70	147
7.67	6.73	146
7.74	6.76	145
7.80	6.79	144
7.87	6.83	143
7.94	6.86	142
8.01	6.89	141
8.08	6.93	140
8.15	6.97	139
8.22	7.01	138
8.29	7.05	137
8.37	7.09	136
8.44	7.13	135
8.52	7.17	134
8.59	7.22	133
8.67	7.26	132
8.75	7.31	131
8.83	7.36	130
8.91	7.41	129
8.99	7.46	128
9.07	7.51	127
9.16	7.57	126
9.25	7.63	125
9.33	7.69	124
9.42	7.75	123
9.51	7.81	122
9.60	7.87	121
9.70	7.94	120
9.79	8.01	119
9.89	8.08	118
9.99	8.16	117
10.09	8.23	116
10.19	8.31	115
10.29	8.40	114
10.40	8.48	113
10.51	8.57	112
10.62	8.66	111
10.73	8.76	110
10.84	8.86	109
10.96	8.96	108
11.08	9.07	107
11.21	9.18	106
11.33	9.29	105
11.46	9.41	104
11.59	9.54	103
11.73	9.67	102
11.87	9.80	101
12.01	9.94	100
12.16	10.09	99
12.31	10.24	98
12.46	10.40	97
12.62	10.56	96
12.79	10.73	95
12.96	10.91	94
13.13	11.10	93
13.31	11.29	92
13.49	11.50	91
13.68	11.71	90
13.88	11.94	89
14.08	12.17	88
14.30	12.42	87
14.51	12.67	86

TABLE 50.8—(*cont.*)

Trench Load (P_v)—*psi*		
Bending Stress Design	Deflection Design	$\frac{D}{t}$† or $\frac{D}{t_1}$
14.74	12.94	85
14.97	13.22	84
15.21	13.52	83
15.46	13.83	82
15.72	14.16	81
15.99	14.50	80
16.28	14.86	79
16.57	15.24	78
16.87	15.64	77
17.19	16.06	76
17.52	16.51	75
17.86	16.98	74
18.22	17.48	73
18.59	18.00	72
18.98	18.56	71
19.39	19.14	70
19.82	19.77	69
20.27	20.43	68
20.73	21.13	67
21.23	21.87	66
21.74	22.67	65
22.28	23.51	64
22.85	24.41	63
23.45	25.37	62
24.07	26.39	61
24.74	27.49	60
25.43	28.66	59
26.17	29.91	58

Trench Load (P_v)—*psi*		
Bending Stress Design	Deflection Design	$\frac{D}{t}$† or $\frac{D}{t_1}$
26.95	31.26	57
27.77	32.71	56
28.64	34.26	55
29.56	35.93	54
30.53	37.74	53
31.57	39.69	52
32.67	41.80	51
33.84	44.09	50
35.08	46.56	49
36.41	49.26	48
37.83	52.19	47
39.34	55.40	46
40.96	58.89	45
42.70	62.73	44
44.57	66.93	43
46.57	71.56	42
48.73	76.66	41
51.06	82.29	40
53.57	88.54	39
56.30	95.48	38
59.25	103.21	37
62.46	111.85	36
65.96	121.54	35
69.79	132.44	34
73.98	144.74	33
78.57	158.68	32
83.64	174.54	31

* $E' = 300$; $K_b = 0.210$; $K_x = 0.105$.

† The $\frac{D}{t}$ for the tabulated P_v nearest to the calculated P_v is selected; when the calculated P_v is halfway between two tabulated values, the smaller $\frac{D}{t}$ should be used.

TABLE 50.9

*Diameter–Thickness Ratios for Laying Condition Type 3**

Trench Load (P_v)—*psi*		
Bending Stress Design	Deflection Design	$\frac{D\dagger}{t}$ or $\frac{D}{t_1}$
3.25	7.26	310
3.29	7.27	308
3.33	7.27	306
3.37	7.27	304
3.41	7.28	302
3.45	7.28	300
3.49	7.28	298
3.54	7.29	296
3.58	7.29	294
3.63	7.30	292
3.67	7.30	290
3.72	7.30	288
3.76	7.31	286
3.81	7.31	284
3.86	7.32	282
3.91	7.32	280
3.96	7.33	278
4.01	7.33	276
4.06	7.34	274
4.11	7.34	272
4.17	7.35	270
4.22	7.35	268
4.28	7.36	266
4.33	7.36	264
4.39	7.37	262
4.45	7.38	260
4.51	7.38	258
4.57	7.39	256
4.63	7.39	254
4.69	7.40	252
4.76	7.41	250
4.82	7.42	248
4.89	7.42	246
4.96	7.43	244
5.03	7.44	242
5.10	7.45	240
5.17	7.46	238
5.24	7.47	236
5.31	7.48	234
5.39	7.48	232
5.47	7.49	230
5.54	7.51	228
5.62	7.52	226
5.70	7.53	224
5.79	7.54	222
5.87	7.55	220
5.96	7.56	218
6.04	7.58	216
6.13	7.59	214
6.22	7.60	212
6.32	7.62	210
6.41	7.63	208
6.51	7.65	206
6.60	7.66	204
6.70	7.68	202
6.80	7.70	200
6.91	7.72	198
7.01	7.74	196
7.12	7.76	194
7.22	7.78	192
7.33	7.80	190
7.45	7.82	188
7.56	7.84	186
7.68	7.87	184
7.80	7.89	182
7.92	7.92	180
8.04	7.95	178
8.16	7.98	176
8.29	8.01	174
8.42	8.04	172
8.55	8.07	170
8.62	8.09	169
8.69	8.11	168
8.75	8.13	167
8.82	8.14	166
8.89	8.16	165
8.96	8.18	164
9.03	8.20	163
9.10	8.22	162
9.17	8.24	161
9.25	8.27	160
9.32	8.29	159
9.39	8.31	158
9.47	8.33	157
9·54	8.36	156

TABLE 50.9—(*cont.*)

Trench Load (P_v)—*psi*		
Bending Stress Design	Deflection Design	$\frac{D\dagger}{t}$ or $\frac{D}{t_1}$
9.62	8.38	155
9.69	8.41	154
9.77	8.43	153
9.85	8.46	152
9.92	8.49	151
10.00	8.52	150
10.08	8.54	149
10.16	8.57	148
10.24	8.60	147
10.33	8.64	146
10.41	8.67	145
10.49	8.70	144
10.58	8.73	143
10.66	8.77	142
10.75	8.81	141
10.83	8.84	140
10.92	8.88	139
11.01	8.92	138
11.10	8.96	137
11.19	9.00	136
11.28	9.04	135
11.37	9.09	134
11.46	9.13	133
11.56	9.18	132
11.65	9.23	131
11.75	9.28	130
11.84	9.33	129
11.94	9.38	128
12.04	9.44	127
12.14	9.49	126
12.25	9.55	125
12.35	9.61	124
12.45	9.67	123
12.56	9.74	122
12.67	9.80	121
12.78	9.87	120
12.89	9.94	119
13.00	10.02	118
13.11	10.09	117
13.23	10.17	116
13.34	10.25	115
13.46	10.34	114
13.58	10.42	113
13.71	10.51	112
13.83	10.61	111
13.96	10.71	110
14.09	10.81	109
14.22	10.91	108
14.36	11.02	107
14.50	11.13	106
14.64	11.25	105
14.78	11.37	104
14.93	11.50	103
15.08	11.63	102
15.23	11.77	101
15.39	11.91	100
15.55	12.06	99
15.71	12.21	98
15.88	12.37	97
16.06	12.54	96
16.23	12.72	95
16.42	12.90	94
16.61	13.09	93
16.80	13.29	92
17.00	13.50	91
17.21	13.72	90
17.42	13.95	89
17.64	14.18	88
17.86	14.43	87
18.10	14.70	86
18.34	14.97	85
18.59	15.26	84
18.85	15.56	83
19.12	15.88	82
19.40	16.21	81
19.68	16.56	80
19.99	16.93	79
20.30	17.31	78
20.62	17.72	77
20.96	18.15	76
21.31	18.61	75
21.68	19.09	74
22.07	19.59	73
22.47	20.13	72
22.88	20.69	71

TABLE 50.9—(*cont.*)

Trench Load (P_v)—*psi*			Trench Load (P_v)—*psi*		
Bending Stress Design	Deflection Design	$\frac{D}{t}$† or $\frac{D}{t_1}$	Bending Stress Design	Deflection Design	$\frac{D}{t}$† or $\frac{D}{t_1}$
23.32	21.29	70	38.97	46.72	50
23.78	21.93	69	40.33	49.25	49
24.26	22.60	68	41.78	51.99	48
24.76	23.32	67	43.33	54.98	47
25.29	24.08	66	44.98	58.25	46
25.85	24.88	65	46.76	61.81	45
26.43	25.74	64	48.66	65.72	44
27.04	26.66	63	50.71	70.01	43
27.68	27.64	62	52.91	74.72	42
28.36	28.68	61	55.28	79.92	41
29.08	29.80	60	57.84	85.67	40
29.83	30.99	59	60.61	92.04	39
30.63	32.27	58	63.61	99.11	38
31.47	33.64	57	66.86	106.99	37
32.36	35.12	56	70.40	115.80	36
33.31	36.70	55	74.27	125.67	35
34.30	38.41	54	78.49	136.78	34
35.37	40.25	53	83.11	149.32	33
36.49	42.24	52	88.19	163.54	32
37.69	44.39	51	93.79	179.71	31

* $E' = 400$; $K_b = 0.189$; $K_x = 0.103$.

† The $\frac{D}{t}$ for the tabulated P_v nearest to the calculated P_v is selected; when the calculated P_v is halfway between two tabulated values, the smaller $\frac{D}{t}$ should be used.

TABLE 50.10

*Diameter-Thickness Ratios for Laying Condition Type 4**

Trench Load (P_v)—*psi*		
Bending Stress Design	Deflection Design	$\frac{D\dagger}{t}$ or $\frac{D}{t_1}$
5.93	9.70	310
6.00	9.70	308
6.07	9.71	306
6.14	9.71	304
6.21	9.71	302
6.29	9.72	300
6.36	9.72	298
6.43	9.73	296
6.51	9.73	294
6.59	9.73	292
6.67	9.74	290
6.74	9.74	288
6.83	9.75	286
6.91	9.75	284
6.99	9.76	282
7.08	9.76	280
7.16	9.77	278
7.25	9.77	276
7.34	9.78	274
7.43	9.78	272
7.52	9.79	270
7.61	9.79	268
7.71	9.80	266
7.80	9.81	264
7.90	9.81	262
8.00	9.82	260
8.10	9.83	258
8.20	9.83	256
8.31	9.84	254
8.41	9.85	252
8.52	9.86	250
8.63	9.86	248
8.74	9.87	246
8.85	9.88	244
8.97	9.89	242
9.08	9.90	240
9.20	9.91	238
9.32	9.92	236
9.44	9.93	234
9.57	9.94	232
9.69	9.95	230
9.82	9.96	228

Trench Load (P_v)—*psi*		
Bending Stress Design	Deflection Design	$\frac{D\dagger}{t}$ or $\frac{D}{t_1}$
9.95	9.97	226
10.08	9.98	224
10.21	9.99	222
10.35	10.01	220
10.49	10.02	218
10.62	10.03	216
10.77	10.05	214
10.91	10.06	212
11.05	10.08	210
11.20	10.09	208
11.35	10.11	206
11 50	10.13	204
11.66	10.15	202
11.81	10.17	200
11.97	10.19	198
12.13	10.21	196
12.29	10.23	194
12.45	10.25	192
12.62	10.27	190
12.79	10.30	188
12.96	10.32	186
13.13	10.35	184
13.30	10.37	182
13.48	10.40	180
13.66	10.43	178
13.84	10.46	176
14.02	10.50	174
14.20	10.53	172
14.39	10.57	170
14.48	10.59	169
14.57	10.60	168
14.67	10.62	167
14.76	10.64	166
14.86	10.66	165
14.96	10.69	164
15.05	10.71	163
15.15	10.73	162
15.25	10.75	161
15.34	10.78	160
15.44	10.80	159
15.54	10.82	158
15.64	10.85	157
15.74	10.87	156

TABLE 50.10—(*cont.*)

Trench Load (P_v)—*psi*		
Bending Stress Design	Deflection Design	$\frac{D\dagger}{t}$ or $\frac{D}{t_1}$
15.84	10.90	155
15.94	10.93	154
16.04	10.96	153
16.14	10.98	152
16.24	11.01	151
16.34	11.04	150
16.45	11.07	149
16.55	11.11	148
16.65	11.14	147
16.76	11.17	146
16.86	11.21	145
16.96	11.24	144
17.07	11.28	143
17.18	11.31	142
17.28	11.35	141
17.39	11.39	140
17.50	11.43	139
17.60	11.48	138
17.71	11.52	137
17.82	11.56	136
17.93	11.61	135
18.04	11.66	134
18.15	11.71	133
18.26	11.76	132
18.37	11.81	131
18.49	11.86	130
18.60	11.92	129
18.72	11.97	128
18.83	12.03	127
18.95	12.09	126
19.06	12.15	125
19.18	12.22	124
19.30	12.28	123
19.42	12.35	122
19.54	12.42	121
19.66	12.50	120
19.78	12.57	119
19.91	12.65	118
20.04	12.73	117
20.16	12.82	116
20.29	12.91	115
20.42	13.00	114
20.55	13.09	113

Trench Load (P_v)—*psi*		
Bending Stress Design	Deflection Design	$\frac{D\dagger}{t}$ or $\frac{D}{t_1}$
20.69	13.19	112
20.82	13.29	111
20.96	13.39	110
21.10	13.50	109
21.24	13.61	108
21.39	13.73	107
21.54	13.85	106
21.69	13.98	105
21.84	14.11	104
22.00	14.24	103
22.16	14.38	102
22.32	14.53	101
22.49	14.68	100
22.66	14.84	99
22.83	15.01	98
23.01	15.18	97
23.20	15.36	96
23.38	15.55	95
23.58	15.75	94
23.78	15.95	93
23.99	16.17	92
24.20	16.39	91
24.42	16.62	90
24.64	16.87	89
24.88	17.12	88
25.12	17.39	87
25.37	17.67	86
25.63	17.97	85
25.90	18.28	84
26.18	18.60	83
26.47	18.94	82
26.77	19.30	81
27.09	19.67	80
27.42	20.07	79
27.76	20.48	78
28.11	20.92	77
28.49	21.38	76
28.87	21.87	75
29.28	22.38	74
29.70	22.93	73
30.15	23.50	72
30.62	24.11	71

TABLE 50.10—(*cont.*)

Trench Load (P_v)—*psi*			Trench Load (P_v)—*psi*		
Bending Stress Design	Deflection Design	$\frac{D}{t}$† or $\frac{D}{t_1}$	Bending Stress Design	Deflection Design	$\frac{D}{t}$† or $\frac{D}{t_1}$
31.11	24.75	70	49.11	52.03	50
31.62	25.43	69	50.70	54.74	49
32.16	26.16	68	52.41	57.69	48
32.72	26.92	67	54.23	60.90	47
33.32	27.74	66	56.18	64.40	46
33.95	28.60	65	58.27	68.23	45
34.61	29.53	64	60.52	72.42	44
35.30	30.51	63	62.93	77.02	43
36.04	31.56	62	65.54	82.08	42
36.81	32.68	61	68.35	87.66	41
37.63	33.88	60	71.39	93.82	40
38.50	35.16	59	74.67	100.65	39
39.42	36.53	58	78.24	108.24	38
40.39	38.00	57	82.11	116.70	37
41.42	39.58	56	86.33	126.15	36
42.51	41.28	55	90.93	136.74	35
43.67	43.12	54	95.97	148.66	34
44.91	45.09	53	101.49	162.12	33
46.22	47.22	52	107.56	177.37	32
47.62	49.53	51	114.25	194.72	31

* $E' = 500$; $K_b = 0.157$; $K_x = 0.096$.

† The $\frac{D}{t}$ for the tabulated P_v nearest to the calculated P_v is selected; when the calculated P_v is halfway between two tabulated values, the smaller $\frac{D}{t}$ should be used.

TABLE 50.11

*Diameter–Thickness Ratios for Laying Condition Type 5**

Trench Load (P_v)—psi		
Bending Stress Design	Deflection Design	$\frac{D\dagger}{t}$ or $\frac{D}{t_1}$
3.06	15.09	660
3.10	15.09	655
3.15	15.09	650
3.20	15.09	645
3.25	15.09	640
3.30	15.09	635
3.35	15.09	630
3.40	15.09	625
3.46	15.09	620
3.51	15.09	615
3.57	15.10	610
3.63	15.10	605
3.68	15.10	600
3.75	15.10	595
3.81	15.10	590
3.87	15.10	585
3.94	15.10	580
4.00	15.10	575
4.07	15.10	570
4.14	15.10	565
4.21	15.10	560
4.29	15.10	555
4.36	15.10	550
4.44	15.11	545
4.52	15.11	540
4.60	15.11	535
4.69	15.11	530
4.77	15.11	525
4.86	15.11	520
4.95	15.11	515
5.05	15.11	510
5.14	15.11	505
5.24	15.12	500
5.35	15.12	495
5.45	15.12	490
5.56	15.12	485
5.67	15.12	480
5.78	15.12	475
5.90	15.13	470
6.02	15.13	465
6.15	15.13	460
6.28	15.13	455
6.41	15.13	450
6.54	15.14	445
6.68	15.14	440
6.83	15.14	435
6.98	15.14	430
7.13	15.14	425
7.29	15.15	420
7.46	15.15	415
7.63	15.15	410
7.80	15.16	405
7.98	15.16	400
8.17	15.16	395
8.36	15.17	390
8.56	15.17	385
8.77	15.17	380
8.98	15.18	375
9.20	15.18	370
9.43	15.19	365
9.66	15.19	360
9.91	15.20	355
10.16	15.20	350
10.42	15.21	345
10.69	15.22	340
10.97	15.22	335
11.26	15.23	330
11.56	15.24	325
11.87	15.24	320
12.19	15.25	315
12.52	15.26	310
12.66	15.27	308
12.80	15.27	306
12.94	15.27	304
13.08	15.28	302
13.23	15.28	300
13.37	15.29	298
13.52	15.29	296
13.67	15.30	294
13.83	15.30	292
13.98	15.30	290
14.14	15.31	288
14.30	15.31	286
14.46	15.32	284
14.62	15.33	282

TABLE 50.11—(*cont.*)

Trench Load (P_v)—*psi*		
Bending Stress Design	Deflection Design	$\frac{D\dagger}{t}$ or $\frac{D}{t_1}$
14.79	15.33	280
14.96	15.34	278
15.13	15.34	276
15.30	15.35	274
15.48	15.35	272
15.65	15.36	270
15.83	15.37	268
16.02	15.37	266
16.20	15.38	264
16.39	15.39	262
16.58	15.40	260
16.77	15.40	258
16.97	15.41	256
17.16	15.42	254
17.36	15.43	252
17.57	15.44	250
17.77	15.45	248
17.98	15.45	246
18.19	15.46	244
18.40	15.47	242
18.62	15.48	240
18.84	15.49	238
19.06	15.51	236
19.28	15.52	234
19.51	15.53	232
19.73	15.54	230
19.97	15.55	228
20.20	15.57	226
20.43	15.58	224
20.67	15.59	222
20.91	15.61	220
21.16	15.62	218
21.40	15.64	216
21.65	15.65	214
21.90	15.67	212
22.15	15.69	210
22.40	15.71	208
22.66	15.73	206
22.92	15.75	204
23.18	15.77	202
23.44	15.79	200
23.70	15.81	198
23.97	15.83	196

Trench Load (P_v)—*psi*		
Bending Stress Design	Deflection Design	$\frac{D\dagger}{t}$ or $\frac{D}{t_1}$
24.24	15.86	194
24.50	15.88	192
24.77	15.91	190
25.04	15.93	188
25.31	15.96	186
25.59	15.99	184
25.86	16.02	182
26.13	16.06	180
26.41	16.09	178
26.68	16.12	176
26.96	16.16	174
27.23	16.20	172
27.51	16.24	170
27.65	16.26	169
27.78	16.28	168
27.92	16.31	167
28.06	16.33	166
28.19	16.35	165
28.33	16.37	164
28.47	16.40	163
28.60	16.42	162
28.74	16.45	161
28.87	16.48	160
29.01	16.50	159
29.15	16.53	158
29.28	16.56	157
29.41	16.59	156
29.55	16.62	155
29.68	16.65	154
29.82	16.68	153
29.95	16.71	152
30.08	16.74	151
30.21	16.78	150
30.34	16.81	149
30.48	16.85	148
30.61	16.89	147
30.74	16.92	146
30.87	16.96	145
30.99	17.00	144
31.12	17.04	143
31.25	17.09	142
31.38	17.13	141

TABLE 50.11—(*cont.*)

Trench Load (P_v)—*psi*		
Bending Stress Design	Deflection Design	$\frac{D\dagger}{t}$ or $\frac{D}{t_1}$
31.50	17.17	140
31.63	17.22	139
31.76	17.27	138
31.88	17.32	137
32.01	17.37	136
32.13	17.42	135
32.25	17.47	134
32.38	17.53	133
32.50	17.58	132
32.62	17.64	131
32.75	17.70	130
32.87	17.76	129
32.99	17.83	128
33.11	17.89	127
33.23	17.96	126
33.35	18.03	125
33.47	18.11	124
33.59	18.18	123
33.71	18.26	122
33.83	18.34	121
33.95	18.42	120
34.07	18.51	119
34.19	18.60	118
34.31	18.69	117
34.43	18.78	116
34 55	18.88	115
34.68	18.98	114
34.80	19.09	113
34.92	19.20	112
35.05	19.31	111
35.17	19.43	110
35.30	19.55	109
35.43	19.68	108
35.56	19.81	107
35.69	19.95	106
35.83	20.09	105
35.96	20.24	104
36 10	20.39	103
36.25	20.55	102
36.39	20.72	101
36.54	20.89	100
36.69	21.07	99
36.85	21.26	98

Trench Load (P_v)—*psi*		
Bending Stress Design	Deflection Design	$\frac{D\dagger}{t}$ or $\frac{D}{t_1}$
37.01	21.45	97
37.17	21.66	95
37.34	21.87	95
37.52	22.09	94
37.70	22.32	93
37.89	22.56	92
38.08	22.82	91
38.28	23.08	90
38.49	23.36	89
38.71	23.65	88
38.93	23.95	87
39.17	24.27	86
39.41	24.60	85
39.67	24.95	84
39.94	25.31	83
40.22	25.70	82
40.51	26.10	81
40.82	26.52	80
41.14	26.97	79
41.48	27.44	78
41.84	27.93	77
42.21	28.46	76
42.60	29.01	75
43.02	29.59	74
43.45	30.20	73
43.92	30 85	72
44.40	31.53	71
44.91	32.26	70
45.46	33.03	69
46.03	33.85	68
46.64	34.71	67
47.28	35.63	66
47.96	36.61	65
48.68	37.65	64
49.44	38.77	63
50.25	39.95	62
51.11	41.21	61
52.02	42.57	60
52.99	44.01	59
54.02	45.56	58
55.12	47.23	57
56.28	49.01	56

TABLE 50.11—(*cont.*)

Trench Load (P_v)—*psi*			Trench Load (P_v)—*psi*		
Bending Stress Design	Deflection Design	$\frac{D}{t}$† or $\frac{D}{t_1}$	Bending Stress Design	Deflection Design	$\frac{D}{t}$† or $\frac{D}{t_1}$
57.53	50.93	55	84.50	97.01	42
58.86	53.00	54	87.85	103.31	41
60.28	55.23	53			
61.79	57.64	52	91.47	110.27	40
63.41	60.25	51	95.40	117.98	39
65.14	63.07	50	99.67	126.56	38
67.00	66.13	49	104.32	136.11	37
68.99	69.46	48	109.40	146.78	36
71.12	73.09	47			
73.41	77.04	46	114.94	158.75	35
			121.02	172.21	34
75.88	81.36	45	127.69	187.41	33
78.54	86.10	44	135.03	204.63	32
81.40	91.29	43	143.14	224.22	31

* $E' = 700$; $K_b = 0.128$; $K_x = 0.085$.

† The $\frac{D}{t}$ for the tabulated P_v nearest to the calculated P_v is selected; when the calculated P_v is halfway between two tabulated values, the smaller $\frac{D}{t}$ should be used.

TABLE 50.12

Thickness for Earth Load Plus Truck Load

Size *in.*	Depth of Cover *ft*	Laying Condition									
		Type 1		Type 2		Type 3		Type 4		Type 5	
		Total Calculated Thickness* *in.*	Use Class	Total Calculated Thickness* *in.*	Use Class	Total Calculated Thickness* *in.*	Use Class	Total Calculated Thickness* *in.*	Use Class	Total Calculated Thickness* *in.*	Use Class
3	2.5	0.18	51	0.17	51	0.16	51	0.15	51	0.14	51
	3	0.17	51	0.16	51	0.16	51	0.15	51	0.14	51
	4	0.17	51	0.16	51	0.15	51	0.14	51	0.14	51
	5	0.16	51	0.16	51	0.15	51	0.14	51	0.14	51
	6	0.16	51	0.16	51	0.15	51	0.14	51	0.14	51
	7	0.16	51	0.16	51	0.15	51	0.14	51	0.14	51
	8	0.17	51	0.16	51	0.15	51	0.15	51	0.14	51
	9	0.17	51	0.16	51	0.15	51	0.15	51	0.14	51
	10	0.17	51	0.16	51	0.15	51	0.15	51	0.14	51
	12	0.17	51	0.17	51	0.16	51	0.15	51	0.14	51
	14	0.18	51	0.17	51	0.16	51	0.15	51	0.14	51
	16	0.18	51	0.17	51	0.17	51	0.15	51	0.14	51
	20	0.19	51	0.18	51	0.17	51	0.16	51	0.15	51
	24	0.19	51	0.19	51	0.18	51	0.16	51	0.15	51
	28	0.20	51	0.19	51	0.19	51	0.17	51	0.15	51
	32	0.21	51	0.20	51	0.19	51	0.18	51	0.15	51
4	2.5	0.19	51	0.18	51	0.17	51	0.15	51	0.15	51
	3	0.18	51	0.17	51	0.16	51	0.15	51	0.14	51
	4	0.17	51	0.16	51	0.16	51	0.15	51	0.14	51
	5	0.17	51	0.16	51	0.15	51	0.15	51	0.14	51
	6	0.17	51	0.16	51	0.15	51	0.15	51	0.14	51
	7	0.17	51	0.16	51	0.16	51	0.15	51	0.14	51
	8	0.17	51	0.16	51	0.16	51	0.15	51	0.14	51
	9	0.18	51	0.17	51	0.16	51	0.15	51	0.14	51
	10	0.18	51	0.17	51	0.16	51	0.15	51	0.14	51
	12	0.18	51	0.17	51	0.16	51	0.15	51	0.14	51
	14	0.19	51	0.18	51	0.17	51	0.15	51	0.15	51
	16	0.19	51	0.18	51	0.17	51	0.16	51	0.15	51
	20	0.20	51	0.19	51	0.18	51	0.16	51	0.15	51
	24	0.21	51	0.20	51	0.19	51	0.17	51	0.15	51
	28	0.22	51	0.21	51	0.20	51	0.18	51	0.15	51
	32	0.22	51	0.21	51	0.21	51	0.19	51	0.16	51
6	2.5	0.21	50	0.20	50	0.18	50	0.16	50	0.15	50
	3	0.20	50	0.19	50	0.18	50	0.16	50	0.15	50
	4	0.19	50	0.18	50	0.17	50	0.16	50	0.15	50
	5	0.19	50	0.17	50	0.17	50	0.15	50	0.15	50
	6	0.19	50	0.17	50	0.17	50	0.15	50	0.15	50
	7	0.19	50	0.18	50	0.17	50	0.16	50	0.15	50
	8	0.19	50	0.18	50	0.17	50	0.16	50	0.15	50
	9	0.20	50	0.18	50	0.17	50	0.16	50	0.15	50
	10	0.20	50	0.18	50	0.17	50	0.16	50	0.15	50
	12	0.21	50	0.19	50	0.18	50	0.16	50	0.15	50
	14	0.21	50	0.20	50	0.18	50	0.17	50	0.15	50
	16	0.22	50	0.21	50	0.19	50	0.17	50	0.15	50
	20	0.23	50	0.22	50	0.21	50	0.18	50	0.16	50
	24	0.24	50	0.23	50	0.22	50	0.19	50	0.16	50
	28	0.25	50	0.24	50	0.23	50	0.20	50	0.16	50
	32	0.26	50	0.25	50	0.24	50	0.22	50	0.17	50

* Total calculated thickness includes service allowance and casting tolerance added to net thickness.

TABLE 50.12—(*cont.*)

Size *in.*	Depth of Cover *ft*	Laying Condition									
		Type 1		Type 2		Type 3		Type 4		Type 5	
		Total Calculated Thickness* *in.*	Use Class	Total Calculated Thickness* *in.*	Use Class	Total Calculated Thickness* *in.*	Use Class	Total Calculated Thickness* *in.*	Use Class	Total Calculated Thickness* *in.*	Use Class
8	2.5	0.24	50	0.22	50	0.20	50	0.18	50	0.16	50
	3	0.23	50	0.21	50	0.19	50	0.17	50	0.16	50
	4	0.21	50	0.19	50	0.18	50	0.16	50	0.15	50
	5	0.21	50	0.19	50	0.18	50	0.16	50	0.15	50
	6	0.21	50	0.19	50	0.18	50	0.16	50	0.15	50
	7	0.21	50	0.19	50	0.18	50	0.16	50	0.15	5C
	8	0.21	50	0.19	50	0.18	50	0.16	50	0.15	50
	9	0.22	50	0.20	50	0.18	50	0.17	50	0.15	50
	10	0.22	50	0.20	50	0.19	50	0.17	50	0.15	50
	12	0.23	50	0.21	50	0.19	50	0.17	50	0.16	50
	14	0.24	50	0.22	50	0.20	50	0.18	50	0.16	50
	16	0.25	50	0.23	50	0.21	50	0.18	50	0.16	50
	20	0.27	50	0.25	50	0.23	50	0.19	50	0.17	50
	24	0.28	50	0.26	50	0.24	50	0.21	50	0.17	50
	28	0.29	51	0.28	50	0.26	50	0.23	50	0.18	50
	32	0.30	51	0.29	51	0.27	50	0.24	50	0.18	50
10	2.5	0.27	50	0.25	50	0.23	50	0.20	50	0.17	50
	3	0.26	50	0.23	50	0.21	50	0.19	50	0.17	50
	4	0.24	50	0.22	50	0.20	50	0.18	50	0.17	50
	5	0.23	50	0.21	50	0.20	50	0.18	50	0.17	50
	6	0.23	50	0.21	50	0.20	50	0.18	50	0.17	50
	7	0.24	50	0.21	50	0.20	50	0.18	50	0.17	50
	8	0.24	50	0.22	50	0.20	50	0.18	50	0.17	50
	9	0.25	50	0.22	50	0.20	50	0.18	50	0.17	50
	10	0.25	50	0.23	50	0.21	50	0.19	50	0.17	50
	12	0.26	50	0.24	50	0.22	50	0.19	50	0.17	50
	14	0.28	50	0.25	50	0.23	50	0.20	50	0.18	50
	16	0.29	50	0.26	50	0.24	50	0.20	50	0.18	50
	20	0.31	51	0.28	50	0.26	50	0.22	50	0.18	50
	24	0.32	51	0.30	50	0.28	50	0.24	50	0.19	50
	28	0.34	52	0.32	51	0.30	50	0.26	50	0.20	50
	32	0.35	52	0.33	51	0.32	51	0.28	50	0.20	50
12	2.5	0.30	50	0.27	50	0.24	50	0.21	50	0.18	50
	3	0.28	50	0.25	50	0.23	50	0.20	50	0.18	50
	4	0.26	50	0.23	50	0.21	50	0.19	50	0.17	50
	5	0.25	50	0.23	50	0.21	50	0.19	50	0.17	50
	6	0.25	50	0.23	50	0.21	50	0.19	50	0.17	50
	7	0.26	50	0.23	50	0.21	50	0.19	50	0.17	50
	8	0.26	50	0.23	50	0.21	50	0.19	50	0.17	50
	9	0.27	50	0.24	50	0.22	50	0.19	50	0.17	50
	10	0.27	50	0.24	50	0.22	50	0.20	50	0.18	50
	12	0.29	50	0.26	50	0.23	50	0.20	50	0.18	50
	14	0.30	50	0.27	50	0.24	50	0.21	50	0.18	50
	16	0.31	50	0.29	50	0.26	50	0.21	50	0.18	50
	20	0.34	51	0.31	50	0.28	50	0.23	50	0.19	50
	24	0.36	52	0.33	51	0.31	50	0.25	50	0.20	50
	28	0.38	52	0.35	51	0.33	51	0.28	50	0.21	50
	32	0.39	53	0.37	52	0.35	51	0.30	50	0.23	50

* Total calculated thickness includes service allowance and casting tolerance added to net thickness.

TABLE 50.12—(*cont.*)

Size in.	Depth of Cover ft	Laying Condition: Type 1 Total Calculated Thickness* in.	Type 1 Use Class	Type 2 Total Calculated Thickness* in.	Type 2 Use Class	Type 3 Total Calculated Thickness* in.	Type 3 Use Class	Type 4 Total Calculated Thickness* in.	Type 4 Use Class	Type 5 Total Calculated Thickness* in.	Type 5 Use Class
14	2.5	0.32	50	0.29	50	0.26	50	0.22	50	0.20	50
	3	0.31	50	0.27	50	0.24	50	0.21	50	0.19	50
	4	0.29	50	0.26	50	0.23	50	0.21	50	0.19	50
	5	0.28	50	0.25	50	0.23	50	0.20	50	0.19	50
	6	0.28	50	0.25	50	0.23	50	0.20	50	0.19	50
	7	0.28	50	0.25	50	0.23	50	0.21	50	0.19	50
	8	0.29	50	0.26	50	0.23	50	0.21	50	0.19	50
	9	0.30	50	0.26	50	0.24	50	0.21	50	0.19	50
	10	0.31	50	0.27	50	0.24	50	0.21	50	0.19	50
	12	0.32	50	0.29	50	0.26	50	0.22	50	0.19	50
	14	0.34	50	0.30	50	0.27	50	0.23	50	0.20	50
	16	0.35	51	0.32	50	0.29	50	0.24	50	0.20	50
	20	0.38	52	0.35	51	0.32	50	0.26	50	0.21	50
	24	0.40	52	0.38	52	0.34	50	0.28	50	0.22	50
	28	0.42	53	0.40	52	0.37	51	0.31	50	0.24	50
	32	0.44	54	0.42	53	0.39	52	0.34	50	0.26	50
16	2.5	0.34	50	0.30	50	0.27	50	0.23	50	0.20	50
	3	0.32	50	0.28	50	0.25	50	0.22	50	0.20	50
	4	0.30	50	0.27	50	0.24	50	0.21	50	0.19	50
	5	0.30	50	0.26	50	0.24	50	0.21	50	0.19	50
	6	0.30	50	0.26	50	0.24	50	0.21	50	0.19	50
	7	0.30	50	0.26	50	0.24	50	0.21	50	0.19	50
	8	0.31	50	0.27	50	0.25	50	0.22	50	0.19	50
	9	0.32	50	0.28	50	0.25	50	0.22	50	0.20	50
	10	0.33	50	0.29	50	0.26	50	0.22	50	0.20	50
	12	0.35	50	0.31	50	0.27	50	0.23	50	0.20	50
	14	0.36	51	0.33	50	0.29	50	0.24	50	0.20	50
	16	0.38	51	0.34	50	0.30	50	0.25	50	0.21	50
	20	0.41	52	0.38	51	0.34	50	0.27	50	0.22	50
	24	0.44	53	0.41	52	0.37	51	0.30	50	0.24	50
	28	0.46	54	0.43	53	0.40	52	0.33	50	0.27	50
	32	0.48	55	0.46	54	0.43	53	0.36	51	0.29	50
18	2.5	0.36	50	0.32	50	0.28	50	0.24	50	0.20	50
	3	0.34	50	0.29	50	0.26	50	0.23	50	0.20	50
	4	0.32	50	0.28	50	0.25	50	0.22	50	0.20	50
	5	0.31	50	0.27	50	0.25	50	0.22	50	0.19	50
	6	0.31	50	0.27	50	0.25	50	0.22	50	0.19	50
	7	0.32	50	0.28	50	0.25	50	0.22	50	0.20	50
	8	0.33	50	0.29	50	0.26	50	0.22	50	0.20	50
	9	0.34	50	0.30	50	0.26	50	0.23	50	0.20	50
	10	0.35	50	0.30	50	0.27	50	0.23	50	0.20	50
	12	0.37	51	0.32	50	0.29	50	0.24	50	0.21	50
	14	0.39	51	0.35	50	0.30	50	0.25	50	0.21	50
	16	0.41	52	0.37	51	0.32	50	0.26	50	0.22	50
	20	0.44	53	0.40	52	0.36	50	0.29	50	0.23	50
	24	0.47	54	0.44	53	0.40	52	0.32	50	0.26	50
	28	0.50	55	0.46	54	0.43	53	0.36	50	0.29	50
	32	0.53	56	0.49	55	0.46	54	0.39	51	0.32	50

* Total calculated thickness includes service allowance and casting tolerance added to net thickness.

TABLE 50.12—(*cont.*)

Size in.	Depth of Cover ft	Type 1 Total Calculated Thickness* in.	Type 1 Use Class	Type 2 Total Calculated Thickness* in.	Type 2 Use Class	Type 3 Total Calculated Thickness* in.	Type 3 Use Class	Type 4 Total Calculated Thickness* in.	Type 4 Use Class	Type 5 Total Calculated Thickness* in.	Type 5 Use Class
20	2.5	0.38	51	0.33	50	0.29	50	0.24	50	0.21	50
	3	0.35	50	0.31	50	0.27	50	0.23	50	0.20	50
	4	0.34	50	0.29	50	0.26	50	0.23	50	0.20	50
	5	0.33	50	0.28	50	0.26	50	0.23	50	0.20	50
	6	0.33	50	0.29	50	0.26	50	0.23	50	0.20	50
	7	0.34	50	0.29	50	0.26	50	0.23	50	0.20	50
	8	0.35	50	0.30	50	0.27	50	0.23	50	0.20	50
	9	0.36	50	0.31	50	0.28	50	0.24	50	0.21	50
	10	0.37	50	0.32	50	0.28	50	0.24	50	0.21	50
	12	0.39	51	0.34	50	0.30	50	0.25	50	0.21	50
	14	0.41	52	0.37	50	0.32	50	0.26	50	0.22	50
	16	0.43	52	0.39	51	0.34	50	0.27	50	0.22	50
	20	0.47	54	0.43	52	0.39	51	0.31	50	0.23	50
	24	0.50	55	0.47	54	0.42	52	0.34	50	0.28	50
	28	0.54	56	0.50	55	0.46	53	0.38	51	0.31	50
	32	0.57	—	0.53	56	0.49	54	0.42	52	0.34	50
24	2.5	0.42	51	0.35	50	0.31	50	0.26	50	0.22	50
	3	0.39	50	0.33	50	0.29	50	0.25	50	0.21	50
	4	0.37	50	0.31	50	0.28	50	0.24	50	0.21	50
	5	0.36	50	0.31	50	0.28	50	0.24	50	0.21	50
	6	0.36	50	0.31	50	0.28	50	0.24	50	0.21	50
	7	0.37	50	0.32	50	0.28	50	0.24	50	0.21	50
	8	0.39	50	0.33	50	0.29	50	0.25	50	0.21	50
	9	0.40	51	0.34	50	0.30	50	0.25	50	0.22	50
	10	0.41	51	0.35	50	0.31	50	0.26	50	0.22	50
	12	0.44	52	0.38	50	0.33	50	0.27	50	0.23	50
	14	0.46	53	0.41	51	0.35	50	0.28	50	0.23	50
	16	0.49	54	0.44	52	0.38	50	0.31	50	0.24	50
	20	0.54	55	0.49	54	0.43	52	0.36	50	0.25	50
	24	0.57	56	0.53	55	0.48	53	0.40	51	0.32	50
	28	0.61	—	0.57	56	0.52	55	0.43	52	0.36	50
	32	0.65	—	0.60	—	0.56	56	0.47	53	0.40	51
30	2.5	†	†	0.40	50	0.34	50	0.28	50	0.23	50
	3			0.37	50	0.32	50	0.27	50	0.23	50
	4			0.35	50	0.31	50	0.26	50	0.22	50
	5			0.35	50	0.31	50	0.26	50	0.22	50
	6			0.35	50	0.31	50	0.26	50	0.22	50
	7			0.36	50	0.31	50	0.26	50	0.23	50
	8			0.37	50	0.33	50	0.27	50	0.23	50
	9			0.39	50	0.34	50	0.28	50	0.23	50
	10			0.40	50	0.35	50	0.28	50	0.24	50
	12			0.44	51	0.37	50	0.30	50	0.24	50
	14			0.47	52	0.40	50	0.32	50	0.25	50
	16			0.51	53	0.43	51	0.37	50	0.26	50
	20			0.57	55	0.50	53	0.43	51	0.29	50
	24			0.62	56	0.56	54	0.48	52	0.37	50
	28			0.67	—	0.61	56	0.51	53	0.43	51
	32			0.71	—	0.66	—	0.55	54	0.47	52

* Total calculated thickness includes service allowance and casting tolerance added to net thickness.
† For pipe 30 in. and larger, consideration should be given to laying conditions other than Type 1.

TABLE 50.12—(*cont.*)

Size *in.*	Depth of Cover *ft*	Laying Condition									
		Type 1		Type 2		Type 3		Type 4		Type 5	
		Total Calculated Thickness* *in.*	Use Class	Total Calculated Thickness* *in.*	Use Class	Total Calculated Thickness* *in.*	Use Class	Total Calculated Thickness* *in.*	Use Class	Total Calculated Thickness* *in.*	Use Class
36	2.5	†	†	0.43	50	0.37	50	0.30	50	0.25	50
	3			0.40	50	0.35	50	0.29	50	0.24	50
	4			0.39	50	0.34	50	0.28	50	0.24	50
	5			0.38	50	0.34	50	0.28	50	0.24	50
	6			0.39	50	0.34	50	0.28	50	0.24	50
	7			0.40	50	0.35	50	0.29	50	0.24	50
	8			0.42	50	0.36	50	0.30	50	0.24	50
	9			0.43	50	0.37	50	0.30	50	0.25	50
	10			0.45	50	0.38	50	0.31	50	0.25	50
	12			0.49	51	0.42	50	0.33	50	0.26	50
	14			0.54	52	0.46	51	0.37	50	0.27	50
	16			0.58	53	0.49	51	0.42	50	0.28	50
	20			0.65	54	0.57	53	0.50	51	0.33	50
	24			0.71	56	0.63	54	0.55	52	0.43	50
	28			0.77	—	0.70	55	0.60	53	0.50	51
	32			0.82	—	0.76	—	0.64	54	0.55	52
42	2.5	†	†	0.46	50	0.40	50	0.32	50	0.26	50
	3			0.44	50	0.38	50	0.31	50	0.25	50
	4			0.42	50	0.37	50	0.30	50	0.25	50
	5			0.42	50	0.37	50	0.30	50	0.25	50
	6			0.42	50	0.37	50	0.30	50	0.25	50
	7			0.44	50	0.38	50	0.31	50	0.25	50
	8			0.46	50	0.39	50	0.32	50	0.26	50
	9			0.48	50	0.41	50	0.33	50	0.26	50
	10			0.50	51	0.42	50	0.33	50	0.27	50
	12			0.55	51	0.47	50	0.35	50	0.28	50
	14			0.60	52	0.52	51	0.42	50	0.29	50
	16			0.64	53	0.56	52	0.48	50	0.30	50
	20			0.73	54	0.64	53	0.57	52	0.37	50
	24			0.80	56	0.71	54	0.63	53	0.49	50
	28			0.87	—	0.79	55	0.69	54	0.57	52
	32			0.93	—	0.86	—	0.73	54	0.63	53
48	2.5	†	†	0.50	50	0.43	50	0.35	50	0.28	50
	3			0.48	50	0.42	50	0.34	50	0.28	50
	4			0.46	50	0.40	50	0.33	50	0.27	50
	5			0.46	50	0.40	50	0.33	50	0.27	50
	6			0.47	50	0.41	50	0.33	50	0.27	50
	7			0.48	50	0.42	50	0.34	50	0.28	50
	8			0.51	50	0.44	50	0.35	50	0.28	50
	9			0.53	50	0.45	50	0.36	50	0.29	50
	10			0.56	51	0.47	50	0.37	50	0.30	50
	12			0.61	51	0.53	50	0.39	50	0.31	50
	14			0.67	52	0.59	51	0.48	50	0.32	50
	16			0.72	53	0.64	52	0.55	51	0.33	50
	20			0.82	54	0.72	53	0.65	52	0.43	50
	24			0.91	56	0.80	54	0.72	53	0.56	51
	28			0.98	—	0.89	55	0.79	54	0.65	52
	32			1.05	—	0.97	—	0.84	55	0.72	53

* Total calculated thickness includes service allowance and casting tolerance added to net thickness.
† For pipe 30 in. and larger, consideration should be given to laying conditions other than Type 1.

TABLE 50.12—(*cont.*)

Size *in.*	Depth of Cover *ft*	Laying Condition: Type 1 Total Calculated Thickness* *in.*	Type 1 Use Class	Type 2 Total Calculated Thickness* *in.*	Type 2 Use Class	Type 3 Total Calculated Thickness* *in.*	Type 3 Use Class	Type 4 Total Calculated Thickness* *in.*	Type 4 Use Class	Type 5 Total Calculated Thickness* *in.*	Type 5 Use Class
54	2.5	†	†	0.54	50	0.46	50	0.37	50	0.30	50
	3			0.52	50	0.45	50	0.37	50	0.30	50
	4			0.51	50	0.44	50	0.36	50	0.30	50
	5			0.51	50	0.44	50	0.36	50	0.30	50
	6			0.52	50	0.45	50	0.37	50	0.30	50
	7			0.53	50	0.46	50	0.37	50	0.30	50
	8			0.56	50	0.48	50	0.38	50	0.31	50
	9			0.59	50	0.50	50	0.39	50	0.32	50
	10			0.62	51	0.52	50	0.41	50	0.32	50
	12			0.68	51	0.60	50	0.43	50	0.34	50
	14			0.74	52	0.67	51	0.54	50	0.35	50
	16			0.80	53	0.72	52	0.62	51	0.36	50
	20			0.91	54	0.81	53	0.73	52	0.48	50
	24			1.01	56	0.89	54	0.81	53	0.63	51
	28			1.09	—	0.99	55	0.88	54	0.73	52
	32			1.17	—	1.08	—	0.94	55	0.81	53

* Total calculated thickness includes service allowance and casting tolerance added to net thickness.
† For pipe 30 in. and larger, consideration should be given to laying condit ons other than Type 1.

TABLE 50.13

Thickness for Internal Pressure

Pipe Size *in.*	Rated Water Working Pressure*—*psi*: 150 Total Calculated Thickness *in.*†	150 Use Class	200 Total Calculated Thickness *in.*†	200 Use Class	250 Total Calculated Thickness *in.*†	250 Use Class	300 Total Calculated Thickness *in.*†	300 Use Class	350 Total Calculated Thickness *in.*†	350 Use Class
3	0.15	51	0.16	51	0.16	51	0.17	51	0.17	51
4	0.16	51	0.16	51	0.17	51	0.18	51	0.18	51
6	0.17	50	0.18	50	0.19	50	0.20	50	0.20	50
8	0.18	50	0.19	50	0.21	50	0.22	50	0.23	50
10	0.21	50	0.22	50	0.23	50	0.25	50	0.26	50
12	0.22	50	0.23	50	0.25	50	0.27	50	0.28	50
14	0.24	50	0.26	50	0.28	50	0.30	50	0.31	50
16	0.25	50	0.27	50	0.30	50	0.32	50	0.34	50
18	0.27	50	0.29	50	0.31	50	0.34	50	0.36	50
20	0.28	50	0.30	50	0.33	50	0.36	50	0.38	51
24	0.30	50	0.33	50	0.37	50	0.40	51	0.43	52
30	0.34	50	0.38	50	0.42	51	0.45	52	0.49	53
36	0.38	50	0.42	50	0.47	51	0.51	52	0.56	53
42	0.41	50	0.47	50	0.52	51	0.57	52	0.63	53
48	0.46	50	0.52	50	0.58	51	0.64	52	0.70	53
54	0.51	50	0.58	50	0.65	51	0.71	52	0.78	53

* These pipe are adequate for the rated working pressure plus a surge allowance of 100 psi.
† Total calculated thickness includes service allowance and casting tolerance added to net thickness.

TABLE 50.14

Rated Working Pressure and Maximum Depth of Cover

Pipe Size *in.*	Thickness Class	Nominal Thickness *in.*	Rated Water Working Pressure *psi**	Laying Condition				
				Type 1	Type 2	Type 3	Type 4	Type 5
				Maximum Depth of Cover—*ft*†				
3	51	0.25	350	98	100‡	100‡	100‡	100‡
	52	0.28	350	100‡	100‡	100‡	100‡	100‡
	53	0.31	350	100‡	100‡	100‡	100‡	100‡
	54	0.34	350	100‡	100‡	100‡	100‡	100‡
	55	0.37	350	100‡	100‡	100‡	100‡	100‡
	56	0.40	350	100‡	100‡	100‡	100‡	100‡
4	51	0.26	350	76	86	96	100‡	100‡
	52	0.29	350	100‡	100‡	100‡	100‡	100‡
	53	0.32	350	100‡	100‡	100‡	100‡	100‡
	54	0.35	350	100‡	100‡	100‡	100‡	100‡
	55	0.38	350	100‡	100‡	100‡	100‡	100‡
	56	0.41	350	100‡	100‡	100‡	100‡	100‡
6	50	0.25	350	32	38	44	56	75
	51	0.28	350	49	57	64	80	100‡
	52	0.31	350	67	77	86	100‡	100‡
	53	0.34	350	91	100‡	100‡	100‡	100‡
	54	0.37	350	100‡	100‡	100‡	100‡	100‡
	55	0.40	350	100‡	100‡	100‡	100‡	100‡
	56	0.43	350	100‡	100‡	100‡	100‡	100‡
8	50	0.27	350	25	30	36	46	64
	51	0.30	350	36	42	49	61	81
	52	0.33	350	47	54	62	77	99
	53	0.36	350	64	73	82	100‡	100‡
	54	0.39	350	80	91	100‡	100‡	100‡
	55	0.42	350	98	100‡	100‡	100‡	100‡
	56	0.45	350	100‡	100‡	100‡	100‡	100‡
10	50	0.29	350	19	24	29	38	55
	51	0.32	350	27	32	38	49	66
	52	0.35	350	35	41	47	59	79
	53	0.38	350	45	52	59	74	95
	54	0.41	350	57	65	74	91	100‡
	55	0.44	350	67	77	86	100‡	100‡
	56	0.47	350	81	92	100‡	100‡	100‡
12	50	0.31	350	17	22	27	36	52
	51	0.34	350	23	28	33	43	60
	52	0.37	350	30	35	41	53	71
	53	0.40	350	36	42	49	61	81
	54	0.43	350	45	52	59	74	95
	55	0.46	350	54	62	71	87	100‡
	56	0.49	350	64	73	83	100‡	100‡

* These pipe are adequate for the rated working pressure plus a surge allowance of 100 psi. Ductile-iron pipe for working pressures higher than 350 psi is available.

† An allowance for a single H-20 truck with 1.5 impact factor is included for all depths of cover.

‡ Calculated maximum depth of cover exceeds 100 ft.

TABLE 50.14—(*cont.*)

Pipe Size *in.*	Thickness Class	Nominal Thickness *in.*	Rated Water Working Pressure *psi**	Laying Condition				
				Type 1	Type 2	Type 3	Type 4	Type 5
				Maximum Depth of Cover—ft†				
14	50	0.33	350	15	19	24	33	49
	51	0.36	350	19	23	28	38	55
	52	0.39	350	24	29	34	44	62
	53	0.42	350	30	35	41	53	71
	54	0.45	350	36	42	49	61	81
	55	0.48	350	43	50	57	71	92
	56	0.51	350	52	59	67	83	100‡
16	50	0.34	350	13	17	21	30	47
	51	0.37	350	16	21	25	34	51
	52	0.40	350	20	25	30	40	57
	53	0.43	350	25	30	36	46	64
	54	0.46	350	30	35	41	53	71
	55	0.49	350	35	41	47	59	79
	56	0.52	350	41	48	55	68	89
18	50	0.35	350	11	15	20	29	42
	51	0.38	350	14	19	23	32	49
	52	0.41	350	18	22	27	36	53
	53	0.44	350	22	26	31	41	58
	54	0.47	350	25	30	36	46	64
	55	0.50	350	30	35	41	53	71
	56	0.53	350	35	41	47	59	79
20	50	0.36	300	10	14	18	27	38
	51	0.39	350	13	17	21	30	44
	52	0.42	350	16	20	25	34	50
	53	0.45	350	19	23	28	38	54
	54	0.48	350	22	27	32	42	59
	55	0.51	350	26	31	37	47	65
	56	0.54	350	30	35	41	53	71
24	50	0.38	250	8	12	17	23	31
	51	0.41	300	10	15	19	27	36
	52	0.44	350	13	17	21	30	41
	53	0.47	350	15	19	24	33	47
	54	0.50	350	18	22	27	36	53
	55	0.53	350	20	25	30	40	57
	56	0.56	350	24	29	34	44	61
30	50	0.39	200	§	10	14	18	25
	51	0.43	250		12	16	21	29
	52	0.47	300		14	19	24	33
	53	0.51	350		17	21	29	38
	54	0.55	350		19	24	33	44
	55	0.59	350		22	27	36	51
	56	0.63	350		26	31	41	57

* These pipe are adequate for the rated working pressure plus a surge allowance of 100 psi. Ductile-iron pipe or working pressures higher than 350 psi is available.
† An allowance for a single H-20 truck with 1.5 impact factor is included for all depths of cover.
‡ Calculated maximum depth of cover exceeds 100 ft.
§ For pipe 30 in. and larger, consideration should be given to laying conditions other than Type 1.

TABLE 50.14—(*cont.*)

Pipe Size *in.*	Thickness Class	Nominal Thickness *in.*	Rated Water Working Pressure *psi**	Laying Condition				
				Type 1	Type 2	Type 3	Type 4	Type 5
				Maximum Depth of Cover—*ft*†				
36	50	0.43	200	§	10	13	17	25
	51	0.48	250		12	16	20	28
	52	0.53	300		15	19	24	32
	53	0.58	350		17	21	28	37
	54	0.63	350		20	25	33	43
	55	0.68	350		23	28	37	50
	56	0.73	350		26	31	41	59
42	50	0.47	200	§	9	13	16	24
	51	0.53	250		12	15	19	27
	52	0.59	300		14	18	22	30
	53	0.65	350		17	22	27	35
	54	0.71	350		20	24	32	42
	55	0.77	350		23	28	38	48
	56	0.83	350		26	31	41	57
48	50	0.51	200	§	9	12	15	23
	51	0.58	250		12	14	18	26
	52	0.65	300		14	18	21	30
	53	0.72	350		17	21	25	34
	54	0.79	350		20	24	30	40
	55	0.86	350		23	28	37	47
	56	0.93	350		26	31	41	55
54	50	0.57	200	§	9	12	15	23
	51	0.65	250		12	14	18	25
	52	0.73	300		14	17	21	29
	53	0.81	350		17	21	25	34
	54	0.89	350		20	25	30	40
	55	0.97	350		23	28	37	47
	56	1.05	350		27	32	42	55

* These pipe are adequate for the rated working pressure plus a surge allowance of 100 psi. Ductile-iron pipe for working pressures higher than 350 psi is available.
† An allowance for a single H-20 truck with 1.5 impact factor is included for all depths of cover.
‡ Calculated maximum depth of cover exceeds 100 ft.
§ For pipe 30 in. and larger, consideration should be given to laying conditions other than Type 1.

ANSI/AWWA C151/A21.51-81

Revision of
A21.51-1976
(AWWA C151-76)

AMERICAN NATIONAL STANDARD

for

DUCTILE-IRON PIPE, CENTRIFUGALLY CAST IN METAL MOLDS OR SAND-LINED MOLDS, FOR WATER OR OTHER LIQUIDS

SECRETARIATS
AMERICAN GAS ASSOCIATION
AMERICAN WATER WORKS ASSOCIATION
NEW ENGLAND WATER WORKS ASSOCIATION

NOTICE

This Standard has been especially printed by the American Water Works Association for incorporation into this volume. It is current as of October 1, 1984. It should be noted, however, that all AWWA Standards are updated at least once in every five years. Therefore, before applying this Standard it is suggested that you confirm its currency with the American Water Works Association.

Revised edition approved by American National Standards Institute, Inc., Nov. 24, 1981.

Published by

AMERICAN WATER WORKS ASSOCIATION
6666 West Quincy Avenue, Denver, Colorado 80235

American National Standard

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Committee Personnel

Subcommittee 1, Pipe, which reviewed this standard, had the following personnel at that time:

EDWARD C. SEARS, *Chairman*
WALTER AMORY, *Vice-Chairman*

User Members	*Producer Members*
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R. BRYANT	H. KENNEDY, JR.
F.E. DOLSON	P.I. MCGRATH, JR.
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W.H. SMITH	T.F. STROUD
	T. UPCHURCH
	T.B. WRIGHT

Standards Committee A21, Cast Iron Pipe and Fittings, which reviewed and approved this standard, had the following personnel at the time of approval:

ARNOLD M. TINKEY, *Chairman*
THOMAS D. HOLMES, *Vice-Chairman*
JOHN I. CAPITO, *Secretary*

Organization Represented	*Name of Representative*
American Gas Association	HARRY J. FORR
American Society of Mechanical Engineers	JAMES S. VANICK
American Society for Testing and Materials	BEN C. HELTON*
	JOSEPH J. PALMER*
American Water Works Association	GERALD S. ALLEN
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	DONALD R. BOYD
	KENNETH W. HENDERSON
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	ROBERT L. LEE
	W. HARRY SMITH
	ARNOLD M. TINKEY
	DAVID L. TIPPIN
	LLOYD W. WELLER

*Liaison representative without vote

Organization Represented	*Name of Representative*
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Individual Producers	ALBERT HELT
New England Water Works Association	STANLEY C. BAKER
Naval Facilities Engineering Command	LEE J. DOSEDLO
Underwriters Laboratories, Inc.	W. CAREY†
Canadian Standards Association	W.F. SEMENCHUK*

*Liaison representative without vote
†Alternate

Table of Contents

NOTE: Metric Tables Not Included In This Handbook.

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Foreword

This foreword is for information only and is not a part of ANSI/AWWA C151/A21.51.

I. History of Standard

American National Standards Committee A21, Cast-Iron Pipe and Fittings, was organized in 1926 under the sponsorship of the American Gas Association, the American Society for Testing and Materials, the American Water Works Association, and the New England Water Works Association. Since 1972, the cosecretariats have been AGA, AWWA, and NEWWA, with AWWA serving as the administrative secretariat. The present scope of Committee A21 activity is:

> Standardization of specifications for cast-iron and ductile-iron pressure pipe for gas, water and other liquids, and fittings for use with such pipe. These specifications to include design, dimensions, materials, coatings, linings, joints, accessories, and methods of inspection and test.

The work of Committee A21 is conducted by subcommittees. The directive to Subcommittee 1—Pipe is as follows:

> The scope of the subcommittee activity shall include the periodic review of all current A21 standards for pipe, the preparation of revisions and new standards when needed, as well as other matters pertaining to pipe standards.

The first edition of A21.51, Standard for Ductile-Iron Pipe for Water and Other Liquids, was issued in 1965, and revisions were issued in 1971 and 1976. Subcommittee 1 reviewed the 1976 edition and submitted a proposed revision to American National Standards Committee A21 in 1980.

II. Major Revisions

1. *Metric conversions.* Metric conversions of all dimensions and physical requirements are included in this standard. Metric conversions of Tables 51.1–51.5 are shown in Appendix B. Metric dimensions are direct conversions of customary US inch-pound units and are not those specified in International Standards Organization (ISO) standards.

2. *Pipe of 3-in. size.* Pipe of 3-in. size with 12-ft laying length has been deleted.

3. *Bell weights.* Bell weights vary due to difference in bell design. Bell weights in this standard have been revised to indicate the minimum bell weights produced in accordance with ANSI/AWWA C111/A21.11-79, Rubber-Gasket Joints for Ductile-Iron and Gray-Iron Pressure Pipe and Fittings, and are adequate for an operating pressure of 350 psi (2.4 MPa).

III. Options

This standard includes certain options that, if desired, must be specified on the purchase order. Also, a number of items must be specified to describe completely the pipe required. The following summarizes the details and available options and lists the sections of the standard where they can be found.

1. Size, joint type, thickness or class, and laying length (Tables)

2. a. Special joints (Sec. 51-3.1)

b. Specifying ductile-iron gland, if required (Sec. 51-3.1)

3. Certification by manufacturer (Sec. 51-4.2)

4. Inspection by purchaser (Sec. 51-5)

5. a. Eliminate outside coating (Sec. 51-8.1)

b. Cement lining (Sec. 51-8.2). Experience has indicated that bituminous inside coating is not complete protection against loss in pipe capacity caused by tuberculation. Cement linings are recommended for most waters.

c. Eliminate inside coatings (Sec. 51-8.3)

d. Special coatings and lining (Sec. 51-8.4)

6. Special marking on pipe (Sec. 51-10)

7. Written transcripts of foundry records (Sec. 51-14)

8. Special tests (Sec. 51-15).

ANSI/AWWA C151/A21.51-81

Revision of
A21.51-1976
(AWWA C151-76)

American National Standard for

Ductile-Iron Pipe, Centrifugally Cast in Metal Molds or Sand-Lined Molds, for Water or Other Liquids

Sec. 51-1—Scope

This standard covers 3-in. through 54-in. ductile-iron pipe centrifugally cast in metal molds or sand-lined molds for water or other liquids with push-on joints or mechanical joints. This standard may be used for pipe with such other types of joints as may be agreed upon at the time of purchase.

Sec. 51-2—Definitions

Under this standard, the following definitions shall apply:

51-2.1 *Ductile-iron:* A cast ferrous material in which a major part of the carbon content occurs as free carbon in nodular or spheroidal form.

51-2.2 *Inspector:* The representative of the purchaser, authorized to inspect on behalf of the purchaser to determine whether or not the pipe meets this standard.

51-2.3 *Manufacturer:* The party that produces the pipe.

51-2.4 *Mechanical joint:* The gasketed and bolted joint as detailed in the latest revision of ANSI/AWWA C111/A21.11, Rubber-Gasket Joints for Ductile-Iron and Gray-Iron Pressure Pipe and Fittings.

51-2.5 *Purchaser:* The party entering into a contract or agreement to purchase pipe according to this standard.

51-2.6 *Push-on joint:* The single rubber-gasket joint as described in ANSI/AWWA C111/A21.11 of latest revision.

Sec. 51-3—General Requirements

51-3.1 *Mechanical or push-on joint requirements.* Pipe with mechanical joints or push-on joints shall conform to the applicable dimensions and weights shown in this standard and to the applicable requirements of ANSI/AWWA C111/A21.11 of latest revision. Unless otherwise specified, the mechanical-joint glands shall be cast iron in accordance with ANSI/AWWA C111/A21.11 of latest revision and bolts shall conform to the requirements of the same standard. Pipe with other types of joints shall comply with the joint dimensions and weights agreed upon at the time of purchase but in all other respects shall fulfill the requirements of this standard.

51-3.2 *Laying length requirements.* The nominal laying length of the pipe shall be as shown in the tables. A maximum of 20 percent of the total number of pipe of each size specified in an order may be furnished by as much as 24 in. (610 mm) shorter than the nominal laying length, and an additional 10 percent may be furnished by as much as 6 in. (152 mm) shorter than the nominal laying length.

Sec. 51-4—Inspection and Certification by Manufacturer

51-4.1 *Quality control and inspection.* The manufacturer shall establish the necessary quality-control and inspection practice to ensure compliance with this standard.

51-4.2 *Manufacturer's statement.* The manufacturer shall, if required on the purchase order, furnish a sworn statement that the inspection and all of the specified tests have been made and the results thereof comply with the requirements of this standard.

51-4.3 *Freedom from defects.* All pipe shall be clean and sound without defects that could impair service. Repairing of defects by welding or other methods shall not be allowed if such repairs could adversely affect the serviceability of the pipe or its capability to meet strength requirements of this standard.

Sec. 51-5—Inspection by Purchaser

51-5.1 *Purchasers' obligations.* If the purchaser desires to inspect pipe at the manufacturer's plant, the purchaser shall so specify on the purchase order, stating the conditions (such as time and the extent of inspection) under which the inspection shall be made.

51-5.2 *Manufacturers' obligations.* The inspector shall have free access to those parts of the manufacturer's plant that are necessary to ensure compliance with this standard. The manufacturer shall make available for the inspector's use such gauges as are necessary for inspection. The manufacturer shall provide the inspector with assistance as necessary for handling of pipe.

Sec. 51-6—Delivery and Acceptance

All pipe and accessories shall comply with this standard. Pipe and accessories not complying with this standard shall be replaced by the manufacturer at the agreed point of delivery. The manufacturer shall not be liable for shortages or damaged pipe after acceptance at the agreed point of delivery, except as recorded on the delivery receipt or similar document by the carrier's agent.

Sec. 51-7—Tolerances or Permitted Variations

51-7.1 *Dimensions.* The spigot end, bell, and socket of the pipe and the accessories shall be gauged with suitable gauges at sufficiently frequent intervals to ensure that the dimensions comply with the requirements of this standard. The smallest inside diameter of the sockets and the outside of the spigot ends shall be tested with circular gauges. Other socket dimensions shall be gauged as may be appropriate.

51-7.2 *Thickness.* Minus thickness tolerances of pipe and bell shall not exceed the following:

Size	Minus Tolerance	
in.	*in.*	*(mm)*
3-8	0.05	(1.3)
10-12	0.06	(1.5)
14-42	0.07	(1.8)
48	0.08	(2.0)
54	0.09	(2.3)

An additional minus tolerance of 0.02 in. (0.5 mm) shall be permitted along the barrel of the pipe for a distance not to exceed 12 in. (305 mm).

51-7.3 *Weight.* The weight of any single pipe shall not be less than the tabulated weight by more than 6 percent for pipe 12 in. or smaller in diameter, or by more than 5 percent for pipe larger than 12 in. in diameter.

Sec. 51-8—Coatings and Linings

51-8.1 *Outside coating.* The outside coating for use under normal conditions shall be an asphaltic coating approximately 1 mil (25μm) thick. The coatings shall be applied to the outside of all pipe, unless otherwise specified. The finished coating shall be continuous, smooth, neither brittle when cold nor sticky when exposed to the sun, and shall be strongly adherent to the pipe.

51-8.2 *Cement-mortar linings.* Cement linings shall be in accordance with the latest revision of ANSI/AWWA C104/A21.4, Cement-Mortar Lining for Ductile-Iron and Gray-Iron Pipe and Fittings for Water. If desired by the purchaser, cement linings shall be specified in the invitation for bids and on the purchase order.

51-8.3 *Inside coating.* Unless otherwise specified, the inside coating for pipe that is not cement-lined shall be an asphaltic material as thick as practicable, at least 1 mil (25 μm), that conforms to all appropriate requirements for seal coat in ANSI/AWWA C104/A21.4 of latest revision.

51-8.4 *Special coatings and linings.* For special conditions, other types of coatings and linings may be available. Such special coatings and linings shall be specified in the invitation for bids and on the purchase order.

Sec. 51-9—Hydrostatic Test

Each pipe shall be subjected to a hydrostatic test of not less than 500 psi (3.45 MPa). This test may be made either before or after the outside coating and inside coating have been applied, but shall be made before the application of cement lining or of a special lining.

The pipe shall be under the full test pressure for at least 10 s. Suitable controls and recording devices shall be provided so that the test pressure and duration may be adequately ascertained. Any pipe that leaks or does not withstand the test pressure shall be rejected.

In addition to the hydrostatic test before application of a cement lining or special lining, the pipe may be retested, at the manufacturer's option, after application of such lining.

Sec. 51-10—Marking Pipe

The weight, class, or nominal thickness, and casting period shall be shown on each pipe. The manufacturer's mark, the year in which the pipe was produced, and the letters "DI" or "DUCTILE" shall be cast or stamped on the pipe. When specified on the purchase order, initials not exceeding four in number shall be cast or stamped on the pipe. All required markings shall be clear and legible, and all cast marks shall be on or near the bell. All letters and numerals on pipe sizes 14 in. and larger shall be not less than ½ in. (13 mm) in height.

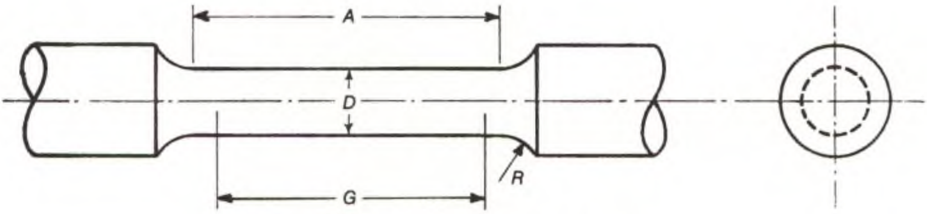


Figure 1 Tensile-Test Specimen

The tensile-test specimen dimensions are given in the following table:

Dimension	Standard Specimen 0.500 *in.* (12.70 *mm*) Round	Small-Size Specimens Proportional to Standard			
		0.350 *in.* (8.89 *mm*) Round	0.250 *in.* (6.35 *mm*) Round	0.175 *in.* (4.44 *mm*) Round	0.125 *in.* (3.18 *mm*) Round
		Dimensions—*in.* (*mm*)			
*T**	0.71 (18.0) and greater	0.50-0.70 (12.7-17.8)	0.35-0.49 (8.9-12.4)	0.25-0.34 (6.4-8.6)	0.18-0.24 (4.6-6.1)
G	2.000 ± 0.005 (50.80 ± 0.13)	1.400 ± 0.005 (35.56 ± 0.13)	1.000 ± 0.005 (25.4 ± 0.13)	0.700 ± 0.005 (17.78 ± 0.13)	0.500 ± 0.005 (12.70 ± 0.13)
D	0.500 ± 0.010 (12.70 ± 0.25)	0.350 ± 0.007 (9.89 ± 0.18)	0.250 ± 0.005 (6.35 ± 0.13)	0.175 ± 0.005 (4.44 ± 0.13)	0.125 ± 0.005 (3.18 ± 0.13)
R	$\frac{3}{8}$ min. (9.6) min.	$\frac{1}{4}$ min. (6.4) min.	$\frac{3}{16}$ min. (4.8) min.	$\frac{3}{32}$ min. (2.4) min.	$\frac{3}{32}$ min. (2.4) min.
A	$2\frac{1}{4}$ min. (57.2) min.	$1\frac{3}{4}$ min. (44.4) min.	$1\frac{1}{4}$ min. (31.8) min.	$\frac{3}{4}$ min. (19.0) min.	$\frac{5}{8}$ min. (15.9) min.

*Thickness of the section from the wall of the pipe from which the tensile specimen is to be machined.

Note 1. The reduced section *A* may have a gradual taper from the ends toward the center with the ends not more than 0.005 in. (0.13 mm) larger in diameter than the center on the standard specimen and not more than 0.003 in. (0.08 mm) larger in diameter than the center on the small-size specimens.

Note 2. If desired, on the small-size specimens the length of the reduced section may be increased to accommodate an extensometer. However, reference marks for the measurement of elongation should nevertheless be spaced at the indicated gauge length *G*.

Note 3. The gauge length and fillets shall be as shown, but the ends may be of any form to fit the holders of the testing machine in such a way that the load shall be axial. If the ends are to be held in grips, it is desirable, if possible, to make the length of the grip section great enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips.

Sec. 51-11—Weighing Pipe

Each pipe shall be weighed before the application of any lining or coating other than the asphaltic coating, and the weight shown on the outside or inside of the bell or spigot end.

Sec. 51-12—Acceptance Tests

The standard acceptance tests for the physical characteristics of the pipe shall be as follows:

51-12.1 *Tensile test.* A tensile test specimen shall be cut longitudinally from

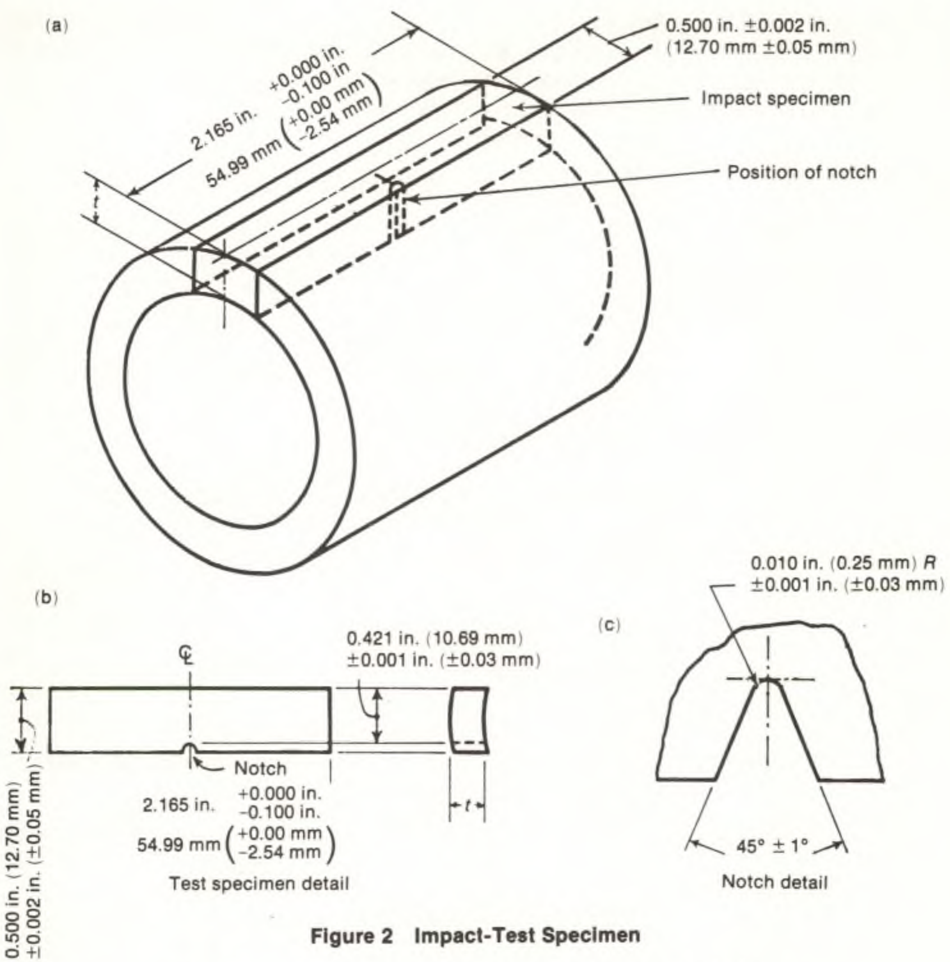


Figure 2 Impact-Test Specimen

In diagrams (a) and (b) the symbol t *is for the pipe-wall thickness.*

the midsection of the pipe wall. This specimen shall be machined and tested in accordance with Figure 1 and ASTM E8-79, Tension Testing of Metallic Materials. The yield strength shall be determined by the 0.2 percent offset, halt-of-pointer, or extension-under-load method. If check tests are to be made, the 0.2 percent offset method shall be used. All specimens shall be tested at room temperature [70° F ± 10° (21°C ± 6°)].

51-12.1.1 *Acceptance values.* The acceptance values for test specimens shall be as follows:

Grade of iron: 60-42-10

1. Minimum tensile strength: 60 000 psi (413.7 MPa).

2. Minimum yield strength: 42 000 psi (289.6 MPa).

3. Minimum elongation: 10 percent.

51-12.2 *Impact test.* Tests shall be made in accordance with ASTM E23-

72(78), Notched Charpy Tests, except that specimens shall be 0.500 in. (12.7 mm) by full thickness of pipe wall. The notched impact test specimen shall be in accordance with Figure 2. If the pipe wall thickness exceeds 0.40 in. (10.2 mm), the impact specimen may be machined to a nominal thickness of 0.40 in. (10.2 mm). In all tests, impact values are to be corrected to a standard wall thickness, $t_s = 0.40$ in. (10.2 mm), by calculation as follows:

$$\text{Impact Value (corrected)} = \frac{t_s}{t} \times \text{Impact Value (actual)}$$

in which t is the thickness of the specimen in inches (millimetres).

The Charpy test machine anvil shall not be moved to compensate for the variation of cross section dimensions of the test specimen.

51-12.2.1 *Acceptance value.* The corrected acceptance value for notched impact test specimens shall be a minimum of 7 ft-lb (9.49 J) for tests conducted at 70°F ± 10° (21°C ± 6°).

51-12.3 *Sampling.* At least one tensile sample shall be taken during each casting period of approximately 3 hours. At least one 70°F ± 10° (21°C ± 6°) Charpy impact sample shall be taken during each operating hour. Samples shall be selected to properly represent extremes of pipe diameters and thicknesses.

Sec. 51-13—Additional Control Tests by Manufacturer

An additional low-temperature impact test shall be made from at least 10 percent of the sample coupons taken for the required 70°F ± 10° (21°C ± 6°) Charpy impact tests specified in Section 51-12.3 to check compliance with the minimum corrected value of 3 ft-lb. (4.07 J) for tests conducted at −40°F (−40°C). Test specimens shall be prepared and tested in accordance with Section 51-12.2.

In addition, the manufacturer shall conduct such other tests as necessary to assure continuing compliance with this standard.

Sec. 51-14—Foundry Records

The results of the acceptance tests (Sec. 51-12) and low-temperature impact tests (Sec. 51-13) shall be recorded and retained for one year and shall be available to the purchaser at the foundry. Written transcripts shall be furnished if specified on the purchase order.

Sec. 51-15—Additional Tests Required by Purchaser

When tests other than those required in this standard are required by the purchaser, such tests shall be specified in the invitation for bids and on the purchase order.

Sec. 51-16—Defective Specimens and Retests

When any physical-test specimen shows defective machining or lack of continuity of metal, it shall be discarded and replaced by another specimen. When any sound test specimen fails to meet the specified requirements, the pipe from which it was taken shall be rejected, and a retest may be made on two additional sound specimens from pipe cast in the same period as the specimen that failed. Both of the additional specimens shall meet the prescribed tests to qualify the pipe produced in that period.

Sec. 51-17—Rejection of Pipe

If the results of any physical acceptance test fail to meet the requirements of Sec. 51-12 or Sec. 51-16, the pipe cast in the same period shall be rejected, except as provided in Sec. 51-18.

Sec. 51-18—Determining Rejection

The manufacturer may determine the amount of rejection by making similar additional tests of pipe of the same size until the rejected lot is bracketed, in order of manufacture, by an acceptable test at each end of the interval in question. When pipe of one size is rejected from a casting period, the acceptability of pipe of different sizes from that same period may be established by making the acceptance tests for these sizes as specified in Sec. 51-12.

TABLE 51.1

*Standard Thickness for Earth Load Plus Truck Load**

Size in.	Depth of Cover ft.	Laying Condition									
		Type 1†		Type 2†		Type 3†		Type 4†		Type 5†	
		Thickness in.	Thickness Class	Thickness in.	Thickness Class	Thickness in.	Thickness Class	Thickness in.	Thickness Class	Thickness in.	Thickness Class
3	2.5	0.25	51	0.25	51	0.25	51	0.25	51	0.25	51
	3	0.25	51	0.25	51	0.25	51	0.25	51	0.25	51
	4	0.25	51	0.25	51	0.25	51	0.25	51	0.25	51
	5	0.25	51	0.25	51	0.25	51	0.25	51	0.25	51
	6	0.25	51	0.25	51	0.25	51	0.25	51	0.25	51
	7	0.25	51	0.25	51	0.25	51	0.25	51	0.25	51
	8	0.25	51	0.25	51	0.25	51	0.25	51	0.25	51
	9	0.25	51	0.25	51	0.25	51	0.25	51	0.25	51
	10	0.25	51	0.25	51	0.25	51	0.25	51	0.25	51
	12	0.25	51	0.25	51	0.25	51	0.25	51	0.25	51
	14	0.25	51	0.25	51	0.25	51	0.25	51	0.25	51
	16	0.25	51	0.25	51	0.25	51	0.25	51	0.25	51
	20	0.25	51	0.25	51	0.25	51	0.25	51	0.25	51
	24	0.25	51	0.25	51	0.25	51	0.25	51	0.25	51
	28	0.25	51	0.25	51	0.25	51	0.25	51	0.25	51
	32	0.25	51	0.25	51	0.25	51	0.25	51	0.25	51
4	2.5	0.26	51	0.26	51	0.26	51	0.26	51	0.26	51
	3	0.26	51	0.26	51	0.26	51	0.26	51	0.26	51
	4	0.26	51	0.26	51	0.26	51	0.26	51	0.26	51
	5	0.26	51	0.26	51	0.26	51	0.26	51	0.26	51
	6	0.26	51	0.26	51	0.26	51	0.26	51	0.26	51
	7	0.26	51	0.26	51	0.26	51	0.26	51	0.26	51
	8	0.26	51	0.26	51	0.26	51	0.26	51	0.26	51
	9	0.26	51	0.26	51	0.26	51	0.26	51	0.26	51
	10	0.26	51	0.26	51	0.26	51	0.26	51	0.26	51
	12	0.26	51	0.26	51	0.26	51	0.26	51	0.26	51
	14	0.26	51	0.26	51	0.26	51	0.26	51	0.26	51
	16	0.26	51	0.26	51	0.26	51	0.26	51	0.26	51
	20	0.26	51	0.26	51	0.26	51	0.26	51	0.26	51
	24	0.26	51	0.26	51	0.26	51	0.26	51	0.26	51
	28	0.26	51	0.26	51	0.26	51	0.26	51	0.26	51
	32	0.26	51	0.26	51	0.26	51	0.26	51	0.26	51
6	2.5	0.25	50	0.25	50	0.25	50	0.25	50	0.25	50
	3	0.25	50	0.25	50	0.25	50	0.25	50	0.25	50
	4	0.25	50	0.25	50	0.25	50	0.25	50	0.25	50
	5	0.25	50	0.25	50	0.25	50	0.25	50	0.25	50
	6	0.25	50	0.25	50	0.25	50	0.25	50	0.25	50
	7	0.25	50	0.25	50	0.25	50	0.25	50	0.25	50
	8	0.25	50	0.25	50	0.25	50	0.25	50	0.25	50
	9	0.25	50	0.25	50	0.25	50	0.25	50	0.25	50
	10	0.25	50	0.25	50	0.25	50	0.25	50	0.25	50
	12	0.25	50	0.25	50	0.25	50	0.25	50	0.25	50
	14	0.25	50	0.25	50	0.25	50	0.25	50	0.25	50
	16	0.25	50	0.25	50	0.25	50	0.25	50	0.25	50
	20	0.25	50	0.25	50	0.25	50	0.25	50	0.25	50
	24	0.25	50	0.25	50	0.25	50	0.25	50	0.25	50
	28	0.25	50	0.25	50	0.25	50	0.25	50	0.25	50
	32	0.25	50	0.25	50	0.25	50	0.25	50	0.25	50
8	2.5	0.27	50	0.27	50	0.27	50	0.27	50	0.27	50
	3	0.27	50	0.27	50	0.27	50	0.27	50	0.27	50
	4	0.27	50	0.27	50	0.27	50	0.27	50	0.27	50
	5	0.27	50	0.27	50	0.27	50	0.27	50	0.27	50
	6	0.27	50	0.27	50	0.27	50	0.27	50	0.27	50
	7	0.27	50	0.27	50	0.27	50	0.27	50	0.27	50
	8	0.27	50	0.27	50	0.27	50	0.27	50	0.27	50
	9	0.27	50	0.27	50	0.27	50	0.27	50	0.27	50
	10	0.27	50	0.27	50	0.27	50	0.27	50	0.27	50
	12	0.27	50	0.27	50	0.27	50	0.27	50	0.27	50
	14	0.27	50	0.27	50	0.27	50	0.27	50	0.27	50
	16	0.27	50	0.27	50	0.27	50	0.27	50	0.27	50
	20	0.27	50	0.27	50	0.27	50	0.27	50	0.27	50
	24	0.27	50	0.27	50	0.27	50	0.27	50	0.27	50
	28	0.30	51	0.27	50	0.27	50	0.27	50	0.27	50
	32	0.30	51	0.30	51	0.27	50	0.27	50	0.27	50

* Truckloads used in computing this table are based on a single H-20 truck with 16 000-lb wheel load and 1.5 impact factor.
† See corresponding illustrations in Fig. 3 of types of laying conditions

TABLE 51.1—(*cont.*)

Size *in.*	Depth of Cover *ft.*	Laying Condition: Type 1† Thickness *in.*	Type 1† Thickness Class	Type 2† Thickness *in.*	Type 2† Thickness Class	Type 3† Thickness *in.*	Type 3† Thickness Class	Type 4† Thickness *in.*	Type 4† Thickness Class	Type 5† Thickness *in.*	Type 5† Thickness Class
10	2.5	0.29	50	0.29	50	0.29	50	0.29	50	0.29	50
	3	0.29	50	0.29	50	0.29	50	0.29	50	0.29	50
	4	0.29	50	0.29	50	0.29	50	0.29	50	0.29	50
	5	0.29	50	0.29	50	0.29	50	0.29	50	0.29	50
	6	0.29	50	0.29	50	0.29	50	0.29	50	0.29	50
	7	0.29	50	0.29	50	0.29	50	0.29	50	0.29	50
	8	0.29	50	0.29	50	0.29	50	0.29	50	0.29	50
	9	0.29	50	0.29	50	0.29	50	0.29	50	0.29	50
	10	0.29	50	0.29	50	0.29	50	0.29	50	0.29	50
	12	0.29	50	0.29	50	0.29	50	0.29	50	0.29	50
	14	0.29	50	0.29	50	0.29	50	0.29	50	0.29	50
	16	0.29	50	0.29	50	0.29	50	0.29	50	0.29	50
	20	0.32	51	0.29	50	0.29	50	0.29	50	0.29	50
	24	0.32	51	0.29	50	0.29	50	0.29	50	0.29	50
	28	0.35	52	0.32	51	0.29	50	0.29	50	0.29	50
	32	0.35	52	0.32	51	0.32	51	0.29	50	0.29	50
12	2.5	0.31	50	0.31	50	0.31	50	0.31	50	0.31	50
	3	0.31	50	0.31	50	0.31	50	0.31	50	0.31	50
	4	0.31	50	0.31	50	0.31	50	0.31	50	0.31	50
	5	0.31	50	0.31	50	0.31	50	0.31	50	0.31	50
	6	0.31	50	0.31	50	0.31	50	0.31	50	0.31	50
	7	0.31	50	0.31	50	0.31	50	0.31	50	0.31	50
	8	0.31	50	0.31	50	0.31	50	0.31	50	0.31	50
	9	0.31	50	0.31	50	0.31	50	0.31	50	0.31	50
	10	0.31	50	0.31	50	0.31	50	0.31	50	0.31	50
	12	0.31	50	0.31	50	0.31	50	0.31	50	0.31	50
	14	0.31	50	0.31	50	0.31	50	0.31	50	0.31	50
	16	0.31	50	0.31	50	0.31	50	0.31	50	0.31	50
	20	0.34	51	0.31	50	0.31	50	0.31	50	0.31	50
	24	0.37	52	0.34	51	0.31	50	0.31	50	0.31	50
	28	0.37	52	0.34	51	0.34	51	0.31	50	0.31	50
	32	0.40	53	0.37	52	0.34	51	0.31	50	0.31	50
14	2.5	0.33	50	0.33	50	0.33	50	0.33	50	0.33	50
	3	0.33	50	0.33	50	0.33	50	0.33	50	0.33	50
	4	0.33	50	0.33	50	0.33	50	0.33	50	0.33	50
	5	0.33	50	0.33	50	0.33	50	0.33	50	0.33	50
	6	0.33	50	0.33	50	0.33	50	0.33	50	0.33	50
	7	0.33	50	0.33	50	0.33	50	0.33	50	0.33	50
	8	0.33	50	0.33	50	0.33	50	0.33	50	0.33	50
	9	0.33	50	0.33	50	0.33	50	0.33	50	0.33	50
	10	0.33	50	0.33	50	0.33	50	0.33	50	0.33	50
	12	0.33	50	0.33	50	0.33	50	0.33	50	0.33	50
	14	0.33	50	0.33	50	0.33	50	0.33	50	0.33	50
	16	0.36	51	0.33	50	0.33	50	0.33	50	0.33	50
	20	0.39	52	0.36	51	0.33	50	0.33	50	0.33	50
	24	0.39	52	0.39	52	0.33	50	0.33	50	0.33	50
	28	0.42	53	0.39	52	0.36	51	0.33	50	0.33	50
	32	0.45	54	0.42	53	0.39	52	0.33	50	0.33	50
16	2.5	0.34	50	0.34	50	0.34	50	0.34	50	0.34	50
	3	0.34	50	0.34	50	0.34	50	0.34	50	0.34	50
	4	0.34	50	0.34	50	0.34	50	0.34	50	0.34	50
	5	0.34	50	0.34	50	0.34	50	0.34	50	0.34	50
	6	0.34	50	0.34	50	0.34	50	0.34	50	0.34	50
	7	0.34	50	0.34	50	0.34	50	0.34	50	0.34	50
	8	0.34	50	0.34	50	0.34	50	0.34	50	0.34	50
	9	0.34	50	0.34	50	0.34	50	0.34	50	0.34	50
	10	0.34	50	0.34	50	0.34	50	0.34	50	0.34	50
	12	0.34	50	0.34	50	0.34	50	0.34	50	0.34	50
	14	0.37	51	0.34	50	0.34	50	0.34	50	0.34	50
	16	0.37	51	0.34	50	0.34	50	0.34	50	0.34	50
	20	0.40	52	0.37	51	0.34	50	0.34	50	0.34	50
	24	0.43	53	0.40	52	0.37	51	0.34	50	0.34	50
	28	0.46	54	0.43	53	0.40	52	0.34	50	0.34	50
	32	0.49	55	0.46	54	0.43	53	0.37	51	0.34	50

† See corresponding illustrations in Fig. 3 of types of laying conditions

TABLE 51.1—(*cont.*)

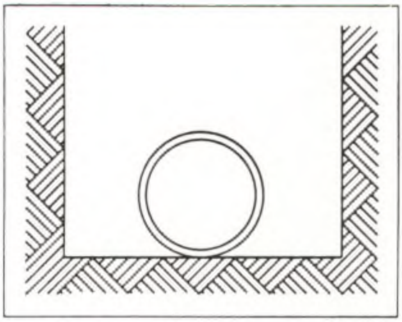
Size *in.*	Depth of Cover *ft.*	Type 1† Thickness *in.*	Type 1† Thickness Class	Type 2† Thickness *in.*	Type 2† Thickness Class	Type 3† Thickness *in.*	Type 3† Thickness Class	Type 4† Thickness *in.*	Type 4† Thickness Class	Type 5† Thickness *in.*	Type 5† Thickness Class
18	2.5	0.35	50	0.35	50	0.35	50	0.35	50	0.35	50
	3	0.35	50	0.35	50	0.35	50	0.35	50	0.35	50
	4	0.35	50	0.35	50	0.35	50	0.35	50	0.35	50
	5	0.35	50	0.35	50	0.35	50	0.35	50	0.35	50
	6	0.35	50	0.35	50	0.35	50	0.35	50	0.35	50
	7	0.35	50	0.35	50	0.35	50	0.35	50	0.35	50
	8	0.35	50	0.35	50	0.35	50	0.35	50	0.35	50
	9	0.35	50	0.35	50	0.35	50	0.35	50	0.35	50
	10	0.35	50	0.35	50	0.35	50	0.35	50	0.35	50
	12	0.38	51	0.35	50	0.35	50	0.35	50	0.35	50
	14	0.38	51	0.35	50	0.35	50	0.35	50	0.35	50
	16	0.41	52	0.38	51	0.35	50	0.35	50	0.35	50
	20	0.44	53	0.41	52	0.35	50	0.35	50	0.35	50
	24	0.47	54	0.44	53	0.41	52	0.35	50	0.35	50
	28	0.50	55	0.47	54	0.44	53	0.35	50	0.35	50
	32	0.53	56	0.50	55	0.47	54	0.38	51	0.35	50
20	2.5	0.39	51	0.36	50	0.36	50	0.36	50	0.36	50
	3	0.36	50	0.36	50	0.36	50	0.36	50	0.36	50
	4	0.36	50	0.36	50	0.36	50	0.36	50	0.36	50
	5	0.36	50	0.36	50	0.36	50	0.36	50	0.36	50
	6	0.36	50	0.36	50	0.36	50	0.36	50	0.36	50
	7	0.36	50	0.36	50	0.36	50	0.36	50	0.36	50
	8	0.36	50	0.36	50	0.36	50	0.36	50	0.36	50
	9	0.36	50	0.36	50	0.36	50	0.36	50	0.36	50
	10	0.36	50	0.36	50	0.36	50	0.36	50	0.36	50
	12	0.39	51	0.36	50	0.36	50	0.36	50	0.36	50
	14	0.42	52	0.36	50	0.36	50	0.36	50	0.36	50
	16	0.42	52	0.39	51	0.36	50	0.36	50	0.36	50
	20	0.48	54	0.42	52	0.39	51	0.36	50	0.36	50
	24	0.51	55	0.48	54	0.42	52	0.36	50	0.36	50
	28	0.54	56	0.51	55	0.45	53	0.39	51	0.36	50
	32	—	—	0.54	56	0.48	54	0.42	52	0.36	50
24	2.5	0.41	51	0.38	50	0.38	50	0.38	50	0.38	50
	3	0.38	50	0.38	50	0.38	50	0.38	50	0.38	50
	4	0.38	50	0.38	50	0.38	50	0.38	50	0.38	50
	5	0.38	50	0.38	50	0.38	50	0.38	50	0.38	50
	6	0.38	50	0.38	50	0.38	50	0.38	50	0.38	50
	7	0.38	50	0.38	50	0.38	50	0.38	50	0.38	50
	8	0.38	50	0.38	50	0.38	50	0.38	50	0.38	50
	9	0.41	51	0.38	50	0.38	50	0.38	50	0.38	50
	10	0.41	51	0.38	50	0.38	50	0.38	50	0.38	50
	12	0.44	52	0.38	50	0.38	50	0.38	50	0.38	50
	14	0.47	53	0.41	51	0.38	50	0.38	50	0.38	50
	16	0.50	54	0.44	52	0.38	50	0.38	50	0.38	50
	20	0.53	55	0.50	54	0.44	52	0.38	50	0.38	50
	24	0.56	56	0.53	55	0.47	53	0.41	51	0.38	50
	28	—	—	0.56	56	0.53	55	0.44	52	0.38	50
	32	—	—	—	—	0.56	56	0.47	53	0.41	51
30	2.5	‡	‡	0.39	50	0.39	50	0.39	50	0.39	50
	3			0.39	50	0.39	50	0.39	50	0.39	50
	4			0.39	50	0.39	50	0.39	50	0.39	50
	5			0.39	50	0.39	50	0.39	50	0.39	50
	6			0.39	50	0.39	50	0.39	50	0.39	50
	7			0.39	50	0.39	50	0.39	50	0.39	50
	8			0.39	50	0.39	50	0.39	50	0.39	50
	9			0.39	50	0.39	50	0.39	50	0.39	50
	10			0.39	50	0.39	50	0.39	50	0.39	50
	12			0.43	51	0.39	50	0.39	50	0.39	50
	14			0.47	52	0.39	50	0.39	50	0.39	50
	16			0.51	53	0.43	51	0.39	50	0.39	50
	20			0.59	55	0.51	53	0.43	51	0.39	50
	24			0.63	56	0.55	54	0.47	52	0.39	50
	28			—	—	0.63	56	0.51	53	0.43	51
	32			—	—	—	—	0.55	54	0.47	52

† See corresponding illustrations in Fig. 3 of types of laying conditions.
‡ For pipe 30 in. and larger, consideration should be given to the use of laying conditions other than Type 1.

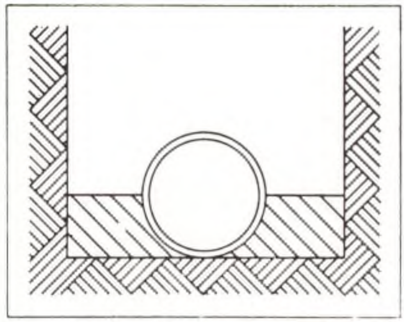
TABLE 51.1—(*cont.*)

Size *in.*	Depth of Cover *ft.*	Laying Condition: Type 1† Thickness *in.*	Type 1† Thickness Class	Type 2† Thickness *in.*	Type 2† Thickness Class	Type 3† Thickness *in.*	Type 3† Thickness Class	Type 4† Thickness *in.*	Type 4† Thickness Class	Type 5† Thickness *in.*	Type 5† Thickness Class
36	2.5	‡	‡	0.43	50	0.43	50	0.43	50	0.43	50
	3			0.43	50	0.43	50	0.43	50	0.43	50
	4			0.43	50	0.43	50	0.43	50	0.43	50
	5			0.43	50	0.43	50	0.43	50	0.43	50
	6			0.43	50	0.43	50	0.43	50	0.43	50
	7			0.43	50	0.43	50	0.43	50	0.43	50
	8			0.43	50	0.43	50	0.43	50	0.43	50
	9			0.43	50	0.43	50	0.43	50	0.43	50
	10			0.43	50	0.43	50	0.43	50	0.43	50
	12			0.48	51	0.43	50	0.43	50	0.43	50
	14			0.53	52	0.48	51	0.43	50	0.43	50
	16			0.58	53	0.48	51	0.43	50	0.43	50
	20			0.63	54	0.58	53	0.48	51	0.43	50
	24			0.73	56	0.63	54	0.53	52	0.43	50
	28			—	—	0.68	55	0.58	53	0.48	51
	32			—	—	—	—	0.63	54	0.53	52
42	2.5	‡	‡	0.47	50	0.47	50	0.47	50	0.47	50
	3			0.47	50	0.47	50	0.47	50	0.47	50
	4			0.47	50	0.47	50	0.47	50	0.47	50
	5			0.47	50	0.47	50	0.47	50	0.47	50
	6			0.47	50	0.47	50	0.47	50	0.47	50
	7			0.47	50	0.47	50	0.47	50	0.47	50
	8			0.47	50	0.47	50	0.47	50	0.47	50
	9			0.47	50	0.47	50	0.47	50	0.47	50
	10			0.53	51	0.47	50	0.47	50	0.47	50
	12			0.53	51	0.47	50	0.47	50	0.47	50
	14			0.59	52	0.53	51	0.47	50	0.47	50
	16			0.65	53	0.59	52	0.47	50	0.47	50
	20			0.71	54	0.65	53	0.59	52	0.47	50
	24			0.83	56	0.71	54	0.65	53	0.47	50
	28			—	—	0.77	55	0.71	54	0.59	52
	32			—	—	—	—	0.71	54	0.65	53
48	2.5	‡	‡	0.51	50	0.51	50	0.51	50	0.51	50
	3			0.51	50	0.51	50	0.51	50	0.51	50
	4			0.51	50	0.51	50	0.51	50	0.51	50
	5			0.51	50	0.51	50	0.51	50	0.51	50
	6			0.51	50	0.51	50	0.51	50	0.51	50
	7			0.51	50	0.51	50	0.51	50	0.51	50
	8			0.51	50	0.51	50	0.51	50	0.51	50
	9			0.51	50	0.51	50	0.51	50	0.51	50
	10			0.58	51	0.51	50	0.51	50	0.51	50
	12			0.58	51	0.51	50	0.51	50	0.51	50
	14			0.65	52	0.58	51	0.51	50	0.51	50
	16			0.72	53	0.65	52	0.58	51	0.51	50
	20			0.79	54	0.72	53	0.65	52	0.51	50
	24			0.93	56	0.79	54	0.72	53	0.58	51
	28			—	—	0.86	55	0.79	54	0.65	52
	32			—	—	—	—	0.86	55	0.72	53
54	2.5	‡	‡	0.57	50	0.57	50	0.57	50	0.57	50
	3			0.57	50	0.57	50	0.57	50	0.57	50
	4			0.57	50	0.57	50	0.57	50	0.57	50
	5			0.57	50	0.57	50	0.57	50	0.57	50
	6			0.57	50	0.57	50	0.57	50	0.57	50
	7			0.57	50	0.57	50	0.57	50	0.57	50
	8			0.57	50	0.57	50	0.57	50	0.57	50
	9			0.57	50	0.57	50	0.57	50	0.57	50
	10			0.65	51	0.57	50	0.57	50	0.57	50
	12			0.65	51	0.57	50	0.57	50	0.57	50
	14			0.73	52	0.65	51	0.57	50	0.57	50
	16			0.81	53	0.73	52	0.65	51	0.57	50
	20			0.89	54	0.81	53	0.73	52	0.57	50
	24			1.05	56	0.89	54	0.81	53	0.65	51
	28			—	—	0.97	55	0.89	54	0.73	52
	32			—	—	—	—	0.97	55	0.81	53

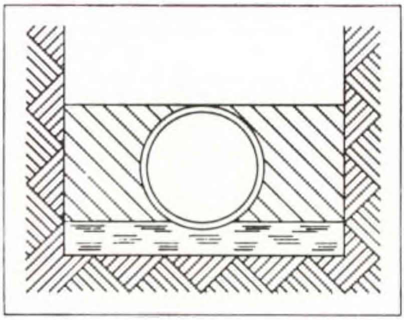
† See corresponding illustrations in Fig. 3 of types of laying conditions.
‡ For pipe 30 in. and larger, consideration should be given to the use of laying conditions other than Type 1.



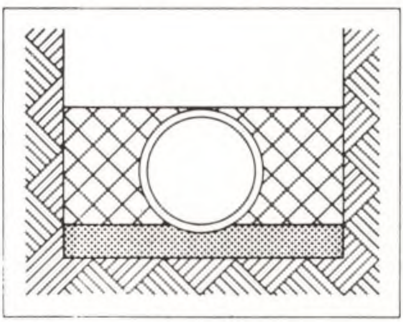
*Type 1** Flat-bottom trench.† Loose backfill.



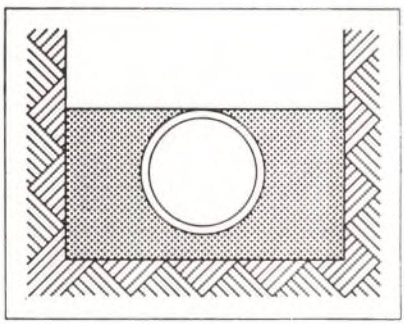
Type 2 Flat-bottom trench.† Backfill lightly consolidated to centerline of pipe.



Type 3 Pipe bedded in 4-in. (100-mm) minimum loose soil.‡ Backfill lightly consolidated to top of pipe.



Type 4 Pipe bedded in sand, gravel, or crushed stone to depth of 1/8 pipe diameter, 4-in. (100-mm) minimum. Backfill compacted to top of pipe. (Approximately 80 percent Standard Proctor, AASHTO§ T-99)



Type 5 Pipe bedded to its centerline in compacted granular material, 4-in. (100-mm) minimum under pipe. Compacted granular or select ‡ material to top of pipe. (Approximately 90 percent Standard Proctor, AASHTO§ T-99)

Figure 3 Standard Laying Conditions

*For pipe 30 in. and larger, consideration should be given to the use of laying conditions other than Type 1.

†"Flat-bottom" is defined as undisturbed earth.

‡"Loose soil" or "select material" is defined as native soil excavated from the trench, free of rocks, foreign materials, and frozen earth.

§American Association of State Highway and Transportation Officials, 341 National Press Bldg., Washington, DC 20004.

TABLE 51.2

Standard Thickness for Internal Pressure

Pipe Size *in.*	Rated Water Working Pressure*—*psi*									
	150		200		250		300		350	
	Thickness *in.*	Thickness Class	Thickness *in.*	Thickness Class	Thickness *in.*	Thickness Class	Thickness *in.*	Thickness Class	Thickness *in.*	Thickness Class
3	0.25	51	0.25	51	0.25	51	0.25	51	0.25	51
4	0.26	51	0.26	51	0.26	51	0.26	51	0.26	51
6	0.25	50	0.25	50	0.25	50	0.25	50	0.25	50
8	0.27	50	0.27	50	0.27	50	0.27	50	0.27	50
10	0.29	50	0.29	50	0.29	50	0.29	50	0.29	50
12	0.31	50	0.31	50	0.31	50	0.31	50	0.31	50
14	0.33	50	0.33	50	0.33	50	0.33	50	0.33	50
16	0.34	50	0.34	50	0.34	50	0.34	50	0.34	50
18	0.35	50	0.35	50	0.35	50	0.35	50	0.35	50
20	0.36	50	0.36	50	0.36	50	0.36	50	0.39	51
24	0.38	50	0.38	50	0.38	50	0.41	51	0.44	52
30	0.39	50	0.39	50	0.43	51	0.47	52	0.51	53
36	0.43	50	0.43	50	0.48	51	0.53	52	0.58	53
42	0.47	50	0.47	50	0.53	51	0.59	52	0.65	53
48	0.51	50	0.51	50	0.58	51	0.65	52	0.72	53
54	0.57	50	0.57	50	0.65	51	0.73	52	0.81	53

* These pipe are adequate for the rated working pressure plus a surge allowance of 100 psi.

TABLE 51.3

Rated Working Pressure and Maximum Depth of Cover

Pipe Size *in.*	Thickness Class	Nominal Thickness *in.*	Rated Water Working Pressure* *psi*	Laying Condition				
				Type 1	Type 2	Type 3	Type 4	Type 5
				Maximum Depth of Cover—*ft*†				
3	51	0.25	350	98	100‡	100‡	100‡	100‡
	52	0.28	350	100‡	100‡	100‡	100‡	100‡
	53	0.31	350	100‡	100‡	100‡	100‡	100‡
	54	0.34	350	100‡	100‡	100‡	100‡	100‡
	55	0.37	350	100‡	100‡	100‡	100‡	100‡
	56	0.40	350	100‡	100‡	100‡	100‡	100‡
4	51	0.26	350	76	86	96	100‡	100‡
	52	0.29	350	100‡	100‡	100‡	100‡	100‡
	53	0.32	350	100‡	100‡	100‡	100‡	100‡
	54	0.35	350	100‡	100‡	100‡	100‡	100‡
	55	0.38	350	100‡	100‡	100‡	100‡	100‡
	56	0.41	350	100‡	100‡	100‡	100‡	100‡
6	50	0.25	350	32	38	44	56	75
	51	0.28	350	49	57	64	80	100‡
	52	0.31	350	67	77	86	100‡	100‡
	53	0.34	350	91	100‡	100‡	100‡	100‡
	54	0.37	350	100‡	100‡	100‡	100‡	100‡
	55	0.40	350	100‡	100‡	100‡	100‡	100‡
	56	0.43	350	100‡	100‡	100‡	100‡	100‡
8	50	0.27	350	25	30	36	46	64
	51	0.30	350	36	42	49	61	81
	52	0.33	350	47	54	62	77	99
	53	0.36	350	64	73	82	100‡	100‡
	54	0.39	350	80	91	100‡	100‡	100‡
	55	0.42	350	98	100‡	100‡	100‡	100‡
	56	0.45	350	100‡	100‡	100‡	100‡	100‡
10	50	0.29	350	19	24	29	38	55
	51	0.32	350	27	32	38	49	66
	52	0.35	350	35	41	47	59	79
	53	0.38	350	45	52	59	74	95
	54	0.41	350	57	65	74	91	100‡
	55	0.44	350	67	77	86	100‡	100‡
	56	0.47	350	81	92	100‡	100‡	100‡
12	50	0.31	350	17	22	27	36	52
	51	0.34	350	23	28	33	43	60
	52	0.37	350	30	35	41	53	71
	53	0.40	350	36	42	49	61	81
	54	0.43	350	45	52	59	74	95
	55	0.46	350	54	62	71	87	100‡
	56	0.49	350	64	73	83	100‡	100‡
14	50	0.33	350	15	19	24	33	49
	51	0.36	350	19	23	28	38	55
	52	0.39	350	24	29	34	44	62
	53	0.42	350	30	35	41	53	71
	54	0.45	350	36	42	49	61	81
	55	0.48	350	43	50	57	71	92
	56	0.51	350	52	59	67	83	100‡
16	50	0.34	350	13	17	21	30	47
	51	0.37	350	16	21	25	34	51
	52	0.40	350	20	25	30	40	57
	53	0.43	350	25	30	36	46	64
	54	0.46	350	30	35	41	53	71
	55	0.49	350	35	41	47	59	79
	56	0.52	350	41	48	55	68	89
18	50	0.35	350	11	15	20	29	42
	51	0.38	350	14	19	23	32	49
	52	0.41	350	18	22	27	36	53
	53	0.44	350	22	26	31	41	58
	54	0.47	350	25	30	36	46	64
	55	0.50	350	30	35	41	53	71
	56	0.53	350	35	41	47	59	79

* These pipe are adequate for the rated working pressure plus a surge allowance of 100 psi. Ductile-iron pipe for working pressures higher than 350 psi is available.
† An allowance for a single H-20 truck with 1.5 impact factor is included for all depths of cover
‡ Calculated maximum depth of cover exceeds 100 ft.

TABLE 51.3—(*cont.*)

Pipe Size *in.*	Thickness Class	Nominal Thickness *in.*	Rated Water Working Pressure* *psi*	Laying Condition				
				Type 1	Type 2	Type 3	Type 4	Type 5
				Maximum Depth of Cover—*ft*†				
20	50	0.36	300	10	14	18	27	38
	51	0.39	350	13	17	21	30	44
	52	0.42	350	16	20	25	34	50
	53	0.45	350	19	23	28	38	54
	54	0.48	350	22	27	32	42	59
	55	0.51	350	26	31	37	47	65
	56	0.54	350	30	35	41	53	71
24	50	0.38	250	8	12	17	23	31
	51	0.41	300	10	15	19	27	36
	52	0.44	350	13	17	21	30	41
	53	0.47	350	15	19	24	33	47
	54	0.50	350	18	22	27	36	53
	55	0.53	350	20	25	30	40	57
	56	0.56	350	24	29	34	44	61
30	50	0.39	200	§	10	14	18	25
	51	0.43	250		12	16	21	29
	52	0.47	300		14	19	24	33
	53	0.51	350		17	21	29	38
	54	0.55	350		19	24	33	44
	55	0.59	350		22	27	36	51
	56	0.63	350		26	31	41	57
36	50	0.43	200		10	13	17	25
	51	0.48	250		12	16	20	28
	52	0.53	300		15	19	24	32
	53	0.58	350		17	21	28	37
	54	0.63	350		20	25	33	43
	55	0.68	350		23	28	37	50
	56	0.73	350		26	31	41	59
42	50	0.47	200	§	9	13	16	24
	51	0.53	250		12	15	19	27
	52	0.59	300		14	18	22	30
	53	0.65	350		17	22	27	35
	54	0.71	350		20	24	32	42
	55	0.77	350		23	28	38	48
	56	0.83	350		26	31	41	57
48	50	0.51	200		9	12	15	23
	51	0.58	250		12	14	18	26
	52	0.65	300		14	18	21	30
	53	0.72	350		17	21	25	34
	54	0.79	350		20	24	30	40
	55	0.86	350		23	28	37	47
	56	0.93	350		26	31	41	55
54	50	0.57	200		9	12	15	23
	51	0.65	250		12	14	18	25
	52	0.73	300		14	17	21	29
	53	0.81	350		17	21	25	34
	54	0.89	350		20	25	30	40
	55	0.97	350		23	28	37	47
	56	1.05	350		27	32	42	55

* These pipe are adequate for the rated working pressure plus a surge allowance of 100 psi. Ductile-iron pipe for working pressures higher than 350 psi is available.

† An allowance for a single H-20 truck with 1.5 impact factor is included for all depths of cover.

§ For pipe 30 in. and larger, consideration should be given to the use of laying conditions other than Type 1

TABLE 51.4

Standard Dimensions and Weights of Push-on-Joint Ductile-Iron Pipe

Size *in.*	Thick-ness Class	Thick-ness *in.*	OD* *in.*	Wt. of Barrel Per Ft *lb*	Wt. of Bell§ *lb*	18-ft Laying Length		20-ft Laying Length	
						Wt. Per Lgth.† *lb*	Avg. Wt. Per Ft‡ *lb*	Wt. Per Lgth.† *lb*	Avg. Wt. Per Ft‡ *lb*
3	51	0.25	3.96	8.9	7.0	165	9.3	185	9.2
	52	0.28	3.96	9.9	7.0	185	10.3	205	10.2
	53	0.31	3.96	10.9	7.0	205	11.3	225	11.2
	54	0.34	3.96	11.8	7.0	220	12.2	245	12.2
	55	0.37	3.96	12.8	7.0	235	13.2	265	13.2
	56	0.40	3.96	13.7	7.0	255	14.1	280	14.0
4	51	0.26	4.80	11.3	9.0	210	11.8	235	11.8
	52	0.29	4.80	12.6	9.0	235	13.1	260	13.0
	53	0.32	4.80	13.8	9.0	255	14.3	285	14.2
	54	0.35	4.80	15.0	9.0	280	15.5	310	15.4
	55	0.38	4.80	16.1	9.0	300	16.6	330	16.6
	56	0.41	4.80	17.3	9.0	320	17.8	355	17.8
6	50	0.25	6.90	16.0	11.0	300	16.6	330	16.6
	51	0.28	6.90	17.8	11.0	330	18.4	365	18.3
	52	0.31	6.90	19.6	11.0	365	20.2	405	20.2
	53	0.34	6.90	21.4	11.0	395	22.0	440	22.0
	54	0.37	6.90	23.2	11.0	430	23.8	475	23.8
	55	0.40	6.90	25.0	11.0	460	25.6	510	25.6
	56	0.43	6.90	26.7	11.0	490	27.3	545	27.2
8	50	0.27	9.05	22.8	17.0	425	23.7	475	23.7
	51	0.30	9.05	25.2	17.0	470	26.1	520	26.0
	52	0.33	9.05	27.7	17.0	515	28.6	570	28.6
	53	0.36	9.05	30.1	17.0	560	31.0	620	31.0
	54	0.39	9.05	32.5	17.0	600	33.4	665	33.3
	55	0.42	9.05	34.8	17.0	645	35.7	715	35.7
	56	0.45	9.05	37.2	17.0	685	38.1	760	38.0
10	50	0.29	11.10	30.1	24.0	565	31.4	625	31.3
	51	0.32	11.10	33.2	24.0	620	34.5	690	34.4
	52	0.35	11.10	36.2	24.0	675	37.5	750	37.4
	53	0.38	11.10	39.2	24.0	730	40.5	810	40.4
	54	0.41	11.10	42.1	24.0	780	43.4	865	43.3
	55	0.44	11.10	45.1	24.0	835	46.4	925	46.3
	56	0.47	11.10	48.0	24.0	890	49.3	985	49.2

*Tolerance of OD of spigot end: 3–12 in., ±0.06 in.; 14–24 in., +0.05 in., −0.08 in.; 30–54 in., +0.08 in., −0.06 in.

§The bell weights shown above are adequate for 350 psi operating pressure. Bell weights vary due to differences in push-on joint design. The manufacturer shall calculate pipe weights using standard barrel weights and weights of bells being produced.

†Including bell; calculated weight of pipe rounded off to nearest 5 lb.

‡Including bell; average weight per foot based on calculated weight of pipe before rounding.

TABLE 51.4—*(cont.)*

Size *in.*	Thick-ness Class	Thick-ness *in.*	OD* *in.*	Wt. of Barrel Per Ft *lb*	Wt. of Bell§ *lb*	18-ft Laying Length		20-ft Laying Length	
						Wt. Per Lgth.† *lb*	Avg. Wt. Per Ft‡ *lb*	Wt. Per Lgth.† *lb*	Avg. Wt Per Ft‡ *lb*
12	50	0.31	13.20	38.4	29.0	720	40.0	795	39.8
	51	0.34	13.20	42.0	29.0	785	43.6	870	43.4
	52	0.37	13.20	45.6	29.0	850	47.2	940	47.0
	53	0.40	13.20	49.2	29.0	915	50.8	1015	50.7
	54	0.43	13.20	52.8	29.0	980	54.4	1085	54.2
	55	0.46	13.20	56.3	29.0	1040	57.9	1155	57.8
	56	0.49	13.20	59.9	29.0	1105	61.5	1225	61.4
14	50	0.33	15.30	47.5	45.0	900	50.0	995	49.8
	51	0.36	15.30	51.7	45.0	975	54.2	1080	54.0
	52	0.39	15.30	55.9	45.0	1050	58.4	1165	58.2
	53	0.42	15.30	60.1	45.0	1125	62.6	1245	62.4
	54	0.45	15.30	64.2	45.0	1200	66.7	1330	66.4
	55	0.48	15.30	68.4	45.0	1275	70.9	1415	70.7
	56	0.51	15.30	72.5	45.0	1350	75.0	1495	74.8
16	50	0.34	17.40	55.8	54.0	1060	58.8	1170	58.5
	51	0.37	17.40	60.6	54.0	1145	63.6	1265	63.3
	52	0.40	17.40	65.4	54.0	1230	68.4	1360	68.1
	53	0.43	17.40	70.1	54.0	1315	73.1	1455	72.8
	54	0.46	17.40	74.9	54.0	1400	77.9	1550	77.6
	55	0.49	17.40	79.7	54.0	1490	82.7	1650	82.4
	56	0.52	17.40	84.4	54.0	1575	87.4	1740	87.1
18	50	0.35	19.50	64.4	59.0	1220	67.7	1345	67.4
	51	0.38	19.50	69.8	59.0	1315	73.1	1455	72.8
	52	0.41	19.50	75.2	59.0	1415	78.5	1565	78.2
	53	0.44	19.50	80.6	59.0	1510	83.9	1670	83.6
	54	0.47	19.50	86.0	59.0	1605	89.3	1780	89.0
	55	0.50	19.50	91.3	59.0	1700	94.5	1885	94.2
	56	0.53	19.50	96.7	59.0	1800	100.0	1995	99.7
20	50	0.36	21.60	73.5	74.0	1395	77.6	1545	77.2
	51	0.39	21.60	79.5	74.0	1505	83.6	1665	83.2
	52	0.42	21.60	85.5	74.0	1615	89.6	1785	89.2
	53	0.45	21.60	91.5	74.0	1720	95.6	1905	95.2
	54	0.48	21.60	97.5	74.0	1830	101.6	2025	101.2
	55	0.51	21.60	103.4	74.0	1935	107.5	2140	107.1
	56	0.54	21.60	109.3	74.0	2040	113.4	2260	113.0

*Tolerance of OD of spigot end: 3-12 in., ±0.06 in.; 14-24 in., +0.05 in., −0.08 in.; 30-54 in., +0.08 in., −0.06 in.

§The bell weights shown above are adequate for 350 psi operating pressure. Bell weights vary due to differences in push-on joint design. The manufacturer shall calculate pipe weights using standard barrel weights and weights of bells being produced.

†Including bell; calculated weight of pipe rounded off to nearest 5 lb.

‡Including bell; average weight per foot based on calculated weight of pipe before rounding.

TABLE 51.4—*(cont.)*

Size *in.*	Thick-ness Class	Thick-ness *in.*	OD* *in.*	Wt. of Barrel Per Ft *lb*	Wt. of Bell§ *lb*	18-ft Laying Length		20-ft Laying Length	
						Wt. Per Lgth.† *lb*	Avg. Wt. Per Ft‡ *lb*	Wt. Per Lgth.† *lb*	Avg. Wt. Per Ft‡ *lb*
24	50	0.38	25.80	92.9	95.0	1765	98.1	1955	97.7
	51	0.41	25.80	100.1	95.0	1895	105.4	2095	104.8
	52	0.44	25.80	107.3	95.0	2025	112.6	2240	112.0
	53	0.47	25.80	114.4	95.0	2155	119.7	2385	119.2
	54	0.50	25.80	121.6	95.0	2285	126.9	2525	126.3
	55	0.53	25.80	128.8	95.0	2415	134.1	2670	133.6
	56	0.56	25.80	135.9	95.0	2540	141.2	2815	140.7
30	50	0.39	32.00	118.5	139.0	2270	126.2	2510	125.4
	51	0.43	32.00	130.5	139.0	2490	138.2	2750	137.4
	52	0.47	32.00	142.5	139.0	2705	150.2	2990	149.4
	53	0.51	32.00	154.4	139.0	2920	162.1	3225	161.3
	54	0.55	32.00	166.3	139.0	3130	174.0	3465	173.2
	55	0.59	32.00	178.2	139.0	3345	185.9	3705	185.2
	56	0.63	32.00	190.0	139.0	3560	197.7	3940	197.0
36	50	0.43	38.30	156.5	184.0	3000	166.7	3315	165.7
	51	0.48	38.30	174.5	184.0	3325	184.7	3675	183.7
	52	0.53	38.30	192.4	184.0	3645	202.6	4030	201.6
	53	0.58	38.30	210.3	184.0	3970	220.5	4390	219.5
	54	0.63	38.30	228.1	184.0	4290	238.3	4745	237.3
	55	0.68	38.30	245.9	184.0	4610	256.1	5100	255.1
	56	0.73	38.30	263.7	184.0	4930	273.9	5460	272.9
42	50	0.47	44.50	198.9	224.0			4200	210.1
	51	0.53	44.50	224.0	224.0			4705	235.2
	52	0.59	44.50	249.1	224.0			5205	260.3
	53	0.65	44.50	274.0	224.0			5705	285.2
	54	0.71	44.50	298.9	224.0			6200	310.1
	55	0.77	44.50	323.7	224.0			6700	334.9
	56	0.83	44.50	348.4	224.0			7190	359.6
48	50	0.51	50.80	246.6	274.0			5205	260.3
	51	0.58	50.80	280.0	274.0			5875	293.7
	52	0.65	50.80	313.4	274.0			6540	327.1
	53	0.72	50.80	346.6	274.0			7205	360.3
	54	0.79	50.80	379.8	274.0			7870	393.5
	55	0.86	50.80	412.9	274.0			8530	426.6
	56	0.93	50.80	445.9	274.0			9190	459.6
54	50	0.57	57.10	309.8	335.0			6530	326.6
	51	0.65	57.10	352.7	335.0			7390	369.4
	52	0.73	57.10	395.6	335.0			8245	412.3
	53	0.81	57.10	438.3	335.0			9100	455.0
	54	0.89	57.10	480.9	335.0			9955	497.7
	55	0.97	57.10	523.4	335.0			10805	540.2
	56	1.05	57.10	565.8	335.0			11650	582.6

*Tolerance of OD of spigot end: 3-12 in., ±0.06 in.; 14-24 in., +0.05 in., −0.08 in.; 30-54 in., +0.08 in., −0.06 in.

§The bell weights shown above are adequate for 350 psi operating pressure. Bell weights vary due to differences in push-on joint design. The manufacturer shall calculate pipe weights using standard barrel weights and weights of bells being produced.

†Including bell; calculated weight of pipe rounded off to nearest 5 lb.

‡Including bell; average weight per foot based on calculated weight of pipe before rounding.

TABLE 51.5

Standard Dimensions and Weights of Mechanical-Joint Ductile-Iron Pipe

Size *in.*	Thickness Class	Thickness *in.*	OD* *in.*	Wt. of Barrel Per Ft *lb*	Wt. of Bell§ *lb*	18-ft Laying Length		20-ft Laying Length	
						Wt. Per Lgth.† *lb*	Avg. Wt. Per Ft‡ *lb*	Wt. Per Lgth.† *lb*	Avg. Wt. Per Ft‡ *lb*
3	51	0.25	3.96	8.9	9.0	170	9.4	185	9.3
	52	0.28	3.96	9.9	9.0	185	10.4	205	10.3
	53	0.31	3.96	10.9	9.0	205	11.4	225	11.3
	54	0.34	3.96	11.8	9.0	220	12.3	245	12.2
	55	0.37	3.96	12.8	9.0	240	13.3	265	13.2
	56	0.40	3.96	13.7	9.0	255	14.2	285	14.2
4	51	0.26	4.80	11.3	13.0	215	12.0	240	12.0
	52	0.29	4.80	12.6	13.0	240	13.3	265	13.2
	53	0.32	4.80	13.8	13.0	260	14.5	290	14.4
	54	0.35	4.80	15.0	13.0	285	15.7	315	15.7
	55	0.38	4.80	16.1	13.0	305	16.9	335	16.8
	56	0.41	4.80	17.3	13.0	325	18.0	360	18.0
6	50	0.25	6.90	16.0	18.0	305	17.0	340	16.9
	51	0.28	6.90	17.8	18.0	340	18.8	375	18.7
	52	0.31	6.90	19.6	18.0	370	20.6	410	20.5
	53	0.34	6.90	21.4	18.0	405	22.4	445	22.3
	54	0.37	6.90	23.2	18.0	435	24.2	480	24.1
	55	0.40	6.90	25.0	18.0	470	26.0	520	25.9
	56	0.43	6.90	26.7	18.0	500	27.7	550	27.6
8	50	0.27	9.05	22.8	24.0	435	24.1	480	24.0
	51	0.30	9.05	25.2	24.0	480	26.6	530	26.4
	52	0.33	9.05	27.7	24.0	525	29.1	580	28.9
	53	0.36	9.05	30.1	24.0	565	31.4	625	31.3
	54	0.39	9.05	32.5	24.0	610	33.8	675	33.7
	55	0.42	9.05	34.8	24.0	650	36.1	720	36.0
	56	0.45	9.05	37.2	24.0	695	38.5	770	38.4
10	50	0.29	11.10	30.1	31.0	575	31.9	635	31.7
	51	0.32	11.10	33.2	31.0	630	34.9	695	34.8
	52	0.35	11.10	36.2	31.0	685	38.0	755	37.8
	53	0.38	11.10	39.2	31.0	735	40.9	815	40.8
	54	0.41	11.10	42.1	31.0	790	43.8	875	43.7
	55	0.44	11.10	45.1	31.0	845	46.9	935	46.7
	56	0.47	11.10	48.0	31.0	895	49.7	990	49.6
12	50	0.31	13.20	38.4	37.0	730	40.5	805	40.2
	51	0.34	13.20	42.0	37.0	795	44.1	875	43.8
	52	0.37	13.20	45.6	37.0	860	47.7	950	47.4
	53	0.40	13.20	49.2	37.0	925	51.3	1020	51.0
	54	0.43	13.20	52.8	37.0	985	54.8	1095	54.7
	55	0.46	13.20	56.3	37.0	1050	58.4	1165	58.2
	56	0.49	13.20	59.9	37.0	1115	62.0	1235	61.8
14	50	0.33	15.30	47.5	61.0	915	50.9	1010	50.6
	51	0.36	15.30	51.7	61.0	990	55.1	1095	54.8
	52	0.39	15.30	55.9	61.0	1065	59.3	1180	59.0
	53	0.42	15.30	60.1	61.0	1145	63.5	1265	63.2
	54	0.45	15.30	64.2	61.0	1215	67.6	1345	67.2
	55	0.48	15.30	68.4	61.0	1290	71.8	1430	71.4
	56	0.51	15.30	72.5	61.0	1365	75.9	1510	75.6

*Tolerances of OD of spigot end: 3–12 in., ±0.06 in.; 14–24 in., +0.05 in., −0.08 in.; 30–48 in., +0.08 in., −0.06 in.

§The bell weights shown above are adequate for 350 psi operating pressure and are in accordance with ANSI/AWWA C111/A21.11-79. Bell weights vary due to differences in bell design. The manufacturer shall calculate pipe weights using standard barrel weights and weights of bells being produced.

†Including bell; calculated weight of pipe rounded off to nearest 5 lb.

‡Including bell; average weight per foot based on calculated weight of pipe before rounding.

TABLE 51.5—*(cont.)*

Size *in.*	Thickness Class	Thickness *in.*	OD* *in.*	Wt. of Barrel Per Ft *lb*	Wt. of Bell§ *lb*	18-ft Laying Length		20-ft Laying Length	
						Wt. Per Lgth.† *lb*	Avg. Wt. Per Ft‡ *lb*	Wt. Per Lgth.† *lb*	Avg. Wt. Per Ft‡ *lb*
16	50	0.34	17.40	55.8	74.0	1080	59.9	1190	59.5
	51	0.37	17.40	60.6	74.0	1165	64.7	1285	64.3
	52	0.40	17.40	65.4	74.0	1250	69.5	1380	69.1
	53	0.43	17.40	70.1	74.0	1335	74.2	1475	73.8
	54	0.46	17.40	74.9	74.0	1420	79.0	1570	78.6
	55	0.49	17.40	79.7	74.0	1510	83.8	1670	83.4
	56	0.52	17.40	84.4	74.0	1595	88.5	1760	88.1
18	50	0.35	19.50	64.4	85.0	1245	69.1	1375	68.7
	51	0.38	19.50	69.8	85.0	1340	74.5	1480	74.0
	52	0.41	19.50	75.2	85.0	1440	79.9	1590	79.4
	53	0.44	19.50	80.6	85.0	1535	85.3	1695	84.8
	54	0.47	19.50	86.0	85.0	1635	90.7	1805	90.2
	55	0.50	19.50	91.3	85.0	1730	96.0	1910	95.6
	56	0.53	19.50	96.7	85.0	1825	101.4	2020	101.0
20	50	0.36	21.60	73.5	98.0	1420	78.9	1570	78.4
	51	0.39	21.60	79.5	98.0	1530	84.9	1690	84.4
	52	0.42	21.60	85.5	98.0	1635	90.9	1810	90.4
	53	0.45	21.60	91.5	98.0	1745	96.9	1930	96.4
	54	0.48	21.60	97.5	98.0	1855	103.0	2050	102.4
	55	0.51	21.60	103.4	98.0	1960	108.8	2165	108.3
	56	0.54	21.60	109.3	98.0	2065	114.7	2285	114.2
24	50	0.38	25.80	92.9	123.0	1795	99.7	1980	99.0
	51	0.41	25.80	100.1	123.0	1925	106.9	2125	106.2
	52	0.44	25.80	107.3	123.0	2055	114.1	2270	113.4
	53	0.47	25.80	114.4	123.0	2180	121.2	2410	120.6
	54	0.50	25.80	121.6	123.0	2310	128.4	2555	127.8
	55	0.53	25.80	128.8	123.0	2440	135.6	2700	135.0
	56	0.56	25.80	135.9	123.0	2570	142.7	2840	142.0
30	50	0.39	32.00	118.5	205.0	2340	129.9	2575	128.8
	51	0.43	32.00	130.5	205.0	2555	141.9	2815	140.8
	52	0.47	32.00	142.5	205.0	2770	153.9	3055	152.8
	53	0.51	32.00	154.4	205.0	2985	165.8	3295	164.7
	54	0.55	32.00	166.3	205.0	3200	177.7	3530	176.6
	55	0.59	32.00	178.2	205.0	3415	189.6	3770	188.4
	56	0.63	32.00	190.0	205.0	3625	201.4	4005	200.2
36	50	0.43	38.30	156.5	279.0	3095	172.0	3410	170.4
	51	0.48	38.30	174.5	279.0	3420	190.0	3770	188.4
	52	0.53	38.30	192.4	279.0	3740	207.9	4125	206.3
	53	0.58	38.30	210.3	279.0	4065	225.8	4485	224.2
	54	0.63	38.30	228.1	279.0	4385	243.6	4840	242.0
	55	0.68	38.30	245.9	279.0	4705	261.4	5195	259.8
	56	0.73	38.30	263.7	279.0	5025	279.2	5555	277.7
42	50	0.47	44.50	198.9	364.0			4340	217.1
	51	0.53	44.50	224.0	364.0			4845	242.2
	52	0.59	44.50	249.1	364.0			5345	267.3
	53	0.65	44.50	274.0	364.0			5845	292.2
	54	0.71	44.50	298.9	364.0			6340	317.1
	55	0.77	44.50	323.7	364.0			6840	341.9
	56	0.83	44.50	348.4	364.0			7330	366.6
48	50	0.51	50.80	246.6	443.0			5375	268.8
	51	0.58	50.80	280.0	443.0			6045	302.2
	52	0.65	50.80	313.4	443.0			6710	335.6
	53	0.72	50.80	346.6	443.0			7375	368.8
	54	0.79	50.80	379.8	443.0			8040	402.0
	55	0.86	50.80	412.9	443.0			8700	435.0
	56	0.93	50.80	445.9	443.0			9360	468.0

***Tolerances of OD of spigot end: 3–12 in., ±0.06 in.; 14–24 in., +0.05 in., −0.08 in.; 30–48 in., +0.08 in., −0.06 in.**

§The bell weights shown above are adequate for 350 psi operating pressure and are in accordance with ANSI/AWWA C111/A21.11-79. Bell weights vary due to differences in bell design. The manufacturer shall calculate pipe weights using standard barrel weights and weights of bells being produced.

†Including bell; calculated weight of pipe rounded off to nearest 5 lb.

‡Including bell; average weight per foot based on calculated weight of pipe before rounding.

Appendix A

This appendix is for information only and is not a part of ANSI/AWWA C151/A21.51.

TABLE A.1

Pipe Thicknesses Required for Different Tap Sizes as per ANSI B2.1 for Standard Taper Pipe Threads With Two, Three, and Four Full Threads

Pipe Size *in.*	No. of Threads	Tap Size—*in.*									
		½	¾	1	1¼	1½	2	2½	3	3½	4
		Pipe Thickness—*in.*									
3	2	0.18	0.21	0.28							
3	3	0.26	0.29	0.37							
3	4	0.33	0.36	0.46							
4	2	0.17	0.19	0.26	0.31						
4	3	0.25	0.27	0.35	0.40						
4	4	0.32	0.34	0.44	0.49						
6	2	0.17	0.18	0.23	0.27	0.30					
6	3	0.25	0.26	0.32	0.36	0.39					
6	4	0.32	0.33	0.41	0.45	0.48					
8	2	0.16	0.17	0.22	0.24	0.27	0.33				
8	3	0.24	0.25	0.31	0.33	0.36	0.42				
8	4	0.31	0.32	0.40	0.42	0.45	0.51				
10	2	0.15	0.17	0.21	0.23	0.25	0.30	0.44			
10	3	0.23	0.25	0.30	0.32	0.34	0.39	0.56			
10	4	0.30	0.32	0.39	0.41	0.43	0.48	0.69			
12	2	0.15	0.16	0.20	0.22	0.24	0.28	0.40	0.48		
12	3	0.23	0.24	0.29	0.31	0.33	0.37	0.52	0.60		
12	4	0.30	0.31	0.38	0.40	0.42	0.46	0.65	0.73		
14	2	0.15	0.16	0.20	0.22	0.23	0.26	0.38	0.45	0.51	0.58
14	3	0.23	0.24	0.29	0.31	0.32	0.35	0.50	0.58	0.64	0.70
14	4	0.30	0.31	0.38	0.40	0.41	0.44	0.63	0.70	0.76	0.83
16	2	0.15	0.16	0.20	0.21	0.22	0.25	0.37	0.43	0.48	0.54
16	3	0.23	0.24	0.29	0.30	0.31	0.34	0.50	0.56	0.60	0.66
16	4	0.30	0.31	0.38	0.39	0.40	0.43	0.62	0.68	0.73	0.79
18	2	0.15	0.15	0.19	0.21	0.22	0.24	0.35	0.41	0.46	0.51
18	3	0.23	0.23	0.28	0.30	0.31	0.33	0.48	0.54	0.58	0.64
18	4	0.30	0.30	0.37	0.39	0.40	0.42	0.60	0.66	0.71	0.76
20	2	0.15	0.15	0.19	0.20	0.21	0.23	0.34	0.39	0.44	0.49
20	3	0.23	0.23	0.28	0.29	0.30	0.32	0.46	0.52	0.56	0.62
20	4	0.30	0.30	0.37	0.38	0.39	0.41	0.59	0.64	0.69	0.74
24	2	0.14	0.15	0.19	0.20	0.21	0.22	0.32	0.37	0.40	0.45
24	3	0.22	0.23	0.28	0.29	0.30	0.31	0.44	0.50	0.52	0.58
24	4	0.29	0.30	0.37	0.38	0.39	0.40	0.57	0.62	0.65	0.70
30	2	0.14	0.15	0.19	0.19	0.20	0.21	0.31	0.34	0.37	0.41
30	3	0.22	0.23	0.28	0.28	0.29	0.30	0.44	0.46	0.50	0.54
30	4	0.29	0.30	0.37	0.37	0.38	0.39	0.56	0.59	0.62	0.66
36	2	0.14	0.14	0.18	0.19	0.20	0.21	0.30	0.33	0.35	0.38
36	3	0.22	0.22	0.27	0.28	0.29	0.30	0.42	0.46	0.48	0.50
36	4	0.29	0.29	0.36	0.37	0.38	0.39	0.55	0.58	0.60	0.63
42	2	0.14	0.14	0.18	0.19	0.19	0.20	0.29	0.32	0.34	0.36
42	3	0.22	0.22	0.27	0.28	0.28	0.29	0.42	0.44	0.46	0.48
42	4	0.29	0.29	0.36	0.37	0.37	0.38	0.54	0.57	0.59	0.61
48	2	0.14	0.14	0.18	0.18	0.19	0.20	0.29	0.31	0.32	0.35
48	3	0.22	0.22	0.27	0.27	0.28	0.29	0.42	0.44	0.44	0.48
48	4	0.29	0.29	0.36	0.36	0.37	0.38	0.54	0.56	0.57	0.60
54	2	0.14	0.14	0.17	0.18	0.18	0.19	0.28	0.30	0.32	0.34
54	3	0.21	0.21	0.26	0.27	0.27	0.28	0.41	0.43	0.44	0.47
54	4	0.29	0.29	0.35	0.35	0.36	0.37	0.53	0.55	0.57	0.59

TABLE A.2

Pipe Thicknesses Required for Different Tap Sizes as per AWWA C800 for Standard Corporation Stop Threads With Two, Three, and Four Full Threads*

Pipe Size *in.*	No. of Threads	Tap Size—*in.* ½	⅝	¾	1	1¼	1½	2
		Pipe Thickness—*in.*						
3	2	0.21	0.24	0.25	0.33			
3	3	0.29	0.32	0.33	0.41			
3	4	0.36	0.39	0.40	0.49			
4	2	0.19	0.22	0.23	0.30	0.36		
4	3	0.27	0.30	0.31	0.38	0.45		
4	4	0.34	0.37	0.38	0.46	0.54		
6	2	0.18	0.20	0.20	0.26	0.30	0.35	
6	3	0.26	0.28	0.28	0.34	0.39	0.44	
6	4	0.33	0.35	0.35	0.42	0.48	0.53	
8	2	0.17	0.18	0.19	0.24	0.27	0.31	0.39
8	3	0.25	0.26	0.27	0.32	0.36	0.40	0.48
8	4	0.32	0.33	0.34	0.40	0.45	0.49	0.57
10	2	0.17	0.17	0.18	0.23	0.25	0.28	0.35
10	3	0.25	0.25	0.26	0.31	0.34	0.37	0.44
10	4	0.32	0.32	0.33	0.39	0.43	0.46	0.53
12	2	0.16	0.17	0.17	0.22	0.24	0.26	0.32
12	3	0.24	0.25	0.25	0.30	0.33	0.35	0.41
12	4	0.31	0.32	0.32	0.38	0.42	0.44	0.50
14	2	0.16	0.17	0.17	0.21	0.23	0.25	0.30
14	3	0.24	0.25	0.25	0.29	0.32	0.34	0.39
14	4	0.31	0.32	0.32	0.37	0.41	0.43	0.48
16	2	0.16	0.16	0.17	0.21	0.22	0.24	0.28
16	3	0.24	0.24	0.25	0.29	0.31	0.33	0.37
16	4	0.31	0.31	0.32	0.37	0.40	0.42	0.46
18	2	0.15	0.16	0.16	0.20	0.21	0.23	0.27
18	3	0.23	0.24	0.24	0.28	0.30	0.32	0.36
18	4	0.30	0.31	0.31	0.36	0.39	0.41	0.45
20	2	0.15	0.16	0.16	0.20	0.21	0.23	0.26
20	3	0.23	0.24	0.24	0.28	0.30	0.32	0.35
20	4	0.30	0.31	0.31	0.36	0.39	0.41	0.44
24	2	0.15	0.15	0.16	0.19	0.21	0.22	0.24
24	3	0.23	0.23	0.24	0.27	0.30	0.31	0.33
24	4	0.30	0.30	0.31	0.35	0.39	0.40	0.42
30	2	0.15	0.15	0.16	0.19	0.20	0.21	0.23
30	3	0.23	0.23	0.24	0.27	0.29	0.30	0.32
30	4	0.30	0.30	0.31	0.35	0.38	0.39	0.41
36	2	0.14	0.15	0.15	0.19	0.20	0.20	0.22
36	3	0.22	0.23	0.23	0.27	0.29	0.29	0.31
36	4	0.29	0.30	0.30	0.35	0.38	0.38	0.40
42	2	0.14	0.14	0.15	0.18	0.19	0.20	0.21
42	3	0.22	0.22	0.23	0.26	0.28	0.29	0.30
42	4	0.29	0.29	0.30	0.34	0.37	0.38	0.39
48	2	0.14	0.14	0.15	0.18	0.18	0.19	0.20
48	3	0.22	0.22	0.23	0.26	0.27	0.28	0.29
48	4	0.29	0.29	0.30	0.34	0.36	0.37	0.38
54	2	0.14	0.14	0.14	0.17	0.18	0.19	0.20
54	3	0.22	0.22	0.22	0.25	0.27	0.28	0.29
54	4	0.29	0.29	0.29	0.34	0.36	0.36	0.38

* This thread is commonly known to the trade as the Mueller thread.

AWWA C151-81
4 February 1982

Superceding
AWWA C151-76
7 August 1981
USE INSTEAD OF
WW-P-421 (in part)
13 September 1976

Department of Defense Acceptance Notice

This nongovernment document was adopted and approved for use by the Department of Defense (DoD) on 4 February 1982. The American Water Works Association has furnished the clearance required by existing regulations. Copies of the document are stocked by DoD Single Stock Point, Naval Publications and Forms Center, Philadelphia, PA 19120, for issue to DoD activities only. Contractors and industry groups must obtain copies from AWWA, 6666 West Quincy Ave., Denver, CO 80235.

Title of Document: American National Standard for Ductile Iron Pipe, Centrifugally Cast in Metal Molds or Sand-Lined Molds, for Water or Other Liquids

Date of Specific Issue Adopted: November 24, 1981

Releasing Industry Group: American Water Works Association

NOTE: Must be used in conjunction with AWWA C106, C110, C111, and C115.

Custodians: Army—ME
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SECTION III

DUCTILE IRON PIPE FOR GRAVITY FLOW SERVICE

Because of its high strength and ability to carry great earth loads, ductile iron pipe has found wide acceptance in service as gravity flow waste lines and culvert pipes.

In sewer service, ductile iron pipe with standard push-on joints has virtually eliminated infiltration as well as exfiltration. Its resistance to impact, convenient pipe lengths and easy joint assembly have caused engineers and those responsible for construction to become aware of its many advantages, and its use in sewer service has increased rapidly in recent years.

Ductile iron pipe joints are ideally suited for gravity flow pipelines as exhibited by the following test results:

1,000 psi internal pressure
430 psi external pressure
14 psi negative air pressure
No leakage—No infiltration

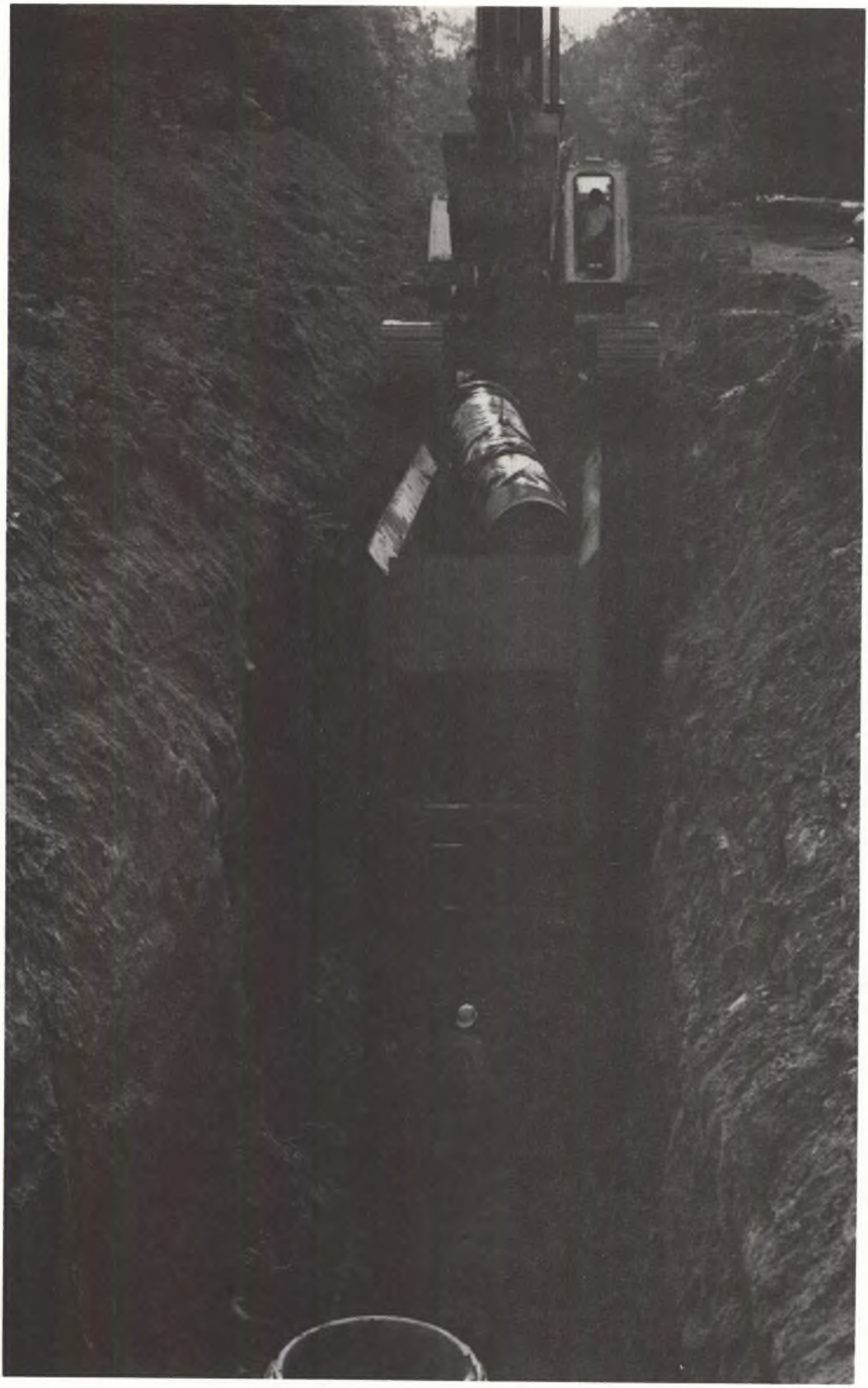
An advantage of ductile iron pipe in sewer service is the fact that its inside diameter is greater than nominal. This results in greater flow capacity for a given pipe size, and thus considerable savings may be effected.

Ductile iron pipe is available with standard shop linings or cement-mortar linings for normal domestic sewage. Special linings are available for more aggressive wastes.

Still another valuable feature of ductile iron pipe in sewer service is its ability to withstand great depths of earth cover under nominal laying conditions (see ASTM A746 Table 12 & Table 13).

Ductile iron gravity flow pipelines should be designed and specified in accordance with ASTM Standard Specification A746.

Exceptional ring and beam strengths make ductile iron pipe an ideal structure for culvert pipes. ASTM Standard Specification A716 is a useful reference when specifying culvert piping.



ASTM Designation: A 746 – 82

Standard Specification for
DUCTILE IRON GRAVITY SEWER PIPE[1]

This standard is issued under the fixed designation A 746; the number immediately following the designation indicates the ear of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last approval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

. Scope

1.1 This specification covers 4 to 54-in. ducle iron gravity sewer pipe centrifugally cast in netal molds or sand-lined molds with push-on oints. This specification may be used for pipe vith other types of joints, as may be agreed pon at the time of purchase.

1.2 This specification covers trench load degn procedures for both cement-lined pipe and exible-lined pipe. Maximum depth of cover ables are included for both types of linings.

. Applicable Documents

2.1 *ASTM Standards*:

A 377 Standard Specifications for Gray Iron and Ductile Iron Pressure Pipe[2]

E 8 Tension Testing of Metallic Materials[3]

E 23 Notched Bar Impact Testing of Metallic Materials[4]

2.2 *ANSI/AWWA Standards*:[5]

C104/A21.4 Cement Mortar Lining for Ductile-Iron and Gray-Iron Pipe and Fittings for Water

C111/A21.11 Rubber Gasket Joints for Ductile-Iron and Gray-Iron Pressure Pipe and Fittings

C150/A21.50 Thickness Design for Ductile-Iron Pipe

2.3 *ASCE Standards*:[6]

Manuals and Reports on Engineering Practice, No. 37, (WCPF Manual of Practice No. 9). "Design and Construction of Sanitary and Storm Sewers."

. Symbols

A = outside radius of pipe, ft $= \dfrac{D}{24}$ $\left(\text{in metres} = \dfrac{D}{2000}\right)$

a = conversion factor, lb/ft^2 to psi = 144 (kg/m^2 to kPa = 120)

B = 1.5 ft (0.457 m)

b = conversion factor, lb/linear ft to psi = 12 (kg/linear metre to kPa = 0.031)

C = surface load factor (Table 6)

D = outside diameter, in. (Table 5)

E = modulus of elasticity, 24×10^6 psi (165.5×10^6 kPa)

E' = modulus of soil reaction, psi (Table 2)

F = impact factor, 1.5

f = design bending stress, 48 000 psi (331×10^3 kPa)

H = depth of cover, ft (m)

K_b = bending moment coefficient (Table 2)

K_x = deflection coefficient (Table 2)

P = wheel load, 16 000 lb (7257 kg)

P_e = earth load, psi (kPa)

P_t = truck load, psi (kPa)

P_v = trench load, psi (kPa) $= P_e + P_t$

R = reduction factor which takes into account the fact that the part of the pipe directly below the wheels is aided in carrying the truck load by adjacent parts of the pipe that receive little or no load from the wheels (Table 4)

t = net thickness, in. (mm)

t_1 = minimum manufacturing thickness, in., $t + 0.08$, (in mm, $t + 2.0$)

w = soil weight, 120 lb/ft^3 (1922 kg/m^3)

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[1] This specification is under the jurisdiction of ASTM Committee A-4 on Iron Castings.

Current edition approved Jan. 29, 1982. Published March 1982. Originally published as A 746 – 77. Last previous edition A 746 – 77.

[2] *Annual Book of ASTM Standards*, Part 2.

[3] *Annual Book of ASTM Standards*, Parts 6, 7, and 10.

[4] *Annual Book of ASTM Standards*, Part 10.

[5] Available from the American National Standards Institute, 1430 Broadway, New York, N. Y. 10018.

[6] Available from the American Society of Civil Engineers, 345 East 47th St., New York, N. Y. 10017.

ΔX = design deflection, in. (mm),

$$\left[\frac{\Delta X}{D} = 0.03\right], \text{ or}$$

$$\left[\left(\frac{\Delta X}{D} = 0.05\right) \text{ for flexible linings}\right]$$

4. General Requirements

4.1 The pipe shall be ductile iron in accordance with Section 9.

4.2 Push-on joints shall comply with all applicable requirements of ANSI/AWWA C111/A21.11.

Pipe with other types of joints shall comply with the joint dimensions and weights agreed upon at the time of purchase, but in all other respects shall fulfill the requirements of this specification.

4.3 Unless otherwise specified, pipe shall have a nominal length of 18 or 20 ft (5.5 or 6.1 m). A maximum of 20 % of the total number of pipe of each size specified in an order may be furnished as much as 24 in. (610 mm) shorter than the nominal laying length, and an additional 10 % may be furnished as much as 6 in. (152 mm) shorter than the nominal laying length.

5. Tolerances or Permitted Variations

5.1 *Dimensions*—The plain end, bell, and socket of the pipe shall be gaged with suitable gages at sufficiently frequent intervals to assure that the dimensions comply with the requirements of this specification.

5.2 *Thickness*—Minus thickness tolerances of pipe and bell shall not exceed those shown in Table 3.

NOTE—An additional minus tolerance of 0.02 in. (0.5 mm) shall be permitted along the barrel of the pipe for a distance not to exceed 12 in. (305 mm).

5.3 *Weight*—The weight of any single pipe shall not be less than the tabulated weight by more than 6 % for pipe 12 in. or smaller in diameter, nor by more than 5 % for pipe larger than 12 in. in diameter.

6. Coating and Lining

6.1 *Outside Coating*—The outside coating for use under normal conditions shall be an asphaltic coating approximately 1 mil (0.025 mm) thick. The coating shall be applied to the outside of all pipe, unless otherwise specified. The finished coating shall be continuous, smooth, neither brittle when cold nor sticky when exposed to the sun, and shall be strongly adherent to the pipe.

6.2 *Cement-Mortar Linings*—If desired, cement linings shall be specified in the invitation for bids and on the purchase order. Cement linings shall be in accordance with ANSI/AWWA C104/A21.4.

6.3 *Lining*—Unless otherwise specified, the lining for pipe not cement-lined shall be an asphaltic material, minimum 1 mil (0.025 mm) thick, and conforming to all appropriate requirements for seal coat in ANSI/AWWA C104/A21.4.

6.4 Unless otherwise specified, the manufacturer at his option may furnish either cement-mortar-lined or asphaltic-lined pipe.

6.5 *Special Linings*—For severely aggressive wastes, other types of linings may be available. Such special linings shall be specified in the invitation for bids and on the purchase order.

7. Pipe Design

7.1 This section covers the design of ductile iron pipe for trench loads.

7.2 *Determining the Total Calculated Thickness and Standard Thickness*:

7.2.1 Determine the trench load, P_v. Table 1 gives the trench load, including the earth load, P_e, plus the truck load, P_t, for 2.5 to 32 ft (0.76 to 9.75 m) of cover.

7.2.2 Determine the standard trench class from the descriptions in Table 2 and select the appropriate table of diameter-thickness ratios from Tables 7 to 11. Enter the calculated trench load, P_v, in the column headed "Bending Stress Design" and read the required ratio D/t. Divide the pipe outside diameter, D, (Table 5) by the ratio D/t to obtain the net thickness, t, required by the design for bending stress.

7.2.3 Enter the calculated trench load, P_v, in the appropriate column headed "Deflection Design" and read the required D/t_1. Divide the outside diameter, D, by the ratio D/t_1 to obtain the minimum thickness, t_1, required by the design for deflection. Deduct the 0.08-in. (2.0-mm) service allowance to obtain the corresponding net thickness, t. (If the calculated P_v is less than the minimum P_v listed in the table, the design for the trench load is not controlled by deflection and this determination need not be completed.)

7.2.4 Compare the net thicknesses from 7.2.2 and 7.2.3 and select the larger of the two. This will be the net thickness, t.

7.2.5 Add the service allowance of 0.08 in. (2.0 mm) to the net thickness, t. The resulting thickness is the minimum manufacturing thickness, t_1.

7.2.6 Add the casting tolerance from Table 3 to the minimum manufacturing thickness, t_1. The resulting thickness is the total calculated thickness.

7.2.7 In specifying and ordering pipe, use the total calculated thickness to select one of the standard class thicknesses in Table 5. Select the standard thickness nearest to the calculated thickness. When the calculated thickness is halfway between two standard thicknesses, select the larger of the two.

7.3 *Design Example*—Calculate the thickness for 30-in. cement-lined ductile iron pipe laid on a flat-bottom trench with backfill lightly tamped to the centerline of pipe, Laying Condition Type 2, under 10 ft (3 m) of cover.

7.3.1 Earth load, Table 1, P_e = 8.3 psi
Truck load, Table 1, P_t = 0.7 psi

Trench load, $P_v = P_e + P_t$ = 9.0 psi

7.3.2 Entering P_v of 9.0 psi in Table 8, the bending stress design requires D/t of 128.

Net thickness, t, for bending stress

$$= D/(D/t) = 32.00/128 = 0.25$$

7.3.3 Reentering P_v of 9.0 psi in Table 8, the deflection design requires D/t_1 of 108.

Minimum thickness t_1 for deflection design

$$= D/(D/t_1) = 32.00/108$$

	= 0.30 in.
Deduct service allowance	−0.08 in.
Net thickness t for deflection control	= 0.22 in.

7.3.4 The larger net thickness is 0.25 in., obtained by the design for bending stress.

7.3.5	Net thickness	= 0.25 in.
	Service allowance	= 0.08 in.
	Minimum thickness	= 0.33 in.
7.3.6	Casting tolerance	= 0.07 in.
	Total calculated thickness	= 0.40 in.

7.3.7 The total calculated thickness of 0.40 in. is nearest to 0.39, Class 50, in Table 5. Therefore, Class 50 is selected for specifying and ordering.

7.4. *Design Method*:

7.4.1 Calculations are made for the thicknesses required to resist the bending stress and the deflection due to trench load. The larger of the two is selected as the thickness required to resist trench load.

7.4.2 To this net thickness is added a service allowance to obtain the minimum manufacturing thickness and a casting tolerance to obtain the total calculated thickness.

7.4.3 The thickness for specifying and ordering is selected from a table of standard class thicknesses.

7.4.4 The reverse of the above procedure is used to determine the maximum depth of cover for pipe of a given thickness class.

7.4.5 *Trench Load*, P_v—Trench load is expressed as vertical pressure, psi, and is equal to the sum of earth load, P_e, and truck load, P_t.

7.4.6 *Earth Load*, P_e—Earth load is computed by Eq 3 for the weight of the unit prism of soil with a height equal to the distance from the top of the pipe to the ground surface. The unit weight of backfill soil is taken to be 120 lb/ft^3 (1922 kg/m^3).

7.4.7 *Truck Load*, P_t—The truck loads shown in Table 1 were computed by Eq 4 using the surface load factors in Table 6 for a single AASHO H-20 truck on an unpaved road or flexible pavement, 16 000-lbf (71 kN) wheel load and 1.5 impact factor. The surface load factors in Table 6 were calculated by Eq 5 for a single concentrated wheel load centered over an effective pipe length of 3 ft (0.91 m).

7.4.8 *Design for Trench Load*—Tables 7 through 11, the tables of diameter-thickness ratios used to design for trench load, were computed by Eqs 1 and 2. Equation 1 is based on the bending stress at the bottom of the pipe. The design bending stress, f, is 48 000 psi (331 MPa) that provides at least 1.5 safety factor based on minimum yield strength and 2.0 safety factor based on ultimate strength. Equation 2 is based on the deflection of the pipe ring section. The design deflection Δ_x is 3 % of the outside diameter of the pipe for cement-lined pipe and 5 % for pipe with flexible linings. Design values of the trench parameters, E', K_b, and K_x are given in Table 2.

7.4.9 Tables similar to Tables 7 through 11 may be compiled for laying conditions other than those shown in this specification by calculating the trench loads, P_v, for a series of diameter-thickness ratios, D/t and D/t_1, using Eqs 1 and 2 with values of E', K_b, and K_x appropriate to the bedding and backfill conditions.

7.5 *Design Equations*:

$$P_v = \frac{f}{3\left(\frac{D}{t}\right)\left(\frac{D}{t}-1\right)\left[K_b - \frac{K_x}{\frac{8E}{E'\left(\frac{D}{t}-1\right)^3}+0.732}\right]} \quad (1)$$

$$P_v = \frac{\Delta_x}{\frac{D}{12K_x}}\left[\frac{8E}{\left(\frac{D}{t_1}-1\right)^3} + .732\,E'\right] \quad (2)$$

$$P_e = \frac{w_H}{a} \quad (3)$$

$$P_t = \frac{CRPF}{bD} \quad (4)$$

$$C = \frac{1}{3} - \frac{2}{3\pi}\arcsin\left[H\sqrt{\frac{A^2+B^2+H^2}{(A^2+H^2)(H^2+B^2)}}\right] + \frac{2}{3\pi}\left(\frac{A\cdot H\cdot B}{\sqrt{A^2+H^2+B^2}}\right)\left(\frac{1}{A^2+H^2}+\frac{1}{B^2+H^2}\right) \quad (5)$$

NOTE—In Eq 5, angles are in radians.

8. Hydrostatic Test

8.1 Each pipe shall be subjected to a hydrostatic test of not less than 500 psi (3.45 MPa). This test may be made either before or after the outside coating and the asphaltic lining have been applied, but shall be made before the application of cement lining or of a special lining.

8.2 The pipe shall be under the full test pressure for at least 10 s. Suitable controls and recording devices shall be provided so that the test pressure and duration may be adequately ascertained. Any pipe that leaks or does not withstand the test pressure shall be rejected.

8.3 In addition to the hydrostatic test before application of a cement lining or special lining, the pipe may be retested, at the manufacturer's option, after application of such lining.

9. Acceptance Tests

9.1 The standard acceptance tests for the physical characteristics of the pipe shall be as follows:

9.2 *Tension Test*—A tension test specimen shall be cut longitudinally from the midsection of the pipe wall. This specimen shall be machined and tested in accordance with Fig. 1 and Method E 8. The yield strength shall be determined by the 0.2 % offset, halt-of-pointer, or extension-under-load methods. If check tests are to be made, the 0.2 % offset method shall be used. All specimens shall be tested at room temperature 70 ± 10°F (21.1 ± 5.5°C).

9.2.1 *Acceptable Values*—The acceptance values for test specimens shall be as follows:

Grade of Iron:	60–42–10
Minimum tensile strength, psi (MPa)	60 000 (413.7)
Minimum yield strength, psi (MPa):	42 000 (289.6)
Minimum elongation, %:	10

9.3 *Impact Test*—Tests shall be made in accordance with Method E 23, except that specimens shall be 0.500 in. (12.70 mm) and full thickness of pipe wall. The notched impact test specimen shall be in accordance with Fig. 2. If the pipe wall thickness exceeds 0.40 in. (10.2 mm), the impact specimen may be machined to a nominal thickness of 0.40 in. (10.2 mm). In all tests, impact values are to be corrected to a standard wall thickness, t_s = 0.40 in. (10.2 mm), by calculation as follows:

$$\text{Impact value (corrected)} = \frac{t_s}{t} \times \text{impact value (actual)}$$

where: t = the thickness of the specimen, in. (mm).

9.3.1 *Acceptance Value*—The corrected acceptance value for notched impact test specimens shall be a minimum of 7 ft·lbf (9 J) for tests conducted at 70 ± 10°F (21 ± 6°C).

9.4 *Sampling*—At least one tension sample shall be taken during each casting period of approximately 3 h. At least one 70 ± 10°F (21 ± 6°C) Charpy impact sample shall be taken during each operating hour. Samples shall be selected to properly represent extremes of pipe diameters and thicknesses.

10. Additional Control Tests by Manufacturer

10.1 Low-temperature impact tests shall be made from at least 10 % of the test pipe specified in 9.4 to assure compliance with a minimum corrected value of 3 ft·lbf (4 J) for tests conducted at −40°F (−40°C). Test specimens shall be prepared and tested in accordance with 9.3.

10.2 In addition, the manufacturer shall conduct such other control tests as necessary to assure continuing compliance with this specification.

11. Additional Tests Required by Purchaser

11.1 When tests other than those required in this specification are required by the purchaser, such tests shall be specified in the invitation for bids and on the purchase order.

12. Inspection and Certification by Manufacturer

12.1 The manufacturer shall establish the necessary quality-control and inspection practice to ensure compliance with this specification.

12.2 The manufacturer shall, if required on the purchase order, furnish a sworn statement that the inspection and all of the specified tests have been made and the results thereof comply with the requirements of this specification.

12.3 All pipes shall be clean and sound without defects that will impair their service. Repairing of defects by welding or other method shall not be allowed if such repairs will adversely affect the serviceability of the pipe or its capability to meet strength requirements of this specification.

13. Inspection by Purchaser

13.1 If the purchaser desires to inspect pipe at the manufacturer's plant, the purchaser shall so specify on the purchase order, stating the conditions (such as time and the extent of inspection) under which the inspection shall be made.

13.2 The inspector shall have free access to those parts of the manufacturer's plant that are necessary to assure compliance with this specification. The manufacturer shall make available for the inspector's use such gages as are necessary for inspection. The manufacturer shall provide the inspector with assistance as necessary for handling of pipe.

14. Delivery and Acceptance

14.1 All pipe and accessories shall comply with this specification. Pipe and accessories not complying with this specification shall be replaced by the manufacturer at the agreed point of delivery. The manufacturer shall not be liable for shortages or damaged pipe after acceptance at the agreed point of delivery, except as recorded on the delivery receipt or similar document by the carrier's agent.

15. Foundry Records

15.1 The results of the acceptance tests (Section 9) and low-temperature impact tests (Section 10) shall be recorded and retained for 1 year, and shall be available to the purchaser at the foundry. Written transcripts shall be furnished, if specified on the purchase order.

16. Defective Specimens and Retests

16.1 When any physical test specimen shows defective machining or lack of continuity of metal, it shall be discarded and replaced by another specimen. When any sound test specimen fails to meet the specified requirements, the pipe from which it was taken shall be rejected, and a retest may be made on two additional sound specimens from pipe cast in the same period as the specimen that failed. Both of the additional specimens shall meet the prescribed tests to qualify the pipe produced in that period.

17. Rejection of Pipe

17.1 If the results of any physical acccept-ance test fail to meet the requirements of Section 9 or 16, the pipe cast in the same period shall be rejected, except as provided in Section 18.

18. Determining Rejection

18.1 The manufacturer may determine the amount of rejection by making similar additional tests of pipe, of the same size as the rejected pipe, until the rejected lot is bracketed, in order of manufacture, by an acceptable test at each end of the interval in question. When pipe of one size is rejected from a casting period, the acceptability of pipe of different sizes from that same period may be established by making the acceptance tests for these sizes as specified in Section 9.

19. Marking Pipe

19.1 The weight, class or nominal thickness, and casting period shall be shown on each pipe. The manufacturer's mark, the year in which the pipe was produced, and the letters "DI" or "DUCTILE" shall be cast or stamped on the pipe. Markings shall be clear and legible and all cast marks shall be on or near the bell. All letters and numerals on pipe sizes 14 in. and larger shall not be less than ½ in. (12.7 mm) in height.

20. Weighing Pipe

20.1 Each pipe shall be weighed before the application of any lining or coating other than the asphaltic coating and the weight shown on the outside or inside of the bell or plain end.

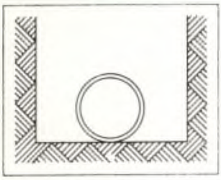
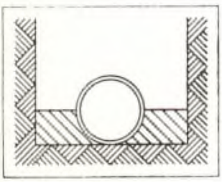
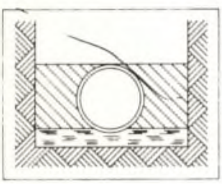
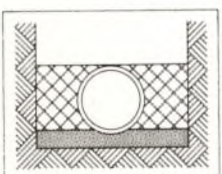
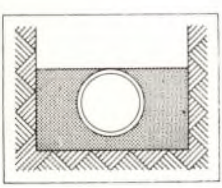
TABLE 1 Earth Loads (P_e), Truck Loads (P_t), and Trench Loads (P_v), psi[A]

Depth of Cover, ft (m)	P_e	4-in. Pipe		6-in. Pipe		8-in. Pipe		10-in. Pipe		12-in. Pipe		14-in. Pipe		16-in. Pipe	
		P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v
2.5 (0.8)	2.1	9.9	12.0	9.9	12.0	9.8	11.9	9.7	11.8	9.6	11.7	8.7	10.8	8.2	10.3
3 (0.9)	2.5	7.4	9.9	7.3	9.8	7.3	9.8	7.2	9.7	7.2	9.7	6.6	9.1	6.2	8.7
4 (1.2)	3.3	4.5	7.8	4.4	7.7	4.4	7.7	4.4	7.7	4.4	7.7	4.4	7.7	4.1	7.4
5 (1.5)	4.2	3.0	7.2	3.0	7.2	3.0	7.2	2.9	7.1	2.9	7.1	2.9	7.1	2.8	7.0
6 (1.8)	5.0	2.1	7.1	2.1	7.1	2.1	7.1	2.1	7.1	2.1	7.1	2.1	7.1	2.0	7.0
7 (2.1)	5.8	1.6	7.4	1.6	7.4	1.6	7.4	1.6	7.4	1.6	7.4	1.6	7.4	1.5	7.3
8 (2.4)	6.7	1.2	7.9	1.2	7.9	1.2	7.9	1.2	7.9	1.2	7.9	1.2	7.9	1.2	7.9
9 (2.7)	7.5	1.0	8.5	1.0	8.5	1.0	8.5	1.0	8.5	1.0	8.5	1.0	8.5	1.0	8.5
10 (3.0)	8.3	0.8	9.1	0.8	9.1	0.8	9.1	0.8	9.1	0.8	9.1	0.8	9.1	0.8	9.1
12 (3.7)	10.0	0.6	10.6	0.6	10.6	0.6	10.6	0.5	10.5	0.5	10.5	0.5	10.5	0.5	10.5
14 (4.3)	11.7	0.4	12.1	0.4	12.1	0.4	12.1	0.4	12.1	0.4	12.1	0.4	12.1	0.4	12.1
16 (4.9)	13.3	0.3	13.6	0.3	13.6	0.3	13.6	0.3	13.6	0.3	13.6	0.3	13.6	0.3	13.6
20 (6.1)	16.7	0.2	16.9	0.2	16.9	0.2	16.9	0.2	16.9	0.2	16.9	0.2	16.9	0.2	16.9
24 (7.3)	20.0	0.1	20.1	0.1	20.1	0.1	20.1	0.1	20.1	0.1	20.1	0.1	20.1	0.1	20.1
28 (8.5)	23.3	0.1	23.4	0.1	23.4	0.1	23.4	0.1	23.4	0.1	23.4	0.1	23.4	0.1	23.4
32 (9.8)	26.7	0.1	26.8	0.1	26.8	0.1	26.8	0.1	26.8	0.1	26.8	0.1	26.8	0.1	26.8

Depth of Cover, ft (m)	P_e	18-in. Pipe		20-in. Pipe		24-in. Pipe		30-in. Pipe		36-in. Pipe		42-in. Pipe		48-in. Pipe		54-in. Pipe	
		P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v	P_t	P_v
2.5 (0.8)	2.1	7.8	9.9	7.5	9.6	7.1	9.2	6.7	8.8	6.2	8.3	5.8	7.9	5.4	7.5	5.0	7.1
3 (0.9)	2.5	5.9	8.4	5.7	8.2	5.4	7.9	5.2	7.7	4.9	7.4	4.6	7.1	4.4	6.9	4.1	6.6
4 (1.2)	3.3	3.9	7.2	3.9	7.2	3.6	6.9	3.5	6.8	3.4	6.7	3.3	6.6	3.1	6.4	3.0	6.3
5 (1.5)	4.2	2.6	6.8	2.6	6.8	2.4	6.6	2.4	6.6	2.3	6.5	2.3	6.5	2.2	6.4	2.1	6.3
6 (1.8)	5.0	1.9	6.9	1.9	6.9	1.7	6.7	1.7	6.7	1.7	6.7	1.7	6.7	1.6	6.6	1.6	6.6
7 (2.1)	5.8	1.4	7.2	1.4	7.2	1.3	7.1	1.3	7.1	1.3	7.1	1.3	7.1	1.2	7.0	1.2	7.0
8 (2.4)	6.7	1.2	7.9	1.1	7.8	1.1	7.8	1.1	7.8	1.1	7.8	1.0	7.7	1.0	7.7	1.0	7.7
9 (2.7)	7.5	1.0	8.5	0.9	8.4	0.9	8.4	0.9	8.4	0.8	8.3	0.8	8.3	0.8	8.3	0.8	8.3
10 (3.0)	8.3	0.8	9.1	0.7	9.0	0.7	9.0	0.7	9.0	0.7	9.0	0.7	9.0	0.7	9.0	0.7	9.0
12 (3.7)	10.0	0.5	10.5	0.5	10.5	0.5	10.5	0.5	10.5	0.5	10.5	0.5	10.5	0.5	10.5	0.5	10.5
14 (4.3)	11.7	0.4	12.1	0.4	12.1	0.4	12.1	0.4	12.1	0.4	12.1	0.4	12.1	0.4	12.1	0.4	12.1
16 (4.9)	13.3	0.3	13.6	0.3	13.6	0.3	13.6	0.3	13.6	0.3	13.6	0.3	13.6	0.3	13.6	0.3	13.6
20 (6.1)	16.7	0.2	16.9	0.2	16.9	0.2	16.9	0.2	16.9	0.2	16.9	0.2	16.9	0.2	16.9	0.2	16.9
24 (7.3)	20.0	0.1	20.1	0.1	20.1	0.1	20.1	0.1	20.1	0.1	20.1	0.1	20.1	0.1	20.1	0.1	20.1
28 (8.5)	23.3	0.1	23.4	0.1	23.4	0.1	23.4	0.1	23.4	0.1	23.4	0.1	23.4	0.1	23.4	0.1	23.4
32 (9.8)	26.7	0.1	26.8	0.1	26.8	0.1	26.8	0.1	26.8	0.1	26.8	0.1	26.8	0.1	26.8	0.1	26.8

[A] 1 psi = 6.894757 kPa

TABLE 2 Design Values for Standard Laying Conditions

Laying Condition	Description	E′ psi[A]	Bedding Angle, deg	K_b	K_x
 Type 1	Flat-bottom trench[C] Backfill not tamped.	150	30	0.235	0.108
 Type 2	Flat-bottom trench[C] Backfill lightly tamped[C] to centerline of pipe.	300	45	0.210	0.105
 Type 3	Pipe bedded in 4-in. (102 mm) min loose soil[E] Backfill lightly tamped[D] to top of pipe.	400	60	0.189	0.103
 Type 4	Pipe bedded in sand, gravel, or crushed stone to depth of ⅛ pipe diameter, 4-in. (102 mm) min. Backfill lightly compacted[D] to top of pipe.	500	90	0.157	0.096
 Type 5	Pipe bedded in compacted granular material to centerline of pipe. Carefully compacted[D] granular or select[D] material to top of pipe.	700	150	0.128	0.085

[A] 1 psi = 6.894757 kPa

[B] Laying condition Type 1 is limited to 24-in. and smaller pipe.

[C] Flat-bottom is defined as undisturbed earth.

[D] These laying conditions can be expected to develop the following backfill densities (Standard Proctor): Types 2 and 3, approximately 70 %; Type 4, approximately 75 %; Type 5, approximately 85 %.

[E] Loose soil or select material is defined as native soil excavated from the trench, free of rocks, foreign materials, and frozen earth.

TABLE 3 Allowances for Casting Tolerance

Size, in.	Casting Tolerance, in. (mm)
4–8	0.05 (1.3)
10–12	0.06 (1.5)
14–42	0.07 (1.8)
48	0.08 (2.0)
54	0.09 (2.3)

TABLE 4 Reduction Factors (R) for Truck Load Calculations

Size, in.	Depth of Cover, ft (m)			
	<4 (1.2)	4 to 7 (1.2 to 2.1)	8 to 10 (2.4 to 3.0)	>10 (3.0)
	Reduction Factor			
4 to 12	1.00	1.00	1.00	1.00
14	0.92	1.00	1.00	1.00
16	0.88	0.95	1.00	1.00
18	0.85	0.90	1.00	1.00
20	0.83	0.90	0.95	1.00
24 to 30	0.81	0.85	0.95	1.00
36 to 54	0.80	0.85	0.90	1.00

TABLE 5 Standard Outside Diameters and Thickness Classes

Size, in.	Outside diameter, in. (mm)	Thickness Class		
		50	51	52
		Thickness, in. (mm)		
4	4.80 (121.9)	. . .	0.26 (6.6)	0.29 (7.4)
6	6.90 (175.3)	0.25 (6.4)	0.28 (7.1)	0.31 (7.9)
8	9.05 (229.9)	0.27 (6.9)	0.30 (7.6)	0.33 (8.4)
10	11.10 (281.9)	0.29 (7.4)	0.32 (8.1)	0.35 (8.9)
12	13.20 (335.3)	0.31 (7.9)	0.34 (8.6)	0.37 (9.4)
14	15.30 (388.6)	0.33 (8.4)	0.36 (9.1)	0.39 (9.9)
16	17.40 (442.0)	0.34 (8.6)	0.37 (9.4)	0.40 (10.2)
18	19.50 (495.3)	0.35 (8.9)	0.38 (9.7)	0.41 (10.4)
20	21.60 (548.6)	0.36 (9.1)	0.39 (9.9)	0.42 (10.7)
24	25.80 (655.3)	0.38 (9.7)	0.41 (10.4)	0.44 (11.2)
30	32.00 (812.8)	0.39 (9.9)	0.43 (10.9)	0.47 (11.9)
36	38.30 (972.8)	0.43 (10.9)	0.48 (12.2)	0.53 (13.5)
42	44.50 (1130.3)	0.47 (11.9)	0.53 (13.5)	0.59 (15.0)
48	50.80 (1290.3)	0.51 (12.9)	0.58 (14.7)	0.65 (16.5)
54	57.10 (1450.3)	0.57 (14.5)	0.65 (16.5)	0.73 (18.5)

TABLE 6 Surface Load Factors for Single Truck on Unpaved Road

Depth of Cover, ft (m)	Pipe Size														
	4-in.	6-in.	8-in.	10-in.	12-in.	14-in.	16-in.	18-in.	20-in.	24-in.	30-in.	36-in.	42-in.	48-in.	54-in.
	Surface Load Factor, *C*														
2.5 (0.8)	0.0238	0.0340	0.0443	0.0538	0.0634	0.0726	0.0814	0.0899	0.0980	0.1130	0.1321	0.1479	0.1604	0.1705	0.1784
3 (0.9)	0.0177	0.0253	0.0330	0.0402	0.0475	0.0546	0.0614	0.0681	0.0746	0.0867	0.1028	0.1169	0.1286	0.1384	0.1466
4 (1.2)	0.0107	0.0153	0.0201	0.0245	0.0290	0.0335	0.0379	0.0422	0.0464	0.0545	0.0657	0.0761	0.0853	0.0936	0.1008
5 (1.5)	0.0071	0.0102	0.0134	0.0163	0.0194	0.0224	0.0254	0.0283	0.0312	0.0369	0.0449	0.0525	0.0595	0.0661	0.0720
6 (1.8)	0.0050	0.0072	0.0095	0.0116	0.0138	0.0159	0.0181	0.0202	0.0223	0.0264	0.0323	0.0381	0.0435	0.0486	0.0534
7 (2.1)	0.0038	0.0054	0.0071	0.0087	0.0103	0.0119	0.0135	0.0151	0.0167	0.0198	0.0243	0.0288	0.0329	0.0370	0.0409
8 (2.4)	0.0029	0.0042	0.0055	0.0067	0.0079	0.0092	0.0104	0.0117	0.0129	0.0154	0.0189	0.0224	0.0258	0.0290	0.0322
9 (2.7)	0.0023	0.0033	0.0043	0.0053	0.0063	0.0073	0.0083	0.0093	0.0103	0.0122	0.0151	0.0179	0.0207	0.0233	0.0259
10 (3.0)	0.0019	0.0027	0.0035	0.0043	0.0051	0.0060	0.0068	0.0076	0.0084	0.0100	0.0123	0.0147	0.0169	0.0191	0.0213
12 (3.7)	0.0013	0.0019	0.0025	0.0030	0.0036	0.0042	0.0047	0.0053	0.0059	0.0070	0.0086	0.0103	0.0119	0.0135	0.0151
14 (4.3)	0.0010	0.0014	0.0018	0.0022	0.0027	0.0031	0.0035	0.0039	0.0043	0.0052	0.0064	0.0076	0.0088	0.0100	0.0112
16 (4.9)	0.0007	0.0011	0.0014	0.0017	0.0020	0.0024	0.0027	0.0030	0.0033	0.0040	0.0049	0.0059	0.0068	0.0077	0.0087
20 (6.1)	0.0005	0.0007	0.0009	0.0011	0.0013	0.0015	0.0017	0.0019	0.0021	0.0025	0.0032	0.0038	0.0044	0.0050	0.0056
24 (7.3)	0.0003	0.0005	0.0006	0.0008	0.0009	0.0011	0.0012	0.0013	0.0015	0.0018	0.0022	0.0026	0.0030	0.0035	0.0039
28 (8.5)	0.0002	0.0003	0.0005	0.0006	0.0007	0.0008	0.0009	0.0010	0.0011	0.0013	0.0016	0.0019	0.0022	0.0026	0.0029
32 (9.8)	0.0002	0.0003	0.0004	0.0004	0.0005	0.0006	0.0007	0.0008	0.0008	0.0010	0.0012	0.0015	0.0017	0.0020	0.0022

TABLE 7 Diameter-Thickness Ratios for Laying Condition Type 1

NOTE—$E' = 150$ psi[A] $K_b = 0.235$ $K_x = 0.108$

Trench Load P_c, psi[A]				Trench Load P_c, psi[A]			
Bending Stress Design	Deflection Design		D/t^D or D/t_1	Bending Stress Design	Deflection Design		D/t^D or D/t_1
	3 % [B] max	5 % [C] max			3 % [B] max	5 % [C] max	
5.17	3.89	6.48	150	8.86	7.12	11.87	100
5.21	3.91	6.52	149	8.99	7.26	12.11	99
5.26	3.94	6.57	148	9.13	7.41	12.35	98
5.30	3.97	6.62	147	9.27	7.57	12.61	97
5.35	4.00	6.67	146	9.41	7.73	12.88	96
5.40	4.03	6.72	145	9.56	7.89	13.15	95
5.45	4.06	6.77	144	9.71	8.07	13.45	94
5.49	4.09	6.82	143	9.87	8.25	13.75	93
5.54	4.13	6.88	142	10.03	8.44	14.07	92
5.59	4.16	6.94	141	10.20	8.64	14.40	91
5.65	4.20	6.99	140	10.37	8.85	14.74	90
5.70	4.23	7.05	139	10.55	9.06	15.11	89
5.75	4.27	7.12	138	10.74	9.29	15.48	88
5.80	4.31	7.18	137	10.93	9.53	15.88	87
5.86	4.35	7.25	136	11.13	9.78	16.30	86
5.91	4.39	7.31	135	11.34	10.04	16.73	85
5.97	4.43	7.38	134	11.55	10.31	17.19	84
6.03	4.47	7.46	133	11.78	10.60	17.67	83
6.09	4.52	7.53	132	12.01	10.90	18.17	82
6.15	4.56	7.61	131	12.25	11.22	18.70	81
6.21	4.61	7.69	130	12.50	11.56	19.26	80
6.27	4.66	7.77	129	12.76	11.91	19.85	79
6.33	4.71	7.85	128	13.03	12.28	20.46	78
6.40	4.76	7.94	127	13.31	12.67	21.11	77
6.46	4.82	8.03	126	13.60	13.08	21.79	76
6.53	4.87	8.12	125	13.91	13.51	22.52	75
6.60	4.93	8.22	124	14.23	13.97	23.28	74
6.67	4.99	8.32	123	14.56	14.45	24.08	73
6.74	5.05	8.42	122	14.91	14.96	24.93	72
6.82	5.11	8.52	121	15.27	15.50	25.83	71
6.89	5.18	8.63	120	15.65	16.07	26.78	70
6.91	5.25	8.74	119	16.05	16.68	27.79	69
7.05	5.32	8.86	118	16.46	17.32	28.86	68
7.13	5.39	8.98	117	16.89	18.00	30.00	67
7.21	5.46	9.11	116	17.35	18.73	31.21	66
7.29	5.54	9.24	115	17.83	19.50	32.49	65
7.38	5.62	9.37	114	18.33	20.32	33.86	64
7.47	5.71	9.51	113	18.85	21.19	35.32	63
7.56	5.79	9.65	112	19.40	22.12	36.87	62
7.65	5.88	9.80	111	19.98	23.12	38.53	61
7.75	5.97	9.96	110	20.59	24.18	40.30	60
7.85	6.07	10.12	109	21.23	25.32	42.20	59
7.95	6.17	10.20	108	21.91	26.54	44.23	58
8.05	6.27	10.46	107	22.63	27.85	46.42	57
8.16	6.38	10.63	106	23.38	29.26	48.76	56
8.27	6.49	10.82	105	24.18	30.77	51.28	55
8.38	6.61	11.01	104	25.02	32.39	53.99	54
8.49	6.73	11.22	103	25.92	34.15	56.92	53
8.61	6.86	11.43	102	26.86	36.05	60.08	52
8.74	6.99	11.64	101	27.87	38.10	63.50	51

TABLE 7 *Continued*

Trench Load P_v, psi[A]				Trench Load P_v, psi[A]			
Bending Stress Design	Deflection Design		D/t^D or D/t_1	Bending Stress Design	Deflection Design		D/t^D or D/t_1
	3 %[B] max	5 %[C] max			3 %[B] max	5 %[C] max	
28.94	40.32	67.20	50	46.84	83.54	139.23	39
30.07	42.73	71.22	49	49.30	90.28	150.47	38
31.28	45.35	75.58	48	51.96	97.80	163.00	37
32.57	48.20	80.34	47	54.86	106.20	177.00	36
33.95	51.31	85.52	46				
35.42	54.72	91.19	45	58.02	115.62	192.70	35
37.00	58.44	97.40	44	61.46	126.21	210.36	34
38.69	62.53	104.22	43	65.23	138.18	230.29	33
40.50	67.03	111.71	42	69.36	151.73	252.88	32
42.46	71.99	119.98	41	73.92	167.15	278.58	31
				78.94	184.77	307.96	30
44.56	77.47	129.11	40				

[A] 1 psi = 6.894757 kPa

[B] Maximum 3 % deflection is recommended for rigid or semirigid linings such as cement mortar.

[C] Maximum 5 % deflection is recommended for flexible linings such as asphaltic and plastic.

[D] The D/t for the tabulated P_v nearest to the calculated P_v is selected. When the calculated P_v is halfway between two tabulated values, the smaller D/t should be used.

TABLE 8 Diameter-Thickness Ratios for Laying Condition Type 2

NOTE—$E' = 300$ psi[A] $K_b = 0.210$ $K_x = 0.105$

Trench Load P_v, psi[A]				Trench Load, P_v, psi[A]			
Bending Stress Design	Deflection Design		D/t^D or D/t_1	Bending Stress Design	Deflection Design		D/t^D or D/t_1
	3 %[B] max	5 %[C] max			3 %[B] max	5 %[C] max	
7.42	6.61	11.02	150	12.01	9.94	16.57	100
7.48	6.64	11.06	149	12.16	10.09	16.81	99
7.54	6.67	11.11	148	12.31	10.24	17.06	98
7.61	6.70	11.16	147	12.46	10.40	17.33	97
7.67	6.73	11.21	146	12.62	10.56	17.60	96
7.74	6.76	11.27	145	12.79	10.73	17.89	95
7.80	6.79	11.32	144	12.96	10.91	18.19	94
7.87	6.83	11.38	143	13.13	11.10	18.50	93
7.94	6.86	11.43	142	13.31	11.29	18.82	92
8.01	6.89	11.49	141	13.49	11.50	19.17	91
8.08	6.93	11.55	140	13.68	11.71	19.52	90
8.15	6.97	11.61	139	13.88	11.94	19.89	89
8.22	7.01	11.68	138	14.08	12.17	20.28	88
8.29	7.05	11.74	137	14.30	12.42	20.69	87
8.37	7.09	11.81	136	14.51	12.67	21.12	86
8.44	7.13	11.88	135	14.74	12.94	21.57	85
8.52	7.17	11.95	134	14.97	13.22	22.04	84
8.59	7.22	12.03	133	15.21	13.52	22.53	83
8.67	7.26	12.10	132	15.46	13.83	23.05	82
8.75	7.31	12.18	131	15.72	14.16	23.60	81
8.83	7.36	12.26	130	15.99	14.50	24.17	80
8.91	7.41	12.35	129	16.28	14.86	24.77	79
8.99	7.46	12.43	128	16.57	15.24	25.40	78
9.07	7.51	12.52	127	16.87	15.64	26.07	77
9.16	7.57	12.62	126	17.19	16.06	26.77	76
9.25	7.63	12.71	125	17.52	16.51	27.52	75
9.33	7.69	12.81	124	17.86	16.98	28.30	74
9.42	7.75	12.91	123	18.22	17.48	29.13	73
9.51	7.81	13.02	122	18.59	18.00	30.00	72
9.60	7.87	13.12	121	18.98	18.56	30.93	71
9.70	7.94	13.24	120	19.39	19.14	31.91	70
9.79	8.01	13.35	119	19.82	19.77	32.95	69
9.89	8.08	13.47	118	20.27	20.43	34.05	68
9.99	8.16	13.60	117	20.73	21.13	35.22	67
10.09	8.23	13.72	116	21.23	21.87	36.46	66
10.19	8.31	13.86	115	21.74	22.67	37.78	65
10.29	8.40	13.99	114	22.28	23.51	39.18	64
10.40	8.48	14.14	113	22.85	24.41	40.68	63
10.51	8.57	14.29	112	23.45	25.37	42.28	62
10.62	8.66	14.44	111	24.07	26.39	43.99	61
10.73	8.76	14.60	110	24.74	27.49	45.81	60
10.84	8.86	14.76	109	25.43	28.66	47.76	59
10.96	8.96	14.93	108	26.17	29.91	49.86	58
11.08	9.07	15.11	107	26.95	31.26	52.10	57
11.21	9.18	15.30	106	27.77	32.71	54.51	56
11.33	9.29	15.49	105	28.64	34.26	57.10	55
11.46	9.41	15.69	104	29.56	35.93	59.89	54
11.59	9.54	15.89	103	30.53	37.74	62.90	53
11.73	9.67	16.11	102	31.57	39.69	66.15	52
11.87	9.80	16.33	101	32.67	41.80	69.67	51

TABLE 8 *Continued*

Trench Load P_v, psi[A]				Trench Load, P_v, psi[A]			
Bending Stress Design	Deflection Design		D/t^D or D/t_1	Bending Stress Design	Deflection Design		D/t^D or D/t_1
	3 %[B] max	5 %[C] max			3 %[B] max	5 %[C] max	
33.84	44.09	73.48	50	51.06	82.29	137.16	40
35.08	46.56	77.61	49	53.57	88.54	147.57	39
36.41	49.26	82.10	48	56.30	95.48	159.13	38
37.83	52.19	86.99	47	59.25	103.21	172.02	37
39.34	55.40	92.33	46	62.46	111.85	186.42	36
40.96	58.89	98.16	45	65.96	121.54	202.56	35
42.70	62.73	104.54	44	69.79	132.44	220.73	34
44.57	66.93	111.55	43	73.98	144.74	241.23	33
46.57	71.56	119.26	42	78.57	158.68	264.46	32
48.73	76.66	127.76	41	83.64	174.54	290.90	31
				89.23	192.67	321.11	30

[A] 1 psi = 6.894757 kPa

[B] Maximum 3 % deflection is recommended for rigid or semirigid linings such as cement mortar.

[C] Maximum 5 % deflection is recommended for flexible linings such as asphaltic and plastic.

[D] The D/t for the tabulated P_v nearest to the calculated P_v is selected. When the calculated P_v is halfway between two tabulated values, the smaller D/t should be used.

TABLE 9 Diameter-Thickness Ratios for Laying Condition Type 3

NOTE—$E' = 400$ psi[A] $K_b = 0.189$ $K_x = 0.103$

Trench Load P_v, psi[A]				Trench Load P_v, psi[A]			
Bending Stress Design	Deflection Design		D/t^D or D/t_1	Bending Stress Design	Deflection Design		D/t^D or D/t_1
	3 %[B] max	5 %[C] max			3 %[B] max	5 %[C] max	
10.00	8.52	14.19	150	15.39	11.91	19.85	100
10.08	8.54	14.24	149	15.55	12.06	20.10	99
10.16	8.57	14.29	148	15.71	12.21	20.35	98
10.24	8.60	14.34	147	15.88	12.37	20.62	97
10.33	8.64	14.39	146	16.06	12.54	20.90	96
10.41	8.67	14.45	145	16.23	12.72	21.20	95
10.49	8.70	14.50	144	16.42	12.90	21.50	94
10.58	8.73	14.56	143	16.61	13.09	21.82	93
10.66	8.77	14.62	142	16.80	13.29	22.15	92
10.75	8.81	14.68	141	17.00	13.50	22.50	91
10.83	8.84	14.74	140	17.21	13.72	22.86	90
10.92	8.88	14.80	139	17.42	13.95	23.24	89
11.01	8.92	14.87	138	17.64	14.18	23.64	88
11.10	8.96	14.93	137	17.86	14.43	24.06	87
11.19	9.00	15.00	136	18.10	14.70	24.49	86
11.28	9.04	15.07	135	18.34	14.97	24.95	85
11.37	9.09	15.15	134	18.59	15.26	25.43	84
11.46	9.13	15.22	133	18.85	15.56	25.93	83
11.56	9.18	15.30	132	19.12	15.88	26.46	82
11.65	9.23	15.38	131	19.40	16.21	27.01	81
11.75	9.28	15.46	130	19.68	16.56	27.60	80
11.84	9.33	15.55	129	19.99	16.93	28.21	79
11.94	9.38	15.64	128	20.30	17.31	28.86	78
12.04	9.44	15.73	127	20.62	17.72	29.54	77
12.14	9.49	15.82	126	20.96	18.15	30.26	76
12.25	9.55	15.92	125	21.31	18.61	31.01	75
12.35	9.61	16.02	124	21.68	19.09	31.81	74
12.45	9.67	16.12	123	22.07	19.59	32.65	73
12.56	9.74	16.23	122	22.47	20.13	33.55	72
12.67	9.80	16.34	121	22.88	20.69	34.49	71
12.78	9.87	16.45	120	23.32	21.29	35.49	70
12.89	9.94	16.57	119	23.78	21.93	36.55	69
13.00	10.02	16.69	118	24.26	22.60	37.67	68
13.11	10.09	16.82	117	24.76	23.32	38.86	67
13.23	10.17	16.95	116	25.29	24.08	40.13	66
13.34	10.25	17.09	115	25.85	24.88	41.47	65
13.46	10.34	17.23	114	26.43	25.74	42.91	64
13.58	10.42	17.37	113	27.04	26.66	44.43	63
13.71	10.51	17.52	112	27.68	27.64	46.06	62
13.83	10.61	17.68	111	28.36	28.68	47.80	61
13.96	10.71	17.84	110	29.08	29.80	49.66	60
14.09	10.81	18.01	109	29.83	30.99	51.65	59
14.22	10.91	18.18	108	30.63	32.27	53.78	58
14.36	11.02	18.37	107	31.47	33.64	56.07	57
14.50	11.13	18.55	106	32.36	35.12	58.53	56
14.64	11.25	18.75	105	33.31	36.70	61.17	55
14.78	11.37	18.95	104	34.30	38.41	64.02	54
14.93	11.50	19.16	103	35.37	40.25	67.08	53
15.08	11.63	19.38	102	36.49	42.24	70.40	52
15.23	11.77	19.61	101	37.69	44.39	73.98	51

TABLE 9 *Continued*

Trench Load P_v, psi[A]				Trench Load P_v, psi[A]			
Bending Stress Design	Deflection Design		D/t^D or D/t_1	Bending Stress Design	Deflection Design		D/t^D or D/t_1
	3 %[B] max	5 %[C] max			3 %[B] max	5 %[C] max	
38.97	46.72	77.86	50	57.84	85.67	142.78	40
40.33	49.25	82.08	49	60.61	92.04	153.39	39
41.78	51.99	86.65	48	63.61	99.11	165.18	38
43.33	54.98	91.64	47	66.86	106.99	178.32	37
44.98	58.25	97.08	46	70.40	115.80	193.00	36
				74.27	125.67	209.46	35
46.76	61.81	103.02	45	78.49	136.78	227.97	34
48.66	65.72	109.53	44	83.11	149.32	248.87	33
50.71	70.01	116.68	43	88.19	163.54	272.56	32
52.91	74.72	124.54'	42	93.79	179.71	299.51	31
55.28	79.92	133.20	41	99.97	198.18	330.31	30

[A] 1 psi = 6.894757 kPa
[B] Maximum 3 % deflection is recommended for rigid or semirigid linings such as cement mortar.
[C] Maximum 5 % deflection is recommended for flexible linings such as asphaltic and plastic.
[D] The D/t for the tabulated P_v nearest to the calculated P_v is selected. When the calculated P_v is halfway between two tabulated values, the smaller D/t should be used.

TABLE 10 Diameter-Thickness Ratios for Laying Condition Type 4

NOTE—E' = 500 psi[A] K_b = 0.157 K_x = 0.096

Trench Load P_v, psi[A]				Trench Load P_v, psi[A]			
Bending Stress Design	Deflection Design 3 %[B] max	Deflection Design 5 %[C] max	D/t[D] or D/t_1	Bending Stress Design	Deflection Design 3 %[B] max	Deflection Design 5 %[C] max	D/t[D] or D/t_1
16.34	11.04	18.40	150	22.49	14.68	24.47	100
16.45	11.07	18.46	149	22.66	14.84	24.74	99
16.55	11.11	18.51	148	22.83	15.01	25.02	98
16.65	11.14	18.56	147	23.01	15.18	25.30	97
16.76	11.17	18.62	146	23.20	15.36	25.61	96
16.86	11.21	18.68	145	23.38	15.55	25.92	95
16.96	11.24	18.74	144	23.58	15.75	26.25	94
17.07	11.28	18.80	143	23.78	15.95	26.59	93
17.18	11.31	18.86	142	23.99	16.17	26.94	92
17.28	11.35	18.92	141	24.20	16.39	27.32	91
17.39	11.39	18.99	140	24.42	16.62	27.71	90
17.50	11.43	19.06	139	24.64	16.87	28.11	89
17.60	11.48	19.13	138	24.88	17.12	28.54	88
17.71	11.52	19.20	137	25.12	17.39	28.99	87
17.82	11.56	19.27	136	25.37	17.67	29.45	86
17.93	11.61	19.35	135	25.63	17.97	29.95	85
18.04	11.66	19.43	134	25.90	18.28	30.46	84
18.15	11.71	19.51	133	26.18	18.60	31.00	83
18.26	11.76	19.59	132	26.47	18.94	31.57	82
18.37	11.81	19.68	131	26.77	19.30	32.16	81
18.49	11.86	19.77	130	27.09	19.67	32.79	80
18.60	11.92	19.86	129	27.42	20.07	33.45	79
18.72	11.97	19.95	128	27.76	20.48	34.14	78
18.83	12.03	20.05	127	28.11	20.92	34.87	77
18.95	12.09	20.15	126	28.49	21.38	35.64	76
19.06	12.15	20.26	125	28.87	21.87	36.45	75
19.18	12.22	20.36	124	29.28	22.38	37.31	74
19.30	12.28	20.47	123	29.70	22.93	38.21	73
19.42	12.35	20.59	122	30.15	23.50	39.17	72
19.54	12.42	20.71	121	30.62	24.11	40.18	71
19.66	12.50	20.83	120	31.11	24.75	41.25	70
19.78	12.57	20.96	119	31.62	25.43	42.39	69
19.91	12.65	21.09	118	32.16	26.16	43.59	68
20.04	12.73	21.22	117	32.72	26.92	44.87	67
20.16	12.82	21.36	116	33.32	27.74	46.23	66
20.29	12.91	21.51	115	33.95	28.60	47.67	65
20.42	13.00	21.66	114	34.61	29.53	49.21	64
20.55	13.09	21.82	113	35.30	30.51	50.85	63
20.69	13.19	21.98	112	36.04	31.56	52.60	62
20.82	13.29	22.15	111	36.81	32.68	54.47	61
20.96	13.39	22.32	110	37.63	33.88	56.46	60
21.10	13.50	22.50	109	38.50	35.16	58.60	59
21.24	13.61	22.69	108	39.42	36.53	60.88	58
21.39	13.73	22.88	107	40.39	38.00	63.34	57
21.54	13.85	23.08	106	41.42	39.58	65.97	56
21.69	13.98	23.29	105	42.51	41.28	68.81	55
21.84	14.11	23.51	104	43.67	43.12	71.86	54
22.00	14.24	23.74	103	44.91	45.09	75.15	53
22.16	14.38	23.97	102	46.22	47.22	78.71	52
22.32	14.53	24.22	101	47.62	49.53	82.55	51

TABLE 10 *Continued*

Trench Load P_v, psi[A]				Trench Load P_v, psi[A]			
Bending Stress Design	Deflection Design		D/t[D] or D/t_1	Bending Stress Design	Deflection Design		D/t[D] or D/t_1
	3 %[B] max	5 %[C] max			3 %[B] max	5 %[C] max	
49.11	52.03	86.72	50	71.39	93.82	156.37	40
50.70	54.74	91.24	49	74.67	100.65	167.75	39
52.41	57.69	96.15	48	78.24	108.24	180.40	38
54.23	60.90	101.50	47	82.11	116.70	194.50	37
56.18	64.40	107.33	46	86.33	126.15	210.25	36
				90.93	136.74	227.91	35
58.27	68.23	113.71	45	95.97	148.66	247.77	34
60.52	72.42	120.70	44	101.49	162.12	270.20	33
62.93	77.02	128.36	43	107.56	177.37	295.61	32
65.54	82.08	136.80	42	114.25	194.72	324.53	31
68.35	87.66	146.09	41	121.65	214.54	357.57	30

[A] 1 psi = 6.894757 kPa

[B] Maximum 3 % deflection is recommended for rigid or semirigid linings such as cement mortar.

[C] Maximum 5 % deflection is recommended for flexible linings such as asphaltic and plastic.

[D] The D/t for the tabulated P_v nearest to the calculated P_v is selected. When the calculated P_v is halfway between two tabulated values, the smaller D/t should be used.

TABLE 11 Diameter-Thickness Ratios for Laying Condition Type 5

NOTE—$E' = 700$ psi[A] $K_b = 0.128$ $K_x = 0.085$

Trench Load P_v, psi[A]				Trench Load, P_v, psi[A]			
Bending Stress Design	Deflection Design		D/t[D] or D/t_1	Bending Stress Design	Deflection Design		D/t[D] or D/t_1
	3 %[B] max	5 %[C] max			3 %[B] max	5 %[C] max	
30.21	16.78	27.96	150	36.54	20.89	34.82	100
30.34	16.81	28.02	149	36.69	21.07	35.12	99
30.48	16.85	28.08	148	36.85	21.26	35.43	98
30.61	16.89	28.14	147	37.01	21.45	35.76	97
30.74	16.92	28.20	146	37.17	21.66	36.10	96
30.87	16.96	28.27	145	37.34	21.87	36.45	95
30.99	17.00	28.34	144	37.52	22.09	36.82	94
31.12	17.04	28.40	143	37.70	22.32	37.20	93
31.25	17.09	28.48	142	37.89	22.56	37.61	92
31.38	17.13	28.55	141	38.08	22.82	38.03	91
31.50	17.17	28.62	140	38.28	23.08	38.47	90
31.63	17.22	28.70	139	38.49	23.36	38.93	89
31.76	17.27	28.78	138	38.71	23.65	39.41	88
31.88	17.32	28.86	137	38.93	23.95	39.91	87
32.01	17.37	28.94	136	39.17	24.27	40.44	86
32.13	17.42	29.03	135	39.41	24.60	41.00	85
32.25	17.47	29.12	134	39.67	24.95	41.58	84
32.38	17.53	29.21	133	39.94	25.31	42.19	83
32.50	17.58	29.30	132	40.22	25.70	42.83	82
32.62	17.64	29.40	131	40.51	26.10	43.50	81
32.75	17.70	29.50	130	40.82	26.52	44.21	80
32.87	17.76	29.61	129	41.14	26.97	44.95	79
32.99	17.83	29.71	128	41.48	27.44	45.73	78
33.11	17.89	29.82	127	41.84	27.93	46.56	77
33.23	17.96	29.94	126	42.21	28.46	47.43	76
33.35	18.03	30.05	125	42.60	29.01	48.34	75
33.47	18.11	30.18	124	43.02	29.59	49.31	74
33.59	18.18	30.30	123	43.45	30.20	50.33	73
33.71	18.26	30.43	122	43.92	30.85	51.41	72
33.83	18.34	30.56	121	44.40	31.53	52.56	71
33.95	18.42	30.70	120	44.91	32.26	53.77	70
34.07	18.51	30.85	119	45.46	33.03	55.05	69
34.19	18.60	30.99	118	46.03	33.85	56.41	68
34.31	18.69	31.15	117	46.64	34.71	57.85	67
34.43	18.78	31.31	116	47.28	35.63	59.39	66
34.55	18.88	31.47	115	47.96	36.61	61.02	65
34.68	18.98	31.64	114	48.68	37.65	62.76	64
34.80	19.09	31.82	113	49.44	38.77	64.61	63
34.92	19.20	32.00	112	50.25	39.95	66.58	62
35.05	19.31	32.19	111	51.11	41.21	68.69	61
35.17	19.43	32.39	110	52.02	42.57	70.94	60
35.30	19.55	32.59	109	52.99	44.01	73.36	59
35.43	19.68	32.80	108	54.02	45.56	75.94	58
35.56	19.81	33.02	107	55.12	47.23	78.71	57
35.69	19.95	33.25	106	56.28	49.01	81.69	56
35.83	20.09	33.48	105	57.53	50.93	84.89	55
35.96	20.24	33.73	104	58.86	53.00	88.34	54
36.10	20.39	33.99	103	60.28	55.23	92.05	53
36.25	20.55	34.25	102	61.79	57.64	96.07	52
36.39	20.72	34.53	101	63.41	60.25	100.41	51

TABLE 11 *Continued*

Trench Load P_v, psi[A]				Trench Load, P_v, psi[A]			
Bending Stress Design	Deflection Design		D/t[D] or D/t_1	Bending Stress Design	Deflection Design		D/t[D] or D/t_1
	3 %[B] max	5 %[C] max			3 %[B] max	5 %[C] max	
65.14	63.07	105.12	50	91.47	110.27	183.78	40
67.00	66.13	110.22	49	95.40	117.98	196.64	39
68.99	69.46	115.77	48	99.67	126.56	210.93	38
71.12	73.09	121.81	47	104.32	136.11	226.84	37
73.41	77.04	128.40	46	109.40	146.78	244.63	36
75.88	81.36	135.61	45	114.94	158.75	264.58	35
78.54	86.10	143.49	44	121.02	172.21	287.01	34
81.40	91.29	152.15	43	127.69	187.41	312.34	33
84.50	97.01	161.68	42	135.03	204.63	341.04	32
87.85	103.31	172.18	41	143.14	224.22	373.70	31
				152.11	246.61	411.02	30

[A] 1 psi = 6.894757 kPa

[B] Maximum 3 % deflection is recommended for rigid or semirigid linings such as cement mortar.

[C] Maximum 5 % deflection is recommended for flexible linings such as asphaltic and plastic.

[D] The D/t for the tabulated P_v nearest to the calculated P_v is selected. When the P_v is halfway between two tabulated values, the smaller D/t should be used.

TABLE 12 Pipe Selection Table (Cement-Lined Pipe)

Pipe Size, in.	Thickness Class	Nominal Thickness, in. (mm)	Laying Condition: Type 1	Type 2	Type 3	Type 4	Type 5
			Maximum Depth of Cover, ft (m)[A]				
4	51	0.26 (6.6)	76 (23.1)	86 (26.0)	96 (29.2)	[B]	[B]
	52	0.29 (7.4)	[B]	[B]	[B]	[B]	[B]
6	50	0.25 (6.4)	32 (9.7)	38 (11.6)	44 (13.4)	56 (17.0)	75 (22.9)
	51	0.28 (7.1)	49 (14.9)	57 (17.4)	64 (19.5)	80 (24.3)	[B]
	52	0.31 (7.9)	67 (20.4)	77 (23.5)	86 (26.0)	[B]	[B]
8	50	0.27 (6.9)	25 (7.6)	30 (9.1)	36 (11.0)	46 (14.0)	64 (19.5)
	51	0.30 (7.6)	36 (10.9)	42 (12.9)	49 (14.9)	61 (18.6)	81 (24.7)
	52	0.33 (8.4)	47 (14.3)	54 (16.5)	62 (18.9)	77 (23.5)	99 (30.1)
10	50	0.29 (7.4)	19 (5.8)	24 (7.3)	29 (8.9)	38 (11.6)	55 (16.8)
	51	0.32 (8.1)	27 (8.2)	32 (9.8)	38 (11.6)	49 (15.0)	66 (20.1)
	52	0.35 (8.9)	35 (10.6)	41 (12.5)	47 (14.3)	59 (18.0)	79 (24.0)
12	50	0.31 (7.9)	17 (5.1)	22 (6.7)	27 (8.2)	36 (11.0)	52 (15.9)
	51	0.34 (8.6)	23 (7.0)	28 (8.5)	33 (10.0)	43 (13.1)	60 (18.2)
	52	0.37 (9.4)	30 (9.1)	35 (10.7)	41 (12.5)	53 (16.1)	71 (21.6)
14	50	0.33 (8.4)	15 (4.6)	19 (5.8)	24 (7.3)	33 (10.0)	49 (14.9)
	51	0.36 (9.1)	19 (5.8)	23 (7.0)	28 (8.5)	38 (11.6)	55 (16.8)
	52	0.39 (9.9)	24 (7.3)	29 (8.9)	34 (10.3)	44 (13.4)	62 (18.9)
16	50	0.34 (8.6)	13 (4.0)	17 (5.1)	21 (6.4)	30 (9.1)	47 (14.3)
	51	0.37 (9.4)	16 (4.9)	21 (6.4)	25 (7.6)	34 (10.4)	51 (15.5)
	52	0.40 (10.2)	20 (6.1)	25 (7.6)	30 (9.1)	40 (12.1)	57 (17.3)
18	50	0.35 (8.9)	11 (3.3)	15 (4.6)	20 (6.1)	29 (8.9)	42 (12.8)
	51	0.38 (9.7)	14 (4.2)	19 (5.8)	23 (7.0)	32 (9.7)	49 (14.9)
	52	0.41 (10.4)	18 (5.5)	22 (6.7)	27 (8.2)	36 (11.0)	53 (16.2)
20	50	0.36 (9.1)	10 (3.0)	14 (4.3)	18 (5.5)	27 (8.2)	38 (11.6)
	51	0.39 (9.9)	13 (4.0)	17 (5.1)	21 (6.4)	30 (9.1)	44 (13.4)
	52	0.42 (10.7)	16 (4.9)	20 (6.1)	25 (7.6)	34 (10.4)	50 (15.2)
24	50	0.38 (9.7)	8 (2.4)	12 (3.7)	17 (5.1)	23 (7.0)	31 (9.4)
	51	0.41 (10.4)	10 (3.0)	15 (4.6)	19 (5.8)	27 (8.2)	36 (11.0)
	52	0.44 (11.2)	13 (4.0)	17 (5.1)	21 (6.4)	30 (9.1)	41 (12.5)
30	50	0.39 (9.9)	[C]	10 (3.5)	14 (3.7)	18 (5.5)	25 (7.6)
	51	0.43 (10.9)		12 (3.7)	16 (4.9)	21 (6.4)	29 (8.9)
	52	0.47 (11.9)		14 (4.3)	19 (5.8)	24 (7.3)	33 (10.0)
36	50	0.43 (10.9)	[C]	10 (3.5)	13 (4.0)	17 (5.1)	25 (7.6)
	51	0.48 (12.2)		12 (3.7)	16 (4.9)	20 (6.0)	28 (8.5)
	52	0.53 (13.5)		15 (4.6)	19 (5.8)	24 (7.3)	32 (9.8)
42	50	0.47 (11.9)	[C]	9 (2.7)	13 (4.0)	16 (4.9)	24 (7.3)
	51	0.53 (13.5)		12 (3.7)	15 (4.6)	19 (5.8)	27 (8.2)
	52	0.59 (15.0)		14 (4.3)	18 (5.5)	22 (6.7)	30 (9.1)
48	50	0.51 (13.0)	[C]	9 (2.7)	12 (3.7)	15 (4.6)	23 (7.0)
	51	0.58 (14.7)		12 (3.7)	14 (4.3)	18 (5.5)	26 (7.9)
	52	0.65 (16.5)		14 (4.3)	18 (5.5)	21 (6.4)	30 (9.1)
54	50	0.57 (14.5)	[C]	9 (2.7)	12 (3.7)	15 (4.6)	23 (7.0)
	51	0.65 (16.5)		12 (3.7)	14 (4.3)	18 (5.5)	25 (7.6)
	52	0.73 (18.5)		14 (4.3)	17 (5.1)	21 (6.4)	29 (8.9)

[A] These pipes are adequate for depths of cover from 2.5 ft (0.76 m) up to the maximum shown including an allowance for single H-20 truck with 1.5 impact factor.

[B] Calculated maximum depth of cover exceeds 100 ft (30.5 m).

[C] Laying Condition Type 1 is limited to 24 in. and smaller pipe.

TABLE 13 Pipe Selection Table (Pipe with Flexible Lining)

Pipe Size, in.	Thickness Class	Nominal Thickness, in. (mm)	Laying Condition				
			Type 1	Type 2	Type 3	Type 4	Type 5
			Maximum Depth of Cover, ft (m)[A]				
4	51	0.26 (6.6)	76 (23.1)	86 (26.0)	96 (29.2)	[B]	[B]
	52	0.29 (7.4)	[B]	[B]	[B]	[B]	[B]
6	50	0.25 (6.4)	32 (9.7)	38 (11.6)	44 (13.4)	56 (17.0)	75 (22.9)
	51	0.28 (7.1)	49 (14.9)	57 (17.4)	64 (19.5)	80 (24.3)	[B]
	52	0.31 (7.9)	67 (20.4)	77 (23.5)	86 (26.0)	[B]	[B]
8	50	0.27 (6.9)	25 (7.6)	30 (9.1)	36 (11.0)	46 (14.0)	64 (19.5)
	51	0.30 (7.6)	36 (10.9)	42 (12.9)	49 (14.9)	61 (18.6)	81 (24.7)
	52	0.33 (8.4)	47 (14.3)	54 (16.5)	62 (18.9)	77 (23.5)	99 (30.1)
10	50	0.29 (7.4)	19 (5.8)	24 (7.3)	29 (8.9)	38 (11.6)	55 (16.8)
	51	0.32 (8.1)	27 (8.2)	32 (9.8)	38 (11.6)	49 (15.0)	66 (20.1)
	52	0.35 (8.9)	35 (10.6)	41 (12.5)	47 (14.3)	59 (18.0)	79 (24.0)
12	50	0.31 (7.9)	17 (5.1)	22 (6.7)	27 (8.2)	36 (11.0)	52 (15.9)
	51	0.34 (8.6)	23 (7.0)	28 (8.5)	33 (10.0)	43 (13.1)	60 (18.2)
	52	0.37 (9.4)	30 (9.1)	35 (10.7)	41 (12.5)	53 (16.1)	71 (21.6)
14	50	0.33 (8.4)	15 (4.6)	19 (5.8)	24 (7.3)	33 (10.0)	49 (14.9)
	51	0.36 (9.1)	19 (5.8)	23 (7.0)	28 (8.5)	38 (11.6)	55 (16.8)
	52	0.39 (9.9)	24 (7.3)	29 (8.9)	34 (10.3)	44 (13.4)	62 (18.9)
16	50	0.34 (8.6)	13 (4.0)	17 (5.1)	21 (6.4)	30 (9.1)	47 (14.3)
	51	0.37 (9.4)	16 (4.9)	21 (6.4)	25 (7.6)	34 (10.4)	51 (15.5)
	52	0.40 (10.2)	20 (6.1)	25 (7.6)	30 (9.1)	40 (12.1)	57 (17.3)
18	50	0.35 (8.9)	11 (3.3)	15 (4.6)	20 (6.1)	29 (8.9)	45 (13.7)
	51	0.38 (9.7)	14 (4.2)	19 (5.8)	23 (7.0)	32 (9.7)	49 (14.9)
	52	0.41 (10.4)	18 (5.5)	22 (6.7)	27 (8.2)	36 (11.0)	53 (16.2)
20	50	0.36 (9.1)	10 (3.0)	14 (4.3)	18 (5.5)	27 (8.2)	44 (13.4)
	51	0.39 (9.9)	13 (4.0)	17 (5.1)	21 (6.4)	30 (9.1)	47 (14.3)
	52	0.42 (10.7)	16 (5.9)	20 (6.1)	25 (7.6)	34 (10.4)	50 (15.2)
24	50	0.38 (9.7)	8 (2.4)	12 (3.7)	17 (5.1)	25 (7.6)	42 (12.8)
	51	0.41 (10.4)	10 (3.0)	15 (4.6)	19 (5.8)	28 (8.5)	45 (13.7)
	52	0.44 (11.2)	13 (4.0)	17 (5.1)	21 (6.4)	30 (9.1)	47 (14.3)
30	50	0.39 (9.9)	[C]	10 (3.5)	14 (3.7)	22 (6.7)	39 (11.9)
	51	0.43 (10.9)		12 (3.7)	16 (4.9)	25 (7.6)	42 (12.8)
	52	0.47 (11.9)		14 (4.3)	19 (5.8)	27 (8.2)	44 (13.4)
36	50	0.43 (10.9)	[C]	10 (3.5)	14 (3.7)	22 (6.7)	39 (11.9)
	51	0.48 (12.2)		12 (3.7)	16 (4.9)	25 (7.6)	42 (12.8)
	52	0.53 (13.5)		15 (4.6)	19 (5.8)	27 (8.2)	44 (13.4)
42	50	0.47 (11.9)	[C]	9 (2.7)	13 (4.0)	22 (6.7)	39 (11.9)
	51	0.53 (13.5)		12 (3.7)	16 (4.9)	25 (7.6)	42 (12.8)
	52	0.59 (15.0)		14 (4.3)	18 (5.5)	27 (8.2)	44 (13.4)
48	50	0.51 (13.0)	[C]	9 (2.7)	13 (4.0)	21 (6.4)	39 (11.9)
	51	0.58 (14.7)		12 (3.7)	16 (4.9)	24 (7.3)	41 (12.8)
	52	0.65 (16.5)		14 (4.3)	18 (5.5)	27 (8.2)	44 (13.4)
54	50	0.58 (14.5)	[C]	9 (2.7)	13 (4.0)	21 (6.4)	38 (11.6)
	51	0.65 (16.5)		12 (3.7)	16 (4.9)	24 (7.3)	41 (12.8)
	52	0.73 (18.5)		14 (4.3)	18 (5.5)	27 (8.2)	44 (13.4)

[A] These pipes are adequate for depths of cover from 2.5 ft (0.76 m) up to the maximum shown including an allowance for single H-20 truck with 1.5 impact factor.

[B] Calculated maximum depth of cover exceeds 100 ft (30.5 m).

[C] Laying Condition Type 1 is limited to 24 in. and smaller pipe.

TABLE 14 Standard Dimensions and Weights of Push-on Joint Ductile Iron Pipe

Size, in.	Thickness Class	Thickness, in. (mm)	Outside Diameter,[A] in. (mm)	Weight of Barrel per ft, lb (kg)	Weight of Bell,[B] lb (kg)	18 ft (5.5 m) Weight per Length[C] lb (kg)	Laying Length Average Weight per ft[D] lb (kg)	20 ft (6.1 m) Weight per length[C] lb (kg)	Laying Length Average Weight per ft[D] lb (kg)
4	51	0.26 (6.6)	4.80 (121.9)	11.3 (5.1)	9.0 (4.1)	210 (95)	11.8 (5.4)	235 (107)	11.8 (5.4)
	52	0.29 (7.4)	4.80 (121.9)	12.6 (5.7)	9.0 (4.1)	235 (107)	13.1 (5.9)	260 (118)	13.0 (5.9)
6	50	0.25 (6.4)	6.90 (175.3)	16.0 (7.3)	11.0 (5.0)	300 (136)	16.6 (7.5)	330 (150)	16.6 (7.5)
	51	0.28 (7.1)	6.90 (175.3)	17.8 (8.1)	11.0 (5.0)	330 (150)	18.4 (8.3)	365 (166)	18.3 (8.3)
	52	0.31 (7.9)	6.90 (175.3)	19.6 (8.9)	11.0 (5.0)	365 (166)	20.2 (9.2)	405 (184)	20.2 (9.2)
8	50	0.27 (6.9)	9.05 (229.9)	22.8 (10.3)	17.0 (7.7)	425 (193)	23.7 (10.8)	475 (215)	23.7 (10.8)
	51	0.30 (7.6)	9.05 (229.9)	25.2 (11.4)	17.0 (7.7)	470 (213)	26.1 (11.8)	520 (236)	26.0 (11.8)
	52	0.33 (8.4)	9.05 (229.9)	27.7 (12.6)	17.0 (7.7)	515 (234)	28.6 (13.0)	570 (259)	28.6 (13.0)
10	50	0.29 (7.4)	11.10 (281.9)	30.1 (13.7)	24.0 (10.9)	565 (256)	31.4 (14.2)	625 (283)	31.3 (14.2)
	51	0.32 (8.1)	11.10 (281.9)	33.2 (15.1)	24.0 (10.9)	620 (281)	34.5 (15.6)	690 (313)	34.4 (15.6)
	52	0.35 (8.9)	11.10 (281.9)	36.2 (16.4)	24.0 (10.9)	675 (306)	37.5 (17.0)	750 (340)	37.4 (17.0)
12	50	0.31 (7.9)	13.20 (335.3)	38.4 (17.4)	29.0 (13.2)	720 (327)	40.0 (18.1)	795 (361)	39.8 (18.1)
	51	0.34 (8.6)	13.20 (335.3)	42.0 (19.1)	29.0 (13.2)	785 (356)	43.6 (19.8)	870 (395)	43.4 (19.7)
	52	0.37 (9.4)	13.20 (335.3)	45.6 (20.7)	29.0 (13.2)	850 (386)	47.2 (21.4)	940 (426)	47.0 (21.3)
14	50	0.33 (8.4)	15.30 (388.6)	47.5 (21.5)	45.0 (20.4)	900 (408)	50.0 (22.7)	995 (451)	49.8 (22.6)
	51	0.36 (9.1)	15.30 (388.6)	51.7 (23.5)	45.0 (20.4)	975 (442)	54.2 (24.6)	1080 (490)	54.0 (24.5)
	52	0.39 (9.9)	15.30 (388.6)	55.9 (25.4)	45.0 (20.4)	1050 (475)	58.4 (26.5)	1165 (528)	58.2 (26.4)
16	50	0.34 (8.6)	17.40 (442.0)	55.8 (25.3)	54.0 (24.5)	1060 (481)	58.8 (26.7)	1170 (531)	58.5 (26.5)
	51	0.37 (9.4)	17.40 (442.0)	60.6 (27.5)	54.0 (24.5)	1145 (519)	63.6 (28.8)	1265 (574)	63.3 (28.7)
	52	0.40 (10.2)	17.40 (442.0)	65.4 (29.7)	54.0 (24.5)	1230 (558)	68.4 (31.0)	1360 (617)	68.1 (30.9)
18	50	0.35 (8.9)	19.50 (495.3)	64.4 (29.2)	59.0 (26.8)	1220 (553)	67.7 (30.7)	1345 (610)	67.4 (30.6)
	51	0.38 (9.7)	19.50 (495.3)	69.8 (31.7)	59.0 (26.8)	1315 (596)	73.1 (33.2)	1455 (660)	72.8 (33.0)
	52	0.41 (10.4)	19.50 (495.3)	75.2 (34.1)	59.0 (26.8)	1415 (642)	78.5 (35.6)	1565 (710)	78.2 (35.5)
20	50	0.36 (9.1)	21.60 (548.6)	73.5 (33.3)	74.0 (33.6)	1395 (633)	77.6 (35.2)	1545 (701)	77.2 (35.0)
	51	0.39 (9.9)	21.60 (548.6)	79.5 (36.1)	74.0 (33.6)	1505 (683)	83.6 (37.9)	1665 (755)	83.2 (37.7)
	52	0.42 (10.7)	21.60 (548.6)	85.5 (38.8)	74.0 (33.6)	1615 (733)	89.6 (40.6)	1785 (810)	89.2 (40.5)
24	50	0.38 (9.7)	25.80 (655.3)	92.9 (42.1)	95.0 (43.1)	1765 (801)	98.1 (44.5)	1955 (887)	97.7 (44.3)
	51	0.41 (10.4)	25.80 (655.3)	100.1 (45.4)	95.0 (43.1)	1895 (860)	105.4 (47.8)	2095 (950)	104.8 (47.5)
	52	0.44 (11.2)	25.80 (655.3)	107.3 (48.7)	95.0 (43.1)	2025 (919)	112.6 (51.1)	2240 (1016)	112.0 (50.8)
30	50	0.39 (9.9)	32.00 (812.8)	118.5 (53.8)	139.0 (63.0)	2270 (1030)	126.2 (57.2)	2510 (1139)	125.4 (56.9)
	51	0.43 (10.9)	32.00 (812.8)	130.5 (59.2)	139.0 (63.0)	2490 (1129)	138.2 (62.7)	2750 (1247)	137.4 (62.3)
	52	0.47 (11.9)	32.00 (812.8)	142.5 (64.6)	139.0 (63.0)	2705 (1227)	150.2 (68.1)	2990 (1356)	149.4 (67.8)

TABLE 14 *Continued*

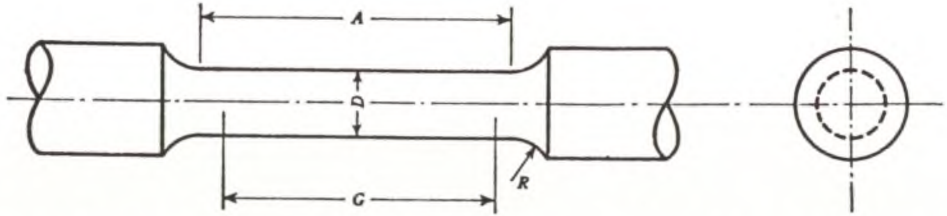
Size, in.	Thickness Class	Thickness, in. (mm)	Outside Diameter,[A] in. (mm)	Weight of Barrel per ft, lb (kg)	Weight of Bell,[B] lb (kg)	18 ft (5.5 m) Weight per Length[C] lb (kg)	Laying Length Average Weight per ft[D] lb (kg)	20 ft (6.1 m) Weight per length[C] lb (kg)	Laying Length Average Weight per ft[D] lb (kg)
36	50	0.43 (10.9)	38.30 (972.8)	156.5 (71.0)	184.0 (83.5)	3000 (1361)	166.7 (75.6)	3315 (1504)	165.7 (75.2)
	51	0.48 (12.2)	38.30 (972.8)	174.5 (79.2)	184.0 (83.5)	3325 (1508)	184.7 (83.8)	3675 (1667)	183.7 (83.3)
	52	0.53 (13.5)	38.30 (972.8)	192.4 (87.3)	184.0 (83.5)	3645 (1653)	202.6 (91.9)	4030 (1828)	201.6 (91.4)
42	50	0.47 (11.9)	44.50 (1130.3)	198.9 (90.2)	224.0 (101.6)			4200 (1905)	210.1 (95.3)
	51	0.53 (13.5)	44.50 (1130.3)	224.0 (101.6)	224.0 (101.6)			4705 (2134)	235.2 (106.7)
	52	0.59 (15.0)	44.50 (1130.3)	249.1 (113.0)	224.0 (101.6)			5205 (2361)	260.3 (118.1)
48	50	0.51 (13.0)	50.80 (1290.3)	246.6 (111.9)	274.0 (124.3)			5205 (2361)	260.3 (118.1)
	51	0.58 (14.7)	50.80 (1290.3)	280.0 (127.0)	274.0 (124.3)			5875 (2665)	293.7 (133.2)
	52	0.65 (16.5)	50.80 (1290.3)	313.4 (142.2)	274.0 (124.3)			6540 (2966)	327.1 (148.4)
54	50	0.57 (14.5)	57.10 (1450.3)	309.8 (140.5)	335.0 (152.0)			6530 (2962)	326.6 (148.1)
	51	0.65 (16.5)	57.10 (1450.3)	352.7 (160.0)	335.0 (152.0)			7390 (3352)	369.4 (167.6)
	52	0.73 (18.5)	57.10 (1450.3)	395.6 (179.4)	335.0 (152.0)			8245 (3740)	412.3 (187.0)

[A] Tolerances of outside diameter of spigot end: 4 to 12 in., ± 0.06 in. (± 1.5 mm); 14 to 24 in., + 0.05 in. (+ 1.3 mm), − 0.08 in. (− 2.0 mm); 30 to 54 in., + 0.08 in. (+ 2.0 mm), − 0.06 in. (− 1.5 mm).

[B] Bell weights vary due to differences in push-on joint design. The manufacturer shall calculate pipe weights using standard barrel weights and weights of bells being produced.

[C] Including bell; calculated weight of pipe rounded to nearest 5 lb (2.3 kg).

[D] Including bell; average weight per foot based on calculated weights of pipe before rounding.



NOTE 1—The reduced section (*A*) may have a gradual taper from the ends toward the center with the ends not more than 0.005 in.[11] (0.13 min) larger in diameter than the center on the standard specimen and not more than 0.003 in. (0.08 mm) larger in diameter than the center on the small size specimens.

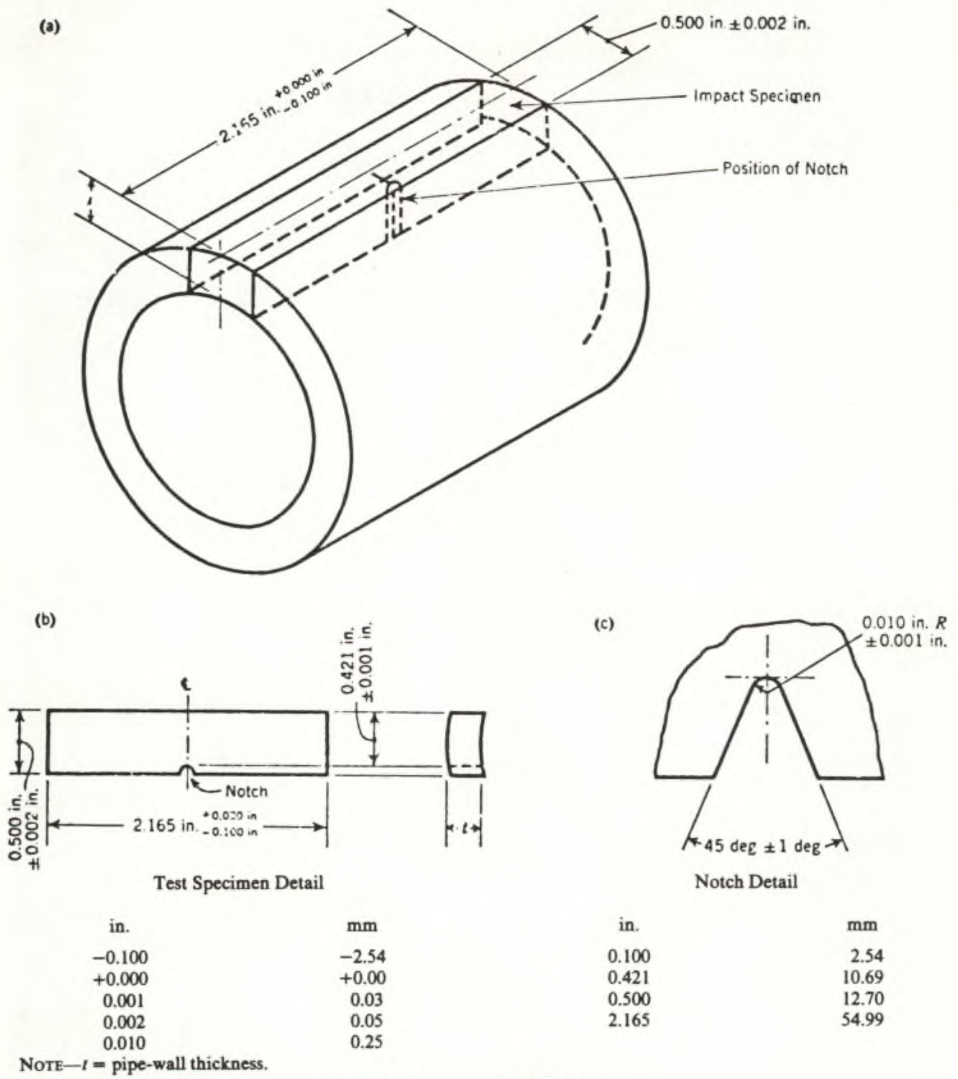
NOTE 2—If desired, on the small size specimens the length of the reduced section may be increased to accommodate an extensometer. However, reference marks for the measurement of elongation should nevertheless be spaced at the indicated gage length (*G*).

NOTE 3—The gage length and fillets shall be as shown, but the ends may be of any form to fit the holders of the testing machine in such a way that the load shall be axial. If the ends are to be held in grips it is desirable, if possible to make the length of the grip section great enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips.

Dimension	Standard Specimen 0.50-in. (12.7-mm) Round		Small-Size Specimens Proportional to Standard: 0.350-in. (8.89-mm) Round		0.250-in. (6.35-mm) Round		0.175-in. (4.45-mm) Round		0.125-in. (3.18-mm) Round	
	Dimensions, in. (mm)									
G	2.000 ± 0.005	(50.80 ± 0.13)	1.400 ± 0.005	(35.56 ± 0.13)	1.000 ± 0.005	(25.40 ± 0.13)	0.700 ± 0.005	(12.78 ± 0.13)	0.500 ± 0.005	(12.70 ± 0.13)
D	0.500 ± 0.010	(12.70 ± 0.25)	0.350 ± 0.007	(8.89 ± 0.18)	0.250 ± 0.005	(6.35 ± 0.13)	0.175 ± 0.005	(4.44 ± 0.13)	0.125 ± 0.005	(3.18 ± 0.13)
R, min	⅜	(9.5)	¼	(6.4)	3⁄16	(4.8)	3⁄32	(2.4)	3⁄32	(2.4)
A, min	2¼	(57.2)	1¾	(44.4)	1¼	(31.8)	¾	(19)	⅝	(15.9)
T[A]	0.71 and greater	(18.0)	0.50 to 0.70	(12.2 to 17.8)	0.35 to 0.49	(8.9 to 12.4)	0.25 to 0.34	(6.4 to 8.6)	0.18 to 0.24	(4.6 to 6.1)

[A] Thickness of the section from the wall of the pipe from which the tension specimen is to be machined.

FIG. 1 Tension Test Specimen



Test Specimen Detail

Notch Detail

in.	mm	in.	mm
−0.100	−2.54	0.100	2.54
+0.000	+0.00	0.421	10.69
0.001	0.03	0.500	12.70
0.002	0.05	2.165	54.99
0.010	0.25		

NOTE—t = pipe-wall thickness.

FIG. 2 Impact Test Specimen

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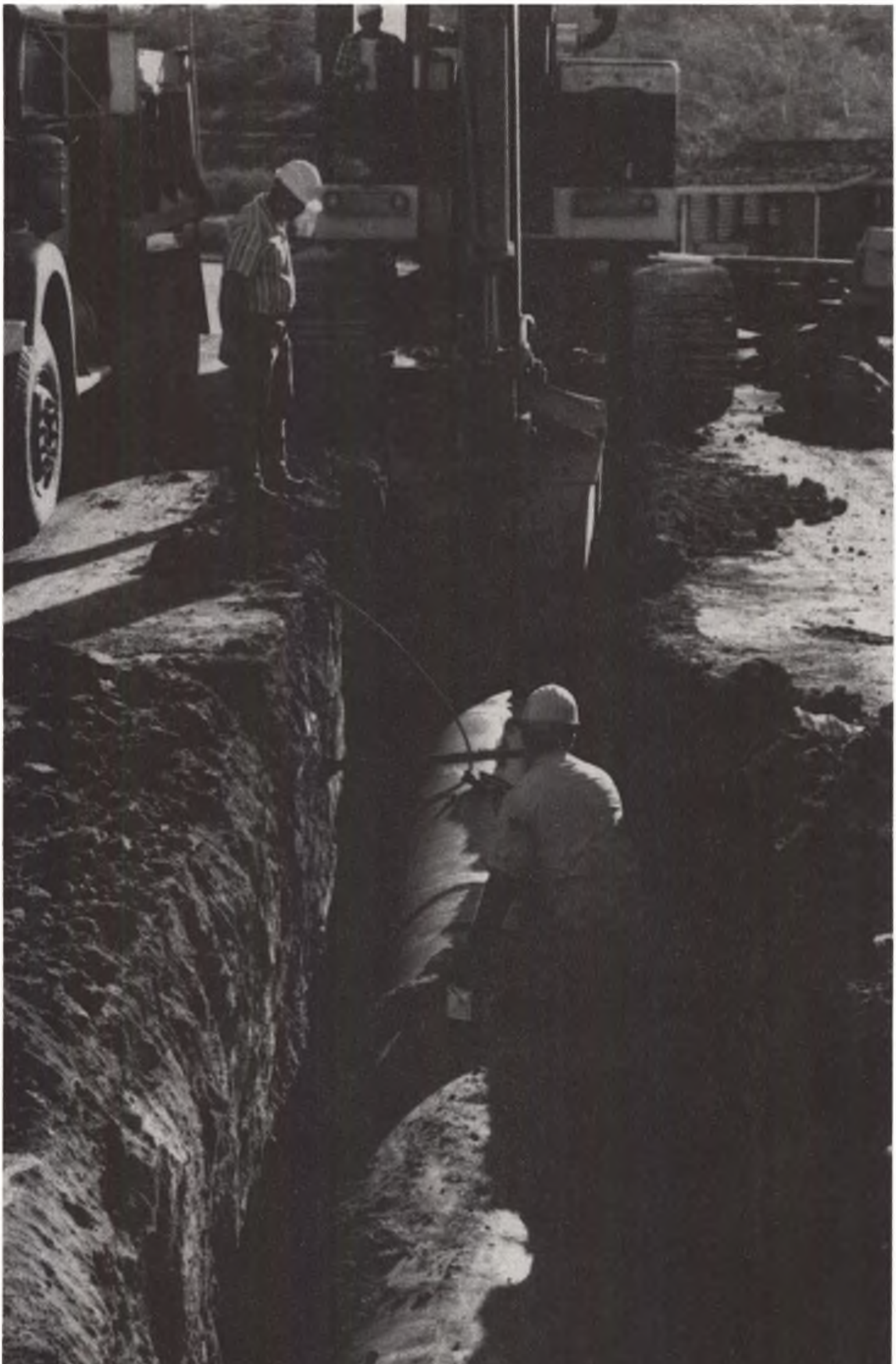

Designation: A 716 – 82

Standard Specification for DUCTILE IRON CULVERT PIPE[1]

This standard is issued under the fixed designation A 716; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This specification covers 14 to 54-in. ductile-iron culvert pipe centrifugally cast in metal molds or sand-lined molds.

2. Applicable Documents

2.1 *ASTM Standards*:

A 377 Specification for Gray Iron and Ductile Iron Pressure Pipe[2]

E 8 Methods of Tension Testing of Metallic Materials[3]

E 23 Notched Bar Impact Testing of Metallic Materials[3]

2.2 *ANSI Standards*:

A21.50 Thickness Design for Ductile-Iron Pipe[4]

A21.51 Ductile-Iron Pipe Centrifugally Cast in Metal Molds or Sand-Lined Molds for Water or Other Liquids[4]

3. General Requirements

3.1 The pipe shall be manufactured of ductile iron that meets the requirements of Sections 6 and 7. See Table 1 for pipe thicknesses and weights.

3.2 The pipe shall be provided with suitable joints, such as push-on or other types of joints that prevent lateral displacement. Plain-end pipe for use with suitable couplings may be furnished.

3.3 Unless otherwise specified, pipe shall have a nominal length of 18 or 20 ft (5.5 or 6.1 m). A maximum of 20 % of the total number of pipe of each size specified in an order may be furnished as much as 24 in. (610 mm) shorter than the nominal laying length, and an additional 10 % may be furnished as much as in 6 in. (152 mm) shorter than the nominal laying length.

4. Tolerances or Permitted Variations

4.1 *Dimensions*—The plain end, bell, and socket of the pipe shall be gaged with suitable gages at sufficiently frequent intervals to assure that the dimensions comply with the requirements of this specification.

4.2 *Thickness*—Minus thickness tolerances of pipe and bell shall not exceed those shown below:

Nominal Size, in.	Minus Tolerance, in. (mm)
14 to 42	0.07 (1.8)
48	0.08 (2.0)
54	0.09 (2.3)

NOTE—An additional minus tolerance of 0.02 in (0.05 mm) shall be permitted along the barrel of the pipe for a distance not to exceed 12 in. (305 mm)

4.3 *Weight*—The weight of any single pipe shall not be less than the tabulated weight by more than 5 %.

5. Coating

5.1 All pipe shall be coated inside and outside with an asphaltic material approximately 1 mil (0.025 mm) thick. The finished coating shall be continuous, smooth, neither brittle when cold or sticky when exposed to the sun, and shall be strongly adherent to the pipe.

6. Acceptance Tests

6.1 The standard acceptance tests for the physical characteristics of the pipe shall be as follows:

6.2 *Tension Test*—A tension test specimen shall be cut longitudinally from the midsection

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[1] This specification is under the jurisdiction of ASTM Committee A-4 on Iron Castings.

Current edition approved Oct. 29, 1982. Published December 1982. Originally published as A 716 – 75. Last previous edition A 716 – 78.

[2] *Annual Book of ASTM Standards*, Vol 01.02.

[3] *1982 Annual Book of ASTM Standards*, Part 10.

[4] Available from the American National Standards Institute, 1430 Broadway, New York, N. Y. 10018.

of the pipe wall. This specimen shall be machined and tested in accordance with Fig. 1 and Methods E 8. The yield strength shall be determined by the 0.2 % offset, halt-of-pointer, or extension-under-load methods. If check tests are to be made, the 0.2 % offset method shall be used. All specimens shall be tested at room temperature 70 ± 10°F (21.1 ± 5.5°C).

6.2.1 *Acceptable Values*—The acceptance values for test specimens shall be as follows:

Grade of iron	60-42-10
Minimum tensile strength, psi (MPa)	60 000 (413.7)
Minimum yield strength, psi (MPa)	42 000 (289.6)
Minimum elongation, %	10

6.3 *Impact Test*—Tests shall be made in accordance with Method E 23, except that specimens shall be 0.500 in. (12.70 mm) and full thickness of pipe wall. The notched impact test specimen shall be in accordance with Fig. 2. If the pipe wall thickness exceeds 0.40 in. (10.2 mm), the impact specimen may be machined to a nominal thickness of 0.40 in. (10.2 mm). In all tests, impact values are to be corrected to a standard wall thickness, t_s = 0.40 in. (10.2 mm), by calculation as follows:

$$\text{Impact value (corrected} = \frac{t_s}{t} \times \text{impact value (actual)}$$

where:

t = the thickness of the specimen, in. (mm).

6.3.1 *Acceptance Value*—The corrected acceptance value for notched impact test specimens shall be a minimum of 7 ft·lbf (9 J) for tests conducted at 70 ± 10°F (21.1 ± 5.5°C).

6.4 *Sampling*—At least one tension specimen shall be taken during each casting period of approximately 3 h. At least one 70 ± 10°F (21.1 ± 5.5°C) Charpy impact specimen shall be taken during each operating hour. Specimens shall be selected to properly represent extremes of pipe diameters and thicknesses.

7. Additional Control Tests by Manufacturer

7.1 Low-temperature impact tests shall be made from at least 10 % of the test pipe specified in 6.4 to assure compliance with a minimum corrected value of 3 ft·lbf (4 J) for tests conducted at −40°F (−40°C). Test specimens shall be prepared and tested in accordance with 6.3.

7.2 In addition, the manufacturer shall conduct such other control tests as necessary to assure continuing compliance with this specification.

8. Additional Tests Required by Purchaser

8.1 When tests other than those required in this specification are required by the purchaser, such tests shall be specified in the invitation for bids and on the purchase order.

9. Inspection and Certification by Manufacturer

9.1 The manufacturer shall establish the necessary quality-control and inspection practice to ensure compliance with this specification.

9.2 The manufacturer shall, if required on the purchase order, furnish a sworn statement that the inspection and all of the specified tests have been made and the results thereof comply with the requirements of this specification.

9.3 All pipes shall be clean and sound without defects that will impair their service. Repairing of defects by welding or other method shall not be allowed if such repairs will adversely affect the serviceability of the pipe or its capability to meet strength requirements of this specification.

10. Inspection by Purchaser

10.1 If the purchaser desires to inspect pipe at the manufacturer's plant, the purchaser shall so specify on the purchase order, stating the conditions (such as time and the extent of inspection) under which the inspection shall be made.

10.2 The inspector shall have free access to those parts of the manufacturer's plant that are necessary to assure compliance with this standard specification. The manufacturer shall make available for the inspector's use such gages as are necessary for inspection. The manufacturer shall provide the inspector with assistance as necessary for handling of pipe.

11. Delivery and Acceptance

11.1 All pipe and accessories shall comply with this standard specification. Pipe and accessories not complying with this standard specification shall be replaced by the manufacturer at the agreed point of delivery. The manufacturer shall not be liable for shortages or damaged pipe after acceptance at the agreed point of delivery, except as recorded on the delivery receipt or similar document by the carrier's agent.

12. Foundry Records

12.1 The results of the acceptance tests (Section 6 and low-temperature impact tests (Section 7)) shall be recorded and retained for 1 year, and shall be available to the purchaser at the foundry. Written transcripts shall be furnished, if specified on the purchase order.

13. Defective Specimens and Retests

13.1 When any physical-test specimen shows defective machining or lack of continuity of metal, it shall be discarded and replaced by another specimen. When any sound test specimen fails to meet the specified requirements, the pipe from which it was taken shall be rejected, and a retest be made on two additional sound specimens from pipe cast in the same period as the specimen that failed. Both of the additional specimens shall meet the prescribed tests to qualify the pipe produced in that period.

14. Rejection of Pipe

14.1 If the results of any physical acceptance test fail to meet the requirements of Section 6 or Section 13, the pipe cast in the same period shall be rejected, except as provided in Section 15.

15. Determining Rejection

15.1 The manufacturer may determine the amount of rejection by making similar additional tests of pipe, of the same size as the rejected pipe, until the rejected lot is bracketed, in order of manufacture, by an acceptable test at each end of the interval in question. When pipe of one size is rejected from a casting period, the acceptability of pipe of different sizes from that same period may be established by making the acceptance tests for these sizes as specified in Section 6.

16. Marking Pipe

16.1 The weight, class or nominal thickness, and casting period shall be shown on each pipe. The manufacturer's mark, the year in which the pipe was produced, and the letter "DI" or "DUCTILE" shall be cast or stamped on the pipe. When specified on the purchase order, initials not exceeding four in number shall be cast or stamped on the pipe. All required markings shall be clear and legible and all cast marks shall be on or near the bell. All letters and numerals shall be not less than ½ in. (12.7 mm) in height.

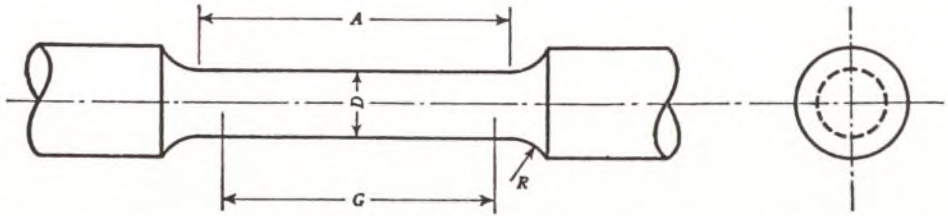
17. Weighing the Pipe

17.1 Each pipe shall be weighed and the weight shown on the outside or inside of the bell or spigot end.

TABLE 1 Standard Wall Thickness[A] and Weight of Push-On Joint Ductile-Iron Culvert Pipe

Nominal Diameter, in.	Nominal Thickness For Class 50 Ductile Iron Pipe in. (mm)	Maximum Depth Of Cover for Class 50 Ductile Iron Pipe ft (m)	18-ft (5.5-m) Laying Length, Weight per Length, lb (kg)	20-ft (6.1-m) Laying Length, Weight per Length, lb (kg)
14	0.33 (8.4)	49 (14.9)	900 (408)	995 (451)
16	0.34 (8.6)	47 (14.3)	1060 (481)	1170 (531)
18	0.35 (8.9)	45 (13.7)	1220 (553)	1345 (610)
20	0.36 (9.1)	44 (13.4)	1395 (633)	1545 (701)
24	0.38 (9.7)	42 (12.8)	1765 (801)	1955 (887)
30	0.39 (9.9)	39 (11.9)	2270 (1030)	2510 (1139)
36	0.43 (10.9)	39 (11.9)	3000 (1361)	3315 (1504)
42	0.47 (11.9)	39 (11.9)	...	4200 (1905)
48	0.51 (13.0)	39 (11.9)	...	5205 (2361)
54	0.57 (14.5)	38 (11.6)	...	6530 (2962)

[A] Nominal thickness is based on Class 50 ductile-iron pipe installed in Type 5 trench condition in accordance with ANSI A21.50, as shown in Fig. 3, with a maximum ring deflection of 5 % and ring stress of 48 000 psi (331 MPa). Minimum allowable depth of cover is 2 ft (0.61 m). Wall thickness of pipe to serve at other depths of cover may be calculated in accordance with ANSI A21.50, allowing 5 % maximum ring deflection.



NOTE 1—The reduced section (*A*) may have a gradual taper from the ends toward the center with the ends not more than 0.005 in. (0.13 mm) larger in diameter than the center on the standard specimen and not more than 0.003 in. (0.08 mm) larger in diameter than the center on the small size specimens.

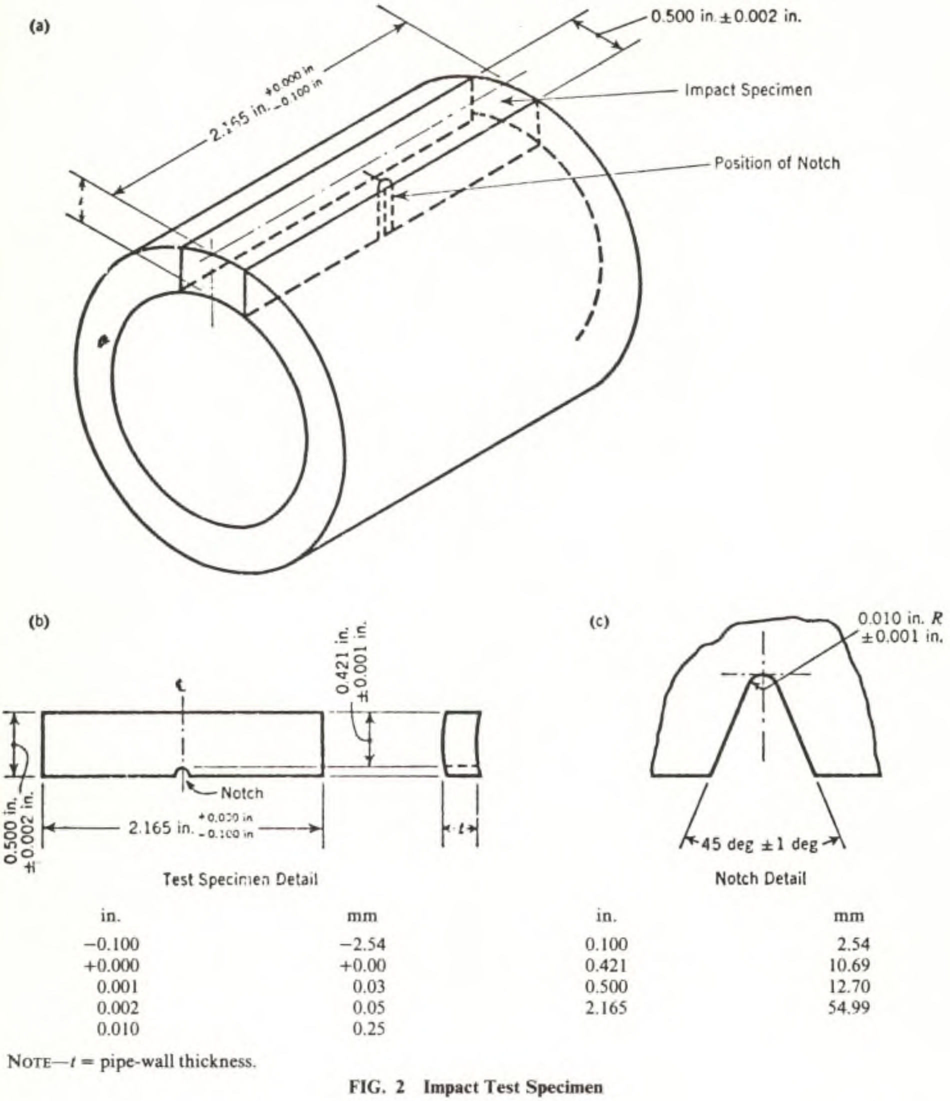
NOTE 2—If desired, on the small size specimens the length of the reduced section may be increased to accommodate an extensometer. However, reference marks for the measurement of elongation should nevertheless be spaced at the indicated gage length (*G*).

NOTE 3—The gage length and fillets shall be as shown, but the ends may be of any form to fit the holders of the testing machine in such a way that the load shall be axial. If the ends are to be held in grips it is desirable, if possible to make the length of the grip section great enough to allow the specimen to extend into the grips a distance equal to two thirds or more of the length of the grips.

Dimension	Standard Specimen 0.50-in (12.7-mm) Round	Small-Size Specimens Proportional to Standard 0.350-in. (8.89-mm) Round	0.250-in. (6.35-mm) Round	0.175-in. (4.45-mm) Round	0.125-in. (3.18-mm) Round
G	2.000 ± 0.005 (50.80 ± 0.13)	1.400 ± 0.005 (35.56 ± 0.13)	1.000 ± 0.005 (25.40 ± 0.13)	0.700 ± 0.005 (17.78 ± 0.13)	0.500 ± 0.005 (12.70 ± 0.13)
D	0.500 ± 0.010 (12.70 ± 0.25)	0.350 ± 0.007 (8.89 ± 0.18)	0.250 ± 0.005 (6.35 ± 0.13)	0.175 ± 0.005 (4.44 ± 0.13)	0.125 ± 0.005 (3.18 ± 0.13)
R, min	3/8 (9.5)	1/4 (6.4)	3/16 (4.8)	3/32 (2.4)	3/32 (2.4)
A, min	2 1/4 (57.2)	1 3/4 (44.4)	1 1/4 (31.8)	3/4 (19)	5/8 (15.9)
T[a]	0.71 and greater (18.0)	0.50 to 0.70 (12.7 to 17.8)	0.35 ± 0.49 (8.9 to 12.4)	0.25 to 0.34 (6.4 ± 8.6)	0.18 to 0.24 (4.6 to 6.1)

[a] Thickness of the section from the wall of the pipe from which the tension specimen is to be machined.

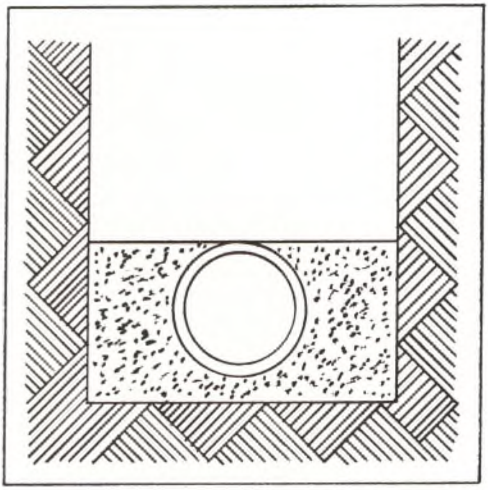
FIG. 1 Tension-Test Specimen



in.	mm	in.	mm
−0.100	−2.54	0.100	2.54
+0.000	+0.00	0.421	10.69
0.001	0.03	0.500	12.70
0.002	0.05	2.165	54.99
0.010	0.25		

NOTE—t = pipe-wall thickness.

FIG. 2 Impact Test Specimen



NOTE—Pipe is bedded to its centerline in compacted granular material with a minimum of 4 in. under the pipe. Compacted granular or select[A] material is used to the top of the pipe. (Material is compacted to approximately 90 % Standard Proctor in accordance with AASHTO Specification T-99.[B])

[A] Loose soil or select material is defined as native soil excavated from the trench, free of rocks, foreign material, and frozen earth.

[B] AASHTO T-99, Moisture Density Relations of Soils Using a 5.5-lb (2.5-kg) Rammer 12-in. (305-mm) Drop.

FIG. 3 Type 5 Trench

SECTION IV

DUCTILE AND GRAY CAST IRON FITTINGS

Introduction

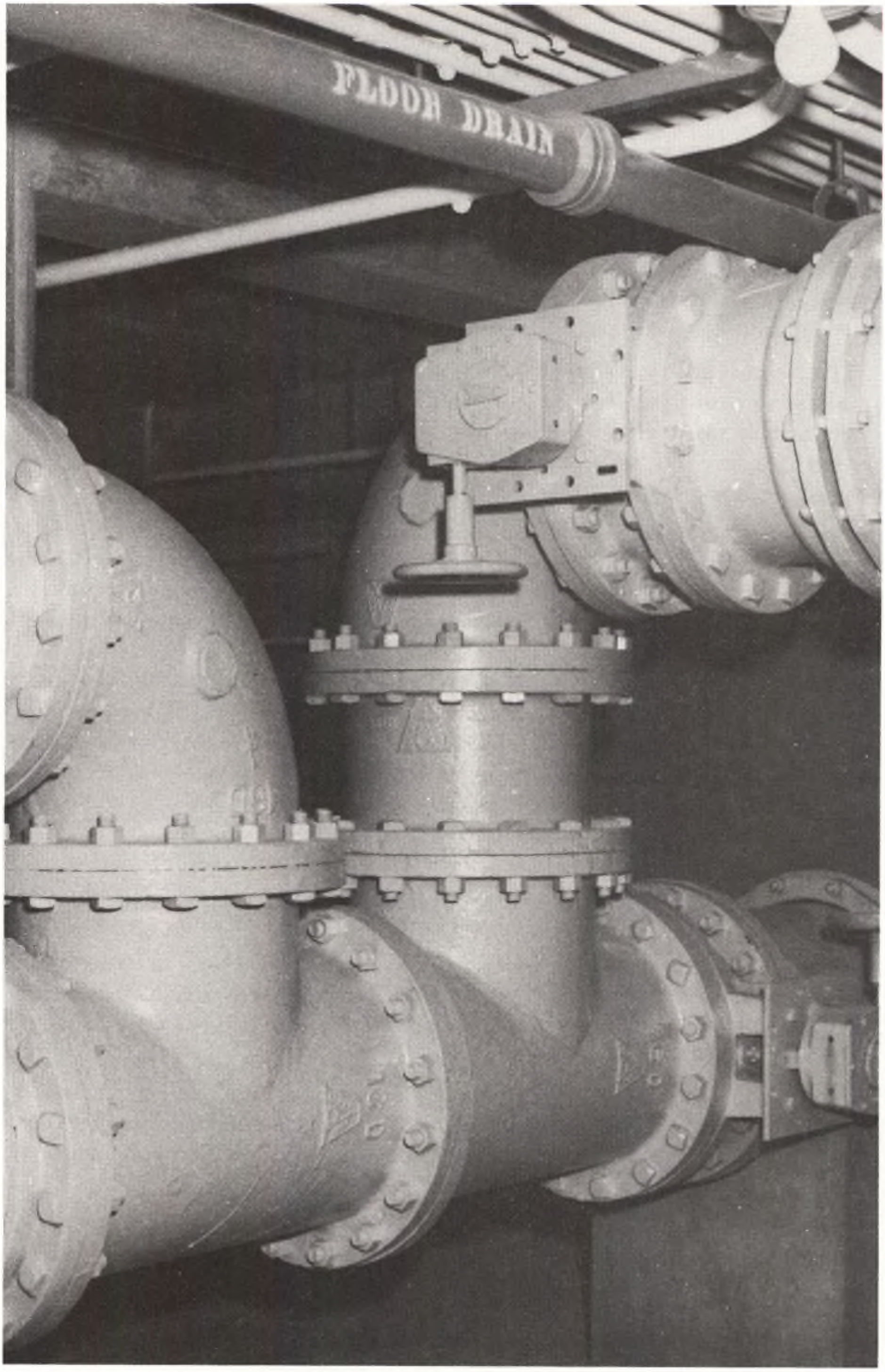
Fittings are produced in accordance with ANSI/AWWA C110/A21.10 Standard and ANSI Standard B16.1, as well as manufacturer's standards. Due to their irregular shapes, fittings are statically cast. They are available in either gray or ductile iron and are equipped with mechanical, push-on, flanged joints, or plain ends.

Preparatory to pouring iron, molds forming the outside contours of the fittings are assembled with cores that form the openings through the fittings. Iron is poured into the mold assembly and flows into the void surrounding the core. After cooling, the fittings are removed from the mold, cleaned, inspected, gauged for dimensional accuracy, weighed, lined and coated as required.

In general, gray and ductile iron fittings of the following configurations are furnished in accordance with the ANSI/AWWA C110/A21.10 Standard: bends, tees, crosses, base bends and tees, reducers, sleeves, caps, plugs, offsets, connecting pieces, and tapped tees. Included in the fittings manufactured per manufacturer's standard with overall dimensions in accordance with ANSI/AWWA C110/A21.10 or ANSI B16.1 and having ANSI/AWWA C110 wall thickness as applicable are the following: long-radius fittings, reducing elbows, reducing on-the-run tees, side outlet fittings, eccentric reducers, laterials and true wyes. Manufacturer's standards govern other special fittings and in most cases are produced in accordance with applicable provisions of ANSI/AWWA C110/A21.10. All fittings manufactured per ANSI/AWWA C110/A21.10 have a minimum safety factor of 3.0 times the rated working pressure. Flanges faced and drilled per this standard will match ANSI B16.1 Class 125 Flanges. Pressure ratings shown in ANSI/AWWA C110/A21.10 should not be confused with 125 lb. and 250 lb. flange ratings covered by ANSI B16.1 which are steam pressure ratings.

The minimum grade of cast iron used in fittings is 25,000 psi iron strength with higher grades where necessary to secure higher pressure ratings. Ductile iron used in fittings must have a minimum tensile strength of 70,000 psi, a minimum yield strength of 50,000 psi and a minimum elongation of 5%.

Ductile iron compact fittings are now being produced in 3" through 12" sizes. These fittings utilize the high strength of ductile iron and are thinner and lighter than the ANSI/AWWA C110/A21.10 fittings; while maintaining a pressure rating of 350 psi.


FLOOR DRAIN

ANSI/AWWA C110/A21.10-82
[Revision of ANSI A21.10-1977 (AWWA C110-77)]

AMERICAN NATIONAL STANDARD

for

DUCTILE-IRON AND GRAY-IRON FITTINGS, 3 IN. THROUGH 48 IN., FOR WATER AND OTHER LIQUIDS

ADMINISTRATIVE SECRETARIAT

AMERICAN WATER WORKS ASSOCIATION

COSECRETARIATS

AMERICAN GAS ASSOCIATION
NEW ENGLAND WATER WORKS ASSOCIATION

NOTICE

This Standard has been especially printed by the American Water Works Association for incorporation into this volume. It is current as of October 1, 1984. It should be noted, however, that all AWWA Standards are updated at least once in every five years. Therefore, before applying this Standard it is suggested that you confirm its currency with the American Water Works Association.

Approved by American National Standards Institute, Inc., Aug. 24, 1982.

Published by

AMERICAN WATER WORKS ASSOCIATION
6666 West Quincy Avenue, Denver, Colorado 80235

American National Standard

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User Members	*Producer Members*
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G. F. KEENAN	T. R. BROWN
H. W. SMITH	MICHAEL HARRINGTON
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	T. M. KILEY
	P. I. MCGRATH JR.
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Standards Committee A21, Cast-Iron Pipe and Fittings, which reviewed and approved this standard, had the following personnel at the time of approval.

ARNOLD M. TINKEY, *Chairman*
THOMAS D. HOLMES, *Vice-Chairman*
JOHN I. CAPITO, *Secretary*

Organization Represented	*Name of Representative*
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American Society for Testing and Materials	GEORGE LUCIW
American Water Works Association	G. S. ALLEN
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Underwriters Laboratories, Inc.	W. CAREY
	L. J. DOSEDLO

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Foreword

This foreword is for information only and is not a part of ANSI/AWWA C110/A21.10.

American National Standards Committee A21 on Cast-Iron Pipe and Fittings was organized in 1926 under the sponsorship of the American Gas Association, the American Society for Testing and Materials, the American Water Works Association, and the New England Water Works Association. Since 1972, the cosecretariats have been AGA, AWWA, and NEWWA, with AWWA serving as administrative secretariat. The present scope of Committee A21 activity is standardization of specifications for cast-iron and ductile-iron pressure pipe for gas, water, and other liquids, and fittings for use with such pipe. These specifications to include design, dimensions, materials, coatings, linings, joints, accessories, and methods of inspection and tests.

The work of Committee A21 is conducted by subcommittees. The directive of Subcommittee 3, Fittings, is that the scope of the subcommittee activity shall include the periodic review of all current A21 standards for fittings and the preparation of revisions and new standards, when needed, for fittings to be used with cast-iron and ductile-iron pressure pipe included in A21 standards.

I. History of Standard

The evolution of AWWA and ANSI standards for fittings is presented in this foreword to provide information relative to systems having aged cast-iron pipe and fittings still in service.

The earliest record of an AWWA standard for cast-iron pipe is contained in the proceedings for 1890. In 1902, NEWWA adopted a more detailed standard entitled "Standard Specification for Cast Iron Pipe and Special Castings."

The next AWWA standard for pipe and fittings, 7C.1-1908, was approved May 12, 1908. A second edition, C100-52T, was approved by AWWA Dec. 31, 1952, and by NEWWA Jan. 23, 1953. The third edition, C100-54T, was approved by AWWA Oct. 25, 1954, and finally issued as C100-55, having been advanced from tentative to standard without change June 17, 1955. Standard C100-55 covered fittings in the size range 4–60 in. The fittings were all bell and spigot (caulked joint) of the so-called long-radius design. The outside diameter (OD) for spigots varied with wall thicknesses, which were designated classes A, B, C, and D. Fittings 4–12 in. were made to class D patterns, having only one OD and pressure rating. Fittings 14–24 in. were furnished in class B and D, and fittings 30–60 in. were furnished in classes A, B, C, and D. All fittings made to AWWA 7C.1-1908 and C100-55 had the class identification cast on the fitting.

ASA A21.10-1952 (AWWA C110-52) was approved by ASA Sept. 30, 1952. The standard covered 3–12 in. fittings of the so-called "short-body" design and were the subject of extensive research and tests by Committee A21. The rated pressure given by the standard was 250 psi plus water hammer. The standard provided a 2.5 safety factor plus water hammer based on burst tests. Hydraulic losses were determined and compared with those found with AWWA long-radius fittings. The minimum grade of cast iron in the standard was 25 000 psi tensile strength.

ASA A21.10-1964 (AWWA C110-64) was approved by ASA Jan. 9, 1964. The revision covered 2–48 in. fittings. The design of the 14–48 in. fittings in the revision was based on an exhaustive series of burst tests. The minimum grade of cast iron (25 000 psi tensile strength) was retained and higher grades up to 35 000 psi tensile strength were used to secure higher pressure ratings without changing radically the thicknesses. Ductile iron, grade 80-60-03, was also added in the 14–48 in. sizes with a rated working pressure of 250 psi having the same wall thicknesses as 150-psi rated gray-iron fittings. The minimum safety factor based on burst tests of representative fittings of the weakest type was 3 times the rated working pressure. Tables for flanged fittings and mechanical-joint fittings were added for the first time.

ANSI A21.10-1971 (AWWA C110-71) was approved by ANSI July 14, 1971. Ductile-iron fittings were added in sizes 3–12 in., and were rated for 350 psi working pressure. The grade of ductile iron was changed to 70-50-05 to provide greater toughness. The safety factor against bursting was 3 times the rated working pressure. If required by the purchaser on special order, fittings were required to withstand a hydrostatic proof test not to exceed 1.5 times the rated working pressure without leaks or permanent distortions.

ANSI A21.10a-1972 (AWWA C110a-72) was approved Dec. 17, 1972 as a supplement to ANSI A21.10-71. The pressure rating for 14–24 in. ductile-iron fittings was increased to 350 psi.

ANSI/AWWA C110-77 (ANSI A21.10) was approved by ANSI April 7, 1977. The major change in this revision was the discontinuance of bell-and-spigot fittings (caulked joints) and 2- and 2¼-in. fittings in the standard. These actions were taken because the use of caulked joints had steadily declined until their use had become a rarity and the 2- and 2¼-in. sizes were no longer manufactured in the United States. (Bell-and-spigot fittings are still available from some foundries on special order.) With the elimination of 2- and 2¼-in. sizes, the standard included 3–48 in. mechanical-joint and flanged fittings only. (At least one manufacturer offers 54-in. fittings in flanged and push-on joints; however, 54-in. fittings are still not included as a part of the current standard.)

Another change made in the 1977 edition was in bolt lengths for flanged fittings to comply with ANSI/AWWA C115/A21.15, Standard for Flanged Cast-Iron and Ductile-Iron Pipe with Threaded Flanges. Appendix A was added to the standard to cover bolts, gaskets, and the installation of flanged fittings. Appendix B was added as a listing of special fittings available but which are not a part of the standard. These include reducing bends, Y-branches, blind flanges, reducing tees, bull head tees, flared fittings, side-outlet tees and side-outlet elbows, and wall pipe.

NOTE: Care should be used when connecting mechanical-joint fittings to aged existing cast-iron pipe. The outside diameter of aged pipe should be measured prior to cutting since some pipe was manufactured to a larger diameter than is presently specified in A21 standards. Mechanical-joint sleeves or bell-and-spigot (caulked-joint) sleeves are available to provide transition from existing cast-iron pipe; however, they must be specified on the purchase order. The following standards contain reference dimensions useful in classifying existing cast-iron pipe:

AWWA 7C.1-1908 (AWWA C100-55), Standard Specifications for Cast-Iron Pressure Fittings, Table 1.

ASA A21.2-1953 (AWWA C102-53), American Standard for Cast Iron Pit Cast Pipe for Water or Other Liquids, Tables 2.1 and 2.2.

ANSI A21.6-1975 (AWWA C106-75), American National Standard for Cast-Iron Pipe Centrifugally Cast in Metal Molds for Water or Other Liquids, Tables 6.4, 6.5, and 6.6.

ANSI A21.8-1975 (AWWA C108-75), American National Standard for Cast Iron Pipe Centrifugally Cast in Sand-Lined Molds for Water or Other Liquids, Tables 8.4, 8.5, and 8.6.

ANSI/AWWA C151/A21.51-81, American National Standard for Ductile Iron Pipe Centrifugally Cast in Metal Molds or Sand-Lined Molds for Water or Other Liquids, Tables 51.4 and 51.5.

Center to bottom-of-socket dimensions (dimension *A* in Table 10.3 and dimension *J* in Table 10.4 of this standard) for A21.10 mechanical-joint fittings are the same as the center to bottom-of-socket dimensions for bell-and-spigot (caulked-joint) fittings specified in previous editions of A21.10.

ANSI A21.10a-1972 published as a supplement to ANSI A21.10-1971 was incorporated into the ANSI/AWWA C110-77 revision.

II. Major Revisions

Metric conversions of all dimensions and physical requirements are included in the text portion of this standard. These metric conversions are direct conversions of US customary inch-pound units and are not those specified in International Organization for Standardization (ISO) standards. The conversion factors used are:

Pressure Rating: psi $\times$ 0.00689 = MPa
Iron Strength: 1000 psi $\times$ 6.89 = MPa
Dimensions: in. $\times$ 25.4 = mm
Weight: lb $\times$ 0.4536 = kg.

In the interests of economy, efficiency, and practicality, the figures and tables in this standard have not been reproduced showing metric units. A list of applicable conversion factors, as used in metric conversions in the text of the standard, is shown under each table.

III. Options

This standard includes certain options which, if desired, must be specified in the invitation for bids and on the purchase order. Also, a number of items must be specified to describe completely the fittings required. The following list summarizes the details and available options; it also lists the sections of the standard where they are listed.

1. Size, joint type, pressure rating (Sec. 10-1 and tables)
2. Joint specifications (Sec. 10-3.1)
3. Type of iron (Sec. 10-3.2)
4. End combinations (Sec. 10-3.3)
5. Certification by manufacturer (Sec. 10-4.3)
6. Inspection by purchaser (Sec. 10-5)
7. Cement lining* (Sec. 10-8.2)
8. Special coatings and linings (Sec. 10-8.4)
9. Acceptance tests (Sec. 10-10.1)
10. Special tests (Sec. 10-12)
11. Special flange bolt-hole alignment (Sec. 10-14.3)

IV. Special Service Requirements

The following special service requirements should be noted.

1. The fittings for which this standard is intended are those normally used for water and sanitary sewer systems. Fittings for other services may require special consideration by the purchaser.

*Experience has indicated the petroleum asphaltic inside coating is not complete protection against loss in pipe capacity caused by tuberculation. Cement linings are recommended for most waters.

2. Attention is directed to an apparent conflict between this standard and ANSI Standard B16.1 with regard to pressure ratings for flanged fittings. The scope of A21.10 covers the use of flanged fittings with ductile-iron pipe for water and other liquids to rated working pressures of 150 and 250 psi (1.03 and 1.72 MPa). The ratings of these fittings were established on the basis of hydrostatic testing of fittings to bursting and provide for a safety factor of at least 3.0 at the rated working pressure and at ambient temperature. ANSI B16.1 covers both separate flanges and flanged fittings for service at both ambient and elevated temperatures. The pressure ratings set forth in B16.1, as stated on the flyleaf of that standard, are not based upon burst strength but rather have evolved over an extended period of time of satisfactory performance in a wide range of general service conditions.

3. Although this standard does not specify orientation of bolt holes in the flanges of the mechanical joint, it is at times convenient or necessary to have the bolt holes oriented. The normal but not universal practice is to have the bolt holes straddle the vertical centerline of the fittings, valves, and hydrants. (The vertical centerline of a fitting is determined when the fitting is in the position to change the direction of fluid flowing in a horizontal plane. With standard base bends and standard base tees, the vertical centerline is determined when the fitting is in a position to change the fluid flowing in a vertical plane.) If orientation is known to be necessary, it should be stated on the purchase order.

ANSI/AWWA C110/A21.10-82
[Revision of ANSI A21.10-1977 (AWWA C110-77)]

American National Standard for

Ductile-Iron and Gray-Iron Fittings, 3 in. Through 48 in., for Water and Other Liquids

Sec. 10-1 Scope

This standard covers 3–48 in. gray-iron and/or ductile-iron fittings to be used with gray-iron or ductile-iron pipe for water and other liquids. Specifications for fittings with mechanical joints and flanged joints are listed in the tables at the end of this standard. This standard may also be used for fittings with push-on joints or such other joints as may be agreed upon at the time of purchase. For the 3–24 in. size range, ductile-iron mechanical-joint fittings are rated for 350 psi (2.41 MPa) working pressure; ductile-iron flange-joint fittings are rated for 250 psi (1.72 MPa) working pressure; and gray-iron fittings having all types of joints covered by this standard are rated for 150 or 250 psi (1.03 or 1.72 MPa) working pressures, as shown in the tables. For the 30–48 in. size range, fittings of all types of joints covered by this standard are shown in the tables as gray-iron and/or ductile-iron for rated working pressures of 150 or 250 psi (1.03 or 1.72 MPa), as shown in the tables.

Sec. 10-2 Definitions

Under this standard the following definitions shall apply.

10-2.1. *Ductile iron:* The cast ferrous material in which the free graphite present is in a spheroidal form.

10-2.2. *Flange joint:* The flanged and bolted joint as detailed in Table 10.14.

10-2.3. *Gray iron:* The cast ferrous material in which a major part of the carbon content occurs as free carbon or graphite in the form of flakes interspersed throughout the metal.

10-2.4. *Inspector:* The representative of the purchaser, authorized to inspect on behalf of the purchaser to determine whether or not the fittings meet this standard.

10-2.5. *Manufacturer:* The party that produces the fittings.

10-2.6. *Mechanical joint:* A bolted joint of the stuffing-box type as detailed in Table 10.1 and as described in ANSI/AWWA C111/A21.11, American National Standard for Rubber-Gasket Joints for Ductile-Iron and Gray-Iron Pressure Pipe and Fittings, of the latest revision.

10-2.7. *Purchaser:* The party entering into a contract or agreement to purchase fittings according to this standard.

10-2.8. *Push-on joint:* The single rubber-gasket joint as described in ANSI/AWWA C111/A21.11 of the latest revision.

Sec. 10-3 General Requirements

10-3.1. Fittings with mechanical joints and flange joints shall conform to the dimensions and weights shown in the tables in this standard, unless otherwise agreed upon at the time of purchase. The mechanical joint shall also conform in all respects to ANSI/AWWA C111/A21.11 of the latest revision. Unless otherwise specified, the mechanical-joint gland shall be gray iron in accordance with ANSI/AWWA C111/A21.11 of the latest revision, and bolts and gaskets shall conform to the requirements of the same standard.

Split glands and glands in segments and other variations shall be allowed, provided they meet the other requirements of ANSI/AWWA C111/A21.11.

10-3.2. Fittings with push-on joints shall have weights and dimensions of the bell, socket, and plain end in accordance with the manufacturer's standard design. The manufacturer shall furnish drawings of the joint and gasket if requested by the purchaser. Performance requirements and special requirements for push-on joints shall conform in all respects to the requirements for the push-on joint in ANSI/AWWA C111/A21.11 of the latest revision.

10-3.3. Fittings shall be cast from gray iron or ductile iron, as shown in the tables. When both are shown in the tables, either may be used at the manufacturer's option unless otherwise specified on the purchase order. All fittings shall be capable of withstanding, without bursting, hydrostatic tests of 3 times the rated water working pressure.

10-3.4. Standard fittings shall be furnished with end combinations shown in the tables. When fittings of other designs or dimensions are purchased under this standard, it is the obligation of the purchaser to supply with each order specific details for each size, pressure rating, or type of fitting. Plain ends of mechanical-joint fittings may be furnished with bevels for assembly with push-on joint bells.

NOTE: All-bell fittings, without plain ends, are preferred.

Sec. 10-4 Inspection and Certification by Manufacturer

10-4.1. The manufacturer shall establish the necessary quality control and inspection practice to ensure compliance with this standard. All fittings shall be clean and sound without defects that could impair their service.

10-4.2. Repairing of defects by welding or other methods shall not be allowed if such repairs could adversely affect the serviceability of the fitting or its capability to meet strength requirements of this standard.

10-4.3. The manufacturer shall, if required on the purchase order, furnish a sworn statement that the inspection and all the specified tests have been made and that the results thereof comply with the requirements of this standard.

Sec. 10-5 Inspection by Purchaser

10-5.1. If the purchaser desires to inspect fittings at the manufacturer's plant, he shall so specify on the purchase order, stating the conditions (such as time and extent of the inspection) under which the inspection shall be made.

10-5.2. The inspector shall have free access to those areas of the manufacturer's plant that are necessary to ensure compliance with this standard. The manufacturer shall make available for the inspector's use such gauges as are necessary for inspection. The manufacturer shall provide the inspector with assistance as necessary for the handling of fittings.

Sec. 10-6 Delivery and Acceptance

All fittings and accessories shall comply with this standard. Fittings or accessories that do not comply with this standard shall be replaced by the manufacturer at the agreed point of delivery. The manufacturer shall not be liable for shortages or damaged fittings or accessories after acceptance at the agreed point of delivery except as recorded on the delivery receipt or similar document by the carrier's agent.

Sec. 10-7 Tolerances or Permitted Variations

10-7.1. *Dimensions.* Fittings shall be gauged with suitable gauges at sufficiently frequent intervals to ensure that the dimensions comply with the requirements of this standard. The smallest inside diameter of the sockets and the outside diameter of the plain ends shall be tested with circular gauges. Other socket dimensions shall be gauged as is appropriate.

10-7.2. *Thickness.* Minus tolerances for metal thicknesses, except those shown in Tables 10.1 and 10.2, shall not be more than the following:

Fitting Size *in.*	Minus Tolerance *in. (mm)*
3–6	0.10 (2.5)
8–20	0.12 (3.0)
24–48	0.15 (3.8)

An additional tolerance shall be permitted over areas not exceeding 8 in. (203 mm) in any direction as follows: for 3–12 in. fittings, 0.02 in. (0.5 mm); for 14–48 in. fittings, 0.03 in. (0.8 mm).

10-7.3. *Weight.* The weight of any fitting shall not be less than the nominal tabulated weight by more than 10 percent for fittings 12 in. or smaller in diameter or by more than 8 percent for fittings larger than 12 in. in diameter. The nominal tabulated weight is the weight of the fitting before the application of any lining or coating other than the standard coatings.

Sec. 10-8 Coatings and Linings

10-8.1. *Outside coating.* The outside coating for general use under all normal conditions shall be a petroleum asphaltic coating approximately 1 mil (25 μm) thick. The coating shall be applied to the outside of all fittings, unless otherwise specified. The finished coating shall be continuous, smooth, neither brittle when cold nor sticky when exposed to the sun, and strongly adherent to the fitting.

10-8.2. *Cement-mortar linings.* Cement linings shall be in accordance with ANSI/AWWA C104/A21.4, Standard for Cement-Mortar Lining for Ductile-Iron and Gray-Iron Pipe and Fittings for Water, of the latest revision. If desired, cement linings shall be specified in the invitation for bids and on the purchase order.

10-8.3. *Inside coating.* Unless otherwise specified, the inside coating for fittings that are not cement-lined shall be a petroleum asphaltic material as thick as practicable [at least 1 mil (25 μm)] and conform to all appropriate requirements for sealcoat in ANSI/AWWA C104/A21.4 of the latest revision.

10-8.4. *Special coatings and linings.* For special conditions, other types of coatings and linings may be available. Such special coatings and linings shall be specified in the invitation for bids and on the purchase order.

Sec. 10-9 Markings on Fittings

Fittings shall have distinctly cast upon them the pressure rating, nominal diameters of openings, manufacturer's identification, and the number of degrees or fraction of the circle on all bends. Ductile-iron fittings shall have the letters "DI" or "Ductile" cast on them. Cast letters and figures shall be on the outside and shall have dimensions no smaller than the following:

Size *in.*	Height of Letters *in. (mm)*	Relief *in. (mm)*
Less than 8	As Large as Practical	As Large as Practical
8–10	¾ (19)	$^3/_{32}$ (2.5)
12–48	1¼ (32)	$^3/_{32}$ (2.5)

Sec. 10-10 Acceptance Tests

10-10.1. *Physical test—gray-iron fittings.* The standard acceptance test for the physical characteristics of gray-iron fittings shall be one of the following:

1. Transverse test conducted in accordance with ASTM A438-62 (1976).
2. Tensile test conducted in accordance with ASTM A48-76.

10-10.1.1. *Choice of test.* Unless specified by the purchaser, either the tensile test or the transverse test, at the option of the manufacturer, shall be used as the acceptance test. The acceptance values for tensile and transverse tests shall be as shown in the table at the bottom of this page.

For 20-in. and 24-in. fittings with a body thickness greater than 1 in. (25.4 mm) a 2-in. (50.8-mm) test bar shall be used.

10-10.2. *Physical test—ductile-iron fittings.* The standard acceptance test for the physical characteristics of ductile-iron fittings shall be a tensile test from coupons cast from the same iron as the fittings. The coupons shall be cast and the tests made in accordance with ASTM A536-77, except the grade shall be 70-50-05. Either the keel block or the Y-block shall be used as the test coupons at the option of the manufacturer. The acceptance values shall be as follows: minimum tensile strength, 70 000 psi (483 MPa); minimum yield strength, 50 000 psi (345 MPa); minimum elongation, 5 percent.

10-10.3. *Sampling.* At least one sample shall be taken during each period of approximately 3 hours while the melting unit is operated continuously.

Sec. 10-11 Chemical Limitations for Gray-Iron Fittings

Analyses of the iron in gray-iron fittings shall be made at sufficiently frequent intervals to ensure compliance with the following limits: phosphorous, 0.90 percent maximum; sulfur, 0.15 percent maximum.

Control of the other chemical constituents shall be maintained to meet the physical property requirements of this standard. Samples for chemical analyses shall be representative and shall be

Iron Strength *psi, 1000's (MPa)*	Fitting Size *in.*	Bar Diam. *in. (mm)*	Span* *in. (mm)*	Min. Breaking Load *lb (kg)*	Min. Tensile Strength† *psi, 1000's (MPa)*
25 (172)	3–14	1.20 (30.5)	18 (457)	2000 (907)	25 (172)
30 (207)	14–24	1.20 (30.5)	18 (457)	2200 (998)	30 (207)
30 (207)	20–48	2.00 (50.8)	24 (610)	7600 (3447)	30 (207)
35 (241)	16–24	1.20 (30.5)	18 (457)	2400 (1089)	35 (241)
35 (241)	20–36	2.00 (50.8)	24 (610)	8300 (3765)	35 (241)

*ASTM A438-62 (1976)
†ASTM A48-76

obtained from either acceptance test specimens or specimens cast for this purpose.

Sec. 10-12 Additional Tests Required by the Purchaser

If tests other than those provided in this standard are required by the purchaser, such tests shall be specified in the invitation for bids and on the purchase order. Although it is not customary to make hydrostatic proof tests of fittings at the foundry, such tests may be made on special order at additional cost. If proof tests at the foundry are required by the purchaser for an order of fittings, the fittings shall withstand, without leaks or permanent distortion, hydrostatic test pressures not to exceed 1.5 times the rated water working pressures.

Sec. 10-13 Defective Specimens and Retests

When any physical test specimen shows defective machining or lack of continuity of metal, it shall be discarded and replaced by another specimen cast in the same sampling period as the specimen that failed.

Sec. 10-14 Special Requirements for Flanged Fittings

10-14.1. *Flanges.* Flanges shall conform to the dimensions shown in Table 10.14, which are adequate for water service of 250 psi (1.7 MPa) working pressure.

NOTE: The bolt circle and bolt holes of these flanges match those of the class 125 flanges shown in ANSI B16.1 and can be joined with class 125 B16.1 flanges. Flanges in A21.10 cannot be joined with class 250 B16.1 flanges.

10-14.2. *Facing.* Flanges shall be plain faced without projection or raised face and shall be furnished smooth or with shallow serrations. Flanges may be back faced or spot faced for compliance with the flange-thickness tolerance specified in this standard. Bearing surfaces for bolting shall be parallel to the flange face within 3 degrees.

10-14.3. *Bolt holes.* Bolt holes shall be in accordance with the dimensions shown in Table 10.14. They shall be equally spaced and shall straddle the centerline of the fitting.

10-14.3.1. Misalignment of corresponding bolt holes of two opposing flanges shall not exceed 0.12 in. (3.0 mm).

10-14.3.2. If bolt-hole alignment other than provided for in this standard is required by the purchaser, it shall be specified in the invitation for bids and on the purchase order.

10-14.4. *Laying-length dimensions.* Face-to-face dimensions shall conform to a tolerance of ±0.06 in. (1.5 mm) for sizes 3–10 in. and ±0.12 in. (3.0 mm) for sizes 12–48 in. Center-to-face tolerances shall be one half those of face-to-face tolerances. The largest opening shall govern the tolerance for all openings.

TABLE 10.1

Standard Mechanical-Joint Dimensions—in.*

Size *in.*	Plain End *A*	*B*	*C*	*D*	*F*	*φ deg*	*X*	*J*	K_1	K_2	*L*	*M*	*N*	*O*	*P*	*S*	*Y*	Bolts No.	Bolts Size	Bolts Lgth.	Weight—*lb* Bell	Weight—*lb* Gland Bolts Gasket
3	3.96 ±.06	2.50	4.84 ±.04	4.94 +.06 −.04	4.06 +.07 −.03	28	3/4 +.06 −.0	6.19 ±.06	7.69 −.12	7.69 −.12	.94 −.06	.62 −.06	.75	.31	.63	.52 −.10	.12	4	5/8	3	11	7
4	4.80 ±.06	2.50	5.92 ±.04	6.02 +.06 −.04	4.90 +.07 −.03	28	7/8 +.06 −.0	7.50 ±.06	9.12 −.12	9.12 −.12	1.00 −.06	.75 −.06	.75	.31	.75	.65 −.10	.12	4	3/4	3½	16	10
6	6.90 ±.06	2.50	8.02 ±.04	8.12 +.06 −.04	7.00 +.07 −.03	28	7/8 +.06 −.0	9.50 ±.06	11.12 −.12	11.12 −.12	1.06 −.06	.88 −.06	.75	.31	.75	.70 −.10	.12	6	3/4	3½	23	16
8	9.05 ±.06	2.50	10.17 ±.04	10.27 +.06 −.04	9.15 +.07 −.03	28	7/8 +.06 −.0	11.75 ±.06	13.37 −.12	13.37 −.12	1.12 −.08	1.00 −.08	.75	.31	.75	.75 −.12	.12	6	3/4	4	31	25
10	11.10 ±.06	2.50	12.22 +.06 −.04	12.34 +.06 −.04	11.20 +.07 −.03	28	7/8 +.06 −.0	14.00 ±.06	15.69 −.12	15.62 −.12	1.19 −.08	1.00 −.08	.75	.31	.75	.80 −.12	.12	8	3/4	4	41	30
12	13.20 ±.06	2.50	14.32 +.06 −.04	14.44 +.06 −.04	13.30 +.07 −.03	28	7/8 +.06 −.0	16.25 ±.06	17.94 −.12	17.88 −.12	1.25 −.08	1.00 −.08	.75	.31	.75	.85 −.12	.12	8	3/4	4	51	40
14	15.30 +.05 −.08	3.50	16.40 +.07 −.05	16.54 +.07 −.05	15.44 +.06 −.07	28	7/8 +.06 −.0	18.75 ±.06	20.31 −.12	20.25 −.12	1.31 −.12	1.25 −.12	.75	.31	.75	.89 −.12	.12	10	3/4	4½	79	45
16	17.40 +.05 −.08	3.50	18.50 +.07 −.05	18.64 +.07 −.05	17.54 +.06 −.07	28	7/8 +.06 −.0	21.00 ±.06	22.56 −.12	22.50 −.12	1.38 −.12	1.31 −.12	.75	.31	.75	.97 −.12	.12	12	3/4	4½	97	55
18	19.50 +.05 −.08	3.50	20.60 +.07 −.05	20.74 +.07 −.05	19.64 +.06 −.07	28	7/8 +.06 −.0	23.25 ±.06	24.83 −.15	24.75 −.15	1.44 −.12	1.38 −.12	.75	.31	.75	1.05 −.15	.12	12	3/4	4½	117	65
20	21.60 +.05 −.08	3.50	22.70 +.07 −.05	22.84 +.07 −.05	21.74 +.06 −.07	28	7/8 +.06 −.0	25.50 ±.06	27.08 −.15	27.00 −.15	1.50 −.12	1.44 −.12	.75	.31	.75	1.12 −.15	.12	14	3/4	4½	140	85
24	25.80 +.05 −.08	3.50	26.90 +.07 −.05	27.04 +.07 −.05	25.94 +.06 −.07	28	7/8 +.06 −.0	30.00 ±.06	31.58 −.15	31.50 −.15	1.62 −.12	1.56 −.12	.75	.31	.75	1.22 −.15	.12	16	3/4	5	185	105
30	32.00 +.08 −.06	4.00	33.29 +.08 −.06	33.46 +.08 −.06	32.17 +.08 −.06	20	1⅛ +.06 −.0	36.88 ±.06	39.12 −.18	39.12 −.18	1.81 −.12	2.00 −.12	.75	.38	1.00	1.50 −.15	.12	20	1	6	315	220
36	38.30 +.08 −.06	4.00	39.59 +.08 −.06	39.76 +.08 −.06	38.47 +.08 −.06	20	1⅛ +.06 −.0	43.75 ±.06	46.00 −.18	46.00 −.18	2.00 −.12	2.00 −.12	.75	.38	1.00	1.80 −.15	.12	24	1	6	445	285
42	44.50 +.08 −.06	4.00	45.79 +.08 −.06	45.96 +.08 −.06	44.67 +.08 −.06	20	1⅜ +.06 −.0	50.62 ±.06	53.12 −.18	53.12 −.18	2.00 −.12	2.00 −.12	.75	.38	1.00	1.95 −.15	.12	28	1¼	6	570	400
48	50.80 +.08 −.06	4.00	52.09 +.08 −.06	52.26 +.08 −.06	50.97 +.08 −.06	20	1⅜ +.06 −.0	57.50 ±.06	60.00 −.18	60.00 −.18	2.00 −.12	2.00 −.12	.75	.38	1.00	2.20 −.15	.12	32	1¼	6	725	475

* See Fig. 10.1.

Metric conversions: Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

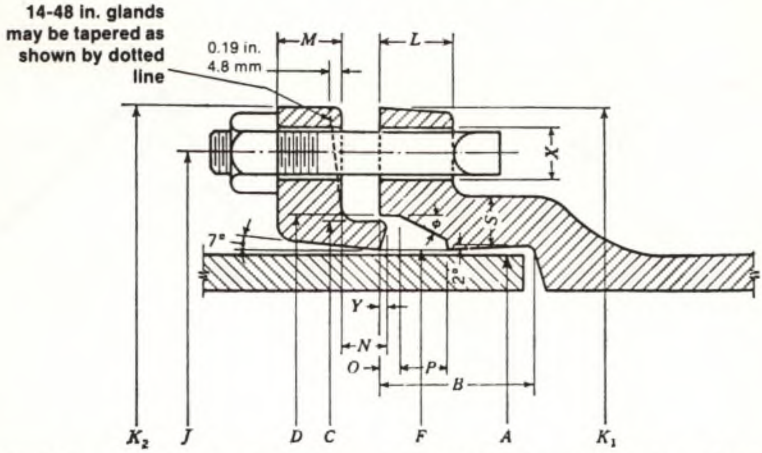


Fig. 10.1. 3–48 in. Standard Mechanical-Joint Fittings Dimensions (See Table 10.1)

1. Diameter of cored holes may be tapered an additional 0.06 in. (1.5 mm).

2. Dimension A in Table 10.1 is the outside diameter of the plain end of the fitting.

3. In the event of ovalness of the plain end OD, the mean diameter measured by a circumferential tape shall not be less than the minimum diameter shown in the table. The minor axis shall not be less than the above minimum diameter plus an additional minus tolerance of 0.04 in. (1.0 mm) for sizes 8–12 in., 0.07 in. (1.8 mm) for sizes 14–24 in., and 0.10 in. (2.5 mm) for sizes 30–48 in.

4. K_1 and K_2 are the dimensions across the bolt holes. For sizes 3-48 in., the gland may be polygon shaped.

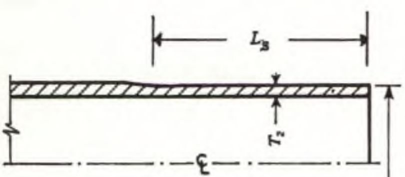


Fig. 10.2. Mechanical-Joint Plain-End Dimensions and Tolerances (See Table 10.2)

1. All sizes of fittings with plain ends have 8 in. (203 mm) of added laying length as compared with the laying length of standard all-bell fittings.

2. In Fig. 10.2, dimension L is minimum length of the plain end which must be gaged to ensure that the outside diameter is within the dimensions and tolerances specified in Table 10.2.

Metric conversions:
Iron strength: psi (1000's) × 6.89 = MPa;
Pressure rating: psi × 0.00689 = MPa;
Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

TABLE 10.2

Plain-end Dimensions and Tolerances for Mechanical-Joint Fittings

Size in.	OD—in.	T_2—in.	L_3—in.
3	3.96±0.06	0.48−0.10	5.5
4	4.80±0.06	0.47−0.10	5.5
6	6.90±0.06	0.50−0.10	5.5
8	9.05±0.06	0.54−0.12	5.5
10	11.10±0.06	0.60−0.12	5.5
12	13.20±0.06	0.68−0.12	5.5
14	15.30+0.05 −0.08	0.66−0.12	8.0
16	17.40+0.05 −0.08	0.70−0.12	8.0
18	19.50+0.05 −0.08	0.75−0.12	8.0
20	21.60+0.05 −0.08	0.80−0.12	8.0
24	25.80+0.05 −0.08	0.89−0.15	8.0
30	32.00+0.08 −0.06	1.03−0.15	8.0
36	38.30+0.08 −0.06	1.15−0.15	8.0
42	44.50+0.08 −0.06	1.28−0.15	8.0
48	50.80+0.08 −0.06	1.42−0.15	8.0

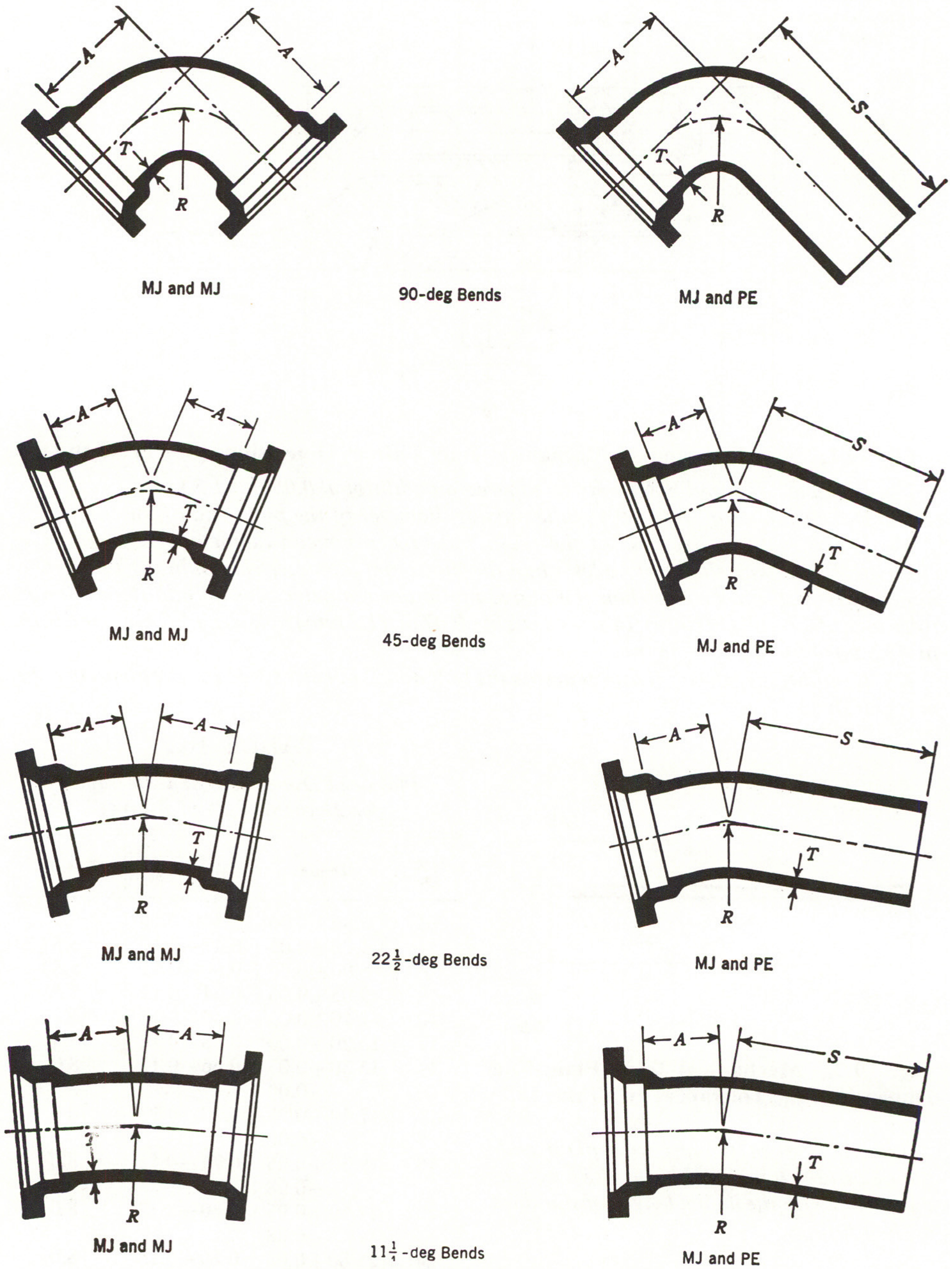


Fig. 10.3. Mechanical-Joint Bends (See Table 10.3)

TABLE 10.3

*Mechanical-Joint Bends**

Size in.	Pressure Rating psi	Iron Strength psi (1000's)	Dimensions—in.				Weight—lb†	
			T	A	S	R	MJ & MJ	MJ & PE
				90-deg Bends				
3	250	25	0.48	5.5	13.5	4.0	35	35
3	350	DI‡	0.48	5.5	13.5	4.0	35	35
4	250	25	0.52	6.5	14.5	4.5	55	50
4	350	DI	0.52	6.5	14.5	4.5	55	50
6	250	25	0.55	8.0	16.0	6.0	85	80
6	350	DI	0.55	8.0	16.0	6.0	85	80
8	250	25	0.60	9.0	17.0	7.0	125	120
8	350	DI	0.60	9.0	17.0	7.0	125	120
10	250	25	0.68	11.0	19.0	9.0	190	190
10	350	DI	0.68	11.0	19.0	9.0	190	190
12	250	25	0.75	12.0	20.0	10.0	255	255
12	350	DI	0.75	12.0	20.0	10.0	255	255
14	150	25	0.66	14.0	22.0	11.5	340	325
14	250	25	0.82	14.0	22.0	11.5	380	365
14	350	DI	0.66	14.0	22.0	11.5	340	325
16	150	30	0.70	15.0	23.0	12.5	430	410
16	250	30	0.89	15.0	23.0	12.5	490	470
16	350	DI	0.70	15.0	23.0	12.5	430	410
18	150	30	0.75	16.5	24.5	14.0	545	520
18	250	30	0.96	16.5	24.5	14.0	625	600
18	350	DI	0.75	16.5	24.5	14.0	545	520
20	150	30	0.80	18.0	26.0	15.5	680	650
20	250	30	1.03	18.0	26.0	15.5	790	755
20	350	DI	0.80	18.0	26.0	15.5	680	650
24	150	30	0.89	22.0	30.0	18.5	1,025	985
24	250	30	1.16	22.0	30.0	18.5	1,215	1,175
24	350	DI	0.89	22.0	30.0	18.5	1,025	985
30	150	30	1.03	25.0	33.0	21.5	1,690	1,585
30	250	30	1.37	25.0	33.0	21.5	2,030	1,920
30	250	DI	1.03	25.0	33.0	21.5	1,690	1,585
36	150	30	1.15	28.0	36.0	24.5	2,475	2,310
36	250	30	1.58	28.0	36.0	24.5	3,045	2,880
36	250	DI	1.15	28.0	36.0	24.5	2,475	2,310
42	150	30	1.28	31.0	39.0	27.5	3,410	3,200
42	250	30	1.78	31.0	39.0	27.5	4,255	4,050
42	250	DI	1.28	31.0	39.0	27.5	3,410	3,200
48	150	30	1.42	34.0	42.0	30.5	4,595	4,330
48	250	30	1.96	34.0	42.0	30.5	5,745	5,475
48	250	DI	1.42	34.0	42.0	30.5	4,595	4,330

* Dimension details of mechanical-joint bells are shown in Table 10.1; dimension details of plain ends are shown in Table 10.2.
† Weight does not include accessory weights. See Table 10.1 for accessory weights.
‡ Ductile Iron.

Metric conversions: Iron strength: psi (1000's) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

TABLE 10.3

Mechanical-Joint Bends (contd.)*

Size *in.*	Pressure Rating *psi*	Iron Strength *psi (1000's)*	Dimensions—*in.*				Weight—*lb*†	
			T	*A*	*S*	*R*	MJ & MJ	MJ & PE
45-deg Bends								
3	250	25	0.48	3.0	11.0	3.62	30	30
3	350	DI‡	0.48	3.0	11.0	3.62	30	30
4	250	25	0.52	4.0	12.0	4.81	50	45
4	350	DI	0.52	4.0	12.0	4.81	50	45
6	250	25	0.55	5.0	13.0	7.25	75	70
6	350	DI	0.55	5.0	13.0	7.25	75	70
8	250	25	0.60	5.5	13.5	8.44	110	105
8	350	DI	0.60	5.5	13.5	8.44	110	105
10	250	25	0.68	6.5	14.5	10.88	155	155
10	350	DI	0.68	6.5	14.5	10.88	155	155
12	250	25	0.75	7.5	15.5	13.25	215	215
12	350	DI	0.75	7.5	15.5	13.25	215	215
14	150	25	0.66	7.5	15.5	12.06	270	255
14	250	25	0.82	7.5	15.5	12.06	300	280
14	350	DI	0.66	7.5	15.5	12.06	270	255
16	150	30	0.70	8.0	16.0	13.25	340	320
16	250	30	0.89	8.0	16.0	13.25	380	360
16	350	DI	0.70	8.0	16.0	13.25	340	320
18	150	30	0.75	8.5	16.5	14.50	420	395
18	250	30	0.96	8.5	16.5	14.50	470	445
18	350	DI	0.75	8.5	16.5	14.50	420	395
20	150	30	0.80	9.5	17.5	16.88	530	500
20	250	30	1.03	9.5	17.5	16.88	595	565
20	350	DI	0.80	9.5	17.5	16.88	530	500
24	150	30	0.89	11.0	19.0	18.12	755	715
24	250	30	1.16	11.0	19.0	18.12	865	825
24	350	DI	0.89	11.0	19.0	18.12	755	715
30	150	30	1.03	15.0	23.0	27.75	1,380	1,275
30	250	30	1.37	15.0	23.0	27.75	1,620	1,510
30	250	DI	1.03	15.0	23.0	27.75	1,380	1,275
36	150	30	1.15	18.0	26.0	35.00	2,095	1,930
36	250	30	1.58	18.0	26.0	35.00	2,525	2,360
36	250	DI	1.15	18.0	26.0	35.00	2,095	1,930
42	150	30	1.28	21.0	29.0	42.25	2,955	2,745
42	250	30	1.78	21.0	29.0	42.25	3,635	3,425
42	250	DI	1.28	21.0	29.0	42.25	2,955	2,745
48	150	30	1.42	24.0	32.0	49.50	4,080	3,815
48	250	30	1.96	24.0	32.0	49.50	5,040	4,770
48	250	DI	1.42	24.0	32.0	49.50	4,080	3,815

* Dimension details of mechanical-joint bells are shown in Table 10.1; dimension details of plain ends are shown in Table 10.2.
† Weight does not include accessory weights. See Table 10.1 for accessory weights.
‡ Ductile Iron.

TABLE 10.3

Mechanical-Joint Bends (contd.)*

Size *in.*	Pressure Rating *psi*	Iron Strength *psi (1000's)*	Dimensions—*in.*				Weight—*lb*†	
			T	*A*	*S*	*R*	MJ & MJ	MJ & PE
22½-deg Bends								
3	250	25	0.48	3.0	11.0	7.56	30	30
3	350	DI‡	0.48	3.0	11.0	7.56	30	30
4	250	25	0.52	4.0	12.0	10.06	50	45
4	350	DI	0.52	4.0	12.0	10.06	50	45
6	250	25	0.55	5.0	13.0	15.06	75	70
6	350	DI	0.55	5.0	13.0	15.06	75	70
8	250	25	0.60	5.5	13.5	17.62	110	105
8	350	DI	0.60	5.5	13.5	17.62	110	105
10	250	25	0.68	6.5	14.5	22.62	160	160
10	350	DI	0.68	6.5	14.5	22.62	160	160
12	250	25	0.75	7.5	15.5	27.62	220	220
12	350	DI	0.75	7.5	15.5	27.62	220	220
14	150	25	0.66	7.5	15.5	25.12	275	260
14	250	25	0.82	7.5	15.5	25.12	300	285
14	350	DI	0.66	7.5	15.5	25.12	275	260
16	150	30	0.70	8.0	16.0	27.62	345	325
16	250	30	0.89	8.0	16.0	27.62	385	365
16	350	DI	0.70	8.0	16.0	27.62	345	325
18	150	30	0.75	8.5	16.5	30.19	430	405
18	250	30	0.96	8.5	16.5	30.19	480	455
18	350	DI	0.75	8.5	16.5	30.19	430	405
20	150	30	0.80	9.5	17.5	35.19	535	505
20	250	30	1.03	9.5	17.5	35.19	605	575
20	350	DI	0.80	9.5	17.5	35.19	535	505
24	150	30	0.89	11.0	19.0	37.69	765	725
24	250	30	1.16	11.0	19.0	37.69	880	840
24	350	DI	0.89	11.0	19.0	37.69	765	725
30	150	30	1.03	15.0	23.0	57.81	1,400	1,295
30	250	30	1.37	15.0	23.0	57.81	1,650	1,540
30	250	DI	1.03	15.0	23.0	57.81	1,400	1,295
36	150	30	1.15	18.0	26.0	72.88	2,135	1,970
36	250	30	1.58	18.0	26.0	72.88	2,580	2,410
36	250	DI	1.15	18.0	26.0	72.88	2,135	1,970
42	150	30	1.28	21.0	29.0	88.00	3,020	2,810
42	250	30	1.78	21.0	29.0	88.00	3,720	3,510
42	250	DI	1.28	21.0	29.0	88.00	3,020	2,810
48	150	30	1.42	24.0	32.0	103.06	4,170	3,905
48	250	30	1.96	24.0	32.0	103.06	5,160	4,895
48	250	DI	1.42	24.0	32.0	103.06	4,170	3,905

* Dimension details of mechanical-joint bells are shown in Table 10.1; dimension details of plain ends are shown in Table 10.2.
† Weight does not include accessory weights. See Table 10.1 for accessory weights.
‡ Ductile Iron.

TABLE 10.3

Mechanical-Joint Bends (contd.)*

Size in.	Pressure Rating psi	Iron Strength psi (1000's)	Dimensions—in.				Weight—lb†	
			T	A	S	R	MJ & MJ	MJ & PE
11¼-deg Bends								
3	250	25	0.48	3.0	11.0	15.25	30	30
3	350	DI‡	0.48	3.0	11.0	15.25	30	30
4	250	25	0.52	4.0	12.0	20.31	50	45
4	350	DI	0.52	4.0	12.0	20.31	50	45
6	250	25	0.55	5.0	13.0	30.50	75	70
6	350	DI	0.55	5.0	13.0	30.50	75	70
8	250	25	0.60	5.5	13.5	35.50	110	105
8	350	DI	0.60	5.5	13.5	35.50	110	105
10	250	25	0.68	6.5	14.5	45.69	160	160
10	350	DI	0.68	6.5	14.5	45.69	160	160
12	250	25	0.75	7.5	15.5	55.81	220	220
12	350	DI	0.75	7.5	15.5	55.81	220	220
14	150	25	0.66	7.5	15.5	50.75	275	260
14	250	25	0.82	7.5	15.5	50.75	305	285
14	350	DI	0.66	7.5	15.5	50.75	275	260
16	150	30	0.70	8.0	16.0	55.81	345	325
16	250	30	0.89	8.0	16.0	55.81	385	365
16	350	DI	0.70	8.0	16.0	55.81	345	325
18	150	30	0.75	8.5	16.5	60.94	430	405
18	250	30	0.96	8.5	16.5	60.94	480	455
18	350	DI	0.75	8.5	16.5	60.94	430	405
20	150	30	0.80	9.5	17.5	71.06	540	510
20	250	30	1.03	9.5	17.5	71.06	610	575
20	350	DI	0.80	9.5	17.5	71.06	540	510
24	150	30	0.89	11.0	19.0	76.12	770	730
24	250	30	1.16	11.0	19.0	76.12	885	845
24	350	DI	0.89	11.0	19.0	76.12	770	730
30	150	30	1.03	15.0	23.0	116.75	1,410	1,305
30	250	30	1.37	15.0	23.0	116.75	1,655	1,550
30	250	DI	1.03	15.0	23.0	116.75	1,410	1,305
36	150	30	1.15	18.0	26.0	147.25	2,145	1,980
36	250	30	1.58	18.0	26.0	147.25	2,595	2,425
36	250	DI	1.15	18.0	26.0	147.25	2,145	1,980
42	150	30	1.28	21.0	29.0	177.69	3,035	2,825
42	250	30	1.78	21.0	29.0	177.69	3,740	3,535
42	250	DI	1.28	21.0	29.0	177.69	3,035	2,825
48	150	30	1.42	24.0	32.0	208.12	4,190	3,925
48	250	30	1.96	24.0	32.0	208.12	5,195	4,925
48	250	DI	1.42	24.0	32.0	208.12	4,190	3,925

* Dimension details of mechanical-joint bells are shown in Table 10.1; dimension details of plain ends are shown in Table 10.2.
† Weight does not include accessory weights. See Table 10.1 for accessory weights.
‡ Ductile Iron.

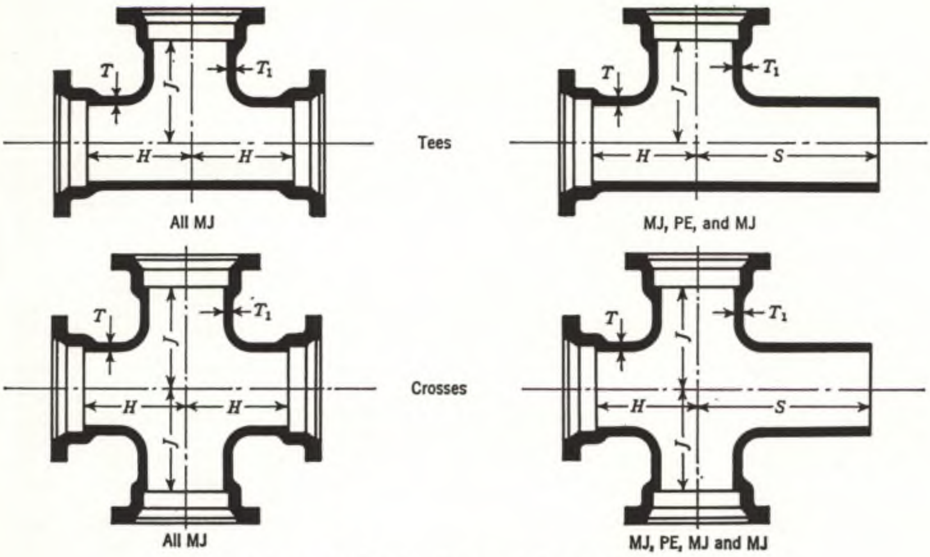


Fig. 10.4. Mechanical-Joint Tees and Crosses (See Table 10.4)

TABLE 10.4

*Mechanical-Joint Tees and Crosses**

Size *in.* Run	Size *in.* Branch	Pressure Rating *psi*	Iron Strength *psi (1000's)*	Dimensions—*in.* T	T_1	H	J	S	Weight—*lb*† Tee All MJ	Tee MJ, PE & MJ	Cross All MJ	Cross MJ, PE, MJ & MJ
3	3	250	25	0.48	0.48	5.5	5.5	13.5	55	55	70	70
3	3	350	DI‡	0.48	0.48	5.5	5.5	13.5	55	55	70	70
4	3	250	25	0.52	0.48	6.5	6.5	14.5	75	70	90	85
4	3	350	DI	0.52	0.48	6.5	6.5	14.5	75	70	90	85
4	4	250	25	0.52	0.52	6.5	6.5	14.5	80	75	105	100
4	4	350	DI	0.52	0.52	6.5	6.5	14.5	80	75	105	100

* Dimension details of mechanical-joint bells are shown in Table 10.1; dimension details of plain ends are shown in Table 10.2.
† Weight does not include accessory weights. See Table 10.1 for accessory weight.
‡ Ductile Iron.

Metric conversions: Iron strength: psi (1000's) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

TABLE 10.4

Mechanical-Joint Tees and Crosses (contd.)*

Size *in.*		Pressure Rating *psi*	Iron Strength *psi* *(1000's)*	Dimensions—*in.*					Weight—*lb*†			
									Tee		Cross	
Run	Branch			T	T_1	H	J	S	All MJ	MJ, PE & MJ	All MJ	MJ, PE, MJ & MJ
6	3	250	25	0.55	0.48	8.0	8.0	16.0	110	105	125	120
6	3	350	DI‡	0.55	0.48	8.0	8.0	16.0	110	105	125	120
6	4	250	25	0.55	0.52	8.0	8.0	16.0	115	110	140	135
6	4	350	DI	0.55	0.52	8.0	8.0	16.0	115	110	140	135
6	6	250	25	0.55	0.55	8.0	8.0	16.0	125	120	160	155
6	6	350	DI	0.55	0.55	8.0	8.0	16.0	125	120	160	155
8	4	250	25	0.60	0.52	9.0	9.0	17.0	165	160	185	180
8	4	350	DI	0.60	0.52	9.0	9.0	17.0	165	160	185	180
8	6	250	25	0.60	0.55	9.0	9.0	17.0	175	170	205	200
8	6	350	DI	0.60	0.55	9.0	9.0	17.0	175	170	205	200
8	8	250	25	0.60	0.60	9.0	9.0	17.0	185	180	235	230
8	8	350	DI	0.60	0.60	9.0	9.0	17.0	185	180	235	230
10	4	250	25	0.68	0.52	11.0	11.0	19.0	235	235	260	260
10	4	350	DI	0.68	0.52	11.0	11.0	19.0	235	235	260	260
10	6	250	25	0.68	0.55	11.0	11.0	19.0	250	250	285	285
10	6	350	DI	0.68	0.55	11.0	11.0	19.0	250	250	285	285
10	8	250	25	0.68	0.60	11.0	11.0	19.0	260	260	310	310
10	8	350	DI	0.68	0.60	11.0	11.0	19.0	260	260	310	310
10	10	250	25	0.80	0.80	11.0	11.0	19.0	310	310	380	380
10	10	350	DI	0.80	0.80	11.0	11.0	19.0	310	310	380	380
12	4	250	25	0.75	0.52	12.0	12.0	20.0	315	315	340	340
12	4	350	DI	0.75	0.52	12.0	12.0	20.0	315	315	340	340
12	6	250	25	0.75	0.55	12.0	12.0	20.0	325	325	360	360
12	6	350	DI	0.75	0.55	12.0	12.0	20.0	325	325	360	360
12	8	250	25	0.75	0.60	12.0	12.0	20.0	340	340	385	385
12	8	350	DI	0.75	0.60	12.0	12.0	20.0	340	340	385	385
12	10	250	25	0.87	0.80	12.0	12.0	20.0	390	390	460	460
12	10	350	DI	0.87	0.80	12.0	12.0	20.0	390	390	460	460
12	12	250	25	0.87	0.87	12.0	12.0	20.0	410	410	495	495
12	12	350	DI	0.87	0.87	12.0	12.0	20.0	410	410	495	495
14	6	150	25	0.66	0.55	14.0	14.0	22.0	435	420	475	460
14	6	250	25	0.82	0.55	14.0	14.0	22.0	485	470	525	505
14	6	350	DI	0.66	0.55	14.0	14.0	22.0	435	420	475	460
14	8	150	25	0.66	0.60	14.0	14.0	22.0	450	435	500	485
14	8	250	25	0.82	0.60	14.0	14.0	22.0	500	480	550	535
14	8	350	DI	0.66	0.60	14.0	14.0	22.0	450	435	500	485
14	10	150	25	0.66	0.68	14.0	14.0	22.0	465	450	540	525
14	10	250	25	0.82	0.68	14.0	14.0	22.0	515	500	585	570
14	10	350	DI	0.66	0.68	14.0	14.0	22.0	465	450	540	525
14	12	150	25	0.82	0.75	14.0	14.0	22.0	540	525	630	615
14	12	250	30	0.82	0.75	14.0	14.0	22.0	540	525	630	615
14	12	350	DI	0.66	0.75	14.0	14.0	22.0	495	475	585	570

* Dimension details of mechanical-joint bells are shown in Table 10.1; dimension details of plain ends are shown in Table 10.2.
† Weight does not include accessory weights. See Table 10.1 for accessory weights.
‡ Ductile Iron.

TABLE 10.4

Mechanical-Joint Tees and Crosses (contd.)*

Size *in.*		Pressure Rating *psi*	Iron Strength *psi* *(1000's)*	Dimensions—*in.*					Weight—*lb*†			
									Tee		Cross	
Run	Branch			T	T_1	H	J	S	All MJ	MJ, PE & MJ	All MJ	MJ, PE MJ & MJ
14	14	150	25	0.82	0.82	14.0	14.0	22.0	585	570	710	695
14	14	250	30	0.82	0.82	14.0	14.0	22.0	585	570	710	695
14	14	350	DI‡	0.66	0.66	14.0	14.0	22.0	520	500	635	620
16	6	150	30	0.70	0.55	15.0	15.0	23.0	540	520	575	555
16	6	250	30	0.89	0.55	15.0	15.0	23.0	615	590	650	630
16	6	350	DI	0.70	0.55	15.0	15.0	23.0	540	520	575	555
16	8	150	30	0.70	0.60	15.0	15.0	23.0	550	530	605	585
16	8	250	30	0.89	0.60	15.0	15.0	23.0	625	605	675	655
16	8	350	DI	0.70	0.60	15.0	15.0	23.0	550	530	605	585
16	10	150	30	0.70	0.68	15.0	15.0	23.0	570	550	645	625
16	10	250	30	0.89	0.68	15.0	15.0	23.0	645	620	710	690
16	10	350	DI	0.70	0.68	15.0	15.0	23.0	570	550	645	625
16	12	150	30	0.70	0.75	15.0	15.0	23.0	590	570	685	665
16	12	250	30	0.89	0.75	15.0	15.0	23.0	660	640	745	725
16	12	350	DI	0.70	0.75	15.0	15.0	23.0	590	570	685	665
16	14	150	30	0.89	0.82	15.0	15.0	23.0	710	690	830	810
16	14	250	35	0.89	0.82	15.0	15.0	23.0	710	690	830	810
16	14	350	DI	0.70	0.66	15.0	15.0	23.0	620	600	735	715
16	16	150	30	0.89	0.89	15.0	15.0	23.0	740	720	895	875
16	16	250	35	0.89	0.89	15.0	15.0	23.0	740	720	895	875
16	16	350	DI	0.70	0.70	15.0	15.0	23.0	650	625	790	770
18	6	150	30	0.75	0.55	13.0	15.5	21.0	590	565	625	600
18	6	250	30	0.96	0.55	13.0	15.5	21.0	670	645	705	680
18	6	350	DI	0.75	0.55	13.0	15.5	21.0	590	565	625	600
18	8	150	30	0.75	0.60	13.0	15.5	21.0	605	580	655	630
18	8	250	30	0.96	0.60	13.0	15.5	21.0	685	655	730	705
18	8	350	DI	0.75	0.60	13.0	15.5	21.0	605	580	655	630
18	10	150	30	0.75	0.68	13.0	15.5	21.0	620	595	685	660
18	10	250	30	0.96	0.68	13.0	15.5	21.0	700	670	760	735
18	10	350	DI	0.75	0.68	13.0	15.5	21.0	620	595	685	660
18	12	150	30	0.75	0.75	13.0	15.5	21.0	640	615	725	700
18	12	250	30	0.96	0.75	13.0	15.5	21.0	715	690	790	765
18	12	350	DI	0.75	0.75	13.0	15.5	21.0	640	615	725	700
18	14	150	30	0.75	0.66	16.5	16.5	24.5	755	730	870	845
18	14	250	30	0.96	0.82	16.5	16.5	24.5	865	840	990	965
18	14	350	DI	0.75	0.66	16.5	16.5	24.5	755	730	870	845
18	16	150	30	0.96	0.89	16.5	16.5	24.5	905	880	1,060	1,035
18	16	250	35	0.96	0.89	16.5	16.5	24.5	905	880	1,060	1,035
18	16	350	DI	0.75	0.70	16.5	16.5	24.5	785	760	930	905
18	18	150	30	0.96	0.96	16.5	16.5	24.5	945	920	1,130	1,105
18	18	250	35	0.96	0.96	16.5	16.5	24.5	945	920	1,130	1,105
18	18	350	DI	0.75	0.75	16.5	16.5	24.5	820	795	995	965
20	6	150	30	0.80	0.55	14.0	17.0	22.0	725	695	760	730
20	6	250	30	1.03	0.55	14.0	17.0	22.0	830	800	865	835
20	6	350	DI	0.80	0.55	14.0	17.0	22.0	725	695	760	730
20	8	150	30	0.80	0.60	14.0	17.0	22.0	735	705	790	760
20	8	250	30	1.03	0.60	14.0	17.0	22.0	845	810	890	860
20	8	350	DI	0.80	0.60	14.0	17.0	22.0	735	705	790	760

* Dimension details of mechanical-joint bells are shown in Table 10.1; dimension details of plain ends are shown in Table 10.2.
† Weight does not include accessory weights. See Table 10.1 for accessory weights.
‡ Ductile Iron.

TABLE 10.4

Mechanical-Joint Tees and Crosses (contd.)*

Size *in.*		Pressure Rating *psi*	Iron Strength *psi* *(1000's)*	Dimensions—*in.*					Weight—*lb*†			
									Tee		Cross	
Run	Branch			*T*	T_1	*H*	*J*	*S*	All MJ	MJ, PE & MJ	All MJ	MJ, PE, MJ & MJ
20	10	150	30	0.80	0.68	14.0	17.0	22.0	755	725	820	790
20	10	250	30	1.03	0.68	14.0	17.0	22.0	860	825	920	890
20	10	350	DI‡	0.80	0.68	14.0	17.0	22.0	755	725	820	790
20	12	150	30	0.80	0.75	14.0	17.0	22.0	775	745	860	830
20	12	250	30	1.03	0.75	14.0	17.0	22.0	875	840	955	920
20	12	350	DI	0.80	0.75	14.0	17.0	22.0	775	745	860	830
20	14	150	30	0.80	0.66	14.0	17.0	22.0	795	765	905	875
20	14	250	35	1.03	0.82	14.0	17.0	22.0	910	875	1,025	990
20	14	350	DI	0.80	0.66	14.0	17.0	22.0	795	765	905	875
20	16	150	30	0.80	0.70	18.0	18.0	26.0	945	915	1,085	1,055
20	16	250	35	1.03	0.89	18.0	18.0	26.0	1,095	1,060	1,245	1,215
20	16	350	DI	0.80	0.70	18.0	18.0	26.0	945	915	1,085	1,055
20	18	150	35	1.03	0.96	18.0	18.0	26.0	1,140	1,110	1,330	1,300
20	18	350	DI	0.80	0.75	18.0	18.0	26.0	985	950	1,155	1,120
20	20	150	35	1.03	1.03	18.0	18.0	26.0	1,185	1,155	1 415	1,385
20	20	350	DI	0.80	0.80	18.0	18.0	26.0	1,020	990	1 230	1,200
24	6	150	30	0.89	0.55	15.0	19.0	23.0	985	945	1,025	985
24	6	250	30	1.16	0.55	15.0	19.0	23.0	1,145	1,105	1,180	1,140
24	6	350	DI	0.89	0.55	15.0	19.0	23.0	985	945	1,025	985
24	8	150	30	0.89	0.60	15.0	19.0	23.0	1,000	960	1,045	1,005
24	8	250	30	1.16	0.60	15.0	19.0	23.0	1,160	1,115	1,200	1,160
24	8	350	DI	0.89	0.60	15.0	19.0	23.0	1,000	960	1,045	1,005
24	10	150	30	0.89	0.68	15.0	19.0	23.0	1,020	980	1,085	1,045
24	10	250	30	1.16	0.68	15.0	19.0	23.0	1,170	1,130	1,230	1,190
24	10	350	DI	0.89	0.68	15.0	19.0	23.0	1,020	980	1,085	1,045
24	12	150	30	0.89	0.75	15.0	19.0	23.0	1,030	990	1,110	1,070
24	12	250	30	1.16	0.75	15.0	19.0	23.0	1,185	1,145	1,260	1,220
24	12	350	DI	0.89	0.75	15.0	19.0	23.0	1,030	990	1,110	1,070
24	14	150	30	0.89	0.66	15.0	19.0	23.0	1,055	1,015	1,155	1,115
24	14	250	30	1.16	0.82	15.0	19.0	23.0	1,220	1,180	1,325	1,285
24	14	350	DI	0.89	0.66	15.0	19.0	23.0	1,055	1,015	1,155	1,115
24	16	150	30	0.89	0.70	15.0	19.0	23.0	1,075	1,035	1,200	1,160
24	16	250	35	1.16	0.89	15.0	19.0	23.0	1,245	1,200	1,375	1,335
24	16	350	DI	0.89	0.70	15.0	19.0	23.0	1,075	1,035	1,200	1,160
24	18	150	30	0.89	0.75	22.0	22.0	30.0	1,400	1,360	1,590	1,550
24	18	250	35	1.16	0.96	22.0	22.0	30.0	1,660	1,615	1,865	1,820
24	18	350	DI	0.89	0.75	22.0	22.0	30.0	1,400	1,360	1,590	1,550
24	20	150	35	1.16	1.03	22.0	22.0	30.0	1,720	1,680	1,965	1,925
24	20	350	DI	0.89	0.80	22.0	22.0	30.0	1,450	1,410	1,675	1,630
24	24	150	35	1.16	1.16	22.0	22.0	30.0	1,815	1,775	2,155	2,115
24	24	350	DI	0.89	0.89	22.0	22.0	30.0	1,535	1,490	1,835	1,795
30	6	150	30	1.03	0.55	18.0	23.0	26.0	1,730	1,615	1,770	1,655
30	6	250	30	1.37	0.55	18.0	23.0	26.0	2,050	1,935	2,085	1,970
30	6	250	DI	1.03	0.55	18.0	23.0	26.0	1,730	1,615	1,770	1,655
30	8	150	30	1.03	0.60	18.0	23.0	26.0	1,745	1,630	1,795	1,680
30	8	250	30	1.37	0.60	18.0	23.0	26.0	2,060	1,945	2,110	1,990
30	8	250	DI	1.03	0.60	18.0	23.0	26.0	1,745	1,630	1,795	1,680

* Dimension details of mechanical-joint bells are shown in Table 10.1; dimension details of plain ends are shown in Table 10.2.
† Weight does not include accessory weights. See Table 10.1 for accessory weights.
‡ Ductile Iron.

TABLE 10.4

Mechanical-Joint Tees and Crosses (contd.)*

Size *in.*		Pressure Rating *psi*	Iron Strength *psi* *(1000's)*	Dimensions—*in.*					Weight—*lb*†			
									Tee		Cross	
Run	Branch			*T*	T_1	*H*	*J*	*S*	All MJ	MJ, PE & MJ	All MJ	MJ, PE, MJ & MJ
30	10	150	30	1.03	0.68	18.0	23.0	26.0	1,760	1,645	1,830	1,715
30	10	250	30	1.37	0.68	18.0	23.0	26.0	2,075	1,960	2,135	2,020
30	10	250	DI‡	1.03	0.68	18.0	23.0	26.0	1,760	1,645	1,830	1,715
30	12	150	30	1.03	0.75	18.0	23.0	26.0	1,780	1,665	1,865	1,750
30	12	250	30	1.37	0.75	18.0	23.0	26.0	2,090	1,970	2,165	2,045
30	12	250	DI	1.03	0.75	18.0	23.0	26.0	1,780	1,665	1,865	1,750
30	14	150	30	1.03	0.66	18.0	23.0	26.0	1,800	1,685	1,905	1,790
30	14	250	30	1.37	0.82	18.0	23.0	26.0	2,120	2,005	2,230	2,115
30	14	250	DI	1.03	0.66	18.0	23.0	26.0	1,800	1,685	1,905	1,790
30	16	150	30	1.03	0.70	18.0	23.0	26.0	1,820	1,705	1,950	1,835
30	16	250	30	1.37	0.89	18.0	23.0	26.0	2,145	2,030	2,280	2,165
30	16	250	DI	1.03	0.70	18.0	23.0	26.0	1,820	1,705	1,950	1,835
30	18	150	30	1.03	0.75	18.0	23.0	26.0	1,845	1,730	2,000	1,885
30	18	250	35	1.37	0.96	18.0	23.0	26.0	2,170	2,055	2,330	2,215
30	18	250	DI	1.03	0.75	18.0	23.0	26.0	1,845	1,730	2,000	1,885
30	20	150	30	1.03	0.80	18.0	23.0	26.0	1,875	1,760	2,060	1,945
30	20	250	35	1.37	1.03	18.0	23.0	26.0	2,205	2,090	2,395	2,280
30	20	250	DI	1.03	0.80	18.0	23.0	26.0	1,875	1,760	2,060	1,945
30	24	150	35	1.37	1.16	25.0	25.0	33.0	2,880	2,765	3,180	3,065
30	24	250	DI	1.03	0.89	25.0	25.0	33.0	2,400	2,280	2,675	2,560
30	30	150	35	1.37	1.37	25.0	25.0	33.0	3,105	2,990	3,640	3,520
30	30	250	DI	1.03	1.03	25.0	25.0	33.0	2,595	2,480	3,075	2,955
36	8	150	30	1.15	0.60	20.0	26.0	28.0	2,520	2,345	2,565	2,390
36	8	250	30	1.58	0.60	20.0	26.0	28.0	3,050	2,870	3,095	2,915
36	8	250	DI	1.15	0.60	20.0	26.0	28.0	2,520	2,345	2,565	2,390
36	10	150	30	1.15	0.68	20.0	26.0	28.0	2,535	2,360	2,600	2,425
36	10	250	30	1.58	0.68	20.0	26.0	28.0	3,065	2,885	3,120	2,940
36	10	250	DI	1.15	0.68	20.0	26.0	28.0	2,535	2,360	2,600	2,425
36	12	150	30	1.15	0.75	20.0	26.0	28.0	2,550	2,375	2,630	2,455
36	12	250	30	1.58	0.75	20.0	26.0	28.0	3,075	2,895	3,140	2,960
36	12	250	DI	1.15	0.75	20.0	26.0	28.0	2,550	2,375	2,630	2,455
36	14	150	30	1.15	0.66	20.0	26.0	28.0	2,570	2,395	2,665	2,490
36	14	250	30	1.58	0.82	20.0	26.0	28.0	3,105	2,925	3,205	3,025
36	14	250	DI	1.15	0.66	20.0	26.0	28.0	2,570	2,395	2,665	2,490
36	16	150	30	1.15	0.70	20.0	26.0	28.0	2,585	2,410	2,705	2,530
36	16	250	30	1.58	0.89	20.0	26.0	28.0	3,125	2,945	3,245	3,065
36	16	250	DI	1.15	0.70	20.0	26.0	28.0	2,585	2,410	2,705	2,530
36	18	150	30	1.15	0.75	20.0	26.0	28.0	2,610	2,435	2,750	2,575
36	18	250	30	1.58	0.96	20.0	26.0	28.0	3,150	2,970	3,290	3,110
36	18	250	DI	1.15	0.75	20.0	26.0	28.0	2,610	2,435	2,750	2,575
36	20	150	30	1.15	0.80	20.0	26.0	28.0	2,635	2,460	2,805	2,630
36	20	250	35	1.58	1.03	20.0	26.0	28.0	3,175	2,995	3,345	3,165
36	20	250	DI	1.15	0.80	20.0	26.0	28.0	2,635	2,460	2,805	2,630
36	24	150	30	1.15	0.89	20.0	26.0	28.0	2,690	2,515	2,910	2,735
36	24	250	35	1.58	1.16	20.0	26.0	28.0	3,230	3,050	3,450	3,270
36	24	250	DI	1.15	0.89	20.0	26.0	28.0	2,690	2,515	2,910	2,735
36	30	150	35	1.58	1.37	28.0	28.0	36.0	4,345	4,170	4,790	4,615
36	30	250	DI	1.15	1.03	28.0	28.0	36.0	3,545	3,365	3,965	3,790
36	36	150	35	1.58	1.58	28.0	28.0	36.0	4,590	4,410	5,280	5,105
36	36	250	DI	1.15	1.15	28.0	28.0	36.0	3,745	3,565	4,370	4,190

* Dimension details of mechanical-joint bells are shown in Table 10.1; dimension details of plain ends are shown in Table 10.2.
† Weight does not include accessory weights. See Table 10.1 for accessory weights.
‡ Ductile Iron.

TABLE 10.4

Mechanical-Joint Tees and Crosses (contd.)*

Size *in.*		Pressure Rating *psi*	Iron Strength *psi* *(1000's)*	Dimensions—*in.*					Weight—*lb*†			
									Tee		Cross	
Run	Branch			*T*	T_1	*H*	*J*	*S*	All MJ	MJ, PE & MJ	All MJ	MJ, PE, MJ & MJ
42	12	150	30	1.28	0.75	23.0	30.0	31.0	3,555	3,335	3,640	3,420
42	12	250	30	1.78	0.75	23.0	30.0	31.0	4,385	4,160	4,450	4,225
42	12	250	DI‡	1.28	0.75	23.0	30.0	31.0	3,555	3,335	3,640	3,420
42	14	150	30	1.28	0.66	23.0	30.0	31.0	3,575	3,355	3,675	3,455
42	14	250	30	1.78	0.82	23.0	30.0	31.0	4,415	4,190	4,515	4,290
42	14	250	DI	1.28	0.66	23.0	30.0	31.0	3,575	3,355	3,675	3,455
42	16	150	30	1.28	0.70	23.0	30.0	31.0	3,595	3,375	3,715	3,495
42	16	250	30	1.78	0.89	23.0	30.0	31.0	4,435	4,210	4,550	4,325
42	16	250	DI	1.28	0.70	23.0	30.0	31.0	3,595	3,375	3,715	3,495
42	18	150	30	1.28	0.75	23.0	30.0	31.0	3,615	3,395	3,755	3,535
42	18	250	30	1.78	0.96	23.0	30.0	31.0	4,455	4,230	4,595	4,370
42	18	250	DI	1.28	0.75	23.0	30.0	31.0	3,615	3,395	3,755	3,535
42	20	150	30	1.28	0.80	23.0	30.0	31.0	3,640	3,420	3,810	3,590
42	20	250	30	1.78	1.03	23.0	30.0	31.0	4,480	4,255	4,645	4,420
42	20	250	DI	1.28	0.80	23.0	30.0	31.0	3,640	3,420	3,810	3,590
42	24	150	30	1.78	1.16	23.0	30.0	31.0	4,530	4,305	4,745	4,520
42	24	250	DI	1.28	0.89	23.0	30.0	31.0	3,690	3,470	3,910	3,690
42	30	150	30	1.78	1.37	31.0	31.0	39.0	5,800	5,575	6,210	5,985
42	30	250	DI	1.28	1.03	31.0	31.0	39.0	4,650	4,425	5,040	4,815
42	36	150	DI	1.28	1.15	31.0	31.0	39.0	4,880	4,655	5,425	5,200
42	36	250	DI	1.78	1.58	31.0	31.0	39.0	6,075	5,850	6,655	6,430
42	42	150	DI	1.28	1.28	31.0	31.0	39.0	5,085	4,860	5,840	5,615
42	42	250	DI	1.78	1.78	31.0	31.0	39.0	6,320	6,095	7,145	6,920
48	12	150	30	1.42	0.75	26.0	34.0	34.0	4,870	4,580	4,955	4,665
48	12	250	30	1.96	0.75	26.0	34.0	34.0	6,025	5,735	6,095	5,805
48	12	250	DI	1.42	0.75	26.0	34.0	34.0	4,870	4,580	4,955	4,665
48	14	150	30	1.42	0.66	26.0	34.0	34.0	4,885	4,595	4,985	4,695
48	14	250	30	1.96	0.82	26.0	34.0	34.0	6,055	5,770	6,155	5,865
48	14	250	DI	1.42	0.66	26.0	34.0	34.0	4,885	4,595	4,985	4,695
48	16	150	30	1.42	0.70	26.0	34.0	34.0	4,905	4,615	5,025	4,735
48	16	250	30	1.96	0.89	26.0	34.0	34.0	6,075	5,785	6,195	5,905
48	16	250	DI	1.42	0.70	26.0	34.0	34.0	4,905	4,615	5,025	4,735
48	18	150	30	1.42	0.75	26.0	34.0	34.0	4,925	4,635	5,065	4,775
48	18	250	30	1.96	0.96	26.0	34.0	34.0	6,095	5,805	6,235	5,945
48	18	250	DI	1.42	0.75	26.0	34.0	34.0	4,925	4,635	5,065	4,775
48	20	150	30	1.42	0.80	26.0	34.0	34.0	4,950	4,660	5,115	4,825
48	20	250	30	1.96	1.03	26.0	34.0	34.0	6,120	5,830	6,285	5,995
48	20	250	DI	1.42	0.80	26.0	34.0	34.0	4,950	4,660	5,115	4,825
48	24	150	30	1.42	0.89	26.0	34.0	34.0	4,995	4,705	5,210	4,920
48	24	250	30	1.96	1.16	26.0	34.0	34.0	6,165	5,880	6,375	6,085
48	24	250	DI	1.42	0.89	26.0	34.0	34.0	4,995	4,705	5,210	4,920
48	30	150	30	1.96	1.37	26.0	34.0	34.0	6,315	6,025	6,670	6,385
48	30	250	DI	1.42	1.03	26.0	34.0	34.0	5,140	4,855	5,495	5,210
48	36	150	30	1.96	1.58	34.0	34.0	42.0	7,835	7,545	8,360	8,075
48	36	250	DI	1.42	1.15	34.0	34.0	42.0	6,280	5,995	6,790	6,500
48	42	150	DI	1.42	1.28	34.0	34.0	42.0	6,510	6,225	7,150	6,860
48	42	250	DI	1.96	1.78	34.0	34.0	42.0	8,130	7,845	8,815	8,530
48	48	150	DI	1.42	1.42	34.0	34.0	42.0	6,765	6,475	7,655	7,370
48	48	250	DI	1.96	1.96	34.0	34.0	42.0	8,420	8,135	9,380	9,095

* Dimension details of mechanical-joint bells are shown in Table 10.1; dimension details of plain ends are shown in Table 10.2.
† Weight does not include accessory weights. See Table 10.1 for accessory weights.
‡ Ductile Iron.

Fig. 10.5. Mechanical-Joint Base Bends (See Table 10.5)

For other dimensions of base bends, see Table 10.3

TABLE 10.5

Mechanical-Joint Base Bends

Size *in.*	Pressure Rating *psi*	Iron Strength *psi (1000's)*	Dimensions—*in.*				Weight—*lb*†		
			*R**	*S* Diam.	*T*	*U*	MJ & MJ	MJ & PE	Base Only
3	250	25	4.88	5.00	0.56	0.50	45	45	10
3	350	DI‡	4.88	5.00	0.56	0.50	45	45	10
4	250	25	5.50	6.00	0.62	0.50	65	60	10
4	350	DI	5.50	6.00	0.62	0.50	65	60	10
6	250	25	7.00	7.00	0.69	0.62	105	100	20
6	350	DI	7.00	7.00	0.69	0.62	105	100	20
8	250	25	8.38	9.00	0.94	0.88	165	160	40
8	350	DI	8.38	9.00	0.94	0.88	165	160	40
10	250	25	9.75	9.00	0.94	0.88	235	235	45
10	350	DI	9.75	9.00	0.94	0.88	235	235	45
12	250	25	11.25	11.00	1.00	1.00	320	320	65
12	350	DI	11.25	11.00	1.00	1.00	320	320	65
14	150	25	12.50	11.00	1.00	1.00	410	395	70
14	250	25	12.50	11.00	1.00	1.00	450	435	70
14	350	DI	12.50	11.00	1.00	1.00	410	395	70
16	150	30	13.75	11.00	1.00	1.00	505	485	75
16	250	30	13.75	11.00	1.00	1.00	565	545	75
16	350	DI	13.75	11.00	1.00	1.00	505	485	75
18	150	30	15.00	13.50	1.12	1.12	660	635	115
18	250	30	15.00	13.50	1.12	1.12	740	715	115
18	350	DI	15.00	13.50	1.12	1.12	660	635	115
20	150	30	16.00	13.50	1.12	1.12	800	770	120
20	250	30	16.00	13.50	1.12	1.12	910	875	120
20	350	DI	16.00	13.50	1.12	1.12	800	770	120
24	150	30	18.50	13.50	1.12	1.12	1,155	1,115	130
24	250	30	18.50	13.50	1.12	1.12	1,345	1,305	130
24	350	DI	18.50	13.50	1.12	1.12	1,155	1,115	130
30	150	30	23.00	16.00	1.19	1.15	1,880	1,775	190
30	250	30	23.00	16.00	1.19	1.15	2,220	2,110	190
30	250	DI	23.00	16.00	1.19	1.15	1,880	1,775	190
36	150	30	26.00	19.00	1.25	1.15	2,725	2,560	250
36	250	30	26.00	19.00	1.25	1.15	3,295	3.130	250
36	250	DI	26.00	19.00	1.25	1.15	2,725	2,560	250
42	150	30	30.00	23.50	1.44	1.28	3,820	3,610	410
42	250	30	30.00	23.50	1.44	1.28	4,665	4,460	410
42	250	DI	30.00	23.50	1.44	1.28	3,820	3,610	410
48	150	30	34.00	25.00	1.56	1.42	5,110	4,845	515
48	250	30	34.00	25.00	1.56	1.42	6,260	5,990	515
48	250	DI	34.00	25.00	1.56	1.42	5,110	4,845	515

*Dimension *R* is a finished dimension; unfinished bases will be ⅛ in. (3 mm) longer; for base drilling see Table 10.15.
†Weight does not include accessory weights. See Table 10.1 for accessory weights.
‡Ductile Iron.

Metric conversions: Iron strength: psi (1000's) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

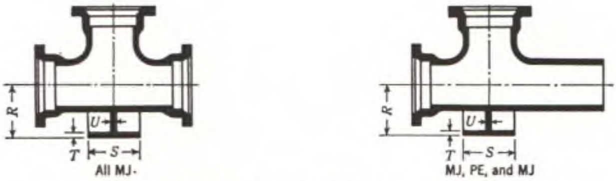


Fig. 10.6. Mechanical-Joint Base Tees (See Table 10.6)

For other dimensions of base tees, see Table 10.4.

TABLE 10.6

Mechanical-Joint Base Tees

Size *in.*	Pressure Rating *psi*	Iron Strength *psi (1000's)*	Dimensions—*in.*				Weight—*lb*†		
			*R**	*S* Diam.	*T*	*U*	All MJ	MJ, PE & MJ	Base Only
3	250	25	4.88	5.00	0.56	0.50	60	60	5
3	350	DI‡	4.88	5.00	0.56	0.50	60	60	5
4	250	25	5.50	6.00	0.62	0.50	90	85	10
4	350	DI	5.50	6.00	0.62	0.50	90	85	10
6	250	25	7.00	7.00	0.69	0.62	140	135	15
6	350	DI	7.00	7.00	0.69	0.62	140	135	15
8	250	25	8.38	9.00	0.94	0.88	215	210	30
8	350	DI	8.38	9.00	0.94	0.88	215	210	30
10	250	25	9.75	9.00	0.94	0.88	340	340	30
10	350	DI	9.75	9.00	0.94	0.88	340	340	30
12	250	25	11.25	11.00	1.00	1.00	455	455	45
12	350	DI	11.25	11.00	1.00	1.00	455	455	45
14	150	25	12.50	11.00	1.00	1.00	635	620	50
14	250	30	12.50	11.00	1.00	1.00	635	620	50
14	350	DI	12.50	11.00	1.00	1.00	570	550	50
16	150	30	13.75	11.00	1.00	1.00	790	770	50
16	250	35	13.75	11.00	1.00	1.00	790	770	50
16	350	DI	13.75	11.00	1.00	1.00	700	675	50
18	150	30	15.00	13.50	1.12	1.12	1,020	995	75
18	250	35	15.00	13.50	1.12	1.12	1,020	995	75
18	350	DI	15.00	13.50	1.12	1.12	895	870	75
20	150	35	16.00	13.50	1.12	1.12	1,260	1,230	75
20	350	DI	16.00	13.50	1.12	1.12	1,095	1,065	75
24	150	35	18.50	13.50	1.12	1.12	1,895	1,855	80
24	350	DI	18.50	13.50	1.12	1.12	1,615	1,570	80
30	150	35	23.00	16.00	1.19	1.15	3,225	3,110	120
30	250	DI	23.00	16.00	1.19	1.15	2,715	2,600	120
36	150	35	26.00	19.00	1.25	1.15	4,750	4,570	160
36	250	DI	26.00	19.00	1.25	1.15	3,905	3,725	160
42	150	DI	30.00	23.50	1.44	1.28	5,355	5,130	270
42	250	DI	30.00	23.50	1.44	1.28	6,590	6,365	270
48	150	DI	34.00	25.00	1.56	1.42	7,100	6,810	335
48	250	DI	34.00	25.00	1.56	1.42	8,755	8,470	335

*Dimension *R* is a finished dimension; unfinished bases will be ⅛ in. (3 mm) longer; for base drilling see Table 10.15.
†Weight does not include accessory weights. See Table 10.1 for accessory weights.
‡Ductile Iron.

Metric conversions: Iron strength: psi (1000's) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

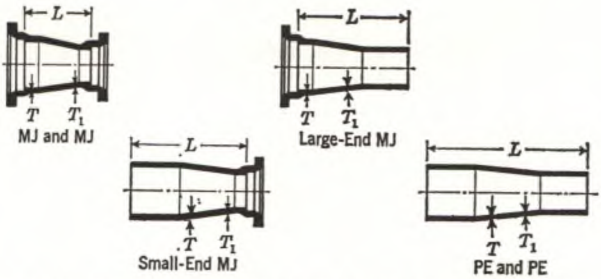


Fig. 10.7. Mechanical-Joint Reducers (See Table 10.7)

TABLE 10.7

*Mechanical-Joint Reducers**

Size *in.*		Pressure Rating *psi*	Iron Strength *psi* *(1000's)*	Thickness *in.*		MJ & MJ		Small-End MJ		Large-End MJ		PE & PE	
Large End	Small End			*T* Large End	T_1 Small End	*L* *in.*	Weight† *lb*	*L* *in.*	Weight† *lb*	*L* *in.*	Weight† *lb*	*L* *in.*	Weight† *lb*
4	3	250	25	0.52	0.48	7	40	15	35	15	40	23	35
4	3	350	DI‡	0.52	0.48	7	40	15	35	15	40	23	35
6	3	250	25	0.55	0.48	9	55	17	50	17	55	25	50
6	3	350	DI	0.55	0.48	9	55	17	50	17	55	25	50
6	4	250	25	0.55	0.52	9	60	17	60	17	60	25	55
6	4	350	DI	0.55	0.52	9	60	17	60	17	60	25	55
8	4	250	25	0.60	0.52	11	80	19	80	19	80	27	75
8	4	350	DI	0.60	0.52	11	80	19	80	19	80	27	75
8	6	250	25	0.60	0.55	11	95	19	90	19	90	27	85
8	6	350	DI	0.60	0.55	11	95	19	90	19	90	27	85
10	4	250	25	0.68	0.52	12	105	20	100	20	100	28	100
10	4	350	DI	0.68	0.52	12	105	20	100	20	100	28	100
10	6	250	25	0.68	0.55	12	115	20	115	20	115	28	115
10	6	350	DI	0.68	0.55	12	115	20	115	20	115	28	115
10	8	250	25	0.68	0.60	12	135	20	130	20	130	28	130
10	8	350	DI	0.68	0.60	12	135	20	130	20	130	28	130
12	4	250	25	0.75	0.52	14	135	22	130	22	130	30	130
12	4	350	DI	0.75	0.52	14	135	22	130	22	130	30	130
12	6	250	25	0.75	0.55	14	150	22	150	22	145	30	145
12	6	350	DI	0.75	0.55	14	150	22	150	22	145	30	145

* For dimension details of mechanical-joint bells, see Table 10.1; for dimension details of plain ends, see Table 10.2. Eccentric reducers with the same dimensions and weights given for concentric reducers are available from most manufacturers if specified on the purchase order.

† Weight does not include accessory weights. See Table 10.1 for accessory weights.

‡ Ductile Iron.

Metric conversions: Iron strength: psi (1000's) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

TABLE 10.7

Mechanical-Joint Reducers (contd.)*

Size *in.*		Pressure Rating *psi*	Iron Strength *psi (1000's)*	Thickness *in.*		MJ & MJ		Small-End MJ		Large-End MJ		PE & PE	
Large End	Small End			T Large End	T_1 Small End	L *in.*	Weight† *lb*	L *in.*	Weight† *lb*	L *in.*	Weight† *lb*	L *in.*	Weight† *lb*
12	8	250	25	0.75	0.60	14	165	22	165	22	165	30	165
12	8	350	DI‡	0.75	0.60	14	165	22	165	22	165	30	165
12	10	250	25	0.75	0.68	14	190	22	190	22	185	30	185
12	10	350	DI	0.75	0.68	14	190	22	190	22	185	30	185
14	6	150	25	0.66	0.55	16	190	24	175	24	185	32	170
14	6	250	25	0.82	0.55	16	200	24	185	24	200	32	185
14	6	350	DI	0.66	0.55	16	190	24	175	24	185	32	170
14	8	150	25	0.66	0.60	16	210	24	190	24	205	32	190
14	8	250	25	0.82	0.60	16	220	24	205	24	220	32	205
14	8	350	DI	0.66	0.60	16	210	24	190	24	205	32	190
14	10	150	25	0.66	0.68	16	230	24	215	24	230	32	215
14	10	250	25	0.82	0.68	16	245	24	230	24	245	32	230
14	10	350	DI	0.66	0.68	16	230	24	215	24	230	32	215
14	12	150	25	0.66	0.75	16	255	24	240	24	255	32	240
14	12	250	25	0.82	0.75	16	270	24	255	24	275	32	260
14	12	350	DI	0.66	0.75	16	255	24	240	24	255	32	240
16	6	150	30	0.70	0.55	18	230	26	210	26	230	34	210
16	6	250	30	0.89	0.55	18	250	26	230	26	250	34	230
16	6	350	DI	0.70	0.55	18	230	26	210	26	230	34	210
16	8	150	30	0.70	0.60	18	250	26	230	26	250	34	230
16	8	250	30	0.89	0.60	18	270	26	250	26	270	34	250
16	8	350	DI	0.70	0.60	18	250	26	230	26	250	34	230
16	10	150	30	0.70	0.68	18	280	26	255	26	275	34	255
16	10	250	30	0.89	0.68	18	300	26	280	26	300	34	280
16	10	350	DI	0.70	0.68	18	280	26	255	26	275	34	255
16	12	150	30	0.70	0.75	18	305	26	285	26	305	34	285
16	12	250	30	0.89	0.75	18	325	26	305	26	330	34	310
16	12	350	DI	0.70	0.75	18	305	26	285	26	305	34	285
16	14	150	30	0.70	0.66	18	335	26	310	26	315	34	295
16	14	250	30	0.89	0.82	18	370	26	350	26	355	34	335
16	14	350	DI	0.70	0.66	18	335	26	310	26	315	34	295
18	8	150	30	0.75	0.60	19	295	27	270	27	295	35	270
18	8	250	30	0.96	0.60	19	320	27	295	27	320	35	295
18	8	350	DI	0.75	0.60	19	295	27	270	27	295	35	270
18	10	150	30	0.75	0.68	19	325	27	300	27	320	35	295
18	10	250	30	0.96	0.68	19	350	27	325	27	350	35	325
18	10	350	DI	0.75	0.68	19	325	27	300	27	320	35	295
18	12	150	30	0.75	0.75	19	350	27	325	27	350	35	325
18	12	250	30	0.96	0.75	19	380	27	355	27	385	35	360
18	12	350	DI	0.75	0.75	19	350	27	325	27	350	35	325
18	14	150	30	0.75	0.66	19	380	27	355	27	365	35	340
18	14	250	30	0.96	0.82	19	425	27	400	27	410	35	385
18	14	350	DI	0.75	0.66	19	380	27	355	27	365	35	340
18	16	150	30	0.75	0.70	19	415	27	390	27	395	35	370
18	16	250	30	0.96	0.89	19	465	27	440	27	445	35	420
18	16	350	DI	0.75	0.70	19	415	27	390	27	395	35	370
20	10	150	30	0.80	0.68	20	375	28	345	28	375	36	345
20	10	250	30	1.03	0.68	20	410	28	380	28	410	36	380
20	10	350	DI	0.80	0.68	20	375	28	345	28	375	36	345

* For dimension details of mechanical-joint bells, see Table 10.1; for dimension details of plain ends, see Table 10.2. Eccentric reducers with the same dimensions and weights given for concentric reducers are available from most manufacturers if specified on the purchase order

† Weight does not include accessory weights. See Table 10.1 for accessory weights.

‡ Ductile Iron.

TABLE 10.7

Mechanical-Joint Reducers (contd.)*

Size *in.*		Pressure Rating *psi*	Iron Strength *psi (1000's)*	Thickness *in.*		MJ & MJ		Small-End MJ		Large-End MJ		PE & PE	
Large End	Small End			T Large End	T_1 Small End	L *in.*	Weight† *lb*	L *in.*	Weight† *lb*	L *in.*	Weight† *lb*	L *in.*	Weight† *lb*
20	12	150	30	0.80	0.75	20	405	28	375	28	405	36	375
20	12	250	30	1.03	0.75	20	440	28	410	28	445	36	415
20	12	350	DI‡	0.80	0.75	20	405	28	375	28	405	36	375
20	14	150	30	0.80	0.66	20	430	28	400	28	415	36	385
20	14	250	30	1.03	0.82	20	485	28	455	28	470	36	440
20	14	350	DI	0.80	0.66	20	430	28	400	28	415	36	385
20	16	150	30	0.80	0.70	20	470	28	435	28	445	36	415
20	16	250	30	1.03	0.89	20	530	28	500	28	510	36	475
20	16	350	DI	0.80	0.70	20	470	28	435	28	445	36	415
20	18	150	30	0.80	0.75	20	510	28	475	28	485	36	455
20	18	250	30	1.03	0.96	20	575	28	545	28	550	36	520
20	18	350	DI	0.80	0.75	20	510	28	475	28	485	36	455
24	12	150	30	0.89	0.75	24	550	32	510	32	550	40	510
24	12	250	30	1.16	0.75	24	610	32	570	32	615	40	575
24	12	350	DI	0.89	0.75	24	550	32	510	32	550	40	510
24	14	150	30	0.89	0.66	24	575	32	535	32	560	40	520
24	14	250	30	1.16	0.82	24	660	32	620	32	645	40	605
24	14	350	DI	0.89	0.66	24	575	32	535	32	560	40	520
24	16	150	30	0.89	0.70	24	615	32	575	32	595	40	555
24	16	250	30	1.16	0.89	24	705	32	665	32	685	40	645
24	16	350	DI	0.89	0.70	24	615	32	575	32	595	40	555
24	18	150	30	0.89	0.75	24	660	32	620	32	635	40	595
24	18	250	30	1.16	0.96	24	760	32	720	32	735	40	695
24	18	350	DI	0.89	0.75	24	660	32	620	32	635	40	595
24	20	150	30	0.89	0.80	24	705	32	665	32	675	40	635
24	20	250	30	1.16	1.03	24	815	32	775	32	785	40	745
24	20	350	DI	0.89	0.80	24	705	32	665	32	675	40	635
30	18	150	30	1.03	0.75	30	990	38	885	38	965	46	860
30	18	250	30	1.37	0.96	30	1,160	38	1,050	38	1,130	46	1,025
30	18	250	DI	1.03	0.75	30	990	38	885	38	965	46	860
30	20	150	30	1.03	0.80	30	1,050	38	945	38	1,020	46	915
30	20	250	30	1.37	1.03	30	1,225	38	1,120	38	1,195	46	1,090
30	20	250	DI	1.03	0.80	30	1,050	38	945	38	1,020	46	915
30	24	150	30	1.03	0.89	30	1,165	38	1,060	38	1,125	46	1,020
30	24	250	30	1.37	1.16	30	1,360	38	1,255	38	1,320	46	1,215
30	24	250	DI	1.03	0.89	30	1,165	38	1,060	38	1,125	46	1,020
36	20	150	30	1.15	0.80	36	1,450	44	1,285	44	1,420	52	1,255
36	20	250	30	1.58	1.03	36	1,730	44	1,560	44	1,695	52	1,530
36	20	250	DI	1.15	0.80	36	1,450	44	1,285	44	1,420	52	1,255
36	24	150	30	1.15	0.89	36	1,580	44	1,410	44	1,535	52	1,370
36	24	250	30	1.58	1.16	36	1,885	44	1,720	44	1,845	52	1,680
36	24	250	DI	1.15	0.89	36	1,580	44	1,410	44	1,535	52	1,370
36	30	150	30	1.15	1.03	36	1,855	44	1,690	44	1,750	52	1,585
36	30	250	30	1.58	1.37	36	2,225	44	2,060	44	2,120	52	1,950
36	30	250	DI	1.15	1.03	36	1,855	44	1,690	44	1,750	52	1,585
42	20	150	30	1.28	0.80	42	1,915	50	1,705	50	1,880	58	1,670
42	20	250	30	1.78	1.03	42	2,320	50	2,110	50	2,285	58	2,080
42	20	250	DI	1.28	0.80	42	1,915	50	1,705	50	1,880	58	1,670

* For dimension details of mechanical-joint bells, see Table 10.1; for dimension details of plain ends, see Table 10.2. Eccentric reducers with the same dimensions and weights given for concentric reducers are available from most manufacturers if specified on the purchase order.

† Weight does not include accessory weights. See Table 10.1 for accessory weights.

‡ Ductile Iron.

TABLE 10.7

Mechanical-Joint Reducers (contd.)*

Size *in.*		Pressure Rating *psi*	Iron Strength *psi* *(1000's)*	Thickness *in.*		MJ & MJ		Small-End MJ		Large-End MJ		PE & PE	
Large End	Small End			*T* Large End	T_1 Small End	*L* *in.*	Weight† *lb*	*L* *in.*	Weight† *lb*	*L* *in.*	Weight† *lb*	*L* *in.*	Weight† *lb*
42	24	150	30	1.28	0.89	42	2,060	50	1,855	50	2,020	58	1,810
42	24	250	30	1.78	1.16	42	2,495	50	2,285	50	2,455	58	2,245
42	24	250	DI‡	1.28	0.89	42	2,060	50	1,855	50	2,020	58	1,810
42	30	150	30	1.28	1.03	42	2,370	50	2,165	50	2,265	58	2,055
42	30	250	30	1.78	1.37	42	2,885	50	2,675	50	2,780	58	2,570
42	30	250	DI	1.28	1.03	42	2,370	50	2,165	50	2,265	58	2,055
42	36	150	30	1.28	1.15	42	2,695	50	2,485	50	2,530	58	2,320
42	36	250	30	1.78	1.58	42	3,310	50	3,100	50	3,145	58	2,935
42	36	250	DI	1.28	1.15	42	2,695	50	2,485	50	2,530	58	2,320
48	30	150	30	1.42	1.03	48	3,005	56	2,740	56	2,900	64	2,635
48	30	250	30	1.96	1.37	48	3,680	56	3,410	56	3,570	64	3,305
48	30	250	DI	1.42	1.03	48	3,005	56	2,740	56	2,900	64	2,635
48	36	150	30	1.42	1.15	48	3,370	56	3,100	56	3,205	64	2,940
48	36	250	30	1.96	1.58	48	4,160	56	3,890	56	3,990	64	3,725
48	36	250	DI	1.42	1.15	48	3,370	56	3,100	56	3,205	64	2,940
48	42	150	30	1.42	1.28	48	3,750	56	3,480	56	3,540	64	3,275
48	42	250	30	1.96	1.78	48	4,655	56	4,390	56	4,445	64	4,180
48	42	250	DI	1.42	1.28	48	3,750	56	3,480	56	3,540	64	3,275

* For dimension details of mechanical-joint bells, see Table 10.1; for dimension details of plain ends, see Table 10.2. Eccentric reducers with the same dimensions and weights given for concentric reducers are available from most manufacturers if specified on the purchase order.
† Weight does not include accessory weights. See Table 10.1 for accessory weights.
‡ Ductile Iron.

TABLE 10.8

*Mechanical-Joint Tapped Tees**

Size *in.*	Pressure Rating *psi*	Iron Strength *psi* *(1000's)*	*T* *in.*	*L* *in.*	Max. Tap in Boss *in.*	Weight† *lb*
3	250	25	0.48	8	2½	35
3	350	DI‡	0.48	8	2½	35
4	250	25	0.52	8	2½	45
4	350	DI	0.52	8	2½	45
6	250	25	0.55	8	2½	70
6	350	DI	0.55	8	2½	70
8	250	25	0.60	8	2½	95
8	350	DI	0.60	8	2½	95
10	250	25	0.68	8	2½	130
10	350	DI	0.68	8	2½	130
12	250	25	0.75	8	2½	165
12	350	DI	0.75	8	2½	165

* Two bosses can be used to make a tapped cross. For dimension details of mechanical-joint bells, see Table 10.1.
† Weight does not include accessory weights. See Table 10.1 for accessory weights.
‡ Ductile Iron.

Metric conversions:
Iron strength: psi (1000's) × 6.89 = MPa;
Pressure rating: psi × 0.00689 = MPa;
Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

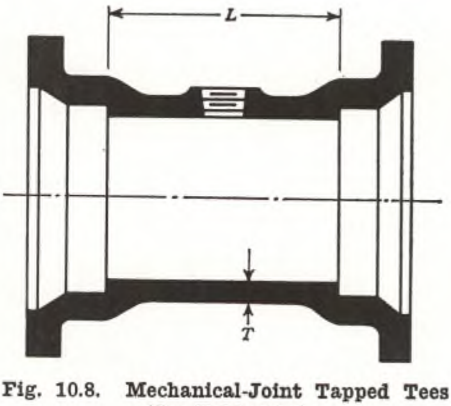


Fig. 10.8. Mechanical-Joint Tapped Tees (See Table 10.8)

TABLE 10.9

*Mechanical-Joint Offsets**

Size in.	PR† psi	Iron Strength psi (1000's)	D in.	T in.	MJ & MJ L in.	MJ & MJ Wgt.‡ lb	MJ & PE L in.	MJ & PE Wgt.‡ lb
3	250	25	6	0.48	19	50	27	50
3	350	DI§	6	0.48	19	50	27	50
3	250	25	12	0.48	22	60	30	60
3	350	DI	12	0.48	22	60	30	60
3	250	25	18	0.48	30	75	38	75
3	350	DI	18	0.48	30	75	38	75
4	250	25	6	0.52	19	75	27	70
4	350	DI	6	0.52	19	75	27	70
4	250	25	12	0.52	22	85	30	80
4	350	DI	12	0.52	22	85	30	80
4	250	25	18	0.52	30	105	38	100
4	350	DI	18	0.52	30	105	38	100
6	250	25	6	0.55	20	110	28	105
6	350	DI	6	0.55	20	110	28	105
6	250	25	12	0.53	26	135	34	130
6	350	DI	12	0.55	26	135	34	130
6	250	25	18	0.55	33	165	41	160
6	350	DI	18	0.55	33	165	41	160
8	250	25	6	0.60	21	160	29	155
8	350	DI	6	0.60	21	160	29	155
8	250	25	12	0.60	28	200	36	195
8	350	DI	12	0.60	28	200	36	195
8	250	25	18	0.60	35	245	43	240
8	350	DI	18	0.60	35	245	43	240
10	250	25	6	0.68	22	220	30	220
10	350	DI	6	0.68	22	220	30	220
10	250	25	12	0.68	30	280	38	280
10	350	DI	12	0.68	30	280	38	280
10	250	25	18	0.68	38	340	46	340
10	350	DI	18	0.68	38	340	46	340
12	250	25	6	0.75	26	320	34	320
12	350	DI	6	0.75	26	320	34	320
12	250	25	12	0.75	37	420	45	420
12	350	DI	12	0.75	37	420	45	420
12	250	25	18	0.75	48	520	56	520
12	350	DI	18	0.75	48	520	56	520
14	150	25	6	0.66	27	380	35	365
14	250	25	6	0.82	27	435	35	420
14	350	DI	6	0.66	27	380	35	365
14	150	25	12	0.66	38	480	46	465
14	250	25	12	0.82	38	560	46	545
14	350	DI	12	0.66	38	480	46	465
14	150	25	18	0.66	49	585	57	570
14	250	25	18	0.82	49	680	57	665
14	350	DI	18	0.66	49	585	57	570
16	150	30	6	0.70	27	460	35	440
16	250	30	6	0.89	27	535	35	515
16	350	DI	6	0.70	27	460	35	440
16	150	30	12	0.70	40	600	48	580
16	250	30	12	0.89	40	715	48	690
16	350	DI	12	0.70	40	600	48	580
16	150	30	18	0.70	50	710	58	690
16	250	30	18	0.89	50	850	58	830
16	350	DI	18	0.70	50	710	58	690

* For dimension details of mechanical-joint bells, see Table 10.1; for dimension details of plain ends, see Table 10.2.

† Pressure rating.

‡ Weight does not include accessory weights. See Table 10.1 for accessory weights.

§ Ductile iron.

Metric conversions:
Iron strength: psi (1000's) × 6.89 = MPa;
Pressure rating: psi × 0.00689 = MPa;
Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

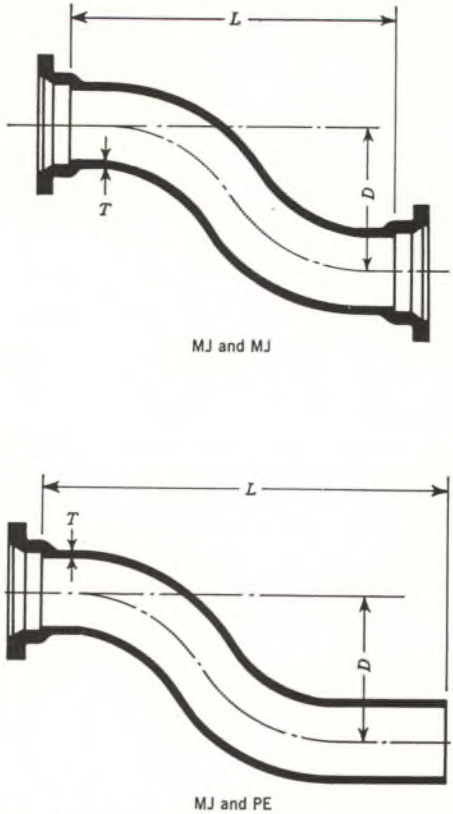


Fig. 10.9. Mechanical-Joint Offsets (See Table 10.9)

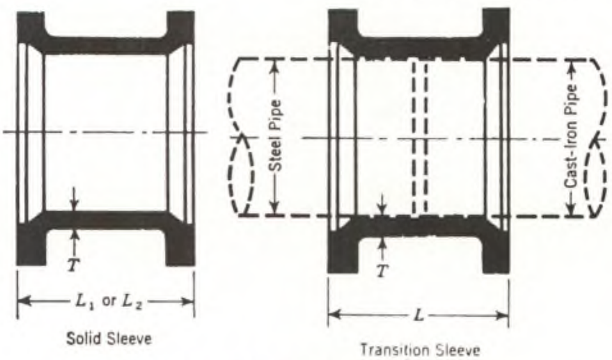


Fig. 10.10. Mechanical-Joint Sleeves (See Table 10.10)

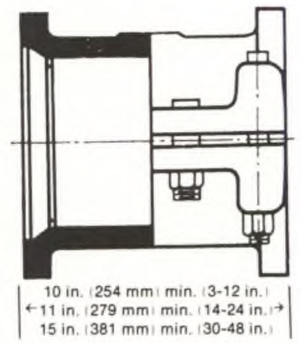


Fig. 10.10a. Mechanical Joint Split Sleeves

Split sleeves are furnished with a pressure rating of 150 psi (1.0 MPa) and can be furnished with boss and tap for service connections. Consult manufacturers for details.

TABLE 10.10

Mechanical-Joint Sleeves

Size *in.*	Pressure Rating *psi*	Iron Strength *psi (1000's)*	T *in.*	Solid Sleeves				Transition Sleeves*		
				L_1		L_2		Fits OD Steel Pipe	L	
				Length *in.*	Wgt.† *lb*	Length *in.*	Wgt.† *lb*		Length *in.*	Wgt.† *lb*
3	250	25	0.48	7.5	25	12	30	3.50	7.5	25
3	350	DI‡	0.48	7.5	25	12	30	3.50	7.5	25
4	250	25	0.52	7.5	35	12	45	4.50	7.5	35
4	350	DI	0.52	7.5	35	12	45	4.50	7.5	35
6	250	25	0.55	7.5	45	12	65	6.62	7.5	45
6	350	DI	0.55	7.5	45	12	65	6.62	7.5	45
8	250	25	0.60	7.5	65	12	85	8.62	7.5	65
8	350	DI	0.60	7.5	65	12	85	8.62	7.5	65
10	250	25	0.68	7.5	85	12	115	10.75	7.5	85
10	350	DI	0.68	7.5	85	12	115	10.75	7.5	85
12	250	25	0.75	7.5	110	12	145	12.75	7.5	110
12	350	DI	0.75	7.5	110	12	145	12.75	7.5	110
14	250	30	0.82	9.5	165	15	225			
14	350	DI	0.82	9.5	165	15	225			
16	250	30	0.89	9.5	200	15	275			
16	350	DI	0.89	9.5	200	15	275			
18	250	30	0.96	9.5	240	15	330			
18	350	DI	0.96	9.5	240	15	330			
20	250	30	1.03	9.5	275	15	380			
20	350	DI	1.03	9.5	275	15	380			
24	250	30	1.16	9.5	360	15	505			
24	350	DI	1.16	9.5	360	15	505			
30	250	30	1.37	15	745	24	1,085			
30	250	DI	1.37	15	745	24	1,085			
36	250	30	1.58	15	1,030	24	1,495			
36	250	DI	1.58	15	1,030	24	1,495			
42	250	30	1.78	15	1,330	24	1,940			
42	250	DI	1.78	15	1,330	24	1,940			
48	250	30	1.96	15	1,645	24	2,405			
48	250	DI	1.96	15	1,645	24	2,405			

* Transition sleeves are furnished with one end designed to fit standard steel pipe and the other to fit plain-end cast-iron pipe.
† Weight does not include accessory weights. See Table 10.1 for accessory weights.
‡ Ductile Iron.

Metric conversions: Iron strength: psi (1000's) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

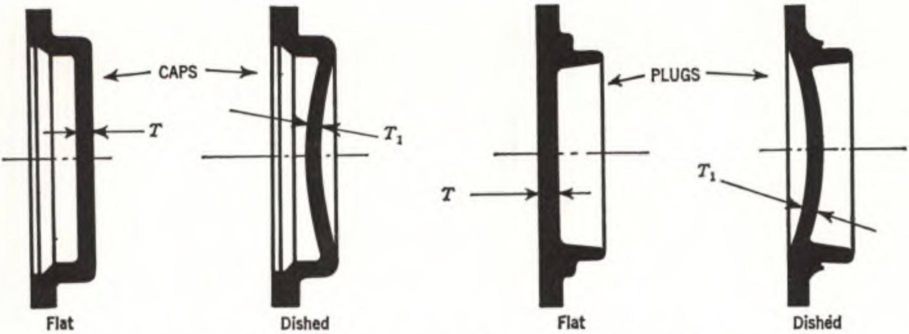


Fig. 10.11. Mechanical-Joint Caps and Plugs (See Table 10.11)

TABLE 10.11

Mechanical-Joint Caps and Plugs

Size *in.*	Pressure Rating *psi*	Iron Strength *psi (1000's)*	Caps				Plugs			
			Dimensions—*in.*		Weight—*lb*		Dimensions—*in.*		Weight—*lb*	
			T	T_1	Flat	Dished*	T	T_1	Flat	Dished*
3	250	25	0.50	0.48	12	12	0.50	0.48	10	10
3	350	DI†	0.50	0.48	12	12	0.50	0.48	10	10
4	250	25	0.60	0.52	15	15	0.60	0.52	15	15
4	350	DI	0.60	0.52	15	15	0.60	0.52	15	15
6	250	25	0.65	0.55	25	25	0.65	0.55	25	25
6	350	DI	0.65	0.55	25	25	0.65	0.55	25	25
8	250	25	0.70	0.60	45	45	0.70	0.60	45	45
8	350	DI	0.70	0.60	45	45	0.70	0.60	45	45
10	250	25	0.75	0.68	60	60	0.75	0.68	65	70
10	350	DI	0.75	0.68	60	60	0.75	0.68	65	70
12	250	25	0.75	0.75	80	80	0.75	0.75	85	90
12	350	DI	0.75	0.75	80	80	0.75	0.75	85	90
14	250	30	1.00	0.82	130	115	1.00	0.82	120	120
14	250	DI	0.82	0.66	120	110	0.82	0.66	115	115
16	250	30	1.11	0.89	175	155	1.11	0.89	155	150
16	250	DI	0.89	0.70	155	150	0.89	0.70	145	145
18	250	30	1.25	0.96	225	215	1.25	0.96	200	190
18	250	DI	0.96	0.75	195	185	0.96	0.75	185	180
20	250	30	1.40	1.03	285	250	1.40	1.03	255	215
20	250	DI	1.03	0.80	240	200	1.03	0.80	225	200
24	250	30	1.50	1.16	400	370	1.50	1.16	390	350
24	250	DI	1.16	0.89	345	300	1.16	0.89	335	290
30	150	30		1.37		680		1.37		660
30	250	DI		1.03		590		1.03		575
36	150	30		1.58		1,005		1.58		975
36	250	DI		1.15		850		1.15		815
42	150	30		1.78		1,535		1.78		1,355
42	250	DI		1.28		1,180		1.28		1,110
48	150	30		1.96		1,950		1.96		1,810
48	250	DI		1.42		1,595		1.42		1,455

* All plugs and caps 30 in. and larger are "dished."
† Ductile Iron.

Metric conversions: Iron strength: psi (1000's) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

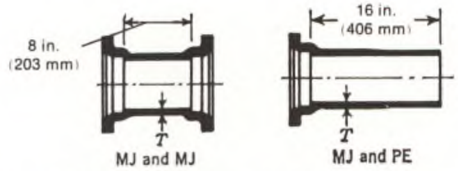


Fig. 10.12. Mechanical-Joint Connecting Pieces (See Table 10.12)

TABLE 10.12

*Mechanical-Joint Connecting Pieces**

Size *in.*	Pressure Rating *psi*	Iron Strength *psi* (*1000*'s)	*T*—*in.*	Weight—*lb*†	
				MJ & MJ	MJ & PE‡
3	250	25	0.48	35	35
3	350	DI§	0.48	35	35
4	250	25	0.52	45	45
4	350	DI	0.52	45	45
6	250	25	0.55	70	65
6	350	DI	0.55	70	65
8	250	25	0.60	95	95
8	350	DI	0.60	95	95
10	250	25	0.68	130	125
10	350	DI	0.68	130	125
12	250	25	0.75	165	165
12	350	DI	0.75	165	165
14	150	25	0.66	220	205
14	250	25	0.82	235	220
14	350	DI	0.66	220	205
16	150	30	0.70	270	250
16	250	30	0.89	290	270
16	350	DI	0.70	270	250
18	150	30	0.75	325	300
18	250	30	0.96	350	325
18	350	DI	0.75	325	300
20	150	30	0.80	390	360
20	250	30	1.03	420	385
20	350	DI	0.80	390	360
24	150	30	0.89	515	475
24	250	30	1.16	555	515
24	350	DI	0.89	515	475
30	150	30	1.03	840	730
30	250	30	1.37	905	795
30	250	DI	1.03	840	730
36	150	30	1.15	1,170	1,005
36	250	30	1.58	1,270	1,105
36	250	DI	1.15	1,170	1,005
42	150	30	1.28	1,500	1,295
42	250	30	1.78	1,635	1,430
42	250	DI	1.28	1,500	1,295
48	150	30	1.42	1,910	1,640
48	250	30	1.96	2,075	1,810
48	250	DI	1.42	1,910	1,640

* For dimensional details of mechanical joints, see Table 10.1; plain ends, Table 10.2.
† Weight does not include accessory weights. See Table 10.1 for accessory weights.
‡ May be furnished from centrifugally cast pipe.
§ Ductile iron.

Metric conversions: Iron strength: psi (1000's) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

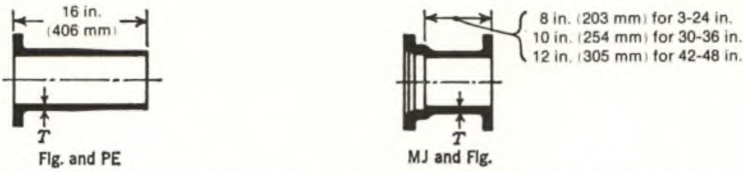


Fig. 10.13. Connecting Pieces, One-End Flanged (See Table 10.13)

TABLE 10.13

*Connecting Pieces, One-End Flanged**

Size *in.*	Pressure Rating *psi*	Iron Strength *psi* *(1000's)*	*T—in.*	Weight—*lb*†	
				MJ & Flg.‡	Flg. & PE‡
3	250	25	0.48	30	30
3	250	DI§	0.48	30	30
4	250	25	0.52	40	40
4	250	DI	0.52	40	40
6	250	25	0.55	60	55
6	250	DI	0.55	60	55
8	250	25	0.60	85	85
8	250	DI	0.60	85	85
10	250	25	0.68	115	115
10	250	DI	0.68	115	115
12	250	25	0.75	155	155
12	250	DI	0.75	155	155
14	150	25	0.66	195	180
14	250	25	0.82	210	195
14	250	DI	0.66	195	180
16	150	30	0.70	240	220
16	250	30	0.89	260	240
16	250	DI	0.70	240	220
18	150	30	0.75	280	255
18	250	30	0.96	305	280
18	250	DI	0.75	280	255
20	150	30	0.80	340	305
20	250	30	1.03	365	335
20	250	DI	0.80	340	305
24	150	30	0.89	455	415
24	250	30	1.16	495	455
24	250	DI	0.89	455	415
30	150	30	1.03	760	600
30	250	30	1.37	840	665
30	250	DI	1.03	760	600
36	150	30	1.15	1,070	830
36	250	30	1.58	1,195	930
36	250	DI	1.15	1,070	830
42	150	30	1.28	1,505	1,115
42	250	30	1.78	1,685	1,250
42	250	DI	1.28	1,505	1,115
48	150	30	1.42	1,885	1,390
48	250	30	1.96	2,140	1,560
48	250	DI	1.42	1,885	1,390

* For dimensional details of mechanical joints, see Table 10.1; plain ends, Table 10.3; flanges, Table 10.14.
† Weight does not include accessory weights. See Table 10.1 for accessory weights.
‡ May be furnished from centrifugally cast pipe.
§ Ductile Iron.

Metric conversions: Iron strength: psi (1000's) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

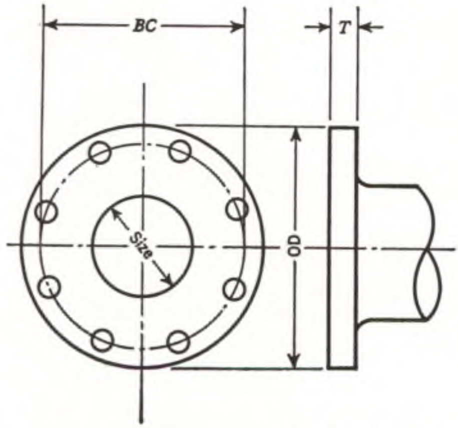


Fig. 10.14. Flange Details (See Table 10.14)

TABLE 10.14

Flange Details

Size *in.*	Dimensions—*in.*					No. of Bolts
	OD	*BC*	*T*	Bolt Hole Diam.	Bolt Diam. & Length—*in.*	
3	7.50	6.00	0.75 ± .12	$\frac{3}{4}$	$\frac{5}{8} \times 2\frac{1}{2}$	4
4	9.00	7.50	0.94 ± .12	$\frac{3}{4}$	$\frac{5}{8} \times 3$	8
6	11.00	9.50	1.00 ± .12	$\frac{7}{8}$	$\frac{3}{4} \times 3\frac{1}{2}$	8
8	13.50	11.75	1.12 ± .12	$\frac{7}{8}$	$\frac{3}{4} \times 3\frac{1}{2}$	8
10	16.00	14.25	1.19 ± .12	1	$\frac{7}{8} \times 4$	12
12	19.00	17.00	1.25 ± .12	1	$\frac{7}{8} \times 4$	12
14	21.00	18.75	1.38 ± .19	$1\frac{1}{8}$	$1 \times 4\frac{1}{2}$	12
16	23.50	21.25	1.44 ± .19	$1\frac{1}{8}$	$1 \times 4\frac{1}{2}$	16
18	25.00	22.75	1.56 ± .19	$1\frac{1}{4}$	$1\frac{1}{8} \times 5$	16
20	27.50	25.00	1.69 ± .19	$1\frac{1}{4}$	$1\frac{1}{8} \times 5$	20
24	32.00	29.50	1.88 ± .19	$1\frac{3}{8}$	$1\frac{1}{4} \times 5\frac{1}{2}$	20
30	38.75	36.00	2.12 ± .25	$1\frac{3}{8}$	$1\frac{1}{4} \times 6\frac{1}{2}$	28
36	46.00	42.75	2.38 ± .25	$1\frac{5}{8}$	$1\frac{1}{2} \times 7$	32
42	53.00	49.50	2.62 ± .25	$1\frac{5}{8}$	$1\frac{1}{2} \times 7\frac{1}{2}$	36
48	59.50	56.00	2.75 ± .25	$1\frac{5}{8}$	$1\frac{1}{2} \times 8$	44

NOTE: For other requirements see Sec. 10-14.

Metric conversions: Iron strength: psi (1000's) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

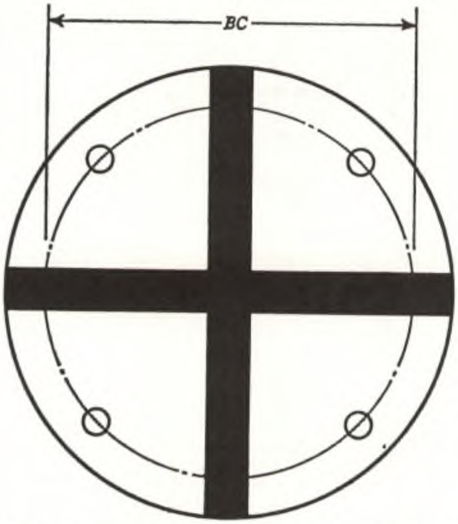


Fig. 10.15. Base Drilling Details (See Table 10.15)

TABLE 10.15

*Base Drilling Details**

Nom. Diam. *in.*	Dimensions—*in.*			Approx. Wgt. of Base—*lb.*	
	BC	Bolt Hole Diam.	No. of Bolts	Bends	Tees
3	3.88	5/8	4	10	5
4	4.75	3/4	4	10	10
6	5.50	3/4	4	20	15
8	7.50	3/4	4	40	30
10	7.50	3/4	4	45	30
12	9.50	7/8	4	65	45
14	9.50	7/8	4	70	50
16	9.50	7/8	4	75	50
18	11.75	7/8	4	115	75
20	11.75	7/8	4	120	75
24	11.75	7/8	4	130	80
30	14.25	1	4	190	120
36	17.00	1	4	250	160
42	21.25	1 1/8	4	410	270
48	22.75	1 1/4	4	515	335

* Bases are not faced or drilled unless so specified in the purchase order.

Metric conversions: Iron strength: psi (1000's) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

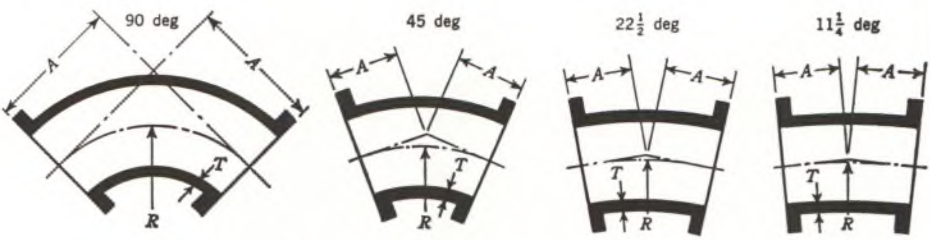


Fig. 10.16. Flanged Bends (See Table 10.16)

TABLE 10.16

*Flanged Bends**

Size *in.*	PR† *psi*	Iron Strength *psi (1000's)*	*T*	90 deg		45 deg		22½ deg		11¼ deg		90 deg	45 deg	22½ deg	11¼ deg
				A	*R*	*A*	*R*	*A*	*R*	*A*	*R*				
			Dimensions—*in.*									Weight—*lb*			
3	250	25	0.48	5.5	4.0	3.0	3.62	3.0	7.56	3.0	15.25	25	20	20	20
4	250	25	0.52	6.5	4.5	4.0	4.81	4.0	10.06	4.0	20.31	45	40	40	40
6	250	25	0.55	8.0	6.0	5.0	7.25	5.0	15.06	5.0	30.50	65	55	55	55
8	250	25	0.60	9.0	7.0	5.5	8.44	5.5	17.62	5.5	35.50	105	90	90	90
10	250	25	0.68	11.0	9.0	6.5	10.88	6.5	22.62	6.5	45.69	165	130	135	135
12	250	25	0.75	12.0	10.0	7.5	13.25	7.5	27.62	7.5	55.81	235	195	205	205
14	150	25	0.66	14.0	11.5	7.5	12.06	7.5	25.12	7.5	50.75	290	220	225	225
14	250	25	0.82	14.0	11.5	7.5	12.06	7.5	25.12	7.5	50.75	330	245	250	255
14	250	DI‡	0.66	14.0	11.5	7.5	12.06	7.5	25.12	7.5	50.75	290	220	225	225
16	150	30	0.70	15.0	12.5	8.0	13.25	8.0	27.62	8.0	55.81	370	280	285	285
16	250	30	0.89	15.0	12.5	8.0	13.25	8.0	27.62	8.0	55.81	430	315	325	325
16	250	DI	0.70	15.0	12.5	8.0	13.25	8.0	27.62	8.0	55.81	370	280	285	285
18	150	30	0.75	16.5	14.0	8.5	14.50	8.5	30.19	8.5	60.94	450	325	335	335
18	250	30	0.96	16.5	14.0	8.5	14.50	8.5	30.19	8.5	60.94	530	375	385	385
18	250	DI	0.75	16.5	14.0	8.5	14.50	8.5	30.19	8.5	60.94	450	325	335	335
20	150	30	0.80	18.0	15.5	9.5	16.88	9.5	35.19	9.5	71.06	580	430	435	435
20	250	30	1.03	18.0	15.5	9.5	16.88	9.5	35.19	9.5	71.06	685	485	505	505
20	250	DI	0.80	18.0	15.5	9.5	16.88	9.5	35.19	9.5	71.06	580	430	435	435
24	150	30	0.89	22.0	18.5	11.0	18.12	11.0	37.69	11.0	76.12	900	630	640	645
24	250	30	1.16	22.0	18.5	11.0	18.12	11.0	37.69	11.0	76.12	1,085	730	755	760
24	250	DI	0.89	22.0	18.5	11.0	18.12	11.0	37.69	11.0	76.12	900	630	640	645
30	150	30	1.03	25.0	21.5	15.0	27.75	15.0	57.81	15.0	116.75	1,430	1,120	1,135	1,150
30	250	30	1.37	25.0	21.5	15.0	27.75	15.0	57.81	15.0	116.75	1,755	1,335	1,385	1,395
30	250	DI	1.03	25.0	21.5	15.0	27.75	15.0	57.81	15.0	116.75	1,430	1,120	1,135	1,150
36	150	30	1.15	28.0	24.5	18.0	35.00	18.0	72.88	18.0	147.25	2,135	1,755	1,790	1,805
36	250	30	1.58	28.0	24.5	18.0	35.00	18.0	72.88	18.0	147.25	2,690	2,155	2,235	2,250
36	250	DI	1.15	28.0	24.5	18.0	35.00	18.0	72.88	18.0	147.25	2,135	1,755	1,790	1,805
42	150	30	1.28	31.0	27.5	21.0	42.25	21.0	88.00	21.0	177.69	3,055	2,600	2,665	2,680
42	250	30	1.78	31.0	27.5	21.0	42.25	21.0	88.00	21.0	177.69	3,880	3,240	3,365	3,390
42	250	DI	1.28	31.0	27.5	21.0	42.25	21.0	88.00	21.0	177.69	3,055	2,600	2,665	2,680
48	150	30	1.42	34.0	30.5	24.0	49.50	24.0	103.06	24.0	208.12	4,095	3,580	3,665	3,695
48	250	30	1.96	34.0	30.5	24.0	49.50	24.0	103.06	24.0	208.12	5,210	4,485	4,660	4,690
48	250	DI	1.42	34.0	30.5	24.0	49.50	24.0	103.06	24.0	208.12	4,095	3,580	3,665	3,695

* Dimension details of flanges are shown in Table 10.14.
† Pressure rating.
‡ Ductile iron.

Metric conversions: Iron strength: psi (1000's) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

Fig. 10.17. Flanged Tees and Crosses (See Table 10.17)

TABLE 10.17

*Flanged Tees and Crosses**

Size—*in.*		Pressure Rating *psi*	Iron Strength *psi (1000's)*	Dimensions—*in.*				Weight—*lb*	
Run	Branch			T	T_1	H	J	Tee	Cross
3	3	250	25	0.48	0.48	5.5	5.5	40	50
4	3	250	25	0.52	0.48	6.5	6.5	60	70
4	4	250	25	0.52	0.52	6.5	6.5	65	80
6	3	250	25	0.55	0.48	8.0	8.0	85	95
6	4	250	25	0.55	0.52	8.0	8.0	90	110
6	6	250	25	0.55	0.55	8.0	8.0	95	120
8	4	250	25	0.60	0.52	9.0	9.0	140	155
8	6	250	25	0.60	0.55	9.0	9.0	145	165
8	8	250	25	0.60	0.60	9.0	9.0	155	195
10	4	250	25	0.68	0.52	11.0	11.0	205	220
10	6	250	25	0.68	0.55	11.0	11.0	215	240
10	8	250	25	0.68	0.60	11.0	11.0	225	265
10	10	250	25	0.80	0.80	11.0	11.0	270	330
12	4	250	25	0.75	0.52	12.0	12.0	290	310
12	6	250	25	0.75	0.55	12.0	12.0	295	320
12	8	250	25	0.75	0.60	12.0	12.0	310	345
12	10	250	25	0.87	0.80	12.0	12.0	360	415
12	12	250	25	0.87	0.87	12.0	12.0	385	460
14	6	150	25	0.66	0.55	14.0	14.0	375	400
14	6	250	25	0.82	0.55	14.0	14.0	420	450
14	6	250	DI†	0.66	0.55	14.0	14.0	375	400
14	8	150	25	0.66	0.60	14.0	14.0	390	425
14	8	250	25	0.82	0.60	14.0	14.0	435	475
14	8	250	DI	0.66	0.60	14.0	14.0	390	425
14	10	150	25	0.66	0.68	14.0	14.0	400	460
14	10	250	25	0.82	0.68	14.0	14.0	450	505
14	10	250	DI	0.66	0.68	14.0	14.0	400	460
14	12	150	25	0.82	0.75	14.0	14.0	470	555
14	12	250	30	0.82	0.75	14.0	14.0	470	555
14	12	250	DI	0.66	0.75	14.0	14.0	425	505
14	14	150	25	0.82	0.82	14.0	14.0	500	595
14	14	250	30	0.82	0.82	14.0	14.0	500	595
14	14	250	DI	0.66	0.66	14.0	14.0	435	530
16	6	150	30	0.70	0.55	15.0	15.0	465	490
16	6	250	30	0.89	0.55	15.0	15.0	540	565
16	6	250	DI	0.70	0.55	15.0	15.0	465	490
16	8	150	30	0.70	0.60	15.0	15.0	475	520
16	8	250	30	0.89	0.60	15.0	15.0	555	590

* Dimension details of flanges are in Table 10.14.
† Ductile Iron.

Metric conversions: Iron strength: psi (1000's) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

TABLE 10.17

Flanged Tees and Crosses (contd.)*

Size—*in.*		Pressure Rating *psi*	Iron Strength *psi* *(1000's)*	Dimensions—*in.*				Weight—*lb*	
Run	Branch			*T*	T_1	*H*	*J*	Tee	Cross
16	8	250	DI†	0.70	0.60	15.0	15.0	475	520
16	10	150	30	0.70	0.68	15.0	15.0	495	555
16	10	250	30	0.89	0.68	15.0	15.0	565	620
16	10	250	DI	0.70	0.68	15.0	15.0	495	555
16	12	150	30	0.70	0.75	15.0	15.0	520	605
16	12	250	30	0.89	0.75	15.0	15.0	590	665
16	12	250	DI	0.70	0.75	15.0	15.0	520	605
16	14	150	30	0.89	0.82	15.0	15.0	610	700
16	14	250	35	0.89	0.82	15.0	15.0	610	700
16	14	250	DI	0.70	0.66	15.0	15.0	530	620
16	16	150	30	0.89	0.89	15.0	15.0	635	755
16	16	250	35	0.89	0.89	15.0	15.0	635	755
16	16	250	DI	0.70	0.70	15.0	15.0	550	665
18	6	150	30	0.75	0.55	13.0	15.5	480	505
18	6	250	30	0.96	0.55	13.0	15.5	560	585
18	6	250	DI	0.75	0.55	13.0	15.5	480	505
18	8	150	30	0.75	0.60	13.0	15.5	495	535
18	8	250	30	0.96	0.60	13.0	15.5	570	605
18	8	250	DI	0.75	0.60	13.0	15.5	495	535
18	10	150	30	0.75	0.68	13.0	15.5	510	560
18	10	250	30	0.96	0.68	13.0	15.5	585	630
18	10	250	DI	0.75	0.68	13.0	15.5	510	560
18	12	150	30	0.75	0.75	13.0	15.5	535	610
18	12	250	30	0.96	0.75	13.0	15.5	605	670
18	12	250	DI	0.75	0.75	13.0	15.5	535	610
18	14	150	30	0.75	0.66	16.5	16.5	630	720
18	14	250	30	0.96	0.82	16.5	16.5	740	830
18	14	250	DI	0.75	0.66	16.5	16.5	630	720
18	16	150	30	0.96	0.89	16.5	16.5	760	880
18	16	250	35	0.96	0.89	16.5	16.5	760	880
18	16	250	DI	0.75	0.70	16.5	16.5	650	765
18	18	150	30	0.96	0.96	16.5	16.5	785	915
18	18	250	35	0.96	0.96	16.5	16.5	785	915
18	18	250	DI	0.75	0.75	16.5	16.5	665	795
20	6	150	30	0.80	0.55	14.0	17.0	610	635
20	6	250	30	1.03	0.55	14.0	17.0	710	735
20	6	250	DI	0.80	0.55	14.0	17.0	610	635
20	8	150	30	0.80	0.60	14.0	17.0	620	665
20	8	250	30	1.03	0.60	14.0	17.0	720	755
20	8	250	DI	0.80	0.60	14.0	17.0	620	665
20	10	150	30	0.80	0.68	14.0	17.0	635	685
20	10	250	30	1.03	0.68	14.0	17.0	735	780
20	10	250	DI	0.80	0.68	14.0	17.0	635	685
20	12	150	30	0.80	0.75	14.0	17.0	660	735
20	12	250	30	1.03	0.75	14.0	17.0	755	820
20	12	250	DI	0.80	0.75	14.0	17.0	660	735
20	14	150	30	0.80	0.66	14.0	17.0	665	745
20	14	250	35	1.03	0.82	14.0	17.0	770	850
20	14	250	DI	0.80	0.66	14.0	17.0	665	745
20	16	150	30	0.80	0.70	18.0	18.0	810	915
20	16	250	35	1.03	0.89	18.0	18.0	950	1,065
20	16	250	DI	0.80	0.70	18.0	18.0	810	915
20	18	150	35	1.03	0.96	18.0	18.0	965	1,100
20	18	250	DI	0.80	0.75	18.0	18.0	820	945
20	20	150	35	1.03	1.03	18.0	18.0	1,005	1,175
20	20	250	DI	0.80	0.80	18.0	18.0	855	1,015

* Dimension details of flanges are in Table 10.14.
† Ductile Iron.

TABLE 10.17

Flanged Tees and Crosses (contd.)*

Size—in.		Pressure Rating psi	Iron Strength psi (1000's)	Dimensions—in.				Weight—lb	
Run	Branch			T	T_1	H	J	Tee	Cross
24	6	150	30	0.89	0.55	15.0	19.0	845	875
24	6	250	30	1.16	0.55	15.0	19.0	1,000	1,025
24	6	250	DI†	0.89	0.55	15.0	19.0	845	875
24	8	150	30	0.89	0.60	15.0	19.0	860	895
24	8	250	30	1.16	0.60	15.0	19.0	1,010	1,045
24	8	250	DI	0.89	0.60	15.0	19.0	860	895
24	10	150	30	0.89	0.68	15.0	19.0	880	930
24	10	250	30	1.16	0.68	15.0	19.0	1,020	1,065
24	10	250	DI	0.89	0.68	15.0	19.0	880	930
24	12	150	30	0.89	0.75	15.0	19.0	890	960
24	12	250	30	1.16	0.75	15.0	19.0	1,040	1,100
24	12	250	DI	0.89	0.75	15.0	19.0	890	960
24	14	150	30	0.89	0.66	15.0	19.0	900	975
24	14	250	30	1.16	0.82	15.0	19.0	1,050	1,125
24	14	250	DI	0.89	0.66	15.0	19.0	900	975
24	16	150	30	0.89	0.70	15.0	19.0	915	1,010
24	16	250	35	1.16	0.89	15.0	19.0	1,070	1,160
24	16	250	DI	0.89	0.70	15.0	19.0	915	1,010
24	18	150	30	0.89	0.75	22.0	22.0	1,220	1,365
24	18	250	35	1.16	0.96	22.0	22.0	1,470	1,620
24	18	250	DI	0.89	0.75	22.0	22.0	1,220	1,365
24	20	150	35	1.16	1.03	22.0	22.0	1,510	1,695
24	20	250	DI	0.89	0.80	22.0	22.0	1,255	1,430
24	24	150	35	1.16	1.16	22.0	22.0	1,585	1,850
24	24	250	DI	0.89	0.89	22.0	22.0	1,330	1,570
30	12	150	30	1.03	0.75	18.0	23.0	1,490	1,565
30	12	250	30	1.37	0.75	18.0	23.0	1,780	1,840
30	12	250	DI	1.03	0.75	18.0	23.0	1,490	1,565
30	14	150	30	1.03	0.66	18.0	23.0	1,490	1,570
30	14	250	30	1.37	0.82	18.0	23.0	1,790	1,865
30	14	250	DI	1.03	0.66	18.0	23.0	1,490	1,570
30	16	150	30	1.03	0.70	18.0	23.0	1,505	1,605
30	16	250	30	1.37	0.89	18.0	23.0	1,810	1,900
30	16	250	DI	1.03	0.70	18.0	23.0	1,505	1,605
30	18	150	30	1.03	0.75	18.0	23.0	1,515	1,615
30	18	250	35	1.37	0.96	18.0	23.0	1,815	1,910
30	18	250	DI	1.03	0.75	18.0	23.0	1,515	1,615
30	20	150	30	1.03	0.80	18.0	23.0	1,540	1,670
30	20	250	35	1.37	1.03	18.0	23.0	1,840	1,960
30	20	250	DI	1.03	0.80	18.0	23.0	1,540	1,670
30	24	150	35	1.37	1.16	25.0	25.0	2,475	2,695
30	24	250	DI	1.03	0.89	25.0	25.0	2,025	2,245
30	30	150	35	1.37	1.37	25.0	25.0	2,615	2,980
30	30	250	DI	1.03	1.03	25.0	25.0	2,150	2,500
36	12	150	30	1.15	0.75	20.0	26.0	2,170	2,240
36	12	250	30	1.58	0.75	20.0	26.0	2,670	2,725
36	12	250	DI	1.15	0.75	20.0	26.0	2,170	2,240
36	14	150	30	1.15	0.66	20.0	26.0	2,175	2,240
36	14	250	30	1.58	0.82	20.0	26.0	2,680	2,740
36	14	250	DI	1.15	0.66	20.0	26.0	2,175	2,240
36	16	150	30	1.15	0.70	20.0	26.0	2,185	2,270
36	16	250	30	1.58	0.89	20.0	26.0	2,690	2,765
36	16	250	DI	1.15	0.70	20.0	26.0	2,185	2,270
36	18	150	30	1.15	0.75	20.0	26.0	2,190	2,280
36	18	250	30	1.58	0.96	20.0	26.0	2,695	2,770
36	18	250	DI	1.15	0.75	20.0	26.0	2,190	2,280
36	20	150	30	1.15	0.80	20.0	26.0	2,210	2,325
36	20	250	35	1.58	1.03	20.0	26.0	2,715	2,810

* Dimension details of flanges are in Table 10.14.
† Ductile Iron.

TABLE 10.17

Flanged Tees and Crosses (contd.)*

Size—*in.*		Pressure Rating *psi*	Iron Strength *psi* *(1000's)*	Dimensions—*in.*				Weight—*lb*	
Run	Branch			*T*	T_1	*H*	*J*	Tee	Cross
36	20	250	DI†	1.15	0.80	20.0	26.0	2,210	2,325
36	24	150	30	1.15	0.89	20.0	26.0	2,255	2,405
36	24	250	35	1.58	1.16	20.0	26.0	2,750	2,880
36	24	250	DI	1.15	0.89	20.0	26.0	2,255	2,405
36	30	150	35	1.58	1.37	28.0	28.0	3,745	4,025
36	30	250	DI	1.15	1.03	28.0	28.0	3,000	3,300
36	36	150	35	1.58	1.58	28.0	28.0	3,930	4,405
36	36	250	DI	1.15	1.15	28.0	28.0	3,160	3,620
42	12	150	30	1.28	0.75	23.0	30.0	3,165	3,240
42	12	250	30	1.78	0.75	23.0	30.0	3,950	4,005
42	12	250	DI	1.28	0.75	23.0	30.0	3,165	3,240
42	14	150	30	1.28	0.66	23.0	30.0	3,170	3,240
42	14	250	30	1.78	0.82	23.0	30.0	3,960	4,020
42	14	250	DI	1.28	0.66	23.0	30.0	3,170	3,240
42	16	150	30	1.28	0.70	23.0	30.0	3,180	3,270
42	16	250	30	1.78	0.89	23.0	30.0	3,970	4,045
42	16	250	DI	1.28	0.70	23.0	30.0	3,180	3,270
42	18	150	30	1.28	0.75	23.0	30.0	3,185	3,275
42	18	250	30	1.78	0.96	23.0	30.0	3,970	4,045
42	18	250	DI	1.28	0.75	23.0	30.0	3,185	3,275
42	20	150	30	1.28	0.80	23.0	30.0	3,205	3,320
42	20	250	30	1.78	1.03	23.0	30.0	3,990	4,080
42	20	250	DI	1.28	0.80	23.0	30.0	3,205	3,320
42	24	150	30	1.78	1.16	23.0	30.0	4,020	4,135
42	24	250	DI	1.28	0.89	23.0	30.0	3,245	3,395
42	30	150	30	1.78	1.37	31.0	31.0	5,225	5,445
42	30	250	DI	1.28	1.03	31.0	31.0	4,125	4,375
42	36	150	DI	1.28	1.15	31.0	31.0	4,265	4,655
42	36	250	DI	1.78	1.58	31.0	31.0	5,360	5,720
42	42	150	DI	1.28	1.28	31.0	31.0	4,470	5,065
42	42	250	DI	1.78	1.78	31.0	31.0	5,580	6,155
48	12	150	30	1.42	0.75	26.0	34.0	4,315	4,390
48	12	250	30	1.96	0.75	26.0	34.0	5,425	5,480
48	12	250	DI	1.42	0.75	26.0	34.0	4,315	4,390
48	14	150	30	1.42	0.66	26.0	34.0	4,315	4,385
48	14	250	30	1.96	0.82	26.0	34.0	5,435	5,495
48	14	250	DI	1.42	0.66	26.0	34.0	4,315	4,385
48	16	150	30	1.42	0.70	26.0	34.0	4,330	4,415
48	16	250	30	1.96	0.89	26.0	34.0	5,445	5,515
48	16	250	DI	1.42	0.70	26.0	34.0	4,330	4,415
48	18	150	30	1.42	0.75	26.0	34.0	4,330	4,420
48	18	250	30	1.96	0.96	26.0	34.0	5,445	5,515
48	18	250	DI	1.42	0.75	26.0	34.0	4,330	4,420
48	20	150	30	1.42	0.80	26.0	34.0	4,350	4,460
48	20	250	30	1.96	1.03	26.0	34.0	5,460	5,545
48	20	250	DI	1.42	0.80	26.0	34.0	4,350	4,460
48	24	150	30	1.42	0.89	26.0	34.0	4,385	4,535
48	24	250	30	1.96	1.16	26.0	34.0	5,485	5,595
48	24	250	DI	1.42	0.89	26.0	34.0	4,385	4,535
48	30	150	30	1.96	1.37	26.0	34.0	5,540	5,705
48	30	250	DI	1.42	1.03	26.0	34.0	4,455	4,670
48	36	150	30	1.96	1.58	34.0	34.0	7,035	7,310
48	36	250	DI	1.42	1.15	34.0	34.0	5,555	5,880
48	42	150	DI	1.42	1.28	34.0	34.0	5,720	6,215
48	42	250	DI	1.96	1.78	34.0	34.0	7,195	7,630
48	48	150	DI	1.42	1.42	34.0	34.0	5,900	6,570
48	48	250	DI	1.96	1.96	34.0	34.0	7,385	8,005

* Dimension details of flanges are in Table 10.14.
† Ductile Iron.

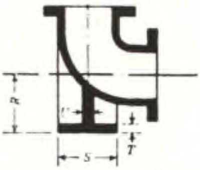


Fig. 10.18. Flanged Base Bends (See Table 10.18)
For other dimensions of base bends, see Table 10.16.

TABLE 10.18

Flanged Base Bends

Size *in.*	Pressure Rating *psi*	Iron Strength *psi (1000's)*	Dimensions—*in.*				Weight—*lb*	
			*R**	*S* Diam.	*T*	*U*	Base Fitting	Base Only
3	250	25	4.88	5.00	0.56	0.50	35	10
4	250	25	5.50	6.00	0.62	0.50	55	10
6	250	25	7.00	7.00	0.69	0.62	85	20
8	250	25	8.38	9.00	0.94	0.88	145	40
10	250	25	9.75	9.00	0.94	0.88	210	45
12	250	25	11.25	11.00	1.00	1.00	300	65
14	150	25	12.50	11.00	1.00	1.00	360	70
14	250	25	12.50	11.00	1.00	1.00	400	70
14	250	DI†	12.50	11.00	1.00	1.00	360	70
16	150	30	13.75	11.00	1.00	1.00	445	75
16	250	30	13.75	11.00	1.00	1.00	505	75
16	250	DI	13.75	11.00	1.00	1.00	445	75
18	150	30	15.00	13.50	1.12	1.12	565	115
18	250	30	15.00	13.50	1.12	1.12	645	115
18	250	DI	15.00	13.50	1.12	1.12	565	115
20	150	30	16.00	13.50	1.12	1.12	700	120
20	250	30	16.00	13.50	1.12	1.12	805	120
20	250	DI	16.00	13.50	1.12	1.12	700	120
24	150	30	18.50	13.50	1.12	1.12	1,030	130
24	250	30	18.50	13.50	1.12	1.12	1,215	130
24	250	DI	18.50	13.50	1.12	1.12	1,030	130
30	150	30	23.00	16.00	1.19	1.15	1,625	190
30	250	30	23.00	16.00	1.19	1.15	1,945	190
30	250	DI	23.00	16.00	1.19	1.15	1,625	190
36	150	30	26.00	19.00	1.25	1.15	2,385	250
36	250	30	26.00	19.00	1.25	1.15	2,940	250
36	250	DI	26.00	19.00	1.25	1.15	2,385	250
42	150	30	30.00	23.50	1.44	1.28	3,465	410
42	250	30	30.00	23.50	1.44	1.28	4,290	410
42	250	DI	30.00	23.50	1.44	1.28	3,465	410
48	150	30	34.00	25.00	1.56	1.42	4,610	515
48	250	30	34.00	25.00	1.56	1.42	5,725	515
48	250	DI	34.00	25.00	1.56	1.42	4,610	515

*Dimension *R* is a finished dimension; unfinished bases will be ⅛ in. (3 mm) longer; details for base drilling are given in Table 10.15.

†Ductile Iron.

Metric conversions: Iron strength: psi (1000's) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

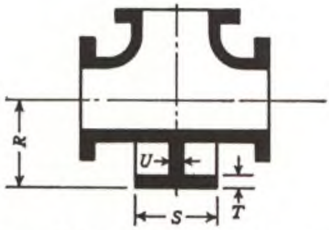


Fig. 10.19. Flanged Base Tees (See Table 10.19)

For other dimensions of base tees, see Table 10.17.

TABLE 10.19

Flanged Base Tees

Size *in.*	Pressure Rating *psi*	Iron Strength *psi (1000's)*	Dimensions—*in.*				Weight—*lb*	
			*R**	*S* Diam.	*T*	*U*	Base Fitting	Base Only
3	250	25	4.88	5.00	0.56	0.50	45	5
4	250	25	5.50	6.00	0.62	0.50	75	10
6	250	25	7.00	7.00	0.69	0.62	110	15
8	250	25	8.38	9.00	0.94	0.88	185	30
10	250	25	9.75	9.00	0.94	0.88	300	30
12	250	25	11.25	11.00	1.00	1.00	430	45
14	150	25	12.50	11.00	1.00	1.00	550	50
14	250	30	12.50	11.00	1.00	1.00	550	50
14	250	DI†	12.50	11.00	1.00	1.00	485	50
16	150	30	13.75	11.00	1.00	1.00	685	50
16	250	35	13.75	11.00	1.00	1.00	685	50
16	250	DI	13.75	11.00	1.00	1.00	600	50
18	150	30	15.00	13.50	1.12	1.12	860	75
18	250	35	15.00	13.50	1.12	1.12	860	75
18	250	DI	15.00	13.50	1.12	1.12	740	75
20	150	35	16.00	13.50	1.12	1.12	1,080	75
20	250	DI	16.00	13.50	1.12	1.12	930	75
24	150	35	18.50	13.50	1.12	1.12	1,665	80
24	250	DI	18.50	13.50	1.12	1.12	1,410	80
30	150	35	23.00	16.00	1.19	1.15	2,735	120
30	250	DI	23.00	16.00	1.19	1.15	2,270	120
36	150	35	26.00	19.00	1.25	1.15	4,090	160
36	250	DI	26.00	19.00	1.25	1.15	3,320	160
42	150	DI	30.00	23.50	1.44	1.28	4,740	270
42	250	DI	30.00	23.50	1.44	1.28	5,850	270
48	150	DI	34.00	25.00	1.56	1.42	6,235	335
48	250	DI	34.00	25.00	1.56	1.42	7,720	335

*Dimension *R* is a finished dimension; unfinished bases will be ⅛ in. (3 mm) longer; details for base drilling are given in Table 10.15.

†Ductile Iron.

Metric conversions: Iron strength: psi (1000's) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

TABLE 10.20
*Flanged Reducers**

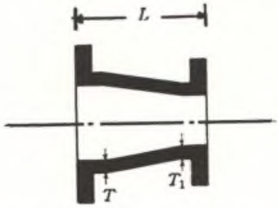


Fig. 10.20. Flanged Reducers (See Table 10.20)

Size—in.		Pressure Rating *psi*	Iron Strength *psi (1000's)*	Dimensions—in.			Wgt. *lb*
Large	Small			T Large End	T_1 Small End	L	
4	3	250	25	0.52	0.48	7	30
6	3	250	25	0.55	0.48	9	40
6	4	250	25	0.55	0.52	9	45
8	4	250	25	0.60	0.52	11	65
8	6	250	25	0.60	0.55	11	75
10	4	250	25	0.68	0.52	12	85
10	6	250	25	0.68	0.55	12	90
10	8	250	25	0.68	0.60	12	110
12	4	250	25	0.75	0.52	14	120
12	6	250	25	0.75	0.55	14	130
12	8	250	25	0.75	0.60	14	145
12	10	250	25	0.75	0.68	14	170
14	6	150	25	0.66	0.55	16	155
14	6	250	25	0.82	0.55	16	165
14	6	250	DI†	0.66	0.55	16	155
14	8	150	25	0.66	0.60	16	175
14	8	250	25	0.82	0.60	16	185
14	8	250	DI	0.66	0.60	16	175
14	10	150	25	0.66	0.68	16	190
14	10	250	25	0.82	0.68	16	205
14	10	250	DI	0.66	0.68	16	190
14	12	150	25	0.66	0.75	16	220
14	12	250	25	0.82	0.75	16	235
14	12	250	DI	0.66	0.75	16	220
16	6	150	30	0.70	0.55	18	190
16	6	250	30	0.89	0.55	18	210
16	6	250	DI	0.70	0.55	18	190
16	8	150	30	0.70	0.60	18	210
16	8	250	30	0.89	0.60	18	230
16	8	250	DI	0.70	0.60	18	210
16	10	150	30	0.70	0.68	18	235
16	10	250	30	0.89	0.68	18	255
16	10	250	DI	0.70	0.68	18	235
16	12	150	30	0.70	0.75	18	265
16	12	250	30	0.89	0.75	18	285
16	12	250	DI	0.70	0.75	18	265
16	14	150	30	0.70	0.66	18	280
16	14	250	30	0.89	0.82	18	315
16	14	250	DI	0.70	0.66	18	280
18	8	150	30	0.75	0.60	19	240
18	8	250	30	0.96	0.60	19	265
18	8	250	DI	0.75	0.60	19	240
18	10	150	30	0.75	0.68	19	265
18	10	250	30	0.96	0.68	19	290
18	10	250	DI	0.75	0.68	19	265
18	12	150	30	0.75	0.75	19	295
18	12	250	30	0.96	0.75	19	320
18	12	250	DI	0.75	0.75	19	295
18	14	150	30	0.75	0.66	19	310
18	14	250	30	0.96	0.82	19	350
18	14	250	DI	0.75	0.66	19	310
18	16	150	30	0.75	0.70	19	340
18	16	250	30	0.96	0.89	19	385
18	16	250	DI	0.75	0.70	19	340
20	10	150	30	0.80	0.68	20	310
20	10	250	30	1.03	0.68	20	340
20	10	250	DI	0.80	0.68	20	310
20	12	150	30	0.80	0.75	20	345
20	12	250	30	1.03	0.75	20	375
20	12	250	DI	0.80	0.75	20	345
20	14	150	30	0.80	0.66	20	355
20	14	250	30	1.03	0.82	20	405
20	14	250	DI	0.80	0.66	20	355
20	16	150	30	0.80	0.70	20	390
20	16	250	30	1.03	0.89	20	445
20	16	250	DI	0.80	0.70	20	390
20	18	150	30	0.80	0.75	20	410
20	18	250	30	1.03	0.96	20	470
20	18	250	DI	0.80	0.75	20	410
24	12	150	30	0.89	0.75	24	480
24	12	250	30	1.16	0.75	24	535
24	12	250	DI	0.89	0.75	24	480
24	14	150	30	0.89	0.66	24	490
24	14	250	30	1.16	0.82	24	565
24	14	250	DI	0.89	0.66	24	490
24	16	150	30	0.89	0.70	24	525
24	16	250	30	1.16	0.89	24	610
24	16	250	DI	0.89	0.70	24	525
24	18	150	30	0.89	0.75	24	550
24	18	250	30	1.16	0.96	24	645
24	18	250	DI	0.89	0.75	24	550
24	20	150	30	0.89	0.80	24	590
24	20	250	30	1.16	1.03	24	695
24	20	250	DI	0.89	0.80	24	590
30	18	150	30	1.03	0.75	30	810
30	18	250	30	1.37	0.96	30	970
30	18	250	DI	1.03	0.75	30	810
30	20	150	30	1.03	0.80	30	870
30	20	250	30	1.37	1.03	30	1,035
30	20	250	DI	1.03	0.80	30	870
30	24	150	30	1.03	0.89	30	970
30	24	250	30	1.37	1.16	30	1,155
30	24	250	DI	1.03	0.89	30	970
36	20	150	30	1.15	0.80	36	1,230
36	20	250	30	1.58	1.03	36	1,495
36	20	250	DI	1.15	0.80	36	1,230
36	24	150	30	1.15	0.89	36	1,345
36	24	250	30	1.58	1.16	36	1,635
36	24	250	DI	1.15	0.89	36	1,345
36	30	150	30	1.15	1.03	36	1,555
36	30	250	30	1.58	1.37	36	1,905
36	30	250	DI	1.15	1.03	36	1,555
42	24	150	30	1.28	0.89	42	1,820
42	24	250	30	1.78	1.16	42	2,235
42	24	250	DI	1.28	0.89	42	1,820
42	30	150	30	1.28	1.03	42	2,060
42	30	250	30	1.78	1.37	42	2,555
42	30	250	DI	1.28	1.03	42	2,060
42	36	150	30	1.28	1.15	42	2,345
42	36	250	30	1.78	1.58	42	2,935
42	36	250	DI	1.28	1.15	42	2,345
48	30	150	30	1.42	1.03	48	2,625
48	30	250	30	1.96	1.37	48	3,270
48	30	250	DI	1.42	1.03	48	2,625
48	36	150	30	1.42	1.15	48	2,950
48	36	250	30	1.96	1.58	48	3,710
48	36	250	DI	1.42	1.15	48	2,950
48	42	150	30	1.42	1.28	48	3,320
48	42	250	30	1.96	1.78	48	4,190
48	42	250	DI	1.42	1.28	48	3,320

* Dimension details of flanges are given in Table 10.14. Eccentric reducers with the same dimensions and weights given for concentric reducers are available from most manufacturers if specified on the purchase order
† Ductile Iron.

Metric conversions: Iron strength: psi (1000's) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

Appendix A
Flanged Fittings—Bolts, Gaskets, and Installation

This appendix is for information only and is not a part of ANSI/AWWA C110/A21.10.

The bolts and gaskets to be used with the flanged fittings are to be selected by the purchaser with due consideration for the particular pressure service and installation requirements.

A.1 Bolts and Nuts

Size, length, and number of bolts are shown in Table 10.14. Bolts conform to ANSI B18.2.1, Square and Hex Bolts and Screws Inch Series Including Hex Cap Screws and Lag Screws, and nuts conform to ANSI B18.2.2., Square and Hex Nuts. Bolts smaller than ¾ in. have either standard square or heavy hex heads and heavy hex nuts. Bolts ¾ in. and larger have either square or hex heads and either hex or heavy hex nuts. Bolts and nuts are threaded in accordance with ANSI B1.1, Unified Inch Screw Threads, (UN and UNR Thread Form) class 2A external and class 2B internal. Bolts and nuts are low-carbon steel and conform to the chemical and mechanical requirements of ASTM A307, Specifications for Carbon Steel Externally Threaded Standard Fasteners, grade B. The carbon steel bolts should be used where gray-iron flanges are installed with flat ring gaskets that extend only to the bolts. Higher strength bolts may properly be used where gray-iron flanges are installed with full-face gaskets. Higher strength bolts may be used where ductile flanges are installed with either ring- or full-face gaskets.

A.2 Gaskets

Gaskets are rubber, either ring or full face, and are ⅛ in. (3.2 mm) thick, unless otherwise specified by the purchaser, conforming to the dimensions shown in Table A.1, Flange Gasket Details.

A.3 Installation

The design, assembly, and installation of the flanged piping system are the responsibility of the purchaser. The following suggestions are for general guidance.

a. The underground use of the flanged joint is generally not desirable because of the rigidity of the joint.

b. Flange faces should bear uniformly on the gasket, and bolts should be tightened uniformly.

c. Users of flanged fittings should be careful to prevent bending or torsional strains from being applied to cast flanges or flanged fittings. Piping systems must be designed so that piping connected to flanges or flanged fittings is properly anchored, supported, or restrained to prevent breakage of fittings and flanges.

TABLE A.1

Flange Gasket Details

Nom. Size *in.*	Dimensions—*in.*						No. of Holes
	Ring		Full Face				
	Nom. *ID*	*OD*	Nom. *ID*	*OD*	*BC*	Bolt Hole Diam.	
3	3	5 3/8	3	7 1/2	6	3/4	4
4	4	6 7/8	4	9	7 1/2	3/4	8
6	6	8 3/4	6	11	9 1/2	7/8	8
8	8	11	8	13 1/2	11 3/4	7/8	8
10	10	13 3/8	10	16	14 1/4	1	12
12	12	16 1/8	12	19	17	1	12
14	14	17 3/4	14	21	18 3/4	1 1/8	12
16	16	20 1/4	16	23 1/2	21 1/4	1 1/8	16
18	18	21 5/8	18	25	22 3/4	1 1/4	16
20	20	23 7/8	20	27 1/2	25	1 1/4	20
24	24	28 1/4	24	32	29 1/2	1 3/8	20
30	30	34 3/4	30	38 3/4	36	1 3/8	28
36	36	41 1/4	36	46	42 3/4	1 5/8	32
42	42	48	42	53	49 1/2	1 5/8	36
48	48	54 1/2	48	59 1/2	56	1 5/8	44

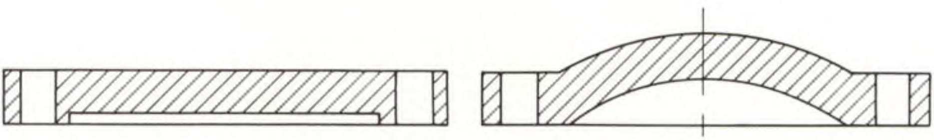
Metric conversions: Iron strength: psi (1000's) × 6.89 = MPa; Pressure rating: psi × 0.00689 = MPa; Dimension: in. × 25.4 = mm; Weight: lb × 0.4536 = kg.

Appendix B

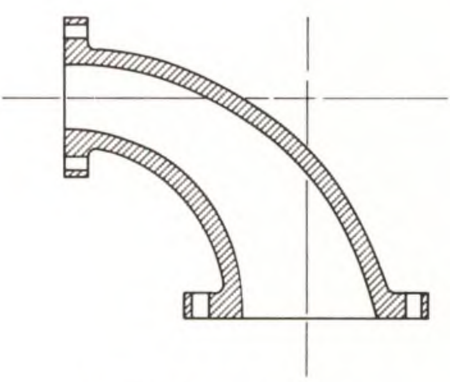
Special Fittings

This appendix is for information only and is not a part of ANSI/AWWA C110.

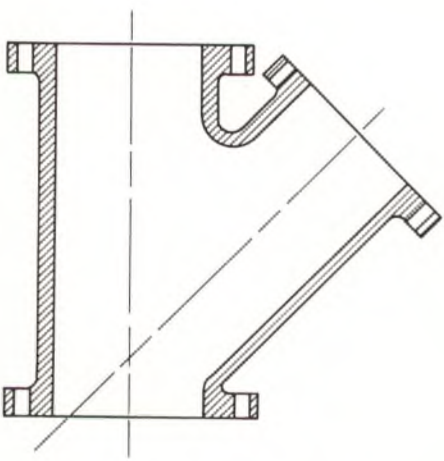
These special fittings are not a part of the standard but are available. For dimensions and pressure ratings, consult your supplier.



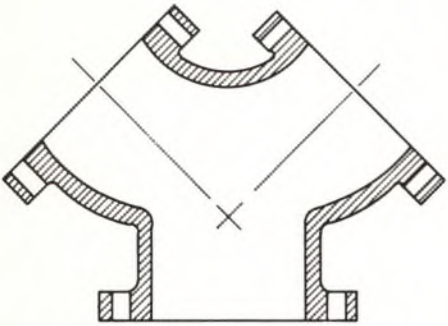
Blind Flanges



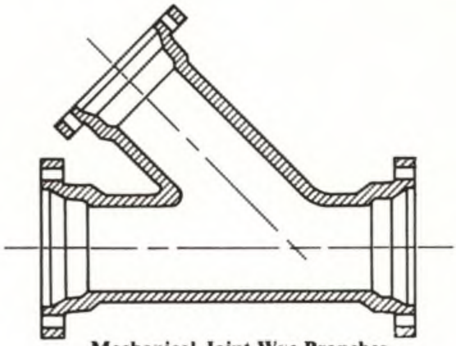
Flanged 90-deg Reducing Bends



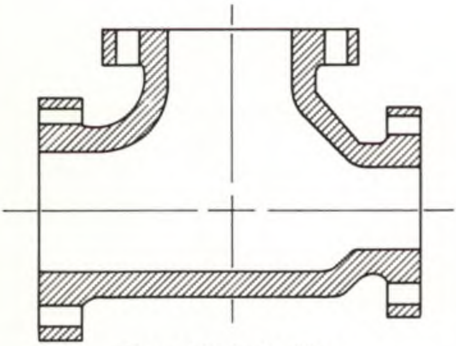
Flange Wye Branches



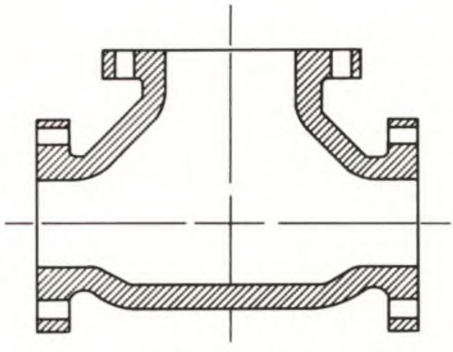
Flanged True Wye



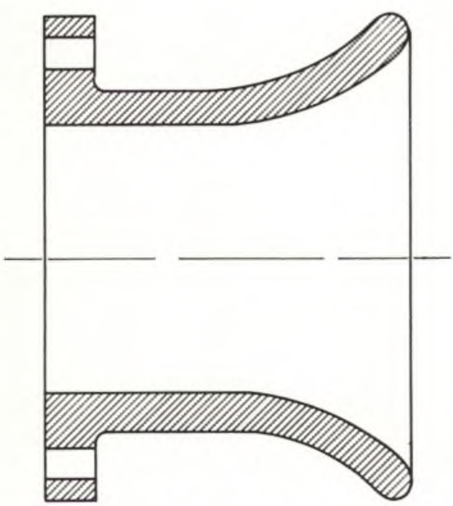
Mechanical-Joint Wye Branches



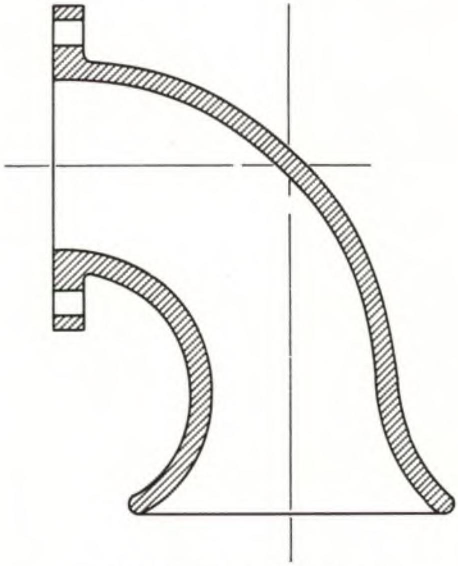
Flanged Reducing Tees



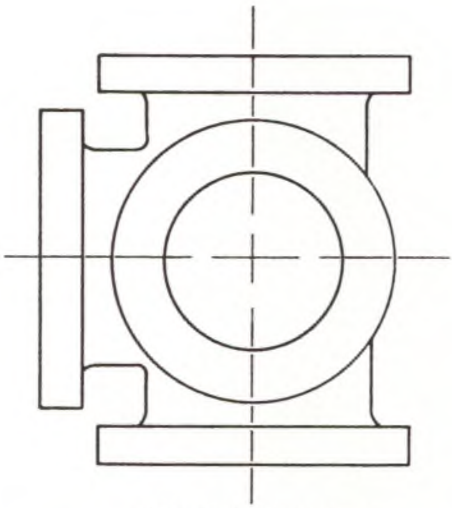
Flanged Bull Head Tees



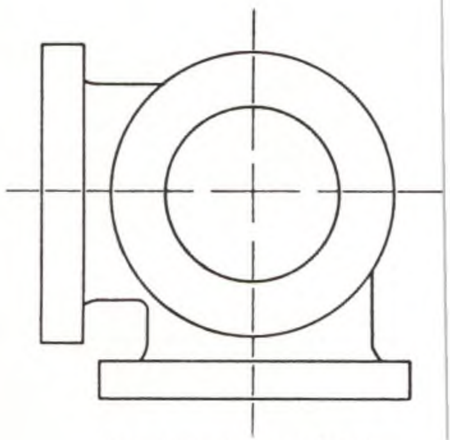
Flange and Flares



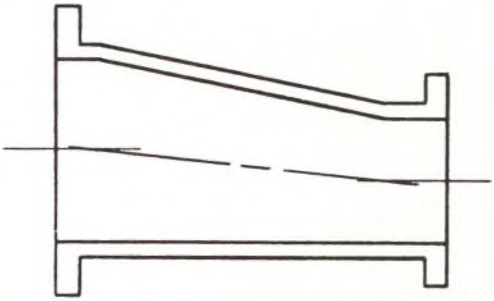
Flange and Flare 90-deg Bends



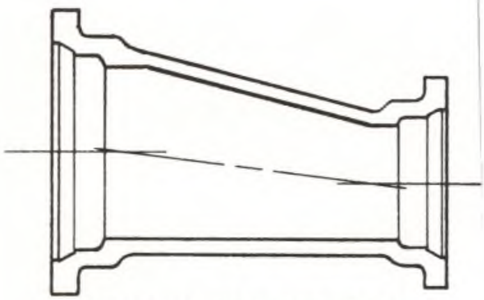
Flanged Side Outlet Tees



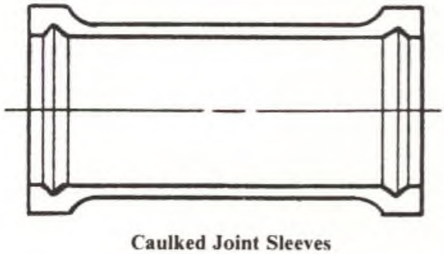
Flanged Side Outlet 90-deg Elbows



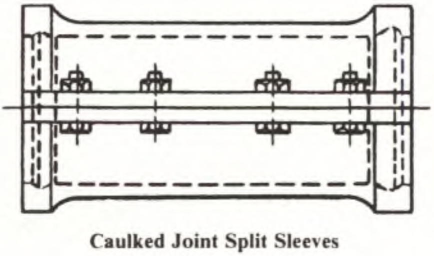
Flanged Eccentric Reducer



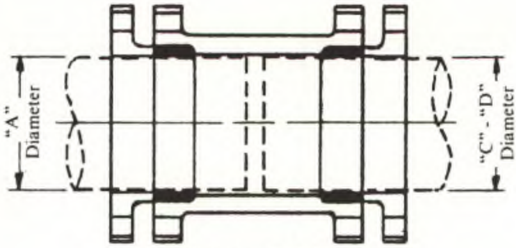
Mechanical Joint Eccentric Reducer



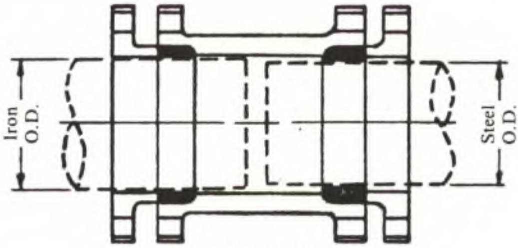
Caulked Joint Sleeves



Caulked Joint Split Sleeves

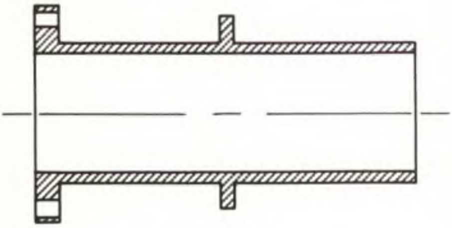


Dual Purpose MJ Sleeves

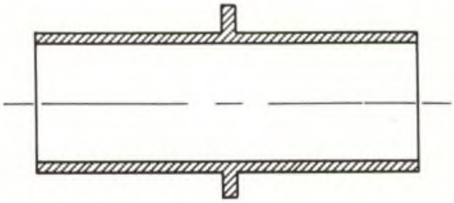


MJ Transition Sleeve

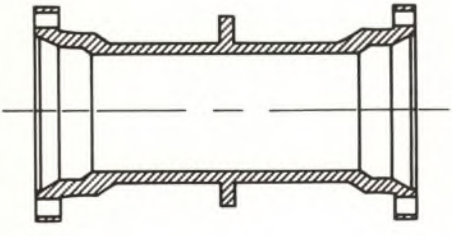
Wall Pipe



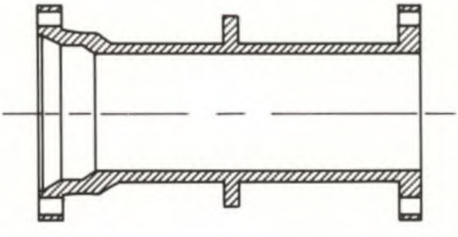
Flange and Plain End



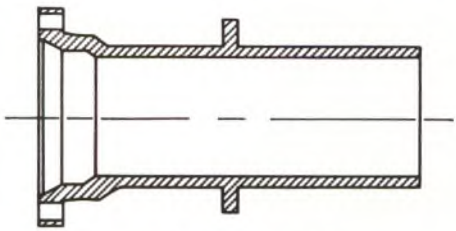
Plain End and Plain End



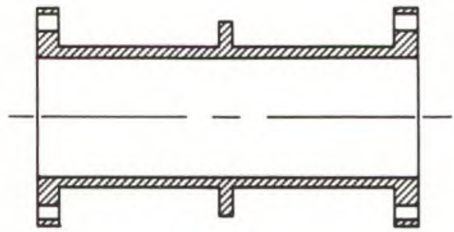
MJ and MJ



MJ and Flange



MJ and Plain End



Flange and Flange

NOTE: Wall pipe can be furnished with tapped holes in flanges or mechanical-joint bells if required. Wall sleeves (other than those shown in Fig. 10.10) are also available on special request.

AWWA C110-82
17 September 1982

SUPERSEDING
AWWA C110-77
7 August 1981
USE INSTEAD OF
WW-P-421 (in part)
13 September 1976

Department of Defense Acceptance Notice

This nongovernment document was adopted and approved for use by the Department of Defense (DoD) on 17 September 1982. The American Water Works Association has furnished the clearance required by existing regulations. Copies of the document are stocked by DoD Single Stock Point, Naval Publications and Forms Center, Philadelphia, PA 19120, for issue to DoD activities only. Contractors and industry groups must obtain copies from AWWA, 6666 West Quincy Ave., Denver, CO 80235.

Title of Document: American National Standard for Ductile-Iron and Gray-Iron Fittings, 3 in. Through 48 in., for Water and Other Liquids

Date of Specific Issue Adopted: August 24, 1982

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Review Activity: DLA—CS

User Activities: Army—CE
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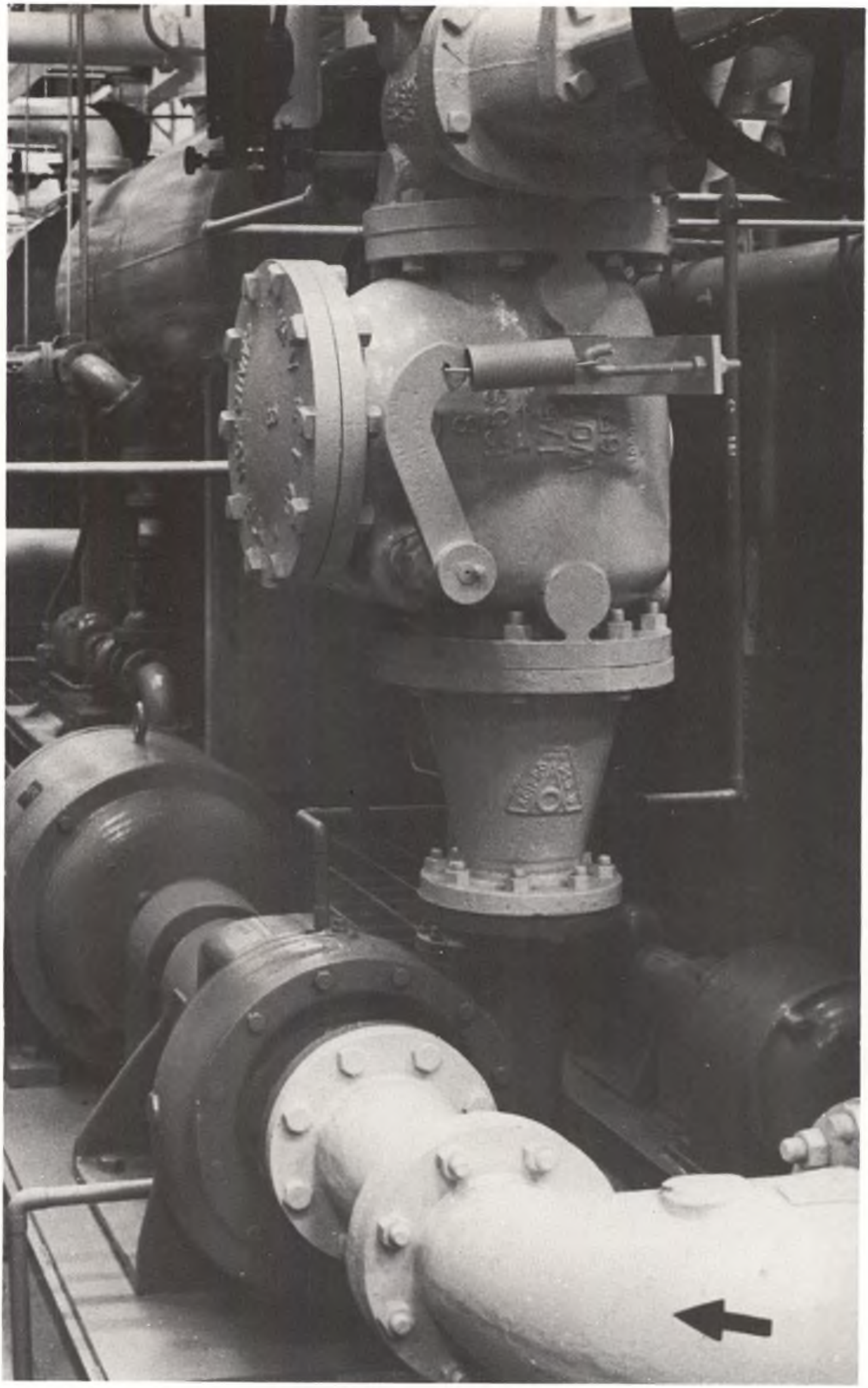
Project No. 4730-0467

FSC 4730

1P-10M-43110-10/82-LL



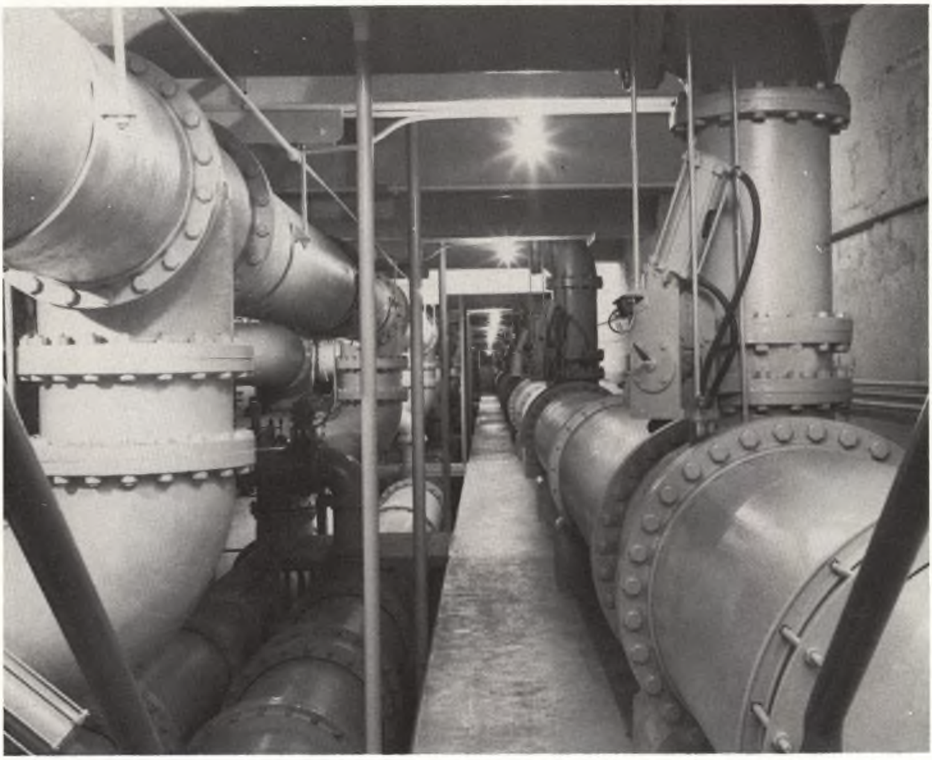
SECTION V

JOINTS FOR DUCTILE IRON PIPE

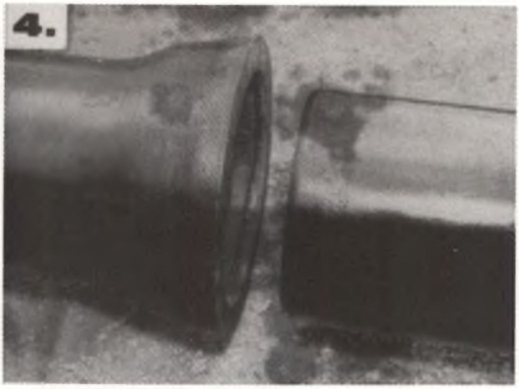
Introduction

Mechanical and push-on joints are covered by ANSI/AWWA C111/A21.11 Standard. Flanged Pipe with Threaded Flanges is covered by ANSI/AWWA C115/A21.15 Standard. Grooved and shouldered type joints are covered by ANSI/AWWA C606 Standard.

Special types of pipe and fittings shown in this Section are available from individual manufacturers for special application. The manufacturer should be consulted for information on design and capabilities of these special products.



PUSH ON JOINT ASSEMBLY



ANSI/AWWA C111/A21.11–80

Revision of
ANSI/AWWA C111/A21.11–79

AMERICAN NATIONAL STANDARD

for

RUBBER-GASKET JOINTS FOR DUCTILE-IRON AND GRAY-IRON PRESSURE PIPE AND FITTINGS

Made Standard Jan. 13, 1953.
This edition approved by AWWA Board of Directors Jun. 15, 1980.
This edition approved by the American National Standards Institute, Inc., Oct. 17, 1980.

ADMINISTRATIVE SECRETARIAT

AMERICAN WATER WORKS ASSOCIATION

CO-SECRETARIATS

AMERICAN GAS ASSOCIATION
NEW ENGLAND WATER WORKS ASSOCIATION

NOTICE

This Standard has been especially printed by the American Water Works Association for incorporation into this volume. It is current as of October 1, 1984. It should be noted, however, that all AWWA Standards are updated at least once in every five years. Therefore, before applying this Standard it is suggested that you confirm its currency with the American Water Works Association.

PUBLISHED BY

AMERICAN WATER WORKS ASSOCIATION
6666 West Quincy Avenue, Denver, Colorado 80235

American National Standard

An American National Standard implies a consensus of those substantially concerned with its scope and provisions. An American National Standard is intended as a guide to aid the manufacturer, the consumer, and the general public; its existence does not in any respect preclude anyone, whether he has approved the standard or not, from manufacturing, marketing, purchasing, or using products, processes, or procedures not conforming to the standard. American National Standards are subject to periodic review, and users are cautioned to obtain the latest editions. Producers of goods made in conformity with an American National Standard are encouraged to state on their own responsibility in advertising and promotional material or on tags or labels that the goods are produced in conformity with particular American National Standards.

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S. C. Baker, *Vice-Chairman*

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P. I. McGrath, Jr.
J. H. Miller
E. C. Sears
Thurman Upchurch
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T. D. Holmes, *Vice-Chairman*
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Underwriters Laboratories, Inc.	W. Carey †
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* Non-voting member
† Alternate

Table of Contents

NOTE: Metric Tables Not Included In This Handbook.

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Foreword

This foreword is for information only and is not a part of ANSI/AWWA C111/A21.11.

American National Standards Committee A21 on Cast-Iron Pipe and Fittings was organized in 1926 under the sponsorship of the American Gas Association, the American Society for Testing and Materials, the American Water Works Association, and the New England Water Works Association. Since 1972, the Co-Secretariats have been A.G.A., AWWA, and NEWWA, with AWWA serving as Administrative Secretariat. The present scope of Committee A21 activity is

> Standardization of specifications for cast-iron and ductile-iron pressure pipe for gas, water, and other liquids and fittings for use with such pipe. These specifications to include design, dimensions, materials, coatings, linings, joints, accessories, and methods of inspection and tests.

The work of Committee A21 is carried out by subcommittees. The scope of Subcommittee 2—Joints for Pipe and Fittings is

> To include an examination of all present A21 standards for joints for cast-iron and ductile-iron pipe and fittings to determine what is needed to bring them up to date. The examinations shall include all related matters concerning joints for cast-iron and ductile-iron pipe and fittings.

A21.11 was reviewed, revised, and reissued in 1964 and again in 1972.

Subcommittee 2 completed its review of A21.11–972 and submitted a proposed revision to Committee A21 in 1977 which led to approval of ANSI/AWWA C111/A21.11–79.

During 1979 Committee A21 reached agreement on a proposed new requirement for the marking of bolts and nuts which was generally acceptable to the bolt manufacturing industry. The significance of this change and other considerations led to approval of this new 1980 revision.

I. Major Revisions

The major changes from the 1972 standard made in the 1979 and subsequent 1980 revisions are as follows:

1. *Metric conversion.* Metric conversion of all dimensions and physical requirements are included in this standard. Metric conversion for Tables 11.1 through 11.4 are in Appendix B. Metric dimensions are direct conversions of customary U.S. inch-pound units and are not those specified in International Standards Organization (ISO) standards.

2. *Mechanical-joint dimensions.* Table 11.1 has been revised to include separate bell thicknesses *S* and bell flange thicknesses *L* for ductile-iron mechanical-joint pipe that are compatible with pipe barrel thicknesses. Thread lengths on $\frac{3}{4} \times 4\frac{1}{2}$-in. and $\frac{3}{4} \times 5$-in. bolts have been increased by 0.25 in.

3. *Mechanical-joint bolts.* The type of bolts to be used or the need for protection should be determined from experience or the study of soil characteristics in accordance with Appendix A of ANSI/AWWA C105/A21.5, "American National Standard for Polyethylene Encasement for Gray and Ductile Cast-Iron Piping for Water and Other Liquids." Table 11.3 has been revised and Table 11.4 has been added to include a reduced shank diameter bolt that is properly sized to accept rolled threads.

4. *Ductile-iron glands.* The minimum elongation of ductile-iron glands has been increased to 5 percent (paragraph 11–6.1.2).

5. *Deletions.* 2-in. and 2¼-in. sizes have been deleted.

6. *Additions.* Section 11–6.5.5 on marking has been added requiring bolts and nuts to have a mark identifying the material and producer. The Committee A21 secretary at AWWA has been authorized to maintain a list of identification marks for general reference.

NOTE: Push-on joints for cast-iron and ductile-iron pipe are designed so that a negative pressure cannot pull the gasket into the pipe. Testing has been performed to confirm this design parameter for joint-sealing capability under the condition of negative pressure within the pipe.

II. Options

This standard includes certain options that, if desired, must be specified in the invitation for bids and on the purchase order. These options can be found in the following sections of the standard:

1. Mechanical-joint pipe and fittings, if requested, may be purchased without glands, gaskets, or bolts (Sec. 11–3.4).
2. Inspection (Sec. 11–4.2).
3. Certification and test records (Sec. 11–5.1).
4. Special requirements for mechanical joint (Sec. 11–6.1 and 11–6.3).
5. Purchaser must request drawings of the joint and gasket, if desired (Sec. 11–7.1).

III. Special Service Requirements

The following special service requirements should be noted:

1. Sec. 11–6.3 provides for tapped holes in the bells of mechanical joints for stud bolts. This option is intended for use when headed bolts or slotted holes will not suffice; for example, when the bell is to be embedded in a concrete wall.
2. Although this standard does not specify orientation of bolt holes in the flanges of the mechanical joint, at times it is convenient or necessary to have the bolt holes oriented. The normal but not universal practice is to have bolt holes straddle the vertical centerline of the fitting, valves, and hydrants. (The vertical centerline of a fitting is determined when the fitting is in the position to change the direction of fluid flowing in a horizontal plane. With standard base bends and standard base tees, the vertical centerline is determined when the fitting is in a position to change the fluid flowing in a vertical plane.) If orientation is known to be necessary, it should be stated on the purchase order.

NOTE: Metric Tables Not Included In This Handbook.

ANSI/AWWA C111/A21.11-80

Revision of
ANSI/AWWA C111/A21.11-79

AMERICAN NATIONAL STANDARD

for

Rubber-Gasket Joints for Ductile-Iron and Gray-Iron Pressure Pipe and Fittings

Sec. 11–1 Scope

This standard covers rubber-gasket joints of the following types for ductile-iron and gray-iron pressure pipe and fittings.

11–1.1 *Mechanical joint.* The mechanical joint is designed for pipe and fittings in sizes 3–48 in. for conveying gas, water, or other liquids.

11–1.2 *Push-on joint.* The push-on joint is designed for pipe and fittings in sizes 3–54 in. for conveying water or other liquids.

11–1.3 *Metric conversions.* Metric conversions are direct conversions of English units and are not those specified in the ISO standard.

Sec. 11–2 Definitions

Under this standard the following definitions shall apply.

11–2.1 *Joints and accessories.* For the purpose of this standard the word "joint" includes accessories.

11–2.2 *Mechanical joint.* A mechanical joint is a bolted joint of the stuffing-box type, as shown in Fig. 11.1. Each joint shall consist of (1) a bell that is cast integrally with the pipe or fitting and provided with an exterior flange having bolt holes or slots, and a socket with annular recesses for the sealing gasket and the plain end of the pipe or fitting, (2) a pipe or fitting plain end, (3) a sealing gasket, (4) a follower gland with bolt holes, and (5) tee-head bolts and hexagonal nuts.

11–2.3 *Push-on joint.* A push-on joint is a single rubber-gasket joint. It is assembled by the positioning of a continuous, molded, rubber ring gasket in an annular recess in the pipe or fitting socket and the forcing of the plain end of the entering pipe or fitting into the socket. The plain end compresses the gasket radially to form a positive seal. The gasket and the annular recess are designed and shaped so that the gasket is locked in place against displacement.

11–2.4 *Purchaser.* The purchaser is the party entering into a contract or agreement to purchase joints according to this standard.

11–2.5 *Manufacturer.* The manufacturer is the party entering into a contract or agreement to furnish joints according to this standard.

11–2.6 *Inspector.* The inspector is the representative of the purchaser, authorized to inspect on behalf of the purchaser to determine whether the requirements of this standard are met.

Sec. 11–3 General Requirements

11–3.1 *Joints.* Joints made in conformance with the provisions of this standard are intended for use on ductile-iron and gray-iron pipe and fittings manufactured in accordance with the following standards, where applicable:

- ANSI/AWWA C106/A21.6–80, "Gray-Iron Pipe Centrifugally Cast in Metal Molds, for Water and Other Liquids."
- ANSI/AWWA C110/A21.10–77, "Gray-Iron and Ductile-Iron Fittings, 3–48 in., for Water and Other Liquids."
- ANSI A21.14–1979, "Ductile-Iron Fittings, 3–24 in., for Gas."
- ANSI A21.51–1976 (AWWA C151–76), "Ductile-Iron Pipe, Centrifugally Cast in Metal Molds or Sand-Lined Molds, for Water or Other Liquids."
- ANSI A21.52–1976, "Ductile-Iron Pipe, Centrifugally Cast, in Metal Molds or Sand-Lined Molds for Gas."
- ASTM A377–66 (1973), "Specification for Cast-Iron and Ductile-Iron Pressure Pipe."

11–3.2 *Pressure rating.* The joints shall have the same pressure rating as the pipe or fittings of which they are a part.

11–3.3 *Assembly.* A recommended method of joint assembly shall be furnished by the manufacturer on request of the purchaser.

11–3.4 *Joint Accessories.* Unless otherwise specified, gaskets, glands, bolts, and nuts shall be furnished with mechanical joints, and gaskets and lubricant shall be furnished with push-on joints; all in sufficient quantity for assembly of each joint.

Sec. 11–4 Inspection

11–4.1 *Inspection.* Inspection shall be made in accordance with the provisions of the standard under which the pipe or fittings are purchased.

11–4.2 *Accessories.* If the purchaser wishes to inspect the manufacture of glands, bolts, or gaskets that may be made by subcontractors, special arrangements must be made at the time the order is placed.

Sec. 11–5 Certification and Test Records

11–5.1 *Affidavit.* The manufacturer shall, if required on the purchase order, furnish a sworn statement that the inspection and all of the tests specified have been made and that the results thereof comply with the requirements of this standard.

11–5.2 *Record.* A record of the specified tests of glands, bolts, and gaskets shall be retained for one year and shall be available to the purchaser at the foundry.

Sec. 11-6 Special Requirements for the Mechanical Joint

11-6.1 *Glands.* Unless otherwise specified, gray-iron glands shall be furnished with ductile-iron pipe and fittings. Glands shall have an asphaltic coating unless otherwise specified and shall have cast or stamped upon them the manufacturer's identification, the nominal size, and the letters "DI" or the word "ductile" if made of ductile-iron.

11-6.1.1 Gray-iron glands. The acceptability of the gray iron used in the glands shall be determined by tests made on bars cast from the same iron as the glands. The test bars shall be ASTM standard bars, cast and tested in accordance with ASTM A48-74 for tensile strength or A438-74 for transverse breaking load. The manufacturer may use either the tensile test or the transverse test as the acceptance test. The required properties are listed in the table below.

11-6.1.2 Ductile-iron glands. The standard acceptance test for the physical characteristics of ductile-iron glands shall be a tensile test from coupons cast from the same iron as the glands. The coupons shall be cast and the tests made in accordance with ASTM A536-72. The ductile-iron from which the glands are cast shall have a minimum elongation of 5 percent.

11-6.2 *Dimensions and tolerances.* The dimensions of the bell, socket, plain end, and gland lip and the diameter and location of the bolt holes shall be gaged at sufficiently frequent intervals to ensure compliance with the dimensions shown in Fig. 11.1 and Table 11.1.

11-6.3 *Bolt holes or slots.* When necessary for the insertion of bolts, the bell flange shall have slots of the same width as the diameter of the bolt holes. When specified, the bell flange shall be furnished with holes tapped for stud bolts.

11-6.4 *Gaskets.* Gasket dimensions shall conform to the dimensions and tolerances shown in Fig. 11.2 and Table 11.2. The size, mold number, gasket manufacturer's mark, the letters "MJ," and the year of manufacture shall be molded in the rubber as shown in Fig. 11.2.

11-6.4.1 Rubber gaskets shall be vulcanized natural or vulcanized synthetic rubber that is free of porous areas, foreign materials, and visible defects. No reclaimed rubber shall be used.

11-6.4.2 Quality control procedures shall be utilized to ensure that gaskets meet the requirements of this standard. The manufacturer shall retain monthly reports of representative results from quality control tests for gaskets manufactured that month.

Properties for Gray-Iron Glands

Class of Iron	Bar Diameter	Span	Minimum Breaking Load	Minimum Tensile
25	1.2 *in.* (30.5 *mm*)	18 *in.* (457 *mm*)	2000 *lb* (8.894 *kN*)	25 000 *psi* (172 *MPa*)
25	2.0 *in.* (50.8 *mm*)	24 *in.* (610 *mm*)	6800 *lb* (30.243 *kN*)	25 000 *psi* (172 *MPa*)

11–6.4.3 The required properties of the gasket rubber and the required methods of test are as follows:

Property	ASTM Test Method	Required Value
Hardness, Shore "A"	D2240-75	75 ± 5
Min. ultimate tensile	D412-68	1500 *psi* (10 *MPa*)
Min. ultimate elongation*	D412-68	150%
Min. Aging†	D572-73‡	60%
Max. compression set	D395-69 Method B	20%
Resistance to ozone Cracking	D1149-64§	No cracking

* Of original length.
† Of original values for tensile and ultimate elongation.
‡ Oxygen pressure method, after 96 hr at 70°C ± 1 deg at 300 psi ± 10 (20.7 bars ± 0.7).
§ After a minimum of 25 hr exposure in 50-pphm ozone concentration at 104°F (40°C) on a loop-mounted gasket with approximately 20 percent elongation at outer surface.

11–6.5 *Bolts and nuts.* Dimensions of tee-head bolts and hexagonal nuts shall comply with the dimensions and tolerances shown in Fig. 11.3 and Table 11.3 or in Fig. 11.4 and Table 11.4. At the manufacturer's option, they shall be made of either high-strength cast-iron containing a minimum of 0.50 percent copper, or high-strength, low-alloy steel. The steel shall have the following characteristics:

Characteristic	Value
Min. yield strength—*psi*	45 000 (310 *MPa*)
Min. elongation in 2 in. (50.8 mm)—percent	20
Max. content—*percent*	
Carbon	0.20
Manganese	1.25
Sulfur	0.05
Min. content—*percent*	
Nickel	0.25
Copper	0.20
Combined (Ni, Cu, Cr)	1.25

11–6.5.1 Threads. The design of internal and external threads shall conform to ANSI B1.1–1974—Unified Screw Threads, and to B1.2–1974—Screw Threads, Gages and Gaging. Thread form shall conform to the standards and to the dimensions of the course-thread series (UNC) Unified Coarse; external threads shall be made in compliance with Class 2A limits, and internal threads shall be made in compliance with Class 2B limits. Bolts shall be threaded concentric to the longitudinal axis of the shank. Nuts shall be tapped concentric to the vertical axis and at right angles to the load surfaces within a tolerance of 2 degrees to ensure axial loading.

11–6.5.2 Proof test. Statistical quality control procedures shall be utilized to assure that bolts and nuts meet the specified test loads without permanent stretch. Samples of assembled bolts and nuts shall be proof tested in tension to the load values designated. For testing, the nuts shall be assembled flush with the end of the bolts. The load shall be applied without impact between the nut and the bolt head in a suitable machine that will ensure axial loading. The specified test loads shall not break the nut or bolt or permanently stretch the bolt. Permanent stretch is defined as 0.002 unit per unit of bolt length. Assembled bolts and nuts shall be tested at the following load values, which have been determined on the basis of a 45 000 psi (310 MPa) stress at root of thread:

Bolt Diameter		Load	
in.	*mm*	*lb*	*kN*
$\frac{5}{8}$	15.9	9 000	40.032
$\frac{3}{4}$	19.1	13 000	60.048
1	25.4	24 500	108.976
$1\frac{1}{4}$	31.8	40 000	177.920

11–6.5.3 Workmanship. Bolt shanks shall be straight within $\frac{1}{16}$ in. per 6 in. of length (1 mm per 100 mm). The two load-bearing surfaces of the bolt heads shall be in a common plane that shall be at right angles to the bolt shank.

11–6.5.3.1 Bolts and nuts shall be sound, clean, and coated with a rust-resistant lubricant; their surfaces shall be free of objectionable protrusions that would interfere with their fit in the made-up mechanical joint.

11–6.5.4 Packing. The nuts shall be assembled on the bolts for packing. They shall be packed in suitable containers that shall be plainly marked with the manufacturer's name, and the size, quantity, and weight of the contents.

11–6.5.5 *Marking.* Bolts and nuts shall have a mark to identify the material and producer. The identification mark shall be cast, forged, or stamped on the bolt and nut. Painted markings are not acceptable. The manufacturer shall, if specified on the invitation for bids or on the purchase order, provide the following information regarding bolts and nuts being furnished: type of material and corresponding identification mark.

Sec. 11–7 Special Requirements for Push-on Joint

11–7.1 *Drawings.* The manufacturer shall furnish drawings of the joint and gasket, if requested by the purchaser.

11–7.2 *Dimensions and tolerances.* The dimensions of the bell, socket, and plain end shall be in accordance with the manufacturer's standard design dimensions and tolerances. Such dimensions shall be gaged at sufficiently frequent intervals to ensure dimensional control.

11–7.3 *Gaskets.* Gasket dimensions shall be in accordance with the manufacturer's standard design dimensions and tolerances. The gasket shall be of such size and shape to provide an adequate compressive force against the plain end and socket after assembly to effect a positive seal under all combinations of joint and gasket tolerances.

Property	ASTM Test Method	Main Body Of Gasket		Harder Portion (if used)	
		Standard (US)	Metric	Standard (US)	Metric
Nominal hardness, Shore "A"	D2240-75	50–65	50–65	80–85	80–85
Tolerance on nominal hardness		±5	±5	±5	±5
Min. ultimate tensile	D412-68	2000 psi	14 MPa	1200 psi	8 MPa
Min. ultimate elongation*	D412-68	300%	300%	125%	125%
Min. aging†	D572-73‡	60%	60%	—	—
Max. compression set	D395-69, Method B	20%	20%	—	—
Resistance to ozone cracking	D1149-64§	No cracking		—	—

* Of original length.
† Of original values of tensile and ultimate elongation.
‡ Oxygen pressure method, after 96 hr. at 70°C ± 1 deg at 300 psi ± 10 (20.7 Bars ± 0.7).
§ After a minimum of 25 hr exposure in 50-pphm ozone concentration at 104°F (40°C) on a loop-mounted gasket with approximately 20 percent elongation at outer surfae.

The trade name or trademark, size, mold number, gasket manufacturer's mark, and year of manufacturer shall be molded on the gaskets. Markings shall not be on the sealing surfaces.

11–7.3.1 Gaskets shall be vulcanized natural or vulcanized synthetic rubber. No reclaimed rubber shall be used. When two hardnesses of rubber are included in a gasket, the soft and hard portions shall be integrally molded and joined in a strong vulcanized bond. Gaskets shall be free of porous areas, foreign material, and visible defects.

11–7.3.2 The required properties of the gasket rubber and the required method of test are in table below.

11–7.3.3 Quality control procedures shall be utilized to ensure that the gaskets meet the requirements of this standard. The manufacturer shall retain monthly reports of representative results from quality control tests for gaskets manufactured that month.

11–7.4 *Lubricant.* The lubricant shall be suitable for lubricating the parts of the joint for assembly. The lubricant shall be nontoxic, shall not support the growth of bacteria, and shall have no deteriorating effects on the gasket material. It shall not impart taste or odor to water in a pipe that has been flushed in accordance with AWWA C601, "Standard for Disinfecting Water Mains." The lubricant containers shall be labeled with the trade name or trademark and the pipe manufacturer's name.

11–7.5 *Marking.* Pipe and fittings having push-on joints shall be marked with the proprietary name or trademark of the joint.

Sec. 11–8 Performance Requirements of the Push-on Joint

The manufacturer shall have qualified the design of his joint by having performed the tests given in this section and shall possess records to show the results of those tests.

11–8.1 *Working-pressure ratings.* The working-pressure rating of the push-on joint is established by subjecting representative sizes to hydrostatic pressures of twice the rated working pressure of the pipe or fitting with which the joint is to be used but in no event less than twice the minimum working pressure rating shown following this paragraph. The hydrostatic pressure shall be applied to joint samples having maximum clearances between the plain end and socket as allowed by the specified tolerances. In addition to those samples tested in the undeflected condition, some samples shall be tested while deflected to the angle recommended as a maximum by the manufacturer. At least one sample shall be tested while the plain end is offset laterally within the socket to the maximum extent permitted by the joint design. The joint shall not leak during any of these tests. The minimum working pressure ratings shall be as follows:

	Minimum Working Pressure Rating	
Joint Size—*in.*	*psi*	*bars*
18 and smaller	350	24
20	300	21
24	250	17
30–54	200	14

11–8.2 *Assembly.* Assembly of representative sizes shall be possible with the joints having minimum clearance between the plain end and socket as allowed by the specified tolerances. These joints shall be capable of being assembled and deflected to the maximum attainable angle, but not in excess of the maximum recommended by the manufacturer, without damage to the gaskets, pipe, or fittings, and without displacement of the gasket from its intended position.

11–8.3 *Gaskets.* The gaskets used for qualifying the joint shall be of the same form and material as the gaskets intended for use in service.

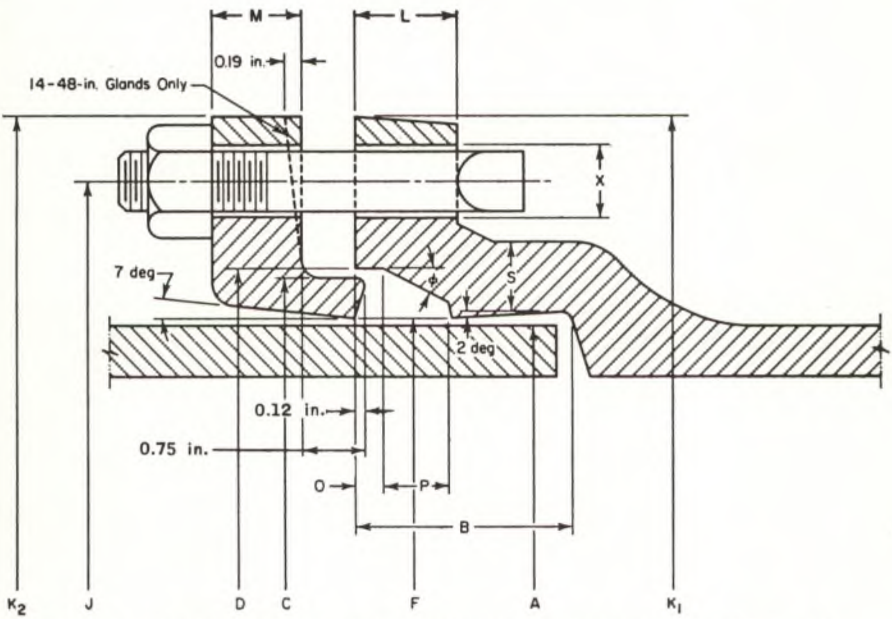

Fig. 11.1. Mechanical-Joint Dimensions for Sizes 3–48 in. (See Table 11.1)

Notes

1. The nominal thickness of the pipe bell *S* shall not be less than the nominal wall thickness of the pipe of which it is a part. The *S* dimensions shown in Table 11.1 for centrifugal pipe are for reference and were used to calculate bell weights.
2. The diameter of cored holes may be tapered an additional 0.06 in.
3. In the event of an ovalness to the outside diameter of the plain end, the mean diameter measured by a circumferential tape shall not be less than the minimum diameter shown in the table. The minor axis shall not be less than the foregoing minimum diameter plus an additional minus tolerance of 0.04 in. for sizes 8–12 in., 0.07 in. for sizes 14–24 in., and 0.10 in. for sizes 30–48 in.
4. K_1 and K_2 are the dimensions across the centerline of the bolt holes. The gland may be polygon in shape for all sizes or square for 3-in. and 4-in. sizes.
5. Gland thickness *M* for sizes 14–48 in. may be tapered as shown, at the option of the manufacturer.
6. The manufacturer may furnish ductile-iron pipe with thicker bell flanges *L* than specified in Table 11.1.
7. The manufacturer may furnish ductile-iron pipe in sizes 30 in. and larger with the bell-flange thicknesses shown in Table 11.1 (dimension *L*), or with reduced bell-flange thicknesses that are compatible with the wall thicknesses of the pipe. When reduced bell-flange thicknesses are furnished, the manufacturer shall provide details of the joint and accessories if requested by the purchaser.

TABLE 11.1

Mechanical-Joint Dimensions—in.

Size	A Plain End	B	C	D	F	φ	X +0.06 −0.00	J ±0.06	K_1		K_2	L			M	O	P	S			Bolts		
									Pipe	Fittings		Pipe Gray	Pipe Ductile	Fittings				Pipe Gray	Pipe Ductile	Fittings	No.	Size	Length
3	3.96 ±0.06	2.50	4.84 ±0.04	4.94+0.06 −0.04	4.06+0.07 −0.03	28°	3/4	6.19	7.62 −0.06	7.69 −0.12	7.69 −0.12	0.94 −0.06	0.87 −0.06	0.94 −0.06	0.62 −0.06	0.31	0.63	0.41	0.40	0.52 −0.10	4	5/8	3
4	4.80 ±0.06	2.50	5.92 ±0.04	6.02+0.06 −0.04	4.90+0.07 −0.03	28°	7/8	7.50	9.06 −0.06	9.12 −0.12	9.12 −0.12	1.00 −0.06	0.91 −0.06	1.00 −0.06	0.75 −0.06	0.31	0.75	0.44	0.41	0.65 −0.10	4	3/4	3½
6	6.90 ±0.06	2.50	8.02 ±0.04	8.12+0.06 −0.04	7.00+0.07 −0.03	28°	7/8	9.50	11.06 −0.06	11.12 −0.12	11.12 −0.12	1.06 −0.06	0.94 −0.06	1.06 −0.06	0.88 −0.06	0.31	0.75	0.48	0.43	0.70 −0.10	6	3/4	3½
8	9.05 ±0.06	2.50	10.17 ±0.04	10.27+0.06 −0.04	9.15+0.07 −0.03	28°	7/8	11.75	13.31 −0.06	13.37 −0.12	13.37 −0.12	1.12 −0.08	0.98 −0.08	1.12 −0.08	1.00 −0.08	0.31	0.75	0.52	0.45	0.75 −0.12	6	3/4	4
10	11.10 ±0.06	2.50	12.22+0.06 −0.04	12.34+0.06 −0.04	11.20+0.07 −0.03	28°	7/8	14.00	15.62 −0.06	15.69 −0.12	15.62 −0.12	1.19 −0.08	0.98 −0.08	1.19 −0.08	1.00 −0.08	0.31	0.75	0.56	0.47	0.80 −0.12	8	3/4	4
12	13.20 ±0.06	2.50	14.32+0.06 −0.04	14.44+0.06 −0.04	13.30+0.07 −0.03	28°	7/8	16.25	17.88 −0.06	17.94 −0.12	17.88 −0.12	1.25 −0.08	0.98 −0.08	1.25 −0.08	1.00 −0.08	0.31	0.75	0.60	0.49	0.85 −0.12	8	3/4	4
14	15.30+0.05 −0.08	3.50	16.40+0.07 −0.05	16.54+0.07 −0.05	16.44+0.06 −0.07	28°	7/8	18.75	20.25 −0.08	20.31 −0.12	20.25 −0.12	1.31 −0.12	1.02 −0.12	1.31 −0.12	1.25 −0.12	0.31	0.75	0.64	0.51	0.89 −0.12	10	3/4	4½
16	17.40+0.05 −0.08	3.50	18.50+0.07 −0.05	18.64+0.07 −0.05	17.54+0.06 −0.07	28°	7/8	21.00	22.50 −0.08	22.56 −0.12	22.50 −0.12	1.38 −0.12	1.08 −0.12	1.38 −0.12	1.31 −0.12	0.31	0.75	0.68	0.52	0.97 −0.12	12	3/4	4½
18	19.50+0.05 −0.08	3.50	20.60+0.07 −0.05	20.74+0.07 −0.05	19.64+0.06 −0.07	28°	7/8	23.25	24.75 −0.08	24.83 −0.15	24.75 −0.15	1.44 −0.12	1.14 −0.12	1.44 −0.12	1.38 −0.12	0.31	0.75	0.73	0.53	1.05 −0.15	12	3/4	4½
20	21.60+0.05 −0.08	3.50	22.70+0.07 −0.05	22.84+0.07 −0.05	21.74+0.06 −0.07	28°	7/8	25.50	27.00 −0.08	27.08 −0.15	27.00 −0.15	1.50 −0.12	1.20 −0.12	1.50 −0.12	1.44 −0.12	0.31	0.75	0.78	0.54	1.12 −0.15	14	3/4	4½
24	25.80+0.05 −0.08	3.50	26.90+0.07 −0.05	27.04+0.07 −0.05	25.94+0.06 −0.07	28°	7/8	30.00	31.50 −0.08	31.58 −0.15	31.50 −0.15	1.62 −0.12	1.26 −0.12	1.62 −0.12	1.56 −0.12	0.31	0.75	0.85	0.56	1.22 −0.15	16	3/4	5
30	32.00+0.08 −0.06	4.00	33.29+0.08 −0.06	33.46+0.08 −0.06	32.17+0.08 −0.06	20°	1⅛	36.88	39.12 −0.12	39.12 −0.18	39.12 −0.18	— —	1.38 −0.12	1.81 −0.12	2.00 −0.12	0.38	1.00	—	0.63	1.50 −0.15	20	1	6
36	38.30+0.08 −0.06	4.00	39.59+0.08 −0.06	39.76+0.08 −0.06	38.47+0.08 −0.06	20°	1⅛	43.75	46.00 −0.12	46.00 −0.18	46.00 −0.18	— —	1.50 −0.12	2.00 −0.12	2.00 −0.12	0.38	1.00	—	0.73	1.80 −0.15	24	1	6
42	44.50+0.08 −0.06	4.00	45.79+0.08 −0.06	45.96+0.08 −0.06	44.67+0.08 −0.06	20°	1⅜	50.62	53.12 −0.12	53.12 −0,18	53.12 −0.18	— —	1.50 −0.12	2.00 −0.12	2.00 −0.12	0.38	1.00	—	0.83	1.95 −0.15	28	1¼	6
48	50.80+0.08 −0.06	4.00	52.09+0.08 −0.06	52.26+0.08 −0.06	50.97+0.08 −0.06	20°	1⅜	57.50	60.00 −0.12	60.00 −0.18	60.00 −0.18	— —	1.50 −0.12	2.00 −0.12	2.00 −0.12	0.38	1.00	—	0.93	2.20 −0.15	32	1¼	6

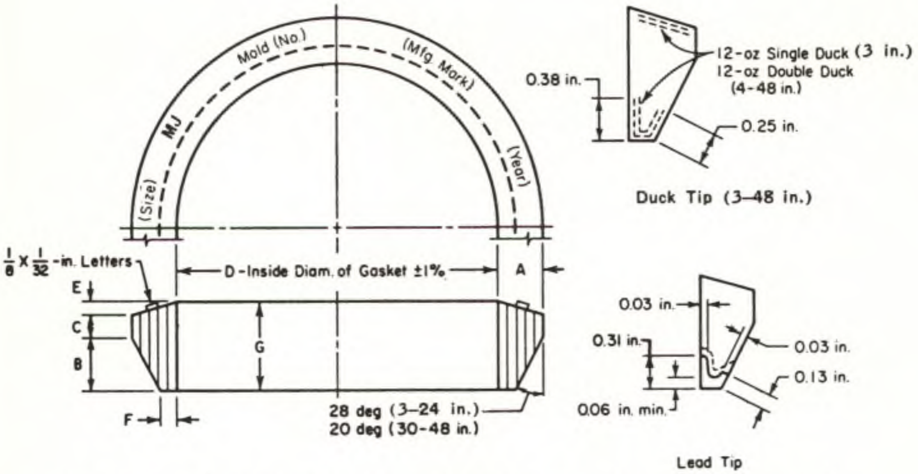

Fig. 11.2. Mechanical-Joint Gasket, 3–48 in. (See Notes and Table 11.2)

Notes

1. Tipped gaskets may be made in the same mold as plain rubber gaskets, but the inside diameter of such reinforced portions shall not exceed the pipe OD.
2. The duck for tips shall be frictioned before molding.

TABLE 11.2

3–48-in. Mechanical-Joint Gasket Dimensions—in.

Pipe Size	Pipe OD	Dimensions of Plain Rubber Gaskets						
		A ±0.01 in.	*B*	*C*	*D* +1 percent −1 percent	*E*	*F* ±0.01 in.	*G* ±0.02 in.
3	3.96	0.48	0.62	0.31	3.86	0.12	0.15	1.05
4	4.80	0.62	0.75	0.31	4.68	0.16	0.22	1.22
6	6.90	0.62	0.75	0.31	6.73	0.16	0.22	1.22
8	9.05	0.62	0.75	0.31	8.85	0.16	0.22	1.22
10	11.10	0.62	0.75	0.31	10.87	0.16	0.22	1.22
12	13.20	0.62	0.75	0.31	12.95	0.16	0.22	1.22
14	15.30	0.62	0.75	0.31	14.99	0.16	0.22	1.22
16	17.40	0.62	0.75	0.31	17.07	0.16	0.22	1.22
18	19.50	0.62	0.75	0.31	19.13	0.16	0.22	1.22
20	21.60	0.62	0.75	0.31	21.20	0.16	0.22	1.22
24	25.80	0.62	0.75	0.31	25.34	0.16	0.22	1.22
30	32.00	0.73	1.00	0.38	31.47	0.16	0.37	1.54
36	38.30	0.73	1.00	0.38	37.67	0.16	0.37	1.54
42	44.50	0.73	1.00	0.38	43.78	0.16	0.37	1.54
48	50.80	0.73	1.00	0.38	49.98	0.16	0.37	1.54

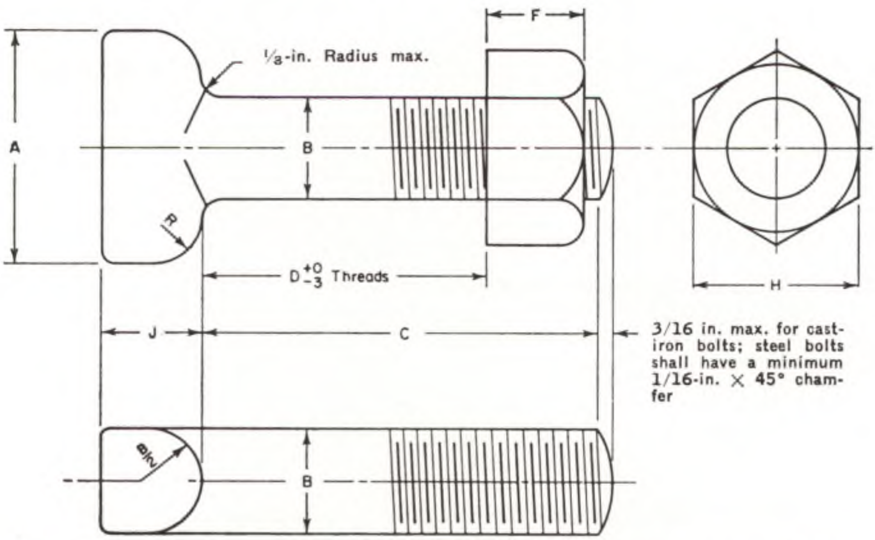

Fig. 11.3. Standard Design for Low-Alloy Steel or Cast-Iron Mechanical-Joint Bolts and Nuts.

Notes

1. Dimension *B* is unthreaded shank.
2. Dimension *D* is measured to face of nut run up finger-tight.
3. Draft, when required to be 6 deg maximum, may be deducted from bolt head dimensions, and radius *B*/2 may be changed to suit draft.
4. Gates, if required, may protrude a maximum of ⅛ in. above the top of the bolt head.

TABLE 11.3

Standard Design for Low-Alloy Steel or Cast-Iron Mechanical-Joint Bolt and Nut Dimensions—in.

Nominal Size	*A* ±0.05	*B** +0.030 −0.074	*C* +0.25 −0.06	*D*	*E*†	*F*	*H*	*J* +0.15 −0.03	*R* Max.
⅝ × 3	1.50	0.625	3.0	1.75	11	0.625±0.04	1.062+0.00 −0.04	0.625	0.312
¾ × 3½	1.75	0.750	3.5	1.75	10	0.750±0.06	1.250+0.00 −0.06	0.750	0.375
¾ × 4	1.75	0.750	4.0	2.25	10	0.750±0.06	1.250+0.00 −0.06	0.750	0.375
¾ × 4½	1.75	0.750	4.5	2.50	10	0.750±0.06	1.250+0.00 −0.06	0.750	0.375
¾ × 5	1.75	0.750	5.0	3.00	10	0.750±0.06	1.250+0.00 −0.06	0.750	0.375
1 × 6	2.25	1.000	6.0	3.75	8	1.000±0.08	1.625+0.00 −0.08	1.000	0.500
1¼ × 6	2.50	1.250	6.0	3.75	7	1.250±0.08	2.000+0.00 −0.08	1.250	0.625

* The tolerance for cast-iron bolts is ±0.03 in.
† Number of threads per inch—Coarse-Thread Series (ANSI B1.1, "Unified Standard for Screw Threads") Class 2A, external fit UNC2A and Class 2B, UNC2B (ANSI B1.2, "Standard for Gages and Gaging").

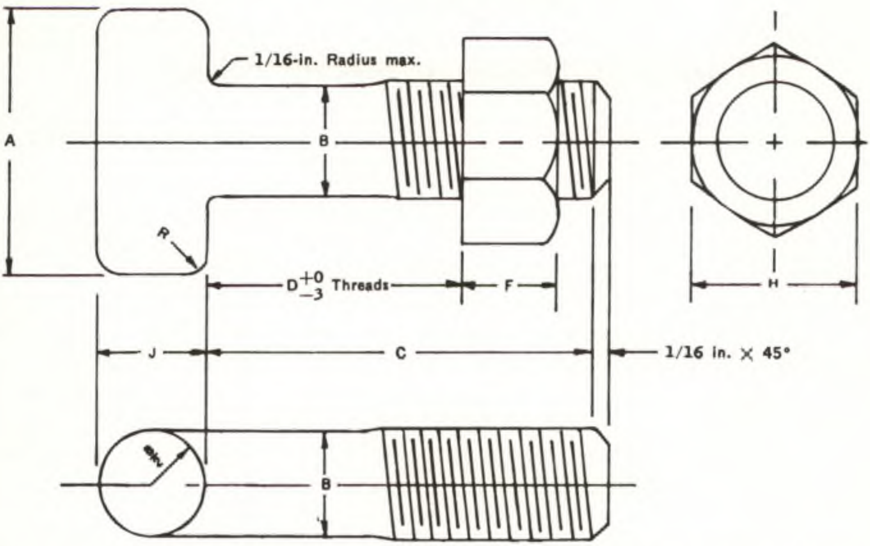

Fig. 11.4. Alternative Design for Alloy Steel Mechanical-Joint Bolts and Nuts.

Notes

1. Rolled thread.
2. Dimension *B* is unthreaded shank.
3. Dimension *D* is measured to face of nut run up finger-tight.

TABLE 11.4

Alternative Design for Alloy Steel Mechanical-Joint Bolt and Nut Dimensions—in.

Nominal Size	*A* ±0.125	*B* +0.030 −0.074	*C* ±0.125	*D*	*E**	*F*	*H*	*J* Min.	*R* Max.
⅝ × 3	1.50	0.625	3.0	1.75	11	0.625+0.006 −0.038	1.062+0.000 −0.031	0.625	0.312
¾ × 3½	1.75	0.750	3.5	1.75	10	0.750+0.008 −0.040	1.250+0.000 −0.038	0.750	0.375
¾ × 4	1.75	0.750	4.0	2.25	10	0.750+0.008 −0.040	1.250+0.000 −0.038	0.750	0.375
¾ × 4½	1.75	0.750	4.5	2.50	10	0.750+0.008 −0.040	1.250+0.000 −0.038	0.750	0.375
¾ × 5	1.75	0.750	5.0	3.00	10	0.750+0.008 −0.040	1.250+0.000 −0.038	0.750	0.375

* Number of threads per inch—Coarse-Thread Series (ANSI B1.1, "Unified Standard for Screw Threads") Class 2A, external fit UNC2A and Class 2B, UNC2B (ANSI B1.2, "Standard for Gages and Gaging").

APPENDIX A

Notes on Installation of Mechanical Joints

This appendix is for information only and is not a part of ANSI/AWWA C111/A21.11.

The successful operation of the mechanical joint specified requires that the plain end be centrally located in the bell and that adequate anchorage be provided where abrupt changes in direction and dead ends occur.

The rubber gasket will seal more effectively (particularly when sealing gas) if the surfaces with which it comes in contact are cleaned thoroughly (for example, with a wire brush) just prior to assembly in order to remove all loose rust or foreign material. Lubrication and additional cleaning should be provided by brushing both the gasket and the plain end (as with soapy water or approved pipe lubricant as per Sec. 11–7.4) just prior to slipping the gasket into the plain end and assembling the joint.

For water and gas service, the normal range of bolt torques to be applied and the lengths of wrenches that should satisfactorily produce the ranges of torques are given in the table below.

When tightening bolts, it is essential that the gland be brought up toward the pipe flange evenly, maintaining approximately the same distance between the gland and the face of the flange at all points around the socket. This may be achieved by partially tightening the bottom bolt first; then, the top bolt; next, the bolts at either side; and, finally, the remaining bolts. This process should be repeated until all bolts are within the range of torques shown below. (In larger sizes (30–48 in.), as many as 5 repetitions may be required.) If effective sealing is not attained at the maximum torque indicated, then the joint should be disassembled, thoroughly cleaned, and reassembled. Overstressing of bolts to compensate for poor installation practice is to be avoided.

Pipe Size *in.*	Bolt Size		Range of Torque		Length of Wrench*	
	Standard (US) *in.*	Metric *mm*	Standard (US) *ft–lb*	Metric *Nm*	Standard (US) *in.*	Metric *mm*
3	$\frac{5}{8}$	15.9	45–60	61–81	8	203
4–24	$\frac{3}{4}$	19.1	75–90	102–122	10	254
30–36	1	25.4	100–120	136–163	14	356
42–48	$1\frac{1}{4}$	31.8	120–150	163–203	16	406

* The torque loads may be applied with torque-measuring or torque indicating wrenches, which may also be used to check the application of approximate torque loads applied by a man trained to give an average pull on a definite length of regular socket wrench.

ANSI/AWWA C115/A21.15-83
[Revision of ANSI A21.15-75 (AWWA C115-75)]

AMERICAN NATIONAL STANDARD

for

FLANGED DUCTILE-IRON AND GRAY-IRON PIPE WITH THREADED FLANGES

ADMINISTRATIVE SECRETARIAT
AMERICAN WATER WORKS ASSOCIATION

COSECRETARIATS
AMERICAN GAS ASSOCIATION
NEW ENGLAND WATER WORKS ASSOCIATION

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This Standard has been especially printed by the American Water Works Association for incorporation into this volume. It is current as of October 1, 1984. It should be noted, however, that all AWWA Standards are updated at least once in every five years. Therefore, before applying this Standard it is suggested that you confirm its currency with the American Water Works Association.

Approved by American National Standards Institute, Inc., Mar. 17, 1983.

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THOMAS D. HOLMES, *Vice-Chairman*
JOHN I. CAPITO, *Secretary*

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NOTE: Metric Tables Not Included In This Handbook.

Foreword

This foreword is for information only and is not part of ANSI/AWWA C115/A21.15.

I. History of Standard

American National Standard Committee A21 on Cast-Iron Pipe and Fittings was organized in 1926 under the sponsorship of the American Gas Association, the American Society for Testing and Materials, the American Water Works Association, and the New England Water Works Association. The present scope of Committee A21 activity is:

standardization of specifications for cast-iron and ductile-iron pressure pipe for gas, water, and other liquids, and fittings for use with such pipe. These specifications to include design, dimensions, materials, coatings, linings, joints, accessories, and methods of inspection and test.

The work of Committee A21 is conducted by subcommittees. The directive to Subcommittee 1, Pipe, is that:

The scope of the subcommittee activity shall include the periodic review of all current A21 standards for pipe, the preparation of revisions and new standards where needed, as well as other matters pertaining to pipe standards.

Flanged fittings are covered in ANSI/AWWA C110/A21.10, Ductile-Iron and Gray-Iron Fittings, 3 in. Through 48 in., for Water and Other Liquids. The flanged pipe used with these fittings has been purchased for many years in accordance with users' and manufacturers' standards. A need for an ANSI standard for flanged pipe was indicated. Consequently, Subcommittee 1 submitted a proposed standard for flanged pipe to Committee A21 in 1974. The standard was adopted in 1975.

The subcommittee completed a review of the standard in 1979. Major revisions are listed in the following section.

II. Major Revisions

1. Metric conversions of all dimensions and physical requirements are included in this standard. Metric conversions of Tables 15.1, 15.2, 15.3, and A.1 are given in Appendix B. Metric dimensions are direct conversions of US customary inch–pound units and are not those specified in International Standards Organization (ISO) standards.

2. Gray-iron flanged pipe in 30–54 in. sizes has been eliminated since there are no producers of gray-iron pipe in these sizes.

3. The requirement for identification of the flanged pipe fabricator where different from the manufacturer of the pipe and flanges has been added.

4. In Sec. 15-8.3, the statement:

Unless otherwise specifically directed by the purchaser, flanges for ductile-iron pipe shall be ductile iron. Flanges for gray-iron pipe shall be gray iron.

has been changed to read:

Either ductile-iron or gray-iron flanges may be used unless otherwise specified by the owner.

5. Under definitions, the term "owner" has been added, and the definition of the term "manufacturer" has been revised.

6. The requirement has been added that flanges be identified as to whether they are made of cast iron or ductile iron.

III. Information Regarding Use of This Standard

A number of items must be specified to describe completely the pipe required. This standard includes certain options that, if desired, must be specified on the purchase order. The following summarizes these details and available options and lists the sections of the standard where they can be found:

A. Required information:

1. Size
2. Whether ductile iron or gray iron
3. Thickness or class
4. Finished length.

B. Options:

1. Certification by manufacturer—Sec. 15-4.2
2. Inspection by purchaser—Sec. 15-5.1
3. The type of material to be used in the flanges—Sec. 15-8.3
4. Bolt-hole alignment—Sec. 15-9.4
5. Outside coating—Sec.15-10.1
6. Cement lining—Sec.15-10.2. Experience has indicated that asphaltic inside coating is not complete protection against loss in pipe capacity because of tuberculation. Cement linings are recommended for most water.
7. Special coatings and linings—Sec. 15-10.5.

C. Since this standard requires the material properties of gray-iron and ductile-iron flanges to comply with the latest revision of ANSI/AWWA C110/A21.10, Ductile-Iron and Gray-Iron Fittings, 3 in. Through 48 in., for Water and Other Liquids, the following material properties specified in ANSI/AWWA C110/A21.10-1982 are listed below for information purposes.

1. Gray-iron flanges, in accordance with ANSI/AWWA C110/A21.10-1982, must be manufactured of the following minimum tensile-strength iron.

Nominal Size *in.*	Min. Tensile Strength *psi (MPa)*
3–12	25 000 (172)
14–24	30 000 (207)

2. Ductile-iron flanges, in accordance with ANSI/AWWA C110/A21.10-1982, must be manufactured of iron with the following minimum physical properties:

70 000 psi (483 MPa) tensile strength
50 000 psi (345 MPa) yield strength
5 percent elongation.

IV. Special Service Requirements

Special service conditions, such as elevated temperatures, the conveyance of acids or chemicals, and the application of glass lining, may require special thread compounds.

Special service requirements must be specified on the purchase order.

ANSI/AWWA C115/A21.15-83
[Revision of ANSI A21.15-75 (AWWA C115-75)]

American National Standard for

Flanged Ductile-Iron And Gray-Iron Pipe With Threaded Flanges

Sec. 15-1 Scope

This standard pertains to ductile-iron pipe sizes 3–54 in. and gray-iron pipe sizes 3–24 in. for flanged pipe with threaded flanges for water or other liquids. The flanged pipe is rated for a maximum working pressure of either 150 or 250 psi (1.03 or 1.72 MPa) as specified in the tables. All flanges are rated for a maximum working pressure of 250 psi (1.72 MPa).

Sec. 15-2 Definitions

Under this standard the following definitions shall apply:

15-2.1. *Ductile-iron:* A cast ferrous material in which a major part of the carbon content occurs as free carbon in nodular or spheroidal form.

15-2.2. *Gray-iron:* A cast ferrous material in which a major part of the carbon content occurs as free carbon in the form of flakes.

15-2.3. *Inspector:* The representative of the purchaser, authorized to inspect in behalf of the purchaser to determine whether or not the flanged pipe meets this standard.

15-2.4. *Manufacturer:* The party that fabricates the flanged pipe.

15-2.5. *Owner:* The party that will own and operate the installed system.

15-2.6. *Purchase Order:* The written authorization prepared by the purchaser, identifying the goods and services desired.

15-2.7. *Purchaser:* The party entering into a contract or agreement to purchase flanged pipe according to this standard.

Sec. 15-3 References

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

ANSI* B2.1—Pipe Threads (Except Dryseal)

ANSI B16.1—Cast Iron Pipe Flanges and Flanged Fittings, Class 25, 125, 250, and 800

*ANSI, American National Standards Institute, 1430 Broadway, New York, NY 10018.

ANSI B16.5—Pipe Flanges and Flanged Fittings, Steel Nickel Alloy and Other Special Alloys (Note: to include ratings for Class 150, 300, 400, 600, 900, 1500, and 2500)

ANSI/AWWA C104/A21.4—Standard for Cement-Mortar Lining for Ductile-Iron and Gray-Iron Pipe and Fittings for Water

ANSI/AWWA C106/A21.6—Standard for Gray-Iron Pipe Centrifugally Cast in Metal Molds, for Water or Other Liquids (withdrawn—reference 1980 edition)

ANSI/AWWA C110/A21.10—Standard for Ductile-Iron and Gray-Iron Fittings, 3 in. Through 48 in., for Water and Other Liquids

ANSI/AWWA C151/A21.51—Standard for Ductile-Iron Pipe, Centrifugally Cast in Metal Molds or Sand-Lined Molds, for Water or Other Liquids.

Sec. 15-4 Inspection and Certification by Manufacturer

15-4.1. The manufacturer shall establish the necessary quality-control and inspection practice to ensure compliance with this standard.

15-4.2. The manufacturer shall, if required on the purchase order, furnish a sworn statement that the flanged pipe comply with the requirements of this standard.

15-4.3. All flanged pipe shall be clean and sound without defects that would impair their service. Repairing of defects by welding or other methods shall not be allowed if such repairs will adversely affect the serviceability of the flanged pipe or its capability to meet strength requirements of this standard.

Sec. 15-5 Inspection by Purchaser

15-5.1. If the purchaser desires to inspect flanged pipe at the manufacturer's plant, the purchaser shall so specify on the purchase order, stating the conditions (such as time and the extent of inspection) under which the inspection shall be made.

15-5.2. The inspector shall have free access to those parts of the manufacturer's plant that are necessary to ensure compliance with this standard. The manufacturer shall make available for the inspector's use such gauges as are necessary for inspection. The manufacturer shall provide the inspector with assistance as necessary for the handling of flanged pipe.

Sec. 15-6 Delivery and Acceptance

All flanged pipe shall comply with this standard. Flanged pipe not complying with this standard shall be replaced by the manufacturer at the agreed point of delivery. The manufacturer shall not be liable for shortages or damaged pipe after acceptance at the agreed point of delivery, except as recorded on the delivery receipt or similar document by the carrier's agent.

Sec. 15-7 Pipe Barrel

15-7.1. Ductile-iron pipe barrels shall conform to the requirements of ANSI/AWWA C151/A21.51, Standard for Ductile-Iron Pipe, Centrifugally Cast in Metal Molds or Sand-Lined Molds, for Water or Other Liquids, of the latest revision, and gray-iron pipe barrels shall conform to the requirements of ANSI/AWWA C106/A21.6-80, Standard for Gray-Iron Pipe Centrifugally Cast in Metal Molds, for Water or Other Liquids (Withdrawn).

15-7.2. The nominal thicknesses of ductile-iron and gray-iron flanged pipe shall not be less than those shown in Tables 15.1 and 15.2.

15-7.3. Threads on the pipe barrel shall be taper pipe threads (NPT) in accordance with ANSI B2.1, Pipe Threads (Except Dryseal), adapted to the gray-iron and ductile-iron pipe outside diameters shown in Tables 15.1 and 15.2.

TABLE 15.1

Ductile-Iron Flanged Pipe With Threaded Flanges

Nominal Pipe Size *in.*	Thickness Class*	Maximum Working Pressure *psi*	Nominal Thickness *in.*	OD *in.*	Weight—*lb* One Flange Only	Weight—*lb* Pipe Barrel per ft
3	53	250	0.31	3.96	7	10.9
4	53	250	0.32	4.80	13	13.8
6	53	250	0.34	6.90	17	21.4
8	53	250	0.36	9.05	27	30.1
10	53	250	0.38	11.10	38	39.2
12	53	250	0.40	13.20	58	49.2
14	53	250	0.42	15.30	72	60.1
16	53	250	0.43	17.40	90	70.1
18	53	250	0.44	19.50	90	80.6
20	53	250	0.45	21.60	115	91.5
24	53	250	0.47	25.80	160	114.4
30	53	250	0.51	32.00	240	154.4
36	53	250	0.58	38.30	350	210.3
42	53	250	0.65	44.50	500	274.0
48	53	250	0.72	50.80	625	346.6
54	53	250	0.81	57.10	760	438.3

*ANSI/AWWA C151/A21.51.

NOTE: The nominal thicknesses of ductile-iron flanged pipe shall not be less than those shown in this table.

TABLE 15.2

Gray-Iron Flanged Pipe With Threaded Flanges

Nominal Pipe Size *in.*	Thickness Class*	Maximum Working Pressure *psi*	Nominal Thickness *in.*	OD *in.*	Weight—*lb* One Flange Only	Weight—*lb* Pipe Barrel per ft
3	24	250	0.38	3.96	7	13.3
4	23	250	0.38	4.80	13	16.5
6	22	250	0.38	6.90	17	24.3
8	22	250	0.41	9.05	27	34.7
10	22	250	0.44	11.10	38	46.0
12	22	150	0.48	13.20	58	59.8
12	23	250	0.52	13.20	58	64.6
14	22	150	0.51	15.30	72	73.9
14	24	250	0.59	15.30	72	85.1
16	22	150	0.54	17.40	90	89.2
16	24	250	0.63	17.40	90	103.6
18	22	150	0.58	19.50	90	107.6
18	24	250	0.68	19.50	90	125.4
20	22	150	0.62	21.60	115	127.5
20	24	250	0.72	21.60	115	147.4
24	23	150	0.73	25.80	160	179.4
24	24	250	0.79	25.80	160	193.7

*ANSI/AWWA C106/A21.6.

NOTE: The nominal thicknesses of gray-iron flanged pipe shall not be less than those shown in this table.

TABLE 15.3

Threaded Flange Detail

Nominal Pipe Size *in.*	OD *in.*	BC *in.*	T *in.*	Bolt Hole Diameter *in.*	Bolt Diameter & Length *in.*	Number of Bolts
3	7.50	6.00	0.75 ± 0.12	¾	⅝ × 2½	4
4	9.00	7.50	0.94 ± 0.12	¾	⅝ × 3	8
6	11.00	9.50	1.00 ± 0.12	⅞	¾ × 3½	8
8	13.50	11.75	1.12 ± 0.12	⅞	¾ × 3½	8
10	16.00	14.25	1.19 ± 0.12	1	⅞ × 4	12
12	19.00	17.00	1.25 ± 0.12	1	⅞ × 4	12
14	21.00	18.75	1.38 ± 0.19	1⅛	1 × 4½	12
16	23.50	21.25	1.44 ± 0.19	1⅛	1 × 4½	16
18	25.00	22.75	1.56 ± 0.19	1¼	1⅛ × 5	16
20	27.50	25.00	1.69 ± 0.19	1¼	1⅛ × 5	20
24	32.00	29.50	1.88 ± 0.19	1⅜	1¼ × 5½	20
30	38.75	36.00	2.12 ± 0.25	1⅜	1¼ × 6½	28
36	46.00	42.75	2.38 ± 0.25	1⅝	1½ × 7	32
42	53.00	49.50	2.62 ± 0.25	1⅝	1½ × 7½	36
48	59.50	56.00	2.75 ± 0.25	1⅝	1½ × 8	44
54	66.25	62.75	3.00 ± 0.25	2	1¾ × 8½	44

Facing: Flanges are plain-faced without projection or raised-face and are furnished smooth or with shallow serrations.

Back facing: Flanges may be back-faced or spot-faced for compliance with the flange thickness tolerances.

Flanges: The flanges are adequate for water service of 250-psi working pressure. The bolt circle and bolt holes of these flanges match those of Class 125 flanges shown in ANSI B16.1 and can be joined with Class 125 B16.1 flanges or Class 150 ANSI B16.5 flanges. The flanges do not match the Class 250 flanges shown in ANSI B16.1 and cannot be joined with Class 250 B16.1 flanged fittings and valves.

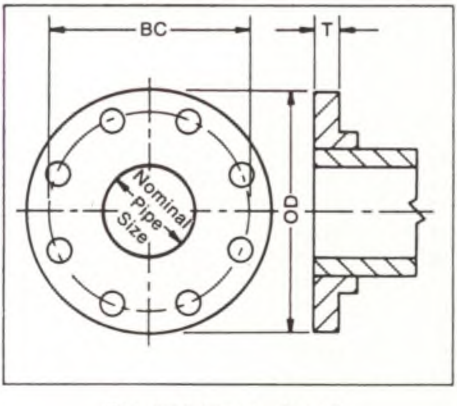

Fig. 15.1 Flange Details
See Table 15.3

Sec. 15-8 Flanges

15-8.1. Flanges shall conform to the dimensions shown in Table 15.3 and Figure 15.1.

15-8.2. All flanges shall have a taper pipe thread (NPT) in accordance with ANSI B2.1, Pipe Threads (Except Dryseal), adapted to the ductile-iron and gray-iron pipe outside diameters shown in Tables 15.1 and 15.2.

15-8.3. Either ductile-iron or gray-iron flanges may be used unless otherwise specified by the owner. Flanges shall conform to the respective chemical and physical properties specified for gray-iron and ductile-iron fittings in ANSI/AWWA C110/A21.10, Standard for Ductile-Iron and Gray-Iron Fittings, 3 in. through 48 in., for Water and Other Liquids.

Sec. 15-9 Fabrication

15-9.1. *Bolt holes.* Bolt holes shall be in accordance with the dimensions shown in Table 15.3. The bolt holes shall be equally spaced.

15-9.2. *Assembly.* Both flange and pipe threads shall be clean prior to application of thread compound. The thread compound shall give adequate lubrication and sealing properties to provide satisfactory pressure-tight joints. Threaded flanges shall be individually fitted and machine-tightened on the threaded pipe by the manufacturer.

NOTE: Flanges are not interchangeable in the field.

15-9.3. *Facing.* The flanges and pipe ends shall be faced after fabrication. Flanges shall be plain-faced without projection or raised-face and shall be furnished smooth or with shallow serrations. Flanges may be back-faced or spot-faced for compliance with the flange thickness tolerance specified in this standard. Bearing surfaces for bolting shall be parallel to the flange face within 3 degrees.

15-9.4. *Flange alignment.* When pipe is furnished with two flanges, the bolt holes shall be aligned unless otherwise specified. Misalignment of corresponding bolt holes of the two flanges shall not exceed 0.12 in. (3.05 mm). The machined flange faces shall be perpendicular to the pipe center line and shall be parallel such that any two face-to-face dimensions 180 degrees apart at the flange OD shall not differ by more than 0.06 in. (1.5 mm).

15-9.5. *Finished pipe length.* Flanged pipe shall be furnished to the lengths specified on the purchase order. When pipe is furnished with two flanges, the face-to-face dimensions shall conform to a tolerance of ±0.12 in. (±3.05 mm). The overall length of flange and plain-end pipe shall conform to a tolerance of ±0.25 in. (±6.35 mm).

15-9.6. *Finished pipe weight.* The weight of any single pipe shall not be less than the calculated weight by more than 10 percent.

Sec. 15-10 Coatings and Linings

15-10.1. *Outside coating.* Unless otherwise specified, the outside coating shall be an asphaltic coating approximately 1 mil (25 μm) thick. The coating shall be applied to the outside of all pipe, unless otherwise specified. The finished coating shall be continuous, smooth, neither brittle when cold nor sticky when exposed to the sun, and shall be strongly adherent to the pipe.

15-10.2. *Cement-mortar linings.* If desired, cement linings shall be specified in the invitation for bids and on the purchase order. Cement linings shall be in accordance with ANSI/AWWA C104/A21.4, Standard for Cement–Mortar Lining for Ductile-Iron and Cast-Iron Pipe and Fittings for Water, of the latest revision.

15-10.3. *Inside coating.* Unless otherwise specified, the inside coating for pipe that is not cement-lined shall be an asphaltic material as thick as practicable at least 1 mil (25 μm) and conforming to all appropriate requirements for seal coat in ANSI/AWWA C104/A21.4, Standard for Cement–Mortar Lining for Ductile-Iron and Cast-Iron Pipe and Fittings for Water, of the latest revision.

15-10.4. *Flange coatings.* A rust-preventive coating shall be applied to the machined faces of the flanges. The rust-preventive coating shall be soluble in commercial solvent for ready removal before pipe installation. Unless otherwise specified, the back of the flanges and the bolt holes shall be coated with standard outside coating (see Sec. 15-10.1).

15-10.5. *Special coatings and linings.* For special conditions, other types of coatings and linings may be available.

Such special coatings and linings shall be specified in the invitation for bids and on the purchase order.

Sec. 15-11 Marking

The length and the weight shall be shown on each pipe. The flange manufacturer's mark and the letters DI, if ductile iron, and CI, if cast iron, shall be cast or stamped on the flanges. If the fabricator is other than the flange manufacturer, the fabricator's mark shall be stamped with a metal die on each flange after assembly.

Appendix A

Bolts, Gaskets, and Installation

This appendix is for information only and is not part of ANSI/AWWA C115/A21.15.

The bolts and gaskets to be used with the flanged pipe are to be selected by the purchaser with due consideration for the particular pressure-service and installation requirements.

Bolts and nuts. Size, length, and number of bolts are shown in Table 15.3. Bolts conform to ANSI B18.2.1, Square and Hex Bolts and Screws Inch Series Including Hex Cap Screws and Lag Screws, and nuts conform to ANSI B18.2.2, Square and Hex Nuts. Bolts smaller than ¾ in. (19.0 mm) have either standard square or heavy hex heads and heavy hex nuts. Bolts ¾ in. (19.0 mm) and larger have either square or hex heads and either hex or heavy hex nuts. Bolts and nuts are threaded in accordance with ANSI B1.1, Standard for Unified Inch Screw Threads (UN and UNR Thread Form), Class 2A, external, and Class 2B, internal. Bolts and nuts of low-carbon steel conforming to the chemical and mechanical requirements of ASTM A307, Specification for Carbon Steel Externally Threaded Standard Fasteners, Grade B, are suitable for use with the flanges covered by this standard when used with the rubber gaskets covered in this appendix. Higher strength bolts should not be used when a gray-iron flange is used with a flat ring gasket.

Gaskets. Gaskets are rubber, either ring or full face, and are ⅛ in. (3.18 mm) thick, unless otherwise specified by the purchaser, conforming to the dimensions shown in Table A.1.

Installation. The design, assembly, and installation of the flanged piping system are the responsibility of the purchaser. The following suggestions are for general guidance:

(a) The underground use of the flanged joint is generally not desirable because of the rigidity of the joint.

(b) Flanged joints should be fitted so that the contact faces bear uniformly on the gasket and then are made up with relatively uniform bolt stress.

(c) Ring gaskets are recommended for 14 in. and larger sizes.

TABLE A.1

Flange Gasket Details

Nominal Pipe Size *in.*	Ring		Full Face				
	ID *in.*	OD *in.*	ID *in.*	OD *in.*	BC *in.*	Bolt Hole Diameter *in.*	Number of Holes
3	3	5⅜	3	7½	6	¾	4
4	4	6⅞	4	9	7½	¾	8
6	6	8¾	6	11	9½	⅞	8
8	8	11	8	13½	11¾	⅞	8
10	10	13⅜	10	16	14¼	1	12
12	12	16⅛	12	19	17	1	12
14	14	17¾	14	21	18¾	1⅛	12
16	16	20¼	16	23½	21¼	1⅛	16
18	18	21⅝	18	25	22¾	1¼	16
20	20	23⅞	20	27½	25	1¼	20
24	24	28¼	24	32	29½	1⅜	20
30	30	34¾	30	38¾	36	1⅜	28
36	36	41¼	36	46	42¾	1⅝	32
42	42	48	42	53	49½	1⅝	36
48	48	54½	48	59½	56	1⅝	44
54	54	61	54	66¼	62¾	2	44

AWWA C115-83
9 March 1983

SUPERSEDING
AWWA C115-75
7 August 1981
USE INSTEAD OF
WW-P-421 (in part)
13 September 1976

Department of Defense Acceptance Notice

This nongovernment document was adopted and approved for use by the Department of Defense (DoD) on 9 March 1983. The American Water Works Association has furnished the clearance required by existing regulations. Copies of the document are stocked by DoD Single Stock Point, Naval Publications and Forms Center, Philadelphia, PA 19120, for issue to DoD activities only. Contractors and industry groups must obtain copies from AWWA, 6666 West Quincy Ave., Denver, CO 80235.

Title of Document: American National Standard for Flanged Ductile-Iron and Gray-Iron Pipe with Threaded Flanges

Date of Specific Issue Adopted: January 30, 1983

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NOTE: Must be used in conjunction with AWWA C110, C111, and C151.

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SECTION VI

LININGS FOR DUCTILE IRON PIPE

Cement-Mortar Lined Ductile Iron Pipe

Historical Development. The first cast iron water mains were not coated or lined, but were installed in the same condition in which they came from the casting molds. After many years' use, it became evident that the interior of the pipe was affected by certain types of water. The use of bituminous coating was proposed, and most of the cast iron pipe sold for water works service after about 1860 were provided with a hot dip bituminous lining and coating, usually of molten tar pitch. In those systems where the water was relatively hard and slightly alkaline, the bituminous linings were generally satisfactory. Where soft or acid waters were encountered, however, problems frequently arose, such as the water becoming red or rusty and a gradual reduction of the flow rate through the pipe. Corrosive water penetrated the pinholes in the tar coating and tuberculation ensued. The need of a better pipe lining to combat tuberculation led to experiments and research with cement mortar as a lining material.

In 1922, the first sement-lined cast iron pipe was installed in the water distribution system of Charleston, South Carolina. This pipe was lined by means of a projectile drawn through the pipe. After over 60 years of service, friction flow tests show that this original cement-lined cast iron pipe has retained a Hazen-Williams coefficient (C Factor) of 130.

This process, however, soon gave way to a centrifugal process. Since 1922 many improvements have been made in the production of cement-lined pipe. Cement-mortar lined pipes are centrifugally lined at the foundry to assure that the best possible quality control is maintained, and that a uniform thickness of mortar is distributed throughout the entire length of the pipe. Cement linings prevent tuberculation by keeping the water from contacting the iron. The linings are smooth and offer very little frictional resistance to the flow of water. All ductile iron pipe installed in water systems today is furnished with cement mortar lining, unless otherwise specified by purchaser.

Lining Process. The centrifugal process of applying cement-mortar linings is used in modern practice. By using this method, excellent quality control of the cement-mortar and the centrifugal lining operation can be maintained. Centrifugal lining enables the pipe manufacturer to produce cement-lined pipe of the highest quality—smooth, free of defects and meeting the rigid requirements of ANSI/AWWA C104/A21.4 Standard, "Cement-Mortar Lining for Ductile Iron and Gray Iron Pipe and Fittings for Water."

The lined pipe are stored in a moist atmosphere during the curing period, or given a seal coating to prevent too rapid loss of moisture. The cement lining adheres to the wall of the pipe so that the pipe may be cut and tapped without damage to the lining.

Economics of Cement Lining. The advantages of cement-lined cast iron pipe go beyond the prevention of tuberculation and are clearly applicable to installations in territories where tuberculating waters do not exist. In order to fully understand the financial advantages of using cement linings, it is necessary to have some knowledge of certain hydraulic phenomena.

When water moves through pipe, friction is developed between the water and the inside of the pipe. The result is that, as the water travels through the pipe, some of the energy imparted to it by the pump is consumed by the friction, resulting in a loss of pressure. The amount of friction so developed is the criterion by which the size of pipe, and the amount of power required for pumping, are determined. When a given amount of water is to be transported, the total amount of friction developed depends on the diameter and length of the pipe and the condition of its interior.

The principal advantages of cement linings are higher flow coefficient when the pipe is new and maintained carrying capacity as the pipe grows older. The economy resulting from the prevention of tuberculation is obvious, but experience has shown that less friction results when cement linings are used even where non-tuberculating waters are transported.

For example, a test made on a new 36-in bituminous lined cast iron supply line showed a coefficient of approximately 135. A test on a new 36-inch cement-lined cast iron line showed a coefficient of 145. Since new pipe was tested in both cases, the difference in values was due to the different conditions of the pipe interiors. See Section X for energy savings associated with the use of cement mortar lined ductile iron pipe.

Special Linings

Special linings are available for service requirements where cement-mortar linings are not applicable. These linings include polyethylene, petroleum asphaltic coal tar epoxy, FDA approved epoxy and others. The pipe manufacturers should be consulted regarding the availability and proper use of these linings.

American Water Works Association

ANSI/AWWA C104/A21.4–80

Revision of
ANSI A21.4–1974
(AWWA C104–74)

AMERICAN NATIONAL STANDARD

for

CEMENT–MORTAR LINING FOR DUCTILE-IRON AND GRAY-IRON PIPE AND FITTINGS FOR WATER

Made Standard December 1939.
This edition approved by AWWA Board of Directors Jan. 28, 1980.
Revised edition approved by the American National Standards Institute, Inc., May 9, 1980.

NOTICE

This Standard has been especially printed by the American Water Works Association for incorporation into this volume. It is current as of October 1, 1984. It should be noted, however, that all AWWA Standards are updated at least once in every five years. Therefore, before applying this Standard it is suggested that you confirm its currency with the American Water Works Association.

ADMINISTRATIVE SECRETARIAT

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CO-SECRETARIATS

AMERICAN GAS ASSOCIATION
NEW ENGLAND WATER WORKS ASSOCIATION

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AMERICAN WATER WORKS ASSOCIATION
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Foreword

This foreword is for information and is not a part of ANSI/AWWA C104/A21.4

I. History of Standard

The first recorded installation of cement–mortar linings in cast-iron pipe was in 1922 at Charleston, South Carolina, under the supervision of J. E. Gibson.

From 1922 to 1929, many installations were made under various manufacturers' specifications. In 1929, American Standards Association (ASA), now the American National Standards Institute (ANSI), Sectional Committee A21, issued a tentative standard for cement–mortar linings, that was published as a tentative standard by AWWA in 1932. After many revisions and refinements, the standard was finally adopted by ASA in 1939 under the designation A21.4—Specifications for Cement–Mortar Lining for Cast-Iron Pipe and Fittings.

During the period 1940–52, considerable research was done on various types of cement, methods of manufacture, and methods of curing cement–mortar to improve the quality of cement–mortar linings. As a result of this research, a revised edition of the 1939 standard was approved and issued in 1953.

The centrifugal process for lining was further developed during the 1940–52 period to provide the controls and techniques necessary for assurance of uniformity of thickness throughout the length of a pipe. Another major revision recognized the ability of cure-assist asphaltic materials to provide controlled curing of the mortar. The use of this method was permitted as a substitute for the moist-curing process.

In 1958, Sectional Committee A21 was reorganized and subcommittees were established to study each group of standards in accordance with ASA's review and revision policy.

Subcommittee 4, Coatings and Linings for Cast-Iron Pipe, was organized to examine the existing ASA A21.4–1953, "Standard for Cement–Mortar Lining for Cast-Iron Pipe and Fittings." The subcommittee completed its study of A21.4–53 and submitted a proposed revision to Sectional Committee A21 in 1963. The revised third edition was approved and issued in 1964.

The 1964 standard reduced the minimum permissible thickness of the lining. The reduction was based on more than 20 years of Cast Iron Pipe Research Association (CIPRA) studies of experimental test lines having cement–mortar linings from $\frac{1}{32}$ in. to $\frac{1}{4}$ in. in thickness, on field tests of linings of these thicknesses that had been in service for more than 30 years, and on the assurance of uniformity of thickness afforded by improvements in the centrifugal lining process.

Two thicknesses of lining were made available, and purchasers who required a lining thickness twice the standard thickness had the option of so specifying.

The cement linings were specified for use in water lines only, a qualification that was made to avoid the use of cement–mortar linings in pipe carrying aggressive liquids, which would react with the lining to produce undesirable results.

The purchaser of cement–mortar-lined pipe or fittings for use with a water that is corrosive to calcium carbonate, such as a very soft water, is advised, before specifying the omission of the seal coat, to satisfy himself by an appropriate test that such a lining will not impart objectionable hardness or alkalinity to the water. The procedure outlined in Sec. 4.12.4, modified by the substitution of the water with which the pipe is to be used for distilled water, is suggested as a convenient form of test.

The 1971 revision incorporated a standard test for toxicity of the seal-coat material.

In the 1974 revision, major changes in the section on Lining Quality were made. Since the wording of this section has caused some problems with literal interpretations, further changes in this section are made in the current revision.

This standard does not include provisions for cement–mortar lining of pipelines in place.

II. Major Revisions

1. Metric conversion. Metric conversions of all dimensions and physical requirements are included in this standard. Metric dimensions are direct conversions of customary US inch–pound units and are not those specified in International Standards Organization (ISO) standards.
2. Sections 4.5, 4.6 and 4.7 have been rewritten to delete reference to resultant lining quality which are properly made in the section on Lining Quality.
3. Section 4.7 has been revised to include the projection method as an allowable means of lining pipe and fittings.
4. Former Sections 4.8, Socket, and 4.9, Protection of Work, have been deleted; the material in the sections having been covered appropriately in terms of end results in other sections. The deletion of these sections resulted in a renumbering of subsequent sections in the standard.
5. Former Section 4.10.4, Permitted Tolerances for Thickness of Lining, has been deleted for practical reasons.
6. Section 4.11 (formerly Section 4.13), Lining Quality, has been rewritten providing new requirements of acceptable lining.
7. Throughout the standard, references to other standards, test methods and so forth have been updated.

III. Options

This standard includes certain options, which, if desired, must be specified, as follows:

1. Thickness of lining. Two thicknesses of lining are available and purchasers who require a lining thickness twice the standard thickness have the option of so specifying (Sec. 4.8).
2. Seal coat. As seal coats other than asphaltic ones are available, this standard makes provision for their use (Sec. 4.12).

American Water Works Association

ANSI/AWWA C104/A21.4–80

Revision of
ANSI A21.4–1974
(AWWA C104–74)

American National Standard for

Cement–Mortar Lining for Ductile-Iron and Gray-Iron Pipe and Fittings for Water

Sec. 4.1 Scope

This standard covers shop-applied cement–mortar linings specified in the ANSI/AWWA C100/A21 series of standards for ductile-iron and gray-iron pipe and fittings for water and is intended for use as a supplement to those standards.

Sec. 4.2 Cement

The cement shall meet the requirements of ASTM C150, "Standard Specification for Portland Cement." The analysis and physical test records of each shipment shall be kept for reference for one year. The type of cement selected shall be left to the option of the pipe and fittings manufacturer.

Sec. 4.3 Sand

4.3.1 *Type of sand.* The sand shall be well graded, from fine to coarse, shall consist of inert granular material having hard, strong, durable, uncoated grains, and shall meet the test requirements of Sec. 4.3.2.

4.3.2 *Testing of sand.* The sand shall be tested in accordance with the following requirements.

4.3.2.1 Sampling. The sand to be tested shall be sampled according to Sections 14 and 15 of ASTM D75, "Standard Methods of Sampling Aggregates."

4.3.2.2 Sieve tests. The sand shall be tested with standard sieves, as defined in ASTM E11, "Standard Specification for Wire-Cloth Sieves for Testing Purposes," and shall meet the requirements listed in Table 1. One sieve analysis shall be performed on each carload of sand delivered. For sand delivered by other means, one sieve analysis shall be made for each 50 tons (45 400 kg).

4.3.2.3 Colorimetric test. The test for impurities shall be in accordance with ASTM C40, "Standard Method of Test for Organic Impurities in Sands for Concrete."

TABLE 1

Requirements for Sand Tested With Standard Sieves

Minimum Thickness of Lining *in.* (*mm*)	Sieve Requirement*	
	100 percent of Sand Shall Pass (Sieve No.)	75 percent of Sand Shall Pass (Sieve No.)
$\frac{1}{16}$ (1.6)	12	20
$\frac{3}{32}$ (2.4)	12	16
$\frac{1}{8}$ (3.2)	12	†
$\frac{3}{16}$ (4.8)	8	†
$\frac{1}{4}$ (6.4)	6	†

* Not more than 10 percent, by weight, of any sand shall pass through sieve No. 100.
† Not applicable.

4.3.2.3.1 When using this test, the sand shall not produce a color darker than required in the standard. However, if it is shown by adequate test that the impurities causing the color are not harmful to the strength or other specified properties of the finished lining, the sand shall be acceptable.

4.3.2.3.2 The colorimetric tests of sand from an established source of supply shall be made once every 6 months. For sand from a new source, these tests shall be made not less than once a month for a period of 6 months.

4.3.2.4 Decantation test. The sand shall be tested according to ASTM C117, "Standard Method of Test for Materials Finer Than No. 200 [75-μm] Sieve in Mineral Aggregates by Washing."

4.3.2.4.1 At the option of the manufacturer, the clay content and sand grain fineness may be determined by using the American Foundrymen's Society (AFS) procedure, described in the *Foundry Sand Handbook,* seventh edition, Section 5. By this latter method, the total percentage finer than No. 200 sieve, as defined in ASTM C119, is equal to the AFS percentage of clay plus the percentage passing through the No. 200 sieve.

4.3.2.4.2 No more than 2 percent shall be lost in the decantation test.

4.3.2.4.3 The decantation tests of sand from an established source of supply shall be made once every 6 months. For sand from a new source, these tests shall be made not less than once a month for a period of 6 months.

4.3.2.5 Test records. The requirements of Sec. 4.3.2.2, 4.3.2.3, and 4.3.2.4 shall be met, and the records shall be filed for reference for one year.

Sec. 4.4 Water

The water used for the mortar shall be potable water that is free from objectionable quantities of any impurities that might reduce the strength, durability, or other desirable qualities of the mortar.

Sec. 4.5 Mortar

Mortar for the lining shall be a mixture composed of cement, sand, and water. Admixtures may be used provided the linings meet all the requirements of this standard. The cement–mortar shall contain not less than one part of cement to two parts of sand, by volume.

Sec. 4.6 Surface of Pipe and Fittings for Lining

The surface to be lined shall be free from projections of iron or other material which may protrude through the lining.

Sec. 4.7 Method of Lining

4.7.1 *Lining of pipe and fittings.* Pipe shall be lined by a centrifugal process or a projection method. Fittings shall be lined by a projection method or by hand application.

4.7.1.1 Waterways and sockets. The waterway surfaces of pipe and fittings shall be completely covered with the specified mortar. The sockets shall be free of mortar.

4.7.2 *Repair of defective or damaged areas of linings.* Defective or damaged areas of linings may be patched by cutting out the defective or damaged lining to the metal so that the edges of the lining not removed are perpendicular or slightly undercut. A stiff mortar shall be prepared in accordance with Sec. 4.5. The cut-out area and the adjoining lining shall be thoroughly wetted, and the mortar applied and troweled smooth with the adjoining lining. After any surface water has evaporated, but while the patch is still moist, it shall be cured as specified in Sec. 4.10.

Sec. 4.8 Thickness of Lining

4.8.1 *Standard thickness.* The thickness of linings for pipe and fittings, as determined in Sec. 4.9, shall not be less than $\frac{1}{16}$ in. (1.6 mm) for 3–12 in. pipe; $\frac{3}{32}$ in. (2.4 mm) for 14–24 in. pipe; and $\frac{1}{8}$ in. (3.2 mm) for 30–54 in. pipe.

4.8.2 *Double thickness.* Linings with thicknesses twice those specified in Sec. 4.8.1 shall be furnished, if specified by the purchaser.

4.8.3 *Taper of linings.* Lining thickness may taper to less than the specified minimum thickness at the ends of the pipe or fitting. The length of the taper shall be as short as practicable and shall not exceed 2 in. (51 mm).

Sec. 4.9 Determination of Thickness

Lining thickness shall be determined at intervals frequent enough to assure compliance. Thickness shall be determined while the mortar is wet.

Sec. 4.10 Curing

The lining shall be cured in such a manner as to produce a properly hydrated mortar lining that is hard and durable and will otherwise meet the requirements of Sec. 4.11. The cure may be affected by the application of a seal coat to the still moist lining.

Sec. 4.11 Lining Quality

The lining surface shall be free from ridges, corrugations or defects that reduce the thickness of the lining to less than the specified thickness.

4.11.1 *Cracking, crazing, and loose areas.* Longitudinal cracks with a length equal to or less than the pipe circumference are acceptable. In pipe larger than 24 in. in diameter, longer longitudinal cracks are acceptable if it can be demonstrated to the satisfaction of the purchaser that such cracks will close and heal.* Circumferential cracks of any length are acceptable. Surface crazing is acceptable. Loose areas of cement lining in a pipe or fitting are acceptable if the lining is intact.†

4.11.2 *Surface appearance.* Due to hand finishing, the linings in fittings may have a surface appearance which differs from that of pipe linings.

* Experience has shown that cracks in interior linings due to mortar shrinkage or deformation of pipe will close upon continuous exposure to water due to swelling of the mortar, and then they will subsequently heal. Closing of interior lining cracks can be demonstrated by having the lined pipe or fitting immersed in water.

† Experience has shown that such linings swell and re-tighten on continuous contact with water.

4.11.3 *Field repair.* Linings may be repaired in the field in accordance with Section 4.7.2.

Sec. 4.12 Seal Coat

4.12.1 *General.* Unless otherwise specified, the cement lining shall be given a seal coat of asphaltic material. Other seal-coat materials may be used, but they shall be agreed upon at the time of purchase and shall be specified on the purchase order.

4.12.2 *Seal-coat characteristics.* The seal coat shall adhere to the mortar lining. After drying for at least 48 hr, the seal coat shall have no deleterious effect upon the quality, color, taste or odor of potable water.

4.12.3 *Limit of toxic substances.*

4.12.3.1 Requirements. The seal-coat material shall not yield chloroform-soluble extractives, corrected for zinc extractives as zinc oleate, in excess of 18 mg/sq in. of surface exposed or of 50 ppm by weight of the water capacity of the test container.

4.12.3.2 Frequency of test. The seal-coat material shall be tested at sufficiently frequent intervals to determine that it meets the requirements prescribed in Sec. 4.12.3.1.

4.12.3.3 Method of testing. The procedure used in the determination of the amount of water-extractable substances shall be in accordance with the Food and Drug Administration (FDA) procedure outlined in Sec. 175.300 of the *Code of Federal Regulations,* Title 21, Chapter 1, Apr. 1, 1978, Food and Drug Administration, US Department of Health, Education and Welfare. The seal-coat material shall be extracted with distilled water at 120°F (49°C) for 24 hr.

4.12.4 *Leaching resistance.*

4.12.4.1 Requirements. The seal-coated pipe shall impart to the water during any 24-hr test period no more than 25 ppm of hardness or 25 ppm of total alkalinity, and shall impart no caustic alkalinity.

4.12.4.2 Frequency of test and records. Leaching tests shall be made at sufficiently frequent intervals to assure compliance. The results of one test each month shall be filed for reference for one year.

4.12.4.3 Method of testing. The seal-coated pipe shall be tested as follows.

4.12.4.3.1 The test specimen shall be at least 6 in. (152.4 mm) in length, either cut or isolated by suitable closure pieces. When a cut section is used, it shall be bedded on end in a shallow pan of molten paraffin. After the paraffin has cooled, the cut section shall be filled nearly to the top with distilled or demineralized water at laboratory temperature. The top shall be covered with a glass plate and sealed with petroleum jelly. If an isolated section is used, it shall be filled through a tap in the closure device with distilled or demineralized water at laboratory temperature.

4.12.4.3.2 In either case, the water in the specimen shall be changed and tested after 24 hr contact on each of three successive days. The method and procedures used in the determination of hardness and alkalinity shall be those prescribed in *Standard Methods for the Examination of Water and Wastewater,* APHA, AWWA, and WPCF (fourteenth edition, 1975).

SECTION VII

EXTERNAL CORROSION PROTECTION

The resistance of gray iron pipe to exterior corrosion has long since been established. Comparative corrosion tests between ductile and gray iron have now shown that the corrosion resistance of ductile iron pipe is equal to or greater than that of gray iron pipe. In a survey of water utility officials throughout the United States, it was found that the vast majority of the soils in water distribution systems are non-corrosive to these pipe materials. DIPRA has developed a system for evaluation of soil corrosivity based on many years of experience. The system is described in the Appendix to ANSI/AWWA C105/A21.5. Most common causes of corrosion involve naturally corrosive soils or soil contaminants such as peat, muck, cinders, mine wastes, deicing salts and stray direct current.

The Ductile Iron Pipe Research Association has completed soil surveys along hundreds of miles of proposed pipeline installation using the standard soil test procedures. These procedures involve environmental characteristics listed in Table A1 of the Appendix to ANSI/AWWA C105/A21.5. With the additional consideration of potential corrosion due to stray direct current, these procedures have proven to be highly dependable since their establishment in 1968. Proper application of polyethylene encasement where the environment is determined to be corrosive has likewise proven to be dependable.

Polyethylene encasement for protection of gray and ductile iron pipe in corrosive soils and locations of potential stray current influence is a universal practice in the USA as well as most European countries and industrial nations throughout the world. Its success is attributed to the uniform environment it provides for the pipe, its dielectric strength, and the barrier it provides between the pipe and the corrosive environment. No attempt is made to make the encasement absolutely watertight. Water, upon entering the annular space between the pipe and the encasement, may possess the corrosive characteristics of the surrounding soil; however, there is no ongoing ingress and egress of water, and the results of the initial corrosion reaction create a stable situation which further enhances the polyethylene encasement protection system. It is estimated that about 5,000 miles of gray and ductile iron pipe are protected with polyethylene encasement in the USA alone. Failures are so few as to be negligible over a period exceeding 25 years.

ANSI/AWWA C105/A21.5-82
[Revision of ANSI/AWWA C105-72 (R77)]

AMERICAN NATIONAL STANDARD

for

POLYETHYLENE ENCASEMENT FOR DUCTILE-IRON PIPING FOR WATER AND OTHER LIQUIDS

ADMINISTRATIVE SECRETARIAT

AMERICAN WATER WORKS ASSOCIATION

CO-SECRETARIATS

AMERICAN GAS ASSOCIATION
NEW ENGLAND WATER WORKS ASSOCIATION

NOTICE

This Standard has been especially printed by the American Water Works Association for incorporation into this volume. It is current as of October 1, 1984. It should be noted, however, that all AWWA Standards are updated at least once in every five years. Therefore, before applying this Standard it is suggested that you confirm its currency with the American Water Works Association.

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Table of Contents

Foreword

This foreword is for information only and is not a part of ANSI/AWWA C105.

I. History of Standard

In 1926, ASA (now ANSI) Committee A21, Cast-Iron Pipe and Fittings, was organized under the sponsorship of AGA, ASTM, AWWA, and NEWWA. The current sponsors are AGA, AWWA, and NEWWA, and the present scope of Committee A21 activity is standardization of specifications for cast-iron and ductile-iron pressure pipe for gas, water, and other liquids, and fittings for use with such pipe. These specifications are to include design, dimensions, materials, coatings, linings, joints, accessories, and methods of inspection and test.

In 1958, Committee A21 was reorganized. Subcommittees were established to study each group of standards in accordance with the review and revision policy of ASA (now ANSI). The present scope of Subcommittee 4, Coatings and Linings, is to review the matter of interior and exterior corrosion of gray and ductile-iron pipe and fittings and to draft standards for the interior and exterior protection of gray and ductile-iron pipe and fittings.

In accordance with this scope, Subcommittee 4 was charged with the responsibility for:

1. Development of standards on polyethylene encasement materials and their installation as corrosion protection, when required, for gray and ductile cast-iron pipe and fittings.
2. Development of procedures for the investigation of soil to determine when polyethylene protection is indicated.

In response to these assignments, Subcommittee 4 has:

1. Developed ANSI A21.5-1972 (AWWA C105-72), Standard for Polyethylene Encasement for Gray and Ductile Cast-Iron Piping for Water and Other Liquids.
2. Developed Appendix A outlining soil-investigation procedures.

In 1976, Subcommittee 4 reviewed the 1972 edition and submitted a recommendation to Committee A21 that the standard be reaffirmed without change from the 1972 edition, except for the updating of this foreword.

In 1981, Subcommittee 4 again reviewed the standard. The major revisions incorporated into the current edition as a result of that review are listed in Sec. VII of this foreword.

II. History of Polyethylene Encasement

Loose polyethylene encasement was first used experimentally in the United States for protection of cast-iron pipe in corrosive environments in 1951. The first field installation of polyethylene wrap on cast-iron pipe in an operating water system was in 1958 and consisted of about 600 ft (180 m) of 12-in. pipe installed in a waste-dump fill area. Since that time, hundreds of installations have been made in severely corrosive soils throughout the United States in pipe sizes ranging from 4–54 in. in diameter. Polyethylene encasement has been used as a soil-corrosion preventative in Canada, England, France, Germany, and several other countries since development of the procedure in the United States.

III. Research

Research by the Cast Iron Pipe Research Association (CIPRA)* on several severely corrosive test sites has indicated that polyethylene encasement provides a high degree of protection and results in minimal and generally insignificant exterior surface corrosion of gray and ductile cast-iron pipe thus protected.

Investigations of many field installations in which loose polyethylene encasement has been used as protection for gray and ductile cast-iron pipe against soil corrosion have confirmed CIPRA's findings with the experimental specimens. These field installations have further indicated that the dielectric capability of polyethylene provides shielding for gray and ductile cast-iron pipe against stray direct current at most levels encountered in the field.

IV. Useful Life of Polyethylene

Tests on polyethylene used in the protection of gray and ductile cast-iron pipe have shown that after 20 years of exposure to severely corrosive soils, strength loss and elongation reduction are insignificant. Studies by the Bureau of Reclamation of the US Department of the Interior† on polyethylene film used underground showed that tensile strength was nearly constant in a 7-yr test period and that elongation was only slightly affected. The Bureau's accelerated soil-burial testing (acceleration estimated to be five to ten times that of field conditions) showed polyethylene to be highly resistant to bacteriological deterioration.

V. Exposure to Sunlight

Prolonged exposure to sunlight will eventually deteriorate polyethylene film. Therefore, such exposure prior to backfilling the wrapped pipe should be kept to a minimum. If several weeks of exposure prior to backfilling are anticipated, Class C material should be used (see Sec. 5-3.1.1).

VI. Options

This standard includes certain options, which, if desired, must be specified. These options are:

1. Color of polyethylene material (Sec. 5-3).
2. Installation method—A, B, or C (Sec. 5-4)—if there is a preference.

VII. Major Revisions

The major revisions in this edition consist of the following:

1. Reference to gray cast-iron pipe in the title and throughout the standard was deleted because gray iron pipe is no longer produced in the United States.
2. Metric conversions of all dimensions are included in this standard. Metric dimensions are direct conversions of customary US inch-pound units and are not those specified in International Organization for Standardization (ISO) standards.

*CIPRA became the Ductile Iron Pipe Research Association in 1979.

†Laboratory and Field Investigations of Plastic Films, US Dept. of the Interior, Bureau of Reclamation, Rept. No. ChE-82 (Sept. 1968).

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ANSI/AWWA C105/A21.5-82
[Revision of ANSI/AWWA C105-72 (R77)]

American National Standard for

Polyethylene Encasement for Ductile-Iron Piping for Water and Other Liquids

Sec. 5-1 Scope

This standard covers materials and installation procedures for polyethylene encasement to be applied to underground installations of ductile-iron pipe. This standard also may be used for polyethylene encasement of fittings, valves, and other appurtenances to ductile-iron pipe systems.

Sec. 5-2 Definition

5-2.1 *Polyethylene encasement:* The encasement of piping with polyethylene film in tube or sheet form.

Sec. 5-3 Materials

5-3.1 *Polyethylene.* Polyethylene film shall be manufactured of virgin polyethylene material conforming to the following requirements of ASTM Standard Specification D-1248-78—Polyethylene Plastics Molding and Extrusion Materials:

5-3.1.1 *Raw material used to manufacture polyethylene film.*
Type: I
Class: A (natural color) or C (black)
Grade: E-1
Flow rate (formerly melt index): 0.4 maximum
Dielectric strength: Volume resistivity, minimum ohm–cm^3 = 10^{15}

5-3.1.2 *Polyethylene film.*
Tensile strength: 1200 psi (8.3 MPa) minimum
Elongation: 300 percent minimum
Dielectric strength: 800 V/mil (31.5 V/μm) thickness minimum

5-3.2 *Thickness.* Polyethylene film shall have a minimum thickness of 0.008 in. (8 mil, or 200 μm). The minus tolerance on thickness shall not exceed 10 percent of the nominal thickness.

5-3.3 *Tube size or sheet width.* Tube size or sheet width for each pipe diameter shall be as listed in Table 5.1.

TABLE 5.1

Tube and Sheet Sizes

Nominal Pipe Diameter *in.*	Minimum Polyethylene Width *in. (cm)*	
	Flat Tube	Sheet
3	14 (35)	28 (70)
4	16 (41)	32 (82)
6	20 (51)	40 (102)
8	24 (61)	48 (122)
10	27 (69)	54 (137)
12	30 (76)	60 (152)
14	34 (86)	68 (172)
16	37 (94)	74 (188)
18	41 (104)	82 (208)
20	45 (114)	90 (229)
24	54 (137)	108 (274)
30	67 (170)	134 (340)
36	81 (206)	162 (411)
42	95 (241)	190 (483)
48	108 (274)	216 (549)
54	121 (307)	242 (615)

Sec. 5-4 Installation

5-4.1 *General.* The polyethylene encasement shall prevent contact between the pipe and the surrounding backfill and bedding material but is not intended to be a completely airtight and watertight enclosure. Overlaps shall be secured by the use of adhesive tape, plastic string, or any other material capable of holding the polyethylene encasement in place until backfilling operations are completed.

5-4.2 *Pipe.* This standard includes three different methods of installation of polyethylene encasement on pipe. Methods A and B are for use with polyethylene tubes and method C is for use with polyethylene sheets.

5-4.2.1 *Method A.* (Refer to Figure 5.1.) Cut polyethylene tube to a length approximately 2 ft (0.6 m) longer than that of the pipe section. Slip the tube around the pipe, centering it to provide a 1-ft (0.3-m) overlap on each adjacent pipe section, and bunching it accordion-fashion lengthwise until it clears the pipe ends.

Lower the pipe into the trench and make up the pipe joint with the preceding section of pipe. A shallow bell hole must be made at joints to facilitate installation of the polyethylene tube.

After assembling the pipe joint, make the overlap of the polyethylene tube. Pull the bunched polyethylene from the preceding length of pipe, slip it over the end of the new length of pipe, and secure it in place. Then slip the end of the polyethylene from the new pipe section over the end of the first wrap until it overlaps the joint at the end of the preceding length of pipe. Secure the overlap in place. Take up the slack width to make a snug, but not tight, fit along the barrel of the pipe, securing the fold at quarter points.

Repair any rips, punctures, or other damage to the polyethylene with adhesive tape or with a short length of polyethylene tube cut open, wrapped around the pipe, and secured in place. Proceed with installation of the next section of pipe in the same manner.

5-4.2.2 *Method B.* (Refer to Figure 5.2.) Cut polyethylene tube to a length approximately 1 ft (0.3 m) shorter than that of the pipe section. Slip the tube around the pipe, centering it to provide 6 in. (15 cm) of bare pipe at each end. Make polyethylene snug, but not tight; secure ends as described in Sec. 5-4.2.1.

Before making up a joint, slip a 3-ft (0.9-m) length of polyethylene tube over the end of the preceding pipe section, bunching it accordion-fashion lengthwise. After completing the joint, pull the 3-ft (0.9-m) length of polyethylene over the joint, overlapping the polyethylene previously installed on each adjacent section of pipe by at least 1 ft (0.3 m); make snug and secure each end as described in Sec. 5-4.2.1.

Repair any rips, punctures, or other damage to the polyethylene as described in Sec. 5-4.2.1. Proceed with installation of the next section of pipe in the same manner.

5-4.2.3 *Method C.* (Refer to Figure 5.3.) Cut polyethylene sheet to a length approximately 2 ft (0.6 m) longer than that of the pipe section. Center the cut length to provide a 1-ft (0.3-m) overlap on each adjacent pipe section, bunching it

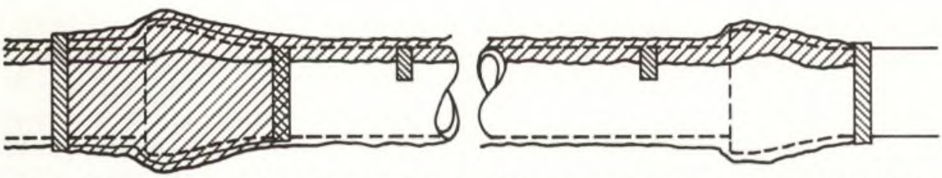

Figure 5.1. Method A: One length of polyethylene tube for each length of pipe, overlapped at joint.

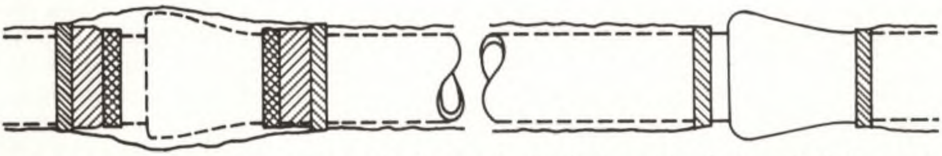

Figure 5.2. Method B: Separate pieces of polyethylene tube for barrel of pipe and for joints. Tube over joints overlaps tube encasing barrel.

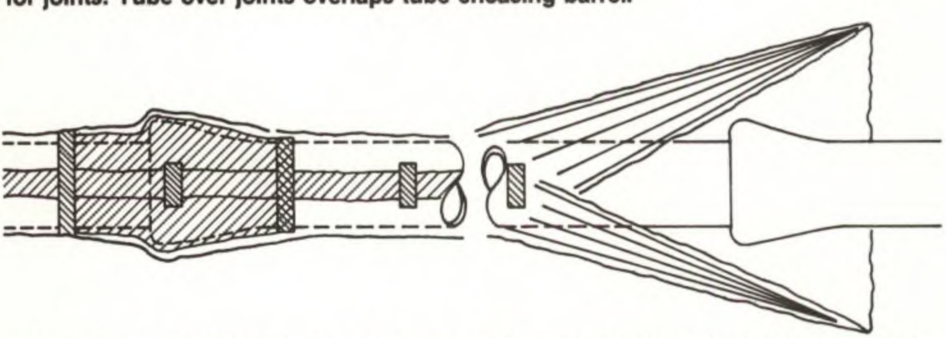

Figure 5.3. Method C: Pipeline completely wrapped with flat polyethylene sheet.

until it clears the pipe ends. Wrap the polyethylene around the pipe so that it circumferentially overlaps the top quadrant of the pipe. Secure the cut edge of polyethylene sheet at intervals of approximately 3 ft (0.9 m).

Lower the wrapped pipe into the trench and make up the pipe joint with the preceding section of pipe. A shallow bell hole must be made at joints to facilitate installation of the polyethylene. After completing the joint, make the overlap as described in Sec. 5-4.2.1.

Repair any rips, punctures, or other damage to the polyethylene as described in Sec. 5-4.2.1. Proceed with installation of the next section of pipe in the same manner.

5-4.3 *Pipe-shaped appurtenances.* Cover bends, reducers, offsets, and other pipe-shaped appurtenances with polyethylene in the same manner as the pipe.

5-4.4 *Odd-shaped appurtenances.* When valves, tees, crosses, and other odd-shaped pieces cannot be wrapped practically in a tube, wrap with a flat sheet or split length of polyethylene tube by passing the sheet under the appurtenance and bringing it up around the body. Make seams by bringing the edges together, folding over twice, and taping down. Handle width and overlaps at joints as described in Sec. 5-4.2.1. Tape polyethylene securely in place at valve-stem and other penetrations.

5-4.5 *Openings in encasement.* Provide openings for branches, service taps, blow-offs, air valves, and similar appurtenances by making an X-shaped cut in the polyethylene and temporarily folding back the film. After the appurtenance is installed, tape the slack securely to the appurtenance and repair the cut, as well as any other damaged areas in the polyethylene, with tape.

5-4.6 *Junctions between wrapped and unwrapped pipe.* Where polyethylene-wrapped pipe joins an adjacent pipe that is not wrapped, extend the polyethylene wrap to cover the adjacent pipe for a distance of at least 2 ft (0.6 m). Secure the end with circumferential turns of tape.

5-4.7 *Backfill for polyethylene-wrapped pipe.* Use the same backfill material as that specified for pipe without polyethylene wrapping, exercising care to prevent damage to the polyethylene wrapping when placing backfill. Backfill material shall be free from cinders, refuse, boulders, rocks, stones, or other material that could damage polyethylene. In general, backfilling practice should be in accordance with the latest revision of AWWA C600, Standard for Installation of Ductile-Iron Water Mains and Their Appurtenances.

Appendix A

Notes on Procedures for Soil Survey Tests and Observations and Their Interpretation to Determine Whether Polyethylene Encasement Should Be Used

This appendix is for information only and is not a part of ANSI/AWWA C105.

In the appraisal of soil and other conditions that affect the corrosion rate of gray and ductile cast-iron pipe, a minimum number of factors must be considered. They are outlined here. A method of evaluating and interpreting each factor and a method of weighing each factor to determine whether polyethylene encasement should be used are subsequently described.

Soil Survey Tests and Observations

1. Earth Resistivity
   (a) Four-pin
   (b) Single-probe
   (c) Saturated-sample
2. pH
3. Oxidation-reduction (redox) potential
4. Sulfides
   (a) Azide (qualitative)
5. Moisture content (relative)
   (a) Prevalence
6. Soil description
   (a) Particle size
   (b) Uniformity
   (c) Type
   (d) Color
7. Potential stray direct current
   (a) Nearby cathodic protection utilizing rectifiers
   (b) Railroads (electric)
   (c) Industrial equipment, including welding equipment
   (d) Mine transportation equipment
8. Experience with existing installations in the area

1. *Earth resistivity.* There are three methods for determining earth resistivity: four-pin, single-probe, and soil-box. In the field, a four-pin determination should be made with pins spaced at approximate pipe depth. This method yields an average of resistivity from the surface to a depth equal to pin spacing. However, results are sometimes difficult to interpret where dry topsoil is underlain with wetter soils and where soil types vary with depth. The Wenner configuration is used in con-

nection with a soil resistivity meter, which is available with varying ranges of resistance. For all-around use, a unit with a capacity of up to 10^4 ohms is suggested because of its versatility in permitting both field and laboratory testing in most soils.

Because of the aforementioned difficulty in interpretation, the same unit may be used with a single-probe that yields resistivity at the point of the probe. A boring is made into the subsoil so that the probe may be pushed into the soil at the desired depth.

Inasmuch as the soil may not be typically wet, a sample should be removed for resistivity determination, which may be accomplished with any one of several laboratory units that permit the introduction of water to saturation, thus simulating saturated field conditions. Each of these units is used in conjunction with a soil resistivity meter.

Interpretation of resistivity results is extremely important. To base an opinion on a four-pin reading with dry topsoil averaged with wetter subsoil would probably result in an inaccurate premise. Only by reading the resistivity in soil at pipe depth can an accurate interpretation be made. Also, every effort should be made to determine the local situation concerning groundwater table, presence of shallow groundwater, and approximate percentage of time the soil is likely to be water saturated.

With gray and ductile cast-iron pipe, resistance to corrosion through products of corrosion is enhanced if there are dry periods during each year. Such periods seem to permit hardening or toughening of the corrosion scale or products, which then become impervious and serve as better insulators.

In making field determinations of resistivity, temperature is important. The result obtained increases as temperature decreases. As the water in the soil approaches freezing, resistivity increases greatly, and, therefore, is not reliable. Field determinations under frozen soil conditions should be avoided. Reliable results under such conditions can be obtained only by collection of suitable subsoil samples for analysis under laboratory conditions at a suitable temperature.

Interpretation of resistivity. Because of the wide variance in results obtained under the methods described, it is difficult specifically to interpret any single reading without knowing which method was used. It is proposed that interpretation be based on the lowest reading obtained, with consideration being given to other conditions, such as normal moisture content of the soil in question. Because of the lack of exact correlation between experiences and resistivity, it is necessary to assign ranges of resistivity rather than specific numbers. In Table A.1, points are assigned to various ranges of resistivity. These points, when considered along with points assigned to other soil characteristics, are meaningful.

2. *pH.* In the pH range of 0.0 to 4.0, the soil serves well as an electrolyte, and total acidity is important. In the pH range of 6.5 to 7.5, soil conditions are optimum for sulfate reduction. In the pH range of 8.5 to 14.0, soils are generally quite high in dissolved salts, yielding a low soil resistivity.

In testing pH, glass and reference electrodes are pushed into the soil sample and a direct reading is made, following suitable temperature setting on the instrument. Normal procedures are followed for standardization.

3. *Oxidation-reduction (redox) potential.* The oxidation-reduction (redox) potential of a soil is significant because the most common sulfate-reducing bacteria can live only under anaerobic conditions. A redox potential

greater than +100 mV shows the soil to be sufficiently aerated so that it will not support sulfate reducers. Potentials of 0 to +100 mV may or may not indicate anaerobic conditions; however, a negative redox potential definitely indicates anaerobic conditions under which sulfate reducers thrive. This test also is accomplished using a pH meter, with platinum and reference electrodes inserted into the soil sample, which permits a reading of potential between the two electrodes. It should be noted that soil samples removed from a boring or excavation can undergo a change in redox potential on exposure to air. Such samples should be tested immediately on removal from the excavation. Experience has shown that heavy clays, muck, and organic soils are often anaerobic, and these soils should be regarded as potentially corrosive.

TABLE A.1

*Soil-Test Evaluation**

Soil Characteristics	Points
Resistivity—*ohm-cm* (based on single-probe at pipe depth or water-saturated soil box):	
<700	10
700-1000	8
1000-1200	5
1200-1500	2
1500-2000	1
>2000	0
pH:	
0-2	5
2-4	3
4-6.5	0
6.5-7.5	0†
7.5-8.5	0
>8.5	3
Redox potential:	
>+100 mV	0
+50 to +100 mV	3.5
0 to +50 mV	4
Negative	5
Sulfides:	
Positive	3.5
Trace	2
Negative	0
Moisture:	
Poor drainage, continuously wet	2
Fair drainage, generally moist	1
Good drainage, generally dry	0

*Ten points—corrosive to gray or ductile cast-iron pipe; protection is indicated.

†If sulfides are present and low or negative redox-potential results are obtained, three points shall be given for this range.

4. *Sulfides.* The sulfide determination is recommended because of its field expediency. A positive sulfide reaction reveals a potential problem due to sulfate-reducing bacteria. The sodium azide–iodine qualitative test is used. In this determination, a solution of 3 percent sodium azide in a 0.1 *N* iodine solution is introduced into a test tube containing a sample of the soil in question. Sulfides catalyze the reaction between sodium azide and iodine, with the resulting evolution of nitrogen. If strong bubbling or foaming results, sulfides are present, and the presence of sulfate-reducing bacteria is indicated. If very slight bubbling is noted, sulfides are probably present in small concentration, and the result is noted as a trace.

5. *Moisture content.* Since prevailing moisture content is extremely important to all soil corrosion, every effort must be made to determine this condition. It is not proposed, however, to determine specific moisture content of a soil sample, because of the probability that content varies throughout the year, but to question local authorities who are able to observe the conditions many times during the year. (Although mentioned under item 1, Earth Resistivity, this variability factor is being reiterated to emphasize the importance of notation.)

6. *Soil description.* In each investigation, soil types should be completely described. The description should include

color and physical characteristics, such as particle size, plasticity, friability, and uniformity. Observation and testing will reveal whether the soil is high in organic content; this should be noted. Experience has shown that in a given area, corrosivity may often be reflected in certain types and colors of soil. This information is valuable for future investigations or for determining the most likely soils to suspect. Soil uniformity is important because of the possible development of local corrosion cells due to the difference in potential between unlike soil types, both of which are in contact with the pipe. The same is true for uniformity of aeration. If one segment of soil contains more oxygen than a neighboring segment, a corrosion cell can develop from the difference in potential. This cell is known as a differential aeration cell.

There are several basic types of soils that should be noted: sand, loam, silt, clay, muck. Unusual soils, such as peat or soils high in foreign material, also should be noted and described.

7. *Potential stray direct current.* Any soil survey should include consideration of possible stray direct current with which the gray or ductile cast-iron pipe installation might interfere. The widespread use of rectifiers and ground beds for cathodic protection of underground structures has resulted in a considerable threat from this source. Proximity of such cathodic protection systems should be noted. Among other potential sources of stray direct current are electric railways, industrial equipment (including welding equipment), and mine-transportation equipment.

8. *Experience with existing installations.* The best information on corrosivity of soil with respect to gray and ductile cast-iron pipe is the result of experience with these materials in the area in question. Every effort should be made to acquire such data by questioning local officials and, if possible, by actually observing existing installations.

Soil-Test Evaluation

When the soil-test procedures described herein are employed, the following tests are considered in evaluating corrosivity of the soil: resistivity, pH, redox potential, sulfides, and moisture. For each of these tests, results are categorized according to their contribution to corrosivity. Points are assigned based on experience with gray and ductile cast-iron pipe. When results of these five test-observations are available, the assigned points are totaled. If the sum is equal to ten or more, the soil is corrosive to gray or ductile cast-iron pipe, and protection against exterior corrosion should be provided. This system is limited to soil corrosion and does not include consideration of stray direct current. Table A.1 lists points assigned to the various test results.

General. These notes deal only with gray and ductile cast-iron pipe, the soil environment in which they will serve, and methods of determining a need for polyethylene encasement.

SECTION VIII

INSTALLATION PROCEDURES FOR DUCTILE IRON PIPE

The installation procedures for ductile iron pipe water mains and appurtenances are covered by the AWWA Standard ANSI/AWWA C-600 included in this section. More specific data and information is available in "The Guide for the Installation of Ductile Iron Pipe" which is available from DIPRA. Information on special installations can be obtained from the pipe manufacturers or DIPRA.

Proper installation procedures are recommended to enhance the long and useful life of ductile iron pipe. It should be noted, however, that experience with ductile iron pipe since the early 1950's has demonstrated its superior resistance to impact, beam loads and ring crushing loads. Therefore, handling and installation procedures, in general, are much less critical for this pipe material. This fact can result in considerable savings in the installed cost of a pipeline project.

American Water Works Association

ANSI/AWWA C600-82
(Revision of AWWA C600-77)

AWWA STANDARD

for

INSTALLATION OF DUCTILE-IRON WATER MAINS AND THEIR APPURTENANCES

AMERICAN NATIONAL STANDARD

NOTICE

This Standard has been especially printed by the American Water Works Association for incorporation into this volume. It is current as of October 1, 1984. It should be noted, however, that all AWWA Standards are updated at least once in every five years. Therefore, before applying this Standard it is suggested that you confirm its currency with the American Water Works Association.

First edition approved by AWWA Board of Directors May 8, 1977.

This edition approved Feb. 1, 1982.

Approved by American National Standards Institute, Inc., Apr. 29, 1982.

AMERICAN WATER WORKS ASSOCIATION
6666 West Quincy Avenue, Denver, Colorado 80235

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Table of Contents

Foreword

This foreword is for information only and is not part of AWWA C600.

I. History of Standard

The first AWWA standard specifications for "Laying Cast-Iron Pipe" (7D.1-1938) were adopted in April 1938. They were intended as a guide in making extensions to existing distribution systems and in preparing specifications for contracts for the construction of new systems or extensions. The standard was to be used as a guide for installing bell-and-spigot cast-iron pipe and did not cover the furnishing and delivery of material, any other type of pipe, or any other type of joint. The standard included a model addendum, which was to be used with project specifications, and was designed to be used as a part of the contract document. The standard was published in the February 1938 edition of *Journal AWWA*.

The standard was revised in 1949, including a change of title to "Standard Specifications for Installation of Cast-Iron Water Mains" (7D.1-T-1949 and C600-49T). The standard was expanded by adding numerous tables and installation guidelines. The model addendum was also expanded. The revised standard was published in the December 1949 edition of *Journal AWWA*.

An additional section, Sec. 9b (Joining of Mechanical-Joint Pipe), was added in May 1954. Sec. 9c (Joining of Push-On Joint Pipe) was added in 1964.

In 1975, the Standards Council formed the present C600 committee to revise C600 to current practices and to add ductile iron as a pipe material. In order to do this, the committee decided to completely change the character of the standard, removing the model addendum and making the standard more in compliance with the style of other AWWA standards.

In 1980, an addendum to the standard was approved that revised parts of Sec. 3.4 regarding mechanical-joint assembly.

II. Information Regarding the Use of This Standard

AWWA C600-82, Standard for Installation of Ductile-Iron Water Mains and Their Appurtenances, can be used as a reference when making extensions to existing distribution systems or when constructing new distribution systems using ductile-iron mains with either mechanical or push-on joints. 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 upon 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.

III. Major Revisions

The current revisions eliminate reference to gray cast-iron pipe as a material for new pipeline installation. At the time of revision, gray cast-iron pressure pipe was no longer being manufactured for waterworks service. References to gray cast-iron pipe that apply to existing piping are retained.

The 1980 addendum regarding mechanical-joint assembly and bolt torque has been incorporated into this revision.

Metric conversions of all dimensions are included in this standard. Metric dimensions are direct conversions of customary US inch-pound units and are not those shown in International Organization for Standardization (ISO) Standards.

Other changes, largely editorial in nature, have been made to clarify various sections of the standard.

American Water Works Association

AWWA C600-82
(Revision of AWWA C600-77)

AWWA Standard for

Installation of Ductile-Iron Water Mains and Their Appurtenances

Section 1—General

Sec. 1.1 Scope

This standard covers installation procedures for ductile-iron mains and their appurtenances for water service.

1.1.1 *Conditions not covered.* Installations that require special attention, techniques, and materials are not covered. Each such installation requires special considerations based on many influencing factors and cannot be covered adequately in a single standard. This type of installation can best be accomplished by competent engineering design in consultation with representatives of the material manufacturing industry. Some of these typical installations are:

1. Piping through rigid walls
2. Subaqueous piping
3. Piping on supports above or below ground
4. Piping requiring insulation
5. Plant- or pump-station piping
6. Pipe through corrosive soil
7. Pipe through unstable soil.

Sec. 1.2 References

1.2.1 This standard references the following documents. They form a part of this standard to the extent specified herein. In any case of conflict, the requirements of this standard shall prevail.

ANSI/AWWA C105/A21.5—Standard for Polyethylene Encasement for Gray and Ductile Cast-Iron Piping for Water and Other Liquids

ANSI/AWWA C111/A21.11—Standard for Rubber-Gasket Joints for

Ductile-Iron and Gray-Iron Pressure Pipe and Fittings

ANSI/AWWA C150/A21.50—Standard for Thickness Design of Ductile-Iron Pipe

ANSI/AWWA C500—Standard for Gate Valves, 3 Through 48 In. NPS, for Water and Sewage Systems

ANSI/AWWA C509—Standard for Resilient-Seated Gate Valves, 3 Through 12 NPS, for Water and Sewage Systems

ANSI/AWWA C601—Standard for Disinfecting Water Mains

AASHTO* T-99—Standard Method of Test for Moisture-Density Relationship for Soils

Installation, Field Testing, and Maintenance of Fire Hydrants, AWWA Manual M17 (1980).

1.2.2 The reader is referred to the following standards for additional information on the use or limitations of specific products.

ANSI/AWWA C104/A21.4—Standard for Cement-Mortar Lining for Ductile-Iron and Gray-Iron Pipe and Fittings for Water

ANSI/AWWA C110/A21.10—Standard for Gray-Iron and Ductile-Iron Fittings, 3 in. Through 48 in., for Water and Other Liquids

ANSI/AWWA C115/A21.15—Standard for Flanged Cast-Iron and Ductile-Iron Pipe with Threaded Flanges

ANSI/AWWA C151/A21.51—Standard for Ductile-Iron Pipe, Centrifugally Cast in Metal Molds or Sand-Lined Molds, for Water or Other Liquids

ANSI/AWWA C502—Standard for Dry-Barrel Fire Hydrants

AWWA C503—Standard for Wet-Barrel Fire Hydrants

ANSI/AWWA C504—Standard for Rubber-Seated Butterfly Valves

Handbook of Occupational Safety and Health Standards for Water Utilities, AWWA (1974).

Sec. 1.3 Definitions

Under this standard, the following definitions shall apply.

1.3.1 *Contractor:* The party responsible for water-main construction.

1.3.2 *Ductile iron:* Cast ferrous material in which a major part of the carbon content occurs as free carbon in nodules or spheroidal form.

1.3.3 *Gray cast iron:* Cast ferrous material in which a major part of the carbon content occurs as free carbon in the form of flakes interspersed through the metal.

1.3.4 *Mechanical joint:* The gasketed and bolted joint as detailed in ANSI/AWWA C111/A21.11.

1.3.5 *Owner:* The municipality or other organization that will own and operate the completed piping system. The owner may designate agents, such as an engineer, purchaser, or inspector, for specific responsibilities with regard to piping construction projects.

1.3.6 *Plans:* Drawings prepared by the owner or designated agent of the owner to show the location and details for the construction of the pipeline and appurtenances.

1.3.7 *Push-on joint:* The single rubber-gasket joint as described in ANSI/AWWA C111/A21.11.

1.3.8 *Specifications:* Detailed procedures and requirements for the installation of the pipeline and appurtenances prepared by the owner or designated agent of the owner. Installation specifications may incorporate this standard by reference but should also include specification of the alternate provisions of the standard and requirements for matters not covered by the standard.

*American Association of State Highway and Transportation Officials, 341 National Press Building, Washington, DC 20004

Section 2—Inspection, Handling, and Storage

Sec. 2.1 Inspection

At the discretion of the owner, all materials furnished by the contractor are subject to inspection and approval at the manufacturer's plant.

2.1.1 *Inspection upon delivery.* All pipe and appurtenances are subject to inspection by the owner at the point of delivery. Material found to be defective due to manufacture or damage in shipment shall be rejected or recorded on the bill of lading and removed from the job site. The owner may perform tests as specified in the applicable AWWA standard to ensure conformance with the standard. In case of failure of the pipe or appurtenance to comply with such specifications, responsibility for replacement of the defective materials becomes that of the manufacturer or contractor.

2.1.2 *Workmanship.* All pipe and appurtenances shall be installed and joined in conformance with this standard and tested under pressure for defects and leaks in accordance with Sec. 4 of this standard.

Sec. 2.2 Handling and Storage

All pipe, fittings, valves, hydrants, and accessories shall be loaded and unloaded by lifting with hoists or skidding in order to avoid shock or damage. Under no circumstances shall such material be dropped. Pipe handled on skidways shall not be rolled or skidded against pipe on the ground.

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

2.2.2 *Storage.* Materials, if stored, shall be kept safe from damage. The interior of all pipe, fittings, and other appurtenances shall be kept free from dirt or foreign matter at all times. Valves and hydrants shall be drained and stored in a manner that will protect them from damage by freezing.

2.2.2.1 Pipe shall not be stacked higher than the limits shown in Table 1. The bottom tier shall be kept off the ground on timbers, rails, or concrete. Pipe in tiers shall be alternated: bell, plain end; bell, plain end. At least two rows of timbers shall be placed between tiers and chocks, affixed to each in order to prevent movement. The timbers shall be large enough to prevent contact between the pipe in adjacent tiers.

2.2.2.2 Gaskets for mechanical and push-on joints to be stored shall be placed in a cool location out of direct sunlight. Gaskets shall not come in contact with petroleum products. Gaskets shall be used on a first-in, first-out basis.

2.2.2.3 Mechanical-joint bolts shall be handled and stored in such a manner that will ensure proper use with respect to types and sizes.

TABLE 1

*Maximum Stacking Heights—Ductile-Iron Pipe**

Nominal Pipe Size *in.*	Number of Tiers
3	18
4	16
6	13
8	11
10	10
12	9
14	8
16	7
18	6
20	6
24	5
30	4
36	4
42	3
48	3
54	3

*For 18- or 20-ft (5.5- or 6.1-m) lengths.

Section 3—Installation

Sec. 3.1 Alignment and Grade

The water mains shall be laid and maintained to lines and grades established by the plans and specifications with fittings, valves, tapped or bossed outlets, and hydrants at the required locations unless otherwise approved by the owner. Valve-operating stems shall be oriented in a manner to allow proper operation. Hydrants shall be installed plumb.

3.1.1 *Prior investigation.* Prior to excavation, investigation shall be made to the extent necessary to determine the location of existing underground structures and conflicts. Care shall be exercised by the contractor during excavation to avoid damage to existing structures.

3.1.2 *Unforeseen obstructions.* When obstructions that are not shown on the plans are encountered during the progress of work and interfere so that an alteration of the plans is required, the owner will alter the plans or order a deviation in line and grade or arrange for removal, relocation, or reconstruction of the obstructions.

3.1.3 *Clearance.* When crossing existing pipelines or other structures, alignment and grade shall be adjusted as necessary, with the approval of the owner, to provide clearance as required by federal, state, and local regulations or as deemed necessary by the owner to prevent future damage or contamination of either structure.

Sec. 3.2 Trench Construction

The trench shall be excavated to the required alignment, depth, and width and in conformance with all federal, state, and local regulations for the protection of the workmen.

3.2.1 *Trench preparation.* Trench preparation shall proceed in advance of pipe installation for only as far as stated in the specifications or as directed by the owner.

3.2.1.1 Discharge from any trench-dewatering pumps shall be conducted to natural drainage channels, storm sewers, or as directed by applicable regulatory agencies.

3.2.1.2 Excavated material shall be placed in a manner that will not obstruct the work nor endanger the workmen, obstruct sidewalks, driveways, or other structures and shall be done in compliance with federal, state, and local regulations.

3.2.2 *Pavement removal.* Removal of pavement and road surfaces shall be a part of the trench excavation, and the amount removed shall depend upon the width of trench required for installation of the pipe and the dimensions of the area required for the installation of valves, hydrants, specials, manholes, or other structures. The dimensions of pavement removed shall not exceed the dimensions of the opening required for installation of pipe, valves, hydrants, specials, manholes, and other structures by more than 6 in. (152 mm) in any direction unless otherwise required or approved by the owner. Methods such as sawing, drilling, or chipping shall be used to ensure the breakage of pavement along straight lines.

3.2.3 *Width.* The width of the trench at the top of the pipe shall be that of the single-pass capabilities of normally-available excavating equipment and ample to permit the pipe to be laid and joined properly and allow the backfill to be placed as specified. Trench widths as shown in Table 2 may be used as a guide. Trenches shall be of such extra width, when required, to permit the placement of timber supports, sheeting, bracing, and appurtenances.

TABLE 2

Suggested Trench Widths at the Top of the Pipe

Nominal Pipe Size *in.*	Trench Width *in. (m)*
4	28 (0.71)
6	30 (0.76)
8	32 (0.81)
10	34 (0.86)
12	36 (0.91)
14	38 (0.97)
16	40 (1.02)
18	42 (1.07)
20	44 (1.12)
24	48 (1.22)
30	54 (1.37)
36	60 (1.52)
42	66 (1.68)
48	72 (1.83)
54	78 (1.98)

3.2.4 *Bell holes.* Holes for the bells shall be provided at each joint but shall be no larger than necessary for joint assembly and assurance that the pipe barrel will lie flat on the trench bottom. Push-on type joints require only minimum depressions for bell holes.

3.2.4.1 Other than noted previously, the trench bottom shall be true and even in order to provide support for the full length of the pipe barrel, except that a slight depression may be provided to allow withdrawal of pipe slings or other lifting tackle.

3.2.5 *Rock conditions.* When excavation of rock is encountered, all rock shall be removed to provide a clearance of at least 6 in. (150 mm) below and on each side of all pipe, valves, and fittings for pipe sizes 24 in. or smaller and 9 in. (230 mm) for pipe sizes 30 in. and larger. When excavation is completed, a layer of appropriate backfill material (see Sec. 3.5) shall be placed on the bottom of the trench to the previously mentioned depths, leveled, and tamped.

3.2.5.1 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.

3.2.5.2 This installation procedure shall be followed when gravel formations containing loose boulders greater than approximately 8 in. (200 mm) in diameter are encountered.

3.2.5.3 In all cases, the specified clearances shall be maintained between the bottom of all pipe and appurtenances and any part, projection, or point of rock, boulder, or stones of sufficient size and placement which, in the opinion of the owner, could cause a fulcrum point.

3.2.6 *Previous excavations.* Should the trench pass over a sewer or other previous excavation, the trench bottom 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.

3.2.7 *Blasting.* Blasting for excavation shall be permitted only after securing the approval of the owner, who will establish the hours of blasting. The blasting procedure, including protection of persons and property, shall be in strict accordance with federal, state, and local regulations.

3.2.8 *Protection of property.* Trees, shrubs, fences, and all other property and surface structures shall be protected during construction unless their removal is shown in the plans and specifications or approved by the owner.

3.2.8.1 Any cutting of tree roots or branches shall be done only as approved by the owner.

3.2.8.2 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 furnished by the contractor.

3.2.8.3 All properties that have been disturbed shall be restored as nearly as practical to their original condition.

3.2.9 *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 a minimum of at least 3 in. (80 mm) or to the depth ordered by the owner and replaced under the directions of the owner with clean, stable backfill material. When such materials are encountered, polyethylene encasement should be used (see Sec. 3.4.5). The bedding shall be consolidated and leveled in order that the pipe may be installed in accordance with Sec. 3.2.4.

3.2.10 *Unstable subgrade.* When the bottom of the trench or the subgrade is found to consist of material that is unstable to such a degree that, in the judgment of the owner, it cannot be removed, a foundation for the pipe and/or appurtenance shall be constructed using piling, treated timber, concrete, or other materials at the direction of the owner.

3.2.11 *Safety.* Appropriate traffic control devices shall be provided in accordance with federal, state, and local regulations to regulate, warn, and guide traffic at the work site.

Sec. 3.3 Pipe Installation

Proper implements, tools, and facilities shall be provided and used for the safe and convenient performance of the work. All pipe, fittings, valves, and hydrants shall be lowered carefully into the trench by means of a derrick, ropes, or other suitable tools or equipment, in such a manner as to prevent damage to water-main materials and protective coatings and linings. Under no circumstances shall water-main materials be dropped or dumped into the trench. Where practical, the trench should be dewatered prior to installation of the pipe.

3.3.1 *Examination of material.* All pipe, fittings, valves, hydrants, and other appurtenances shall be examined carefully for damage and other defects immediately before installation. Defective materials shall be marked and held for inspection by the owner, who may prescribe corrective repairs or reject the materials.

3.3.2 *Pipe ends.* All lumps, blisters, and excess coating shall be removed from the socket and plain ends of each pipe, and the outside of the plain end and the inside of the bell shall be wiped clean and dry and be free from dirt, sand, grit, or any foreign materials before the pipe is laid.

3.3.3 *Pipe cleanliness.* Foreign material shall be prevented from entering the pipe while it is being placed in the trench. No debris, tools, clothing, or other materials shall be placed in the pipe at any time.

3.3.4 *Pipe placement.* As each length of pipe is placed in the trench, the joint shall be assembled and the pipe brought to correct line and grade. The pipe shall be secured in place with approved backfill material.

3.3.5 *Direction of bells.* It is common practice to lay pipe with the bells facing the direction in which work is progressing; however, it is not mandatory. For example, when the main is being laid on a slope, the pipe is frequently laid with the bells facing uphill for ease of installation. The direction of the bells is not functionally related to the direction of flow within the main.

3.3.6 *Pipe plugs.* At times when pipe laying is not in progress, the open ends of pipe shall be closed by a watertight plug or other means approved by the owner. The plug shall be fitted with a means for venting. When practical, the plug shall remain in place until the trench is pumped completely dry. Care must be taken to prevent pipe flotation should the trench fill with water.

3.3.6.1 Prior to removal of the plug for extending the line or for any other reason, air and/or water pressure in the line shall be released.

3.3.7 *Ductile-iron laying conditions.* The specified laying conditions for ductile-iron pipe shall be completed in accordance with ANSI/AWWA C150/A21.50 and as illustrated in Figure 1.

Sec. 3.4 Joint Assembly

3.4.1 *Push-on joints.* Push-on joints shall be assembled as described and illustrated in Figure 2.

3.4.2 *Mechanical joints.* Mechanical joints shall be assembled as described and illustrated in Figure 3 and Table 3.

TABLE 3

Mechanical-Joint Bolt Torque

Pipe Size *in.*	Bolt Size *in.*	Range of Torque *ft-lb (N-m)*
3	⅝	45–60 (61–81)
4–24	¾	75–90 (102–122)
30–36	1	100–120 (136–163)
42–48	1¼	120–150 (163–203)

3.4.3 *Joint deflection.* When it is necessary to deflect pipe from a straight line in either the horizontal or vertical plane, the amount of joint deflection shall not exceed that shown in Tables 4 or 5. The deflections listed are maximum deflections and should not be exceeded. For design purposes, deflection should be limited to 80 percent of the values shown. Figure 4 illustrates the maximum offset S and approximate radius of curve R, which are listed in Tables 4 and 5.

3.4.4 *Pipe cutting.* Cutting pipe for insertion of valves, fittings, or closure pieces shall be done in conformance with all safety recommendations of the manufacturer of the cutting equipment. Cutting shall be done in a safe, workmanlike manner without creating damage to the pipe or cement–mortar lining.

3.4.4.1 Gray-iron pipe may be cut using a hydraulic squeeze cutter, abrasive pipe saw, rotary wheelcutter, guillotine pipe saw, or milling wheel saw.

3.4.4.2 Ductile-iron pipe may be cut using an abrasive pipe saw, rotary wheelcutter, guillotine pipe saw, milling wheel saw, or oxyacetylene torch.

3.4.4.3 Cut ends and rough edges shall be ground smooth, and for push-on joint connections, the cut end shall be beveled.

3.4.5 *Polyethylene encasement.* When the presence of aggressive soil is identified, requiring polyethylene encasement for ductile-iron pipe, the encasement shall be installed in accordance with Sec. 5.4 of ANSI/AWWA C105/A21.5.

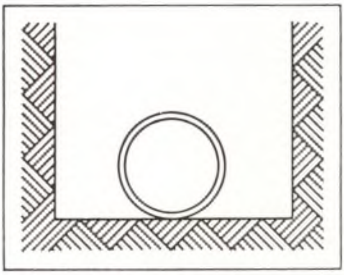
Sec. 3.5 Backfilling

Backfill shall be accomplished in accordance with the specified laying condition as described in Sec. 3.3.

3.5.1 *Backfill material.* All backfill material shall be free from cinders, ashes, refuse, vegetable or organic material, boulders, rocks or stones, frozen soil, or other material that, in the opinion of the owner, is unsuitable.

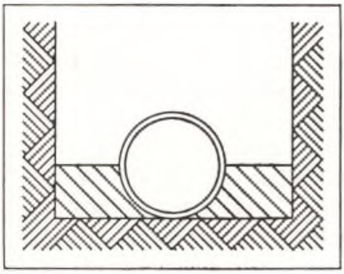
3.5.1.1 From 1 ft (300 mm) above the top of the pipe to the subgrade of the pavement, material containing stones up to 8 in. (200 mm) in their greatest dimension may be used, unless otherwise specified.

3.5.1.2 When the type of backfill material is not indicated on the plans or is not specified, the excavated material may be used, provided that such material consists of loam, clay, sand, gravel, or other materials that, in the opinion of the owner, are suitable for backfilling.



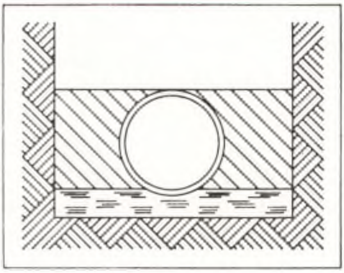
Type 1*

Flat-bottom trench.† Loose backfill.



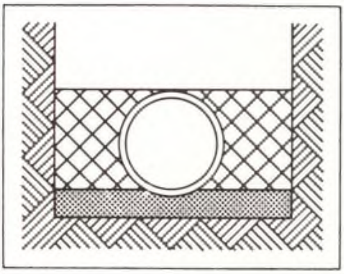
Type 2

Flat-bottom trench.† Backfill lightly consolidated to centerline of pipe.



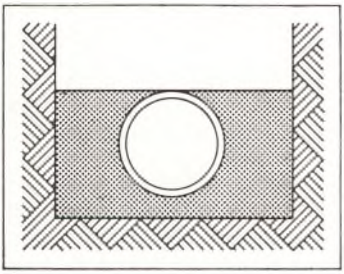
Type 3

Pipe bedded in 4-in. (100-mm) minimum loose soil.‡ Backfill lightly consolidated to top of pipe.



Type 4

Pipe bedded in sand, gravel, or crushed stone to depth of 1/8 pipe diameter, 4-in. (100-mm) minimum. Backfill compacted to top of pipe. (Approximately 80 percent Standard Proctor, AASHTO T-99.)



Type 5

Pipe bedded in compacted granular material to centerline of pipe. Compacted granular or select‡ material to top of pipe. (Approximately 90 percent Standard Proctor, AASHTO T-99.)

*For 30-in. and larger pipe, consideration should be given to the use of laying conditions other than Type 1.

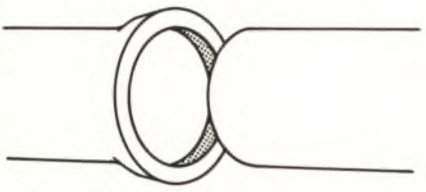
†"Flat-bottom" is defined as undisturbed earth.

‡"Loose soil" or "select material" is defined as native soil excavated from the trench, free of rocks, foreign materials, and frozen earth.

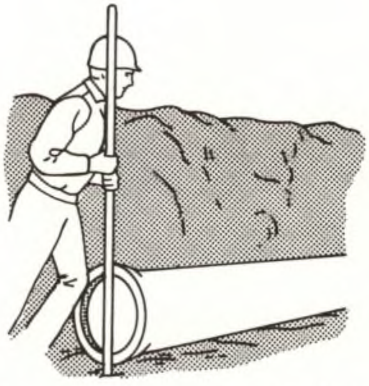
Figure 1. Laying Conditions for Ductile-Iron Pipe

1. Thoroughly clean the groove and bell socket and insert the gasket, making sure that it faces the proper direction and that it is correctly seated.

2. After cleaning dirt or foreign material from the plain end, apply lubricant in accordance with the pipe manufacturer's recommendations. The lubricant is supplied in sterile cans and every effort should be made to keep it sterile.

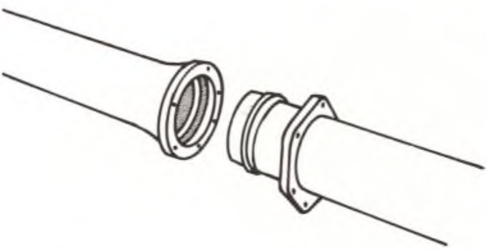


3. Be sure that the plain end is beveled; square or sharp edges may damage or dislodge the gasket and cause a leak. When pipe is cut in the field, bevel the plain end with a heavy file or grinder to remove all sharp edges. Push the plain end into the bell of the pipe. Keep the joint straight while pushing. Make deflection after the joint is assembled.

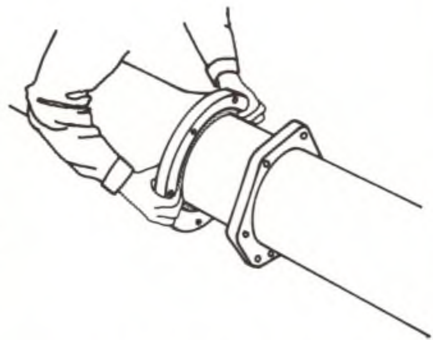


4. Small pipe can be pushed into the bell socket with a long bar. Large pipe require additional power, such as a jack, lever puller, or backhoe. The supplier may provide a jack or lever pullers on a rental basis. A timber header should be used between the pipe and jack or backhoe bucket to avoid damage to the pipe.

Figure 2. Push-On Joint Assembly

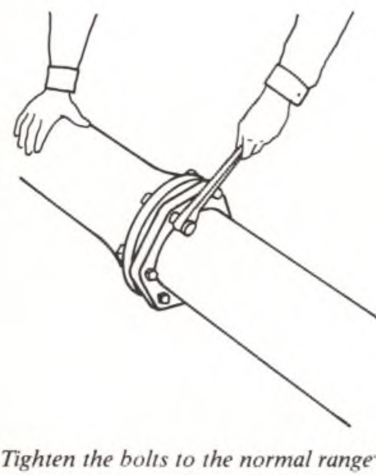


1. Wipe clean the socket and the plain end. The plain end, socket, and gasket should be washed with a soap solution to improve gasket seating. Place the gland on the plain end with the lip extension toward the plain end, followed by the gasket with the narrow edge of the gasket toward the plain end.



2. Insert the pipe into the socket and press the gasket firmly and evenly into the gasket recess. Keep the joint straight during assembly. Make deflection after joint assembly but before tightening bolts.

3. Push the gland toward the socket and center it around the pipe with the gland lip against the gasket. Insert bolts and hand-tighten nuts.



4. Tighten the bolts to the normal range of bolt torque as indicated in Table 3 while at all times maintaining approximately the same distance between the gland and the face of the flange at all points around the socket. This can be accomplished by partially tightening the bottom bolt first, then the top bolt, next the bolts at either side, finally the remaining bolts. Repeat the process until all bolts are within the appropriate range of torque. In large sizes (30 in. through 48 in.), five or more repetitions may be required.

Figure 3. Mechanical-Joint Assembly

TABLE 4

Maximum Joint Deflection Full-Length Pipe—Push-On Type Joint*

Nominal Pipe Size *in.*	Deflection Angle—θ *deg*	Maximum Offset—S† *in. (m)*		Approx. Radius of Curve—R† Produced by Succession of Joints *ft (m)*	
		18 ft (5.5 m) L†	20 ft (6.1 m) L†	18 ft (5.5 m) L†	20 ft (6.1 m) L†
3	5	19 (0.48)	21 (0.53)	205 (62)	230 (70)
4	5	19 (0.48)	21 (0.53)	205 (62)	230 (70)
6	5	19 (0.48)	21 (0.53)	205 (62)	230 (70)
8	5	19 (0.48)	21 (0.53)	205 (62)	230 (70)
10	5	19 (0.48)	21 (0.53)	205 (62)	230 (70)
12	5	19 (0.48)	21 (0.53)	205 (62)	230 (70)
14	3*	11 (0.28)	12 (0.30)	340 (104)	380 (115)
16	3*	11 (0.28)	12 (0.30)	340 (104)	380 (115)
18	3*	11 (0.28)	12 (0.30)	340 (104)	380 (115)
20	3*	11 (0.28)	12 (0.30)	340 (104)	380 (115)
24	3*	11 (0.28)	12 (0.30)	340 (104)	380 (115)
30	3*	11 (0.28)	12 (0.30)	340 (104)	380 (115)
36	3*	11 (0.28)	12 (0.30)	340 (104)	380 (115)
42	2*	7½ (0.19)	8 (0.20)	510 (155)	570 (174)
48	2*	7½ (0.19)	8 (0.20)	510 (155)	570 (174)
54	1½*	5½ (0.14)	6 (0.15)	680 (207)	760 (232)

*For 14-in. and larger push-on joints, maximum deflection angle may be larger than shown above. Consult manufacturer.
†See Figure 4.

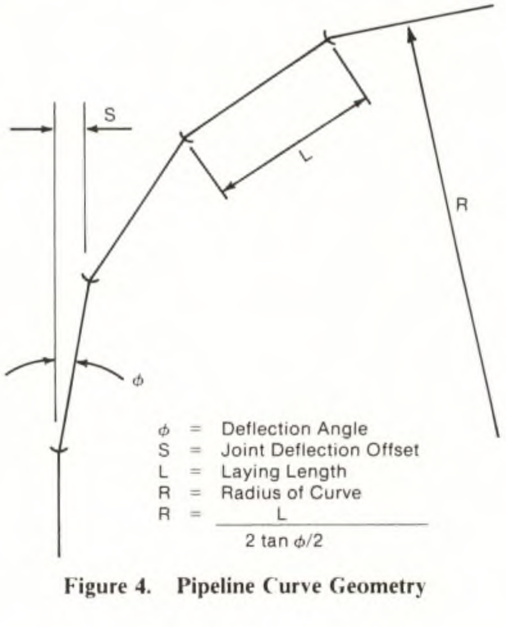


Figure 4. Pipeline Curve Geometry

TABLE 5

Maximum Joint Deflection Full-Length Pipe—Mechanical-Joint Pipe

Nominal Pipe Size *in.*	Deflection Angle—θ *deg*	Maximum Offset—S* *in. (m)*		Approx. Radius of Curve—R* Produced by Succession of Joints *ft (m)*	
		18 ft (5.5 m) L*	20 ft (6.1 m) L*	18 ft (5.5 m) L*	20 ft (6.1 m) L*
3	8–18	31 (0.79)	35 (0.89)	125 (38)	140 (43)
4	8–18	31 (0.79)	35 (0.89)	125 (38)	140 (43)
6	7–07	27 (0.69)	30 (0.76)	145 (44)	160 (49)
8	5–21	20 (0.51)	22 (0.56)	195 (59)	220 (67)
10	5–21	20 (0.51)	22 (0.56)	195 (59)	220 (67)
12	5–21	20 (0.51)	22 (0.56)	195 (59)	220 (67)
14	3–35	13½ (0.34)	15 (0.38)	285 (87)	320 (98)
16	3–35	13½ (0.34)	15 (0.38)	285 (87)	320 (98)
18	3–00	11 (0.28)	12 (0.30)	340 (104)	380 (116)
20	3–00	11 (0.28)	12 (0.30)	340 (104)	380 (116)
24	2–23	9 (0.23)	10 (0.25)	450 (137)	500 (152)
30	2–23	9 (0.23)	10 (0.25)	450 (137)	500 (152)
36	2–05	8 (0.20)	9 (0.23)	500 (152)	550 (167)
42	2–00	7½ (0.19)	8 (0.20)	510 (155)	570 (174)
48	2–00	7½ (0.19)	8 (0.20)	510 (155)	570 (174)

*See Figure 4.

3.5.1.3 If excavated material is indicated on the drawings or specified for backfill, and there is a deficiency due to a rejection of part thereof, the required amount of sand, gravel, or other approved material shall be provided.

3.5.1.4 For purposes of definition: (a) sand is material graded from fine to coarse, containing less than 10 percent by weight of loam and clay that passes a 3/4-in. sieve with no more than 5 percent by weight remaining on a No. 4 sieve; (b) gravel is a reasonably uniform combination, containing no boulders or stones larger than 2 in. (50 mm) and not containing excessive amounts of clay and loam; (c) crushed stone is limestone or dolomite ledge-rock material that all passes a 1/2-in. sieve with no more than 25 percent passing a No. 100 sieve.

3.5.2 *Compaction.* When special backfill compaction procedures are required, they shall be accomplished in accordance with project specifications or applicable federal, state, and local regulations.

3.5.3 *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 the testing.

Sec. 3.6 Valve and Fitting Installation

3.6.1 *Examination of material.* Prior to installation, valves shall be inspected for direction of opening, number of turns to open, freedom of operation, tightness of pressure-containing bolting and test plugs, cleanliness of valve ports and especially seating surfaces, handling damage, and cracks. Defective valves shall be corrected or held for inspection by the owner. Valves shall be closed before being installed.

3.6.2 *Placement.* Valves, fittings, plugs, and caps shall be set and joined to the pipe in the manner specified in Sec. 3.3 for cleaning, laying, and joining pipe, except that 12-in. and larger valves should be provided with special support, such as treated timbers, crushed stone, concrete pads, or a sufficiently tamped trench bottom so that the pipe will not be required to support the weight of the valve. Valves shall be installed in the closed position.

3.6.3 *Valve location.* Valves in water mains shall, where practical, be located within the street property lines unless shown otherwise on the plans.

3.6.3.1 Mains shall be drained through drainage branches or blowoffs. Drainage branches, blowoffs, air vents, and appurtenances shall be provided with valves and shall be located and installed as shown on the plans. Drainage branches or blowoffs shall not be directly connected to any storm or sanitary sewer, submerged in any stream, or be installed in any other manner that will permit backsiphonage into the distribution system.

3.6.4 *Valve protection.* A valve box or a vault shall be provided for every valve.

3.6.4.1 A valve box shall be provided for every valve that has no gearing or operating mechanism or in which the gearing or operating mechanism is fully protected with a gear case. The valve box shall not transmit shock or stress to the valve and shall be centered over the operating nut of the valve, with the box cover flush with the surface of the finished area or such other level as may be directed by the owner.

3.6.4.2 A valve vault designed to prevent settling on the pipe shall be provided for every valve that has exposed gearing or operating mechanisms. The operating nut shall be readily accessible for operation through the opening in the valve vault, which shall be set flush with the surface of the finished pavement or such other level as may be specified. Vaults shall be constructed to permit minor valve repairs and afford protection to the valve and pipe from impact where they pass through the vault walls.

3.6.4.3 In no case shall valves be used to bring misaligned pipe into alignment during installation. Pipe shall be supported in such a manner as to prevent stress on the valve.

3.6.5 *Plugs and caps.* All dead ends on new mains shall be closed with plugs or caps that are suitably restrained to prevent blowing off under test pressure. If a blowoff valve precedes the plug or cap, it too shall be restrained against blowing off. All dead ends shall be equipped with suitable blowoff facilities.

3.6.6 *Additional information.* Additional information regarding installation of gate valves can be found in the appendices of ANSI/AWWA C500 and ANSI/AWWA C509.

Sec. 3.7 Hydrant Installation

3.7.1 *Examination of material.* Prior to installation, inspect all hydrants for direction of opening, nozzle threading, operating-nut and cap-nut dimensions, tightness of pressure-containing bolting, cleanliness of inlet elbow, handling damage, and cracks. Defective hydrants shall be corrected or held for inspection by the owner.

3.7.2 *Placement.* All hydrants shall stand plumb and shall have their nozzles parallel with, or at right angles to, the curb, with pumper nozzle facing the curb, except that hydrants having two-hose nozzles 90 degrees apart shall be set with each nozzle facing the curb at an angle of 45 degrees.

3.7.2.1 Hydrants shall be set to the established grade, with the centerline of the lowest nozzle at least 12 in. (300 mm) above the ground or as directed by the owner.

3.7.2.2 Each hydrant shall be connected to the main with a 6-in. branch controlled by an independent 6-in. valve, unless otherwise specified by the owner.

3.7.2.3 When a dry-barrel hydrant is set in soil that is pervious, drainage shall be provided at the base of the hydrant by placing coarse gravel or crushed stone mixed with coarse sand from the bottom of the trench to at least 6 in. (150 mm) above the drain port opening in the hydrant and to a distance of 1 ft (305 mm) around the elbow. Where groundwater rises above the drain port or when the hydrant is located within 8 ft (2.4 m) (or such distance as required by the applicable regulatory agency) of a sanitary sewer main, the drain port shall be plugged and water pumped from the hydrant when freezing may occur.

3.7.2.4 When a dry-barrel hydrant with an open drain port is set in clay or other impervious soil, a drainage pit 2 ft × 2 ft × 2 ft (0.6 m ×0.6 m ×0.6 m) shall be excavated below each hydrant and filled with coarse gravel or crushed stone mixed with coarse sand under and around the elbow of the hydrant and to a level of 6 in. (150 mm) above the drain port.

3.7.3 *Location.* Hydrants shall be located as shown on the plans or as directed by the owner.

3.7.4 *Protection.* In the case of hydrants that are intended to fail at the ground-line joint upon vehicle impact (traffic hydrants), specific care must be taken to provide adequate soil resistance to avoid transmitting shock moment to the lower barrel and inlet connection. In loose or poor load-bearing soil, this may be accomplished by pouring a concrete collar approximately 6 in. (150 mm) thick to a diameter of 2 ft (0.6 m) at or near the ground line around the hydrant barrel.

3.7.5 *Additional information.* Additional information regarding installation of hydrants can be found in AWWA Manual M17.

Sec. 3.8 Thrust Restraint

3.8.1 *Hydrants.* The bowl of each hydrant shall be well braced against a sufficient area of unexcavated earth at the end of the trench with stone slabs or concrete backing, or it shall be tied to the pipe with suitable metal tie rods, clamps, or restrained joints as shown or directed by the owner.

3.8.2 *Fittings.* All plugs, caps, tees, and bends, unless otherwise specified, shall be provided with reaction backing or suitably restrained joints, as shown or specified by the owner.

3.8.3 *Design.* All thrust restraint shall be designed to withstand the test pressure or the working pressure plus surge allowance, whichever is larger. Adequate factors of safety shall be employed in the design.

3.8.4 *Concrete reaction backing.* Vertical and horizontal reaction backing shall be made of concrete having a compressive strength of not less than 2000 psi (138 Bar*) after 28 days. Backing shall be placed between solid ground and the fitting to be anchored; the area of bearing on the pipe and on the ground in each instance shall be that shown or directed by the owner. The backing shall, unless otherwise shown or directed, be so located as to contain the resultant thrust

*1 Bar = 1 × 10^5 Pascal

force and in such a way that the pipe and fitting joints will be accessible for repair.

3.8.5 *Restrained joints.* Restraining mechanisms for push-on or mechanical joints may be used instead of concrete backing if so indicated in the plans and specifications. Tie rods, clamps, or other components of dissimilar metal shall be protected against corrosion by hand application of a suitable coating or by encasement of the entire assembly with 8-mil thick (0.2-mm) loose polyethylene film in accordance with ANSI/AWWA C105/A21.5.

Sec. 3.9 Flushing

Foreign material left in the pipelines during installation often results 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 should be accomplished by partially opening and closing valves and hydrants several times under expected line pressure with flow velocities adequate to flush foreign material out of the valves and hydrants.

Section 4—Hydrostatic Testing

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

Sec. 4.1 Pressure Test

After the pipe has been laid, all newly laid pipe or any valved section thereof shall be subjected to a hydrostatic pressure of at least 1.5 times the working pressure at the point of testing.

4.1.1 *Test pressure restrictions.* Test pressures shall:

1. Not be less than 1.25 times the working pressure at the highest point along the test section
2. Not exceed pipe or thrust-restraint design pressures
3. Be of at least 2-hour duration
4. Not vary by more than ± 5 psi (0.35 Bar) for the duration of the test
5. Not exceed twice the rated pressure of the valves or hydrants when the pressure boundary of the test section includes closed gate valves or hydrants. NOTE: Valves shall not be operated in either direction at differential pressure exceeding the rated pressure.
6. Not exceed the rated pressure of the valves when the pressure boundary of the test section includes closed, resilient-seated gate valves or butterfly valves.

4.1.2 *Pressurization.* Each valved section of pipe shall be filled with water slowly and the specified test pressure, based on the elevation of the lowest point of the line or section under test and corrected to the elevation of the test gauge, shall be applied by means of a pump connected to the pipe in a manner satisfactory to the owner. Valves shall not be operated in either the opening or closing direction at differential pressures above the rated pressure. It is good practice to allow the system to stabilize at the test pressure before conducting the leakage test.

4.1.3 *Air removal.* Before applying the specified test pressure, air shall be expelled completely from the pipe, valves, and hydrants. If permanent air vents are not located at all high points, the contractor shall install corporation cocks at such points so that the air can be expelled as the line is filled with water. After all the air has been expelled, the corporation cocks shall be closed and the test pressure applied. At the conclusion of the pressure test, the corporation cocks shall be removed and plugged or left in place at the discretion of the owner.

4.1.4 *Examination.* Any exposed pipe, fittings, valves, hydrants, and joints shall be examined carefully during the test. Any damage or defective pipe, fittings, valves, or hydrants that are discovered following the pressure test shall be repaired or replaced with sound material, and the test shall be repeated until it is satisfactory to the owner.

Sec. 4.2 Leakage Test

The leakage test shall be conducted concurrently with the pressure test.

4.2.1 *Leakage defined.* Leakage 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 (0.35 Bar) of the specified test pressure after the air in the pipeline has been expelled and the pipe has been filled with water. Leakage shall not be measured by a drop in pressure in a test section over a period of time.

4.2.2 *Allowable leakage.* No pipe installation will be accepted if the leakage is greater than that determined by the following formula:

$$L = \frac{SD\sqrt{P}}{133\,200}$$

in which L is the allowable leakage, in gallons per hour; S is the length of pipe tested, in feet; D is the nominal diameter of the pipe, in inches; and P is the average test pressure during the leakage test, in pounds per square inch gauge. In metric units,

$$L_m = \frac{SD\sqrt{P}}{2816}$$

in which L_m is the allowable leakage, in litres per hour; S is the length of pipe tested, in metres; D is the nominal diame-

TABLE 6

Allowable Leakage per 1000 ft (305 m) of Pipeline—gph†*

Avg. Test Pressure *psi (Bar)*	Nominal Pipe Diameter—*in.*															
	3	4	6	8	10	12	14	16	18	20	24	30	36	42	48	54
450 (31)	0.48	0.64	0.95	1.27	1.59	1.91	2.23	2.55	2.87	3.18	3.82	4.78	5.73	6.69	7.64	8.60
400 (28)	0.45	0.60	0.90	1.20	1.50	1.80	2.10	2.40	2.70	3.00	3.60	4.50	5.41	6.31	7.21	8.11
350 (24)	0.42	0.56	0.84	1.12	1.40	1.69	1.97	2.25	2.53	2.81	3.37	4.21	5.06	5.90	6.74	7.58
300 (21)	0.39	0.52	0.78	1.04	1.30	1.56	1.82	2.08	2.34	2.60	3.12	3.90	4.68	5.46	6.24	7.02
275 (19)	0.37	0.50	0.75	1.00	1.24	1.49	1.74	1.99	2.24	2.49	2.99	3.73	4.48	5.23	5.98	6.72
250 (17)	0.36	0.47	0.71	0.95	1.19	1.42	1.66	1.90	2.14	2.37	2.85	3.56	4.27	4.99	5.70	6.41
225 (16)	0.34	0.45	0.68	0.90	1.13	1.35	1.58	1.80	2.03	2.25	2.70	3.38	4.05	4.73	5.41	6.03
200 (14)	0.32	0.43	0.64	0.85	1.06	1.28	1.48	1.70	1.91	2.12	2.55	3.19	3.82	4.46	5.09	5.73
175 (12)	0.30	0.40	0.59	0.80	0.99	1.19	1.39	1.59	1.79	1.98	2.38	2.98	3.58	4.17	4.77	5.36
150 (10)	0.28	0.37	0.55	0.74	0.92	1.10	1.29	1.47	1.66	1.84	2.21	2.76	3.31	3.86	4.41	4.97
125 (9)	0.25	0.34	0.50	0.67	0.84	1.01	1.18	1.34	1.51	1.68	2.01	2.52	3.02	3.53	4.03	4.53
100 (7)	0.23	0.30	0.45	0.60	0.75	0.90	1.05	1.20	1.35	1.50	1.80	2.25	2.70	3.15	3.60	4.05

*If the pipeline under test contains sections of various diameters, the allowable leakage will be the sum of the computed leakage for each size.

†To obtain leakage in litres/hour, multiply the values in the table by 3.785.

ter of the pipe, in inches; and *P* is the test pressure, in Bars. These formulae are based on an allowable leakage of 11.65 gpd, per mile, per inch nominal diameter at a pressure of 150 psi.

4.2.2.1 Allowable leakage at various pressures is shown in Table 6.

4.2.2.2 When testing against closed metal-seated valves, an additional leakage per closed valve of 0.0078 gal/h/in. (0.0012 L/h/mm) of nominal valve size shall be allowed.

4.2.2.3 When hydrants are in the test section, the test shall be made against the closed hydrant.

4.2.3 *Acceptance of installation.* Acceptance shall be determined on the basis of allowable leakage. If any test of pipe laid discloses leakage greater than that specified in Sec. 4.2.2, the contractor shall, at his own expense, locate and make repairs as necessary until the leakage is within the specified allowance.

4.2.3.1 All visible leaks are to be repaired regardless of the amount of leakage.

Section 5—Disinfection

A newly installed main shall be disinfected in accordance with ANSI/AWWA C601. Following chlorination, the main should be flushed as soon as possible (within 24 hours) since prolonged exposure to high concentrations of chlorine might damage the asphaltic seal coat.

Section 6—Highway and Railroad Crossings

Sec. 6.1 Casing Pipe

When casing pipe is specified for highways or railroad crossings, the project shall be completed in accordance with applicable federal, state, and local regulations. In the case of railroad crossings, the project should comply further with regulations established by the railroad company. General practice permits boring for casing diameters through 36 in. with maximum length of about 175 ft (53 m); jacking for diameters 30 in. through 60 in. with lengths of about 200 ft (61 m); and tunneling for pipes 48 in. and larger for longer lengths.

Sec. 6.2 Carrier Pipe

The casing pipe should be 6–8 in. (15–20 cm) larger than the outside diameter of the ductile-iron pipe bells. Carrier pipe may be pushed or pulled through the completed casing pipe. Chocks or skids should be placed on the carrier pipe to ensure approximate centering within the casing pipe and to prevent damage during installation. Care must be exercised in order to avoid metal-to-metal contact. In order to avoid the transfer of earth and live loads to the carrier pipe, the space between the carrier and casing pipes should not be filled completely.

Section 7—Service Taps

Sec. 7.1 Tapping

Corporation stops may be installed either before or after pipe installation. Generally, they are located at ten or two o'clock on the circumference of the pipe and may be screwed directly into the tapped and threaded main without any additional appurtenances. When more than one tap in an existing gray cast-iron pipe is necessary to deliver the required flow, they should be staggered around the circumference at least 12 in. (30 cm) apart (not in a straight line). Ductile-iron pipe in all classes may be directly tapped with standard corporation stops; however, torque requirement for the installation may be effectively reduced by the application of two layers of 3-mil (0.1-mm) TFE tape to the male threads of the corporation stop.

AWWA C600-82
25 June 1982

Department of Defense Acceptance Notice

This nongovernment document was adopted and approved for use by the Department of Defense (DoD) on 25 June 1982. The American Water Works Association has furnished the clearance required by existing regulations. Copies of the document are stocked by DoD Single Stock Point, Naval Publications and Forms Center, Philadelphia, PA 19120, for issue to DoD activities only. Contractors and industry groups must obtain copies from AWWA, 6666 West Quincy Ave., Denver, CO 80235.

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SECTION IX

THRUST RESTRAINT

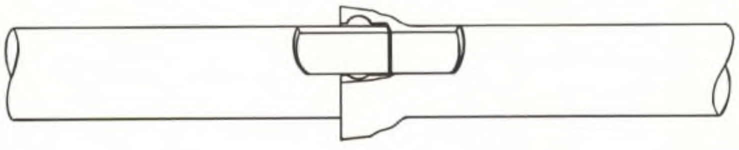
Introduction

This section presents suggested design procedures for the restraint of thrust forces in pressurized, buried ductile iron piping systems. Conservative assumptions are employed along with an explicit safety factor to assure a conservative design with an adequate overall safety factor. In order to facilitate the use of these procedures, soil types have been divided into broad categories with significantly different characteristics. However, because actual soil conditions vary widely, anyone using this procedure as a guide should conduct soil tests to insure that the proper design parameters are chosen for the soil type present at the site of the pipeline project. For any given project, the ultimate responsibility for the proper use of the equations and other data provided in this section rests with the design engineer.

Thrust Restraint

Ductile iron pipe and fittings are most often joined with push-on or mechanical joints. Neither of these joints provides significant restraint against longitudinal separation other than the friction between the gasket and the plain end of the pipe or fitting. Tests have shown that this frictional resistance in the joint is unpredictable, varying widely with installation conditions and other factors that are insignificant in other respects. Thus, these joints must be considered as offering no longitudinal restraint for design purposes.

FIGURE 1
PUSH-ON JOINT



At many locations in an underground or above ground pipeline, the configuration of the pipeline results in unbalanced forces of hydrostatic or hydrodynamic origin that, unless restrained externally, can result in separation of joints.

Generically, these unbalanced hydrostatic and hydrodynamic forces are called THRUST FORCES. In the range of pressures and fluid velocities found in waterworks or wastewater piping, the hydrodynamic thrust forces are generally insignificant in relation to the hydrostatic thrust forces and are usually ignored. Simply stated, thrust forces occur at any point in the piping system where the direction or cross sectional area of the waterway changes. Thus there will be thrust forces at bends, reducers, offsets, tees, wyes, dead ends, and valves.

Balancing thrust forces in underground pipelines is usually accomplished with bearing or gravity thrust blocks, restrained joint systems, or combinations of these methods. Presented herein is a general discussion of the nature of thrust forces as well as suggested approaches to the design of both thrust block and restrained joint systems for balancing these forces. The suggested design approaches are conservatively based on accepted principles of soil mechanics.

The Thrust Force

The internal hydrostatic pressure acts perpendicularly on any plane with a force equal to the pressure (P) times the area (A) of the plane. All components of these forces acting radially within a pipe are balanced by circumferential tension in the wall of the pipe. Axial components acting on a plane perpendicular to the pipe through a straight section of the pipe are balanced internally by the force acting on each side of the plane. Consider, however, the case of a bend as shown in Figure 3.

The forces PA acting axially along each leg of the bend are not balanced. The vector sum of these forces is shown as T. This is the thrust force. In order to prevent separation of the joints, a reaction equal to and in the opposite direction of T must be established.

FIGURE 2

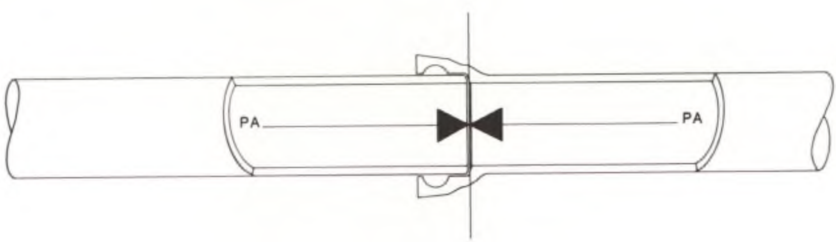


FIGURE 3
THRUST FORCE

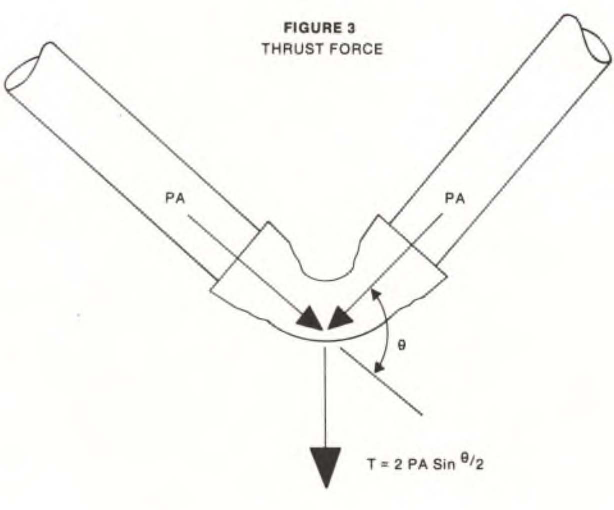
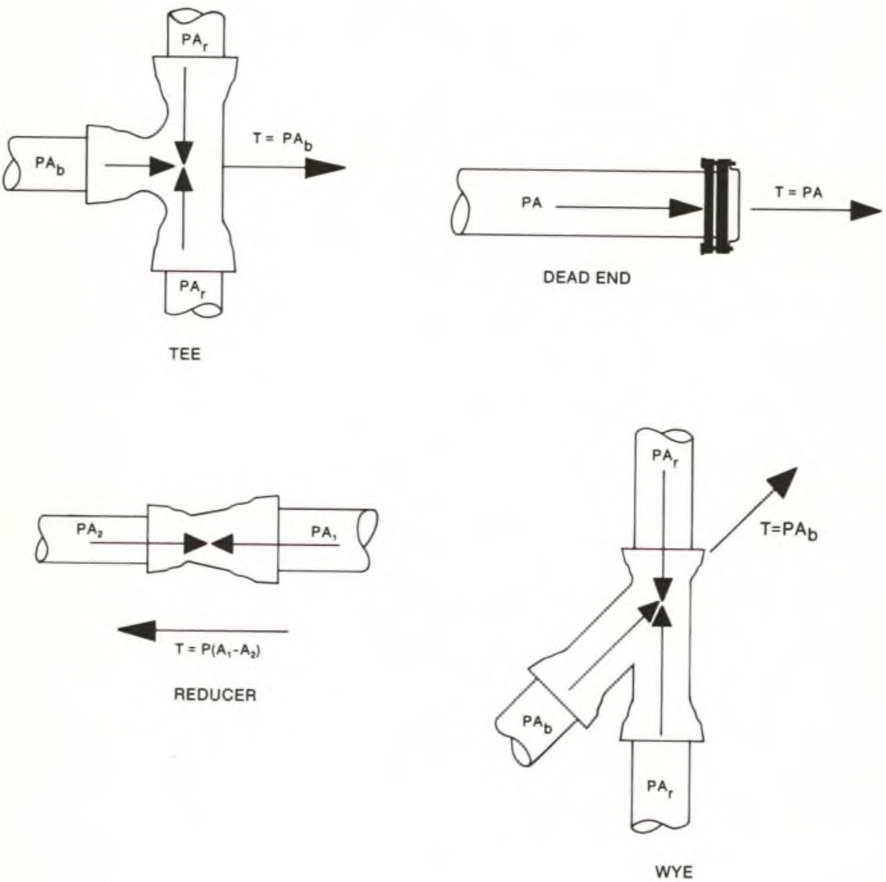


Figure 4 depicts the net thrust force at various other configurations. In each case the expression for T can be derived by the vector addition of the axial forces.

FIGURE 4



Design Pressure

The design pressure, P, is the maximum pressure to which the pipeline will be subjected, with consideration given to the vulnerability of the pipe-soil system when the pressure is expected to be applied. In most cases this will be the test pressure of the pipe, applied shortly after installation when the pipe-soil system is normally most vulnerable.

For buried pipelines, thrust restraint is achieved by transferring the thrust force to the soil structure outside the pipe. The objective of the design is to distribute the thrust forces to the soil structure in such a manner that joint separation will not occur in unrestrained joints.

Thrust Blocks

One of the most common methods of providing resistance to thrust forces is the use of thrust blocks. Figure 5 depicts a typical bearing thrust block on a horizontal bend. Resistance is provided by transferring the thrust force to the soil through the larger bearing area of the block such that the resultant pressure against the soil does not exceed the horizontal bearing area of the block for a particular set of conditions. The parameters involved in the design include pipe size, design pressure, angle of the bend, (or configuration of the fitting involved), and the horizontal bearing strength of the soil.

The following are general criteria for bearing block design.

— Bearing surface should, where possible, be placed against undisturbed soil. Where it is not possible, the fill between the bearing surface and undisturbed soil must be compacted to at least 90% Standard Proctor density.

— Block height (h) should be equal to or less than one-half the total depth to the bottom of the block, (H_T), but not less than the pipe diameter (D'ˡ·

— Block height (h) should be chosen such that the calculated block width (b) varies between one and two times the height.

The required bearing block area is

$$A_b = hb = \frac{T}{S_B}$$

Then, for a horizontal bend,

$$b = \frac{2\,S_f\,PA\,\text{Sin}\,\theta/2}{h\,S_B} \qquad (1)$$

where S_f is a safety factor (usually 1.5 for thrust block design). A similar approach may be used to design bearing blocks to resist the thrust forces at tees, dead ends, etc. Typical values for conservative horizontal bearing strengths of various soil types are listed in Table 1.

In lieu of the values for soil bearing strength shown in Table 1, a designer might choose to use calculated Rankine passive pressure (P_p) or other determination of soil bearing strength based on actual soil properties.

FIGURE 5

BEARING BLOCK

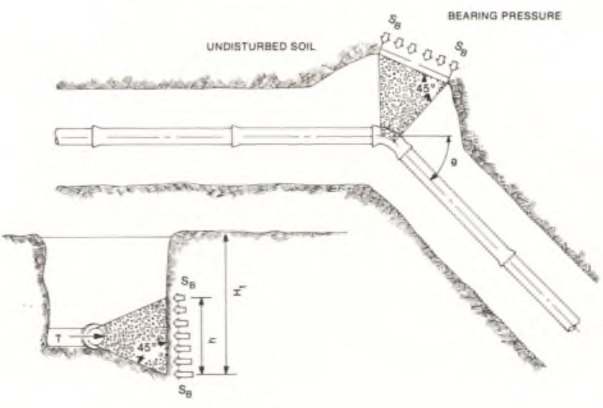


TABLE 1

SOIL	*BEARING STRENGTH S_B (lb/ft²)
Muck	0
Soft Clay	1,000
Silt	1,500
Sandy Silt	3,000
Sand	4,000
Sandy Clay	6,000
Hard Clay	9,000

* Although the above bearing strength values have been used successfully in the design of thrust blocks and are considered to be conservative, their accuracy is totally dependent on accurate soil identification and evaluation. The ultimate responsibility for selecting the proper bearing strength of a particular soil type must rest with the design engineer.

Gravity thrust blocks may be used to resist thrust at vertical down bends. In a gravity block, the weight of the block is the force providing equilibrium with the thrustforce. The design problem is then calculating the required volume of the thrust block of a known density. The vertical component of the thrust force in Figure 6 is balanced by the weight of the block.

It can easily be shown that $T_y = PA \sin \theta$. Then the required volume of the block is

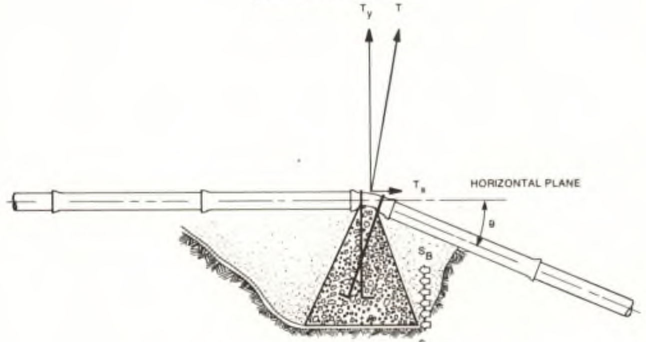
$$V_C = \frac{S_f PA \sin \theta}{W_m} \quad (2)$$

where W_m = density of the block material. In a case such as shown, the horizontal component of the thrust force

$$T_x = PA\,(1 - \cos \theta)$$

must be resisted by the bearing of the right side of the block against the soil. Analysis of this aspect will follow as the above section on bearing blocks.

FIGURE 6
GRAVITY THRUST BLOCK



Restrained Joints

In many cases, because of space limitations or construction difficulties, the use of thrust blocks is not feasible. An alternative method of providing thrust restraint is the use of restrained joints. A restrained joint is a special push-on type or mechanical joint that is designed to provide longitudinal restraint. Restrained joint systems function in a manner similar to thrust blocks, insofar as the reaction of the entire restrained unit of piping with the soil balances the thrust forces.

The objective in designing a restrained joint thrust restraint system is to determine the length of pipe that must be restrained on each side of the focus of a thrust force. This will be a function of the pipe size, the internal pressure, depth of cover and the characteristics of the soil surrounding the pipe. The following is a method of accomplishing the design objective. As with most engineering problems, the exact nature of the interaction of the restrained pipe unit and the soil is extremely complex. However, limitations of the ability to measure the actual parameters involved and limitations on available knowledge of the precise nature of the interaction, require that a practical design procedure be based on various assumptions. The assumptions employed in the following design procedure are, in each case, conservative. This fact together with the explicit safety factor employed in the procedure result in a conservative design with an adequate overall safety factor.

The proposed design equation for horizontal bends (equation 7) and the suggested soil parameters (Table 3) are the outgrowth of a design procedure originally proposed by Carlsen.[1] Carlsen's design procedure was based solely on theoretical considerations and was conservatively limited to well compacted trench conditions. The modification of Carlsen's design procedure embodied herein is the result of full scale tests of 12-inch ductile iron pipe with 45° and 90° bends buried in clay.[2]. The data generated by these tests and data available from model studies with 2-inch pipe in sand[3] confirm the conservatism of the present design procedure. Future work in this field should be devoted to large diameter piping systems, with the objective of further confirming this conservatism.

The thrust force must be restrained or balanced by the reaction of the restrained pipe unit with the surrounding soil. The source of the restraining forces is twofold. First, the static friction between the pipe unit and the soil, and second, the restraint provided by the pipe as it bears against the sidefill soil along each leg of the bend. Both of these forces are presumed to be functions of the restrained length L on each side of the bend, and they are presumed to act in the direction opposing the thrust force (i.e. directly opposing impending movement of the bend).

Figure 7 is a free body diagram of a restrained pipe unit where L is the length of the restrained pipe on each side of the bend. The frictional resistance is shown as a distributed force of unit value F_s. The total frictional resistance on each side of the bend is then $F_s L \cos \theta/2$.

The bearing resistance is shown as a distributed force with a maximum unit value of R_s at the bend, diminishing linearly to 0 at L. This assumption is based on the fact that the bearing resistance (passive resistance in the soil) is proportional to deformation or movement. As the restrained joints take load, maximum movement will occur at the bend. The total bearing resistance on each side of the bend is $\frac{1}{2} R_s L \cos \theta/2$.

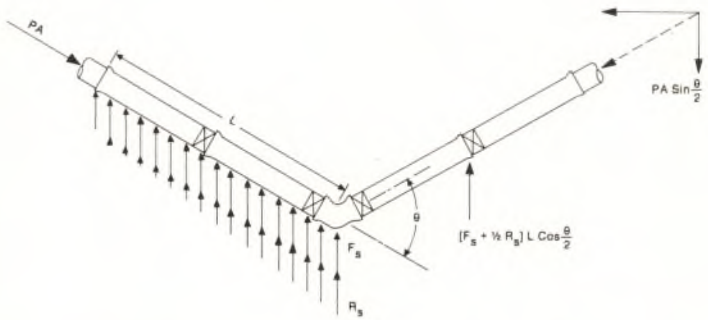
The equilibrium equation for the free body is then

$PA \sin \theta/2 = F_s L \cos \theta/2 + \frac{1}{2} R_s L \cos \theta/2$

Solving for L,

$$L = \frac{PA \tan \theta/2}{F_s + \frac{1}{2} R_s} \qquad (3)$$

FIGURE 7



The Unit Frictional Force, F_s

A static frictional force acting on a body is equal in magnitude to the applied force up to a maximum value. In the conventional analysis, the maximum static friction is proportional to the normal force between the surfaces which provide the friction. The constant of proportionality, in this case called the coefficient of friction, depends upon the nature of the surfaces. Potyondy's empirical work indicates that for friction between pipe and soils, the force is also dependent upon the cohesion of the soil[4].

Thus

$$F_s = A_p C + W \tan \delta$$

where

$C = f_c C_s$

A_p = surface area of the pipe bearing on the soil

$\delta = f_\phi \phi$

$A_p = \frac{\pi D'}{2}$ (assume ½ the pipe circumference bears against the soil)

Values of soil cohesion (C_s) and internal friction angle of the soil (ϕ) must be known or conservatively estimated for the soil at a particular installation. f_c and f_ϕ are related to soil types and pipe material. Conservative values of these parameters for ductile iron pipe in general soil types are presented in Table 3.

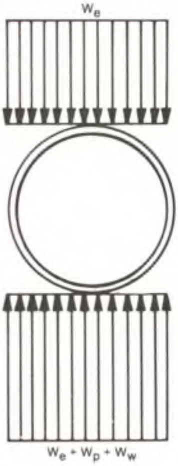
The unit normal force W is given by

$$W = 2\,W_e + W_p + W_w$$

where the earth load (W_e) is taken as the prism load on the pipe in pounds. The earth load (W_e) is doubled to account for the forces acting on both the top and the bottom of the pipe (see Figure 8). The unit weight of the pipe and water ($W_p + W_w$) is given in Table 2.

FIGURE 8

UNIT NORMAL FORCES ON PIPE



Then

$$F_s = \frac{\pi\ D'C}{2} + (2\,W_e + W_p + W_w)\tan\delta. \quad (4)$$

TABLE 2

NOMINAL PIPE SIZE	PIPE OUTSIDE DIAMETER, D′ (FT)	CROSS SECTIONAL AREA OF PIPE, A (sq. in.)	(W_p+W_w)* (LBS/FT)
3	0.33	12.32	14
4	0.40	18.10	19
6	0.58	37.39	32
8	0.75	64.33	50
10	0.93	96.77	71
12	1.10	136.85	96
14	1.28	183.85	126
16	1.45	237.79	158
18	1.63	298.65	192
20	1.80	366.44	230
24	2.15	522.79	317
30	2.67	804.25	466
36	3.19	1152.09	653
42	3.71	1555.28	868
48	4.23	2026.83	1118
54	4.76	2560.72	1407

* Based on Class 50 pipe with standard cement lining. (Class 51 for 3'' and 4''). The difference in $W_p + W_w$ for other pipe classes is not normally significant in relation to these calculations, and these values may be used conservatively regardless of pipe thickness class. However, the designer may use actual pipe weights for optimum design if desired.

Polyethylene Encasement

Limited experimental data suggest that the frictional resistance term (F_s) should be multiplied by a factor of ⅔ for pipe encased in polyethylene film.

The Unit Bearing Resistance, R_s

The maximum unit lateral resistance, R_s at the bend is limited so as not to exceed a rectangular distribution of the Rankine passive soil pressure P_p, which is generally less than the ultimate capacity of the soil to resist pipe movement. Passive soil pressure is a term generally defined as the maximum horizontal pressure that will be resisted by the soil structure without shearing failure of the soil. Horizontal subgrade pressure will result in a deformation of the soil structure. The resistance offered by the subgrade soil increases with this deformation or strain for pressures less than the passive soil pressure. In soils whose density exceeds the critical void ratio, (this condition is usually obtained in stable undisturbed soil and in backfill compacted to approximately 80% or more of the Standard Proctor density) the movement or deformation that occurs in developing the full passive soil pressure is very small in relation to the allowable, or available movement at the bend in restrained push-on or mechanical joint systems used with ductile iron pipe.

The passive soils pressure for a particular soil is given by the Rankine formula:

$$P_p = \gamma H_c N_\phi + 2 C_s \sqrt{N_\phi} \qquad (5)$$

Where:

P_p = passive soil pressure (lbs/ft²)

γ = backfill soil density (lbs/ft³)

H_c = mean depth from surface to the plane of resistance in feet (center line of a pipe or center of bearing area of a thrust block) (ft)

C_s = soil cohesion (lbs/ft²)

$N_\phi = \tan^2 (45^\circ + \phi/2)$

ϕ = internal friction angle of the soil

As discussed above, the full Rankine passive soil pressure, P_p, can be developed with insignificant movement in well compacted soils. For some of the standard laying conditions (See ANSI A21.50) for ductile iron, the design value of passive soil pressure should be modified by a factor K_n to assure that excessive movement will not occur. Empirically determined values for K_n can be found in Table 3.

Therefore,

$$R_s = K_n P_p D' \qquad (6)$$

In this context, the value chosen for K_n depends on the compaction achieved in the trench, the backfill materials, and the undisturbed earth. Thus, equation (3) becomes

$$L = \frac{S_f PA \tan \theta/2}{F_s + \frac{K_n P_p D'}{2}} \qquad (7)$$

where F_s can be determined from equation (4) and P_p can be determined from equation (5). S_f is a safety factor. For most installations, $S_f = 1.5$ is suggested.

In practice, the actual restrained length attained will generally be in multiples of length of an individual piece of pipe (normally 18 or 20 feet). The length calculated by the above procedures indicates the minimum required length. Thus, calculated lengths of 0 to 18 or 20 feet normally call for one restrained joint at the fitting, 18 to 36 or 20 to 40 feet normally for two restrained joints, etc. An exception would be joint deflection on buried full lengths of pipe which does not normally require joint restraint. This is due to the fact that the lateral frictional and passive resistance developed along two full lengths of pipe is normally more than adequate to restrain thrust forces resulting from maximum recommended joint deflection.

TABLE 3

Suggested Values for Soil Parameters and Reduction Constant K_n

SOIL DESIGNATION	SOIL DESCRIPTION	ϕ (DEG.)	f_ϕ	C_s (PSF)	f_c	γ (PCF)	CONSTANT K_n A21.50 LAYING CONDITION 2*	3	4	5
Clay 1	Clay of Medium to Low Plasticity LL < 50 <25% Coarse Particles [CL & CL-ML] +	0	0	300	.50* .80	90	.20	.40	.60	.85
Silt 1	Silts of Medium to Low Plasticity, LL <50, <25% Coarse Particles [ML & ML-CL]+	29	.50* .75	0	0	90	.20	.40	.60	.85
Clay 2	Clay of Medium to Low Plasticity With Sand Or Gravel, LL < 50, 25-50% Coarse Particles [CL]+	0	0	300	.50* .80	90	.40	.60	.85	1.0
Silt 2	Silt of Medium To Low Plasticity w/Sand or Gravel, LL <50, 25-50% Coarse Particles [ML]+	29	.50* .75	0	0	90	.40	.60	.85	1.0
Coh-gran	Cohesive Granular Soils >50% Coarse Particles [GC & SC]+	20	.40* .65	200	.40	90	.40	.60	.85	1.0
Sand Silt	Sand or Gravel w/Silt >50% Coarse Particles [GC & SM]+	30	.50* .75	0	0	90	.40	.60	.85	1.0
Good Sand	Clean Sand >95% Coarse Particles [SW & SP]+	36	.75* .80	0	0	100	.40	.60	.85	1.0

Definition "Coarse Particles" → Held on No. 200 Sieve

*These values to be used for laying condition 2.
+See Table 4 for more detailed soil descriptions.

Note: Values for γ used in this procedure are lower than the soil weight values used in ANSI/AWWA C150/A21.50 for conservatism.

TABLE 4 SOIL CLASSIFICATION CHART-ASTM STANDARD D2487

MAJOR DIVISIONS			GROUP SYMBOLS	TYPICAL NAMES	CLASSIFICATION CRITERIA
COARSE-GRAINED SOILS More than 50% retained on No. 200 sieve*	GRAVELS 50% or more of coarse fraction retained on No.4 sieve	CLEAN GRAVELS	GW	Well-graded gravels and gravel-sand mixtures, little or no fines	$C_U = D_{60}/D_{10}$ Greater than 4; $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
			GP	Poorly graded gravels and gravel-sand mixtures, little or no fines	Not meeting both criteria for GW
		GRAVELS WITH FINES	GM	Silty gravels, gravel-sand-silt mixtures.	Atterberg limits plot below "A" line or plasticity index less than 4. (Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols.)
			GC	Clayey gravels, gravel-sand-clay mixtures	Atterberg limits plot above "A" line and plasticity index greater than 7. (Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols.)
	SANDS More than 50% of coarse fraction passes No.4 sieve	CLEAN SANDS	SW	Well-graded sands and gravelly sands, little or no fines	$C_U = D_{60}/D_{10}$ Greater than 6; $C_Z = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
			SP	Poorly graded sands and gravelly sands, little or no fines	Not meeting both criteria for SW
		SANDS WITH FINES	SM	Silty sands, sand-silt mixtures	Atterberg limits plot below "A" line or plasticity index less than 4. (Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols.)
			SC	Clayey sands, sand-clay mixtures	Atterberg limits plot above "A" line and plasticity index greater than 7. (Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols.)
FINE-GRAINED SOILS 50% or more passes No. 200 sieve*	SILTS AND CLAYS Liquid limit 50% or less		ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands	See plasticity chart
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays	
			OL	Organic silts and organic silty clays of low plasticity	
	SILTS AND CLAYS Liquid limit greater than 50%		MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts	
			CH	Inorganic clays of high plasticity, fat clays	
			OH	Organic clays of medium to high plasticity	
Highly Organic Soils			PT	Peat, muck and other highly organic soils	

Classification on basis of percentage of fines
Less than 5% Pass No. 200 sieve — GW, GP, SW, SP
More than 12% Pass No. 200 sieve — GM, GC, SM, SC
5% to 12% Pass No. 200 sieve — Borderline Classification requiring use of dual symbols

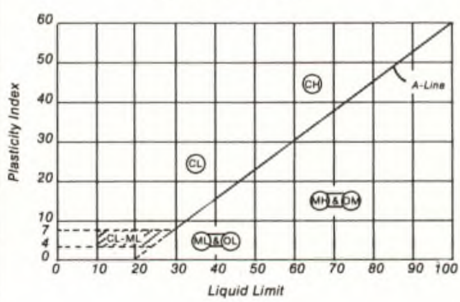
PLASTICITY CHART

For classification of fine-grained soils and fine fraction of coarse-grained soils.

Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols.

Equation of A-line:

$$PI = 0.73 (LL - 20)$$



*Based on the material passing the 3-in. (75-mm) sieve.

The following design equations for vertical bends, tees, reducers and dead ends were derived with assumptions similar to those used in the derivation of the horizontal bend equation (equation 7) above. Space does not permit full discussion of the derivations.

Vertical Down Bends (Figure 9)

$\Sigma F_y = 0$ Gives

$$2PA \sin \theta/2 - 2 F_s L \cos \theta/2 - 2W'L \cos \theta/2 = 0 \qquad (8)$$

$$W' = W_e + W_p + W_w$$

Note: For conservatism, ignore W′ on downslope and limit W′ to 20 feet (approximately one pipe length) on the horizontal run.

Thus, Eq. 8 becomes:

$$2PA \sin \theta/2 - 2 F_s L \cos \theta/2 - W'(20) \cos \theta/2 = 0$$

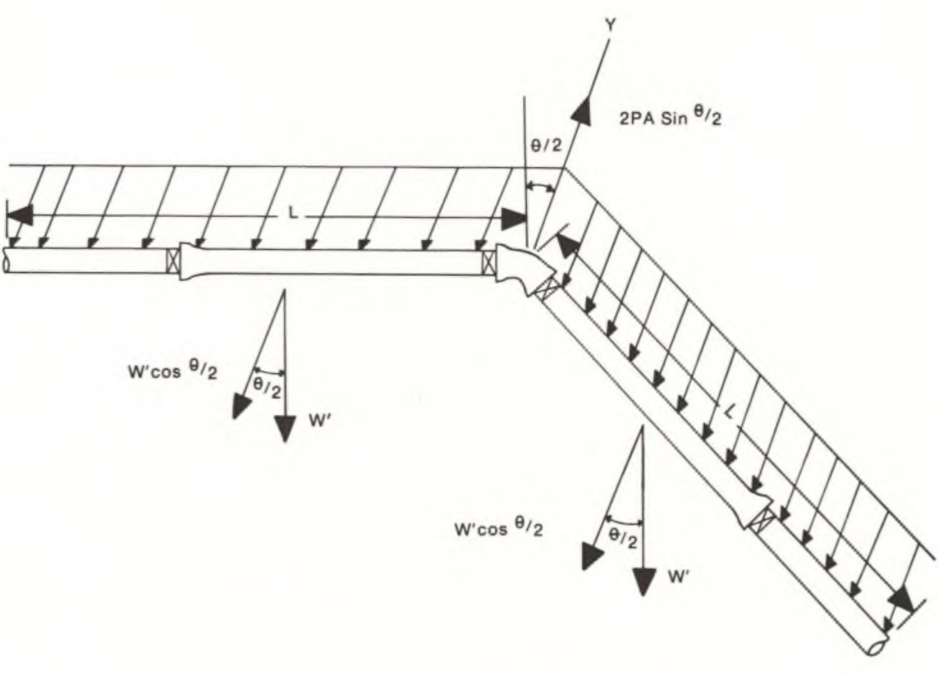
Solving for L,

$$L = S_f \left[\frac{PA \tan \theta/2 - 10W'}{F_s} \right] \qquad (9)$$

S_f = Safety factor. (Usually 1.5)

FIGURE 9

VERTICAL DOWN BENDS



Vertical Up Bends

$$L = S_f \left[\frac{PA \tan \theta/2}{F_s + \frac{K_n P_p D'}{2}} \right]$$

Note: Same equation (7) for horizontal bends. See Figure 7 for force diagram.

Tees (Figure 10)

$$PA_b = L_b (F_s)_b + \left(\frac{K_n P_p D'_r L_r}{2} \right)$$

$$R_s = K_n P_p D'_r$$

$$L_b = S_f \left[\frac{PA_b - \frac{(R_s L_r)}{2}}{(F_s)_b} \right] \quad (10)$$

A_b = Cross sectional area of branch (in.^{2})

L_b = Length of branch (ft)

L_r = Total length between first joints on either side of tee on the run (ft)

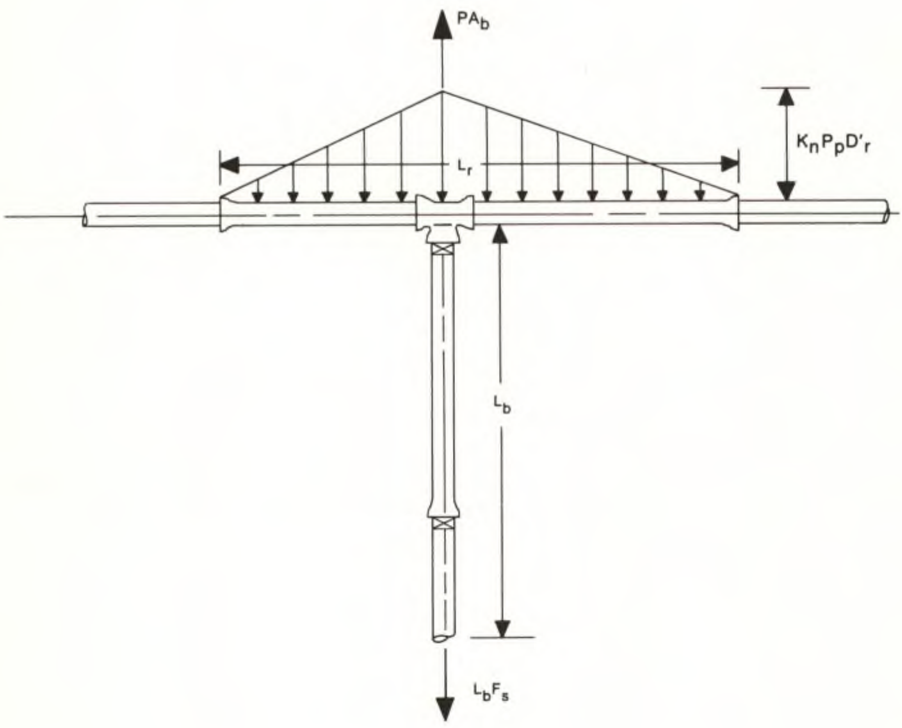
D'_r = Diameter of run (ft)

$(F_s)_b$ = Unit frictional force (lbs/ft) on branch

S_f = Safety Factor. (Usually 1.5)

FIGURE 10

TEES



Reducers (Figure 11)

A_1 = Cross sectional area of larger pipe

A_2 = Cross sectional area of smaller pipe

$$L_1 = S_f \left[\frac{P(A_1 - A_2)}{F_{s_1}} \right] \quad (11)$$

S_f = Safety Factor. (Usually 1.5)

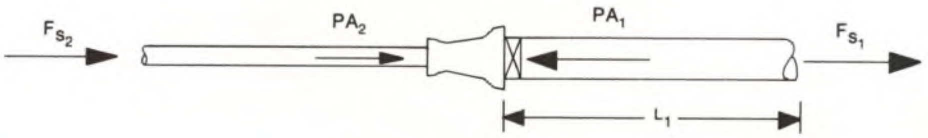
Note: If straight run of pipe on small side of reducer exceeds

$$L_2 = S_f \left[\frac{P(A_1 - A_2)}{F_{s_2}} \right] \quad (12)$$

then no restrained joints necessary

FIGURE 11

REDUCERS



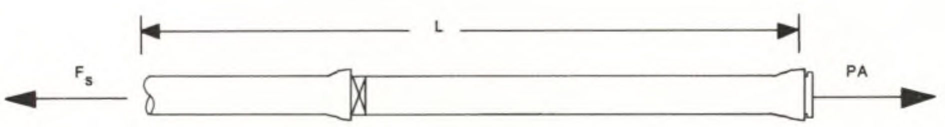
Dead Ends (Figure 12)

$$L = S_f \left[\frac{PA}{F_s} \right] \quad (13)$$

S_f = Safety Factor. (Usually 1.5)

FIGURE 12

DEAD ENDS



Nomenclature

A = Cross sectional area of pipe ($inch^2$) = $36\pi D'^2$ (See Table 2)

A_p = Surface area of pipe exterior (ft^2/ft)

C = Pipe cohesion (lbs/ft^2)

C_s = Soil cohesion (lbs/ft^2) (See Table 3)

D' = Outside diameter of pipe (feet) (See Table 2)

f_c = Ratio of pipe cohesion to soil cohesion (See Table 3)

F_s = Unit frictional force (lbs/ft)

f_ϕ = Ratio of pipe friction angle to soil friction angle (See Table 3)

H = Depth of cover to top of pipe (ft)

H_c = Depth of cover to pipe centerline (ft)

K_n = Trench condition modifier (See Table 3)

L = Minimum required restrained pipe length (ft)

N_ϕ = $\tan^2 (45° + \phi/2)$

P = Design pressure (psi)

P_p = Passive soil pressure (lbs/ft^2)

R_s = Unit bearing resistance (lbs/ft)

S_B = Horizontal bearing strength of soil (lbs/ft^2) (See Table 1)

T = Resultant thrust force (lbs.)

γ = Backfill soil density (lbs/ft^3) (See Table 3)

W = Unit normal force on pipe

= $2W_e + W_p + W_w$ (lbs/ft)

W_e = Earth prism load (lbs/ft) = $\gamma HD'$

W_m = Density of thrust block material (lbs/ft^3)

W_p = Unit weight of pipe (lbs/ft) (See Table 2)

W_w = Unit weight of water (lbs/ft) (See Table 2)

W' = $W_e + W_p + W_w$ (lbs/ft)

θ = Bend angle (degrees)

δ = Pipe friction angle (degrees)

ϕ = Soil internal friction angle (degrees) (See Table 3)

S_f = Safety factor (usually 1.5)

V_G = Volume of thrust block (ft^3)

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1. Carlsen, R.J., "Thrust Restraint for Underground Piping Systems." *Cast Iron Pipe News*, Fall 1975
2. Reference American Cast Iron Pipe Company research paper. (Unpublished)
3. Reference U.S. Pipe & Foundry Company research (Unpublished)
4. Potyondy, J.G., M. Eng., *Skin Friction Between Various Soils and Construction Materials.*
5. ASTM D 2487 — Classification of Soils for Engineering Purposes.

SECTION X

OTHER IMPORTANT FACTORS RELATED TO THE DESIGN AND USE OF DUCTILE IRON PIPE

Flow of Liquids in Pipelines

Factors Affecting Flow Capacity in Water Mains

In some areas of the United States, water mains have lost an appreciable part of their original carrying capacity after years of service, and for this reason consideration of the causes of this trouble and the remedies are of interest. Loss of carrying capacity results in increased costs either because of extra pumping expense or additional capital outlay if larger mains are required. There are many reasons for a reduction in the flow capacity of a pipeline. Increased head loss in a pipeline may be due to one or a combination of the following:

1. Sedimentation; mud, silt or sand.
2. Obstruction of the pipe due to debris: sticks, boards, stones, tools and other objects that may have gotten into the pipe during construction.
3. Partly closed valves.
4. Accumulation of air at summits.
5. Mineral deposits.
6. Slime growths on walls of pipe.
7. Tuberculation.

All of these difficulties can be remedied by proper design, operation and maintenance.

Sedimentation. Transmission mains that carry raw water from rivers or lakes are subject to heavy deposits of silt and sand, especially when the rivers are at flood stage, or the lakes are turbulent. Many of the older distribution systems were supplied with raw water for years before the construction of treatment plants. During low flow conditions, these waters deposit a layer of sediment along the bottom of the pipe. Sand may enter the raw water intake lines at most any time, and it may enter the distribution lines whenever the filters become defective or when the beds are inadequately maintained. If sedimentation has occurred, the remedy is to initiate and follow through with a main flushing program. If this type program is not effective, a pipe cleaning program may be necessary. It is important that the cause of the problem be determined and that remedial measures be undertaken to correct the situation; i.e., redesign of inlet works if required or initiate a preventive operating and maintenance program.

Obstructions in Pipe. Modern pipe laying specifications require that each length of pipe be cleaned out before installation in the line. They also require that the end of the pipeline be closed with a plug after each day's work. In spite of these provisions, it is a fact that at times undesirable objects are left or get placed in pipelines. Careful visual inspection of the pipe interior during installation and proper flushing technique upon completion of the pipeline should eliminate this difficulty.

Partly Closed Valves. In the ordinary operation of a water works system, it becomes necessary from time to time to close valves to carry on maintenance and extension work, and in some systems, valves are throttled for pressure control purposes. Care should be taken to see that closed valves are opened after the construction work is completed and the location of throttle valves properly recorded so that in the event that future operation requires a full opening, these valves may be opened. The opening and closing of valves is an important part of distribution system maintenance. Records should be kept on each valve to ascertain its performance and to be certain that no valves are accidentally left closed or partly closed.

Accumulation of Air at Summits. In supply lines there is occasionally an opportunity for air to accumulate at a summit so that the water can occupy only a portion of the total area of the pipe. The remedy for this difficulty is to provide air release valves at summits of the pipeline. Air release valves are also necessary for filling the lines when they are first placed in service or after being shut down to make repairs. When testing a portion of a new installation, it is important to have air release valves in all summits of that section.

Mineral Deposits. In rare cases, waters are highly mineralized. These minerals are picked up from the rock formations through which the water moves in its underground passage. Some waters are super-saturated and the minerals only loosely held in solution. A small amount of air mixed with water in the pumping operation or a quick change in water temperature, may cause the mineral to be deposited. Natural lime waters usually form a hard deposit on the entire wall of the pipe and decrease the flow by reducing the diameter of the pipe. Mineral deposits in mains are difficult to remove, usually requiring special cleaning tools. Lime and alum deposits that result from softening and filtration processes are sometimes carried out into the mains. As a rule, these deposits are relatively soft and may be removed by ordinary pipe cleaning operations.

Slime Growths. Some water supplies are troubled with organic growths in the mains. Many of the growths may be due to the use of surface water containing microscopic organisms. While most of these organisms have little effect on the quality of the water, they may cling to the walls of the pipe, thereby reducing the rate of flow in the line. Organic growths may be removed by the use of chlorine, a combination of chlorine and ammonia, or copper sulfate. The nature of the treatment depends on each individual case, and the application of chemicals should usually be started by the use of small dosages with gradual increase until the required effect results. A sudden change in chemical dosage could release many of the organisms into the distribution system, thereby causing taste, odor or turbidity complaints from the consumer.

Aggressive Water. Certain soft waters in the United States are aggressive to unprotected iron. Related problems virtually have been eliminated by factory installation of cement-mortar lining in almost all cast and ductile iron pipe used for water and wastewater. Older unlined pipelines may be cement-mortar lined in situ with good results.

Flow Characteristics of Ductile Iron Pipe

All ductile iron pipe for water transmission and distribution is cement-mortar-lined in accordance with ANSI/AWWA C104/A21.4 unless otherwise specified by the purchaser.

The flow of water through this pipe is usually computed by the widely used Hazen-Williams formula:

$$Q = 0.006756 \times CD^{2.63} H^{.54}$$

Where:

Q = discharge in gallons per minute

C = Hazen-Williams flow coefficient

D = actual inside diameter in inches

H = head loss in feet per 1,000 feet

The flow coefficient "C" in the Hazen-Williams formula is in effect a measure of the condition of the pipe interior and is sometimes known as a friction coefficient. Tests employing this formula show that cement-mortar-lined ductile iron pipe also has a larger than nominal inside diameter. The combined result is additional flow or less head loss with ductile iron pipe compared to substitute materials that have nominal or smaller inside diameters. This important flow advantage of ductile iron pipe can also result in a substantial savings in pumping costs. (See Section on Energy Savings with Ductile Iron Pipe).

The nomograph (pg. 300) is based on the Hazen-Williams flow formula and shows relationships between flow coefficient, head loss, internal pipe diameter and discharge rate. If any three of these factors are known, the fourth may be determined by locating a point on the pivot line, which point lies on a common line with two of the known factors. Once the pivot point is established, the unknown factor will lie on a straight line between the pivot point and the third know factor. Arrows (←) on the inside diameter line represent actual inside diameter of cement-mortar-lined ductile iron pipe Class 50.

Example 1 — Maximum Delivery

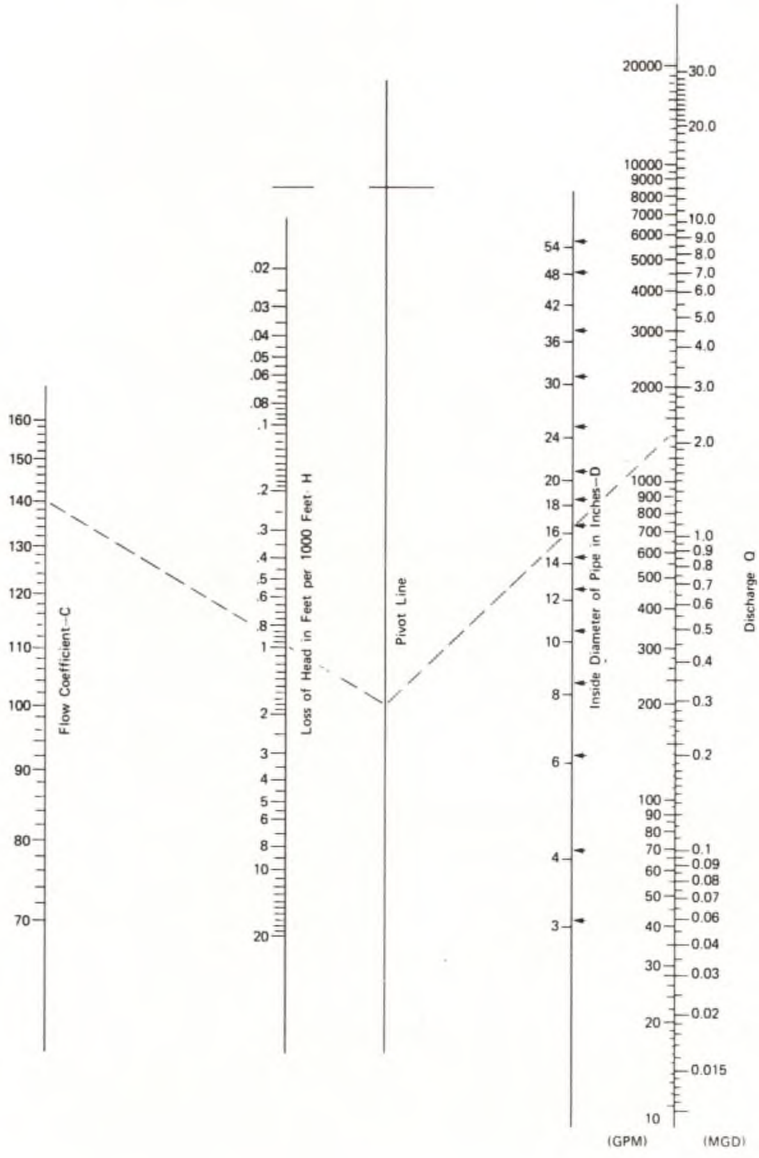
To find the maximum delivery of an 8-inch, Class 50, cement-mortar-lined ductile iron pipe, 7,500 feet in length under 150 feet of head, the available head per 1,000 feet is $\frac{150}{7.5}$ = 20 feet per 1,000 feet. By use of the nomograph, the result is 1,200 gallons per minute or 1.73 million gallons per day.

Example 2 — Determination of Diameter

To find the diameter of pipe necessary to deliver 3,000,000 gallons per day through a pipeline 25,000 feet long under 150 feet of head, the available head per 1,000 feet is $\frac{150}{25}$ = 6 feet per 1,000 feet. By use of the nomograph, the result is 12-inch, Class 50 ductile iron pipe.

NOMOGRAPH FOR PIPE SIZE, HEAD LOSS AND DISCHARGE FOR DUCTILE IRON PIPE

Based on Hazen-Williams Formula: $Q = 0.006756\ CD^{2.63}\ H^{.54}$
For Cement Mortar Lined Ductile Iron Pipe C =140.
(←) Shown are actual Inside Diameters of Cement
Mortar Lined Ductile Iron Pipe, Class 50



Example 3 — Friction Loss

To find the loss of head through a 10-inch pipeline 4,000 feet long, delivering 1,400,000 gallons per day, using a C factor of 140, the head loss is 4 feet per 1,000 feet, or 16 feet for the pipeline. If water is delivered at a point 100 feet above the pump, total head against the pump, is 100 feet (static) plus 16 feet (friction), or a total of 116 feet.

Example 4 — Delivery Determined from Pressure Reduction

Two accurate pressure gauges should be placed at a known distance apart and measurement of the difference in elevation recorded. If on a 12-inch pipe the pressure gauges are 500 feet apart and show a difference in pressure of 2 psi (4.6 feet of head) while one gauge is 1.8 feet above the other, the actual loss of head will be 4.6 plus or minus 1.8 = 6.4 or 2.8 feet per 500 feet or 12.8 or 5.6 feet per 1,000 feet, depending on elevation of the downstream gauge. Assuming that the downstream gauge is at the higher elevation, head loss due to friction is 5.6 feet per 1,000 feet. By use of the nomograph, the result is 1,900 gallons per minute, or 2.74 million gallons per day.

ENERGY SAVINGS WITH DUCTILE IRON PIPE

In all sizes Class 50 through 52, cement mortar lined ductile iron pipe has an internal diameter that is larger than the nominal pipe size. See Table 1. In most pipe made of other material, the inside diameter is equal to the nominal pipe size. Some pipe made of other materials have internal diameters smaller than the nominal size. When this difference is taken into account, significant savings can result from the use of Ductile Iron Pipe.

Pumping Cost

One way to realize the savings available through the use of ductile iron pipe is consideration of pumping cost. The energy required to pump water through pipe is proportional to the quantity of water being pumped as well as to the hydraulic gradient or head loss, as defined by the Hazen-Williams equation. Since pumping cost is directly proportional to the energy required, pumping cost can be expressed by the following equation:

$$PC = 1.65\, H_L\, Q \frac{a}{E} \qquad (1)$$

where

H_L = Hydraulic Gradient or Head Loss in ft/1000 ft.

Q = Flow in Gallons per Minute

a = Unit Cost of Electricity in $/KWH

E = Total Efficiency of Pump System (pump, motor, transmission) %/100

PC = Pumping Cost in $/Year Based on 24 hr. day Pump Operation/1000 ft.

The hydraulic gradient, or head loss as given by the Hazen-Williams equations is

$$H_L = 1000 \left[\frac{V}{1.318C(r)^{0.63}} \right]^{1.852} \quad (2)$$

where V = Velocity in ft/sec

C = Hazen-Williams "C" Factor (140 for ductile iron pipe)

r = Hydraulic Radius in ft (actual inside diameter in feet divided by 4)

The dependence of head loss on internal diameter is illustrated in Tables 2 through 5 showing the comparative head loss at a given flow.

Velocity is related to flow by the equation:

$$V = \frac{Q}{448.8A} \quad (3)$$

where Q = flow in gal/min.

and A = cross sectional area of pipe in ft^2

thus $A = \frac{\pi d^2}{4}$ where d = actual inside diameter (ft.)

Example Calculations

In order to determine the additional energy cost of pumping a given volume of water through a pipe that has a diameter equal to its nominal diameter as compared to pumping the same volume of water through Class 50 Ductile Iron Pipe, the following steps should be employed:

1) Convert flow to gallons per minute.

   Q (GPM) = Q (MGD) x 694.4

   Q (GPM) = Q (ft^3/sec) x 448.8

   Q (GPM) = 448.8AV

   where V = velocity in ft/sec

   A = flow area in ft^2

2) Calculate velocity (V) by using equation 3. (Actual inside diameters should be used and can be obtained from Table 1).

3) Calculate the H_L for each pipe material using equation 2 or from Tables 2 through 5.

4) Calculate the pumping cost (PC) per 1000 ft. for each material using equation 1 (use known or estimated values for "a" and "E").

5) Multiply the PC times the length of the pipeline divided by 1000.

6) Multiply the result of Step 5 by the fraction of each day the pump will operate.

7) Take the difference in pumping cost (Step 6) of each pipe material to obtain the annual savings (AS).

8) Calculate the long term savings (LTS) using the equation

$$LTS = AS \left[\frac{(1 + i)^n - 1)}{i} \right]$$

where "n" is the number of compounding periods and "i" is the periodic decimal interest rate.

9). Calculate the Present Worth (PW) of the annual savings using the equation

$$PW = AS \left[\frac{(1 + i)^n - 1}{i \ (1 + i)^n} \right]$$

Example No. 1

Criteria:

36-inch pipeline
30,000 feet long
Design flow is 13,500 GPM
Unit Power Cost = $0.030/KWH
Pump to Operate 24 hours/day
Pump System Efficiency = 70%
Design life of 50 years
Interest Rate of 8%

Step No.	D1P C1 50, CML	Nominal I.D.
1. Q =	13,500 GPM	13,500 GPM
2. V =	3.99 fps	4.25 fps
3. H_L =	1.11 ft/1000 ft	1.30 ft/1000 ft
4. PC =	$1059.65	$1241.04
5. PC x 30 =	$31,789.61	$37,231.07
6. Step 5 x 1 =	$31,789.61	$37,231.07

7. AS = $37,231.07 − $31,789.61 = $5441.46

8. LTS = $3,122,147.35

9. PW = $66,568.02

Example No. 2

Criteria:

16-inch pipeline
20,000 feet long
Design flow is 3500 GPM
Unit Power Cost = \$0.035/KWH
Pump to operate 16 hours/day
Pump System Efficiency = 70%
Design life of 50 years
Interest rate of 8%

Step No.	DIP Cl 50, CML	Nominal I.D.
1. Q =	3,500 GPM	3,500 GPM
2. V =	5.23 fps	5.57 fps
3. H_L =	4.71 ft/1000 ft	5.53 ft/1000 ft
4. PC =	\$1360.01	\$1596.20
5. PC x 20 =	\$27,200.25	\$31,924.00
6. Step 5 x 16/24 =	\$18,133.50	\$21,282.67

7. AS = \$21,282.67 − \$18,133.50 = \$3149.17

8. LTS = \$1,806,899.76

9. PW = \$38,525.32

The result of these calculations gives: first, the annual savings in energy costs from using Class 50 ductile iron pipe over nominal I.D. pipe; second, a long-term savings derived from investment of the annual savings at a given interest rate for the life of the pipe; and third, and probably most important, the present worth of the projected annual savings. The present worth is the amount that should be used in comparing alternate bids on a pipeline. For instance, in Example No. 1, the calculated PW was \$66,568.02 which means that the owner could justify paying at least that much more initially for ductile iron pipe over a substitute piping material with nominal inside diameter. In reality, a much higher additional cost could be justified since the sample calculations assume that the cost of energy remains constant over the life of the pipeline. To determine the real energy savings with ductile iron pipe, an appropriate inflation factor should be used to account for projected increases in energy costs. This was omitted from the above examples due to the many variables involved in selecting an appropriate value for inflation.

Equivalent Pipelines

Consider a pipeline of diameter D and length L designed to deliver Q gallons per minute of water. As already explained, if the pipe has an internal diameter equal to the nominal diameter D, the head loss over length L due to the friction will be greater than the head loss in an equal length of the same size ductile iron pipe. Again this is due to the larger internal diameter of the ductile iron pipe. A ductile iron pipeline can be designed to produce the same head loss as the nominal diameter pipe over the length L at flow Q. The ductile pipeline, however, will be made up of pipe of size D for only part of the distance L and the next size smaller for the remainder. This approach will yield savings in the initial installation through the use of the smaller pipe for part of the pipeline.

To achieve equivalent flow and head loss in this manner, the smaller size pipe can be used over length S, where S is given by

$$S = \frac{H_N - H_D}{H_D' - H_D} L$$

where

H_N = Head loss per 1000 feet of pipe in the nominal diameter pipe of size D at flow Q

H_D = Head loss per 1000 feet of pipe in the Ductile Iron Pipe of size D at flow Q

$H_{D'}$ = Head loss per 1000 feet of pipe in the Ductile Iron Pipe of the next size smaller than D at flow Q (See Tables 2 through 5).

Example

Find the ductile iron pipeline that is equivalent to a 36-inch pipe with nominal inside diameter, 5000 feet long, delivering 25,000 gallons per minute. The equivalent ductile pipeline will be made up of 36-inch pipe and 30-inch pipe. From Table 4,

H_N (Nominal diameter 36-inch pipe) = 4.07 ft/1000 ft.

H_D (36-inch Class 50 Ductile Iron Pipe) = 3.47 ft/1000 ft.

H_D' (30-inch Class 50 Ductile Iron Pipe) = 8.47 ft/1000 ft.

Then

$$S = \frac{4.07 - 3.47}{8.47 - 3.47} L$$

$$S = .12(5000) = 600$$

thus the equivalent Ductile Iron Pipe would include

4400 ft. of 36-inch pipe and

600 ft. of 30-inch pipe

TABLE 1 — COMPARISON OF FLOW AREAS IN VARIOUS PIPE MATERIALS

Legend:
ID = Inside Diameter
DIP = Ductile Iron Pipe

	Class 50 Cement Lined Ductile Iron Pipe		Class 150 Asbestos Cement			DR 18 PVC Pipe (C-900)			Prestressed Concrete (C-301)			Steel Pipe		
Nominal Pipe Size	ID (in)	Flow Area (ft^2)	ID (in)	Flow Area (ft^2)	% Larger Flow Area For Class 50 DIP	ID (in)	Flow Area (ft^2)	% Larger Flow Area For Class 50 DIP	ID (in)	Flow Area (ft^2)	% Larger Flow Area For Class 50 DIP	ID (in)	Flow Area (ft^2)	% Larger Flow Area For Class 50 DIP
6	6.28	.215	5.85	.187	15.2	6.134	.205	4.8				6.065	.201	7.2
8	8.39	.384	7.85	.336	14.3	8.044	.353	8.8				8.071	.355	8.1
10	10.40	.590	10.00	.546	8.2	9.866	.531	11.1				10.192	.567	4.1
12	12.46	.847	12.00	.785	7.8	11.734	.751	12.8				12.09	.797	6.2
14	14.45	1.14	14.00	1.07	6.5							13.5	.994	14.6
16	16.53	1.49	16.00	1.40	6.7				16.00	1.40	6.7	15.5	1.31	13.7
18	18.61	1.89	18.00	1.77	6.9				18.00	1.77	6.9	17.5	1.67	13.1
20	20.69	2.34	20.00	2.18	7.0				20.00	2.18	7.0	19.5	2.07	12.6
24	24.85	3.37	24.00	3.14	7.3				24.00	3.14	7.3	23.5	3.01	11.9
30	30.97	5.23	30.00	4.91	6.5				30.00	4.91	6.5	29.5	4.75	10.2
36	37.19	7.54	36.00	7.07	6.7				36.00	7.07	6.7	35.5	6.87	9.7
42	43.31	10.23							42.00	9.62	6.3	42.00	9.62	6.3
48	49.53	13.38							48.00	12.57	6.5	48.00	12.57	6.5
54	55.71	16.93							54.00	15.90	6.4	54.00	15.90	6.4

TABLE #2

HEAD LOSS PER 1,000 FEET OF PIPE

Class 50-52 — Cement Mortar Lined
Ductile Iron Pipe
Nominal ID Pipe
C=140

Q		6"			8"			10"			12"	
(gpm)	Class 50	Class 52	Nom. ID	Class 50	Class 52	Nom. ID	Class 50	Class 52	Nom. ID	Class 50	Class 52	Nom. ID
250	3.99	4.37	4.96	.972	1.04	1.22	.34	.36	.41	.14	.15	.17
500	14.40	15.76	17.96	3.51	3.74	4.41	1.23	1.30	1.49	.51	.53	.61
750	30.51	33.39	37.97	7.44	7.92	9.35	2.61	2.76	3.15	1.08	1.13	1.30
1,000	51.99	56.89	64.67	12.74	13.50	15.93	4.45	4.70	5.37	1.84	1.93	2.21
1,500	110.16	120.54	137.03	26.84	28.60	33.75	9.43	9.95	11.38	3.91	4.09	4.68
2,000				45.73	48.73	57.50	16.06	16.96	19.39	6.66	6.97	7.98
2,500							24.27	25.64	29.32	10.06	10.53	12.06
3,000							34.02	35.93	41.09	14.10	14.76	16.90
3,500										18.76	19.64	22.49
4,000										24.03	25.15	28.80

TABLE #3

HEAD LOSS PER 1,000 FEET OF PIPE

Class 50-52 — Cement Mortar Lined
Ductile Iron Pipe
Nominal ID Pipe
C=140

Q 1,000		14"			16"			18"			20"	
(gpm)	Class 50	Class 52	Nom. ID	Class 50	Class 52	Nom. ID	Class 50	Class 52	Nom. ID	Class 50	Class 52	Nom. ID
1	.89	.93	1.04	.46	.48	.54	.26	.27	.31	.16	.16	.18
2	3.23	3.36	3.76	1.68	1.74	1.97	.94	.97	1.11	.56	.58	.66
3	6.83	7.13	7.98	3.55	3.68	4.16	1.99	2.06	2.35	1.19	1.23	1.40
4	11.64	12.14	13.59	6.05	6.28	7.09	3.40	3.51	4.00	2.03	2.09	2.39
5	17.60	18.36	20.55	9.14	9.48	10.72	5.13	5.31	6.04	3.06	3.16	3.62
6	24.67	25.73	28.81	12.82	13.30	15.03	7.20	7.44	8.47	4.30	4.43	5.07
7	32.82	34.24	38.32	17.05	17.69	20.00	9.57	9.90	11.27	5.72	5.89	6.75
8	42.03	43.84	49.08	21.84	22.66	25.61	12.26	12.67	14.43	7.32	7.54	8.64
9				27.16	28.18	31.85	15.25	15.76	17.95	9.10	9.38	10.74
10							18.53	19.16	21.82	11.06	11.40	13.06
11										13.20	13.60	15.58

TABLE #4

HEAD LOSS PER 1,000 FEET OF PIPE
Class 50-52 — Cement Mortar Lined
Ductile Iron Pipe
Nominal ID Pipe
C=140

Q 1,000 (gpm)	24" Class 50	24" Class 52	24" Nom. ID	30" Class 50	30" Class 52	30" Nom. ID	36" Class 50	36" Class 52	36" Nom. ID
2	.23	.24	.27	.079	.081	.092	.032	.033	.038
4	.83	.85	.98	.28	.29	.33	.12	.12	.137
6	1.76	1.80	2.09	.60	.62	.70	.25	.25	.29
8	3.00	3.07	3.55	1.03	1.05	1.20	.42	.43	.49
10	4.53	4.65	5.37	1.55	1.59	1.81	.64	.65	.75
15	9.60	9.85	11.38	3.29	3.38	3.84	1.35	1.39	1.58
20	16.36	16.78	19.39	5.60	5.75	6.54	2.30	2.36	2.69
25				8.47	8.70	9.89	3.47	3.57	4.07
30				11.87	12.19	13.86	4.87	5.00	5.70
35							6.47	6.66	7.59
40							8.29	8.53	9.72

TABLE #5

HEAD LOSS PER 1,000 FEET OF PIPE
Class 50-52 — Cement Mortar Lined
Ductile Iron Pipe
Nominal ID Pipe
C=140

Q 1,000 (gpm)	42" Class 50	42" Class 52	42" Nom. ID	48" Class 50	48" Class 52	48" Nom. ID	54" Class 50	54" Class 52	54" Nom. ID
10	.30	.31	.35	.16	.16	.18	.089	.09	.10
15	.64	.66	.75	.34	.35	.39	.19	.20	.22
20	1.09	1.13	1.27	.57	.59	.66	.32	.33	.37
25	1.65	1.70	1.92	.86	.89	1.00	.48	.50	.56
30	2.32	2.38	2.69	1.21	1.24	1.40	.68	.70	.79
40	3.95	4.06	4.59	2.06	2.11	2.40	1.16	1.19	1.35
50	5.97	6.14	6.93	3.15	3.20	3.62	1.75	1.80	2.04
60				4.37	4.48	5.07	2.45	2.53	2.86
70				5.81	5.96	6.75	3.27	3.36	3.80
80				7.44	7.63	8.64	4.18	4.31	4.87

WATER HAMMER OR SURGE

Water hammer or surge is a real force and has caused failure of many pipelines of various materials. It is the result of a sudden decrease in the pipeline fluid velocity. This rapid deceleration of the liquid mass converts dynamic energy to elastic energy and sets up pressure waves which are transmitted rapidly through the pipeline system. Water hammer can be caused by rapid closure of valves or fire hydrants, quick acting valves, check valves, sudden loss of power at pumping stations, and other situations that effect the velocity of the fluid. While there are surge suppression devices available, experience has shown that these devices do not always properly arrest surge forces due to inactivity, rusting, silting, loss of power, overloading, etc.

Therefore, water hammer must be considered in pipe thickness calculations. It is estimated that in water transmission and distribution systems, a change in velocity of 1 foot per second in critical time can increase the pressure in the pipe by approximately 50 psi. The design procedure for ductile iron detailed in ANSI/AWWA C150/A21.50, includes a standard allowance of 100 psi for water hammer. This figure represents a realistic value for most water piping systems. However, if a system is known to have higher surge pressures, a higher value should be used in design calculations.

Water hammer or surge pressure can be calculated for a simple pipeline using the following equations:

$$P_s = \frac{a\,V\,W}{144\,g} \qquad (1)$$

$$a = \frac{u}{\sqrt{1 + \frac{K\,d}{E\,t}}} \qquad (2)$$

$$u = \sqrt{\frac{K}{W/g}} \qquad (3)$$

(normal use for water is 4660 fps)

$$T_c = \frac{2\,L}{a} \qquad (4)$$

$$P_s' = \frac{T_c}{T_x}\,P_s \qquad (5)$$

Where:

P_s = Surge pressure above initial pressure, psi (when $T_c \geq T_x$)

P_s' = Surge pressure above initial pressure, psi (when $T_c < T_x$)

V = Velocity change, fps

W = Weight of water, 62.4 pcf

g = Acceleration due to gravity, 32.2 fps

a = Wave velocity, fps

u = Wave velocity of fluid, fps

K = Bulk modulus of elasticity of water, 294,000 psi

d = Pipe diameter (nominal), inches

t = Thickness of pipe wall, inches

E = Modulus of elasticity of pipe material,
Ductile iron = 24,000,000 psi
Gray cast iron = 15,000,000 psi

L = Length of pipeline, feet

T_c = Critical time in seconds required for pressure wave to travel 2 L

T_x = Valve closure time in seconds.

The formula for P_s is used for near instantaneous velocity changes and quick closing valves. The value for P_s' from equation (5) is for slow closing valves and considered by many to be an approximation. To obtain more accurate P_s' values, it would be necessary to use other formulas which are considerably more complicated. Because of the high factors of safety incorporated in the standard design procedure for ductile iron pipe, it normally is not necessary to go through this process. However, the use of other materials having lower factors of safety requires a more accurate determination of surge pressure. Such analyses can be found in many reference works.

It is emphasized that the formulas listed here are for simple pipelines. The analysis of water hammer in a network of piping, such as that of a conventional water distribution system, is more complex, and for this reason the standard design for ductile iron pipe includes a 100 psi water hammer allowance.

An example calculation for a ductile iron pipeline 10,000 feet long, 36" in diameter and flowing at 2 fps, with a valve closure of (a) 5 seconds and (b) 20 seconds, is as follows:

$$d = 36", \quad t = 0.43", \quad E = 24 \times 10^6 \text{ psi}$$

$$\text{Eq. (2) } a = \frac{4660}{\sqrt{1 + \frac{294{,}000\ (36)}{24 \times 10^6\ (0.43)}}} = 3274 \text{ fps}$$

$$\text{Eq. (4) } T_c = \frac{2\,(10{,}000)}{3274} = 6.11 \text{ sec.}$$

a) $T_c \geq T_x \ (6.11 \geq 5)$

$$\text{Eq. (1) } P_s = \frac{3274 \times 2 \times 62.4}{144 \times 32.2} = 88.12 \text{ psi}$$

b) $T_c < T_x \ (6.11 < 20)$

$$\text{Eq. (5) } P_s' = \frac{6.11}{20} \times 88.12 = 26.92 \text{ psi}$$

From this example, it is apparent that the standard surge allowance is sufficient (100 psi >88.12 psi) and that the critical time for valve closure is 6.11 seconds. A slower valve closure would therefore diminish the surge pressure.

EXPANSIVE SOILS & THEIR EFFECT ON UNDERGROUND PIPE

Expansive soils can be defined as any soil that swells or shrinks significantly upon wetting or (especially) drying, thus undergoing a volume change. Expansive soils are classified as clay soils containing large fractions of colloid-sized particles ranging from less than 1 micron to 2 microns in size. Such clays found in the continental United States are silicate clays; kaolinite, montmorillonite, hydrous micas or illites, chlorite, vermiculite, and attapulgite.

Positive field determination of an expansive soil and its potentially adverse effect on underground pipe is nearly impossible without proper test equipment. Tentative identification can be made by observing soil characteristics.

A potentially expansive soil may: (1) become very hard on drying and crack or fissure extensively; (2) become very sticky when wetted; (3) be plastic over a wide range of moisture content; (4) have a soapy or slick feeling when rubbed between the fingers; (5) be fine-grained, with little sand or coarse material; or (6) simply be known as a clay.

Experience with other structures in or on the soil can be helpful. Thus expansive soil may be present where there are apparently unexplainable beam breaks in the piping system, plus heaved or cracked pavement, curbs, etc., which cannot be explained by frost action or poor preparation of the support soil.

The soil consolidometer is normally used to determine the swell pressure value of an expansive soil. However, a simpler and faster device with reasonable accuracy is also available—The Soil Potential Volume Change Meter. Readings from this Meter are converted to a swell index value in pounds per square foot (psf). This value can then be converted to Potential Volume Change rating and approximate plasticity index.

Ductile Iron Pipe Research Association (DIPRA) has used this Soil Meter for several years, testing hundreds of samples from many areas of the U.S., including Alaska and Hawaii.

A Potential Volume Change Number is asigned to each swell index value obtained from tests with the meter. Here are the ranges:

Swell Index (p s f)	PVC Number	Category of Expansive Soil
0 - 1700	0 - 2	Noncritical
1700 - 3200	2 - 4	Marginal
3200 - 4700	4 - 6	Critical
4700 and above	6 and above	Very critical

Swell index values of 3000 psf and above (at Potential Volume Change Numbers above 2) are presently considered to indicate soils that may require special pipe selection.

The swell index tests performed by DIPRA and those reported in the Guide to the Use of the FHA Soil Potential Volume Change Meter, FHA 595, indicate a rather wide distribution of expansive soils across the United States. Values from a series of samples follow:

Location	Swell Index (psf)	Location	Swell Index (psf)	Location	Swell Index (psf)
Alabama	9,702	Michigan	3,568	Pennsylvania	3,728
Arkansas	10,473	Minnesota	3,248	Puerto Rico	5,984
California	11,309	Mississippi	17,260	South Dakota	8,604
Colorado	4,958	Missouri	12,897	Tennessee	5,324
Florida	13,610	Montana	5,159	Texas	13,350
Hawaii	10,061	Nebraska	4,747	Washington	3,676
Idaho	15,980	North Carolina	7,132	West Virginia	3,568
Illinois	10,551	North Dakota	4,582	Wyoming	25,920
Iowa	5,076	Oklahoma	8,924		
Louisiana	9,004	Oregon	11,563		

These soils may severely damage structures on or in them, usually more often by swelling than by shrinking. There is little documentation on such damage to pipelines. However, several utilities in areas with highly expansive soils indicate that damage does occur, usually as beam breaks in stronger rigid pipes and both beam breaks and ring crush in weaker rigid pipe. Pipe fabricated from strong ductile material appears to be little affected, and assumes a slightly new position to relieve stress.

Because of short-term experience with new pipe materials, such as plastic, it is not now possible to judge their performance in this environment.

Moisture change in expansive soils is responsible for their volume change. So even though a soil may have a high potential for swell or shrinkage, its actual volume change will depend on the amount of moisture fluctuation. Long, wet periods followed by long, dry periods favor high volume changes. And dry climates (with periodic high ground water tables) or relatively dry soil conditions with a source of moisture (such as a water leak) can also create problems.

The installation trench itself can attract water for a long period of time. Covering the trench with pavement, etc. also invites water invasion and soil-volume changes.

Shallow cover over pipe in expansive soils with relatively long drying periods can damage the pipe as differential soil pressures develop. Deeper burial of the pipe may place it in a more stable moisture condition and permit more earth weight to offset swell pressures from below.

Bedding and backfill around the pipe with selected granular material may also help, although better pipe support to sustain backfill load may be the only benefit.

With more expansive soil, corrosion potential may increase, requiring special corrosion protection. Shrinkage of the soil may damage pipe coatings—particularly tar and asphalt coatings. It appears that loose-fitting polyethylene tube or wrap is well suited for protection in shrinking soil conditions, in that some movement around the pipe by both soil and wrap will not result in damage of this protective system.

DIPRA is now conducting laboratory tests to help answer the following questions on the effect of expansive soils: What is the range of stress applied to the pipe at different swell-pressures? How is the stress applied and in what direction? What are the best methods for pipe installation? For more information regarding the ongoing tests, contact DIPRA office.

EVALUATION OF FROST LOADINGS ON UNDERGROUND PIPE

Background

An awareness of drastic increases in the incidence of breaks in underground pipe during winter and some rather simple deductive reasoning led to the suspicion that the expansion of earth due to freezing is a probable contributor to the problem. Utilities in the northern tier of the United States reported that 60% to 70% of the failures in pipe structures occur during that portion of the winter when frost penetrates below the ground surface.

It is well known that when atmospheric temperature drops below 32° F (0° C) for several hours, shallow soil moisture freezes in lenses, with water traveling by capillary action from adjacent soil to these newly formed lenses. This results in expansion of the water-soil mixture; and if low temperatures persist or decrease, additional lenses are formed, and additional expansion occurs. An approximate force of 150 tons per square foot or larger may develop when water is frozen in a confined volume. The challenge is one of determining what portion of the pressure due to expansion is directed vertically downward in the case of frozen earth and what actual loads are appropriated by underlying pipe.

Visualizing earth expansion due to frost, it is readily apparent that there is a tendency for the shallow earth to expand in all directions. Resulting lateral pressures lock the upper layers of earth into a bridge covering a broadened area. There is upward expansion which may cause damage to streets, highways and buildings, and there is also the downward thrust with which we are concerned.

Research

The Ductile Iron Pipe Research Association (DIPRA) has been involved in research of this subject for over 10 years. Data has been collected from studies in Portland, Maine and primarily in Wheaton, Illinois. From this data and observations from the studies, the following information was reported:

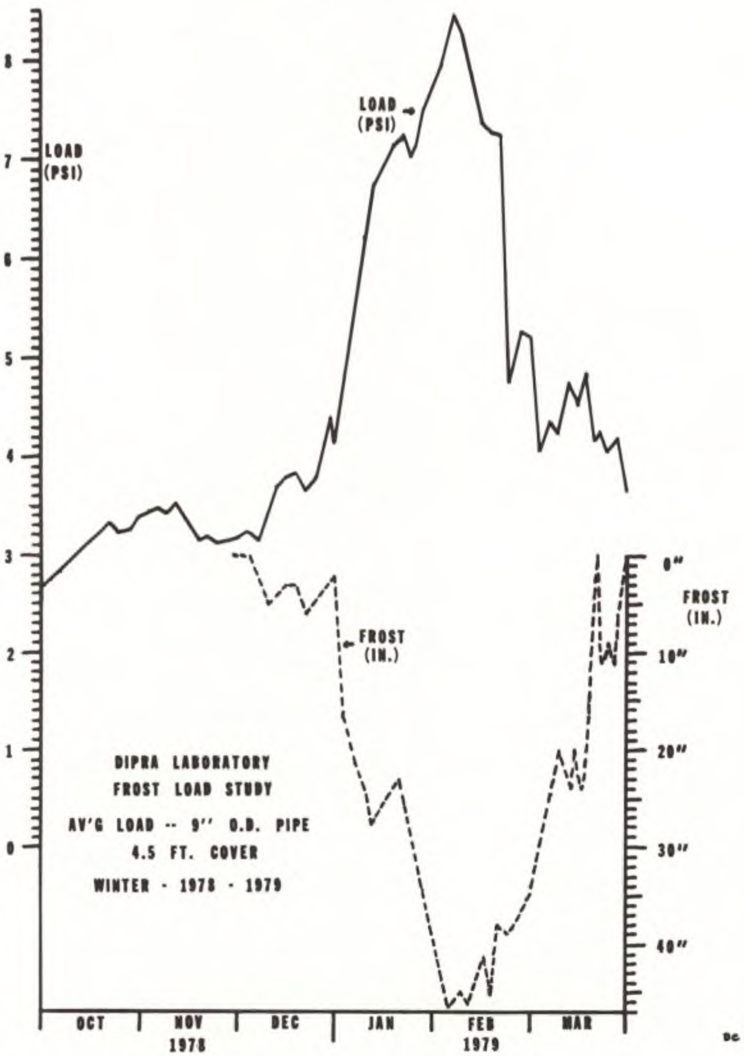
1. Measured earth load on the pipe agrees with the prism load equations, when there is no frost penetration.
2. Measured truck load on the pipe agrees with the AASHTO truck load equations.
3. The earth loads on the pipe vary inversely with soil moisture.
4. Frost penetration into the soil above the pipe can more than double the load on the pipe (See Figure 1).
5. Frozen soil above the pipe reduces live load on the pipe.
6. Frozen soil above the pipe can transmit live load to the pipe from loads applied beyond the trench zone.
7. Earth, frost and live loads are non-uniform along the pipe length.

How do these findings relate to pipe failure from frost loading? Doubling of the load on the pipe and non-uniform loading would be suspected first; however, review of the stresses from this show that other conditions must contribute to cause failure.

The typical frost break is a beam loading failure. Interviews with water utility managers and pipeline repair crews revealed that nearly all beam type breaks are related to a combination of a bedding problem and severe load. The bedding problem can be caused by many things and results in the pipe reacting as a beam. As the load on the pipe increases, such as the case with frost loading, the pipe will fail when this load exceeds the pipe's beam strength. Therefore, piping with low beam strength will be affected more severely.

Because of ductile iron's inherent beam strength, it is the material of choice of most utilities in the northern areas of the United States. DIPRA is not aware of any reported failures of ductile iron pipe due to the increased loading of frost penetration.

FIGURE 1



SECTION XI

GRAY CAST IRON PIPE

Introduction

Gray cast iron pipe was widely used for water transmission and distribution, gravity sewers and force mains, water and sewage treatment plants, and industrial piping applications for over 150 years. Today, gray cast iron pressure pipe is no longer manufactured in the United States. It had been replaced in the same markets by ductile cast iron pipe, which is a stronger and improved product. Most of the gray cast iron pipe installed in the U.S. is still in service, some for over 150 years.

The ANSI/AWWA Standards for gray cast iron pipe have been withdrawn as active Standards but are still available for reference. Those Standards are ANSI A21.1/AWWA C101, ANSI A21.6/AWWA C106 and ANSI A21.8/AWWA C108. Also, the following data is furnished for general information.

Metallurgy of Gray Cast Iron Pipe

Structure

Gray cast iron is essentially an alloy of iron and carbon containing appropriate amounts of silicon, manganese, phosphorus and sulfur. In gray cast iron, a major part of the carbon content occurs as free carbon or graphite in the form of flakes interspersed throughout the metal. The engineering properties specific to gray cast iron are principally due to the presence of these graphite flakes.

The excellent corrosion resistance of cast iron pipe in underground service is well known. The corrosion products of cast iron pipe are tightly adherent and help protect the metal beneath. The appreciable amount of graphite, about 10 percent by volume, together with relatively inert iron oxides and phosphides, causes gray cast iron to be characteristically corrosion resistant.

In corrosive environments where the metallic content of cast iron pipe is reduced by corrosion, the corrosion products of cast iron form an interlocking mat of graphite, phosphides and iron oxides, which is dense and strong enough to enable the pipe to continue to serve indefinitely as an effective conduit in many instances.

Machineability of any metal structure is important, particularly where it must be drilled, tapped, or cut with ordinary tools. At a given hardness level, cast iron is more easily machined than most other metals because the graphite flakes break up the chips and lubricate the cutting tool.

Chemistry

Carbon. Carbon in cast iron may vary from about 3.00 to 3.75 percent. In general, the carbon content is adjusted to suit the particular method of manufacture and the cooling rate of a given size of casting.

Silicon. Silicon promotes graphitization, and, therefore, is a very useful element to control the properties of gray cast iron. The proper use of silicon permits a wide range of different castings to be made with uniform strength and hardness properties.

Phosphorus. Phosphorus in cast iron pipe ranges up to a maximum of 0.90 percent. Phosphorus increases the fluidity of the molten iron and is useful for wear and corrosion resistance.

Manganese and Sulfur. Manganese content is related to the content of sulfur and other elements in the control of physical properties. Sulfur was limited to 0.12 percent maximum in the most recent pipe standards.

Several other elements were present and affected the physical properties. For this reason, the acceptance test requirements of cast iron pipe standards were based on the physical properties.

Quality Control

Modern metallurgical control enabled the foundry to produce quality castings with the desired combination of properties. Tests carried out as a guide to metallurgical control included: frequent chemical analyses for each mix used in the cupola, chill tests for graphitizing tendency, Talbot strips from the pipe wall, ring tests on rings cut from the pipe, full length bursting tests of pipe, impact tests, direct tensile tests, and others. One of the routine tests of the finished product was the hydrostatic test to which every length was subjected. Correlation of the values obtained from all of these tests with service performance of the castings had enabled the cast iron pressure pipe industry to produce progressively better and more reliable cast iron pipe and fittings.

Dimensions of Pit Cast Pipe only
Not of current manufacture or standard

Dimensions of A. W. W. A. Standard Bell and Spigot Pipe

Classes A, B, C and D

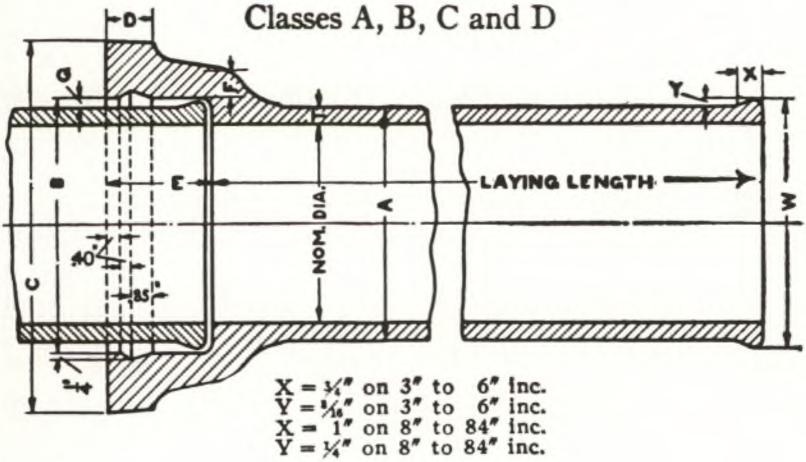


Table No. 1

Nominal Diameter Inches	Class	Dimensions, Inches								
		A	B	C	D	E	F	G	T	W
3	A	3.80	4.60	7.20	1.25	3.50	.65	.40	.39	4.18
	B	3.96	4.76	7.36	1.25	3.50	.65	.40	.42	4.34
	C	3.96	4.76	7.36	1.25	3.50	.65	.40	.45	4.34
	D	3.96	4.76	7.36	1.25	3.50	.65	.40	.48	4.34
4	A	4.80	5.60	8.20	1.50	3.50	.65	.40	.42	5.18
	B	5.00	5.80	8.40	1.50	3.50	.65	.40	.45	5.38
	C	5.00	5.80	8.40	1.50	3.50	.65	.40	.48	5.38
	D	5.00	5.80	8.40	1.50	3.50	.65	.40	.52	5.38
6	A	6.90	7.70	10.50	1.50	3.50	.70	.40	.44	7.28
	B	7.10	7.90	10.70	1.50	3.50	.70	.40	.48	7.48
	C	7.10	7.90	10.70	1.50	3.50	.70	.40	.51	7.48
	D	7.10	7.90	10.70	1.50	3.50	.70	.40	.55	7.48
8	A	9.05	9.85	12.85	1.50	4.00	.75	.40	.46	9.55
	B	9.05	9.85	12.85	1.50	4.00	.75	.40	.51	9.55
	C	9.30	10.10	13.10	1.50	4.00	.75	.40	.56	9.80
	D	9.30	10.10	13.10	1.50	4.00	.75	.40	.60	9.80

Dimensions continued on next page.

Dimensions of Pit Cast Pipe only
Not of current manufacture or standard

Dimensions of A. W. W. A. Standard Bell and Spigot Pipe

Classes A, B, C and D

Table No. 1 (continued)

Nominal Diameter Inches	Class	Dimensions, Inches								
		A	B	C	D	E	F	G	T	W
10	A	11.10	11.90	14.90	1.50	4.00	.75	.40	.50	11.60
	B	11.10	11.90	14.90	1.50	4.00	.75	.40	.57	11.60
	C	11.40	12.20	15.40	1.50	4.00	.80	.40	.62	11.90
	D	11.40	12.20	15.40	1.50	4.00	.80	.40	.68	11.90
12	A	13.20	14.00	17.20	1.50	4.00	.80	.40	.54	13.70
	B	13.20	14.00	17.20	1.50	4.00	.80	.40	.62	13.70
	C	13.50	14.30	17.70	1.50	4.00	.85	.40	.68	14.00
	D	13.50	14.30	17.70	1.50	4.00	.85	.40	.75	14.00
14	A	15.30	16.10	19.50	1.50	4.00	.85	.40	.57	15.80
	B	15.30	16.10	19.50	1.50	4.00	.85	.40	.66	15.80
	C	15.65	16.45	20.05	1.50	4.00	.90	.40	.74	16.15
	D	15.65	16.45	20.05	1.50	4.00	.90	.40	.82	16.15
16	A	17.40	18.40	22.00	1.75	4.00	.90	.50	.60	17.90
	B	17.40	18.40	22.00	1.75	4.00	.90	.50	.70	17.90
	C	17.80	18.80	22.60	1.75	4.00	1.00	.50	.80	18.30
	D	17.80	18.80	22.60	1.75	4.00	1.00	.50	.89	18.30
18	A	19.50	20.50	24.30	1.75	4.00	.95	.50	.64	20.00
	B	19.50	20.50	24.30	1.75	4.00	.95	.50	.75	20.00
	C	19.92	20.92	25.12	1.75	4.00	1.05	.50	.87	20.42
	D	19.92	20.92	25.12	1.75	4.00	1.05	.50	.96	20.42
20	A	21.60	22.60	26.60	1.75	4.00	1.00	.50	.67	22.10
	B	21.60	22.60	26.60	1.75	4.00	1.00	.50	.80	22.10
	C	22.06	23.06	27.66	1.75	4.00	1.15	.50	.92	22.56
	D	22.06	23.06	27.66	1.75	4.00	1.15	.50	1.03	22.56
24	A	25.80	26.80	31.00	2.00	4.00	1.05	.50	.76	26.30
	B	25.80	26.80	31.00	2.00	4.00	1.05	.50	.89	26.30
	C	26.32	27.32	32.32	2.00	4.00	1.25	.50	1.04	26.82
	D	26.32	27.32	32.32	2.00	4.00	1.25	.50	1.16	26.82
30	A	31.74	32.74	37.34	2.00	4.50	1.15	.50	.88	32.24
	B	32.00	33.00	37.60	2.00	4.50	1.15	.50	1.03	32.50
	C	32.40	33.40	38.60	2.00	4.50	1.32	.50	1.20	32.90
	D	32.74	33.74	39.74	2.00	4.50	1.50	.50	1.37	33.24
36	A	37.96	38.96	43.96	2.00	4.50	1.25	.50	.99	38.46
	B	38.30	39.30	44.90	2.00	4.50	1.40	.50	1.15	38.80
	C	38.70	39.70	45.90	2.00	4.50	1.60	.50	1.36	39.20
	D	39.16	40.16	46.96	2.00	4.50	1.80	.50	1.58	39.66

Dimensions continued on next page.

Dimensions of Pit Cast Pipe only
Not of current manufacture or standard

Dimensions of A. W. W. A. Standard

Bell and Spigot Pipe

Classes A, B, C and D

Table No. 1 (continued)

Nominal Diameter Inches	Class	Dimensions, Inches								
		A	B	C	D	E	F	G	T	W
42	A	44.20	45.20	50.80	2.00	5.00	1.40	.50	1.10	44.70
	B	44.50	45.50	51.50	2.00	5.00	1.50	.50	1.28	45.00
	C	45.10	46.10	52.90	2.00	5.00	1.75	.50	1.54	45.60
	D	45.58	46.58	54.18	2.00	5.00	1.95	.50	1.78	46.08
48	A	50.50	51.50	57.50	2.00	5.00	1.50	.50	1.26	51.00
	B	50.80	51.80	58.40	2.00	5.00	1.65	.50	1.42	51.30
	C	51.40	52.40	60.00	2.00	5.00	1.95	.50	1.71	51.90
	D	51.98	52.98	61.38	2.00	5.00	2.20	.50	1.96	52.48
54	A	56.66	57.66	64.06	2.25	5.50	1.60	.50	1.35	57.16
	B	57.10	58.10	65.30	2.25	5.50	1.80	.50	1.55	57.60
	C	57.80	58.80	66.80	2.25	5.50	2.15	.50	1.90	58.30
	D	58.40	59.40	68.20	2.25	5.50	2.45	.50	2.23	58.90
60	A	62.80	63.80	70.60	2.25	5.50	1.70	.50	1.39	63.30
	B	63.40	64.40	71.80	2.25	5.50	1.90	.50	1.67	63.90
	C	64.20	65.20	73.60	2.25	5.50	2.25	.50	2.00	64.70
	D	64.82	65.82	75.22	2.25	5.50	2.60	.50	2.38	65.32
72	A	75.34	76.59	84.19	2.25	5.50	1.87	.63	1.62	75.84
	B	76.00	77.25	85.65	2.25	5.50	2.20	.63	1.95	76.50
	C	76.88	78.13	87.33	2.25	5.50	2.64	.63	2.39	77.38
84	A	87.54	88.79	96.99	2.50	5.50	2.10	.63	1.72	88.04
	B	88.54	89.79	98.79	2.50	5.50	2.60	.63	2.22	89.04

Dimensions of Pit Cast Pipe only
Not of current manufacture or standard

Bell and Spigot Pipe

Classes E, F, G and H

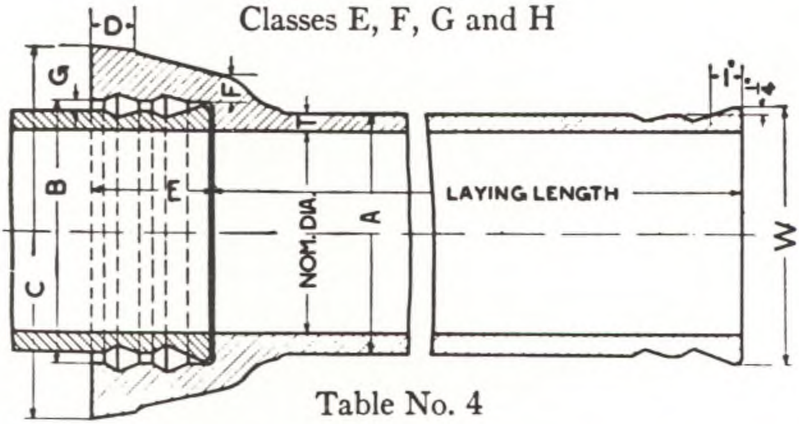


Table No. 4

Nominal Diameter Inches	Class	Dimensions, Inches								
		A	B	C	D	E	F	G	T	W
6	E	7.22	8.02	11.52	1.50	4.00	.75	.40	.58	7.72
	F	7.22	8.02	11.52	1.50	4.00	.75	.40	.61	7.72
	G	7.38	8.18	11.88	1.50	4.00	.85	.40	.65	7.88
	H	7.38	8.18	11.88	1.50	4.00	.85	.40	.69	7.88
8	E	9.42	10.22	13.92	1.50	4.00	.85	.40	.66	9.92
	F	9.42	10.22	13.92	1.50	4.00	.85	.40	.71	9.92
	G	9.60	10.40	14.30	1.50	4.00	.95	.40	.75	10.10
	H	9.60	10.40	14.30	1.50	4.00	.95	.40	.80	10.10
10	E	11.60	12.40	16.30	1.75	4.50	.95	.40	.74	12.10
	F	11.60	12.40	16.30	1.75	4.50	.95	.40	.80	12.10
	G	11.84	12.64	16.74	1.75	4.50	1.05	.40	.86	12.34
	H	11.84	12.64	16.74	1.75	4.50	1.05	.40	.92	12.34
12	E	13.78	14.58	18.68	1.75	4.50	1.05	.40	.82	14.28
	F	13.78	14.58	18.68	1.75	4.50	1.05	.40	.89	14.28
	G	14.08	14.88	19.28	1.75	4.50	1.20	.40	.97	14.58
	H	14.08	14.88	19.28	1.75	4.50	1.20	.40	1.04	14.58
14	E	15.98	16.78	21.08	2.00	4.50	1.15	.40	.90	16.48
	F	15.98	16.78	21.08	2.00	4.50	1.15	.40	.99	16.48
	G	16.32	17.12	21.82	2.00	4.50	1.35	.40	1.07	16.82
	H	16.32	17.12	21.82	2.00	4.50	1.35	.40	1.16	16.82

Dimensions of Pit Cast Pipe only
Not of current manufacture or standard

Dimensions of A. W. W. A. Standard
Bell and Spigot Pipe
Classes E, F, G and H

Table No. 4 (continued)

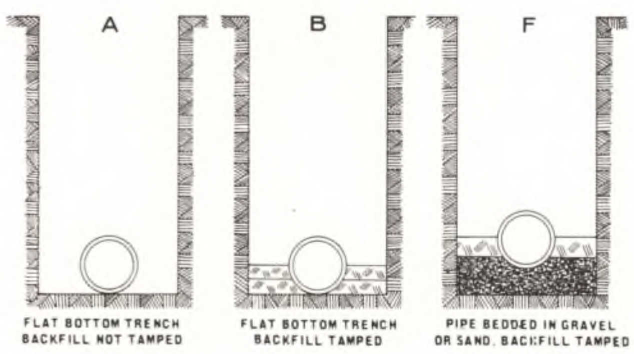
Nominal Diameter Inches	Class	Dimensions, Inches								
		A	B	C	D	E	F	G	T	W
16	E	18.16	18.96	23.56	2.00	4.50	1.25	.40	.98	18.66
	F	18.16	18.96	23.56	2.00	4.50	1.25	.40	1.08	18.66
	G	18.54	19.34	24.44	2.00	4.50	1.45	.40	1.18	19.04
	H	18.54	19.34	24.44	2.00	4.50	1.45	.40	1.27	19.04
18	E	20.34	21.14	26.04	2.25	4.50	1.40	.40	1.07	20.84
	F	20.34	21.14	26.04	2.25	4.50	1.40	.40	1.17	20.84
	G	20.78	21.58	27.08	2.25	4.50	1.65	.40	1.28	21.28
	H	20.78	21.58	27.08	2.25	4.50	1.65	.40	1.39	21.28
20	E	22.54	23.34	28.44	2.25	4.50	1.50	.40	1.15	23.04
	F	22.54	23.34	28.44	2.25	4.50	1.50	.40	1.27	23.04
	G	23.02	23.82	29.52	2.25	4.50	1.75	.40	1.39	23.52
	H	23.02	23.82	29.52	2.25	4.50	1.75	.40	1.51	23.52
24	E	26.90	27.90	33.40	2.25	5.00	1.70	.50	1.31	27.40
	F	26.90	27.90	33.40	2.25	5.00	1.70	.50	1.45	27.40
	G	27.76	28.56	34.86	2.25	5.00	1.95	.50	1.75	28.26
	H	27.76	28.56	34.86	2.25	5.00	1.95	.50	1.88	28.26
30	E	33.10	34.10	40.60	2.25	5.00	1.80	.50	1.55	33.60
	F	33.46	34.46	41.46	2.25	5.00	2.00	.50	1.73	33.96
36	E	39.60	40.60	48.00	2.25	5.00	2.05	.50	1.80	40.10
	F	40.04	41.04	49.04	2.25	5.00	2.30	.50	2.02	40.54

Information Pertaining to Gray Cast-Iron Pipe Not of Current Manufacture or Standard

Standard Thickness Classes of Gray Cast-Iron Pipe

Pipe Size *in.*	Thickness for Standard Thickness Class Number—*in.*										
	20	21	22	23	24	25	26	27	28	29	30
3			**0.32**	0.35	0.38	0.41	0.44	0.48	0.52	0.56	0.60
4			**0.35**	0.38	0.41	0.44	0.48	0.52	0.56	0.60	0.65
6		0.35	**0.38**	0.41	0.44	0.48	0.52	0.56	0.60	0.65	0.70
8	0.35	0.38	**0.41**	0.44	0.48	0.52	0.56	0.60	0.65	0.70	0.76
10	0.38	0.41	**0.44**	0.48	0.52	0.56	0.60	0.65	0.70	0.76	0.82
12	0.41	0.44	**0.48**	0.52	0.56	0.60	0.65	0.70	0.76	0.82	0.89
14	0.43	**0.48**	0.51	0.55	0.59	0.64	0.69	0.75	0.81	0.87	0.94
16	0.46	**0.50**	0.54	0.58	0.63	0.68	0.73	0.79	0.85	0.92	0.99
18	0.50	**0.54**	0.58	0.63	0.68	0.73	0.79	0.85	0.92	0.99	1.07
20	0.53	**0.57**	0.62	0.67	0.72	0.78	0.84	0.91	0.98	1.06	1.14
24	0.58	**0.63**	0.68	0.73	0.79	0.85	0.92	0.99	1.07	1.16	1.25
30	0.68	**0.73**	0.79	0.85	0.92	0.99	1.07	1.16	1.25	1.35	1.46
36	0.75	**0.81**	0.87	0.94	1.02	1.10	1.19	1.29	1.39	1.50	1.62
42	0.83	**0.90**	0.97	1.05	1.13	1.22	1.32	1.43	1.54	1.66	1.79
48	0.91	**0.98**	1.06	1.14	1.23	1.33	1.44	1.56	1.68	1.81	1.95

Standard Laying Conditions for Gray Cast-Iron Pipe



Reference — ANSI A21.1-1967 (AWWA C101-67)

Information Pertaining to Gray Cast Iron Pipe
Not of Current Manufacture or Standard
Standard Dimensions and Weights of Gray Cast Iron Pipe

Size	Thickness Class	Thickness	OD (1)	Weight of Barrel Per Foot (2)	Weight of Bell: Push-on-Joint (3): Cast in Sand Molds (4)	Weight of Bell: Push-on-Joint (3): Cast in Metal Molds (5)	Weight of Bell: Mechanical Joint (6)
In.		Inches		Pounds			
3	22	0.32	3.96	11.4	15	11	11
	23	0.35	3.96	12.4	15	11	11
	24	0.38	3.96	13.3	15	11	11
4	22	0.35	4.80	15.3	19	14	16
	23	0.38	4.80	16.5	19	14	16
	24	0.41	4.80	17.6	19	14	16
	25	0.44	4.80	18.8	19	14	16
6	22	0.38	6.90	24.3	26	25	22
	23	0.41	6.90	26.1	26	25	22
	24	0.44	6.90	27.9	29	25	22
	25	0.48	6.90	30.2	29	25	22
	26	0.52	6.90	32.5	29	25	22
8	22	0.41	9.05	34.7	37	41	30
	23	0.44	9.05	37.1	37	41	30
	24	0.48	9.05	40.3	43	41	30
	25	0.52	9.05	43.5	43	41	30
	26	0.56	9.05	46.6	43	41	30
	27	0.60	9.05	49.7	43	41	30
10	22	0.44	11.10	46.0	50	54	40
	23	0.48	11.10	50.0	50	54	40
	24	0.52	11.10	53.9	56	54	40
	25	0.56	11.10	57.9	56	54	40
	26	0.60	11.10	61.8	56	54	40
	27	0.65	11.10	66.6	56	54	40
12	22	0.48	13.20	59.8	63	66	50
	23	0.52	13.20	64.6	63	66	50
	24	0.56	13.20	69.4	71	66	50
	25	0.60	13.20	74.1	71	66	50
	26	0.65	13.20	80.0	71	66	50
	27	0.70	13.20	85.8	71	66	50
	28	0.76	13.20	92.7	79	66	50
14	21	0.48	15.30	69.7	79	78	78
	22	0.51	15.30	73.9	79	78	78
	23	0.55	15.30	79.5	79	78	78
	24	0.59	15.30	85.1	88	78	78
	25	0.64	15.30	92.0	88	78	78
	26	0.69	15.30	98.8	88	78	78
	27	0.75	15.30	107.0	88	78	78
	28	0.81	15.30	115.0	97	78	78

Information Pertaining to Gray Cast Iron Pipe Not of Current Manufacture or Standard

Standard Dimensions and Weights of Gray Cast Iron Pipe

Size	Thickness Class	Thickness	OD (1)	Weight of Barrel Per Foot (2)	Weight of Bell — Push-on-Joint (3) — Cast in Sand Molds (4)	Weight of Bell — Push-on-Joint (3) — Cast in Metal Molds (5)	Weight of Bell — Mechanical Joint (6)
In.		Inches	Inches	Pounds	Pounds	Pounds	Pounds
16	21	0.50	17.40	82.8	96	96	95
	22	0.54	17.40	89.2	96	96	95
	23	0.58	17.40	95.6	96	96	95
	24	0.63	17.40	103.6	108	96	95
	25	0.68	17.40	111.4	108	96	95
	26	0.73	17.40	119.3	108	96	95
	27	0.79	17.40	128.6	108	96	95
	28	0.85	17.40	137.9	120	96	95
18	21	0.54	19.50	100.4	115	114	113
	22	0.58	19.50	107.6	115	114	113
	23	0.63	19.50	116.5	115	114	113
	24	0.68	19.50	125.4	128	114	113
	25	0.73	19.50	134.3	128	114	113
	26	0.79	19.50	144.9	128	114	113
	27	0.85	19.50	155.4	128	114	113
	28	0.92	19.50	167.5	143	114	113
20	21	0.57	21.60	117.5	135	133	134
	22	0.62	21.60	127.5	135	133	134
	23	0.67	21.60	137.5	135	133	134
	24	0.72	21.60	147.4	149	133	134
	25	0.78	21.60	159.2	149	133	134
	26	0.84	21.60	170.9	149	133	134
	27	0.91	21.60	184.5	149	133	134
	28	0.98	21.60	198.1	168	133	134
24	21	0.63	25.80	155.4	171	179	177
	22	0.68	25.80	167.4	171	179	177
	23	0.73	25.80	179.4	171	179	177
	24	0.79	25.80	193.7	191	179	177
	25	0.85	25.80	207.9	191	179	177
	26	0.92	25.80	224.4	191	179	177
	27	0.99	25.80	240.8	218	179	177
	28	1.07	25.80	259.4	218	179	177
30	21	0.73	32.00	223.7	245	See Note 7	285
	22	0.79	32.00	241.7	245	"	285
	23	0.85	32.00	259.5	245	"	285
	24	0.92	32.00	280.3	271	"	285
	25	0.99	32.00	300.9	271	"	285
	26	1.07	32.00	324.4	271	"	285
	27	1.16	32.00	350.7	318	"	285
	28	1.25	32.00	376.8	318	"	285
	29	1.35	32.00	405.6	318	"	285

Information Pertaining to Gray Cast Iron Pipe
Not of Current Manufacture or Standard
Standard Dimensions and Weights of Gray Cast Iron Pipe

Size	Thickness Class	Thickness	OD (1)	Weight of Barrel Per Foot (2)	Weight of Bell — Push-on-Joint (3) — Cast in Sand Molds (4)	Weight of Bell — Push-on-Joint (3) — Cast in Metal Molds (5)	Weight of Bell — Mechanical Joint (6)
In.		Inches	Inches	Pounds	Pounds	Pounds	Pounds
36	21	0.81	38.30	297.7	310	See Note 7	395
	22	0.87	38.30	319.2	310	"	395
	23	0.94	38.30	344.2	310	"	395
	24	1.02	38.30	372.7	353	"	395
	25	1.10	38.30	401.1	353	"	395
	26	1.19	38.30	432.9	353	"	395
	27	1.29	38.30	468.0	445	"	395
	28	1.39	38.30	502.9	445	"	395
	29	1.50	38.30	541.1	445	"	395
42	21	0.90	44.50	384.6	400	See Note 7	510
	22	0.97	44.50	413.9	400	"	510
	23	1.05	44.50	447.2	400	"	510
	24	1.13	44.50	480.4	460	"	510
	25	1.22	44.50	517.6	460	"	510
	26	1.32	44.50	558.7	460	"	510
	27	1.43	44.50	603.7	585	"	510
	28	1.54	44.50	648.5	585	"	510
	29	1.66	44.50	697.0	585	"	510
48	21	0.98	50.80	478.6	450	See Note7	645
	22	1.06	50.80	516.8	450	"	645
	23	1.14	50.80	554.9	450	"	645
	24	1.23	50.80	597.6	573	"	645
	25	1.33	50.80	644.9	573	"	645
	26	1.44	50.80	696.7	573	"	645
	27	1.56	50.80	752.9	735	"	645
	28	1.68	50.80	808.9	735	"	645
	29	1.81	50.80	869.1	735	"	645

NOTES

1. Tolerances of OD of spigot end: 3-12 in. + 0.06; 14-24 in. + 0.05 in. - 0.08 in; 30-48 in. + 0.08 in. -0.06 in.
2. Barrel weight per foot is same for sand molds, metal molds.
3. Weight of Bell-and-Spigot bells is the same as push-on-bells.
4. In accordance with ANSI A21.8-1975/AWWA C108-75
5. In accordance with ANSI A21.6-1975/AWWA C106-75.
6. Same for cast in sand molds and metal molds.
7. Pipe 30" - 48" not covered by ANSI A21.6-1975/AWWA C106-75

Information Pertaining to Gray Cast Iron Pipe Not of Current Manufacture or Standard

Ratings Standard Class Thicknesses of 18/40 and 21/45 Strengths of Gray Cast Iron Pipe

Pipe Size	Working Pressure	3½ Feet of Cover Laying Condition			5 Feet of Cover Laying Condition			8 Feet of Cover Laying Condition		
In.	psi	A	B	F	A	B	F	A	B	F
		ANSI Class Thickness — 18/40 / 21/45								
3	50	22/22	22/22	22/22	22/22	22/22	22/22	22/22	22/22	22/22
	100	22/22	22/22	22/22	22/22	22/22	22/22	22/22	22/22	22/22
	150	22/22	22/22	22/22	22/22	22/22	22/22	22/22	22/22	22/22
	200	22/22	22/22	22/22	22/22	22/22	22/22	22/22	22/22	22/22
	250	22/22	22/22	22/22	22/22	22/22	22/22	22/22	22/22	22/22
	300	22/22	22/22	22/22	22/22	22/22	22/22	22/22	22/22	22/22
	350	22/22	22/22	22/22	22/22	22/22	22/22	22/22	22/22	22/22
4	50	22/22	22/22	22/22	22/22	22/22	22/22	22/22	22/22	22/22
	100	22/22	22/22	22/22	22/22	22/22	22/22	22/22	22/22	22/22
	150	22/22	22/22	22/22	22/22	22/22	22/22	22/22	22/22	22/22
	200	22/22	22/22	22/22	22/22	22/22	22/22	22/22	22/22	22/22
	250	22/22	22/22	22/22	22/22	22/22	22/22	22/22	22/22	22/22
	300	22/22	22/22	22/22	22/22	22/22	22/22	22/22	22/22	22/22
	350	22/22	22/22	22/22	22/22	22/22	22/22	22/22	22/22	22/22
6	50	22/21	22/21	22/21	22/21	22/21	22/21	22/21	22/21	22/21
	100	22/21	22/21	22/21	22/21	22/21	22/21	22/21	22/21	22/21
	150	22/21	22/21	22/21	22/21	22/21	22/21	22/21	22/21	22/21
	200	22/21	22/21	22/21	22/21	22/21	22/21	22/21	22/21	22/21
	250	22/21	22/21	22/21	22/21	22/21	22/21	22/21	22/21	22/21
	300	22/21	22/21	22/21	22/21	22/21	22/21	22/21	22/21	22/21
	350	22/21	22/21	22/21	22/21	22/21	22/21	22/21	22/21	22/21
8	50	22/20	22/20	22/20	22/20	22/20	22/20	22/20	22/20	22/20
	100	22/20	22/20	22/20	22/20	22/20	22/20	22/21	22/20	22/20
	150	22/20	22/20	22/20	22/20	22/20	22/20	22/21	22/20	22/20
	200	22/20	22/20	22/20	22/20	22/20	22/20	22/21	22/21	22/20
	250	22/20	22/20	22/20	22/20	22/20	22/20	23/22	22/21	22/20
	300	22/20	22/20	22/20	22/21	22/21	22/20	23/22	23/22	22/21
	350	22/21	22/21	22/20	23/21	22/21	22/21	24/23	23/22	23/21
10	50	22/20	22/20	22/20	22/20	22/20	22/20	22/21	22/21	22/20
	100	22/20	22/20	22/20	22/20	22/20	22/20	23/22	22/21	22/20
	150	22/20	22/20	22/20	22/21	22/20	22/20	23/22	22/22	22/21
	200	22/21	22/20	22/20	22/21	22/21	22/20	23/23	23/22	22/21
	250	22/21	22/21	22/20	23/22	22/21	22/21	24/23	23/23	23/22
	300	23/22	22/21	22/21	23/22	23/22	23/21	24/23	24/23	23/22
	350	23/22	23/22	23/22	24/23	24/23	23/22	25/24	24/23	24/23

Information Pertaining to Gray Cast Iron Pipe

<u>Not of Current Manufacture or Standard</u>

Ratings Standard Class Thicknesses of 18/40 and 21/45 Strengths of Gray Cast Iron Pipe

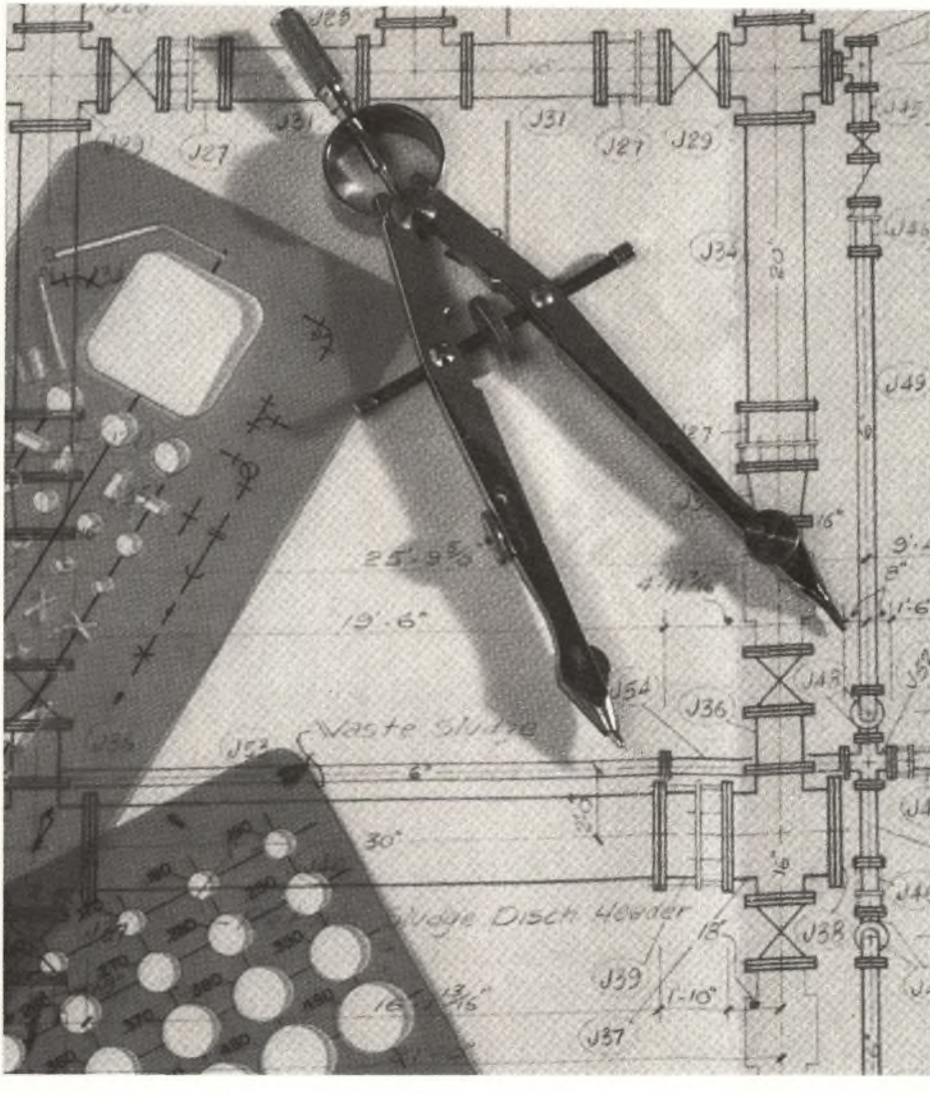
Pipe Size	Working Pressure	3½ Feet of Cover Laying Condition			5 Feet of Cover Laying Condition			8 Feet of Cover Laying Condition		
In.	psi	A	B	F	A	B	F	A	B	F
		ANSI Class Thickness — 18/40 / 21/45								
12	50	22/20	22/20	22/20	22/21	22/20	22/20	23/22	22/21	22/20
	100	22/21	22/20	22/20	22/21	22/20	22/20	23/22	22/22	22/21
	150	22/21	22/20	22/20	22/21	22/20	22/20	23/23	23/22	22/21
	200	22/21	22/21	22/20	22/22	22/21	22/20	24/23	23/22	22/22
	250	23/22	22/21	22/20	23/22	23/22	23/21	24/24	24/23	23/22
	300	23/22	23/22	23/21	24/23	23/22	23/22	25/24	24/23	24/23
	350	24/23	24/22	23/22	24/23	24/23	24/22	25/24	25/24	25/23
14	50	22/21	21/21	21/21	22/21	21/21	21/21	24/23	23/22	22/21
	100	22/21	21/21	21/21	23/22	22/21	21/21	24/23	23/23	22/21
	150	23/22	22/21	21/21	23/22	22/21	21/21	25/24	24/23	23/22
	200	23/22	22/22	22/21	23/23	23/22	22/21	25/24	24/24	24/23
	250	24/23	23/22	23/21	24/23	24/23	23/22	25/25	25/24	24/23
	300	24/23	24/23	24/22	25/24	24/23	24/23	26/25	25/24	25/24
	350	25/24	25/24	25/23	25/24	25/24	25/24	27/25	26/25	25/24
16	50	22/21	21/21	21/21	23/22	22/21	21/21	24/23	23/22	22/21
	100	22/22	22/21	21/21	23/22	22/21	21/21	24/24	23/23	22/22
	150	23/22	22/21	21/21	23/23	22/22	22/21	25/24	24/23	23/22
	200	23/23	23/22	22/21	24/23	23/22	23/22	25/24	24/24	24/23
	250	24/23	23/22	23/22	24/23	24/23	23/22	26/25	25/24	24/23
	300	24/23	24/23	24/23	25/24	25/23	24/23	26/25	26/25	25/24
	350	25/24	25/24	25/23	26/25	25/24	25/24	27/26	26/25	26/25
18	50	22/21	21/21	21/21	22/22	21/21	21/21	24/23	23/22	22/21
	100	22/22	21/21	21/21	23/22	22/21	21/21	24/23	23/22	22/22
	150	23/22	22/21	21/21	23/23	22/22	22/21	25/24	24/23	23/22
	200	23/22	22/22	22/21	24/23	23/22	22/22	25/24	24/23	23/23
	250	24/23	23/22	23/22	24/23	24/23	23/22	26/25	25/24	24/23
	300	24/23	24/23	24/23	25/24	25/24	24/23	26/25	26/25	25/24
	350	26/24	25/24	25/24	26/25	26/24	25/24	27/26	27/25	26/25
20	50	22/21	21/21	21/21	23/22	21/21	21/21	24/23	23/22	22/21
	100	22/22	21/21	21/21	23/22	22/21	21/21	24/23	23/22	22/21
	150	23/22	22/21	21/21	23/23	22/22	22/21	25/24	24/23	23/22
	200	23/23	22/22	22/21	24/23	23/22	22/21	25/24	24/23	23/22
	250	24/23	23/22	23/22	25/24	24/23	23/22	26/25	25/24	24/23
	300	25/24	24/23	24/23	25/24	25/24	24/23	26/25	26/24	25/24
	350	26/24	25/24	25/24	26/25	26/24	25/24	27/26	26/25	26/25

Information Pertaining to Gray Cast Iron Pipe
Not of Current Manufacture or Standard
Ratings Standard Class Thicknesses of 18/40 and 21/45 Strengths of Gray Cast Iron Pipe

Pipe Size In.	Working Pressure psi	3½ Feet of Cover Laying Condition			5 Feet of Cover Laying Condition			8 Feet of Cover Laying Condition		
		A	B	F	A	B	F	A	B	F
		ANSI Class Thickness — 18/40 / 21/45								
24	50	22/22	21/21	21/21	23/22	21/21	21/21	24/23	23/22	22/21
	100	23/22	21/21	21/21	23/23	22/21	21/21	25/24	23/23	22/21
	150	23/22	22/21	21/21	24/23	23/22	22/21	25/24	24/23	23/22
	200	24/23	23/22	22/21	24/24	24/22	23/22	26/25	25/24	24/23
	250	24/24	24/22	23/22	25/24	24/23	24/23	26/25	25/24	25/24
	300	25/24	25/23	25/23	26/25	25/24	25/24	27/26	26/25	26/24
	350	26/25	26/24	26/24	27/25	26/25	26/25	28/26	27/26	26/25
30	50	23/22	21/20	21/20	23/23	22/21	21/20	24/24	23/22	22/21
	100	23/22	22/21	21/20	24/23	22/22	21/20	25/24	23/23	22/22
	150	24/23	22/21	21/20	24/23	23/22	22/21	25/24	24/23	23/22
	200	24/23	23/22	22/21	25/24	24/23	23/22	26/25	25/24	24/23
	250	25/24	24/23	24/22	26/24	25/23	24/23	27/26	26/25	25/24
	300	26/24	25/24	25/23	26/25	26/24	25/24	27/26	26/25	26/25
	350	27/25	26/25	26/25	27/26	27/25	26/25	28/27	27/26	27/26
36	50	23/22	21/20	21/20	24/23	22/21	21/20	25/24	23/22	22/21
	100	23/23	22/21	21/20	24/23	22/22	21/20	25/24	24/23	23/22
	150	24/23	22/22	21/21	25/24	23/22	22/21	26/25	24/23	23/22
	200	25/24	23/22	23/21	25/24	24/23	23/22	26/25	25/24	24/23
	250	25/24	24/23	24/23	26/25	25/24	25/23	27/26	26/25	25/24
	300	26/25	26/24	25/24	27/25	26/25	26/24	28/27	27/26	26/25
	350	27/26	27/25	27/25	28/26	27/26	27/25	28/27	28/26	27/26
42	50	23/22	21/20	21/20	24/23	22/21	21/20	25/24	23/22	22/21
	100	23/23	22/21	21/20	24/23	22/21	21/20	25/24	24/23	22/22
	150	24/23	22/22	21/20	25/24	23/22	22/21	26/25	24/23	23/22
	200	25/24	23/22	23/21	25/24	24/23	23/22	26/26	25/24	24/23
	250	26/24	24/23	24/23	26/25	25/24	25/23	27/26	26/25	25/24
	300	26/25	26/24	26/24	27/26	26/25	26/24	28/27	27/26	26/25
	350	27/26	27/26	27/25	28/26	27/26	27/26	29/27	28/26	28/26
48	50	23/22	21/20	21/20	24/23	22/21	21/20	25/24	23/22	22/21
	100	24/23	22/21	21/20	24/24	22/22	21/20	25/25	24/23	23/22
	150	24/23	23/22	21/20	25/24	23/22	22/21	26/25	25/23	24/22
	200	25/24	23/22	23/22	26/25	24/23	24/22	27/26	25/24	25/25
	250	26/25	25/23	25/23	26/25	25/24	25/24	27/26	26/25	26/24
	300	27/25	26/25	26/24	27/26	27/25	26/25	28/27	27/26	27/25
	350	28/26	27/26	27/26	28/27	28/26	28/26	29/28	28/27	28/26

SECTION XII

ENGINEERING DATA



EQUATION OF PIPE

It is frequently desired to know what numbers of pipe of a given size are equal in carrying capacity to one pipe of a larger size. At the same velocity of flow the volume delivered by two pipe of different sizes is proportional to the squares of their diameters; thus one 4-inch pipe will deliver the same volume as four 2-inch pipe. With the same head, however, the velocity is less in the smaller pipe, and the volume delivered varies about as square root of the fifth power. This table is calculated on this basis. The figures opposite the intersection of any two sizes is the number of the smaller sized pipe required to equal one of the larger; thus, one 4-inch equals 5.7 two-inch.

Diam. In.	1/2	3/4	1	2	3	4	5	6	7	8	10	12	14	16	18	20	24	30	36	42	48	54
2	32.0	11.7	5.7	1.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
3	88.2	32.0	15.6	2.8	1.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
4	181.	65.7	32.0	5.7	2.1	1.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5	316.	115.	55.9	9.9	3.6	1.7	1.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6	499.	181.	88.2	15.6	5.7	2.8	1.6	1.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—
7	733.	266.	130.	22.9	8.3	4.1	2.3	1.5	1.0	—	—	—	—	—	—	—	—	—	—	—	—	—
8	—	372.	181.	32.0	11.7	5.7	3.2	2.1	1.4	1.0	—	—	—	—	—	—	—	—	—	—	—	—
10	—	649.	316.	55.9	20.3	9.9	5.7	3.6	2.4	1.7	1.0	—	—	—	—	—	—	—	—	—	—	—
11	—	—	401.	70.9	25.7	12.5	7.2	4.6	3.1	2.2	1.3	—	—	—	—	—	—	—	—	—	—	—
12	—	—	499.	88.2	32.0	15.6	8.9	5.7	3.8	2.8	1.6	1.0	—	—	—	—	—	—	—	—	—	—
13	—	—	609.	108.	39.1	19.0	10.9	7.1	4.7	3.4	1.9	1.2	—	—	—	—	—	—	—	—	—	—
14	—	—	733.	130.	47.1	22.9	13.1	8.3	5.7	4.1	2.3	1.5	1.0	—	—	—	—	—	—	—	—	—
15	—	—	787.	154.	55.9	27.2	15.6	9.9	6.7	4.8	2.8	1.7	1.2	—	—	—	—	—	—	—	—	—
16	—	—	—	181.	65.7	32.0	18.3	11.7	7.9	5.7	3.2	2.1	1.4	1.0	—	—	—	—	—	—	—	—
17	—	—	—	211.	76.4	37.2	21.3	13.5	9.2	6.6	3.8	2.4	1.6	1.2	—	—	—	—	—	—	—	—
18	—	—	—	243.	88.2	43.0	24.6	15.6	10.6	7.6	4.3	2.8	1.9	1.3	1.0	—	—	—	—	—	—	—
19	—	—	—	278.	101.	49.1	28.1	17.8	12.1	8.7	4.8	3.2	2.1	1.5	1.1	—	—	—	—	—	—	—
20	—	—	—	316.	115.	55.9	32.0	20.3	13.8	9.9	5.7	3.6	2.4	1.7	1.3	1.0	—	—	—	—	—	—
22	—	—	—	401.	146.	70.9	40.6	25.7	17.5	12.5	7.2	4.6	3.1	2.2	1.7	1.3	—	—	—	—	—	—
24	—	—	—	499.	181.	88.2	50.5	32.0	21.8	15.6	8.9	5.7	3.8	2.8	2.1	1.6	1.0	—	—	—	—	—
30	—	—	—	—	—	—	—	—	—	27.2	15.6	10.0	6.7	4.8	3.6	2.8	1.7	1.0	—	—	—	—
36	—	—	—	—	—	—	—	—	—	—	24.6	15.6	10.6	7.6	5.7	4.3	2.8	1.6	1.0	—	—	—
42	—	—	—	—	—	—	—	—	—	—	36.2	22.9	15.6	11.2	8.3	6.4	4.1	2.3	1.5	1.0	—	—
48	—	—	—	—	—	—	—	—	—	—	50.5	32.0	21.8	15.6	11.7	8.9	5.7	3.2	2.1	1.4	1.0	—
54	—	—	—	—	—	—	—	—	—	—	67.8	43.0	29.2	20.7	13.2	12.8	7.6	4.3	2.8	1.9	1.3	1.0

LINEAR EXPANSION OF DUCTILE IRON PIPE (INCHES)

The coefficient of linear expansion of ductile iron may be taken as 0.0000062 per degree Fahrenheit. The expansion or contraction in inches that will take place in a line of given length with various temperature changes is shown in the following table:

Temp. Difference °F	LENGTH OF LINE IN FEET			
	100	500	1000	5280
5	0.037	0.19	0.37	1.96
10	0.074	0.37	0.74	3.93
20	0.149	0.74	0.15	7.86
30	0.223	1.12	2.23	11.78
40	0.298	1.49	2.98	15.71
50	0.372	1.86	3.72	19.64
60	0.446	2.23	4.46	23.57
70	0.520	2.60	5.20	27.50
80	0.595	2.98	5.95	31.43
90	0.670	3.35	6.70	35.35
100	0.744	3.72	7.44	39.28
120	0.893	4.46	8.93	47.14
150	1.116	5.58	11.16	58.92

LINEAR EXPANSION OF CAST IRON PIPE (INCHES)

The coefficient of linear expansion of cast iron may be taken as 0.0000058 per degree Fahrenheit. The expansion or contraction in inches that will take place in a line of given length with various temperature changes is shown in the following table:

Temp. Difference °F	Length of Line in Feet			
	100	500	1000	5280
5	0.035	0.17	0.35	1.83
10	0.070	0.35	0.70	3.67
20	0.139	0.70	1.39	7.34
30	0.209	1.04	2.09	11.01
40	0.278	1.39	2.78	14.70
50	0.348	1.74	3.48	18.35
60	0.418	2.09	4.18	22.04
70	0.487	2.44	4.87	25.72
80	0.557	2.79	5.57	29.39
90	0.626	3.13	6.26	33.05
100	0.696	3.48	6.96	36.71
120	0.835	4.17	8.35	44.10
150	1.043	5.22	10.43	55.10

Pressures in Pounds per Square Inch, Corresponding to Heads of Water in Feet

Head Ft.	0	1	2	3	4	5	6	7	8	9
0	....	0.433	0.866	1.299	1.732	2.165	2.598	3.031	3.464	3.987
10	4.330	4.763	5.196	5.629	6.062	6.495	6.928	7.361	7.794	8.277
20	8.660	9.093	9.526	9.959	10.392	10.825	11.258	11.691	12.124	12.557
30	12.990	13.423	13.856	14.289	14.722	15.155	15.588	16.021	16.454	16.887
40	17.320	17.753	18.186	18.619	19.052	19.485	19.918	20.351	20.784	21.217
50	21.650	22.083	22.516	22.949	23.382	23.815	24.248	24.681	25.114	25.547
60	25.980	26.413	26.846	27.279	27.712	28.145	28.578	29.011	29.444	29.877
70	30.310	30.743	31.176	31.609	32.042	32.475	32.908	33.341	33.774	34.207
80	34.640	35.073	35.506	35.939	36.372	36.805	37.238	37.671	38.104	38.537
90	38.970	39.403	39.836	40.269	40.702	41.135	41.568	42.001	42.436	42.867

Heads of Water in Feet, Corresponding to Pressures in Pounds per Square Inch

Pressure Lbs. per Sq. In.	0	1	2	3	4	5	6	7	8	9
0	....	2.309	4.619	6.928	9.238	11.547	13.857	16.166	18.476	20.785
10	23.095	25.404	27.714	30.023	32.333	34.642	36.952	39.261	41.570	43.880
20	46.189	48.499	50.808	53.118	55.427	57.737	60.046	62.356	64.665	66.975
30	69.284	71.594	73.903	76.213	78.522	80.831	83.141	85.450	87.760	90.069
40	92.379	94.688	96.998	99.307	101.62	103.93	106.24	108.55	110.85	113.16
50	115.47	117.78	120.09	122.40	124.71	127.02	129.33	131.64	133.95	136.26
60	138.57	140.88	143.19	145.50	147.81	150.12	152.42	154.73	157.04	159.35
70	161.66	163.97	166.28	168.59	170.90	173.21	175.52	177.83	180.14	182.45
80	184.76	187.07	189.38	191.69	194.00	196.31	198.61	200.92	203.23	205.54
90	207.85	210.16	212.47	214.78	217.09	219.40	221.71	224.02	226.33	228.64

At 62° F., 1 foot head = 0.433 lb. per square inch; 0.433 × 144 = 62.355 lb. per cubic foot. 1 lb. per square inch = 2.30947 feet head. 1 atmosphere = 14.7 lb. per square inch = 33.94 feet head.

Pressure and Stress Equivalents—Pounds-Force per Square Inch and Thousand Pounds-Force per Square Inch to Kilopascals (Kilonewtons per Square Metre) and Megapascals (Meganewtons per Square Metre)

NOTE 1—This table may be used to obtain SI equivalents of values expressed in psi or ksi. SI values are usually expressed in kPa (kN/m²) when original value is in psi and in MPa (MN/m²) when original value is in ksi.

NOTE 2—This table may be extended to values below 1 or above 100 psi (ksi) by manipulation of the decimal point and addition as illustrated in 4.7.1.

Conversion Relationships: 1 in. = 0.0254 m (exactly)
1 lbf = 4.448 221 615 260 5 N (exactly)

psi / ksi	0	1	2	3	4	5	6	7	8	9
					kPa (kN/m²) MPa (MN/m²)					
0	0.0000	6.8948	13.7895	20.6843	27.5790	34.4738	41.3685	48.2633	55.1581	62.0528
10	68.9476	75.8423	82.7371	89.6318	96.5266	103.4214	110.3161	117.2109	124.1056	131.0004
20	137.8951	144.7899	151.6847	158.5794	165.4742	172.3689	179.2637	186.1584	193.0532	199.9480
30	206.8427	213.7375	220.6322	227.5270	234.4217	241.3165	248.2113	255.1060	262.0008	268.8955
40	275.7903	282.6850	289.5798	296.4746	303.3693	310.2641	317.1588	324.0536	330.9483	337.8431
50	344 7379	351.6326	358.5274	365.4221	372.3169	379.2116	386.1064	393.0012	399.8959	406.7907
60	413.6854	420.5802	427.4749	434.3697	441.2645	448.1592	455.0540	461.9487	468.8435	475.7382
70	482.6330	489.5278	496.4225	503.3173	510.2120	517.1068	524.0015	530.8963	537.7911	544.6858
80	551.5806	558.4753	565.3701	572.2648	579.1596	586.0544	592.9491	599.8439	606.7386	613.6334
90	620.5281	627.4229	634.3177	641.2124	648.1072	655.0019	661.8967	668.7914	675.6862	682.5810
100	689.4757									

Pressure and Stress Equivalents–Metric Engineering to SI Units

NOTE 1—This table may be used for obtaining SI equivalents of quantities expressed in kgf/cm^2 by multiplying the given values by 10^{-2}, that is, by moving the decimal point two places to the left.

NOTE 2—This table may be extended to values below 1 or above 100 kgf/cm^2 by manipulation of the decimal point and addition as illustrated in 4.7.1.

Conversion Relationships: 1 mm = 0.001 m (exactly)
1 kgf = 9.80665 N (exactly)

	0	1	2	3	4	5	6	7	8	9
kgf/mm^2	MPa (MN/m^2)									
0		9.8066	19.6133	29.4200	39.2266	49.0332	58.8399	68.6466	78.4532	88.2598
10	98.0665	107.8731	117.6798	127.4864	137.2931	147.0998	156.9064	166.7130	176.5197	186.3264
20	196.1330	205.9396	215.7463	225.5530	235.3596	245.1662	254.9729	264.7796	274.5862	284.3928
30	294.1995	304.0062	313.8128	323.6194	333.4261	343.2328	353.0394	362.8460	372.6527	382.4594
40	392.2660	402.0726	411.8793	421.6860	431.4926	441.2992	451.1059	460.9126	470.7192	480.5258
50	490.3325	500.1392	509.9458	519.7524	529.5591	539.3658	549.1724	558.9790	568.7857	578.5924
60	588.3990	598.2056	608.0123	617.8190	627.6256	637.4322	647.2389	657.0456	666.8522	676.6588
70	686.4655	696.2722	706.0788	715.8854	725.6921	735.4988	745.3054	755.1120	764.9187	774.7254
80	784.5320	794.3386	804.1453	813.9520	823.7586	833.5652	843.3719	853.1786	862.9852	872.7918
90	882.5985	892.4052	902.2118	912.0184	921.8251	931.6318	941.4384	951.2450	961.0517	970.8584
100	980.6650									

SELECTED CONVERSION FACTORS

To convert from	to	multiply by
atmosphere (760 Hg)	pascal (Pa)	$1.013\ 25 \times 10^{5}$
board foot	metre^{3} (m^{3})	$2.359\ 737 \times 10^{-3}$
Btu (International Table)	joule (J)	$1.055\ 056 \times 10^{3}$
Btu (International Table)/hour	watt (W)	$2.930\ 711 \times 10^{-1}$
Btu (International Table) in./s·ft^{2}·°F (k, thermal conductivity)	watt/metre-kelvin (W/m-K)	$5.192\ 204 \times 10^{2}$
calorie (International Table)	joule (J)	4.186 800*
centipoise	pascal-second (Pa-s)	$1.000\ 000^{*} \times 10^{-3}$
centistokes	metre^{2}/second (m^{2}/s)	$1.000\ 000^{*} \times 10^{-6}$
circular mil	metre^{2} (m^{2})	$5.067\ 075 \times 10^{-10}$
degree Fahrenheit	degree Celsius	$t_{°C} = (t_{°F} - 32)/1.8$
foot	metre (m)	$3.048\ 000^{*} \times 10^{-1}$
foot^{2}	metre^{2} (m^{2})	$9.290\ 304^{*} \times 10^{-2}$
foot^{3}	metre^{3} (m^{3})	$2.831\ 685 \times 10^{-2}$
foot-pound-force	joule (J)	1.355 818
foot-pound-force/minute	watt (W)	$2.259\ 697 \times 10^{-2}$
foot/second^{2}	metre/second^{2} (m/s^{2})	$3.048\ 000^{*} \times 10^{-1}$
gallon (U.S. liquid)	metre^{3} (m^{3})	$3.785\ 412 \times 10^{-3}$
horsepower (electric)	watt (W)	$7.460\ 000^{*} \times 10^{2}$
inch	metre (m)	$2.540\ 000^{*} \times 10^{-2}$
inch^{2}	metre^{2} (m^{2})	$6.451\ 600^{*} \times 10^{-4}$
inch^{3}	metre^{3} (m^{3})	$1.638\ 706 \times 10^{-5}$
inch of mercury (60° F)	pascal (Pa)	$3.376\ 85 \times 10^{3}$
inch of water (60° F)	pascal (Pa)	$2.488\ 4 \times 10^{2}$
kilogram-force/centimetre^{2}	pascal (Pa)	$9.806\ 650^{*} \times 10^{4}$
kip (1000 lbf)	newton (N)	$4.448\ 222 \times 10^{3}$
kip/inch^{2} (ksi)	pascal (Pa)	$6.894\ 757 \times 10^{6}$
ounce (U.S. fluid)	metre^{3} (m^{3})	$2.957\ 353 \times 10^{-5}$
ounce-force (avoirdupois)	newton (N)	$2.780\ 139 \times 10^{-1}$
ounce-mass (avoirdupois)	kilogram (kg)	$2.834\ 952 \times 10^{-2}$
ounce-mass/ft^{2}	kilogram/metre^{2} (kg/m^{2})	0.305 152
ounce-mass/yard^{2}	kilogram/metre^{2} (kg/m^{2})	$3.390\ 575 \times 10^{-2}$
ounce (avoirdupois)/gallon (U.S. liquid)	kilogram/metre^{3} (kg/m^{3})	7.489 152
pint (U.S. liquid)	metre^{3} (m^{3})	$4.731\ 765 \times 10^{-4}$
pound-force (lbf avoirdupois)	newton (N)	4.448 222
pound-mass (lbm avoirdupois)	kilogram (kg)	$4.535\ 924 \times 10^{-1}$
pound-mass/second	kilogram/second (kg/s)	$4.535\ 924 \times 10^{-1}$
pound-force/inch^{2} (psi)	pascal (Pa)	$6.894\ 757 \times 10^{3}$
pound-mass/inch^{3}	kilogram/meter^{3} (kg/m^{3})	$2.767\ 990 \times 10^{4}$
pound-mass/foot^{3}	kilogram/meter^{3} (kg/m^{3})	$1.601\ 846 \times 10$
quart (U.S. liquid)	metre^{3} (m^{3})	$9.463\ 529 \times 10^{-4}$
ton (short, 2000 lbm)	kilogram (kg)	$9.071\ 847 \times 10^{2}$
torr (mm Hg)	pascal (Pa)	$1.333\ 22 \times 10^{2}$
watt-hour	joule (J)	$3.600\ 000^{*} \times 10^{3}$
yard	metre (m)	$9.144\ 000^{*} \times 10^{-1}$
yard^{2}	metre^{2} (m^{2})	$8.361\ 274 \times 10^{-1}$
yard^{3}	metre^{3} (m^{3})	$7.645\ 549 \times 10^{-1}$

* **Exact**

Units of Measurement—Conversion Factors*

*All boldface figures are exact; the others generally are given to seven significant figures.

In using conversion factors, it is possible to perform division as well as the multiplication process shown here. Division may be particularly advantageous where more than the significant figures published here are required. Division may be performed in lieu of multiplication by using the reciprocal of any indicated multiplier as divisor. For example, to convert from centimeters to inches by division, refer to the table headed "To Convert from *Inches*" and use the factor listed at "centimeters" (*2.54*) as divisor.

Units of Length

To Convert from Centimeters

To	Multiply by
Inches	0.393 700 8
Feet	0.032 808 40
Yards	0.010 936 13
Meters	**0.01**

To Convert from Inches

To	Multiply by
Feet	0.083 333 33
Yards	0.027 777 78
Centimeters	**2.54**
Meters	**0.025 4**

To Convert from Meters

To	Multiply by
Inches	39.370 08
Feet	3.280 840
Yards	1.093 613
Miles	0.000 621 37
Millimeters	**1 000**
Centimeters	**100**
Kilometers	**0.001**

To Convert from Feet

To	Multiply by
Inches	**12**
Yards	0.333 333 3
Miles	0.000 189 39
Centimeters	**30.48**
Meters	**0.304 8**
Kilometers	**0.000 304 8**

To Convert from Yards

To	Multiply by
Inches	**36**
Feet	**3**
Miles	0.000 568 18
Centimeters	**91.44**
Meters	**0.914 4**

To Convert from Miles

To	Multiply by
Inches	**63 360**
Feet	**5 280**
Yards	**1 760**
Centimeters	**160 934.4**
Meters	**1 609.344**
Kilometers	**1.609 344**

Units of Measurement—Conversion Factors*

*All boldface figures are exact; the others generally are given to seven significant figures.

Units of Mass

To Convert from Grams

To	Multiply by
Grains	15.432 36
Avoirdupois Drams	0.564 383 4
Avoirdupois Ounches	0.035 273 96
Troy Ounces	0.032 150 75
Troy Pounds	0.002 679 23
Avoirdupois Pounds	0.002 204 62
Milligrams	**1 000**
Kilograms	**0.001**

To Convert from Metric Tons

To	Multiply by
Avoirdupois Pounds	2 204.623
Short Hundredweights	22.046 23
Short Tons	1.102 311 3
Long Tons	0.984 206 5
Kilograms	**1 000**

To Convert from Grains

To	Multiply by
Avoirdupois Drams	0.036 571 43
Avoirdupois Ounces	0.002 285 71
Troy Ounces	0.002 083 33
Troy Pounds	0.000 173 61
Avoirdupois Pounds	0.000 142 86
Milligrams	**64.798 91**
Grams	**0.064 798 91**
Kilograms	**0.000 064 798 91**

To Convert from Avoirdupois Pounds

To	Multiply by
Grains	**7 000**
Avoirdupois Drams	**256**
Avoirdupois Ounces	**16**
Troy Ounces	14.583 33
Troy Pounds	1.215 278
Grams	**453.592 37**
Kilograms	**0.453 592 37**
Short Hundredweights	**0.01**
Short Tons	**0.000 5**
Long Tons	0.000 446 428 6
Metric Tons	**0.000 453 592 37**

To Convert from Kilograms

To	Multiply by
Grains	15 432.36
Avoirdupois Drams	564.383 4
Avoirdupois Ounces	35.273 96
Troy Ounces	32.150 75
Troy Pounds	2.679 229
Avoirdupois Pounds	2.204 623
Grams	**1 000**
Short Hundredweights	0.022 046 23
Short Tons	0.001 102 31
Long Tons	0.000 984 2
Metric Tons	**0.001**

Units of Measurement—Conversion Factors*

*All boldface figures are exact; the others generally are given to seven significant figures.

Units of Mass

To Convert from Avoirdupois Ounces

To	Multiply by
Grains	**437.5**
Avoirdupois Drams	**16**
Troy Ounces	0.911 458 3
Troy Pounds	0.075 954 86
Avoirdupois Pounds	**0.062 5**
Grams	**28.349 523 125**
Kilograms	**0.028 349 523 125**

To Convert from Troy Pounds

To	Multiply by
Grains	**5 760**
Avoirdupois Drams	210.651 4
Avoirdupois Ounces	13.165 71
Troy Ounces	**12**
Avoirdupois Pounds	0.822 857 1
Grams	**373.241 721 6**

To Convert from Short Hundredweights

To	Multiply by
Avoirdupois Pounds	**100**
Short Tons	**0.05**
Long Tons	0.044 642 86
Kilograms	**45.359 237**
Metric Tons	**0.045 359 237**

To Convert from Short Tons

To	Multiply by
Avoirdupois Pounds	**2 000**
Short Hundredweights	**20**
Long Tons	0.892 857 1
Kilograms	**907.184 74**
Metric Tons	**0.907 184 74**

To Convert from Troy Ounces

To	Multiply by
Grains	**480**
Avoirdupois Drams	17.554 29
Avoirdupois Ounces	1.097 143
Troy Pounds	0.083 333 3
Avoirdupois Pounds	0.068 571 43
Grams	**31.103 476 8**

To Convert from Long Tons

To	Multiply by
Avoirdupois Ounces	**35 840**
Avoirdupois Pounds	**2 240**
Short Hundred-Weights	**22.4**
Short Tons	**1.12**
Kilograms	**1 016.046 908 8**
Metric Tons	**1.016 046 908 8**

Units of Measurement—Conversion Factors*

*All boldface figures are exact; the others generally are given to seven significant figures.

Units of Capacity, or Volume, Liquid Measure

To Convert from **Milliliters**

To	Multiply by
Minims	16.230 73
Liquid Ounces	0.033 814 02
Gills	0.008 453 5
Liquid Pints	0.002 113 4
Liquid Quarts	0.001 056 7
Gallons	0.000 264 17
Cubic Inches	0.061 023 74
Liters	**0.001**

To Convert from **Cubic Meters**

To	Multiply by
Gallons	264.172 05
Cubic Inches	61 023.74
Cubic Feet	35.314 67
Liters	**1 000**
Cubic Yards	1.307 950 6

To Convert from **Liters**

To	Multiply by
Liquid Ounces	33.814 02
Gills	8.453 506
Liquid Pints	2.113 376
Liquid Quarts	1.056 688
Gallons	0.264 172 05
Cubic Inches	61.023 74
Cubic Feet	0.035 314 67
Milliliters	**1 000**
Cubic Meters	**0.001**
Cubic Yards	0.001 307 95

To Convert from **Minims**

To	Multiply by
Liquid Ounces	0.002 083 33
Gills	0.000 520 83
Cubic Inches	0.003 759 77
Milliliters	0.061 611 52

To Convert from **Gills**

To	Multiply by
Minims	**1 920**
Liquid Ounces	**4**
Liquid Pints	**0.25**
Liquid Quarts	**0.125**
Gallons	**0.031 25**
Cubic Inches	**7.218 75**
Cubic Feet	0.004 177 517
Milliliters	118.294 118 25
Liters	**0.118 294 118 25**

To Convert from **Liquid Ounces**

To	Multiply by
Minims	**480**
Gills	**0.25**
Liquid Pints	**0.062 5**
Liquid Quarts	**0.031 25**
Gallons	**0.007 812 5**
Cubic Inches	1.804 687 5
Cubic Feet	0.001 044 38
Milliliters	29.573 53
Liters	0.029 573 53

Units of Measurement—Conversion Factors*

*All boldface figures are exact; the others generally are given to seven significant figures.

Units of Capacity, or Volume, Liquid Measure

To Convert from **Liquid Pints**

To	Multiply by
Minims	**7 680**
Liquid Ounces	**16**
Gills	**4**
Liquid Quarts	**0.5**
Gallons	**0.125**
Cubic Inches	**28.875**
Cubic Feet	0.016 710 07
Milliliters	**473.176 473**
Liters	**0.473 176 473**

To Convert from **Liquid Quarts**

To	Multiply by
Minims	**15 360**
Liquid Ounces	**32**
Gills	**8**
Liquid Pints	**2**
Gallons	**0.25**
Cubic Inches	**57.75**
Cubic Feet	0.033 420 14
Milliliters	**946.352 946**
Liters	**0.946 352 946**

To Convert from **Gallons**

To	Multiply by
Minims	**61 440**
Liquid Ounces	**128**
Gills	**32**
Liquid Pints	**8**
Liquid Quarts	**4**
Cubic Inches	**231**
Cubic Feet	0.133 680 6
Milliliters	**3 785.411 784**
Liters	**3.785 411 784**
Cubic Meters	**0.003 785 411 784**
Cubic Yards	0.004 951 13

To Convert from **Cubic Inches**

To	Multiply by
Minims	265.974 0
Liquid Ounces	0.554 112 6
Gills	0.138 528 1
Liquid Pints	0.034 632 03
Liquid Quarts	0.017 316 02
Gallons	0.004 329 0
Cubic Feet	0.000 578 7
Milliliters	16.387 064
Liters	**0.016 387 064**
Cubic Meters	**0.000 016 387 064**
Cubic Yards	0.000 021 43

To Convert from **Cubic Feet**

To	Multiply by
Liquid Ounces	957.506 5
Gills	239.376 6
Liquid Pints	59.844 16
Liquid Quarts	29.922 08
Gallons	7.480 519
Cubic Inches	**1 728**
Liters	**28.316 846 592**
Cubic Meters	**0.028 316 846 592**
Cubic Yards	0.037 037 04

To Convert from **Cubic Yards**

To	Multiply by
Gallons	201.974 0
Cubic Inches	**46 656**
Cubic Feet	**27**
Liters	**764.554 857 984**
Cubic Meters	**0.764 554 857 984**

Units of Measurement—Conversion Factors*

*All boldface figures are exact; the others generally are given to seven significant figures.

Units of Capacity, or Volume, Dry Measure

To Convert from Liters

To	Multiply by
Dry Pints	1.816 166
Dry Quarts	0.908 082 98
Pecks	0.113 510 4
Bushels	0.028 377 59
Dekaliters	**0.1**

To Convert from Cubic Meters

To	Multiply by
Pecks	113.510 4
Bushels	28.377 59

To Convert from Dekaliters

To	Multiply by
Dry Pints	18.161 66
Dry Quarts	9.080 829 8
Pecks	1.135 104
Bushels	0.283 775 9
Cubic Inches	610.237 4
Cubic Feet	0.353 146 7
Liters	**10**

To Convert from Dry Pints

To	Multiply by
Dry Quarts	**0.5**
Pecks	**0.062 5**
Bushels	**0.015 625**
Cubic Inches	**33.600 312 5**
Cubic Feet	0.019 444 63
Liters	0.550 610 47
Dekaliters	0.055 061 05

To Convert from Dry Quarts

To	Multiply by
Dry Pints	**2**
Pecks	**0.125**
Bushels	**0.031 25**
Cubic Inches	**67.200 625**
Cubic Feet	0.038 889 25
Liters	1.101 221
Dekaliters	0.110 122 1

To Convert from Bushels

To	Multiply by
Dry Pints	**64**
Dry Quarts	**32**
Pecks	**4**
Cubic Inches	**2 150.42**
Cubic Feet	1.244 456
Liters	35.239 07
Dekaliters	3.523 907
Cubic Meters	0.035 239 07
Cubic Yards	0.046 090 96

To Convert from Pecks

To	Multiply by
Dry Pints	**16**
Dry Quarts	**8**
Bushels	**0.25**
Cubic Inches	**537.605**
Cubic Feet	0.311 114
Liters	8.809 767 5
Dekaliters	0.880 976 75
Cubic Meters	0.008 809 77
Cubic Yards	0.011 522 74

Units of Measurement—Conversion Factors*

*All boldface figures are exact; the others generally are given to seven significant figures.

Units of Capacity, or Volume, Dry Measure

To Convert from Cubic Inches

To	Multiply by
Dry Pints	0.029 761 6
Dry Quarts	0.014 880 8
Pecks	0.001 860 10
Bushels	0.000 465 025

To Convert from Cubic Feet

To	Multiply by
Dry Pints	51.428 09
Dry Quarts	25.714 05
Pecks	3.214 256
Bushels	0.803 563 95

To Convert from Cubic Yards

To	Multiply by
Pecks	86.784 91
Bushels	21.696 227

Units of Area

To Convert from Square Centimeters

To	Multiply by
Square Inches	0.155 000 3
Square Feet	0.001 076 39
Square Yards	0.000 119 599
Square Meters	**0.000 1**

To Convert from Hectares

To	Multiply by
Square Feet	107 639.1
Square Yards	11 959.90..
Acres	2.471 054
Square Miles	0.003 861 02
Squire Meters	**10 000**

To Convert from Square Feet

To	Multiply by
Square Inches	**144**
Square Yards	0.111 111 1
Acres	0.000 022 957
Square Centimeters	**929.030 4**
Square Meters	**0.092 903 04**

To Convert from Acres

To	Multiply by
Square Feet	**43 560**
Square Yards	**4 840**
Square Miles	**0.001 562 5**
Square Meters	**4 046.856 422 4**
Hectares	**0.404 685 642 24**

Units of Measurement—Conversion Factors*

*All boldface figures are exact; the others generally are given to seven significant figures.

Units of Area

To Convert from **Square Meters**

To	Multiply by
Square Inches	1 550.003
Square Feet	10.763 91
Square Yards	1.195 990
Acres	0.000 247 105
Square Centimeters	**10 000**
Hectares	**0.000 1**

To Convert from **Square Inches**

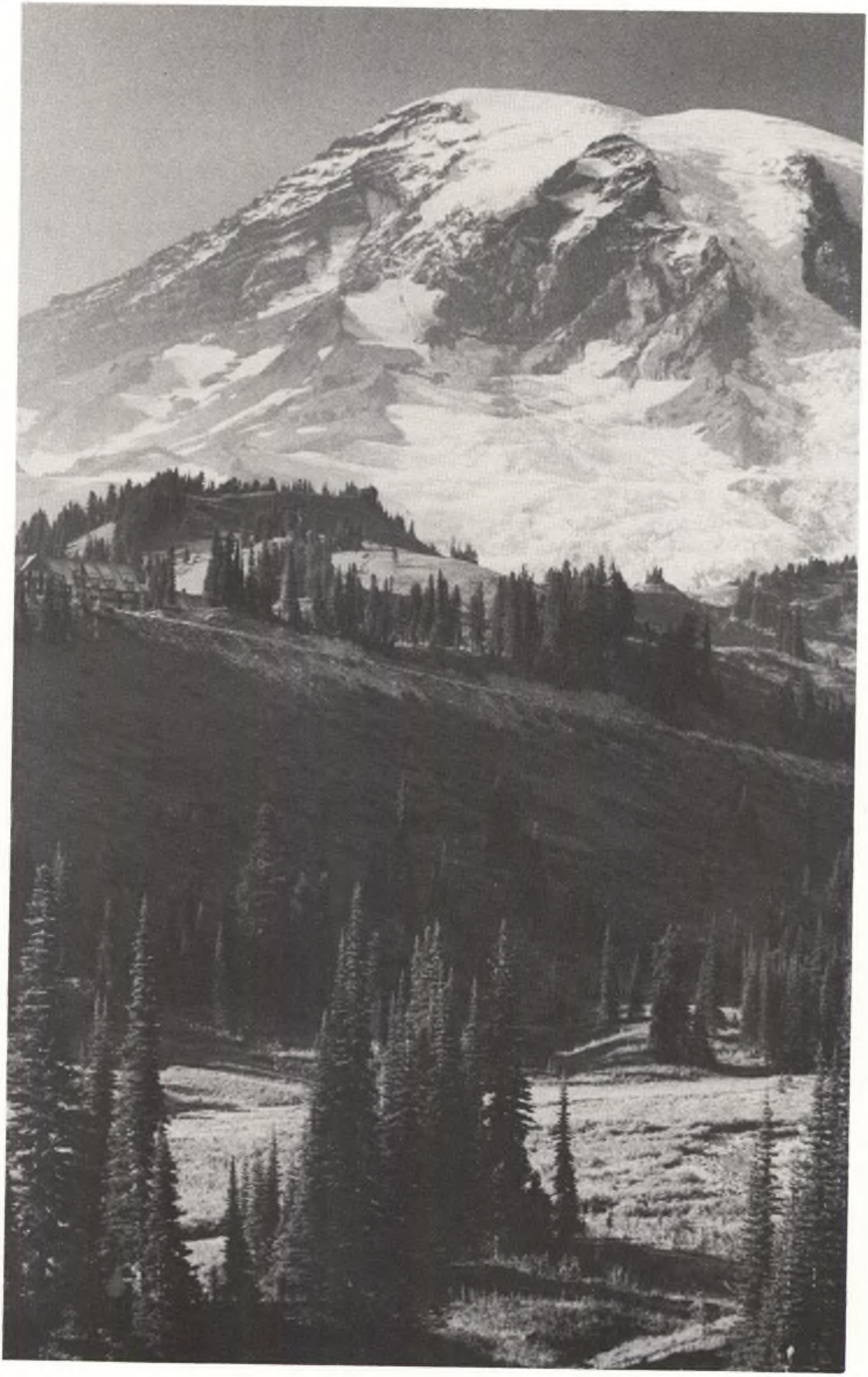
To	Multiply by
Square Feet	0.006 944 44
Square Yards	0.000 771 605
Square Centimeters	**6.451 6**
Square Meters	**0.000 645 16**

To Convert from **Square Miles**

To	Multiply by
Square Feet	**27 878 400**
Square Yards	**3 097 600**
Acres	**640**
Square Meters	**2 589 988.110 336**
Hectares	**258.998 811 033 6**

To Convert from **Square Yards**

To	Multiply by
Square Inches	**1 296**
Square Feet	**9**
Acres	0.000 206 611 6
Square Miles	0.000 000 322 830 6
Square Centimeters	**8 361.273 6**
Square Meters	**0.836 127 36**
Hectares	**0.000 083 612 736**



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